A Socio-Economic and Environmental Inventory of the North Atlantic Region

Sandy Hook to Bay of Fundy

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VOL I

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A Socio-Economic and Environmental Inventory of the North Atlantic Region

including the Outer Continental Shelf and adjacent waters from Sandy Hook, New Jersey, to Bay of Fundy

VOLUME I

Book 3

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6.0 MARITIME STRAND (iw3RINE-TERRESTRIAL Transition ZONE)

6.1 GEOLOGY

The geology of the nearshore area, estuarine and beach, is discussed in Chapter 4, Section 4.2, and Chapter 5, Section 5.2, respectively.

6.2 METEOROLOGY AND CLIMATOLOGY

Near shore and shoreland meteorology and climatology are discussed in Chapter 4, Section 4.5, and Chapter 5, Section 5.2.2.

6.3 HYDROLOGY

Chapter 2, Section 2.3, presents a general picture of the hydrology of the entire study region, including the marine strand. Section 6.4, Maritime Strand Habitat, also treats hydrologic aspects of this environment.

6.4 BIOLOGY-MARITIME STRAND HABITAT

6.4.1 UEFINITION

The maritime strand habitat occupies the landward half of the transition zone between aquatic and terrestrial conditions, the intertidal zone being the seaward half. The habitat is bordered on the seaward side by the high intertidal and on the landward side by the indigenous upland community. Maritime strand communities are unique terrestrial communities, having evolved to withstand the influence of saline ground water (salt marsh communities) and wind-borne salt spray (sand dune communities).

6.4.2 HABITAT DYNAMICS

ENVIRONMENTAL CONDITIONS

As indicated above, there are two well-developed maritime strand communities. Both occur on shores of soft, unconsolidated sediments. Sand dune communities are found bordering sandy, exposed beaches where, because of the porosity of the beach substrate, seawater drains rapidly and thus does not penetrate the water table very far inland (Oosting and Billings, 1942). The major environmental factor influencing plant species composition and zonation is wind-borne salt spray (Oosting and Billings, 1942; Oosting, 1945; Martin, 1959). Such salt spray is the outcome of two other factors important in shaping the topographic profile of the sand strand; the surf zone which produces the salt spray while transporting sand to the beach, and persistent onshore winds which carry the spray and sand inland (Martin, 1959). The interaction between wind-transported sand and the plant community produces the dune complex and will be discussed in greater detail under Section 6.4.3.

The second maritime strand community, the salt marsh, borders quiet, gently sloping shores. Here the soil is much less porous and seawater is retained rendering the water table saline (Miller and Egler, 1950; Martin, 1959). The winds and salt spray characteristic of the more exposed beaches are less persistent and therefore of less importance. The salt marsh habitat has already been discussed in Chapter 4, Section 4.6.4. Included here will be a more complete description of the plant zonation.

A well-developed strand community is very often lacking along rocky shores. This is especially obvious in quiet waters, perhaps because both major environmental factors resulting in the above communities are lacking. The upland community often extends to the very top of the rocky shore in such areas. Where more exposed conditions occur, a band of low shrubs may be found bordering the top of the beach, often of the same species found in the shrub communities on the sand dunes (Gilbert, personal observation). Presumably this band is in response to wind-borne salt spray.

Topics including C-F nutrient and seasonal cycles, food webs, and relative productivity have already been discussed for the salt marsh habitat. Literature describing these aspects for the sand dune communities is totally absent. Research, most of it done several decades ago, has concentrated on description of the plant zonation. It can be assumed that food webs are not well developed since most animal populations are seasonal (insects, most birds) or occasional visitors (raccoons, predatory birds), although this is not well documented. For the strand bordering rocky coasts even description is lacking, perhaps because a well-developed community is absent.

NATURAL STRESS

Maritime strand communities are subjected to several natural stresses, the most important one being salt spray. The amount of wind-borne salt spray decreases with increasing distance inland from shore and, at a locality, also increases with elevation above the ground. Species found in these communities exhibit a gradient of resistance to salt spray, and zonation of species in the dune communities can best be explained as the response to the gradient of spray (Oosting and Billings, 1942; Oosting, 1945; Martin, 1959).

A second stress, of major importance in the salt marsh, is soil/water salinity and, relatedly, tidal flooding. Zonation in the marsh is mainly a result of the differing tolerances of the species to these factors (Miller and Egler, 1950).

In the dune communities, two other natural stresses affect the distribution of species. Because of the porosity of sand, rain water drains rapidly and the only reliable source of ground water, therefore, is the water table. Thus, the level of this table restricts the distribution

of mesic plants (e.g., highbush blueberry, large cranberry). The dune complex is finally characterized by shifting sand. Dunegrass is probably the only species that benefits from the constant movement of sand. Where deposition of sand is 7 cm or more a year, the grass shows its most vigorous growth. The constant accumulation of sand seems to be necessary to the survival of the rhizomes, and dunegrass is most sensitive to destruction by trampling when the new rhizomes are closest to the surface (Martin, 1959). Other dune species have no protection against smothering by sand and their survival is thus dependent on the ability of the dune grass to stop and hold sand.

6.4.3 EFFECT OF NAN-INDUCED STRESS

The dune complex is exceedingly vulnerable to destruction by human activities. As mentioned above, survival of most of the dune communities is dependent on the ability of the dune grass to stabilize shifting sand which, in turn, is extremely sensitive to trampling. When the rhizomes are killed, the grass dies and dune erosion rapidly ensues (Martin, 1959).

On the other hand, attempts to prevent completely any movement of sand (dune "stabi 1 ization") by planting and fertilizing dense growths of sea oats and dune grass or erecting permanent barriers along the shore, have resulted in an extremely unstable condition. When undisturbed, the dune complex as a whole moves inland as a response to the rising sea level. When stabilized, the dunes can not continue moving and consequently the beach in front of the dunes progressively narrows as sea level rises. The narrower the beach, the less area exists for wave energy to dissipate and therefore, the higher the wave impact per unit area becomes, and the more the stabilized dune bears the brunt of storm waves. This, in turn, results in dune erosion and a selective removal of the finer sediments responsible for building and maintaining the beach and dune area. In the end, dune "stabilization" programs have brought about a severe threat to, not only the stability of the area, but its very existance (Dolan, 1972; Dolan, Godfrey, and Odum, 1972).

In the salt marsh, ditching for mosquito control and continuous mowing have been among the most destructive of human activities. Martin (1959) and Redfield (1972) report that ditching of the Island Beach State Park in New Jersey and Barnstable marsh on Cape Cod have had no readily discernible effects. Miller and Egler (1950), however, document the effects of ditching the Wequetequock-Pawcatuck marshes in Connecticut. These effects include an alteration of plant distribution to include a continuous band of Iva ovaria (a shrub) along the ditch edges with evidence that the shrub threatens to expand further into the marsh, and the creation of large, new mosquito breeding areas beyond the levees bordering the ditch. Miller and Egler also document the destruction of the upper marsh edge and relate it to continuous mowing for hay.

6.4.4 BIOLOGICAL COMPONENTS

GENERAL DISTRIBUTION

The general environmental conditions and locations of the plant zones of the maritime strand communities will be described. For constituent plant species, consult the following checklist Section 6.4.5. The description of the dune communities is taken from Martin (1959) and of the salt marsh from Miller and Egler (1950).

The topography of the dune complex is created by the interaction of plants, waves, wind, and sand and gives rise to several microenvironment. Waves transport sand to the shore where it is picked up by the wind and transported inland. When the sand-bearing wind strikes an area of vegetation, especially Ammophilia brevili gulata (dune grass), the wind is slowed and its load dropped among the plants. As the deposition of sand continues, the grass grows up, keeping pace, and trapping still more sand. A dune finally results. Behind the dune, a "shadow" is created characterized by lowered exposure to wind and salt spray. As more dunes are created, the dunes farthest from the sea are more and more protected from these factors. Consequently, more complex communities made up of species with low resistance to wind and spray become established. Eventually these dunes become stabilized and are then known as secondary, "inactive" dunes. Dunes closest to the beach, characterized by constantly moving sand and steep seaward slopes with gradual backslopes are known as primary dunes. The areas between dunes are often zoned by the level of the water table; more mesic species are found at the bottom of the hollow and are replaced by xeric species higher on the slopes.

The varied microenvironment created by this topography are inhabited by the following plant communities. The dunegrass community (DG) occurs on the seaward slopes and tops of the primary foredunes. This area is characterized by high exposure to wind-borne salt spray, constant sand movement, low soil moisture and extreme temperature fluctuations. In low, semiprotected areas, similar in most environmental conditions to the former areas except that the exposure to salt spray and sand movement is less, the beach heather (BH) community occurs. Shrub communities (SC) are found on the backslopes of primary foredunes (xeric thicket), the seaward slopes and tops of secondary foredunes (dune thicket), and in the low hollows between the dunes near the water table (mesic thicket). The species' dominance varies with soil moisture content and the level of exposure to salt spray, but most species occur throughout the range of conditions. The cranberry bog community (CB) is restricted to the hollows between secondary backdunes. As succession proceeds, the shrub communities may be replaced by tree communities (TC). The species composition of the two communities is often the same, but species dominance has shifted in favor of tree species. The shift occurs when the vines and shrubs are overtopped by the trees and are shaded out. Tree communities are generally found on the backslopes of dunes and are more well developed the more protection

there is from salt spray, either due to distance from the beach or protection of a stabilized dune.

On the bay side of barrier beaches and often on the landward edge of salt marshes, reedgrass (RG) and brackish marsh (BM) communities form. Both communities occur where there is good protection from salt spray, low wave action and infrequent tidal flooding. The reedgrass community occurs especially on sandy ridges bordering the bay shore or in a band bordering the upland edge of the salt marsh. The brackish marsh community occurs on salt peat in the transitional zone between fresh and salt marshes. Salinity is therefore generally low.

Plant zones in the salt marsh (SM) itself are determined largely by the amount of tidal flooding which ranges from twice a day at the seaward edge to very infrequent flooding at the upland edge. The resulting gradient in soil water salinity is one of the major stresses in the habitat and local variations result in two minor communities within the major zones. Description of the major zones of a Connecticut salt marsh is as follows. Beyond the upland edge of the marsh on shores with gradual slope a shrub border develops. This border is absent on steep slopes where the upland forest may overhang the marsh. Bordering the upland edge of the marsh, generally about 0.5 m above the marsh on a peaty substratum is the Panicum virgatum (panic grass) community, a tussock grassland. Along the seaward edge of the marsh and bordering the ditches and streams where tidal flooding occurs with every high tide, a band of Spartina alterniflora (saltwater cord grass) is found and is readily recognized by the greater height of the grass than the neighboring communities. Between these two communities is a band of dense grassland consisting of Juncus gerardi (black grass) on the higher elevations and Spartina patens (saltmeadow grass) on the lower elevations. Within these zones are found many depressions or varied sizes and depths. Then the depression is shallow and irregularly flooded by tides, the water slowly evaporates resulting in a marked increase in soil salinity. Such areas are termed salt pannes and are either bare or colonized by Salicornia europaea (glasswort) and S. virginica (woody glasswort). In circular bands around the pannes proceeding outwards are found bands of stunted S. alterniflora, then forbs, then the normal community for the area. When the depression is deep and contains water permanently, Ruppia maritima (pondweed) often colonizes it.

(1) Species Checklist

KEY

DG	Dunegrass community	BM	Brackish marsh
BH	Beach Heather community	SM	Salt marsh
RG	Reedgrass community	CB	Cranberry bog

SC Shrub community
TC Tree community

*Key species

Scientific Name	Common Name	Habitat	Vegetative Type
Acer rubrum	red maple	TC	tree
Agrostis palustris		SM (upper)	
Amelanchier canadensis	shadbush	SC, TC	tree
Ammophilia breviligulata	dune grass	*DG	grass
Anagallis arvensis	scarlet pimpernel	DG	herb
Arenaria peploides	seabeach sandwort	DG, SC	herb
Artemisia caudata	tall wormwood	Sc	herb
Artemisia stelleriana	dusty miller	DG	herb
Aster tenuifolius	saltmarsh aster	SM (upper)	herb
Atriplex arenaria	sea-beach orache	Sc	herb
Baccharis halmifolia	sea myrtle	RG, BM	shrub
Cakile edentula	sea rocket	DG	forb
Chrysopsis falcata	sickle-leaved golden aster	S c	herb
Cichorium intybus	chi tory	DG, SM (upper)	herb
Cladium mariscoides	twig-rush	SM (upper)	sedge
Cladonia spp.		BH	
Corema conradii	broom crowberry	SC	shrub
- -	umbrella sedge	BH "	sedge
Cyperus polystachyos	nut-grass	SM (upper)	sedge
Cysticus scoparius	scotch broom	Sc	shrub
Distichlis spicata	spicata grass	SM (upper)	grass
Drosera filiformis	sundew	CB	sundew

Scientific Name	Common Name	Habitat	Vegetative Type
Dryopteris thelypteris	meadow fern	BM, SC (mesic), TC	fern
Eleocharis rostellata	spike rush	SM (upper)	sedge
Euphorbia polygonifolia	seaside spurge	DG	forb
Festuca rubra	fescue grass	SM (upper)	grass
Gerardia maritima	seaside gerardia	SM (pannes)	herb
Glaux maritima	sea milkwort	SM	herb
Hibiscus palustris		BM	herb
Hudsonia tomentosa	beach heather	*BH	shrub
Ilex opaca	American holly	Sc, TC	tree
Iva orara		SM (Juncus)	shrub
Juncus effusus		CB	rush
Juncus gerardi	black grass	*SM	rush
Juniperus virginiana	red cedar	RG, SC, *TC	tree
Kalmia angustifolia	sheep laurel	SC (mesic), TC	shrub
Lathyrus japonicus	beach pea	DG	herb
Lechea maritima	pi nweed	BH	herb
Limonium carolinianum	sea lavender or marsh rosemary	SM (pannes)	forb
Lycopodium inundatum	bog club-moss	CB	club-moss
Myrica pennsylvanica	bayberry	SC, TC	shrub
Oenothera biennis	evening primrose	Sc	forb
Osmunda cinnamonea	cinnamon fern	SC, TC	fern
O. regalis	royal fern	SC, TC	fern
Panicum amarum	panic grass	BH	grass
P. virgatum	panic grass	*SM (upland edge)	grass

Scientific Name	Common Name	Habitat	Vegetative Type
Parthenocissus quinquefolia	virginia creeper	SC, TC	vine
Phragmites communis	reedgrass	*RG	grass
Pinus rigida	pitch pine	*TC	tree
Plantago decipiens	sea plantain	SM	herb
Polygonum glaucum	seabeach knotweed	SC	herb
Prunus maritima	beach plum	SC, TC	tree
Prunus serotina	black cherry	SC, *TC	tree
Quercus ilicifolia	scrub oak	SC, TC	tree
Rhus copallina	dwarf sumac	SC, TC	tree
Rhus radicans	poison ivy	RG, BM, SC, TC	vine
Rosa rugosa	salt-spray rose	RG, BM	shrub
Rosa virginiana	rose	SC	shrub
Ruppia maritima	pondweed	SM (pools)	
Salicornia europaea	glasswort	SM (pannes)	herb
Salicornia virginica	woody glasswort	SM (pannes)	herb
Salsola kali	saltwort	SM (pannes)	herb
Saponaria officinalis	soapwort	Sc	herb
Sassafras albidium	sassafras	TC	tree
Scirpus americanus	three-square bullrush	SM (upper)	sedge
Scirpus maritimus	saltmarsh bullrush	SM (upper)	sedge
Sisyrinchium arenicola	blue-eyed grass	SM (upper)	grass
Smilax rotundifolia	greenbriar	SC, TC	vine
Solidago sempervirens	seaside goldenrod	*DG, SM (upper)	forb

Scientific Name	Common Name	Habitat	Vegetative Type
Spartina alterniflora	saltwater cordgrass	*SM	grass
Spartina patens	saltmeadow grass	*BM, *SM	grass
Spartina pectinata	tall cordgrass	*SM (upper)	grass
Spergularia sp.	sand spurge	SM	herb
Sphagnum sp.	moss	CB, Sc (mesic)	moss
Spiranthes cernua	ladies' tresses	SM (upper)	herb
Suaeda maritima	sea-blite	SM	herb
Trigiochin maritima	arrow grass	SM	grass
Tripsacum dactyloides		*SM (upper)	grass
Typha latifolia	cat-tail	BM, SM (upper)	reed
Vaccinium corymbosum	highbush blueberry	SC (*mesic), *TC	shrub
Vaccinium macrocarpon	large cranberry	*CB, SC (mesic)	vine
Xanthium echinatium	cocklebur	Sc	herb

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7.1 GENERAL PHYSIOGRAPHY

Two major physiographic provinces are included in the study region, the Coastal Plain Province and the New England Province (see Figure 7-l). These are discussed below.

7.1.1 NEW ENGLAND PROVINCE

This province predominates the area, and is typifiedby a plateau-like upland declining towards the sea,. being fairly level with the exception of a few mountainous zones which withstood the glaciers. Much of the mountainous area as well as large areas of the plateau are underlain by intrusive igneous rocks, mainly granite. The surface has been elevated for some time, as evidenced by the prevalent dissection. In general, valleys are narrow.

The New England Province is subdivided into five distinct sections by Fenneman (1938): the New England Upland, the Seaboard Lowland, the White Mountains, the Green Mountains, and the Taconic section. Further subdivisions may be available (see Figure 7-2 as an example).

THE NEW ENGLAND UPLANDS

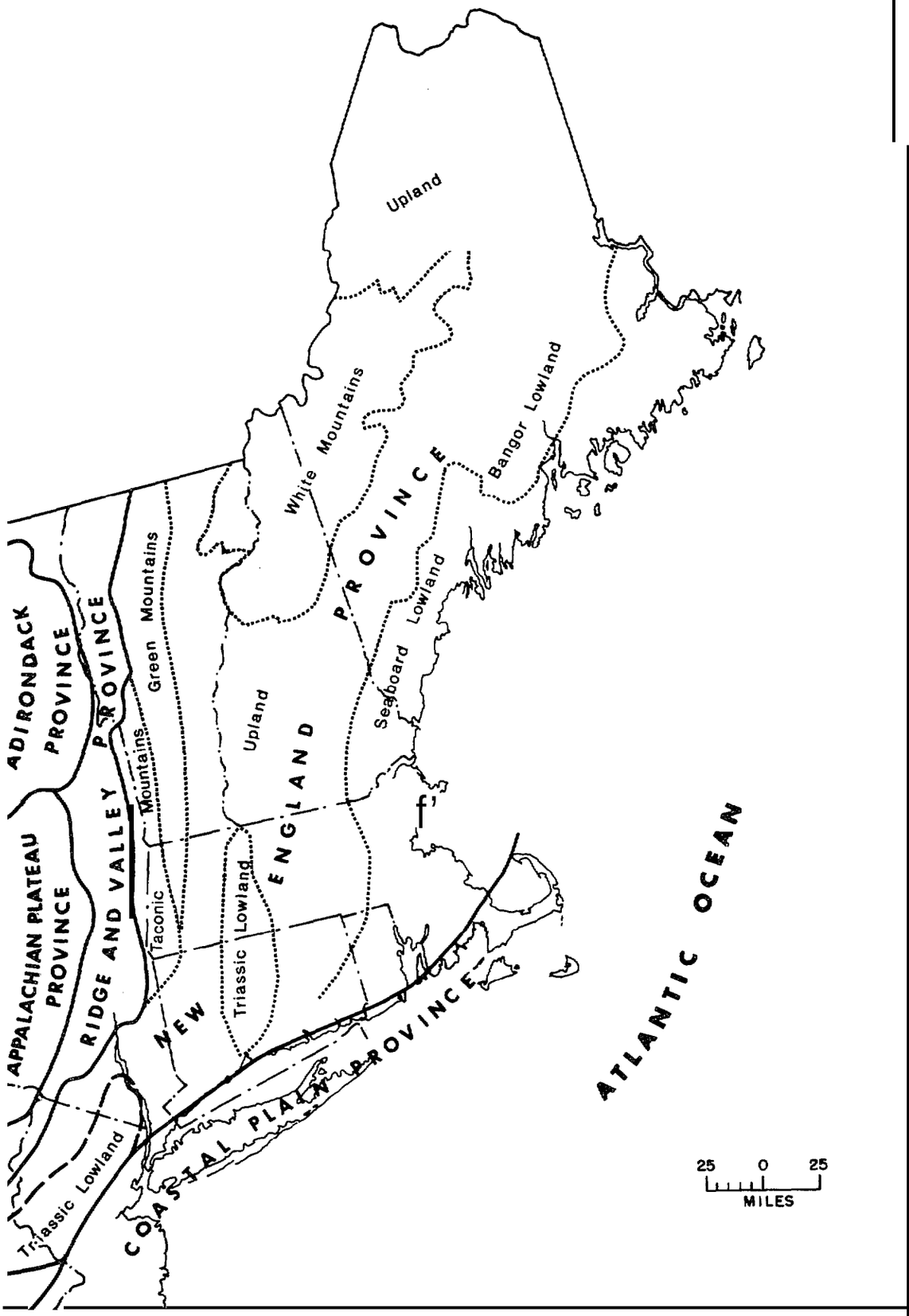
This plateau-like subregion is the most prevalent in the area. It is described generally as an upraised plain with an occasional monadnock (residual hill, usually of exceptionally hard rock) and dissected by narrow valleys and steep slopes. The drainage system has had at least 200 million years to adjust. The largest extent of this subregion lies north of Moosehead Lake, Maine.

North of central New Hampshire and Vermont, the upland becomes less and less of a plain. Numerous monadnocks of various altitudes are found.

SEABOARD LOWLAND

This region is not only lower but smoother than the upland. In most places the transition occurs at the 400' to 500' contour: The region begins 6 to 16 miles inland in Connecticut, continues 10 to 12 miles west of Providence, north-south into Massachusetts, then northeasterly into Maine extending at first 20 miles inland and gradually diverging northward to 60 miles inland at the border of New Brunswick. The Bangor Lowlands are a continuation of the Seaboard Lowlands in terms of occupance and use.

To a large extent this region can be characterized by its erosional history. In addition, parts of the region are underlain by carboniferous sediments and are lower than the rest. These include the Boston Basin, Narragansett Basin, Southeastern New Hampshire and Southwestern Maine.



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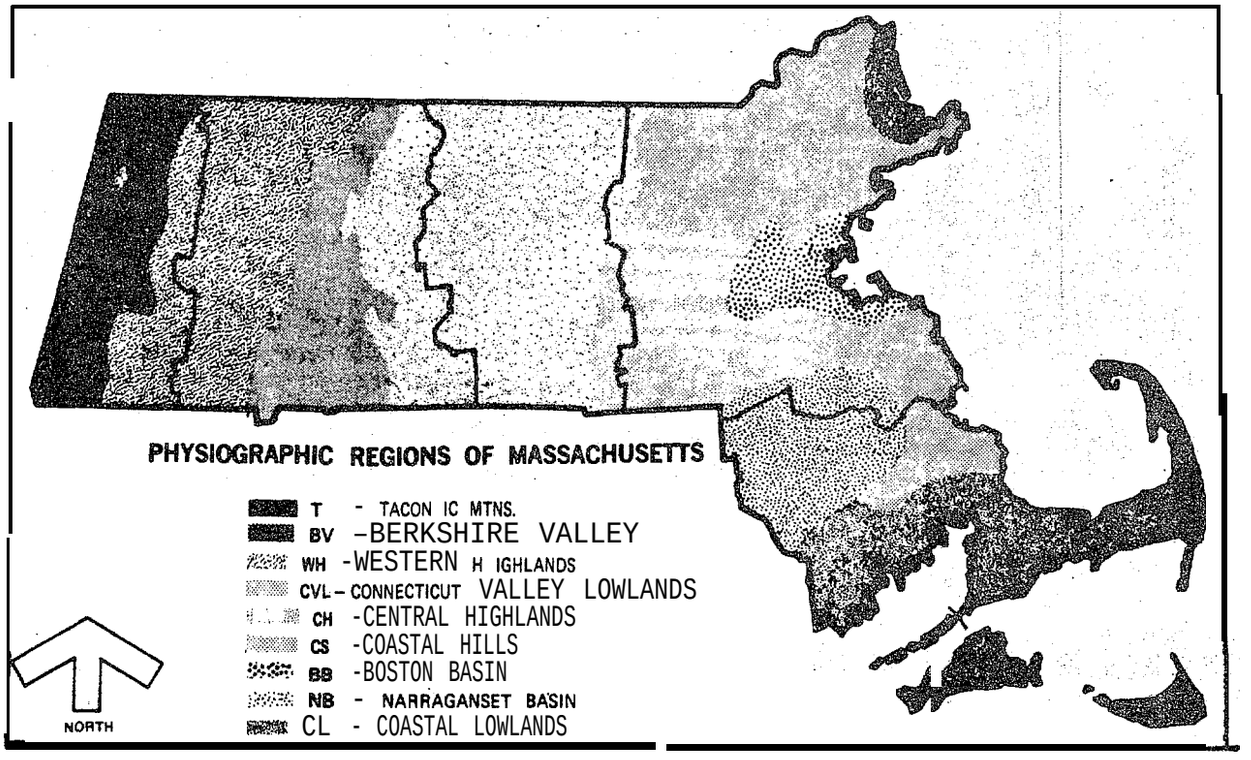
TRIGOM PARC

FIGURE 7-1

Physiographic Provinces
(N. Fenneman, 1938)



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 7-2	Physiographic Regions of Massachusetts (Massachusetts Outdoor Recreation Plan, 1973)

The region also contains triassic lowlands in the Connecticut River " valley, 90 miles long and 20 miles wide, geologically similar to the triassic lowlands of northern New Jersey. In addition, the shore area stands somewhat distinct. It is generally submerged north of the Hudson River as a result of the weight of the glaciers. The narrow coastal plain between Portland and Cape Ann was brought into being by a post-glacial rise (not to be correlated to the Coastal Plain of New York).

MOUNTAINOUS SUBREGIONS

The White Mountains are residual mountains left from erosional processes, and invaded by a plateau at the margins. They are a group, not a range of mountains.

The Green Mountains are linear, the result of a north - south uplift.

The Taconic section is predominantly mountainous, but includes limestone valleys in western Vermont and Massachusetts.

7.1.2 ATLANTIC COASTAL PLAIN

The Atlantic Coastal Plain is a seaward-sloping plain, averaging 75 to 100 miles in width, extending from Long Island south (with the exception of Cape Cod to the north). It is a zone of disposition - beaches are characteristically broad and sandy, and long narrow barrier islands are present off the coast in some areas, including Long Island. Geologically it is underlain by Cretaceus, Tertiary and Quaternary sediments.

7.2 GEOLOGY

Mainland geology is discussed on a regional level in Chapter2, section 2.1.3. For more specific coverage at the state and local levels, refer to the various state geology departments.

7.3 METEOROLOGY AND CLIMATOLOGY

Chapter2, section 2.2 discusses climate and meteorology for the entire study area. More detailed information on selected onshore sites is presented in Chapter 4, section 4.4.

7.4 HYDROLOGY

Chapter 2, section 2.3, describes the surface and groundwater hydrology of the region. Section 7.7 more detailed information is available from U.S. Geological Survey reports and state water resources agencies.

7.5 SOILS

7.5.1 REGIONAL OVERVIEW

The North Atlantic Region, as defined by this study, is predominated by a glaciated and glacially influenced terrain. The mainland is comprised mostly of soils on glaciated uplands, outwash terraces and alluvial plains with complex patterns. Long Island and the Cape Cod area (part of the Atlantic Coastal Plain described in section 7.1, General Physiography), are comprised mostly of soils developed in morainic deposits of sand and gravel outwash which overlie thick coastal plain sediments.

In general, the major soil problems on the mainland are shallowness to bedrock, presence of slowly permeable fragipan (hardpan), steepness of slope, stoniness, droughtiness and wetness; on Long Island and Cape Cod, they include doughtiness, irregular topography, wetness and in some places, slowly permeable fragipan. (New England River Basins Commission- 1973)

7.5.2 SOIL SURVEYS AND ANALYSES

GENERAL DISCUSSION

The Soil Conservation Service, (SCS) U. S. Department of Agriculture, has been conducting soils surveys- and publishing them since 1899. Since 1957, published soil surveys have contained interpretations of use suitabilities for each soil type or association mapped, Most contain estimated yields of the common agricultural crops under defined levels of management, land-capability interpretations, soil-woodland interpretations, rangeland interpretations, engineering uses of soils, interpretations for community planning, suitability of the soil for drainage and irrigation, and suitability of the soil for recreation and wildlife,

Soils maps are available at a variety of scales and levels of detail, to suit a variety of needs. The standard maps prepared by the SCS are usually at a scale of 1:24,000, 1:20,000 or 1:15,840. The latter is termed a "detailed soils map," the former two, "general soils maps," because they map "soil associations," distinctive groupings of soils with one or more major soils and at least one minor soil. General soil maps are useful for comparative analysis - identifying tracts of land within a large region which are most suitable for residential,

industrial, commercial, agricultural, recreational, and other uses. They are not suitable maps for planning individual developments or for selecting the exact location of a road or building. Detailed soil maps must be used for this level of planning.

AVAI LABILITY OF SOIL MAPS

Two recent comprehensive regional studies coordinatedby the New England River Basins Commission (NERBC) have included general soils maps as described above (maps of soil associations). These are the Southeastern New England Study (SENE) which mapped soil associations on 16 watershed maps, and the Long Island Sound Study (LISS) which includes a General Soil Map on a scale of 1:62,500, for the entire study area. These are available from NERBC offices in Boston and New Haven.

Detailed soil surveys are published on a county by county basis. A list of published surveys is contained in Table 7-1. Surveys are also conducted on a town by town basis. These are available in unpublished form from the SCS District Offices. A list of towns surveyed is presented in Table 7-2, together with the appropriate SCS District offices to contact for these. Table 7-3 lists in full the SCS District Offices in the study region.

7.6 TOPOGRAPHY

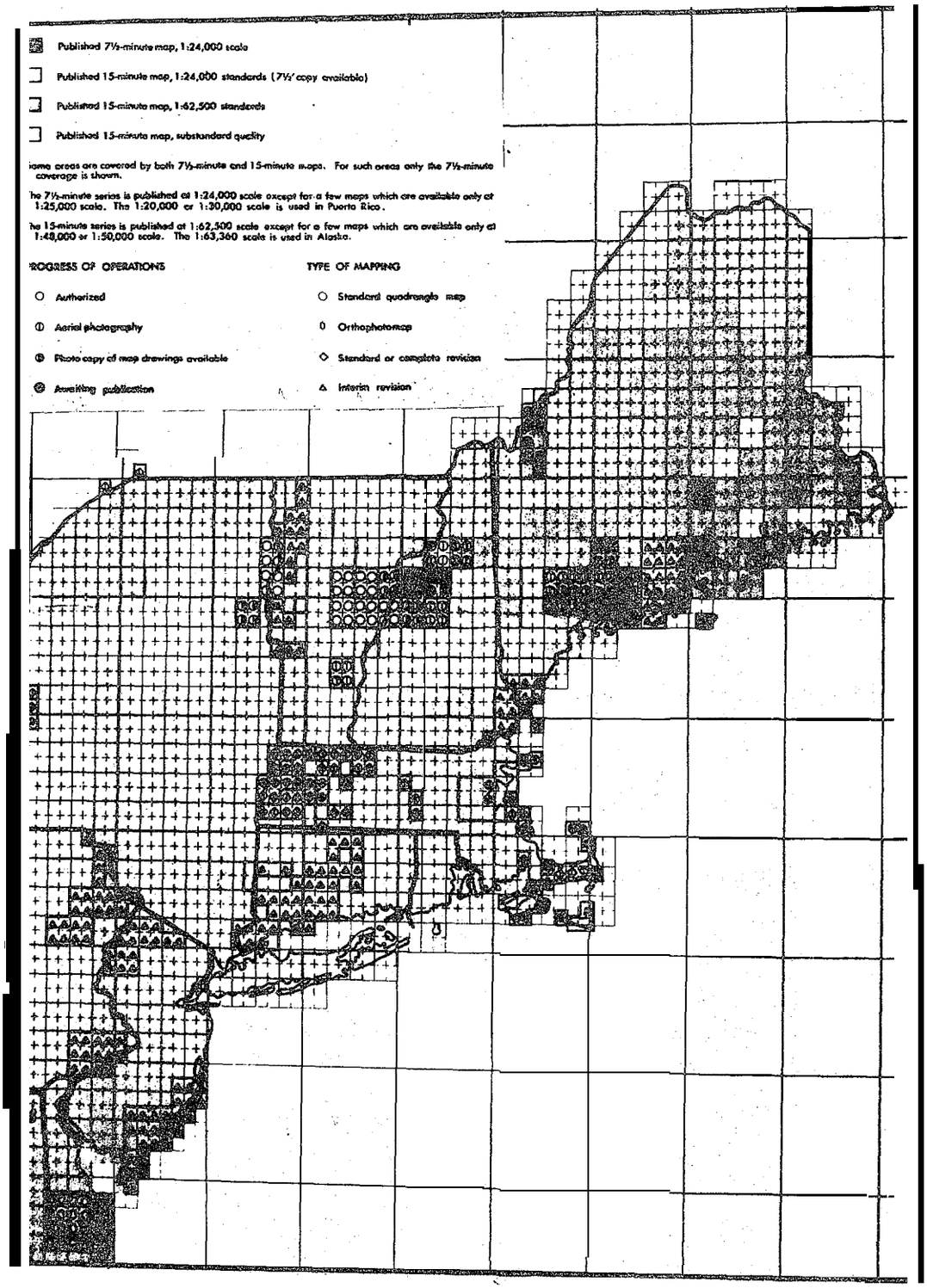
The status of topographic mapping in the study region is shown on Figure 7-3, current to June 30, 1973. The U.S. Geological Survey is the agency involved in this effort. Indices showing the types of maps available for a particular state are available. In general, the maps are drawn either at a scale of 1:24,000 (7½ minute quadrangles) or 1:62,500 (15 minute quadrangles). A general picture of the topography of the area is presented in the discussion of general physiography, section 7.1, Figure 7-1.

Aerial photographs are available from a number of agencies. Figure 7-4 shows the status of aerial photography in the study region.

7.7 VEGETATION

7.7.1 INTRODUCTION

The following discussion is a general treatmentof major vegetative associations found in the terrestrial portion of the study region, excluding the maritime strand habitat discussed in Chapter 6.0. In the broadest sense, forest associations can be considered macro biological associations and freshwater wetlands, lakes and ponds, rivers and streams, shrub and brush, and open fields, micro associa-



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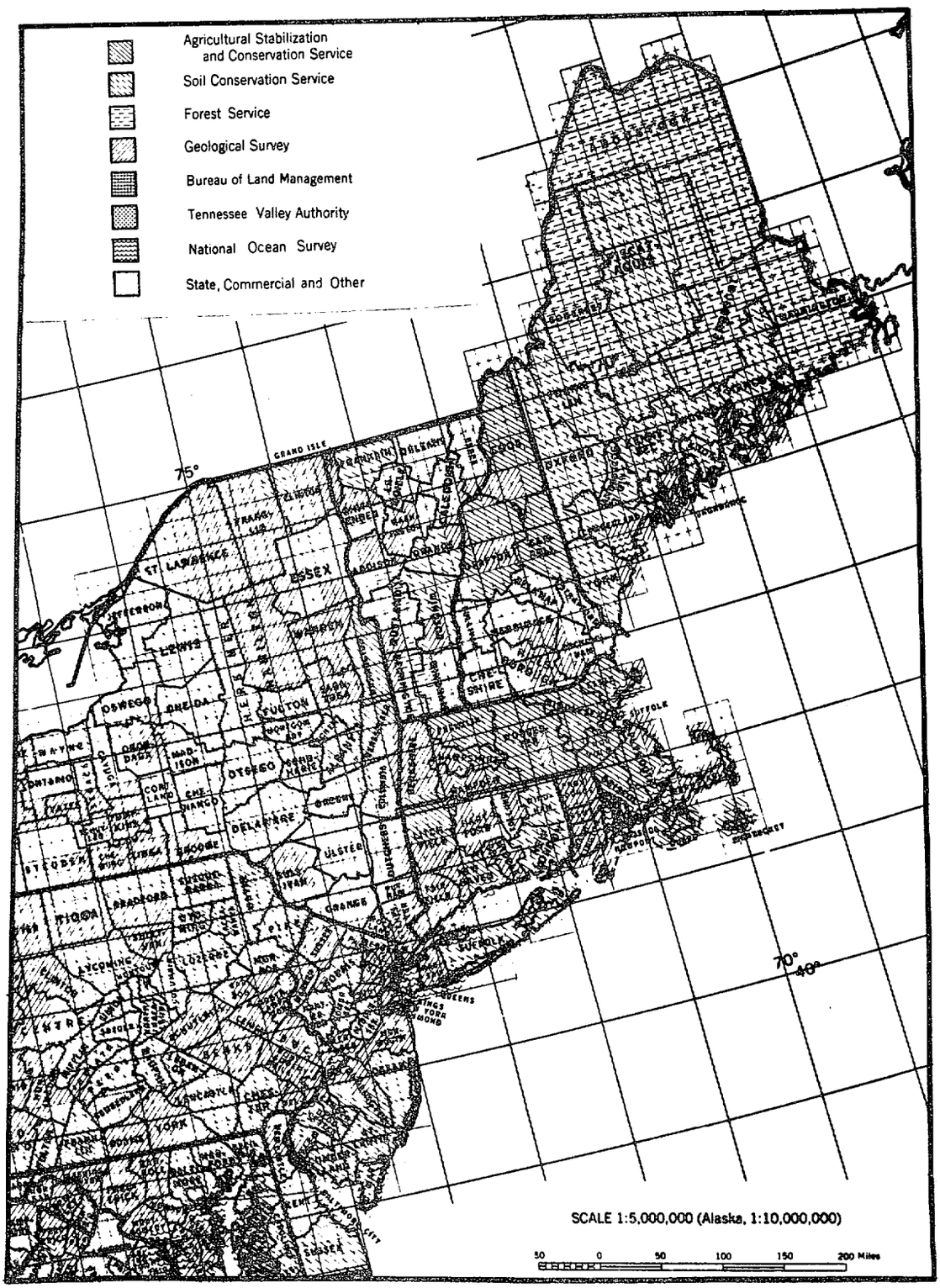
TRIGOM PARC | FIGURE 7-3 | Status of U.S. G.S. Topographic Mapping



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TRIGOM PARC

FIGURE 7-4

Status of Aerial Photography-June 1973

Table 7-1 Detailed Soil Surveys Coastal Counties[a]

MAINE

Androscoggin and Sagadahoc (1970)
Cumberland (1974)
[b]Waldo (1955)
[b]York (1952)

NEW HAMPSHIRE

Strafford (1973)
Rockingham (1959)

MASSACHUSETTS

Essex (1925)
[b]Middlesex (1924)
[b]Norfolk, Bristol, Barnstable (1920)
Plymouth (1969)
Dukes and Nantucket (1925)

RHODE ISLAND

Kent and Washington (1939)
Newport and Bristol (1942)
Providence (1943)

CONNECTICUT

[b]New London (1912)

NEW YORK

[b]Suffolk and Nassau (1928)

NEW JERSEY

Passaic (1974)

[a]Published reports only
[b]Out of print

Sources: USDA, 1973; SCS District Offices in Orono, Maine, Durham N.H., Amherst, Mass., Storrs, Conn., Somerset, N.J. (written communications).

Table 7-2 Soil Survey Completed in Coastal Towns[a]

State/County	Town	SCS District Office
MAINE		
Washington	Calais	Machias
	Perry	"
	Lubec	"
	Eastport	"
	[b]Machiasport	"
	[b]E. Machias	"
	[b]Millbridge	"
	[b]Harrington	"
Hancock	Gouldsboro	Ellsworth
	Brooklin	"
	Hancock	"
	Lamoine	"
	Sedgwick	"
	Stonington	"
	Tremont	"
	Trenton	"
	Verona	"
	Winter Harbor	"
	Sorrento	"
Waldo	Belfast	Belfast
	Winterport	"
	Brooks	"
	Searsport	"
	Stockton Springs	"
	Unity	"
Knox	Owls Head	Rockland
	Camden	"
	Warren	"
	[b]Appleton	"
Lincoln	Nobleboro	Rockland
	Newcastle	"
	S. Bristol	"
	Westport	"
	Dresden	"
	Wiscasset	"
Sagadahoc/Androscoggin	All	Auburn
Cumberland	All	Portland

York	Berwick	Sanford
	Kennebunk	"
	Old Orchard Beach	"
	N. Berwick	"
	Buxton	Portland
NEW HAMPSHIRE		
Strafford	All	
Rockingham	All	
MASSACHUSETTS		
Essex	Salisbury	Acton
	Amesbury	"
	Newburyport	"
	Newbury	"
	Haverhill	"
	Groveland	"
	Rowley	"
	Boxford	"
	North Andover	"
	Andover	"
	Topsfield	"
	Manchester	"
	Beverly	"
Middlesex	Dracut	Acton
	Tewksbury	"
	Wilmington	"
	N. Reading	"
	Woburn	"
	Winchester	"
	Burlington	"
	Lexington	"
	Lincoln	"
	Bedford	"
	Billerica	"
	Chelmsford	"
	Westford	"
	Littleton	"
	Boxborough	"
	Acton	"
	Stow	"
	Concord	"
	Sudbury	"
	Wayland	"
	Natick	"
	Sherborn	"
	Holliston	"
	Ashland	"

Norfolk	Needham	Acton
	Dover	"
	Westwood	"
	Medfield	"
	Walpole	"
	Minis	"
	Medway	"
	Bellingham	"
	Franklin	"
	Norfolk	"
	Wrentham	"
	Foxboro	"
	Sharon	"
	Canton	"
	Stoughton	"
	Avon	"
	Holbrook	"
	Braintree	"
	Cohasset	"
Plymouth	Hingham	Raynham
	Scituate	"
	Norwel 1	"
	Rockland	"
	Lanover	"
	Whitman	"
	East Bridgewater	"
	West Bridgewater	"
	Bridgewater	"
	Hal i fax	"
	Pembroke	"
	Marshfield	"
	Duxbury	"
	Plympton	"
	Middleboro	"
	Carver	"
	Plymouth	"
	Wareham	"
Barnstable	Falmouth	Raynham
	Brewster	"
	Harwick	"
	Orleans	
Bristol	Easton	Raynham
	Mansfield	"
	Norton	"
	Taunton	"
	Dighton	"
	Rehoboth	"
	SwanSea	"

RHODE ISLAND		
Providence	cCumberland	West Warwick
	cCranston	" "
	cE. Providence	" "
Kent	E. Greenwich	West Warwick
	cW. Greenwich	" "
	(Exeter Area)	
Washington	cExete r	West Warwick
	cRichmond (Exeter Area)	" "
	North Kingston	" "
	'Charleston	" "
Newport	Portsmouth	West Warwick"
	Tiverton	" "
	Little Compton	" "
CONNECTICUT		
New London	Bozrah	Norwich
	East Lyme	"
	Groton	"
	Ledyard	"
	Lisbon	"
	Montville	n
	New London	"
	North Stonington	"
	Norwich	"
	Preston	"
	Stonington	"
	Waterford	"
New Haven	Branford	Wallingford
	East Haven	"
	Hamden	"
	Meriden	"
	North Branford	"
	North Haven	"
	Wallingford	"
Fairfield	Wi 1 ton	Bethel '
NEW YORK		
Westchester	'All coastal towns	New City
Bronx	" " "	" "
Queens	" " "	" "
Nassaw	'Northern coastal towns	Riverland
Suffolk	" " "	"

NEW JERSEY		
Middlesex	Monroe East Brunswick	Somerset
Passaic	Whole county	Somerset

---

[a] Towns lying within coastal counties
[b] Field surveys completed only
[c] Partial; does not include entire town
[d] In published form
[e] Within LISS area

Sources: Written Communications, SCS District Offices; NERBC, 1973.

Table 7-3 SCS State/District Offices Coastal Region

MAINE

District Conservationist
Federal Bldg. and P.O.
49 Court Street
Machias 04654
Phone 207-255-3995

District Conservationist
P.O. 60X 456
Federal Bldg.
Ellsworth 04605
Phone: 207-677-8663

District Conservationist
37 Church Street
Belfast 04915
Phone: 207-338-2320

District Conservationist
Federal Bldg.
21 Limerock Street
Rockland 04861
Phone 207-594-5232

District Conservationist
108 Court Street
Auburn 04210
Phone: 207-782-1352

District Conservationist
Federal Bldg. and P.O.
151 Forest Avenue
Portland 04101
Phone: 207-77.5-3131 X0556

District Conservationist
P.O. Bldg. -"
30 School Street
Sanford '04073
Phone: 207-324-2934

NEW HAMPSHIRE

State Conservationist
Federal Bldg.
Durham 03824

MASSACHUSETTS

State Conservationist
29 Cottage Street
Amherst 01002

District Conservationist
Acton 01720

District Conservationist
Raynham 02767

RHODE ISLAND

State Conservationist
222 Quaker Lane
West Warwick 02893

CONNECTICUT

District Conservationist
Rte. 6, Stony Hill
Bethel 06801

District Conservationist
Agricultural Center
Haddam 06438

District Conservationist
562 New London Turnpike
Norwich 06260

District Conservationist
Agricultural Center
Wallingford . 0 6 4 9 2

NEW, YORK

District Conservationist
23 Hampstead Road
New City-10956. . .

District Conservationist
127 East Main Street
Riverhead, 11901

NEW JERSEY

State Conservationist
P.O. Box 219, 1370 Hamilton Street
Somerset 08873

tions within the region. Variability due to soils, geology, hydrology and climatology from one area to the next is so great that it is felt only a general treatment at the macro level (focussing on forest associations) is within the scope of the present study. Detailed inventories of the above listed microenvironment should be undertaken for impact analysis of specific landed activities (pipeline construction, refinery locations, etc.).

7.7.2 FOREST ASSOCIATIONS

GENERAL DISCUSSION

The Society of American Foresters (1967) has classified eastern United States forest cover types into four broad associations: Northern, Central, Southern and Tropical (see Figure 7-5). Within the present study region, two of these occur, the Northern and Central Associations. Within each of these categories, forest types are listed according to their association with soil moisture conditions. Three such divisions are recognized:

1. Dry - Situations which are dry due to light porous soil, shallow soil, steep slopes or ridges, or low rainfall.

2. Fresh to Moist- Situations with reasonably good but not excessive soil moisture.

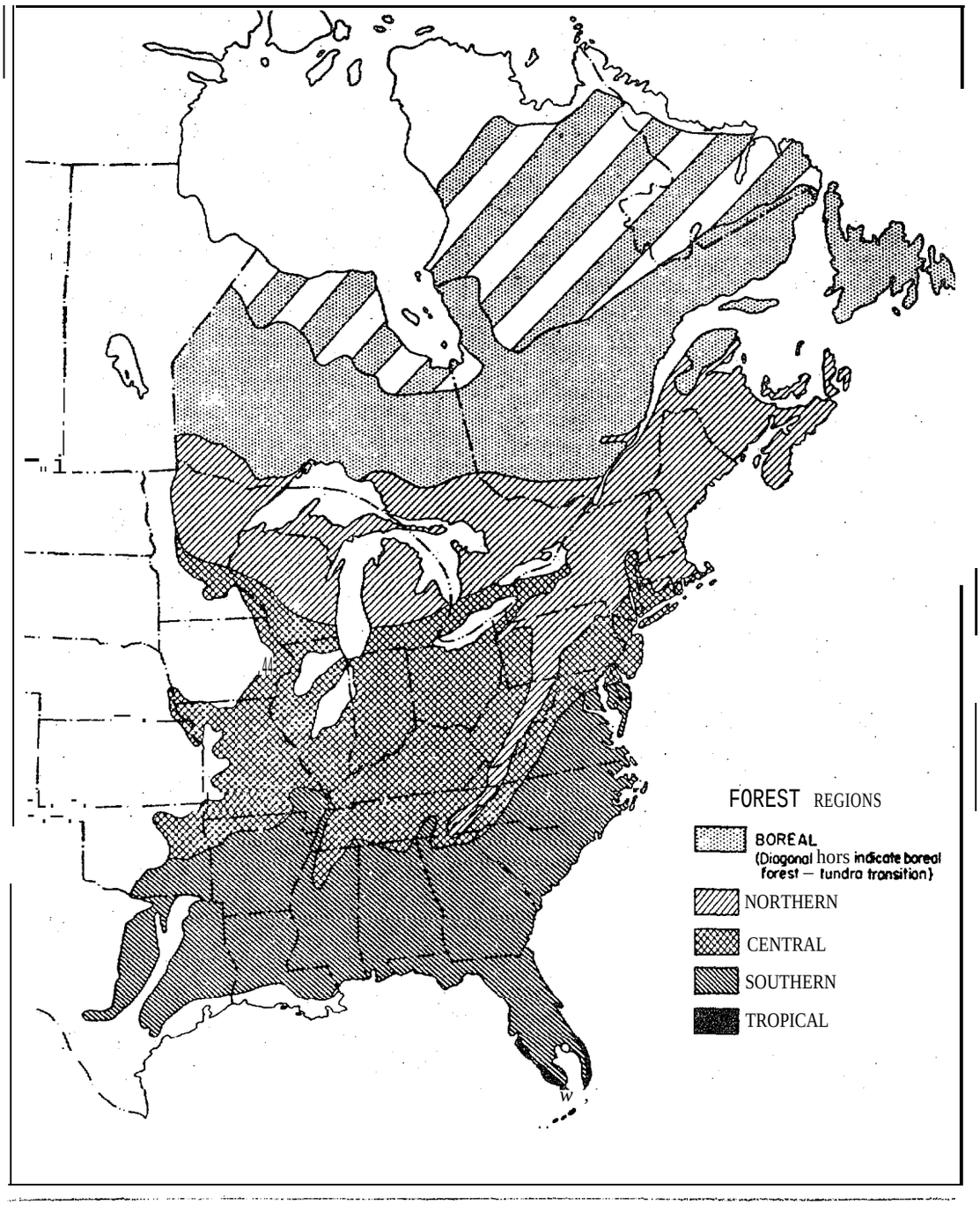
3. Wet - Situations having an excessive supply of moisture, at least part of the year.

Table 7-4 lists the types according to this system. The following discussion will describe in greater detail the forest types and associations found in New England and the New York - New Jersey area.

FOREST COVER TYPES IN NEW ENGLAND

Relatively few maps showing detailed forest associations exist for New England in its entirety. Most mapping efforts have been either broad brush, encompassing the entire United States, or restricted to single states or even regional planning districts. In addition, existing maps are constructed according to differing concepts for differing purposes, and often show little correlation. These are discussed below.

U. S. Forestry Service surveys, often done in conjunction with state forestry agencies, are mapped to show “current cover types.” Figure 7-6 is an example. Under this scheme, a spruce-fir-hardwood forest recently cut for softwoods only would be designated as a hardwood forest. Similarly, an oil field grown over with pine, even though it supported hardwoods prior to cultivation, would be classed as a softwood type. While such maps may be useful for short-range.



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TR W	FIGURE 7-5	Forest Associations in the Study Area

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 7-6

Forest Associations in Maine

Table 7-4 - List of the Forest Cover Types of Eastern North America Showing Arrangement by Forest Regions and Moisture Relationships

Type number	Cover type	Type groups S.A.F.	Type groups U.S. Forest Survey
	Northern Forest Region		
Dry			
14	Northern pin oak		16
15	Red pine		11
42	Bur oak		16
Fresh to moist			
16	Aspen	Aspen-birch-pin cherry	20
17	Pin cherry		20
18	Paper birch		20
19	Gray birch-red maple		20
20	White pine-northern red oak white ash		11
21	White pine	White pine	11
22	White pine-hemlock		11
23	Hemlock		12 or 19
24	Hemlock-yellow birch		19
25	Sugar maple-beech-yellow birch	Northern hardwood-hemlock	19
26	Sugar maple-basswood		19
27	Sugar maple		19
28	Black cherry-sugar maple		19
29	Black cherry		19
30	Red spruce-yellow birch		12
31	Red spruce-sugar maple-beech		12
32	Red spruce		12
33	Red spruce-balsam fir	Spruce-fir	12
34	Red spruce-Fraser fir		12
35	Paper birch-red spruce-balsam fir		12 or 20
36	White spruce-balsam fir-paper birch		1 2
Wet			
12.	Black spruce	Northern coniferswamp	1 2
37	Northern white-cedar		12
38	Tamarack		12
39	Black ash-American elm-red		
	Central Forest Region		
Dry			
40	Post oak-black oak	Oak-Hickory	16
41	Scarlet oak		16
42	Bur oak		16
43	Bear oak	Pitch pine-oak	16
44	Chestnut oak		16
45	Pitch pine		11 or 14

Table 7-4 (Cont.)

Type number	Cover type	Type groups	
		S.A.F.	U.S. Forest Survey
75	Shortleaf pine		14
76	Shortleaf pine-oak	Shortleaf	4 or 15
77	Shortleaf pine-Virginia pine	pine-	14
78	Virginia pine-southern red oak	Virginia	4 or 15
79	Virginia pine	pine-oak	14
46	Eastern redcedar		5 or 16
47	Eastern redcedar-pine	Eastern	5or 16
48	Eastern redcedar-hardwoods	redcedar	5or 16
49	Eastern redcedar-pine-hardwoods		5 or 16
50	Black locust		16
51	White pine-chestnut oak		11
Frest to moist			
52	White oak-red oak-hickory	Oak-	16
53	White oak	Hickory	16
54	Northern red oak-basswood-white ash	Northern	16
55	Northern red oak	red oak	16
56	Northern red oak-mockernut hickory-sweetgum		16 or 17
57	Yellow-poplar	Yellow	16
58	Yellow-poplar-hemlock	poplar	16
59	Yellow-poplar-white oak-northern red oak		16
60	Beech-sugar maple		19
61	River birch-sycamore		18
62	Silver maple-American elm		18
63	Cottonwood		18
64	Sassafras-persimmon		16
65	Pin oak-sweetgum		16 or 17
95	Black willow		18
Wet			
97	Atlantic white-cedar		17

[a]
11. White-red-jack pine
12. Spruce-fir
14. Loblolly-shore leaf pine
15. Oak-pine
16. Oak-hickory
17. Oak-gum-cypress
18. Elm-ash-cottonwood
19. Maple-beech-birch
20. Aspen-birch

Source: S.A. F. (1967)

Table 7-5 ALLOCATION OF S.A.F. FOREST COVER TYPES IN NEW ENGLAND TO NEW ENGLAND FOREST ZONES [a]

Zone	S.A.F. [b] type no.	Stage in succession
1. *Spruce—Fir—Northern Hardwoods*		
A, **Spruce—Fir—Intolerant** Hardwoods		
Red spruce-balsam fir	33	Climax
Paper birch—red spruce-balsam fir	**35**	**Sub-climax**
Red spruce	32	Climax
Balsam fir	5	**Climax** or sub-climax
White **spruce—balsam** fir-paper birch	36	Climax
Black spruce	12	**Climax**
Tamarack	38	Sub-climax
Northern white-cedar	37	Climax
Jack pine	1	"Pioneer
Paper birch	**18**	Pioneer
Aspen	**16**	Pioneer
Pin cherry	**17**	Pioneer
B. Tolerant Hardwoods—Spruce—Fir		
Red spruce-yellow birch	30	Climax
Red spruce—sugar *maple—beech*	**31**	Climax
Hemlock	23	**Climax**
Hemlock—yellow birch	24	Sub-climax
Sugar maple-beech-yellow birch	25	Climax
Paper birch	18	Pioneer
Aspen	16	Pioneer
Pin cherry	17	Pioneer
2. Northern *Hardwoods—Hemlock—White Pine*		
Sugar maple—beech—yellow *birch*	**25**	Climax
White pine	**21**	Sub-climax
Hemlock	**23**	Climax
Sugar maple	**27**	Climax
Northern red oak	**55**	Sub-climax
Red pine	**15**	Sub-climax
Paper birch	**18**	Pioneer
Aspen	**16**	Pioneer
Gray birch—red maple	**19**	Pioneer
Pin cherry	**17**	**Pioneer**
3. Transition *Hardwoods—White Pine-Hemlock*		
White oak—red oak—hickory	52	Climax **or** sub-climax
Northern red oak—basswood-white ash	54	Climax or subclimax
White pine—northern red *oak—white ash*	20	Climax or sub-climax
White, pine—hemlock	22	**Climax or** sub-climax
Hemlock	**23**	**Climax**
Northern red oak	**55**	Climax or sub-climax
Paper birch	**18**	Pioneer
Aspen	**16**	Pioneer
Pin cherry	**17**	Pioneer
Pitch pine	**45**	Sub-climax
4. *Central Hardwoods—Hemlock—White P* in is		
White pine-red oak—white ash	**52**	Climax or sub-climax
White pine-hemlock	**22**	Climax or sub-climax
Hemlock	23	Climax
Northern red oak	**55**	Sub-climax
White oak	53	**Climax**
Gray birch-red maple	**19**	**Pioneer**
Pitch pine	4.5	Sub-climax
Eastern redcedar	46	Pioneer
5. *Central Hardwoods—Hemlock*		
White oak—red oak—hickory	**52**	**Climax** or sub-climax
Yellow-poplar—white oak—northern red oak	**59**	**Climax** or sub-climax
Chestnut oak	**44**	Climax
Eastern redcedar	**46**	Pioneer
Hemlock	23	Climax
White oak	53	Climax
Black ash—American elm—red maple	39	Climax
River birch-sycamore	61	Climax or **sub-climax**
Gray birch—red maple	19	Pioneer
Silver **maple—American** elm	**62**	**Sub-climax**
Atlantic white-cedar	**97**	Climax
Beech—sugar maple	**60**	Climax
Scarlet oak	**41**	**Sub-climax**
Bear Oak	**43**	**Sub-climax**
Pitch pine	**45**	Subclimax
6. *Pitch Pine—Oak*		
Scarlet oak	46	**Sub-climax**
Pitch pine	**45**	**Sub-climax**
Bear oak	43	**Sub-climax**
Chestnut oak	44	**Climax**
White oak—red oak—hickory	**52**	**Climax** or Nil)-elilt):]x

a. The ital icized types are those that characterize the zone
b. See attachment. 7.7-1 for full description

source: Westveld et.al. (1956)

immediate impact analysis, they could be misleading if viewed as indicators of ecological habitats and used for long range ecological impact analysis. Artificially altered forest zones do not reflect the climatic complex which fostered the original forest type, for one reason. In addition, induced changes drastically altered the original ecology, so that a naturally occuring hardwood forest would have a substantially different ecology than one created by the selective cutting of softwoods.

The Society of American Foresters undertook mapping "natural forest vegetation zones" in New England in 1955, with the goal of showing the kinds of forest that originally existed or are likely to develop. (See Figure 7-7). Essentially this involved the reconstruction of climax forests. Such a map is of greater significance for long range ecological impact analysis than those constructed by the Forest Service.

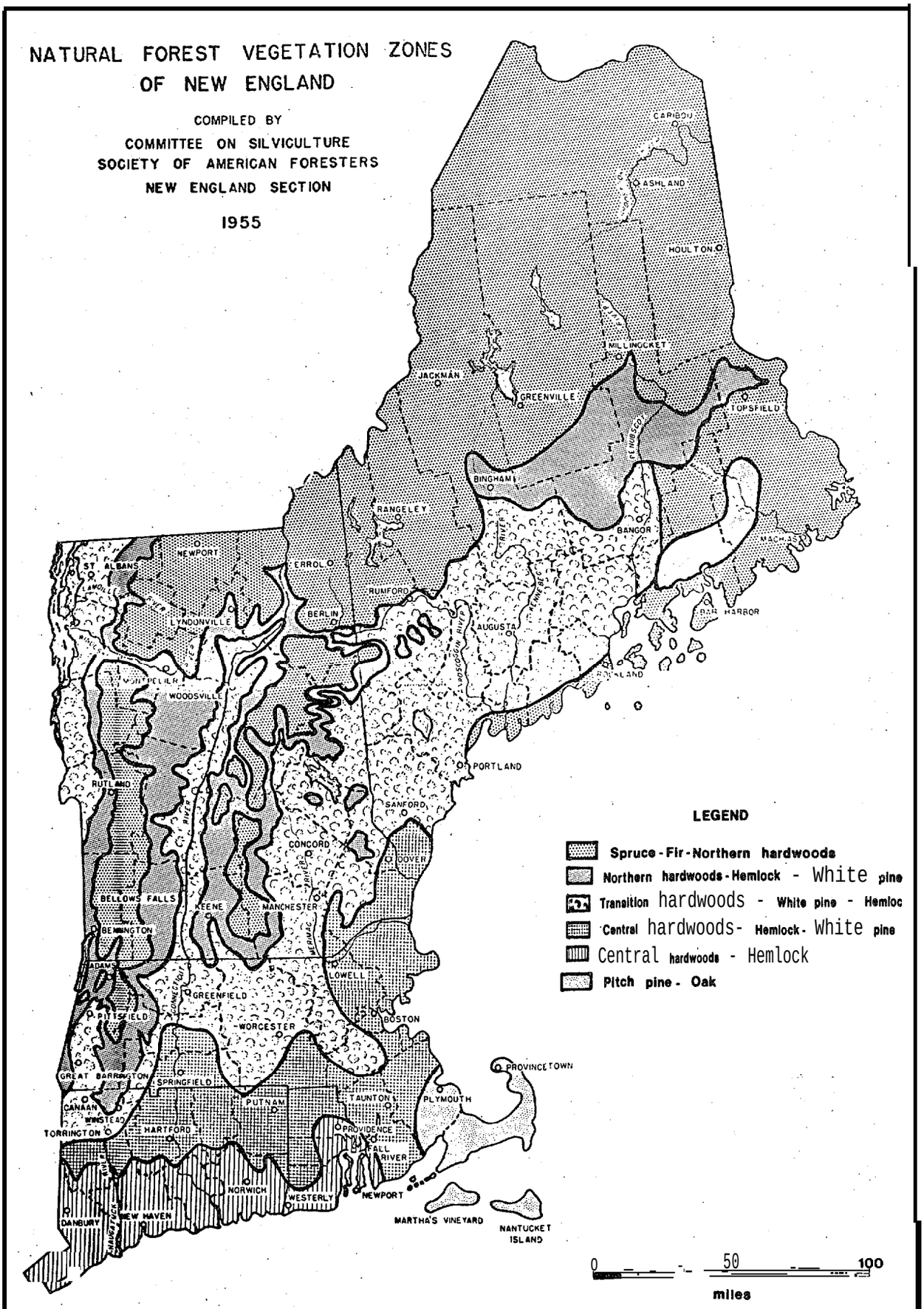
The following extracts from Westveld (1956) describe the six zones mapped on Figure 7-7.

Zone 1

SPRUCE-FIR-NORTHERN HARDWOODS

The most northerly zone, referred to in the past as spruce or spruce-fir, has been renamed the Spruce-Fir-Northern Hardwoods Zone in recognition of the principal species comprising the softwood and hardwood components of these stands. Foresters recognize two subdivisions in this zone: one in which the hardwood component consists principally of the tolerant beech, yellow birch, and sugar maple, the other in which the hardwood component consists of the tolerant paper birch, aspen, and frequently red maple. The latter tend to occupy the higher mountain elevations above the limits of the tolerant species mentioned or swamps and poorly drained areas adjacent to streams and lakes. These sub-zones are so intermingled as to defy demarcation on a zonal map.

Composition varies with forest type. Pure spruce-fir stands are commonly encountered on high slopes, old-field associations, and swamps. On the high slopes red spruce predominates; on old fields white spruce is frequently found as an associate; in swamps black spruce is the key species with tamarack and northern white-cedar frequently present. On the other slopes and well-drained flats, beech, sugar maple, and particularly yellow birch, are common components. Red spruce, the indicator species, is usually in the minority. On the shallower more slowly drained soils, red maple, paper birch, aspen, black ash, cedar, tamarack, and



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTHEASTERN REGION

TRIGOM PARC | FIGURE 7-7 | Natural. Forest Vegetation Zones

white pine occur frequently. Mountain-and striped maple are common understory trees, particularly in the tolerant hardwood subdivisions, and less frequently, mountain-ash. Hemlock occurs in both subdivisions but is more common at the lower elevations in the tolerant hardwood division. In some sections, as in parts of eastern Maine, it may be the predominant conifer. Abandoned fields and pastures are quickly taken over by red and white spruce. While these species usually dominate, balsam fir is often a predominant member. Not infrequently white pine and northern white-cedar occur scatteringly. The temporary paper birch, aspen, and pin cherry stands so commonly encountered are the result principally of fire or windthrow.

The Spruce-Fir-Northern Hardwoods Zone extends from the Berkshires in western Massachusetts northward through the Green and White Mountains and northeastern Maine. It occupies elevations from sea level in eastern Maine to 4,500 feet in the mountainous portions of New England. The soils of this region are strongly podsolized.

Zone 2

NORTHERN HARDWOODS-HEMLOCK-WHITE PINE

The forests of this zone strongly resemble the Tolerant Hardwood subdivision of Zone 1; however, white pine and hemlock, rather than red spruce, characterize the softwood component. Beech, sugar and red maple, and yellow birch dominate the forests. Hemlock, white pine and occasional red and white spruce and balsam fir occur in mixture with light representations of white ash, black cherry, sweet birch, paper birch, northern red oak, American elm, and basswood. In the understory occur occasional horn beam and hophorn beam. Old field associations in this zone are dominated by white pine with additions of hemlock and occasional spruce and balsam fir, As in the Spruce-Fir-Northern Hardwood Zone, destructive fires are usually followed by stands of aspen and paper birch.

This zone just barely reaches into northwestern Connecticut, it covers much of western Massachusetts, southern and central Vermont and New Hampshire and southwestern Maine as a belt extending along the southern edge of the Spruce-Fir-Northern Hardwood Zone. Hickories and oaks other than red oak are absent except near the southern margins of the zone where they are generally restricted to dry hilltops, knobs, and outwash soils. Red oak may be

common throughout and accounts for considerable areas having been typed as oak-hickory in the past. In the north the forests of this zone attain best development on the lower hills and ridges, giving way at higher elevations to types in which spruce and fir supplant white pine and hemlock. Soils are far less strongly podsolized than in the Spruce-Fir-Hardwood Zone and duff mull soils are of frequent occurrence.

Zone 3

Transition Hardwoods-White Pine-Hemlock

The Transition Hardwoods-White Pine-Hemlock Zone, as the name implies, contains a variety of species characteristic of the zones immediately to the north and south of it. Here the beech, birches, and maples of the north overlap the oaks and hickories of the central regions. Thus the majority of hardwoods endemic to New England occur in this zone. These may occur in the same forest. or northern and southern types may alternate in a mosaic. A variety of oaks and hickories tend to occupy hilltops and sandy terraces, along with white pine, some paper birch, quaking and big toothed aspen and occasionally red pine; but typical northern hardwood stands may occur on lower slopes, and "coves, especially on heavier soils. On the latter sites, white-ash, red oak, and black birch often reach a greater degreeof abundance than that attained either north or south, but they are so widespread elsewhere that they can hardly be considered as indicators by themselves.

This zone is part of what used to be called the White Pine Region when old-field white pine covered a large percentage of the landscape. This is in marked contrast to original forest, which tended strongly toward an all-aged forest consisting of a wide variety of hardwoods, principally chestnut, red oak, white ash, red maple, and sugar maple with admixtures of white oak, beech, basswood, ironwood, white pine, and hemlock.

Studies at the Harvard Forest have shown clearly that white pine, the characteristic tree in oldfield associations, is only a stage in succession that follows abandonment of land for agricultural use. After cutting of pine there is a strong tendency toward greatly increased representation of hardwoods, especially on the heavier and richer soils. In light sandy soils, white pine is more easily maintained as a permanent type. Heavy cutting in the past, and particularly during the present war years, have left much of the forest of the region in a depleted and deteriorated condition.

The Transition Hardwoods-White Pine-Hemlock Zone occupies southwestern Maine and most of southern New Hampshire. It covers much of eastern and central Massachusetts and a small area in Connecticut around the town of Union. A larger tongue reaches into northwestern Connecticut skirting the lower boundary of the Northern Hardwoods-Hemlock-White Pine Zone. A belt" follows up the Champlain Valley and a narrow strip extends along the Connecticut River Valley of Vermont and New Hampshire. The soils in this zone are preponderantly of the brown podzolic group. Though incipient true podzol mor profiles are frequently encountered, druff mull and even true mull soils are more common.

Zone 4

Central Hardwoods-Hemlock-White Pine

The boundary between this zone and the Transition Hardwoods-White Pine-Hemlock Zone is not easy to establish. The line established by Raup which marks the boundary between the redcedar and white pine old-field succession was assumed to correlate with the hardwoods boundary. In Connecticut the boundary was drawn where sugar maple, beech, or yellow birch taper off to a lesser abundance than they had further north. White birch, which is conspicuous in the Transition Hardwoods Zone, is very local except in the northern fringe of the central hardwoods.

This zone is characterized by an abundance of so-called central hardwoods with black oak, red oak, white oak, chestnut, shag bark and bitternut hickories the dominant species. Usually present also are red maple, chestnut oak, scarlet oak, and black birch. Chestnut, prior to the blight, was an important species in this zone. Since its destruction it has been largely supplanted by the oaks.

Unlike Zone 5 to the south, white pine is still abundant on sandy sites and some old fields, but it may be absent over large intervening areas because of heavier soils or for historical reasons. Although some white pine is usually present, eastern redcedar tends to dominate old-field associations in this zone.

The Central Hardwoods-Hemlock-White Pine Zone extends from southwestern New Hampshire and southwestern Maine southward through eastern Massachusetts to a roughly east-west line extending across central Connecticut and Rhode Island except as noted in Zones 2 and 3. It includes and replaces

the "Tension Zone" shown in previous maps, which reflected the overlapping of pine from the north and central hardwoods from the south.

Zone 5

Central Hardwoods-Hemlock

Zone 5, Central Hardwoods- Hemlock, is strongly dominated by a wide variety of central hardwoods. The key conifer species in this zone is undoubtedly hemlock, though over extensive areas it occurs only as scattered specimens and groups of reproduction which have expanded in the few decades since fires have been well controlled. Studies by Lutz and others indicate its present paucity is due to repeated heavy cutting and fire and that it is now in process of becoming dominant over wide areas in this zone.

Various species of oaks and hickories are prominent constituents of the sand. Very locally sugar maple, beech, yellow-poplar, and red oak may occupy the better sites associated with lower slopes, coves, swales, and valley bottoms. On sandy sites and thin-soiled ridges and slopes xerophytic species, principally black, scarlet, chestnut, and bear oaks may dominate the stands. The characteristic tree of abandoned fields and pastures in this zone is the eastern redcedar.

This zone in New Englandis restricted mostly to central and southern Connecticut, and southern Rhode Island. Mull and duff mull soils are both common but true podzol mors are of rare occurrence and localized.

Zone 6

Pitch Pine-Oak

Zone 7, Pitch Pine-Oak, occupies a relatively small area in New England. It occurs primarily on Cape Cod in extreme eastern Massachusetts and the two islands of Martha's Vineyard and Nantucket. A few outlyers occur in the sand plain" areas of Rhode Island, Connecticut, and Massachusetts where pitch pine and mixtures of white, black, and' red oak vie for dominance. It is only a small part of an extensive zone reaching south into New Jersey Pine barrens.

The" soils of the region belong to the sandy podzol group. In general; they are light and support mixed stands of oaks

and pines. On the very poor dry soils pitch pine dominates. On the better soils oaks, particularly post oak and bear oak, appear in considerable numbers. Repeated fires encourage the increase of pitch pine and scrub oak. Fires and repeated cuttings have left the majority of the stands in poor condition with slow-growing unhealthy trees.

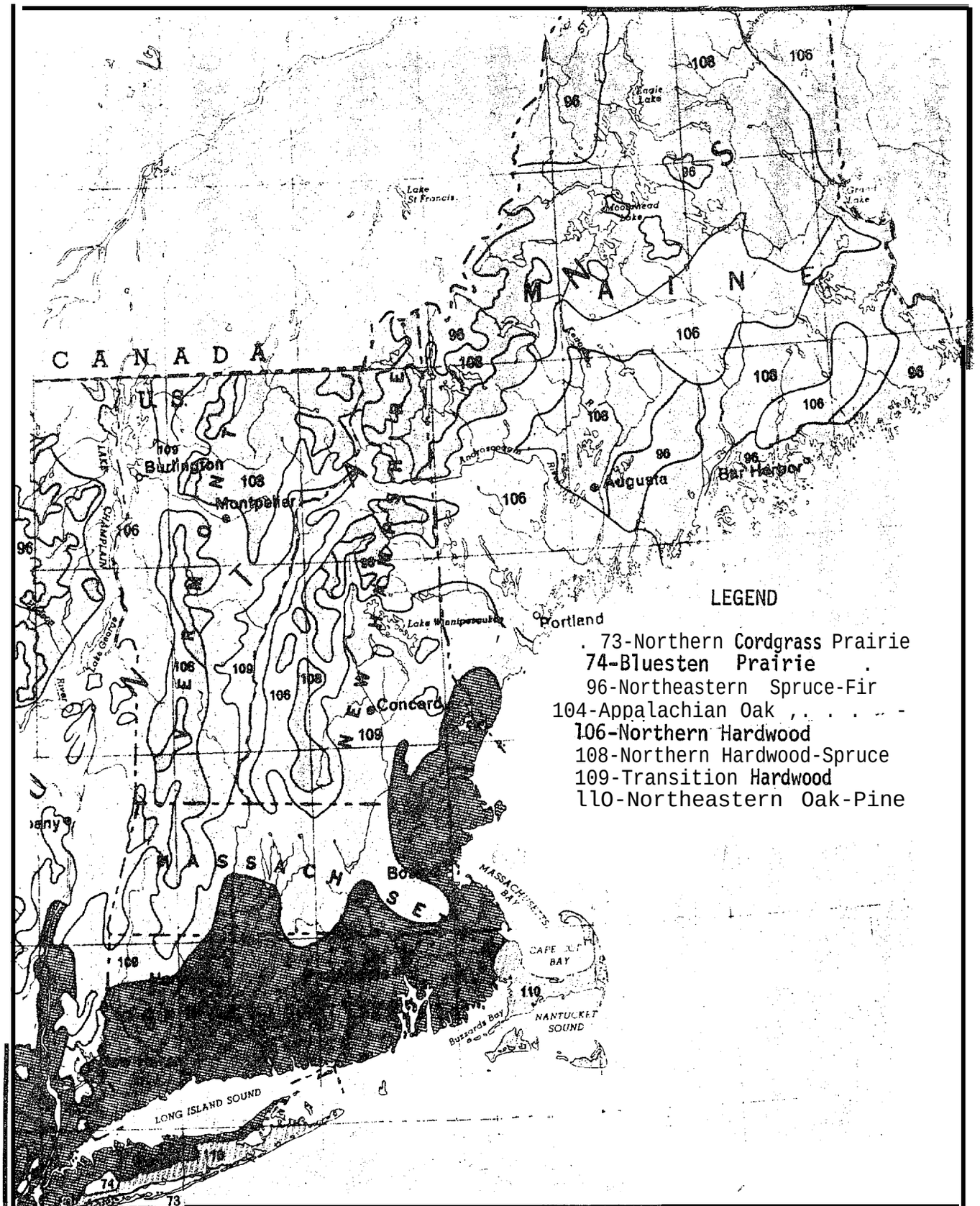
Table 7-5 lists the types found in each zone. A discussion of each type is included in Attachment 7-1.

A. W. Küchler (1964) expanded the above effort to include the entire coterminous United States, again, mapping natural zones, or "potential vegetation" as he termed it. See Figure 7-8 and Attachment 7-2 for a description of the zones.

Both maps presented above (Küchler and S.A.F.) must be qualified due to their generalized nature. Zonal maps lack detailed accuracy, so that forest cover depicted on the maps may not at all times correspond to that encountered on the ground. As might be expected, local variations in soils, climate and hydrology will create small islands and belts of forest types not endemic to the described zone.

FOREST TYPES IN NEW YORK AND NEW JERSEY

See the discussion above on Küchler's map of potential vegetative forest covers (Figure 7-8, and Attachment 7-2).



A SOCIO-ECONOMIC Ah#313JW=K3hJh@iWTAL INVENTORY OF THE NORTH AT LANTIC REGION

TRIGOM PARC	FIGURE 7-8′	Potential Natural Vegetation (A. W. Kuchler, 1964)

ATTACHMENT 7-1: NEW ENGLAND FOREST TYPES

Type 1: JACK PINE

Definition and Composition

Jack pine is pure or predominant. In the Boreal Forest the associates are quaking aspen and paper birch, with some black spruce. In the Northern Forest red pine, northern pin oak, quaking and bigtooth aspen, paper birch, black spruce, and white spruce are associates. Aspen and paper birch are usually coordinate, the others subordinate in mixtures, although red pine may be coordinate.

Nature and Occurrence

Typically, jack pine occupies the driest, most porous sands usually originating from glacial outwash, or is found on eskers; it also occurs on more moist, sandy soils near swamps and on rocky hills and ledges. It tends to occupy more moist sites to the northward. Of limited occurrence in New England and New York and the Maritime Provinces in Canada, the type spreads out in Ontario, Michigan, Wisconsin, and Minnesota into the Prairie Provinces of Canada. The present wide extent of the type is due to past forest fires; in fact, the type has been greatly increased because of fire. With better fire protection the type will no doubt change in composition and shrink in area. Stands are almost always even-aged. Jack pine is a pioneer on the driest sites where it can be considered as a physiographic climax. It is succeeded by red pine or northern pin oak in the central Lake States and by spruce - fir mixtures further north.

Transition Forms and Variants

In the Lake States jack pine - northern pin oak and jack pine - red pine are common transition forms. Northward (northern Minnesota and especially in Canada) jack pine - black spruce is frequently encountered as a typical mixed type in which the proportion of jack pine decreases as stands become older. Jack pine - paper birch and jack pine - aspen are also transition forms.

Type 5: BALSAM FIR

Definition and Composition

Balsam fir is pure or predominant. Its associates are many and varied in different parts of its range including, in the Boreal Forest, black spruce, white spruce, and paper birch. On upland sites in the Northern Forest associates are white spruce, paper birch, quaking and bigtooth aspen, red spruce, yellow birch, beech, red maple, hemlock; in swamps, black spruce, tamarack, red maple, maple, black ash, northern white-cedar.

Nature and Occurrence

This is a very common type in Quebec, northern New England, and the mountainous sections of eastern New York. It is also fairly

widespread in the northern part of the Lake States, especially in mixtures with other species, but somewhat less so as a distinct type in Ontario. In occurs on upland sites on low lying moist flats and in swamps. In the northeastern United States the balsam fir type is relatively spotty, although extensive areas occur particularly in ones on upper slopes. Pure stands are usually the results of heavy cuttings, blowdowns, or may follow infestations of spruce budworm. In New England, balsam fir tends to give way to red spruce, but may be climax in the zone below timberline; it also tends toward a climax type in Quebec and in the Lake States where it replaces aspen and paper birch in the succession.

Transition Forms and Variants

Subdivisions recognized in New England are fir flat, fir slope, and fir swamp. In the Lake States it either is on upland in mixture with aspen and paper birch (sometimes with yellow birch, red maple, and sugar maple) or in swamps with northern white-cedar, black spruce, black ash and balsam poplar. Balsam fir is subclimax in the Boreal Region, where it occupies black spruce upland sites after clear-cutting. It is also an extensive quasi-climax in the southern part of the Boreal Region; young stands in the latter condition are found pure or with an admixture of paper birch, aspen, and white spruce. This type belongs to the better sites. Balsam fir is found in pure stands in Quebec and the Maritime Provinces of Canada, but seldom in pure stands in Ontario.

Type 12: BLACK SPRUCE

Definition and Composition

Black spruce predominates either pure or in mixture with a number of different associates which vary in composition from north to south and are usually minor in proportion. In the Boreal Forest they are: balsam fir, jack pine, quaking aspen, paper birch, tamarack, and northern white-cedar. Proceeding southward to the Northern Forest, jack pine and aspen drop out while black ash and red maple occasionally appear as minor associates.

Nature and Occurrence

Blacks spruce is a very widespread type. It occurs not only in acid peat swamps where it tends to be pure, but also on moist flats and uplands. It is a subclimax type.

Transition Forms and Variants

This is the northern limit type of the Boreal Forest with no transition to associate species, as they are all subclimax. In the Boreal Forest pure black spruce stands are not only found in swamps or semi-denuded areas, but also on slopes, including mountain slopes. In the latter case, the species, constitutes the climatic climax. Minor associates are balsam fir, white spruce, and paper birch; with the exception of white spruce, the other species are more abundant when the stands are young; later on they decrease in number. In Minnesota where it occurs mostly in

poorly drained peat swamps the type tends to be pure but may have some tamarack in mixture. It is sometimes referred to as spruce bog. In Michigan it occurs also on muck soils in association with northern white-cedar, balsam fir, black ash, and red maple. In New York and New England the type is of very scattered distribution. This type is essentially the same as No. 204 of the western types.

Type 15: RED PINE

Definition and Composition

Red ("Norway") pine is pure or predominates in mixtures with white, jack or pitch pines. Among the associates jack pine is coordinate, white pine either coordinate or subordinate, and northern pin oak, white oak, and red maple are subordinate. Paper birch, quaking and bigtooth aspen are sometimes in mixture as coordinates in young stands. In central and southeastern New York, chestnut oak, hemlock, northern red oak, and white pine are common associates.

Nature and Occurrence

Red pine is primarily a type of the southern part of Ontario, Quebec and the Lake States, but has spotty distribution from the Maritime Provinces of Canada through New England, New York, and northern Pennsylvania at elevations from sea level to 1,700 feet. It occurs on sandy and gravelly locations or dry sandy learn soils; often on shallow-soiled rocky knolls and lake shores where it remains as a type only in small scattered patches. In succession it replaces jack pine and in turn gives way to white pine.

Transition Forms and Variants

Red pine commonly starts out as a subordinate species in a jack pine type but takes over as the shorter lived jack pine drops out of the stand. Old stands sometimes break up and are invaded by paper birch as an understory orby shrub species in the Lake States. The type is being expanded greatly through reforestation.

Type 16: ASPEN

Definition and Composition

Quaking aspen, bigtooth aspen, and balsam poplar compose the type singly or in various combinations with each other or with associates. Balsam poplar is not an important constituent except along streams and swamp margins in the Lake States. Paper birch and pin cherry are common associates. Most other species in the Northern Forest Region occur at times as subordinates. An understory of balsam fir is frequently present. Toward the Great Plains bur oak, green ash, American elm, paper birch, boxelder, and pin cherry are in mixture with aspen and balsam poplar.

Nature and Occurrence

The aspen type is very widespread. It is universal throughout the Northern and Boreal Forests and occurs commonly in the Central Forest Region from sea level to elevations of 4,000 feet. It is a ubiquitous type and is found on all kinds of soils except the

very driest sands and wettest swamps. It occurs chiefly on burns, clear-cut areas, and less frequently on abandoned fields and pastures. Thus it is a pioneer type after fires and is relatively short lived. Pin cherry when in mixture, disappears early; all other species tend to outlive aspen. Aspen is succeeded by one of the white pine, northern hardwood, spruce-firs or oak groups of types.

Transition Forms and Variants

The proportion of paper birch varies considerably, and in the Boreal Forest Region a transition type of aspen-paper birch is recognized. Also in the Boreal Forest it forms a transition type with jack pine (jack pine - aspen).

Type 17: PIN CHERRY

Definition and Composition

Pin cherry is pure or predominates. Its associates in the north are quaking and bigtooth aspen, paper birch, red maple, northern red oak, which are either coordinate with or subordinate to the pin cherry. In the southern Appalachians yellow birch, red spruce, Fraser fir, and mountain-ash are associates.

Nature and Occurrence

The type is universal throughout the northern and boreal forests and less commonly is found in the Central Forest from elevations above 600 feet in the north to 4,500 feet in North Carolina. Pin cherry is not exacting as to soil and is a short-lived pioneer type which originates on clear-cut or heavily burned areas. In the north it is scarcely more than a shrub type where it is succeeded by aspen or by the northern hardwood, northern red oak-basswood-white ash, or by the white pine type. In the southern Appalachians it is followed by red spruce, red spruce-Fraser fir or by types of the northern hardwood group.

Transition Forms and Variants

As the type springs up after fire it is fairly well defined but with the encroachment of longer lived species it becomes less so until it loses identity.

Type 18: PAPER BIRCH

Definition and Composition

Paper birch is pure or predominating. Associates include variable proportions of quaking and bigtooth aspen, balsam fir, red spruce, white spruce, white pine, yellow birch, hemlock, red maple, northern red oak, basswood, and others. Most associates are subordinate. Frequently an understory of conifers or tolerant hardwoods is present.

Nature" and Occurrence

The type is universal throughout the Northern Forest Region and the Boreal Forest. In Canada it is found from the Maritime Provinces throughout Ontario and Quebec into Manitoba; in the United

States throughout northern and central New England, northern New York, and the northern halves of the Lake States from near sea level to 3,000 feet on a wide range of upland sites, Paper birch pioneers on burned and clear-cut areas. It is succeeded by the spruce-fir or northern hardwood group of types and sometimes by white pine.

Transition Forms and Variants

The type merges with aspen more than any other and forms such a mixture in the Boreal Forest that an aspen-paper birch type is recognized. It also forms a transition with jack pine and is prominent in types where white spruce and balsam fir are the key species.

Type 19: GRAY BIRCH - RED MAPLE

Definition and Composition

Gray birch and red maple predominate in mixture, with the birch usually being the most numerous. Principal associates are quaking and bigtooth aspen, pin cherry, yellow and paper birch, white pine, white ash, sugar maple, northern red and white oak, and eastern redcedar.

Nature and Occurrence

The type occurs over large areas in Nova Scotia, New Brunswick, southern Quebec, and into eastern Ontario, in central and southern New England, the eastern half of New York, northern New Jersey, and northeastern Pennsylvania from near sea level to 2,000 feet. It occupies a wide variety of sites from sand plains to heavy-soiled uplands and wet margins of streams and ponds, Gray birch-red maple originates on abandoned farm land and on cutover white pine areas on the lighter class of soils. It is succeeded by white pine or by one of several hardwood types. Gray birch is short-lived and disappears in less than 60 years.

Transition Forms and Variants

The type is well defined in the pioneer stage but fades out as more permanent species take over. Eastern redcedar-gray birch is an important variant.

Type 20: WHITE PINE - NORTHERN RED OAK - WHITE ASH

Definition and Composition

Eastern white pine, northern red oak, and white ash compose the type. Red maple is the chief associate but others may appear, among the more common of which are basswood, yellow birch, big-tooth aspen, sugar maple, beech, paper birch, black cherry, hem-lock, and sweet birch.

Nature and Occurrence

This type occurs in central New England and New York at elevations from sea level to 1,500 feet. It is generally found on deep, fer-tile, well-drained soils. It also occurs in Canada on fairly warm dry sites within the zone of the Northern Forest. “A very

similar type appears in northeastern" Iowa, principally on-steep rocky land, limestone or sandstone outcrops; or on sandy soil. The type often follows "old field" white pine in New England but occurs also on land never cleared for agriculture. It may be permanent in some places but in general tends toward the white pine hemlock type or the northern hardwood -hemlock type group.

Type 21: WHITE pINE .

Definition and Composition

Eastern white pine is pure or predominant. Pure stands are characteristic. In the East the associates on light soils are red pine, pitch pine, gray birch, quaking and bigtooth aspen, red maple, pin cherry and white oak. On heavier soils in the Northeast, paper birch, sweet birch, yellow birch,gray birch, black cherry, white ash, northern red oak, sugar maple, basswood, hemlock, red spruce, and northern white-cedar are associated. In the Lake States gray birch, sweet birch, and pitch pine are absent, but balsam fir becomes a subordinate associate in more northerly locations. In the southern Appalachians on moist sites, yellow-poplar, hemlock, northern red oak, and white oak are the main associates. On drier sites, chestnut oak, scarlet oak, shortleaf pine, and pitch pine come in.

Nature and Occurrence

The type occurs throughout the Northern Forest with outposts in the Boreal and Central Forest regions from the Maritime Provinces of Canada through Maine and northern New England west to western Ontario and Minnesota, and south along the Appalachian Mountains to northern Georgia. It is abundant in central New England and northeastern New York at elevations from sea level to 2,500 feet. The type is also widespread in the southern part of Ontario and Quebec. In the southern Appalachians of West Virginia, Virginia, Tennessee, North Carolina, and north Georgia, it is found at elevations of from 1,500 to 4,000 feet, but occasionally as high as 4,100 feet. In Tennessee and North Carolina it was formerly best developedat elevations of 3,000 to 4,000 feet. In the Lake States white pine has been replaced over large areas by aspen; it is most abundant in central lower Michigan, in north-central Wisconsin, and east central Minnesota; being less common further northward. Typically the type prefers a fresh, sandy loam upland but occurs occasionally on clay, in swampy areas, and on loamy sands. White pine is frequently the first type to occupy agricultural land after abandonment where it occurs on land of all soil types. In the southern Appalachians it occupies mountain slopes, flats, and valleys varying widely in soil character from sandy to clayey loam and from relatively moist to dry. The type is a long-lived temporary one, usually subclimax but approaching permanence on sandy soils. On heavier soils it is usually

succeeded by sugar maple-beech-yellow birch, northern red oak-basswood-white ash, hemlock, sugar maple-basswood, white oak, or white spruce-balsam fir, paper birch.

Transition" Forms and Variants

Middle aged and young-mature stands are fairly well defined; older stands on the heavier soils are less so as successional trends toward more tolerant species take effect, White pine seldom succeeds itself except after fires or under special cultural treatment.

Type 22: WHITE PINE - HEMLOCK

Definition and Composition

The type is composed chiefly of eastern white pine and eastern hemlock which are predominant in mixture. The associates are numerous, but none is particularly characteristic. The principal ones are beech, sugar maple, basswood, red maple, yellow birch, black cherry, white ash, paper birch, sweet birch, northern red oak, white oak, chestnut oak, yellow-poplar, cucumbertree, and red spruce.

Nature and Occurrence

White pine-hemlock occurs in small bodies, is much scattered but is not rare. It is present in eastern Ontario and eastward in Canada (but is of very limited occurrence in New Brunswick), in central and southern New England, New York, northeastern Ohio, northern New Jersey, central and northeastern Pennsylvania. It extends southward on mountains to North Carolina and Tennessee where it is rare. In New England, elevations where the type occurs may range from sea level to 1,500 feet, to 3,000 feet in Pennsylvania, and from 1,000 to 4,000 feet in Tennessee and North Carolina. The type is found on a wide range of sites from sand plains to heavy upland soils, but favors cool locations, ravines and north slopes in the southern portion of its range, Although near climax, white pine-hemlock is probably succeeded ultimately by northern hardwoods or hemlock. Occasionally the type is the result of long continuous grazing of farm woods containing scattered pine and hemlock in mixture with the hardwoods .

Transition Forms and Variants

Variations in the type depend largely on the proportion of different hardwoods in mixture which in the north tends toward the sugar maple-beech-yellow birch type.

Type 23: HEMLOCK

Definition and Composition

Eastern hemlock is pure or predominant over any single associate. Among the associated species are beech, sugar maple, yellow birch, basswood, red maple, black cherry, white ash, balsam fir, red spruce, white pine, paper birch, sweet birch, northern red oak, and white oak.

Nature and Occurrence

Formerly an extensive type especially in Pennsylvania it occurs throughout the Northern Forest except in Minnesota at elevations from sea level to 5,000 feet, but above 1,500 feetin the southern Appalachians where it is found in pure stands. It is of limited occurrence in New Brunswick. From Pennsylvania southward it prefers cool locations, moist ravines, and north slopes. In the northern part of the range somewhat drier and warmer situations are tolerated. In northern Wisconsin and Michigan it usually occurs in small bodies much intermingled with sugar maple-beech-yellow birch but aggregating a considerable area. The type is essentially climax but over long periods tends to give way to sugar maple.

Transition Forms and Variants

In the Lake States the type grades off into hemlock yellow birch which is now recognized as a separate type. In the mountains of Virginia a hemlock-white oak variant is sometimes present. In the northeast a hemlock-hardwood mixture is not uncommon,

Type 24: 'HEMLOCK - YELLOW BIRCH

Definition and Composition

Hemlock and yellow birch are predominant in mixture, Associates are red maple, sugar maple, American elm, basswood, black ash, and northern white-cedar.

Nature and Occurrence

Typically a type of northern Wisconsin and Upper Michigan, it extends into Ontario to the eastward; also at high elevations in the southern Appalachians. Hemlock-yellow birch prefers moist flats, where the two component species have a close affinity for one another. The type is probably subclimax which converts to the climax hemlock as the less tolerant yellow birch drops out of the stand.

Transition Forms and Variants

The better drained and drier areas occupied by the type grade off into sugar maple-beech-yellow birch. The wetter portions merge into the black ash-American elm-red maple type,

Type 25: SUGAR MAPLE - BEECH - YELLOW BIRCH

Definition and Composition

Sugar maple, beech and yellow birch are the component species. Associated are varying admixtures of basswood, red maple, hemlock, northern red oak, white ash, white pine, balsam fir, black cherry, paper birch, sweet birch, American elm, rock elm, eastern hophornbeam, red spruce, and white spruce. In 'the southern Appalachians and in Pennsylvania, yellow buckeye and cucumbertree appear. Beech is absent west of eastern Wisconsin and adjacent upper Michigan.

Nature and Occurrence

The type occurs throughout the Northern Forest, although it is less commonly found in Ontario and is rare in Minnesota. It is the basic hardwood type in Nova Scotia, New Brunswick, and southwestern Quebec, northern New England and New York, where it goes up to 2,500 feet. In the Lake States it goes to 1,600 feet, and in the southern Appalachians it occurs in a zone from 3,500 to 5,500 feet. The type prefers loamy soils of excellent fertility and good moisture conditions, but extends into quite sandy soils in places. It covers extensive areas, except where the forest is broken by settlement, and in southern Pennsylvania and the southern Appalachians where distribute on is spotty. The type is climax. In advanced stages sugar maple, beech, and hemlock assume increasing importance.

Transition Forms and Variants

Proceeding westward from eastern Wisconsin where beech drops out, the type is first sugar maple-yellow birch, which is classed as a variant, then gives way to sugar maple-basswood which is recognized as a cover type. On moister sites in the Lake States the type often grades into hemlock-yellow birch. Yellow birch, formerly recognized as a type, is of such limited occurrence that it is here classed as a variant of the sugar maple-beech-yellow birch type,

Type 27: SUGAR MAPLE

Definition and Composition

Sugar maple is either pure or predominant. A small proportion of other species may be present, such as yellow birch, sweet birch, white ash, beech, northern red or white oak,

Nature and Occurrence

This type occurs throughout the Northern Forest extending into the northern part of the Central Forest. In the southern Appalachians it appears at elevations of 3,000 to 4,500 feet, but elsewhere is at lower altitudes. In northern Ohio it is found chiefly as pastured woods which have been developed for sugar production. Deep, fertile, well-drained soils with good moisture are preferred, The type exists usually in small patches where it may be classed as climax. In places it owes its origin to cultural practices.

Transition Forms and Variants

Sugar maple merges into the sugar maple-beech-yellow birch type in the Northern Forest and the beech-sugar maple type in the Central Forest.

Type 30: RED SPRUCE - YELLOW BIRCH

Definition and Composition

Red spruce and yellow birch predominate. In the north the associates are balsam fir, red maple, paper birch, northern white-cedar, and occasionally white spruce; in the southern Appalachians

they are Fraser fir, yellow buckeye, beech, sugar maple, and mountain-ash.

Nature and Occurrence

This is a common type in Nova Scotia, New Brunswick, southeastern Quebec, the north shore of the lower St. Lawrence River, northern New England, and New York at low elevations on lower slopes and moist well-drained flats. In the southern Appalachians it appears at elevations of 3,500 to 5,000 feet. Owing to heavy losses from "birch dieback" this type covers less acreage than formerly. On moist sites it is possibly climax.

Transition Forms and Variants

The type sometimes is referred to as yellow birch. Pure yellow birch, however, occurs over such limited areas that it is-no longer recognized as a separate cover type.

Type 31: RED SPRUCE - SUGAR MAPLE - BEECH

Definition and Composition

Sugar maple and beech predominate. Red spruce, the indicator species, is usually in the minority. Balsam fir, hemlock, and red maple are often present.

Nature and Occurrence

This is a common type in the Maritime Provinces of Canada, adjacent portions of Quebec, northern New England, and the mountainous portions of New York. It is found on deep, well-drained, fertile soils of lower slopes, benches, and ridges where it is probably a climax type.

Type 32:'. RED SPRUCE

Definition and Composition

Red spruce is either pure or predominant. Associates in the north are balsam fir, paper birch, yellow birch, sugar maple, beech, red maple, hemlock, white ash, and mountain-ash. In the southern Appalachians, Fraser fir and yellow buckeye are added.

Nature and Occurrence

The type occurs in the Maritime Provinces of Canada, adjacent portions of Quebec, northern New England, mountainous areas of New York, in Pennsylvania, and in the southern Appalachians. Red spruce is found near sea level in eastern Maine and in the maritimes, from 1,500 to 4,500 feet in New York, above 3,200 feet in West Virginia, and upwards of4,500 feet in elevation in North Carolina and Tennessee. It grows on moderately well-drained to poorly drained flats but not true swamps, on well-drained slopes though not on the best soils, and on thin-soiled upper slopes. It appears on a wide variety of soils on abandoned fields and pastures. The type covers large areas in eastern Canada. New England, and New York, but is much less abundant in the southern Appalachians. It is probably near climax on moist

flats on thin-soiled slopes at high elevations; in other locations it tends to be replaced by tolerant hardwoods such as sugar maple and beech.

Transition Forms and Variants

In New York and New England three variants are generally recognized, as follows: spruce flat, spruce slope, and old-field spruce. In West Virginia red spruce-hemlock is a characteristic variant.

Type 33: RED SPRUCE - BALSAM FIR

Definition and Composition

The type may consist of red spruce and balsam fir only or they may be the predominant trees in mixture with a number of associates. The principal associates are red maple and paper birch with lesser and varying quantities of white pine, hemlock, white spruce, and northern white-cedar.

Nature and Occurrence

Found throughout the Maritime Provinces of Canada, adjacent Quebec, northern New England, and New York, the type occupies-moderately drained to poorly drained flats, but not swamps. It also occurs on thin-soiled upper slopes where the species are restricted to red spruce, balsam fir and paper birch. The type is subclimax and is succeeded by red spruce.

Type 35: PAPER BIRCH - RED SPRUCE - BALSAM FIR

Definition and Composition

Paper birch, red spruce, and balsam fir are predominant. Quaking and bigtooth aspen, red maple, yellow birch, white pine, and northern white-cedar occur as scattered associates.

Nature and Occurrence

Found extensively in the Maritime Provinces of Canada, adjacent portions of Quebec, in Maine, and less frequently in northern New Hampshire and Vermont the type has a fairly wide range on upland soils. The distribution is determined more by treatment than site. It originates on burns in the red spruce types or may succeed the paper birch type. In initial stages aspen is commonly present but owing to its short life is eliminated from the stand. It is succeeded by the red spruce type.

Type 36: WHITE SPRUCE - BALSAM FIR - pApER BIRCH

Definition and Composition

Component species of the type are white spruce, balsam fir, and paper birch. The first two are the key species although they may not always predominate. Quaking and bigtooth aspen, black spruce, and jack pine may also occur as associates in the mixture, and less Commonly white pine, balsam poplar, northern white-cedar, sugar maple, black ash, and yellow birch.

Nature and Occurrence

The type occurs throughout the Northern Forest in Canada, locally in northern Michigan, and in northern Minnesota, The type is also present over large areas in Maine, and has scattered representation in other parts of New England and New York on upland loamy soils. The type is climax, but the paper birch gradually fades out, Along its southern border the type gives way to tolerant hardwoods.

Transition Forms and Variants

The proportion of the component species varies greatly in different localities.. In the Lake States, balsam fir tends to be much more prominent in the type than white spruce. Consequently the type is frequently referred to as balsam fir-white spruce-paper birch. This is especially appropriate in second-growth stands because the balsam reproduces much more abundantly than the spruce.

Type 37: NORTHERN WHITE - CEDAR

Definition and Composition

Northern white-cedar is pure or predominates. In the Boreal Forest the associates Include limited proportions of balsam fir and tamarack. In the, Northern Forest where the type covers more area the associates are more numerous, including not only balsam fir and tamarack but also yellow birch, paper birch, black ash, red maple, black spruce, white pine, and hemlock.

Nature and" Occurrence

This type occurs on sites with slow drainage, not strongly acid, and not in stagnant bogs because water movement is necessary for maintenance of the cedar. In the Lake States it is found typically on seepage areas and occasionally on limestone uplands adjacent to the Great Lakes. The type is of very spotty distribution in the northeastern United States and rare in Nova Scotia. It is a climax type.

Transition Forms and Variants

In Canada a transition to black spruce is 'common and the type is referred to as black spruce-northern white-cedar. In Michigan the type usually is quite mixed with other species so that various names-have been applied such as mixed conifer swamp or cedar-tamarack-spruce-balsam.

Type 38: TAMARAK

Definition and Composition

Tamarack is either pure or predominant. Common associates are either black spruce or northern white-cedar, or, less frequently both. Other associates, mostly subordinate, include red maple, black ash, and quaking aspen.

Nature and Occurrence

The type is found commonly in wet swamps in the-Northern Forest, particularly in the Lake States and in southern Ontario. Elsewhere in the Northern Forest it is rare. Although a type of the Northern Forest, it also extends into the Boreal Forest, to the north and

into the Central Forest to the south in isolated areas. Occurrence is chiefly on peat soi 1s but muck soils are also occupied by the type. It is succeeded by black spruce on poorly drained aci d peat or by the northern whi te-cedar type in better drained, less acid swamps.

Transition Forms and Variants

Tamarack-black spruce or tamarack-black spruce-northern whi te-cedar are common variants.

Type 39: BLACK ASH - AMERICAN ELM - RED MAPLE

Definition and Composition

The three type species occur in different proportions, but together predominate- over" any other species which occur in mixture. Black ash occurs least often in other types and therefore may be considered an indicator species for this type. Black ash is rarely as abundant as the other two species except in the Lake States. In the Central Forest region red maple and American elm are most abundant. In New England red maple predominates and may often be pure. In the Lake States and in the western portion of the Northern Forest in Canada the associates are balsam poplar, balsam fir, yellow birch, and less commonly, white pine, tamarack, northern white-cedar and basswood; in northern Ohio and Indiana, silver maple, swamp white oak, sycamore, pin oak, blackgum, and cottonwood; in New England, yellow birch, blackgum, sycamore, and toward the north tamarack, and black spruce; in New York, white ash, slippery and rock elms, yellow birch, blackgum, sycamore, hemlock, bur oak, swamp white oak, and silver maple.

Nature and Occurrence

The type occurs throughout the Northern Forest in Canada intruding into the Boreal along river valleys and alluvial flats; throughout the Lake States, northeastern Indiana, northern Pennsylvania, northern New Jersey, New York, and New England. It occupies moist to wet muck or shallow peat soils, and is found in swamps, gullies, and small depressions of slow drainage or in elongated areas along small sluggish streams, occasionally covering extensive areas where it is climax for the site. Drainage for agriculture has reduced the type area in the Central Forest.

Transition Forms and Variants

In the Lake States it frequently grades into northern white-cedar on the wetter sites and into hemlock-yellow birch as drainage becomes better.

Type 41: SCARLET OAK

Definition and Composition

Scarlet oak predominates, but black oak and southern red oak are coordinate associates. Other associates are chestnut oak, white oak, post oak, hickories, pitch pine, blackgum, sweetgum, black locust, sourwood, flowering dogwood, with occasional shortleaf and Virginia pines.

Nature and Occurrence

This type is found on the mountains and foothills of the Allegheny and Appalachian ranges, from Maryland to Georgia, usually below an elevation of 3,000 feet, extending to the plateaus, also in hill regions of Ohio, Indiana, Illinois, Kentucky and southeastern Missouri, but not in Arkansas. It occupies dry ridges, south- or west-facing slopes and flats, but often moister situations probably as a result of logging or fire. The place in succession is not clear, but it probably approaches climax on dry soils giving way to chestnut oak in places.

Transition Forms and Variants

There are many slight variants due to the large number of associated species. Small patches of almost pure black oak are occasionally found within the type. The type grades into post oak-blackjack oak-black oak on very dry sites.

Type 42: B UR OAK

Definition and Composition

Bur oak is pure or predominant. Asociates vary but include northern pin oak, northern red oak, white oak, black oak, basswood, American elm, green ash, boxelder, hackberry, cottonwood, and hophornbeam in the northern part of the type range, and American elm, shellbark hickory, white ash, basswood, hornbeam, swamp white oak, pin oak, red maple, and cottonwood in the southern extent of the type.

Nature and Occurrence

The type is found in the central west from the prairies of Ohio, Indiana, Illinois, and Iowa to Nebraska and northward through central Minnesota, and North Dakota into Canada, where it occurs over small areas only. It occurs on dry exposed sites of sandy plains or on loamy slopes of south and west exposures. Elsewhere it is on heavy loams usually black prairie loam from well drained to fairly dry. Primarily it is a local type, spotty in distribution, It occurs westward along upper slopes of stream bluffs. It is a pioneer type on the edge of prairies, being gradually succeeded by northern pin oak or by white oak-black oak-red oak mixtures in Minnesota and Iowa.

Type 43: BEAR OAK

Definition and Composition

Bear oak is pure or predominant. Associated with it are pitch pine, white pine, shortleaf pine (in New Jersey), chinkapin, scarlet oak, black oak, northern red oak, chestnut oak, dwarf chinkapin oak, black locust, red maple, sassafras, and blackgum.

Nature and Occurrence

Bear oak, a scrub type, occurs on the drier sites. It is the prevailing type in the anthracite fields of Pennsylvania, Elsewhere it is less prominent, but often occupies extensive areas in southern New England, particularly the Cape Cod region, the east end of Long Island, eastern New York where it is spotty, New Jersey,

northeastern, central, and southern Pennsylvania, western Maryland, and mountains of Virginia and West Virginia from sea level to 3,000 feet. It is a temporary type following heavy cutting and repeated fires.

Type 44: CHESTNUT OAK

Definition and Composition

Chestnut oak is pure or predominant. The common associates are scarlet oak, white oak, black oak, post oak, pitch pine, blackgum, sweetgum, and red maple. Occasionally associates are white pine, red oak, shortleaf pine, Virginia pine, and sourwood.

Nature and Occurrence

The type occurs on rocky outcrops with thin soil in southern New England, New York (except the Adirondacks), Pennsylvania, New Jersey, and southward along mountain ranges to Georgia and Alabama at elevations of 1,500 to 4,000 feet. It is also found on the sandy Coastal Plain of New Jersey. At the higher elevations it seeks warm aspects. In the mountains it occupies narrow strips along ridges; in the Coastal Plain it covers wider areas. The type is permanent in some localities, but it frequently follows fire and clearcutting in types containing a mixture of red oak and chestnut oak.

Transition Forms and Variants

Chestnut oak-white pine-red oak is a variant.

Type 45: PITCH PINE

Definition and Composition

Pitch pine is pure or predominant. Chief associates are chestnut oak and scarlet oak; minor ones include Table-Mountain pine, black oak, and blackgum.

Nature and Occurrence

The type occupies relatively infertile ridges, dry flats and slopes or coastal sands. Sites range from dry to poorly drained. It occurs in northern New England as well as the pine plains of Connecticut and Rhode Island, and the Cape Cod region; also New York and Pennsylvania. In addition it is found in the Coastal Plain from Maryland northward into New Jersey. Elevations in New Jersey are from sea level to 1,900 feet. Pitch pine is a temporary type, resulting from the fire, in the absence of which hardwoods will gradually become predominant.

Type 46: EASTERN REDCEDAR

Definition and Composition

Eastern redcedar is pure or predominant. Associates in the Northeast are gray birch, red maple, sweet birch, quaking and bigtooth aspen; in the Ozarks they are blackjack oak, post oak, black oak, and shortleaf pine.

Nature and Occurrence

The type is, scattered throughout the Central Forest and occasionally is found in the Southern Forest in Tennessee and Alabama, northern and central Mississippi, northern Arkansas, eastern Texas, and Oklahoma; also in parts of southern Wisconsin and Minnesota, and in very small patches in southern Canada. It occupies dry uplands usually abandoned pastures or fields, but can grow well on good sites. It is common, however, on limestone outcrops and other shallow soils. Eastern redcedar is a temporary type and is succeeded by various hardwood types.

Transition Forms and Variants

Cedar brake is a name sometimes given the type in Alabama. It also is called cedar hammock. In the Northeast, redcedar - gray birch is a variant.

Type 52: WHITE OAK - RED OAK - HICKORY

Definition and Composition

White oak, northern red oak, and hickory predominate in the Central Forest, although black oak is sometimes prominent, and black oak, southern red oak and scarlet oak replace northern red oak in the Southern Forest. There are many combinations of oaks, hickories, and other hardwoods in association and these vary from place to place. In the north they may include northern pin oak, scarlet oak, bur oak, shagbark or bitternut hickory, white or green ash, sugar maple, and occasionally a few black cherry, butternut, or bigtooth aspen; further south they are American elm, winged elm, red maple, black walnut, basswood, black locust, chinkapin, beech, sweetgum, and blackgum; in southeastern Pennsylvania associates include yellow-poplar, pignut hickory, shagbark hickory, mockernut hickory, white ash, red maple, beech, and blackgum with an understory of flowering dogwood. In the Southern Forest the common associates are blackgum, sweetgum, and elm.

Nature and Occurrence

This type is widespread through the Central Forest at elevations from 500 to 2,000 feet particularly in the midwest but also extending as far south as the Arkansas Ozarks, northern Mississippi, Alabama and Georgia, north into the Lake States and southern Ontario over very small areas, and east into southern Pennsylvania and New Jersey. . A wide variety of well-drained upland soils are occupied. This type is climax in its central and southerly portions but in the north is succeeded by types in which sugar maple is predominant. Cutting of the oaks has increased the proportion of hickory.

Transition Forms and Variants

This is the so-called mixed oak type of the Central and Southern Forests, which is often referred to by the generic term oak-hickory. Variants include white oak-black oak-northern red oak, and white oak-black oak (or black oak-white oak). Black oak which occurs pure over small areas is included with the type.

Type 54: NORTHERN RED OAK - BASSWOOD - WHITE ASH

Definition and Composition

Northern red oak, basswood, and white ash form the whole or a prominent part of the stand. Associates in New England are red maple (characteristic), yellow birch, quaking and bigtooth aspen, sugar maple, paper birch, and beech; in New York and western Pennsylvania add black cherry, white oak, sweet birch, butternut, American elm, and hemlock; in the southern Appalachians and middle western states, yellow buckeye, yellow birch, sweet birch, sugar maple, and black cherry. White ash is generally unimportant or absent in the southern Appalachians. On the western edge of the range American and slippery elm are important components.

Nature and Occurrence

The type is found throughout the Central Forest and southern part of the Northern Forest. In the Appalachians it occurs from West Virginia to northern Georgia and Alabama at elevations between 3,000 and 5,000 feet. Elsewhere it is at low elevations. Occupied are deep, fertile, moist, well-drained soils. The type is semi-permanent although the proportion of hemlock and sugar maple tends to increase. It is sometimes referred to as transition hardwoods.

Type 55: 'NORTHERN RED OAK

Definition and 'Composition

Northern red oak is pure or predominant. Associates are black oak, scarlet oak, chestnut oak, and yellow-poplar.

Nature and Occurrence

The type occurs through the southern Appalachians from West Virginia to northern Georgia at elevations from 2,000 to 3,000 feet in West Virginia, and 3,000 to 5,500 feet in North Carolina; also in southern Michigan, southern Wisconsin and adjacent areas in Minnesota, Iowa, and Illinois where it increased in area about the time of settlement and over small areas in southern Canada. In the Appalachians it has a spotty distribution, occurring on ridge crests and north slopes. In the midwest it occupies rolling land, slopes, and benches adjacent to prairies, usually on loamy soil. It is probably subclimax over most of its range but tends to pioneer in southern Canada on warm, dry sites, frequently with paper birch.

Type 59: YELLOW-POPLAR - WHITE OAK - NORTHERN RED OAK

Definition and Composition

Yellow-poplar, white oak, and northern red oak predominate. Associated are" black oak, hemlock, blackgum, and other moist-site species; also hickories on drier sites.

Nature and Occurrence

The type occurs in the southern Appalachians, between altitudes of 500 and 4,000 feet on northerly slopes, coves, and moist flats.

It is irregular and spotty but may form considerable strips on moist slopes. The place in succession is not known.

Transition Forms and Variants

Yellow-poplar-white oak-sugar maple is a form reported from Kentucky and Tennessee especially on limestone soil. On the wettest site on which yellow-poplar grows, the variant is yellow-poplar-white oak-blackgum-red maple.

Type 60: BEECH - SUGAR MAPLE

Definition and Composition

Beech and sugar maple predominate. In association are red maple, white oak, northern red oak, hemlock, red elm, American elm, basswood, and mockernut hickory, sweet birch, yellow-poplar, cucumber-tree, black cherry, black walnut. Pawpaw is commonly found as an understory tree in this type.

Nature and Occurrence

The type is primarily one of the Ohio valley and tributaries of that river. It occurs in southern New York, southern Michigan, valleys of southwestern Pennsylvania, southeastern Ohio and mountainous parts of Kentucky and Tennessee, and is abundant in southern Ontario. It occupies morainal hills of Ohio, central Indiana and adjacent Michigan and talus slopes under cliffs. On some areas, due to cutting, beech may comprise 70 percent of the stand while on other areas sugar maple may predominate for the same reason, The type prefers moist, fertile soils, and is found on all sites except very dry or swampy ones. The type is often labelled "mixed mesophytic" by the ecologist and is considered to be climax.

Type 61: RIVER BIRCH - SYCAMORE

Definition and Composition

River birch and sycamore predominate. Associates include red maple, black willow, and other moist-site hardwoods.

Nature and Occurrence

The type is widespread. It occurs in southern New England, New Jersey, Pennsylvania, and in tributaries of the Ohio and Mississippi Valleys to the southern portion of the Lake States, Oklahoma, Missouri, and Tennessee; also within the Allegheny and Piedmont Plateau areas and Appalachian Mountains, reaching altitudes of 1,000 feet in the northern and 2,500 feet in the southern part of the Appalachians, Moist soils are occupied at the edges of creeks and rivers in strips and small stands. The place in succession is not known.

Type 62: SILVER MAPLE - AMERICAN ELM

Definition and Composition"

Silver maple and American elm usually predominate but in some cases September elm replaces the American. Associates are red maple, slippery elm, swamp white oak, cottonwood, sycamore, white or green

ash, and many other moist-site hardwoods, varying with the region. Silver maple is the indicator species.

Nature and Occurrence

The type is universal throughout the Central Forest extending into Canada on silty soils of river bottoms and flood plains as long strips along the larger streams and sometimes on low lake shores. Occasionally it occurs in swamps. Silver maple-American elm is subclimax and often follows cottonwood and willow stands.

Type 97: ATLANTIC WHITE- CEDAR

Definition and Composition

Atlantic white-cedar is characteristically pure, although sometimes it is only predominant. The associates are apt to increase in abundance after fire or cutting, They include, in the north, gray birch, pitch pine, hemlock, and blackgum; elsewhere, pond pine, baldcypress, swamp tupelo, sweetbay, redbay, loblolly-bay, slash pine, spruce pine, and buckwheat tree ("tit i"). Red maple is a common associate throughout the entire range,

Nature and Occurrence

The type occupies many detached tracts in the Coastal Plain from southern Maine to northern Florida and southern Mississippi in a comparatively narrow zone near the coast. It is most abundant in the Coastal Plain of New Jersey, the Carolinas, and western Florida. Occasionally it is found in a swamp in the hills of northern New Jersey. Usually it is confined to sandy-bottomed, peaty, interior, and river swamps, wet depressions, and stream banks. Itis a subclimax type, largely in even-aged stands, which under natuaral succession, is replaced slowly by swamp hardwoods, especially on the more fertile soils. Factors favoring the perpetuation of Atlantic white-cedar include certain types of fire, flooding, windthrow, and clear-cutting. The type is sometimes called juniper glade or cedar glade.

Source: S.A. F. (1967)

Attachment 7-2: Potential Vegetation Types defined by Küchler (1964)

73 NORTHERN CORDGRASS PRAIRIE (DISTICHLIS-SPARTINA)

Physiognomy: Usually dense, medium tall grassland

Dominants: Seashore saltgrass (Distichlis spicata)
Smooth cordgrass (Spartina alterniflora)
Saltmeadow cordgrass (Spartina patens)

Other Components: Gerardia martima, Juncus gerardi, Limonium carolinianum, Plantago decipiens, Salicornia spp., Triglochin maritima "

Occurrence: Along Atlantic coast, from New England southward to North Carolina

74 BLUESTEM PRAIRIE (ANDROPOGON-PANICUM-SORGHASTRUM)

Physiognomy: Dense vegetation of tall grasses and many forbs

Dominants: Big bluestem (Andropogon gerardi)
Little bluestem (Andropogon scoparius)
Switchgrass (Panicum vergatum)
Indian grass (Sorghastrum nutans)

Other Components: Amorpha canescens, Antennaria neglects, Aster ericoides, A. laevis, Baptisia leucantha, B. leucophaea, Bouteloua curtipendula, Erigeron strigosus, Galium tinctorum, Helianthus grosseserratus, Koeleria cristata, Liatris aspera, L. punctata, L. scarriosa, Panicum leibergii, P. scribnerianum, Phlox pilosa Psoralea argophylla, P. floribunda, Ratibida columnifera, R. pinnata, Rosa arkansana, Silphium laciniatum, Solidago altissima, S. missouriensis, S. rigida, Sporobolus heterolepis (northern part), Stipa spartea (northern part)

Occurrence: North Dakota and Minnesota southward to Oklahoma

96 NORTHEASTERN SPRUCE-FIR FOREST (PICEA-ABIES)

Physiognomy: Dense needleleaf evergreen forest, low to medium tall, or in the form of krummholz in high attitudes with a modest admixture of broadleaf deciduous trees

Dominants: Balsam fir (Abies balsamea)
Red spruce (Picea rubens)

Other Components: Acer rubrum, Betula papyrifera, B. populifolia, Populus grandidentata, P. tremuloides, Sorbus americana

Occurrence: New England to West Virginia

104 APPALACHIAN OAK FOREST (QUERCUS)

Physiognomy: Tall broadleaf deciduous forest

Dominants: White oak (Quercus alba)

Other Components: Acer rubrum, A. saccharum, Betula lenta, Carya cordiformis, C. glabra, C. tomentosa, Castanea dentata (formerly a co-dominant, now insignificant), Fagus grandifolia, Liriodendron tulipifera, Pinus strobus (northern part), Quercus coccinea, Q. ilicifolia, Q. mublenbergii, Q. prinus, Q. velutina, Tsuga canadensis (northern part)

Occurrence: Appalachian Mountains, westward to Ohio

106 NORTHERN HARDWOODS (ACER-BETULA-FAGUS-TSUGA)

Physiognomy: Tall, broadleaf deciduous forest with an admixture of needleleaf evergreen trees

Dominants: Sugar maple (Acer saccharum)
Yellow birch (betula allegheniensis)
Beech (Fagus grandifolia)
Hemlock (Tsuga canadensis)

Other Components: Acer pensylvanicum, A. rubrum, A. spicatum, Fraxinus americana, Kalmia latifolia, Pinus strobus, Prunus serotina, Taxus canadensis, Tilia americana, Ulmus americana

Occurrence: New England, New York, and the northern parts of Pennsylvania, Michigan, and Wisconsin; small area in the southern Appalachian Mountains

108 NORTHERN HARDWOODS-SPRUCE FOREST (ACER BETULA FAGUS PICEA TSUGA)

Physiognomy: Tall, dense forests of broadleaf deciduous and needleleaf evergreen trees

Dominants: Sugar maple (Acer saccharum)
Yellow birch (Betula allegheniensis)
Beech (Fagus grandifolia)
Red spruce (Picea rubens)
Hemlock (Tsuga canadensis)

Other Components: Abies balsamea, Acer rubrum, A. spicatum, Betula papyrefera, Pinus strobus, P. resinosa, Tilia americana, Viburnum alnifolium

Occurrence: New England, New York

110 NORTHERN OAK-PINE FOREST (QUERCUS-PINUS)

Physiognomy: Medium tall forest of broadleaf deciduous and needleleaf evergreen trees. In places the forest is low, even shrubby

Dominants: Pitch pine (Pinus rigida)
Scarlet oak (Quercus coccinea)
Black oak (Quercus velutina)

Other Components: Gaylussacia baccata, Kalmia angustifolia, K. latifolia, Pinus echinata, Quercus marilandica, Q. prinus, Q. stellata

Occurrence: New England to New Jersey

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The following chapter is a description of the phytoplankton in the offshore waters, nearshore, and estuaries of the study region. It is a review of pertinent literature and recent research in the field. The first portion deals with the Gulf of Maine and how it can be considered's separate entity, and the second with the southern study region, a part of the Mid-Atlantic Bight.

8.1 GULF OF MAINE

8.1.1 NATURAL DIVISIONS

The entire Gulf can easily be divided into eight discrete and homogeneous components. Regions of the Gulf of Maine (Figures 8-1 and 8-2) include:

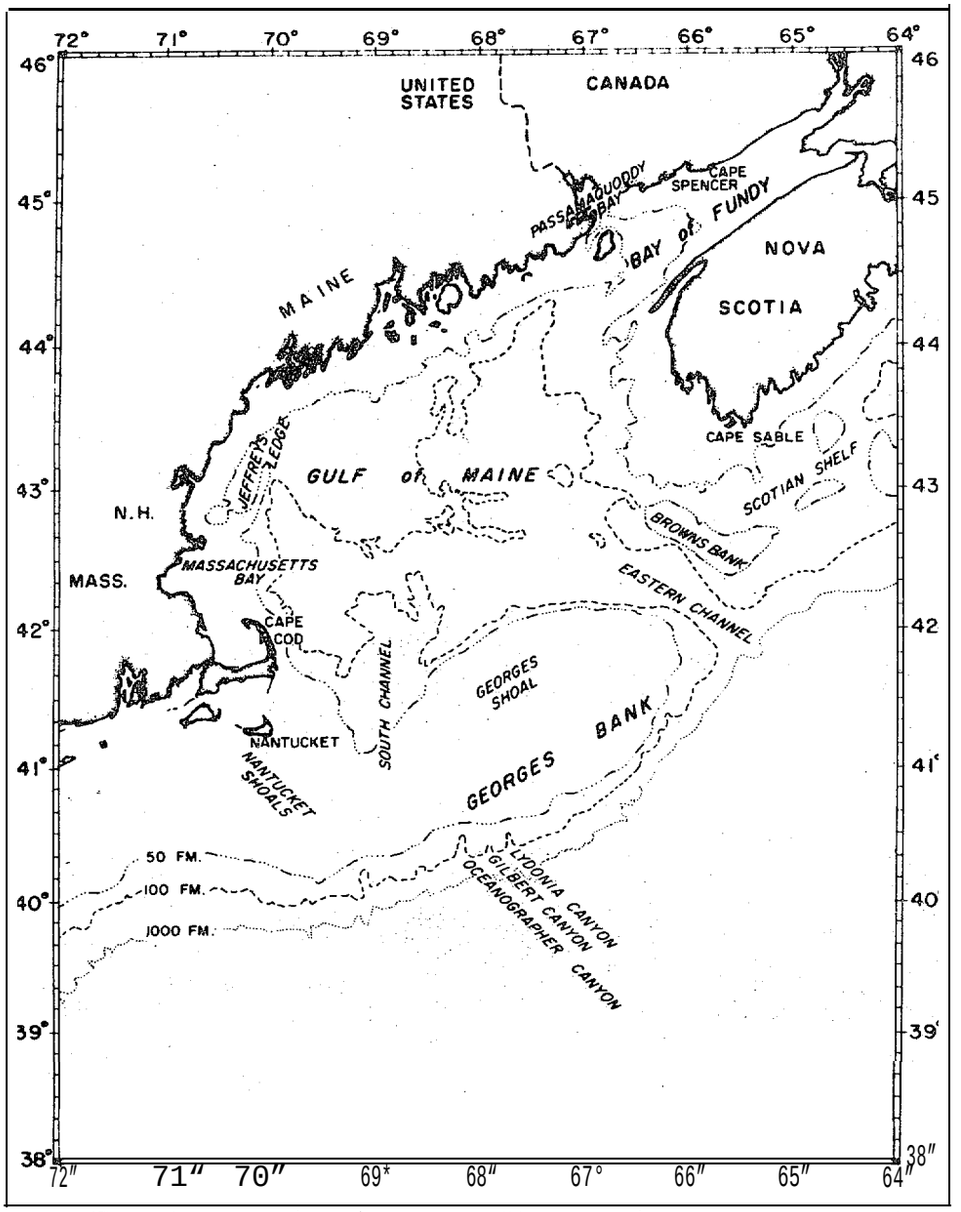
(1) The Central Basin
(2) The Bay of Fundy
(3) Cape Elizabeth to Grand Manan Island
(4) Cape Ann to Cape Elizabeth
(5) Massachusetts Bay, including Cape Cod Bay
(6) Estuarine Waters
(7) Georges Bank
(8) Southern Nova Scotia Coast and Banks

The deep waters (greater than 100 meters) are located near the center of the Gulf of Maine, forming the Central Basin. This region is often considered to be bowl-shaped-with the shallow waters constituting the rim and the central portion, the basin. Approximately 25,920 sq km of the Gulf contain waters of depths greater than 100 meters. The coastal portion of the Gulf of Maine contains two large bays, Massachusetts Bay in the southwest (including Cape Cod Bay) and the Bay of Fundy in the northeast. The coastline between these two features, from Cape Ann to Grand Manan Island, can easily be divided at Cape Elizabeth into two components, each with quite unique coastal characteristics.

The southern rim of the Gulf of Maine is formed by the shoal waters of Georges Bank. Because of its large size and unique characteristics, this region is considered separately.

The southern and western shore of Nova Scotia, including Browns and German Banks as well as the shoal waters of the region, have been considered as a unit primarily because of the oceanic waters to which they are continually exposed; not very many phytoplankton data are available from this location.

Each of these natural divisions will be treated, describing the organisms found.

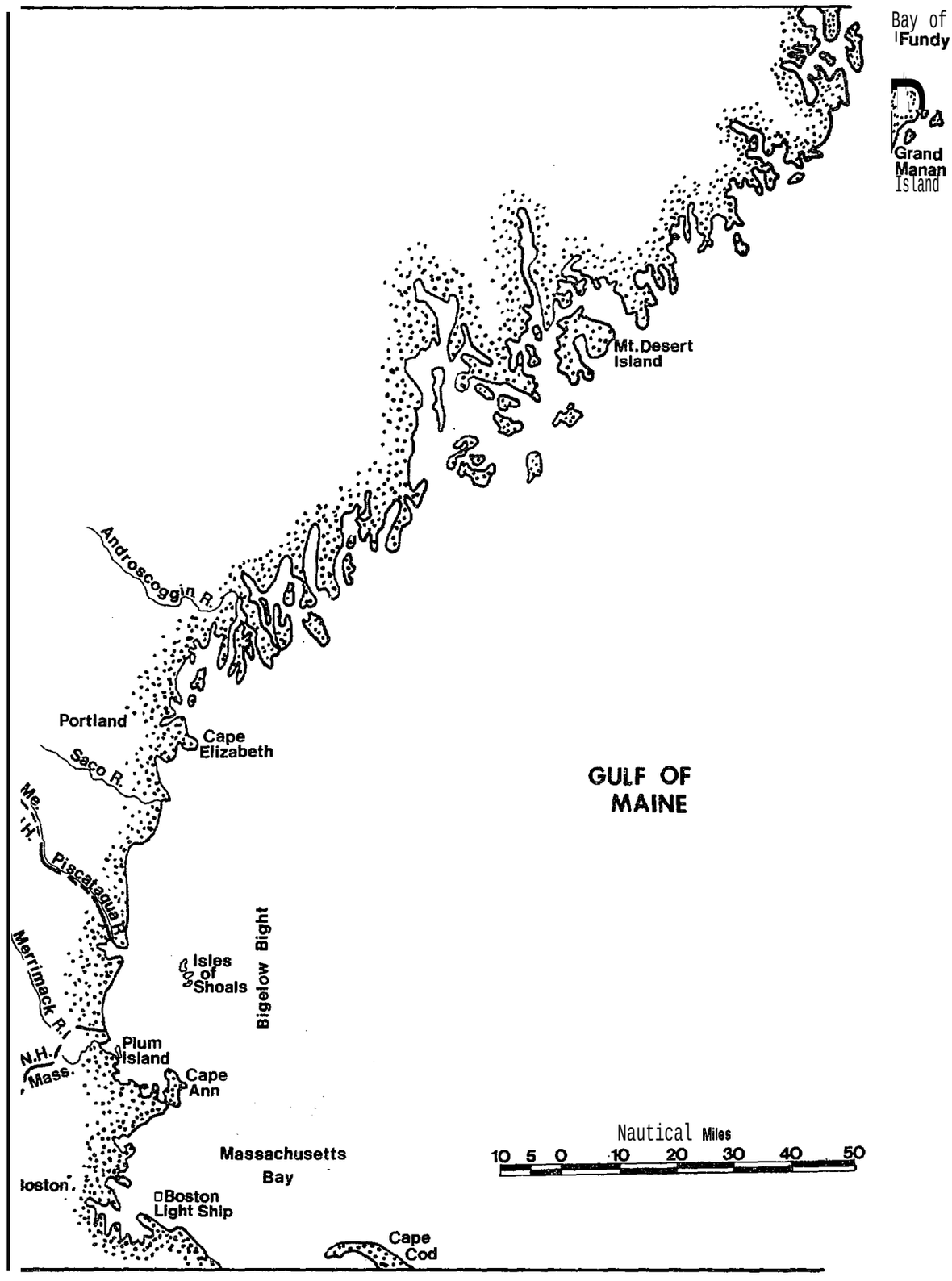


A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 8-1

Gulf of Maine (Lillick, 1938)



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC	FIGURE 8-2	Regions of the Gulf of Maine

8.1.2 FACTORS AFFECTING PHYTOPLANKTON COMPOSITION

Some of the major factors which influence the composition of phytoplankton in the Gulf of Maine and which tend to keep the population uniform include circulation and vertical stability temperature and salinity, and light penetration. Although several of these factors have been considered in detail in other sections of the report review, it will be helpful to discuss each of them briefly, Before considering the individual regions, it is desirable to review the variation of these factors over the entire Gulf of Maine.

CIRCULATION AND VERTICAL STABILITY

Land drainage is an important element in determining the circulation patterns observed in the Gulf of Maine. Although the rainfall in this region is rather uniform over the entire year (slight increase during the summer period), the runoff produced as a result of this rainfall follows a definite seasonal cycle with maximum runoff cointiding with maximum snow melt in the spring. The time of maximum runoff occurs on different dates within the Gulf beginning in the southern portion as a result of increasing spring temperatures.

Water is not added to the Gulf of Maine uniformly along the entire coast; most of the fresh water enters the northern portions. Nearly 80 percent of the land drainage enters the Gulf in the Presumpscot Androscoggin, Kennebec, Penobscot, Machias, St. Croix, and St. John Rivers. The only major rivers entering the Gulf to the south of Cape Elizabeth are the Saco and the Merrimack. Approximately 90 percent of the entire land drainage is delivered to the north of Cape Elizabeth; no major rivers drain directly into Massachusetts Bay. It is believed that this drainage pattern provides the energy to generate the anti-clockwise circulation pattern which is characteristic of the Gulf of Maine. Surface waters flow to the west along the Maine coast from the Bay of Fundy towards Cape Cod. Some of' this water then follows the contour of the basin around Georges Bank and back to the southern coast of Nova Scotia, where it is moved toward the Bay of Fundy and then turned toward the west along the Maine coast. Some of the runoff water is lost over the southeastern portion of the Gulf and is replaced with oceanic water of Nova Scotia or Gulf Stream origin. This counterclockwise gyre is continuous throughout the year and in the entire water column, but it is stronger during the spring and at the surface. Coastal upwellings are common features of the western coastal region of the Gulf. It appears that wind may tend to increase or decrease the rate of movement of the water, but it does not alter the general pattern.

TEMPERATURE AND SALINITY

The coastal waters of the Gulf of Maine range in temperature from a winter low of 2.0 to a high of 20 C during the months of July and August. The waters deeper than 100m maintain a temperature of between 2- 6 C over most of the year. Ice is a common winter feature in the estuarine waters of the Gulf; usually Great Bay, N.H., is completely ice-covered during December and January, but in the winter of 1972 - 73, ice was nearly absent in the Bay (Mulligan and Donovan, in prep.). Summer temperatures in Massachusetts Bay are somewhat higher than in the rest of the Gulf because of the general lack of circulation and relatively shallow depths. Vertical stratification develops in the coastal waters but is generally transient in waters shallower than 20 m due to tidal mixing and strong vertical turbulence.

Since a reduction in salinity is a function of the quantity of fresh water added, the waters of lowest salinity are found along the northern and western coastal regions, and the highest spring salinities are found on the eastern side of the Gulf. Some of the water moving over Browns and German Banks is low temperature coastal water from Eastern Nova Scotia, and this water has reduced salinity.

Salinity ranges from 28 to 33‰ in the open Gulf with ranges of 0 - 29‰ in Great Bay and 27 - 33‰ in Massachusetts Bay. The 10 year averages measured at the Boston Light Ship in Massachusetts Bay had a high of 32.38‰ in January and a low of 30.71‰ recorded in May. Vertical differences in salinity are generally less than 1‰.

DISSOLVED AND SUSPENDED MATERIALS

Dissolved organic compounds are abundant in the coastal waters of the Gulf of Maine. The influence of these compounds in the phytoplankton is unknown, but various possible effects have been suggested. Margalef (1968) proposed that the presence of dissolved organic matter favored dinoflagellates including Gonyaulax tamarensis, or inhibited other phytoplankton. Prakash and Rashid (1968) found that humic substances exerted a stimulator effect on marine dinoflagellates. Detrital materials may also serve as a food source (Riley, 1959; Beklemishev, 1962), or, with sufficient accumulation, an auto-inhibiting mechanism to phytoplankton (Volesky, Zajic and Knetting, 1970). Other possibilities exist but these have not been studied specifically in the Gulf of Maine.

The organic nitrogen compounds have been reviewed by Vaccaro (1963) and carbon compounds by Redfield (1934). There have been few attempts to relate phytoplankton populations to these parameters in the Gulf of Maine, although vitamin B12 in land drainage was thought to be responsible for the coastal blooms of Skeletonema costatum (Curl, 1962).

Tryon and Hartman (1959) and. Provasoli (1963) reviewed the vitamin requirements of phytoplankton.

Limited trace metal analyses have been made in the Gulf of Maine, but only the work of Gran (1933) attempted to relate the concentration of these to plankton populations e.g. iron. Most of the attempts to relate dissolved inorganic compounds to phytoplankton populations have involved neither nitrogen nor phosphorus and silicon when diatoms are involved. Most of our discussion will be concerned with concentrations and importance of these three elements.

Although silicon declines in concentration during the spring bloom period, it does not appear that this element is limiting diatom growth in this region (Riley and Chester, 1971). Redfield, Smith and Ketchum (1937) and Ketchum and Corwin (1965) reviewed the renewal of phosphorus to the surface waters of the Gulf of Maine, and Ketchum, Vaccaro and Corwin (1958) reviewed the nitrogen and phosphorus cycles in New England waters. Phosphorus values in the Gulf of Maine" are seldom reduced to less than 20 mg/l (Bigelow, Lillick and Sears, 1940). Phosphorus is not considered to be a limiting element., although Rakestraw (1933) showed critically low P-P04 values at three stations in the Gulf of Maine in 1932, and Gran and Braarud (1935) considered it limiting in 1932 in the Bay of Fundy. Ketchum (1947) has shown that the rate of uptake of phosphorus was dependent on the concentration of nitrate, but not the reverse.

Nitrogen, because the values of $N\text{-}NO_3$ were frequently reduced to less than 10 mg/l and sometimes to zero, is considered to be a limiting element in the Gulf of Maine (Bigelow et al., 1940). Critical $N\text{-}NH_4$ values are missing from the early studies. Vacarro (1963) has shown that $N\text{-}NH_4$ is abundant in the Gulf of Maine and may be an important source of nitrogen during certain times of the year, with maximum concentrations occurring in August in stratified waters. Inclusion of $N\text{-}NH_4$ values reduces the fluctuations in the N/P ratios. He also shows that phosphorus undergoes less fluctuation in concentration in the water column. Despite the absence of $N\text{-}NH_4$ values, Bigelow et al., 1940, Lillick, 1937, and Harvey, 1933, considered nitrogen as a limiting element. Since nitrogen and phosphorus values are high for several months before spring diatom blooms are initiated, high concentrations of these elements are not considered responsible for initiating the spring bloom. Whether deficiencies of these elements bring the spring blooms to a conclusion has been disputed by Hulburt (1968). Lane (1973) suggests that no single factor could precipitate such an event but combinations o-F several actors are more likely to be responsible.

LIGHT PENETRATION

The study of light and its penetration into the waters of the Gulf of

Maine was initiated and conducted by Clark and Oster (1934). Their results showed that blue light penetrated to greater depths than red light in the Gulf of Maine, but the increased wave action of the deeper waters minimizes the differences. They also showed the compensation depth (the depth at which respiration equals photosynthesis) was 4.5 times deeper in the open gulf than in the coastal waters of Woods Hole. The measurements of the depth of the euphotic zone in Great Bay, N.H., and along the coast from Rye, N.H., to Boston Harbor, Massachusetts, showed a range of 0.5 to 28 m (Mulligan and Donovan, in prep.; Mulligan and deLara, in prep.). The coastal waters, especially the most northwestern ones, including the Bay of Fundy, show reduced transparency and increased turbidity corresponding to the increased quantities of runoff. The waters of the open gulf have the highest transparencies because the runoff water and its suspended material are absent from the basin. Rakestraw (1933) has shown more thorough mixing in Georges Bank in 1932 than in the open gulf.

Permanent summer stratification is established in coastal waters in depths greater than 20 m; shallower waters are more thoroughly mixed, due to tidal mixing and vigorous coastal currents. The stratified conditions eliminate nutrient regeneration from bottom waters. Since bacterial maxima closely correspond with diatom maxima (Reuszer, 1933), regeneration of nutrients occurs in the surface lighted zone (Bigelow, 1940). Clark et al. (1934) studied zooplankton migration and indicated they moved into the upper lighted zone not in search of food but actually in response to light quality and intensity. Barlow and Bishop (1965) have shown this to be a means of restoring phosphorus to upper water layers. This is also a mechanism for introducing particulate matter to surface waters.

Phytoplankton have been shown to comprise only about 23 percent (with a range of 12 to 30 percent) of coastal particulate matter by volume, in a study conducted in the Gulf of California by Zeitzschel (1970); diatom cells contributed only an average of 10 percent of the phytoplankton number. Phytoplankton are likely only minor constituents of the total particulate matter during most the year in the Gulf of Maine. Only during the actual spring bloom do phytoplankton become major components by volume. Spencer and Sachs (1970) indicate that 10 percent of the suspended material in the Gulf of Maine has been contributed by the rivers of the North Atlantic coastal plain. Bond and Meade (1966) suggested most of the mineral matter suspended in offshore waters was contributed from longshore or offshore sources and not from river effluents. Suspended matter in the water column reaches a minimum at 50 in Gulf of Maine coastal waters and then increases exponentially to the bottom (Spencer and Sachs, 1970). The turbid bottom water should have little influence on the productivity of the phytoplankton which occurs nearer the surface.

8.1.2 THE PHYTOPLANKTON; AN OVERVIEW OF SEASONAL DYNAMICS IN THE GULF OF MAINE

The annual cycles of phytoplankton in the various portions of the Gulf of Maine are similar. The main differences are in species composition, dates of initiation of the spring bloom, ultimate size of populations, and length of dominance. A general pattern. of the development and duration of phytoplankton populations in specific areas was formulated by the early workers in this area. Bigelow (1926) surveyed the offshore areas along the circumference of the Gulf, while the studies of Lillick (1937, 1940) and Sears (1941) were concentrated mainly on Georges Bank and the basin area to the north of it. Braarud (1934) and Gran and Braarud (1935) described the seasonal changes of the phytoplankton populations in the Bay of Fundy and in the western basin and coastal area." More recent investigations by Mulligan and Wessel (in prep.), Mulligan and de Lara (in prep.), McAlice (1972), and Donovan and Mulligan (in prep.) supply a more quantitative picture of the phytoplankton dynamics along the western coastal region and in specific embayments and inshore areas.

The main features of the phytoplankton cycle in the Gulf of Elaine are:

(1) Smal l population size in winter months from November to February. This plankton is generally dominated by Ceratium or Coscinodiscus and sometimes by Rhizosolenia or Thalassionema populations.

(2) From February to June, various diatoms rise to bloom proportions. Several key areas are assumed to be the initial foci of the spring bloom in the Gulf of Maine. On the western coastal area, for example, at the outlet of the Merrimack River into the Bigelow Bight, the first appearance of the diatom Thalassiosira occurs. This species dominates the spring population for 2 to 6 weeks in this area. The population spreads north and south, around Cape Ann, appearing in bloom proportions in the Bay of Fundy six weeks later.

.(3) Spring 'blooms of Chaetoceros communities occur subsequent to Thalassiosira blooms, continuing for 1 to 4 weeks. Chaetoceros debilis and decipiens are the main components of the late spring population in many areas, while C. socialis is -common in Massachusetts Bay and in inshore areas to the north, and C. compresses . dominates in the Bay of Fundy.

(4') Summer blooms of smal 1 -sized coccol ithophores are common in the open basins of the Gulf, although Rhizosolenia spp. and Peridinians may also become important.

(5) Skeletonema costatum and Rhizosolenia spp. may bloom from June to early fall in the more coastal areas of the Gulf. Various species-of Ceratium may dominate in the western and northern coastal regions, while neritic diatoms become abundant in the Georges Bank area.

(6) Secondary late summer and fall blooms of some neritic diatoms do occur. Skeletonema, Guinardia, Leptocylindrus and Rhizosolenia spp. are examples.

Although similarities exist throughout the Gulf of Maine, the individual regions develop their unique populations, and for this reason, each region will be considered as an individual entity. The species list (Pelagic habitat 3.5.1) gives a more detailed summary of the seasonal distributions and peak populations of the various species in each individual sector.

8.1.4 HISTORICAL PERSPECTIVE

Studies of the phytoplankton in the Gulf of Maine were initiated with the works of Bigelow in 1912. He completed his studies on the offshore region of the Gulf in 1940. With his publications in 1926 and 1927, Bigelow provided a comprehensive analysis of this large coastal region and we are indebted to him more than to any other for much of the available information on this region. Subsequent offshore phytoplankton studies were undertaken by Bigelow, Sears and Lillick (1940), by Riley (1941; 1947), by Lillick (1937; 1938; 1940), and by Sears (1941). These studies together with the work of Gran and Braarud (1935) in the Bay of Fundy and in the offshore waters (Gran, 1933; Braarud, 1934) provide about all of the available taxonomic information on the phytoplankton of the Gulf of Maine.

Bigelow's studies were generally not within eight kmof the coastline and covered a tremendous sampling area. Although he recognized the necessity of doing so, Bigelow was unable to sample large expanses of the Gulf at any one time and had to either rely on extrapolations as to the conditions at unsampled locations or utilize data from cruises in the unsampled regions obtained in previous or subsequent years. Altogether, Bigelow obtained 1,000 tows from the region from 1912 to 1928, In this manner, a large quantity of information on seasonal phytoplankton populations was obtained.

These early phytoplankton studies dealt primarily with plankton obtained with nets. The difficulties which arise from sampling in this manner are well known, but at the time this was the only method in current use. Quantitative analyses were attempted from the data and the data were usually considered as cells/m2 or mg/m2. Even

though there are difficulties, it is necessary to utilize this data, especially because in many cases it is all that is available.

The following limitations are evident in the data:

(1) Seasonal cycles are fabricated from sampling in various years. This is especially dangerous in view of the large temporal and annual variability over time.

(2) Most of the studies were limited to surface populations.

(3) A great deal of extrapolation was necessary in order to consider similar regions together. This is done, recognizing the risk of over-generalizing.

(4) The net allowed the escape of Coccolithophores, small diatoms and micro-flagellates.

(5) The plankton net permits, at best, only an order-of-magnitude estimate of phytoplankton abundance.

Workers subsequent to Bigelow were able to employ quantitative methods similar to those currently in use today. The more modern methods of settling and centrifugation which were used in studies after 1931 provided a more accurate assessment of phytoplankton population size and species composition than was possible when only the plankton net was used.

The coastal waters of the region have received little attention. It seems unlikely that such a situation would exist in view of the large population density in the region, but this is the case with regard to phytoplankton systematic studies, distributions and primary productivity estimates. Up to the late 1940's, the Gulf of Maine was the place to work and new techniques and theories were tested in the region. After this time the studies of phytoplankton in the Gulf of Maine are very few in number. .

Early workers at the Canadian Biological Laboratory in New Brunswick, including McMurrich (1917) and Fritz (1921) collected information on the phytoplankton of the Bay of Fundy. Davidson (1934) continued their work on the Canadian coastal waters; while Burkholder (1933) carried out's study on Frenchman Bay. The studies of Fish (1925) and Lillick (1940) extended southward into Massachusetts Bay. Endemic problems with paralytic shellfish poisoning in the Bay of Fundy led Canadian workers to observe hydrographic and biological conditions, especially the phytoplankton. These workers included Needler (1949), Prakash (1967), and Prakash, Medcof and Tennant (1971). Hulburt and Corwin (1970) and Hulburt (1968) examined some physical, chemical, and

biological characteristics of an estuarine system in Maine, but more comprehensive systematic and hydrographic studies in inland and coastal waters were conducted by McAlice (1970) and Mulligan (unpublished). The recent works are especially noteworthy in that they continue the more extensive quantitative studies initiated by Lillick (1937), Sears (1941) and Riley (1941, 1947).

The data to be discussed in the individual regions in the Gulf of Maine in the remaining sections have been drawn mostly from references already mentioned. Unless specifically indicated to the contrary, most of the phytoplankton populations discussed were collected near the surface.

Primary productivity rates were calculated for different portions of the Gulf of Maine by Gran and Braarud (1935) with the oxygen technique; Riley (1947) from the concentration of pigment and estimates of photosynthesis and respiration, and by Teal and Kanwischer (1966) utilizing pC02 values. Radioactive carbon productivity values are being collected off Cape Ann by Yentsch (unpublished) and in Massachusetts Bay by Parker and Mulligan (unpublished).

8.1.5 DISCUSSION BY REGION

THE CENTRAL BASIN OF THE GULF OF MAINE

The central basin of the Gulf of Maine is considered to be that portion of the Gulf where the water exceeds 200 meters in depth. This central basin or bowl is approximately 25,920 sq km. The temperature fluctuations are slight in this region because of the large volume of water present. Summer temperatures run on the average 10 to 13 C while winter temperatures are listed as 2 to 5 C. The water below 100 m varies little from 2 C and 32‰ salinity. Surface water salinity varies least of all locations in the Gulf (from 32 to 33‰).

The bowl is actually "Y" shaped with a western and eastern arm. The maximum depth in these deep areas is approximately 336 m (Bigelow, 1927). The waters in the central basin would be subject to some counterclockwise motion, although not to the degree experienced in the waters at the rim of the bowl. The basin is well removed from surface runoff, and the salinity should fluctuate but little. Maximum light penetration is possible in the central basin, and vertical stability is thermally maintained by the development of a strong thermocline. This stable water column together with the increased water transparency enables light to be photosynthetically active at greater depths, thereby spreading out the zone of productivity (Gran, 1933).

During the winter, Coscinodiscus, Ceratium longipes, C. tripes and C. bucephalum and three oceanic Chaetoceros (C. decipiens, C. atlanticum,

C. criophilum) comprise the dominant organisms in this very sparse community, which continues until the end of March. Within this period, Ceratium longipes is increasing, while Ceratium tripes is declining in abundance. Ceratia are generally more abundant than the other genera (Lillick, 1940).

During the spring bloom, in April and May, Chaetoceros dominates offshore, with C. densum constituting 50 percent of the plankton in the western basin by May 5, 1915 (Bigelow, 1926). On April 9, 1920 (ibid.) Chaetoceros decipiens and Thalassiosira nordenskioeldii were the dominant forms. On April 18, 1920 Chaetoceros atlanticum, C. decipiens, Rhizosolenia hebetata var. semispina and Thalassiosira nordenskioeldii were abundant in net tows from the region. Rhizosolenia setigera spreads into the central Gulf by the end of April, with Halosphaera present in the center of the basin during May. By mid-May. to the first week in June, the maximum diatom population-present-in the central Gulf was observed. The central basin reaches the lowest ebb after the spring bloom, when diatoms disappear rapidly by mid-June. The population at that time will reach a level-only one-fourth of the size of the winter population (Bigelow et al., 1940).

Ceratium is on the increase in the central region in the summer. In some years, radiolarians become abundant in the western central Gulf. By mid-August, 1932, Gran (1933) found Ceratium fusus and Pontosphaera huxleyi dominant. Ceratium tripes is the dominant plant in the central basin, while Peridinium crassipes and P. depressum reach their maximum numbers in the central Gulf in May. Blooms of Pontosphaera huxleyi occur in July and August and Lillick (1940) found Rhizosolenia alata abundant at that time.

Diatoms are gone from the central Gulf by early October (Bigelow et al., 1940); Peridinium spp. continue in abundance.

From the data available on the open Gulf, it is not possible to obtain an accurate seasonal picture; there appears to be a large gap from early October to mid-February. Just what is happening at this time is difficult to speculate on. In any case, Bigelow et al. (1940) suggest that this central basin of the Gulf of Maine may be low in productivity because of the short spring bloom and the apparent lack of a second diatom bloom in the fall.

Organisms which can move (e.g Ceratia) are favored by stratified conditions because they can actively seek the optimal level in the water column (Gran, 1933). Neritic diatoms are not too common in this region because of its distance from land. Gran (1933), however, suggests. that the absence of iron (normally contributed inland runoff) from these .offshore regions might account for the scarcity of neritic forms.

THE BAY OF FUNDY

The Bay of Fundy is located at the northeastern corner of the Gulf of Maine between 45° 40′ N latitude and 67° W longitude. The Bay is 161 km long and 56 km wide and is bounded on the north and east by Nova Scotia and on the west by the coast of Maine and New Brunswick. Grand Manan Island is considered to be its southern boundary.

TheSt. Croix and the St. John Rivers are the major sources of fresh water to the Bay and together drain about one-half of the entire Gulf of Maine drainage basin. The waters circulate within the Bay of Fundy in a counterclockwise motion. Very active vertical turbulence is the rule in this region because of the large tidal amplitude of the Bay of Fundy. The mean range of tides is 17 m. Water in the Bay is contributed from three sources; (1) fresh water from rivers and rainfall, (2) coastal water from the Gulf of Maine and the Nova Scotia current, and (3) high salinity slope water moving into the Bay through the deep channel entrance. Salinity of the waters is always less than 35‰ and is lowest during spring, showing a low value of 29%. The temperature range is free from 0 to 20 C.

Waters are well mixed and homogeneous to a depth of 100 m during February, but by April and May, solar radiation has produced a three-layer system: (1) fresh, warm surface layer, (2) medium-salinity, cold intermediate layer, and (3) a warmer, saltier bottom layer. From September into early winter this stratification gradually declines and finally breaks down. The great turbulence in the Bay results in large concentrations of dissolved plant nutrients within the water column.

Initial studies of the Bay of Fundy and Passamaquoddy Bay were conducted by McMurrick (1917), Fritz (1921), and Davidson (1934). Gran and Braarud (1935) conducted a detailed study of the phytoplankton and hydrographic conditions in 1932 in an attempt to determine the effect of a dam on the productivity of the Bay of Fundy. It is from these investigations that most of the knowledge on this region is based. The early workers had provided a general overview of the phytoplankton, noting the importance of neritic diatoms, especially Biddulphia aurita, and the small concentrations of dinoflagellates. It may be however, that the use of plankton nets allowed them to miss many small forms such as Gonyaulax tamarensis, which has become abundant in that region in subsequent years (Prakash, 1967). It is obvious that characterization of the population in terms of a stable, vertical composition would be difficult, due to the extreme tidal amplitude (Gran and Braarud, 1935).

Gran and Braarud (1935) reported the following as typical for the year 1932 at four stations in the Bay of Fundy. The samples were

"whole water samples" preserved with neutralized formalin and concentrated by centrification.

March, 1932--

The population was generally scanty, composed of mostly diatoms (total no, = 8,860/liter) with rather similar results at all four stations. The population was well mixed with depth and included some silicoflagellates and dinoflagellates. The following diatoms were present in the water column at this time with none exhibiting dominance:

Chaetoceros debilis, C. compresses, Ditylum brightwelli, Skeletonema costatum, Thalassiosira decipiens, Asterionella japonica, Corethron hystrix, Rhizosolenia hebatata var. semispina, Cocconeis sp. and Pleurosigma sp.

April, 1932--

Thalassiosira nordenskioeldii was the dominant organism at this time, reaching a maximum population of 760,000 cells/liter. Porosira gracialis was also abundant. Variations in the total size of the populations at each location resulted mainly from the variable quantities of Chaetoceros in the samples (mainly C. compresses, C. debilis and C. subsecundus). Diatoms were more sparse at the outer stations and occurred there in greater depths. Resting spores of some of the organisms were found at 75 m, indicating the diatoms' maximum had passed. A lot of detritus was present in the water.

May, 1932--

The population of the phytoplankton was high, but there had been a general decline in the dominance of Thalassiosira nordenskioeldii. This organism maintained dominance only where the temperature remained at 3-5 C. Although present at other stations, Chaetoceros compresses, C. debilis, and C. diadema assumed dominance. At other stations, cells of Ceratium, Peridinium, and Exuviella outnumbered those of Chaetoceros.

June, 1932--

There was an extreme decline in the population with only a few thousand cells/liter present. Each station had different dominant species including Melosira sulcata, Thalassiosira decipiens, Chaetoceros debilis, Skeletonema costatus, Leptocylindrus danicus, Detonula confervacea, Eutripea sp., Peridinium sp. Rhizosolenia fragilissima, and Ceratium furca and tripes.

July and August, 1932--

The organisms in the Bay of Fundy in this period were similar to those present in June. Gran and Braarud (1935) have grouped them into four characteristic associations or "societies".

(1) *Skeletonema* society--composed of neritic diatoms of local origin.

(2) *Constricts* society --neritic diatoms introduced with currents from the Nova Scotia region of the Gulf. *Chaetoceros constrictus* is a characteristic organism.

(3) *Triquetum* society --neritic autotrophic peridinians of uncertain origin covering large portions of the surface waters and characterized by *Peridinium triquetum*.

(4) *Tripos-fusus* society--oceanic Ceratia, coccolithophores (*Pontosphaeraa*) and diatoms (*Rhizosolenia*) introduced from the offshore waters across the Gulf.

September, 1931, 32--

Summer phytoplankton declined over the entire Bay and, although the societies were still present, the numbers declined.

The following is a species list of organisms collected by Gran and Braarud (1935) in the Bay of Fundy in 1932, with reference to their characteristic type:

A. Oceanic species

1. Arctic oceanic

Ceratium arcticum
Dinophysis arctica

2. Boreal oceanic

Chaetoceros atlanticus
C. borealis
C. convolutus
C. decipiens
Coscinodiscus centralis
C. curvatulus
C. radiatus
Nitzschia delicatissima
N. seriata
Rhizosolenia hebatata Var. semispina
Thalassiothrix longissima
Ceratium longipes
Peridinium depressum
P. ovatum
P. pallidum

3. Temperate oceanic,

Chaetoceros densus
Corethron hystrix
Rhizosolenia alata
R. imbricata v. Shrubsolii
R. styliformis
Ceratium bucephalum
C. fusus
C. tripos
Dinophysis acuta
Peridinium crassipes
Coccolithus pelagicus
Pontosphaera huxleyi

B. Neritic species

1. Arctic neritic

Achnanthes taeniata
Asterionella kariana
Bacteriosira fragilis
Chaetoceros furcellatus
Fragilaria oceanic
Navicula Vanhoeffini
Thalassiosira hyalina

2. Boreal neritic

Biddulphia aurita
Chaetoceros compressus
C. debilis
C. diadema
C. laciniosus
C. pseudocrinitus
C. radicans
C. similis
C. simplex
C. socialis
C. teres
Exuviella baltica
Dinophysis acuminata
D. norwegica
Coscinosira polychorda
D. ostrupi
Detonula conferuacea
Leptocylindrius danicus
L. minimus
Porosira gracialis
Rhizosolenia fragilissima
R. setigera
Skeletonema costatum
Thalassionema nitzschoides
Thalassiosira bioculata
T. decipiens
T. gravida
T. nordenskioel.dii

3. Temperate neritic

Actinocyclus Ehrenbergi
Asterionella japonica
Biddulphia regia
Cerataulina Bergoni
Chaetoceros affinis
C. brevis
Ditylum Brightwelli
Eucampia zoodiacus
Guinardia flaccida
Lauderia borealis
C. cinctus
C. constricts
C. danicus
C. didymus
Coscinodiscus excentricus
Dactyliosolen mediterraneus
Gonyaulax tamarensis
Peridinium faeroense
P. triquetum
P. trochoideum

Streptotheca thamesis

c. Tycopelagic species

2. Boreal tycopelagic

Actinoptychus undulatus
Biddulphia alternans
Melosira sulcata
Navicula distans
Nitzschia closterium
Pleurosigma Normani

The studies of Gran and Braarud (1935) include no data on the fall and winter conditions in the Bay of Fundy. Observations by Bigelow (1928) will be utilized to attempt to fill in the gaps to the annual cycle and to further summarize some of the highlights.

The consensus for the Bay of Fundy seasonal phytoplankton cycle from Bigelow (1926), Bigelow et al. (1940), and Lillick (1940) can be summarized as follows:

Thalassionema nitzschioides was more dominant in the winter flora than Coscinodiscus.

Thalassiosira decipiens precedes T. nordenskioeldii, with the bloom well under way by mid-April and continuing for four weeks.

Rhizosolenia setigera, Ditylum Brightwelli, Thalassothrix longissima and Skeletonema costatum are suggested as being important in the autumn plankton in the Bay of Fundy.

Although Bigelow (1926) indicates the phytoplankton numbers to be low, he suggests high productivity due to the long period of large populations (1 to 3 months).

Gran and Braarud (1935) indicate that vertical turbulence, which moves the organism down into deep water where light intensity is not adequate for-photosynthesis, is the cause of reduced productivity. They feel that productivity would increase were dams to be built across the approaches to Passamaquoddy Bay.

NORTH COASTAL REGION - CAPE ELIZABETH TO GRAND MANAN ISLAND

The coastal region from Cape Elizabeth to the entrance of the Bay of Fundy covers 242 km. This region is generally considered to include the waters out to a depth of 100 m. It is this portion of the coastal region where the majority of large estuarine waters are found. Coastal islands abound in this region. The tidal ranges are

second in size only to those found in the Bay of Fundy.

This portion of the coastline contains rivers which together with the Bay of Fundy provide a great majority of the entire drainage basin of the Gulf. This large drainage, combined with the large tidal ranges and the dominant southern movement of the water, all interact to produce a homogeneous water mass with large vertical turbulence.

The phytoplankton population reaches its minimum in late autumn to early winter (Bigelow et al"., 1940). There are an increasing number of neritic forms and a decline in Peridinium sp. and Coscinodiscus sp., with Ceratium sp. dominating from November to January. In late December to January, Coscinodiscus sp. numbers increase.

Diatoms do not start blooming until April with the most active production at the northern rim (Bigelow et al., 1940). Swarming occurs in late April to early May from Portland, Maine, to Grand Manan, and blooms occur for several weeks over the north coastal region. Lauderia can dominate north of Cape Elizabeth prior to specimens of Chaetoceros and Thalassiosira (Bigelow, 1926). Lillick (1940) observed a five week Thalassiosira bloom in coastal waters, with a Chaetoceros flora developing in May east of Portland, that may dominate the summer flora for four to six weeks in the north coastal belt.

Bigelow (1926) observed a dominant Thalassiosira population in April and May in this region. On May 11, 1915, Thalassiosira nordenskioeldii made up 100 percent of the population in the waters off Mt. Desert Island. Chaetoceros spp. joined T. nordenskioeldii as the dominant organisms on July 11 in 1915, with T. gravida becoming dominant by July 19, 1915. In the coastal region, the spring bloom continues for two or three weeks beyond the time of the Central basin bloom, with large diatom populations observed near Mt. Desert Island at the end of June. . .

Rhizosolenia alata was the major organism in July and August, with Skeletonema costatum dominating in this region in late summer (Lillick, 1940). Burkholder (1933) showed that the maximum diatom population occurred in August, and Bigelow (1926) observed that Asterionella japonica was dominant in September, 1912. On September 15, 1915, however, Coscinosira polychorda was an abundant organism around Mt. Desert Island and Coscinodiscus spp. also become more abundant in this region in September and October. Thalassiothrix longissima is abundant at different times during the summer bloom period from May to October (Bigelow, 1926).

Diatoms bloom until late October in this area and the dinoflagellates, present in late summer, increase in numbers into the fall and winter.

Ceratium longipes persists for the longest period in this region, usually until October, with C. arcticum increasing in winter. Peridinium spp. may equal Ceratium spp. cluing September and October.

Although the diatom population does not become abundant until late in the spring in the north coastal region, this is still a zone of intense productivity, primarily because of the length of time of the diatom bloom (lasting until late fall, Bigelow, 1926). There are no clear-cut divisions into spring and summer and fall blooms, but rather a continuous bloom of diatoms reaching their maxima at different times during this period. These large diatom populations are maintained in the north coastal region due to the consequences of active vertical mixing, characteristic of this part of the Gulf of Maine.

CAPE ELIZABETH TO CAPE ANN

This portion of the coast, also referred to as the Bigelow Bight, lies along the central coastal region of the Gulf of Maine for a distance of approximately 70 km. The coastline is only slightly elevated with several massive granitic headlands including those at Great Boars Head, Hampton, New Hampshire, and Bald Head Cliffs in Ogunquit, Maine. The majority of the coastline, however, is composed of sandy-barrier beaches-behind which extensive tidal marshes have developed. The marshlands in the southern. region include Rowley-Essex-Ipswich wetlands; the Newbury-Plum Island wetlands; Seabrook-Hampton wetlands; Rye-Portsmouth wetlands and the York-Kittery wetlands,

Several of the marshlands have been examined in detail by the state of Massachusetts (Jerome, Chesmore, Anderson and Grice, 1965; Jerome, Chesmore and Anderson, 1968; Jerome, Chesmore and Anderson, 1969). There are seven rivers of significant size which drain into this region of the Gulf of Maine. The smaller rivers include the Annisquam, the Ipswich, the York, and the Hampton. The Merrimack is the largest river followed in size by the Casco and the Piscataqua. At the heads of these rivers are estuaries and extensive salt marshes which, although located to the interior of the coastline, make direct contributions to the fertility of the coastal waters. The substrate under these coastal waters is primarily sand with several deposits of commerical grade gravel. Several offshore islands occur along this coastal transect with the Isles of Shoals the most familiar of all.

The bottom contour gradually slopes out to the 100 m water depth which is located about 10 km from the shore. The tidal ranges along this portion of the coast are on the order of 2 to 3.3 m.

The currents in this portion of the Gulf of Maine flow toward the

south (Graham, 1970). In addition, Graham (1970) also points out that coastal upwellings are a major feature of this region. Hulburt (1970) working off Cape Neddick discovered large vertical movements of coastal waters. This apparently is characteristic of the narrow coastal rivers which are abundant in the region to the north of Cape Elizabeth. Stable thermoclines do not appear to develop in waters less than 20 m, due to vertical turbulence. It is from this region that the spring diatom bloom in the Gulf of Maine is triggered, possibly under the influence of the drainage from the Merrimack River.

From later autumn to mid winter, the phytoplankton population in this area is at its lowest ebb. From December, 1933, to January, 1934, Lillick (1940) showed a change in dominance from the Coscinodiscus-Ceratium winter plankton to dominance by neritic forms. Ceratium arcticum was collected in the coastal regions in winter.

This region is the center of abundance for Thalassiosira nordenskioeldii which blooms from late February until April, with about a five-week period of dominance (Lillick, 1940). Chaetoceros spp. can bloom in mid-January" in Ipswich Bay. In the 'first week of March. 1920, the phytoplankton were abundant and by mid-May the phytoplankton were blooming. A Chaetoceros spring population continued to be abundant until May 25 at the Isles of Shoals. The most active production occurs during April (Bigelow et al., 1940). A Chaetoceros flora replaces the Thalassiosira population which becomes maximum when Thalassiosira reaches its lowest level. The typical Chaetoceros flora, which may last for three to six weeks, may have 30 species with C. debilis and C. compresses the most important. On April 9, 1920, Thalassiosira gravida showed dominance with Chaetoceros contortum and C. debilis in Ipswich Bay. On the same date at the Isles of Shoals, T. nordenskioeldii and C. decipiens were dominant, with Rhizosolenia hebatata var. semispina abundant. Ceratium is the dominant organism by the end of May. A variable situation develops due to the fluctuation in movement-of northern water. Ceratium tripos replaces C. longipes by October. Skeletonema costatum is present in late summer. Asterionella japonica bloomed in coastal Maine waters in July, August, 1932 (Bigelow, 1940).

By the end of autumn, summer diatoms are gone from the area extending from Massachusetts Bay to Cape Elizabeth. Coscinodiscus sp. returns to Maine coastal waters in September and October.

The Thalassiosira-Chaetoceros spring bloom and the late summer Skeletonema costatum population are typical features of a standard seasonal phytoplankton cycle. There is an apparent lack of abundance of the summer phytoplankton. The most interesting feature of all, however, is the mechanism which results in phytoplankton populations spreading to the north when the water mass movement, both at the surface and in deeper water, is to the south.

MASSACHUSETTS BAY, INCLUDING CAPE COD BAY

This portion of the Gulf of Maine occupies approximately 1,200 sq km and can be enclosed by an arc from Cape Cod to Cape Ann with a circumference of 30 km. The coastline is not unlike the region between Cape Ann and Cape Elizabeth in terms of its low profile and preponderance of barrier beaches. It is unlike this region in that (1) there are no major river systems draining into the Bay, (2) the population and degree of industrialization is greater and (3) many of the productive wetlands have been filled and destroyed.

The coastline of this portion of the Gulf of Maine is irregular and many fine natural harbors exist. Others have been developed using breakwaters. In general, the inshore waters are less than 15 m deep and the bottom is quite irregular with many shoals. About 20 offshore islands are present in Massachusetts Bay, depending on the stage of the tide which has a range of from 2 to 3 m.

The water circulation within Massachusetts Bay is rather complicated. There is a general southward drift into Cape Cod Bay, but this is not a constant counterclockwise movement. The waters from Lynn Harbor circle and move toward the north around Nahant. Surface waters move into Massachusetts Bay around Cape Ann especially in the spring. There is a net movement of water out of the Bay, mostly around the tip of Race Point on Cape Cod.

Because the water is shallow, the temperatures within Massachusetts Bay exhibit the widest fluctuations of Gulf of Maine waters (0 to 20 C). Salinities range from 28 to 33‰. There appears to be a tendency for water to be trapped within Cape Cod Bay resulting in even greater temperature fluctuations. An eddy exists at the entrance to outer Boston Harbor caused by the alternation of tidal currents.

The minimum phytoplankton populations are observed in winter with Ceratium tripes, the dominant organism, and C. longipes present in smaller numbers. Rhizosolenia alata occurs in southern Massachusetts Bay from December to early February, becoming the dominant species in Cape Cod Bay in late December and January.

The spring bloom generally occurs about three weeks later than it does in the Bigelow Bight. By April 3, plankton nets become clogged with diatoms; Ceratium longipes becomes the most abundant dinoflagellate in that period. After the diatom bloom, Phaeocystis becomes dominant in April in southern Massachusetts Bay. From the end of April to mid-May, diatoms are very scarce in the remainder of the Bay. In the first week of May, Ceratium spp. usually dominates the phytoplankton south of Cape Ann. On May 4, 1921, Dictyum Brightwelli was plentiful in Massachusetts Bay (Bigelow, 1926). Since Massachusetts Bay blooms only for a very short time (a few days or weeks), perhaps productivity is low in relation to other parts of the Gulf (Bigelow,

et al., 1940).

In July and August, Rhizosolenia alata can dominate Massachusetts Bay" plankton and on August 24, 1922, south of the Boston Light Ship, this diatom made up 100 percent of the population (Bigelow, 1926). Skeletonema costatum may-also dominate in-inner portions of the Bay in late August. In the outer portions, Ceratium spp. are the dominant organisms, with C. tripes predominating in the southern portions of Massachusetts Bay by the last week in August, But the variable inflow of water from the area north of Cape Ann makes seasonal descriptions difficult.

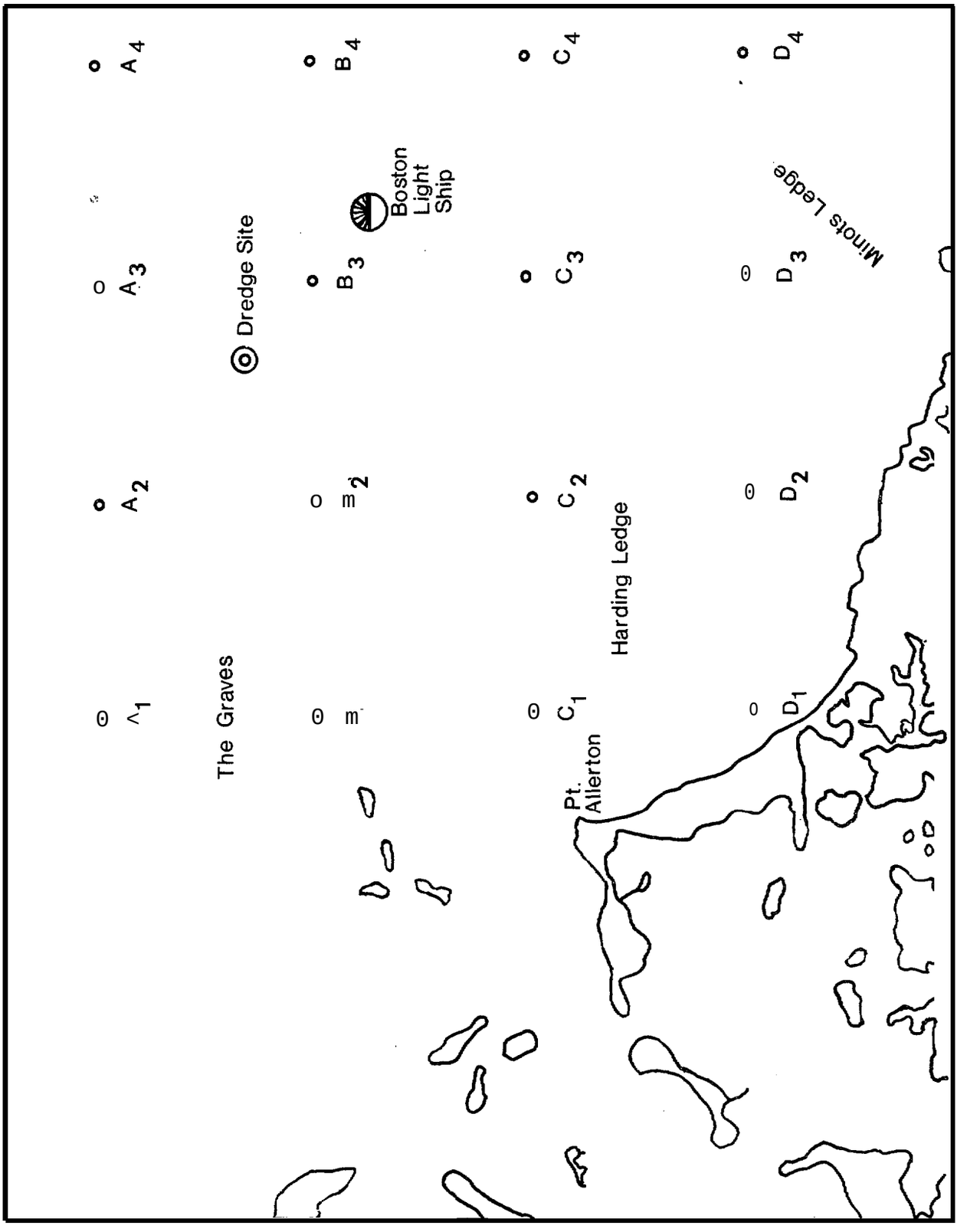
In autumn, there is generally a continuous bloom of the diatom Skeletonema costatum, from the last week of August to the end of October. On October 1, 1915, S. costatum made up the entire population off Race Point (Bigelow, 1926). Ceratium tripes outnumbers C. longipes by mid-September and becomes abundant in Massachusetts Bay in early November.

Some of the data (Mulligan, unpublished) obtained from the N.O.M.E.S. (New England Offshore Mining Environmental Study) program in Massachusetts Bay from December, 1972, to June, 1974, will-be presented in the next section, and compared to the observations made by previous workers in this region. The 1971-72 coastal studies undertaken 'from Rye, N.H., to Boston, Mass., have also provided new information on phytoplankton distribution and are included as section 8.1.10.
Financial assistance for these studies was provided from the Sea Grant-Raytheon 'Program, the Environmental Research Laboratory and the Massachusetts Department of Natural Resources.

Valuable assistance with the collection of samples and interpretation of the NOMES data was obtained from many persons, including Ann Wessel and Carol Pinney, identification and counting of phytoplankton; Richard Beauregard, field collection and analysis of hydrographic data; John Parker, primary productivity studies (a portion, of which will be presented for a Ph.D. degree); Frances S. deLara, laboratory analysis and establishmentof phytoplankton cultures. Special thanks, 'are given to Tom Norris, Mike Donovan, Jeff Wells, John Clay, Kirby Sturtevant, Nancy Parker, Elizabeth Kouleharis, Bob Murphy, Nona Chiarello, Susan Gabrous, Dr. Larry Harris, Dr. David Meeker, Kurt Buck, Mike Gallen, Bernie Ackerman, Dave Junkins, Captain Ned McIntosh of-the U.N.H. Research Vessel Jere A. Chase and Captain Don Phipps of the R/V Walter E. Phipps.

NOMES Sampling Program in Massachusetts Bay

The sampling scheme for phytoplankton consists of 16 stations in Massachusetts Bay arranged in an 13x13 km grid (Fig. 8-3). From , "' December, 1972, to May, 1973, we attempted to sample hi-monthly.



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 8-3

Nomes Sampling Stations in Massachusetts Bay

From June to December, 1973, the proposed plan was to sample the 5 primary stations hi-monthly and the remaining stations once a month. Only one trip. per month was made in winter when productivity was low. This plan was adhered to as faithfully as possible. Schedule changes were due to rough seas, vessel breakdowns and maintenance.

The station grid is oriented in north-south, east-west directions and the stations are labeled A through D, (north to south) and 1 through 4 (east to west). Polar coordinates for the corners of the grid are as follows:

A_1 42 22′ 95" N 7051′	A_4 42 22′ 95″ N 50" W 70 43′ 50" W
D_1 42 17′ 10" N 70 51′ 50″ W	D_4 42 17′ 10″ N 70 43′ 50″ w

Station D_1 has been eliminated from the sampling schedule because of insufficient depth and shifting sand bars. Also, an additional station sampled on some dates. is located between B_2 and B_3 in the center of the proposed dredge site labeled D.S. To facilitate accurate and fast relocation of sample sites, a Raydist computerized navigational system was utilized. The range in depth is 10 to 50m in the sample area. The primary stations are $A_{2,4}$, $B_{2,3}$, C and C_4. Another station was added later 16 km NE from A_4 and labeled O.C.

Summary of Hydrographic Data: To assist in interpreting phytoplankton data with respect to the surrounding environment, hydrographic and physical-chemical measurements were made in conjunction with routine water sampling. This data includes. vertical profiles at each station of salinity, temperature, and light transmittance. Also, M.I.T. conducted water chemical analysis on samples collected in conjunction with phytoplankton samples. This data has been made available to us for some dates.

(1) Salinity: The salinity range for the year (Table 8-1) was between 28.6 and 33.0‰ at the surface. The low value occurred on May 5, 1973; the high value on September 29, 1973. From December to" March values averaged about 30.2‰ to 31.2‰. The water column appeared well mixed; no vertical stratification was evident during this period. Salinity values were higher with distance from shore. After March, salinity values decreased from spring runoff. Seasonal climatological conditions also brought about the initiation of vertical heterogeneity. Lowest salinity values of the year occurred during the spring from April to June. From July to September, values rose again to between 30 and 33 Vertical stratification continued until around mid-December. December 22 is the first date of mixing and homogeneous salinity profiles.

(2) Temperature: Temperature showed typical trends for this area

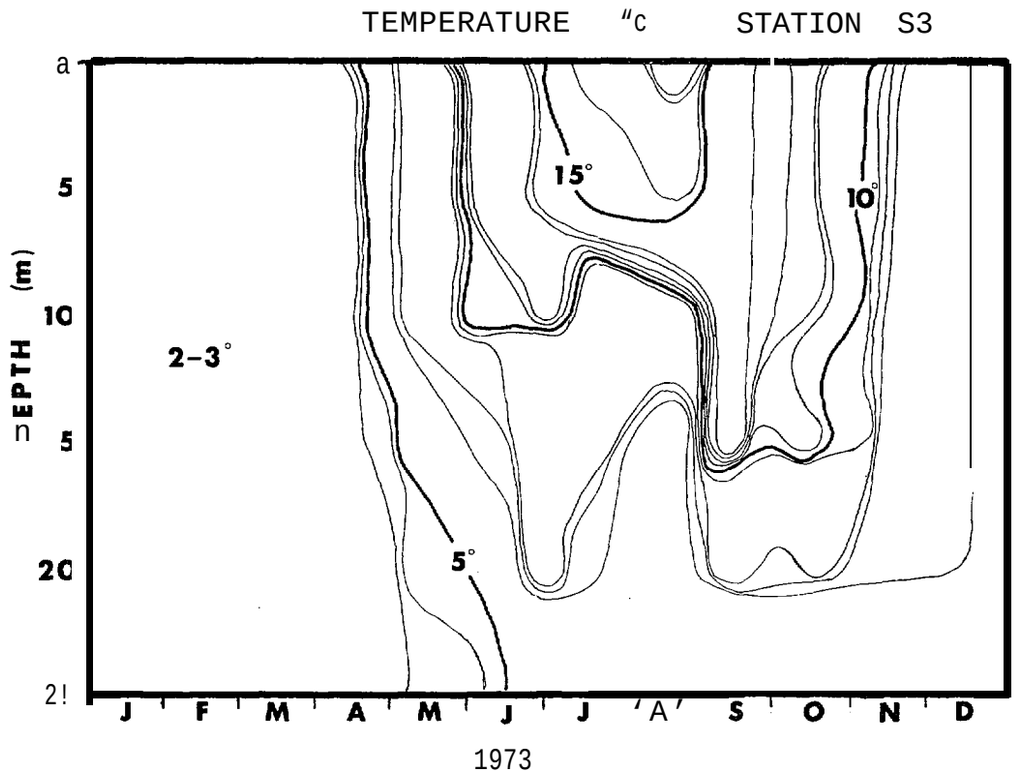
Table 8-1 Salinity Values in Massachusetts Bay

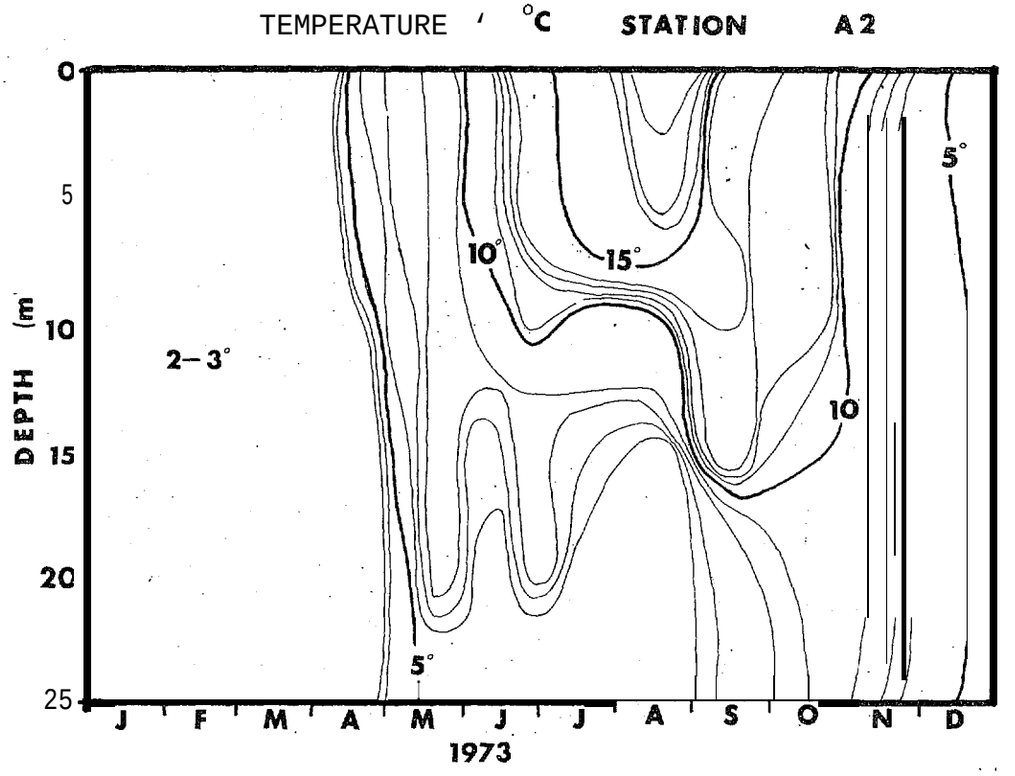
Station 1972 Depth	Salinity Values 12/19	1/13	2/1	2/10	3/21	3/31	4/23	5/5	5/19	9/10	9/29	1973 10/13	12/1	12/22
A2 Surf.	30.5	30.9	31.2	30.5	30.7	29.8	29.1	29.3	29.3	31.9	32.1	32.1	28.6	30.7
5m.	〃	〃	〃	30.4	〃	30.1	29.2	29.0	〃	〃	32.2	〃	29.1	
10m.	〃	31.0	〃	30.2	〃	30.6	29.8	29.1	〃	〃	〃	32.3	26.6	
15m.	〃	〃	〃	30.1	〃	〃	30.2	29.5	〃	31.8	32.0	32.5	〃	
20m.	〃	〃	31.1	30.5	〃	〃	30.6	29.6	〃	32.4	32.7	32.8	〃	
25m.							〃	29.8	29.8					
A4 Surf.	30.8	31.0	31.2	30.7	30.7	29.9	29.1	29.0	29.3	31.8	31.8	32.3	24.1	*
5	〃	〃	〃	〃	〃	30.0	〃	〃	〃	32.0	32.2	32.4	24.8	
10	〃	〃	〃	30.8	〃	30.1	29.4	29.2	〃	〃	32.3	32.3	〃	
z 15	〃	〃	31.3	30.9	〃	〃	29.8	29.4	〃	31.8	32.2	32.4	〃	
20	〃	〃	〃		〃	30.3	30.1	29.9	29.9	32.6	32.6	32.8		
25							30.4	30.2	30.2					
B3 Surf.	30.3	30.6	31.3	31.1	30.7	30.0	29.2	29.2	*	31.6	32.0	32.2	32.5	30.7
5	〃	〃	〃	31.0	〃	〃	29.4	〃		31.9	32.1	32.4	30.0	〃
10	〃	〃	〃	〃	〃	30.3	〃	〃		〃	〃	〃	31.5	30.2
15	〃	〃	31.2	〃	〃	〃	29.5	〃		〃	32.5	32.3	31.9	30.6
20	〃	〃	〃	〃	〃	〃	30.3	29.9		32.1	32.8	32.9	〃	〃
25							30.6	30.2						
C2 Surf.	29.8	29.7	30.8	29.8	30.2	29.5	29.1	29.2	29.0	31.4	32.0	31.9	33.1	*
5	〃	30.2	〃	30.4	〃	〃	29.2	〃	〃	31.5	31.9	32.2	〃	
10	30.0	30.3	30.9	〃	30.6	29.8	29.4	〃	〃	31.6	32.1	32.2	〃	
15	30.1	30.6	〃	30.2	30″	〃	30.0	〃	29.1	32.1	32.3	32.3		
20	30.2	〃		30.4	〃	30.1	30.2	29.5	29.6	32.2	32.8	32.9		
25							〃		29.8					

(U.S. C.G. Oceanographic Report No. 53). The temperature range over the year was 0 to 18.8 C. From December to March temperatures were near the lower part of the range, 0-5 C. Profiles (Figs. 8-4A to 8-4E) were essentially homogeneous, indicating typical winter conditions characterized by vertical mixing. In April, the situation began to change with the warming of the surface waters and, eventually, the development of a marked thermocline. Stratification increased and by mid-summer, three layers were well-defined: the surface layer to about 10 m had temperatures between 12 and 17 C.; from 10 to 20m had temperatures between 8 and 9 C; and from 20 m to the bottom had temperatures between 5 and 6 C. By September the "surface" layer extended down to 15 m. October through December, 1973, saw the coming of winter conditions causing cooling of the surface layer, reduction of the three-layered system to two and eventual ly, vertical homology. Station C_2 does not clearly show a three-layered system because of the shallower depth. Also, being closer to shore, there is more fresh water at C_2, thus, in January, the temperature of this surface water was below 1 C.

(3) Light transmittance: The euphotic zone is defined as that part of the water column for which there is sufficient light to support active photosynthesis. Sufficient light is considered to be 1 percent of that which strikes the surface. The depth of the euphotic zone was obtained by measuring with a light meter that depth at which only 1 percent of the surface light remains. These values were plotted for the primary stations (Figs. 8-5A to 8-5E). At station B_3, the depth of the euphotic zone ranged from 11 to 26 m (bottom) over the year. Maximum values occurred during the months December, January, and February. By late February, spring phytoplankton and or runoff contributed to a decrease in euphotic depth, and by March 31, a minimum was reached (11 m). The following two cruises, April 28 and May 5, showed 1 percent values were down to the bottom (26 m). A second decrease in euphotic depth occurred in June (depth of the euphotic zone = 13 m). This depth increased more gradually with time down to 20 m in August, then a third decrease occurred on September 10 (11 m). The euphotic zone then gradually increased again to the bottom, back to winter conditions. Curves for the other stations follow this general trend. Differences. in absolute depth of the euphotic zone from the other stations are functions of their location with respect to land and the depth to bottom. These factors both affect the amount of suspended sediments. The shallowest depth of euphotic zone recorded was 4 m at stations C_2 and C_4 on March 31, 1973.

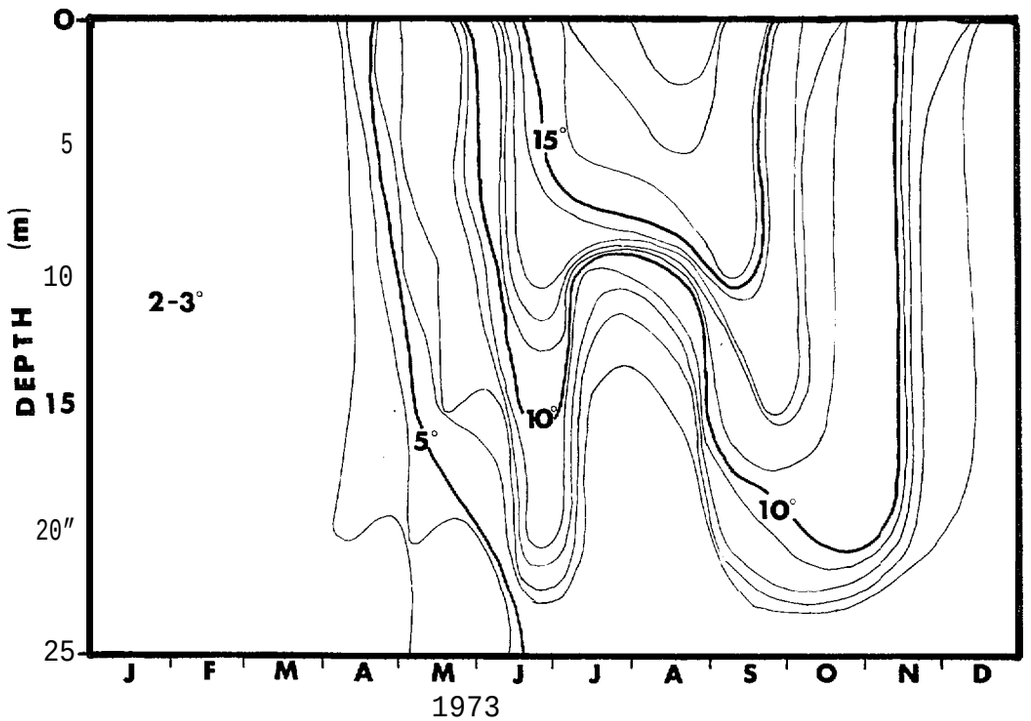
(4) Chlorophyll a: Chlorophyll a values for each depth for which phytoplankton samples were taken were measured in the laboratory spectrophotometrically or on board by fluorimetry. These values have been integrated over depth and the values described for the 5 primary stations (Fig. 8-6). These values showed the expected bimodal seasonal changes. Values ranged between about 10 mg/m^2 in the winter to about 250 mg/m^2 during bloom conditions. A high value of

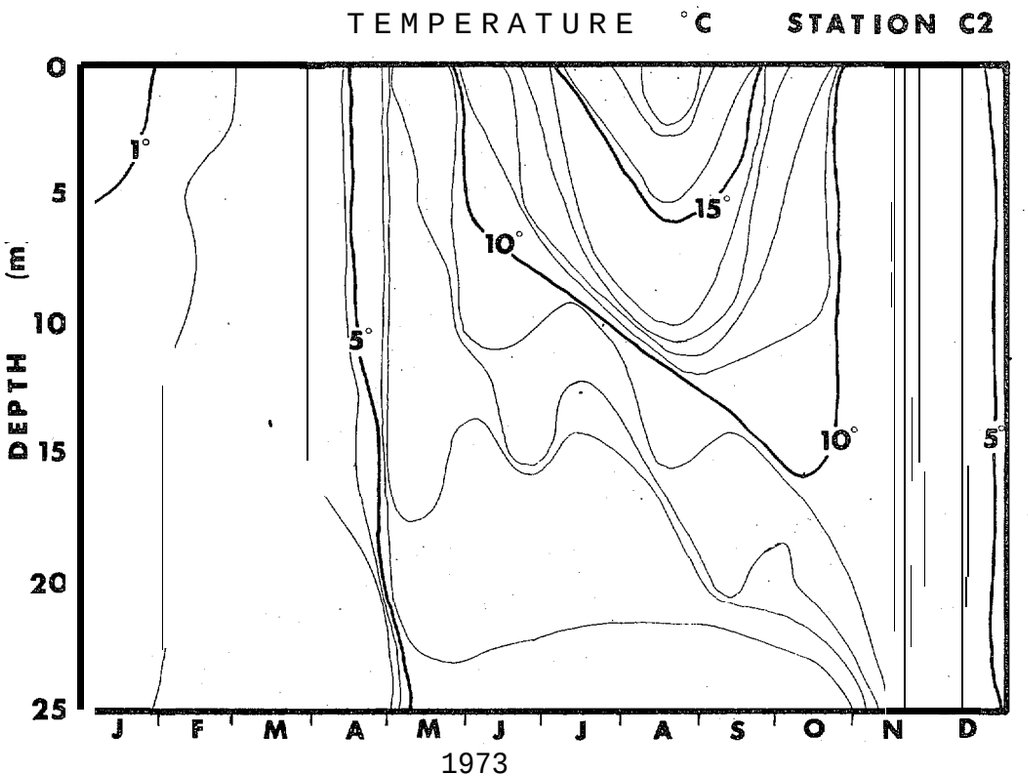

TEMPERATURE "c STATION S3
a
5
10
5
20
2!
EPTH (m)
15°
10°
2-3°
5°
J F M A M J J A S O N D
1973



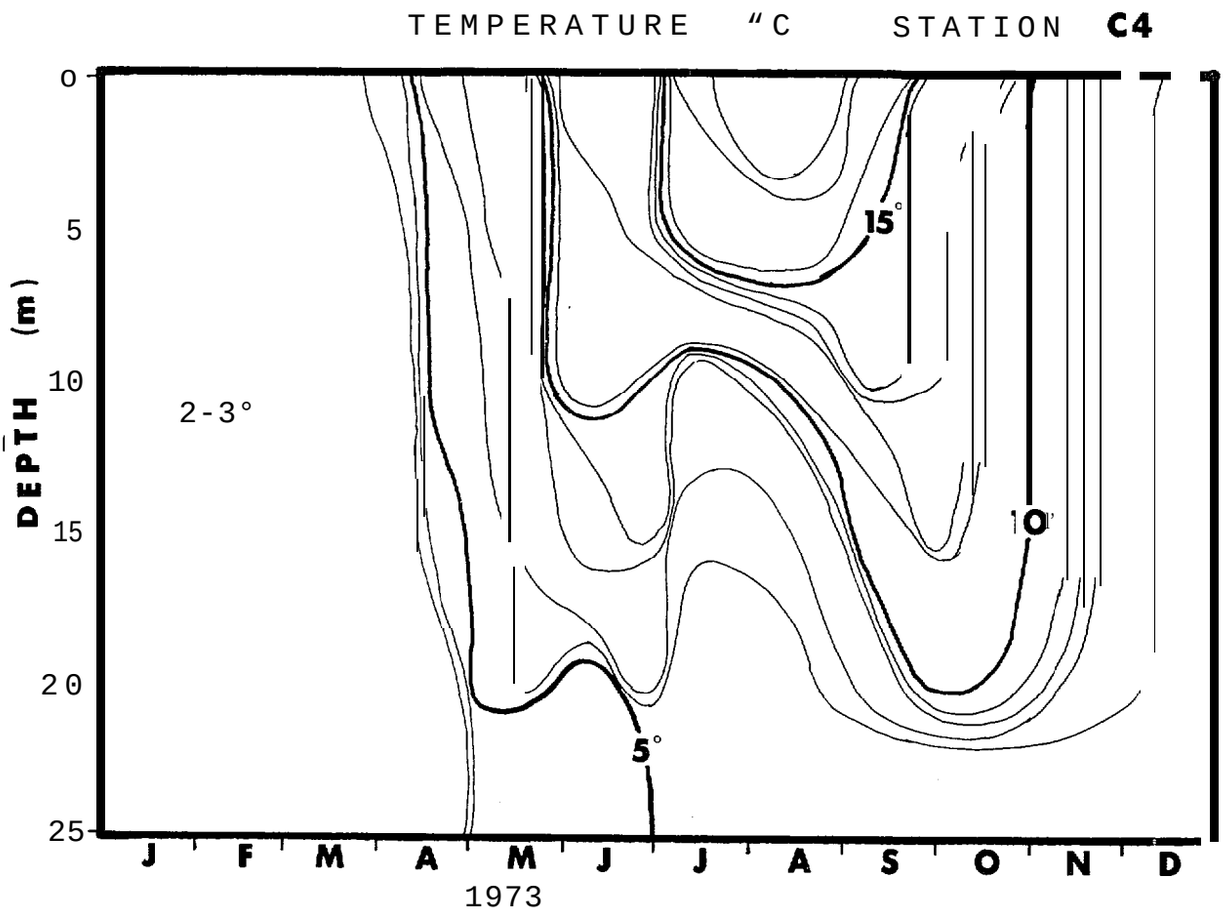
A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-4b	Temperature Values Station A2

TEMPERATURE 'C STATION A4

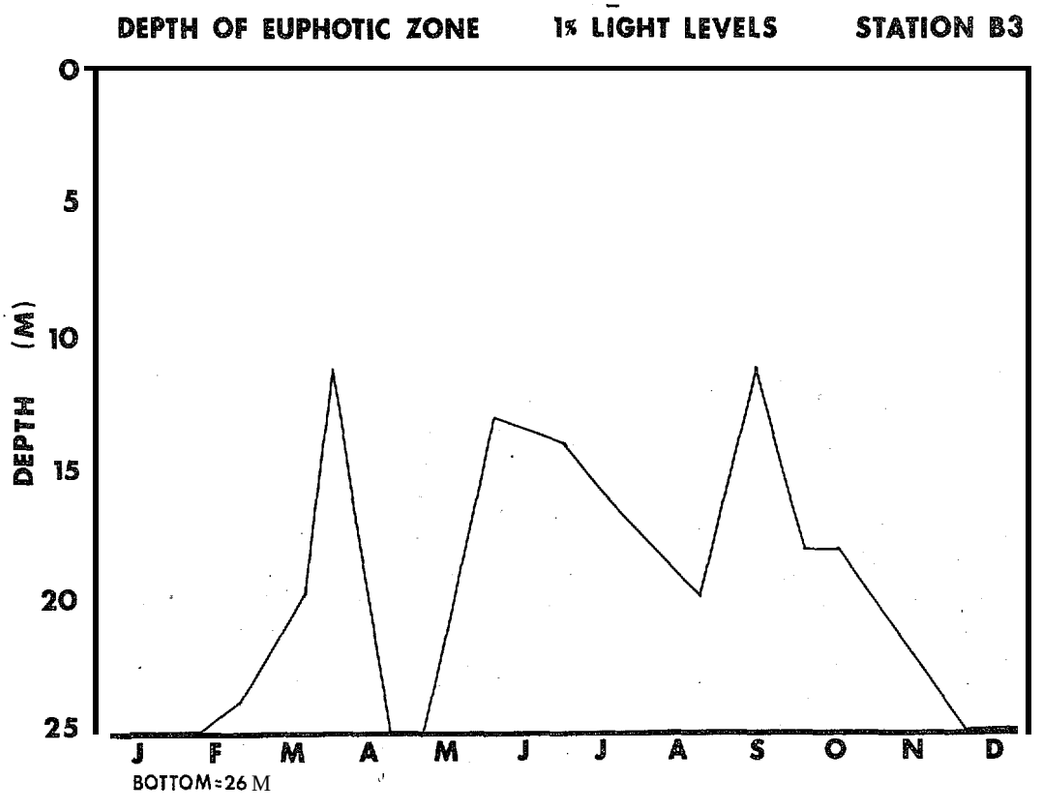




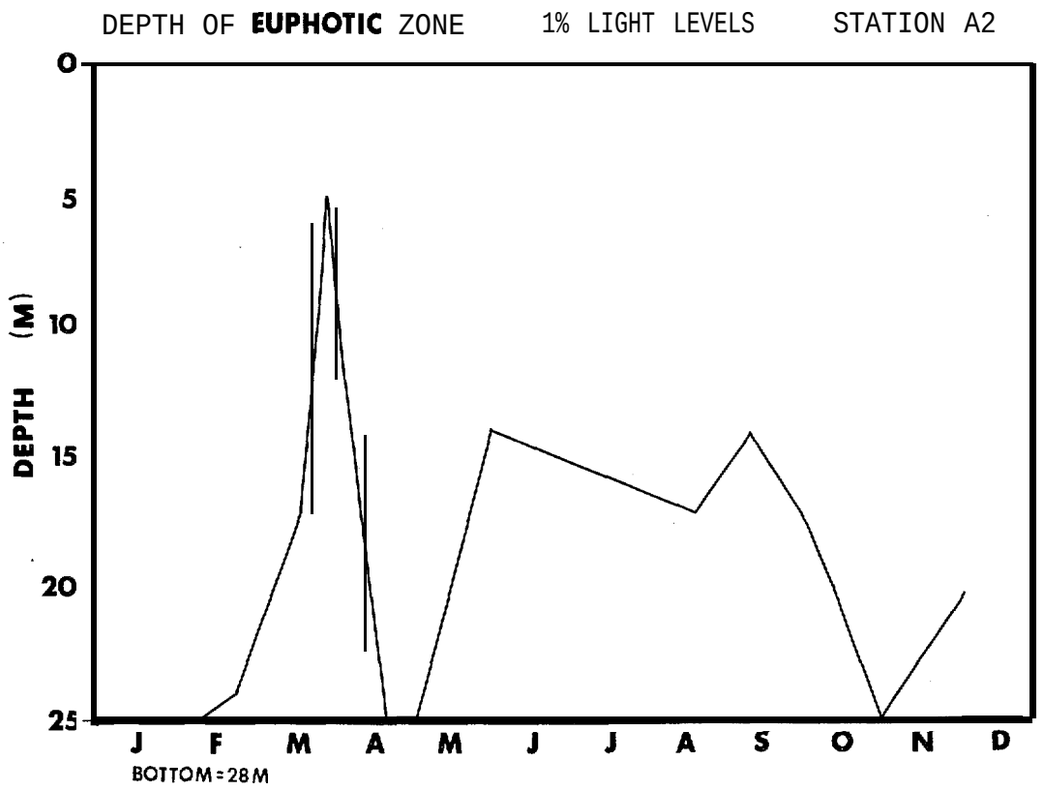
A SOCIO-ECONOMIC AND ENVIRONMENTAL inventory OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE "8-4d	Temperature Values Station C2

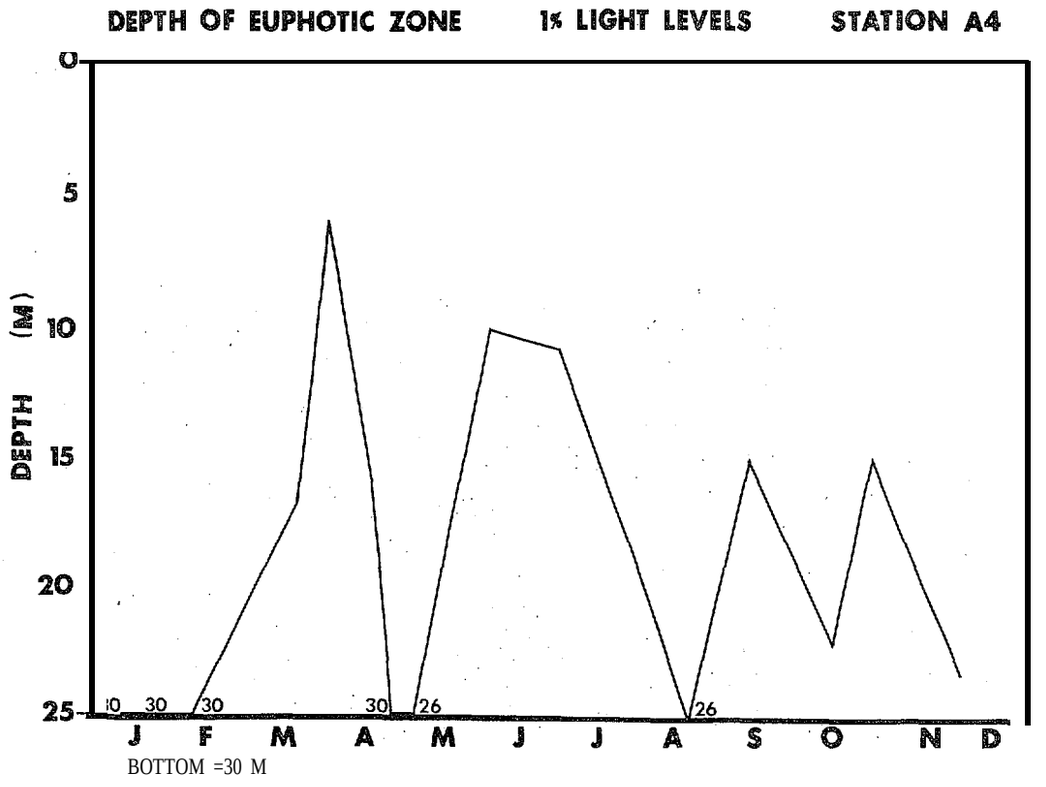


A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-4e	Temperature Values Station C4

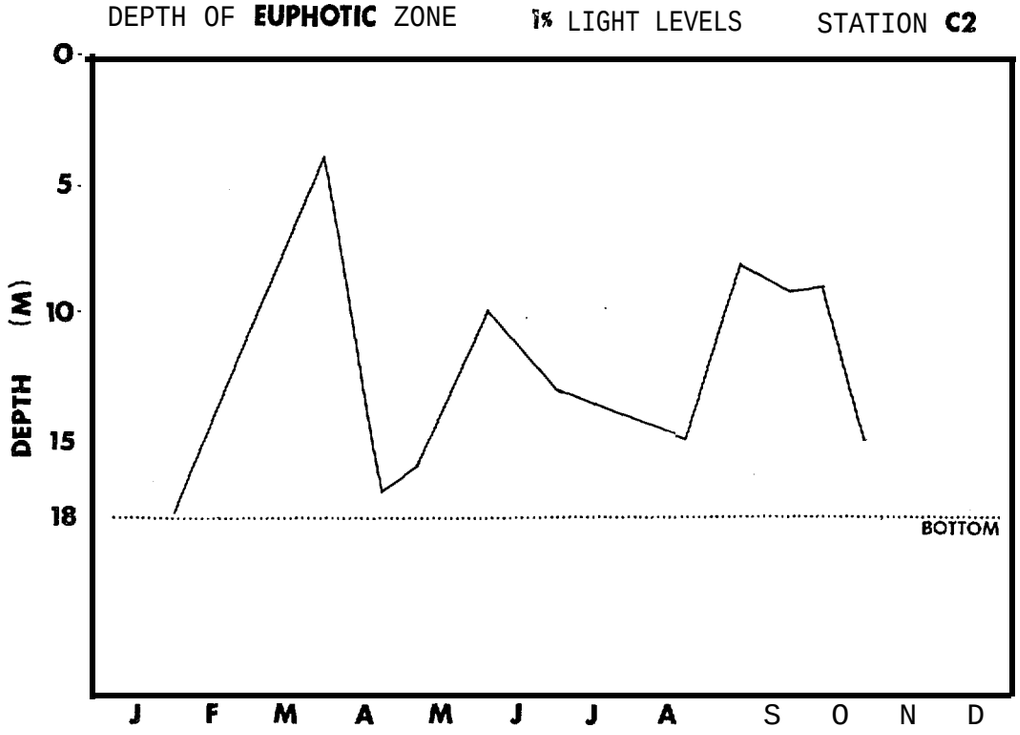


A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-5a	Depth of Euphotic Zones Station B3

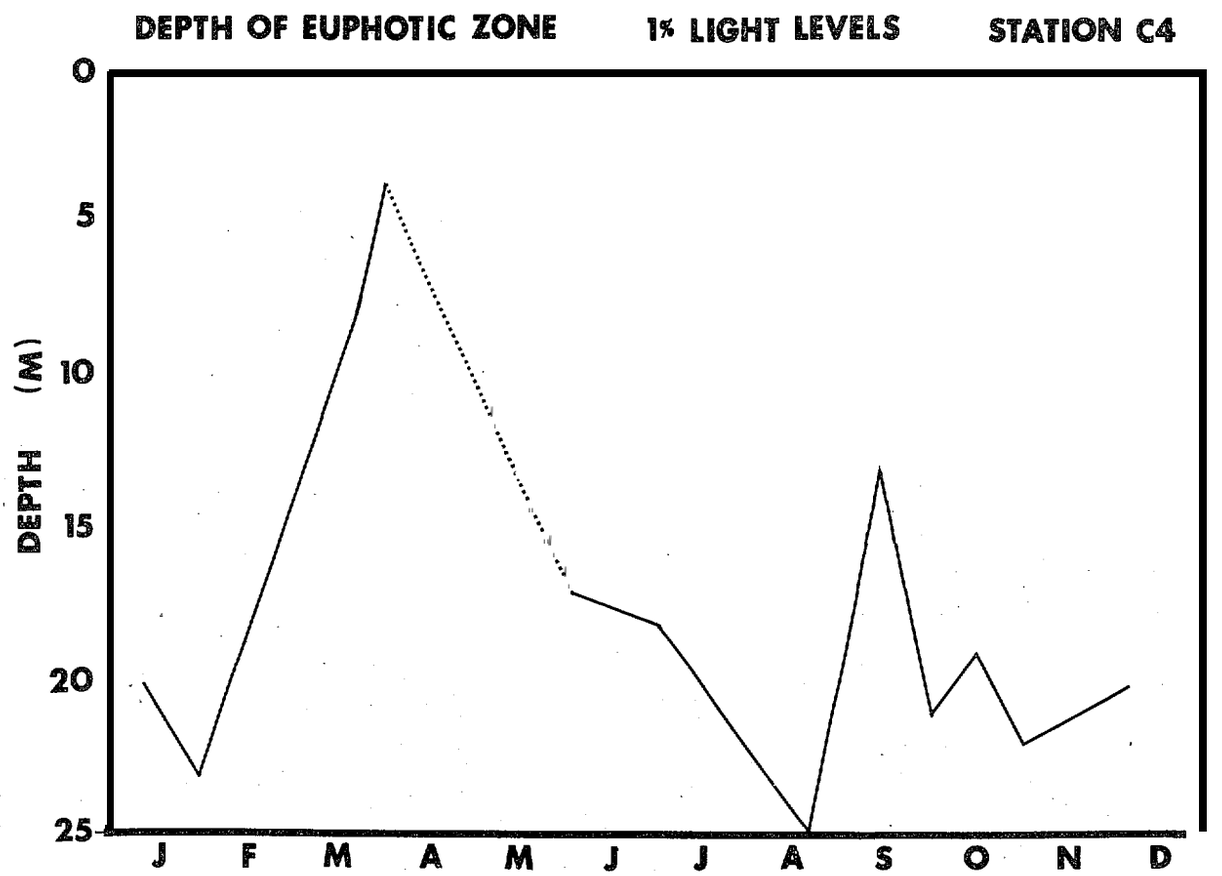

DEPTH OF EUPHOTIC ZONE 1% LIGHT LEVELS STATION A2
DEPTH (M)
0
5
10
15
20
25
J F M A M J J A S O N D
BOTTOM = 28 M



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-5c	Depth of Euphotic Zones Station A4



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-5d	Depth of Euphotic Zones Station C2



A SOCIO-ECONOMIC AND ENVIRONMENTAL inventory OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-5e	Depth of Euphotic Zones Station C4

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
n ? IGOM PARC	FIGURE 8-6	Chlorophyll a Values

480 mg/m^2 occurred at station C_2. In most cases, the spring peak, which occurred in late March and early April, was higher than the fall, mid-September, peak; however, at station B_2, the fall peak occurred earlier (in mid-August) than at other stations, and reached higher proportions than the spring bloom. Another minor peak occurs in October. At A_2 this represents a substantial amount of chlorophyll, about 180 mg/m^2. The influence of the shoreline on chlorophyll seems to indicate that the closer to shore, the higher the cholorphyll values, This is probably due to nutrient availability from freshwater runoff and from the bottom sediments.

Seasonal Cycle of Phytoplankton: Winter 1972-73. Samples collected on December 19, 1972 were primarily composed-of Thalassionema nitzschioides, Skeletonema costatum, Thalassiosira sp. and Chlamydomonas sp. (r = 4u). The cell counts for each species were less than 50 cells/ml. There was no depth preference or any apparent inshore-offshore or north-south trend. Many empty pennate diatom frustules were present. A slight increase in population size (to 60 cells/ml) was evident on January 13, 1973. The green flagellate (X16) had disappeared and Cylindrotheca closterium was also collected at each station with a maximum count of 43 cells/ml.

Three samples in February, 1973, saw the initial appearance of diatoms destined to play a major role in the spring bloom. On February 1, Thalassionema nitzschioides and Skeletonema costatum had increased to 96 and 72 cells/ml respectively, and Nitzschia delicatissima appeared at levels to 38 cells/ml. At this time, Thalassiosira nordenskioeldii, T. decipiens, and Porosira glacialis made their initial appearance. The population on February 10 was similar with some, important changes. Skeletonema costatum reached 105, cells/ml in the deeper water of the southern inshore stations and disappeared from the more northern, offshore stations. Chaetoceros socialis was collected at the inshore southern stations with 48 cells/ml; Detonula confervacea was also found for the first time. The presence of Scenedesmus sp. in the sample indicated influence of fresh water runoff in the sampling area. Although the sampling program on February 24 was abbreviated, no further movement toward spring bloom conditions was evident.

Spring 1973. The spring bloom was definitely in progress during the March 21 sampling. Detonula confervacea was the dominant organism (maximum 1290 cells/ml) and was present at all stations and at all depths. Cell numbers increased from north to south. On this date, the largest population at the surface occurred at the inshore stations. Large numbers of resting spores were present at all depths on the off-shore stations. Six other species reached maximum concentrations of 115 to 230 cells/ml on this date including Thalassiosira gravida (230 cells/ml), T. nordenskioeldii (115 cells/ml), T. sp. (species impossible to determine because of viewing angle - 160 cells/ml), Porosira glacialis (140 cells/ml), Skeletonema costatum (130 cells/

Table 8-2 Dominant Phytoplankton from 12-19-72 - 12-22-73

Bacillariophyceae	Volume Cell (u^3)	Amount Carbon Cell (picograms)	Dates of Occurrence	Date of maxi mum occurrence	# Cells at maximum/ml	Total volume of species at peak (u3x105)	Total picograms carbon at peak ($x10^4$)
Chaetoceros debilis	929.	78.	3/21 5/19 4/23 6/2	6/2/73	910.	8.5	7.1
C. decipiens	4500.	304.	3/21 4/17	4/17/73	196.	8.8	1.6
C. didymus	884.	82.	10/13/73	10/13/73	32.	.28	.26
C. socialis	200.	27.	2/10 3/21 4/23 5/19 6/2	4/12/73	3400.	6.8	9.2
C. subsecundus	12,000.	717.	3/31/73	3/31/73	50.	6.	3.6
Coscinodiscus sp. 1	250.	34.	10/28 12/22	12/1/73	48.	.12	.16
Cylindrotheca closterium	1200.	112.	1/13 9/10- 2/10- 9/30 3/21		206.	2.5	2.3
Detonula confervacea	545.	57.	3/21 3/31	3/31/73	2900.	16.	1.7
Guinardia flaccida	58,000.	1988.	12/1 2/22	12/22/73	50.	29.	9.9
Leptocyliodrus danicus	880.	99.	7/14 0/28	9/1 0/73	4900.	43.	49.
L. minimus	180.	25.	10/28 2/1	10/28/73	39.	.07	.10
Nitzschia delicatissima	340,	43.	9/30 0/28	10/13/73	280.	.95	1.2
Porosira glacialis	44,000.	1572.	3/21 3/31	3/21/73	140.	62.	22.
Rhizosolenia delicatula	1000.	103.	10/28 12/1	10/28/73	1200.	12.	12.
R. faeroense	18,000.	937.	3/21 3/31	3/31/73	33.	5.9	3.1
R. fragilissina	1500.	129.	7/14 9/30 8/20 10/28	7/14/73	970.	15.	13.
Skeletonema costatum	480.	52.	12/19 5/19 2/10 6/2 3/21 7/14 3/31 12/1	10/13/73	3300.	16.	17.
Thalassionema nitzschoides	720.	76.	12/19 4/17 2/24 3/31	3/31/73	100.	.72	.76
Thalassiosira decipiens	3000.	242.	2/10 3/21 3/31	2/1 0/73	38.	1.1	.92

Table 8-2 (continued)

Others:	Volume Cell (u^3)	Amount Carbon Cell (picograms)	Dates of Occurrence	Date of maximum occurrence	# Cells at maximum/ml	Total volume of species at peak (u3x105)	Total picograms carbon at peak ($x10^4$)
T. gravida	2800.	218.	3/21- 4/13	3/31/73	426.	12.	9.3
T. nordenskioeldii	3900.	260.	3/21- 4/17	4/1 3/73	700.	27.	18.
T-. species 1	3600.	244.	12/19 3/21 1/13 4/23	4/23/73	160.	5.8	3 . 9
T. species 2	59.	9.	5/19 10/28 7/14	5/1 9/73	190.	.11	.17
Dinophyceae							
Amphidinium crassum	1 3 0 0 .	119.	5/5 6/30 7/14	5/5/73	170.	2.2	2.0
Peridinium triqueta	1500.	113.	.5/19 10/30 6 / 3 0 8/20	8/20/73	103.	1.5	1.2
Chlorophyceae							
K16-Chlamydamonas	280.	37.	12/19 5/5- 3/21 7/14 3/31 9/10	6/30/73	900.	2.5	3.3
Euglenophyceae							
Euglena	820.	84.	3/21 4/23 4/13 9/10	3/21,3/31 6/2	48.	3.9	.4
Chrysophyceae							
Cyracosphaera	2600.	202.	10/13	10/13/73	41.	1.1	.83
K23-doublets	7.	2.	3/21	3/21/73	383.	2.7	7.7
Eutripea	240.	33.	3/21 8/20 3/31 9/30 4/23 10/28 6/30	5/5/73	43.	.1	.14
1	15.	4.	12/19/72 12/1/73	12/19/72	870.	.13	.35

ml), and Chaetoceros socialis (125 cells/ml). Chaetoceros compresses, C. decipiens, C. debilis, Thalassiosira rotula and T_. condensate were minor members of the plankton.

Samples collected on March 31 indicate that this was the maximal bloom period. At this time, the Chaetoceros community begins to dominate. Detonula confervacea was still the most abundant form at the southern inshore stations (2900 cells/ml) but it had declined to low levels at all other locations in the Bay. Chaetoceros socialis had the second largest population with a maximum number of 2200 cells/ml occurring at the central stations. Although common at all stations, Thalassiosira nordenskioeldii numbered 614 cells/ml in the northeastern portion of the Bay and spores were frequently encountered in the southwestern inner shore. T. gravida was more abundant (426 cells/ml) in the inner stations. Chaetoceros debilis (331 cells/ml) and C. compresses (90 cells/ml) were prevalent at the outer stations. Skeletonema costatum was abundant (250 cells/ml) in the inshore stations at the same time that the Porosira glacial is population had declined in abundance.

Three sampling dates in April show Chaetoceros socialis continuing as the major organism ranging from 2600 cells/ml on April 13 to 3400 cells/ml on April 17 to 1200 cells/ml on April 23. Spores from these organisms were extremely abundant on the first two sampling dates. C. debilis declines from 510 cells/ml on April 13 to 330 cells/ml on April 23. Thalassiosira nordenskioeldii declined from more than 700 cells/ml on April 13 to less than 200 cells/ml. No spores were collected after April 13. At the end of the month, the smallest populations occurred at the offshore stations. Peaks at the offshore stations were found at greater depths.

On early May (May 5) the diatom bloom appeared to be ended but a burst of activity was apparent on May 19. Chaetoceros socialis and C. debilis reached numbers of 420 and 210 cells/ml respectively, but the populations were not very healthy. Skeletonema costatum was the dominant organism (1200 cel Is/ml) and showed a definite inshore maximum, but many of the cells were dying. On May 5, unicellular Chlorophyceae were abundant (up to 890 cells/ml) and Amphidinium crassum (170 cells/ml) was the dominant of 12 dinoflagellate species; small numbers of Dinobryon sp. were collected at each station. The Chlorophycean algae were reduced to lower levels by May 19.

Summer 1973. Chaetoceros socialis, C. debilis, and Skeletonema costatum were present in low numbers in the Bay on June 2. Of the three organisms, only Chaetoceros debilis was present (910 cells/ml) at an offshore control station established 10 miles northeast of the Boston Light Ship. By June 30, the population in Massachusetts Bay was quite small and only the unicellular Chlorophyceae (X16), Amphidinium crassum and Carteria sp. were common with maximum concentrations of 900, 130 cells/ml, respectively.

The July 14 samples showed a dramatic resurgence of the diatom population; Rhizosolenia delicatula, maximum at 1200 cells/ml, R. fragilissima maximum at 970 cells/ml; and Skeletonema costatum at 520 cells/ml. Skeletonema costatum reached nearly 1000 cells/ml at the offshore control station while the other two species declined to very low levels from their maximum values at the inner southwestern stations. Most of the July population was confined to waters 5 m or less in depth. During August (Aug. 20) the Rhizosolenia sp. declined while Skeletonema costatum increased to 900 cells/ml. Leptocylindrus danicus (150 cells/ml) appeared in the samples for the initial time and Nitzschia delicatissima reached a concentration of 240 cells/ml.

Fall 1973. Leptocylindrus danicus bloomed in September and reached the highest concentration of any species at any time in the Bay on September 10 at 4900 cells/ml. This population appeared to be confined to the southwestern region of the Bay. Skeletonema costatum had dropped to less than 100 cells/ml by that date. Although L. danicus declined to 2700 cells/ml on September 30, a fall bloom of diatoms was in progress. Skeletonema costatum reached 1500 cells/ml at the inner southwestern station and declined in number at the offshore stations after the pattern of L. danicus. Rhizosolenia delicatula and R. fragilissima returned at the offshore stations (224 and 120 cells/ml, respectively) and Nitzschia delicatissima also reappeared (144 cells/ml).

On October 13, Skeletonema costatum reached its largest size (3280 cells/ml) in the southwestern corner of the Bay; Leptocylindrus danicus continued to decline to 300 cells/ml. Nitzschia delicatissima doubled in numbers from the previous sampling date, while Rhizosolenia species were much reduced. By October 28, Skeletonema costatum was still dominant but had declined to 300 cells/ml. L. danicus declined to 200 cells/ml and R. delicatula and R. fragilissima increased to about 140 cells/ml, while N. delicatissima nearly disappeared.

Winter 1973. The December 1 collections showed a small Coscinodiscus sp. ($r = 7.5\mu$; 32 cells/ml) and Guinardia flaccida (24 cells/ml) as the major forms. By late December, G. flaccida had achieved dominance over Coscinodiscus, at least at the central station near the Boston Light Ship.

Nutrients and Seasonal Cycling in Massachusetts Bay

Phosphate, nitrite, and nitrate concentrations were assessed in Massachusetts Bay in a somewhat random manner during 1970-1972 by M.I.T. (Frankel and Pearce, 1973). Some of the findings have been included to parallel our phytoplankton observations. Phosphate concentrations of six of the grid stations in the Bay were not significantly different during 1972 and the values were pooled to obtain an average PO_4 value for each sample date. The 1972 annual range of PO_4 was 0.132 - 3.00

ug-at P/l. The yearly mean was 1.61 ug-at P/l, and seasonal variation was observed. Maximum concentrations occurred in October while the seasonal minimum was in July. Generally lower PO_4 concentrations were observed in offshore waters as compared to an inshore station near Deer Island in Boston Harbor, which is the site of a sewage outfall.

Although no seasonal profile of nitrate is available, NO_2 concentrations in 1972 may provide some insight to the seasonal nitrogen flux. Strong seasonal trends of nitrite concentrations were observed in Massachusetts Bay. Highest values were recorded in the winter months (December - January). Steady reduction through the spring produced a summer minimum in June. Nitrite increased throughout the summer and by late August and September, 1972, a second maximum was obtained with concentrations nearly as high as the winter maximum.

During the winter - spring of 1973, the UNH phytoplankton team proposed and established the NOMES sampling stations in Massachusetts Bay (ibid, 1973). In late March, water samples were collected and delivered to M.I.T. for analysis of NO_2, NO_3, and PO_4. Although NH3 concentrations were highly desirable, they were not obtained.

Nitrate concentrations were reduced from 4 urn/1 or greater in March at the central grid station (B3) to zero from late April to mid-May at all but the deepest collections (at 20 m depth). At a station farther from shore (A_a), nitrate concentrations in the surface waters reached zero at a later time (early May), and then fluctuated widely. Zero nitrate values were obtained at the stations closest to shore (Al), where the initial nitrate concentrations were highest. Nitrite concentrations were much lower than nitrate but showed similar changes with time.

Phosphate concentrations were highest in deep water and declined to the lowest concentrations at all but the stations close to shore in early May. Extreme values ranged from about 0.5 to 2 micromoles per liter. Lowest concentrations at the inshore station occurred in late June, 1973.

Primary Productivity and Chlorophyll a Data in Mass. Bay

Primary productivity and chlorophyll a data have been obtained for five grid stations and the offshore control station in Massachusetts Bay for the period, March - October, 1973. The location of the five stations, A_2, A_4, B_3, C_2, and C4 within the grid has been mentioned previously, with the lower numbers representing the more inshore north-south transects. Chlorophyll a analysis to date consists of mg/m^3 for all dates at 16 stations, however only the B_3 station values have been integrated over depth and are shown in the following table.

(Table 8-3).

Date:	3/21	3/31	4/13	4/23	5/5	6/30	7/14	8/20	9/10
mg/m^2	143	159	169	63.	23	38	43	24	33

(Table 8-4). In-situ C-14 Primary Productivity

Date:	9/29	10/13	10/28
mg/m^2	71	83	99

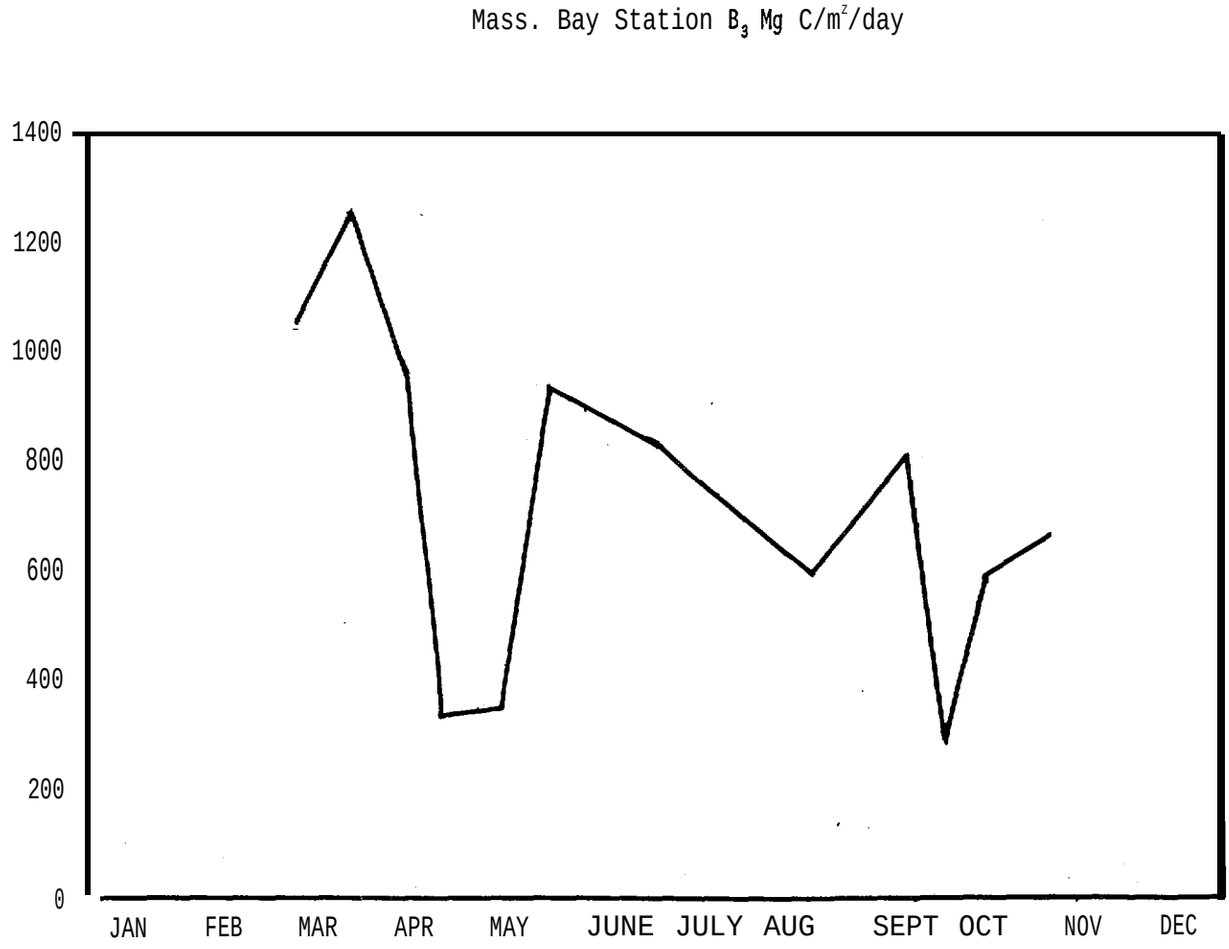
In situ C-14 primary production analysis has been made for station B_3 and is presented below as $mgC/m^2/hr$ and $mgC/m^2/day$ (Parker and Mulligan, in preparation).

Date	$mg/C/m^2/hr$	$mgC/m^2/day$
3/21	172	1383
3/31	160	1170
4/13	129	1202
4/23	43	322
5/5	39	284
5/19	120	963
6/30	72	881
7/14	85	757
8/20	71	607
9/10	102	839
9/29	30	240
10/13	94	615
10)28	99	672

Simulated C-14 measurements were made using an onboard incubation tank. Samples were collected at each of the major stations at depths corresponding to surface light attenuations of 100, 50, 10 and 1 percent of surface light intensity. These samples were incubated for 4 hours at ambient sea surface temperature, and values of $mgC/m^3/hr$ were calculated and integrated over depth to obtain $mgC/m^2/hr$ estimates as shown in Table 8-4.

Data for carbon fixation and $chlorophyll/m^2$ have been statistically analysed, where productivity depends upon the amount of total chlorophyll a in the water column. Analysis of variance for the regression shows that a significant quantity (95 percent) of the variation in productivity can be accounted for by variation in mg chlorophyll a/m^2.

The annual cycle of primary production is coming apparent (Fig. 8-7'). There is a bimodal spring bloom with the early peak occurring in April. The second and lesser peak occurred in the middle of May followed by



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-7	Annual Cycle of Primary Productivity in Massachusetts Bay

decreasing values of primary production through the summer months. A fall bloom in the middle of September also appears but its intensity is less than either spring peaks. An annual estimate based upon this data suggests that about 250 gC/m^2/year should be expected in the Mass. Bay area. This value is typical of Eastern Atlantic coastal waters.

There is a very distinct decrease of productivity from the inshore to the offshore stations (Fig. 8-8; able 8-5). Stations located along north-south transect #2 show the highest productivity while stations along transect #4 are typically lower by about half. These stations are also quite similar to our offshore control station which is located approximately 8 miles out from B_3 and probably is not influenced as much by Boston Harbor. Station 33 is located between the #2 and #4 transects and tends to substantiate the trend of shoreward increase in productivity. Values of carbon fixation at 6_3 average about 80mgC/m^2/hr while those of transects #2 and #4 average 130 and 60 mgC/m^2/hr respectively.

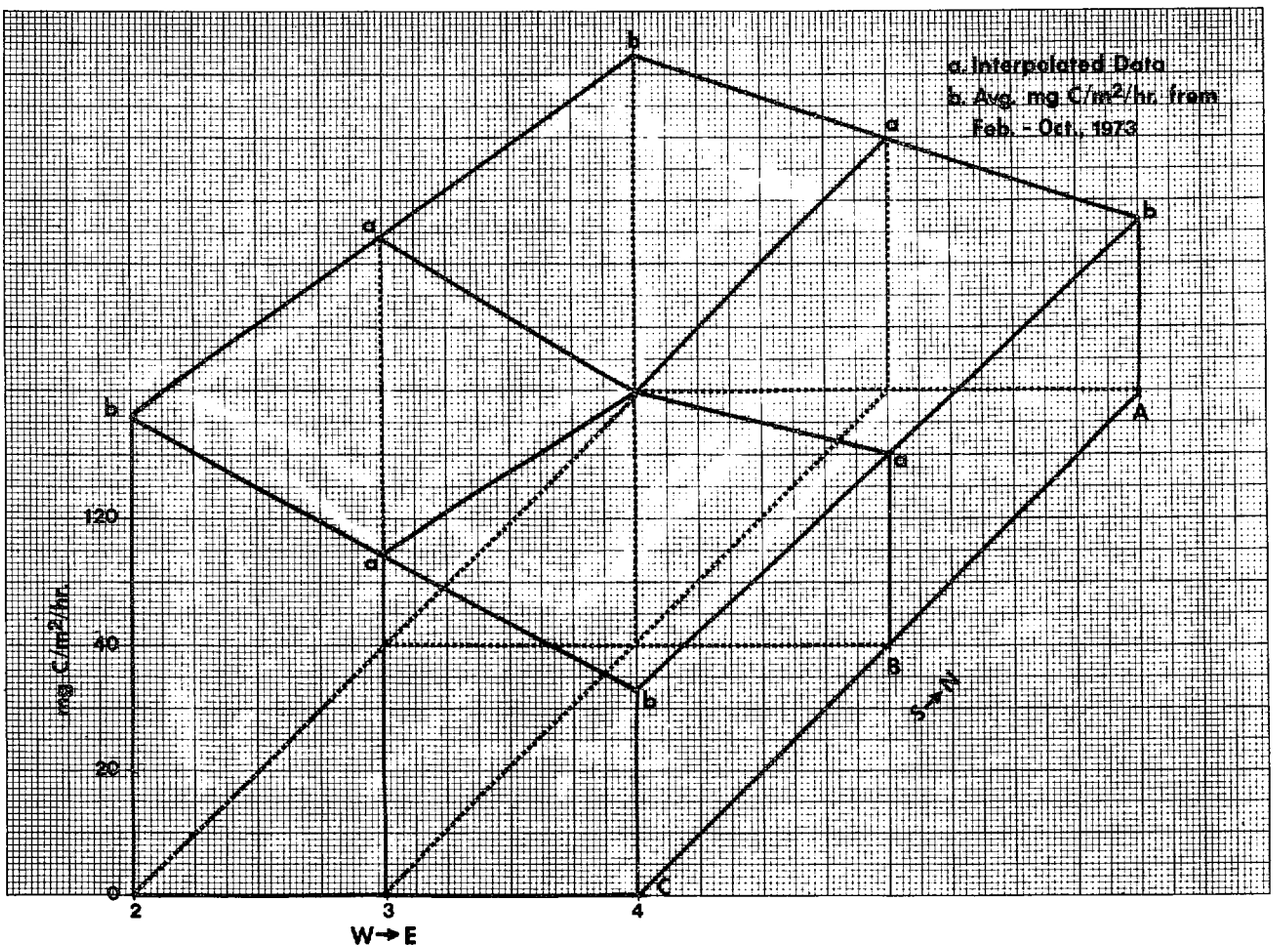
Continued sampling through the end of the 1974 spring bloom should provide enough data to identify the significant trends in Massachusetts Bay phytoplankton productivity.

Date	A_2	A_4	mgC/m^2/hr 63	C_2	C_4	Offshore Control
7/1 4/73	186	42	86	128	45	43
8/20/73	92	60	71	212	81	-
9/10/73	32	12	102	134	36	46
9/29/73	78	22	30	41	39	-
10/13/73	108	78	94	172	79	-
10/28/73	140	118	99	222	114	-
Average	106	55	80	152	66	44

Table 8-5. Simulated in situ carbon fixation corrected for percent difference between in situ and on deck values obtained at station B_3.

RYE, N.H., TO BOSTON HARBOR, MASS., SAMPLING PROGRAM

A coastal phytoplankton study, supported by Raytheon-U.N.H. Sea Grant funds, was initiated in the summer of 1971, in order to examine the variability of phytoplankton along an 80 km coastal transect from Rye, N.H., to Boston, Mass. Hydrographic and phytoplankton distribution data were collected at six stations, located about 2-5 km offshore, including three stations north of Cape Ann, Mass. - Rye, Merrimack, and Annisquam - and three to the south of Cape Ann - Bakers Island in Salem Harbor, Flip Rock, and Pope Rock. Station depths at MLW



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-8	Primary Productivity Values at Massachusetts Bay Stations

varied from 9 m at Annisquam to 15 m at Bakers Island.

Sampling was conducted on a monthly basis, at three depths, from August, 1971, to, August, 1972, except during the late spring bloom period, when sampling was extended to twice a month. Cruises in 1971 and 1972 were on the R.V. Jere Chase. The following observations on the hydrographic conditions and, biological activity were made. The areas north and south of Cape Ann are contrasted and compared with data collected on previous cruises in the region. Station locations are shown in Fig. 8-9.

Currents

The physical appearance of this coastal area was described earlier and the interspersal of sandy stretches among the rocky shore area noted. The general movements of the surface waters at all stations is offshore arid to the south past Cape Cod, but variable as in most exposed areas. The fresh water Merrimack River outflow, besides joining waters flowing southeast from Rye, also moves directly south into the Annisquam area north of Cape Ann.

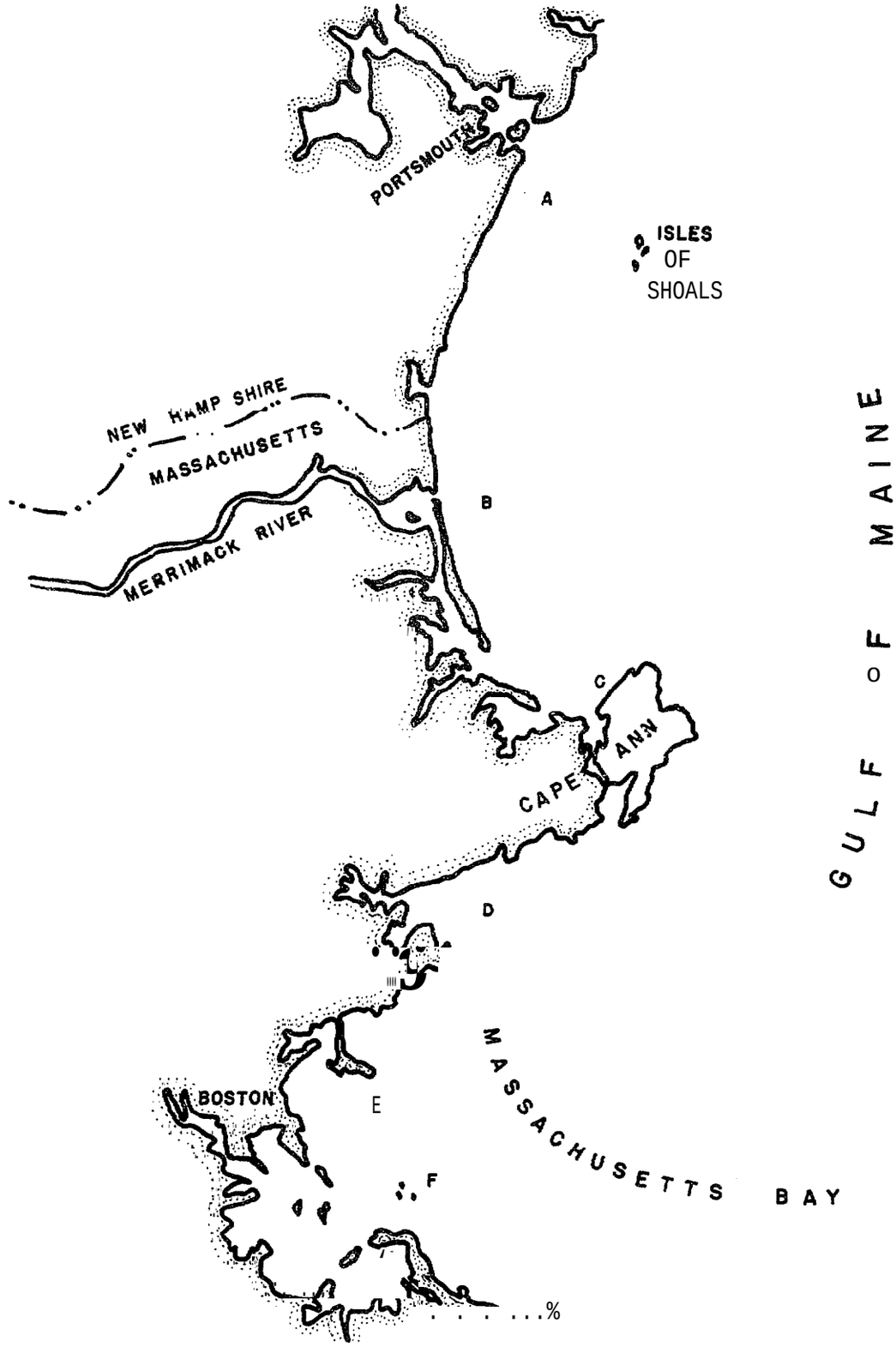
The three stations south of Cape Ann are under the influence of similar currents. Water in the area of Bakers Island in Salem' Harbor and Flip Rock flow mainly offshore, with some northly sweep off Flip Rock (Bigelow, 1927). The Pope Rock Station is located in an area of direct southern current movement into Massachusetts Bay.

Salinity

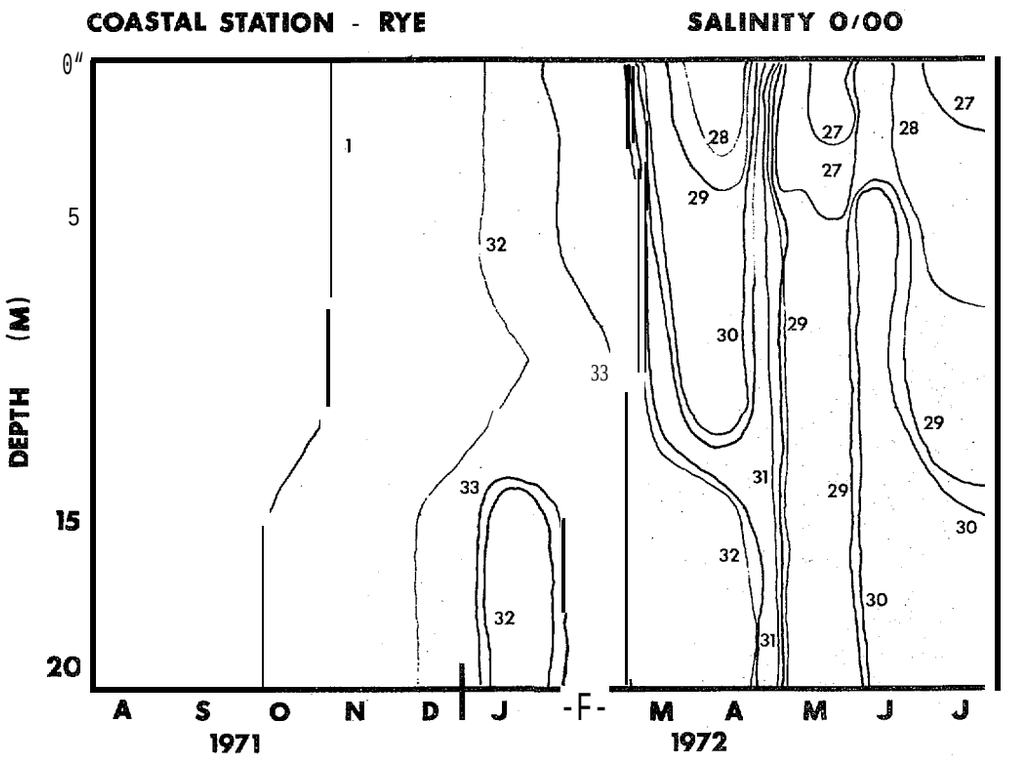
Salinity values were uniform north and south of Cape Ann with a range of 9.3 to 33.8 o/oo; the lowest values occurring in late April, 1972. Salinity at the Rye Station was relatively uniform in the water column during the sampling period. Spring runoff from the Great Bay Estuary caused reduced salinities in April (28 o/oo) and a temporary layering of the water column. Heavy rainfall in May and July also decreased the surface salinities. A cross section on Figure 8-10 and 8-11 show these.

Salinities recorded at the Merrimack and Annisquam Stations were highest" in January and February, Increases in rainfall and fresh water runoff' of the Merrimack were reflected in lower surface values during 'the year. The minimum surface salinity values during the sampling period were observed at the Merrimack Station, and they appeared to be mixed southward especially during the spring into the water column at the. Annisquam region. The reduced spring values at Merrimack and Annisquam made comparison of the regions north and south of. Cape' Ann difficult.

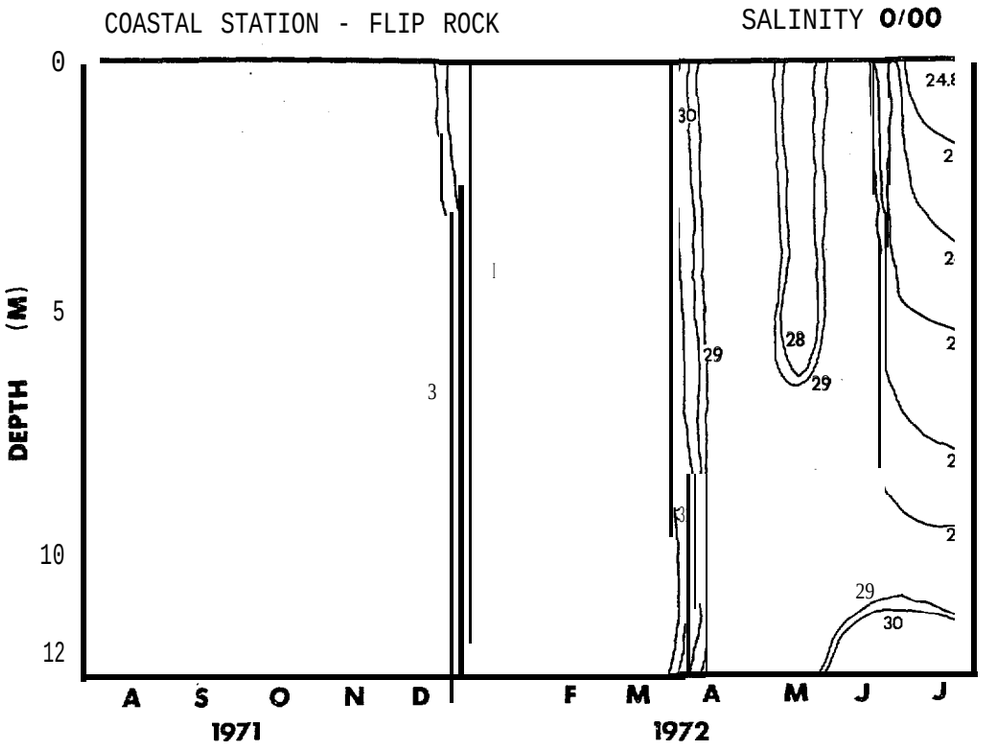
Records of the salinity values at Bakers Island and Flip Rock show the most constant readings of any stations in February, 1972. Salinity.



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-9	Sampling Stations-Rye, N.H. to Boston, Mass.



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-10	Salinity Values-Rye


COASTAL STATION - FLIP ROCK
SALINITY 0/00
DEPTH (M)
0
5
10
12
A
S
O
N
D
F
M
A
M
J
J
1971
1972
30
29
28
29
3
29
30

profiles similar to those observed at Rye in magnitude were noted at Bakers Island in June, while lower salinities and extreme stratification developed in July at both Bakers Island and Flip Rock. The maximum salinity at Pope Rock was observed in early January and an obvious halocline was apparent in July '(25.2-30.5 o/oo).

Temperature

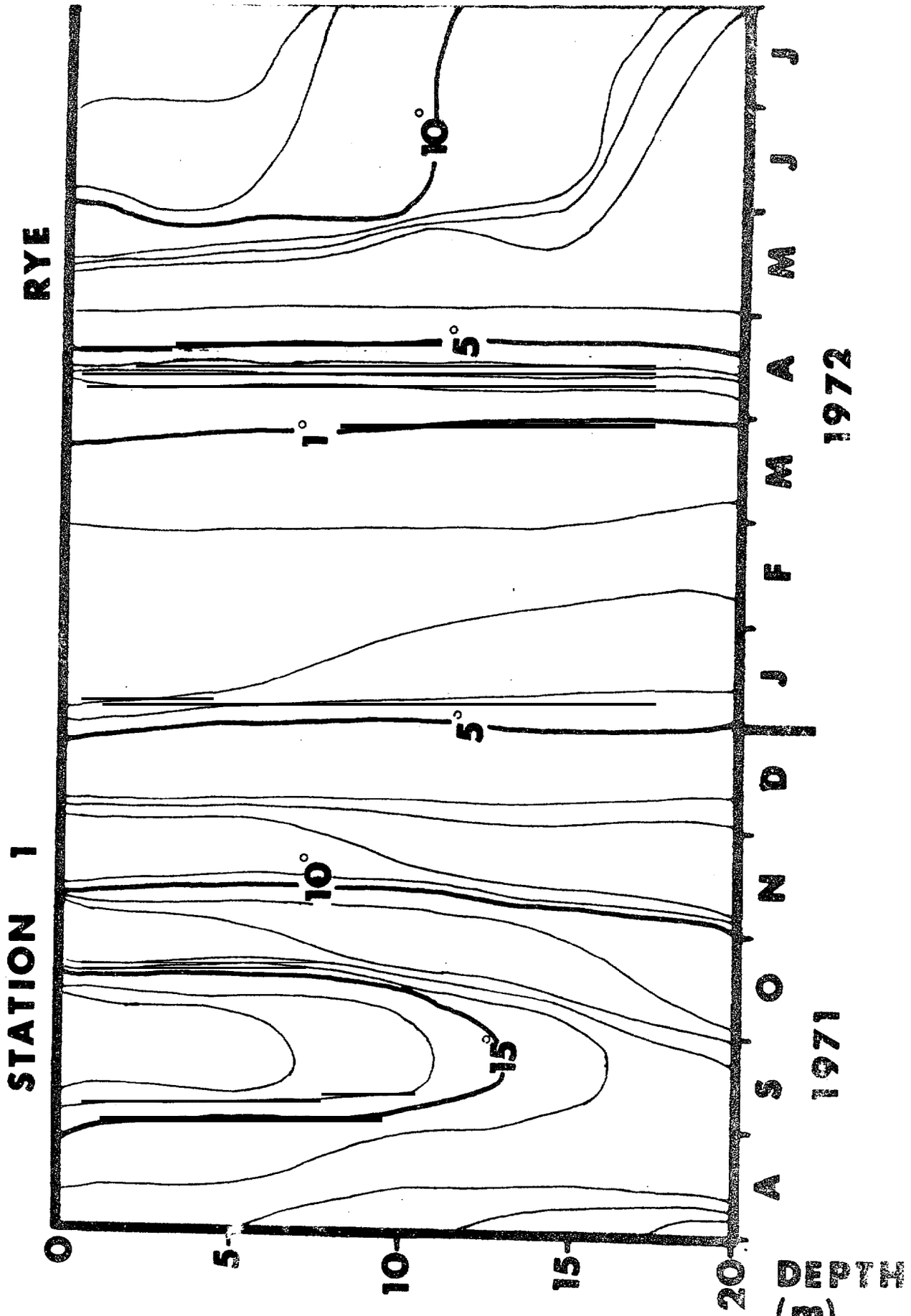
The range of temperatures in the entire sampling area through the year extended from a low of 1.0 C'in January to a maximum of 18.1 C in September. At Rye, where the waters are fairly well mixed at all times, no distinct thermocline was observed, although a 2 C difference between surface and bottom was noted for the seasonably warm months (Figures 8-12 to 8-17). The temperatures throughout the year were, in general, lower than those of all other stations. The temperatures at the Merrimack and Annisquam Stations were quite similar with no vertical stratification observed from September, 1971, to April, 1972. Temperature differences between the warmer surface waters and the colder waters below 5 m developed in early summer and increased to 7 C in August, due in part to the higher temperatures of Merrimack River runoff. Winter surface and bottom temperatures were similar at all three stations north of Cape Ann.

In general, surface temperatures reached 3-4 C higher during the summer south of Cape Ann than at the Rye-Station. The water at Bakers Island appeared to be well mixed during most of the year. Vertical stratification developed in May with a 4 C difference between the surface and 13 m values. But in early June, the temperature from the surface to 10 mwas constant at 10 C. These reduced temperature and salinity values suggest that colder, more mixed waters, possibly from Rye, were carried south and inshore in late May. A rapid warming trend seems to be responsible for the high temperatures (18 C) and stratification noted at the next sampling in July at Bakers Island.

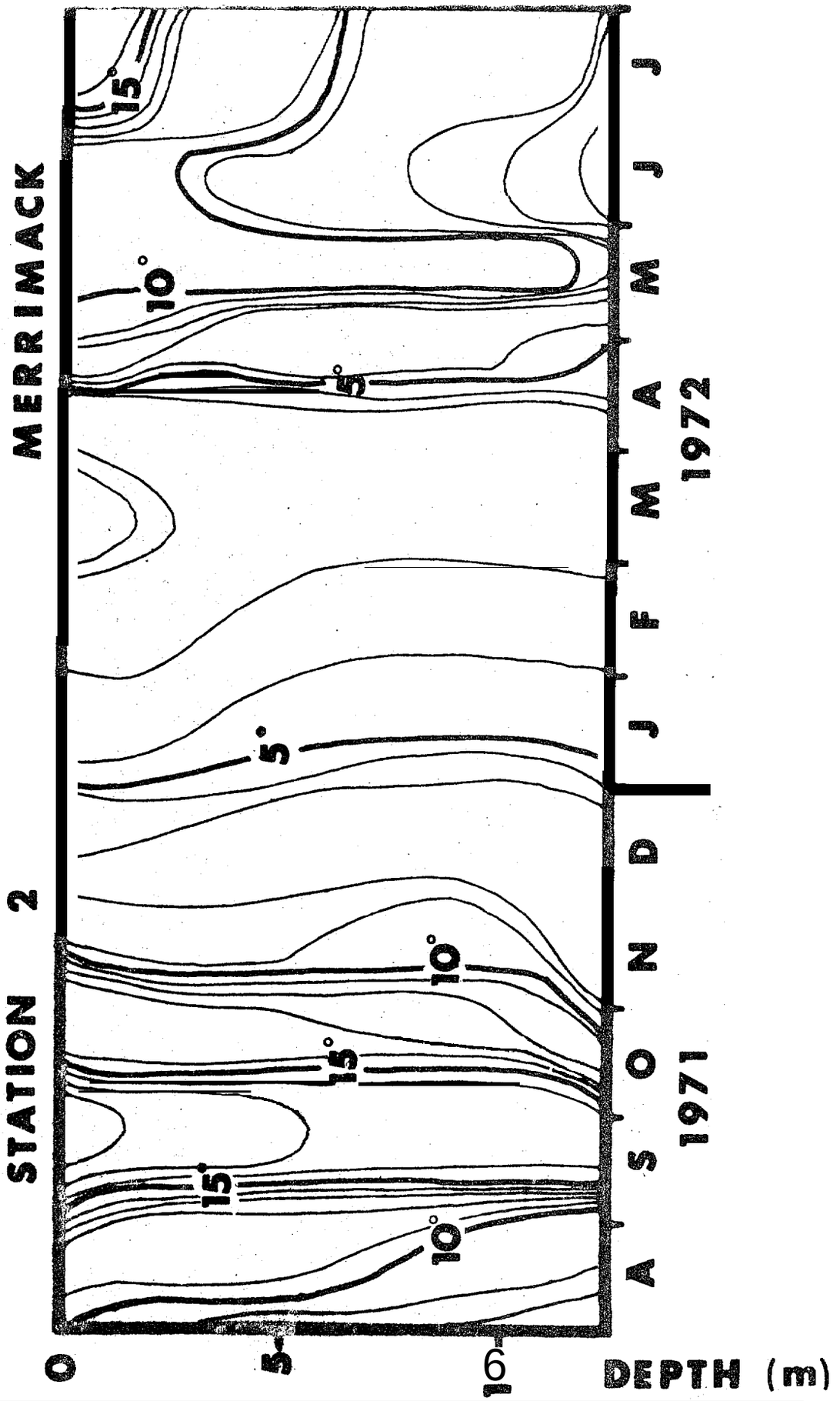
The temperatures at the Flip Rock and Pope Rock Stations were parallel throughout the sampling period. A typical thermocline developed in late May and was evident in the water column through September, with the greatest, difference (8-9 C) between the surface and waters below 10 m observed in July.

Percent Light Transmittance

The waters north of Cape Ann were generally clearer than the southern stations (Figures 8-18, 8-19) and were more transparent during August and December. At Rye, the greatest light penetration values in the entire water column were observed in August. During the rest of the sampling period, the readings remained fairly high, with a significant decrease in mid-May. The bottom of the euphotic zone was located at 10 m in April.

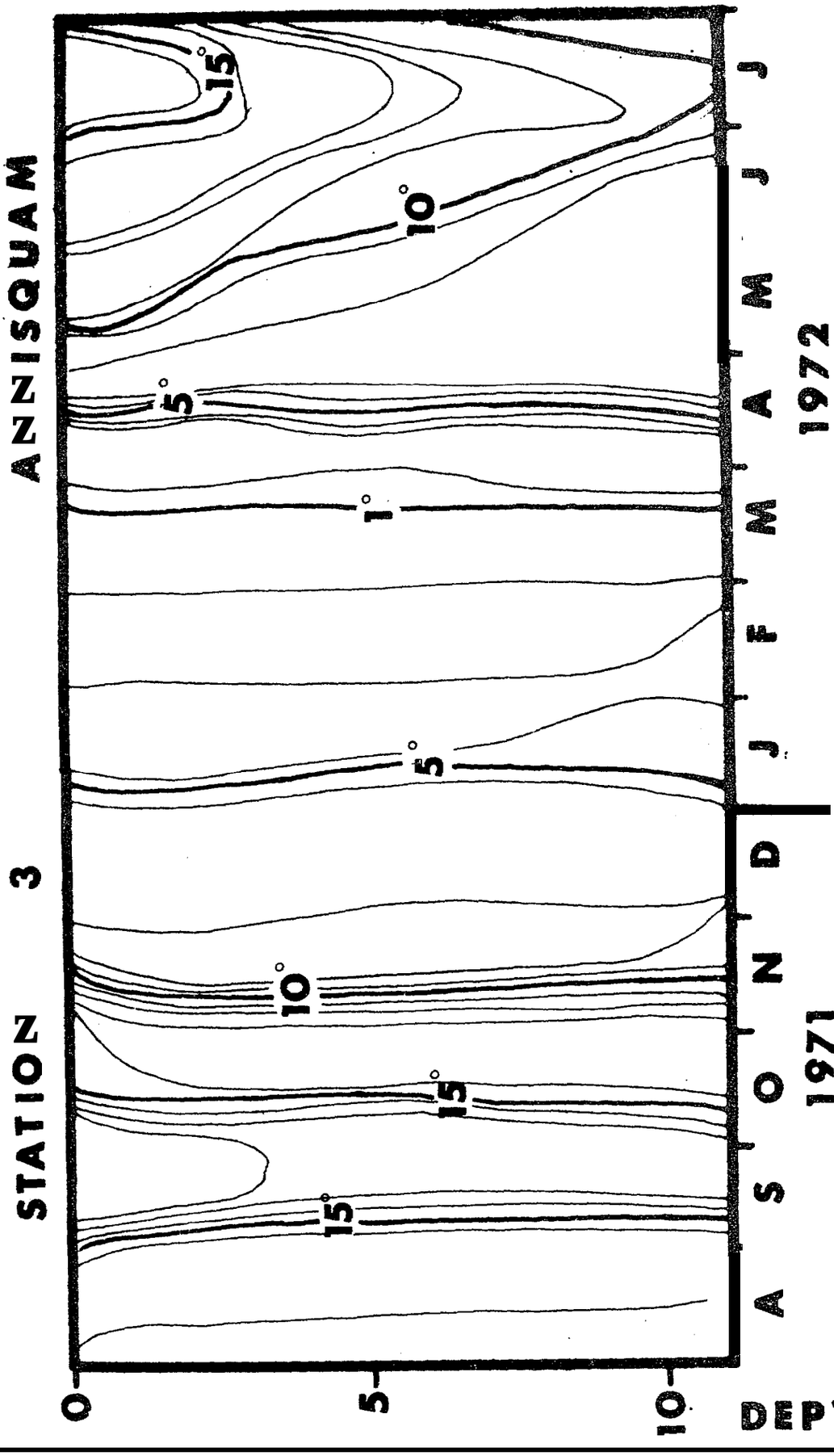


A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
n ? w	FIGURE 8-12	Temperature Values Rye 8-55



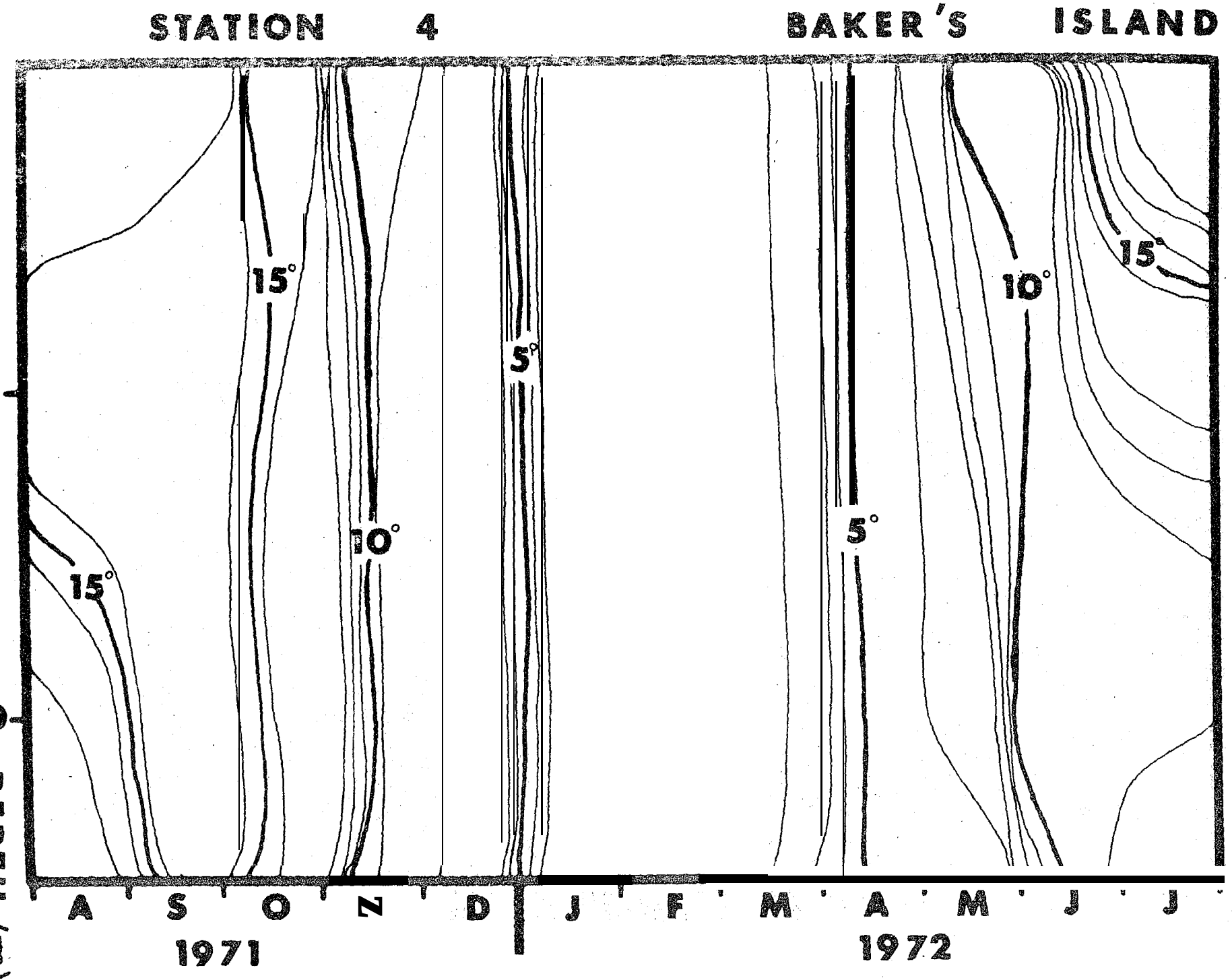
A SOCIO-ECONOMIC AND ENVIRONMENTAL inventory OF THE NORTH ATLANTIC REGION

TRIGOM PARC | FIGURE 8-13 | Temperature Values Merrimack

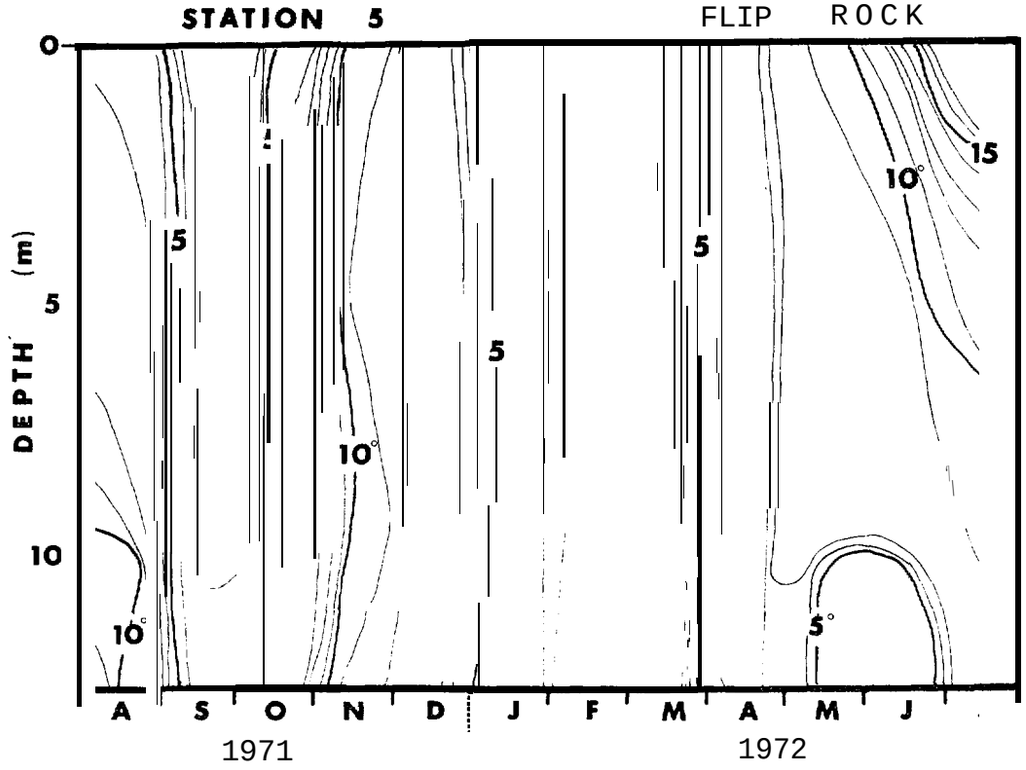


A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

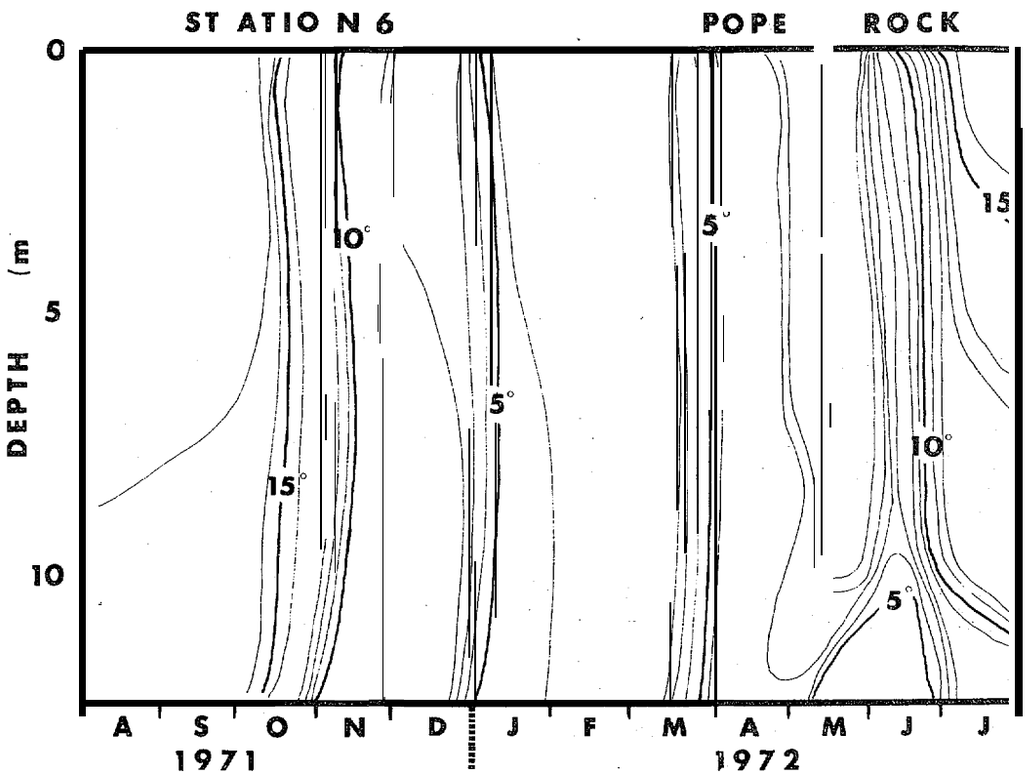
TRIGOM PAGE | FIGURE 8-14 | Temperature Values in



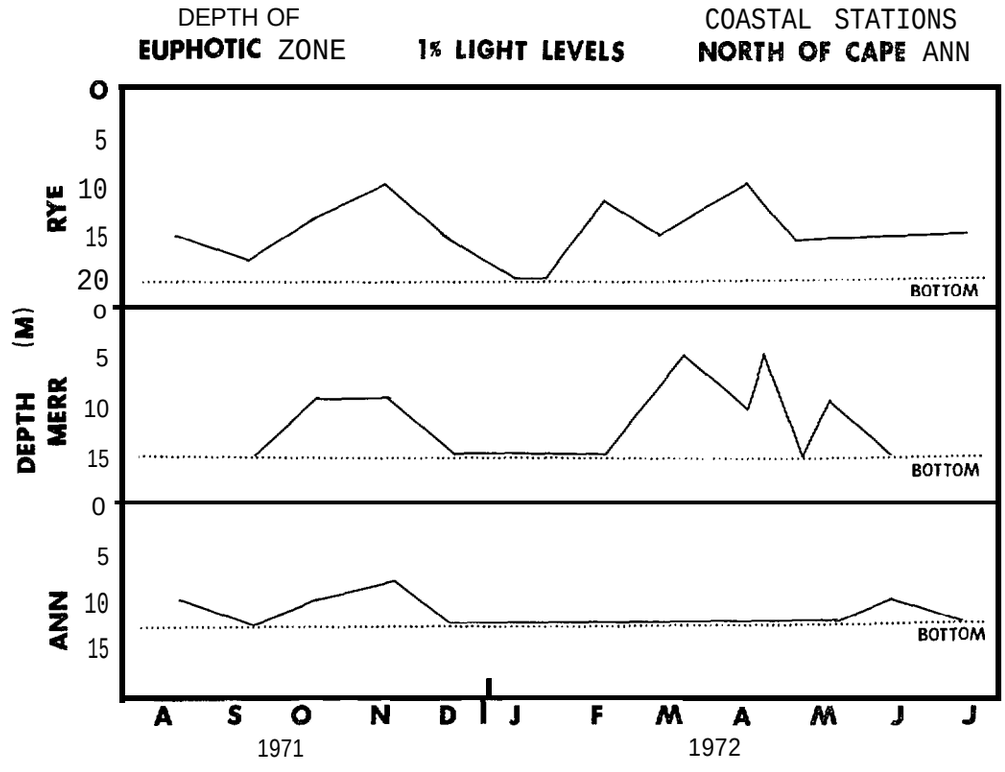
TRIGOM PARC | FIGURE 8-15 | Temperature Values _Bakers island

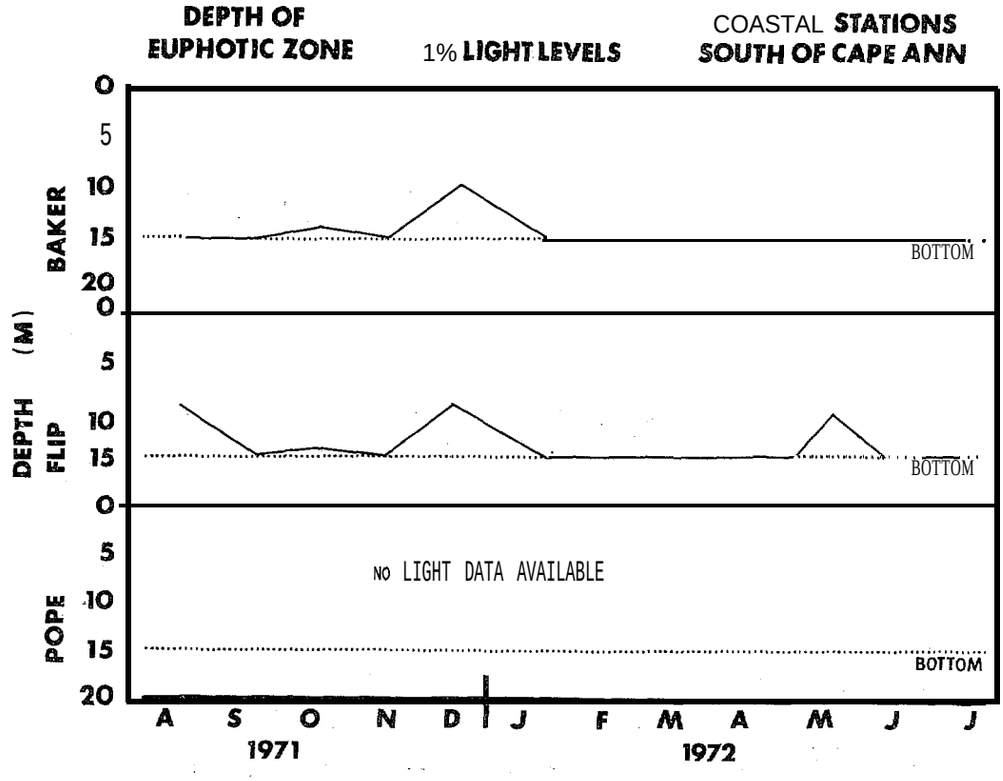


A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-16	Temperature Values Flip Rock



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-17	Temperature Values Pope Rock


DEPTH OF
EUPHOTIC ZONE
1% LIGHT LEVELS
COASTAL STATIONS
NORTH OF CAPE ANN
DEPTH (M)
RYE
MERR
ANN
0
5
10
15
20
BOTTOM
A S O N D J F M A M J J
1971
1972



A SOW-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-19	Euphotic Zone-South of Cape Ann

Light transmittance at the Merrimack Station was generally consistent throughout the year at 1 m, with the maximum transparency recorded in August. Values dropped in October, suggesting a fall phytoplankton bloom during this period. Decreases in transparency in the deeper waters in April correlate with a large phytoplankton population, while the depressed surface values in April and May are due to runoff from the Merrimack River containing phytoplankton and large quantities of silt. This seems plausible because of the sudden decline and quick recovery within the month. Movement of deep offshore waters into the Merrimack area in May could be responsible for the drop in light transmission in the deeper samples at that time. The shallowest depth for the euphotic zone was reached during March and on the second sampling dates in April and May.

Light transmittance at the Annisquam Station was fairly high throughout the year with the highest values recorded during August, December, and March. The low values observed in October and April corresponded to periods of peak chlorophyll a concentrations and, especially in the spring, to the period of high runoff. Low values in the water column in June may be due to a well decomposed, deep water offshore phytoplankton population that flowed south from Merrimack, The percent light level was reached at 10 m in October, November, and June, and the rest of the readings at 10 m were at or below 10 percent.

The water mass off Bakers Island decreased in transparency in October as the fall bloom developed. The 10 m light values were reduced to 1 percent in December. Lack of biological activity during this month suggests that resuspended sediments due to storms were responsible. No significant correspondence could be made between the percent light transmittance readings and biological activity in the spring. Because of sea conditions, no cruises were taken in mid-April south of Cape Ann and the maximum spring population in that region may have occurred during this period.

The Flip Rock Station also had low light transmittance in October due to biological activity, but the minimum surface values were observed in late August and mid-May. No increases in chlorophyll a concentrations were observed in mid-May, as the maximum had already passed, but chlorophyll a values in late August and early September were the highest observed-in the entire sampling area at that time.

The data compiled for the Pope Rock Station is incomplete and no readings were taken during the spring bloom in late April. Depressed values for percent light transmittance observed in October and early May, however, were probably due to increased phytoplankton populations. Less than 1 percent of the surface light was recorded at the bottom in October, May, and June.

Biological Data: Chlorophyll a (Figure 8-20)

Water was analyzed to determine chlorophyll *a* concentrations/m^3 at all stations at 5 m depth intervals after the methods of Strickland and Parsons (1973). Chlorophyll b and carotenoid values were also determined. The chlorophyll *a* values were integrated over depth in Fig.8-20.

In general, chlorophyll and carotenoid values at the Rye Station followed the general trend of biological activity in the stations north of Cape Ann, although the values were lower during most the year. The highest values for both pigment groups were recorded in early April, 1972, (10.2 mg/m^3) at the 5-10 m depth interval. A smaller phytoplankton bloom and the presence of detrital matter in, October, 1971, caused chlorophyll values to peak at 6 mg/m^3. Throughout the rest of the year values remained low.

Seasonal variation in the amount of chlorophyll *a*/m^3 is. apparent at the Merrimack Station. Peaks in the amount of pigmentation were noted during September, 1971, and April, 1972. Following September, the bloom slackened through October, and high levels of chlorophyll *a* were observed in the deep samples in November, suggesting a gradual sinking of the bloom-forming population. Winter and summer values were low, except for deep samples in February, where wave action may have resuspended bottom sediments. The increase in chlorophyll *a* values in the deeper waters at Merrimack in late May seems to have been caused by the influx of high salinity, offshore waters. The phytoplankton population in this bottom water elevated values, but because the phaeophytin concentration was extremely high, the population is assumed to have been grazed or decomposed.

Chlorophyll *a* at the Annisquam Station was at a maximum in the fall and spring and minimum in the winter and summer. The fall bloom was hi-modal in the upper layers of water with peaks in September and November, with a maximum reading of 6.4 mg/m^3. A large percentage of the high chlorophyll values (9 mg/m^3) observed in the deeper water in September was phaeophytin, due to decomposed matter from the bottom. Concentrations were uniformly low during the winter. A large phytoplankton population began developing in mid-April, with 'surface values of 12 mg/m^3. May values dropped to 2.2. In early June the chlorophyll *a* readings rose to 11 mg/m^3 but the large amount of phaeophytin present, and the corresponding salinity and temperature values observed, suggest that the decomposed population and detrital mass, located in the deeper water at Merrimack in May, had been mixed southward into the Annisquam region in June.

The water mass off Bakers Island exhibited a characteristic fall bloom, with large concentrations of chlorophyll *a* recorded in September throughout the water column. Late April samples showed a rise to 4 mg/m^3. Although no sample was taken for early April, it

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
n ?IGOM PARC	FIGURE 8-20	Chlorophyll a Values

seems plausible that this station might have had a bloom population at some time previous to this date. The percent light transmission values and the appearance of the phytoplankton observed in late April indicate residual effects below the surface usually exhibited following a bloom. Small summer blooms of phytoplankton and increased detrital material present in June and August caused chlorophyll a values to rise (4 and 7 mg/m^3, respectively).

The large chlorophyll a values, recorded in September at the Flip Rock Station at all depths, corresponded at the surface to increases in biological activity. The presence of phaeophytin and decreased light transmission in the deep samples suggests the decomposing and sinking of some phytoplankton and perhaps some resuspended material. The high values recorded in October (10 mg/m^3) were due to a second phytoplankton bloom and, in part, to the remnants of the September population, which appeared in the deeper waters at this station.

No water samples were collected in early April and although chlorophyll values were relatively low in late April (3.5 mg/m^3), the presence of characteristic spring bloom. diatoms suggests that chlorophyll values might have been higher in early April. The large amount of chlorophyll a, mainly present as phaeophytin, in the deep waters in June may be due to resuspended detrital material, as no significant population was noted. Recorded values rose to 11 mg/m^3 in July due to observed biological activity.

The chlorophyll values at the surface at Pope Rock in August, 1971, (15.4 mg/m^3) were the highest recorded at any station during the sampling period. Various phytoplankters bloomed during August, September, and October, creating high chlorophyll values over this three-month period. Increasing amounts of detritus were visually observed and corresponded with increasing phaeophytin in the water column as the blooming populations decomposed. No early April sample was taken at Pope Rock, but a very large chlorophyll a reading (12.5) was recorded in late April. This indicated that the spring bloom may have been larger or occurred later at Pope Rock than at the other areas both north and south of Cape Ann. Values similar in magnitude to those at Flip Rock were observed in June. However, the largest chlorophyll a concentrations were at the surface and were accompanied by large numbers of Skeletonema costatum.

Phytoplankton

The "phytoplankton were identified, counted, and reported on the basis of cell numbers/liter. When cell numbers are converted to cell volumes/m^3, we shall have a better measure of phytoplankton abundance. A more significant correlation could then be made between this biological parameter and hydrographic conditions.

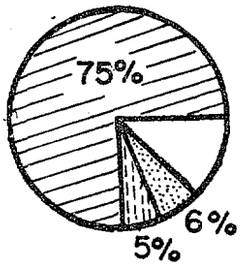
All six stations sampled are located in areas which are under the influence of river runoff, tidal and non-tidal currents, and unusual weather conditions. These variables make comparison between stations quite difficult. In most cases, only populations present near the surface have been tabulated and some continuity between stations is lost.

From August, 1971, to July, 1972, more than 50 species of phytoplankton were noted in collections at the Rye Station. Bacillariophyceae were the dominant forms, (Table 8-6 and 8-7) followed by dinoflagellates, Chlorophyceae, Chrysophyceae, and Euglenophyceae. The diatom Thalassionema nitzschoides appeared in all samples taken from August to April in moderate numbers (2.5-63.7 cells/1 x 10-3). No other species was present as frequently. This diatom was, in part, responsible for elevated chlorophyll readings in October, 1971, but it appeared that detrital material seemed to be of more importance, since larger numbers of Thalassionema were observed in November and February, when chlorophyll values were reduced. Cocconeis scutellum and Cylindrotheca closterium occurred in five monthly samples, usually when no bloom organisms were present.

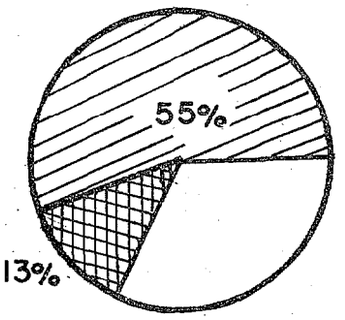
Members of the genus Chaetoceros appeared only during the month of April, but were the dominant phytoplankton species that month at Rye. The dominant species present on April 13 were Chaetoceros debilis (726 cells/1. x 10 3) and Thalassiosira nordenskioeldii (58.6 cells). This indicates that the largest diatom bloom occurred in early April which correlates well with the recorded chlorophyll values. The circle graphs (Figures 8-21 a and b) show the relative proportions of the species present in the surface sample on April 20. The diversity of species had increased at the surface, and the number of dominant species had decreased from the previous sample date. Chaetoceros debilis was present throughout the water column in early May, but by May 17 the number present at the surface had decreased and the high counts at 5 and 10 m showed that the bloom organism passed its peak and was sinking.

Skeletonema costatum madeup63 percent of the summer bloom in mid-July Figures 8-22 a and b) with 493 cells/1. $\times 10^{-3}$. Numerous other species were present, including some dinoflagellates which often occur later in the summer.

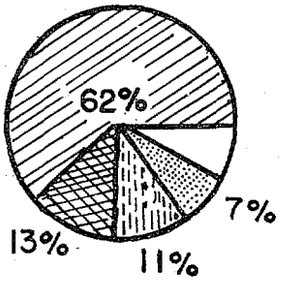
Bacillariophyceae predominate both in number of species and individuals at the Merrimack Station, with no other classes reaching peak populations during the sampling period. The fall bloom consists of several diatom species. Guinardia flaccida dominates in September, and although it occurs in relatively low numbers (38.2/1 x 10-3), the large size of the cells could explain the high pigment concentration on the surface on that date. Four other species, Leptocylindrus danicus, L. minimus, Thalassionema nitzschoides and Skeletonema costatum, were also



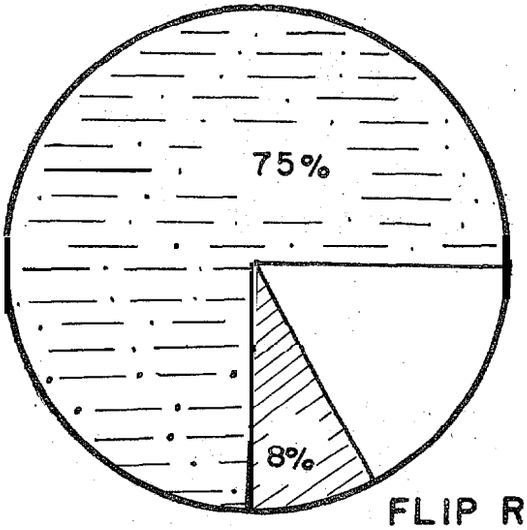
RYE



MERRIMACK



BAKERS ISLAND



FLIP ROCK

SPRING BLOOM

APRIL 20, 1972

⟷ (RADIUS)

1,0 00,000 CELLS/LITER

CHAETOCEROS COMPRESSUS

CHAETOCEROS SUBSCENDUS

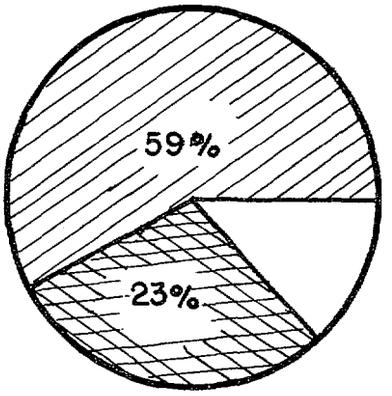
THALASSIOSIRA NORDENSKIÖELDII

CHAETOCEROS DEBILIS

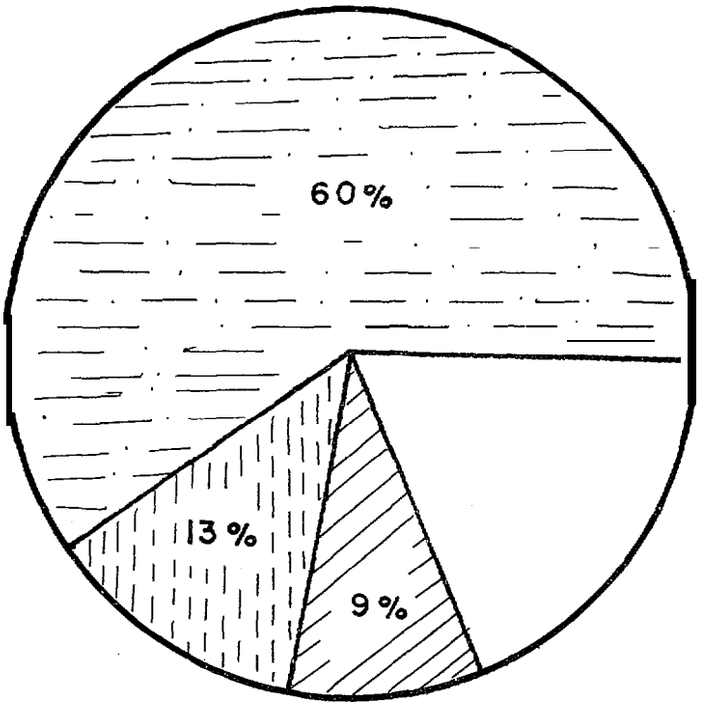
OTHERS

X 23

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-21a	Spring Bloom Populations Rye, Merrimack, Bakers Island, Flip Rock

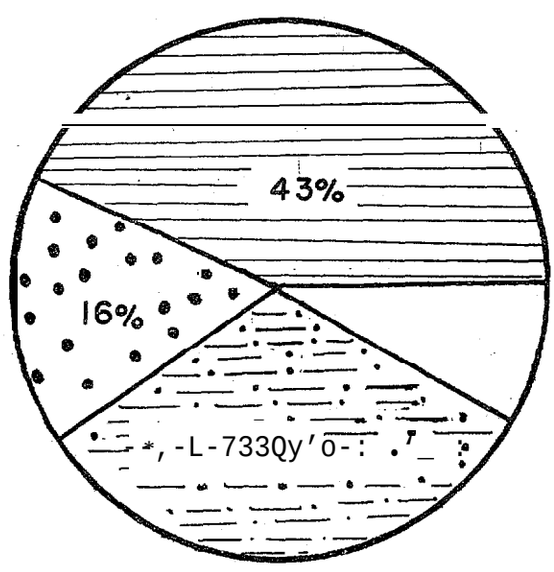


ANNISQUAM

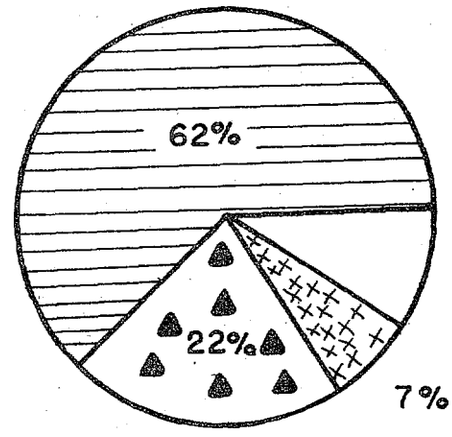


POPE ROCK

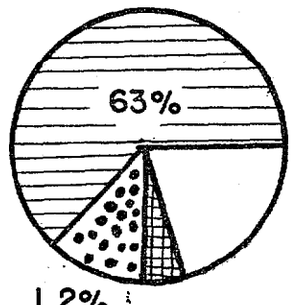
A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-21b	Spring Bloom Populations Annisquam, Pope Rock



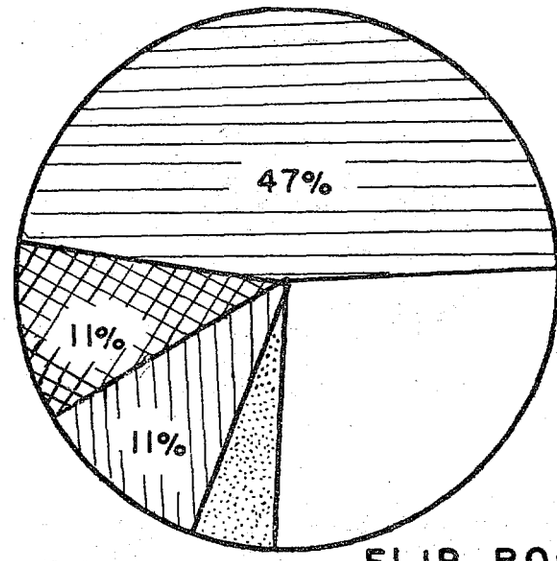
MERRIMACK



BAKERS ISLAND



RYE



FLIP ROCK

SUMMER BLOOM

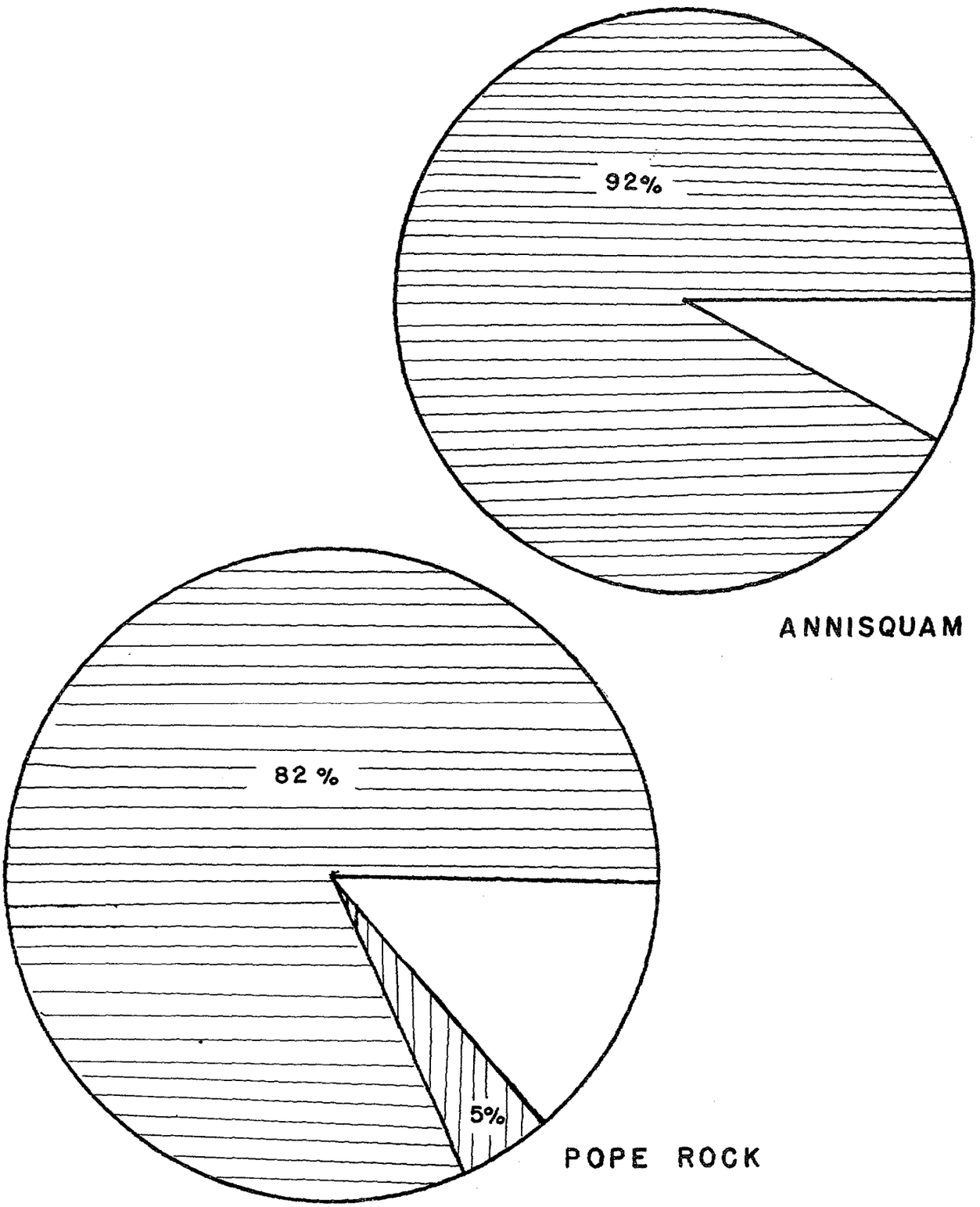
JULY 12, 1972

(RADIUS)

1,000,000 CELLS/LITER

- SKELETONEMA
- EUTRIPEA SP.
- RHIZOSOLENIA DEL.
- CHAETOCEROS COMPRESSUS
- CARTERIA SP.
- THALASSIOSIRA SP. 2
- CLAMYDAMONAS
- PHAEOCYSTIS POUCHETI
- X 23
- OTHERS

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRI	FIGURE 8-22a	Summer Bloom Rye, Merrimack, Bakers Island, Flip Rock



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 8-22b Summer Bloom Anni square, Pope Rock

abundant with a total count of 148 cells/l x 10^{-3}. High chlorophyll values in October in deep samples could indicate a sinking of the September Guinardia population. Thalassionema nitzschoides and Skeletonema costatum increased in numbers in November, but in general, the trend toward reduced winter population size and increased species diversity' continued. T. nitzschoides was present during eight months with a peak population recorded in November at the surface.

The species diversity rapidly increased in March and April to 25 and 37 species, respectively, as the population developed to bloom proportions. Chaetoceros species dominated the spring bloom in mid-April, with C. debilis (469 cells/1 x 10^{-3}) constituting 55 percent of the total population. On the two sampling periods in May, large amounts of detrital material and many fresh water species from Merrimack River outflow were observed in the surface samples. In late May, a possible influx of deep oceanic water brought a diverse, but unhealthy, population into the deep waters at the Merrimack Station, causing elevated phaeophytin values.

Skeletonema costatum (651 cells/1 x 10^{-3}) was responsible for 43 percent of the summer bloom populations with some small, green colonial forms, contributing much of the remainder. Species diversity in June and July dropped quite low.

The greatest species diversity at the Annisquam Station was seen in April and July, when 29 and 31 species, respectively, were recorded. The rest of the year was considerably poorer in species composition, averaging less than 10 species per month. The phytoplankton population observed in the surface sample at Annisquam in August, 1971, was low, but did contain a mixed group of dinoflagellate species, typical of late summer. The diatoms, S. costatum (166.2 cells/ml) and Guinardia flaccida (35.7 cells/ml), were the dominant forms in the small September bloom. A large number of Leptocylindrus danicus and L. minimus were recorded in October, but the small size of the cells made this population's effect less significant. The second peak in the bimodal fall bloom was due to the presence of Thalassionema nitzachoides (242/1 x 10-3), the diatom species with the highest rate of occurrence over the entire sampling period. No major population was observed from. December to March.

Chlorophyll a values in early April suggest the presence of a large phytoplankton population at the surface, but no sample was counted for that date. However, one week later on April 20, the diatoms C. debilis (663 cel 1s/1 x 10^{-3}) and C. compresses (265/1 x 10^{-3}) appeared at bloom proportions, but chlorophyll values recorded were one-fourth those from the previous week. It appears, therefore, that the maximum spring population did not occur on April 20, but sometime in early April.

Small numbers of organisms were found at the surface during May at

Annisquam, but remnants of the spring bloom were observed in the 5 m and deep samples. The June phytoplankton population was quite diverse, with no dominance by any single organism. The large amount of detritus and fresh water organisms observed in the surface and 5 m samples correlated with the theory that the decomposed population observed in the deep waters at Merrimack during the previous month appeared to move southward to Annisquam in June. The largest population observed in the deep waters at Merrimack during the previous month appeared to move southward to Annisquam in June. The largest population observed at Annisquam during the year was in late June with Skeletonema costatum recorded at 2009 cells/l x 10^{-3} at the surface. This organism constituted 92 percent of the phytoplankton on that date.

Species diversity was low at Bakers Island, exceeding 10 species in only two months during the year (April and July). The small bloom in September at Bakers Island was composed of three diatom species, Nitzschia seriata, 158, Skeletonema costatum, 41, and Guinardia flaccida, 31 cells/l x 10^{-3}, respectively. These species were present in lower numbers in October and November and an increasing number of Thalassionema, present in eight months of the sampling period, were found. In December - March, Thalassionema was the dominant form, although the total phytoplankton populations were quite small.

Chaetoceros debilis, C. compresses, and Thalassiosira nordenskioeldii were the major components of the spring bloom recorded on April 20, with 398, 82, and 69 cells/1 x 10^3, respectively. These species were present in lower numbers in early may throughout the water column, and many Chaetoceros resting spores were observed in late May.

A Carteria sp. present from late April to July reached its peak population in early June with 135 cells/1 x 10-3 recorded for that date. 741/1 x 10-3 of Skeletonema costatum were present in the surface sample taken at Bakers Island in July, constituting 62 percent of the summer bloom at this station.

In general, phytoplankton populations in the water mass off the Flip Rock Station followed the seasonal pattern observed at the other stations. More species were present as compared to Bakers Island, but there were only four months when the number of species exceeded ten.

High chlorophyll values recorded in September at Flip Rock indicate the presence of a large phytoplankton population. The most numerous diatom species were Nitzschia seriata, Thalassiosira decipiens, and Guinardia flaccida, although large numbers of a small (6 x 2 μ) unknown species were noted. A bloom of Leptocylindrus danicus (229/1 x 10^{-3}) elevated the chlorophyll a values at the surface in October. The only population of any significant proportions from November to February was Thalassionema nitzschoides which peaked in November and then remained low until April.

On April 20, a spring bloom population at Flip Rock was observed composed mainly of Phaeocystis (1160 cells/1 x 10-3), various Chaetoceros species and Thalassiosira nordenskioeldii. Phaeocystis pouchetii was responsible for 75 percent of the population observed. Because of weather conditions no sampling occurred from early March to late April, and it is possible that a larger population may have been present during that time containing species more typical of a spring bloom in this area.

Species composition increased quite rapidly after April and the largest number of species observed on any one sampling date was in July. In May, only small populations were observed in the surface sample, but remnants of the late April bloom were seen in the deeper waters. Skeletonema costatum (47 percent), Chaetoceros compresses (11 percent), and Eutripea (11 percent) comprised the greater proportion of the large summer bloom at Flip Rock.

The Pope Rock Station differed somewhat from other stations observed south of Cape Ann. The phytoplankton population in August, September, and October were all quite high, due to the blooming of four diatom species. In August, a Coscinodiscus sp. and S. costatum were the dominant organisms. S. costatum (247 cells/1 x 10^{-3}) reached its fall peak in September, with Nitzschia seriata and Leptocylindrus danicus comprising the majority of the remaining population. The largest number of L. danicus cells was observed in October, accompanied by S. costatum and Coscinodiscus sp. No major population was seen in November - March, although Thalassionema was present during this entire period in small numbers.

The April 20 sample at Pope Rock showed a large, diverse population, accompanied by high chlorophyll values. This peak in population numbers and pigmentation so late in April was not observed at any other station. Phaeocystis contributed to the spring bloom at Pope Rock. Because of its very small size, however, its significance is lessened and the larger diatoms found could be more important. Thalassiosira nordenskioeldii and Chaetoceros debilis with populations of 251 and 175 cells/1 x 10^{-3} were the dominant diatoms, while the presence of S. costatum and Detonula confervacea (a typically estuarine form) should be noted.

The Skeletonema population reached its peak in early June, with 2164 cells/1 x 10^{-3}, but large numbers were also observed in July. Eutripea and Carteria sp. were present during the summer bloom. S. costatum was responsible for 82 percent of the population observed.

Comparison of Previous and Current Studies in the Regions to the North and South of Cape Ann

Although the earlier investigations of Bigelow (1926) and Lillick (1937, 1940) concentrated on regions more than 8 km from the coast and employed somewhat qualitative methods, some comparisons can be drawn between them and the more recent inshore studies in Massachusetts Bay and in the Bigelow Bight Region. The surveys of the phytoplankton in these areas, undertaken by Mulligan and Wessel (in prep.) and Mulligan and de Lara (in prep.) (although incompletely analyzed) indicate distinct qualitative similarities.

Yearly variations in species present, in times of their initial appearances and in duration of their populations recorded by the early investigators, were also noted by present workers. In the Bigelow Bight Region, some of the major species, Thalassiosira nordenskioeldii, Chaetoceros debilis, C. compresses, and Skeletonema costatum, that made up the spring and summer bloom populations in the sampling of 1920, 1922, and 1936 were observed to be dominant in 1971-7>. Additional organisms, such as Guinardia flaccida and Leptocylindrus spp., were observed in the recent studies but not recorded in abundance by Bigelow (1926) or Lillick (1940), north of Cape Ann. Thalassionema nitzschoides was the dominant phytoplankter in the 1971-72 winter season, while a Coscinodiscus-Ceratium community comprised the populations observed by the early investigators. The spring bloom in the Bigelow Bight Region, assumed to be controlled in part by the snow-melt outflow of the Merrimack River, generally occurred at the same time as previously suggested, but the recent sampling was not detailed enough to completely substantiate this fact.

The phytoplankton dynamics of the region south of Cape Ann, namely Massachusetts Bay, differs from that of the Bigelow Bight Region in terms of less influence from river drainage and reduced productivity. The initiation of the spring bloom as described by both Bigelow (1926) and Mulligan and Wessel (in prep.) occurs about three weeks later here. Previous attempts to describe the seasonal cycles were concentrated on offshore waters, where more oceanic forms are present. Mulligan and Wessel (in prep.), in a study of inshore waters, observed that the species common to both areas were present for similar lengths of time. Bigelow (1926) and Lillick (1940) found the typical spring Gulf community of Thalassiosira gravida and T. nordenskioeldii followed by Chaetoceros debilis in Mass. Bay. Mulligan and Wessel (in prep.), however, in addition to the Thalassiosira-Chaetoceros flora, observed Detonula confervacea to be the dominant spring phytoplankter with Chaetoceros socialis second in abundance. A typical decline in diatom abundance after the spring flowering was noted by all investigators, and the concurrent appearance of Phaeocystis sp. in some years was noted. Rhizosolenia alata and Peridinians characterized the summer population recorded in the previous sampling,

Table 8-6 The most abundant species recorded from Stations Rye through Pope Rock 1971-72.

Species	maximum cells/l x 10^{-3} observed	date observed	Station
Skeletonema costatum	2164.5	6-08-72	Pope Rock
X 1 (r=1.4u)	1816.7	9-23-71	Annisquam
Chlamydomonas sp.	1551.7	12-16-71	Flip Rock
Phaeocystis pouchetii (as single cells)	1160.6	4-20-72	Flip Rock
Chaetoceros debilis	663.8	4-20-72	Annisquam
Chaetoceros compresses	.265.0	4-20-72	Annisquam
Thalassiosira nordenskioeldii	251.0	4-20-72	Pope Rock
Phaeocystis pouchetii (in colonies)	244.6	7-12-72	Merrimack
Thalassionema nitzschioides	242.1	11-18-71	Annisquam
Leptocylindrus danicus	229.3	10-21-71	Flip Rock
Eutripea sp.	169.2	7-12-72	Flip Rock
Nitzschia seriata	158.0	9-23-71	Bakers Island'
Leptocylindrus minimus	140.1	10-21-71	Annisquam
Carteria sp.	135.0	6-08-72	Bakers Island
Rhizosolenia delicatula	99.4	10-21-71	Flip Rock
Thalassiosira sp.1	84.1	8-23-71	Pope Rock
Fragilaria sp.	68.8	3-09-72	Merrimack
Detonula confervacea	65.0	4-20-72	Pope Rock
Chaetoceros didymus	49.7	6-08-72	Merrimack

Table 8-7 Comparison of the frequency of occurrence and the abundance of some more frequent species recorded from Stations Rye through Pope Rock, 1971-1972.

Species	frequency of occurrence ratio	abundance scale*
Thalassionema nitzschioides	.67	9
x l (r=1.4u)	.58	2
Cylindrotheca closterium	.44	31
Cocconeis scutellum	.32	48
Skeletonema costatum	.32	1
Leptocylindrus danicus	.24	10
Thalassiosira sp. 1	.24	28
Navicula sp. 2	.22	37
Chlamydomonas sp.	.22	29
Navicula sp. 9	.18	42
Chaetoceros compresses	.17	6
Navicula sp. 1	.17	38
Licmophora abbreviate	.15	47
Distephanus speculum	.15	41
Eutripea sp.	.15	11
Thalassiosira sp. 2 (r=2.5)	. 14	27

* scale derived by comparing maximum populations of each species over the entire sampling period where the number 1 is the most abundant on a scale from 1-55.

but Rhizosolenia delicatula, R. fragilissima, and Skeletonema costatum were found to be dominant in the 1971-72 summer season.

The fall phytoplankton community observed by Mulligan and Wessel (in prep.) was somewhat similar to those of Bigelow (1926) and Lillick (1940). In all cases, the diatom Skeletonema costatum rose to bloom proportions from late August to October in Massachusetts Bay. The large numbers of the genus Ceratium, observed by Lillick (1940), were not present in 1972, but Guinardia flaccida and Leptocylindrus spp. were quite abundant at that time.

ESTUARINE WATERS

Coastal estuaries are numerous in the Gulf of Maine and present a wide range of environmental features to which successful phytoplankton colonizers must adapt. These estuaries of variable salinities may be shallow and slightly mixed, or deep and well mixed by tidal flushing. The estuaries in which phytoplankton populations have been examined are more typical of the latter. The Great Bay Estuarine System of New Hampshire and the Montsweag Bay-Back Bay Estuarine System of Maine are described as examples of Gulf of Maine Estuarine Systems.

Great Bay Estuarine System, New Hampshire

The Great Bay Estuarine System is the larger of two estuaries situated in New Hampshire and for a portion of its length constitutes the boundary between New Hampshire and Maine. The entrance to the estuary is opposite the Isles of Shoals and, beginning at Portsmouth Harbor, extends inland along the Piscataqua River and through Little Bay and into Great Bay, a distance of about 25 km. Tidal dams have been placed on each of the rivers which drain into Great Bay Estuarine System; of the eight major rivers, the Lamprey and the Salmon Falls are gauged by the U.S. Geological Survey (Figure 8-23).

Analysis of the runoff shows a definite seasonal pattern with the period of maximal runoff occurring in March - May. Highest runoff for both watersheds occurs in April. The period of maximum runoff follows the spring thaw and coincides with minimal salinities in the Great Bay Estuary. Minimum discharges from the two rivers were noted in August and September.

The estuary is vertically mixed and a fresh to salt gradient exists from the head of the estuary to the mouth. Large volumes of coastal water enter, mix and leave the estuary during the semidiurnal tides, creating surface currents up to 6 knots in the narrower portions of the estuary. Tidal amplitudes range from greater than 2.6 m at the head of the estuary to less than 2.3 m in Great Bay. Great Bay Estuary has approximately 161 km of coastline and drains a 2400 sq km area. The estuary is rather shallow and approximately 50 percent of

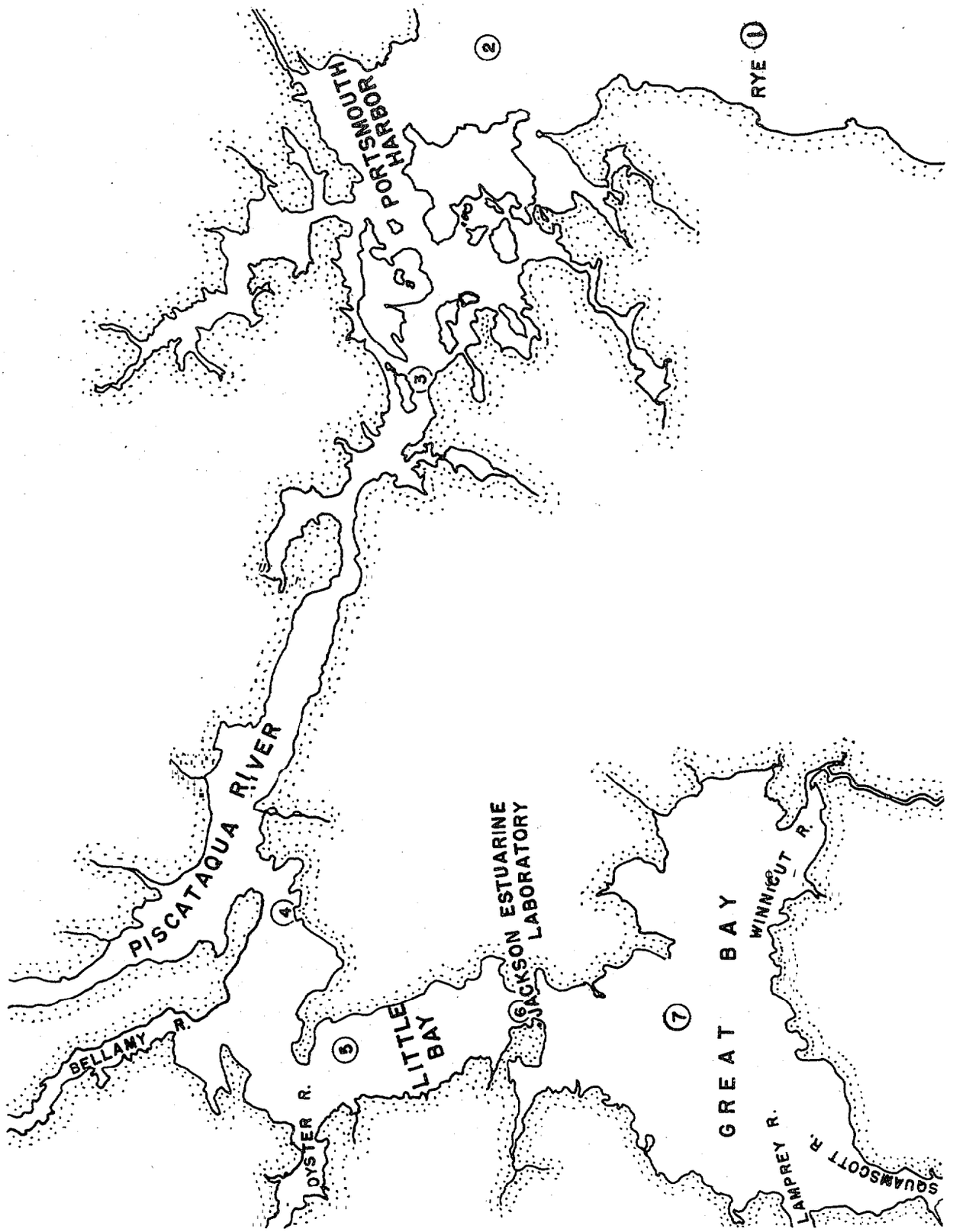
the area is exposed at low tide. Wave action in the shallow zones introduces sediment and detritus into the water column reducing the transparency of the water. The flushing time of the estuary is not known at this time.

Salinities within Great Bay vary from 9.0 to 30.50/00. At the mouth of the river at Rye, N.H. they range from 23.5 to 340/00. Temperature variations within the estuary are greater than those recorded on the open coast (<-1 to 25.7 C). Ice covers most of Great Bay during the winter. In mild winters, little ice is formed, causing lower than normal salinities during the winter and higher than normal salinities during the spring. The estuarine phytoplankton population appears to be greatly influenced by whether ice forms in the estuary during the winter; the size of the spring population appears to be proportional to the quantity of ice.

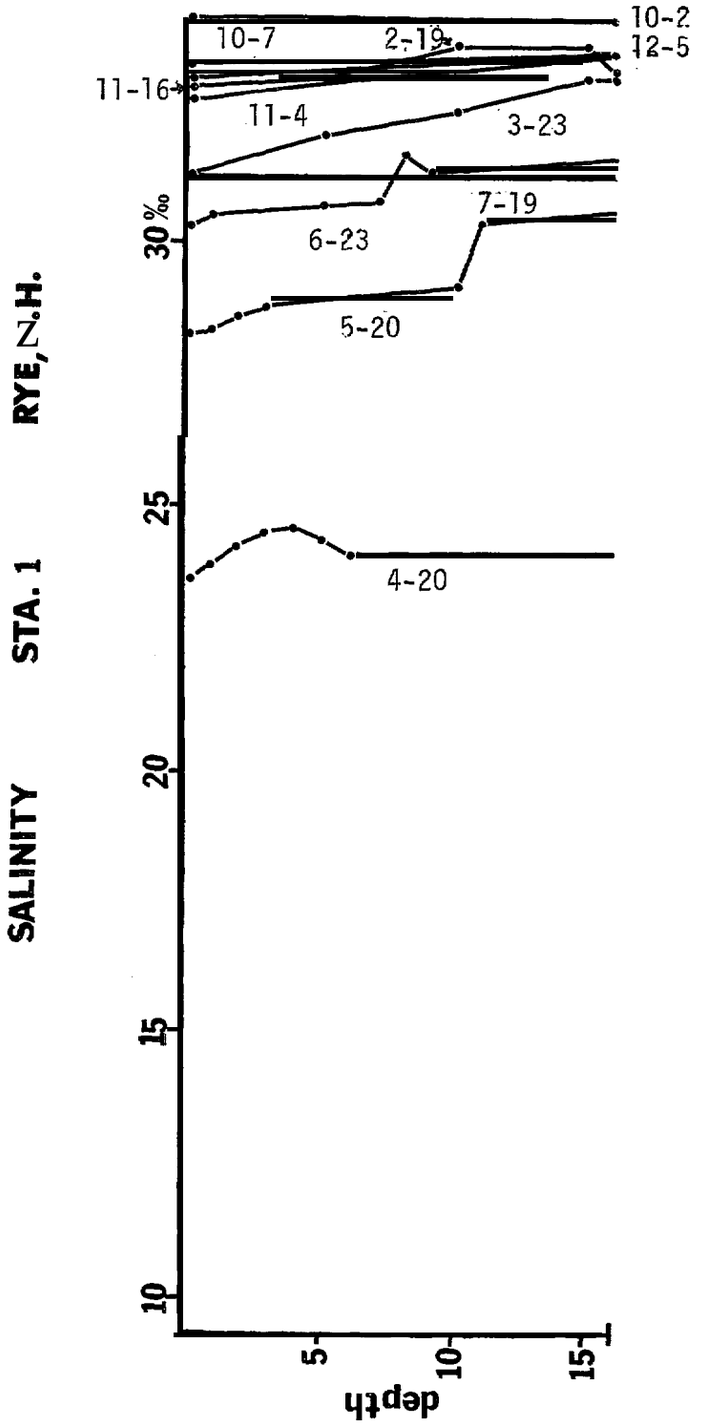
During 1970-71 detailed studies were conducted at 7 stations within the Great Bay Estuarine System. Salinity (Figures 8-24 and 8-25), temperature (Figures 8-26 and 8-27), and light profiles (Figures 8-28 and 8-29) were obtained and the phytoplankton populations identified and quantified. Since that time additional phytoplankton studies have been initiated on Great Bay, including: Recruitment and development of the spring phytoplankton bloom (Donovan and Mulligan, unpublished); Annual study of temporal and spatial variability in phytoplankton populations due to tidal changes (O'Shea and Mulligan, unpublished); and Seasonal cycle of phytoplankton dynamics at 16 stations from the mouth of the Great Bay Estuarine System to the isles of Shoals (Buck and Mulligan, unpublished). The discussion which follows has been excerpted from the above-mentioned studies.

Maximum surface chlorophyll concentrations were recorded during the spring throughout the entire estuarine system (Table 8-8). Populations occurring at the head of the estuary (Stations 6 and 7), showed values twice those recorded at the river mouth and 2 to 4 times those found in the vicinity of Portsmouth Harbor (Station 3). Vertical turbulence may be acting to keep the phytoplankton populations in this portion of the estuary at reduced levels as has been shown to be the case for the Bay of Fundy by Gran and Braarud (1935). This factor may also be responsible for the smaller populations observed at the coastal station situated at the entrance of the Harbor (Station 1, Rye, N.H.).

Detonula confervacea was the dominant diatom comprising greater than 90 percent of the entire population. It exhibited its characteristic bimodal peak in 1971 (also in 1972) reaching large populations at

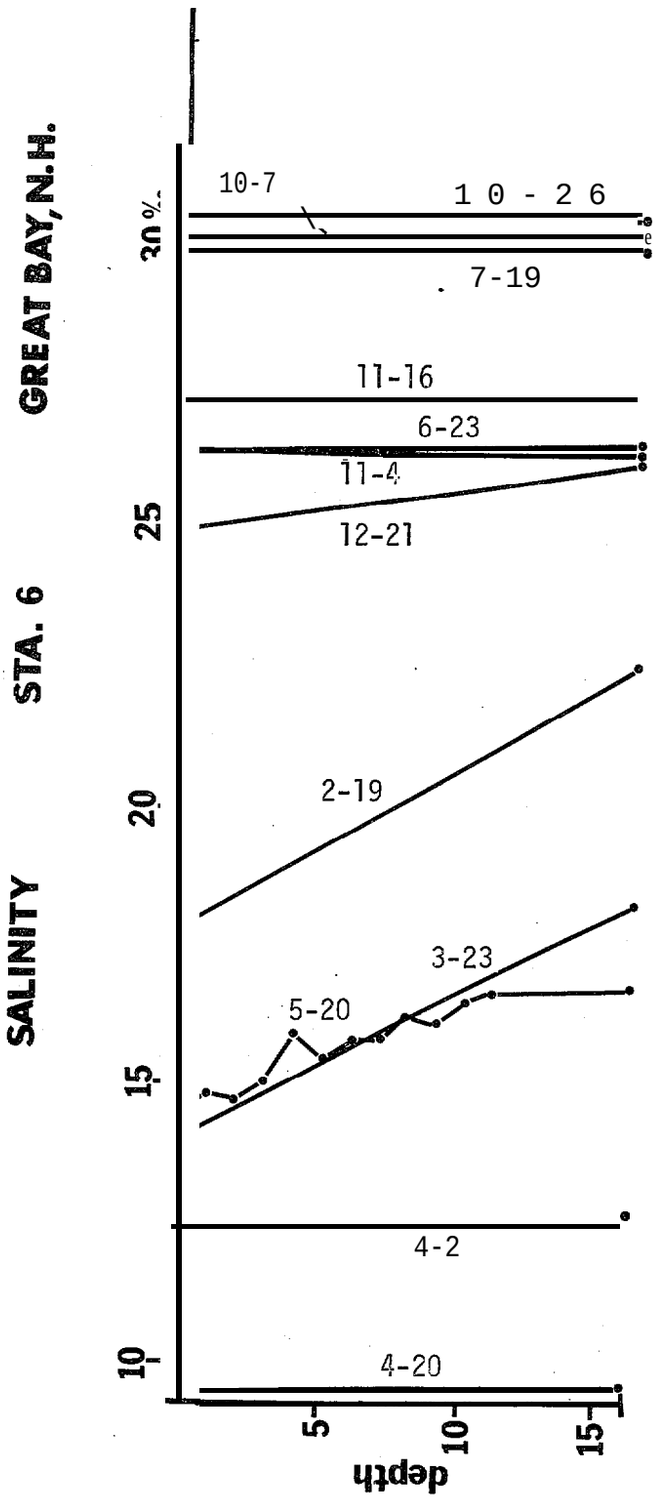


A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-23	Great Bay Estuarine System, N.H.

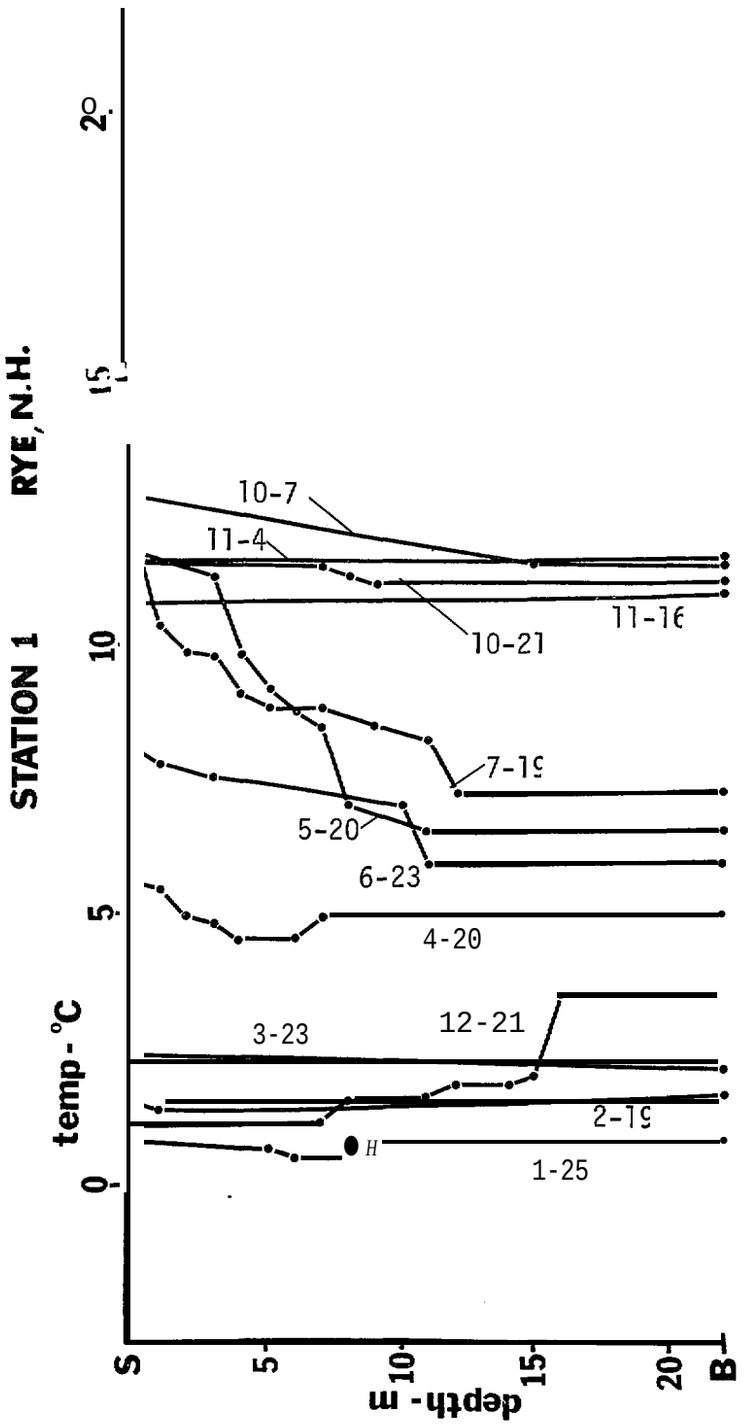


A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

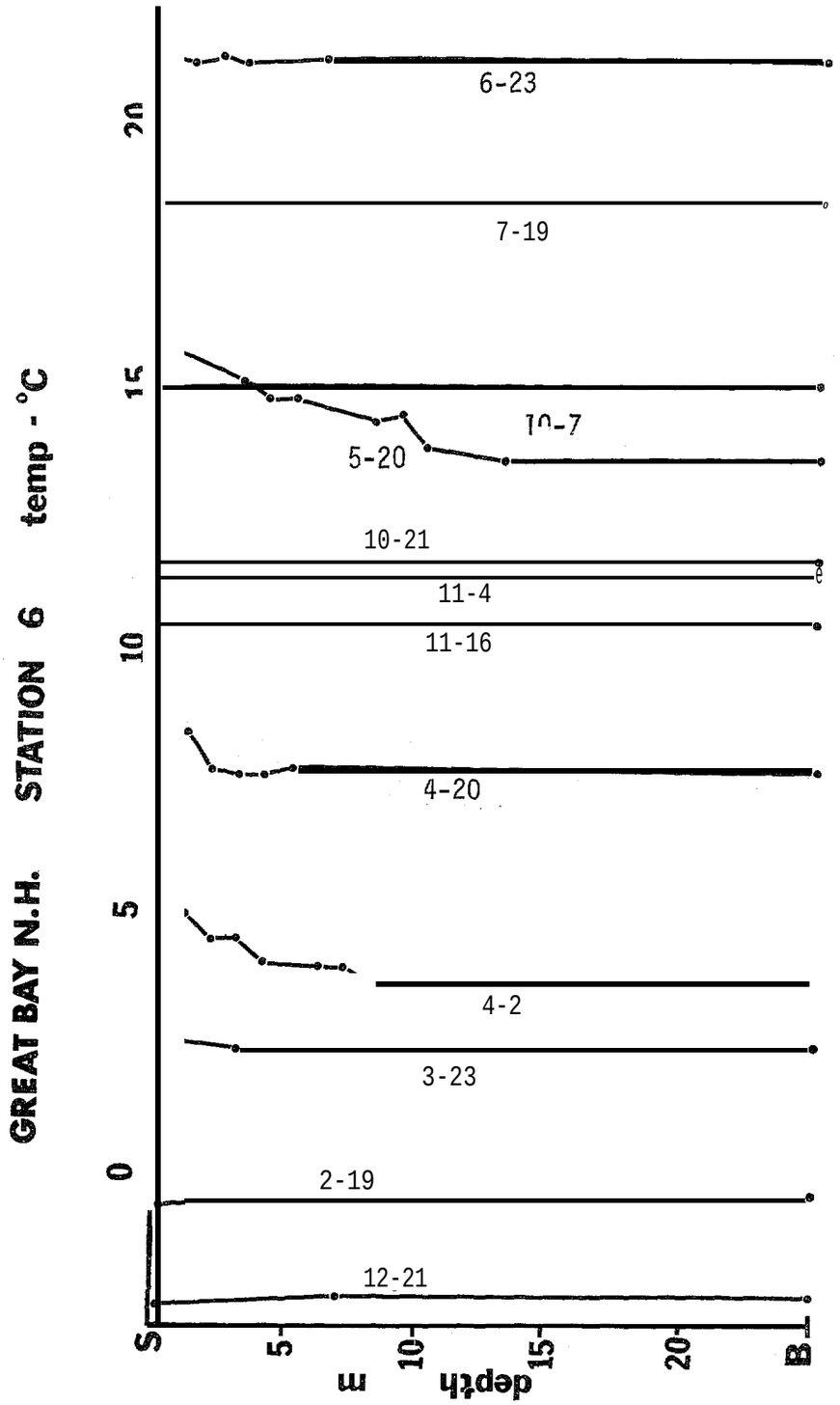
TRIGOM PARC	FIGURE 8-24	Salinity Values Rye, N.H.



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
n ?IGOM PARC	FIGURE 8-25	Salinity Values' Great Bay

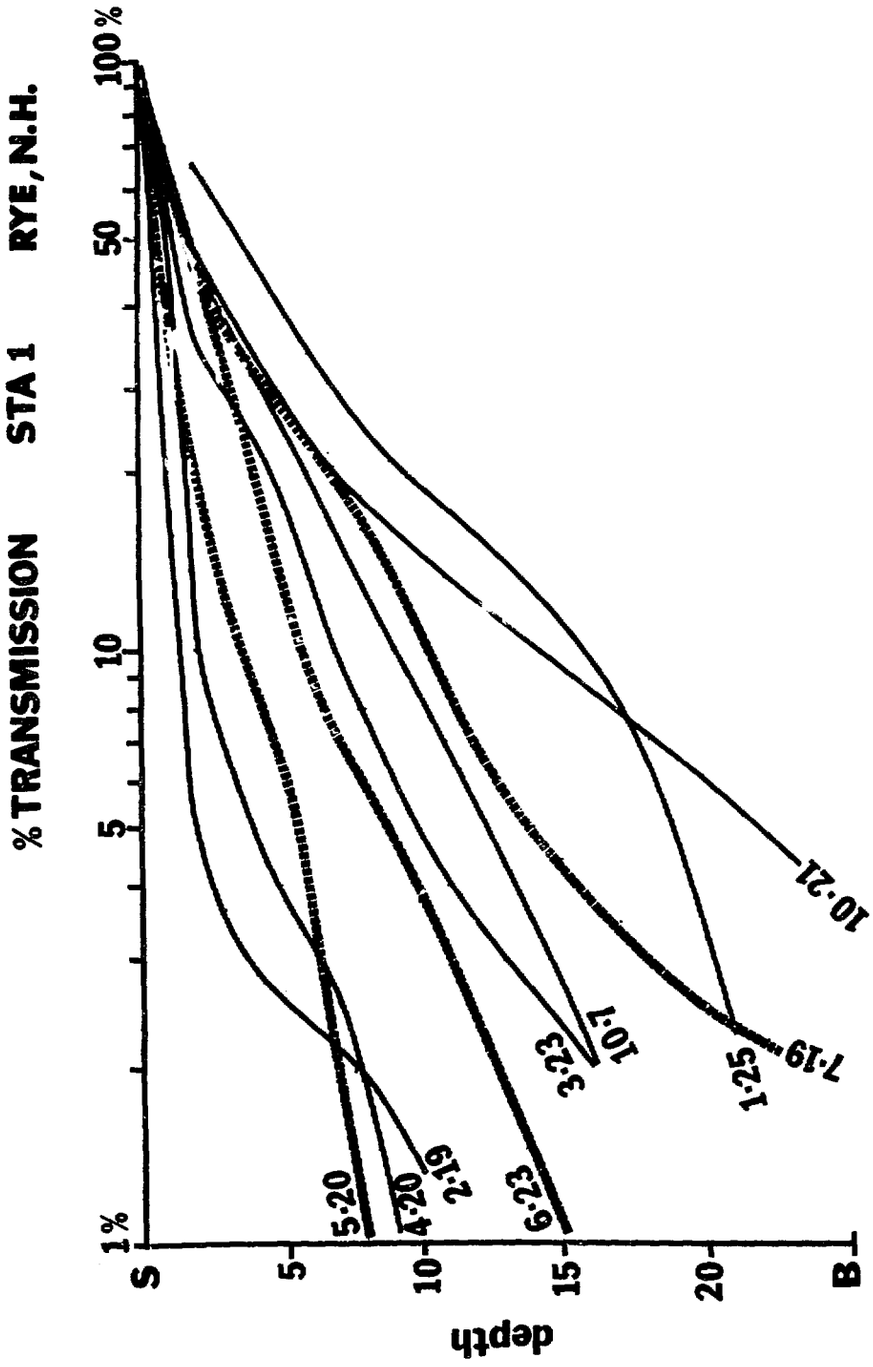


A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-26	Temperature Values Rye, N.H.



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION]

TRIGOM PARC	FIGURE 8-27	Temperature Values Great Bay


% TRANSMISSION STA 1 RYE, N.H.
100%
50
10
5
1%
S
5
10
15
20
B
depth
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7·19
1·25
10·7
3·23
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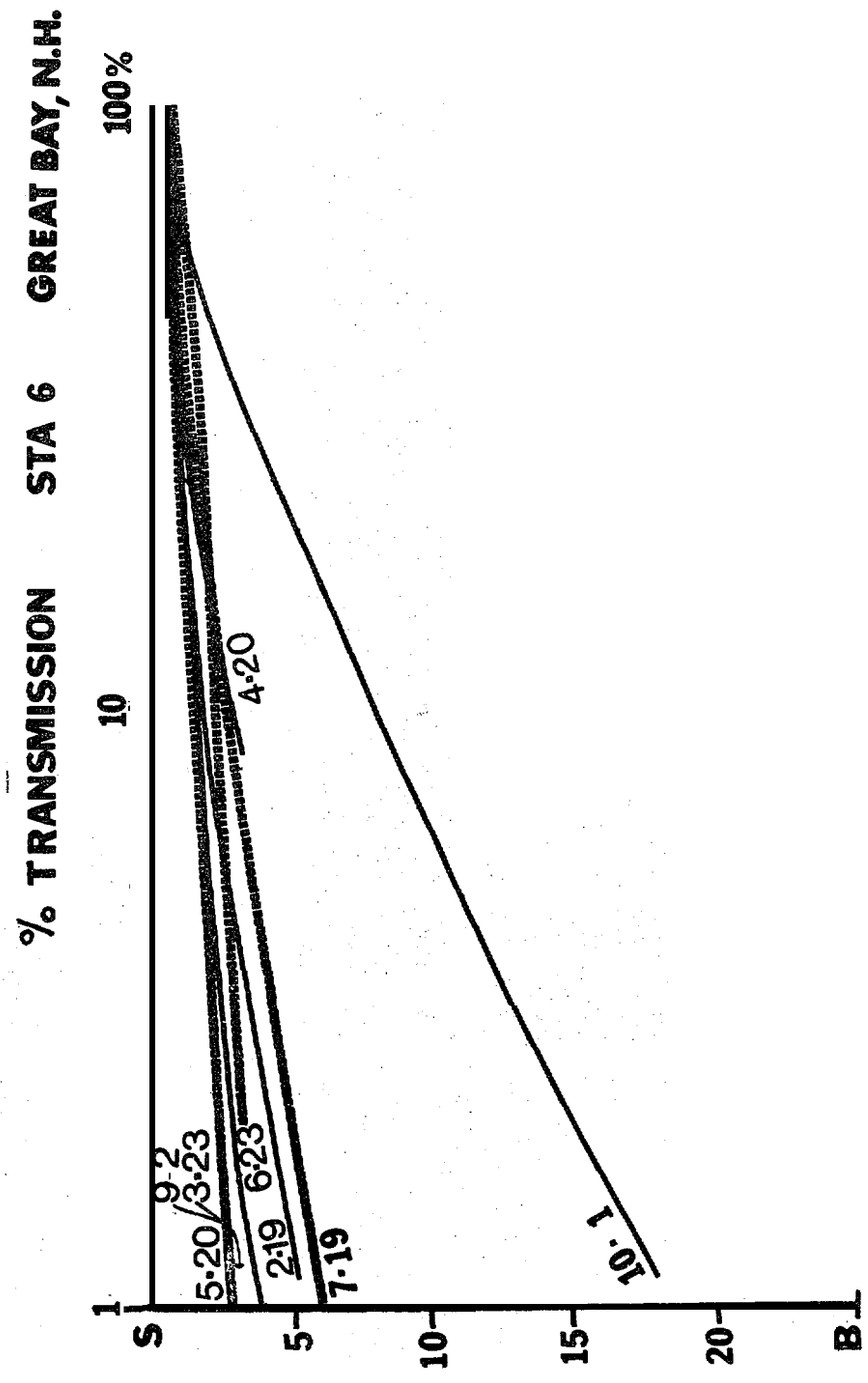
2·19
5·20



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 8-29	% Light Transmission Values-Great Bay ,

Table 8-8

Chlorophyll a concentrations (mg/m^3) of surface waters at 7 stations in the Great Bay Estuary of New Hampshire

DATE	1971								1971						
STATION	10/21	71/4	11/16	11/30	12/21	1/31	2/19	3/23	4/20	5/20	6/22	7/19	8/27	9/1	10/13
1	1.6	5.4	3.2	1.4	0.9	1.3	1.0	0.5	5.0	1.3	1.0	1.8	2.2		0.9
2	1.6	3.5	2.6	1.2	0.8	0.8	0.7	0.9		1.2	1.0	1.6	2.2	2.3	0.9
3	1.3	2.0	1.9	1.6	1.0	1.0		2.?	13.8	2.4	2.7	2.7	1.5	2.3	1.1
4	1.7	1.5	1.6	1.7	1.2		1.3	3.1	19.0		4.0	2.7	2.2	2.1	1.7
5	2.2	1.4	1.7	1.2	1.5		1.7								
6	2.0	2.0	2.0	1.2	1.0			2.0	20.8	0.5	6.1	3 . 7	2.8	3.2	1*5
7	2.1	2.0	2.1	1.3	1.2			2.6	20.9	0.1	6.2	4.2	3.1	4.4	1.8

Stations 6 and 7 in February and April. Maximum cell numbers reached 7×10^6 in 1971, 2 x 107 in 1972 and 3×10^4 in 1973, when the spring phytoplankton population failed to develop (Fig. 8-30). The mild winter in 1972-73 produced lower winter salinities and higher spring salinities and this may have been partially responsible for the population decline observed in Spring, 1973. In-situ incubation experiments conducted in 1972-73 determined that the population could have developed within the water column and did not have to result from a population introduced from some other location, where it had developed.

The Detonula population comes to an abrupt end in early May and in 1971 was replaced briefly with a species of Cryptomonas. Small numbers of phytoplankton are present during the remainder of the year and include many organisms which have been introduced into the water column from their normal benthic habitat (tycopelagic), including species of Cocconeis, Cylindrotheca, Isthmia, Gyrosigma, Licomorpha, Biddulphia, and Navicula.

Nitzschia frigida produces a small pulse which occurs when the water reaches its coldest point in February. This organism normally will grow on ice surfaces, but has not been reported from elsewhere in the Gulf of Maine.

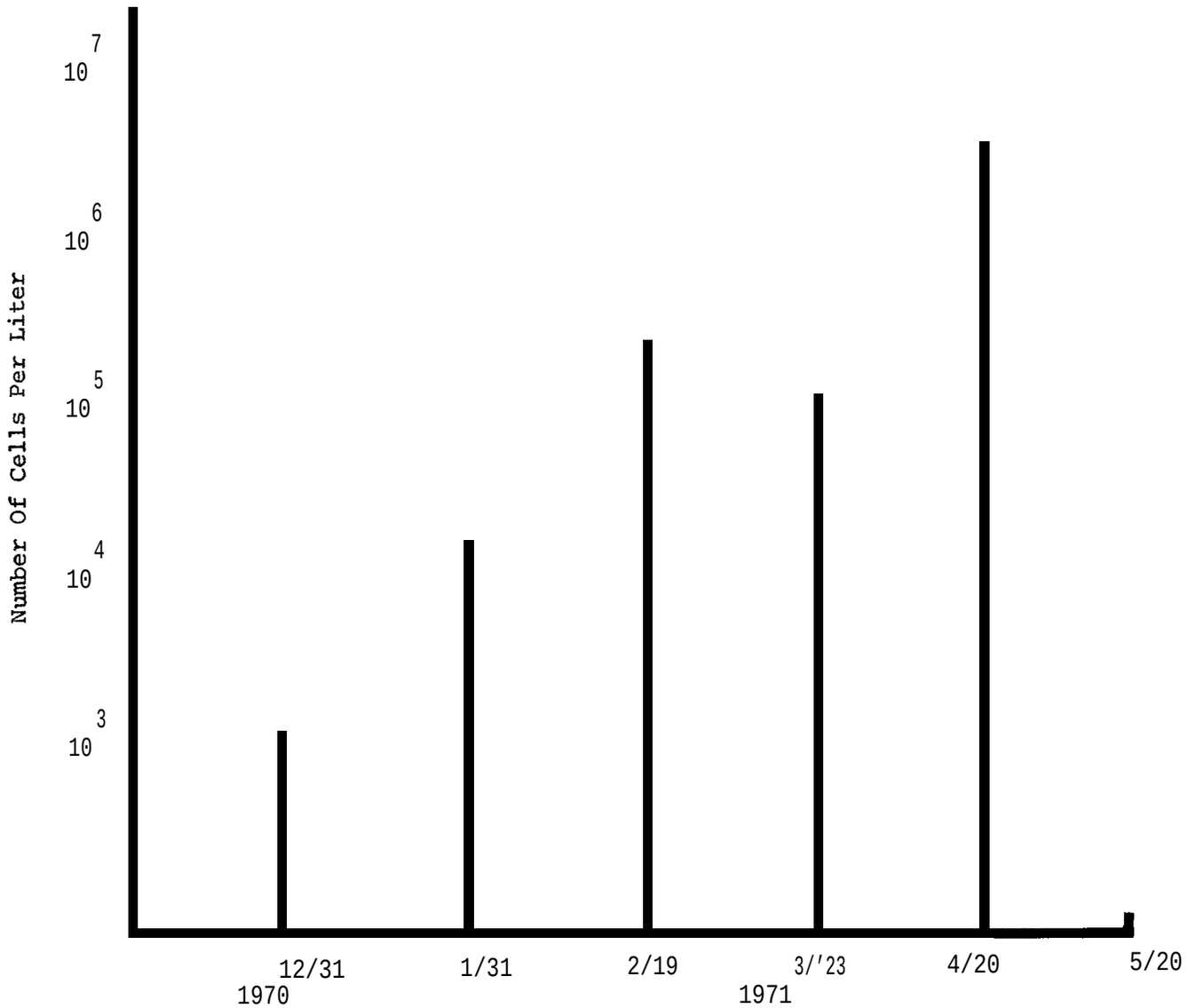
The Great Bay Estuarine System, with the exception of the large spring bloom of diatoms, appears to be primarily a "detritus" system with the majority of the material introduced at the base of the food chain in the form of decomposing particulate organic material.

Montsweag Bay - Back River Estuarine System, Maine

During 1969-1971, a team of scientists from the Ira Darling Marine Research Center of the University of Maine, including D. Dean, B. McAlice, R. Vadis, and others conducted a research study in the Montsweag Bay-Back River area of the Sheepscot and Damariscotta Rivers for the Maine Yankee Power Company. A description of the hydrographic conditions and phytoplankton populations is presented by McAlice (1972).

The Montsweag Bay - Back River Estuarine Region is located about 65 km north of Cape Elizabeth, inland from Boothbay Harbor, Maine. The waters in the Montsweag Bay Region are quite shallow (70 percent of the area is less than 3 m deep at MLW), with an average tidal range of 2.6 m. Extreme temperature and salinity variations occur annually, but despite the importance of tidal currents, stable vertical stratification of salinity and temperature occurs at nearly all stations. Dissolved oxygen concentrations showed a slight decline in summer months but became somewhat supersaturated from late fall to spring.

Nitrate-nitrogen concentrations followed the typical cycles with low levels recorded in the spring. There was a unique decline in mid-summer



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 8-30

Detonula confervacae Population in Great Bay Estuary - 1970-71

which appears to indicate a bloom preceding the fall bloom which also occurred. Silica followed the nitrate pattern with lowest values occurring from late spring to late summer. Phosphorus, however, showed maximum concentrations during the summer period; this is quite atypical when compared to the classic phosphorus cycle described by Cooper (1938).

The euphotic zone ranged from 5 to 10 m in the deeper portions of the estuary but was considerably reduced in the shallow waters of Montsweag Bay.

Phytoplankton

About 140 species were found in Montsweag Bay during the sampling period, with diatoms dominant throughout the year. The standing crop of phytoplankton was not large by coastal or estuarine standards. The annual average was 10^6 cells/1 with few species exceeding 10^6 cells/1. This is of the same order as the standing crops reported by Gran and Braarud (1935) for inshore areas of the Bay of Fundy.

Spring: The spring bloom was signaled by an increase in the number of Biddulphia aurita in February and March. Thalassiosira nordenskioeldii grew rapidly from early March to mid-April (10^5 cells/1) and then declined rapidly, with complete disappearance by the end of June. Chaetoceros debilis succeeded T. nordenskioeldii and reached its largest cell density of 10^6 cells/1 by mid-June. It remained, however, a dominant member of the summer and autumn flora. Detonula confervacea occurred during the spring and was absent only during the warmest part of the year in Montsweag Bay; it rarely exceeded 10^3-10^4 cells/1.

Summer: A diverse diatom flora constituted the summer community in Montsweag Bay. Skeletonema costatum and several species of Chaetoceros, especially C. affinis, debilis, and lorenzianus were the dominants. Dinoflagellates reached their largest numbers in the summer season. Peridinium depressum was the dominant dinoflagellate with Ceratium fusus, C. longipes, and Dinophysis also present.

Fall and Winter: Considerable variation in species composition and in absolute and relative abundances typified late summer and fall phytoplankton populations. Guinardia flaccida, Leptocylindrus danicus, and L. minimus increased in number in late summer and sporadically pulsed during the fall season. Asterionella japonica dominated in September and October and was replaced by a cold-season flora composed of A. bleakleyi, Chaetoceros concavicornis, C. socialis, Detonula confervacea, and Ceratium tripes.

Some comparisons can be made between the phytoplankton populations of the Montsweag Bay - Back River Estuarine Area and those of the Great Bay Estuary; the most obvious involves the spring bloom populations. In the case of Great Bay, Detonula confervacea is the dominant organism

constituting 90 percent of the total cell count at that time, but varying in size from 3.0×10^4 - 7×10^6 during successive springs. This is typical of spring conditions in Narragansett Bay (Pratt, 1959, 1965; Smayda, 1957) but, in the Montsweag Bay system, more coastal forms such as Thalassiosira and Chaetoceros dominate the spring phytoplankton blooms. The Biddulphia aurita spring population at Montsweag Bay parallels the situation reported to occur in the Bay of Fundy by Gran and Braarud (1935). The bloom of Nitzschia frigida in early spring in Great Bay has not been reported to occur elsewhere in the Gulf of Maine. The general low population levels found in Great Bay during most of the year agree with" observations of McAlice (1972) in Montsweag Bay, and of Burkholder (1933) in the upper reaches of Frenchman Bay. The shallow conditions and extreme tidal mixing in Great Bay create a reduced water transparency and present a poor environment for phytoplankton growth during most of the year; oceanic phytoplankton populations do not become established in the Great Bay Estuarine System. With the exception of the extensive spring bloom period from February to May, the Great Bay Estuary is primarily a detrital system. Evidently, the long fjord-type estuaries, typical of those which line the coast of Maine, allow near-oceanic conditions to prevail and therefore favor the development of phytoplankton more typical of exposed coastal environments.

GEORGES BANK AREA

As delineated by Bigelow (1927), Georges Bank is a region comprising approximately 25,920 sq km. It lies between Lat. 40° 42' and 42° 10'N., and between Long. 66° and 69° W. From the 100 m contour on the Eastern Channel slope to the deepest trough in the South Channel, the Bank spans, along its long axis, about 225 km. The maximum north-south width is about 130 km.

The water is shallowest over the northwestern third of the Bank, where depths may be as shallow as 5 to 6 m in interrupted areas, such as Georges or Cultivator Shoals. Surrounding these extremely shallow points of the northwestern sector, the Bank is somewhat deeper but generally still less than 40 m. The remainder of the Bank to the south and east ranges in depth from 60 to 80 m.

Georges Bank is a submerged northeasterly extension of the continental shelf of southern New England which has been reworked by waves and tidal currents. The sediments on Georges Bank were probably derived from the underlying coastal plain, or possibly from the central region of the Gulf of Maine (Ross, 1970). Wave and current action has carried away the finer-sized particles, leaving the coarser sediments. The deeper waters on either side of Georges Bank are the reposits of the finer-sized particles transported from the Banks.

Two kinds of currents have been found working on the Bank - clockwise tidal currents and residual drift (Riley and Bumpus, 1946). One clock-

wise eddy circulates over the shallowest northwestern part of the Bank and another flows around the rim of the Bank from outside the northwestern region around to the southeastern edge (Bumpus, 1960). These currents may attain a maximum velocity of 3 to 4 knots at the water's surface (Riley and Bumpus, 1946). In the winter or spring, water may flow directly across the Bank from the northwestern to southeastern part (Riley, 1941) and out of the Gulf of Maine.

Vertical mixing is continuous, due to the shallowness of the Georges Bank region and the effects of wind and currents. Riley and Bumpus (1946) found evidence of this in the homogeneous temperature and salinity conditions throughout much of the Georges Bank water. In addition, Georges Bank is characterized by a low N:P ratio, typical of shallow regions (Riley, 1941). Compared to Cooper's (1938) average N:P ratio of 15:1 for oceanic waters, Georges Bank ranges from 4:1 in April to at most 11:1 in September (Riley, ?941). As nutrients are regenerated at the Bank bottom, vertical mixing returns them to the surface. The more rapidly regenerated phosphate continues at high concentrations in this way.

Seasonal Cycle of Phytoplankton

Winter: Coinciding with the January minimum for the phytoplankton of the Gulf of Maine as a whole, Georges Bank also supports its lowest phytoplankton population during this month. From a December reading of 3 to 4 million cells per 0.1 sq m of ocean surface, January values decreased to 2 to 3 million, or slightly more than half of December's (Bigelow, Sears and Lillick, 1940). The Gulf proper has a maximum winter population of 900,000 to 1 million, localized just east of Geroges Bank and in the shoal waters close to Cape Cod.

Bigelow (1926) suggests that Thalassiosira is the most abundant organism, while Lillick (1940) characterizes the northwestern part of the Bank as dominated by Coscinodiscus and the eastern and northeastern regions show a community of neritic diatoms and peridinians. Coscinodiscus and Ceratium comprise less of the total population than they do in most portions of the Gulf.

Riley (1941) attributes the sparseness of phytoplankton to the winter minimum in solar radiation, although Fish (1925) has shown abundant blooms at the same time in Cape Cod Bay. Direct evidence of this was a photosynthesis rate of about half that of September and March, although large quantities, of nutrients are available during the period. Reduced light decreases the rate of photosynthesis and also narrows the euphotic zone..

A distinct vertical gradient exists in the phytoplankton population, with the growth rate at a maximum closest to the surface (Riley," 1941). Braarud (?934), however, suggests inhibition of phytoplankton by light

at the surface. The crop does not reach large proportions because vertical mixing carries a substantial portion out of the euphotic zone. Water transparencies during the winter are similar to those of September and the differences between light intensities of lower depths were therefore not markedly increased. Riley (1941) suggests that the length of daylight, more than light intensity, might be the more important factor inhibiting phytoplankton growth. The surface crop measured 40 percent of September's values, the total crop only 20 percent. However, since the phytoplankton populations for the two periods were different, it is difficult to attribute the observed population differences to any single factor.

Spring Bloom: The spring burst in the diatom crop may increase its size to anywhere from 26 to 44 million cells/0.1 sq m on Georges Bank (Bigelow, Sears and Lillick, 1940). The flowering usually occurs in late February to early March, as it does in the western coastal belt of the Gulf, and generally spreads out from an initiating center in the shallowest regions of the northwestern or southwestern sectors. Blooms can be delayed until late March in some years.

Although Thalassiosira initiates the spring flowering in most parts of the Gulf, the data of both Sears (1941) and Lillick (1940) indicate it may not be as important or abundant an organism on Georges Bank Bigelow (1926) considered Chaetoceros as the initial dominant organism having a patchy distribution from mid-February throughout the spring until mid-May. C. decipiens and C. debilis are the Bank's dominant species, together comprising about 60 percent of the diatoms in March (Sears, 1941). C. decipiens, the larger of the two species, apparently precedes C. debilis in reaching a peak. C. decipiens is rarely so dominant elsewhere in the Gulf of Maine.

While Sears' data covers the March to June period of only one year, 1940, the information is more detailed than other studies as far as the composition of the Georges Banks diatoms is concerned. She showed that the vernal bloom on Georges Bank is a succession of diatom populations - first of larger organisms, then of progressively smaller organisms. During April, Sears found Thalassiosira also underwent a moderate bloom (13 percent of the population), but dwindled again to 3 percent by May. The most active productivity on Georges Bank probably occurs during April. In late April, 1913, Rhizosolenia styliformis was the dominant organism. This is the major North Atlantic offshore form.

Georges Bank is one of the initial foci of the spring bloom. Riley (1941) and Bigelow, Sears and Lillick (1940) relate the imitation of the bloom to shallow water depth, which, for this spring period, does not exceed the zone of productivity. Whereas turbulence will prevent the development of a rich bloom if the phytoplankton crop is depressed through a layer of water of any considerable thickness, in the shoal regions, the active mixing in March favors the production of phytoplankton

Gran and Braarud, 1935). By March there is significant solar radiation at lower depths of the shallow regions for growth not to be kept down through dissipation of the surface crop. In most instances deep water regions require some degree of vertical stability in order for a bloom to occur (Bigelow, 1926). Loss of vertical stability also brings blooms to an end.

The Georges Bank flowering lasts about one month and is followed by about nine weeks of moderate to very active productivity (Sears, 1941), but the period of diatom abundance is more prolonged here than in most parts of the Gulf. Morevoer, the bloom spreads out to the edges of the Bank and beyond. When the Georges Bank bloom peaks, the waters surrounding the Bank, particularly to the southeast, are just as abundant (Sears, 1941). Later, however, these waters become almost barren of diatoms. Bigelow (1926) suggests that because the population is present for a longer period, this region is one of the most productive of the Gulf.

From the end of March to mid-April there is an increase in the phytoplankton population of from two to ten fold stall depths. In deeper regions the total crop of the water column may increase three fold (Riley, 1941); the population becomes more uniform regardless of depth.

Several factors account for this trend towards more equalized crop density in the water column. Increased solar radiation causes greater light penetration of the waters and, therefore, an expansion of the euphotic zone, and at the same time, the surface water growth becomes inhibited by nutrient depletion (Riley, 1941). Light may also be inhibiting in the surface water.

In May, although Georges Bank supports a larger population of phytoplankton than the Gulf as a whole, there is a decline from the March and April populations. Zooplankton reach large proportions and Riley and Bumpus (1946) record a significant negative correlation between the population changes of zooplankton and phytoplankton during the month of May. As demonstrated by Conover (1964), the majority of zooplankton are filter feeders and tend to strain an almost constant volume of water for a given time irrespective of the amount of food in the water. This implies that a stable fraction of the phytoplankton population is consumed in successive units of time. The grazing rate, therefore, becomes a function of the size of the zooplankton population (Riley, 1946).

Lillick (1940) and Sears (1941) both point to Chaetoceros as the predominant organism in May, making up about 60 percent of the phytoplankton crop. C. debilis declines in importance from its April dominance (from 220,000 cells/liter to 17,000 cells/liter), as does C. decipiens, but the genus as a whole maintains its relative importance. Thalassiosira drops significantly, from about 72,000 cells/liter to about 5,800. Rhizosolenia increases in numbers, but the Chaetoceros population of

almost 70,000 cells/liter still dwarfs Rhizosolenia's 5000.

Summer: June shows the combined effects of favorable light conditions, low nutrient concentration, large quantities of zooplankton and rather high temperatures. At about this time two very small organisms, Leptocylindrus mimimus and a small species of Thalassiosira become relatively abundant, making up about a third of the diatom population. Phytoplankton production continues moderately through the month (Sears, 1941). Dinoflagellates do not become abundant on Georges Bank during the summer period, but Ceratium is generally the more abundant form.

During the next two months summer diatom blooms occur and remain confined or become widespread. Georges Bank as a whole is a fairly homogeneous population, but has a patchy distribution, which differs markedly from the inner Gulf. It is quite similar to the very shallow coastal waters. Neritic diatoms are scarce, but characteristically some littoral diatoms are found, among them: Pleurosigma normani, Paralia sulcata, and Navicula distans. Rhizosolenia shrubsolei and Nitzschia seriata occur with abundances of about 800 to 1,500 cells/liter (Gran, 1933). Guinardia flaccida is abundant in July and August and was originally believed to be a "Georges Bank only" form. Mulligan (unpublished) has found it to be dominant in coastal samples to the north and south of Cape Ann. Eucampia zodiacus can be dominant but apparently does not occur each summer. Thalassiothrix longissima and Skeletonema costatum also become important during the summer in Georges Bank, while Rhizosolenia semispina was shown to make up 100 percent of the organisms in a tow collected from Martha's Vineyard in late" August, 1914.

Fall: Although detailed samples have not been reported for the fall, Prorocentrum micans reached a population of 2,500 cells/liter in October. The extent and size of the fall bloom in this region is not known. Riley (1941) has made the following measurements of productivity utilizing the light and dark bottle oxygen technique. He suggests that these productivity values are no different from those of the surrounding waters.

Net Phytoplankton Productivity Estimates (mg C/m^2/day)

Sept.	Jan.	March	April	May	June
140	-50	190	950	540	630

Throughout this late summer period, temperature and salinity values are fairly constant for the entire water column, suggesting strong vertical mixing. Accordingly, phytoplankton distributions are uniform from surface to bottom, with only a slight maximum at 20 to 30 meters depth. At the very surface, higher temperatures or light or nutrient depletion apparently inhibit growth and/or flotation.

SOUTHERN NOVA SCOTIA COASTS AND BANKS

This region including Browns Bank and German Banks is under the direct

influence of the Nova Scotian Current, a cold current which flows westward at the surface into the Gulf of Maine every spring (Bigelow, 1927). These waters, which are colder than the waters in the central portion of the Gulf during the spring and lower in salinity, can be found as far west as the eastern basin. Temperature reductions from this current within the Gulf are not as great as those to the east of Cape Sable. During the summer the surface waters in this current which moves into the Gulf of Maine are warmer than surface water found in other portions of the central Gulf.

Water long southern Nova Scotia moves to the west toward the Maine coast but Bigelow (1927) suggests, based on phytoplankton distributions, that sometimes this water may also move south over Georges Bank.

The depth of the water in this region is variable with the shallowest water (3 m) occurring over Lurchers Shoals, approximately 30 km off Yarmouth, Nova Scotia. Browns Bank and German Bank lie in water of about 55 m depth.

Seasonal Cycle of Phytoplankton

Winter: Sparse diatom populations exist during this period, but Coscino discus and peridinians are the dominant forms. Small numbers persisted until March 11, 1920, but by late March diatoms replaced peridinians.

Spring: This is a region which serves as an initial seed area for the eastern and central Gulf Basin; from mid-March through the end of April, diatom flowerings continue. The Thalassiosira community usually lasts for 2 to 4 weeks in this region. The Chaetoceros community flowers for about 4 to 6 weeks until the end of May and is generally more dominant than Thalassiosira. Chaetoceros contortum, C. debilis, C. decipiens and C. laciniosum were the dominant forms on April 15, 1920 (Bigelow, 1926). Ceratium may sometimes replace diatoms as early as the first week of May. Ceratium longipes and C. arcticum are the dominant organisms at this time.

Summer and Fall: On June 19, 1915, the phytoplankton consisted mostly of Rhizosolenia semispina and Chaetoceros decipiens; Coscinodiscus persists throughout the summer in this region. In general, however, the summer and fall phytoplankton populations of this region have not been well described. It is likely that a secondary diatom bloom occurs, composed primarily of offshore forms such as Rhizosolenia styliformis. Because water from this region spreads widely over the central and eastern portion of the Gulf, the composition of phytoplankton should be well known. In addition, it is within this water mass that organisms from the open North Atlantic are introduced into the Gulf of Maine.

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8.2 THE MID-ATLANTIC BIGHT - CAPE COD TO THE NEW JERSEY COAST

The following section contains a review of the phytoplankton in the southern portion of the study area, from Cape Cod to the New Jersey coast. It is primarily a summary of information on phytoplankton contained in the Coastal and Offshore Environmental Inventory prepared by the University of Rhode Island for the American Petroleum Industry (Smayda 1973).

8.2.1 NATURAL DIVISIONS

The portion of the study area that is part of the Mid-Atlantic Bight has three natural divisons with respect to phytoplankton; the coastal salt ponds, the major sounds and embayments (Nantucket Sound, Vineyard Sound, Block Island Sound, Long Island Sound, Narragansett Bay, and Raritan Bay) and the offshore waters out to the continental slope. Figure 8-31 illustrates the coastal and salt pond areas of southern New England and New York and indicates where major studies have been located. Both the salt ponds and some of the sounds and embayments are highly productive of phytoplankton as a result of the accumulation of nutrients in their systems and have also been subject to intensive study that has resulted in considerable quantitative information. In contrast the offshore waters are less productive and have received very little study with respect to the phytoplankton. Therefore, the productivity and species composition of these waters are not well known.

8.2.2 FACTORS AFFECTING PHYTOPLANKTON COMPOSITION

CIRCULATION

Except for passages between different bodies of water, the tidal currents in this part of the study area are of moderate velocity, 1 knot in the inner part of the shelf and less than 0.1 knot over the outer parts of the shelf. The non-tidal circulation over the continental shelf is, in general, a movement with the land on the right with speeds in the order of 5 nautical miles per day which results from winds, fresh water stream flow, and the geostrophic effects of the temperature and salinity distribution. There may be a shoreward component to the drift during the warm half of the year and an offshore component during the cold half. A persistent bottom drift, in terms of tenths of nautical miles per day, occurs from just beyond mid-shelf toward the coast and into the estuaries.

TEMPERATURE AND SALINITY

A wide range in seasonal temperature is characteristic of the waters south of Cape Cod. The annual range of surface temperature at any

location may be greater than 15 C in the slope water to greater than 20 C next to the shore (Walford and Wickland 1968, Colton and Stoddard 1972). The best description of the annual temperature cycle is given by Bigelow (1933).

The distribution of salinity over the continental shelf below Cape Cod is coastal in character with values increasing from 32°/oo and less next to the land and 32-33.5°/oo out to the mid-zone of the shelf to 34-35°/00 near the continental edge. There is little difference in salinity length wise to the coast. Generally, salinity is at its maximum at the end of winter and at its minimum by early summer through the discharge of land water.

DISSOLVED AND SUSPENDED MATERIALS

Enough information exists on the occurrence of dissolved oxygen, phosphate, nitrate, ammonia, and chlorophyll in the study area below Cape Cod to describe the major features of the horizontal and vertical distribution and the seasonal fluctuations of these factors. Information on trace metals and organic substances are inadequate.

Along the shelf and the estuaries biologically reactive components are removed from the surface waters and regenerated at depths. During the fall, thermal stratification breaks down, and the biologically active constituents are mixed back into the surface waters. The high degree of correlation between many of the chemical parameters, i.e. oxygen, PH, phosphate, nitrate, and ammonia can be related to photosynthetic and respirational processes.

8.2.3 THE PHYTOPLANKTON; AN OVERVIEW

The phytoplankton community is characterized floristically by great species diversity. The major constituent of the phytoplankton is the diatoms, while less important segments include the dinoflagellates, coccolithophorids, silicoflagellates, and microflagellates. Although the floristic characteristics of the inshore waters are fairly well known, there is a great lack of information for noncoastal waters. The following is a list of some of the more common phytoplankton species throughout the coastal waters from Cape Cod to Sandy Hook:

Dominant species

Diatoms	Seasons of Greatest Abundance
Skeletonema costatum	all year
Thalassionema nitzschioides	all year
Paralia sulcata	fall-winter

Common Species (with peaks of similar abundance)

Diatoms	Seasons of Greatest Abundance
Cerataulina pelagicus	late spring-fall
Chaetoceros radians	summer
Leptocylindrus danicus	all year
Nitzschia longissima	summer-fall
Thalassiosira gravida	summer-fall
T. rotula	summer-fall
Dinoflagellates	
Peridinium trochiodeum	spring-fall
Silicoflagellates	
Distephanus speculum	spring

Common species (with dissimilar times of peak abundance)

Chaetoceros curvisetum	summer-fall
C. decipiens	spring-summer
Dinoflagellates	
Prorocentrum scutelum	summer-fall

Several environmental parameters have important effects on phytoplankton populations and their maintenance. Aside from recruitment by-means of current transport, which is common in some areas (Fish, 1925; Riley, 1952a), reproduction and succession are affected by:

(1) Temperature, which directly affects growth rate

(2) Radiation levels, which determine the amount of photosynthesis that can occur. In turn this is responsible for net gains of energy.

(3) Nutrient levels, which may be critical for growth and reproduction. Phosphorus and in some cases silica levels are important. However, Ryther and Dunstan (1971) report that nitrogen is the limiting variable in most areas. Organic substances such as vitamins and exudates also may play an important role in the dynamics of the phytoplankton community.

(4) Stability of the water column, which affects the sinking rate of the organisms. Sinking can take these organisms out of the euphotic zone.

(5) Grazing pressures, both selective and nonselective, have effects on the community structure.

8.2.4 DISCUSSION BY REGION

COASTAL SALT PONDS

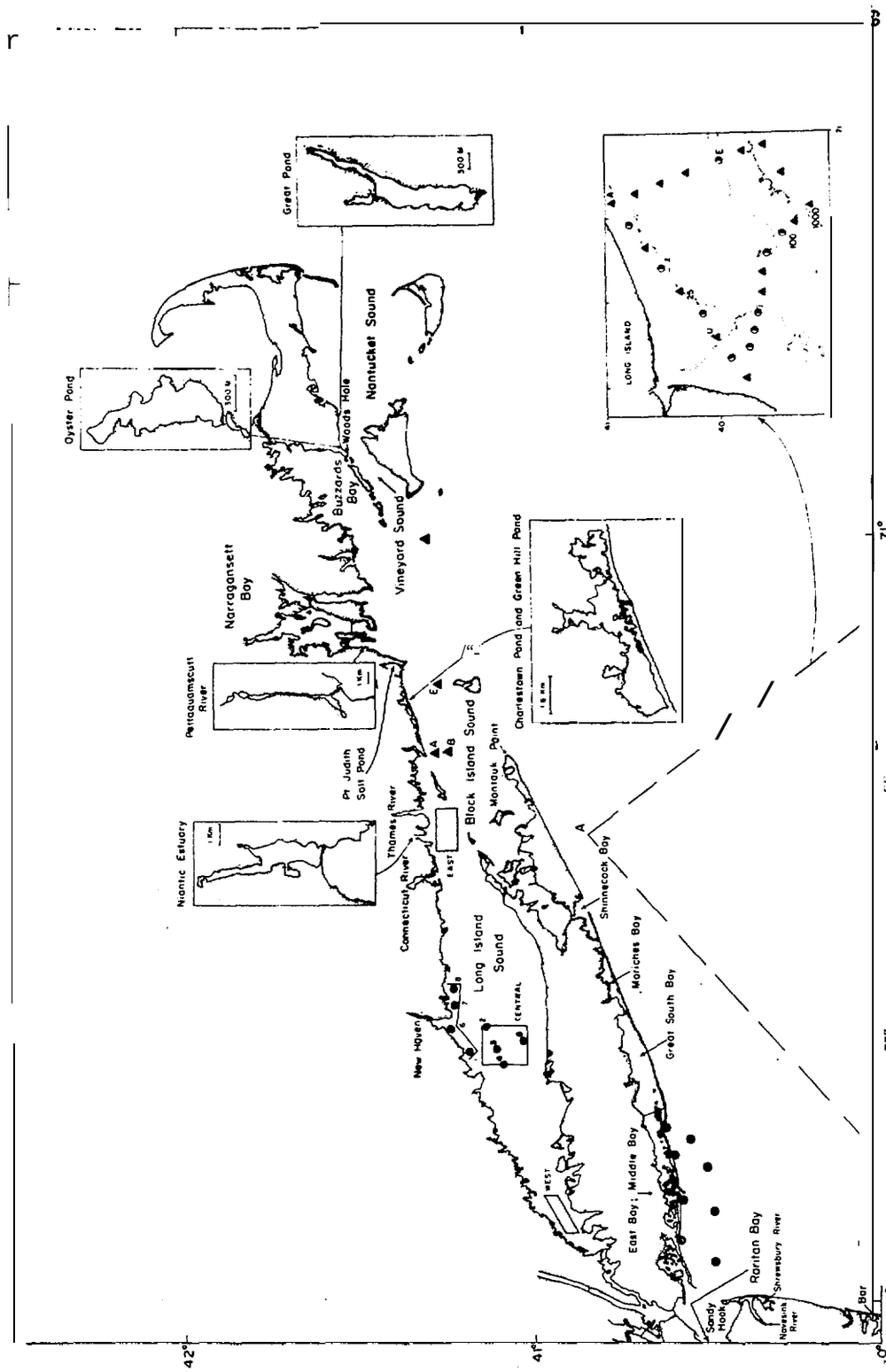
The coastal salt ponds generally have high levels of productivity. The primary producers are composed of four different plant communities: the macrophytes, thee epiphytic microscopic plants ("Aufwuchs"), and the phytoplankton and benthic microalgae. The high productivity results from the essential plant nutrients that are "trapped" in the salt ponds by accretion through fresh water runoff and by nutrients introduced from offshore areas. Runoff produces a head of fresh water with a net seaward transport. This causes a two-layer system to develop., less dense water flows seaward at the surface, and dense water from offshore flows in along the bottom. The effect is to introduce nutrients from offshore (Conover, 1961; Hulburt, 1956). Thus the coastal embayments are systems in which nutrient enrichment (with its resultant productivity) occurs through both its fresh and salt water sources.

The productivity, species composition, and seasonal succession of phytoplankton varies between salt ponds depending on individual situations. A number of these salt ponds will he briefly described.

Oyster Pond, Mass. (Figure 8-31) is a small (62 acre) shallow, eutrophic pond with restricted communication with Vineyard Sound (Emery, 1969). Its characteristics result in low salinity, winter ice, and anoxic conditions in deep water. Brackish conditions create the dominance of the blue-green" algal genera Anabaena, Merismopedia, Microcystis, and Oscillatoria. The most common diatom genus was Chaetoceros.

Great Pond, Mass., is a small (320 acre) tidal embayment formed from a drowned river mouth. It has a marked seasonal variation in salinity and a flushing time of 2.6 to 12.7 days (Barlow, 1956). Hulbert (1956) revealed three phytoplankton communities: a Vineyard Sound-derived diatom flora dominated by Leptocylindrus minimus and Skeletonema costatum, a pond type consisting mainly of microflagellates, and a river-derived community of an unidentified Chlamydomonas species. The main phytoplankton bloom consisted of the microflagellates of the pond community in the summer and at this time the productivity was greater than that of Vineyard Sound.

Charleston- Green Hill Ponds, Rhode Island. This is a shallow, salt pond complex totaling 2010 acres (Conover, 1961; Smayda, 1961) with an exchange rate of 9.4 percent per day. The salinity varies from 6.0- .



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TRIGOM PARC

FIGURE 8-31

Phytoplankton Study Locations (Smayda, 1973)

31.0 o/oo and temperature from 0-26 C. Three major plant communities are found: the spermatophytes, the Aufwuchs, and the phytoplankton. For phytoplankton, an abundant heterogeneous flagellate population accompanies a normal, diatom-dinoflagel late component. There was no evidence of a regular winter or spring maximum as in the contiguous waters. There is a considerable net gain of phosphate and nitrate from Block Island Sound, and phosphorus appears to be the primary limiting nutrient over most of the pond system.

Niantic River, Corm. This is a tidal estuary draining into Niantic Bay. Depths range from shallow, partially exposed flats to a maximum depth of6m (Marshall, 1960). It has a weak fresh water inflow, a range in salinity of 5-30 o/oo and a temperature range of 0-25 C.

Marshall and Wheeler (1965) and Marshall "(1967) demonstrated that the biomass of dinoflagellates and Chrysophyceans considerably exceeded those of diatoms except during October. Two large dinoflagellate blooms occurred in the estuary, dominated by Peridinium triquetrum in late winter and Exuviaella baltica in the late fall. Dominant Chrysophyseans consisted of Calycomonas gracialis and C. ovalis, while the dominant diatoms were those found in coastal waters - i.e. Skeletonema costatum, Asterionel la japonica and Thalassiosira nordenskioeldii. Marshall (1960) concludecthat the estuary was an effective concentrating system, utilizing the production of nearshore waters as well as those from within the estuary.

Estimates of the annual net primary productions ($g/C/m^2$) in representative, southern New England coastal salt ponds is given in Table 8-9. It demonstrates that, in contrast to open coastal water, the role of the phytoplankton is subordinate in primary production to the other floral communities. Impact studies, therefore, in these environments can not be restricted to the phytoplankton alone.

Long Island Bays." An extensive barrier beach system along the south shore of Long Island forms a series of contiguous, connected embayments (Figure 8-31). These are shallow embayments (1 to 2 m depth) with hard, sandy bottoms and four major inlets.

One of the most important implications for the phytoplankton is the major duckling industry along the tributaries to the bays, which discharges waste products into the embayments resulting in a high degree of organic pollution (Foehrenbach, 1969; Ryther, 1954; Ryther and Dunstan, 1971). Lackey (1963) recognized three undesirable conditions, developed to various degrees, in the Long Island Bays, 1) algal and non-algal plant problems, 2) animal kills and 3) increasing eutrophication.

The phytoplankton composition of these bays has been studied by Lackey (1963), Ryther (1954), Hulburt (1963), Lackey (1967) and Mandelli, Burkholder, Doheny and Brody (1970). Except for the areas

Table 8-9. Estimates of Annual Net Primary Production (g C/m^2) in Representative Southern New England Coastal Salt Ponds (From Marshal 1, 1970).

	g $C/m^2/yr$
Macroflora	125
Benthic Microflora	90
Phytoplankton	50
Allochthonous Matter	0-10
	265-275

Table 8-10. Some of the major phytoplankton components of Narragansett Bay, The times of peak densities are indicated by asterisks.

	W	S	S	F	Maximum cells/L
Diatoms					
Skeletonema costatum	x*	x*	x"	x	$13x10^6$, $29x10^6$
Asterionella japonica	x*	x	x*	x	$13x10^6$, $3x10^6$
Thalassionema nitzschioides	x*	x	x	x	
Detonula confervacea	x*	x			$13x10^6$
Thalassiosira nordenskioeldi i	x*	x		x	$2x10^6$
T. gravida	x	x	x*	x	
T. nana		x	x		
Rhizosolenia fragilissima	x	x	x*	x	1,000
Leptocylindrus danicus	x*	x	x	x	700
L. minimus	x*	x*	x	x	$1x10^5$
Nitzschia seriata	x	x*	x*	x	
Gyrodinium spp.	x	x*	x*	x	
Dinoflagellates					
Peridinium trochordeum	x	x*	x*	x	$8x10^5$
P. triquetrum		x*	x	x	
Prorocentrum gracile			x*	x	
Massartia sp.	x	x	x	x	
Microflagellates (Cryptophyceans)					
Chilomonas sp.	x	x	x	x	
Cryptomonas sp.	x	x	x	x	
Rhodomonas sp.			x	x	
Olithodiscus luteus		x	x	x*	
Ciliates					
Mesodinium sp.	x	x*	x	x	

Table 8-11. Some of the major phytoplankton components of Vineyard Sound. The times of peak densities are indicated by asterisks.

	W	S	S	F	Maximum cells/L
Diatoms	x				
Skeletonema costatum			x*	x*	46,782; 30,000
Rhizosolenia alata	x			x*	1,300
R. calcar avis			x*	x	700
R. setigera	x*		x	x	
R. hebetata f. semspina	x*		x*	x	330
Guinardia flaccida		x*	x	x	18,500
Leptocylindrus danicus	x		x*	x	4,874
L. minimus			x*	x	42,964
Corethron hystrix			x*		36,708
Thalassionema nitzschioides	x	x	x	x	7,965
Nitzschia seriata	x		x*	x*	14,306; 17,600
Thalassiosira nordenskioeldii	x*		x*	x	2,800; 1,196
Chaetoceros constrictus			x*	x	1,496
Ch. didymus	x	x	x	x	2,200
Ch. spp.			x	x*	4,000
Dinoflagellates					
Peridinium spp.			x*	x	1,588
P. simplex		x	x*		3,184
Prorocentrom minimum			x*		6,480
P. scutellum	x*		x		2,160
Silicoflagellates					
Distephanus speculum			x*	x	1,755

that were more exposed to the open water, and in which there were the typical spring and summer alternation of diatoms and dinoflagellates (Leptocylindrus 'minibus, Skeletonema costatum, Thalassiosira nana, Chaetoceros simplex, Peridinium depressum and Ceratium spp.), the chlorophytes Nannochloris and Stichococcus have virtually replaced the normal tidal estuarine phytoplankton concentrations as a result of duck wastes entering the system (Ryther, 1954).

NARRAGANSETT BAY

Narragansett Bay (Figure 8-31) has a total area of about 260 sq km, a length of 42 km and a mean depth of about 10 m with a maximum of 60 m at the mouth (Hicks, 1959). The annual range in salinity is about 29-33 o/oo and the Bay is generally well mixed throughout with only a slight summer stratification (Hicks, 1963), which has a great influence on the seasonal phytoplankton cycle. The annual temperature range is about -1 to 25 C which contributes to the occurrence of boreo-arctic plankton species in the Bay. This represents the southernmost extension of this thermal group along the eastern seaboard.

Narragansett Bay has a somewhat atypical nutrient cycle (Smayda, 1957) with a phosphate cycle that is at a maximum in the summer and a minimum in the winter the converse of that reported for contiguous areas. The nitrate concentration (Pratt, 1965; Martin, 1965) is almost undetectable during most of the year except during the fall and early winter, probably due to the excretion of NH_3 by the zooplankton which contributes significantly to the nitrogen of the Bay during this time of year (Martin, 1968).

The major phytoplankton components of Narragansett Bay are given in Table 8-10. In terms of standing crop, the phytoplankton of the Bay exceeds that reported for the other east coast embayments (Smayda, 1957; Pratt, 1959, 1965). Primary production is also high (Smayda, 1957). The distinctive characteristic of the seasonal cycle is the development of the major phytoplankton bloom from December through April rather than a brief, spring bloom that is found in contiguous waters. This has been attributed to the relative shallowness of the Bay that allows complete mixing and insures adequate residence of the phytoplankton in the euphotic zone (Smayda, 1957). The magnitude of the bloom has been related to the nutrient reserve available prior to its inception (Pratt, 1965) and its termination results either from nutrient limitation (Pratt, 1965) or increased grazing by the zooplankton (Martin, 1965). A smaller late summer-fall phytoplankton pulse also occurs.

The species composition of the phytoplankton has been established by Smayda (1957) and Pratt (1959). The diatom Skeletonema costatum dominates overwhelmingly (80 percent of the total population). Unlike the contiguous areas, the arctic diatom Detonula confervacea

and the microflagellate Olisthodiscus luteus are extremely important. The appearance of D. confervacea in the Bay probably results from the relatively low temperatures found there.

VINEYARD SOUND

Vineyard Sound shows characteristics of both offshore and inshore waters. The temperature range is between -1.0 and 22 C and in the summer the cold waters north of Cape Cod form a barrier for southern neritic species and a southern barrier for more northern species (Fish, 1925). Coastal drainage tends to maintain a degree of vertical stability of the water column (i.e. reduced mixing).

Lillick (1937) described the phytoplankton cycles near the western entrance to Vineyard Sound. While the cycle resembles more the offshore waters with its spring and fall maxima than it does the cycle in enclosed neritic waters, it appears to be intermediate between these two types. More than 100 species were reported. The diatoms dominated throughout the year, particularly Rhizosolenia alata, R. calcaravis, R. setigera and Ginuardia flaccida in the summer and Skeletomema costatum, Leptocylindrus danicus, and L. minimus in the fall. Dinoflagellates, particularly Prorocentrum minimum and Peridinium simplex, also appeared throughout the year, particularly in the summer and fall. The major phytoplankton species are given in Table 8-11.

Lillick concluded that nitrate was more important than phosphate in controlling phytoplankton production because the seasonal cycles in nitrate concentration and phytoplankton abundance were more closely correlated with phosphate. Subsequent observations (Vaccaro, 1963) indicate that in New England coastal waters, excess amounts of phosphorus are usually found throughout the year and that the annual variations in available phosphorus are much less pronounced than those for nitrogen.

BLOCK ISLAND SOUND

Riley (1952a) describes the hydrography of Block Island Sound. In the Sound, the surface water moves westward between the Rhode Island coast and Block Island and thence joins the southeasterly flow from Long Island out past Montauk Point (Long Island). Strong thermal stability is found only in the outer waters off Block Island. The temperature and salinity conditions indicate that it is less typical of open coastal waters than Vineyard Sound and is intermediate between it and the more dilute, eutrophic waters of Long Island Sound to the west.

The major components of the phytoplankton in Block Island are given in Table 8-12. Riley (1952b) describes the phytoplankton as having two major pulses, an early spring flowering in February- March and a

Table 8-12. Some of the major phytoplankton components of Block Island Sound. The times of peak densities are indicated by asterisks.

Diatoms	W	S	S	F	Maximum cells/1 #/1
Skeletonema costatum	x*	x	x*	x	$5x10^6;1x10^6$
Thalassionema nitzschioides	x*	x	x*	x	$2x10^5;8x15^3$
Rhizosolenia faeroense		x			
Chaetoceros didymus		x	x	x	
C. curvisetus			x	x	
C. decipiens		x	x		
C. compresses		x	x		
Leptocylindricus danicus		x*	x	x*	$1x10^4;1x\ 0^5$
L. minimus			x	x	
Thalassiosira subtilis	x				
Cylindrotheca closterium	'x	x*	. x *		$1.2x10^4;8x10^3$
Nitzschia seriata		x*	x	x*	$1x10^4;7x10^3$
Asterionella japonica	x*	x *	x		$1.\ x10^4;7x10^3$
Guinardia flaccida	x	x*	x*		$8x''\ 0^3;2x10^3$

moderately large population developing in late summer. This cycle is similar to that of Vineyard Sound and is typical of coastal, temperate waters. Although the seasonal cycles are similar, the population levels and mean abundance in Block Island Sound are greater than those of Vineyard Sound by 20-fold. Also the overwhelming dominance of Skeletonema costatum (83 percent of the total population) in Block Island Sound contrasts with its scarcity in Vineyard Sound.

The environmental factors responsible for the observed hytoplankton cycle are unclear. Riley (1952b) concluded that probably neither the phosphate cycle nor zooplankton grazing was important. The indications are that Block Island Sound exists in a state of ecological imbalance, producing more phytoplankton than is consumed, with the excess taken off by physical dispersal to the southeast past Long Island.

LONG ISLAND SOUND

Long Island Sound is the most thoroughly studied body of water in the United States in respect to phytoplankton research. The Sound is a semi-enclosed body of water about 160 km long, a maximum of 27 km wide and 3200 km^2 in area (Riley, 1955). The mean depth is 22 m with maximum depths of 100 m in the eastern end. The annual runoff is about 35 percent of the volume of the Sound.

The circulation in the sound is controlled by river discharge and consists of three main eddies: counterclockwise in the west and east ends of the Sound with a clockwise eddy in between (Riley, 1952a). There is a net eastward flow of water out of the Sound where it mixes with Block Island Sound water and then moves southeastward past Montauk Point. There is a compensating inward flow of bottom water, thus establishing a two-layer system.

The surface temperature ranges from 1.3 to 19 C in the eastern end and from 0 to 23 C in the western end. A small seasonal thermocline occurs. There is a salinity gradient in the Sound with fresher water (3 to 5 o/oo) in the western end than the eastern end where surface salinity ranges from 31 to 32 o/oo, except during times of river flooding.

The seasonal cycles of phosphate and nitrate (Riley and Conover, 1956) for the central portion of the Sound were similar in general features to those characteristic of temperate, open coastal waters. The regional differences in the seasonal cycles were not pronounced, but differences in maximum concentration do occur (Riley, 1959). The concentration of both nutrients decreases from west to east. Thus, the surface gradients from west to east during autumn-winter maximums were, for phosphate 3.0, 2.2, and 1.0 umoles/l and for nitrate 15.0, 9.0, and 6.0 umoles/l. There were similar west-east gradients for ammonia and dissolved organic nitrogen concentrations (Harris, 1959).

The seasonal pulses in phosphate and nitrate are attributable to a balance between phytoplankton use, excretion, reaeneration, and enrichment. Both positive and negative gradients have been observed for both nutrients on a seasonal basis mirroring the balance between utilization, regeneration, and excretion in the water column (Riley, 1959; Harris, 1959). The two-layered transport system in Long Island Sound provides a mechanism which favors the retention of nutrients within the Sound and which regulates the nutrient supply at a slightly higher level than in adjacent waters.

The phytoplankton of Long Island Sound are characterized by marked regional and seasonal differences. The" regional differences are similar to those found for the nutrients, that is a west to east gradient. The seasonal cycle is given for the central basin (Conover, 1956; Riley, 1959; Riley and Conover, 1967) which is intermediate between the richer western end and poorer eastern end. In the sound, a major flowering occurs between January and March followed by an irregular series of minor flowerings during the spring and summer which vary in time and intensity depending on the availability of inorganic nitrogen and vernal temperatures. An autumn flowering usually occurs followed by a lull in growth prior to the late winter bloom. This cycle is similar to that of other New England coastal waters although there are differences in phytoplankton abundance, composition, and timing.

The major components of the phytoplankton in Long Island are given in Table 8-13. There is succession in both abundance and species composition of diatoms, dinoflagellates, and silicoflagellates (Conover, 1956; Riley and Conover, 1967; Riley, 1967a). The diatoms and silicoflagellates have a winter maximum and the dinoflagellates are abundant during the summer. About 200 species have been recorded, 40 of which were classified as major constituents. The flora is mainly a mixture of temperate and boreal" species of littoral and neritic tendencies (Riley and Conover, 1967). The dominant species in the major late winter bloom are Skeletonema costatum and Thalassiosira nordenskioeldii. Temperatures and light conditions seem to govern the timing and the relative dominance of these two species. Riley (1967a) observed that the radiation level from mid-December to the onset of the bloom was the most important factor involved. Following the winter bloom the supply of nutrients and, secondarily, grazing by zooplankton regulate the series of pulses and maintain a relatively low population density until the autumn maximum. In the autumn, the strong vertical mixing following the breakdown of the summer thermocline results in the fall flowering.

Four species are important in Long Island Sound but not in contiguous waters: Schroederella delicatula, Exuviaella apora, Gonaulax minima, and Prorocentrum triestinum.

Riley (1956) estimated the net annual production for Long Island Sound

Table 8-13. Some of the major phytoplankton of Long Island Sound. The times of peak densities are indicated by asterisks.

	W	S	S	F	Maximum cells/l
Diatoms					
Skeletonema costatum	x*	x	x*	x	35x 10^6; 4x 10^6
Thalassiosira nordenskioeldii	x*	x			6 x 10^6
T. decipiens	x*	x	x	x*	1.5x 10^6; 2.6 x 10^5
T. rotula	x	x	x	x*	7.8x 10^5
Rhizosolenia delicatula	x	x*	x	x	5.6 x 10^5
R. fragillissima		x	x		1.4X 10^5; 3.9x 10^5
Thalassionema nitzschioides	x*	x*	x.	x	4x 10^5; 5.2 x 10^5
Schroederella delicatula	x	x*			1.6x 10^6
Cerataulina pelagica	x	x*	x*	x	2 x 10^6
Chaetoceros curvisetus	x		x*	x	3.7x 10^5
Ch. debile	x	x	x	x	3.6 X 10^5
Ch. spp.	x	x*	x		2.3 x 10^6
Leptocylindricus danicus	x	x*	x	x	9.1 x 10^6
Asterionella japonica	x	x*	x	x*	1.5 x 10^6; 3 x 10^6
Nitzschia seriata	x	x*	x	x	1 x 10^6
Dinoflagellates					
Exuviella apora			x*		3 x 10^5
Peridinium trochiodeum	x	x*	x	x	1.1 x 10^6
Prorocentrum scutellum	x		x*	x	6 x 10^5
Silicoflagellates					
Distephanus speculum	x	x	x*	x	1 x 10^5

as 205 g C/m? which compares to 285 g C/m^2 for B lock Island Sound and that 100-.160′ g C/m^2 for the continental shelf waters. Riley (1955) has observed that′ although the high primary production in the Sound is utilized by a great number of small animals, this area is relatively inefficient in the production of both groundfish and carnivorous invertebrate epifauna as compared to Block Island Sound, Georges Bank, or the English Channel.

RARITAN BAY

Raritan Bay is a shallow, heavily pol 1 uted, 40 km long (east to west) triangular embayment (Jeffries, 1962). The depths increase eastward to 9 m. Along the eastwest gradient salinities range from a spring low of 11.0-19.1 o/oo to a summer high of 24.0-27.0 o/oo. The water is extremely turbid with summer secchi disk readings, of 1 to 2 m. (Patten, 1961a). The nutrient concentrations along the east-west gradient demonstrate the marked pollution, and the seasonal variations are associated with discharge from the Raritan River. Jeffries (1962) points out that the lowest nitrate value found in Raritan Bay was higher than the mean summer level of Long Island Sound.

The composition and dynamics of the phytoplankton of Raritan Bay have been investigated by Patten (1961a, 1961b, 1962) and in Sandy Hook by Kawamura (1966). The major components of the phytoplankton are shown in Table 8-14. Diatoms are most abundant during spring and late summer while the chlorophycean Nannochloris atomus and several dinoflagellates dominated during the summer. The dominant winter flora is diatomaceous. The annual succession. is a spring diatom flowering followed by the dominance of Nannochloris and phytoflagellates until mid-autumn when diatoms prevail. The heavy occurrence of Nannochloris is a good indicator of the polluted conditions in Raritan Bay.

The summer population of phytoplankton in Raritan Bay frequently produces red tide blooms by such species as the dinoflagellates Massartia rotunda and Nannochloris. Clearly Raritan Bay has an extremely abundant phytoplankton standing crop which, as chlorophyll, exceeds on a volume basis concentrations-reported for New England coastal waters.

THE CONTINENTAL SHELF

The only detailed quantitative data for this area is from early work by Riley (1939), Riley and Gorgy (1948) and Riley, Stommel and Bumpus (1949) and more recently from data gathered from a triangular grid of 25 stations in the continental shelf area off New York. The salinity in this region is less than 34 o/oo. Nutrient data′ is presented by Ketchum, Vaccaro and Corwin (1958), Ryther and Yentsch (1958) and Vaccaro (1963). The waters are generally thermally strati-

Table 8-14. Some of the major phytoplankton components of Raritan Bay. The times of peak densities are indicated by asterisks.

	W	S	S	F	Maximum cells/l
Diatoms					
Skeletonema costatum		x*	x		17.3 x 10^6
Thalassiosira gravida		x	x		
Chaetoceros decipoiens		x	x	x	
Gyrosigma acuminatum		x	x		
Nitzschia serata	x				
Leptocylindrus danicus	x				
Rhizosolenia setigera	x				
R. imbricata	x				
R. alata	x				
Asterionella japonica	x				
Thalassionema nitzschioides	x				
Guinardia flaccida	x				
Melosira sulcata	x				
Actinoptychus undulatus	x				
Microflagellates (Chlorophyceans)					
Nannochloris atomus		x	x*	x	57.3x 10^7
Dinoflagellates					
Prorocentrum micans			x		
Peridinium trochoideum		x	x		
P. breve			x		
P. divaricatum			x		
Massartia rotundata			x		
Oxyrrhis marina			x		

Table 8-15. Some of the major phytoplankton components of the Continental shelf west of New York and south of Long Island. The times of peak densities are indicated by asterisks."

	W	S	S	F	Maximum cells/1
Diatoms					
Skeletonema costatum	x*		x	x	$3x\ 10^5$
Chaetoceros socialis	x*			x	$2.75\ x10^5$
Ch. wighami			x		$5x\ 10^3$
Ch. debilis	x	x*			$5\ x\ 10^3$
Asterionella japonica	x*			x	$1.4X\ 10^5$
Thalassionema nitzschioides	x		x	x*	$1\ x\ 10^5$
Rhizosolenia faeroense	x				$2.5\ X\ 10^4$
R. alata		x			
R. Spp.			x		$1.25x\ 10^4$
Thalassiosira nordenskioeldi i	x	x		x*	$5\ x\ 10^4$
Leptocylindrus danicus			x		$5\ x\ 10^4$
Nitzschia seriata	x	x*			$1.8x\ 10^4$
Cylindrotheca(Nitzschia) closterium			x		$1.5X\ 10^4$
Guinardia flaccida			x		$8\ x10^3$
Coscinoscira oestrupi			x		$3x\ 10^3$
Dinoflagellates					
Prorocentrum micans			x		$3x\ 10^3$

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8.3 KEY SPECIES

The following are life history descriptions of a number of important members of the Phytoplankton.

Diatoms

Asterionella japonica

Biddulphia aurita

Chaetoceros compresses

Chaetoceros debilis

Chaetoceros decipiens

Chaetoceros socialis

Chaetoceros subsecundus

Coscinodiscus eccentrics

Cylindrotheca closterium

Detonula confervacea

Guinardia flaccida

Leptocylindrus danicus

Leptocylindrus minimus

Porosira glacialis

Rhizosolenia spp.

Rhizosolenia delicatula

Rhizosolenia fragilissima

Rhizosolenia hebetata

Rhizosolenia styliformis

Skeletonema costatum

Thalassionema nitzschioides

Thalassiosira decipiens

Thalassiosira gravida

Thalassiosira nordenskioeldii

Dinoflagellates

Ceratium longipes and *C. tripes*

Gonyaulax tamarensis

fied, and nutrients are present in low concentrations from July to September. In November the upper 50 m becomes enriched with nitrate and phosphate as mixing takes place. By January the shelf waters are homogeneous and nutrients are at a maximum. In May, following the spring phytoplankton bloom, the nutrients are reduced and remain so throughout the summer.

The phytoplankton composition and abundance is treated by Hulburt (1963, 1966, 1970) and Hulburt and Rodman (1963). The major constituents of the phytoplankton are shown in Table 8-15. The populations are composed mainly of diatoms. There is a distinct floristic difference between communities lying to the south and north of approximately 40° 40' N, i.e. Skeletonema costatum to the south and Thalassiosira nordenskioeldii to the north of Long Island. There are other opposing dominants also. The mean population density during November through March exceeds by eight-fold that during the remainder of the year. There is a considerably lower population abundance in these waters relative to the more enclosed waters of southern New England. The prevalence of diatoms in these waters contrasts with the predominance of coccolithophores in the open ocean and the chlorophyte Nannochloris in Long Island bays.

Asterionella japonica

Asterionella japonica is a pennate diatom with cells united into spiral, star-like colonies. Eight to twenty cells are joined, at the corners of the enlarged region, by a gelatinous membrane. Usually two chromatophores in small plates are located in the knob-like basal area. Riley and Segar (1969) characterized the pigments of A. japonica, finding fucoxanthin to be the principal xanthophyll (84 percent). Diadinoxanthin constituted 10 percent of the carotenoid pigments and B-carotene 6 percent. The chlorophyll a:c ratio was 1:0.68.

A. japonica is a neritic species, widespread in south temperate waters. It is common in European waters, reaching a maximum in April in the English Channel and the southern North Sea. Cupp (1943) reports up to 1.3×10^6 cells/l off the west coast of the U.S. in August, 1927.

(1) Reproduction. The principal method of reproduction is by cell division, where the protoplasm divides into each valve and the valves separate, each forming another valve on the inside. This gradually reduces the size of the diatoms until a minimum size is reached. Auxospore formation has been reported in some members of the Fragilariaceae, such as Synedra, but no such structures have been reported for A. japonica.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. In early experiments, Riley (1952) found the coefficient of increase, k, for Asterionella japonica to be .86 doublings/day. Kain and Fogg (1958), using optical density of algal suspensions as a measure of growth, measured a growth rate constant for A. japonica of k=0.7-1.2, in unialgal, but not bacteria-free cultures. They found the optimal conditions for exponential growth to be 20-25 C, 30-35 o/oo and 4000 lux from fluorescent white light. Braarud (1961) suggested a discrepancy in temperatures producing optimal growth of A. japonica in nature and in culture, although Conover (1956) refers to this species as eurythermal. Qusim et al. (1972) determined the light saturation point, Ik, of A. japonica from photosynthesis-light curves to be 14.50 kilolux.

N & P: Kain and Fogg (1958) found the minimum nitrate required by cells of A. japonica was 0.255 µg-atm N/cell and that medium with 0.1-0.3 mM nitrate was limiting. 'Variation in the nitrate concentration from 1 to 10 mM had no statistically significant effect on the relative growth constant, but there was a marked difference in the OD/cell, with values at 10 mM three times greater than at 1 mM. Eppley and Thomas (1969), using the optimum growth conditions set up by Kain and Fogg (1958), measured the growth rates and rates of nitrate uptake by N-depleted cells of A. japonica and Chaetoceros gracilis, as functions of the nitrate concentration of the medium. Both the growth and N-uptake rates were hyperbolic. They suggested that nitrate and ammonia were 'the nutrients most limiting the size of the phytoplankton crop and its specific growth rate. Coastal phytoplankton communities show K_s (half-saturation constant) values greater than 1 µM for nitrate uptake, while oceanic communities have a low Ks, approximately 0.2 µM.

K_s (µM/l)		Doublings/Day	
Growth	Uptake	um	Vm
1.5 ± 1.4	1.3*0.5.	1.97 ± 0.24	7.25 ± 0.32
1.2 ± 1.2	0.7 ± 0.3	1.90 ± 0.18	6.62 ± 0.37

Vince and Valiela (1973) tested the effects of ammonium and phosphate enrichments on a naturally-occurring population of Skeletonema costatum, Asterionella japonica and Chaetoceros spp. from Vineyard Sound. Combined ammonium and phosphate enrichments yielded the most cells and chlorophyll a. There was no change in the species composition., so the observed changes were due to physiological responses.

Kain and Fogg (1958) found that phosphate was not limiting with a 0.01 to 0.31 mM concentration. Goldberg et al. (1951) obtained a value for the minimum phosphate per cell of 5×10^{-8} µg-at/cell for A. japonica. They also determined the phosphate concentration found to limit the rate of growth of A. japonica to be 0.25 µg-at/l. Thomas and Dodson (1968) agreed on this value, but found the minimum concentration of A. japonica cells to be 5×10^{-11} µg-at/u^3.

Trace metals: Kain and Fogg (1958) observed that the maximum population of Asterionella was reached with 0.1-0.5 mM SiO_3 but that the thickness of the diatom frustule differed with the concentration of silicate. A pH of 7.5-8.25 was found to be optimal, while 8.5-8.75 was inhibitory. Concentrations of 0.0342-0.342 mM EDTA seemed equally effective, but greater amounts were inhibitory.

Goldberg (1952) observed no growth of A. japonica in medium until the initial iron concentration exceeded 0.8 mM/l. With the use of radioactive iron, he found that this species utilized only particulate and/or colloidal iron as a growth nutrient. A minimal content of iron/cell needed for further division was established at 10×10^{-8} mM/l.

(4) Natural mortality. No information.

(5) Migration characteristics. No information.

(6 & 7) Distribution and density in the Gulf of Maine. In the Bay of Fundy and along the Maine Coast, north of Cape Elizabeth, A. japonica reaches a yearly maximum in August. Its occurrence has been noted from March to September, with a center of distribution and maximum population around Grand Manan Island. Gran and Braarud (1935) recorded 4.5x104 cells/1 in August, 1932 in this area. A. japonica is generally found in association with Skeletonema costatum, the dominant phytoplankton species when present. Bigelow (1926) found A. japonica widely distributed in small numbers along the coast from Cape Elizabeth to western Nova Scotia and dominant between Grand Manan Channel and Seguin Island. The unusual abundance of this organism in the northern Gulf in 1912 may have been due to a greater summer influence of colder Bay of Fundy waters (ibid.).

Burkholder (1933) recorded small numbers of this species in the open Gulf area near Mt. Desert Island in August, 1930. Sears (1941) found A. japonica to become common on Georges Bank from March to June, 1940. Approximately 3×10^3 cells/1 were recorded in April, when the Chaetoceros and Thalassiosira spp. were blooming.

Riley (1952), in his study of the phytoplankton of Block Island

Sound, 1949, observed A. japonica to be abundant bimodally, in February and Nay-June. Smayda (1957) found that A. japonica comprised 25 percent of the total population of lower Narragansett Bay and was distributed bimodally, reaching its first and lesser maximum during September-October when the temperature was 16.5 C and second during January, with a mean of 3 C.

McAlice (1972) found this neritic diatom present throughout the year in the Montsweag Bay-Sheepscot River-Back River area and dominant in September and October.

(8) Food . Not applicable.

(9) Predation. No information.

(10) Competition. No information.

(11) Responses to the environment (natural factors, pollutants). No information.

Biddulphia aurita

Biddulphia aurita (Lyngb.) Breb & Godey is a centric diatom which forms straight or zigzag chains and is very variable in size. Its cell walls are strongly siliceous, punctuated with areola in rows on both valves and girdle. Small spines may be found on the valves and are more common on the warmer-water species.

It is a non-motile, mainly littoral species widespread from Antarctica to the sub-tropics, but most common in northern (arctic and boreal) seas. Cupp (1937) found it to be abundant at Scotch Cap, Alaska, in April and May and common off southern California, in small numbers. It has a short burst of growth as a neritic organism in the spring.

(1) Reproduction. No information.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Lui & Reels (1972) studied the nitrogen metabolism of aquatic organisms and found that Biddulphia aurita can grow with either nitrate, nitrite, or ammonia as the sole nitrogen source. In their culture. studies, a dilution of Guillard's "F" medium, F/4, was the basic growth medium. The cultures were incubated at 10 C in a 12 hour, light/dark cycle with 50 ft/c of light provided by "cool-white" fluorescent bulbs. The B. aurita cells were found to remove NH_4 from the medium, 2.3-2.4 times faster than NO_3 or NO_2. Lui and Reels (ibid.)

proposed that this is probably due to a necessary step-wise reduction of $NO_3 \rightarrow NO_2 \rightarrow NH_4$ by B. aurita, shown by the absence of nitrate and nitrite reductase enzymes in NH_4-only medium.

Qusim et al. (1972) found the light saturation value (Ik) for Biddulphia sinensis, a tropical marine phytoplankton, to be 17.75 kilolux. The light saturation value for B. aurita is probably lower, more near the value for Coscinodiscus radiatus, 11.50, due to its more northern and littoral habitat.

(4) Natural mortality. No information.

(5) Migration characteristics. Not applicable.

(6) Distribution and niche preference. B. aurita has been reported throughout the year in various regions of the Gulf of Maine. It is usually confined to the coastal belt, but very few observations have been made in the Gulf outside the 100 m contour (Lillick, 1940). Lillick (1940) found it scarce in early winter but its numbers increased in late December and January in the western coastal belt and along the western coast of Nova Scotia. Bigelow (1926) found B. aurita co-dominant with Coscinodiscus and Actinoptychus near Seal Island, Nova Scotia in March, 1920. Large numbers were also noted off the Merrimack River in March, and off Yarmouth, Nova Scotia, in April, 1920 by Bigelow (1926). In the Bay of Fundy, B. aurita develops concurrently with species of Thalassiosira and Chaetoceros in the latter part of April (Fritz, 1921 ; Davidson, 1934; Gran and Braarud, 1'335), but reaches maximum abundance within a few days, and its numbers are usually diminished before the end of May. Thalassiossira and Chaetoceros reach their large bloom populations after B. aurita has peaked.

Riley (1952) found B. aurita most abundant in February and March, 1949, in Block Island Sound.

McAlice (1972) reported large numbers of B. aurita in the spring at Montsweag Bay, parallel to the situation reported by Gran and Braarud (1935), for the Bay of Fundy but occurring 4-6 weeks earlier.

Mulligan (in prep.) reports the presence of small numbers of B. aurita in-Great Bay, N.H., throughout the year.

(7) Population densities. Noinformation.

(8) Food. Not applicable.

(9) Predation. No information.

(10) Competition. No information.

(11) Responses to the environment (natural factors, pol 1 utants). No information.

Chaetoceros compresses

Chaetoceros compresses Laud. (=C. contortus Schutt) has wide, four-cornered cells, 7 - 24 μ in diameter, united into straight chains, and more or less twisted about the axis of "the chain. The setae are usually fine, but occasionally near the center of the chain are found two pairs of thickened and twisted bristles, curved, towards the same end of the chain. Four to twenty small chromatophores are present in each cell.

(1) Reproduction. Auxospores (23 μ) are formed perpendicular to the mother chain. Two types of resting spores have been noted.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Smayda (1958) states that this species is both euryhaline and eurythermal. Brunei (1962) gives the optimal temperature for growth, 8.5 C, and the optimal salinity, 23.4 o/oo.

(4') Natural mortality. No information.

(5) Migration characteristics. Not applicable.

(6 & 7) Distribution and population density. Cupp (1943) and Lebour (1930) state that this neritic species has a boreal to south-temperate distribution, but Smayda (1958) refers to it as cosmopolitan. C. compressus has a wide distribution and is one of the most common Chaetoceros sp. in the Gulf of Maine (Gran and Braarud, 1935). It is present from March to September, with maximum populations recorded in April in Massachusetts Bay and north of Cape Ann, and in June to August near the Bay of Fundy. Bigelow (1926) found it dominant off Cape Elizabeth in March and April, 1920, while Gran and Braarud (1935) recorded a large population (2.14 x 10^5 cells /1) in June in the Bay of Fundy. Lillick (1940) observed that this species may constitute up to 7 percent of the spring Chaetoceros bloom and that it was dominant in several years along the western and northern coasts.

McAlice (1972) recorded the presence of~.'compressus in June, July and November in Montsweag Bay, Maine. Mulligan and de Lara (in prep.) found C. compresses to be secondary only to C. debilis on April 20, 1972, with 2.65 x 105 cells/1 recorded at the

Annisquam Station, north of Cape Ann.

(8) Food. Not applicable.

(9) Predation. No information.

(10) Competition. No information.

(11) Responses to the environment (natural factors, pollutants). No information.

Chaetoceros debilis

Chaetoceros debilis Cleve is a marine centric diatom with long spirally twisted chains of cells 8-36 μ in diameter, with no special end cells. One chromatophore, situated at the girdle side, is present per cell. Thin setae, arising within corners of cells, cross outside their base and extend outward from the spiral.

C. debilis, usually termed a neritic, boreal-north-temperate species, is an important member of the diatom population on the northern European coast, propagating just after the temperature minimum of early spring at about 5-6 C in March to April. According to Smayda's classification this organism would be referred to as a mero-adiaphoric species.

(1) Reproduction. Resting spores, centrally located within the cells, are common. Paasche (1961) discusses the biological role of resting spores in this species.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. C. debilis begins to bloom when the temperature is above 5-6 C (Bigelow, et al., 1940) and reaches its maximum growth when temperatures are between 10-12 C (Davidson, 1934). It may continue blooming along the eastern portion of the coast into autumn. Burkholder (1933) records 3 x 10^5 cells/liter of C. debilis in the summer in Frenchman's Bay. This species also grows best in the upper 10 m of the water column. Brunel (1962) list 6.9 C as the optimal temperature and 26.1 o/oo as the optimal salinity.

(4) Natural mortality. No information.

(5) Migration characteristics. Not applicable.

(6 & 7) Distribution and population density. In the Gulf of Maine Chaetoceros spp. take the place ~~of~~ Thalassiosira in the spring bloom beginning and expanding over the Gulf in the same fashion as Thalassiosira. Gran and Braarud (1935) describe this species

as the most common neritic Chaetoceros sp. in the Gulf. Davidson (1934) found that C. debi l is dominated the diatom vegetation after the decline of Thalassiosira.

Lillick (1940) 'observed that C. debilis dominated the phytoplankton in 6 out of 10 years, and in April, 1939, constituted almost 100 percent of the population off Gloucester, Mass. In late April (as in 1934) C. debilis usually accounts for at least 65 percent of the Chaetoceros flora present. Gran and Braarud (1935) recorded 8 x 10^4 cells/liter of C. debilis in May in the Bay of Fundy, where it was present from April to September.

Mulligan and Wessel (in prep.), however, found the maximum abundance of C. debilis, in Massachusetts Bay to be 9 x 10^5 cells/liter in early June, 1973. In April, 1972, 6.6 x 10^5 cells/liter were recorded at the Annisquam Station, north of Cape Ann (Mulligan and de Lara, in prep.). McAlice (1972) found C. debilis to be present from February to November, 1971, and dominant from May to July i-n Montsweag Bay, Maine.

(8) Food. Not applicable.

(9) Predation. No information.

(10) Competition. No information.

(11) Responses to the environment (natural factors, pollutants). No information.

Chaetoceros decipiens

Chaetoceros decipiens Cleve has flattened, oblong-shaped cells, 9-84 μ wide, united in long, straight stiff chains. The apertures between cells vary in size and shape, according to the season of the year. Speci al end-spines, shorter and thicker than those of other Chaetoceras spp. are present. Four to ten chromatophores are contained in each cell.

(1) Reproduction. No resting spores are known, but microspore have been seen in an early stage of formation.

(2) Fecundity and larval l i f e . Not applicable.

(3) Growth and longevity. Brunei (1962) refers to this species as euryhaline and gives its optimal temperature as 5.7 C and optimal salinity as 23.2. o/oo.

(4) Natural mortality. No information.

(5) Migration characteristics. Not applicable.

(6 & 7) Distribution and population densities. This species has an arctic-boreal distribution and is listed as the most common oceanic Chaetoceros present in the Gulf of Maine (Gran and Braarud, 1935). It has been recorded throughout the year, although it never occurs in great abundance within the Gulf at any season. The highest count recorded (before 1973) was 3.6 x 10^3 cells/1 near Mt. Desert Island on August 14, 1932 (ibid.). Bigelow (1926), however, found it to be a major component of the spring bloom in localized areas along the western and northern coasts in some years. Lillick (1940) states that it may account for about 1 percent of the spring Chaetoceros bloom,

McAlice (1972) observed its presence throughout 1971 and its dominance in July and December in Montsweag Bay. Mulligan and Wessel (in prep.) recorded 1.96 x 10^5 cells/1 of C. decipiens on April 17, 1973 in Massachusetts Bay.

(8) Food. Not applicable.

(9) Predation. No information.

(10) Competition. No information.

(11) Responses to the environment (natural factors, pollutants). No information.

Chaetoceros social is

Chaetoceros socialis Laud. consists of short, curved chains of cells 6 to 12 μ wide, united in large circular colonies by mucilaginous slime and often by very fine, long setae which are enmeshed together. One chromatophore is found on the girdle side of each cell.

(1) Reproduction. Smooth resting spores are found in the middle of the mother cell.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. This species is referred to as euryhaline and stenothermal, preferring cold water temperatures around 2 C (Brunei, 1962).

(4) Natural mortality. No information.

(5) Migration characteristics.

(6 & 7) Distribution and Densities. This neritic, north temperate species has a wide distribution, occurring abundantly on the coast of northern Europe in the early spring. C. socialis is present from February to June in the Gulf of Maine, with maximum populations recorded in April and May. Bigelow (1926) observed that this species dominated the flora in late February and in May, 1920 on the southwestern portion of Georges Bank. Gran and Braarud (1935) noted its presence in April and May in the Bay of Fundy and its abundance in late April south of Nova Scotia. Lillick (1940) states that this, species may account for 2 percent of the spring bloom Chaetoceros flora.

McAlice (1972), however, found C. socialis present from March to May and in November and December in the Montsweag Bay estuarine system. Mulligan and Wessel (in prep.) recorded 3.4×10^6 cells/1 on April 17, 1973 in Massachusetts Bay.

(8) Food. Not applicable.

(9) Predation. No information.

(10) Competition. No information.

(11) Responses to the environment (natural factors, pollutants). No information.

Chaetoceros subsecundus

Chaetoceros subsecundus (Grun.) Hust. [= C. diadema (Ehr.) Gran] is a centric marine diatom that has rectangular cells with weakly rounded corners, 12 to 44 μ wide and united in straight chains. It has definite end spines, diverging at an acute angle from the cell. One chromatophore per cell is found attached to the broad side of the girdle.

(1) Reproduction. The formation of auxospores, microspore and resting spores have been documented in the literature. Hargraves (1972) observed that four distinct cell types could be distinguished in the different phases of the sexual and asexual life cycle.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Brunel (1962), who refers to this species as cosmopolitan in distribution, gives the optimal temperature for growth, 1.9 C, and the optimal salinity, 23.1 o/oo.

Hargraves (1973), in his culture studies of C. subsecundus, found that growth conditions of 2 C and constant light of 2000 lux, in f/2 medium provided good growth.

(4) Natural mortality No information.

(5) Migration characteristics. Not applicable.

(6 & 7) Distribution and Density. This neritic, boreal-arctic species is present in the Gulf of Maine from March to September. Fritz (1921) found it throughout the year near St. Andrews, New Brunswick, with maxima in May and September. Gran and Braarud (1935) observed that C. subsecunduswas most abundant in April in the Gulf of Maine, and in May in the Bay of Fundy, when they recorded 4 x 10^4 cells/1. Lillick (1940) termed it a spring and summer form in the Gulf. It typically accounted for 2 percent of the spring Chaetoceros bloom.

McAlice (1972) found C. subsecundus present from April to June and in October in the fjord-type Montsweag Bay estuary. Mulligan and de Lara (in prep.) recorded the maximum population of this species, 5 x 10^4 cells/1, in late April, 1972 in Massachusetts Bay.

(8) Food. Not applicable.

(9) Predation. No information.

(10) Competition. No information.

(11) Responses to the environment (natural factors, pollutants). No information.

Coscinodiscus eccentricus

Coscinodiscus eccentrics Ehr. [= Thalassiosira eccentrics (Ehr.) Cleve] is a disc-shaped, centric diatom, with cells 50 - 90 μ in diameter and numerous small chromatophores. They are usually found as single cells, although chains of 3 to 4 cells, connected by a single thread, have been reported in culture and in a few natural populations. Fryxell and Hasle (1972) proposed that, due to this chain-forming ability and to the morphological features observed with electron microscopy that are characteristic of the genus Thalassiosira, this species should be referred to as Thalassiosira eccentrica. It has incorrectly been referred to as C. excentricus by many authors.

(1) Reproduction. Reproduction in this species is accomplished by the normal division process and by auxospore formation (Lebour, 1930). Auxospores are formed periodically by the separation of the valves, with a large bladder-like mass of protoplasm coming from one end of the cell. Fryxell and Hasle (1972) found auxospores were produced when salinity of the culture medium was reduced or the culture was transferred every week instead of every two weeks.

Holmes (1966) attempted to determine the conditions necessary for auxospore formation in Coscinodiscus concinnus. Sixty-four combinations of temperature and light were tested. He found that colorless male gametes were produced and released from parent cells over a wide light and temperature range; the maximum number developed a day or two before auxospore appearance. Holmes found a shorter photoperiod increased auxospore production and suggested in nature, auxospore formation should occur near the sea surface where light intensity was high.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Fryxell and Hasle (1972) in their taxonomic paper report that C. eccentrics has grown in culture at 10, 15, 20 and 25 C.

Jenkins (1938), in early culture studies, measured the O_2 Production of C. eccentrics as an index of photosynthesis and found it directly proportional to light energy. Cooper (1938) calculated the C:N:P ratio of the same clone.

Yentsch and Vaccaro (1958) in their attempts to measure nitrogen in the oceans, found the nitrogen to chlorophyll a ratio for a Coscinodiscus sp. to be 13.2:1.

(4) Natural mortality. No information.

(5) Migration characteristics. Not applicable.

(6 & 7) Distribution and Density. Hendey (1964) describes C. eccentrics as one of the most common and widespread diatoms in the neritic plankton, with a worldwide distribution. Cupp (1943) and Lebour (1930), however, classify it as temperate-oceanic, but often occurring near the coast. Lillick (1940) records its presence throughout the year in selected areas of the Gulf of Maine, but states that it is usually dominant only "in the winter flora, at times 50 - 100 percent of the total population. Bigelow (1926) found C. eccentricus to be the dominant organism near the mouth of the Merrimack River in late December and early January, 1920 to 1921, and the most abundant diatom in the Ceratium-dominated

communities in the eastern basin, in the deeper areas of the Bay of Fundy and off western Nova Scotia. Gran (1933) observed C. eccentrics regularly in August, 1932, and found it to be more abundant over Georges Bank than in the deeper areas of the Gulf of Maine. Gran and Braarud (1935) found this species to be most abundant in August and September in the Bay of Fundy, particularly along the New Brunswick Coast, although its presence was noted from April to September and in December.

Lillick (1940) found C. eccentrics to be dominant in western Nova Scotia and the northern coastal belts of the Gulf, forming up to 48 percent of the total population in the winter of 1933. C. eccentrics was also dominant along the western side of the central basin, but only part of a more complex flora on the eastern side of the Gulf.

Mulligan and Wessel (in prep.) and McAlice (1972) do not report the presence of this species in either Massachusetts Bay, Great Bay estuary or in the Monstweag Bay estuarine system.

(8) Food. Not applicable.

(9) Predation. No information.

(lo) Competition. No information.

(11) Responses to the environment (natural factors, pollutants). No information.

Cylindrotheca closterium

Cylindrotheca closterium (Ehr.) Reimann and Lewin C= Nitzschia closterium (Ehr.) W. Smith], the marine pennate diatom consists of motile single cells, with hair-like bent ends, and valves 25 to 100 u in length. Each cell has two chromatophores, in the central portion of the-cells, not in the hair-like ends.

(1) Reproduction. Reproduction in C. closterium follows the pattern of of other pennate diatoms.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Cylindrotheca closterium has been studied in the laboratory as to light intensity and temperature effects under conditions similar to those found in nature. Maddux and Jones (1964) observed 30 lumens per m2 to be the optimal light intensity and 16 C the optimal temperature, although temperatures

from 10 to 18 C were favorable. Ryther (1954) found good growth rates from 10 to 20 C and a salinity optimum of 34 o/oo; at 15.5 C; .48 divisions/day were measured. C. closterium was also found to grow well with both nitrate and nitrite as nitrogen sources, poorly with ammonia and slowly with urea and other organic nitrogen sources. No large increase in growth was noted with the addition of more phosphorus (ibid.).

Brown and Richardson (1968) measured the dependency of various cellular processes on light intensity. They found that the growth of C. closterium was light dependent at low intensities but independent at intermediate and high intensities. Cell volume was sharply influenced by light intensity, dropping 110 percent between 50 and 200 foot candles with no further significant change. Chloroplast size and pigmentation decreased continuously with increased light intensities.

Carpenter (1970) measured the minimum phosphorus requirements of C. closterium in axenic steady-state chemostat culture, at 15.5 C and 5380 lux in a 19 hr. light to 5 hr. dark cycle. This species requires 1.055x10-5 g-at P/cell/generation, with an average cell doubling time of .20 divisions/day. Ketchum (1939) found using C. closterium, that the rate of phosphorus assimilation was related to the concentration of both phosphate and nitrate in the medium. Nitrate assimilation, however, was independent of phosphorus concentration.

Hood and Park (1962) proposed that marine phytoplankton organisms, such as C. closterium, were able to use bicarbonate ions directly from sea water. Steeman-Nielsen (1963), however, argued hat their claim was unwarranted. The quantitative calcium requirements of Cylindrotheca closterium were measured by Taylor (1964). He found that this species had a growth response to calcium at concentrations between 0.05 and 0.5 mM. At higher levels there appeared to be inhibition of growth.

Lewin (1966) concluded that boron was essential to the growth of most diatom species, including Cylindrotheca closterium.

(4) Natural mortality. No information.

(5) Migration characteristics. No information.

(6 & 7) Distribution and Density. This neritic species is ubiquitous in distribution along the coasts. It is very common in littoral areas and is frequently found in the plankton. It is referred to as a cosmopolitan species by some authors. C. closterium must be considered an important phytoplankton in the Gulf of Maine, not only because of its widespread distribution, but because it has

been utilized as a test organism in many culture studies.

In general, C. closterium accompanies Nitzchia seriata in some waters in the Gulf and it is of importance in the spring and summer, although present throughout the year. Gran (1933) and Braarud (1934) observed C. closterium on Georges Bank in small numbers at all depths in the summers of 1932 and 1933. Gran and Braarud (1935) recorded this species as present from April to September in the Bay of Fundy and Gulf of Maine reaching its maximum in July with 2,000 cells/1. Lillick (1940) observed a large population of C. closterium in August, 1936, when Rhizosolenia spp. were dominant.

Mulligan and de Lara (in prep.) found that C. closterium had a frequency of occurrence ratio of .44 in the Rye, N.H. to Boston, Mass. samples in 1971. This species was observed throughout the year in Massachusetts Bay, with a maximum abundance in September, 1973 of 2×10^5 cells/1. McAlice (1972) recorded C. closterium in small numbers throughout his entire sampling period in Montseaq Bay, Maine.

(8) Food. Not applicable.

(9) Predation. No information.

(10) Competition. No information.

(11) Responses to the environment (natural factors, pollutants). No information.

Detonula confervacea

Detonula confervacea (Cleve) Gran is a marine centric diatom found in abundance in only limited areas of the Gulf of Maine. The diameter of D. confervacea cells varies from 5 to 15 μ. The cells are colonial in habit, and form long chains joined valve to valve. A single row of marginal spines, with no unpaired apicule, is located on each circular valve. Several intercalary bands and numerous chromatophores are present. Two or more resting spores, first described by Gran (1900), are produced per cell. Smayda (1969) states that temperature is not the primary factor inducing resting spore formation, since significant numbers of spores have been recorded in nature (Pratt, unpublished; Mulligan and Wessel, in prep.) and in culture (Smayda, ibid.) when temperatures were optimal for vegetative growth.

(1) Reproduction. No information.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Physiological studies on Detonula confervacea were initiated by Guillard and Ryther (1962) in their attempt to show's relationship between D. confervacea and various clones of Cyclotella nana. Electron micrographs and culture studies, however, revealed distinct differences between the two species, and in fact, among the clones of Cyclotella nana. Guillard and Ryther (ibid.) found that D. confervacea had a temperature optimum of 10 C, with no growth at temperatures above 15 C, and exhibited good growth at salinities between 8-32 o/oo. This organism was observed to have no vitamin requirements and a preference for NO_3^-N as a nitrogen source (Guillard, 1963). Ryther and Guillard (1962) found that the respiratory coefficient (gm C respired/hr/gm chlorophyll) of D. confervacea, 0.2 to 0.3, did not increase with temperature between 5 and 25 C following preconditioning at 5 and 10C. Kuenzler and Perras (1965) observed alkaline phosphate production in D. confervacea when cultures were deprived of PO_4-P.

Smayda (1969) performed very comprehensive studies on the influence of temperature, light and salinity on cell division of D. confervacea. Following appropriate preconditioning, growth did not occur at 16 C or at, 5 o/oo, but was excellent, with a mean daily cell division rate (k) of 1.2 to 1.5, under certain combinations of light and salinity at 2, 7 and 12 C. Better growth was noted at 7 and 12 C. The optimal salinity range was found to be 15-30 o/oo and no dependence on temperature was observed. A discrepanty therefore, exists between temperatures during period of natural abundance (1 C) and those producing optimal growth in culture (7 and 12 C), although Mulligan (unpublished) found large numbers at 10 C in Great Bay, N.I-i. in 1971. From his laboratory observations, Smayda proposed that in nature a light-temperature relationship exists, where the optimal light intensity increases with increasing temperature. This condition may, in part, be responsible for the termination of Detonula bloom populations in various areas and for the exclusion of Detonula from regions with hydrographic conditions that seem suitable for its growth.

(4) Natural mortality. No information.

(5) Migration characteristics. Not applicable.

(6 & 7) Distribution and Density. It is arctic in distribution, reaching its maximum abundance at temperatures below 0 C. Seidendfaden and Grontved (1938) repurtea large populations near West Greenland when the temperature ranged between -0.9 to -0.3 C and Bursa (1961) observed the dominance of Detonula near Baffin Island when ixmpera-

tures were below 0 C. Large populations of Detonula have been observed under ice in various areas, but surveys by Pratt (1959, 1965) and Donovan and Mulligan (in prep.) demonstrate that winter ice cover is not essential but can stimulate the growth of this species. Donovan and Mulligan (in prep.) however, found no resting spores present in preserved or fresh samples or in bottom mude samples in Great Bay Estuary, N.H. from 1971 to 1973.

Smayda (1969) reports that Detonula confervacea and Skeletonema costatum initiate the late winter-spring bloom in Narragansett Bay, a temperate coastal area. In February, 1964, 13.3x106 cells/1 were observed when the water temperature was -0.3 C. D. confervacea has not been reported south of Narragansett Bay or-in Block Island or Long Island Sound. Guillard and Ryther (1962) do however report its presence in Moriches Bay.

Lillick (1940) gives a seasonal distribution for this species, reporting its presence in January and March through July in the Gulf of Maine. According to Bigelow (1926) D. confervacea was significantly abundant only in the area of the Isles of Shoals in March, 1920. Braarud (1934) found D. confervacea moderately abundant in July, 1933, but largely sub-ordinate to Pontosphaera huxleyi, in the northern region of Georges Bank. Gran and Braarud (1935) observed it in the Bay of Fundy, proper, only in June, but stated that it was rather common at some stations in the central and outer parts of the Bay, their maximum reported abundance was about 13x103 cells/1 at 9.5 C.

In 1973, Mulligan and Wessel (in prep.) found D. confervacea to be the dominant organism observed in late March in Massachusetts Bay. It was present at all stations at all depths and the maximum population recorded was 2.9x106 cells/l.on March 31, 1973 at a southern inshore station.

Donovan and Mulligan (in prep.) and Mulligan (in prep.) report that D. confervacea is the dominant spring organism in Great Bay, N.H., constituting over 90% of the total cell count, but the maximum population varies (in size) from $3.0x10^4$ to $7x10^6$ cells/liter in successive years from 1971-1973. D. confervacea has a characteristic bimodal occurrence reaching peak populations in February and April and usually is not observed after early May. Buck and Mulligan (in prep.) also collected it in abundance at the Isles of Shoals. McAlice (1972) notes its presence in the Montsweag Bay estuarine system, but apparently the more oceanic conditions present in that area do not allow for the development of a dominant D. confervacea population.

(8) Food. Not applicable.

(9) Predation. No information.

(10) Competition. No information.

(11) Responses to the environment (natural factors, pollutants). No information.

Guinardia flaccida

Guinardia flaccida (Castr.) Perag. is a marine centric diatom with cells typically cylindrical, having a diameter of 30 to 70 μ. Both single cells and cells united in chains by the entire valve surface are found. The cell walls are weakly siliceous and the presence of an irregular tooth at the margin of the valve is a distinctive characteristic. Many platelike chromatophores are found near the cell walls, each with one pyrenoid.

(1) Reproduction. Guinardia flaccida has not been observed to form resting spores. It does. form auxospores, rounded masses, from ordinary cells.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Riley (1952) performed some simple experiments on the reproductive (growth) capacity of various phytoplankton species. Guinardia flaccida was found to have a coefficient of increase, k, of .19, a rather low reproductive capacity.

(4) Natural mortality. No information.

(5) Migration characteristics. Not applicable.

(6 & 7) Distribution and Density. Both Cupp (1943) and Lebour (1930) describe Guinardia flaccida as a neritic, south to temperate species, while Smayda (1958) classifies it as holoparactic, or a pelagic organism confined to the coastal region.

Bigelow (1926) reports that Guinardia flaccida may at times dominate the summer diatom flora on Georges Bank. In July, 1913 G. flaccida flowered on the western end of the Bank and in July, 1914, this south-temperate species was dominant on the northeast part of the Bank. Gran (1933) found G. flaccida at all stations, on Georges Bank in July, 1932, but not in great numbers toward the' bottom. (340 cells/l at 60 M). In July, 1933 on the northeast portion of

Georges Bank. Braarud (1934) found G. flaccida and Detonula confervacea moderately abundant, but su-t to Pontosphaera huxleyi. In September, 1933, 100,000 cells/liter were recorded near Sequin Island. Braarud suggested that variation in the abundance of G. flaccida from year to year may be due to a dependence upon fairly turbulent waters.

Gran and Braarud (1935) found G. flaccida in sparse numbers in the Bay of Fundy region, with the maximum recorded in Passamoquoddy Bay in September, 1931, with 460 cells/1. Sears (1941) observed G. flaccida on Georges 'Bank from April to late June, but the greatest abundance recorded (about 700 cells/1 in April, 1940) was far smaller than the large populations of Chaetoceros spp. Lillick (1940) recorded Guinardia flaccida's presence throughout the year, but because of its regular occurrence in late summer and early autumn, referred to it as a warm water form in the Gulf of Maine. Mulligan and Wessel (in prep.), however, record Guinardia flaccida as dominant in Massachusetts Bay in December, 1973 over Coscinodiscus sp. with 5.0×10^4 cells/liter. Therefore, Guinardia flaccida cannot be considered a "warm water, Georges Bank only" form, as proposed by Lillick (1940). McAlice (1972) found regular pulses of G. flaccida in association with Leptocylindrus sp. in the fall season in Montsweag Bay estuarine system.

(8) Food. Not applicable.

(9) Predation. No information.

(10) Competition. No information.

(11) Responses to the environment (natural factors, pollutants). No information.

Leptocylindrus danicus

Leptocylindrus danicus Cleve is a marine centric diatom with elongated, cylindrical cells, 6 to 11 u in diameter, united in long, stiff chains by the whole valve surface. In many cases, only one cell-wall may be found between two valves. Many round disc plates or granular chromatophores may be found in each thin-walled cell.

(1) Reproduction. Reproduction is accomplished by normal cell division and by the formation of auxospores. Resting spores, covered with spicules, were first described by Gran (1900) and later found in culture by Allen, in Plymouth.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Optimal growth conditions for L. danicus are described by Brunei (1962) as 8.6 C and 31.8 o/oo. Riley and Conover (1967) suggest that although a narrow range of favorable radiation exists for Leptocylindrus, above average radiation values at the end of the winter bloom correspond to its flowerings in Long Island Sound. They also suggest that there may be just one species, L. danicus, and that L. minimus is merely a smaller form of L. danicus. Lebour (1930) suggests that this species may prefer areas of high salinity.

(4) Natural mortality. No information.

(5) Migration characteristics. Not applicable.

(6 & 7) Distribution and Density. L. danicus has been described as a north-temperate, neritic species, with a widespread distribution. Smayda (1958) classifies Leptocylindrus danicus as a cosmopolitan diatom species and it is, therefore, eurythermal. It is very abundant and can become dominant on N. European coasts in May and June.

L. danicus is more significant in the coastal areas of the Gulf of Maine than in the extreme inland or offshore areas. It has been recorded throughout the year in various coastal areas. Bigelow (1926) reports the presence of this species at the western end of Georges Bank in February, 1920. Gran (1933) observed that L. danicus occurred regularly at all stations on Georges Bank in August, 1932 from 20 meters to the bottom, with the maximum abundance at 20m (1240 cells/1). In July, 1933, Braarud (1934) found small populations of L. danicus on Georges Bank at 15 and 25 m.

In the Bay of Fundy, L. danicus is found from May to September, with the largest populations (5,000 cells/1) occurring in July during the summer minimum described by Gran and Braarud (1935). Lillick (1940) includes L. danicus in a list of winter diatom species that in certain yea-increase in numbers and become abundant in the western coastal belt or on tne southern rim of the Gulf in early spring. She also states that L. danicus is commonly associated with the spring Thalassiosira community, but never accounts for more than 1 percent of flora present.

Mulligan and Wessel (in prep.) found Leptocylindrus danicus present from July to late October in Massachusetts Bay, with the maximum population of 4.9x106 cells/liter recorded on September 10, 1973. 'This diatom was the most' abundant species in terms of cell numbers and total picograms carbon/ml present (49 x 10^4) in Massachusetts Bay in 1973.

In the Rye, N.H. to Boston, Mass. survey, 2.3x10^5 cells/1 of L.

danicus were recorded at the Flip Rock Station, in Massachusetts Bay, on October 21, 1971. This diatom was also observed at the other stations along the coast (Mulligan and deLara, in prep.). McAlice (1972) found considerable variation in the late summer and fall plankton in Montsweag Bay, but L. danicus, L. minimus, and Guinardia flaccida were sporadically abundant.

(8) Food. Not applicable.

(9) Predation. Not applicable

(10) Competition. Not applicable.

(11) Responses to the environment (natural factors, pollutants). Not applicable.

Leptocylindrus minimus

Leptocylindrus minimus Gran, similar in appearance to L. danicus, has smaller cells, about 5μ in diameter, and only two long, plate-like chromatophores per cell.

(1) Reproduction. Not applicable.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Not applicable

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Not applicable.

(6) and (7) Distribution and density. This boreal, neritic species is secondary in importance to L. danicus, but often reaches sizeable populations, primarily in the early spring and late-summer-fall seasons. Gran (1933) observed small numbers of L. minimus, up to 640 cells/1., on Georges Bank in August, 1932. Sears (1941) found L. minimus to be the most abundant species on Georges Bank in late June, recording 5,993 cells/1. L. minimus had approximately the same distribution as L. danicus in the Bay of Fundy, with its maximum frequency recorded in June (8000 cells/1) along the Maine coast and in July in Passamaquoddy Bay (Gran & Braarud, 1935). Lillick (1940) observed that L. minimus was also associated with the spring Thalassiosira community in the Gulf of Maine.

L. minimus was secondary to Rhizosolenia delicatula in Massachusetts

Bay in late October, 1973', with c.9 x 104 cells/l., and dominant in late February, 1974. It had also been abundant in the Annisquam area, north of Cape Ann, in October, 1971, with 1.4x105 cells /l. (Mulligan and Wesse9, in prep.; Mulligan and deLara, in prep.).

(8) Food. Not applicable.

(9) Predation. Not applicable.

(lo) Competition. Not applicable.

"(11) Responses to the environment (natural factors, pollutants). Not Applicable.

Porosira glacialis

Porosira glacialis (Grun.) Jorg. is a marine centric diatom with drum-shaped cells, held in loose chains by indistinct gelatinous threads. The cells vary in diameter from 30-70μ and each contains numerous plate-like chromatophores.

(1) Reproduction. Not applicable

(2) Fecundity and larval life. Not applicable

(3) Growth and longevity. The optimum growth requirements of Porosira glacialis are given by Brunei (1962) as 1.6 C and 25.9 o/oo.

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Not applicable.

(6) and (7) Distribution and density. P. glacialis is an arctic-neritic species, occurring in abundance in the North Sea plankton in the early spring. Gran and Braarud (1935) report it abundant in the inner areas of the Bay of Fundy in April with nearly 30,000 cells/1. It was less common in the outer areas of the Bay in April and its numbers decreased greatly in May. It was rare from June to August. Lillick (1940) observed that P. glacialis was a regular and important member of the Thalassiosira plankton in European waters and was also concurrent with Thalassiosira in the Gulf of Maine in late March or April. She recorded a maximum count of 2.8x107 cells/column and $7x10^3$ cells/liter in March, but noted its presence from March to August.

P. glacialis made its first appearance in 1973 in Massachusetts Bay

in February, as the Thalassiosira population was increasing (Mulligan and Wessel, in prep.). Detonula confervacea, in fact, was the dominant organism in the spring bloom of 1973 in Massachusetts Bay, but P. glacialis (1.4×10^5 cells/1.) was an important member of the remaining diatom flora. McAlice (1972) observed Porosira glacialis in the March phytoplankton in Montsweag Bay.

(8) Food. Not applicable.

(9) Predation. Not applicable.

(lo) Competition. Not applicable.

[11) Responses to the environment (natural factors, pollutants). Not applicable.

Rhizosolenia spp.

Rhizosolenia spp., the type form of the marine centric diatom Rhizosolenia alata, has straight, cylindrical cells, 7 to 18μ in diameter. The valves are shortly conical, ending in tubelike, somewhat curved, oblique processes. At the base of the tube is a depression into which the apex of the adjoining cell fits. Many small chromatophores are visible through the weakly siliceous cell walls. Resting spores and auxospores, growing out in the same plane as the main cell, are common.

(1) Reproduction. Not applicable.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Wimpenny (1936) measured the diameter variation in cells of R. alata and R. styliformis and proposed that, according to the theory of natural selection, an increase of temperature favored the survival of wider diatoms.

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Not applicable.

(6) and (7) Distribution and density. R. alata, a temperate, oceanic species usually occurring near the coast, is ranked by Lillick (1940) as the most important member of this genus in the Gulf of Maine. It usually has two bloom periods, one of low intensity in February or March, and a second of greater intensity, but irregular in distribution, in August. Bigelow (1926) found that R. alta dominated the phytoplankton in Cape Cod Bay from mid-November through January and early February in 1925. He also recorded its dominance in the

moderately abundant plankton of outer Massachusetts Bay in August, 1922. It was also abundant off Mt. Desert Island in July, 1915 and just north of Georges Bank in July, 1913. $5x10^4$ cells/l. of R. alata were recorded by Gran (1933) in August, 1932 on the eastern part of Georges Bank and Gran and Braarud (1935) found an abundant population in the northern part of the Gulf and in the Bay of Fundy, on the same date. Lillick (1940) observed that R. alata constituted 80 percent of the plankton population in the western basin in March, 1934 and dominated there in August, 1936. It therefore appears that Rhizosolenia alata usually blooms in the northern and western (Nova Scotia) coastal belts and on Georges Bank in mid-summer.

(8) Food. Not applicable.

(9) Predation. Not applicable.

(lo) Competition. Not applicable.

(11) Responses to the environment (natural factors, pollutants). Not applicable.

Rhizosolenia delicatula

Rhizosolenia delicatula Cleve has cylindrical cells, 9 to 6μ in diameter. with almost completely flat valves, rounded only slightly on the margins. A short, marginal spine is found which fits into a corresponding depression on the adjacent cell. Usually, each cell has 2 large chromatophores found near the girdle wall.

(1) Reproduction. Not applicable.

(2) Fecundity and larval life. Not applicable,

(3) Growth and longevity. Not applicable.

(4) Natural mortality. Not applicable.

(5) Migration characteristics'. Not applicable.

(6) and (7) This species has a temperate, neritic distribution. Grail (1972) observes that it is not recorded quantitatively very often, but maximum concentrations of R. delicatula are provided by-several authors:

cells/liter	author
8,000	Braarud, et al., 1953

99,400	Mulligan and Wessel, in prep. Mass. Bay-1971
108,000	Steeman-Neilsen, 1935
500,000	Conover, 1956 Long Island Sound
222,500	Smayda, 1963 Gulf of Panama
500,000	Grail, 1972 Roscoff, France
1,200,000	Mulligan and Wessel, in prep. Mass. Bay-1973

Moebus (1972) found that there was increased anticoliform activity in water taken from the North Sea after a flowering of Rhizosolenia delicatula.

(8) Food. Not applicable.

(9) Predation. Not applicable,

(10) Competition. Not applicable.

(11) Responses to the environment (natural factors, pollutants). Not applicable.

Rhizosolenia-fragilissima

Rhizosolenia fragilissima Breb. has cylindrical cells, rounded ends, is 12 to 24µ in diameter, and is united in short straight chains. A small spine, located near the center of the valve, fits into a depression in the adjacent cell. It has numerous small, plate-like chromatophores, distributed over the entire cell wall.

(1) Reproduction. Besides normal cell division, auxospore formation has been noted. Ignatiades and Smayda (1970a) observed 3 instances of auxospore (mean diameter=21.6µ) formation during their culture studies on R. fragilissima in Narragansett Bay. With growth conditions of 15 C, 25 o/oo and 1000 ft/C; auxospores were formed after 7½ months of continuous division, when the mean cell diameter decreased to 4.8µ in the parent culture. When R. fragilissima was grown at 1800 ft/C and 9 C (the lowest temperature allowing growth in culture), auxosporulation was induced. A 21-day-old culture, with a mean cell diameter of 10 to 11µ, also produced auxospores, probably due to an overcrowding situation.

No resting spores have been observed for this species and Ignatiades and Smayda (1970b) suggest the possibility of a sedentary vegetative stage which could account for its over-wintering ability. Their dark-viability experiments when R. fragilissima remained viable for only 23 days, show, however, that only those cells settling in shallow well-lighted areas would be able to over-winter.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Ignatiades and Smayda (1970a) found the optimal growth conditions to be 18 to 25 C, 20 to 25o/oo, and 600 ft/C light intensity, although several light-temperature-salinity trends were noted. Growth did not occur below 9 C nor 5 0/00.

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Not applicable.

(6) and (7) Distribution and density. Lebour (1930) and Cupp (1943) refer to R. fragilissima as a neritic, boreal-temperate species, while Hendey (1937) lists it as typically warm water and Margalef (1961) as cosmopolitan. Under Smayda's classification (1958), "R. fragilissima becomes holo-paractic, a species confined to inshore areas, but riot producing a resting-spore stage in its life cycle. Two sub-groupings of R. fragilissima (R. f. bergonii and R. f. faeronsis) are proposed by Ianatiades and Smayda (1970a), where R. f. faeronsis would designate populations found below 9 C and R. f. bergonii, the others. This designation provides an explanation for the descrepancy found between laboratory and natural responses as to the lower temperature limit allowing growth of R. fragilissima. Other alternatives, such as the separation into two species or the existence of thermalclones, are possible.

Bigelow (1926) does not include R. fragilissima in his list of diatoms found in the Gulf of Maine. Gran (1933) includes R. faeroensis in his counts of R. fragilissima and states that this species may occur in abundance in the Gulf, although only small numbers were found in August, 1932, just north of Georges Bank.. Braarud (1934) found small numbers of R. fragilissima present at the surface and at 30 m in July, 1933 on Georges Bank. Gran and Braarud (1935) observed R. fragilissima from April to September in coastal stations in the Gulf of Maine and the Bay of Fundy. A distinct maximum was found in June, when 8000 cells/l. were recorded in the outer reaches of the Bay of Fundy. Lillick (1940) gives little information on this species, except that it may increase in abundance in late spring or early summer. Sears (1941) found R. fragilissima in relatively small proportions mixed with the dominant Chaetoceros flora in the spring of 1940 on Georges Bank.

Mulligan and Wessel (in prep.) found the maximum population of R. fragilissima (9.7×10^5 cells/l.) on July, 14, 1973 in Massachusetts Bay, where it was observed from July to late October. A pulse of R. faeroensis was noted in March, 1973.

In Narragansett Bay, R. fragilissima is numerically the most important of the species of this genus reported (Smayda, 1957).

Ignatiades and Smayda (1970b) observed that the annual cycle of R. fragilissima in Narragansett Bay is dependent on temperature conditions and nutrient levels. The concentrations of silica and trace metals in nearshore waters, and the chelation properties of these waters, seems to be responsible for the coastal preference of Rhizosolenia fragilissima.

(8) Food. Not applicable.

(9) Predation. Not applicable.

(10) Competition. Not applicable.

(11) Responses to the environment (natural factors, pollutants). Not applicable.

Rhizosolenia hebetata

Rhizosolenia hebetata f. semispina, one of the dimorphic forms of R. hebetata, has long, cylindrical cells, 5 to 12μ in diameter, with its valves longitudinally drawn out. It has numerous small, plate-like chromataphores.

(1) Reproduction. Seaton (1970) describes the formation of auxospores in R. hebetata f. semispina. He suggests that the presence of developmental stages of microspore, occuring simultaneously with the auxospores, provides corroborative, though circumstantial, evidence of oogamous sexual reproduction in this species, as first proposed by Ramsfjield (1959).

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Holmes (1966) determined the cytological changes induced by nitrate or phosphate limitation in R. hebetata f. semispina. A reduction in chlorophyll a and a decrease in the number of chromatophores was observed with nitrate and inorganic phosphorus deficiencies. Silica deficiencies produced morphological abnormalities, consisting usually of an abnormal valve lacking an apical spine. R. hebetata semispina was cultured in f/2 medium, at 18 C and 0.09 langlies/min. illumination.

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Nonapplicable.

(6) and (7) Distribution and density. Lebour (1930) lists this species as an oceanic, boreal-arctic form and CUpp (1943) refers to it as a warm-water or summer form.

Lillick (1940) describes its distribution in the Gulf of Maine and states that. late-summer or early fall flowerings of this species appear to be limited to the southern side of the Gulf and are sporadic. Bigelow (1926) found R. hebetata to be the dominant species south of Martha's Vineyard in August, 1914. R. f. hebetata, however, was once the dominant diatom species off the western coast of Nova Scotia in June 1915, and was abundant in the area of Isles of Shoals in April, 1920 (Bigelow, 1926). Gran (1933) and Bigelow (ibid) described it as scarce or absent in 1914, 1916 and 1933 in the various regions of the Gulf they studied. Gran and Braarud (1935) found it regularly from April to June, but never abundant, with the maximum population recorded, 300c/l., in April.

(8) Food. Not applicable.

(9) Predation. Not applicable.

(lo) Competition. Not applicable.

(11) Responses to the environment (natural factors, pollutants). Not applicable.

Rhizosolenia styliformis

Rhizosolenia styliformis Brightwell, a large marine centric diatom, has non-compressed cylindrical cells, 20 to 70µ in diameter and 600 to 1500/µ in length. It has pointed apical processes, with a long cavity penetrating the tip of the valve, and numerous small, round chromatophores. Winpinney (1936) proposed that all the forms of R. styliformis, except various oceanic, should become varieties of R. hebetata Bailey. Seaton (1970) discusses this proposal, but "recommends no taxonomic change at this time.

(1) Reproduction. Besides normal cell division, auxospore formation has been noted.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Qusim, et al., (1972) in their experiments on the effect of illumination intensity and quality on photosynth.e-

sis found a very high saturation point (I_k = 23.50 kilolux) for Rhizosolenia styli formis.

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Not applicable.

(6) and (7) Distribution and density. Cupp (1943} refers to R. styliformis as an oceanic north-temperate species, which prefers regions of high salinity. Bigelow (1926) points out that R. styliformis is important on Georges Bank and Nantucket Shoals, where large numbers have been repeatedly recorded in July and August. In July, 1916, R. styliformis and Thalassiothrix longissima, both oceanic species, co-dominated on the western end of Georges Bank (ibid). Bigelow (ibid) also noted its presence in Massachusetts Bay off Gloucester in April, 1920. Gran (1933) recorded 520 cells/1. of R. styliformis on Georges Bank at 60 m in August, 1932. Braarud (1934) observed this species in July, 1933 with 1500 cells/1. on Georges Bank. Gran and Braarud (1935) found this large oceanic species to be rare in the Bay of Fundy, but observed it in the Gulf from April to August. Lillick (1940) states that R. styliformis is a leading member of the late summer flora, especially on Georges Bank.

McAlice (1972) and Mulligan and Wessel (in prep.) do not report its presence in either Massachusetts Bay, the Bigelow Bight region or Montsweag Bay.

(8) Food. Not applicable.

(9) Predation. Not applicable.

(lo) Competition. Not applicable.

(11) Responses to the environment (natural factors, pollutants). Not applicable.

Parasites: The alga Richelia intercellularis, first described by Schmidt (1901), is often found on cells of R. styliformis.

Further studies: Garstand (1937), using measurements of R. styliformis taken by Wimpenny (1936), discussed the value of population curves of this species as indicators of water movements and mixture in the North Sea.

Skeletonema costatum

Skeletonema costatum (Grev.) Cleve (=Stephanopyxis costata) is a marine,

centric diatom with lens-shaped or round-ended cylindrical cells, 3 to 20μ in diameter, held in long, usually straight chains by means of silica rods. The spaces between cells are usually longer than the cells themselves. One chromatophore is found per cell.

Riley and Segar (1969) analyzed the pigments present in Skeletonema costatum. The chlorophyll a to c ratio was 1:0.66. Fucoxanthin constituted 97 percent of the caratenoid pigment and B-caratene 3 percent. No diadinoxanthin was found in this clone.

Anita (1967) compared the adolase activity of several marine plankton algae and found that S. costatum appeared to contain principally Type II or bacterial-fungal type adolase. Blumer, et al., (1971) analyzed the hydrocarbons of S. costatum and observed that $n\text{-}C_{21}$:6(3,6,9,12,15,18-heneicosahexane) was the predominant hydrocarbon present. A trace of pristane, n-p was also found.

Smayda and Boleyn (1966a) determined the mean sinking rate of S. costatum, which varied from 0.30 to 1.35m/day. The rate was influenced by cell age, cell size, cell shape, and the mode of colony formation. They suggest " that the formation of silica rods and chains by this species is an adaption to flotation.

(1) Reproduction. Migita (1967) observed sexual reproduction in batch cultures ~~of Skeletonema costatum.~~ Synchronization of sexual reproduction appears to be the result of returning a station phase (nutrient-limited) culture a a medium saturated with nutrients. Davis, et al., (1973) grew S. costatum in a silicate-limited continuous culture which resulted in the synchronization of the sexual cycle. Four main stages of the life cycle are described: Intransition from vegetative growth to sexual reproduction, II-all cells involved in reproduction (production of egg cell and gametes, fertilization and auxospore formation) and no growth or nutrient uptake observed, III-new vegetative cells with very high growth rates, IV-cells returned to division rate, under the control of the limiting nutrient, silicate.

The conditions necessary for sexual reproduction were also described (ibid). Ample nutrients and a temperature of17 to 23 C, with an optimum of 20 C is required. Weak light is optimal for the formation of male gametes, but strong light is required for the formation of egg cells.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Smayda (1973) observed that the maximum mean division rate of S. costatum is 4 divisions/day, at 20 C, with minima at 2 C and 30 to 40 C. The maximal laboratory growth rates observed for this species by other authors are given-below (Davis,

et al. , 1973)

Temperature(C)	Light(ly/min)	Growth Rate, hr	Reference
10		0.037-0.11(corrected)	Braarud, (1945)
20	0.055	0.035-0.12	Curl and McLeod, (1961)
21	0.07	0.06	Eppley and Sloan, .(1966)
20	0.25	0.069	Jitts, et. al., (1964)
20	0.017	0.066	Jorgensen, (1966, 1968)
20	0.07	0.13	Jorgensen and Steeman-Nielsen, (1965)
20		0.09	Lewin and Guillard, (1963)
20	0.10	0.12	McAllister, et al., (1964)
20		0.16	Smayda, (1973)

Light: Jitts, et al., (1964) states that the optimal radiation intensity for this species is .25 ly/minute, but goes on to state that its overwhelming dominance in so many areas is a result of its broad tolerance of temperature and light. Kiefer (1973) found that the chloroplasts of S. costatum were not seriously affected by high-light intensities. Strathmann (1967), however, found that cells of S. costatum grown at 15 C with 1,000 to 2,000 lux illumination had a greater mean length and volume than those at 20 C with the same illumination or at 15 C with 250 to 1,000 lux. Iverson and Curl (1973) obtained the quantized action spectrum of photosynthesis for S. costatum with the carbon-14 technique. Antia and Cheng (1970) found that S. costatum, with the ability to withstand high-light intensities, showed the lowest potential for survival in darkness at 20 C, ranging from one to three weeks.

Nutrient requirements: Silicon--Smayda (1973) found that S. costatum was stimulated by the addition of a double enrichment of silicate into the growth medium. Paasche (1973) studied the silicate-uptake kinetics in five diatom species, including S. costatum. He found that the relationship between the uptake rate and silicate concentration could be described by a Michael is-Menten type of hyperbola, provided a correction was made for the presence in the medium of reactive silicate, that apparently could not be used by the diatoms. The half-saturation constant for Skeletonema was 0.80 ug-at Si/liter. Paasche suggests that this species may do well in late spring and sinner, when silicate concentrations are low, since it grows well in low silicate waters.

Iron and Boron: Smayda (1973) found that S. costatum benefited from the omission of iron in its growth medium. Lewin and Chen (1971), however, observed that S. costatum, although able to survive in a culture medium without iron added, was benefited by the

addition of Fe-EDTA. This discrepancy may be due to the ability of EDTA to make iron more available for algal growth.

Lewin (1966) observed that boron is essential to the growth of S. costatum.

Prakash, et al., (1973) found that humic and fulvic acids extracted from the residues of littoral marine macro-algae stimulated the growth of S. costatum in culture. This response was probably due to the chelation of metals in the medium. However, in some coastal waters, large amounts of humic substances may be inhibitory due to excessive metal binding.

Ionic requirements (Na and K): Droop (1958) found the minimum concentration of sodium necessary for the growth of S. costatum to be 3000 mg Na/l. or about 130mM NaCl. McLachlan (1964) observed that the growth of this species was reduced at or below 200mM Na and in a medium with one-tenth the normal potassium found in sea water. Droop (1955) first showed a vitamin B_{12} requirement for this species.

Vitamins: Curl (1962) proposed that the high concentration of vitamin B_{12} in land drainage was responsible for coastal blooms of S. costatum. Carlucci and Bowes (1970a) observed that Skeletonema produced and excreted thiamine and biotin when growing with either 12 or 2μ vit. B_{12}/liter. They also measured the concentration of vitamins per cell of S. costatum (1970b).

Nitrogen and phosphorus: The effects of ammonium and phosphate enrichment on Vineyard Sound seawater containing S. costatum and other diatom species was observed by Vince and Valiela (1973). The addition of ammonium produced more cells and chlorophyll a than the controls or phosphate enrichments. However, enrichment with both nutrients, regardless of the N:P ratio, yielded the most cells and chlorophyll a. They assumed, therefore, that nitrogen is the primary limiting nutrient, with phosphate showing secondary limiting effects.

McCarthy (1972) measured the uptake of urea, an organic nitrogen source, by S. costatum. The half-saturation constant for Skeletonema was K_s=1.41 and the Vmax=.0151. This K_s value for urea is similar to that for ammonia and since the concentration of urea and ammonia is similar in the marine environment, McCarthy concluded that this species is capable of utilizing ecologically significant concentrations of urea.

Carpenter, et al., (1972) measured the growth rate of S. costatum as effected by different nitrogen sources: with ammonia, 1.23 divisions/day; with nitrate 1.35; with urea, 1.58. They determined

the K_2 value for urea for S. costatum to be 8.5µg-at. urea N/l. At the urea concentrations of its habitat, they calculated that the division rate for this species, growing on urea as a sole N-source, would be 2.2 days, similar to diatoms growing in inshore habitats.

Carlucci, et al., (1970) found that S. costatum excreted nitrite, when 150 µg-at nitrate-N per liter was present. They suggest that excretion of nitrite by phytoplankton may be important to the concentration of nitrite in sea water.

Holmes (1966) detected morphological changes in S. costatum cells grown in nitrogen-deficient media. The chromatophore of nitrate-limited cells could not be detected with a light microscope, because of weak pigmentation.

Organic matter: Sloan and Strickland (1966) determined that S. costatum was probably not capable of a heterotrophic existence. This species did not show any ability to fix carbon from glucose, acetate or glutamate.

Ignatiades (1973) and Ignatiades and Fogg (1973) discuss the factors affecting the release of organic matter by S. costatum. Both the laboratory and field studies show that the liberation of organic products is mainly associated with photosynthesis. Ackman, et al., (1964) and Brockerhoff, et al., (1964) determined the fatty acid distribution in the lipids of S. costatum and the relationship of these compounds to marine food chains.

(4) Natural mortal ity. Not applicable.

(5) Migration characteristics. Not applicable.

(6) Distribution and density. Smayda (1958) refers to this species as
and cosmopolitan and it is indeed one of the most numerous and widely
(7) distributed plankton species. It is both eurythermal and euryhaline.

S. costatum, a species of major importance in the early spring diatom maximum in the waters of northern Europe, has two flowering periods in the Gulf of Maine. A population of considerable abundance develops in late summer, while a far less productive flowering occurs in winter spring. Bigelow (1926) found S_. costatum to be responsible for the late summer blooms in Massachusetts Bay in September and October, 1915 and August, 1922 and to be abundant on the western part of Georges Bank on July 9, 1913. Gran (1933) found only a small population of this species on Georges Bank or in the basin to the north in August, 1932 and Bigelow (ibid) and Braarud (1934) did not detect itat all in the summer of 1916 or 1933, respectively. Gran and Braarud (1935) found S_. costatum to

increase in numbers in"" February and March, to bloom-in late summer and remain dominant into the fall season, in the Bay of Fundy. A large population was observed in July in Passamaquoddy Bay and $5x10^5$ cells/1. were recorded near Mt. Desert Island in August, 1932. S. costatum was also abundant ($3.9x10^4$ cells/1.) along the western Nova Scotian coast in August, 1932 (ibid).

Mulligan and deLara (in prep.) recorded 2.2x106 cells/1. of Skeletonema costatum at Pope Rock in Massachusetts Bay on June 8, 1972 and $3.3x10^6$ cells/liter in October, 1973 near the Boston Lightship (Mulligan and Wessel, in prep.). These were the peak periods, although S. costatum was found throughout the year in Massachusetts Bay. McAlice (1972) also found S. costatum throughout the year in Montsweag Bay, with bloom populations present from July to September.

(8) Food. Not applicable.

(9) Predation. Temora longicornis was observed by Berner (1962) to assimilate S. costatum. Wimpenny (1973) found that the brine shrimp Artemia salina and Tigriopus sp. grazed on S. costatum. He observed that the cells of grazed populations were larger than those of ungrazed populations.

(lo) Competition: Pratt (1966) examined the relationship of Skeletonema costatum and Olisthodiscus luteus in Narragansett Bay and in culture studies. He proposed that O. luteus achieves dominance by production of large amounts ofan ectorine (of tannoid nature) that inhibits Skeletonema and that S. costatum dominates because of its superior reproductive rate and the stimulator effect of the ectorine in low concentrations.

Conover (1956) suggested that competition between S. costatum and Thalassiosira nordenskioeldii in Long Island Sound was controlled by light and temperature.

Carlucci and Bowes (1970) examined vitamin production and uitlization by phytoplankton in mixed cultures. Relationships between S. costatum and other marine phytoplankton were discussed.

S. costatum has also been reported to increase the anticoliform activity of seawater after blooming (Sieburth and Pratt, 1962; Sieburth, 1964).

(11) Responses to the environment (natural factors, pollutants). Hirayama and Hirano (1970) examined the effects of high temperature and residual chlorine on S. costatum to determine if the effluent from power plants could cause great damage. Exposure to 37 C for 10 minutes completely inhibited the photosynthetic ability of this species and exposure to chlorine at a concentra-

tion of 1.5 to 2.3ppm for 5 to 10 minutes was lethal.

Menzel, et. al., (1970) determined that S. costatum was susceptible to damage from exposure to chlorinated hydrocarbons. Growth rates decreased due to blocked cell division in response to the presence of DDT, dieldrin and endrin.

Steeman-Nielsen and Wium-Andersen (1971) examined the influence of copper on photosynthesis and growth in Skeletonema.

The University of New Hampshire study on the Impact of an Oil Refinery on the N. H. Marine Environment (1974) discusses the effects of the introduction of oil into the marine environment on marine phytoplankton, in general. Various authors have observed that oil is responsible for the following: retardation of growth rates and production of abnormal cell growth (Mommaerts-Billiet, 1973; Smith, 1967), decrease in population size (Lacase, reported in Davis, 1972; Mommaerts-Billiet, 1973) and reduction in the length of the dominance by some organisms and inhibition of others (Fischer and Wurster, 1973; Mironov, 1972).

Thalassionema nitzschioides

Thalassionema nitzschioides Grun. is a marine pennate diatom with narrow linear cells, often slightly curved, 30 to 80µ in length and 2 to 3.5p in diameter. The cells are united into zigzag bands or star-shaped colonies by small gelatinous cushions on each cell.

(1) Reproduction. As in other pennate diatoms, auxospore formation takes place only when the individuals have reached a certain reduced size.

Resting spores have not been recorded for T. nitzschioides, but Ostenfeld (1913) suggests that a vegetative sedentary stage may be part of its life cycle.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Riley and Conover (1967) found that T. nitzschioides had its best growth at low temperatures and reduced radiation, although it has broader ranges of tolerance to the environmental extremes of southern areas. Riley (1952) found the coefficient of increase, k, in his limited growth studies, for T. nitzschioides at maximum development was 19 hours at a mean temperature between 19 to 21 C. This occurred during May and September in the Black Sea. He stated that this division rate was inhibited by the presence of Skeletonema costatum and Chaetoceros

socialis.

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Not applicable.

(6) and (7) Both Lebour (1930) and Cupp (1943) describe T. nitzschioides as a north-temperate neritic species. Smayda (1958), however, refers to it as cosmopolitan, with a circumglobal distribution. It is confined primarily to neritic areas, but can survive in oceanic environments if transported there. It is pronouncedly eurythermal and euryhaline, although specific clones or stocks of this species may have optimum salinity and temperature ranges.

Thalassionema nitzschioides occurs throughout the year in the Gulf of Maine, but is of primary importance in the offshore waters in the early spring and fall. Bigelow (1914) observed T. nitzschoides to be co-dominant with Chaetoceros spp. and Ceratium tripes in the vicinity of Cape Ann in January, 1913 and abundant in a Chaetoceros-dominated community in the North Channel in April, 1920. Gran (1933) observed this species on Georges Bank only in August, 1932,. evenly distributed from surface to bottom in numbers from 200 to 1200 cells/liter. Gran and Braarud (7935) found T. nitzschioides well-distributed in the entire Bay of Fundy region from April to September, with the maximum population, $1x10^5$ cells/l. observed in September, 1934. Lillick (1940) states that T. nitzschioides may at times be a dominant member of the scanty winter-early spring flora in the Gulf of Maine. In December, 1933, this species was abundant in a Peridinium-dominated community in the eastern side of the Gulf. In January, 1934, T. nitzschioides constituted 26 percent of the Population in the western region of Georges Bank. This species may also have a second flowering period in the early fall on Georges Bank. Sears (1941) found T_. nitzschioides present in the Georges Bank region from March to late June and most abundant in March and April.

Mulligan and deLara (in prep.) in their Rye, N. H. to Boston, Mass. study found T. nitzschioides to be the most frequently occurring organism at most of the stations observed. 2.4x105 cells/liter were recorded in April, 1972 at the Annisquam Station, north of Cape Ann." T. nitzschioides was found in Massachusetts Bay from January to May and in December, 1973, with the maximum populaton ($1x10^5$ cells/1.) recorded in March (Mulligan and Wessel, in prep.). McAlice (1972) reported that small flowerings of T. nitzschioides occurred in Montsweag Bay in April and October, 1971, and that it was present throughout most of the rest of the year.

(8) Food. Not applicable.

(9) Predation. Not applicable.

(10) Competition. Not applicable.

(11) Responses to the environment (natural factors, pollutants). Not applicable.

Thalassiosira decipiens

Thalassiosira decipiens (Grun.) Jorg. is a centric diatom with disc-shaped cells, 21 to 54μ in diameter, united in loose chains with very long spaces between the cells. Each cell, with a row of strongly curved marginal spines, has sculpturing of the valve similar to that of T. eccentrics and contains many small chromatophores.

(1) Reproduction. See other Thalassiosira spp. No resting spores have been observed in this, species.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Smayda (1958) states that T. decipiens is capable of good growth in both neritic and oceanic habitats.

Paasche (1973) studied the silicate-uptake of this species and found the mean value of the half-saturation constant for T. decipiens to be 3.37μg at Si/liter. He also noted that this species had a low intrinsic growth rate.

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Not applicable.

(6) and (7) Distribution and density. This neritic, boreal to north-temperate species is very common, although not abundant, in European waters. Gran and Braarud (1935) suggest that its prominence in the winter plankton is due to its slow rate of propagation and relatively low light requirements.

T. decipiens is also a prominent species in the spring Thalassiosira bloom in the Gulf of Maine. On two occasions, T. decipiens was found to be more numerous than T. nordenskioeldii: near Sequin Island in late March, 1920 and in late April, 1934 (Lillick, 1940). In 1934 the codominance by this species extended eastward to the ridge separating the eastern and western basins, where $1x10^6$ cells/liter of T. decipiens (45 percent of the population) was recorded. Gran and Braarud (1935) observed that this species is the commonest of all diatoms in the Bay of Fundy region during

the year. The maximum population was recorded in April, but it was still abundant in May and July in the Bay of Fundy and Passamaquoddy Bay. Mulligan and Wessel (in prep.) observed 3.8×10^4 cells/liter in late April in Massachusetts Bay, where its presence had been noted from early February.

(8) Food. Not applicable.

(9) Predation. Not applicable.

(10) Competition. Not appl i cable.

(11) Responses to the environment (natural factors, pollutants). 'Not applicable.

Thalassiosira gravida

Thalassiosira gravida Cleve is a centric" diatom with disc-shaped cells, 20 to 54µ in diameter, united in close chains by a thick thread. Its valves are flat, with very small marginal spines, arranged in several irregular rows. A very detailed description of this species, including its European distribution and form variation, was carried out by Paasche (1961)

(1) Reproduction. Cupp (1943) and Lebour (1930) note that auxospores are quite common. Resting spores with strongly arched smooth valves, with coarser areolae, have also been observed frequently.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. It can probably be assumed that this species is similar to T. nordenskioeldii in growth requirements. Brunei (1962) lists its optimum temperature as 4.2 Canal its optimum salinity as 31.8o/oo.

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Not applicable.

(6) and (7) Distribution and density. This neritic, northern form follows the general pattern of distribution of T. nordenskioeldii in the Gulf of Maine and is present from April to September. It was recorded in abundance as great as 1×10^5 cells/liter in the northeastern part of the Gulf of Maine in April by Gran and Braarud (1935), and Bigelow (1926) ranked it second to T. nordenskioeldii in his spring collections. Gran and Braarud (1935) also found it to be somewhat abundant in the coastal area south of Nova Scotia in

April. Bigelow, et al., (1940) give the average spring density of T. gravida to be 1x10^5 cell/liter. Mulligan and Wessel (in prep.) recorded 4.3x105 cells/liter of T. gravida in late March in Massachusetts Bay and McAlice (1972) found this species present from March to July and dominant in April in Montsweag Bay, Maine.

(8) Food. Not applicable.

(9) Predation. Not. applicable.

(10) Competition. Not applicable.

(11) Responses to the environment (natural factors, pollutants). Not applicable.

Thalassiosira nordenskioeldii

Thalassiosira nordenskioeldii Cleve is a marine centric diatom with short cells, octangular in girdle view and circular in the valve view, 14 to 35µ in diameter. The cells with many plate-like chromatophores are united in long flexible chains by a mucilage thread. Small spines are present on the valve edges, directed obliquely outwards, with long radiating mucilage threads also present.

(1) Reproduction. The principle methods are cell division and auxospore formation, depending on cell size and age and growth conditions. Sexual cycles have been noted for some Thalassiosira spp. Resting spores, with strongly arched primary and flatter secondary valves, are common.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Raymont (1963) gives the average rate of cell division in the natural environment under optimum conditions as one cell division per day. McAllister, et al., (1961) found that the mean cell division rate of T. nordenskioeldii in culture was one cell division per 30-38 hours over the period of most constant growth.

Growth of this species is best below 5 C (Bigelow, et al., 1940) and in the upper 10 meters of the water column (Raymont, 1963), but only at low light intensities (Jitts, et al., 1964). The temperature optimum is listed as 2.3 C and the optimum salinity as 27.9o/oo (Brunei, 1962). Braarud (1937), however, observed that there was a discrepancy between optimum temperatures in nature and in culture. Growth in culture is favored at temperatures distinct-

ly higher than in its natural habitat. The combination of temperature and light intensity probably limit the growth of Thalassiosira to the early spring. Conover (1956) found that these factors control competition between T. nordenskioeldii and S. costatum in Long Island Sound. Sorokin, et al., (1973), in studies of the production and decomposition of organic matter in the Sea of Japan, found that the cause of a winter bloom of T. nordenskioeldii under the ice was related to optimum illumination and nutrient supply during the period.

Response to and production of inhibiting substances: Prakash, et al., (1973) found that humic and fulvic acids extracted from decomposed macro-algae decreased the size of T. nordenskioeldii in culture, although some stimulation of population growth was noted.

Aubert, et al., (1968) observed the in-activation of test cells of the bacteria Staphylococcus aureus by T. nordensk"ioeldii and S. costatum.

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Not applicable.

(6) and (7) Distribution and density. This neritic, boreal-arctic species is the dominant phytoplankter in the Gulf of Maine, but only blooms with intensity in the spring. The spring bloom originates in shallow water in two centers, one between Boston Harbor and Cape Elizabeth, the other in the coastal waters south of Nova Scotia. The time of this event varies yearly, ranging from late February to early April. During its peak bloom, it is accompanied by T. decipiens, whose relative importance increases northward, and T. gravida. In the western coastal area, the spring Thalassiosira bloom lasts from two to seven weeks, but it can continue into summer in coastal areas east of Mt. Desert Island. In the open Gulf, it lasts only a few weeks and then declines rapidly. Bigelow, et al., (1940) describe it as going from 93 percent of the total phytoplankton to complete disappearance in four days.

Table 11. Recorded densities of T. nordenskioeldii in the Gulf of Maine.

Density	Date	Location	Reference
100 percent of tow	May, 1915	Mt. Desert Island	Bigelow (1926)
1 x 10^6	Spring	Gulf (in general)	Bigelow, et. al., (1940)
5 x 103	Summer	" " "	" " "
5 x 10^2	Fall	" " "	" " "

Table II (cont.)

65 percent of pop.	March, 1934	Sequin Island	Lillick, 1940
12 percent of pop.	Late April-May 1934	West Coast	"
60 percent of pop.	" " "	Eastern basin	"
20 percent of pop.	" " "	E. Georges Bank	"
10 percent of pop.	" " "	Western basin	"
7×10^5 (2×10^5)	Mid-April	Mass. Bay	Mulligan & Wessel (in prep.)
2.5×10^5	" "	" "	"

(8) Food. Not applicable.

(9) Predation. The Thalassiosira spp. are important components of the food of most all the grazing animals of the plankton, as well as benthic filter-feeding invertebrates and some of the filter-feeding vertebrates. Conover (1964) specifically refers to T. nordenskioeldii as an important food of Calanus hyperboreus, and Poulet (1973) found that Pseudocalanus minutus fed on Thalassiosira spp, as well as other marine diatoms.

(lo) Competition. Not applicable.

(11) Responses to the environment (natural factors, pollutants). Not applicable.

Ceratium longipes

Ceratium longipes (Bail.) Gran and Ceratium tripes Mull. The two species of the genus Ceratium, which are most important in the Gulf of Maine, are considered together as their periods of dominance and growth requirements are inter-related.

The dinoflagellate genus Ceratium consists of hi-flagellated individuals covered with a theta of several plates with a formula of 4'5''5' ''2''". The epitheca has a long apical horn with an apical pore on the top and the hypotheca is typically drawn out into two hollow side horns. C. longpipes, with a breadth of 51 to 57µ, has a strongly bent apical horn, with the left horn diverging from it. C. tripes, with a breadth of 60 to 80µ, is usually larger than C. longipes and two or three of its horns may be parallel, but rarely diverging.

(1) Reproduction. In the genus Ceratium, reproduction is normally accomplished by cell division, although encystment spores have been

found for many other dinoflagellate species.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. Nordli (1953) studied the effects of different temperatures and salinities on the growth of several Ceratium species, i.e., tripes, fusus and furca. In relation to the importance of these species along the Norwegian coast, Nordli (1953) found that C. tripes is capable of growth at a salinity of 10 o/oo, while C. fusus and C. furca do not grow at this salinity.

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Not applicable.

(6) and (7) Distribution and density. Both species are oceanis, with C. longipes having an arctic-boreal distribution and C. tripos a temperate distribution. They are both present throughout the year in the Gulf of Maine. Lillick (1940) describes the seasonal cycle of these organisms. Ceratium tripos dominates the offshore plankton during the winter, while C. longipes is very scarce. During the spring bloom of diatoms, both species are at their minimum. Ceratium tripes also continues to be scarce after the diatom population diminishes, but C. longipes then increases to its maximum in July, when the Gulf as a whole supports the most abundant Ceratium population of the year, During August, C. longipes decreases in number but C. tripes multiplies, resulting in a reversal of the importance of the two species. Documentation by Bigelow (1926) and Lillick (1940) shows the spread of this phenomenon from the southern and western portions of the basin in August to the Bay of Fundy in late September and its consistency from year to year.

(8) Food . Not applicable.

(9) Predation. The species of this genus are consumed by a number of marine animals; however, the genus is probably not as important a food item as' some of the diatom species. Calanus finmarchicus has been observed to avoid eating Ceratium, while Euadne spp., a highly selective feeder, prefers certain species of Ceratium. Poulet (1973), in culture studies, found that Pseudocal anus minutus preferred to consume particles less than 39µ in' diameter, but it could shift its grazing from small to large particles, i.e., Ceratium sp., when, the densityof small particles decreased.

Bioluminescence: Tett (1971) examined the role of dinoflagellates in causing bioluminescence in seawater. He found that the occurrence of bioluminescence in Ceratium tripes was dubious.

(10) Competition. Not applicable.

(11) Responses to the environment (natural factors, pollutants). Not applicable.

Gonyaulax tamarensis

Gonyaulax tamarensis Lebour is a marine dinoglagellate species with roundish cells, 36µ in length, usually longer than broad. It has a smooth theta, with a posteriorly expanded longitudinal furrow and a relatively undisplaced girdle. This dinogflagellate species is associated with the Red Tide phenomena, a cause of paralytic shellfish toxicity on the Atlantic coast of Canada and the U. S.

(1) Reproduction. Prakash '(1967) observed cyst formation in old cultures of G. tamarensis, as well as in cultures which had been exposed to temperatures above 25 C and below 5 C. Temperature appeared to be the most important factor involved in cyst formation. Limited encystment was also noted under non-optimum conditions of nutrients, salinity and light. As a rule, the cells of these species discarded the surrounding theta and developed a cyst which may be smooth or moderately spinous.

(2) Fecundity and larval life. Not applicable.

(3) Growth and longevity. G. tamarensis is capable of growth under a wide range of temperatures and salinities (Mulligan, 1973). Prakash (1967) has shown that this species achieves dominance in the surface waters of the Bay of Fundy when the average temperature is 11.3 C and the average salinity 31.9 o/oo. Needler (1949) found a positive correlation between high temperatures and high concentrations of G. tamarensis, but Prakash's data does not confirm this. Prakash and Tennent (1971) credit salinity as being a more important environmental factor than temperature and in non-axenic cultures of this organism, they found optimal growth at salinities of 15 to 23 o/oo and reduced growth at higher salinities. However, salinities of this low level have not been recorded in the Bay of Fundy during bloom periods of G. tamarensis.

G. tamarensis has been found to require organic compounds for growth including humic acids (ibid).

Prakash and Medcof (1962) discuss the hydrographic and meteorological factors affecting shellfish toxicity at Head Harbor, New Brunswick and correlate variations in toxicity with summer rises in water temperature. Mulligan (1973) correlated the September,

1972 red tide bloom in the Gulf of Maine with an upwelling of deep water, development of a "seed" population during unusually dry weather in August, and heavy rainfall in September.

(4) Natural mortality. Not applicable.

(5) Migration characteristics. Not applicable.

(6) and (7) Distribution and density. The occurrence of this neritic-boreal species has been noted repeatedly in the Gulf of Maine. Gran and Braarud (1935) indicate it as a common coastal form in the Bay of Fundy from May to September reaching populations of 2800 cells/l. They also report its presence at one station in April. Lillick (1937) collected it south of the Gulf of Maine, in the Woods Hole region, from July to September in 1935, and noted its presence (Lillick, 1940) in the Gulf of Maine from March to December. Burkholder (1933) did not locate it in a summer study of phytoplankton of Penobscot Bay and Frenchman's Bay, Maine. Prakash (1967) stated that G. tamarensis never occurred in enough abundance south of Maine to cause shellfish poisoning. However, in September, 1972, a bloom of G. tamarensis occurred along the Atlantic coast from Massachusetts to Maine and created severe economic problems for the shellfish and finfish industries of New England (Mulligan, 1973).

(8) Food. Not applicable.

(9) Predation. Not applicable.

(lo) Competition. Not applicable.

(11) Responses to the environment (natural factors, pollutants). Not applicable.

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9.1 DEFINITION AND GENERAL FEATURES

9.1.1 DISTRIBUTION OF ZOOPLANKTON IN THE STUDY AREA

The zooplankton comprise the animal component of the plankton of the seas. Some of these animals swim or float in the water column throughout their entire life history (holoplanktonic), whereas many other species are pelagic for only a portion of their life history (meroplanktonic). Although many species in the zooplankton are capable of swimming and changing position vertically in the water column, they are not capable of effective horizontal movement against the flow of tides and currents (Raymont, 1966). The zooplankton is drawn from a very large variety of animal phyla. Every phyla in the animal kingdom is represented in the holoplankton with the exception of sponges, bryozoans, brachiopods, ascidians and mammals. In the meroplankton are the larvae of bottom invertebrates such as trochophore, veliger and zoea larvae; the nauplii of cirripedes, echinoderm larvae, medusae of the hydromedusae, the eggs and larvae of most fish species. Table 9-1 gives the major representative groups present in the holoplankton and meroplankton.

Plankton may be categorized in two major community groups -- the neritic and oceanic plankton. The neritic zooplankton community is present along the coast and seaward to approximately the 100 m bottom contour, which in most areas marks the edge of the continental shelf. In addition, a specialized euryhaline group is restricted to estuaries. The neritic zooplankton community is comprised of those holoplanktonic species which are characteristic of coastal waters plus a relatively large proportion of meroplanktonic members. Oceanic zooplankton, on the other hand, is almost entirely holoplanktonic. Although the neritic and oceanic communities are identifiable (generally any one species can be assigned to one group of the other), members of each group broadly overlap geographically. Moreover, water currents, topography of the coast and depth influences the seaward extension of neritic plankton.

Characteristic components of neritic zooplankton in the area of studv longicornis, calanus minut stell offshor community throughout the study area. Characteristic members of this group include the amphipods Hyperia galba and Parathemisto gaudichaudii and the copepods Metridia longa, the pteropod Euchaeta norvegica, Oithona similis, Clione limacina and the Chaetognatha Sagitta serrandotata. The Middle basins of the Gulf of Maine which are deeper than 100 m are usually dominated by oceanic zooplankton (Bigelow, 1926).

Fish and Johnson (1937) also found that neritic plankton were scarce in the central Gulf of Maine over the deep basins. Many species are too widely distributed to be easily categorized as either neritic or oceanic (e.g., Calanus finmarchicus and Pleurobrachia pileus.)

The euryhaline estuarine zooplankton include a large proportion of meroplankton and tychoplankton as well as a typical holoplankton component. The most abundant copepod of this latter group in the study area are the congeners Acartia tonsa and Acartia clausii. Other common estuarine copepods include Tortanus discaudatus and Oithona brevicornis.

Tychoplankton are normally bottom-dwelling forms which are swept up or deliberately swim up into the water column. Unlike the meroplankton which are larval forms, the tychoplankton are mostly juvenile and adults. Incursions of these organisms into the water column usually occurs at night and sometimes in considerable numbers. Harpacticoid copepods are a common tychoplanktonic form. As an example of a tychoplanktonic community, six groups form the nighttime tychoplankton of the lower Sheepscot River estuary of Maine: (1) Mysidacea, (2) Isopoda, (3) Amphipoda, (4) Cumacea, (5) Polychaeta, and (6) Mollusca. Species of these groups (Table 9-2) were captured in buoyed and anchored nets set in tidal flows at night (Graham and Venno, 1968) and identified by Michael Mazurkiewicz and Bernard McAlice of the Ira C. Darling Center of the University of Maine. In an unpublished report, Mazurkiewicz states, "Although it is generally recognized that many benthic crustaceans migrate periodically, surprisingly few studies have dealt with this phenomenon. Russell (1925) and Watkin (1939, 1941) reported that benthic crustaceans migrate pelagically in great number at night but are absent from daytime plankton. Watkin (1939) also noted that pelagic migrations exhibit seasonal tidal and lunar periodicities. Mating and the release of young occur in mid-winter. However, pelagic migrations are not always associated with reproduction behavior since all developmental stages of some amphipods, from immatures to adults, have been observed in nocturnal plankton (Mills, 1967). Thus, pelagic migrations may also serve as the chief means of dispersal of benthic invertebrates, such as amphipods, which lack pelagic larvae." According to Thorson (1957) pelagic larvae provide their chief means of dispersal for about two-thirds of the benthic invertebrates of cold temperate regions. In estuaries bordering the Gulf of Maine, tidal ranges and the large resultant strong tidal currents may be a very effective dispersal agent for juvenile benthic crustacea.

A ubiquitous and often dominant community particularly in the Gulf of Maine, but also extending southward along the coast, is the calanoid community (Bigelow, 1926). This 'community, characteristic of colder waters of the North Atlantic is dominated by the calanoid copepod Calanus finmarchicus. This species is usually accompanied

Table 9-2 Species captured in buoyed and anchored nets at night in the Sheepscot River Estuary. Identified by Bernard J. McAlice.

Mysidacea
- Erythrops erythrophthalma (Goës)
- Heteromysis formosa Smith
- Mysis mixta Lilljelug
- M. stenolepis Smith
- Neomysis americana (Smith)
- Praunus flexuosus (Müller

Cumacea
- Diastylis polita Smith
- D. quadrispinosa G.O. Sars
- D. Sculpta G.O. Sars
- Endorella emarginata (Krøyer)
- E. hispida G.O. Sars
- Leucon americanus Zimmer
- Oxyurostylis smithi Colman

Isopoda
- Edotea montosa (Say)
- Idotea baltica (Pallas)
- I. phosphorea Harger

Amphipoda
- Ampelisca abdita Mills
- A. agassizi (Judd)
- A. vadorum Mills
- Anonyx mugax (Phipps)
- Calliopius laeviusculus (Krøyer)
- Corophium acherusicum Costa
- C. volutator (Pallas)
- D. falcata Bate
- D. monocantha Metzger
- D. ponecta
- Gammarus lawrencianus Bousfield
- G. mucronatus Say
- G. oceanicus Segerstrale
- Jassa marmorata Holmes
- Leptocheirus pinguis (Stimpson)
- Metopa olderi (Bate)
- M. spectabilis G.O. Sars
- Monoculodes sp.
- Orchomenella pingius (Bock)

Table 9-2 (continued)

Phoxocephalus holbolli (Krøyer)
Podocerus falcatus (Montague)
Pontocrates sp.
Pontogeneia inermis (Krøyer)
Pontoporeia femorata (Krøyer)
Stenothoe minuta Holmes
Unicola irrorata Say

Polychaeta
11 species

Mollusca
2 species

by a number of other characteristic species including Metridia lucens, Pseudocalanus minutus, Euchaeta norvegica, Thysanoessa spp., Sagitta elegans and the euphausid Meganyctiphanes norvegica. This community is augmented and replaced by an increasingly greater proportion of neritic species as the coast is approached. However, Calanus finmarchicus is often dominant in neritic samples and apparently is as successful in nearshore environments as offshore except that it is apparently not able to reproduce successfully in inshore' water. The calanoid community is limited in its seaward extension by the warmer waters of the Gulf Stream but to the North and East extends over the Atlantic to Greenland and Europe (Raymont, 1966). Calanus finmarchicus was also found to dominate summer collections in Block Island Sound (Jeffries, unpublished; see Jeffries and Johnson (1973).

The reasons for the inability of neritic holoplankton to spread into the oceanic environment is not known (Bigelow, 1926, Sherman, unpublished manuscript). Graham, (personal communication) assigns considerable importance to coastal currents which provide an opportunity for retention of neritic forms. Raymont (1966) and others have suggested biological conditioning of the water by exocrines, vitamins and other organic trace materials as a possibility. In the coastal area from Sandy Hook to the Bay of Fundy neritic zooplankton predominate. Oceanic forms occasionally extend inshore, particularly in the Gulf of Maine.

9.2 CHARACTERISTICS OF THE PELAGIC LIFE OF ZOOPLANKTON

The members of the zooplankton, in spite of representing most animal phyla, have certain similarities which are adaptive to a pelagic life style. Most zooplankton are quite small from a fraction of a millimeter to several millimeters in size. Some of the larger medusae, such as Aurelia, on the other hand, may be a foot or more in diameter. Besides small size, which retards the rate of sinking, zooplankton have other attributes which allow them to remain in the water column for extended periods or to elect the optimum vertical position in the water column. Most zooplankton have some kind of ability to swim, either through swimming appendages, ciliary bands, flagella or muscular movement. These various adaptations for swimming do not allow for much more than resisting sinking and allowing the animal to maintain its position in the water column. Other modifications and structures possessed by zooplankton to prevent or retard the rate of sinking include: oil globules which serve as hydrostatic organs (e.g., copepods), development of spines and hairs (e.g., crustacean), gas bladders (e.g., siphonophores), thin shells and skeleton members (e.g., Molluscs). In denser cold high saline water the rate of sinking for a given organism would be less than in warm, brackish waters. Generally, plankton from cold water tends to be

larger than warm water forms. Also brackish water animals of the same species (Acartia, Labidocera, Centropages) tend to be smaller (Sewall, 1948). Some animals (e.g., Medusae, ctenophores, tunicates and pteropod molluscs) prossess a physiological mechanism whereby their body fluids are maintained at about the same density as sea water. Denton and Shaw (1962) have shown that this is accomplished by a replacement of heavy sulfate ions in the body fluid with lighter chloride ions.

5.3 ENVIRONMENTAL RELATIONSHIPS

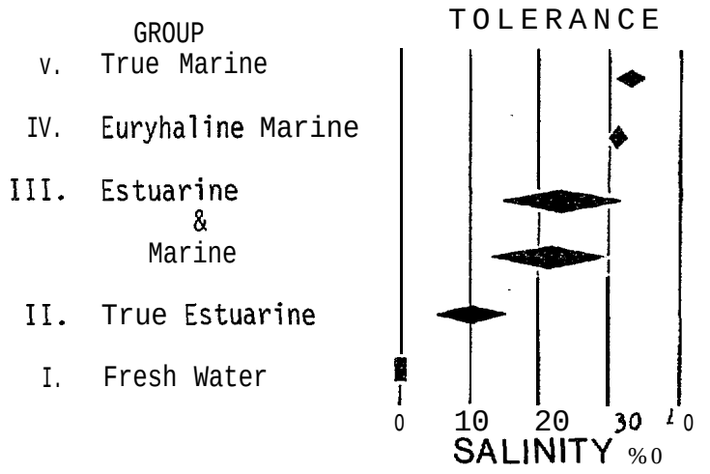
9.3.1 SALINITY

Jeffries (1967) and Jeffries and Alzara (1970) have classified estuarine and neritic copepods into five. groups based on their ability to reproduce along a salt gradient: (1) Fresh water species which occur in estuaries as strays; (2) True estuarine which propagate in brackish water; (3) Estuarine and Marine which commonly reproduce in estuaries but also to a limited extent in open coastal waters; (4) Euryhaline-marine species which reach maximum population densities along-the coasts near the mouths of estuaries; and (5) Stenohaline-marine which reproduce only in open neritic waters. (Figure 9-1). Outside of estuaries, salinity probably has little effect on coastal neritic plankton where salinity varies usually by only 1-2 percent.

9.3.2 TEMPERATURE

Temperature has a considerable effect on the respiratory, feeding, reproduction, size and migrations of zooplankton. Einarsson (1945) has discussed the effect of temperature on reproduction and breeding cycles for the euphausids Meganyctiphanes and' Thysanoessa spp. in the North Atlantic. Loosanoff, Miller and Smith (1951) have demonstrated that the duration of the larval plankton stage is influenced by temperature. The larvae of Mercenaria Mercenaria settle in 5 to 7 days at 30 C and in 16 to 24days at 18C. Thus, the duration of the meroplanktonic stage of benthic invertebrates is dependent on temperature ranges and initiated by critical spawning temperatures. Temperature is undoubtedly, therefore, extremely important in determining the year class success of local population of many species.

Temperature changes and seasonal succession of zooplankton is closely correlated not only because of the direct effect of temperature on the metabolism and reproduction of the animals but also on the density structure of the water column. Conditions of water stability and surface warming are necessary to promote phytoplankton blooms and to enable zooplankton to feed efficiently. The decrease



A SOCIO-ECONOMIC AND ENVIRONMENTAL inventory OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 9-1	Salinity Ranges for Population Maintenance (Jeffries and Algara) 9-9

in water column stability from west to east along the coast of Maine has been cited by Sherman (MS) as responsible for the decrease in standing crop of zooplankton from west to east.

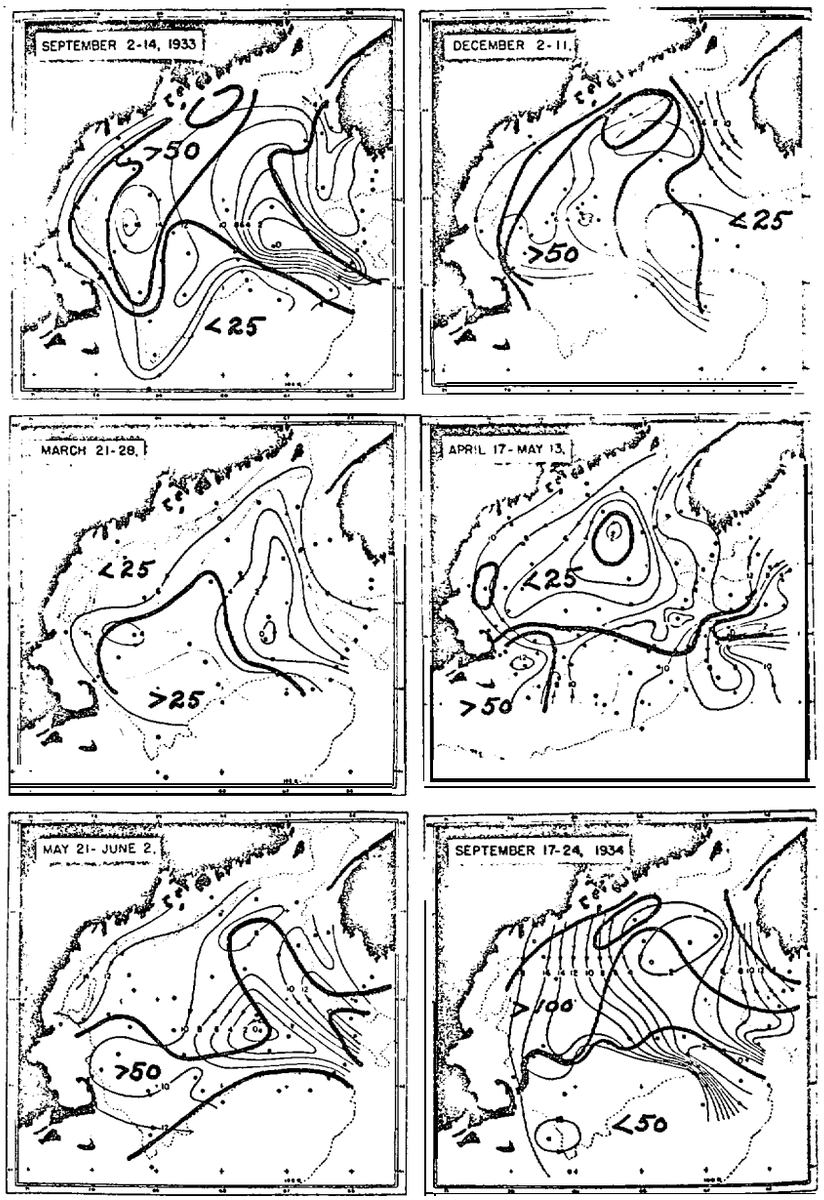
9.3.3 LIGHT

In the Gulf of Maine, Bigelow (1926) showed that the surface water down to a depth of about 25 mwas occupied by a surface community composed of the copepods Acartia, Temora, Centropages and Anomalocera; the medusa Aurelia, Cyanea and Phialidium; appendicularians and and cladocerans, fish eggs and larvae, and by a large proportion of meroplankton. Below 25 m and down to about 100 m the water column was occupied by the typical Calanus community. He also recognized a Euchaeta community below 100 m composed of Euchaeta Norvegica and Eukrohnia hamata along with Meganyctiphanes. He noted that the Calanus community could spread into the deeper layers and that there was no clear barrier between the three strata. Hardy and Bainbridge (1954) have measured the vertical swimming speed of zooplankton experimentally. Over a period of one hour, Calanus could move upward at a rate of 15 m, Acartia 9 m, Centropages about 30 m and Meganyctiphanes 90 m. For short bursts of speed (two-minute duration) much greater speeds were measured; e.g., Calanus at over 100 m/hr and Meganyctiphanes and Tomopteris achieved speeds of over 200 m/hr. Clarke (1934) has shown that in the Gulf of Maine, Calanus and Metridia migrated over 120 m from deep water to the surface at night. These observations were made at a deep water station 200 m in the Gulf. Over Georges Banks he found that Calanus showed very little diurnal vertical movement and was restricted to the upper 30 m. Metridia, on the other hand, showed pronounced vertical migration at both locations. The difference, he speculated, was due to different generations of Calanus occurring over the deeper basins and over Georges Bank.

9.3.4 TRANSPORT BY CURRENTS

The center of abundance of the calanoid community is transported by the surficial circulation of the Gulf of Maine. This conclusion by Redfield (1941) is illustrated in his Figure 9-2 showing the counter-clockwise shift with time of the center of the community's abundance and the Gulf surface circulation. The population density is controlled by the addition of relatively barren water from the east. A breeding stock is maintained by a recurrent counterclockwise eddy in the late spring. Redfield (1941") states that the Gulf appears to be an area from which the calanoid community spreads to other waters, but which receives relatively small recruitment from without its borders.

The calanoid community spreads to the coastal habitat and the lower bays of the inland water habitat. Shoreward movements of water in compensation for estuarine discharge and those generated by winds, changes in bottom topography and density gradients (Graham, 1970)



HEAVY CONTOURS, INDICATE THE RELATIVE DENSITY OF THE Calanus finmarchius POPULATION

provide transport mechanisms for the zooplankton species. The coastal salinity distribution and the distribution of larvel herring, Clupea harengus harengus Linnaeus, are correlated in the spring suggesting that this Important commercial species is also , transported into the coastal and inland water habitats. (Graham, Chenoweth and Davies, 1972). Unlike the calanoid community, the larval herring penetrate the inland water habitat to the upper ends of the bays and lower estuaries.

Redfield (1939) has also shown that the anti-clockwise circulation of the Gulf of Maine is effective in transporting Limacina retroversa. This species immigrates into the Gulf from the offshore waters to the east where the major center of production is presumably located. In the period of study, two populations entered, the first in December was transported around the Gulf for a period of six months before disappearing by the following June. In April of that year, a second population entered from the east, and again was spread by the counterclockwise circulation of the Gulf. Redfield concluded that Limacina populations were not able to maintain themselves in the Gulf of Maine without periodic immigrations from centers of reproduction outside of the Gulf in spite of some limited reproduction in the Gulf.

Bigelow (1926) and Redfield and Beale (1940) have also related the immigrations and maintenance of various species of chaetognaths in various parts of the Gulf of Maine at different seasons of the year. Sagitta elegans is maintained successfully year-round on Georges Banks apparently as a result of the clockwise, anticyclonic eddy of Georges Banks. S. elegans does reproduce successfully in the Gulf, but immigration from outside is minimal. The population is apparently unable to take advantage of the general counterclockwise drift of the Gulf and is swept out and lost, causing large fluctuations in population abundance. Sagitta serratodentata, on the other hand, is an immigrant which comes into the Gulf in slightly warmer surface waters over the Eastern channel during the summer months but does not reproduce at all in the colder Gulf waters. Additional chaetognath species are similar immigrants which do not reproduce in the Gulf and soon die off. Their distribution and abundance can be related to the inflowing water masses which they occupy .

Those species which penetrate and those species which originate in the estuaries and embayments are largely retained there. In the case of meroplankton, Carriker (1967) suggests that three mechanisms theorized by Bousfield (1955) for the retention of barnacle larvae, Cirrepedia, apply to most plantonic larvae of benthic invertebrates with minor modifications. These are:1) a changing-vertical distribution of successive planktonic stages of larvae, 2) a non-tidal

drift seawards at the surface, and another landward along the bottom, superimposed in tidal oscillation, and 3) counterclockwise circulation o-f the larvae completed within the planktonic duration in the outer estuary.

Larval fishes, by changing their vertical distribution, also are retained in the estuary by the non-tidal drift seaward at the surface and landward on the bottom, superimposed on a tidal oscillation, e.g., larval "herring in the Sheepscot River estuary of Maine (Graham, 1972).

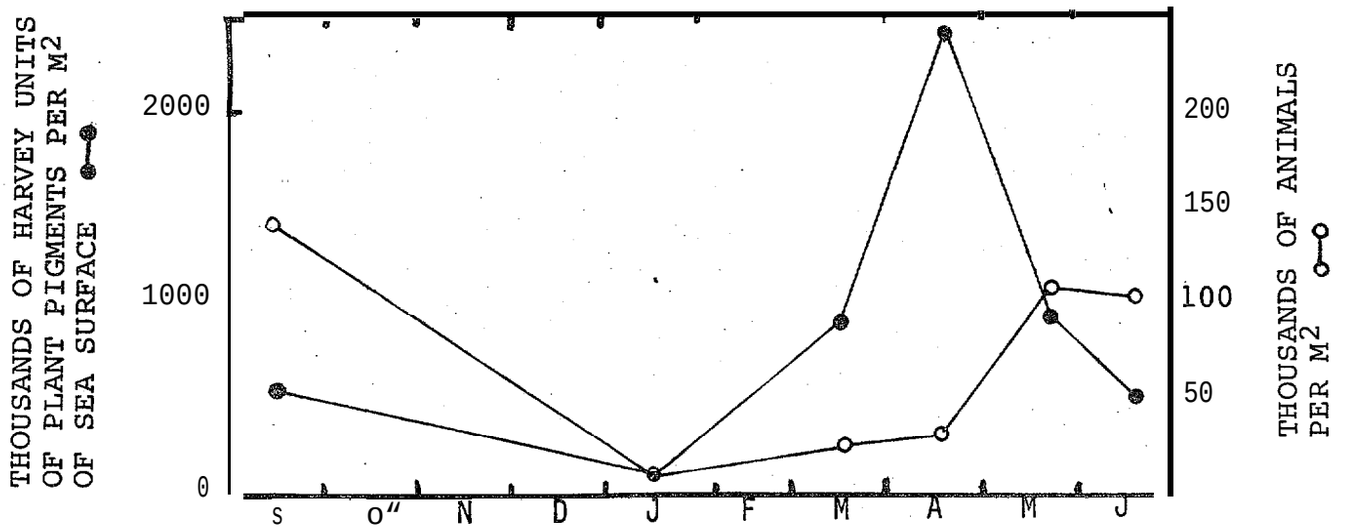
9.4 PHYTOPLANKTON - ZOOPLANKTON RELATIONSHIPS

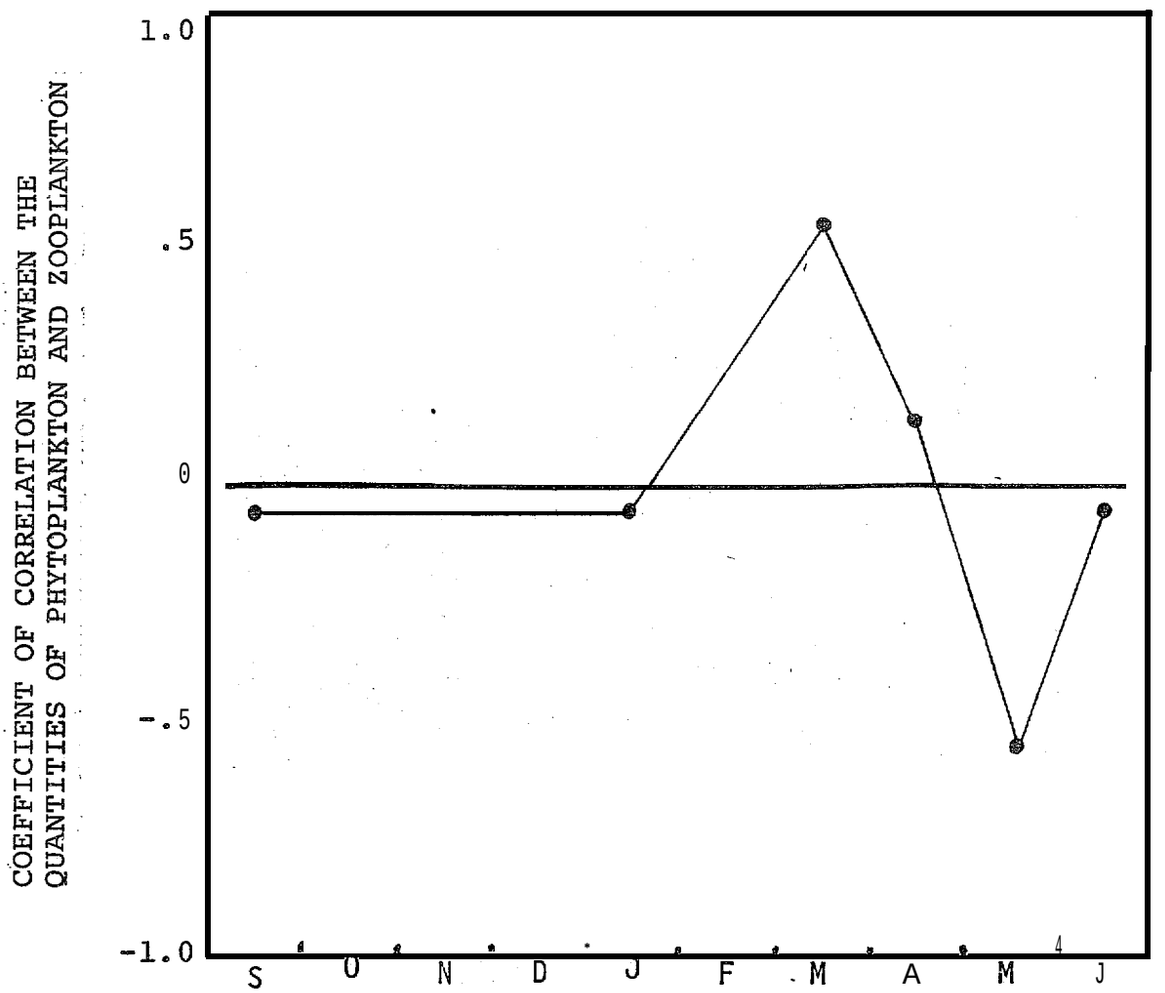
A number of workers have investigated the relationship between phytoplankton populations and the abundance of zooplankton within the study area. Early work in the Gulf of Maine area by Bigelow, Lillick, and Sears (1940) found that the grazing of zooplankton regulated the ply toplankton population. On Georges Bank, Riley and Bumpus (1946) found that seasonal cycles in diatom phytoplankton abundance is correlated to seasonal fluctuations in the abundance of many species of zooplankton including Calanus finmarchicus, Pseudocalanus minutus, cyclopoid cœpods, Centro pages spp., Metridia spp., Decapod lar Sagittae, and Limacina spp. He attributed a marked change from early spring positive to a late spring negative correlation between phytoplankton and zooplankton abundance ('Figure 9-3) to the effect of grazing by the zooplankton on phytoplankton.

Riley (1947) compared these relationships of phytoplankton - zooplankton abundance on Georges Banks with Woods Hole. He found a similar picture with some variations which he attributed to differences in an onset of spring phytoplankton flowering and shallower water which enables small quantities of nutrients to reach the euphotic zone at irregular intervals yeilding small bursts of phytoplankton.

Other workers who have investigated the effect of grazing by zooplankton have not been as successful in relating the quantitative importance of zooplankton in mediating the size of phytoplankton populations. In Long Island Sound Conover (1956) found that nutrient depletion was much more important than grazing by zooplankton in regulating the phytoplankton population after spring flowering. Acartia spp,. the dominant copepod species in Long Island Sound have been found by Riley (1956) to be very inefficient feeders, and are not important elements in the dynamics of phytoplankton population in Long Island Sound.

Ryther (1954) working in heavily fertilized Moriches Bay on Long Island found that grazing by the limited populations of zooplankton





A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 9-3	Correlation Between Phytoplankton and Zooplankton Abundance and Grazing by Zooplankton (Riley and Bumpus, 1946)

did not appear to have much effect on the large phytoplankton populations which were composed mainly of small flagellates. Deevey (1948) also could not discover any clear evidence that zooplankton numbers and grazing intensity had any effect on fluctuations in phytoplankton cell numbers in Tisbury Great Pond on Marthas Vineyard Island.

Pratt (1965) and Martin (1970) have found in Narragansett Bay that a relaxation in grazing pressure appears to bring about initiation of the winter-spring phytoplankton flowering.

The atypical phytoplankton cycle in Narragansett Bay has also been related to nutrient (NH_3 and PO_4) regeneration by zooplankton (Martin, 1968). He found that zooplankton excrete both N and P in excess of phytoplankton requirements when phytoplankton populations were declining and nutrients were low, and that is is unlikely that nutrient limitation is responsible for this cessation of the winter-spring bloom.

The grazing effect by zooplankton on phytoplankton appears to be much more important and predictable in higher latitudes and in offshore waters (Raymont, 1963). Riley (1946) and Riley, Stommel, and Bumpus (1948) have developed a mathematical model to predict phytoplankton production on Georges Bank. Riley (1947) has applied the models to data taken from Vineyard Sound. The model predicts the seasonal cycle in phytoplankton abundance with very good accuracy. An important factor in these models is the numerical abundance and grazing of zooplankton.

Many of the problems in the quantative assessment of zooplankton dynamics are probably related to the characteristic discontinuous distribution of zooplankton populations, the vertical movement of zooplankton and most importantly problems associated with sampling gear and methods. Jeffries and Johnson (1973) have reviewed some of these problems in their earlier report and caution that comparisons of zooplankton abundance and distribution among various workers must be related to the sampling methods used such as net size, mesh size, length of tow and portion of water column sampled. The tables collected in this section have the mesh and kind of tow noted when this information was known.

9.5 TROPHIC RELATIONSHIPS

As discussed by Jefferies and Johnson (1973.). The relationships of individual species with their food resources are far from clear. For a given species the early stages of development may be herbiverous and later stages carnivorous. In addition, diets may change for a given species when it is transported to a different area by

currents. As a rule, small copepod species are herbivorous and large ones carniverous. Some forms (e.g., Mysids) are known to feed on organic detritus. Table 9-3 gives the major sources of food for key species based on observations to date.

Larval molluscs feed on small algae, >10μ in diameter, but bacteria and flagellates often do not produce good growth. For the oyster, its food requirements may change with age of the larvae.

Cirreped larvae have food requirements that change with species. Balanus balanoides has been reared successfully on diatoms (Skeletonema, Ditylum, Asterionella), but not on a flagellate diet.

In early stages, some larval fishes take phytoplankton. But, larval herring, Clupea harengus, taken at sea the plant material could be from poorly digested plant remains in captured copepods. Food and feeding studies of larval fishes within the coastal habitat have largely been confined to the herring (Sherman and Honey, 1971). Larval herring are selective feeders, feeding on the nauplii of copepods and decopods when the larval herring are small', 2-20 mm. At larger size their prey become more varied in size and species, and they become opportunistic feeders. Table 9-4, from Sherman and Honey (1971) indicates the major taxa forming the diet of larval herring. They suggest that although the number of prey injested from autumn through spring increased for feeding larvae, the decrease in the number of larvae feeding in winter indicates that the low availability of food may be critical to larval survival in winter.

Tychoplankton feed primarily on detritus and plant material on the bottom. In some instances it appears unlikely that their mouth parts could operate efficiently off the bottom. Thus, it is questionable whether these part-time plankters compete for food in the neritic waters at night when they move upward into the water.

9.6 QUANTITATIVE FOOD REQUIREMENTS

The food requirements of zooplankton are not well known. A mean rate of 70^cm ³/Calanus/day of filtration of water is considered about sufficient to cover maintenance requirements. In winter, it might be insufficient, but Raymont (1966) suggests that food might be sought by Calanus rather than just filtering blindly. Acartia, Temora, Pseudocalanus, and perhaps Calanus can feed by a sweeping of their maxilla and increasing the amount of food collected. Animal food may be of special importance during periods of active reproduction which may cease when there is extensive searching for limited food. Raymont (1966) states that in inshore water phytoplankton is generally more than sufficient for zooplankton growth and reproduction during

Table 9-3. Feeding types of major zooplankton species

Species	Herbivorous	Carnivorous	Omnivorous
Acartia clausi	xx		x
A. tonsa	xx		x
Calanus finmarchicus	xx		x
Centropages hamatus		xx	
C. -typicus		xx	
Pseudocalanus minutus	xx		
Temora longicornis	xx		x
Labidocera aestiva		xx	
Tortanus discaudatus		xx	
Sagitta elegans		xx	
Oithona brevicornis	xx		
Oithona similis	xx		

xx = main food type x = secondary but often necessary food sources

Table 9-4 Seasonal variations in the zooplankton food of larval herring in central Maine coastal waters. The number of larvae feeding on each of the major zooplankton taxa and copepod species are listed by season [N = number of larvae with food] from Sherman and Honey (1971)

Major taxa	Autumn N = 55 Number	Percent	Winter N = 73 Number	Percent	Spring[1] N = 145 Number	Percent	Total N = 273 Number	Percent
Copepods[2]	44	80	70	96	116	80	230	84
Cirriped larvae	-	–	–	–	97	67	97	36
Crustacean eggs	–	–	7	10	51	3.5	58	21
Tintinnids	-	–	–	–	24	17	24	9
Crustacean nauplii[3]	15	27	4	6	1	<1	20	7
Copepod species:								
Pseudocalanus minutus	-		42	60·0	56	48·3	98	42·6
Oithona	2	4·5	22	31·4	41	35·3	65	28·3
Copepodites	42	95·4	7	10·0	12	10·3	61	26·5
Harpacticoid-cyclopoid sp.	2	4·5	1	1·4	54	46·6	57	24·8
Copepod[4] remains	3	6·8	10	14·3	39	33·6	52	22·6
Acartia sp.[5]	1	2·3	4	5·7	15	12·9	20	8·7
Others[6]	–		6	8·6	8	6·9	14	6·1

[1]) Major taxa present in the spring, but in less than one percent of the feeding larvae were fish eggs, gastropod eggs, isopods, annelid larvae and phytoplankton remains.
[2]) Includes copepodites and copepod remains.
[3]) Includes copepod and decapod nauplii.
[4]) Copepod fragments from which no species determinations could be made.
[5]) Two species were present, *Acartia longiremis* and *A. clausi*.
[6]) Other species included: *Eurytemora herdmani*, *Metridia lucens*, and *Temora longicornis*, each of which occurred in less than 5 percent of the larvae.

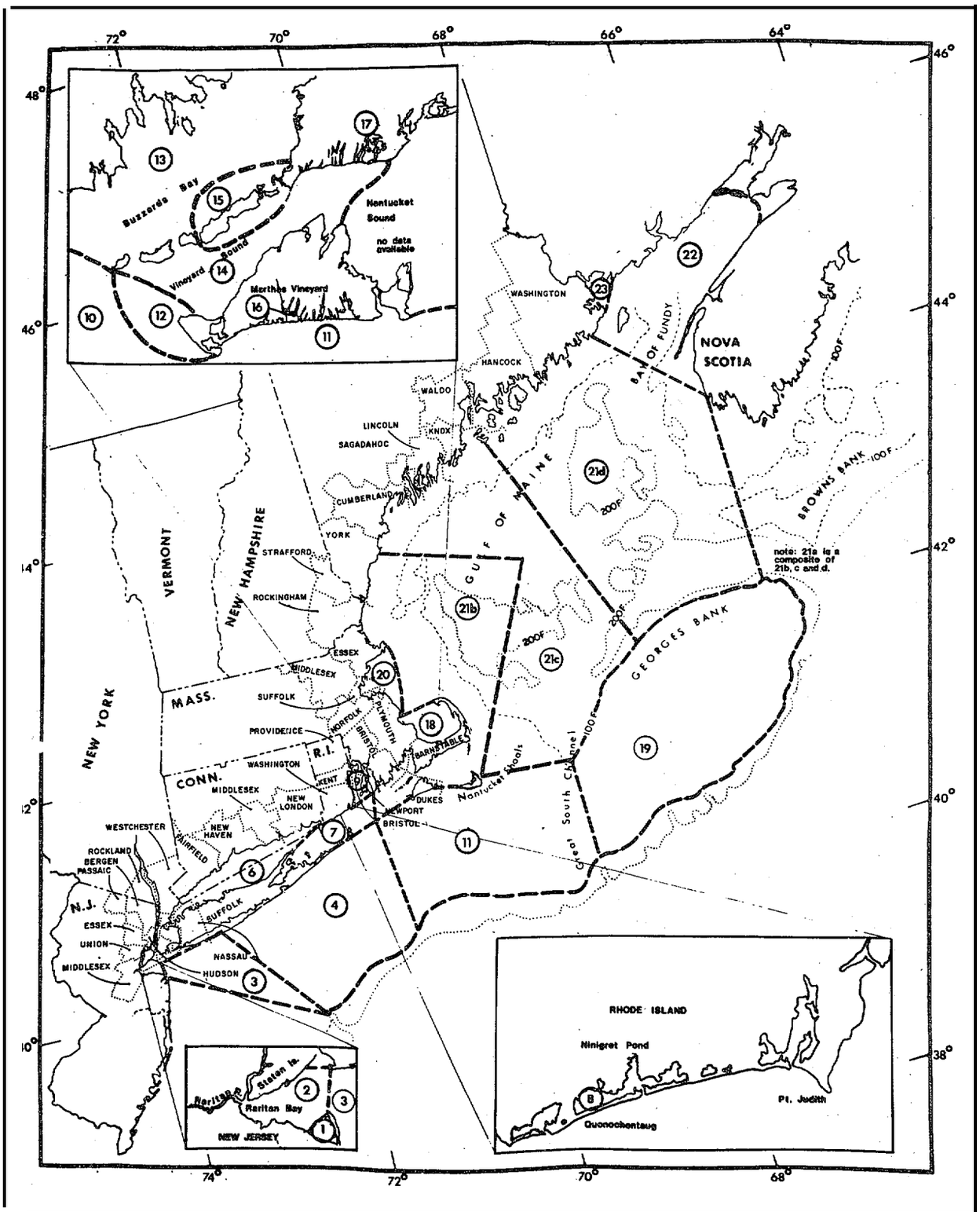
spring and summer. It is also likely to be sufficient for maintenance requirements during winter.

Zooplankton is noted for its large variability but at least some of this variability is only apparent. Large peaks in standing crops occur and these are usually given particular attention by scientists. Often the peaks are short lived (weeks). A considerable change in species composition may occur from one station to the next in the open ocean. Indeed, adjacent bays may have abundances of different species or one bay may have an abundance of plankton and the adjacent bay very little plankton. This would suggest that the presence of zooplankton as forage is very chancy, sometimes leading to hardships in the development of larger predators such as larval and juvenile fishes, perhaps even adults. However, most zooplankton studies consider entire assemblages of species and these usually only in their adult form.

Information given by Fish and Johnson (1937) suggests that coastal zooplankters may provide considerable continuity as forage during the spring through autumn period when their predators, such as juvenile herring (Sherman and Perkins, 1971), are present along the coast. They found that the maxima of different dominant copepods in the Bay of Fundy and the adjacent Gulf of Maine (including the coastal area) occurred at a successively later periods during the summer. Calanus finmarchicus was most abundant in May; Pseudocalanus minutus was most abundant in June; and Oithona similis was most abundant in August. Consider also that the maxima of these adults are preceded by maxima of nauplii and early copepodite stages which necessarily are more abundant than the adults. Therefore, a low abundance of an adult copepod is not necessarily evidence of that species unimportance within a plankton community. Rather, it may be indicative of a high mortality during its early larval stages caused by predators which select small prey. Large differences in the population size of plankters occur between summer and winter. One might conclude that the sparsity and dispersion of zooplankters in the winter results in a declining availability of zooplankton forage. However, the distribution of a predator, such as larval herring, is also sparse and dispersed during winter probably reducing intraspecific competition.

9.7 COMPARATIVE TABLES OF ZOOPLANKTON DISTRIBUTION AND ABUNDANCE IN COASTAL AND ESTUARINE WATERS

The tables following which summarize existing zooplankton data along the Atlantic Coast from the Bay of Fundy to Sandy Hook augment and include similar tabular data collected by Jeffries and Johnson (1973) for the area from Cape Hatteras to Nantucket Shoals. Tables 9-5 through 9-29 show seasonal abundance and densities for each of the geographic areas (Figure 9-4) from which zooplankton has been



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 9-4	Geographic Locations of Zooplankton Collection

collected throughout the region. The tables represent an attempt to bring together data collected over a long period of time by many investigators using a variety of sampling gear and protocols. In some cases data has been transformed; in other cases it has been estimated or interpolated from graphical displays. Therefore, some error is unavoidable. The legend for Tables 9-5 through 9-29 follows. Refer to Table 9-30 and Figure 9-4 for referenced data areas.

LEGEND FOR TABLES 9-5 THROUGH 9-29

For a given month, the following symbols are used in Tables 9-5 through 9-29. (--) No data available; (+) Catches have been recorded but the population is not at its maximum, or, presence has only been mentioned for that month with no specific reference to relative abundance; (o) The area was sampled during the month, but the species was not found; (max) indicates population was at a maximum but no numbers were available. Numbers signify the yearly maximum where recorded in the literature. Standing crops of zooplankton in various areas of the Sandy Hook, New Jersey region is given in this series of tables. Numbers in parentheses following each location refer to geographic areas shown in Figure 9-4.

Table 9 - 5 Sandy Hook)

	J	F	M	A	M	J	J	A	S	O	N	D	
Obelia spp	-	-	-	-			-	-	-	-	-	-	#/m^3
Synchaeta littoralis	-	-	-	-	184,000		-	-	-	-	-	-	#/m^3
Littorina spp eggs	-	-	-	-	535 Max	Max	-	-	-	-	1	-	#/m^3
Gastropod larvae	-	-	-	-	9,300		-	-	-	-	-	-	#/m^3
Pelecypod larvae &	-	-	-	-	28,700		-	-	-	-	-	-	#/m^3
Polychaete larvae	-	-	-	-	47,500		-	-	-	-	-	-	#/m^3
Evadne nordmanni	⊙	⊙	+	+	8	+	+	+	⊙	⊙	⊙	⊙	# m^3
Penilia avirostris	Present but no monthly occurrence data available. Average #/m^3 15												
Podon leuckarti	"	"	"	"	"		"	"	Average #/m^3 90				
Podon polyphemoides	0	0	+	+	2,300		+	+	0	0	0	0	#/m^3
Acartia clausi	+	300	+	+	+	+	⊙	⊙	⊙	⊙	⊙	+	#/m^3
Acartia tonsa	+	0	0	0	+	33,000	+	23,000	+	+	+	+	#/m^3
Calanus finmarchicus	⊙	⊙	⊙	⊙	8	0	⊙	⊙	⊙	⊙	⊙	⊙	#/m^3
Centropages hamatus	⊙	⊙	⊙	⊙	⊙	+	⊙	⊙	⊙	⊙	⊙	⊙	
Centropages typicus	⊙	⊙	⊙	⊙	⊙	+	⊙	⊙	⊙	⊙	8	+	#/m^3

Table 9-5 Sandy Hook (cent' d)

	J	F	M	A	M	J	J	A	S	O	N	D	
Eurytemora affinis	+	+	+	+	1,610	+	0	0	0	0	0	+	#/m^3
Eurytemora americana	0	+	+	Max		0	0	0	0	0	0	0	
Eurytemora herdmani	Present, but no monthly occurrence data available												
Labidocera aestiva	0	0	0	0	0	0	0	0	0	37	0	0	#/m^3
Paracalanus crassirostris	0	0	+	Max	0	+	+	279	+	+	0	0	#/m^3
Pseudocalanus minutus		Max	-	Max	-	-	-	-	-				
Pseudodioptomus coronatus	+	+	+	0	10,500	0		+	606	+	+		#/m^3
Temora longicornis	0	+	+	81	+	+	+	0	0	0	0	0	#/m^3
Tortanus discaudatus	Present, but no monthly occurrence data available												
Tachidius littorals		+	+	+	13,000	+	0	0	0	+			#/m^3
Oithona brevicornis	Presnet, but no monthly occurrence data available												
Oithona similis	+	Max	+	+	400		0	0	+	+	+	+	#/m^3
Balanus sp. larvae		-	-		4,300		Max	Max	-		+		#/m^3
Crangon septemspinosus larvae	Present, but no monthly occurrence data available. Average #/m^3 31.												

Table 9-6 Raritan Bay 2

	J	F	M	A	M	J	J	A	S	O	N	D	
Rotifer spp	-	-	⊙	⊙	130,000	+	+	+	+	-	-	-	#/m^3
Mya arenaria larvae	-	-	-	-	-	79,300	-	-	-	-	-	-	#/m^3
Pelecypod larvae and eggs	-	-	-	-	+	79,300	+	+	15,800	⊙	⊙	⊙	#/m^3
Polychaete larvae	⊙	⊙	⊙	⊙	+	+	14,700	+	+	+	+	⊙	#/m^3
Acartia clausi	+	+	+	+	+	100,000	+	-	-	-	+	-	#/m^3
Acartia tonsa	+	+	+	+	+	62,500	+	60,600	+	+	+	+	#/m^3
Centropages hamatus	+	+	+	+	+	max	max	max	max	0	0	+	
Centropages typicus	0	0	0	0	0	max	max	max	max	+	+	+	
Eurytemora affinis	+	+	+	+	150,000	+	12,000	-	-	-	-	+	#/m^3
Eurytemora americana	+	+	+	+	+	-	-	-	-	-	-	-	
Labidocera aestiva	Present, but no monthly occurrence data available ----------												
Paracalanus crassirostris	+	+	+	0	0	max	max	max	max	+	+	+	
Pseudocalanus minutus	max	max	max	+	+	+	0	0	0	0	0	+	
Temora longicornus	max	max	max	+	+	+	+	+	+	0	0	+	
Oithona similis	+	+	max	max	max	max	+	+	+	+	+	+	
Balanus sp. larvae	⊙	⊙	⊙	⊙	+	+	+	+	7,600	0	⊙	⊙	#/m^3

Table 9-6 (cont.)

	J	F	M	A	M	J	J	A	S	O	N	D
Cancer spp. larvae	-	-	+	O	0	0	0	0	0	+	+	+
Carcinus maenas larvae			0	0	0	+	+	0	0			
Crangon septemspinosus larvae			+	0	+	0	0	+	+			
Neopanope texana sayi larvae			0	0	0	0	+	+	0			
Pagurus longicarpus larvae			0	0	0	0	0	+	+			

Table 9-7 New York Bight 3

	J	F	M	A	M	J	J	A	S	O	N	D	
Pelecypod larvae and eggs	+	+	+	+	+	+	+	+	8.400	+	+	+	#/m^3
Polychaete larvae	+	+	+	2,000	+	+	+	+	+	+	+	+	#/m^3
Evadne spp	-	-	-	-	+	+	+	+	+	+	-	-	
Podon spp	-	-	-	-	-	-	23,941	+	-	-	-	-	#/m^3
Acartia clausi	+	+	+	+	+	+	+	+	+	+	+	+	
Acartia tonsa	Present, but no monthly occurrence data available ----------												
Calanus finmarchicus	-	-	+	+	+	+	-	-	-	-	-	-	
Centropages hamatus	+	+	+	+	+	+	9.908	+	+	+	13.999	+	#/m^3
Centropages typicus	-	-	-	-	-	+	+	-	-	-	-	-	
Paracalanus crassirostris and P. parvus	+	+	+	+	+	+	+	max	+	+	21.000	+	#/m^3
Pseudocalanus minutus	+	+	+	2,000	+	+	4.381	+	+	+	+	+	#/m^3
Temora longicornis	+	+	2.500	+	+	+	28,790	+	+	+	+	+	#/m^3
Tortanus discaudatus	+	+	+	+	+	3,711	+	+	+	+	0	+	#/m^3
Oithona brevicornis and O. similis	+	+	+	+	+	49,000	+	+	+	+	+	+	#/m^3
O. brevicornis, O. similis, O.plumifera	+	+	+	+	+	+	2.800	+	+	+	max	+	#/m^3

Table 9-7 (cont.)

	J	F	M	A	M	J	J	A	S	O	N	D
Sagitta elegans	+	+	+	+	max	max	max	+	+	+	+	+
Echinoderm larvae				+				+	+	+	-	-
Salpa Spp								+	+	+	-	-

Table 9-8 Shelf South of Montauk Bay 4

	J	F	M	A	M	J	J	A	S	O	N	D	
Pleurobrachia pileus	—	—	max	—	—	-	O	—	O	—	—	⊙	·· Λ̄
Aglantha digitale	—	O	+	O	+	⊙2	+	-	-	⊙	—	—	cc/m³
Obelia spp	—	—	O	—	-	375	—	—	O	-	-	O	*Λ̄
Clione limacina	—	O	—	O	+	0.1	⊙	-	-	O	—	—	·· Λ̄
Limacina retroversa	—	+	-	+	⊙7	+	+	—	—	+	—	—	cc/m³
Tomopteris helgolandica	Present, but no monthly data available												
Acartia tonsa	-	-	-	-	—	—	-	-	+	-	—	-	
Calanus finmarchicus	+	-	—	+	+	+	+	+	+	+	+	+	
Candacia armata	-	-	⊙	-	-	-	+	-	+	-	—	+	
Centropages hamatus	-	-	+	-	-	—	—	+	-	—	-	-	
Centropages typicus	+	-	-	+	—	+	+	—	1.30⊙	+	+	4⊙⊙	#/m³
Labidocera aestiva	—	—	—	-	—	—	-	—	-	-	-	+	
Metridia lucens	-	+	+	⊙2	+	+	+	-	+	+	—	+	#/m³
Paracalanus parvus	+	+	+	—	+	+	+	-	+	+	-	+	
Pseudocalanus minutus	-	—	+	-	-	-	5,451	—	-	-	-	+	#/m³

Table 9-8 (cont.)

	J	F	M	A	M	J	J	A	S	O	N	D	
Temora longicornis	—	-	+	-	-	—	+	+	+	-	—	-	
Oithona similis	—	-	-	—	—	-	+	-	+	—	—	250	*Λ
Oithona atlantica	-	—	⊙	—	—	—	⊙	—	+	—	—	+	
Parathemisto gaudi chaudi	+	⊙1	+	+	+	+	+	+	+	+	+	+	cc/m^3
Meganyctiphanes norvegica	O	+	O	+	+	max	+	O	+	+	⊙	O	
Thysanoessa inermis	—	—	O	—	—	—	+	-	+	—	—	⊙	
Thysanoessa longicaudata	—	—	⊙	-	—	-	+	—	+	—	—	O	
Sagitta elegans	+	+	+	+	+	+	+	÷	+	+	+	÷	
Sagitta serratodentata	—	max	+	+	+	+	+	—	+	+	—	39	#/m^3
Salpa fusiformis	-	-	0	-	-	-	max	-	0	-	-	0	
Oikopleura labradoriensis	-	0	-	+	0	0.1	0	-	-	0	-	-	#/m^3

Table 9-9 Long Island Sound ≤)

	J	F	M	A	M	J	J	A	S	O	N	D	
Rathkea octopunctata	+	O	+	+	+	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
Rotifer spp.	O	+	+	7.⊙⊙⊙	+	+	⊙	⊙	⊙	O	+	O	# ⊐^{3}
Gastropod larvae	+	⊙	⊙	+	+	+	1.8⊙⊙	≯9⊙⊙	+	+	+	+	#/m^3
Ostrea virginica larvae	⊙	⊙	⊙	⊙	⊙	+	33.≡6⊙	35.≡40	+	⊙	⊙	⊙	*Λ̃
Pelecypod larvae eggs	⊙	÷	+	+	+	+	81.3⊙⊙	+	+	+	+	⊙	*Λ̃
Autolytus spp	⊙	⊙	+	+	+	+	⊙	⊙	+	+	⊙	⊙	
Tomopteris spp	⊙	⊙	+	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
Polychaete larvae	+	+	+	+	÷	+	1.90⊙	+	+	+	+	+	#/m^3
Evadne nordmanni	⊙	⊙	O	+	+	6.⊙⊙	+	+	⊙	⊙	⊙	O	#/m^3
Penilia avirostris	⊙	⊙	⊙	⊙	⊙	⊙	÷	+	11,⊙⊙	+	⊙	O	#/m^3
Podon intermedius	⊙	⊙	⊙	⊙	⊙	+	+	⊙	⊙	+	⊙	⊙	
Podon leuckarti	⊙	⊙	⊙	⊙	⊙	+	⊙	⊙	⊙	⊙	⊙	⊙	
Podon polyphemoides	0	0	0	0	+	+	30,000	0	0	0	0	0	#/m^3
Acartia clausi	+	+	+	70,000	83,000	+	+	0	0	0	+	+	#/m^3
Acartia tonsa	÷	+	+	+	+	+	+	+	25,⊙⊙	+	÷	+	#/m^3

Table 9- 9 (cont.)

	J	F	M	A	M	J	J	A	S	O	N	D	
Calanus f inmarchicus	+		+	+	+	+					+		
Candacia armata	0	0	0	0	0	0	0	0	0	0	+	+	
Centropages hamatus	+	+	+	+	+	+	+				+	+	
Centropages typicus				+		+				+		+	
Eurytemora Sp	0	0	0	0	0	0	0	0	0	0	+	0	
Labidocera aestiva						+	+	+	max				
Metridia lucens	0	0	0	+	0	0	0	0	0	0	+	0	
Paracalanus crassirostris	+	+	+	+	+	+	+	66,000	+	+	+	+	#/m^3
Paracalanus parvus	0	0	0	0	+	+	+	0	0	0	+	0	
Pseudocalanus minutus	+	+	+	3,800	+	+	+				+	+	#/m^3
Temora longicornis	+		+	+	+	61,000	+			+	+		#/m^3
Tortanus discaudatus	+			+	+	+	+			+	+		
Microstella norvegica	0	0	0	+	0	0	0	0	0	0	0	0	
Oithona brevicornis and O. similis	+	+	+	+	+	+	+	+	29,000	+	+	+	#/m^3
Oithona Sp	+	+	+	+	+	+	+	+	46,000	+	+	+	#/m^3

Table 9- 9 (cont.

	J	F	M	A	M	J	J	A	S	O	N	D	
Balanus sp. larvae	500	+	+	+	+	0	0	0	0	0	0	0	#/m^3
Callinectes sapudis	⊙	⊙	⊙	⊙	⊙	+	+	+	+	+	⊙	⊙	
Cancer irroratus larvae	⊙	⊙	⊙	⊙	+	+	+	+	⊙	+	⊙	⊙	
Crangon septemspinosus larvae	⊙	⊙	⊙	+	+	+	+	+	+	+	+	+	
Hippolyte spp. larvae	⊙	⊙	+	+	+	+	+	+	+	⊙	⊙	⊙	
Libinia spp.	⊙	⊙	⊙	⊙	⊙	0	+	+	+	+	⊙	0	
Neopanope texana sayi larvae	⊙	⊙	⊙	⊙	⊙	0	+	+	+	+	⊙	⊙	
Pinnixia spp. larvae	⊙	⊙	⊙	⊙	⊙	⊙	+	+	+	+	⊙	⊙	
Pinnotheres maculatus larvae	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	+	⊙	⊙	
Upogebia spp. larvae	⊙	⊙	⊙	⊙	⊙	⊙	+	+	+	+	⊙	⊙	
Squilla empusa	⊙	⊙	⊙	⊙	⊙	0	+	+	200	+	⊙	0	#/m^3
Cyphonautes larvae (bryozoans)	0	0	+	+	0	125	0	+	+	165	0	0	#/m^3
Sagitta elegans	+	+	+	+	+	+	+	—	—	+	+	+	
Echinoderm larvae	⊙	⊙	⊙	⊙	⊙	+	+	+	+	⊙	⊙	⊙	
Fritillaria spp	⊙	⊙	⊙	+	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
Oikopleura dioica	⊙	⊙	⊙	⊙	⊙	⊙	⊙	+	5,500	+	+	⊙	#/m^3

Table 9-10 Block Island Sound (7)

	J	F	M	A	M	J	J	A	SO	N	D	
Mnemiopsis leidyi	0	0	0	0	0	0	+	+	+	+	0	0	
Aglantha digitale	0	0	0	0	0	+	0	0	0	0	0	0	
Obelia spp	0	+	+	+	581	+	+	+	+	+	+	+	#/m³
Clione limacina	0	0	0	0	+	0	0	0	0	0	0	0	
Limacina retroversa	+	0	0	0	+	0	0	0	0	0	0	0	
Gastropod eggs & larvae	29/+	+/+	+/+	+/+	+/+	0/400	0/+	0/71 1	0/+	0/+	0/+	+/+	#/m³
Pelecypod larvae & eggs	+	+	+	+	+	4000	+	+	+	7000	+	+	#/m³
Tomopteris spp	+	+	0	+	0	0	0	+	0	"0	0	0	
Polychaete larvae	0	+	+	+	300	+	+	+	+	+	+	+	#/m³
Evadne nordmanni	+	0	0	+	+	2500	+	2183	+	+	+	+	
Evadne spinifera	0	0	0	0	0	0	+	527	+	0	0	0	#/m³
Penilia avirostris	0	0	0	0	0	0	+	10179	+	+	+	0	#/m³
Podon intermedius	(	3	0	0	0	+	+	1484	+	+	+	0	#/m³
Podon leuckarti	0	0	+	+	+	2000	+	0	0	0	0	0	#/m³
Podon polyphemoides	0	0	0	0	0	+	296	+	0	0	0	0	#/m³

Table 9-10 Block sland Sound (cont'd)

	J	F	M	A	M	J	J	A	S	O	N	D	
Acartia clausi	+	+	+	+	+	+	+	+	O	+	+	+	
Acartia tonsa	+	+	+	0	0	+	+	2100	+	+	+	+	#/m^3
Calanus finmarchicus	+	+	+	+	+	127	+	+	+	+	+	+	#/m^3
Candacia armata	⊙	⊙	⊙	⊙	⊙	⊙	O	+	+	+	+	+	
Centropages hamatus	+	+	+	+	+	6:112	+	+	+	+	+	+	#/m^3
Centropages typicus	15⊙⊙	+	+	+	+	+	+	+	⊙25	+	50	+	#/m^3
Eurytemora americana	⊙	⊙	⊙	+	+	⊙	+	⊙	⊙	⊙	⊙	⊙	
Eurytemora herdmani	Present, but no monthly occurrence data available												
Eurytemora spp	⊙	⊙	⊙	+	+	+	43 *	+	⊙	⊙	⊙	⊙	#/m^3
Labidocera aestiva	+	⊙	0	0	0	+	+	8	+	+	+	+	#/m^3
Metridia lucens	⊙	⊙	⊙	⊙	+	23	+	+	⊙	+	⊙	+	#/m^3
Paracalanus crassirostris	+	+	0	+	+	+	+	+	+	631	+	3000	#/m^3
Paracalanus parvus	+	+	+	⊙	⊙	⊙	+	95⊙⊙	+	+	+	+	#/m^3
Pseudocalanus minutus	1200	Max	+	1700	+	+	+	+	+	+	+	+	#/m^3

Table 9-10 Block Island Sound (cent' d)

	J	F	M	A	M	J	J	A	S	O	N	D	
Pseudodi optomus coronatus	+	0	0	0	0	0	0	0	+	2	0	+	#/m^3
Temora 1 ongi cornis	+	+	+	+	+	1600	+	+	+	+	+	+	#/m^3
To rtanus discaudatus	+	+	+	+	+	373	+	+	+	i·	0	0	#/m^3
Oi thona brevi cornis	+	+	+	14	+	+	+	+	+	+	+	·l·	#/m^3
Oithona similis	+	+	+	+	+	·l·	5000	+	+	+	+	+	#/m^3
Oithona sp.	+	+	o	55	+	0	0	+	+	0	0	+	#/m^3
Balanus sp. larvae	22	+	+	29	+	+	0	o	0	0	0	+	#/m^3
Callinectes sapudis	0	0	0	0	0	+	+	+	+	+	0	0	
Cancer irroratus larvae	O	0	0	+	·l·	68	+	i·	+	+	0	0	#/m^3
Carcinus maenas larvae	O	0	0	o	+ - l -		+	0	0	0	0	0	
Crangon septem-spinosus larvae	O	0	0	+	19	+	+	·l·	i·	11	i·	+	#/m^3
Neopanope texana sayi larvae	0	0	0	o	0	0	+	21	0	0	0	0	#/m^3
Pagurus spp larvae	o	0	0	0	+	34	+	i·	+	+	+	0	#/m^3
Pinnixia chaetopter-ana larvae	0	0	0	0	0	0	0	25	+	i·	0	0	#/m^3

Table 9-10 Block Island Sound (cent'd)

	J	F	M	A	M	J	J	A	sO	N	D	
Pinnotheres maculatus larvae	o	0	0	0	0	0	72	+	+	+	o	+	#/m^3
Polyonyx macrocheles larvae	0	0	0	0	0	0	0	0	0	0	+	+	
Upogebia spp larvae	0	0	0	0	i·	0	+	77	0	0	o	o	#/m^3
Squilla empusa	0	0	0	0	0	0	0	+	+	+	0	0	
Cyphonautes larvae (bryozoans)	0	+	+	+	+	300	300	+	i·	+	0	+	#/m^3
Sagitta elegans	+	+	+	i·	51	+	·l·	+	+	+	+	·l·	#/m^3
Sagitta serratodentata	o	0	0	0	o	0	0	+	0	+	o	+	
Echinoderm larvae	0	o	+	-	l -	+	+	0	0	·l·	+	0	
Doliolum nationalism	0	0	0	0	0	0	+	7500	i·	+	+	0	#/m^3
Frittillaria spp	0	+	200	260	+	o	0	0	0	0	o	0	#/m^3
Oikopleura labradoriensis	0	0	0	+	+	1·	65	0	0	0	0	0	#/m^3
Oikopleura dioica	0	0	0	0	0	0	3500	+	+	+	+	0	#/m^3
Oikopleura spp	0	0	0	+	0	0	+	+	113	+	+	0	#/m^3

Table 9-11 Rhode Island Salt Ponds (8)

	J	F	M	A	M	J	J	A	S	O	N	D	
Mnemiopsis leidyi	0	0	0	0	0	0	0	0	Max	Max	+	+	
Obelia spp	⊙	⊙	+	+	+	+	⊙	⊙	+	+	+	+	
Aurelia aurita	⊙	⊙	⊙	⊙	+	⊙	⊙	+	+	⊙	⊙	⊙	
Dactylometra quinquecirrha	⊙	⊙	⊙	⊙	+	⊙	⊙	+	+	⊙	⊙	⊙	
Synchaeta spp	⊙	⊙	+	+	+	+	⊙	⊙	⊙	⊙	⊙	⊙	
Gastropod larvae	⊙	⊙	+	+	+	+	4,010,000	+	+	+	+	+	#/m^3
Mercenaria mercenaria larvae	0	0	0	0	0	+	+	+	22,700	0	0	0	#/m^3
Mya arenaria larvae	⊙	⊙	+	+	+	+	+	+	+	+	+	+	
Mytilus spp larvae	0	⊙	+	+	+	+	+	+	+	+	+	+	
Ostrea virginica larvae	⊙	⊙	⊙	⊙	⊙	+	+	27,360	+	+	+	+	#/m^3
Pelecypod larvae & eggs	⊙	⊙	+	+	+	+	+	27,360	22,700	+	+	+	#/m^3
Polydora spp.	-1-0	⊙	+	-1-0	+	+	+	+	+	+	+	+	
Nereis spp	-1-0	⊙	0	-1-0	0	+	+	+	+	0	0	0	
Polychaete & larvae	0	0	+	+	+	126,500	+	+	+	+	+	+	#/m^3

Table 9-Ii Rhode Island Salt Ponds (cent'd)

	J	F	M	A	M	J	J	A	SO	N	D	
Evadne nordmanni	0	0	+	+	-	+	0	0	0	0	0	0	
Evadne spinifera	0	0	0	0	0	+	+	+	+	0	0	0	
Podon polyphemoides	0	0	+	+	+	+	++	+	+	0	0	0	
Acartia tonsa		-	-			+	10,050	+	+				#/m^3
Calanus finmarchicus	Present, but no monthly data available												
Centropages hamatus	+	+	-	-		+	+	+	+				
Eurytemora affinis	+	0	0	0	0	+	+	+	+	+	+	+	
Eurytemora americana	0	0	0	0	0	+	+	+	+	0	0	0	
Paracalanus crassirostris	+	+	+	0	0	0	0	+	+	+	+	+	
Pseudodioptomus coronatus	+	+	+	0	0	+	+	+	+	+	+	+	
Temora longicornis	+	+	-	-									
Tortanus discaudatus	Present, but no monthly occurence data available												
Tortanus setacaudatus	0	"o	+	+	+	+	+	0	0	0	0	0	
Oithona brevicornis	53,200		+	+	0	+	+	10,000	+	+	+	+	+	#/m^3

Table 9-11 Rhode Island Salt Ponds (cent'd)

	J	F	M	A	M	J	J	A	SO	N	D
Balanus sp. larvae	+	+	+	+	+	+	+	+	0	0	+
Cancer irroratus larvae	0	0	0	0	0	+	0	0	0	0	0	0
Carcinus maenas larvae	0	0	+	0	0	0	0	0	0	0	0	0
Crangon septem-spinosus larvae	0	0	0	0	0	+	+	0	0	0	0	0
Neopanope texana sayi larvae	0	0	0	0	0	+	+	+	0	0	0	0

Table 9-12 Narragansett Bay (9)

			M										
Mnemiopsis leidyi	0	0	⊙	⊙	⊙	0	0	+	+	+	+	0	
Obelia spp.	⊙	+	+	+	72	+	+	+	+	+	+	⊙	#/m^3
Rathkea octopunctata	⊙	+	125	+	⊙	⊙	⊙	⊙	0	⊙	⊙	⊙	#/m^3
Synchaeta spp.	⊙	⊙	⊙	+	2⊙⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	#/m^3
Littorina spp eggs	+	+	20⊙	+	+	+	⊙	⊙	⊙	⊙	⊙	⊙	#/m^3
Gastropod eggs & larvae	+/+	+/+	+/+	1214/+	+/1531	+/+	0/5297	0/+	0/+	+/+	+/+	+/0	#/m^3
Pelecypod larvae & eggs	+	+	+	+	+	+	+	+	+	+	1400	+	#/m^3
Tomopteris spp	⊙	⊙	+	⊙	⊙	0	⊙	⊙	⊙	⊙	⊙	+	#/m^3
Polychaete larvae	+	+	+	+	Max	+	Max	+	+	+	1300	+	#/m^3
Evadne nordmanni	0	0	0	+	1438	+	2050	+	+	+	+	+	#/m^3
Penilia avirostris	⊙	⊙	⊙	⊙	⊙	⊙	+	6289	+	+	+	⊙	#/m^3
Podon intermedius	0	⊙	⊙	⊙	⊙	⊙	40⊙	+	+	186	+	+	# m^3
Podon leuckarti	⊙	⊙	⊙	⊙	8⊙	+	⊙	⊙	⊙	⊙	⊙	⊙	# m^3
Podon polyphemoides	0	0	0	0	+	3700	3600	+	+	+	+	+	#/m^3

Table 9-,12 Narragansett Bay (cent'd)

	J	F	M	A	M	J	J	A	SO	N	D	
Aca rti a clausi	1400	+	+	+	+	+	+	+	+	+	+	#/m^3
Acarti a tonsa	+	+	+	+	+	+	5000	+	+	4000	+	#/m^3
Calanus finmarchicus	+	+	+	0	4	+	+	+	0	0	+	#/m^3
Centropages hamatus	+	+	-	1 -	+	400	+	+	+	+	+	#/m^3
Centropages typi cus	+	+	+	3	o	+	+	+	+	130	+	#/m^3
Eurytemora affi nis	+	0	0	0	0	0	+	o	0	0	0	
Eurytemora americana	+	+	+	+	0	0	0	0	0	0	0	
Eurytemora herdmani	o	0	0	2200	0	1250	+	+	0	0	0	#/m^3
Eurytemora s pp	0	0	+	+	+	+	658	o	0	0	0	#/m^3
Labidocera a es ti va	0	0	0	0	0	+	+	6	+	+	+	
Metridia lucens	0	+	0	0	0	0	0	0	0	o	0	
Paracalanus crassirostris	0	0	0	0	+	0	+	+	8200	+	+	+	#/m^3
Paracalanus parvus	+	+	0	0	0	+	+	+	+	500	+	+	#/m^3
Pseudocalanus mi nutus	+	+	-1-	1500	+	+	700	+	+	+	+	#/m^3
Pseudodioptomus coronatus	+	+	+	+	+	+	7500	+	+	260	+	+	#/m^3

Table 9-12 Narragansett Bay (cont'd)

	J	F	M	A	M	J	J	A	S	O	N	D	
Temora longicornis	+	+	+	2⊙⊙	+	+	+	+	+	O	+	+	#/m^3
Tortanus discaudatus	+	+	+	+	25⊙	+	+	+	+	+	+	+	#/m^3
Tortanus setacaudatus	Present, but no monthly occurrence data available												
Microstella norvegica	+	+	+	1000	+	+	+	+	+	+	+	+	#/m^3
Tachidius littoralis	⊙	⊙	+	+	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	
Oithona brevicornis	+	+	+	+	+	+	+	+	+	13000	+	+	#/m^3
Oithona similis	+	+	+	+	+	+	117	+	+	+	+	+	#/m^3
Oithona sp.	+	+	+	+	+	+	+	55⊙⊙	+	220⊙⊙	+	+	#/m^3
Balanus sp. larvae	1166	+	+	+	+	+	+	+	+	+	+	+	#/m^3
Mysidacea	+	+	+	+	Max	+	0	0	+	0	+	0	
Hyperia galba	⊙	⊙	⊙	+	+	+	⊙	⊙	⊙	⊙	⊙	⊙	
Cancer spp. larvae	⊙	⊙	⊙	+	+	+	15	13	+	+	⊙	⊙	#/m^3
Carcinus maenas larvae	0	0	0	0	+	+	+	45	+	⊙	⊙	⊙	#/m^3
Crangon septemspinosus larvae	0	0	+	+	93	+	+	+	48	+	+	0	#/m^3

Table 9-12 Narragansett Bay (cont'd

	J	F	M	A	M	J	J	A	S	O	N	D	
Hippolyte zostericola larvae	-	-	0	0	0	0	+	0	+	-	-	-	
Libinia spp	⊙	⊙	⊙	⊙	⊙	+	+	175	+	⊙	⊙	⊙	#/m^3
Neopanope texara sayi larvae	0	0	0	0	0	+	+	430	+	0	0	0	#/m^3
Pagarus spp. larvae	⊙	⊙	⊙	⊙	+	+	1⊙	50	+	+	0	0	#/m^3
Palaemonetes vulgaris	-	-	⊙	⊙	⊙	⊙	⊙	⊙	+	-	—	—	
Pinnixia chaetopterana larvae	0	0	0	0	0	+	511	+	+	+	0	0	#/m^3
Pinnotheres maculatus larvae	0	⊙	⊙	⊙	⊙	⊙	2368	+	+	+	⊙	⊙	#/m^3
Polyonyx macrocheles larvae	⊙	⊙	⊙	⊙	⊙	0	15⊙	+	+	+	⊙	⊙	#/m^3
Upogebia spp larvae	⊙	⊙	⊙	⊙	⊙	⊙	≤4⊙	+	+	⊙	⊙	0	#/m^3
Squilla empusa	-	-	0	0	0	0	+	0	0	-	-	-	#/m^3
Cyphonautus larvae (Bryozoans)	+	+	+	70	+	+	33	+	+	+	+	+	#/m^3
Sagitta elegans	+	+	+	3⊙	+	+	+	0	+	+	+	+	#/m^3
Oikopleura dioica	0	0	0	0	0	0	110	+	+	+	0	0	#/m^3
Oikopleura spp	0	0	0	0	0	0	+	11,600	+	+	+	0	#/m^3

Table 9-13 Rhode Island Sound (10)

	J	F	M	A	M	J	J	A	S	O	N	D	
Acartia tonsa				+	+	+	1-	+	+	+	+	+	
Calanus finmarchicus	+	+	+	+	+	+	16,712	+	+	+	+	+	#/m^3
Centropages hamatus		-	-		+	max	max		max	"-		max	
Centropages typicus							+	max	+	+	+	+	
Labidocera aestiva							-			+	+	+	
Paracalanus parvus		-	-			+	+	max	+	- "	-		
Pseudocalanus minutus	+	i	- -	l -	+	max	max	max	+	+	+		
Temora longicornis	Present, but no monthly occurrence data available ----------												
Sagitta elegans	Present, but no month ly occurrence data available ----------												
Sagitta enflata	-	-						- 1	- -		+	+	-
Sagitta serratodentata		-	-					+	+	+	+	+	

Table 9- 14 Shelf South of Cape Cod (11)

	J	F	M	A	M	J	J	A	S	O	N	D	
Pleurobrachia pileus							+						
Aglantha digitale							+						
Limacina re trovers a	0	+	+	1	325	+	+	+	+	+	0	0	cc/20 min. tow
Acartia tonsa	Present, but no month ly occurrence data available ----------												
Calanus f inmarchicus		+	+	+	+	+	max						
Centropages hamatus	Present, but no month ly occurrence data available ----------												
Centropages typi cus		+	+	+	+	+	max						
Metridia lucens							+						
Pseudocalanus minutus	Present, but no monthly occurrence data available ----------												
Temora longicornus							1						
Parathemisto gaudichaudii							+	+					
Thysanoessa inermis								+					
Sagitta elegans		+	+	+	+	+	+						
Sagitta serratodentata							+						
Salpa fusiformis	-						--5,000--						cc/20 min. tow
Doliolus spp							+						#/m^3

Table 9-15 Gay Head - Cuttyhunk (12)

	M	A	M	J	J	A	S	O	N	D	
Acartia tonsa	-	-	+	+	+	+	+	+	+	+	
Calanus finmarchicus	-	-	-	-	+	529	+	-	-	-	#/m^3
Centropages hamatus	-	-	-	+	max	max	-	+	-	-	+
Centropages typicus	-	-	-	-	-	+	max	+	+	+	+
Labidocera aestiva	-	-	-	-	-	-	-	-	+	+	+
Paracalanus parvus	-	-	-	-	-	+	+	max	+	-	-
Pseudocalanus minutus	+	+	+	+	+	+	+	+	+	+	-
Sagitta elegans	Present, but no monthly occurrence data available----------										

Table 9-16 Buzzards Bay (13)

	J	F	M	A	M	J	J	A	S	O	N	D	
Acartia claus	-	+	-	2,173	-	-	-	+	+	-	-	+	#/m^3
Acartia longiremis	-	+	-	7	-	-	-	⊙	⊙	-	-	⊙	#/m^3
Acartia tonsa	-	+	-	+	+	+	+	+	1,775	+	+	+	#/m^3
Calanus finmarchicus	+	+	+	+	+	8,000	+	+	+	+	+	+	#/30 min.tow
Centropages hamatus	o	+	o	1,440	+	mas	max	+	+	o	o	3,100	#/m^3
Centropages typicus	o	+	o	o	o	o	max	max	+	+	+	62	#/m^3
Eurytemora herdmani	-	+	-	29	-	-	-	+	⊙	-	-	+	#/m^3
Labidocera aestiva	o	o	o	o	o	o	o	225	-	+	-	+	#/m^3
Metridia lucens	-	⊙	-	⊙	-	-	-	⊙	⊙	-	-	⊙	
Paracalanus crassirostris	-	+	-	+	-	-	-	14.6	+	-	-	+	#/m^3
Paracalanus parvus	-	o	-	o	-	-	+	+	+	-	-	36	#/m^3
Pontella meadii	-	o	-	o	-	-	-	+	o	-	-	⊙	
Pseudocalanus minutus	+	75	+	+	-	+	-	+	+	+	⊙	-	#/m^3
Pseudedioptomus coronatus	-	+	-	+	-	-	-	+	+	-	-	63	#/m^3
Temora longicornis	-	+	-	+	-	-	-	+	o	-	-	64	#/m^3
Tortanus discaudatus	-	+	-	+	-	-	-	⊙	⊙	-	-	+	

Table 9-16 Buzzards Bay (cont.)

	J	F	M	A	M	J	J	A	S	O	N	D	
Microstella norvegica	-	+	-	o	-	-	-	o	o	-	-	+	
Oithona brevicornis	-	+	-	+	-	-	-	+	+	-	-	1,260	#.*
Oithona similis	+	+	+	+	+	+	+	+	+	+	+	39⊙	*^
Oithona nana	-	⊙	-	⊙	-	-	-	+	+	—	—	⊙	
Sagitta elegans	+	+	+	+	+	+	+	+	+	+	+	+	

Table 9-17 Vinyard Sound (14)

	J	F	M	A	M	J	J	A	S	O	N	D	
Acartia tonsa	-	-	-	+	+	+	max	+	+	max	+	+	
Calanus finmarchicus	-	-	-	-	+	+	8,000	+	-	-	-	+	#/30 min.tow
Centropages hamatus	-	max	+	+	+	max	max	+	+	+	+	+	
Centropages typicus	+	+	+	+	+	+	max	max	+	+	+	max	
Labidocera aestina	-	-	-	-	-	-	+	-	+	+	+	+	
Paracalanus parvus	-	-	-	-	-	+	+	max	+	-	-	-	
Pseudocalanus minutus	+	+	+	+	+	+	+	+	-	+	-	-	
Temora longicornis	+	+	+	+	+	+	+	+	+	+	+	+	
Tortanus discaudatus	+	max	+	+	+	+	+	+	+	+	+	-	
Oithona similis	+	-	-	-	-	-	-	-	+	+	+	+	
Sagitta elegans	+	+	+	+	+	+	+	-	-	-	+	+	

Table 9-18 Woods Hole (15)

	J	F	M	A	M	J	J	A	S	O	N	D
Mnemiopsis leidyi	+	⊙	○	+	+	⊙	○	+	+	+	⊙	○
Pleurobrachia pileus	+	+	+	+	+	⊙	⊙	⊙	⊙	⊙	⊙	+
Aglantha digitale	⊙	⊙	+	+	⊙	⊙	⊙	○	⊙	⊙	⊙	⊙
Obelia spp	+	+	○	+	+	⊙	⊙	+	+	⊙	⊙	+
Aurelia aurita	⊙	○	+	+	+	⊙	⊙	+	⊙	⊙	⊙	⊙
Dactylometra quinquecirrha	⊙	⊙	⊙	+	+	+	⊙	⊙	⊙	⊙	⊙	⊙
Cyanea capillata	—	—	+	+	+	—	—	—	—	—	—	—
Clione limacina	⊙	○	+	+	+	⊙	⊙	⊙	+	⊙	⊙	⊙
Littorian spp. eggs	⊙	⊙	+	max	+	+	+	⊙	⊙	⊙	⊙	⊙
Gastropod larvae	+	+	+	+	+	+	+	+	+	+	+	+
Mercenaria mercenaria larvae	⊙	⊙	⊙	⊙	○	+	+	+	+	+	+	+
Mya arenaria larvae	⊙	⊙	⊙	○	○	⊙	+	+	+	+	+	+
Mytilius spp larvae	⊙	⊙	⊙	○	⊙	+	+	+	+	+	+	+
Autolytus spp	+	+	+	+	+	+	+	+	+	+	+	+
Nereis spp	⊙	⊙	⊙	+	⊙	⊙	○	⊙	+	+	⊙	⊙
Tomopteris helgolandica	+	+	+	+	⊙	⊙	⊙	⊙	⊙	⊙	⊙	+
Polychaete larvae	+	+	+	+	+	+	+	+	+	+	+	+

Table 9-18 Woods Hole (cont.)

	J	F	M	A	M	J	J	A	S	O	N	D	
Evadne nordmanni	+	0	0	0	+	+	+	+	+	+	max	+	
Podon intermedius	o	0	0	0	+	+	+	+	max	max	+	+	
Podon polyphemoideso		0	0	0	0	0	+	·1·	0	0	o	0	
Acartia longiremis	max	+	+	+	+	0	0	0	0	max	max	+	
Acartia tons a				+	+	+	max	+	+	max	·1·	+	
Calanus finmarchicus	-				+	·1·	+	6				+	#/m^3
Centropages hamatus	+	Max	+	+	+	max	max	+	+	+	+	+	
Centropages typicus	+	·t	+	+	+	+	max	max	+	+	+	max	
Eurytemora affinis	+	+	+	0	0	0	0	0	0	0	0	0	
Eurytemora herdmani	+	+	+	·1·	+	+	+	+	0	0	0	0	
Labidocera aestiva							+	+	+	+	+	+	
Metridia lucens	+	0	0	0	0	0	0	0	0	0	0	+	
Paracalanus parvus	0	0	0	0	0	+	+	max	+	+	+	+	
Pontella meadii	0	0	0	0	0	0	+	+	0	0	0	0	
Pseudocalanus minutus	max	+	+	+	+	+	+	·1·	+	+	+	+	
Pseudodioptomus coronatus	+	+	+	+	+	1·	+	+	+	+	+	+	

Table 9-18 Woods Hole (cont.)

	J	F	M	A	M	J	J	A	S	O	N	D
Temora longicornis	+	+	+	+	+	+	+	+	+	+	+	+
Tortanus discaudatus	+	max	+	+	+	+	+	+	+	+	+	+
Microstella norvegica	⊙	⊙	+	+	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
Tachidius brevicornis	+	+	+	+	+	⊙	⊙	⊙	⊙	o	⊙	+
Oithona similis	+	–	–	–	–	–	–	–	+	+	+	+
Balanus sp. larvae	max	+	+	+	+	+	max	+	+	+	o	+
Mysidacea Neomysis americana larvae	+	+	+	+	+	+	+	⊙	⊙	⊙	⊙	+
Parathemisto gaudichaudii	+	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
Thysanoessa inermis	o	o	o	o	+	max	+	⊙	⊙	⊙	o	+
Thysanoessa longicaudata	⊙	o	o	o	+	max	+	o	o	o	o	+
Callinectes sapudis	⊙	o	o	o	o	o	o	+	max	+	o	o
Cancer irroratus and C. borealis	⊙	o	⊙	o	+	+	max	+	+	+	+	⊙
Carcinus maenas larvae	⊙	⊙	⊙	⊙	o	⊙	⊙	+	+	+	+	⊙
Crangon septemspinosus larvae	o	⊙	⊙	⊙	+	+	max	+	+	+	+	+
Hippolyte zostericola larvae	o	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	+	+	+

Table 9-18 - Woods Hole (cent.)

	J	F	M	A	M	J	J	A	S	o	N	D
Libinia spp	o	o	o	0	0	+	max	+	+	+	0	0
Neopanope texana sayi larvae	o	0	0	0	+	+	+	max	+	+	0	0
Pagurus spp larvae "	o	0	0	0	+	max	+	+	max	+	+	0
Palaemonetes vulgaris	0	0	0	0	0	0	+	+	max	+	+	0
Pinnixia chaetopterana and P. sayana larvae	0	0	0	0	0	+	+	+	max	+	0	0
Pinnotheres maculatus larvae	0	0	0	0	0	0	+	+	max	+	0	0
Polyonyx macrocheles 1 arvae	0	0	0	0	0	0	+	+	+	+	0	0
Upogebia spp. larvae	0	0	0	0	0	0	0	+	0	0	0	0
Squilla empusa	o	0	0	0	0	+	+	+	+	0	+	0
Sagitta elegans	+	+	+	+	+	+	+				+	+
Sagitta serratodentata	+	+	o	0	0	0	0	+	0	0	0	0

Table 9-19 Tisbury Great Pond (16)

	J	F	M	A	M	J	J	A	S	O	N	D	
Synchaeta littorals	+	+	+	+	315,(300.		+	+	+	+ o	+	+	#/m³
Gastropod larvae	o	+	+	+	+	37,000 +		+	+	+	+	o	#/m³
Nercenaria mercenaria larvae	o	o	0	0	0	+	+	+	0	0	0	o	
Mya arenaria larvae	o	0	0	+	+	+	+	+	0	0	0	0	
Mytilus larvae	o	0	0	+	+	+	0	0	0	0	0	0	
Ostrea virginica larvae	o	0	0	0	0	15,000	+	+	o	0	0	0	#/m³
Pelecypod Larvae and eggs	o	0	0	+	+	15,000	+	+	+	+	+	+	#/m³
Polychaete larvae	o	+	+	105,000	+	+	+	+	+	+	+	+	#/m³
Podon polyphemoides	o	o	0	0	+	13,000	0	0	0	0	0	o	
Acartia clausi	Present but no monthly data available ----------												
Acartia tonsa	-	-	-	-	-	,	10,050	+	-	-	-	-	#/m³
Centropages hamatus	Present buy "no monthly data available ----------												
Eurytemora affinis	+	+	17,000	+	+	+	+	o	0	0	+	0	#/m³
Paracalanus crassirostris	o	o	+	+	0	0	0	+	0	0	0	0	
Tachidius brevicornis	o	0	+	+	+	+	+	0	0	0	0	0	
Oithona brevicornis	o	0	+	+	+	3,100	+	+	0	0	0	0	#/m³
Balanus sp larvae	+	+	+	+	max	max	+	+	+	0	+	+	

Table 9-20 Falmouth Great Pond (17)

	J	F	M	A	M	J	J	A	S	o	N	D
Mnemiopsis leidyi	0	0	0	0	0	0	+	o	0	0	0	0
Synchaeta spp.	Present but no monthly data available ----------											
Podon polyphemoides	Present but no monthly data available ----------											
Acartia clausi	+	+	+		+	+	+					
Acartia tonsa	Present but no monthly data available ----------											
Centropages hamatus	Present but no monthly data available ----------											

Table 9-21 - Cape Cod Bay (18)

	J	F	M	A	M	J	J	A	SO	N	D	
Acartia clausi		+	-	219	-	-	-	+	+		188	#/m3
Acarti a longiremis		+	-	8	-	-	-	o	0		+	#/m3
Acartia tonsa		+	+				--	661	+		+	#/m3
Cal anus finimarchicus		4 f	-	1,188	-	-	-	+	+		+	#/m3
Centropages hamatus		+	-	+				+	+		988	#/m3
Centropages typi cus		+	-	+				+	+		1,776	#/m3
Eurythemora herdmani	-	+	-	6	-	-	-	+	0		+	#/m3
Labidocera aestiva		0"	-	0	-	-	-	4	0		0	
Metridia lucens		+	-	69	-	-	-	0	+		+	#/m3
Paracalanus crassirostris		+	-	o	-	~	-	+	+		220	#/m3
Paracalanus parvus		o	-	0	-	-	-	+	+		1,118	#/m³
Pseudocalanus minutus		+	-	+				+	+		2.510	#/m3
Pseudodioptomus coronatus		+	-	17	-	-	-	+	+		+	# / m 3
Temora longicornis		- !	- -	+				51	+		+	#/m³
Microstella norvegica		+	-	+	-	-	-	0	0		+	
Oithona brevicornis		+	-	+	-	-	-	+	+		29	#/m³
Oithona similis		+	-	+				+	+		3,818	#/m3
Oithona nana O. plumifera		+	-	5	-	-	-	+	+		+	

Table 9-21 - Cape Cod Bay (18) (cent'd)

	J	F	M	A	M	J	J	A	S	O	N	D	
Tortanus discaudatus	-	+	-	30	-	-	-	+	+	-		+	#/m^3

Table 9-22 Georges Bank (19)

	J	F	M	A	M	J	J	A	S	O	N	D	
Pleuobrachia pileus	-	0	0	0	+	-	-	-	-	-	-	-	
Beroe cucumis	-	0	-	-	0	-	0	-	-	-	-	-	
Aglantha digitale	-	-	+	-	-	-	-	-	-	-	-	-	
Cyanea capillata	-	-	-	-	-	+	+	+	-	-	-	-	
Clione limacina	-	-	+	+	-	-	0	-	-	-	-	-	
Limocina retroversa	0	0	+	0	0	0	0.125	Max	+	0	0	0	cc/30 min tow
Tomopteris catherina	⊙	o	o	o	0	o	o	o	o	o	o	o	
Acartia clausi	+	÷	+	+	1,425	+	-	+	+	+	+	+	$\#/m^2$
Acartia longerimis	-	-	+	863	-	-	-	-	-	-	-	-	$\#/m^2$
Calanus finmarchicus	+	+103,200		+	17,000	800/m^3	+	+	+	+	+	+	$\#/m^2$, $\#/m^3$
Centropages hamatus	—	-	—	⊙	⊙	0.5	-	+	⊙	—	-	—	*^
Centropages typicus	-	+	-	—	-	—	-	—	-	-	-	-	
Euchaeta norvegica	-	+ 7,750		-	-	-	-	-	-	-	-	-	$\#/m^2$
Eurytemora herdmani	-	-	+	+	-	-	-	-	-	-	-	-	
Metridia lucens	+	+	+	⊤	+	280	+	÷	+	+	+	+	$\#/m^3$
Paracalanus parvus	-	5,000	-	+	-	-	-	-	-	-	-	-	$\#/m^2$
Pseudocalanus minutus	+	+	+	+	+	430	⊤	+	4,000	÷	+	+	$\#/m^3$

Table 9-22 -Georges Bank (cent'd)

	J	F	M	A	M	J	J	A	S	O	N	D	
Temora longicornis	-		+	+	+	11.6	+	+	-				#/m^3
Oithona similis					-	1,016	-						#/m^3
Mysidacea	+	-	1.94	+	+	+	-		+				#/m^3
Parathemisto gaqdi- chaudii	(.29 (+	+	- i -	+	+	+	+	+	0.24			+	#/m^3
Meganyctiphanes norvegica	+	+	+	+	+	+	+		0.30				#/m^3
Thysanoessa inermis	+	+	0.21	+	+	+	Max	+	+	-			#/m^3
Thysanoessa longicaudata	-		+	+	+	-	-						
Thysanoessa raschii	Present, but no monthly occurrence data available ----------												
Sagitta elegans	+	+	+	+	+	112	Max	Max	+	+	+	+	#/m^3
Sagitta maxima							+	+	-	-	-	-	
Sagitta enflata									-	f	-	-	- -
Sagitta serratodentata		+	-	+				+	+	-	-	-	
Salpa fusiformis	-	-	-	-	-	-	-		+	-	-	-	
Oikopleura dioica				+									

Table 9-23 Massachusetts Bay (20)

	J	F	M	A	M	J	J	A	S	O	N	D	
Pleurobrachia pileus	+	o	+	Max	0	+	+	+	+	+	+	+	
Beroe cucumis	-	-	-	+			Max	Max		-	+	-	
Aglanthe digitale	-	0	0	0	0	-	Max			+	-	-	
Nanomia cara	Present, but no monthly occurrence data available										-----	----	
Aurelia aurita							Max	Max					
Cyanea capillata	-				-	+	+	+	+	-	-		
Tomopteris catharina	-	+	+	+	0		+	+		0	0	0	
Calanus finmarchicus	Max	Max	+	1,250	+	+	147,000	+	+	+	+	+	#/m^2
Calanus hyperboreus	+	0	0	0							0	0	
Centropages typicus	0	0	0	0					Max	24,450	+	+	#/m^2
Euchaeta norvegica	+	0	0	0								+	
Eurytemora herdmani	-						+					+	
Metridia lucens	+	+	+	+	+		+	+		+	+	+	
Paracalanus parvus									+	24,450	-		#/m^2
Pseudocalanus minutus	+	+	+	+	+	+	+	+	+	+	+	+	
Temora longicornis	0	0	0	0					-	-	0	0	

Table 9-23 -Massachusetts Bay (Cent'd)

	J	F	M	A	M	J	J	A	S	O	N	D
Tortanus discaudatus	O	+	0	0							·1·	+
Balanus sp. larvae			+	+	o	o	-	0	0			
Parathemisto gaudichaudii	+	+	+	+	+	+	0			(Max (+	Max	+
Meganyctiphanes norvegica	-	o	0	0	O	-	- F			0	o	-
Thysanoessa inermis		0	0	0	0	0	+	0		0		
Thysanoessa raschii		0	0	0	0	-	+			0		
Sagitta elegans		+	+	·1·	+	(Max (+	(Max (+	(Max (+	+	+		
Sagitta serratodentata								·1·	+	·1·	+	+
Oikopleura spp .		·1·	0	0	o	-	o			+		

Table 9-24 - Gulf of Maine (21a)

	J	F	M	A	M	J	J	A	S	O	N	D	
Pleurobrachia pileus	+	+	+	+	+	+	+	+	+	+	+	+	
Beroe cucumis			+	+	+	-	+	+			+	-	
Aglanthe digitale	+	+	+	+	+	+	+	+	+	+	+	+	
Nanomia cara	Max	+	+	0	0	0	+	+	+	-	-	Max	
Obelia spp.							+						
Aurelia aurita							Max	Max					
Cyanea capillata	0	0	0	0	0	+	+	+	+	+	0	0	
Clione limacina	+	Max	Max	Max	Max	+	+	+	+	-	-	+	
Limacina retroversa	+	+	+	1,127	+	+	+	+	+	+	+	1,360	#/m^2
Evadne nordmanni	0	0	0	+	+	+	+	Max	+	0	0	0	
Acartia clausi	+			+	5,500	+	+	+	+	11,205	+	+	#/m2
Acartia longiremis	+		+	+	+	+	+	+	+	14,225	+	+	#/m^2
Anomalocera pattersoni							+	+					
Calanus finmarchicus	+	+	+	+	459,000	-	+	86,000	+	+	+	+	#/m^2
Calanus hyperboreus	+												
Centropages hamatus	+	+	+	+	-	-	+	+	+	+	+	+	
Centropages typicus	+	+	+	+	+	0	+	1,500	+	+	+	+	#/m^2

Table 9-24 - Gulf of Maine (cent'd)

	J	F	M	A	M	J	J.	A	S	O	N	D	
Euchaeta norvegica	+	·1·	+	+	+	+	+	3,000	+	+	+	+	#/m^2
Metridia lucens	·1·	+	·1·	+	Max	+	+	+	+	Max	+	+	
Paracalanus parvus	+	+	+	+	25,000	+	·1·	23,450	+	+	+	+	#/m^2
Pseudocalanus minutus	+	+	+	+	+	+	+	(56,000 (Max	+	·1·	+	+	#/m^2
Temora longicornis	+	0	1·	+	+	+	+	18,000	+	+	0	+	#/m^2
Microstella norvegica				+	+	1·	Max	(1,264 (Max	0			- .	#/m^3
Oithona similis				+	+	+		3,735					#/m^3
Oithona sp.	·1·				·1·	+	·1·		+	-			ave.#/m^3 0.2
Hyperia galba					+	+	+		+				
Meganyctiphanes norvegica			+	+	+	+		Max	Max	Max			
Thysanoessa inermis	+	+	1·	+	+	+	+	+	+	+	i·	·1·	
Thysanoessa longicaudata		+	+	+	+		·1·	1·	+				
Thysanoessa raschii	·1·		Max	Max	Max		0	0		+	+	+	
Eukrohnia hamata	+	+	+	+	·1·	·1·	+	63	1-	+	+	(Max (+	#/m^2
Sagitta elegans	+	+	·t	+	+	+	11,580	·1·	+	1·		+	#/m^2

Table 9-24 -- Gulf of Maine (cent'd)

	J	F	M	A	M	J	J	A	S	O	N	D
Sagitta maxima	+	-	+	+	(Max (+	0	0	0	+			1
Sagitta enflata	0	-	0	0	0	o	-		+			0
Sagitta serratodentata	+	+	+	+	+	+	-	+	(Max (+	Max	+	1
Oikopleura dioica		·	-				0					

Table 9-25 - Western Gulf of Maine (21b)

	J	F	M	A	M	J	J	A	S	O	N	D	
Pleurobrachia pileus	-	-	-	+	⊙	⊙	-	+	+	-	-	-	
Beroe cucumis	-	-	-	+	⊙	⊙	-	0	0	-	-	+	
Aglanthe digitale	-	+	-	+	+	+	-	+	⊙	+	-	-	
Nanomia cara	-	-	-	+	+	+	-	+	+	-	-	-	
Obelia spp.	-	-	-	⊙	0	+	-	+	⊙	-	-	-	
Cyanea capillata	-	-	-	⊙	⊙	+	-	⊙	⊙	-	-	-	
Synchaeta johanseni	-	-	-	-	-	-	-	1,132	-	-	-	-	#/m^3
Clione limacina	+	Max	Max	Max	Max	+	-	+	+	-	-	-	
Limacina retroversa	0	-	+	1,127	+	+	-	Max	+	-	-	0	#/m^2
Gastropod eggs & larvae	⊙	⊙	⊙	⊙	⊙	+	+	+	+	+	+	+	
Pelecypod eggs & larvae	+	+	+	⊙	⊙	+	+	+	+	+	+	+	
Tomopteris catherinae	-	-	+	+	+	+	+	+	+	⊙	⊙	-	
Polychaete larvae	+	+	+	+	+	+	+	+	+	+	+	+	
Evadne nordmanni	-	-	-	+	+	+	-	+	+	-	-	-	
Podon leukarti	-	-	-	⊙	⊙	+	-	⊙	⊙	-	-	-	
Acartia clausi	+	-	-	+	5.5⊙⊙	+	-	+	+	+	+	+	#/m^2
Acartia longiremis	+	-	-	+	10.-	+	+	+	+	+	+	+	#/m^3

Table 9-25 - Western Gulf of Maine (cent'd)

	J	F	M	A	M	J	J	A	S	O	N	D	
Anomalocera pattersoni				0	o	+	-	+	+	-			
Cal anus finmarchicus	+	+	1·	·1·	459,000	+	700/m^3	+	+	+	+	+	#/m^2.#/m^3
Candacia armata	+	-			0	0	0			+			
Centropages hamatus	+	-		+	+	+	0	0	0	+			
Centropages typicus	+(2,625 (max	+		+	+	+	+	+	+	108/m^3			#/m^2,#/m^3
Euchaeta norvegica	0			i·	+	+	0	+	+	+			
Eurytemora herdmani								+	+				
Eurytemora sp.	0				+	+	+			0			
Metridia lucens	·1·	+	·1·	+	(16,500 (Max	+	13/m^3	1·	·1·	Max	+	+	#/m^2,#/m^3
Paracalanus parvus					25,000	+	+	16,100					#/m^2
Pseudocalanus minutus	+	+	+	+	+	+	(1,400 (200	(Max (+	+	+	·1·	+	#/m^3,nauplii, adults
Temora longicornis	+	0		·1·	5.5	+	+	(Max (+	·1·	+	0		#/m^3
Tortanus discaudatus	+			0	+	+	3.8	+	0	·t			#/m^3
Microstella norvegica				+	+	+	+	·1·					Max number recorded 100,000/m^3
Parathalestris croni				+	0	0	-	0	0				
Oithona similis	+			5,423	+	+	+	+		+			#/one minute tow Max reported Nauplii 34,852/m^3 adults 3,555/m^3

Table 9-25 - Western Gulf of Maine (cent'd)

	J	F	M	A	M	J	J	A	S	O	N	D
Balanus sp. larvae				+	+	0		0	0			
Hyperia galba				0	0	0		0	+			
Parathemisto gaudichaudii	+	+	+	+	+	+		+	+	Max	Max	+
Meganyctiphanes norvegica	-			+	+	+		+	+			
Thysanoessa inermis				+	+	+		+	+			
Thysanoessa longicaudata	-			+	0	0	0	+	0			
Thysanoessa raschii	0	0	0	+	+	+		0	0		0	0
Cancer spp. larvae				0	0	i		+	0			
Hyas coarctatus larvae				0	0	0		+	0			
Pagurus Spp. larvae				0	0	+		+	+			
Eukrohnia hamata			+									
Sagitta elegans	+	+	+	+	+	+	+	+	(Max (+	Max		+
Echinoderm larvae	0	0	0	0	0	+	+	+	+	+	+	+
Fritillaria borealis	-			+	+	+		+	+			
Oikopleura labra - doriensis	-			+	+	+		+	+			

Table 9-26 - Central Gulf of Maine (21c)

	J	F	M	A	M	J	J	A	S	O	N	D	
Pleurobrachia pileus	II	-	+	+	⊙	⊙	-	Max	⊙	+	-	-	
Beroe cucumis		-	-	+	⊙	⊙	-	0	⊙	-	-	-	
Aglanthe digitale	-	-	-	+	+	+	-	+	⊙	-	-	-	
Nanomia cara	-	II	-	+	+	+	-	+	0	-	-	-	
Obelia spp.	-		-	⊙	+	+	-	0	0	-	-	-	
Cyanea capillata	-	-	-	0	+	0	-	0	0	-	-	-	
Synchaeta johanseni	-	-	-	-	-	-	-	4,52⊙	-	-	-	-	#/m^3
Clione limacina	+	Max	Max	Max	Max	+	+	+	+	+	+	+	
Limacina retroversa	0	-	217	+	+	+	+	Max	+	-	-	0	#/m^2
Tomopteris catharina	-	-	-	+	+	+	-	+	+	-	-	-	
Evadne nordmanni	-	-	-	⊙	+	⊙	-	+	⊙	-	-	-	
Podon leukarti	-	-	-	⊙	⊙	+	-	⊙	⊙	-	-	-	
Acartia clausi	+	-	-	+	1,437	+	+	+	+	+	+	+	#/m^2
Acartia longiremis	+	10	+	+	+	+	2.5	+	+	+	+	+	#/m^3
Acartia tonsa	0	⊙	0	⊙	+	+	+	+	+	+	+	⊙	
Anomalocera pattersoni	-	-	-	⊙	⊙	+	-	+	⊙	-	-	-	
Calanus finmarchicus	+	+	+	+	30	+	+	+	+	+	+	+	#/m^3

Table 9-28 - Central Gulf of Maine cont'd)

	J	F	M	A	M	J	J	A	S	O	N	D	
Candacia armata	+	-	-	-	⊙	⊙	⊙	—	—	⊙	-	—	
Centropages hamatus	⊙	-	—	⊙	⊙	⊙	+	+	⊙	+	—	-	
Centropages typicus	+	+	+	-	+	+	+	-	-	51	-	-	#/m^3
Euchaeta norvegica	+	-	-	+	+	+	⊙	+	+	⊙	—	—	
Eurytemora herdmani	-	-	-	-	-	-	+	-	-	-	-	-	
Eurytemora sp.	0	-	-	-	0	0	+	-	-	0	-	-	
Metridia lucens	+	+	+	+	Max	+	+	+	+	(12,25⊙ (Max	+	+	#/m^2
Pseudocalanus minutus	+	+	+	+	+	+	3	(Max (+	+	+	+	+	#/m^3
Temora longicornis	+	⊙	—	⊙	+	+	+	(Max +	0	2.5	0	-	#/m^3
Tortanus discaudatus	+	—	-	+	+	+	⊙.5	⊙	⊙	+	—	-	#/m^3
Microstella norvegica	—	—	-	+	+	+	+	5,66≡	-	-	—	—	#/m^3
Parathalestris croni	-	—	-	+	+	⊙	-	⊙	⊙	—	—	-	
Oithona similis	+	-	-	+	+	+	+	4,53⊙	-	+	—	-	#/m^3
Balanus sp. larvae	—	—	—	+	+	⊙	II	⊙	⊙	-	-	-	
Hyperia galba	—	—	-	0	+	+		⊙	⊙	-	-	-	
Parathemisto gaudichaudii	+	+	+	+	+	+	—	+	+	—	-	+	

Table 9-28 Central Gulf of Maine (cont'd)

	J	F	M	A"	M	J	J	A	' S	O	N	D
Meganyctiphanes norvegica	-			·1·	+	+		+	+			
Thysanoessa inermis				+	+	·1·		·1·	+			
Thysanoessa longicaudata	O	0	o	+	0	0		+	·1·			
Thysanoessa raschii				·1·	0	0		0	0'			
Cancer spp. larvae				0	0	0		+	0			
Crangon septem-spinosus larvae				0	+	0		0	0			
Hyan coarctatus larvae				+	+	+		+	0	-		
Pagurus spp. larvae				+	+	+		+	0			
Eukrohnia hamata								+				
Sagitta elegans	+	+	·1·	·1·	+	+	+	+	(Max (+	Max		+
Sagitta serratodentata	·t	+	+	+	+	+		+	(Max (+	(Max (+	+	+
Fritillaria borealis	-			·t	+	+		+	0			

Table 9-27 - Outer Gulf of Maine (21d)

	J	F	M	A	M	J	J	A	S	O	N	D	
Pleurobrachia pileus	+	-	+	$						t		+	
Beroe cucumis	-	-	-	-			+						
Aglanthe digitale			+	-									
Cyanea capillata	Present, but no monthly occurrence data available ----------												
Limacina retroversa	+	+	+	+	+	+	+	+	+	+	+	+	
Mytilus Spp. eggs	-			+	+	+		2,827	+	-			#/m^3
Podon polyphemoides	Present, but no monthly occurrence data available --------												
Acartia clausi	0				+	+	0			O	-	-	
Acartia longiremis	+				+	+	2.0	-		+			#/m^3
Calanus finmarchicus	+	+	+	+	(329,200 (300/m^3	+	+	+	+	+	+	+	#/m^2, #/m^3
Calanus hyperboreus	+				0	0	0			0	-	-	
Candacia armata	t		+	-	t	0	+			0	-	-	
Centropages hamatus	0				0	0	0			0	-	-	
Centropages typicus	+	+	4,115	-	41,100	+	+			+			#/m2
Euchaeta norvegica	0		+	0	0	0	0	4,690		0	-	-	#/m^2
Eurytemora herdmani								+	+	-	-	-	

Table 9-27 - Outer Gulf of Maine (cent'd)

	J	F	M	A	M	J	J	A	S	O	N	D	
Eurytemora sp.	o				0	0	+			0	-	-	
Metridia lucens	+	+	+	+	Max	+	+	+	+	(3 (Max	+	+	#/m^3
Paracalanus parvus								23,450	-	-	-	-	#/m^2
Pseudocalanus minutus	+	1	+	+	+	+	+	(Max (+	6,752	4.5/m^3	-t	+	#/m^2, #/m^3
Temora longicornis	+	0			+	+	+	(Max (+	-	2.4	0	-	#\m^3
Tortanus discaudatus	+				+	- l -	+			+			
Oi thona similis	+			+	+	+	1	6,265	-	+	-	-	#/m^3
Parathemisto gaudichaudii	+	+	+	-				200				+	cc/m^2
Meganyctiphanes norvegica	-		+	-									
Thysanoessa raschii	Present, but no monthly occurrence data available ----------												
Eukrohnia hamata	+	-	-					+					
Sagitta elegans	+	+	+	+	+	Max	Max	Max	+	+	-	+	
Sagitta maxima		·	-				0	0	+	-	-	-	
Sagitta serratodentata	+	+	(Max (+	Max	i	- +	-	+	(Max (+	(Max (-l-	1-	+	
Salpa fusiformis	-				-	-		+					
Oikopleura labadoriensis	-			+	+	- ! - , -		+	'o	-	-	-	

Table 9-28 Bay of Fundy (22)

	J	F	M	A	M	J	J	A	S	O	N	D	
Pleurobrachia pileus	-	-	[illegible]	+	+	⊙	[illegible]	+	⊙	-	-	[illegible]	
Beroe cucumis	-	-		+	+	⊙		0	⊙	-	-	[illegible]	
Aglanthe digitale	-	-	-	+	+	+	-	+	+	-	-	-	
Nanomia cara	-	-	-	+	+	+	-	+	+	-	-	-	
Obelia spp.	-	-	-	0	0	0	-	0	+	-	-	-	
Aurelia aurita	-	-	-	⊙	⊙	⊙	-	⊙	+	-	-	-	
Cyanea capillata	-	-	-	⊙	+	+	-	+	-	-	-	-	
Synchaeta johanseni	-	-	-	-	-	-	-	34,687	-	-	-	-	#/m^3
Clione limacina	-	-	-	+	+	+	-	+	+	-	-	-	
Limacina retroversa	-	-	+	+	+	+	-	+	+	-	-	1,3≤⊙	#/m^2
Littorina spp. eggs	-	-	-	+	+	+	-	+	+	-	-	-	
Mytilus spp. larvae	-	-	-	+	+	+	-	47,460 25,780	+	-	-	-	#/m^3 eggs and larvae
Tomopteris catharina	-	-	-	+	+	+	-	+	+	-	-	-	
Evadne nordmanni	-	-	-	⊙	+	+	-	+	+	-	-	-	
Podon leukarti	-	-	-	⊙	⊙	⊙	-	+	⊙	-	-	-	
Acartia clausi	Present, but no monthly occurrence data available ---------												
Acartia longiremis	+	+	+	+	+	+	+	+	+	+	+	+	
Anomalocera pattersoni	-	-	-	⊙	⊙	⊙	-	+	+	-	-	-	

Table 9-28 - Bay of Fundy (cent'd)

	J	F	M	A	M	J	J	A	S	O	N	D	
Calanus finmarchicus	+	↓	+	+	+	+	+	+	+	+	+	↓	
Candacia armata						+			↓		+	+	
Centropages hamatus				0	0	0		+	0				
Centropages typicus				0	0	+		+	↓				
Euchaeta norvegica			+	+	+	+		+	+				
Eurytemora herdmani				0	0	0		+	+				
Metridia lucens	+	+	+	+	+	+	+	+	+	+	+	i-	
Pseudocalanus minutus	+	+	+	Max	↓	+	↓	+	↓	+	+	+	
Temora longicornis				0	+	↓		4·	+				
Tortanus discaudatus	+			0	+	+		+	+				
Microstella norvegica				+	+	+	Max	(776 (Max	+				#/m^3
Parathalestris croni				+	+	+		0 "	0				
Oithona similis				+	+	+		10,160 adults 35,970 manpl i i	+				#/m^3

Table 9-28 - Bay of Fundy (cent'd)

	J	F	M	A	M	J	J	A	S	O	N	D	
Balanus sp. larvae	-		0	2,742	+	0		0	0				#/one minute tow
Hyperia galba	-			+	+	+		+	+				
Parathemis to gaudichaudii	-			+	+	1		+	1				
Meganyctiphanes norvegica	+		275	+	+	+		+	+			1	#/m^2
Thysanoessa inermis				+	1	+		+	+				
Thysanoessa longicandata	-			+	+	0		+	0				
Thysanoessa raschii				+	1	+		0	+				
Cancer spp. larvae	0	0	0	+	+	i	+	+	+	+	1	+	
Crangon septemspinosus larvae	-			0	+	0		0	0				
Hyas coarctatus	-			+	+	+		+	i				
Pagurus Spp. larvae	-			+	+	+		+	+				
Sagitta elegans	Max	Max	Max	+	+	+		1	+	1		+	
Sagitta serratodentata	0	0	Max	1	+	+	+	+	+	0	+	+	
Salpa fusiformis	-	-	-					+					
Fritillaria borealis	-	-	-	+	+			+	0				
Oikopleura labadoriensis				+	1	+		1	0				

Table 9-29 Quoddy Region (23)

	J	F	M	A	M	J	J	A	S	O	N	D	
Acartia clausi	+	+	+	+	+	Max	1,265	Max	+	+	+	+	av.#/15 min tow
Aglantha digitale	Max	Max	+	+	+	+	+	+	+	+	+	Max	
Aurelia aurita	+	+	+	+	+	+	+	+	Max	Max	Max	+	
Balanus balanoides nauplii	0	0	+	+	+	+	+	+	0	0	0	0	
Calanus finmarchicus	14,717	+	+	+	+	Max	20,541	Max	+	3,147	+	+	"
Caligus rapax	0	0	+	+	+	+	+	+	Max	Max	Max	0	
Crab zoea	+	+	+	+	+	Max	Max	Max	+	+	+	+	
Cladocerans (Podon,Evadne)	0	0	+	+	+	Max	Max	Max	+	+	+	0	
Centropages typicus	+	+	+	+	+	+	+	+	+	13,854	+	+	"
Clione limacina	Max	Max	+	+	+	Max	Max	Max	+	+	+	Max	
Diastylis Spp.	+	+	+	+	+	+	+	+	+	+	+	+	
Euchaeta norvegica	+	+	+	+	+	Max	Max	Max	+	+	+	+	
Euphausiids	+	+	+	+	+	Max	Max	Max	+	+	+	+	
Euphausiid eggs	0	0	-	1	-	+	+	Max	Max	Max	0	0	0	0
Eurytemora herdmani	0	0	+	+	+	+	1,624	+	+	+	+	0	
Euthemisto compressa	+	+	+	+	+	+	+	+	Max	Max	Max	+	
Fritillaria and Oikopleura	+	+	+	+	+	Max	Max	Max	0	0	0	+	

Table 9-29 Quoddy Region (23) Cent' d)

	J	F	M	A	M	J	J	A	S	O	N	D	
Harpacticoids	+	+	Max	Max	Max	+	+	+	+	+	+	+	
Hydroids (floating)	+	+	+	+	+	Max	Max	Max	+	+	+	+	
Limacina retroversa	+	+	Max	Max	Max	+	+	+	+	+	+	+	
Metridia lucens	+	+	+	+	+	+	+	+	+	+	+	+	
Mytilus edulis (larvae)	0	0	+	+	+	+	+	+	Max	Max	Max	0	
Nereid larvae (trochophores)	0	0	+	+	+	+	+	+	+	+	+	0	
Nereis virens	+	+	+	+	+	Max	Max	Max	+	+	+	+	
Oithona similis	+	+	+	+	+	Max	Max	Max	+	+	+	+	
Pleurobrachia pileus	+	+	+	+	+	Max	Max	Max	+	+	+	+	
Pseudocalanus minutus	+	+	+	+	+	+	31,448	+	+	+	+	+	Av.#/15 min tow
Sagitta elegans	+	+	+	+	+	Max	Max	Max	+	+	+	+	
Stephanomia cara	Max	Max	+	+	+	+	+	+	+	+	+	Max	
Temora longicornis	+	+	+	+	+	+	+	+	Max	Max	Max	+	
Tomopteris catherina	Max	Max	+	+	+	+	+	+	+	+	+	Max	
Tortanus discaudatus	+	+	+	+	+	+	4,607	+	+	+	+	+	"

Table 9-30 . . Key to References (given in Tables 9-5 through 9-29)

Area	References	a) Type of Net b) And Type of Tow
1. (SH) Sandy Hook Table 9-5	Sage and Herman, 1972	a) #8 Net b) surface tow
	Yamazi, 1966	a) 14,641 meshes/in^2 b) bottom to surface vertical tow
2. (RB) Raritan Bay Table 9-6	Jeffries, 1962a	a) not specified b) not specified
	Jeffries, 1962b	a) #18, #12, #10 b) oblique + surface samples
	Jeffries, 1962c	a) CB #12 b) oblique
	Jeffries, 1964	a) #12 net b) oblique tows
	Jeffries, 1967	a) not specified b) not specified
3. (NYB) New York Bight Table 9-7	National Marine Fisheries Service, 1972	a) #8 net b) simultaneous 3 depth horizontal tows
	Riley, Stommel and Bumpus, 1949	a) not specified b) oblique hauls
	Bigelow and Sears, 1939	a) 48-54 meshes/inch rear 29-38 meshes/inch front b) oblique tows

4.	(SSMP) Continental Shelf South of Montauk Bay Table 9-8	Grice and Hart, 1962	a) #6 net b) oblique tows
		Clarke, 1940	a) #10 net b) oblique tows
		Bigelow and Sears, 1939	a) 48-54 meshes/inch rear 29-38 meshes/inch front b) oblique tows
		Bigelow, 1915	a) #3 net, #20 net b) oblique tows
6.	(LIS) Long Island Sound Table 9-9	Conover, R. J., 1956	a) not specified b) not specified
		Riley, 1956	a) #20 net b) oblique tows
		Deevey, 1956	a) #2 net, #10 net b) oblique tows
		Richards, 1959	a) #2 net, #10 net b) surface tows
		Wheatland, 1956	a) #2 net b) oblique tows
		Loosanoff and Engle, 1940	a) not specified b) not specified
7.	(BIS) Block Island Sound Table 9-10	Deevey, 1952a	a) #2 net b) surface tows

		Deevey, 1952b	a) #2 net, #10 net b) oblique tows
		Frolander, 1955	a) #6 net, #12 n35, #14 net b) oblique tows
		Merriman and Sclar, 1952	a) #2 net b) surface tows
		Austin and Stoops, 1973	a) 150µ, 250µ, 363µ, Net b) surface tows
8.	(RISP) Rhode Island Salt Ponds Table 9-11	Conover, R. J., 1961	a) #12 net b) surface tows
		Williams, 1906	a) not specified b) not specified
		Nixon and Oviatt (in press)	a) #10 net b) vertical tows, bet-surf.
		Jeffries, 1955	a) #2, #12 b) oblique, surface
9.	(NB) Narragansett Bay Table 9-12	Faber, 1966a	a) #12 net b) surface tows
		Faber, 1966b	a) #12 net b) surface tows
		Frolander, 1955	a) #6 net, #12 net, #14 n35 b) oblique tows
		Jeffries, 1964	a) #12 net b) oblique tows
		Jeffries, 1969	a) #2 net b) oblique tows

		Martin, 1965	a) #2 net, #12 net b) oblique tows
		Martin, 1966	a) #2 net, #10 net b) oblique tows
		Martin, 1968	a) #2 net, #12 net b) oblique tows
		Williams, 1906	a) not specified b) not specified
		Herman, 1958	a) #2 net b) surface tows
		Faber, 1959	a) #2 net, #12 net b) surface tows
		Hillman, 1964	a) #2 net b) oblique tows
10.	(RIS) Rhode Island Sound Table 9-13	Clarke and Zinn, 1937	a) not specified b) oblique tows
		Riley and Gorgy, 1948	a) #10 net b) oblique tows
		Bigelow and Sears, 1939	a) 48-54 meshes/inch rear 29-38 meshes/ inch front b) oblique tows
11.	(SSCC) Continental Shelf South of Cape Cod Table 9-14	Bigelow, 1915	a) #3 net, #20 net b) surface and vertical tows
		Bigelow, 1917	a) #5 net, #20 net b) surface and vertical tows

		Sears and Clarke, 1940	a) 48-54 meshes/inch rear 29-38 meshes/inch front b) oblique tows
		Wheeler, 1899	a) not specified b) not specified
		Bigelow and Sears, 1939	a) 48-54 meshes/inch rear 29-38 meshes/inch front b) oblique tows
12.	(GH) Gay Head-Cuttyhunk Table 9-15	Clarke and Zinn, 1937	a) not specified b) oblique tows
		Wheeler, 1899	a) not specified b) not specified
		Bigelow and Sears, 1939	a) 48-54 meshes/inch rear 29-38 meshes/inch front b) oblique tows
13.	(BB) Buzzard's Bay Table 9-16	Clarke and Zinn, 1937	a) not specified b) oblique tows
		Anraku, 1964	a) #10 net b) oblique tows
14.	(VS) Vineyard Sound Table 9-17	Clarke and Zinn, 1937	a) not specified b) oblique tows
15*	(WH) Woods Hole Table 9-18	Clarke and Zinn, 1937	a) not specified b) oblique tows
		Wheeler, 1899	a) not specified b) not specified
		Fish, 1925	a) #2 net, #20 net b) vertical, surface and bottom tows

16.	(TGP) Tinsbury Great Pond (Martha's Vineyard) Table 9-19	Deevey, 1948	a) #2 net b) not specified
17.	(FGP) Falmouth Great Pond (Massachusetts) Table 9-20	Barlow, 1955	a) #2 net, #10 net b) surface and bottom tows
18.	(CCB) Cape Cod Bay Table 9-21	Anraku, 1964	a) #10 net b) oblique tows
19.	(GB) Georges Bank Table 9-22	Clarke and Bishop, 1948	a) 0366 mm mesh b) oblique
		Bigelow, 1926	a) #3, #20 net b) oblique, horiz., vertical
		Paushties, 1963	a) not specified b) not specified
		Whitely, 1948	a) 6 mesh/cm outer 11 cm\inner b) oblique
		Deevey, 1956	a) #2, #10 b) oblique
		Clarke et.al., 1943	a) #2 b) oblique
		Colton et.al., 1962	a) #0, 60 mesh/in b) horiz. surf. 10m, and oblique
		Riley and Bumpus, 1946	a) not specified b) not specified
		Bigelow 1914, 1915, 1917	a) #5, #20 b) vertical and horizontal

		Redfield and Beale, 1940	a) #0, .38 mesh/in. b) 1.5m Heligdand larva net vert. haul
20.	(MB) Massachusetts Bay Table 9-23	Bigelow, 1926	a) #3, #20 net b) oblique, horizontal, vert.
		Fish, and Johnson, 1937	a) #10, #20, 0000xx, Oxx b) horizontal, surf., 50m, bottom, oblique
		Bigelow 1914, 1914a, 1915, 1917.	a) #5, #20 b) vertical and horiz.
		Redfield and Beale, 1940	a) #0, 38 mesh/in b) 1.5 m. Heligoland larva net - vert. haul
21a.	(GM) Gulf of Maine Table 9-24	Riley, 1939	a) 29-38 mesh/in front 48-54 mesh/in rear b) oblique tows
		Fish and Johnson, 1937	a) #10, #20, 0000x, 0ss b) oblique, horizontal at surf., 50m, bottom
		Bigelow, 1926	a) #3, #20 nets b) oblique, horizontal, vert.
		Redfield, 1941, 1939	a) #0 net b) vertical tows
		Sherman, 1964, 1966, 1968, 1970	a) 0.37 mm b) oblique
		Colton et.al., 1962	a) #0, 60 mesh/in b) horiz. surf, 10m, and oblique

		Fish, 1936a, 1936b, 1936c, 1955	a) #lo b) oblique
		Redfield and Beale, 1940	a) #o b) vertical
		Bigelow, 1914, 1914a, 1915, 1917	a) #5, #20 b) vertical and horizontal
21b.	(WGM) Western Gulf of Maine (equivalent to Massachusetts sector, (Redfield, 1941)) Table 9-25	Fish and Johnson, 1937	a) #10, #20, 0000xx, Oxx b) horizontal surf., 50m, bottom, and oblique tows
		Redfield, 1941, 1939	a) #O net b) vertical tows
		Sherman, 1964, 1966,1968, 1970	a) 037mm b) oblique
		Graham et.al., 1972	a) #1, #2, #4 b) oblique
		Fish, 1936a, 1936b, 1936c, 1955	a) #lo b) oblique
		Redfield and Beale, 1940	a) #o b) vertical
		Bigelow, 1914, 1914a, 1915, 1917	a) #5, #20 b) vertical and horizontal
		Bigelow, 1926	a) #3, #20 b) oblique, horizontal, vertical

21c.	(CGM) Central Gulf of Maine (equivalent to Sequin and Cultivator Sectors, (Redfield, 1941)) includes Boothbay area Table 9-26	Fish and Johnson, 1937	a) #10, #20, oooox, oxx b) horizontal at surf, 50m, and bottom and oblique
		Redfield, 1941, 1939	a) #0 net b) vertical tows
		Sherman, 1964, 1966, 1968, 1970	a) 0.37mm net b) oblique
		Graham and Boyar, 1963	a) 0.51mm mesh b) surf, oblique
		Graham et.al., 1972	a) #1, #2, #4 b) oblique
		Fish, 1936a, 1936b, 1936c, 1955	a) #10 b) oblique
		Redfield and Beale, 1940	a) #0 b) vertical
		Bigelow, 1914, 1915, 1917	a) #5, #20 b) vertical and horizontal
21d.	(OGM) Outer Gulf of Maine (equivalent to Mt. Desert and Georges sectors, (Redfield, 1941)) Table 9-27	Redfield, 1941, 1939	a) #0 net b) vertical tows
		Sherman, 1964, 1966, 1968, 1970	a) 0.37mm b) oblique
		Graham et.al., 1972	a) #1, #2, #4 b) oblique

		Fish, 1936a, 1936b, 1936c, 1955	a) #lo b) oblique
		Redfield and Beale, 1950	a) #o b) vertical
		Bigelow, 1914, 1915, 1917	a) #5, #20 b) vertical and horizontal
22.	Bay of Fundy Table 9-28	Fish and Johnson, 1937	a) #10, #20, 0000xx, 0xx nets b) oblique, horizontal at surf, 50m, bottom
		Messieh et.al., 1971	a) #0 net b) vertical and oblique
		Fish, 1936a	a) #lo b) oblique
		Fish, 1936b	a) #lo b) oblique
		Fish, 1936c, 1955	a) #lo b) oblique
		Bigelow, 1914, 1915, 1917	a) #5, #20 b) vertical and horizontal
		Redfield and Beale, 1940	a) #0, 38 mesh/in b) 15m Heligoland larva net, vert. haul
23.	Passamaquoddy Bay and. Cobscook Bay Table 9-29	Legare and Maclellan, 1960	a) #o b) oblique at 0, 10, 20 m

Table 9-31 Standing crops of zooplankton by volume displacement in the Sandy Hook to Bay of Fundy area

AREA	MESH OF NET	#	AVER. DEPTH m.	ul/m^3 AVER..	ul/m^3 RANGE	u l /m* AVERAGE	SALINITY AVER.	SALINITY RANGE	TEMP AVER.	TEMP RANGE	REF
1 SH	8		4.8m	166	600-4200	796	23	13.7-32.6	130	0.1-25.4	Sage & Herman 1972
3 NYB	8		30	629	217-917	18880		------		----	Grace & Hart 1962
			30	500	----	.,15000	-	-------	--	----	Riley et al 1949
4 SSMB	6		60	1070[a]	120-3710	64000a,	,	..25-34	"	3.5-19	Grace & Hart, 1962
	6		200	270	[a] 40-760	54000[a]		25-34		3.5-19	Grace & Hart, 1962
6 LIS	2		20	270	50-800	5400	26.9	24.5-28.1	11.1	1-23	Deevey, 1956
	10		20	1075	210-3370,	21500	26.9	24.5-28.1	11.1′	1-23	Deevey, 1956
7 BIS	2		30	167*′	C.1-492*'	5015*′	31.1′	29.8-32.4′	11.9	5-21 '	Deevey, 1952b
	10		30	655*'	50-1800*'	19650*'	31.1'	29.8-32.4′	11.9′	5-21′	Deevey, 1952b
	6		20	211	50-600	4220	31.5	30.9-32.6	11	3-20	Frolander, 1950
	14		20	329′	80-70′	6580 '	31.5	30.9-32.6	11	3-20	Frolander, 1955
	2	3	4	208′	45-8547	7072′	-	----	-′	----	Jeffries, 1969
8 RISP	12		2	1000	100-2400	2000	28	22-27	11.8	0-25	Conover, 1961
	12		2	612	100-1500	1224	19	15-20	13.7	0-29	Conover, 1961
9 NB	6		10	257	70-500	2570	30.6	29.4-32	11.5	2-20	Frolander, 1955

' Incomplete yearly date
* mg/m^3 wet weight t o ul/m^3
[a] data from Williams et al. 1968

Table 9-31 Standing crops of zooplankton by volume displacement in the Sandy Hook to Bay of Fundy area (cent'd)

AREA	MESH # OF NET	AVER. DEPTH m.	ul/m³ AVER.	ul/m³ RANGE	ul/m* AVERAGE	SALINITY AVER.	SALINITY RANGE	TEMP AVER.	TEMP RANGE	REF
9 NB (cont)	12	10	184′	100-250′	1840′	30.6	29.4-32	11.5	2-20	Frolander, 1955
	13	10	266′	150-400′	2660′	30.6	29.4-32	11.5	2-20	Frolander, 1955
	2	7	375*′	46-882*′	2628*′					Jeffries, 1969
	10	10	694*′	124-1494*I	6938*′	30′	29.5-30.2′	13.8′	1-24′	Martin, 1966
	10	30	302*′	166-581*′	9047*′	31′	30.5-31.5′	13′	3-21′	Martin, 1966
17 FGP	10	1	950	1-4000	950		0-32			Barlow, 1955
19 GB	2	70	956′	159-2180′	66900′		31.5-35.3		2.1-16.5	Riley& Bumpus 1946
	2	65	852′	308-2385′	55380′		31.5-35.3		2.1-16.5	Deevey, 1956 (from Riley & Bumpus, 1946)
	6 mesh/cm outer 11 mesh/cm inner (CB sampler)	75		220-1780′		32.84;	31.5-35.3	6.3;	2.1-19.3	Whitely, 1948
	6 mesh/cm outer 11 mesh/cm inner (Stramin net)	75		110-710′		32.84;	31.5-35.3	6.3;	2.1-19.3	Whitely, 1948
	O. 366mm	75	850′	200-1500′	63,750	32.84;	31.5-35.3	6.3;	2.1-19.3	Be′ etal, 1971 (from Clarke & Bishop, 1948)
20	3,20	110	1492′	90-2455′	164,160′		30.48-32.92		1.5-18.9	Bigelow, 1926

′ Intm plete yearly date
* mg/m³ wet weight to ul/m³

Table 9-31 Standing crops of zooplankton by volume displacement in the Sandy Hook to Bay of Fundy area (cent'ti)

AREA	MESH # OF NET	AVER. DEPTH m.	ul/m³ AVER.	ul/m³ RANGE	ul/m²	SALINITY AVER.	SALINITY RANGE	TEMP AVER.	TEMP RANGE	REF
21a	5,20	100	2903'	1700-4300'	290,300		30.93-33.6		0.96-15.5	Bigelow, 1917
	0				144,420					Redfield, 1941
	29-38mesh/in front 48-54 mesh/in rear	190'	120-260'							Be'etal., 1971 (from Bigelow & Sears, 1939)
21b	3,20	190	891	342-1316'	169,380		31.44-34.27		3.5-20.0	Bigelow, 1926
21b (cent)	0				71,850'					Redfield, 1941
	0.37mm	712		77-140		31.61	29.54-32.70	10.21	]221-15.8	Sherman, 1963, 1966, 1968
21C	0				93,429'					Redfield, 1941
	0.37mm	178		121-264		31.82	29.78-32.72	7.27	0.9-168	Sherman,1963, 1966, 1968
21d	0				85,143'					Redfield, 1941 ,
	0.37mm.	31		15-49		32.06	31.30-32.80	6.14	1.2-12.5	

'Incomplete yearly data

Table 9-32 Standing crops of zooplankton by numbers of individuals in the Sandy Hook to Bay of Fundy area

AREA	MESH OF NET	# AVER. DEPTH m.	#/m³ AVER.	#/m³ RANGE	#/m² AVER.	SALINITY AVER.	SALINITY RANGE	TEMP AVER.	TEMP RANGE	REF
1 S H	8	4.8	8168	127-52,000	39202	23	13.7-32.6	13.0	0.1-25.4	Sage & Herman 1972
6 LIS			-39,100′	3,600-109,400′		26.9	24.5-28.1	11.1	1-23	Riley, 1956
	10	20	61,998	14,325-161,385	1,239,958	26.9	24.5-28.1	11.1	1-23	Deevey, 1956
9 NB	12	13	8,583	1,000-25,000	111,583		28-32	10.9	1-21	Faber, 1966b
	12	8	36,091 ′	20,000-66,000′	288,727′	29.14′	28.5-29.7′	10.96′	2-21	Martin, 1965
	12	18	31,636′	7,000-73,000′	569,453′	31.34′	31-32	10.4′	2.3-19′	Martin, 1965
16 TGP	2		18,932	500-100,000		17.41	0-31	12.3	0-25	Deevey, 1948
19 GB	2	70	986 ′	200-1929′	69,000		31.5-35.3		2.1-16.5	Riley & Bumpus 1946
	2	65	1231 ′	462-2308′	80000 ′		31.5-35.3		2.1-16.5	Deevey, 1956 (from Riley & Bumpus, 1946)

′ Incomplete yearly data

Tab' e 9-33: Maximum Standing Crop of Zooplankton for Sandy look Bay (Area 1) ,

Month	cc/m^3	#/m^3
Jan.	0.6	1,000
Feb.	'0.9	1,000
March	0.8	1,500
Apri l	1.4	6,000
May	4.2	52,000
June	3.0	14,000
July	3.1	14,000
Aug.	5,4	28,000
Sept.	2.9	17,000
Oct.	2.9	13,000
No V.	0.7	3,000
Dec.	0.7	1,000

f rem: Sage and Herman, (1972)

maximum density May 52,002/m^3
minimum density March 127/m^3

Table 9-34 Maximum volume of zooplankton, cubic centimeters per water column one square meter, for the Gulf of Maine.

Month	Entire Region	Western	Central	Outer
Jan.	65	65	71	11
Feb.				
March	31	31	25	14
Apr.	54	Apr/May 28	Apr/May 57	Apr/May 54
May	199	54 (May)	199 May)	65 May)
June	93	May/June 99	May/June 82	May/June 93
July	-			
Aug.				
Sept.	226	155	155	226
Oct.				
Nov.				
Dec.	133	71	65	133

from: Redfield, 1941

Table 9-35

Maximum Volumes o-F Zooplankton Standing Crop, cubi c centimeters per cubic meter, i n the GuI f of Mai ne by season.

	Winter	Spring	Summer	Fall
Western Gulf of Maine	0.077	0.243	1.040	1.490
Central Gulf of Maine	0.264	0.191	0.121	0.135
Outer Gulf of Maine	0.028	0.031	0.049	0.015

from: Sherman, 1963, 1966, 1968

Table 9-36

Average zooplankton volumes cubic centimeter per water column one square meter Georges Bank, Area 19

Month	Volume	Numbers/m^2 Water Column
Jan.	11.1	14,000
Feb.		
March	58.2	24,000
April	81.3	32,000
May	152.6	106,000
June	60.1	103,000
July		
Aug.		
Sept.	38.1	135,000
Oct.		
Nov.		
Dec.		

from: Riley and Bumpus, 1946

Table 9-37: Average Zooplankton volumes, cubic centimeters per water column one square meter, for Georges Bank. (Area 19).

Month	Volumes	Numbers per m^2 water column
Jan.	20	45,000
Feb.	40	30,000
March	62	40 ,000
Apri 1	85	70,000
May	155	110,000
June	70	100,000
July		
Aug.	-	-
Sept.	37	150 ,000
Oct.	35	110,000
Nov.	28	90,000
Dec.	22	55,000

from: Deevey, 1956

Table 9-38: Comparison of average zooplankton volumes, cubic centimeters per cubic meter, on Georges Bank, with a Clark-Bumpus Plankton sampler and a Stramin Net,(Area 19).

Month	Plankton Sampler	Strami n Net
Jan.	0.22	0.22
Feb.	-	
March	0.22 - 0.48	0.11 - 0.21
Apri 1	0.99- 1.16	0.14 - 0.25
May	1.13- 1.16	0.18- 0.44
June	1.21 - 1.78	0.47 - 0.71
July		
Aug.		
Sept.		
Oct.		
Nov.		
Dec.		

from: Whitely, 1948

Table 9-39 Maximum average zooplankton volumes"; " in cubic centimeters per water column of one square meter, for Massachusetts Bay .(Area- 20).

Month	cc/m^2
Jan.	
Feb.	-
March	25
Apri 1	10
May	270
June	-
July	250
Aug.	180
Sept.	
Oct.	250
Nov.	
Dec.	

from: Bigelow, 1926

Table 9-40 Maximum average volume of plankton in Gulf of Maine (Area 21a).

Month	cc/m^3
Jan.	
Feb.	
March	
Ap ri I	
May	3.8
June	1 7
July	4 3
Aug.	2 4
Sept.	2 12
Oct.	3 1
Nov.	-
Dec.	-

from: Bigelow, 1917

Table 9-41 Maximum Volumes of Zooplankton Standing Crop in the Gulf of Maine and Bay of Fundy, expressed as cubic centimeters per 40 minute tow with a meter net (Area 21a and 22).

Month	Gulf of Maine	Bay of Fundy
Jan.		
Feb.		
March		
April	870	245
May	1,187	1,250
June	508	630
July		
Aug.	381	497
Sept.	387	
Oct.		-
Nov.		(average only) 500
Dec.		

from: Fish and Johnson, 1937

Table 9-42 Maximum Average Zooplankton Volumes, cubic centimeters per water column one meter square, for the Western Gulf of Maine (Area 21 b).

Month	cc/m2
Jan.	
Feb.	175
March	
April	1;:
May	250
June	250
July	65
Aug.	200
Sept.	
Oct.	
Nov.	
Dec.	

from: Bigelow, 1926

Table 9-43: Additional Estimates of, Zooplankton Standing CrOp for Georges Bank, Gulf of Maine and coastal western North Atlantic.

	ml/1000 m^3	net mesh	depth
Georges Bank (19) . (Clarke and Bishpp, 1948	summer 1,500 winter 200	0.366 mm 0.366 mm	0- 25m 0-25m
Gulf of Maine (21a) (Bigelow and Sears, 1939,	summer 260 wi nter 120	'front-29-38 mesh/in rear -48-54 mesh/ir	variable
Coastal Western North Atlantic (Riley, 1939)	Max., 8,100	0.158 mm	0- 25m

from: Be' et al., 1971

9.8 DOMINANCE ORDERS OF ZOOPLANKTON IN VARIOUS AREAS OF THE SANDY HOOK, NEW JERSEY TO BAY OF FUNDY REGION (TABLES 9-44a-d TO 9-49)

Table 44a Dominance orders of zooplankton on Continental Shelf South of Cape Cod, Rhode Island Sound and Narragansett Bay averages by season. tr=trace

Winter

1. Acartia clausi usually dom. 10-75 percent of total 200
2. Pseudocalanus minutus 8-30 percent
3. Balanus balanoides 4-7 percent
4. A. tonsa tr - 40 percent usually not significant
5. Temora longicornis tr - 3 percent
6. Tortanus discaudatus tr - 3 percent
7. Gastropod eggs and larvae tr - 4 percent

Spring

1. Acartia clausi
2. Pseudocalanus minutus 9-25 percent
3. Evadne nordmanni 3-17 percent
4. Acartia tonsa tr - 40 percent usually not dominant
5. Centropages hamatus tr - 9 percent
6. Gastropod eggs and larvae tr - 6 percent
7. Tortanus discaudatus tr - 4 percent
8. Podon polyphemoides tr - 4 percent
9. Temora longicornis tr - 3 percent
10. Fish eggs tr - 2 percent

Summer

1. Acartia tonsa 10-87 percent
2. A. clausi tr - 20 percent usually not dominant
3. Centropages hamatus tr - 24 percent
4. Evadne nordmanni 3-9 percent
5. Pseudocalanus minutus 1-3 percent
6. Podon polyphemoides tr - 12 percent
7. Decapod larvae tr - 7 percent
8. Tortanus discaudatus tr - 6.7 percent
9. Temora longicornis tr - 6 percent
10. Gastropod larvae tr - 5 percent

Fall

1. Acartia tonsa 24-82 percent usually more than 50 percent

2. A. clausi 2-29 percent starting surge
3. Podon polyphemoides tr - 7 percent
4. Pseudocalanus minutus tr - 2 percent
5. Oithona sp. tr - 4 percent
6. Temora Longicornis tr - 1 percent
7. Podon intermedius tr - 1 percent

Table 9-44b Dominance orders of zooplankton in Block Island Sound

Minter

(1)	Paracalanus minutus	10 - 70 percent
(2)	pages typicus	tr - 25 percent
(3)	Oithona similis	tr - 25 percent
(4)	Acartia tonsa	tr - 15 percent
(5)	Centropages hamatus	tr - 6 percent
(6)	Sagitta elegans	tr - 3 percent
(7)	Balanus larvae	tr - 5 percent
(8)	Paracalanus crassirostris	tr - 10 percent
(9)	Evadne spp.	tr - 10 percent
(lo)	Tortanus discaudatus	tr - 7 percent

Spring

(1)	Paracalanus minutus	6 -.42 percent
(2)	Centropages hamatus	tr - 24" percent
(3)	Temora longicornis	1.5 - 11 percent
(4)	Oithona smilis	tr - 12 percent
(5)	Evadne spp.	tr - 11 percent
(6)	Acartia clausi	tr - 9 percent
(7)	Centropages typicus	tr - 7 percent
(8)	Calanus finmarchicus	tr - 21 percent
(9)	Fritillaria sp.	tr - 15 percent
(lo)	Hydromedusae	tr - 8 percent

Summer

(1)	Acartia tonsa	tr - 50 percent
(2)	Centropages typicus	2 - 30 percent
(3)	C. hamatus	2 - 23 percent
(4)	Temora longicornis	tr - 8 percent
(5)	Pseudocalanus minutus	tr - 8 percent
(6)	Poden intermedius	tr - 7 percent
(7)	Oikopleura spp.	tr - 9 percent
(8)	Doliolum spp	tr - 14 percent
(9)	Evadne spp.	tr - 11 percent
(lo)	Penilia sp.	tr - 6 percent

Table 44b (cond't)

Fall		
(1)	Centropages typicus	1 - 34 percent
(2)	Acartia tonsa	tr - 58 percent
(3)	Penilia sp.	tr - 19 percent
(4)	Podon intermedius	tr - 23 percent
(5)	Pseudocalanus minutus	tr - 27 percent
(6)	Doliolum sp.	tr - 5 percent
(7)	Oikopleura sp.	tr - 3 percent
(8)	Paracalanus spp.	tr - 10 percent
(9)	Oithona similis	tr - 24 percent
(lo)	Evadne spp.	tr - 13 percent

Table 9-44c Dominance orders of zooplankton in Long Island Sound

Winter		
(1)	Acartia clausi	35 percent
(2)	Oithona spp.	15 percent
(3)	Paracalanus crassirostris	4 percent
(4)	Acartia tonsa	13 percent
(5)	Pseudocalanus minutus	13 percent
(6)	Temora longicornis	14 percent
Spring		
(1)	Acartia clausi	56 percent
(2)	Temora longicornis	35 percent
(3)	Pseudocalanus minutus	5 percent
(4)	Acartia tonsa	1 percent
Summer		
(1)	Acartia tonsa	31 percent
(2)	Paracalanus crassirostris	17 percent
(3)	Oithona spp.	15 percent
Fall		
(1)	Oithona spp.	42 percent
(2)	Paracalanus crassirostris	25 percent
(3)	Acartia tonsa	22 percent
(4)	A. clausi	8 percent

Table 9-44d Dominance order of zooplankton in Raritan Bay, New York Bight and Sandy Hook Bay

Winter		
(1)	Harpacticoids	16 percent
(2)	Acartia tonsa	10 percent
(3)	Eurytemora affinis	8 percent
(4)	Acartia clausi	6 percent
(5)	Pseudodiaptomus coronatus	3 percent

Table 9-44d (cent'd)

Spring			
	(1)	Harpacticoids	18 percent
	(2)	*Eurytemora affinis*	12 percent
	(3)	Cladocera	7 percent
	(4)	*Acartia clausi*	6 percent
	(5)	*Paracalanus crassirostris*	1 percent
Summer			
	(1)	*Acartia tonsa*	49 percent
	(2)	Cladocera	7 percent
	(3)	*Paracalanus crassirostris*	2 percent
	(4)	*Acartia clausi*	1 percent
Fall			
	(1)	*Acartia tonsa*	36 percent
	(2)	Harpacticoids	3 percent
	(3)	*Pseudocalanus crassirostris*	3 percent
	(4)	*Eurytemora affinis*	1 percent
	(5)	*Paracalanus crassirostris*	1 percent

Table 9-45 Dominance order of zooplankton in Sandy Hook Bay
Average over a year (Area 1)

Species	Av #/m^3	Percent	Rank
Acartia tonsa	4224	30.5	1
Copepodites	3543	25.6	2
Eurytemora affinis	1396	10.1	3
Podon polyphemoides	747	5.4	4
Tachidius littoralis	738	5.3	5
Nauplii	582	4.2	6
Littorina capsules	535	3.9	7
Evadne nordmanni	278	2.0	8
Pseudodiaptomus coronatus	232	1.7	9
Gastropoda	221	1.6	10
Acartia clausii	212	1.5	11
Paracalanus crassirostris	211	1.5	12
Pseudocalanus minutus	133	1.0	13
Oithona similis	114	0.8	14
Tisbe furcata	105	0.8	15
Polychaeta	98	0.7	16
Podon leuckarti	90	0.6	17
Eurythemora americana	69	0.5	18
Temora longicornis	58	0.4	19
Tortanus discaudatus	39	0.3	20
Labidocera aestiva	37	0.3	21
Zoea	35	0.3	22
Crangon septemspinosus	31	0.2	23
Eurytemora herdmani	18	0.1	24
Centropages typicus	18	0.1	24
Penilia avirostris	15	0.1	25

from: Sage and Herman, 1974

Table 9-46 Dominance order of zooplankton in Sandy Hook Bay (Area 1) For May-June, 1962

Species	Percent of total zooplankton
1. Synchaeta littorals	18-72
2. Copepod nauplii	10-32
3. Benthic larvae	3-39
4. Acartia clausi	7-25
5. Pseudodioptomus coronatus	1-7

from: Yamazi, 1966

Table 9-47 Dominance order of copepods - Gulf of Maine, coastal waters, 1963-1966.

Species	Percent of total zooplankton
Calanus finmarchicus	89.34
Centropages typicus	23.08
Pseudocalanus minutus	6.18
Temora longicornis	6.00
Metridia lucens	4.11
Acartia longiremis	2.04
Oithona similis	1.41
Tortanus discaudatus	0.76
Centropages hamatus	0.40
Oithona spinirostris	0.23
Eurytemora herdmani	0.15
Acartia clausi	0.12
Metridia longa	0.06
Eurytemora affinis	0.04
Euchaeta norvegica	0.02
Calanus hyperboreus	0.01
Candacia armata	<0.01, >0.001
Anomalocera patersonii	<0.01, >0.001
Oithona plumifera	<0.01, >0.001
Aetidius armatus	<0.01, >0.001

from: Sherman 1964, 1966, 1968

Table 9-48 Dominance order - Bay of Fundy averaged over the year

Species	"Relative percent of total biomass
Calanus finmarchicus	38.6
Centropages typicus	22.6
Pseudocalanus minutus	10.0
Euphausiid eggs	8.9
Metridia lucens	7.1
Sagitta elegans	2.2
Tomopteris catherina	1.0
Nanomia cara	1.0
Meganyctiphanes norvegica	0.7
Clione limacina	0.7
Oikopleura labradoriensis	0.5
Thysanoessa sp.	0.3
Oithona plumifera	0.2
Limacina retroversa	0.2
Thysanoessa inermis	0.1
Parathemisto gaudichaudii	0.1
Temora longicornis	0.1
Parathalestris croni	0.04
Euchaeta norvegica	0.04
Thysanoessa raschii	0.01
Fritillaria borealis	0.01
Aglantha digitale	0.01

from: Fish and Johnson, 1937

Table 9-49 Dominance order of copepods in the Quoddy region
Average over two years

Species	Average Percent
Calanus finmarchicus	42
Pseudocalnus minutus	28
Centropages typicus	14
Tortanus discaudatus	6
Acartia clausi	2
Eurytemora herdmani	2
All others	6

from: Legare and McClellan (1960)

9.9 LIFE HISTORY DESCRIPTIONS OF KEY SPECIES

Key zooplankton species in the study area are given in Table 9-50. Species were selected because they are either dominant in abundance, ubiquitous or representative of a special group within the habitat. In a few instances species were designated as key species even though their distribution is not well understood.

Life history characteristics of most of the key species are summarized according to the following organization:

1. Reproduction
2. Fecundity and larval life
3. Growth and longevity
4. Natural mortality
5. Migration characteristics
6. Distribution and niche preference
7. Population densities
8. Food
9. Predation
10. Competition
11. Responses to the environment

This information was collected from readily available information and should not be construed as a comprehensive literature review of these species.

Table 9-50 Key zooplankton species in Sandy Hook, N.J. to Bay of Fundy area (excluding fishes and tychoplankton).

Species	Biogeographic Region	Distribution	Life history description follows
Copepoda			
Acartia longiremis	N	Neritic	x
Acartia tonsa	S	Estuarine and Neritic	x
Acartia clausi	S	Estuarine and Neritic	x
Centropages hamatus	N&S	Neritic	X
Centropages typicus	N&S	Neritic and Oceanic	X
Eurytemora herdmani	N	Neritic	
Eurytemora affinis	S	Estuarine and Neritic	
Microstella norvegica	N	Neritic	x
Temora longicornis	N&S	Neritic	
Pseudocalanus minutus	N&S	Neritic and Oceanic	X
Calanus finmarchicus	N&S	Neritic and Oceanic	X
Euchaeta norvegica	N	Oceanic	x
Oithona similis	N&S	Oceanic	x
Oithona brevicornis	S	Estuarine	x
Tortanus discaudatus	N&S	Neritic	x
Euphausiacea			
Thysanoessa inermis	N	Oceanic	
Meganyctiphanes norvegica	N	Neritic and Oceanic	x
Chaetognatha			
Sagitta elegans	N&S	Oceanic	x
Appendicularia			
Oikopleura labradoriensis	N	Neritic and Oceanic	
Coelenterata			
Aurelia aurita	N	Neritic	x
Cladocera			
Evadne nordmanni	N	Neritic	x
Ctenophora			
Pleurobrachia pileus	N	Neritic and Oceanic	x
Amphipoda			
Parathemisto gaudichaudii	N	Oceanic	
Pteropoda			
Limacina retroversa	N	Oceanic	x

9.9.1 Acartia longiremis, Acartia tonsa, Acartia clausi

A small, neritic copepod, these three copepods are closely similar in appearance and habits. All inhabit neritic areas, especially slightly brackish bays and estuaries. Acartia clausi and A. tonsa are important in the southern area, and in addition A. longerimis is sometimes important in areas north of Cape Cod.

(1) Reproduction. Spawning takes place in the water mass occupied by the populations. The reproductive period is cyclical throughout the year, being the culmination of each generation. There are several generations a year, their duration and frequency depending, among other things on temperature. Superimposed on the cycle of generations, however, is a seasonal cycle of abundance. When temperature, food supply, competition, predation, and reproductive rate are at favorable levels, populations of one species or another increase. These seasonal periods of abundance vary according to species and geographic location. The following data illustrate the patterns for the New England area.

For Acartia clausi the seasonal periods of abundance are given as follows:
Gulf of Maine: Summer and autumn (Sherman, 1970)
Sheepscot River: April-October (McAlice, 1973) "
Woods Hole: October-February (Fish, 1925)
Block Island Sound: February-May (Deevey, 1952)
Narragansett Bay: March-July (Jeffries, 1962)
Long Island Sound: February-July (Deevey, 1956)

For A. longiremis:
Gulf of Maine: Spring, summer, and autumn (Sherman, 1970)
Sheepscot River: Year round, but chiefly spring, fall and early winter (McAlice, 1973)
Woods Hole: January-May (Fish, 1925)
Block Island Sound: March-June (Deevey, 1952)

For A. tonsa:
Sheepscot River: May-November (McAlice, 1973)
Woods Hole: May-November (Fish, 1925)
Narragansett Bay: July-October (Jeffries, 1962)
Block Island Sound: July-November (Deevey, 1952)
Long Island Sound: July-October (Deevey, 1956)

Both Acartia clausi and A. tonsa have four generations in Long Island Sound (Conover, 1956). A. clausi 's occur in December, February, April, and June. A. tonsa's occur in

July, September, October, and November to December. Thus, A. clausi is defined as a winter-spring species, and A. tonsa as a summer-fall species. (Jeffries and Johnson, 1973).

Reproduction is sexual and fertilization is accomplished by copulation. The males have modified antennae by which they clasp the female. Sperm is transferred to the seminal receptacle of the female in a spermatophore; the fifth legs of the male are adapted structurally to make this maneuver. Eggs are fertilized as they are released into the water.

(2) Fecundity and larval life. Average egg production for A. tonsa observed by Heinle (1970) was 130 per female over a period of 4 days. No data for other species.

All life history stages are pelagic. Eggs are released from the female and not carried in brood sacs or clusters. Eggs of A. clausi hatch in 16 days at 0 C and about 4 days at 10 C (McLaren, Corkett and Zillioux, 1969); eggs of A. tonsa hatch in one day at 20 C (Heinle, 1970). Observations of A. clausi in laboratory culture indicate that the time of development from egg to spawning adult is about 30 days at 20 C and 60 days at 12 C. Field data for A. clausi (Jeffries, 1962) indicates a generation cycle of 8-10 weeks; for A. tonsa, 6-8 weeks.

(3) Growth and longevity. Growth rates discussed under #2. Growth proceeds through 6 naupliar and 5 copepodite stages before maturity is attained. The natural life span of each generation does not extend much beyond the time of breeding.

(4) Natural mortality. No mortality data except for A. tonsa in laboratory culture, An artificially imposed predation rate greater-than 20-23% per day led to the extinction of the cultures. (Heinle, 1970).

(5) Migration characteristics. No information.

(6) Distribution and niche preference. Acartia tonsa was reported from all the study areas except the New York Bight area, whereas A. clausi was restricted to the bay areas, Long Island Sound, and Block Island Sound. This genus is the dominant. group in the inland waters and plays

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9.9.2 Centropages hamatus and Centropages typicus

There are two important species: Centropages hamatus and C. typicus. C. hamatus is a typical coastal neritic species and is important north and south of Cape Cod. C. typicus is important north of Cape Cod and in offshore waters south of Cape Cod. The latter is an important member of the calanoid community in the Gulf of Maine (Bigelow, 1926) and is often dominant in autumn (Sherman, MS).

(1) Reproduction. Spawning areas include coastal and offshore waters. Faber (1959) observed there may have been two spring broods of this genus transported into Narragansett Bay. Clarke and Zinn (1937) observed only one brood in the Vineyard Sound region during the early summer. Bigelow (1926) concluded there was only one brood in the Gulf of Maine.

(2) Fecundity and larval life. All larval stages are pelagic. The generation time is about two months from egg to adult (Marshall, 1949).

(3) Growth and longevity. No information

(4) Natural mortality. No information

(5) Migration characteristics. No information

(6) Distribution and niche preference. Centropages hamatus, a spring-summer species, is of the most importance in the coastal areas where it often is dominant to C. typicus. C. typicus is of more consequence in the offshore waters and although it is present year round, it is primarily a summer-fall species (Jeffries and Johnson, 1973).

Bigelow (1926) found C. typicus to be always restricted to to surface waters and was never found deeper than 100 m. However, Grice and Hart (1962) found that C. typicus was moderately abundant in deeper slope waters of the Gulf of Maine. The center of abundance of C. typicus is off Massachusetts Bay north of Cape Cod, but is also abundant out to the edge of the continental shelf of southern New England (Bigelow, 1926).

(7) Population densities. The month of observed maxima and the density, expressed as numbers per cubic meter are given below.

Centropages hamatus	AREA					
month	1 SH June	3NYB Nov.	9NB May	7BIS June	13BB March	19GB June
density	5 / m³	13,999/m^3	400/m^3	6112/m^3	3100/m^3	0.5/m^3
C. typicus	1 SH Nov.	10RIS Aug.	13BB Dee.	11SSCC July	9NB Nov.	
	18/m3		62/m^3		130/m^3	
	761S Jan., Sept.		4SSMB Sept., Dec.			
	1500;1025/m^3		1300;400/m^3			

North of Cape Cod, maximum densities of C. typicus have been 24,450/m^2 for Massachusetts Bay in October, 1500/m^2 for the Gulf of Maine in August, 2,626/m^2 for western Gulf of Maine in February, and to 100/m^2 for outer Gulf of Maine in May.

(8) Food. Both species are omnivorous and prefer animal food. (Anraktt and Omari, 1963).

(9) Predation. No information

(lo) Competition. No information

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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9.9.3 Microsetella norvegica

One of the microcopepods. Smaller and less widely distributed than Oithona, it is an important copopod of the boreal coastal waters of the Gulf of Maine.

(1) Reproduction. Fish (1955) observed breeding concentrations in the Gulf of Maine as follows:

March: outer part of western basin between Georges Bank and Cape Cod, and eastern basin near the entrance to Bay of Fundy.
May: western portion of inner Gulf.
June: eastern and western basins.
July-August: inner Gulf, especially along a band just to seaward of the 100-meter isobath.

These observations are for a single year and may or may not be regular spawning areas. During the winter, moderate breeding concentrations have also been observed close to shore in the Sheepscot River area (Stickney, 1959)

In the Gulf of Maine there are four major spawning periods: March, May, July and September (Fish 1955). During the winter there appear to be at least one and possibly two spawning periods in inshore areas. In the Sheepscot River these were in November and February (Stickney, unpublished data from observations made in 1954 and 1955).

The spawning behavior follows that of copepods in general, i.e. copulation during which the male transfers a spermatophore to the female. Eggs are fertilized by the stored sperm as they are laid, in brood sacs carried by the female. One copulation apparently provides enough sperm to fertilize several broods of eggs.

(2) Fecundity and larval life. No quantitative information on the number of eggs produced per female. Judging from the size of the egg-sac and the size of the eggs, the number appears to be about 25-35 per cluster. No information on the number of broods of eggs produced by one female, but in other harpacticoids which have been studied in the laboratory, at least two and as many as 12 clusters are produced at intervals of 2-5 days.

Microsetella norvegica is pelagic through all life history stages.

(3) Growth and longevity. Generation time is about 2 months at 11-13.5 C with 4 generations between spring and fall (Fish, 1955). Also at least one generation in winter with a generation time of about three months at 4-8°C (Stickney. 1959 and unpublished data).

(4) Natural mortality. No information.

(5) Migration characteristics. No information.

(6) Distribution and niche preference. No information.

(7) Population densities. Highest concentrations observed by Fish were over 100,000 per cubic meter in local areas near coast, and general densities throughout Gulf of Maine 2000-5000 per cubic meter at times of seasonal maxima. Winter populations in Sheepscot River were 3000-7000 per cubic meter (Stickney, unpublished).

(8) Food. Probably herbivorous, feeding on smaller members of the phytoplankton and possibly the nannoplankton. No specific information.

(9) Predation. Microsetella supplements Oithona as a food of larval plankton feeders in mid summer, particularly in coastal areas of Frenchman Bay and Mt. Desert, Maine and eastward where they are locally abundant and where there is a lack of other Copepod species.

(lo) Competition. No specific information. Probably Oithona and other herbivorous microcopepods compete for food.

(11) Responses to the environment (natural factors, pollutants). No information.

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9.9.4 Pseudocalanus minutus

A relatively small copecod, one of the three most abundant species of copepods in the Gulf of Maine.

(1) Reproduction. Although specific data on spawning areas is not available, it is probable that most of the spawning is accomplished in coastal and offshore waters as this is a euryhaline-marine copepod (Jeffries and Johnson, 1973).

P. minutus spawn throughout the Gulf of Maine and the Bay of Fundy. It is probable that the principle spawning area of P. minutus is located in the outer Gulf rather than near shore. Propagation in the area west of Mt. Desert Island does not appear sufficient to account for the large numbers of P. minutus appearing eastward along the coast and into the Bay of Fundy as the season advances. The western coastal area seems to be an important source of the first brood only.

Propagation begins in March and continues in a succession of generations until September. Eggs appear at progressively later periods (monthly intervals) in the outer Gulf, western area (Mt. Desert to Casco Bay) and the Bay of Fundy in the east suggesting three major breeding stocks respectively. These stocks do not necessarily originate in these areas.

Outer stock	- 4 breeding periods, exact times not traceable.
Western stock	- 3 and possibly 4 breeding periods: March-April, May-June, July-August and September.
Eastern stock	- 3 breeding periods: April-May, June-July, and August.

There is no evidence of successful propagation in the Bay

of Fundy and the western area declines in. importance after the first brood. Subsequent propagation of all breeding stocks appears to be centered in the outer Gulf. (Fish,1936).

(2) Fecundity and larval life. One ovisac contains 1 or 2 eggs. In the breeding season there are approximately 180 eggs (Corkett and McLaren, 1969).

Egg through late copepodite stage, is pelagic.

(3) Growth and longevity. Time to grow from nauplius to adult is about 2 months. Probably over winters in the late copepodite stage.

(4) Natural mortality. Unlike Calanus finmarchius in which mortality is greatest following the final moult, the decline in P. minutus is greatest during the nauplius stages. Table V, p. 204 from Fish and Johnson (1937) compares the decline in numbers per minute of tow in the Bay of Fundy and Gulf of Maine.

Total Region 1932	April-June		August-September	
Stage	P. min.	C. fin.	P. min.	C. fin.
Nauplius	10,568	2,160	4,476	638
Early copepodite	1,468	1,103	230	48
Late copepodite	1,079	514	292	10

Since the abundance of adult Calanus usually exceeds Pseudocalanus, a second period of strong mortality may exist during maturation for the latter species.

(5) Migration characteristics. No information.

(6) Distribution and niche preference. This species is a dominant species both inland and offshore as well as being present in many coastal areas. They are perhaps of most significance in some of the estuaries, such as Narragansett Bay. However, Bigelow and Sears (1939) observed maximum densities in localized areas 30-35 miles offshore. Their distribution, as is the case with most copepods, is effected by currents throughout the area.

In the Gulf of Maine, P. minutus does appear to be transported shoreward in the spring and this transport may be in relation to residual surface currents (counter-clockwise eddy in the Gulf of Maine). Since it also occurs inshore in swarms during the winter its distribution might also be related to coastal currents. Essentially., its transport is not well understood.

(7) Population densities. 2,800 per $100m^3$ along coastal Gulf of Maine (Sherman, 1966). This estimate is for adult and possibly copepodite stages. In the lower Sheepscot River, Maine in July, adults $200/m^3$, copepodites 1-V $8/m^3$, nauplii $1400/m^3$ (McAlice, personal communication).

South of Cape Cod, the month of observed maxima and the density, as numbers per cubic meter are given below. Bigelow and Sears (1939) observed localized maxima 30-35m off shore.

Area				
Narragansett Bay	Block Island Sound	Long Island Sound	Raritan Bay	New York Bight
April-1,500	April-1,700	April-3800	Dec	July-4381

Total counts are for members of the genus Pseudocalanus, which were not distinguished from one another.

(8) Food. Pseudocalanus is herbivorous, feeding on small diatoms and flagellates.

(9) Predation. Pseudocalanus, because of its smaller size, is one of the principal food of larval fish. In coastal areas of the Gulf in the winter it is the main source of food for larval herring. It is also eaten by sagittae and medusae.

(10) Competition. Because it probably takes smaller food, it would more likely compete with Oithona than Calanus. However, as mentioned for Calanus, its yearly maxima does not occur at the same time as the other two species.

(11) Responses to the environment (natural factors, pollutants). No information.

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9.9.5 Calanus finmarchicus

A Calanoid copecod. 'it occurs abundantly throughout the Gulf of Maine, and shelf waters south of Cape Cod. It is of a relatively large size, and is the most important single planktonic animal in the Gulf of Maine.

(1) Reproduction. Spawning areas have not been defined in the southern region, but offshore waters are probably most important with some spawning occuring in coastal waters.

North of Cape Cod, the primary area is in the southwestern part of the Gulf of Maine, along Cape Cod, including Massachusetts Bay and northward to Isle of Shoals. A secondary area of spawning may be located in the eastern basin of the Gulf of Maine, the northern channel and near Cape Sable. Over the greater part of the Bay of Fundy and the turbulent coastal region of the Gulf east of Petit Manan there is no evidence of successful production of Calanus. However, a small portion of the eastern stock survives at the western limits of the region since

successive generations can be traced. (Fish,1936; Fish & Johnson,1937).

Vernal warming appears to initiate spawning. Fertilization takes place in winter when the stage V copepodites moult to become adults and females are found bearing spermatophores. But the ovaries are not developed at this time and may remain undeveloped until spring. Along the coast there are two periods of propagation east of Mt. Desert, April - May and July - August." West of Mt. Desert there are three; March - April, June - July, and September.

Clarke and Zinn (1937) observed two times of spawning per year off Woods Hole; in the spring, begining in April, and in the early summer.

(2) Fecundity and larval life. Total production of 200 to 300 eggs usually but may reach 586 eggs. Usually 20 to 60 eggs are laid in 24 hours, but may reach 150. The 586 eggs were produced in 74 days. Egg production takes place in a series of bursts each lasting about 1 week. Some eggs are not fertilized and thus the birth rate is slightly below its fecundity.

Larval life style - The larval forms of Calanus occur in nauplii stages I through VI and the copepodite stages I through V. Eggs, nauplii and young copepodites are found mainly in the upper water, the top 30 meters. All stages are pelagic. In autumn the remaining copepodite stages III, IV and V go deep and development stops. In mid-winter the stage V copepodites moult into stage VI or adults and fertilization occurs, (Marshall & Orr,1972).

(3) Growth and longevity. Growth rate - Along the western coast of the Gulf of Maine the complete cycle of growth and development requires 71-79 days for the first brood and 78-81 for the second brood, about 2½ months from egg to spawning adult. Together, the spring and summer group has a maximum existence of four months and the winter group also has a maximum existance of four months. The following tables give an idea of the proportion of time spent in the various stages and their sized or length indicating growth.

Stages	I-II	11-111	III-IV	IV-V	V-VI
Proportionate time	1	1.53	1.69	1.95	5.59
Days	2	3	3	3.5	10.5

Stage	length mm	Stage	length mm		
Nauplii	0.59	IV	2.10	Males	3.0 mm
I	0.94	V	2.48		
II	1.25	VI	2.83	Females	3.1 mm
III	1.65				

(4) Natural mortality. Exceedingly high mortality rate in the mature stage. The species is largely annual with all adults dying off in September.

(5) Migration characteristics. See Distribution and niche preference.

(6) Distribution and niche preference. South of Cape Cod this species is most successful in the offshore waters, but was reported in all the study areas except Raritan and Sandy Hook Bays. Transportation by currents appears to be critical for the dissemination of this species from its areas of breeding towards the inland waters.

North of Cape Cod C. finmarchicus is transported by the surficial circulation of the Gulf of Maine gyre. Redfield (1941), presents a hypothesis describing the' drift of the Calanoid community. Calanus undertakes extensive diurnal vertical migration in the summer.

(7) Population densities. South of Cape Cod. The month of observed maxima and the density, expressed as numbers per cubic meter or numbers per 30 minute haul, are given below.

	Vineyard Sound	Buzzard Bay Area	Rhode Island Sound	Narragansett Bay	Block Island Sound
Month	July	July	July	May	June
Density	8000/30min haul	672/m^3	16712/m^3	4/m^3	127/m3

Maximum densities of population North of Cape Cod - 459,900 m^2 off Gloucester (Bigelow.1926) and 70,000 m^3 in upper 20 m. of coastal Maine (Sherman, 1968).

(8) Food. Calanus is primarily a filter feeding herbivore feeding on what is common in the microplankton at any given time. It can also actively seek out food using its maxilla as "scoop nets". Its primary food is the following diatom genera:

Coscinodiscus
Biddulphia
Skeletonema
Thalassiosira
Chaetoceros
Rhizosolenia

It also' eats some species of dinoflagellates (but not Ceratium) and small flagellates. It is able to consume food of a wide size range.

There is some evidence that Calanus will eat small crustaceans and other planktonic animals during seasons when its regular food is scarce.

(9) Predation. Calanus is the principal food of many of the pelagic fishes: The clupeoids in particular. Calanus is the main food of herring, shad, alewife, Sand lance, and mackerel. Many of the-flat fishes and-ground fishes will also feed on Calanus, particularly during their larval and juvenile stages. i.e. Cod, Haddock, Pollock. Other predators include sagittae, ctenophores, large euphausiids, and medusae.

(lo) Competition. Probably competes with any of the hervivorous, filter feeding planktonic crustaceans for food. North of Cape Cod the seasonal maxima of Calanus (Play) is out of phase with the other two principal herbivorous copepod species, Pseudocalanus (June) and Oithona (August), so that competition between the three species is probably minimized.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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9.9.6 Euchaeta norvegica

A large, powerful copepod of the deeper waters. Although not as abundant as the smaller copepods, it is the characteristic plankton animal in the deeper waters of the Gulf of Maine.

(1) Reproduction. Euchaeta spawns almost entirely below 100m throughout the year in the Gulf of Maine. During the spawning act the male clasps the female with his-modified first antenna. He then seizes the spermatophore with his modified left leg (modified into a complicated hand) and transfers it to the female near her genital opening. He then leaves the female and fertilization takes place as the eggs are laid and deposited in a, sac attached to the genital segment of the female.

(2) Fecundity and larval life. There is no information on fecundity. The larvae are pelagic with six naupliar stages and five copepodid stages.

(3) Growth and longevity. No information on growth rates; the adult female attains 8mm, the adult male 7mm.

(4) Natural mortality. No information.

(5) Migration characteristics. No information.

(6) Distribution and niche preference. Generally distributed throughout the Gulf of Maine at all times of the year. They are found in 80 percent of all hauls below 100 m.

(7) The following average densities have been recorded:

June-Sept.	Feb.-May	Annual ave
1200 per m^2	800 per m^2	930 per m^2

(8) Food. Food - Euchaeta is a large, carnivorous copepod (or omnivore with animal preferences) which uses its large

maxilla to capture animal food. Probably feeds chiefly on the smaller crustaceans.

(9) Predation. Euchaeta is not a major food item for many fish because of the depth at which it lives. It is preyed on by large euphausiids and the pollock.

(10) Competition. No information.

(11) Responses to the environment. (Natural factors, pollutants). No information.

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9.9.7 Oithona similis

Oithona - A small cyclopoid copepod which exists over a wide range of temperature and salinity. The Oithona genus has two important members in the southern region, Oithona similis and Oithona brevicornis. O. similis is important north of Cape Cod as well and is one of the three most abundant species of- copepod in the-Gulf of Maine. In some of the study areas these species were not distinguished from one another. Although not as much information is available for O. brevicornis, it is assumed it is similar in many respects to its congener O. similis.

(1) Reproduction. Spawning in the Gulf of Maine is widespread, but varies greatly in different parts of the investigative region. Until July the western part of the Gulf is most important. The eastern part of the Gulf is most important in mid-summer. The Bay of Fundy and the eastern sector of the Maine coast are relatively unimportant spawning areas. But, they receive important contributions from the

eastern basin. There is some evidence that the larval stock in the Gulf is supplemented by important contributions from another production area, probably from the vicinity of the outer banks.

Propagation begins in the Gulf of Maine in March and continues in a succession of generations until September. Two breeding stocks are distinguishable because spawning begins one month later in the eastern than in the western Gulf of Maine. There four broods of the western stock; March, May, July and September. There are three broods of the eastern stock; April, June and August.

South of Cape Cod Oithona similis spawns in the coastal and offshore waters while O. brevicornis spawns i-n estuarine waters. Water currents disperse the larvae to adjacent waters. Exact locales for spawning have not been determined.

Faber (1959) recorded three to four spawning periods in Narragansett Bay for O. brevicornis and reported that O. similis spawns periodically throughout the year in coastal areas. He noted that the main breeding months for the summer-fall species, O. brevicornis, are July, August, and September.

(2) Fecundity and larval life. Possibly the number of egg sacs taken in relation to the number of early nauplii is indicative of their fecundity: 1,947/11, 765; 1,855/15,363; 1,409/8,044; and 1,224/10,981. About 5 to 7 eggs would have been produced by each female bearing one ovisac during the breeding season. Since they may bear two sacs at once a better guess might be 5 to 10 eggs per female.

Oithona has a pelagic nauplii and copepodite stages. Developmental period lasts from 2 months in early spring to 6 weeks in summer..

(3) Growth and longevity. See above.

(4) Natural mortality. Highest mortality is in the nauplius stage. Naupii in August of 1932 numbered 34,852 per cubic meter and copepodites and adults numbered only 332 the subsequent September. A similar relation was obtained for August-September of 1931: 33,925 to 94. (Fish,1936).

(5) Migration characteristics. No information

(6) Distribution and niche preference. This genus is important in the inland waters, as a result of Oithona brevicornis,

and in the coastal regions as a result of O. similis. O. brevicornis is primarily important during the summer-fall period. While O. similis is a year-round species.

The adult stock in the spring appears to approach the coast from offshore with rising vernal temperatures. In Maine estuaries, ovigenous females and larvae are found right through the winter.

(7) Population densities. The maximum densities are listed by species and by study area. The month of observed maxima and the density, expressed as numbers per cubic meter, are given below.

	AREA			
Oithona similis	9NB	7BIS	13BB	4SSMB
month	July	July	December	December
density	117/m3	5000/m^3	390/m^3	250/m^3
O. brevicornis		9NB	7BIS	13BB
month		October	April	December
density		13,000/m^3	14/m3	1,260/m^3
O.spp	6LIS	3NYB	9NB	
month	Sept.	June	October	
density	29,000/m^3	49,000/m^3	22,000/m^3	

The report for Long Island Sound of 29,000/m^3 was probably predominantly O. brevicornis while the report for the New York Bight of 49,000/m^3 was probably dominated by O. similis.

In the Gulf of Maine, the largest mean number of nauplii of O. similis was 34,852 per cubic meter and adults, 3,550 per cubic meter.

(8) Food. Very little information probably omnivore, inefficient filte rer.

(9) Predation. Oithona is a major source of food for summer larval plankton feeders because of its small size.

(lo) Competition. Probably competes for food with Pseudocalanus and other small herbivorous planktonic crustaceans, although its yearly maxima does not occur at the same time as Pseudocalanus or Calanus.

(11) Responses to the environment (natural factors, pollutants). No information.

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9.9.8 Tortanus discaudatus

(1) Reproduction. Breeding period' extends from early summer through early autumn with little or no reproduction taking place-in late autumn, winter or early spring. Spawning occurs at night in the upper strata of the water. 100 percent of the eggs hatch in 3-4 days at 12-13 C. (Johnson, 1967).

The male clasps the female with its modified first antennae and transfers a spermatophore which is fastened in the vicinity of the genital opening of the female. The male then leaves and fertilization takes place when the eggs are shed into the water. The eggs develop a thick chitinous case with a broad thin flange encircling the egg.

(2) Fecundity and larval life. Tortanus lays 15-30 eggs per female with a second smaller batch of eggs deposited within 10 days.

Eggs are spawned directly into coastal waters where they , float during the incubation period. The larvae are pelagic with six naupliar stages and five copepodid stages.

(3) Growth and longevity. Nauplius stage I ranges. in size from 0.12-0.14 mm. Nauplius stage VI about 0.36 mm. Copepodid stages range from 0.55 mm. for stage I to 1.4 mm for stage V.

(4) Natural mortality. No information.

(5) Migration characteristics. No information.

(6) Distribution and niche preference. Tortanus is restricted to coastal waters.

(7) Population densities.

	New York Bight No/m3	Block Island Sound No/m3	Narragansett Bay No/m3	Western Gulf of Maine No/m3	Central Gulf of Maine No/m3
Max density	3,711	373	350	100,000	0.5

(8) Food. Tortanus is exclusively carnivorous and has the relatively high respiratory rate typical of carnivores. Presumably it feeds on small crustaceans and planktonic larvae.

(9) Predation. Considering the size of Tortanus and its distribution they are probably preyed on by coastal carnivorous plankton feeders. Larger sized gadoid fish larvae are known to take them (Marak, 1960), and probably juvenile and adult plankton feeders do as well.

(10) Competition. No specific information - they would not compete for food with most other copepod species, being carnivorous.

(11) Responses to the environment (natural factors, pollutants). No information.

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9.9.9 Meganyctiphanes norvegica

An extremely abundant euphausiid crustacean and a major component of the food of many marine animals.

(1) Reproduction. Spawning ranges from April to September. Females produce one brood per year. The yound produced over winter as juveniles are sexually mature the following year.

Major spawning occurs along the coast westward from Mt. Desert, in the open Gulf probably in water 150 to 200 meters deep., and in southwestern Nova Scotia. East of Mt. Desert, water temperature or some associated factor prevented the incubation of eggs which are thought to drift into the area. Young and adults are found west of Mt. Desert, but only adults to the east.

The eggs-are fertilized before they are released by the female. Usually females move to the surface to spawn, but" occasionally spawn during the day in deeper water. Environmental factors control the. time of spawning, however, it is probably not temperature alone. Some factor associated with the increase in the spring plankton bloom may also contribute to the regulation of spawning.

(2) Fecundity and larval life. The number of eggs laid by a gravid female is given by Mauchline and Fisher (1969) as 530. This was a calculated value from the egg size and egg volume in a gravid ovary and may underestimate the fecundity.

Fertilized eggs are shed into the upper surfaces of the water. The eggs sink (5.5-7.5m/hr. at 33 O/oo and 15 C) and the larvae hatch out on the bottom in shallow water, or at lower depths in deep water. Those that hatch in deep water migrate to the surface again. There are four larval stages; nauplius, metanauplius, calyptopis, and furcilia. However, there is considerable variation in development, particularly in the furcilia stage in shallow water.

The larval stages usually are higher in the water column than the adults and don't show extensive diurnal movements.

There is no clear-cut metamorphosis to the juvenile stage; the larvae just graduate into juveniles. Metamorphosis is generally in spring and they winter-over as juveniles.

(3) Growth and longevity. The rate of growth varies considerably with area. The following growth data is for the Firth of Clyde and southern Iceland.

Month	Clyde (mm)	Iceland (mm)
May	4	1
July	13	7
Sept	21	15
Nov	22	19
Jan	22	21
Mar	25	22
May	33	24
July	34	27
Sept	35	29
Nov	35	30
Jan	36	31
Mar	37	31
May	43	

The maximum size obtained is greater in colder water. In the Gulf of Maine the maximum size is probably 38-95 mm.

The life span of M. norvegica is 3+ years, with a small percentage (5-10%) living to breed for a third time.

(4) Natural mortality. There is the usual heavy mortality during the egg, nauplius, and metanauplius stages. Data from both the Barents Sea and the Clyde illustrate this mortality.

eggs/m^3 200-400/m^3
surviving calyptopis stage larvae - 10 -100/m^3

Thereafter the greatest mortality for all age groups occurs during the spring breeding season. During the first breeding, numbers are reduced by about one half. The next year the mortality is greater and only about 5-10 percent survive to breed the third year.

(5) Migration characteristics. See below.

(6) Distribution and niche preference. M. norvegica is abundant in the coastal shelf and slope waters; therefore the whole Gulf of Maine. Euphausiids display a diurnal movement, remaining in deep water (100-400m) during the day and moving near the surface at night. The movement up and down is in response to an optimum light intensity. The older individuals tend to remain in deeper water than the young during the day. In shallow areas Euphausiids are found just above the bottom during the day.

In the Gulf of Maine M. norvegica is thought to make seasonal movements, moving into the Coast from the shelf waters from January to May. This is thought to be related to prespawning aggregations. Once spawning takes place the populations tend to disperse.

(7) Population densities. Dense swarms of M. norvegica are reported for Georges Bank, Stellwagen Bank off Massachusetts and in the coastal area at least between Casco Bay and Penobscot Bay. Sherman (1968) gives densities for Euphausids (presumably most were M. norvegica) for the western Gulf of Maine Coast.

Season	No./100m^3
Winter	31
Spring	444
Summer	2259
Autumn	72

(8) Food. M. norvegica has a varied diet and is capable of feeding by

1. Filter feeding phytoplankton and small zooplankton
2. Actively capturing larger zooplankton and
3. Detritus feeding.

Major food items reported are:

Detritus (plant fragments and crustacean remains)
Algae
Diatoms (Thalassiosira and others)
Dinoflagellates (Ceratium, Peridinium and others)
Tintinnids
Radiolarians
Coccolithophores
Sagitta
Crustaceans

(9) Predation. Predators are numerous and include birds, seals and whales, fish, and invertebrates. Most of the North Atlantic food fish are either directly or indirectly dependent on M. norvegica for part of-their diet. Such species as:

Clupea harengus	Scomber scombrus
Gadus morhua	Sebastes marinus
Pollachius virens	Merluccius bilinearis
Urophysis chuss	

prey on euphausids as a major part of their diet.

The squid Loligo sp and such birds as gulls and kittiwakes feed on euphausiids

(10) Competition. Competitors - No information. probably they compete with any other species that have similar food habits.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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9.9.10 Sagitta elegans

The carnivorous chaetognath, or arrow worm, is a universally abundant member of the macroplankton community in the Gulf of Maine

(1) Reproduction. Centers of reproduction lie just north and south of Georges Bank, Nantucket Shoals, vicinity of Cape Sable, coastal area of western Gulf of Maine, Bay of Fundy and perhaps Massachusetts Bay. Due to the paucity of information for the southern region, one may only surmise that spawning is greatest in the offshore waters as it is in the northern sector. This is supported by S. elegan's classification as a stenohaline marine species (Jeffries and Johnson, 1973).

There is a prolonged spawning period beginning in the spring and extending through the autumn. Two generations are produced each year Spring and Fall (Zo, 1973). Maturity is reached from six weeks to about 1 year.

Four breeding seasons, January, May, July, and September were noted by Clarke and Zinn (1937) which are similar to the breeding seasons off Plymouth, England.

It is thought that the hermaphrodite Chaetognaths copulate for cross fertilization.

(2) Fecundity and larval life. Egg to adult probably 2-4 months in Gulf of Maine (Zo, 1973) Zo's (1973) data suggest 10-750 eggs/female. The larvae are pelagic.

(3) Growth and longevity. Growth rate is correlated with temperature. As the temperature of the water rises toward June the size of mature Sagitta elegans increases.

(4) Natural mortality. No information. "

(5) Migration characteristics. No information.

(6) Distribution and niche preference. S. elegans is neritic in some localities. One explanation is that the young move into estuaries and embayments by transport within residual bottom currents. Coastal estuaries and embayments and Georges Bank may serve as nursery grounds for the young.

South of Cape Cod Sagitta elegans was observed in all the study areas except Raritan and Sandy Hook Bays. It is of most importance in the offshore waters where it is endemic. As stated above, the young probably move inland by transport of bottom currents.

The distributional range of S. elegans may be controlled by the distribution of oxygen because in the Northern Pacific S. elegans occurred only within water containing 6 ml/1 of oxygen. It may survive in waters as low as 13 °/oo but the high salinity at the edge of the Gulf Stream constitutes a barrier.

(7) Population densities. Along the western coast of the Gulf of Maine a maximum of 2200/100m^3 was obtained above the 20 m depth. On Georges Bank 5840/100 m3 were obtained in the water column. The month of observed maxima and the density in Narragansett Bay and Block Island Sound expressed as numbers per cubic meter are given below.

	Area	
	Narragansett Bay	Block Island Sound
month	Apri 1	May
No./m^3	30	51

(8) Food. Active, well armed carnivores. Feed on crustaceans Tortanus (principally the small copepods Pseudocalanus, Acartia, Oithona, Tortanus) and young fish. They are also cannabalistic. Larval herring (7-12mm) as well as other commercially important larval fish have been reported as being preyed on by Sagitta.

(9) Predation. Major predators are medusea, ctenophores, juvenile and adult fish. Juvenile and adult herring are known to eat Sagitta, as well as mackerel and pollock.

(lo) Competition. Any of the carnivorous members of the macroplankton, i.e. euphausiids and ctenophores as well as any species that feed on copepods (Calanus, Pseudocalanus, Euchaeta).

(11) Responses to the environment (natural factors, pollutants). No Information gathered.

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9.9.11 Aurelia aurita

The moon jelly is the most abundant of the scyphomedusoid jellyfish in the region. Found in coastal and shelf waters from Greenland to the West Indies.

(1) Reproduction. Spawning takes place in the water where concentrations of medusae occur. Sperm is shed into the surrounding water, but eggs are fertilized internally.

Sexual reproduction takes place in mid- or late summer. No information on control of timing. Asexual reproduction occurs in early spring, probably initiated by the falling water temperature during the winter. Strobilation can be artificially induced by gradually cooling the water (Spangenberg, 1968) and is suppressed by high temperatures.

In sexual reproduction, the eggs are released from the ovaries into the diverticula of the stomach, where they are fertilized by sperm taken in from the water along with food particles. The fertilized eggs are passed down into pockets in the oral arms where they develop into planula larvae.

In asexual reproduction, the sessile scyphostome develops a series of segments or annulae in its body (strobilae). These gradually develop into a stack of saucer-like ephyrae, which eventually separate and become free living.

(2) Fecundity and larval life. No information on fecundity.

The life cycle of Aurelia alternates between a pelagic medusa and a sessile, hydra-like seyphostome. Sexual reproduction of the medusae results in the birth of pelagic larvae, or planulae, which metamorphose after about two days to produce the sessile scyphostome. (Costello, et. al. 1957). The scyphostome develops vegetatively for 8 or 9 months, overwintering in this form. In early spring it reproduces asexually by a peculiar process of budding (strobilation) to produce a number ofmedusoid pelagic larvae (ephyrae). These develop in about 4 months into the adult medusae.

Asexual reproduction by strobilation varies. Some strains of Aurelia consistently produce 25 or 30 ephyrae each year, others only 3 or 4. (Spangenberg,1968). Under poor feeding conditions or too high a temperature, strobilation produces only a single ephyra.

(3) Growth and longevity. The life cycle is generally completed in one year. The ephyra grows from a diameter of perhaps 7 mm. to a medusa of 150 mm. or more in about 4 months. The growth of the sessile form is much slower; at the age of 8 months when strobilation begins, the scyphotome is only 1,2-15 mm. in height. The scyphostome may live for two more years, producing a new generation of ephyrae each spring. (Hyman, 1940).

(4) Natural mortality. No information.

(5) Migration characteristics. No information.

(6) Distribution and niche preference. No information gathered.

(7) Population densities. Local populations of Aurelia medusae may be very dense. No information on numbers, but when concentrated by wind or currents, patches 10-100 meters in diameter occur in which individual medusae are in contact with one another in a nearly solid mass. These patches are visible in the water at some distance as pinkish discolorations.

(8) Food. Aurelia feeds on zooplankton and diatoms which are entangled in the mucus coating of the disc and are thence transported by ciliary movement to the mouth.

(9) Predation. Apparently there are few predators. The ocean sunfish Mola is said to eat jellyfish (Bigelow and Schroeder, 1953) and also the lumpfish Cyclopterus.

(lo) Competition. No outstanding competitors, but all plankton feeding pelagic fish and invertebrates would compete to some extent for food. During the sessile scyphistome stage competition for space with hydroids, anemones, sponges, bryozoans or ascidians would probably be more critical.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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9.9.12 Evadne nordmanni

A neritic, marine, cladoceran crustacean. Found along the coast particularly near the surface during the warmer months.

(1) Reproduction. E. nordmanni generally breeds in shallow coastal areas. 'Jo-1933) states that the only justification for calling it a neritic species is that it seems to prefer the coastal areas for breeding. However, there is no evidence that this is absolutely necessary for breeding.

In the Gulf of Maine, reproduction occurs from April to September. During this period successive broods are produced and, according to Shermans (1968, 1970) data, at any time within these limits intense parthenogenic reproduction can create periods of high density. Bainbridge (1958) found most sexual reproduction occurring in October with formation of resting eggs.

The age at first spawning is probably immediately after the animal is released from the parent's brood pouch. Newly released young commonly have embryos developing in their brood pouches.

E. nordmanni has two reproductive phases. The main one is by parthenogenisis where the female deposits eggs in a brood pouch and these develop into free swimming young. During periods of intensive breeding, late stage female embryos will themselves develop eggs while still in their mother's brood pouch. (Bainbridge, 1958).

The second phase is sexual and results in the development of a large "resting" or "winter" egg which is left in the cast shell of the female after molting. The sexual phase and the resulting resting eggs occur after a period of "depression" in which the animals experience some type of stress. There is considerable discussion as to the cause of depression in Cladocerans. (Bainbridge 1958, Jorgenson, 1953). Of the several causes proposed (lower food supply, lower temperature, or an inherant cycle) the evidence at present seems to point to lower food supply (Bainbridge, 1958).

(2) Fecundity and larval life. For the parthenogenic phase of reproduction the number of embryos produced per brood is 6-9 during the intensive period of reproduction and 2-5 as "depression" and the sexual phase approaches (Jorgensen- 1933). The size of the female and the number of embryos produced was best correlated with food supply (Bainbridge 1958). I could find no information on the number of broods produced per season.

There is apparently no larval stage. The developed embryo is released from the female as a freeswimming young, presumably resembling the adult.

(3) Growth and longevity. No specific information, however growth to maturity is probably quite rapid because the young are in an advanced stage when released and there is evidence of a number of broods maturing during the season.

(4) Natural mortality. No information.

(5) Migration characteristics. No information.

(6) Distribution and niche preference. Generally E. nordmanni is considered a neritic species (Raymont, 1963; Fish & Johnson, 1937) and is found in our area mainly along the periphery of the inner Gulf. However, it may extend into deeper waters and Jorgenson (1933) considers it only neritic in the sense that its principal breeding areas are in shallow coastal locations.

E. nordmanni concentrates close to the surface and Jorgenson (1933) states that the optimum 1 ight intensity must be high for this species.

(7) Population densities. E. nordmanni occurs seasonally. In the Gulf of Maine it was found from April to September with the most abundant period occuring in August. Fish and Johnson (1937) give the following relative percent of total plankton 'along the inner perphery of the Gulf during the month of August.

	Western	Central	Eastern
Relative %	0.6	2.3	2.7

Bainbridge (1958) found E. nordmanni most abundant in the Clyde Sea in June where he recorded a maximum density of 1636/m^3 .

Sherman (1968, 1970) gives the concentration of cladocerans in the Gulf of Maine coastal waters for the years 1965-68. Cladocerans were found from spring to autumn with the season of maximum density varying from year to year. He recorded a maximum density for the four years as 1674/100m^3 in the fall of 1966.

(8) Food. Evadne is principally herbivorous but is a selective feeder, taking only certain types of phytoplankton. In British waters Bainbridge (1958) found Evadne fed almost exclusively on Tintinnids, Peridnians and Ceratium furca. Diatoms are apparently unimportant.

(9) Predators. Probably coelenterates, chaetognaths, and large crustacean larvae. Evadne is a slow, weak swimmer and may be more easily caught. There is evidence in British waters (Bainbridge, 1958) that populations of Evadne are greatly reduced by predation.

(lo) Competition. No information.

(11) Responses to the environment (natural factors, pollutants), No information gathered.

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9.9.13 Pleurobrachia pileus

A common ctenophore. Planktonic in habit, it can be extremely and erratically abundant.

(1) Reproduction. P. pileus spawns all around the shoal, peripheral area of the Gulf (Bigelow, 1926).

It probably reproduces at irregular intervals although it is generally thought to lay eggs in late summer and autumn and that the eggs winter over and mature the following spring. Greve (1970) found the minimum size for reproduction was 5.5 mm diameter and that most began to reproduce by 11 mm diameter.

Greve (1970) reports that a high concentration of adult P. pileus activates the gonads of well fed specimens and the eggs are released in less than two days. Complete embryonic development occurs within 24 hrs. at 15 C.

P. pileus is hermaphroditic with the sex cells released through the month. Fertilization is external with the embryo developing in the planktonic egg and emerging as a cydippid larvae. (Hyman, 1940).

(2) Fecundity and larval life. There is no information on fecundity.

P. pileus produce cydippid larvae from free floating eggs. These resemble the adult closely and soon assume the adult morphology through slight changes. They are planktonic during the larval period as well as through adult life. (Hyman -1 940)

(3) Growth and longevity. Greve (1970) gives the following rates of growth for laboratory reared P. pileus.

Days	Diameter (mm)
10	0.9
20	1.8
30	4.0
40	8.8
50	11.2
60	12.2
70	12.9

P. pileus grow much larger in colder water than warmer and can reach 30 mm diameter in cold water (Bigelow, 1926).

(4) Natural mortal ity. The heaviest mortality occurs in the young ctenophores at a size ranging from 0.1 to 2.0 mm diameter. In laboratory rearing experiments (Greve, 1970) less than 1% of the young survived. After reaching 2-3 mm diameter, mortality decreases. P. pileus has been noted to be very sensitive to vibration and to thanges in temperature and salinity in the laboratory. (Greve, 1970).

(5) Migration characteristics. No information.

(6) Distribution and niche preference. P. pileus is found all around the periphery of the Gulf in shoal water during March and April. It extends its range out into the open Gulf from May to Autumn forming a line from Cape Cod to Cape Sable. It is not found over the eastern channel or on eastern Georges Bank. Its area of distribution contracts again to the coastal periphery in the Autumn-Winter seasons. Thus, although it does not depend on the bottom it is more neritic than oceanic. (Bigelow, 1926).

Both Bigelow (1926) and Fish and Johnson (1937 report that P. pileus swarms continually all year around in the shoal water west of Nova Scotia.

P. pileus is a weak swimmer and generally drifts with the tides and currents and often are concentrated in large numbers. They are found in the upper strate of the water; Bigelow found them no deeper than 30-50 meters.

(7) Population densities. P. pileus can be found in dense concentrations all along the shallow periphery of the Gulf of Maine. Bigelow (1926) found no evidence of a general ebb and flow of abundance in the Gulf seasonally, although there are local fluctuations. The appearance and disappearance of P. pileus is very sporadic and unpredictable. Quantitative data on density is difficult to get. In many cases plankton nets will be almost filled with ctenophores and contain many liters of them.

Ctenophores are important to the pelagic community because when they concentrate they can destroy large numbers of plankton animals, including fish eggs and larvae. In some instances this could have a significant impact on the reproduction of some fishes such as cod or haddock.

(8) Food . P. pileus is a non-selective, . voracious carnivore, feeding on whatever is available in the plankton. In Scottish waters (Frazer, 1970) crustaceans made up 80-90 percent of their diet and when concentrated they were capable of rapidly reducing the zooplankton population. The most abundant food items were:

Calanus spp.
Temora longicornis
Oithona sp.
Invertebrate eggs
cirriped larvae

Thee extent to which P. pileus destroys fish eggs and larvae is not well known, although a number of authors have reported serious predation on fish eggs, larvae and small fish of species such as cod, haddock and herring. Fraser (1970) found 1 ittle evidence of the destruction of fish eggs and larvae at the time of his study.

{9) Predation. Several fish feed on P. pileus occasionally, but not as a main part of their diet:

Cyclopterus lumpus
Gadus morhua
Scomber scombrus
Squalus acanthius

They are also preyed on by large medusoid ceolenterates.

(10) Competition. There has been speculation that, because they feed so heavily on copepod populations, P. pileus compete with fish species that feed on copepods also. The herring is cited as an example. They depend on heavy concentrations of Calanus during the summer so that winter fat can be stored.

(11) Responses to the environment (natural factors, pol 1 utants). No information gathered.

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9.9.14 Limancina retroversa

A small pelagic pteropod mollusc whose population is partially sustained by immigration from outside the Gulf of Maine.

(1) Reproduction. Apparently spring is the primary spawning season.

(2) Fecundity and larval life. After reaching 1mm in size Limacina produces eggs in small numbers continuously. The young are pelagic.

(3) Growth and longevity. Growth is faster in summer than in winter.

May to June	0.4 to 1.2 mm	From figure 9 of Redfield (1'339)
Dec. to April	0.6 to 1.6 mm	
May to June	1.6 to 2.1 mm	

Maximum mean catch per haul of a Heligoland larval net, mouth opening 143 cm diameter, no. O silk, 30 meshes to the inch, was 224 during Jan. 8-13.

(4) Natural mortal ity. 60% of the population may die during winter, 66% may die as they grow from 0.6 - 0.9 mm in January to 1.5 - 1.8 mm in May. Parents may not survive after breeding.

(5) Migration characteristics. No information.

(6) Distribution and niche preference. Introduced to the eastern Gulf of Maine as small specimens in December. A second population appeared in late spring possibly containing specimens from offshore of the Gulf of Maine and some bred within the Gulf.

Young invade the Gulf of Maine from offshore, grow to sexual maturity and perhaps reproduce in the Gulf. They drift in the surface water 50 m depth counterclockwise in the Gulf at about 150 miles in. four months or 1.25 miles per day. They are less plentiful in the coastal zone out to the 100 meter insobath. L. retroversa was only 0.2 percent by number of the population in the Bay of Fundy.

(7) Population densities. No information.

(8) Food . Limacina is a filter feeder that collects small organisms from the water by means of fin cilia on its fins (modified foot). Probably its food is small unicellur algae.

(9) Predation. Limacina is a food item for herring and mackerel and probably other plankton feeders, however, it is not as important a part of their diet as it is in other areas because of Limacina's relatively low abundance.

(lo) Competition. No specific information. Presumably they compete with other herbivorous members of the Calanus plankton community.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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10.0 BENTHIC INVERTEBRATES

10.1 TAXONOMIC REPRESENTATION

The benthic invertebrates include representatives from 20 of the 22 phyla in the animal kingdom, only the exclusively pelagic Ctenophora and Chaetognatha and the parasitic Acanthocephala excepted. Some complete phyla and certain classes of many others comprise mainly microscopic organisms; notwithstanding the ecological importance of these inconspicuous groups and their astronomical numbers, they will be dealt with here collectively as meiobenthos. "These groups include the Protozoa, Rotifera, Gastrotricha, Tardigrada, and Nematoda.

The macrobenthos, that is, the larger and more conspicuous organisms, which account for about 96 percent of the biomass (Wigley and McIntyre 1964). in bottom sediments, represent 17 phyla, but in the New England region most species are included in only 9: Porifera, Cnidaria (Coelenterata), Rhynchocoela (Nemertinea), Bryozoa, Mollusca, Annelida, Arthropods, Echinodermata, and Chordata.

(1) Porifera. These are the sponges. They are usually found attached to rocks, sunken timbers, shell deposits, gravel, and other hard substrata. Sponges are primitive organisms with a simple organization, hardly above a colonial assemblage of "ciliated cells. The cells are arranged to form the walls of an elaborate system of channels through which water is circulated by ciliary action, and the whole assembly is supported by a network of calcareous or silicaceous spicules, or by a tough skeleton of spongin. (This skeleton is the "sponge" of commerce}.

Some of the most common or important sponges in our region are Cliona celata, the boring sponge, an encrusting species on mollusc shells; Haliclona (Chalina) oculata, the "dead man's fingers", a branching species; Microciona prolifera, a bright red, multi-lobed encrusting species; and Halichondria panicea, another encrusting species. The regional sponge fauna has been treated extensively by Hartman (1958), Lambe (1896), Procter (1933), Kingsley (1901) and Miner (1950).

(2) Cnidaria. The hydroids, jellyfish, corals and sea anemones. There are three classes: Hydrozoa, Scyphozoa, and Anthozoa, all with some representatives in the benthic fauna. Cnidaria are characterized by a hollow, vase-like body with two cell or tissue layers, one external, the other lining the digestive cavity or coelenteron. The oral end is surrounded by tentacles armed with specialized stinging cells.

(a) Hydrozoa. . The hydroids, usually colonial, individual members or polyps on branched stems or stolons, often arborescent, forming long plumes. Most hydroids include a pelagic medusa stage in their life history. The polyps themselves are small, but the colonies are conspicuous. Almost all are attached to some firm substrate. There are more than a hundred species in the New England region. Detailed descriptions and figures are given by Fraser (1944).

(b) Scyphozoa. Those are the jellyfish, most of which are pelagic. For many, a sessile juvenile stage is part of the benthic fauna. A few genera, such as Lucernaria and Haliclystus are sessile in the adult stage.

(c) Anthozoa. This group includes the sea anemones, sea plumes and corals. The sea plumes and corals are colonial, the polyps occupying pits in a skeletal structure of calcareous spicules on a branched stem or in a stony, calcareous mass, Sea anemones are solitary and grow to a comparatively large size. Some species are attached by their bases to a firm substrate, others occupy mucus lined burrows in the sediment. Unlike the hydroids and the jellyfish, both of which have major life history stages that are pelagic, the pelagic phase of the anthozoan life cycle is a minute ciliated larva. Vegetative reproduction by budding is a common method of reproduction in this group.

The common sea plumes in this region are Alcyonium, Pennatula and Clavularia. The only coral is Astrangea danae. There are numerous species of anemones or anemone-like anthozoans; some of the more common or conspicuous are Metridium senile, Tealia felina, Bolocera tuediae, a stinging species, Actinothoe (=Sagartia) modesta, Cerianthus borealis and Ceriantheopsis americana. The last three species live in sediments. Regional species have been cataloged by Hand (1964), Hargitt (1914) and Kingsley (1901).

(3) Rhynchocoela. Nemertean worms; these are soft-bodies, unsegmented, somewhat flattened worms, often of bright colors, characterized by an evertible proboscis. Some grow to very large sizes; Euplectonema giganteum, a deep-water species, attains a length of 3.5 meters; the common Cerebratulus lacteus, more than a meter. The group has been treated in detail by Coe (1943).

(4) Ectoprocta. This group contains a great many species, which form encrusting or branching colonies on rocks, shell, seaweed and other smooth, firm surfaces. The animals themselves are relatively small. They are characterized by a tentacle-bearing ring, or lophophore, surrounding the mouth and a U-shaped digestive tract with the anal opening near the mouth but outside the ring of

tentacles. The colonies are conspicuous as patches on shells or. rocks, perforated with intricate patterns of close-set pores. Some of the branched species, such as Bugula or Eucrantia (=Gemmelaria) superficially resemble hydroid colonies. Detailed treatment of regional species can be found in Osburn (1921, 1933).

(5) Mollusca. This group, which contains the slugs, snails, clams and octopi, is one of the largest and best represented phyla in the marine benthos, and contains several species of commercial importance. Molluscs are characterized in having a muscular foot, a mantle which covers the body and secretes the shell, a visceral mass made up of digestive organs and gonads, gills, and a well organized nervous system with several nerve centers or ganglia. Many species have eyes, ranging from mere light sensitive pigment spots. to the image forming eyes of the cephalopods.

There are two major classes and four minor classes in the benthic fauna. The bivalves, or Pelecypoda, include the clams, mussels and oysters; the Gastropoda include snails (often called conches, whelks or winkles in specific instances) and the sea slugs. The minor classes are the Scaphopoda (tooth shells), Polyplacophora (chitons), Aplacophora (solenogasters) and the Cephalopoda (squids and octopi).

(a) Pelecypoda. Characterized by a paired shell, the valves connected by a dorsal hinge. Some of the more common or conspicuous species are the surf-clam Spisula solidissima, the mahogany quahog Arctics islandica, and the sea scallop Placopecten magellanicus. Many small inconspicuous species exist in enormous numbers, making up a significant Portion of the biomass. Typical of these are several species of Nucula, Yoldia, Astarte, Thyasira and Tellina. In shallow waters Mulinia lateralis is very common.

(b) Gastropod. The gastropod have a single shell (the shells of some are much reduced or absent) usually of spiral development, and a rasplike feeding organ, the radula. Two main groups are present in the benthic fauna: the prosobranchs which include most of the typical marine snails, have one pair of tentacles, a horny operculum to cover the shell opening and an anterior gill; the opisthobranchs typically have two pairs of tentacles, a posterior gill, no operculum and in some groups, no shell.

Common prosobranchs in the benthos are the boring snail Polynices heros, the whelks Buccinum undatum and Busycon canaliculatum, distaff shells of the genus Colus, and Nassarius trivittatus, related to the intertidal mud snail.

There are also a host of inconspicuous snails of such genera as Epitonium, Alvania and Margarites. Common opisthobranchs are the tiny but abundant Retusa and the nudibranchs or sea slugs.

The molluscs of the region are figured and described in such texts as Abbott (1954), Miner (1950) and Bousfield (1960). Species lists for various parts of the coast are given in Gould and Binney (1870), Sumner, Osburn and Cole (1913), Procter (1933), and Johnson (1934). Aspects of the physiology and ecology of molluscs are discussed in Wilbur and Yonge (1964). Loosanoff and his co-workers have described the reproductive physiology and early development of regional bivalves in numerous papers. Summaries of larval development can be found in Loosanoff and Davis (1963) and Thorson (1946).

(6) Annelida. The great majority of benthic annelids belong to the class Polychaeta. These are segmented worms with setiferous parapodial lobes arranged bilaterally on each segment. Other appendages may include tentacles and gills. There are a great variety of species with diverse morphological adaptations to different modes of living. Some species are entirely pelagic. Others, such as the Syllidae, Phyllodocidae, Nereidae and Nephtyidae are benthic, but very active and frequent swimmers. Other groups are sedentary, living in various tubes and burrows. The Sabellidae, Terebellidae, Spionidae, Ampharetidae and Amphictenidae are typically tube dwellers. Some tube dwellers build their homes in soft sediments, others on the surface of rocks and shells. The Polynoidae are armored with overlapping scales, or elytrae, on their dorsal surface. Some of the commonest benthic polychaetes are also common intertidally: the bamboo worm Clymenella torquata, the sand worm Nereis virens, or the blood worm Glycera dibranchiata. Others are almost exclusively benthic: Nephtys incisa, Melinna cristata, or Pherusa plumosa, for example. Detailed lists, figures and keys for regional species of polychaetes are given by Webster (1880), Webster and Benedict (1884, 1887), Procter (1933), Hartmann (1944, 1965), Pettibone (1963), Hartmann and Fauchald (1971) and Gosner (1971). Descriptions of larval development and ecological notes for some of our regional species can be found in Thorson (1946) and Rasmussen (1973), even though these works refer particularly to European waters.

(7) Arthropoda. Most of the benthic arthropods belong to the class Crustacea. The Pantopoda (sea spiders), Merostomata (horseshoe crabs) and Acarina (mites) are the important other arthropod groups. The arthropods are characterized by a segmented exoskeleton with jointed appendages. In the crustacea, the exoskeleton is often hardened with mineral deposits, there are two pairs of antennae and the appendages are bi-ramous. The structural variations in

the crustacea are great and few generalizations can be made about the class as a whole. There are eight subclasses according to the classification of Waterman (1960), two of which are exclusively planktonic, one exclusively parasitic; two (Ostracoda and Mystacocarida) are represented only in the meiobenthos. All other benthic crustacea belong to the classes Cephalocarida (containing only one known species), Cirrepedia (barnacles) and Malacostraca.

Of the Malacostraca, there are seven important groups in the benthos:

Stomatopoda	Mantis shrimp
Cumacea	
Tanaidacea	
Isopoda	Marine "sow bugs"
Amphipoda	Water fleas, beach fleas
Mysidacea	Mysid shrimp
Decapoda	Crabs, shrimp and lobsters

Regional species of the various groups are described in numerous works: Cirrepedia (Pilsbry 1916, Zullo 1963); Tanaidacea and Isopoda (Kunkel 1918, Richardson 1909); Amphipoda (Kunkel 1918, Holmes 1905, Bousfield 1973); Mysidacea (Tattersall 1951, Wigley 1964); Decapoda (Williams 1965, Rathbun 1905, 1939).

(8) Echinodermata. Echinoderms are coelomate invertebrates with a basically penta-radial symmetry and a tough epidermis in which are embedded calcareous spicules or plates. In the holothurians (sea cucumbers) the calcareous spicules are widely separated and the skin is flexible; in the Echinoidea (sea urchins) the plates are tightly contiguous, creating a rigid shell. The phylum is also characterized by the water vascular system and the presence of numerous flexible and contractile tube feet, operated by variations of hydrostatic pressure in the water vascular system.

There are five classes, each with conspicuously distinctive characteristics. The Asteroidea (starfish), Ophiuroidea (brittle or serpent stars), Echinoidea and Holothuroidea are important and abundant members of the regional benthos. A few species of a fifth class, the Crinoidea (sea lilies also occur in our waters ar great depths.

Typical starfish are Asterias forbesi and A. vulgaris, Solaster papposus and S. endeca and Ctenodiscus crispatus; typical brittle stars are Ophiura robusta, Ophiopholis aculeata and the spectacular Gorgonocephalus arcticus; common echinoids are Arbacia punctulata, Strongylocentrotus droebbachiensis, and Echinarachnius parma.

Common holothurians are Cucumaria frondosa, Psolus phantapus, Caudina arenata, Molpadia oolitica, Schlerodactyla briarius and Leptosynapta inhaerens. Psolus and Cucumaria are found creeping about on firm surfaces or hiding in rocky crevices; the others are burrowers in sediments. Detailed descriptions, lists and figures of regional echinoderms are given by various authors as follows: Verrill (1895), Clark (1904), Coe (1912), Deichmann (1930), Miner (1950) and Gosner (1971).

(9) Chordata. The chordates in the benthic fauna belong to the class Ascidiacea, the tunicates or sea squirts. They are characterized by a rather leathery outer covering, or tunic, with two openings - an incurrent and an excurrent siphon. The first leads into a pharynx or branchial chamber the walls of which are pierced with numerous gill slits. Water is circulated through this straining device for respiration and collection of food particles.

Ascidians may be single individuals or colonies of individuals imbedded in a common matrix. They are found attached to or encrusting rocks, shells, timbers, etc. Typical simple ascidians are Molgula, Styela, Ciona or Boltenia; colonial ascidians include Amaroucium and Botryllus. Descriptions, lists and figures for regional ascidians are given by Kingsley (1901), Van Name (1910, 1912) and Miner (1950).

10.2 ECOLOGICAL GROUPS

The benthic fauna can be classified according to morphology or phylogeny, but from an ecological standpoint it may be more useful to classify them according to their place in the ecosystem, or "niche". The first broad distinction can be made between those organisms that live on the exposed surface of the substrate, the epifauna, and those that burrow or inhabit various kinds of tubes or permanent burrows within the sediments, the infauna. A second major distinction can be made between groups of organisms according to their method of feeding, and a third according to the kind of substrate on or in which they live.

There are four basic feeding categories: deposit feeders, suspension feeders, herbivores and predators.

Deposit feeders take their nourishment from particulate organic material, living or dead, that has accumulated on the bottom. They may be either selective deposit feeders and eat only those particles which are suitable for food; or they may be non-selective deposit feeders, consuming the bottom sediments indiscriminantly, digesting the nutritive portion and casting the remainder out as feces.

Suspension feeders take their nourishment from particulate organic materials, living or dead, that is suspended in the water over the bottom.

They may be filter feeders, which circulate or pump the surrounding water through some straining mechanism and feed on the accumulated particles; or they may be tentacular feeders, accumulating particles on the surface of numerous tentacles. The collected food items are transported thence to the mouth along rows of beating cilia, or the tentacles themselves pulled inward to the mouth with their burden of accumulated food.

Herbivores feed on plants. Where there is light enough, and sessile algae are present on available surfaces, herbivores feed by browsing. Organisms which feed predominantly on diatoms and other single celled algae are herbivores, although they could be classed as suspension feeders or deposit feeders as well.

Predators feed on other animals. Those that overpower or kill prey that is in the same order of size as themselves are obvious predators. When they feed on meiofauna or small zooplankters, they could conceivably be classed as selective deposit feeders or suspension feeders.

Arbitrary classifications of this sort are sometimes hard to apply, but whatever they may be called, certain methods of feeding and categories of food are similar in a great number of organisms of widely different taxonomic status, or they may differ in some closely related species.

The third kind of major categories are distinguished according to the bottom types on or in which the animals live. Although there are almost as many different kinds of bottom as one chooses to recognize, varying through mixtures of clay and silt to gravel, boulders and bedrock, a few broad classes are sufficient to describe the habitat niches of most species: clay-silt, silt-sand, sand, gravel or shell, and rock. The depth at which the organism lives within the sediment may also distinguish one or more niches.

Not only does the nature of the sediment help determine what species will be found in it, but also the organisms may help determine the properties of the sediment. Rhoads and Young (1971), for example, found that the sea cucumber _Molpadia oolitica_ reworked the sediments in Cape Cod Bay, producing vertical sorting, and that its fecal deposits provided a more stable substrate for certain suspension feeders than the loose sediments. between the deposits. The various textures given to the sediments by the fabricated tubes of worms and amphipods and the accumulation of shells left behind by previous generations of molluscs are also familiar examples.

10.3 DISTRIBUTION AND COMMUNITY ORGANIZATION

The geographic region covered in this report actually includes portions of two distinct temperature or climatic zones separated roughly at the latitude of Cape Cod. From the Cape northward the region is boreal; southward, warm-temperate. These zones encompass far more territory,

both northward and southward, than is to be considered here. A subdivision is more convenient, and for that reason the terms Acadian and Virginian are sometimes used for the regions Nova Scotia to Cape Cod, and Cape Cod to Cape Hatteras respectively. The benthic fauna, therefore, contains both Acadian (Boreal) and Virginian (Warm-temperate) species. The faunal composition as a whole, however, does not conform exactly to these geographic divisions. A great many species are distributed throughout both areas. The abundance of other species attenuates gradually on one side or the other of the Cape. The ocean quahog Arctics and the surf clam Spisula, for instance, while broadly distributed south of Cape Cod, are still present in fair numbers along the coast of Maine.

A special case of the extension of a species beyond its normal range is the relict population. This occurs when historic climatic conditions permitted a general range extension of a species, but subsequent changes eliminated the peripheral populations except in enclaves where local conditions continued to be at least minimally favorable. Typical examples are the intermittent local populations of oysters and quahogs along the New Hampshire and Maine coast. Such relict populations are a phenomenon of coastal and neritic areas and probably do not occur in offshore bottoms, however. Furthermore, because temperature conditions are less variable in deeper ocean waters than in shallow and intertidal areas, the faunal divisions can be expected to be less pronounced in the former.

Where a species is eliminated at the periphery of its range, it is frequently replaced by a related species. Thus the Virginian sea urchin Arbacia is replaced north of Cape Cod by the boreal Strongylocentrotus; the Virginian anemone Ceriantheopsis americana by Cerianthus borealis; and the trumpet worm Pectinaria gouldii by P. hyperborea.

The general geographic distribution of benthic invertebrates has been established over the years from the observations of many biologists, from the early studies ofLeidy (1855), Stimpson (1854), Verrill (1873), Kingsley (1901), Sumner, Osburn and Cole (1913) to the more recent work of Procter (1933) and Dexter (1944, 1947). The quantitative approach to the distribution of benthos, such as that pioneered in Europe by Peterson (1911) has been rare in this region until very recently, and then limited largely to the coastal areas south of Cape Cod.

Beginning with Lee (1944) quantitative surveys have been made in Menemsha Bight, Marthas Vinyard; in Long Island Sound (Sanders 1956); Greenwich Bay, Rhode Island (Stickney and Stringer 1957); Buzzards Bay, Massachusetts (Sanders 1958, 1960); Narragansett Bay (Phelps 1958); Long Island Sound (Carey 1962); Long Island Sound (Richards and Riley 1967); New York Bight (Sandy Hook Laboratory 1972); Moriches Bay, L.I. (O'Connor 1972); and off the southern shore of Long Island (Steimle

and Stone 1973). A few quantitative studies have been made offshore on the Continental Shelf and Georges Bank. Much of the data have yet to be published, although some reports are available (Wigley and " McIntyre 1964, Wigley and Emery 1968, Wigley and Theroux 1970, Wigley 1968). North of Cape Cod quantitative studies are scarce. The survey of the Mt. Desert Island region in Maine (Procter 1933) although systematic and thorough, was not strictly quantitative. The fauna of the Sheepscot River estuary in Maine was studied quantitatively by Hanks (1964) and that in Cape Cod Bay by Young and Rhoads (1971).

Even casual observation shows that different populations of organisms occur on different kinds of bottom. It is a common practice, therefore, to define bottom populations in terms of the substrate that they occupy (the biotope). Thus one may recognize a silt-clay (or mud) fauna, a silty-sand fauna, a sand fauna, a gravel, rubble or shelly bottom fauna, or a hard or rocky bottom fauna.

Wigley (1968) has described the benthic fauna of the New England fishing banks in this way. He lists the characteristic species of four biotopes: a sand bottom, a silty-sand bottom, a gravel, and a mud bottom.

Some of the characteristic species of the sand bottom were:

Echinarachnius parma	sand dollar
Lunatia (=Polynices) heros	large boring moon snail
Nassarius trivittatus	another snail
Spisula solidissima	surf clam
Astarte castanea	chestnut clam
Crangon septemspinosus	sand shrimp
Pagurus acadianus	hermit crab
Chiridotea sp.	an isopod

Of the silty--sand bottom:

Amphioplus abdita	brittle star
Thyone (=Havelockia) scabra	sea cucumber
Arctics islandica	ocean quahog
Colus pygmaeus	snail
Dichelopandalus leptocernus	shrimp
Edotea sp.	an isopod
Diastylis sp.	a cumacean
Scalibregma sp.	a polychaete
Nephtys sp.	antoher polychaete
Cerianthus borealis	burrowing anemone

Of the mud bottom:

Briaster fragilis	heart urchin

Ophiura sarsi and O. robusta	brittle stars
Ctenodiscus crispatus	mud star
Musculus discors	bivalve
Pandalus spp.	shrimp
Geryon quinquedens	red crab
Haploops tubicola	amphipod
Sternaspis, Amphitrite, Onuphis and other polychaetes	

Of the gravel bottom:

Polymastia, Cliona, Myxilla and other sponges	
Tubularia, Eudendrium, Sertularia and other hydroids	
Terebratulina septentrionalis	brachiopod
Modiolus, Anemia and Musculus	bivalves
Serpula and Spirorbis	polychaetes
Nudibranchs of many species	
Solaster and Crossaster	Starfish
Ophiolis sp.	brittle star
Hyas sp.	toad crab
Boltenia, Amaroucium, Ascidea and other tunicates	

Nearly all of the species listed for the gravel bottom are epifaunal.

Another way of describing the benthic fauna is in terms of the community, a somewhat different concept than the biotope. The community concept, originally" used by terrestrial plant ecologists, was first applied to marine benthos by Petersen (1913). It is based on the observation that certain groupings of species occur together more or less consistently from place to place over very broad areas of bottom, even when separated by many miles. These species apparently have common requirements of the environment, in some cases including the presence of one another. It is the characteristic group of species rather than the bottom type that defines the community. In this sense, there may be several kinds of mud-bottom or sand-bottom community. Although usually a community is related to a bottom type, since this is one of the environmental determinants, it is conceivable that the same community could occur on different kinds of bottom. The community implies a similarity in total environmental requirements or some degree of necessary interaction among its members. Where interactions are a significant factor, the community may be termed an association. In widely separated communities of the same kind, there may be taxonomic differences in some of the species, but they are usually closely related and occupy the same niche. Because of the considerable amount of investigation of bottom fauna in European waters, especially around Denmark, communities in that part of the world are well documented (Thorson 1957). A community is designated by the names of one or two of its predominant species.

It is risky to assign community status to various aggregations or distributions of benthic organisms without sufficiently broad surveys to

determine that they are characteristic and consistent.

On the basis of the limited number of studies that have been made, a few communities have been fairly well defined. One of these is the Nephtys-Nucula community of silt-clay bottoms. The characteristic species are Nephtys incisa and Nucula proxima (or N. annulata). The list of other species includes many which are common in silt-clay bottoms wherever they are sampled in inshore areas: Yoldia limatula, Pitar morrhuana, Lyonsia hyalina and Cylichna alba (molluscs); Ninoe nigripes, Lumbrinereis fragilis or L. tenuis (polychaetes); and Leptocheirus pinguis (amphipod). This community has been described by Sanders (1956) in Long Island Sound and in Buzzards Bay (1958); and by Hanks (1964) in Sheepscot Bay, Maine. Steimle and Stone (1973) describe a community containing many of the same species in fine sand and silt south of Long Island.

Another community was described by Dexter (1944) as the Strongylocentrotus-Buccinum biome in Ipswich Bay, Massachusetts. He used this designation in an attempt to demonstrate an east coast analog of a Strongylocentrotus community described by Shelford (1935) on the Pacific coast. Dexter's data, however, strongly indicate that the sand dollar Echinarachnius parma should have been given characterizing status instead of the sea urchin Strongylocentrotus. The components of this community are similar to those found and photographed by Wigley and Theroux (1970) on Georges Bank in sand or silty-sand. It is an epifaunal sand bottom community, and in addition to Echinarachnius parma and Buccinum undatum other characteristic species are Neptunea decemcostata, Colus stimpsoni, Asterias vulgaris or forbesi, and Cancer borealis or irroratus.

A sand bottom community, characterized by Echinarachnius parma, Tellina agilia, Protohaustorius deichmanni and Spisula solidissima was described off Long Island by Steimle and Stone (1973).

Another community appears to be that dominated by the tubicolus amphipod Ampelisca. It is common on silt-clay or silt-sand bottoms. One or more species of the genus: A. abdita, A. vadorum, or A. agassizi occur in densities of several thousand per square meter, giving a carpet-like texture to the bottom. Ampelisca communities have been described in Long Island Sound by Sanders (1956), in Greenwich Bay, R. I., by Stickney and Stringer (1957), in Narragansett Bay by Phelps (1958) and Pratt (1967), and in Rhode Island Sound by Pratt, Saila and Sissenwine (1973).

" A community in Menemsha Bight, Marthas Vinyard in fine sand was described by Lee (1944) characterized by Arctics islandica, Clymenella torquata and Pitar morrhuana. Whether this is merely a local co-occurrence of these species, or a community duplications of which can be found consistently in different localities is not certain until more localities are sampled.

It is significant to note that the best quantitative data for infaunal communities has been obtained on soft bottoms, Stable sand or other firm sediments are difficult to sample with standard quantitative grabs, and have been somewhat avoided for that reason.

It is probable that even those populations that appear to be communities and have been designated as such by various authors are only incompletely defined and contain species that are overlaps from contiguous communities or are of strictly local importance. Once a community can be accurately defined, however, and the niches of its members understood, it should be a very useful means of assessing benthic populations. The community composition reflects the net effect of many environmental factors, some of which very likely can be detected in no other way, and not only does it provide a means of comparing environments from one locality to another, but it also serves as a sensitive indicator of environmental changes.

10.4 REPRODUCTION

The development of communities and the maintenance of benthic populations is dependent on many processes, one of the most important being the reproduction of its members. The ecology of reproduction in benthic invertebrates has been discussed extensively and in detail by Thorson (1946). Reproduction and larval development take place in a great variety of ways, differing from group to group and from species to species. Some of the essential principles can be summarized here.

The simplest reproductive method is asexual, achieved through fission or budding of the parent animal. It is common in the Porifera and Cnidaria, and occurs occasionally in the more advanced phyla such as Nemertinea, Ectoprocta and Annelida. Nearly all species reproduce sexually at some phase of their life history, however. Some are dioecious, with separate male and female individuals, and some are hermaphroditic, with both female and male gametes produced in the same individual. Hermaphroditism is common in the Ectoprocta, and opisthobranch snails. A form of hermaphroditism known as protandy occurs in some molluscs and arthropods. In this form, most of the individuals first become functional males and later transform into females. Typical protandrous species are the quahog Mercenaria, the slipper limpet Crepidula, and the northern shrimp Pandalus.

Fertilization may be internal or external, the sperm being transferred to the female during copulation or both eggs and sperm released into the surrounding water where the union takes place. Where fertilization is internal, the fertilized eggs are incubated in protective cases attached to the substrate (e.g., Buccinum, Busycon and other snails) or in brood pouches or egg masses attached to the female, e.g. amphipods or crabs. The method of fertilization and egg incubation varies from

species to species and may differ even between species of the same genus. For example, the bivalve Nucula delphinodonta rears its eggs in a brood sac, while the closely related Nucula proxima releases them into the water.

In most invertebrates the reproductive cycle is more or less direct. The eggs develop into. larvae which may be pelagic during all, part, or none of their larval period according to species; the larvae then pass through a transitional period (metamorphosis) when their life style and structure change into that of the immature adult or juvenile. In many of the Cnidaria, however, a more complex reproductive cycle occurs known as mutagenesis, or alternation of generations. A typical example is that of the hydroid Obelia. The hydroid colony reproduces asexually; pelagic medusae are produced from specialized buds. These medusae (resembling small jellyfish) are the sexual generation and produce eggs and sperm. The fertilized eggs develop into ciliated larvae which ultimately metamorphose into polyps to start new hydroid colonies,

Where eggs are fertilized externally and left to drift in the plankton, the hazards to survival are so great that the eggs must be produced in enormous numbers, often several million per female. Where eggs are kept protected until the larva has reached a fairly advanced stage, the numbers are much smaller. Typically, incubated eggs have a larger yolk supply to nourish the embryo during the early stages of development. Pelagic eggs generally develop into active larvae capable of capturing their own food shortly after fertilization, although some species produce pelagic lecithotrophic eggs in which the embryo develops to an advanced stage within the egg before hatching, e.g. Peneid shrimp.

Thorson (1946) has pointed out that brooded eggs are most characteristic of cold water species because low temperature slows development and the resultant duration of a pelagic larval life would be extended too long for larvae exposed to its hazards to have an adequate survival rate.

Breeding seasons vary with different species, taking place for one species or another at all times of the year. The times of gametogenesis and spawning are determined by physiological mechanisms in the organism as well as by external variables such as temperature cycles or changes in day length. -Spawning itself is frequently triggered by a relatively rapid change in temperature. Where gametes are released into the surrounding water, epidemic spawning may occur, in which many individuals in the same area spawn at the same time. Evidence from experiments with some species of shallow water bivalves such as the oyster and quahog indicates that chemical substances in the sperm help induce spawning in this fashion (Galtsoff, 1964; Loosanoff, 1953). Chemical inducement for spawning has also been reported in the European starfish Asterias rubens (Vevers, 1949).

A few motile species undertake migrations in connection with their reproductive behavior. For example, in the Gulf of Maine, ovigerous shrimp (Pandalus) migrate to coastal waters in the fall and winter for the brooding and hatching of their eggs. Lobsters appear to make analogous migrations (Cooper and Uzmann 1971).

The distribution of benthic invertebrates is determined to a great extent by the patterns of dispersal of the larvae and subsequent processes of selection which determine whether a metamorphosing or juvenile organism can survive in the area where it settles. In most cases, this selection is a passive one in some degree--either the organism survives or it doesn't. In some species, however, the larvae or juveniles are able to exercise some selection themselves. It has been shown, for instance, that the polychaetes Notomastus and Ophelia will not metamorphose unless the substrate is suitable (Wilson 1937, 1948, 1951, 1952), and such behavior may be characteristic of many-other-species as well. Scheltema (1962) has observed similar behavior in the intertidal snail Nassarius obsoletus. Juvenile clams, Mya arenaria, move about considerably, presumably seeking suitable substrate.

While the dispersal of pelagic larvae seems often to be a chance result of the vagaries of tides and currents, the interaction between these agencies and the behavior of some species creates a mechanism to insure a particular distribution that has definite survival value to the population. Bousfield (1955) has shown that the retention of barnacles in an estuary results from the fact that the younger larvae stay in the upper layers of water where the net drift is downstream, but as they grow older and approach metamorphosis they sink to the deeper layers where the net drift is upstream. Similar mechanisms may well operate in other situations.

10.5 ABUNDANCEAND PRODUCTIVITY

The pioneering work in quantitative benthic ecology by Petersen (1911, 1913); Blegvad (1914, 1922, 1925 etc.); and Sparck (1929, 1935) was largely in response to the need of estimating the food available to fish. This is still a vital need, because many of our valuable commercial fish species feed on the benthic fauna. Quantitative measurements are also a" means of understanding the benthic ecosystem, either from the viewpoint of the descriptive ecologist, e.g. Petersen (1913) or Shelford (1935) or for the more modern and pragmatic need to assess the impact of man's industry on the environment, e.g. Gordon, Rhoads and Turekian (1972), Saila, Pratt and Polgar (1972) and the Sandy Hook Laboratory (1972),.

The most elementary quantitative measurement of the benthic fauna is one of enumeration: the number of individuals or species per unit area. For many purposes this is adequate. A more useful measure for

assessing the bottom, especially for trophic studies, is the weight of living organisms per unit area. Unfortunately, even today there is a lack of standardization of approach in obtaining quantitative benthic data. ,.Some investigators concern themselves only with enumeration, others obtain "wet" weights of living or preserved samples, and still others, "dry" weights. It is possible to estimate one kind of weight if the other is given, by using conversion tables such as those of Thorson (1957), provided species identity and enumeration are also given. In this way, some different collections of data can be made comparable.

The weight of living organisms per unit area is the "biomass" and is a useful, kind of data. Biomass, however, is merely a measure of the standing crop, the amount of living material present at some instant in time. The standing crop, whether measured by weight or number, is apt to be misleading. It does not take into account temporal fluctuations, such as the transitory presence of large numbers of newly settled juveniles nor does it give any indication of the rate at which the area is producing living material. Dense populations of old, slow growing individuals which give the appearance of a rich fauna are not uncommon, but they represent years of accumulation and could be depleted in a short time. One of the most meaningful quantitative assessments of the benthic populations is the measurement of productivity: the rate at which the populations produce new living material by growth and reproduction. This in turn determines the yield, the amount that can be grazed off or harvested while leaving the standing crop more or less intact. Because there is so little information on the natality, growth and mortality rates for most of the benthic invertebrates, estimates of productivity are difficult to make.

Sanders (1956) calculated the productivity of four common non-commercial species in Long Island Sound: Nephtys incisa, Pectinaria (=Cistenides) gouldii, Pandora gouldiana and Yoldia limatula. He estimated an annual production of about 2.1 times the biomass of the standing crop for these relatively long-lived species. Short-lived species, such as Ampelisca or Leptocheirus were estimated to have an annual productivity of 5 times the standing crop. By applying these factors to the remaining species, long- or short-lived, Sanders arrived at a mean productivity for the small infauna of the area of 21.42 grams per square meter.

Richards and Riley (1967), using similar computations, estimated the productivity of four additional species in the same area: Asterias forbesi, Neomysis americana, Crangon septemspinosus, and Ampharete acutifrons. For these species, an annual productivity of 5.04 grams per square meter was calculated, 87 percent of which was attributable to the starfish Asterias.

A further step in the assessment of benthic invertebrate populations is the determination of caloric content. This has been done in a few instances. The standing crop of the benthic fauna in St. Margarets Bay,

Nova Scotia was studied by Brawn, Peer and Bentley (1968) and the biomass and caloric content of the various species determined, In addition, a correlation between these values and the sediment composition was demonstrated. The highest caloric content was yielded from mixed sediments containing about equal proportions of sand and silt-clay.

These kinds of quantitative benthic ecology are valuable and important, but so far only limited areas of the sea bottom have been investigated in this way. The abundance, distribution and productivity of the benthic fauna over the greatest part of the coast are unknown. The only exceptions are for a few species of commercial importance. The distributions of Arctics, Spisula and Placopecten have been charted (Parker 1966; Merrill and Ropes 1969; Wigley and Emery 1968) and substantial population data have been collected for Placopecten (Merrill and Posgay 1964; Merrill, Posgay and Nichy 1961).

Not only distribution and abundance data, but also the essential life history information, are lacking for nearly all of the species that make up the benthic fauna over thousands of square miles of sea bottom off our coast. Undoubtedly some information is available but yet unpublished, and some is being gathered at the present time. Even some of the data presently available are difficult to use. Reports of investigations made for different purposes present data in different ways: some give only enumerations; some give weights, but only for entire samples or for selected taxonomic groups; some give wet or preserved weights only, others dry weights and still others ash-free or organic weights. A standard quantitative sampling routine, from the design of the sampler to the presentation of data, might be a desirable requisite for all future investigations of this kind.

10.6 ECOLOGICAL INTERACTIONS

That living organisms interact with one another and that the welfare of one species can be directly or indirectly dependent on the welfare of another is axiomatic in ecology. In the face of the significant impact that human industry is now capable of inflicting on the environment, far too little is known about the interactions in marine populations.

Four basic kinds of direct interaction are immediately apparent: predation, competition, commensalism and parasitism. These general relationships may have specific manifestations; competition, for example, may appear as competition for space or food, or as territoriality, aggression or even cannibalism. Interactions are not only important within the benthic community but also with other communities. Thus the benthos may be a souce of food for the community of fishes and may derive its food from the plankton community.

Perhaps the most commonly studied interaction is that of feeding. The manner of feeding and the kinds of food in general are known for a great many species. From morphology, habitat and taxonomic relationships-they can be inferred for a great many more. Virtually nothing is known, however, of the nutritional requirements, the degree of dependence on particular food items, or the quantities eaten. Most predators feed on a wide variety of prey organisms, which conversely are fed upon by a number of different predators. Unless we know the quantities of food required or the relative need or preference for certain items, it is difficult to assess the impact on either predator or prey species that any significant change in abundance of one or the other would have. Food web studies to determine these facts are rare for sea bottom communities. Miller, Mann and Scarratt (1971) attempted to calculate the energy flow in a seaweed-lobster community in St. Margarets Bay, N. S. The seaweed consumption of the sea urchin Strongylocentrotus and the snail Littorina, and the phytoplankton consumption of Mytilus, Modiolus and Ophiopholis were balanced against the predation of Asterias and Homarus upon them. From the data, the authors calculated that production of lobster prey exceeded consumption by the lobsters, that plant production exceeded the quantity grazed by the herbivores, and that a decrease in the abundance of predators competing with the lobster would increase lobster production.

Inter- and intra-specific competition is another area where some general information is available or can be inferred, but little is known specifically or quantitatively. Sometimes the very numbers of individuals make the extent of their competition obvious. The sand dollar Echinarachnius often covers the sea floor in several layers (Zenkevitch 1963), collecting the available plankton and detritus as food, and completely denying the space to other species which might occupy the same habitat, such as the scallop Placopecten.

Competition is expressed not only in the simple occupation of space or in food "stealing". Those species, which by their defecation, burrowing, tube building etc. make the substrate unsuitable for another species are competitors as well. Rhoads and Young (1970) found that Yoldia, Nucula and other deposit feeders created a watery, unstable surface layer on the sediment which made it unsuitable for suspension feeders. Some deposit feeding bivalves compete with one another for space to the extent that their distribution is determined partly by the scope of their feeding siphons. The spatial arrangement of Tellina at" certain densities was found by Holme (1950) to be overdispersed, or tending toward uniformity, which he interpreted as indicating territoriality. Similar uniformities of distribution suggesting territoriality were found in other invertebrates by Connell (1963). A good example of a territorial species is the lobster.

Because of the great number of benthic invertebrates and the rather limited categories of food and methods of feeding, it is reasonable to assume that there must be fairly universal competition for food, although the

extent of that competition and the effect it may have on the abundance and distribution of the various species requires more detailed and specific information on the quantity of food required and that available in any particular case.

Another behavior pattern which affects the distribution of some benthic species, quite the opposite of territoriality, is gregariousness. This behavior is very marked among the echinoderms. Sea urchins, starfish and brittle stars are frequently found aggregated in dense and localized patches (Reese 1966).

Commensalism and parasitism are very specific interactions. Commensalism is a relation between two species such that one satisfies some biological need from its intimate association with another, as food or protection, without injuring or destroying the host. Typical commensal relationships are the colonial growth of the hydroid Hydractinia on the shells of snails used by hermit crabs or the habitation of certain polynoid worms in the tubes of other polychaetes. The advantage to Hydractinia is apparently that of obtaining fragments of food as the hermit crab feeds; the polynoid worms are afforded protection in the tube of the host. Wigley and Theroux (1971) describe an interesting case of commensalism between the scallop Placopecten and juvenile red hake (Urophycis) which conceal themselves in the scallop's mantle cavity. The mantle cavities of several species of bivalves provide the home for the commensal crab Pinnotheres. Other pinnotherid crabs are commensal in worm tubes. The relation between commensal and host is often obligatory, the commensal seldom being found not in association with its host. Some commensal relations seem almost accidental, however. The shells of crabs and lobsters are frequently covered with encrustations of barnacles, bryozoans or mussels, all of which are perfectly able to live successfully on a non-living substrate, but which seem to derive some advantage from their commensal existence.

There are varying degrees of dependency on the host. When this dependency is reflected in radical modifications of structure and physiology and when the sustenance is taken directly from the tissues of the host (as opposed to the mere sharing of its food) the relation is that of parasitism. Many parasites undergo several life history stages, each one passed in the tissues of a different host organism. Through the parasite, the presence of one host species is of indirect concern to another. A group of organisms that typify this relationship are the trematode worms. Adult trematodes may parasitize a fish or a sea bird. The eggs, released in the water may be eaten by a browsing snail. These develop in the snail into a larval form which multiplies asexually within the snail, eventually to emerge and infect a third host such as a fish or bivalve mollusc. The third host is eaten by a fish or sea bird and the parasite there develops into the adult sexual form. There are many such parasitic chains in the sea, involving many species of both host and parasite, and many variants in the details of the life cycle.

The interact-ions here are not only between parasite and host, but also between the several hosts. The presence of one host species is detrimental to the other. Parasitism can sometimes be used to advantage in studying populations of the host species, since the parasite serves as a natural biological tag. For example, Uzmann (1970) was able to furnish evidence to distinguish inshore and offshore populations of lobsters from the relative incidence of two parasites: the nematode Ascarophis, which is almost exclusively limited to offshore populations, and the acanthocephalan Corynosoma which infests coastal lobsters.

10.7 SEASONAL AND OTHER TEMPORAL CHANGES

The species composition of bottom communities often shows seasonal or annual cycles because of the influx of newly metamorphosed juveniles of many species. These changes may be temporary if conditions are not suitable for the newcomers. If these young are the progeny of species already indigenous to the area, they will create seasonal increases in density and changes in the size distribution of those species. Seasonal migrations into or out of an area also cause changes in community structure.

It is a common observation in benthic studies made in one locality in more than one year, that changes in community structure occur from year to year or over longer periods of time. Stickney and Stringer (1957) reported that in one year the tubicolous polychaete Spiochaetopterus oculatus was abundant in the sandy areas of Greenwich Bay, R. I., while in the following year it was rare in this substrate. Over longer periods of time, even greater changes in fauna occur. O'Connor (1972) listed six species in Moriches Bay, L. I. that were abundant in 1938 and rare in 1969-1970, and three species that were rare in 1938 but abundant 31 years later. The eel-grass (Zostera) community, very characteristic of shallow waters prior to 1932, was radically changed by the disappearance of eel-grass in subsequent years (Dexter 1944). Secular temperature changes have brought about marked increases and decreases of green crab (Carcinides moenas) populations along the New England coast. These were in turn reflected in fluctuations of the soft clam (Mya arenaria) populations on which the green crab is a predator (G"lude 1955; Welch 1968).

10.8 SUMMARY

The benthic invertebrates are a diverse and numerous group, comprising about 20 phyla and thousands of species. Their form and habits vary so widely that it would be impossible to discuss the entire group in detail here, even if the details were known. Probably most of the species "in our area are now known and described, and we have some general knowledge of their distribution and habitat preference. Nevertheless, the greatest part of the sea bottom along our coast, especially that north of Cape Cod, remains unexplored in any quantitative way. We know very

little of community structure and the interactions among the organisms. Except for a few species of economic importance or of special zoological interest, we know virtually nothing of natality and mortality rates, growth rates, food requirements, temperature limitations and other physiological parameters. Bottom productivity, food webs, and energy flows have been studies in only a few localities.

Although it would be impossible to provide here descriptions, life histories and habits of all the benthic invertebrates, a sampling of this kind of information should be valuable for illustrative purposes. A few species, because of their economic importance, their abundance or ubiquity, or their special interest in other ways, have been selected as "key species", and a brief biological synopsis for each is included here. A complete species list for the sea bottom and other habitats is provided elsewhere in this report.

10.9 KEY SPECIES

The following key species, for which brief life history descriptions are provided, are a selection of important species of the several biological habitats discussed in Chapters 3, 4, and 5. For a discussion of the characteristics of the habitats and a more complete list of the organisms found therein the reader is referred to the above chapters. Listed below are the key species and the habitats in which they are most commonly found.

Offshore bottom

- Ampelisca vadorum
- Ampharete acutifrons
- Arctics islandica
- Cancer irroratus, C. borealis
- Ceriantheopsis americanus
- Emerita talpoidea
- Homarus americanus
- Nephtys incisa
- Nucula annulata/proxima
- Ophiura robusta
- Pandalus borealis
- Placopecten magellanicus
- Polinices duplicata
- Spisula solidissima

Mussel-oyster reef

- Asterias forbesi, A. vulgaris
- Crassostrea virginica
- Mytilus edulis
- Polydora spp.
- Urosalpinx cinerea

Worm-clam flat

- Arenicola marina
- Clymenella torquata
- Corophium volutator
- Crangon septemspinosus
- Ensis directus
- Glycera dibranchiata
- Limulus polyphemus
- Macoma balthica
- Mercenaria mercenaria
- Mya arenaria
- Nassarius obsoletus
- Nereis virens
- Nucula annulata/proxima
- Pectinaria gouldii
- Polinices duplicata
- Polinices heros
- Streblospio benedicti
- Tellina agilis

Salt pond

Callinectes sapidus
Capitella capitata
Crangon septemspinosus
Crassostrea virginica
Gemma gemma
Hydroides dianthus
Leptochelia savignyi
Mercenaria mercenaria
Mya arenaria
Nassarius obsoletus
Nereis virens
Spisula solidissima

Salt marsh

Carcinus maenus
Clymenella torquata
Crangon septemspinosus
Cyathura polita
Diptera larvae, *Aedes sollicitans*
Littorina littorea
Melampus bidentatus
Modiolus demissus
Nereis succinea
Orchestia spp.
Uca sp.

Sandy beach

Echinarachnius parma
Haustorius canadensis
Nephtys caeca
Pagurus longicarpus
Spisula solidissima
Tellina agilis

Rocky shores

Arbacia punculata
Asterias forbesi, *A. vulgaris*
Balanus balanoides
Cancer irroratus, *C. borealis*
Homarus americanus
Littorina littorea
Metridium dianthus (*M. senile*)
Mytilus edulis
Strongylocentrotus droebachiensis
Thais lapillus

The life history descriptions include information in the following topic areas, where such information is available:

(1) General description
(2) Reproduction characteristics, cycles
(3) Fecundity and larval life
(4) Growth and longevity
(5) Natural mortality
(6) Migration characteristics
(7) Population densities
(8) Distribution and niche preference
(9) Responses to environmental factors
(10) Food
(11) Predation, competition

10.9.1 *Ampelisca vadorum*

A small, tube-dwelling amphipod, colonies of which virtually carpet extensive areas of the sea bottom. Often erroneously identified as *A. spinipes*.

(1) Reproduction. *Ampelisca vadorum* breeds in April through May when the water temperature reaches 8-10 C, and again in July through September. Age at sexual maturity is less than 100 days for the summer population, less than 300 days for the winter generation. The male grasps the female and remains attached for several days. After a molt, the female deposits eggs in brood sac on ventral surface; eggs are fertilized as they are extruded.

(2) Fecundity and larval life. A single female produces 25-40 eggs (Mills 1967) which develop and hatch in the brood pouch.

(3) Growth and longevity. Growth rate varies with temperature. At 18 C, individuals reach a mean size of 4 mm at an instantaneous rate of 3.47% a day; at 220, a mean size of 7.8 mm is attained at a rate of .326% a day; at 10°, a mean size of 6.7 mm is reached at a rate of .708% a day; and at 2°, a mean size of 7.3 mm reached at a rate of 0.38% a day (Mills 1967).

(4) Natural mortality. Life cycle is completed in 40 to 100 days; overwintering generation lives 300 days or more. No information on mortality within these periods.

(5) Migration characteristics. The animal is relatively sedentary and does not make migrations over large distances.

(6) Distribution and niche preference. Occupy ribbonlike tubes of mud and secreted material in silty sand bottoms from low tide to 64 meters.

(7) Population densities. Local populations may number several thousand per square meter. Exact values for this species alone are not available; mixed populations of *A. vadorum* and *A. abdita* numbered as high as 3000-5700 per sq. meter in Narragansett Bay (Pratt 1967; Stickney and Stringer 1957).

(8) Food. *Ampelisca* feeds on microorganisms and detritus (Hunt 1925) obtained by generating a current of water with the pleopods and straining it through setae, or by scraping the sediment with the antennae; to some extent, both a setous suspension feeder and selective deposit feeder.

(9) Predation. Predators are bottom feeding fish (e.g., flounders,

gadoids, sculpins, cunners), starfish and crabs, particularly spider crabs.

(10) Competition. One or more species of Ampelisca share the habitat with A. vadorum; these and other amphipods as well as some of the polychaetes and small bivalves compete for food and space.

(11) Responses to the environment (natural factors, pollutants). No information located.

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10.9.2. Ampharete acutifrons

Ampharete acutifrons is one of several common sedentary tentacled polychaetes of the family Ampharetidae; has no common name.

(1) Reproduction. Two spawning periods, spring and fall, in Long Island Sound; first spawning at age of 5-6 months (Richards and Riley 1967).

(2) Fecundity and larval life. Fecundity and larval development not known for this species. Thorson (1946) indicates a short-non-pelagic larval period for other species of the genus,

(3) Growth and longevity. Life span does not greatly exceed one year. Individuals hatched in April average 4.7 mm in length in June, 10.6 in August, 12.9 in November and 18.3 the following April (Richards and Riley 1967).

(4) Natural mortality. Mortality is heavy (about 95%) after the first spawning (Richards and Riley 1967).

(5) Migration characteristics. No migrations reported, but short movements from place to place occur.

(6) Distribution and niche preference. Found in silty-sand sediments at depths to 11 meters from Maine to Virginia; lives in tubes constructed of mucoid material and sand grains.

(7) Population densities. Population densities in Long Island Sound: Maximum, 236 per m^2, average for densest locality, 99.3 per m2 (Richards and Riley 1967). In Rhode Island Sound, up to 120 per m^2 (Pratt, Saila and Sissenwine 1972). In Cape Cod Bay, 30 per m^2 (Young and Rhoads 1971). In the Sheepscot River, Maine, 32.1 per m^2 (Hanks 1964).

(8) Food . Ampharete is a selective, tentacular deposit feeder. Among food items are diatoms and dinoflagellates.

(9) Predation. The species is preyed upon particularly by the winter flounder, Pseudopleuronectes americana (Richards and Riley 1967).

(lo) Competition. No definite information on competitors; two species of similar habits, Amage auricula and Melinna cristata are often found in the habitat.

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.10.9.3 Arbacia punctulata

The purple sea urchin; the common New England sea urchin south of Cape Cod. It is about 5 cm in diameter (excluding spines) and dark purplish brown in color. A standard laboratory animal used for invertebrate embryological studies.

(1) Reproduction. The animals ripen in early summer and spawn from June to mid-August in the Cape Cod area. Eggs and sperm are shed into the water where fertilization occurs.

(2) Fecundity and larval life. Female produces about 4 million eggs. These develop into free swimming larvae in 1 to 2 days, and the larvae metamorphose in about 2 weeks at 20 C (Costello, Davidson, Eggers, Fox, and Henley, 1957). The larvae feed on planktonic algae, and are distinctly selective as to species. In the laboratory they will develop well on Dynaliella, Rhodomonas, and other flagellates but not on diatoms alone. Larvae will not metamorphose unless suitable substrate is present, and have been observed to remain pelagic for as long as 4 months. After 2 months, they lose the ability to metamorphose at all (Hinegardner, 1959).

(3) Growth and longevity. Average growth is 3 mm a year and average life span is 4 to 8 years.

(4) Natural mortality. No information found.

(5) Migration characteristics. No information found. It is unlikely that this species migrates extensively.

(6) Distribution and niche preference. Range is from Cape Cod to the Gulf of Mexico, on rocky or shelly bottoms from low tide to 225 meters.

(7) Population densities. No information on absolute numbers found. Coe (1912) states that the species undergoes periodic fluctuations in abundance.

(8) Food. Arbacia feeds on marine vegetation and is also a scavenger (Parker, 1932).

(9) Predation. No information on natural predators. Probably eaten by gulls (as is the green sea urching) and bottom feeding fish. In the Woods Hole area man is probably the chief predator as large numbers of this species are collected annually for experimental studies.

(lo) Competition. No information found on competitors.

(11) Responses to the environment (natural factors and pollutants). No information found.

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10.9.4 Arctics islandica

The ocean, mahogany, or black quahog is superficially similar to the common quahog (Mercenaria) differing most noticeably in the dark periostracum that covers the shell. It supports a limited commercial fishery, but is presently underutilized.

(1) Reproduction. The spawning season begins in late June or early July when the water temperature reaches 13.5 C. Maximum spawning is in August and is completed in early October (Loosanoff 1953). No information on spawning behavior nor of stimuli that trigger spawning. The species does not respond to manipulations of temperature in the laboratory, nor to sperm suspensions in the water; it has been observed to spawn spontaneously.

(2) Fecundity and larval life. No precise information on the fecundity of the species. It is about the same size as Mercenaria, and if the number of eggs produced is similar it should be about 25 million. They are released and fertilized in the surrounding water and larval development is pelagic, lasting about 60 days at 10 C (Landers 1973).

(3) Longevity and growth. Growth rates have not been satisfactorily determined because of the uncertainty of reading annual checks on shells. According to Turner (1949), chemical analysis of shells by European investigators indicated an age of 6 years for "average" sized individuals (presumably about 80-90 mm).

(4) Natural mortality. No information on mortality rates. There is evidence, however, that adults sometimes suffer heavy mass mortalities. Enormous numbers of recently dead shells have been observed or dredged up (Merrill, Chamberlain and Ropes 1969).

(5) Migration characteristics. Arctics is a sedentary species and does not move about or migrate.

(6) Distribution and niche preference. Arctics is common in mud or silty-sand bottoms from Newfoundland-e Hatteras at depths of 11 to 250 meters.

(7) Population densities. No precise information on densities. Off the middle Atlantic coast, 5-minute tows with a 30-inch dredge yielded 3 to 4 bushels (Parker 1966). Turner (1949) estimated abundance in Vineyard Sound, Mass., at "one or two bushels per ten minute tow" with a "small" dredge.

(8) Food. The food in nature is not known. It is a filter feeder and has been maintained in the laboratory on artificially cultured unicellular algae (Landers 1973}.

(9) Predation. Polynices heros, the boring snail, is one known predator. Bottom feeding fish prey on juveniles which are found abundantly in their stomachs (Gould and Binney 1870).

(10) Competition. Merrill and Ropes (1969) found Spisula in the same habitat with Arctics in 93 of 208 stations where either was found. To that extent, at least, Spisula could be considered a competitor, since the feeding habits of both species are similar. No other species occupying the same ecological niche appears to be abundant enough to be a serious competitor.

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10.9.5 *Arenicola* marina

The lugworm; found in mud or muddy sand intertidally and in shallow water from Long Island Sound northward. It lives in U-shaped tubes. head shaft into which sediments and detritus collect, tail shaft out of which fecal pellets are cast (Wells 1945).

(1) Reproduction. *Arenicola* spawns for a two week period in mid-July. The ova and sperm are emptied onto the sand surface where fertilization takes place. Large numbers of fertilized eggs are formed into an egg mass and attached to the bottom or some object near the burrow. The animal becomes sexually mature in two years.

(2) Fecundity and larval life. *Arenicola* lays egg masses containing approximately 300,000 embryos. From these, trochophore larvae hatch in 4-5 days. The larvae swim for 24 hours or less and then settle to the bottom. The larvae stay attached to the substrate and live between the stones. At 4 months the larvae have the body segments of the adults but no gills. When the larvae are 8 mm long they take up the habits of the adults, and swim to deeper waters.

(3) Growth and longevity. The worms are .0015 mm at birth, 0.250 after 30 days, 3 mm at 4 months and 8 mm when the animal takes up the habits of the adult.

(4) Natural mortality. After reproduction, 40 percent of the parents die (2 years old).

(5) Migration characteristics. *Arenicola* is sedentary.

(6) Distribution and niche preference. *Arenicola* is found in mud and muddy sand in shallow water and intertidally and therefore are characteristic animals of worm flats. They are fairly sedentary within the worm flat except for the males during mating season.

(7) Population density. No information available.

(8) Food. Arenicola ingests mud with minimal selection, although it may reject unsuitable particles or ingest larger items. Whole organisms have been found in the digestive tract, but whether deliberately or accidently is not known.

(9) Predators. Principal predators are crabs, fishes and birds.

(lo) Competitors. No information.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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10.9.6. Asterias forbesi & A. vulgaris

These common starfishes are closely similar in habits and appearance. They can be most easily told apart by the color of their madreporic plate; A. vulgaris has a yellowish plate, while A. forbesi is bright orange-red. Both species usually have five arms and grow to 6 to 12 inches in diameter.

(1) Reproduction. Asterias vulgaris spawns during May and early June (Medcof 1961). A. forbesi in L. I. Sound spawns from mid-June (or whenever the temper-caches 15 C) throughout the summer until early September (Loos anoff 1964). The time of spawning appears to depend on the time and temperature available for the maturation of the gonads, and the attainment of warm enough water for spawning. A rapid rise in temperature to 20 C will stimulate the spawning process although spawning has been observed when temperatures did not exceed 16° (Galtsoff and Loosanoff 1939). Eggs and sperm are released into the water where fertilization takes place.

(2) Fecundity and larval life. Fecundity varies with size. No information on number of eggs. Related species, A. rubens observed to release 2.5 million eggs at one spawning (Hyman 1955). Both species have a pelagic larval period lasting, three to four weeks (Coe 1912; Medcof 1961).

(3) Growth and longevity. In Canadian Atlantic waters, A. vulgaris reaches a diameter of 37-38 mm the first season and 62-63 mm the second (Medcof 1961). A. forbesi in southern New England attains an average diameter of 54 mm in about four months, but may grow faster. Rate of growth is strikingly dependent on the amount of food consumed: at 5½ weeks a poorly fed starfish was about 4 mm in diameter, while a well fed individual was over 50 mm. The fastest growing starfish observed was 105 mm at the age of a little over 4 months (Mead 1901).

(4) Natural mortality. Adult starfish have relatively few natural enemies; at sizes above 12-13 mm loss by predation is small (Coe 1912), although only a small fraction of 1 percent of the larvae attain this size. Mortalities of newly set juveniles may be very high since the abundance of larger starfish in some years is relatively low even when the previous year's set of their class was relatively abundant (Loosanoff 1964). Conversely, in other years survival appears to be unusually high, and year old starfish may be relatively abundant following a set of relatively low abundance.

(5) Migration characteristics. Starfish do not travel great distances (Loosanoff 1961) except passively when borne by strong currents, and it is unlikely that they migrate to spawn. Thousands of starfish may be carried by tidal currents, however, and this process often quickly negates efforts to clean oyster bottoms of these predators. To be transported in this way the starfish curls up its arms, releases itself from the bottom and floats just above the substrate. When the current slackens, the animal is deposited in a new area (Galtsoff 1964).

(6) Distribution and niche preference. These starfishes are familiar to most visitors to the shore because of their commonness in tide pools, and on rocks and beaches in the northeastern United States. A. forbesi occurs from Maine to the Gulf of Mexico, although it is rare north of Cape Cod, Its depth range is from the intertidal zone to about 50 meters. In a southward direction from Cape Cod it becomes increasingly rare in the intertidal zone. A. vulgaris ranges from Labrador to Cape Hatteras. It is the common intertidal starfish north of Cape Cod, but like its congener it exhibits tropical submergence and is only found in very deep water in the southern part of its range. It has been captured from as deep as 655 meters.

(7) Population densities. Medcof (1961) gives densities for A. vulgaris as 6.000-60,000 per acre, but does not say which sizes are included. Galtsoff (1964) provides-data which indicate densities of about 900 adult A. forbesi per acre in L, I. Sound. If juvenile star-

fish were included, this figure would undoubtedly be substantially higher. Maximum densities of starfish in Narragansett Bay and Buzzards Bay as reported by Galtsoff and Loosanoff (1939) were about 2 individuals per square meter, or 8000 per acre, although no information was given to indicate whether the smallest starfish were included in the samples.

The abundance of starfish varies markedly from year to year. Although there appear to be no definite cycles of abundance, there are periods of one or several years when they are very numerous, separated by periods of scarcity.

(8) Food. Asterias feeds on molluscs which are not buried deeply in the sediments. They are voracious predators on mussels and oysters particularly; the young feed on juvenile clams and other bivalves. They are also scavengers and will feed on dead fish, etc. Starfish have the ability of forcing open the valves of shellfish by attaching with the sucking discs of their numerous tube feet and exerting a steady pull. They insert the stomach, everted through the mouth, directly into the tissues of their prey. Temperature influences the rate of feeding with the number of oysters consumed per unit time increasing to 20 C and then dropping off rapidly between 20 and 25 C (MacKenzie 1969).

No definitive information that starfish respond to chemical cues for feeding is available. Since they do locate and feed predominantly on relatively immobile items (bivalves, carrion) and have no demonstrable other sense organs for this purpose, it seems likely that chemical cues are involved. They are not, however, able to detect the presence of food beyond a distance of a few centimeters (Galtsoff and Loosanoff 1939).

(9) Predation. Small starfish are eaten by bottom feeding fish; larval starfish by plankton feeding fish and, according to Thorson (1946), larval shrimp and crabs feed extensively on larvae. Adult starfish appear to have few predators", although the herring gull feeds on them when other food is scarce.

(lo) Responses to the environment (natural factors, pollutants). Not a great deal is known about the environmental physiology or responses to pollutants of echinoderms in general, and these species in particular. They are relatively stenohaline, meaning that they cannot withstand great variations in salinity. Galtsoff (1964) notes that salinities of 16-18 o/oo present a barrier to these species, and it is probable that few individuals can even approach this salinity limit. Sensitivity to temperature variation and low dissolved oxygen levels are characteristics which often co-occur with salinity sensitivity, so it is likely that these species are

stenotopic to these factors as well. Riley and Segar (1970) present a heavy metal analysis of the closely related European species A. rubens but without comparative or pathological studies we can not evaluate the significance of their values.

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10.9.7 Balanus balanoides

(1) Reproduction. Most barnacles are sexually mature at the end of their first year. The onset of breeding activity begins in early October and egg development takes 35 days at 8C (Crisp 1964).

Barnacles are cross fertilizing hermaphrodites. The eggs are placed in the mantle cavity where they are fertilized and remain until the release of the nauplii. The breeding cycle is closely synchronized with the annual temperature fluctuation and with nutrition. The eggs and nauplii remain in the mantle cavity from 60-70 days at Woods Hole to 140 days farther to the north. Fertilization occurs earlier in higher latitudes and the release of nauplii occurs later. The former is synchronized with falling "temperatures and the latter with the spring phytoplankton bloom (Crisp 1964).

(2) Fecundity and larval life. The naupliar stages are pelagic and are a dominant part of the meroplankton in coastal waters during the spawning season. First stage nauplii are released into the-water in "swarms" and they remain planktonic through the next five naupliar stages. The stage VI nauplius metamorphoses Into the cypris larva which is planktonic for a short time and then settles to the bottom, selects a suitable substrate, and metamorphoses into the adult barnacles (Tighe-Ford et al. 1970). Connell (1961) found an average of 1.5 days between settlement of cyprids and completed metamorphosis into the adult barnacle.

Barnes & Barnes (1958) reports the rate of development of the planktonic phase as 21 days at 6.6 C at Woods Hole and 40 days at 1-2 C at Halifax, N. S. Tighe-Ford et al. (1970) report the development time to the cypris stage of experimental animals as 21-34 days at 10 Co Probably a reasonable average of time from the first naupliar to the end of the cypris stage would be about 30 days in the Gulf of Maine with slightly shorter time on the southern coast and longer on the northern coast.

Fuller (1946) reports the period of attachment for barnacles in the Lamoine area of the Maine coast as being from mid-May to mid-July with a peak from mid-June to early July.

Barnacle larvae are an important part of the meroplankton in the winter-spring seasons. The exact time that "swarming" of the larvae takes place varies with location along the coast of the Gulf of Maine. Fish (1925) reports the release of nauplii in the Woods Hole region from December to March, and that the date of release starts later to the north and east. McAlice (1972) reports

naupliar stages of the barnacle in the plankton of the Sheepscot River - Montsweag Bay areas of Maine in high numbers in March and April. Fish & Johnson (1937) found Balanus larvae swarming in the mouth of the Bay of Fundy in April and May.

(3) Growth and longevity. Moore (1934) and Barnes and Powell (1953) show that, after settlement, growth is rapid during spring and summer of the first year, ceases in the winter and then resumes again in the spring and summer of the second year, but to a lesser extent. The following data is from Barnes and Powell (1953) and is for British waters:

	Approximate mean length (mm)
June 1950	7
Aug. 1950	13
Nov. 1950	17
June 1951	18
Aug. 1951	20
Oct. 1951	20

Fuller (1946) gives growth rates of barnacles for the first 12 weeks after settlement in the Lamoine area of Maine.

Age	Average base diameter (mm)
4 weeks	4.0
8 weeks	6.0
12 weeks	8.0

Tighe-Ford et al. (1970), Moore (1935) and Crisp (1960) showed that growth was more rapid in flowing water than static water. Barnacles in the high tide zones and in wave exposed localities tend to be larger (Moore 1935). But Barnes & Powell (1953) found no difference in maximum size of barnacles between tide zones and found that barnacles grow quite well when completely submerged.

(4) Natural mortality. Most barnacles die after spawning in their third year but those in the high tidal zones live for 5 years or more (Moore 1934).

No information on natural mortality rates for the Gulf of Maine. However, Fuller (1946) claims there is a very high mortality rate in September and October, presumably a short time after the animals have settled. He gives no information on the cause or extent of the mortality.

Connell (1961) studies the mortality of B. balanoides in Scottish

waters. He found the highest mortality during cyprid settlement (average 20% per day, March 28-May 11, 1955) and less for metamorphosed barnacles (average 3.7 - 1.6% per day). Mortality during the subsequent three years varied widely between different settling groups, particularly in the extreme high and the extreme low tide levels. Mortality was less variable in the middle tide level.

(5) Migration characteristics. Sessile, do not migrate.

(6) Distribution and niche preference. B. balanoides is distributed in the littoral zone throughout the study area.

(7) Population density. The density of planktonic larvae for the New Hampshire-Maine coastal area is given by Sherman (1968) as 1830 nauplii/100m^3 (maximum value). McAlice (1972) reports that barnacle nauplii in the Sheepscot River - Montsweag Bay area of Maine account for 20% of the total plankton in March and 20-40% in April. Maximum density in the mouth of the Bay of Fundy was 2742 per minute tow with a meter net (Fish & Johnson 1937). The density of barnacle settlement on asbestos shingles in the Lamoine area, Maine (Fuller 1946) was:

Depth (ft.)	Dates	No./sq. ft./week
3	June 24-Aug. 4	340
15	June 25-July 23	500
30	July 9 -Aug. 4	1340

The density of barnacle on the Isle of Man, England, was given as a maximum of 118,000/m^2 by Moore (1935).

(8) Food. Balanus is a plankton feeder, primarily phytoplankton. It is sensitive to the type of plankton in the water, remaining closed when peridinians are abundant, and feeding when the plankton is comprised of diatoms (Moore 1935), or flagellates and small crustacea (Crisp 1962).

(9) Predation. The greatest enemy of Balanus is Thais lapillus which feeds primarily on the older and larger barnacles. Other predators include polychaetes, fish, and crabs. Blennies have been found to feed heavily on barnacles (Connell 1961). In the upper levels, newly settled barnacles may be eaten by Littorina saxatilis (Moore 1935).

In the Gulf of Maine, the' herring Clupea harengus feeds heavily on the planktonic cypris stage during its period of peak abundance in the late winter and early spring.

(10) Competition, A spatial competition exists among the barnacles themselves, as young barnacles will sometimes settle on older ones cutting off their food supply and the older ones will die. A heavy cover of algae such as Fucus may prevent cyprid larvae from reaching the rock surface. Larger Balanus can under cut and remove fronds of Fucus vesiculosus. However, the presence of large algae such as Fucus and Ascophyllum nodosum is definitely harmful to barnacles and in most places they are not found in touching distance of them, due at" least in part to the algae screening the barnacles from an adequate food supply. Any Chthamalus stellatus in contact with Balanus were crushed, smothered, displaced or sometimes lifted on the shells of Balanus. In Florida, barnacles on continuously submerged panels were smothered by growths of colonial tunicates and encrusting bryozoa (Connell 1961). The polychaete worm Spirorbis borealis grows only where the barnacle can not.

(11) Responses to the environment (natural factors and pol 1 utants). Gametogenesis may be inhibited at temperatures above 10 C (Barnes 1959); thus creating a temperature block to reproduction at the southern extreme of its range.

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10.9.8 Callinectes sapidus

Callinectes sapidus is also commonly known as the common blue crab, hard-shell or soft-shell carb. It is highly valued as an edible species. The color is a variation of dark green shades, while the legs are suffused with bright blue. The carapace is 2.5 times as wide as long, moderately convex and nearly smooth. The chelipeds of the male are large and powerful while much smaller in the female. In males the carapace is 200-230 mm and 198 mm in the female. The largest males are generally found in low salinities.

(1) Reproduction. Mating occurs from June to September in Chesapeake Bay. This period may be slightly shortened in southern New England waters. Mating requires 5-12 hours for completion. Females mate only once then migrate to, higher salinities where eggs are held 2-9 months before spawning. If spawning occurs in early June, it may occur again in August, but if the first eggs are released in August some are then held to the following May or June. Only a portion of the eggs are fertilized during the first spawning period. As the eggs pass from the ovaries to the outside, they are fertilized by sperm held in the seminal receptacles. Outside the body, they attach to hairs of the four pairs of swimmerets on the abdomen where they may remain for two or more weeks. Some sperm may remain viable in the seminal receptacles for a period of one year, permitting the once-mated female to spawn a second time. Females usually mate during the fall of the second summer or spring of the third, after attaining a width of 6" (Van Engel, 1958). A female may mate with 2 or more males. A cradle-like posture with the male above and the female below is assumed for 2-3 days. During this period the female sheds the soft shell and then exposes the genital pores on her ventral side. Mating may occur either during the day or night. After mating, the male again "cradles" the female for 2 or more days (Van Engel, 1958).

(2) Fecundity and larval life. The average female produces a sponge containing from 700,000 to 2 million eggs (Van Engel, 1958). The blue crab has two pelagic larval stages, the zoea and megalops stages. The zoea undergoes 7-8 stages before metamorphosis to the megalops, during a period from 31-49 days. The megalops requires approximately 6-20 days before metamorphosis to the first crab.

(3) Growth and longevity. Growth is very rapid. Zoea grow from 1/100 inches to 1/25 inches in width in one month. Crabs attain adult size in 1 to 1½ years. Molting occurs according to the following schedule:

Size	Frequency
1/5"	3-5 days
1/2"	10-15 days
4"	20-50 days

At each molt there is a one quarter to one third increase in width from the original size before molting. Those hatched in May attain 2½ inches by November and 5 inches by the following August. Those hatched in August or September grow to only 1/2" and attain 3/4" by the next summer. In the latter group, maturity is delayed until May of the third summer. Molting does not occur during the period from November to April. It takes a 4-5" crab from 2-3 hours to complete a molt. After 18-20 molts the female stops growing and is considered mature. The male generally matures after 18-19 molts, but may continue to molt, 3 to 4 more times. An adult female may measure 6 inches in width. The maximum age for male and female is 3 to 3½ years (Van Engel, 1958).

(4) Natural mortality. Only 10^{-6} percent of the eggs survive to become mature crabs. Females mate only once, usually during the end of the second summer or beginning of the third summer. After shedding their eggs the next summer, they frequently move offshore and die.

(5) Migration characteristics. The female migrates after mating in the fall to deeper channels and again in the spring when they continue to migrate to the mouths of the bays where they will release the larvae. After release they move offshore and die or may return the next year in the "ocean" crab run.

(6) Distribution and niche preference. The blue crab is a common inhabitant of muddy and sandy shores of the East Coast and Gulf coast. Its range extends from" Massachusetts to Texas and a few have been reported as far north as Nova Scotia and as far south as Uruguay. It is common in grassy bays and estuaries and shallow oceanic water from the waters edge to 40 meters.

(7) Population densities. Densities are difficult to estimate because this is a migratory species. In Chesapeake Bay the average annual production is 60 million pounds, valued at about 3 million dollars" from 1948 to 1958 (Van Engel, 1958).

(8) Food. . The blue crab is a predacious species with a voracious appetite. It feeds on oysters, clams, tunicates, fishes, some. vascular plant material and organic detritus. It prefers fresh prey to putrid flesh.

(9) Predation. Predators include the greater scaup (Aythya marila) and man.

(10) Competition. Competitors include the green crab and some of the shore birds which have similar diets.

(11) Responses to the environment (natural factors and pollutants). The blue crab is a euryhaline species. They can invade low salinities if allowed to adjust slowly to the reduced chlorinity. A salinity of 20 o/oo is required for metamorphosis to the first crab stage. At 25 o/oo and a temperature of 24-29 C the time is reduced from 6 to 20 days to 5 to 13 days. There are no differences in zoeal development from 20 o/00 to 31.1 o/00. Below 20 O/oo the zoea rarely finishes the first molt (Costlow and Bookhout, 1959).

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10.9.9 Cancer irroratus & C. borealis

The rock crab (C. irroratus) and the Jonah crab (C. borealis) are closely related and similar in appearance. There is a limited commercial fishery for them in New England. Considering their familiarity and their economic potential, surprisingly little biological information is available for either species, although some research is now in progress, particularly on C. irroratus.

(1) Reproduction. In Maine, C. irroratus breeds in the late fall and winter when the eggs are laid and fertilized. Copulation occurs following the molt-of the female. The eggs are carried through the winter and hatch from May through August the following summer. It breeds somewhat later and the eggs hatch somewhat earlier south of Cape Cod.

(2) Fecundity and larval 1 ife. Several hundred thousand eggs are laid and carried under the abdomen of the female. The larvae pass through five planktonic zoeal stages and one megalops stage before settling on the bottom as juveniles. The duration of larval life is about 30 clays at 20 C and 40 days at 15 C.

(3) Growth and longevity. In Maine, the young crabs attain a carapace width of a little over 10 mm at the end of the first year. There is presently no published information on the growth rates of either species, but data is being collected on growth and other population statistics by the Maine Department of Marine Resources and other research agencies.

(4) Natural mortality. No information on mortality rates.

(5) Migration characteristics. There appear to be limited seasonal offshore-onshore migrations, but no detailed information is available.

(6) Distribution and niche preference. Cancer irroratus occurs on sandy or mud bottoms from low water to 600 meters, Labrador to South Carolina. C. borealis occurs in rocky areas, from low water to 800 meters, Nova Scotia to Florida. " C. irroratus is an active species, burrowing into the sediment as necessary for protection. C. borealis is more secretive, hiding in rocky crevices.

(7) Population densities. No information available on population densities.

(8) Food. Both species are predatory, feeding on bivalves and other invertebrates.

(9) Predation. The young of both species are preyed upon heavily by bottom feeding fish. Large cod are capable of eating adult crabs.

(10) Competition. No specific information on competitors. Studies are currently being made in Maine to investigate possible interactions with lobsters.

(11) Responses to the environment (natural factors, pollutants). No information.

10.9.10 Capitella capitata

C_. capitata is a polychaete worm which closely resembles an earthworm. Its entire body is conspicuously ringed with many segments and tapers at both ends. It is blood-red in color and has a body about 5" long.

(1) Reproduction. Copulation takes place between male and female with the transfer of a spermatophore, retained by female until "eggs are

ready to be laid. Eggs incubated and hatched in burrow of female. l-latch in 10-14 days (Thorson 1946).

(2). Fecundity and larval life. Larvae are pelagic for about 5 days Thorson 1946).

(3) Growth and longevity. No information.

(4) Natural mortality. No information.

(5) Migration. No migration, worm sedentary, tubicolous.

(6} Distribution and niche preference. It is a cosmopolitan species which is abundant near the low tide mark in wet, gravelly places under stones and in either mud or sand.

(7) Population densities. 1,253 individuals/m^2 reported by Phelps (1964) for a shallow salt pond in southern R.I.

(8) Food. It is a deposit feeder with a diet consisting of detritus, bacteria and benthic algae.

(9) Predation. Predators are numerous. Generally they include crustaceans, fish, starfish and hydroids.

(lo) Competition. No information.

(11) Responses to the environment (natural factors and pollutants). When little or no oxygen is present, the animals stop eating and die after several days. At a concentration of 2.9 ppm 0_2 they will eat, but it must be 3.5 ppm before they can reproduce and complete their life cycle (Reish & Barnard, 1960).

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10.9.11 Carcinus maenus

Carcinus maenas (Carcinides maenas) is also commonly known as the green shore crab. It differs from other swimming crabs in that it does not have the last pair of legs expanded as oval paddles. The carapace is usually 5-7.5 cm across and varies in color from greenish black to orange. It is a very active crab with chelipeds short in proportion to the width.

(1) Reproduction. The female becomes sexually mature in the first year and probably the first summer. Mating occurs during molting in July, August or September. Two clusters of eggs may be produced, the first in November-December (60%) and a second in May (40%). There is a minimal 1 1/2- 4 1/2 month delay. Sperm remain viable for approximately 10 months. In the third week of May approximately 80% of the females produce eggs.

(2) Fecundity and larval life. The green crab has a pelagic larval stage. Eleven stages of development have been reported including a zoeal and megalops stage. A single female produces approximately 200,000 eggs per season.

(3) Growth and longevity. There is a 40-50% growth during development. Females become mature in their first year and probably the first summer when they reach a size of about 2 cm. Males reach maturity at about 2.5-3 cm. After attaining 3 cm the crab molts once a year. The growth rate is 1/5 to 1/3 of the original size after each molt. 'Average year size classes were as follows:

Year class	Size (females)	Size (manes)
1	36 mm	36 mm
2 "	42 mm	42 mm
3	50 mm	48 mm
4	---	56 mm

(4) Natural mortality. Larval mortality unknown; most adults die in their third year, although some live 5-6 years.

(5) Migration. Females migrate to higher salinities during winter, but can live in lower salinities in summer.

(6) Distribution and niche preference. It ranges from Cape Cod to New Jersey. It is found intertidally in shallow water on sand or mud bottoms in rock, shells or vegetation.

(7) Population densities. The green crab is the most common crab along the southern New England coast in marine and brackish waters. Animals are abundant locally but population densities were not available.

(8) Food. A voracious predator, its diet includes live gobies, molluscs, especially Mya arenaria, and snails.

(9) Predation. Predators include the greater sculp, gulls, and terns.

(lo) Competition. Competitors include the mud crab, Panopeus herbstii and the blue crab.

(11) Responses to environment (natural factors and pollutants). Eggs are destroyed by temperatures less than about 8 C. Increased salinity will offset the' effect of a severe temperature drop, e.g., at 10 C, 26 O/oo and at 3 to 4 C, 32 ^{O}/oo. The following temperature-salinity combinations have been described as limits for development: 16.3 C at 41-53 ^{O}/oo and 17.0 C at 15.7-20 ^{O}/oo. It is a euryhaline species and can live up to 8 days in air.

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109.12 Ceriantheopsis americanus

Ceriantheopsis americanus is a burrowing sea-anemone but differs structurally from other burrowing anthozoans in having two rings of tentacles on the oral end instead of one.

(1) Reproduction. The species is a protandric hermaphrodite. Sperm is shed into the water first, followed by the eggs, and fertilization is external. No information on-spawning season.

(2) Fecundity and larval life. The larvae are pelagic but the duration of larval life is not known. Tentacled form develops before larva settles to bottom. No information on fecundity.

(3) Growth and longevity. No information.

(4) Natural mortality. No information.

(5) Migration. Sedentary species; no migrations.

(6) Distribution and niche preference. C. americanus occurs from Cape Cod to Florida in shallow water to 21 meters, occupying mucus-lined burrows in silt or silty-sand. A related but larger species, Cerianthus borealis, is found north of Cape Cod in colder and deeper water.

(7) Population densities. A few have been recorded as follows:

New York Bight	38 per m^2	{Sandy Hook Laboratory, 1972)
Long Island Sound	40 per m^2	(Gordon, Rhoads & Turekian, 1972)
Rhode Island Sound	60 per m^2	(Saila, Pratt & Polgar, 1972) '

(8) Food . This species is a tentacular suspension feeder.

(9) Predation. One known predator is the winter flounder, which feeds on the exposed oral ends of the animals.

(lo) Competition. Specific competitors are not known.

(11) Responses to the environment (natural factors, pollutants). No information.

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10.9.13 Clymenella torquata

A tubicolous, infaunal polychaete. It is the most abundant maldarid polychaete in boreal waters.

(1) Reproduction. Spawning lasts 2 or 3 days and may occur any time during late April to the middle of May. The stimulus to spawn may be related to the extra exposure during spring low tides (Newell, 1951). Sanders, Goudsmit, Mills and Hampson (1962) state that the spring warming of the water may be the conditioner and the spring tides the trigger to spawning.

(2) Fecundity and larval life. No information on fecundity. The large, yolked eggs and larvae, which are bottom dwelling, omit the trochophore stage. There is no planktonic, free-swimming stage.

The young larvae are described by Newell (1951) as spherical, uniformly ciliated and demersal. Larvae reach 0.6 mm in 7 days and change from ciliated swimming to notopodia. They are ensheathed in layers of mucous. In 24-25 days they have developed into small worms.

(3) Growth and longevity. No information on adults. The tube of sand grains that encase the worm are typically 10-15 cm long.

(4) Natural mortality. No information.

(5) Migration characteristics, Clymenella is non-migratory.

(6) Distribution and niche preference. Clymenella the most politan of the 5 species of maidanid polychaetes studied by Mangum (1964). It was found primarily in sandy and muddy bottoms; in Massachusetts to North Carolina its habitat is predictably protected bottoms of fine sand, in Maine it is confined to the soft sediments o-F sand and mud. The highest density, however, was found in the coarse sediments of Passamaquoddy Bay. Clymenella is characteristically subtidal in areas of low tide range, but north of Cape Cod, where the tidal amplitude exceeds 2 m, it is found in the intertidal zone.

Clymenella occupies portions of certain flats in colonies that are distributed in patches. One patch in Barnstable Harbor covered an estimated 150,000 m^2 (Sanders, et al., 1962).

(7) Population densities. The density of colonies of Clymenella have been reported by several authors. Kenny (1969) found a maximum density in North Carolina of 400 per m^2 near the low watermark. Dexter (1947) found up to 609 per $60m^2$ dredge haul. Lee (1944) found the average number per 20 liters of bottom material was 100, and the maximum density was at the 20 meter depth contour. Sanders, et al. (1962) gives 615 per m2 as maximum density in Barnstable Harbor. Mangum (1964) gives the following densities:

Passamaquoddy Bay, N.B.	$675/m^2$
Western Bay, Maine: Station 1	$250/m^2$
Station 2	$275/m^2$

(8) Food. Clymenella is a non-selective deposit feeder which feeds on detritus 8 to 30 cm below the surface of the sediments (Mangum, 1964). It lies head down in the sediment ingesting food and egesting waste through the tail shaft into the water above the substratum. According to Sanders, et al. (1962) the stomach contents contained sand, detritus and diatoms.

(9) Predation. A large number of Clymenella were observed by Mangum (1964) to be regenerating posterior parts, indicating heavy Predation. Probably bottom fishes such as flatfish, sculpins and cunner, as well as carnivorous. invertebrates, prey on them.

(lo) Competition. In the northern part of its range, and in the coarser sediments Clymenella torquata overlaps with C. zonalis. These species appear to have identical habits and where they overlap C. torquata seems to be the successful competitor (Mangum, 1964). Mangum observed that where several maldanid polychaetes are found together, their density is reduced compared to areas where one species is found alone.

It was noted by Sanders, et al. (1962) that Mya arenaria was excluded from dense patches of Clymenella and he indicated that there was some biological interaction between these two species.

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10.9.14 Corophium volutator

This is one of a large group of amphipods most of which are tube builders. Corophium inhabits muddy sediments intertidally and in shallow water, frequently in brackish or estuarine environments.

(1) Reproduction. Corophium spawns in burrows in mud flats and brackish pools. Large specimens over 7 mm in length begin breeding in February and smaller specimens do not become mature until March to April (their young breed the next spring). The young that are born early in the year become mature and breed in July to August. The young are carried in the brood pouch for 4 weeks and some females may produce 4 to 5 broods per year. Copulation is the result of chance collisions between male and female. The male grasps the female and carries her for several days or longer. Soon after molting, the deposition of the eggs takes place; and the males fertilize the eggs as they are being discharged.

(2) Fecundity and larval life. There is no information on fecundity. The larvae hatch from eggs and remain attached to their mother in the brood pouch for about a month until they become miniature adults and are liberated into the burrow. Development is direct.

(3) Growth and longevity. Corophium does not live over one year, usually somewhat less. No information on growth.

(4) Natural mortality. No information.

(5) Migration characteristics. Corophium is non-migratory.

(6) Distribution and niche preference. Corophium is mainly concentrated in about 5 cm of mud flats, brackish pools, and salt marsh pools almost to the mean high water level.

(7) Population densities. Maximum densities have been recorded of 11,000 per m^2 to 63,000 per m^2.

(8) Food. Corophium feeds in two different ways. It may crawl about on the surface of the mud selectively feeding on organic detritus or microflora and fauna; or it may remain in its burrow and scrape this material towards its mouth with its enlarged antennae. A second method of feeding consists of remaining in the tube or burrow and straining particulate organic material from the water taken in as respiratory current.

(9) Predation. Principal predators are various shore and wading birds, gulls, and flounders.

(10) Competitors. Nereis diversicolor occupies the same habitat, sometimes in very great numbers. Its feeding habits are similar and it is probably-a competitor.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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10.9.15. Crangon septemspinosus

The common sand shrimp, also known as Crangon vulgaris Fabricius. It has a short, somewhat dorsally flattened rostrum. The first pair of legs are chelate. The carapace has a dorsal spine posterior to the rostrum and is translucent and pale gray with minute stellate dark spots. Crangon occurs in great numbers on sandy fiats and in tide pools. Its irregular gray color imitates that of the sandy bottoms so closely as to render it practically unseen by predators when resting motionless on the bottom or-when partially buried in the sand.

(1) Reproduction. The sand shrimp spawns from March to October with a peak in June and July. Ovigerous females appear year-round except in December. First egg-bearers are the larger females, but year-old animals may spawn.

(2) Fecundity and larval life. Approximately 500-7,500 eggs are produced by a single female.

(3) Growth and longevity. Growth rate is about 1 mm per month. Longevity varies from 1 year of age to 3 years for females and 2 years for males.

(4) Natural mortality. No information.

(5) Migration. Juveniles known to move during mid-summer to late fall from estuaries to offshore. Young are abundant on Georges Bank in September.

(6) Distribution and niche preference. The sand shrimp is abundant throughout its entire range from Labrador to North Carolina and less common in the south. It is abundant on sandy flats and in tide Pools as well as sandy bottoms in deeper waters offshore. Between tides it burrows into the moist sand to a considerable depth.

(7) Population densities. No information.

(8) Food. The diet of these shrimp consists of organic detritus, polychaetes, mysids, decapod larvae, eggs, isopods, bivalves (Mytilus and Gemma) and amphipods; it is both a predator and a scavenger.

(9) Predation. Common predators include the weak-fish, kingfish, bluefish, flounders, -striped bass (its principal food) as well as cod, dogfish and skates.

(10) Competition. Competitors include several species of crabs, horseshoe crabs, small bottom feeding fish such as Fundulus, flounder.

(11) Responses to the environment (natural factors and pollutants). They are particularly sensitive to insecticides, especially organochlorides and organophosphorus compounds (Eisler, N.D.).

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10.9.16 Crassostrea virginica

The American or Eastern oyster, Crassostrea virginica, is one of the most important shellfish resources of the western hemisphere. Principal oyster fisheries in the United States occur on the Gulf coast, in Chesapeake and Delaware Bays, and in Long Island Sound, with areas of secondary importance all along the east coast.

(1) Reproduction. The oyster reproduces in the summer. The environmental cue for spawning is a rise in water temperature. The actual time and temperature of spawning varies with geographic area, such that southern populations spawn earlier and at a higher temperature than northern populations. In Long Island Sound the spawning season is generally from late June to late August (Loosanoff, 1965). In Massachusetts, Belden (1912) found spawning oysters from mid-June to mid-August with peak spawning between late June and mid-July. A temperature of 21 C was required.

Oysters are protandric. They begin spawning as males after about 10 months of growth. During the second year of growth some males

become females and in the third year a larger percentage change. It is possible for an oyster to change sex several times during its life.

After ripening of the gonads, spawning itself is usually begun by a male who is more sensitive to physical stimuli. The presence of sperm in the water, in combination with the other prerequisite conditions, causes ripe females to spawn. The gametes are released directly into the water column where fertilization takes place.

(2) Fecundity and larval life. The average female oyster releases over 50 million eggs per year. Of these less than a dozen reach maturity. The first two to three weeks of life are spent as planktonic larvae feeding in the water column. Through behavioral responses to salinity and light, the larvae are able to be returned by the currents to approximately their area of origin. The actual length of larval life depends on the temperature, with development proceeding faster at higher temperatures. Throughout their larval life oysters are exposed to intense predatory pressures and it is at this stage that the greatest mortality occurs. The larvae must find a suitable substrate upon which to "set". The ideal substrate is the shells of preceding oyster generations, but spat set will also occur on shells of other species, rocks, pilings, etc. It has been shown that the presence of spat, i.e., settled larvae, on shells serves to atrract and stimulate setting of other larvae (Hidu and Haskin, 1971). This gregarious setting increases the chances of survival of the species by aiding a larva in finding a suitable substrate and further by producing concentrations of adult oysters which in turn provide substrate for succeeding generations.

(3) Growth and 1 ongevi ty. The growth of oysters depends on numerous factors, both inherent and environmental. The work of Shaw (1963), for example, indicates that oysters from different geographic areas grow at different rates in the same environment, Oysters suspended off the bottom generally grow faster than those on the ' bottom. Shaw (1962) gives growth rates for off-bottom grown oysters in Cape Cod waters as follows (shell height in millimeters):

Figures from Milford, Connecticut (Loosanoff, 1946) for comparison:

	Cape Cod	Connecticut
1st Season	11 mm	19 mm
2nd Season	49 mm	59 mm
3rd Season	72 mm	78 mm

For oysters grown on the bottom, Shaw gives the following for Cape Cod:

Ist Season	11 mm
2nd Season	36 mm
3rd Season	52 mm

Sterl (1972) gives the following growth rates for Maine oysters, grown off-bottom:

1st and 2nd Seasons	29.3 mm
3rd Season	62 mm
4th Season	90.7 mm

Sterl's measurements made in August, hence for any given age, would lack two month's growth in comparison with Shaws measurements made in November.

Longevity is of little significance for a commercially exploited species as most adults are removed from the population as soon as they reach marketable size. This is usually about three years for the oyster. The maximal life span of the oyster under natural conditions is about 40 years.

(4) Natural mortality. Where oysters are protected from predators, mortality rates after setting are moderate. Shaw (1962) found that for oysters grown off the-bottom, mortality was-17.7-percent from the end of the first season to the end of the second, and 26.4 percent during the third. The mortality rate for 2 years of bottom grown oysters was estimated at 90 percent. Bottom grown oysters are subject to heavy predation especially during the first season. In the first 6 months, MacKenzie (1970) lists several causes for mortality and the portion of the total rate due to each. Of an average 75 percent mortality, 45 percent was due to predation, 10 percent to overgrowth by competitors and epifauna, 8 percent to starvation and 12 percent to other causes. The percentage of mortality within each category will vary between geographic areas. Mortality may be inversely related to salinity, especially where diseases are a factor.

Disease is one of the most serious causes of mortality. Two pathogens which have caused high mortality in other areas occur in the study area (Sindermann, 1968; Krantz, Buchanan, Farley, and Carr, 1972). These pathogens, Minchinia nelsoni and Dermocystidium marinum, however do not appear to cause significant mortality in New England ('MacKenzie, 1970b; Newman, 1971). Other oyster diseases include: mmetabolic diseases, viral diseases (possibly Malpeque Bay disease"important in the Canadian Maritime Provinces), bacterial

diseases, fungal diseases (Mycelial disease, microcell disease and "shell disease), and protozoan diseases (Minchinia costalis) (Rosenfield, 1969).

(5) Migrations. Sedentary species, no migrations.

(6) Distribution and niche preference. Crassostrea virginica occurs from Prince Edward Island, Canada, to the Gulf of Mexico. In recent years it has been introduced on the west coast and to other continents for aquacultural purposes. In nature the oyster lives in sheltered shallow and intertidal marine and estuarine water. Where predation is heavy its distribution is more likely to be limited to intertidal or estuarine regions. The epidemics of the early 1960's severely reduced high salinity populations so that in some regions, i.e. Chesapeake Bay, dense populations occur only in mesohaline zones.

The substrate requirements of the oyster result in the formation of reefs, where the accumulated shells of preceding generations have formed geological structures which are ideal -For the-setting of 1 arvae. These reefs are characteristic estuarine features. In high salinity intertidal areas oyster larvae set on scattered shells which results in clumps of oysters separated by muddy substrate. These areas are often called oyster beds.

(7) Population densities. Oyster populations are small and scattered in New England north of Cape Cod. Also much of the data relating to the size of populations in the North Atlantic area are in terms of production rather than population density. The following data for past and recent oyster populations in this general region may be illustrative, however.

In a dense population in the Piscataqua River, Maine, Harriman (1964) estimated 300-400 bushels per acre. Dense natural populations in the Potomac River were estimated by Frey (1946) at an average of over 14,000 individuals per acre (figures in bushels per acre given only for marketable oysters of over 3 inches). A very dense natural population in Delaware Bay averaged over 700,000 oysters of various sizes plus 250,000 spat per acre, or 1,476 bushels per acre (Moore, 1911). On the managed beds in Long Island Sound densities of over 3,000 bushels per acre have been reported (MacKenzie, 1970b).

(8) Food. The oyster is a suspension feeder. It filters a mixture of suspended particles from the water and sorts them according to size on its gills. Certain material, called pseudofeces, is rejected in a mucous mass. Non-rejected material is passed into the gut. Which component of this material is actually assimilated is unknown. In laboratory situations oysters have been successfully reared on

several species of phytoplankton, but in nature it is probable that phytoplankton represents only part of the diet. Another major part is probably the bacteria flora which thrives on the large surface area of suspended silt and detrital particles.

(9) Predation. In high salinity areas oysters are plagued by a number of predators. Chief among them are the oyster drills, Urosalpinx cinerea and Eupleura candata, and the starfish, Asterias vulgaris and A. forbesi. In certain regions the polyclad flatworm, Stylochus ellipticus must be considered a serious predator of oyster spat. Several crabs are known to feed on oysters but for the most part they are generalists and rarely put great stress on oyster populations. Likewise, in local situations, the whelks, Busycon canaliculatum and B. carica can decimate an oyster population. Occasionally rays have been known to settle in large numbers on an individual bed and eat a large percentage of the population. Urosalpinx has been chosen as a key species because of its documented impact on oysters, as have the two species of Asterias which are also important predators on mussel beds.

(lo) Competition. There are many species which cohabit with oysters and a few of them can be harmful without feeding directly on them. The boring sponges of the genus Cliona weaken oyster shells and make them less attractive. The oyster crab, Pinnotheres ostreum actually lives within the oyster's mantle cavity and causes a lowering of oyster quality. Mud worms of the genus Polydora can be harmful in two ways. P. websteri bores into the shell and causes the oyster to spend energy to wall off the intruder that would otherwise go to growth, while P. ligni builds mud tubes on the shells which have been known to occur in such density as to cause complete mortality of the oyster population. These two species in combination have been chosen as a key species. Several species of fouling organisms live on oyster shells but it is unclear as to how seriously they affect oyster recruitment and survival. Often mentioned in this group are gastropod of the genus Crepidula and encrusting bryozoa. A large alga, Codium fragile, has caused problems as it uses oyster shells to anchor its holdfast. When it grows to full size it exerts enough drag on the water currents to pull the oyster off the bottom.

(11) Responses to the environment (natural factors, pollutants). Within its geographic range oysters are exposed to water temperatures as low as OC to as high as 36 C. Furthermore, during exposure intertidal oysters must bear even more extreme temperatures. C. virginica ceases to feed at 6 or 7 C, its maximum ciliary activity occurs at about 25 to 36 C, but rapidly declines above 32 C and most body functions cease at 42 C. The important implication of this to our region is that the oyster does not feed, hence does not grow, during the several months that water temperatures are less than about

8 C. (Much of the above information was derived from Gal tsoff, 1964).

Diaz (1973) investigated the effect of brief temperature increases, as might occur during passage through an electrical generating or other industrial plant, on the mortality, growth, and setting of oyster larvae. His results showed that these brief temperature increases significantly increased mortality and decreased setting, although only the higher temperatures impaired growth.

The American oyster is a euryhaline organism meaning that it can withstand a wide range of salinities. The greatest densities of oysters are found in the polyhaline (18-30 °/oo) and mesohaline (5-18 °/oo) zones. Some populations actually occur where salinity is below 5 o/oo for significant periods of the year but such areas must be considered precarious for oyster production for they are especially susceptible to freshening from abnormal land runoff, By closing their shells oysters can withstand freshwater flow for a limited period of time, however, after a week or so significant mortalities occur. The ability to live in the mesohaline zone is very significant from the production standpoint because many predators, pests and disease organisms cannot survive these 10W, variable salinities and hence, the oyster can grow in relative safety.

Estuarine organisms, including oysters, must usually be tolerant to higher levels of turbidity than marine species. It has been found however that increased turbidity does have detrimental effects. As little as 0.1 gm of silt per liter of seawater reduced the pumping rate, hence feeding rate, of adult oysters by 57 percent (Loosanoff and Tommers, 1948). Also, 0.188 g/1 of silt caused a significant decrease in the percentage of oyster eggs developing normally (Davis and Hidu, 1965). A layer of silt one to two millimeters thick is enough to make an otherwise adequate surface unsuitable for spat set (Galtsoff, 1964) and thicker layers can cause mortality of adult oysters. This amount of deposition can be caused by land runoff or dredging operations (Rose, 1973).

As with most organisms oysters can be affected by low levels of dissolved oxygen. However, most concentrations of oysters occur in shallow well-mixed water so the problem, at present, is not a serious one. There is some evidence that some species of oysters may have anaerobic metabolic pathways that can be utilized when environmental oxygen is inadequate or when the shell must be closed for some other reason.

The effect of pollutants on the oyster is currently a very active area of research. Some of the results already published can be mentioned here.

Laboratory experiments with zinc dissolved in seawater showed decreases in larval growth and increases in larval abnormality and mortality in the species Ostrea edulis and Crassostrea gigas (Brereton, et al., 1973). Calabrese, et al. (1973) tested the toxicity of 11 metals on embryos of the American oyster and found that mercury, silver, copper, and zinc were very toxic while nickel, lead, and cadmium were relatively toxic. Arsenic, chromium, manganese, and aluminum were slightly toxic or nontoxic. Cunningham and Tripp (1973) investigated the uptake and deputation of mercury by adult oysters and found that high mortality could be associated with water mercury levels of 100 ppb, and that uptake was a much more rapid process than deputation. After six months in clean water, all of the accumulated mercury was not yet removed from the tissues.

Chronic exposure to low levels of mixed pesticides has been shown to affect growth, cause pathological tissue changes and to break down the oyster's defense against infection. Oysters can accumulate relatively high levels of pesticides but can also eliminate them completely in three months or less (Lowe, Wilson, Rick, and Wilson, Jr., 1971).

The effects of oil drilling fluids on adult oysters was tested in Mexico and they were found to have a profound effect on survival. In concentrations of over 200 ppm of fluids a mortality of 50 percent was reached within a week. Individual components of the fluid had various effects on mortality (Cabrera, 1971).

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10.9.1.7 Cyathura polita

An isopod which has until recently been called Cyathura carinata (Kroyer). It is about 20mm long, has short stout antennae and a fingerlike process with a slender curved spine which suggests a chela. The remaining six pairs of legs are used for walking.

(1) Reproduction. Females have a marsupium which carries juveniles prior to their release.

(2) Fecundity and larval life. The young hatch out in the adult or near adult form. As a result the number of eggs produced is smaller since they must be larger to accommodate a larger yolk capacity.

(3) Growth and longevity. Juveniles are 5-8 mm, adults 21 mm (Haefner, Mazurkiewiez, and Burbank, N.D.)

(4) Natural mortality. No information.

(5) Migration. No information.

(6) Distribution and niche preference. The range extends from Greenland along the entire eastern seaboard to Norfolk, Virginia. It occurs abundantly between tides or around the low water mark, particularly in brackish waters. In estuaries where zonation of marsh grasses occurs and the water is in constant motion. Substrates include vegetable debris and clay. It is a burrowing species which constructs an unlined tube (Haefner, et al.).

(7) Population densities. 545/m^2 reported by Phelps (1964) for a shallow salt pond in southern Rhode Island. This species is considered abundant.

(8) Food. Cyathura is a scavenger which picks up bits of food along the intertidal zone.

(9) Predation. There are many predators, particularly young fish and worms.

(lo) Competition. No information.

(11) Responses to the environment. (natural factors, pollutants). It is a euryhaline species, which seems to be more abundant in brackish water. It requires non-polluted areas with, high dissolved oxygen levels (Haefner, et al.).

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10.9.18 Diptera larvae, Aedes solicitans

Of the numerous species of dipterous insects that live in salt marshes, two are selected here as representative: the salt-marsh mosquito, Aedes sollicitans, and chironomids.

Aedes:

(1) 'Reproduction. Aedes sollicitans breeds throughout the spring, summer and fall in the southerly portions of its range, but not until midsummer in the north. A related species, A. cantator, which breeds at lower temperatures is the spring and early summer salt marsh mosquito in Maine. Breeding areas are the level salt marsh areas between mean and extreme high tide levels, or in fringing low woods and fields.

(2) Fecundity and larval life. Aedes lays from 50 to several hundred eggs, singly not in rafts. They are laid in dried mud in depressions of the salt marsh. These depressions are flooded periodically by spring tides and rains. Embryos must be well developed inside the eggs before flooding will cause them to hatch. A temperature of 10 C or higher is required for hatching. Larval development takes one week to 12 days depending on temperature.

(3) Growth and longevity. Growth occurs only during larval life and is fixed at 4 stages or instars per generation, Growth depends largely on temperature.

(4) Natural mortality. No quantitative information. Excessive flooding of marshes may increase mortality by flushing out pools or opening them to predatory fish. Estimates indicate a greater production of mosquitoes when flooding occurs eight or fewer times a month, and low production when it occurs 25 or more times a month.

(5) Migration characteristics. Aedes migrates only as an adult; it may fly as much as 40-50 miles from breeding places.

(6) Distribution and niche preference. Aedes lives in salt marsh pools all along the coast.

(7) Population densities. Maximum densities of Aedes larvae estimated at 30-50 million per acre (Chandler, 1950). Smith observed 117 larvae emerge from 2 square inches of soil in New Jersey.

(8) Food. Aedes larvae presumably are detritus feeders.

(9) Predation. The chief and most effective predators on Aedes larvae are small fish such as Fundulus and Cyprinodon.

(10) Competition. No information on competition.

(11) Responses to the environment (natural factors and pollutants). Factors which contribute to low oxygen concentration promote larval development.

Chironomids:

(1) Reproduction. Chironomid larvae are found from April through October, 2-3 generations a year.

(2) Fecundity and larval life. Each female lays 200-500 eggs (Jamnback, 1969).

(3) Growth and longevity. No information found.

(4) Natural mortality. No information found.

(5) Migration characteristics. No migrations:

(6) Distribution and niche preference. According to species, intertidal or shallow water mud flats, drainage ditches, river banks, etc. all along coast..

(7) Population densities. As high as 8,000 "per m^2; in Sheepscot River estuary, Maine observed at 20-300 per m^2. ,

(8) Food . Not known for certain. Probably detritus feeders, although some species observed to prey on small oligochaete worms (Loden, 1974).

(9) Predation. Chironomid larvae are eaten by various bottom feeding fish.

(lo) Competition. In some transitional areas of low salinity or other environmental stress, chironomids appear to be one of the few mud dwellers adapted for survival and have few competitors. In more saline or cleaner water, the number of species competing increases, e.g., Nereis diversicolor, Heteromastus filiformis, Corophium, etc.

(11) Responses to the environment (natural factors and pollutants). No information obtained.

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10.9.19 Echinarachnius parma

The sand dollar; a disc-shaped sea urchin with a dense covering of minute spines.

(1) Reproduction. No information on age at first spawning. Spawning in Moods Hole area takes place from March to July (Costello, Davidson,

Eggers, Fox, and Henley, 1957). Males and females release gametes into surrounding water. No information on timing or triggering mechanisms.

(2) Fecundity and larval life. Echinarachnius has a pelagic larval period; no information on its duration, but according to Thorson (.1946) 3 to 4 weeks is characteristic for echinoderms in northern waters in summer.

(3) Growth and longevity. Growth is relatively slow. Diameter 4 months after metamorphosis is about 1 mm. Diameter at age of 7 years, estimated from growth rings is about 48 mm in Woods Hole region. Faster growing individuals have been observed; two specimens from the Maine coast were 60mm at age 3 and 70mm at age between 3 and 4years (Boolootian, 1966).

(4) Natural mortality. No information.

(5) Migrations. Species only slightly motile; no large scale movements.

(6) Distribution and niche preference. Lives on sandy or silty-sand bottoms in depths of 1 to 1600 meters. Found on the U.S. Atlantic coast from Labrador to New Jersey.

(7) Population densities. Local populations can achieve enormous densities. Beds on the sea floor have been observed several layers thick, with all individuals in close contact (Zenkevitch, 1963); assuming an average diameter of 60 mm, this would amount to more than 500 per square meter. Usual densities are less than this.

(8) Food. Food consists of organic detritus and possibly phytoplankton which settles to the sea bottom. This accumulates on the aboral or upper surface, and is transported by the numerous ciliated spines and tube feet under the rim of the shell and thence to the mouth (Zenkevitch, 1963). Echinarachnius is said also to feed on recently metamorphosed molluscs and polychaetes (Savilov, 1959).

(9) Predation. Predators on the pelagic young are probably numerous. Thorson (1946) says larval shrimp and crabs feed on echinoderm larvae; they are also undoubtedly eaten by fish and other feeders on zooplankton. The adults are preyed upon by bottom feeding fish including flounder, tautog and cod (Coe, 1912) and haddock (Wigley, 1956).

(lo) Competition. No information to suggest that any particular species are important as competitors. Numerous worms, molluscs, and crustacea which are selective deposit feeders or micropredators would appear to compete to some extent for food.

(11) Responses to the environment (natural factors and pollutants). No information.

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10 9.20 Emerita talpoidea

The mole crab, an active sand-burrowing anomuran decapod. The following life history data are based on studies made well south of New England; times and seasons may differ in the norther part of its range.

(1) Reproduction. The spawning period in Rhode Island and the Woods Hole area is in July and August. Males are sexually mature during their first summer and are much smaller than the females, to which they attach themselves several at a time. Fertilization is accomplished by the transfer of a spermatophore (Pearse, Humm, and Wharton, 1942).

(2) Fecundity and larval life. No information on fecundity. Larvae are pelagic and pass through at least 6 zoeal stages. Laboratory reared zoeae metamorphosed to megalopsin 28 days at 30 C (Rees, 1959). The megalops stage is passed in the wave washed sand.

(3) Growth and longevity. Emerita attains a carapace length of 3 to 4 mm at the end of the first summer. The following spring, the males average 7 mm in carapace length, the females 10 mm. One year old males are about 10 mm in carapace length, females 18 mm. Males die after mating again at the end of their first year. Females survive the second winter, reaching a mean carapace length of 21 mm. The largest females may reach a carapace length of 26mm (Pearse, Humm, and Wharton, 1942).

(4) Natural mortality. No information.

(5) Migration characteristics. Short migrations to deeper water outside the surf zone take place in winter.

(6) Distribution and niche preference. Emerita occurs in the wave washed sand of exposed beaches from Cape Cod south.

(7) Population densities. Adults are gregarious, but no information on densities.

(8) Food . Emerita is a suspension feeder, using the antennae to trap food particles.

(9) Predation. Important predators are fish such as the striped bass and shore birds such as sandpipers, black skimmers and terns.

(lo) Competition. There appear to be no important competitors.

(11) Responses to the environment (natural factors and pollutants). No information.

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10.9.21 Ensis directus

The razor clam; a common mollusc of sandy and sandy mud shores.

(1) Reproduction. Breeds in subtidal sandy and sandy mud flats to 10 meters depth, Labrador to the West coast of Florida (Pratt, 1935) in temperatures ranging from 15 - 22 C (Loosanoff and Davis, 1963). The age of maturity is not known. Fertilization is external, the sexes are separate and there is no indication of sexual inversion (Chanley, 1969; Grave and Smith, 1936).

(2) Fecundity and larval life. The maximum number of eggs at one spawning was 12,585,000 and the number of eggs spawned in one week (3 separate spawnings) 20,535,000 (Loosanoff and Davis, 1963).

Larvae are found on worm and clam flats as free living pelagic larvae of the veliger type. They metamorphose and set 10 to 27 days after fertilization at 24 C and at a size range of 210 to 270 microns (Loosanoff and Davis, 1963; Chanley, 1969).

(3) Growth and longevity. Eggs range from 64-73 microns. The larvae grow to 270 microns in 10 to 27 days. The maximum dimensions of adults are 15 cm long, 25 mm wide and 16 mm deep (Pratt, 1925; Loosanoff and Davis, 1963).

(4) Natural mortality. Little known. Mortality may reach 100 percent in the juvenile stages due to changes in sediments (Harrison, Lynch, and Altschaeffl, 1964).

(5) Migration characteristics. Ensis is sedentary.

(6) Distribution and niche preference. Ensis is found on sandy flats and sandy mud just above low tide to subtidal 10 meter depth. They are found from Labrador to west coast of Florida. The distribution of the larvae is hydrodynamically controlled (Pratt, 1935; Harrison, et al., 1964).

(7) Population densities. Ensis has not been adequately sampled. Sanders (1962) found 10 adults/m^2 in Barnstable Harbor, Massachusetts, and approximately 5/m2 have been found in Sagadahoc Bay, Maine.

(8) Food . Ensis is a filter feeder on planktonic algae.

(9) Predation. Ensis is known to be preyed on by the moon snails Polinices and Lunatia (Turner, 1955).

(10) Competition. Gemma gemma may compete with settled juveniles of Ensis.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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10.9.22 Gemma gemma

Gemma gemma is commonly known as the Amethystine Gem shell. It is very small, about the size of a pea, nearly orbicular with a shining surface closely crowded with concentric furrows. The anterior part of the shell is white or rose color. The posterior and dorsal is reddish purple. Inside it is shining white with a purple posterior.

(1) Reproduction. Spawning occurs during a 2 month span although the period of highest intensity may last only about 3 weeks. Approximately 30 percent in June, 50 percent in July and 10 percent in August, averaged over a 3 month period. A few females attain sexual maturity in the fall of the first year at an age of 4 months and carry young through the winter which they then release the following summer. Embryo production ceases for the winter, but begins again in the spring and continues through the summer. During summer, the shelled embryos, which have been held in the brood chamber all winter are liberated with those initiated during late spring. Spawning or release of juveniles is in the natural habitat of the adults. Settling generally occurs at the immediate site of release (Sellmer, 1967). A second brood is produced by those

females which have released the first brood. Whether the second brood is released the same summer is not known, but this may be possible since development can occur within one week. If they are not released they probably die because both male and females were seen to die during the second winter (Sellmer, 1967).

(2) Fecundity and larval life. A gravid clam contains a maximum of 300 young. Generally 100-200 juveniles are released per female per season. It has no larval stage as the female is ovoviviparous. Juveniles develop in demibranchs or brood pouches and are released as recognizable clams in less than a week after fertilization takes place. At the time of release they immediately enter the, sand since they lack a swimming organ.

(3) Growth and longevity. Juveniles in summer average 375 microns in length and attain 2 mm in the fall. They reach adult size of 4-5 mm the following spring. Growth begins in April and ends at the latest in November. A few females attain sexual maturity in the fall of the first year at an age of 4 months. Maximum size is 5 mm (Sellmer, 1967).

(4) Natural mortality. Mortality is nearly 40 percent per month. The mean life span is 1.13 months. The maximum life span is 2 years. Nearly 80 percent of each cohort dies during the first month of life. Predation is extremely heavy.

(5) Migration characteristics. No migrations.

(6) Distribution and niche preference. Gemma has a range which extends from Labrador to Texas. Its habitat extends throughout the intertidal region and down to a depth of approximately 7 feet below mean low tide. It is often abundant on tide flats usually in sand or fine mud-sand mixtures.

(7) Population densities. Densities may reach 200,000/m^2 in summer in the area of Union Beach, New Jersey. Biomass is from 2-200 g/m^2. Densities measured during summer show these ranges.

10,000-100,000/m^2	June
100,000-200,000/m^2	Late June
10,000/m^2	mid-July

Year class densities also vary:

June, 1956 ($10^5/m^2$) July, 1957 ($5 \times 10^2/m^2$)
June, 1957 ($10^6/m^2$) July, 1958 ($10^3/m^2$)

Phelps (1964) reported a density of 13,000/m^2 nia salt pond in southern Rhode Island.

(8) Food. The diet consists of particulate matter consisting of detrius, bacteria, and plankton which is collected by ciliary mechanisms on the gills.

(9) Predation. Predators probably include all those organisms which prey on newly set quahogs. These would include crabs {blue crab and green crab), certain fish, including Fundulus and tautog as well as certain shore birds, including the black duck and gulls. The boring gastropod may also prey on Gemma.

(lo) Competition n. Competitors probably include Mya arenaria and M. mercenaria which occupy the same habitat and have similar diets.

(11) Responses to the environment (natural factors and pollutants). Most adults tolerate a salinity extreme of 27.6 °/oo to 13.1 °/oo. Most live in the upper 3 inches of the substrate." Temperature-probably controls the time of spawning since males release sperm during April and May and again in October and November in Raritan Bay, N.J. (Sellmer, 1967). Juveniles survive best in salinities of 24.4 °/oo to 27.7 o/oo and temperatures of 16.5 to 24.5 C (Sellmer, 1967).

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10.9.23 Glyceria dibranchiata

The bloodworm; found in mud or muddy sand intertidally to 400 meters, Gulf of St. Lawrence to Texas. It is the basis for a commercial bait fishery in Maine.

(1) Reproduction. Glycera spawn in intertidal and shallow subtidal mud flats during June to July, mostly June. A bottom temperature in excess of 13 C seems necessary for spawning to occur. Spawning begins about 2 hours before high water, although this may vary slightly from place to place. The larger, 3 year old worms and the 4year old worms are the chief spawners and it is doubtful that they spawn again.

Male bloodworms usually emit two long streams of sperm while swimming close to the surface. The streams are cohesive and do not

break up immediately on emission, Emission time was 2 to 5 minutes after which they descend to the bottom. Females emerge from their burrows and swim rapidly at the surface for no longer than a minute, then suddenly the body wall ruptures near the posterior third of the worm and a cloud of eggs is released. Females then sink to the bottom.

(2) Fecundity and larval life. A female 25 cm long yields 3 million eggs, a female 45 cm long yields 9 million eggs.

After shedding and fertilization the eggs sink. In 7 to 8 hours a swimming blastula is formed, after 18 hours a trochophore larvae is formed, and after about 2 days a Nectochaete is formed which has features similar to the adult. The time to metamorphosis is not known. Only the trochophore is pelagic for about one day, probably near the bottom.

(3) Growth and longevity. Glycera probably lives no longer than 4 years. The following growth rates are given by Creaser (1973).

Assumed year class	Calculated mean length (cm) ± SD	Percentage of sample
1	7 ± 3	3.08
2	17 ± 4	40.96
3	27 ± 4	36.92
4	36 ± 4	17.97
5	47 ± 3	1.07

(4) Natural mortality. Adults (3 to 4years old) die after spawning.

(5) Migration characteristics. Glycera shows only local movements.

"(6) Distribution and niche preference. Glycera is found in mud or muddy sand intertidally to 400 meters. Its movements are local and not well known.

(7) Population densities. Densities of 537 per square meter of mud flat have been recorded.

(8) Food . Glycera is primarily a deposit feeder, although it is also a predator. Sanders, Goudsmit, Mills, and Hampson (1962) found remains of polychaetes in Glycera stomachs. Biologists of the Maine Department of Marine Resources have observed Glycera to feed on' the sand worm Nereis.

(9) Predators. Glycera burrows deeply in the mud and seldom emerges or swims about. For that reason it is not heavily preyed upon except during spawning. Spawning worms are preyed upon by herring

gulls, striped bass, and probably other birds and fishes. Glycera has also been recorded in haddock and green crab stomachs.

(10) Competitors. Very little information on competitors. There is some indication that Glycera may compete with Nereis virens.

(11) Responses to the environment (natural factors, pollutants). NO information gathered.

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10.9.24 Haustorius canadensis

One of the several c"losely similar species of amphipods of rather small size and pale color, frequently found in sand.

(1) Reproduction. Eggs are laid in spring and carried in the female brood pouch; they hatch throughout the summer, but predominantly in June. Evidence indicates only one brood per female per season. Breeding begins when water temperature reaches about 14 C.

(2) Fecundity and larval life. The brood size ranges from 5 to 25 eggs with a mean of 11. Embryos develop within the brood pouch and young are released as small juveniles. Development time estimated at about 28 days.

(3) Growth and longevity. Size increases from about 2 mm at hatching to 7.5 mm the following June. Growth is arrested in winter at temperatures below 5 C. Most individuals die after the breeding season at the age of about a year.

(4) Natural mortality. No quantitative data on mortality during the first year of life, but presumably mortality is nearly 100 percent shortly after the beginning of the second year.

(5) Migration characteristics. Although the species can swim (especially at night) no migration as such is known.

(6) Distribution and niche preference. Found mainly intertidally in sandy beaches from the Gulf of St. Lawrence to Chesapeake Bay. Prefers sands which remain water saturated at low tide.

(7) Population densities. At Cape Cod, Massachusetts mean densities ranged from 135/m^2 in October to 1,035/m^2 in August.

(8) Food. Diatoms and interstitial meiofauna; the species can filter algae from the water, but the common occurrence of sand grains in the digestive tract suggests some non-selective ingestion of sediments and the meiofauna included therein.

(9) Predation. Shore birds such as plovers and sandpipers appear to be the chief predators. Flounders and other fish may also be predators.

(lo) Competition. Intraspecific competition with other haustoriids unlikely because of the different parts of the beach occupied. Competition with other species probably not serious. South of Cape Cod Emerita could be a competitor.

(11) Responses to the environment (natural factors and pollutants).

Temperature: Total mortality at 41 C
Can survive at least 3 minutes at 39 C

Salinity: Can survive 96 hours at 10 o/oo salinity"; some mortality occurs at 5 o/oo

Oxygen: 24 hour 50 percent lethal concentration is 0.336 ml per liter at 25 C (Sameoto, 1969a,b)

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10.9.25 Homarus americanus

The American lobster; basis for a lucrative fishery along the U.S. northern Atlantic coast. Pound for pound the most valuable American fishery. There are two major populations of lobsters: the inshore, or coastal lobsters, and the offshore Georges Bank and Continental Shelf lobsters. South of Cape Cod there may be some mixing of the two.

(1) Reproduction. The lobster breeds during the summer. Copulation follows immediately after the molting of the female. Sperm is stored in the seminal receptacle of the female and released to fertilize the eggs as they are extruded. Some lobsters extrude their eggs shortly after mating; others not until the following year. Eggs are carried on the pleopods of the female over the winter and hatch the following summer. Hatching occurs in June and July on the offshore banks, in July and August on the Maine coast, and as early as May south of Cape Cod. Lobsters do not reach sexual maturity for at least 5 years.

(2) Fecundity and larval life. The number of eggs produced by a single female depends on her age and size: a one-pound lobster produces about 10 thousand, a large 18-pound lobster about 130 thousand. During the incubation period about 35 percent are lost. After hatching, the pelagic larvae molt through 4 instars before they achieve the characteristic lobster appearance and settle to the bottom. The fifth stage is attained in about 3 weeks at 20 C and 5 to 6weeks at 15 C.

(3) Growth and 1 ongevi ty. After settling to the bottom the lobster usually molts 4 more times before growth is arrested by the first winter. At this age the total length is about 45 mm (carapace length 15 mm), although this size varies considerably according to nutrition, etc. Subsequent growth is also highly variable. Hughes and Matthiessen (1962) give the mean carapace length at the end of each growing season for laboratory reared lobsters as follows:

1st year	13.5 mm	6th	94.4 mm
2nd year	29.0 mm	7th	104.0 mm
3rd	45.7 mm	8th	113.8 mm
4th	63.2 mm	9th	127.7 mm
5th	82.2 mm	10th	153.0 mm

Juveniles molt 2 to 3 times annually, adults about once a year.

(4) Natural mortality. Mortality of larvae and small juveniles is very high, probably exceeding 99 percent. Older juveniles and adults suffer a lower natural mortality, but fishing mortality is heavy. On the Maine coast it is estimated at about 95 percent a year.

(5) Migration characteristics. Inshore lobsters do not migrate extensively, moving apparently randomly a few miles at the most. Lobsters from Georges Bank and the shelf travel greater distances. Mean distances travelled by tagged lobsters released at various sites on the edge of the Continental Shelf varied from 28 to 80 miles {Cooper and Uzmann, 1971). Although the migrations seemed to have a random element, a distinctive onshore-offshore pattern was evident. Migrations also showed a seasonal tendency, with the onshore movement predominant in spring and early summer.

{6) Distribution and niche preference. Homarus americanus occurs from Labrador to Cape Hatteras in depths from low tide to 700 meters or more. Although they prefer irregular bottoms which provide crevices in which to hide, lobsters frequently occur in sand or mud in which they make or find burrows.

(7) Population densities. This is difficult to determine and no good data appear to have been recorded. Most sampling is weak in accounting for the juveniles.

(8) Food. The food of the adult lobster consists principally of fish, alive or dead, and of invertebrates that come within its reach. Stomach analyses show, in order of abundance: fish; crustaceans, chiefly isopods and decapods; molluscs, largely small gastropod; algae; echinoderms and hydroids. The isopod Cirolana concharum is frequently eaten, and in large numbers. Lobster eggs are eaten, and lobsters are cannibals from birth. They are great scavengers and are also very fond of clams, digging up the bottom in search of them (Herrick, 1911).

(9) Predation. Lobster larvae are preyed upon by surface feeding fish; small lumpfish, hiding in floating seaweed are also known to feed on lobster larvae. Cunners and other small bottom feeding fish are very likely predators on early juveniles. Wolf fish are also said to feed on larger juveniles. Soft, recently molted individuals are particularly susceptible to predation. Larger lobsters are preyed upon by larger carnivorous fish, such as cod, skates, or sharks. According to Herrick (1911) the cod is, next to man, the most destructive enemy.

(lo) Competition. The lobster competes with other bottom carnivores and scavengers for food, and with certain burrowing crabs and fish for space. Lobsters are extremely territorial and aggressive, and intraspecific competition is significant.

(11) Responses to the environment (natural factors, pollutants).

Upper lethal temperature (LT50) for lobster larvae:

Acclimated to 15 C, 30 C for 6-hour exposure, 34 C for less than l-hour exposure
Acclimated to 21.5 C, 30.5 C for 6-hour exposure, 35.8 C for less than l-hour exposure
(Perkins and Kensler, unpublished data)

Lower lethal salinity for lobster larvae:

100 percent mortality at 16.4-17 °/oo, temperature range 15-17.5 C
33 percent mortality at 21-22 °/oo, temperature range 15-17.5 C
(Templ eman, 1936)

Lethal threshold concentrations for lobster larvae of crude oil emulsified in sea water (96 hour LC 50) ranged from .03 ml per liter to .002 ml per liter at 20-21 C. Concentrations of .01 ml per liter caused death in 9 days, and .006 ml per liter inhibited development (Wells, 1972).

The temperature, salinity and oxygen thresholds for adult lobsters have been determined by McLeese (1956) as follows:

Acclimation conditions			Lethal	Lethal	Lethal
Temperature C	Salinity o/oo	Oxygen mg/l	Temperature C	Salinity o/oo	Oxygen mg/l
		2.9	20.6,	11.0	0.72
5	20	4.3	22.0	9.0	0.77
		6.4	23.7	9.0	0.72
		2.9	22.4	12.0	0.57
5	25	4.3	22.1	12.4	0.51
		6.4	24.6	9.2	0.24
		2.9	24.0	10.8	0.29
5	30	4.3	25.2	11.5	0.33
		6.4	25.7	6.0	0.20
		2.9	27.3 '	9.0	0.86
15	20	4.3	27.7	9.0	0.79
		6.4	27.8	8.2	1.20
		2.9	27.5a	10.7	0.80
15	25	4.3	28.2	10.7	0.90
		6.4	28.0	9.5	1.00
		2.9	27.8	10.6	0.66
15	30	4.3	28.2	11.0	0.83
		6.4	28.4	11.2	0.83
		2.9	28.5	11.5	1.72
2 5	20	4.3	29.0	11.5	1.58
		6.4	29.3	11.1	1.26
		2.9	29.0	14.3	1.17
25	25	4.3	29.5	14.8	1.20
		6.4	29.6	14.0	1.60
		2.9	28.7	15.4	1.30
25	30	4.3	29.5	16.0	1.25
		6.4	30.5	16.4	1.17

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10.9.26 Hydroides dianthus

A common and very beautiful serpulid worm about 3 inches in length. It has a crown of branchiae which is long and slender and radiates from a united base. They are plumelike and may be banded with white and green. Often they are brown, banded with white and yellow. The greenish to yellow collar is translucent and the branching veins show through as irregular, dark-green lines due to the green blood of this species. The collar is often one third as long as the body, which gradually tapers toward the posterior. There is a funnel-shaped operculum which closes the tube of the worm when it withdraws. H. dianthus constructs long twisted calcareous tubes on mollusk shells.

(1) Reproduction. No information.

(2) Fecundity and larval life. No information.

(3) Growth and longevity. No information.

(4) Natural mortality. No information.

(5) Migration. A sedentary species.

(6) Distribution and niche preference. Very common from Cape Cod to Florida. It is usually found on sandy substrates in intertidal to subtidal areas. It is sedentary and builds long calcareous tubes on mollusk shells such as M. mercenaria and Mya arenaria.

(7) Population densities. 113/m^2 reported by Phelps (1964) for a salt pond in southern R. I.

(8) Food. A filter feeder which collects fine suspended particulate matter as well as plankton by means of its feathery tentacles.

(9) Predation. Crabs, fish, birds, starfish are among the predators.

(10) Competition. No information.

(11) Responses to the environment (natural factors, pollutants). No information.

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10.9.27 Leptochelia savignyi

A swimming tanaid crustacean with large compound eyes. The male has large chelae while those of the female are small. The rest of the legs are locomotory. It is white in color.

(1) Reproduction. No information.

(2) Fecundity and larval life. Eggs are brooded in a marsupium and hatch at the postlarval manta stage.

(3) Growth and longevity. No information.

(4) Natural mortality. No information.

(5) Migration. No information, but probably unlikely.

(6) Distribution and niche preference. It is distributed from Cape Cod to New Jersey and occurs abundantly in eelgrass and seaweed near the surface, usually intertidal.

(7) Population densities. Extremely abundant; Phelps {1964) reported 31,762/m^2 in the sandy areas of a shallow salt pond in southern R. I.

(8) Food. A deposit feeder, which burrows in find mud or sand. Its diet consists of detritus, bacteria and benthic algae.

(9) Predation. Predators include fish, crabs and other bottom feeders.

(10) Competition. No information.

(11) Responses to the environment (natural factors and pollutants. No information.

REFERENCES

Phelps, D. K. 1964. Functional relationships of benthos in a coastal lagoon, Ph.D. Thesis. Univ. of Rhode Island.

10.928 Limulus polyphemus

The horseshoe crab; one of the few surviving species of an essentially fossil group of arthropods, more closely allied with the arachnids than the crustaceans.

(1) Reproduction. Limulus spawns during times of spring tides, usually in May, in the intertidal zone of sandy shores. During spawning the males surround a female to form a spawning group (usually 1-3 males, large mating groups can only form in calm water). One male perches on top of the female and may remain there for weeks. The female digs beach nests 16 cm deep with a new hole every 10-15 cm so that 10-15 nests, each 30 cm in diameter, form a row 2-4 m long. As the female deposits the eggs in the nests the male spreads sperm over them much in the manner of frogs. Each female may make several nests with 200-300 eggs apiece.

(2) Fecundity and larval life. A female will lay from 200 to 1,000 eggs. The young are planktonic larvae in a condition resembling the adult but with the opisthosoma showing separate segments and without the caudal spine (young are called the trilobite stage).

(3) Growth and longevity. The young animal has several annual molts. Animals 9 cm or more molt once a year with their length increased by 1/4 each molt. There are at least 16 molts until the animal reaches maturity. At maturity the animal probably stops molting. Its life span is from 14 to 19 years.

(4) Natural mortality. No information.

(5) Migration characteristics. Tagged horseshoe crabs observed to migrate distances up to 21 miles (Shuster, 1950).

(6) Distribution and niche preference. Limulus is generally found on sandy bottoms below the tide level Nova Scotia to Texas.

(7) Population densities. Densities of from 0 to 450 individuals per m^2 have been recorded during August.

(8) Food. Limulus feeds on various polychaetes, nemerteans, and bivalves such as Mya, Gemma, and Macoma (Shuster, 1950). These are seized as the animal plows a shallow furrow through the sediment. The base of the legs that surround the mouth are toothed and make an effective crushing devise for shelled organisms.

(9) Predation. No information on predators of Limulus. The larger ones are probably fairly immune to predation, while the larvae and very small juveniles are probably eaten by fish or crabs. Occasional fragments of Limulus exoskeletons have been found in green crab stomachs (Ropes, 1968). The eggs, laid in the sand, are preyed upon by Crangon (Price, 1962) and probably by other invertebrates and fish.

(lo) Competition. Competitors include crabs, bottom feeding fish, ducks and other shore birds.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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10.9.29 Littorina littorea

Littorina is the common edible winkle found along rocky shores and wet muddy sand, living under widely varying conditions.

(1) Reproduction. Littorina spawns on rocks or wet muddy sand when covered by water. They spawn at night during times of flood tide. The spawning season occurs from November to May but mainly from February to March. They become sexually mature during the second winter if the shells are higher than 11-12 mm, usually at about 18 months. The helmet-like gelatinous egg capsules are pelagic. Free

swimming veliger larvae are common in the spring plankton. The young metamorphose into tiny winkles and attach to Lichina pygmea (a lichen) from the end of May to the end of June.

(2) Fecundity and larval life. There are 1-5 eggs per capsule but there may be as many as 9 (Bequaert, 1943). Thousands of eggs are laid by each female per season, up to 5,000 eggs per female (Tattersall, 1920). Development is rapid, 5-6 days (Pelseneer, 1911).

(3) Growth and longevity. The growth rate is as follows: 14 mm shell height at 6 months, 17.4 mm at 1 1/2 years, 22.4 mm at 2 1/2 years, 25.4 mm at 3 1/2 years, 27.3 mm at 4 1/2 years, and the largest recorded was 36 mm (Moore, 1937). According to Smith and Newell (1955), Littorina grows to 2-12 mm the first year, 3-16 mm the second year, and 17 mm the third year. Sexual maturity is attained in the second year. Females grow faster than males and three quarters of the shells over 25 mm belong to females. There was a progressive decrease in growth with height above water level (Hayes, 1929). See also Green and Green (1932).

(4) Natural mortality. During the period after settlement the natural mortality rate is high - 94 percent in July and August. The mortality rate for the first year is 66 percent, and for the second year and after, 57 percent. "Two year olds make up the bulk of the population. Only a few survive beyond two years. Longevity is 4 to 10 years, 20 in captivity.

(5) Migration characteristics. Batchelder (1915) discusses migration of Littorina in the Oyster River, New Hampshire. Also, there is an upward migration on the shore at dusk due to random activity and a downward migration at dawn due to negative phototaxis.

(6) Distribution and niche preference. Intertidal and shallow water, Labrador to New Jersey.

(7) Population densities. Littorina is very abundant. An estimate of maximum density of a local population has been given as 50 per m2.

(8) Food. Littorina feeds when moistened by the tide and are quiescent when exposed to the drying effects of wind and sun. They eat fucoids, washed up weed, algal detritus, diatoms and lichens.

(9) Predation. Predators probably include gulls and flounders.

(lo) Competition. Littorina littorea competes with L. obtusata for food and space but L. littorea extends lower. Other competitors for space include gastropods, mussels, ascidians, polyzoans, barnacles, hydroids, corals and sponges. L. littorea may also occur in Macoma communities (see Macoma balthica).

(11) Responses to the environment (natural factors and pollutants). The lethal temperature is 41 C and lethal salinity is 12.5 °/oo (Gowanloch and Hayes, 1926).

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10.9.30 Macoma balthica

This is a locally common bivalve mollusk with a fairly oval, moderately globose shell, usually less than 2.5 cm in length, found on intertidal mud flats.

(1) Reproduction. The spawning season varies with-locality, occurring during August-September in the Passamaquoddy Bay area and April-May on Cape Cod (south shore). The age of sexual maturity also varies, but is usually attained during the second year. Gametes are shed into the water column where fertilization and development take place.

Sea water temperature of 7-14 C may be the stimulus for spawning.

(2) Fecundity and larval life. Large females (17 mm) release thousands of eggs at each spawning (11-42,000). Histological evidence indicates that several partial spawnings take place throughout the spawning season. The pelagic veliger larva lives in the water column for 2-5 weeks. Veligers of 3 weeks age raised in the laboratory are capable of settlement and metamorphosis.

(3) Growth and longevity. Growth rate depends on locality and probably temperature. Growth is slow in the St. Lawrence River, an average size of 12 mm being reached at 12 years of age. In a population on the south shore of Cape Cod, an average of 20 mm was reached after 3 years of age. In Maine, growth probably ceases during the winter and resumes after spawning. Life span depends on locality, and ranges from 6-25 years. On the Maine coast, average longevity is probably 8 years.

(4) Natural mortal ity. No information.

(5) Migration characteristics. Sedentary, does not migrate.

(6) Distribution and niche preference. In Maine, the species is found intertidally from mean tide level to slightly above mean low water on substrates varying from muddy sands and pebbles to sticky mud.

(7) Population densities. In sites sampled in Maine, densities of 200-300 per m^2 were found in the Cobscook-Passamaquoddy Bay area and 400 per m2 in Sagadahoc Bay.

(8) Food, This species feeds on the organic matter (detritus, bacteria, meiofauna) in the substratum. The inhalant siphon is extended along the surface of the substrate and actively picks up pieces of the sediment which then pass down the siphon. The material is then sorted by the labial palps and passed to the mouth.

(9) Predation. Species is preyed upon by flounders, dabs, plaice, asteroids, black ducks and scaup.

(10) Competitors. This species is a member of the boreal Macoma community of which the following species occur on this coast: M. balthica (dominant), Mya arenaria, Arenicola marina, Hyaropia tötteni, Corophium volutator and Littorina littorea. The amphipod Corophium volutator probably competes with M. balthica both for food and by preventing successful larval settlement.

(11) Responses to the environment (natural factors and pollutants). No information.

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10.931 Melampus bidentatus

A pulmonate gastropod also known as Melampus lineatus (Say) and commonly as the salt-marsh snail. It has a translucent brownish horn-color shell with a shining surface. The shell is broadest at about the upper third, thus producing a short conical spire. It is approximately 1/2" in height and has five or six whorls. The aperture is narrow, quite long and rounded at the bottom.

(1) Reproduction. Snails breed in the grass of the salt marsh. Eggs are laid in gelatinous capsules on the stems of Spartina and other grasses at the 'level of spring high tide. "Spawning occurs from early June to mid-July at two week intervals on the occasion of spring tides. The first spawning occurs in the second year of life. Spawning is initiated by a combination of increasing temperature and day length. Prior to spawning the snails congregate and after spawning disperse. Congregation is stimulated by an internal timing mechanism which appears to be based on day length, temperature and an unknown factor which synchronizes the behavior with the hi-weekly occurrence at spring tide (Teal and Teal, 1969).

(2) Fecundity and larval life. A single snail produces an average of 850 eggs in a gelatinous mass. Eggs incubate for 13 days before hatching, the pelagic larvae metamorphose in 6 weeks. Melampus is unlike other pulmonates in that it has a pelagic larval period (Hunter and Abley, 1966).

(3) Growth and longevity. Snails are 0.6-0.7 mm at metamorphosis, and reach a maximum size of 12.3 mm in a life span of 3-4 years (Hunter and Abley, 1966).

(4) Natural mortal ity. No information.

(5) Migrations. No migrations are involved in its life history, except in dispersal of the larvae by currents.

(6) Distribution and niche preference. This species is found in abundance from Prince Edward Island to the Gulf of Mexico. It is characteristic of the emergent marsh in the intertidal zone, It usually crawls along the stems and leaves of Spartina alterniflora and can be found on the mud of the marsh during low tide.

(7) Population densities. This snail is the dominant gastropod in the region of the high marsh. It is usually found not far from the high tide mark and moves to keep out of the tidal reach on a cyclical basis.

(8) Food . Feeds on algal detritus deposited by the tides on the grass stems.

(9) Predation. Predators include black ducks, clapper rail, and probably the larvae of certain flies of the family Sciomyzidae (Teal and Teal, 1969).

(10) Competition. A likely competitor is the gastropod Littorina littorea since it shares the same habitat and a similar diet.

(11) Responses to the environment (natural factors and pollutants). No information.

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10.9.32 Mercenaria mercenaria

M. mercenaria also known as Venus mercenaria has several common names: hardshell clam, quahog, and little neck. It is one of the most important of sea-food products. The shell is solid and oval in shape with a heart-shaped lunule. Inside it is a porcellanous white with deep violet blotches near the muscle scar and a purple or violet border around the ventral margin. The outer shell is a dingy white with very prominent concentric lines of growth, rather far apart at the umbo and quite crowded and close together in the middle and ventral parts of the shell. The shell is 3" or more in length.

(1) Reproduction. Spawning occurs from June to mid-August in Massachusetts waters with highest intensity in late June to mid-July (approximately 20 days). The average age is 2 years and usually occurs during the-third summer. The average size is 1 1/4" to 1 1/2". Size, not age seems to determine maturity. One report suggests that only the size class 2 1/2" to 3 3/4" spawns. Carriker (1961) reports that spawning and the densest swarms occur during neap tides, probably because of warmer temperatures during the ebb slack period. Gametes are released through excurrent siphons. This takes only 10 minutes in the female and 35 minutes in the male.

(2) Fecundity and larval life. Several million eggs are produced by each female, but the number fertilized is unknown. Mercenaria has a pelagic larval stage called a veliger. In laboratory rearing the veliger is free-swimming for 10-12 days at 22 C. The length of time to setting increases with a decrease in temperature. Setting occurs in 5-7 days at 30 C while at 18 C it takes 16-24 days. Carriker (1961) reported the appearance of the veliger 16 hours after fertilization. He also reported that the veliger is indifferent to salinity gradients of 5-20 o/oo at 22 C and shows only a slowing of swimming at 15-20 °/oo. A creeping stage called the pediveliger follows the free-swimming stage and may last for 6-20 days. It is 200-230 microns. Ninety-one percent of the pediveliger ultimately attach to the substrate by byssal threads when set. This aids them in maintaining their position until the foot becomes well developed.

(3) Growth and longevity. Veligers reach nearly 200 microns in approximately 8 days at temperatures of 23.4-26.2 C and salinity of 30.4-31.4 °/oo. In a census of the clam population in Little Egg Harbor, N.J. the following size classes were determined:

mm	Number
5 - 2 4	132
25-37	74
38-50	223
51-63	432
64-75	235
76-84	82

The rate of growth is greatly dependent on the environment. The annual growth for different size clams for a sample population is as follows:

Size mm	Age
5	6 months
51.9	2.5 years

74.25	4.5 years
89.50	7.5 years
96.00	10.5 years
101.3	16.5 years

Growth occurs only during the summer months beginning around May 1 when the water temperature reaches 9,4 C and ceases around November 1 when it drops below 7.2 C. The percentage annual growth occurs as follows:

May	3.78 percent
June	10.81 percent
July	19.02 percent
August	25.56 percent
September	26.24 percent
October	12.85 percent
November	1.74 percent

(4) Natural mortality. Between 18-30 C mortality was observed to be low in laboratory reared veligers. Survival was 85 percent. Heavy mortality occurred at temperatures greater than 33 C or lower than 15 c. In the field Carriker (1961) observed only a 2.6 percent survival rate. He also reported that 720 set clams 10-40 mm in size had a 76 percent survival and 400 set clams 35-58 mm had a 91 percent survival. He observed that survival was much better in coarse sand than in either mud or sand. Heavy predation by crabs caused high mortality. He measured newly released veligers in densities of 2,780 larvae/100 liters and reported that only 72/100 liters would reach setting size, about 25 percent.

(5) Migration. Spawning takes place in the region of the adult habitat. There is no population migration except by current dispersal of the larvae.

(6) Distribution and niche preference. M. mercenaria occurs from Gulf of St. Lawrence to the Yucatan, but distribution is intermittent north of Cape Cod. It is abundant on sandy or muddy bottoms between tides and in shallow water.

(7) Population densities. Approximately 270,000/m^2 of recently set clams have been reported in Orr's Cove, Maine. At Little Egg Harbor, N.J. 0.50/ft^2 with maximum numbers at a minimum depth of 1 ft. below mean low tide. A maximum of 160/3 ft2 in 2 ft. of water. Densities are greater near submerged objects or in eddies or on sides of swift currents.

(8) Food. Mercenaria feeds on particulate matter consisting of detritus, bacteria, and plankton by means of ciliary mechanisms on the gills and labial palps. Food is carried across the gill filaments

by means of water currents generated by the cilia. Sorting is done by the palps and food then passes to the mouth both by ciliary and muscular movements.

(9) Predation. Predators include the blue crab, the green crab, starfish, Fundulus, striped bass, cunner, the black duck, golden eye, laughing gull, scoter and boring gastropod, Polinices, and Lunatia as well as Urosalpinx and Busycon. Heavy predation occurs in the very early stages, particularly in the pelagic and recently set clams.

(lo) Competition. Few competitors except in the case of other burrowing ciliary feeding species which include Mya arenaria, Gemma gemma, Spisula solidissima, and Aequipecten irradians.

(11) Responses to the environment (natural factors and pollutants). M. mercenaria shows some hypertonicity in dilute sea water (blood mM Cl 374, in sea water 319 mM Cl). The tissue from young specimens has a higher respiratory rate than those from older animals. Spawning can be delayed by transferring ripe or nearly ripe individuals into subnormal temperatures (Loosanoff and Davis, 1951). Development of the eggs into the straight hinge stage requires salinities in excess of 22.5 o/oo and temperatures ranging from 17.5 C to 30 c.

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10.9.33 *Metridium dianthus* (M. senile)

The common sea anemone, a cnidarian related to the corals; has a luxurious growth of tentacles on the oral end, fastens to bottom with basal end.

(1) Reproduction. Sexual reproduction takes place in June and July, probably first at the age of one year. Eggs and sperm are released in the water surrounding colonies. A single female spawns at intervals of 2 to 10 days for about a month (Costello, Davidson, Eggers, Fox, and Henley, 1957).

Sexual reproduction seems to be a minor means of reproducing the species. Its chief function may be to promote dispersal. *Metridium* reproduces asexually in two ways: by longitudinal fission, wherein the entire body divides lengthwise into two halves, and by pedal laceration, wherein small sections, or buds, break off the base or pedal disc. Each of these fragments develops its own base, mouth, tentacles and internal organs (Hickson, 1906; Hargitt, 1914; Hyman, 1940).

(2) Fecundity and larval life. No information on fecundity.

(3) Growth and longevity. No exact information on growth rates. Fairly large individuals of 50 or more mm in diameter have been observed in laboratory tanks within a year after cleaning.

(4) Natural mortality. No information.

(5) Migration characteristics. Species is only slightly motile and does not move great distances.

(6) Distribution and niche preferences. *Metridium* is found from the littoral zone to 165 meters, often abundant on wharf pilings, in tide pools and in intakes for the cooling water used in power plants.

(7) Population densities. Local populations vary in density according to the availability of substrate. Clusters often crowd suitable surfaces in den sites of several hundred per square meter, but the clusters may be very limited in size.

(8) Food . *Metridium* feeds on both living and dead particulate organic matter that happens to contact its tentacles. This may include zooplankton, small shrimp, mysids, fish, etc. Larger prey are subdued by toxic nematocysts in the tentacles. The tentacles and oral disc are mobile and transfer the food item to the mouth. Planula larvae feed on phytoplankton. Chemical cues assist in feeding. Chemoreceptors on tentacles and mouth respond to juices from animal tissue in the water (Hyman, 1940).

(9) Predation. There appear to be few predators on Metridium. Hargitt (1914) states "as far as I am aware, actinians are immune from predatory attacks." However, the nudibranch Aeolidia is said to feed on sea anemones (Barrett, 1969), and it is abundant in the habitat of Metridium.

(lo) Competition. The substrates usually occupied by Metridium are frequently crowded with other organisms which would compete for both space and food. Among the more important of these are hydroid colonies such as Tubularia or Obelia, sponges, ascidians like Molgula, Halocynthia or Ciona, barnacles, and mussels.

(11) Responses to the environment' (natural factors and pollutants). No information.

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10.9.34 Modiolus demissus

Modiolus demissus is also known as the ribbed mussel. It has numerous radiating ribs, coarser posteriorly and much finer anteriorly. The brittle shell is delicately and finely scalloped around its thin edge. It is greenish yellow, iridescent inside and has a purple tinge. It is

2 to 3" in length.

(1) Reproduction. No information.

(2) Fecundity and larval life. It has a pelagic larval stage termed a veliger. Eggs are approximately 100 microns in diameter. The veliger metamorphoses to the straight hinge stage in 24 hours at room temperature. The average measurements are 110-115 microns long by 85-90 microns wide. The maximum size is 303P x 260P (Loosanoff and Davis, 1963).

(3) Growth and longevity. Lent (1969) reports the size class distribution in a marsh between the mean high tide line and the mean low tide line (approximately 4.5 feet):

Size (mm)	Numbers
o- 9.9	31
10-19.9	128
20-29.9	95
30-39.9	99
40-49.9	100
50-59.9	85
60-69.9	81
70-79.9	61
80-89.9+	20

The mussel attains sexual maturity at approximately 45 mm. Small mussels are greatly limited by predation and large by competition. Thus the largest size class is about 40-49.9 mm.

(4) Natural mortality. No information.

(5) Migration. Probably does not occur except by dispersal of larvae. Mussels attach to the substrate by means of byssal threads.

(6) Distribution and niche preference. It occurs from Canada to Brazil in Spartina marshes, especially in the banks along the lower edge of the emergent marsh and extending into the marsh to the high tide mark. Often only the anterior end of the mussel is visible in the mud and vegetation.

(7) Population densities. The mussel exhibits a clumped distribution in Spartina roots. Densities of 103 individuals/m^2 have been reported (Phelps, 1964). They are extremely abundant in the lower emergent marsh and are thigmokinetic.

(8) Food. The ribbed mussel is a filter feeder with a diet consisting of detritus, bacteria, and plankton.

(9) Predation. Predators include the racoon and the oyster drill, Urosalpinx cinerea.

(10) Competition. No information.

(11) Responses to the environment (natural factors and pollutants). The adult is eurythermal and euryhaline. It tolerates a temperature range of -22 C to 40 C and salinities of.5 o/oo to 75 o/oo (Lent, 1969).

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10.9.35 Mya arenaria

The soft-shell clam; abundant almost everywhere throughout the region, living in nearly all kinds of cohesive sediments. Although predominantly intertidal, it is frequently found subtidally in estuaries. It is the basis for a valuable commercial fishery in New England and Chesapeake Bay.

(1) Reproduction. Spawning and fertilization take place in the water above or near the clam beds. The spawning season varies according to latitude and geographic differences in water temperature. The following data (Ropes and Stickney, 1965} collected from various sources illustrate typical spawning seasons:

Prince Edward Island	May or early June through August
New Brunswick	Mid-June through August
Eastern Maine	Early June to mid-August
Western Maine	May through September
Massachusetts	June through September
Rhode Island	Mid-April to mid-June and (possibly again) mid-August to mid-November

Mya is sexually mature and capable of spawning at two years of age in Massachusetts (Belding, 1930). The onset of sexual maturity

appears to depend on growth rate, so the age at which spawning is possible could be expected to be earlier in some regions and later in others. Spawning occurs on a rising temperature. Laboratory experiments (Stickney, 1964) indicate the necessity of several periodic temperature elevations, such as might occur with a tidal cycle. In these experiments, successful spawning was achieved with a temperature rise from 13 to 18 C. The clams were most sensitive to spawning stimuli in May and June; later in the summer they were quite refractory (Stickney, 1963).

(2) Fecundity and larval life. A 6 to 8 mm clam is capable of producing approximately 3 million eggs a year. Mya has a pelagic larval life, lasting 12 to 13 days at 13 to 22 C, 32 °/oo salinity. At less than 10 C the larval period probably exceeds a month.

(3) Growth and longevity. Mya reaches a length of 15 to 20mm at the end of the first growing season in warm water, as south of Cape Cod. On the shores of the Gulf of Maine, the first season's growth seldom exceeds 10 mm, and averages about 5 mm (Stickney, 1964).

South of Cape Cod, the average sizes at 1 through 4 years of age are 50, 62, 70 and 75 mm. In Massachusetts, the sizes for the respective years are 32, 46, 55 and 65 mm (Turner, 1948). Averages for the Maine coast as a whole years 1 through 6 are 13.4, 23.4, 32.6, 41.4, 48.0, and 53.4mm. These Maine values include data from the western coast where growth is similar to that in Massachusetts and from the eastern coast where growth is much slower. The first year's growth figure is probably inaccurate because it is based on measurements of clams whose age was uncertain; they could have been 1/2 year or 1 year old (Dow and Wallace, 1957).

(4) Natural mortality. Belding (1930) gives the history of a clam population in Rowley, Massachusetts where a set of 20,000 juveniles per square meter was reduced to 4,000 one-year-olds the second year. Under extreme pressure from predators, as from green crabs in the early 1950's, mortality has been nearly total in a comparable period of time.

Turner (1953) gives an account of a clam population in Quincy, Massachusetts which illustrates mortality rates to be expected in very dense populations:

Newly set juveniles	100,000/sq. M.	Mean Size	9 mm
After first year	18,000/sq. M.	Mean Size	7 mm
After second year	4,000/sq. M.	Mean Size	25 mm
After third year	1,000/sq. M.	Mean Size	38 mm

Here the mortality amounts to between 70-80 percent a year. It is interesting that in the first year the mortality affected chiefly

the larger-individuals, since the mean size of the population declined. This conclusion was supported by the observation that the dead shells were generally larger than-the living ones. T h e first year's density and size figures may also be affected by the inclusion of members of a new year class, as it is nearly impossible to distinguish late spawned members of one year class from early spawned members of the next.

(5) Migration characteristics. Mya is non-migratory.

(6) Distribution and niche preference. Spatfall appears to be primarily around MLW, however, Matthiessen (1960). reports. hydrodynamic concentrations of juveniles at higher tide levels. At the upper limit of their zone of abundance, Mya are stunted due to reduced time for suspension feeding. Sediments range from clean medium-fine sand (where shel 1 is egg-shaped and white) through anaerobic mud (where shell is often discolored by sulfides) to mud-and-gravel where shell is discolored and lumpy due to growth around the stony obstacles. Mya often live at the base of Spartina alterniflora, among the roots where difficult for predators to get them, and these individuals may serve as a source of recruitment for the rest of the flats.

(7) Population densities. In 1907, a year for which a thorough compilation of data was made, the average production of Massachusetts clam flats was about 30 bushels per acre (Turner, 1948). Turner calculated that 25 two-inch clams per .092 m^2 were equivalent to 540 bushels per acre. Belding (1930) had previously determined that flats could support densities of up to 25 per .092 m2 with no loss of growth due to crowding.

(8) Food. Like filter feeding bivalves generally, the exact food items utilized by Mya in nature are not known for certain, but it can and does utilize several species of unicellular algae in laboratory culture. Such planktonic algae as Dicrateria, Monochrysis, Cyclotella, Phaedactylum, and Olithodiscus all have been found to promote at least some growth in juvenile clams. Other algae do not, e.g. Chlorella. Non-living particulate organic matter may be utilized in nature, but such items as pulverized seaweed, flour or fish protein concentrate were not successful in laboratory experiments (Stickney, 1965).

(9) Predation. Predators include diving ducks, winter flounder, other bottom feeding fish, horseshoe crabs, the boring snails Polynices heros, and duplicata and the green crab, Carcinus.

(lo) Competition. Bradley and Cooke (1959) believe Gemmgemma to-be a competitor of juvenile Mya. Mya is frequently absent where polychaetes are present in great. numbers, so there may be some competition from these. When Mytilus edulis spreads widely over the clam flats, it is probably the most serious competitor of adult Mya.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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10.9.36 Mytilus edulis

Mytilus edulis, the common blue mussel, is an abundant intertidal organism from the Arctic Ocean to the Middle Atlantic states. Mytilus is an epifaunal species which maintains its byssal attachment throughout life. In Europe, it is harvested commercially and is the basis of many aquacultural operations.

(1) Reproduction. Spawning occurs in the summer when temperatures are above 10 to 12 C (Nelson, 1928). As with other marine bivalves, sex products are released into the water column where fertilization takes place. The environmental factor that causes initiation of spawning is unknown. Mytilus can be forced to spawn by several methods in the laboratory (Breese, Millemann, and Dimick, 1963), but none of these methods is of any relevance in the environment.

(2) Fecundity and larval life. A female mussel may produce between 5 and 12 million eggs in a single year (Field, 1923). Survival and growth rate of larvae is dependent on both salinity and temperature. Survival is 70 percent or better in salinities of 15 to 40 o/oo when the temperature is between 5 and 20 C. Survival will be reduced when either factor is outside of these ranges, especially when the other is near the limits of the range (Brenko and Calabrese, 1969). Optimum growth of the larvae occurs at 20 C in salinities from 25 to 30 $^{o}/_{oo}$. The pelagic larval life lasts from two to three weeks, with 16 to 17 days being the average. Larval Mytilus can delay metamorphosis if they are not in contact with a suitable substrate, but each day that it delays metamorphosis it becomes less selective until it will finally settle anywhere (Bayne, 1965).

(3) Growth and longevity. In Massachusetts, Field (1923) states that mussels attain a length of 2 to 4 cm in the first year, 4 to 6 cm in the second and then grow at a rate of 0.3-0.8 cm a year until they reach 7 to 8 cm in 5 to 7 years. Newcombe (1935) observed a bed of mussels that had an average length of 18 to 22 mm in the spring but had grown to 55 to 60 mm by late summer. Individuals of this species have the potential to live at least 7 years, although mussel beds are relatively unstable and it is unusual for one to survive so long.

(4) Natural mortality. As with any opportunistic species natural mortality is high. Most mortality occurs in the larval and post settlement stages, but it is not limited to these times. Newcombe (1935) noted a population density of 4,000/m2 of one year old mussels in spring. By the end of summer the density had been reduced to 700/m^2. Most of this mortality was undoubtedly due to predation. Subtidally predation can cause complete mortality of mussel populations. Mussels are also subjected to mortality by the destruction of their beds by storm waves. This is a density dependent mortality with large, dense beds being most affected (Harger and Landenberger, 1972).

(5) Migration characteristics. No migration.

(6) Distribution and niche preference. While Mytilus is found from the Arctic Ocean to South Carolina, reproducing populations do not occur south of the Chesapeake Bay. The summer-water temperature in these southern areas causes complete mortality of the individuals that set in the previous fall. Throughout its range Mytilus is restricted to an essentially intertidal existence due to heavy predation in the sublittoral.

(7) Population densities. Field (1923) estimated mussel density in one intertidal area to be between 4,000-6,000 bushels/acre.

(8) Food. Mytilus is principally a suspension feeder although a potential for deposit feeding has been demonstrated (Theisen, 1972). Food material is undoubtedly a mixture of phytoplankton and the bacterial coating of suspended particles. The latter may be the most important, as mussels have been raised on bacteria alone. Further circumstantial evidence for this is the fact that Mytilus can retain particles down to 2μ and most of the suspended particles in their environment are smaller than 5μ (Vahl, 1972) which is smaller than most plankters.

(9) Predation. Mussels are the prey of many species including: the gastropod Thais lapillus, Lunatia heros, Buccinum undatum, Urosalpinx cinerea, Busycon carica and Busycon canaliculatum; the starfish Crossaster papposus, Asterias forbesi and A. vulgaris; and gulls and ducks. Urosalpinx and Asterias spp. have been chosen as key species because of the role they play in the mussel and/or oyster community.

(10) Competition. Mytilus does not have any severe competitors for either space or food. It is usually able to overgrow most other species and by the buildup of silty material makes an environment less fit for competitors. Unfortunately this makes it less stable for the mussels as well. It has been suggested that the barnacle, Balanus balanoides, competes for food with the mussel (Newcombe, 1935) but this has not been substantiated.

(11) Responses to the environment (natural factors and pollutants). The blue mussel is principally a polyhaline-euhaline organism although it might occasionally be found in mesohaline water. As noted above it cannot withstand high temperatures.

There has been a moderate amount of research on the effect of pollutants on this species. Brown and Newell (1972) determined that copper was effective in inhibiting oxygen consumption but found no effect for zinc. Scott and Major (1972) found also that copper inhibited respiration and further that it decreased the heart rate

and increased mortality. The major pathway of accumulation seems to be through the feeding process (Pentreath, 1973). Gilfillan has 'determined that Mytilus is not extremely sensitive to crude oil extract and it appears to be somewhat more resistant to oil than another common mussel, Modiolus demissus (Gilfillan, 1973).

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10.9.37 Nassarius obsoletus

The mud snail; abundant on sandy or muddy tidal flats from New Brunswick to Florida.

(1) Reproduction. Spawning takes place in the living area on mud flats, but some firm substrate must be available for the deposition of egg capsules, In New England the spawning season is June through August; the beginning and end appear to be about two weeks later in Maine than on Cape Cod (Scheltema, 1967; Jenner, 1956). Sexual maturity is attained at size of 12 to 14 mm (Scheltema, 1964).

The gonads develop during the fall and winter. Spawning is initiated by elevation of water temperature and can be induced artificially during the winter by warming the water (Scheltema, 1967). Fertilization is internal and eggs are subsequently laid in capsules attached to stones, etc. Schooling behavior occurs shortly after spawning period and snails migrate to centers of aggregation where they spend the winter (Jenner, 1956, 1957; Sindermann, 1961). That this migration may be controlled by the reproductive cycle is indicated by the fact that in parasitically castrated snails migrations does not occur.

(2") Fecundity and larval 1 ife. No information on fecundity. Egg capsules contain 30-300 eggs each, but no data to show how many are produced by a single snail (Costello, Davidson, Eggers, Fox, and Henley, 1957).

Nassarius has a partially pelagic larval life. Eggs are laid in attached capsules in which embryonic development takes place, lasting 7 to 8 days at 28 C to 16 days at 16 C. Development is arrested below 11 to 13 C. Pelagic larval stage lasts 11 days at 25 C to 23 days at 17 C. This is followed by a creeping-swimming period of variable duration depending on temperature and success in finding a suitable substrate. It may last from 1 to 20 days before metamorphosis (Scheltema, 1967).

(3) Growth and longevity. Growth rates were found for southern populations only, the closest. being Cape Cod: shell length first season 4.8 mm, second season 8.5-9 mm, third season 11.6-13.5 mm (Scheltema, 1964).

(4) Natural mortality. No information.

(5) Migration characteristics. Nassarius shows only local movement.

(6) Distribution and niche preference. No information.

(7) Population density. The distribution is patchy and changeable on the flats. During feeding. and breeding season they are spread out in densities of perhaps 100 per square meter (Stickney, personal observation; Jenner, 1956; Sindermann, 1961).

(8) Food. According to Scheltema (1964) Nassarius is a deposit feeder, consuming organic detritus and the microflora of the sediments. It is also a scavenger, feeding on dead animal tissue whenever it can be found.

(9) Predators. No information on predators. Apparently adult Nassarius is not extensively preyed upon. From the known feeding habits of green crabs and horseshoe crabs, it can be inferred that these species might feed on small juvenile Nassarius. Related species of Nassarius have been found in the stomachs of haddock (Wigley, 1956) and it is possible that N. obsoletus is eaten by bottom-feeding fish.

(lo) Competitors. The habits of the snail Hydrobia are similar to Nassarius and because the former occasionally occurs in great numbers in the habitat of Nassarius it could be a competitor, especially to the juveniles. Other deposit feeders in the habitat, such as polychaetes and amphipods would also be competitors to some extent.

(11) Responses to the environment (natural factors, pollutants). No information.

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10.9.38 Nephtys incisa & N. caeca

Nephtys incisa is an active muscular worm about 70 to 150 mm long with prominent parapodia.

(1) Reproduction. Spawns periodically throughout the year, with peaks in spring and fall in Long Island Sound (Carey, 1962); ripe females found in Buzzards Bay in August; recently metamorphosed juveniles found in August on the coast of Maine (Pettibone, 1963).

(2) Fecundity and larval life. No information on the number of eggs produced, nor on the larval life. It is assumed the larvae are pelagic, since other species of the genus have pelagic larvae.

(3) Growth and longevity. No information.

(4) Natural mortal ity. No information.

(5) Migration characteristics. May swim or crawl about locally but does not migrate.

(6) Distribution and niche preference. Nephtys incisa occurs from low tide to about 1,800 meters in mud and silty-clay sediments from Greenland to Chesapeake Bay.

(7) Population densities. Various population densities of N. incisa are given as follows:

Sheepscot River, Maine	Mean of 47.4 per m^2	(Hanks, 1964)
Buzzards Bay	400-1700 per m^2	(Sanders, 1958).
Narragansett Bay	295 per m^2	(Pratt, 1967)
	275 per m2	(Phelps, 1958)
	340 per m^2	(Blake, 1969)
Long Island Sound	Up to 1429 per m^2	(Sanders, 1956)
New York Bight	80-175 per m^2	(Sandy Hook Lab. data)

(8) Food . Non-selective deposit feeder.

(9) Predation. It is preyed upon by bottom feeding fish (e.g., skates, sculpin, haddock, flounder) and by starfish, crabs, and shrimp.

(lo) Competition. Nephtys incisa along with the bivalves Nucula and Yoldia may help create a sediment type excluding suspension feeders (Rhoads and Young, 1970).

(11) Responses to the environment (natural factors and pollutants)., No information found.

Nephtys caeca is a very similar species inmost respects to N. incisa. The main differences are the niche preferences and food habits. N. caeca is more frequently found in sand and is predatory, feeding on other worms, small crustacea and molluscs. Little is known of the life history of either species.

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10.9.39 Nereis succinea

N. succinea is a polychaete worm commonly termed a clam worm and also known as Nereis limbata by embryologists. It is 5 to 6" in length and can be distinguished by its slender, short, light amber colored jaws and by its small parapodia. Its greyish, pink body is marked by an orange-brown line down each side of its posterior.

(1) Reproduction. Swarming of sexually mature individuals occurs at the surface at dusk from June through September. Males shed sperm first, which induces the females to release the eggs. Fertilization occurs in the water.

(2) Fecundity and larval life. Larvae are pelagic; no information on fecundity.

(3) Growth and longevity. No information.

(4) Natural mortality. No information.

(5) Migration. Vertical migration in water column associated with spawning.

(6) Distribution and niche preference. N. succinea is very common from New England to the Gulf of Mexico. It is abundant in peat or mud banks along the lower borders of Spartina. It is frequently associated with Mya arenaria, Macoma balthica and Corophium volutator, and in oyster reef communities.

(7) Population densities. 166/m^2 reported in mud by Phelps (1964) in a shallow salt pond of southern Rhode Island.

(8) Food. It is a deposit feeder with a diet consisting of bacteria, detritus, and benthic algae.

(9) Predation. Predators are numerous, including fish, crustaceans, starfish, and other annelids.

(10) Competition. No information

(11) Responses to the environment (natural factors and pollutants). It is often found in areas subjected to some lowering of the salinity by drainage. It can tolerate chlorides of 4.7 to 9.8 g/1 and salinities of 8.5 to 17.7 o/oo (Smith, R. I.).

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10.9.40 Nereis virens

The sand worm; one of several closely related species, N. virens is of some importance as fish bait. It is found intertidally in mud or muddy sand and to a depth of 160 meters, Newfoundland to Virginia.

(1) Reproduction. Nereis spawns on sand-mud flats, both tidal and intertidal. It probably begins sexual development at 3 years and reaches sexual maturity a year later. Spawning occurs in May and is centered around the new moon, about 6 days before and 6 days after. Males appear first on the rising tide swimming close to the surface of the mud and releasing a continuous stream of sperm. Females deposit eggs at the openings of their burrows, but do not leave them. One factor controlling the onset of spawning is the spring rise in temperature, March to May.

(2) Fecundity and larval life, Fecundity varies from 100,000 eggs for a 25 cm female to 1,700,000 eggs for a 68 cm female.

N. virens may possess two modes of reproduction, one with epitokous individuals swarming at the sea surface and giving rise to pelagic larvae and the other with atokous individuals swimming close to the surface of the mud and giving rise to non-pelagic larvae. Thus, the possibility exists that N. virens may vary its mode of reproduction with environmental conditions.

Bass and Brafield (1972) describe the larval stage of Nereis in British waters. Experimentally, after 28 to 30 hours from fertilization at 13 C the hatched larvae laid on the bottom. Although the monotrochophore larvae rotated they did not change position. On the fourth day the larvae were developed into the trochophore stage and late in this stage on the sixth day the larvae became planktonic for about 12 to 15 hours. During this period the larvae swam up to the surface and rested there appearing as closely packed rafts. Those at the center of the raft ceased movement while those around the periphery spun in and out of contact with the mass until they settled. They returned to the benthic-pelagic habit as incipient nectochaete larvae. Swimming ceased on the 12th day and the larvae, having consumed their yolk, began to feed. They adhered to sand grains and only strong currents could dislodge them. After a period of attachment the larvae moved down between the sand grains just below the surface of the substratum. With further addition of segments the worms moved horizontally through the sand but did not make burrows. Possibly burrows are made some time after 16 weeks from fertilization.

(3) Growth and longevity. Larval Nereis were grown experimentally from 180 to 600 in 29 days with a very large variation in growth. For young worms, growth-is by segment proliferation until a maximum of 60 to 70 segments is reached and thereafter growth is by enlargement of existing segments. The maximum number of segments (120-150) is reached at the end of two years and appears to coincide with the onset of sexual maturity in three year old worms.

(4) Natural mortal ity. Little information. Survival after spawning is unlikely.

(5) Migration characteristics. Nereis shows only local movements.

(6) Distribution. The brevity of the pelagic stage presumably limits the distribution to suitable areas of the littoral zone and minimizes the danger of their drift into regions of the estuary with unsuitable salinities. Larvae may be transported to the sublittoral zone where they settle and then migrate back to the littoral zone when either 16 weeks or 1 year old.

(7) Population densities. Worm populations at Wiscasset, Maine reach a density of 1.6 worms per square foot.

(8) Food. According to Rasmussen (1973) and Pettibone (1963), Nereis virens is predatory, feeding on other invertebrates. It also feeds on algae and other vegetation. Prey is seized with jaws on an evertible proboscis and hauled back into the burrow.

(9) Predators. Nereis is eaten by Carcinus maenas and other crabs, by horseshoe crabs, and by various bottom-feeding fish. During the breeding season many of the large spawning individuals, swimming at the surface, are eaten by gulls,

(lo) Competitors. In certain hydrographic transition zones, Nereis virens must compete with substantial populations of N. diversicolor or N. succinea. In some habitats the predatory Nephtys caeca may be numerous enough to compete. In other habitats the burrowing amphipod Corophium or various spionid worms are sufficiently numerous to be competitors for space with juvenile Nereis.

(11) Responses to the environment (natural factors, pollutants). No information.

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10.9.41 Nucula annulata & N. proxima

This species is one of several in the genus common along our coast. It belongs to a primitive group of bivalves (Protobranchs); it appears to have been incorrectly identified as N. proxima in most of the literature (Hampson, 1971).

(1) Reproduction. The spawning season in Long Island Sound is given by Carey (1962) as early spring and late summer. On the coast of Maine the species spawns during the summer (Drew, 1901).

(2) Fecundity and larval life. No information available on the number of eggs produced. The larvae have a short, non-feeding pelagic period (yolk larvae) metamorphosing in about 60 hours (Blake, 1969).

(3) Growth and longevity. The growth rate is about 1.0 mm a year in Long Island Sound (Sanders, 1956), 1.0 to 2.0 mm a year in laboratory tank (Blake, 1969). Attain size of about 10 mm.

(4) Natural mortality. NO information.

(5) Migration characteristics. Sedentary, do not migrate.

(6) Distribution and niche preference. Nucula annulata is abundant in silt-clay sediments from Nova Scotia to Virginia.

(7) Population densities. A few examples of population densities have been given as follows:

Sheepscot River, Maine	400 per m2	Hanks, 1964
Buzzards Bay	Up to 3000 per m2	Sanders, 1958
Long Island Sound	Up to 6000 per m2	Sanders, 1956

(8) Food. Nucula is a selective deposit feeder, collecting edible organic particles with prehensile labial palps. Diatoms are an important dietary component (Hunt, 1925).

(9) Predation. Predators include bottom-feeding fish such as sculpin, cod, hake, and flounders, starfish, crabs, and drilling snails.

(lo) Competition. Competitors to some extent would be the bivalve Yoldia of similar habits, and selective deposit feeding amphipods or polychaetes.

(11) Responses to the environment (natural factors and pollutants). No information.

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10.9.42 Ophiura robusta

One of several species of serpent, or brittle stars, characterized by a disclike body and five slender, flexible arms.

(1) Reproduction. Ophiura robusta spawns in the spring or early summer. Age at sexual maturity is not known.

(2) Fecundity and larval life. Thorson (1946) estimates about 5,000 eggs per female. Larvae are pelagic, but the length of the larval period is not known precisely. Thorson states that young larvae are taken in the plankton from April through June, while metamorphosing larvae occur from the end of July through September, suggesting a long larval life of 2 to 3 months.

(3) Growth and longevity. This is a small species of the genus, with a disc diameter of only about 10 mm. Other larger species of Ophiura attain this size in 2 years, but no information is available on the growth rate of O. robusta.

(4) Natural mortality. No information.

(5) Migration characteristics. Although they are able to move about, these starfish are not known to undertake migrations as such.

(6) Distribution and niche preference. The species is found from Greenland to Cape Cod in the western Atlantic, from 6 to 1000 meters on muddy bottoms.

(7) Population densities. Little information on population densities. They have an uneven distribution with a tendency to form local concentrations. Petersen (1918) figures a portion of a community containing 31 individuals on a 0.25 square meter section of a clay bottom at a depth of 27 meters in the Kattegat.

(8) Food. Ophiura preys on small invertebrates, such as crustacea, bivalves, other echinoderms, and ascidians, as well as feeding on detritus and meiobenthos.

(9) Predation. Predators are bottom feeding fish, e.g. haddock, cod, wolf fish; also asteroid starfish.

(lo) Competition. Competitors would be small bottom feeding fish, shrimp, some polychaetes.

(11) Responses to the environment (natural factors and pollutants). No information.

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10.9.43 Orchestia sp.

A rather small amphipod which is also known as a beach hopper. They range in color from dark green-olive-brown to light brown. They have large eyes, short first antennae and gnathopods which are sub-chelate and heart-shaped. The most common species of this region are Orchestia platensis and O. uhleri.

(1) Reproduction. Spawning occurs between high and low water marks under

moist seaweed. Females have been reported carrying eggs from May through September. The young have been observed free in the sand at the end-of July. They have several broods per year.

(2) Fecundity and larval life. Larvae hatch from eggs and enter a brood pouch. The total time of eggs and young in a brood pouch is not more than 2 weeks. Development is direct. Each female carries 7 to 15 eggs.

(3) Growth and longevity, No information.

(4) Natural mortality. They have an annual life cycle.

(5) Migration. No information, but not likely to occur.

(6) Distribution and niche preference. They range from New England to Florida. O. uhleri is apparently limited to the northern part of the range. They prefer the intertidal region and seek moist areas covered by seaweed, or tidal debris. They are considered semi-terrestrial, often occurring far up on the beach.

(7) Population densities. They are exceedingly abundant locally but no values available.

(8) Food. It is a particle feeder. They can use the gnathopods to gather small particles of food such as detritus, bacteria and benthic algae.

(9)" Predation. Predators probably include many small bottom feeding fishes, birds, and crabs.

(lo) Competition. Competitors probably include other intertidal amphipods including the caprellids and gammarids as well as other types of scavengers including the shore crabs, Carcinus and Xanthid crabs.

(11) Responses to the environment (natural factors and pollutants). No information.

10.9.44 Pagurus longicarpus

A small but abundant hermit crab usually occupying the shell of the snail Littorina, although other snail shells are also used. It is characterized by the relatively long and slender claws.

(1) Reproduction. Breeding season is from May to mid-September in Massachusetts (Summer, Osburn and Cole, 1913). Eggs are carried

on pleopods of females until they hatch.

(2) Fecundity and larval life. Larvae pass through 4 pelagic zoeal and 1 megalops stage before attaining the juvenile form. At 20 C and 30 O/oo salinity the durations of each of the stages is as follows: Zoea I, 3 days: Zoea II, 2.9 days; Zoea III, 3.6 days; Zoea IV, 5.6 days; Megalops, 7,3 days - a total of 22.4 days (Roberts, 1971a).

(3) Growth and longevity. No information found.

(4) Natural mortality. No information found.

(5) Migration characteristics. No information found to indicate that any migrations occur, but displaced crabs from localities Up to ten miles from the collecting site showed a slight tendency to orient toward their home direction in laboratory experiments.

(6) Distribution and niche preference. Pagurus longicarpus is found from Nova Scotia to Florida and Texas in shallow, often estuarine water to depths of 50 meters or more.

(7) Population densities. No exact data found. It is extremely abundant. Williams (1965) calls it "one of the commonest decapod crustaceans in shallow water along the coast of the Eastern United States."

(8) Food . According to Sanders, Goudsmit, Mills and Hampson (1962) this species feeds on diatoms, detritus, and algae. It is also a scavenger.

(9) Predators. No information on predators.

(lo) Competition. Judging from the diet, many selective deposit feeders would compete for food; for example, Nereis, Nassarius, Corophium would be in this category and all occupy the same habitat. There is also intraspecific competition for "houses" among hermit crabs. periodically, as the crab grows, larger snail shells must be found and occasional fighting over the possession of a shell occurs.

(11) Responses to the environment (natural factors and pollutants). Larval stages can tolerate salinities down to 18 o/oo (Roberts, 1971B). Salinity discontinuities of 2 o/oo can be detected. Adults have been maintained for 5 days at all combinations of 11, 22 and 30 C and 18, 35 and 48 ^{O}/oo salinity (Kinne, Shirley, and Meen, 1963).

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10.9.45 *Pandalus* borealis

The northern shrimp, about 15 cm long, pink in color. It is found abundantly in cold northern waters and is the basis for a valuable commercial fishery in the Gulf of Maine.

(1) Reproduction. Pandalus is a protandric hermaphrodite. Rest individuals begin life as males, only about 5 percent or less being primary females. At the age of 2 1/2 to 3 1/2 years, in boreal waters, sex reversal takes place; the transition occurs about two years later in arctic waters, at ages of 4 to 5. Males are sexually mature at ages 1 to 3; females from 3 and older. Breeding takes place in the summer or fall, depending on water temperature and latitude. In the Gulf of Maine, the breeding season is in August or early September. Eggs are laid and fertilized at that time, carried over the winter on the pleopods of the females and hatch the following March or April.

(2) Fecundity and larval life. Females carry 300 to 3500 eggs according to their age and size. After hatching, the young shrimp have a pelagic larval life of about two months during which they molt periodically through 6 to 8 larval instars.

(3) Growth and longevity. Growth varies according to temperature. In The Gulf of Maine, total lengths at different ages are given as follows (Haynes and Wigley, 1969):

Age 6 months	45.7 mm
18 months	94.2 mm
30 months	126.3 mm
42 months	145.5 mm
48 months	154 mm

Pandalus reaches a maximum size of 170 mm and age of 8 years.

(4) Natural mortality. Natural mortality is high, especially during the pelagic larval period. Apollonio and Dunton (1969) estimate a mortality of 99 percent from hatching to maturity. About half the females die after their first breeding cycle.

(5) Migration characteristics. In the Gulf of Maine, shrimp migrate according to age group. Juveniles leave the "nursery" area near shore for deeper and cooler water in their second or third summers. Mature shrimp return to inshore areas in the fall, but the older second-time spawners return somewhat later than do the younger ones (Apollonio and Dunton, 1969).

(6) Distribution and niche preference. Pandalus borealis in the western Atlantic is found from Greenland and Newfoundland to Cape Cod, usually on muddy bottoms at depths of 9 to 329 meters in the Gulf of Maine, maximum recorded depth 900 meters. Usual depth range, 100-250 meters.

(7) Population densities. No good data on population densities.

(8) Food . Pandalus gets a considerable part of its food from the bottom and eats, in part, the remains of dead animals and plants. At night it rises in the water and feeds throughout the water column. In the Gulf of Maine, shrimp stomachs with only mud and debris were common, indicative of the bottom feeding habit. Molluscan food predominates in the winter, crustaceans in the summer. Some of the various categories of food items found in shrimp stomachs are copepods, polychaetes, radiolarians, foraminiferans, tintinnids, diatoms, peridinians, mysids, gammarids, shrimp, holothurians, ophiuroids (Apollonio and Dunton, 1969).

(9) Predation. Predators are chiefly carnivorous fish, e.g. cod, hake, haddock, sculpins, redfish, halibut, Greenland halibut.

(lo) Competition. Competitors include the two congeneric species P. montagui and P. propinquus.

(11) Responses to the environment (natural factors and pollutants). Although shrimp larvae can tolerate temperatures as high as 14 C, the maximum temperature for survival of the adults is about 11.5 C, while temperatures above about 5 C seem to have adverse effects. Minimum temperature is about -2.0 C. Salinity limits are between 30 and 35 °/oo.

Pandalus appears to be relatively sensitive to toxic substances. No information found for P. borealis, but Portmann (1968) gives the following for P. montagui:

48 'ours '°50	for copper	0.2	ppm
	for zinc	10	ppm
	for nickel	100	ppm
	for phenol	20	ppm

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10.9.46 Pectinaria gouldii

The trumpet or "ice cream cone worm;" a tube dwelling polychaete worm of sand and mud bottom. It lives in tubes constructed of mucous and sand grains connected together to look like a "sugar cone."

(1) Reproduction. Pectinaria breeds in sand and mud bottoms to 25 meters (Pratt, 1935). Fertilization is external, the sexes are separate but the breeding season is not known.

(2) Fecundity and larval life. Pectinaria has a pelagic trochophore larval stage ('dear, 1966; Barnes, 1968); its fecundity is not known.

(3) Growth and longevity. Pectinaria grows to 15 mm after 1 year, 25 mm after 2 years, and 35 mm after 3 years. Its weight increases by approximately .0006-.0008 g/month and attains a weight of .02 gms after 2 years (Sanders, 1956).

(4) Natural mortality. The life span of Pectinaria is probably not more than 3 years (Sanders, 1956). The mortality of a related species,

P. hyperborea, was 99 percent in 2 years (Peer, 1970) and the life span of P. australis was only 12 to 18 months with extremely high mortality.

(5) Migration characteristics. Pectinaria is not migratory.

(6) Distribution and niche preference. It is distributed in sand and mud bottoms, particularly silt clay transitional sediments, intertidal to 20 m. It lives in tubes constructed of mucous and sand grains from Maine to North Carolina (Gordon, 1964; Sanders, 1956; O'Connor, 1972).

(7) Population densities. The following population densities of local populations have been recorded: Barnstable Harbor, 40/m2 (Sanders, 1962); Long Island Sound, 213/m^2 (Sanders, 1956). Maximum dry weight (grams): 0.9/m^2, Moriches Bay Long Island (O'Connor, 1972); 1.25/m^2 Long Island Sound (Sanders, 1956).

(8) Food. Pectinaria is a deposit feeder. It shovels sand grains into its "trumpet" by means of its setae and digests diatoms and detritus from the grains.

(9) Predation. No information.

(lo) Competition. Probably competes with other deposit feeders in the area.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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10.9.47 Placopecten magellanicus

The sea scallop or giant scallop; the basis for valuable commercial fishe ry in New England.

(1) Reproduction. The spawning seasons are given by various authorities as follows:

Cape Cod Bay	Late September-early October (Posgay, 1950)
Georges Bank	Last week in September (Posgay and Norman, 1958)
Penobscot Bay	July-October, peak in September (Baird, 1953)
Digby, N.S.	August-September (Dickie, 1955)

No definite information on minimum age at spawning, but Posgay and Norman (1958) refer to the spawning of scallops 50-90 mm in size. The smallest of these would have just completed their second year of age. Usually spawning begins in the third or fourth year (Baird, 1967).

Spawning may be initiated by a slight rise in temperature. Scallops in aquaria have been observed to spawn apparently spontaneously. Spawning temperatures in nature have been given as between 8 and 11 C (Posgay and Norman, 1958); Dickie (1955) believes that more successful spawning occurs between 9.5 and 11 C than below 9.5 C.

(2) Fecundity and larval life. There appears to be no definite information on fecundity but as in other large bivalves with pelagic larvae, eggs probably number in the millions. The scallop has a pelagic larval life, but little is known of this period as very few have been reared to metamorphosis under close observation. Canadian workers have successfully reared a few individuals and the larval period was said to be about 40 days. Other workers have reared the larvae to a size of about 200 microns in 2 to 3 weeks at 13 to 18 C, and at that growth rate the time to metamorphosis was estimated to be 4 weeks (H. Hidu, personal communication).

(3) Growth and longevity. Growth rates for Maine waters (Baird, 1967) and for Georges Bank (Merrill, Posgay and Nichy, 1961) are given

as follows:

	Maine	Georges Bank
1st season	2 mm	--
2nd season	5-12 mm	20 mm
3rd season	56 mm	55 mm
4th season	74 mm	82 mm
5th season	90 mm	98 mm
6th season	104 mm	110 mm
7th season	112 mm	119 mm
8th season	119 mm	131 mm
9th season	125 mm	134 mm

(4) Natural mortal ity. Mortality rates have been estimated for adult scallops; based on the numbers of living and recently dead individuals in dredge catches, both Dickie (1955) and Merrill and Posgay (1964) estimated an average annual natural mortality rate of about 10 percent. No data or reliable method of estimating mortality rate of scallops under 3 years old (Medcof and Bourne, 1964).

(5) Migration characteristics. Scallops do not migrate substantial distances despite an ability to move about locally on the bottom.

(6) Distribution and niche preference. P. magellanicus is found from Labrador to Cape Hatteras on sandv or silty-sand bottoms from a few meters to 200 meters deep, resting horizontally on the surface of the sediment.

(7) Population densities. Research cruises on Georges Bank from 1958 to 1963 covering over 200 localities obtained catches of 0 to 1700 scallops per thousand square meters covered; catches exceeded 500 per thousand square meters in only about 1 percent of the localities, and exceeded 100 in about 31 percent of the localities (Merri 11 and Posgay, 1964). Because of the inefficiency of the. dredge, the actual densities of the scallops on the bottom were undoubtedly higher. Dow (1969) estimated the efficiency of a commercial dredge between 5 and 15 percent; if this is correct, the densities of scallops corresponding to the above catches would be 3 to 10 or more per square meter in 1 percent of the localities and 0.6 to 2 in 31 percent of the localities. In most places, density would be less than one per square meter. Dickie (1955) from observations made by underwater photography, estimated densities of 0.3 to 1.3 per square meter in waters near Digby, N.S.

(8) Food. The specific food items of scallops in nature are not known. They will feed and grow on several species of phytoplankton in the laboratory. They are filter feeders, straining plankton and probably suspended detritus from the water and ingesting it.

(9) Predation. Medcof and Bourne (1964) list the following as known predators of scallops: cod, plaice, wolf fish and two species of starfish, Asterias vulgaris and Crossaster papposus.

(10) Competition. The large bivalves Spisula and Arctics are often found in the same habitat with scallops. Since they both feed on the same food supply, they might be classed as competitors, although there is no evidence that such competition is serious. Sand dollars (Echinarachnius parma), which often crowd the bottom in enormous numbers, could be serious competitors for space and food.

(11) Responses to the environment (natural factors and pollutants). No information.

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10.9.48 Polinices duplicata & P. heros

This is one of several species of moon snails, or sand collar snails. It is a fairly large, globose snail, distinguished from others in the genus by the presence of a massive callous over the umbilicus of the shell .

(1) Reproduction. The species spawns from June to September at water temperatures of 17 C or above, although individuals containing ripe gametes can be found throughout the year. Within 10 to 12 days after copulation, females produce a nidus, or collar shaped egg capsule of cemented sand grains in which the eggs are embedded in gelatinous pockets. These fragile sand collars, about 20 cm in diameter, are frequently found on beaches and sand flats during the breeding season (Hanks, 1963).

(2) Fecundity and larval life. Each female produces an average of 5600 eggs which develop within the sand collar for 10 to 12 days at temperatures of 18 to 20 C. After this period of incubation, they emerge as veligers and live a pelagic existence for about 30 days. They metamorphose and become bottom dwelling at a size of 0.5 to 0.7mm (Hanks, 1963).

(3) Growth and longevity. NO information on growth rates. The adult snail is about 50 to 60 mm in height.

(4) Natural mortality. No information.

(5) Migration characteristics. Intertidal populations move out of the water to spawn.

(6) Distribution and niche preference. The species occurs on sandy or silty-sand tidal flats and offshore shallow bottoms from Massachusetts Bay south.

(7) Population densities. No information.

(8) Food. P. duplicata is a voracious predator on other molluscs, particularly clams, on which it feeds by engulfing them with its

massive fleshy foot and rasping a hole In the victim's shell with its radula. Sawyer (1950) found that at 21 C, ten small snails consumed an average of 6.7 soft-shell clams a day. At 10 C the feeding rate dropped to one-fifth that at the higher temperature,

(9) Predation, Predators on adult Polynices are probably rare. The very young snails may be fed upon by crabs or bottom feeding fish.

(lo) Competition. Polynices competes with green crab to the extent that both feed on young bivalves.

(11) Responses to the environment natural factors and pollutants). No information.

Polynices heros is a closely related larger snail of similar habits. Little is known of its life history. It differs from P. duplicata in its niche preference. It is more common in deeper water and more exposed shores.

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10.9.49 Polydora sp.

Polydora ligni and P. websteri, often referred to as mud worms, are small, sedentary, tube-dwelling worms of the family Spionidae. Both are common members of the oyster assemblage and P. ligni also occurs on mussel beds. They are representative of the species which occur in these habitats that may have influence on the success of the oyster or mussel without preying on, or directly competing with them.

(1) Reproduction'. Reproduction of both species begins early in the spring. Details of sperm transfer and fertilization in Polydora are yet to be published but it seems likely that, in many cases, the sperm is transferred directly to the receiving animal by copulatory organs or spermatophores (Blake, 1969). Eggs are contained in egg capsules fastened to the inside of the tubes of the spawning females.

(2) Fecundity and larval life. P. ligni egg capsules have been collected in Maine from April to July and contain up to 132 eggs per capsule while P. websteri egg capsules, which contain from 50 to 55 eggs, have been collected from March to July (Blake, 1969). Each female produces several egg capsules at a time-and probably has two or more broods in a single season. Development of the larvae progresses to the 3-setiger stage in the egg capsule and then continues in the water column. During development in the egg capsule, larvae have often been observed feeding on the unfertilized eggs within the same capsule. The larvae remain in the water column until they reach the 17-setiger stage at which time they metamorphose and begin their benthic existence. During the early pelagic stages the larvae of these species are photopositive, but become photonegative just before metamorphosis. Both species metamorphose best in the presence of the proper substrate and P. ligni is especially gregarious in its setting behavior as it seems-to be attracted to the tubes of previously set P. ligni. Larvae of P. ligni can be found in Maine waters from April to the first of-October while P, websteri is present from March to the end of September (Blake, 1969).

(3) Growth and longevity. Growth of the larval stages is temperature dependent. No information is available on the growth rate of larval P. ligni, but larval P. websteri grows best at between 10 C and 15 C where the 14-setiger stage can be reached in 42 days (Blake, 1969). After metamorphosis the closely related European species, P. ciliata is known to add one segment a day until after 3 weeks the worms are about 40 segments long. At this time they reproduce. After a possible second batch of eggs, one to two weeks after release of the first larvae, most of the animals die (Daro and Polk, 1973). The longevity of Polydora is then measured in months and it probably takes at least two generations to complete a calendar year.

(4) Natural mortal ity. No information.

(5) Migration characteristics. No information.

(6) Distribution and niche preference. P. ligni occurs along the entire coast of North America. It is most common in estuaries where it builds tubes of silt on tidal flats and subtidally on stones, shells, etc. P. websteri is found all along the east coast of the U.S. and in California and Oregon. It can be common in a number of shallow water habitats but is best known for its boring into calcareous substrates such as oyster shells. A description of its boring activities can be found in Haigler (1969).

(7) Population densities. Both of these species are abundant, but P. ligni often occurs in astronomical densities. Larsen (1974) reported densities of 10,721/m^2 which must be considered a normal post-

reproductive level to P. ligni. Densities in Delaware Bay have been over 666,000/m^2, which caused oyster mortalities because of the sedimentation that results from so many worms collecting silt to build tubes (Galtsoff, 1964). P. ciliata has been observed in densities of 1,000,000/m^2 (Daro and Polk, 1973).

(8) Food. As young larvae, Polydora feeds on small phytoplankton and detritus. Older larvae are principally carnivorous, feeding on zooplankton, although they also consume phytoplankton and detritus. Adult Polydora are selective deposit feeders. They scrape the sediment surface with their palps and the cilia on the palps transports the particles to the mouth. P. ciliata has often been seen to reach out of their tubes to feed on dead or decomposing animals (Daro and Polk, 1973).

(9) Predation. No specific predators of Polydora are mentioned in the literature although they are most likely utilized as food by many of the smaller predators of the oyster and mussel assemblages. A good deal of the predatory mortality of Polydora could be caused by small fish.

(lo) Competition. Competitors of Polydora could include any species which occupies habitat space or feeds in a similar manner on the sediment surface. Most intense competition is probably derived from other members of the family Spionidae. Larsen (1974) noticed that the peaks of abundance of three similar, and presumably competing, spionids, P. ligni, P. websteri and Boccardia hamata, occurred in different segments of the James River Estuary, Virginia, which suggests competitive exclusion.

[11] Responses to the environment (natural factors, pollutants). Extensive work on the environmental requirements of these species has not been undertaken so there is no detailed information on their responses to the various natural and artificial ecological factors. We may infer from their wide geographic distribution and estuarine occurrence that they have relatively broad temperature and salinity limits. Furthermore, although they cite no references, Daro and Polk (1973) say: "Being typically euryoecious Polydora can withstand diverse pollution longer than many other organisms."

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10.9.50 Spisula solidissima

S. solidissima is also known as the surf clam or Hen clam. It is a large species with a heavy, solid, somewhat triangular shell. It is the largest bivalve on the Atlantic seaboard measuring up to 7" in length. The shell has nearly central umbones and a very strong hinge. The surface of the valves is smooth or slightly roughened by the concentric growth lines and a thin, olive-brown epidermis is present. . . It also has been called Macra solidissima. It has a large foot and a relatively slender shell which permits rapid burrowing in unconsolidated sediments.

(1) Reproduction. Gonads are well developed from May until late July. Major spawning occurs in mid-July and August, a minor one in mid-October and November. There is a single spawning in cool years (Ropes, Chamberlin, and Merrill, 1969). The first spawning occurs when the animals reach 50 mm in size at approximately 1 to 2 years (Belding, 1910). Sexes are separate and sperm and eggs are released through excurrent siphons (Ropes, et al., 1969).

(2) Fecundity and larval life. It is estimated that the female releases at least one million eggs annually (Turner, 1953). The larvae are pelagic and the trochophore stage lasts 28 hours at 22 C. Metamorphosis to the veliger stage and the setting size is reached in 19 days at 22 C (Loosanoff and Davis, 1963).

(3) Growth and longevity. The fertilized egg measures 53 microns in diameter and grows to 21 mm in 6 months, 45 mm in 1 year, 69 mm in 2 years, 91 mm in 3years and reaches commercial size, 125 mm in 5 to 6 years. It continues to grow throughout life and attains its maximum size off Cape Cod at 75-100 mm and off Long Island at 175 mm.

(4) Natural mortality. No information, but reported to have a life span of 17 years.

(5) Migration. Spisula is distributed by current dispersal of pelagic larvae. Large numbers of the surf clam sometimes appear on shore following storms. These have literally "shouldered" each other

out of the sediment (Olsen, 1970).

(6) Distribution and niche preference. Its range extends from the Gulf of St. Lawrence to Cape Hatteras with the heaviest concentrations occurring off southeastern Long Island. Animals are usually found only in sand buried 2 to 20 cm below the surface. They may come to the surface and perform leaps of several feet when under stress of crowding or predator attack.

(7) Population densities. It is very abundant, 450 to 775/m2 reported for Easton Beach, R.I.; 105/m^2 for a R.I. salt pond (Phelps, 1964).

(8) Food. The surf clam is a filter feeder. It lies near the sediment surface and extends short fused siphons into the water. Its diet consists mainly of suspended particulate matter and plankton.

(9) Predation. Predators include Lunatia in deeper water and Polinices in shallower water. Smaller clams provide food for cod, haddock, and diving ducks.

(lo) Competition. Competitors probably include M. mercenaria, Gemma gemma, and Mulinia lateralis (the little surf clam).

(11) Responses to the environment (natural factors and pollutants). A gradual warming of the water causes gonad ripening, spawning begins when the water reaches 15 C. The clams become inactive when the temperature reaches 4 C. Its upper lethal limit is between 26 and 28 C for adults; younger animals survive higher temperatures. The southern limit occurs at about 23 C. Spisula's distribution would suggest that it is restricted to fairly high salinities.

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10.9.51 Streblospio benedicti

A common, inconspicuous, tubicolous polychaete found in estuaries, on beaches, or where the substratum consists of fine mud with considerable debris.

(1) Reproduction. Streblospio is sedentary and therefore releases its young where it is located. Dean (1965) reports spawning from June to October in the Mystic estuary. " Temperature is probably a major factor determining spawning season. Dean (1970) suggests the cooler summer waters of Penobscot Bay as a possible reason for the lack of Streblospio in that estuary.

(2) Fecundity and larval life. Streblospio is one of the few polychaetes that is larviporous. The eggs develop and hatch within the female. If the female-remains undisturbed the" larvae hatch at the 9-setiger stage. They are usually pelagic for 3 days or less (Dean, 1965). However, their larval life ranged from 8 to 22 days in estuaries on the Maine coast (Dean, 1970). At the end of the pelagic stage they metamorphose quickly (24 hours) and settle to the bottom. Metamorphosis does not take place unless the proper substrate is present (Dean, 1965). The total number of larvae released by five females from Maine estuaries ranged from 378 to 542.

(3) Growth and longevity. There is little information on the growth of adults. The adults are probably annuals.

(4) Natural mortality. No information.

(5) Migration characteristics. Streblospio is sedentary.

(6) Distribution. Streblospio ranges from the Bay of Fundy to Cape Hatteras, from the littoral zone to brackish waters (5-15 $^{0}/_{oo}$) and commonly on Mytilus beds (Gosner, 1971}. Stickney (1959) found it in the Sheepscot estuary in high salinity, intertidal sediments.

(7) Density. The following densities were from selected sampling areas in 3 estuaries in Maine: Penobscot, Damariscotta and Sheepscot (Dean, 1970):

Location	No./m^2
Penobscot	30
Damariscotta	13,550
Sheepscot	993

The studies showed Streblospio dominant in the Damariscotta, variable in the Sheepscot and infrequent in the Penobscot. Seasonally they were found from June to August with heaviest concentrations in June.

Sanders, Goudsmit, Mills, and Hampson (1962) give the maximum density in Barnstable Harbor as 26,100/m^2.

(8) Food. Streblospio is a non-selective deposit feeder which feeds by means of cephalic tentacles that move over the surface of the sediment. A ciliated groove in the ventral surface of the tentacles carries food to the mouth. Sanders, et al. (1962) found stomach contents consisted of sand, detritus and diatoms.

(9) Predation. No specific information but as Streblospio is one of the abundant primary consumers of soft bottoms, it is probably an important food of the bottom feeding, carnivorous vertebrates and invertebrates.

(lo) Competition. No specific information. Streblospio could be expected to compete to some degree for food and space with other non-selective deposit feeders.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

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10.9.52 Strongylocentrotus droebachiensis

The common green sea urchin, sea hedgehog or sea egg. It is an echinoderm frequently used in embryological and physiological research (see also Arbacia). A small market and fishery exists for them as an exotic seafood item.

(1) Reproduction. Boolootian (1966) gives the spawning season as late winter in LaMoine, Maine with peak gonad index occurring in February and March. The urchins are spawned out after March. Eggs and sperm are released into the water; at 4 to 5 C development to the gastrula stage takes 3 days (Thorson, 1946).

(2) Fecundity and larval life. Eggs develop into echinopluteus larvae which are pelagic and planktotrophic, feeding on diatoms and other microscopic organisms. They have six short arms that are directed backwards and are propelled through the water by long cilia called epaulettes (Hyman, 1955). The larvae are described by Boolootian (1966) as moving in a gliding, rotating motion with the anal region held down. They swim about in the surface water for 4 to 6 weeks before metamorphosing into a small urchin less than 1 mm in diameter. Thorson (1946) says that larval life is 2 1/2 months in Danish waters.

(3) Growth and longevity. Growth data for the Maine coast (Swan, 1958, 1961) and for the Norwegian coast (Grieg, 1928) are available:

	Maine	Norway
1st year	8-10 mm	5-6 mm in diameter
2nd year	24-26 mm	15 mm
3rd year	40-44 mm	24 mm
4th year	52-54 mm	40 mm
5th year	---	50 mm
6th year	---	60 mm

Growth varies greatly by location and food (Swan, 1961). Urchins fed Laminaria (kelp) increased in diameter 60 percent more than those fed Ascophyllum (rockweed). Urchins from Washington (Pacific

Coast) grew 65 to 70 percent larger than those on the Maine coast.

(4) Natural mortality. No information.

(5) Migration characteristics. Although urchins creep about considerably, there is no evidence of migration.

(6) Distribution and niche preference. Found on rocky bottoms from low water to 1,150 meters, Arctic to New Jersey; rare south of Cape Cod.

(7) Population densities. Maximum density found by Swan (1958) in York, Maine: 1,305 individuals in 3 m^2. In Ipswich Bay, Massachusetts, Dexter (1947) reported 12 individuals in a 100 m^2 dredge haul on level bottom, and 2 individuals in 60 m^2 in Cape Ann inlet.

(8) Food. Laminaria (kelp) is a preferred food. Beers (1963) found Laminaria fragments and filamentous green algae in stomachs. Other foods are the seaweeds Ascophyllum, Nereocystis, Corallina and Chondrus. Strongylocentrotus is also a scavenger on dead animal remains.

(9) Predation. Cod, wolf fish, sculpins, sea ravens, and haddock feed on sea urchins. Gulls and other shore birds feed on them especially in winter when other food is scarce.

(lo) Competition. No information available.

(11) Responses to the environment (natural factors and pollutants). Intolerant of low salinity (Topping and Fuller, 1942).

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10.9.53 Tellina agilis

Information about this species is derived from studies at Barnstable Harbor, Massachusetts by W. Gilbert (1973), unless indicated otherwise.

(1) Reproduction. These dioecious (gonochoristic) clams become sexually mature at a shell length of 5 to 6 mm.

Sullivan (1948) found veliger larvae as water temperatures reached 20 C, which implies that spawning occurs around 15 to 20 C. Semi-annual spatfall at Barnstable Harbor, Massachusetts is evidence for a semi-annual spawning that is interrupted during the summer (as sediment temperature goes above 20 C) and terminated in fall (as temperature falls below 15 C). Intertidal sediments usually warm up to threshold temperatures before subtidal sediments in the same area. Gametes are shed into the sea water where fertilization occurs.

(2) Fecundity and larval life. A pelagic veliger stage was available at Prince Edward Island, Canada, during July and August (Sullivan, 1948). A given individual may spend 2 weeks to more than a month in the plankton, depending on water temperature (see #1). Shelled larvae metamorphose at a length of 0.25 mm and settle to the bottom sediments as "spat."

(3) Growth and longevity. Growth averages 0.5-l .0 mm per month, except from December through March, when growth stops. Growth is more rapid in intertidal areas than subtidal ones.

(4) Natural mortality. Maximum longevity is 2 to 3 years (maximum length = 16 mm) Boss (1968). During a year of study, mortality was approximately 15 percent per month over most of the zone of abundance. On rippled sand flats where juveniles (<2.5 mm) may be hydrodynamically concentrated, mortality was 25 percent per month.

(5) Migration characteristics. No information,

(6) Distribution and niche preference. Geographic range is from the Gulf of St. Lawrence to Georgia.

T. agilis is found in protected and semi-protected coastal waters:

(a) In shallow, sandy bottoms with a zone of abundance from 1 to 5 m below mean tide level, where they derive nutrition from benthic diatoms (see #8). Due to attenuation of light at greater depths (dependent on water clarity), diatom productive ty may not be sufficient to sustain tellin predators.

(b) In deeper areas (to 45 m) where nutrition may come from detritus (or associated bacteria. - see #8) that settles out of the water column.

(c) In either of the above cases:

(1) sediment composition includes >1/3 fine and medium sand (0.13-0.50 mm diameter) but <1/6 mud (0.06 mm diameter);

(2) salinity of water column >18pptand <33 ppt (Castagna and Chanley, 1973).

(d) Contrary to Gosner (1971), T_. agilis is not found within clumps of eel grass (Zostera marina). Stauffer (1937) points out that T. agilis was equally abundant at various localities before and after the disappearance of the eel grass in the 1930's and that Cumingia tellinoides was the bivalve that did disappear with the eel grass. T. agilis adults lie on their left valve when buried and move laterally through the substrate as they forage, a behavior not possible among eel grass roots. While tellins occur in the sand adjacent to and between clumps of eel grass, they are replaced by Cumingia tellinoides within the clumps.

T. agilis is usually found within the upper 3 cm strata of sediment, with juveniles nearer the surface.

Juveniles may be clumped; adults of T. agilis under intertidal conditions were evenly dispersed and territorial. Size of territory depended on size of the individual and conditions of food, but at Barnstable Harbor, Massachusetts, a 7 to 9 mm tellin would have a territory of around 10 cm2.

(7) Population density. Varies seasonally but tends to oscillate around an annual mean density ranging from 290/m^2 (mean length = 4.5 mm) intertidally to 2,460/m^2 (mean length = 2.4 mm) subtidally. Juvenile density is directly correlated with depth below mean tide level, possibly because less time is available for spatfall in the intertidal. Mean length of all age groups decreases with depth and density because of slower growth at high densities, apparently due to intraspecific competition for food.

Hanks (1964) found average densities of 17/m^2 in the Sheepscot River, Maine and Sanders (1958) found densities of 6-360/m^2 in Buzzards Bay, Massachusetts.

(8) Food. T. agilis is a "sand-grain feeder" (Reid, 1971) and ingests sediment particles with its extensible (2 to 4 time shell length) inhalent siphon; benthic diatoms attached to the sand grains are digested. The tellins extend their inhalent siphons onto the sediment surface to feed, particularly during daytime low tides when the benthic diatoms migrate to the sediment surface and become concentrated there.

These deposit feeders also feed on detritus that settles onto the sediment in areas of quiet water and muddy sand. In this case, nutrition may be derived from the bacterial film around the particles of detritus.

Tellins are often observed with the tip of their inhalent siphons flush with the sediment surface, filtering the water. Whether this activity is only for respiration or also to supplement the diet by suspension feeding is not known, but the latter is a possibility.

(9) Predation. O-group winter flounder (Pseudopleuronectes americanus) feed on the extended siphons of T. agilis while the latter feed on surface sediments. The fish will also take a bite out of a tellin's foot when a dislodged clam attempts to re-burrow (Gilbert and Suchow, 1974) thus permitting the trematode parasite Monorcheides cumingiae to complete its life cycle. The tellins appear to be able to regenerate their siphons after such "cropping," a situation that has been reported for the European T. tenuis (Edwards, Steele, and Trevallion, 1970).

Adult winter flounder and scup (Stenotomus chrysops) ingest whole tellins, as do horseshoe crabs (Limulus polyphemus), and various diving ducks like bufflehead (Bucephala albeola), old squaw

(Clangula hyemolis), harlequin duck (Histrionics histionicus), king eider Somateria spectabilis), and common scoter (Oidemia nigra) as reported by Cottam 1939). Naticid snails (Lunatia heros, L. pallida, and Polinices duplicates) prey heavily on T. agilis. Lobster (Homarus americanus) have also been observed to feed on T. agilis (Gilbert and Suchow, 1974).

(10) Competition. T. agilis probably competes with deposit-feeding snails such as Nassarius obsoletus and Hydrobia sp. at the upper limit of its zone of abundance, and with sand dollars (Echinarachnius parma), burrowing sea cucumbers (Leptosynapta inhaerens), and certain deposit-feeding polychaete annelids (trumpet worms, Pectinaria gouldii). These tellins are replaced by Cumingia tellinoides in eel grass clumps and by Macoma tenta in muddy sediments.

(11) Responses to the environment (natural factors and pollutants). No information.

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10.9.54 Thais lapillus

The dog whelk or dog winkle. A white or white banded with orange or brown shell common on rocky shores.

(1) Reproduction. Spawning takes place throughout the year with no special season noted. The age of the first spawning is 2 1/2 to 3 years. Spawning takes place during the early summer at Woods Hole (Costello, Davidson, Eggers, Fox and Henley, 1957). At Plymouth, England spawning occurs all year but the capsules are most abundant in the early summer (Costello, et al., 1957). Spawning occurs at 9 C in March (Largen, 1967). In Maine, spawning occurs at 5 to 7 C, and day length may be a factor in inducing it (Milliken, 1967).

(2) Fecundity and larval life. Larvae hatch from long slender vase-shaped egg capsules laid in rock crevasses, attached to the substrate by a short stalk. The egg capsules contain 300-1,000 eggs, 6-31 capsules being laid at one time (Moore, 1938). After hatching, the larvae move down to lower tide level, and live among tubicolous polychaetes on the underside of stones for the first few months.' Young shells of less than 5 mm are rarely found above the low tide level. At about 8 to 10mm shell length they change their habits and climb up the shore to the barnacle zone (Moore, 1938).

Larvae hatch in the crawling stage through a hole at the top of the egg capsule. Development from fertilization to hatching takes about four months (Thorson, 1946; Milliken, 1967). There is no swimming or planktonic stage. The embryo has a round sparsely ciliated velure and transforms into a typical veliger with a well-formed velure. At metamorphosis, tentacles appear and the velure slowly regresses. The larva is a miniature of the adult upon hatching (Costello, et al., 1957).

(3) Growth and longevity. Growth information is mainly for Thais in British waters. Growth given by Moore (1938) is for shell height. Growth only occurs when the animal is sexually immature.

Year	Shell Height mm
1	3- 8
2	10-15
3	21-26

Sexual maturity is reached in 2 1/2 to 3years and at that time growth ceases. Growth and size at maturity varies from place to place, i.e., range in x shell height at sexual maturity for eight locations were:

18.9	27.4
19.9	28.7
24.6	29.4
27.0	29.5

Colton {1916) recorded the oldest individual at 7 years. Thais attains a larger size on a diet of Mytilus than it does on barnacles (Moore, 1938). Only snails with a thick, toothed lip on the shell opening are mature (Moore, 1936).

For more information on growth see Adams (1947).

(4) Natural mortality. From the 300-1,000 eggs laid in capsules, only a few mature. The remainder develop into a yolk column that is consumed by the normal embryos. Colton (1916) gives a natality rate of 10 to 12; Thorson (1946)gives 15 to 25, Carpenter (1857) gives 12 to 30 and Milliken (1967)gives 4 to 16.

(5) Migration characteristics. No migration.

(6) Distribution and niche preference. Thais is distributed from Cape Cod to the Bay of Fundy in the littoral zone (Gosner, 1971). It is found in tidal communities on hard surfaces. It occupies the lower third of the shore in areas where there are mussels and barnacles (Dexter, 1947). Coleman (1933) says its distribution is from one foot above mean sea level to halfway between mean and low spring tides, or from 55 percent to 10 percent emersion. Its distribution is limited by the 19 C summer isotherm in the southern part of its range, and by the -1 C winter isotherm in the north (in Plymouth, England) (Largen, 1967).

(7) Population densities. Moore (1938) gives densities in one location as up to 200 per square meter for sizes >10 mm in the lower tide zone, and up to 40 per square meter for sizes <10 mm.

Dexter (1947) found the maximum number in 100 m2 dredge hauls was 13 with 32 percent occurrence in the hauls. See also Dexter (1944),

(8) Food. Thais feeds heavily on adult barnacles, Balanus balanoides and Chthamalus stellatus, and prefers the larger individuals. Predation is heavier at lower tidal levels (Connell, 1961). Thais will eat mussells (Mytilus edulis) if no barnacles are present, and will switch to mussels if the supply of barnacles has been exhausted. They do not make the switch easily and will often at first waste time by drilling through the shell. After a while they learn to feed easily on the mussels but will switch back to barnacles as soon as the supply increases and will then ignore the mussels completely. Young' Thais eat the polychaete Spirorbis borealis (Moore, 1938), and may also feed on small Mytilus. At 8 to 10 mm they change over to a diet of barnacles. They also eat various gastropod including Patella vulgata, Gibbula cinerarea and G. umbilicals, Littorina littorea, L. obtusata (Moore, 1938).

(9) Predation. The purple sandpiper Calidris maritima eats small Thais, 1 to 9 mm in length. Shells of Thais were found in the nest of the herring gull, Larus argentatus; the gull has been observed eating Thais as has the oyster-catcher Haematopus ostralegus and some thrushes. A few Thais were found in two fish, Labrus bergylta and Gadus virens (Connell, 1961). Probably the most serious enemies are birds.

(10) Competition. The population of Thais is more dense under Fucus than in bare areas (Connell, 1961).

(11) Response to the environment (natural factors and pollutants). Col ton (1916) suggests that the presence of ice is a limiting factor on populations. They are very susceptible to extreme cold and ice conditions. The upper lethal temperature limit is 32 to 34 C (Milliken, 1967). They can survive 9.5 days in fresh water (Pelseneer, 1935).

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10.9.55 Uca sp.

Uca pugilator (Bose) is commonly known as the sand fiddler or china-back fiddler. The carapace of the male is a dull lightish purple or bluish gray with irregular markings of brown or dark gray, a large patch of deep

purplish blue at the base with white tubercles, articulations yellowish, fingers mostly white. Chelipeds in male very unequal, in females equal but small. Uca pugnax (Smith) is commonly known as the mud fiddler. The carapace of the male is dark greenish olive, middle and anterior portion mottled with grayish white, front variably light blue between and above bases of ocular peduncles, margin tinged with brown, pale brownish yellow at articulations and fingers nearly white. Females less mottled with white dorsally and without blue in front. Chelipeds in male very unequal, in female equal and small.

(1) Reproduction. U. pugnax breeds in the region of Woods Hole during July 4-15 and in the region of Long Island during mid-August. U. pugilator breeds in the region of Woods Hole in early August and on Long Island from July 6 to early August (breeding season must be related to latitude). Gray (1942) reported that U. minax spawns during one to three days and spawning or extrusion is slowed by cool temperatures. Copulation is thought to occur in the underground chamber of the male while both are hard shelled. U. pugilator and U. pugnax are known to enter the water to allow the eggs to hatch. Hatching occurs 15-20 days after spawning during 7-10 pm and is completed in less than 1 hour. In Chesapeake Bay, zoea are found in the plankton at temperatures of 25 C on the ebbing tide.

(2) Fecundity and larval life. U. minax females produce sponges bearing 100,000 to 300,000 eggs with an average of 200,000. The number of eggs depends greatly on the size of the female. Uca sp. has a pelagic larval stage consisting of five zoeal stages and a megalops. In addition there is a transitory prezoeal stage. The first two zoeal stages are usually abundant at the surface, the third at some intermediate depth and 4 to 5 are at the bottom. Zoeal stages collectively require about 1 month for completion. The second stage, megalops also requires nearly a month and is a powerful swimmer. At the end of the megalops stage it enters the crab stage undergoing two weak stages and finally emerging as an active small crab measuring 2 mm across the carapace. Larval development is known to be slow at 15 C and shortened at 30 C.

(3) Growth and longevity. At the time of extrusion an egg is approximately 0.09 mm and increases to 0.27 mm in approximately 15 to 20 days at the time of hatching. Adult males reach these average maximum measurements:

U. minax	25 mm length, 38 mm width
U. pugnax	15 mm length, 23 mmwidth
U. pugilator	17 mm length, 26 mmwidth

(4) Natural mortality. No information.

(5) Migration. No migration except in the form of larval dispersal.

, .(6) Distribution and niche preference. U. minax is distributed from Buzzards Bay, Massachusetts to Texas, U. pugnax from Cape Cod to Florida and U. pugilator from Boston Harbor to Texas. U. minax occurs in marshes at some distance from water of high salinity. It is usually found on muddy substrates where flooding with fresh water occurs or on a mud and sand substrate. It is sometimes found in the area immediately preceding the Salicornia-Distichlis zone. It has also been observed at the edge of low woodlands. The crabs live in burrows which they dig to various depths, but the maximum is about 2 feet. The openings are often considerably above high tide level, and the bottoms reach to ground water level. The burrows are only wide enough to accommodate the occupant. Usually only one crab lives in a burrow, though at times two females may occupy a single burrow, and burrows of females sometimes communicate with burrows of males, the connection being made by the female. Young crabs are sometimes found in the burrows of females, never in those of males. U. pugnax lives primarily on intertidal flats of mud or clay among the roots of Spartina, but overlapping to some extent the sandier habitat frequented by U. pugilator. The maximum number of burrows occur about 2 feet below high-tide mark, and often the burrows have mud towers at the mouths when the beach is littered with debris. In a mixed population of Uca U. pugnax always chooses the side of any surface irregularity for a hole entrance in preference to flat ground. Burrows may extend to 2 feet and terminate at the water level. U. pugnax digs most actively when the tide is falling and often hastens to plug burrows when the tide is rising to cover the burrow. U. pugilator is found in less numbers on sandy and muddy beaches bordering marshes and along banks of tidal creeks. The crabs also occur farther from water in sandy situations of Salicornia-Distichlis marsh and at times in Juncus marsh where the soil is sandy. The species burrows much as does U. pugnax and populations of the two species are often intermingled though U. pugilator prefers sandier situations. The choice of a burrow site depends upon many factors, among them phototaxis and thigmotaxis. Burrows may have any shape, but are unbranched and usually dug at an angle to the surface of the ground, the length depending in part on the moisture in the ground. The crabs plug the opening as soon as they feel the water level rising in the burrow and do this by pulling in the edges and ramming sand up from below. The end chamber functions as an air chamber during high tide.

(7) Population densities. Miller (1965) describes densities on the south shore of Cape Cod as the ratio of carapace area to sample area. For U. pugilator and U. pugnax the values are 5 to 10 percent. He defines less than 3 percent as sparse, 3 to 6 percent as moderate and 6 percent as very dense. U. pugnax is moderate to very dense and U. pugilator is moderate. Crane (1943) took a cen-

sus of U. pugnax in an area 6" x 6" x 4" (144 in^3) and counted 11 crabs (4 young, 5 females and 2 males). Two females or a young fiddler may occupy the same burrow, but single males always occupy their own burrows (Gray, 1942).

(8) Food . U. minax is omnivorous, but avoids highly putrified debris. Fiddler crabs can subsist on a mixture of sand. clay, and fermented marsh grass and may sometimes kill and eat U. pugnax and U. pugilater. It can and does feed under water. U. pugnax feeds largely on minute algae left on the sand by the outgoing tide. Algae is picked up by means of the small cheliped in males and females, the latter obtaining more food in a given time. It frequently feeds under water and often remains outside the burrow and feeds as the tide rises. It can subsist on bacteria and organic debris. U. pugilator has a similar diet to U. pugnax, actively on small particles in sand. It may wander into tide pools and shallow creeks to feed underwater at low tide. It is well-adapted to feeding on coarse substrate such as protected sandy beaches.

(9) Predation. The fiddler crab is an important component of the diet of certain shore birds, particularly the clapper rail and herons, also terrapins and raccoons. Sesarma reticulatum is also a predator as well as U. minax.

(lo) Competition. There may be some competition between U. pugnax and pugilator since the populations are known to intermingle on occasion. Other competitors might include the herbivorous gastropod which have similar diets.

(11) Responses to the environment (natural factors and pollutants). Salinity tolerance and temperature studies indicate that U. minax prefers fresh to salt water, U. pugnax prefers 30 °/oo to fresh water. U. pugnax had a 50 percent mortality in fresh water in 1.5 days and a 50 percent mortality at 7 o/oo in 3 days, while U. pugilator had a 50 percent mortality in fresh water in 3.5 days and 50 percent survival after 10 days at 7 °/oo.

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10.9,56 **Urosalpinx** cinerea

The Atlantic Oyster Drill, Urosalpinx cinerea, is a rather small gastropod snail (0.7") with a large, well deserved reputation as an oyster pest.

(1) Reproduction. Urosalpinx begins to spawn when it is about two years old (Hancock, 1959). Oviposition follows copulation by about six weeks. The principal spawning time in the Cape Cod region is from July to August, with a second smaller spawning in late September (Galtsoff, Prytherch, and Engle, 1937). The eggs are deposited, in-egg capsules on the sides, undersides, and inside crevices on oyster shells and other hard substrates.

(2) Fecundity and larval life. Development is direct and nonpelagic, i.e., it proceeds without a pelagic larval stage and the juveniles are essentially miniature adults. Carriker (1955) tabulated data from many sources and found that a female drill deposits between 0 and 96 egg cases per. season which contain between 0 and 22 eggs each. Estimates of mortality during the 18 to 56 days of incubation within the egg cases vary from 13.9 percent to 42 percent with the lower figure perhaps the most realistic (Carriker, 1955).

(3) Growth and longevity. The best growth data for Urosalpinx are presented by Cole (1942) for an English population and his results are included here as modified by Carriker (1955).

Probable age in years in July	Average height, mm	
	Males	Females
Ist summer	10	-
1	10 -18	20
2	18 -23	25
3	23 -25	27
4	25 -27	29
5	27 -29	31
6	29 -31	33
7	31 -31.5	35
8	32.5-34	36.5
9	34 -35.5	38
10	35.5-36.5	39
11	37.5	40
12	38.5	41
13	39	42
14		43

There are naturally variations in growth rates between different geographic areas, but for the most part these differences are probably minor. On the Eastern Shore of Virginia, however, there exists

a giant race of Urosalpinx which, of course, would not conform. Longevity can be considered to be 15 years or more although this will seldom be approached in nature and Cole (1942) suggests 10 years as the normal life expectancy in English waters.

(4) Natural mortality. There is little information on the natural mortality of Urosalpinx. Carriker (1955) reported an increase in mortality from 5 percent in December to 30 percent in March. These mortalities, however, were on cultivated oyster beds and it is likely that the drills, sluggish from the cold, were turned up and dislodged by dredges and therefore exposed to excess predation.

(5) Migration characteristics. There is little evidence that Urosalpinx undergoes spawning migrations (Hancock, 1959) although movements of up to 75 feet a day have been reported (Galtsoff, et al., 1937). In all probability any directional movement by Urosalpinx is related to water temperature as when they move to more shallow water in the spring.

(6) Distribution and niche preference. Coincident with distribution of bivalves upon which it feeds (see #8). See also #7.

(7) Population densities. Absolute natural population densities are not usually reported as Urosalpinx is most often captured with baited traps and the data is presented as catch per unit effort. In an exception to this procedure, Stauber (1943) obtained counts of from 237 to 943/m^2 on an intertidal oyster reef in Delaware Bay. MacKenzie (1970) presents density data from 12 Long Island Sound sites where average density ranged from 0.3 to 40.8/m^2 with the median of these averages being 2.1/m^2. Stauber's values are unquestionably extremes and the normal population levels usually are within the range reported by MacKenzie.

The Atlantic oyster drill is distributed from Nova Scotia to Florida and has been introduced into California, Washington and northern Europe (Abbott, 1968). It is mainly associated with oysters although it occurs on mussel beds and in other shallow water or intertidal habitats with hard substrates.

(8) Food. Urosalpinx feeds heavily on many bivalve species including: the American oyster, Crassostrea edulis; the blue mussel, Mytilus edulis; the hooked mussel, Brachidontes recurvus; the hard clam, Mercenaria mercenaria; and the soft clam Mya arenaria. The slipper limpets of the genus Crepidula and other small gastropods are also devoured and, in fact, cannibalism seems to be a major source of mortality, In most cases, the drills prefer the younger, thinner shelled individuals of a species and present little threat to adult oysters and mussels.

(9) Predation. Major predators of Urosalpinx include other members of this species, the gastropod Eupleura caudata and Polinices duplicates (Flower, 1954), and the starfishes, Asterias forbesi and A. vulgaris.

(10) Competition. Competition is primarily with other drill-type predators, especially E. caudata, but actual data on the intensity of competition is lacking. Manzi (1970) noted that at all combinations of temperature and salinity. in his experiments that Urosalpinx consumed more oyster spat than E. caudata.

(11) Responses to the environment (natural factors and pollutants). Development of estuarine populations of Urosalpinx are limited by its low tolerance to reduced salinities. Although the actual lower limit of tolerance appears to vary geographically it seems safe to say that Urosalpinx is seldom a problem below 16 to 18 °/oo. The activity of Urosalpinx is influenced by water temperature and as the temperature declines the animals return to the sediment surface from elevated objects where some burrow into the sediment and intertidal individuals either bury themselves in the sediment or migrate to deeper water (Carriker, 1955). The drills become inactive in winter and essentially hibernate. Manzi (1970) observed that the highest feeding rates for Urosalpinx occur at 25 C and 26.5 O/OO. It appears that the oyster drill may be photonegative (Cole, 1942).

Chemical control of Urosalpinx and other pest organisms has been experimented with but results are contradictory. Haven, Castagna, Chanley, Wass, and Whitcomb (1966) concluded that the pesticides Polystream and, Sevin were ineffective in controlling drills and had deleterious effects on associated organisms. On the other hand, MacKenzie (1970) found Polystream to be a useful tool for drill control.

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Chapter 11 Macrophytes

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11.1 GENERAL FEATURES

The vegetation of coastal marine communities in the region from Sandy Hook, New Jersey to Eastport, Maine, is dominated by species from two major plant groups, the angiosperms or seed-bearing plants and the macroscopic algae. The angiosperms include the beach or dune grasses, the transitional tidal marsh plants, and the shallow submergent grasses (Petry and Norman, 1968). The macroscopic algae, the major element of the benthic flora, includes species from the Cyanophyta (blue-green algae), the Chlorophyta (green algae), the Phaeophyta (brown algae), and the Rhodophyta (red algae) (Dawson, 1966).

The benthic flora of the New England coast exhibits a well-defined geographical distribution which was first described by Harvey in his work Nereis Boreali-Americana (1852-1858) and again by Farlow in 1881. Their observations led them to conclude that Cape Cod, Massachusetts, is a geographical barrier between northern species of benthic algae with sub-arctic tendencies and a southern boreal flora adapted to warmer waters. Taylor (1957) describes the major groups of algae according to their distribution in this region. Of twenty species occurring almost exclusively north of Cape Cod, ten are brown and nine are red. A second group, which occurs primarily north of the Cape, but. successfully ranges westward into Long Island Sound, contains seven species of green algae, eight brown species, and five red species. A few species are not geographically limited either north or south of the Cape, but extend throughout the entire range. Of these, ten are green, four are brown, and five are red. A few species have a distinct center of abundance south of Cape Cod, but may occur consistently north of the boundary. This group includes six green species, four brown, and two, red. Finally, there is a group which occurs exclusively south of Cape Cod and includes seventeen red species, one green species, and two brown. Thus, there is a general shift of dominance from the brown algae in the sub-arctic group to red algae in the boreal group and a general distribution of the green algae throughout the range.

The recognition of Cape Cod as a geographical barrier for benthic algae is supported by the well-studied current system of the region. North of Cape Cod low water temperatures result from the southward flow of a small portion of the Labrador current which continues through the summer months (Halvorson and Dawson, 1974). The region south of Cape Cod including Martha's Vineyard, Buzzards Bay, Narragansett Bay, and Long Island Sound are protected from the cold water diverted by the Cape and are subsequently warmed by the northward-flowing Gulf Stream. In addition, the southern waters are generally shallow, permitting a quick response to atmospheric and seasonal changes (Halvorson, et al., 1974).

Beach and tidal marsh vegetation exhibits a much more cosmopolitan distribution than the benthic flora in the region from Sandy Hook to Eastport. The tidal marsh grasses, particularly Spartina alterniflora and

Spartina patens as well as Distichlis spicata, Salicornia and Juncus gerardi occur from Nova Scotia to Texas (Cooper, 1973) The species composition of the beach communities is fairly uniform-along the East Coast of the United States. The submergent grasses Zostera marina (eel grass) and Ruppia maritima (ditch grass) are common throughout the temperate regions of the world.

An examination of the coastline of the region suggests that the variations in topography are a second important factor influencing the distribution and abundance of certain floral communities, particularly benthic algae. The area of northern New Jersey is essentially sandy with salt marshes behind the beaches or adjacent to estuaries. Stone jetties and pilings are scattered. Thus the predominant species of benthic algae are those which grow on shells, mud, or eelgrass, since few species of algae are able to attach to a sandy substrate. In the vicinity of Long Island Sound the presence of rocky reefs and stretches of boulders affords an increase in the benthic flora. In this area Laminaria, a kelp, is abundant in deeper water and two other browns, Ascophyllum and Fucus, are abundant on rocky surfaces.

The southern coast of Connecticut is a mixture of sandy beaches and rock outcropping, while the southern shore of Rhode Island is dotted with sandy barrier beaches and protected salt ponds. In the area of Narragansett Bay, Rhode Island, large rock outcropping produce a dramatic change in the abundance of benthic algae. Cape Cod presents another long sand barrier, but the presence of scattered boulders supports a much richer benthic flora than the New Jersey shore. North of the Cape, sub-arctic species gradually displace the boreal species of the south as rocky reefs and cliffs with tide pools become a distinctive feature of the shore. Long stretches of boulder-strewn beaches are common. Salt marshes diminish in frequency and the tidal range increases from 10 to 20 feet or more (Taylor, 1957).

The changes in both topography and temperature in the vicinity of Cape Cod produce a transitional zone rather than a sharp geographic boundary in the distribution of benthic algae and other floral types.

11.2 DISTRIBUTION OF MAJOR FLORAL GROUPS

In the region between Sandy Hook and Eastport several marine habitats have been defined, each with distinct floral communities. These habitats include sandy beaches, salt marshes, rocky shore, and salt ponds. The vegetation of the sandy beach consists of a variety of herbs or grasses such as the beach grass, Ammophila breviligulata. The flora of the salt marsh community is composed of a mixture of grasses, sedges, and rushes. The rocky shore habitat is dominated exclusively by benthic marine algae, while the salt pond flora includes well-established stands of the shallow

submergent grasses, Zostera marina and Ruppia maritima, as well as a diverse mixture of benthic algae.

Certain floral distribution patterns are evident in each of these habitats. The composition and pattern of distribution of the species in any habitat results from the environmental conditions dominant in the specific habitat. These include tidal range, salinity, light, wave action, substrate, and several other related factors. Each habitat can be easily partitioned into a series of distinct zones. A zone is by definition a region which exhibits uniformity in structure and composition in the presence of a given set of environmental conditions. The zone or plant communities which are described for the marine habitats examined have a well-defined structure with recognizable dominant and sub-dominant species. Typical distribution patterns for the sandy beach, salt marsh, and rocky shore are shown in Tables 11-1 to 11-3. The sandy beach pattern shown in Table 11-1 consists of four zones. The littoral zone or surf zone is generally devoid of vegetation. A narrow fringe of Cakile edentula or sea rocket forms at its upper margin and represents zone II. A dense grass community of Ammophila on the top and lee side of the primary dunes forms zone III which is followed by a heather-shrub. zone.

A typical New England tidal marsh is shown in Table 11-2. In the tidal marsh there is daily tidal flooding of the first zone containing Spartina alterniflora. The second zone of Spartina patens is only periodically flooded by spring tides or storm tides. The upper zones III and IV are flooded only during severe storm conditions.

The rocky shore is generally divided into three zones as shown in Table 11-3. Representative species for each of these zones in both the northern sub-arctic region and the southern boreal region are shown. In both areas there are species in common. The greatest species differences occur in the mid- to sub-littoral zone where diversity appears to be greatest.

The uniformity of conditions in the sub-littoral region of the salt pond makes recognition of a vertical zonation pattern difficult. The sub-littoral zone is frequently dominated by dense beds of eelgrass with characteristic epiphytes.

Both physical and biological factors influence the composition of each zone. In the sandy beach habitat plant species in the middle beach zone exhibit an extreme xerophytic character. Their succulent nature permits survival in a very porous soil of drifting sand within range of intensive salt spray. Cakile edentula, especially abundant in this zone, is particularly well-adapted, with a long branching taproot which catches sand during dune buildup. Salsola kali, another succulent, is also found in this zone (Harshberger, 1900). The dune grass community covers only

Table 11-1 Species distribution on a sandy beach

LITTORAL ZONE I	UPPER LITTORAL ZONE II,	SUPRALITTORAL ZONE III	UPPER BORDER ZONE IV
Devoid of vegetation	Cakile edentula	Ammophila breviligulata	Hudsonia tomentosa
		Scattered species:	Scattered species:
		Lathyrus japonicus Solidago sempervirons Xanthium echinatum	Strophostylis helvola Scirpus sp. Panicum virgatum Gerardia maritima Rhus capallina Myrica cerifera Baccharis halimifolia

Source: Halvorson and Dawson, 1974

Table 11-2 Species distribution in a New England tidal marsh

LITTORAL ZONE I	UPPER LITTORAL ZONE II	SUPRALITTORAL ZONE III	UPPER BORDER ZONE V
Spartina alterniflora	Spartina patens	Juncus gerardi	Panicum virgatum
Scattered species:		Distichlis spicata	
Limonium carolinianum		Scattered species:	
Salicornia sp.		Spergularia marina	
Plantago juncoides		Suaeda maritima	
Suaeda maritima		Plantago juncoides	
Distichlis spicata		Distichlis spicata	
		Solidago sempervirens	
		Aster subulatus	
		Gerardia maritima	
		Salsola kali	
		Sabatia stellaris	

Sources: Halvorson and Dawson, 974
Cooper, 1973
Martin, 1959

Table II-3 Species distribution on a rocky shore

INFRALITTORAL	LITTORAL	SUPRALITTORAL
ZONE I	ZONE II	ZONE III
Northern Region Species:	Northern Region Species:	Northern Region Species:
Laminaria agardhii Laminaria digitata	Fucus spiralis Fucus vesiculosus Fucus edentatus Ascophyllum nodosum	Calothrix crustacea Plectonema sp.
Southern Region Species:	Sub-zone:	Southern Region Species:
Laminaria agardhii	Chondrus crispus Corallina officinalis Alaria esculenta Rhodymeniapalmata Chordaria falgelliformis Halosaccion ramentaceum Leathesia difformis Pylaiella littorals Cladophora sp. Hildenbrandia-prototypes	Calothrix crustacea Prasiola stipetata Enteromorpha intestinalis
	Southern Region Species:	
	Fucus edentatus Fucus vesiculosus Ascophyllum nodosum	
	Sub-zone:	
	Dumontia incrassata Scytosiphon lomentaria Enteromorpha linza Gigartina stellata chondrus crispus	Ulva lactuca Rhodymenia palmata Ralfsi verrucosa Bangia fuscopurpurea Blidingia minima

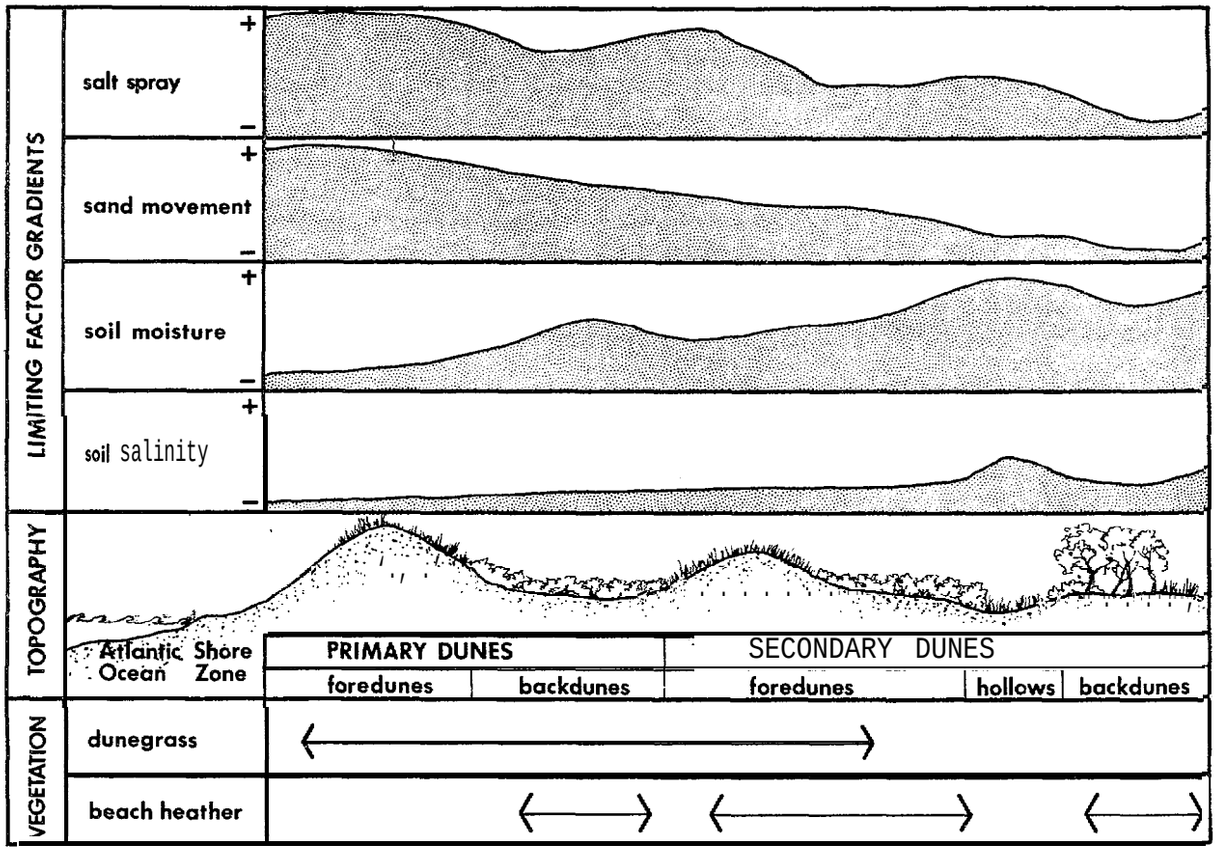
Sources:
TRIGOM Pub. 2A, 1973
Halvorson and Dawson, 1974
Stephenson and Stephenson 1972

8.4 percent of the top and lee sides of the dunes. The remainder is bare sand. The vegetation includes Ammophila which contributes 82 percent of the cover and Solidago sempervirens, Cakile edentula, Euphorbia polygonifolia, and Lathyrus japonicus, which make up the balance. Ammophilia is well-adapted to areas of extreme conditions including high exposure to salt spray, wind erosion and deposition, very low moisture, and temperature extremes. Behind the dunes-about 30 percent of the sand has a cover of vegetation. Beach heather forms low, sprawling cushions which spread radially along the ground, providing about 90 percent of the total cover. Other species include Cladonia sp., Panicum virgatum, Cyperus grayii, and Lechea maritima. These species survive best in protected areas of the dunes where they are shielded from wind and salt spray. Their xeric character makes-them well adapted to the very dry character of this zone.. In some cases species in the region of high to moderate salt spray exhibit a stunting of the terminal growth and well developed low spreading growth shapes. The interrelationship of the most significant factors influencing community types in the sandy beach habitat are shown in Figure 11-1 (Martin, 1959).

In the tidal marsh, environmental influences exert strong selective control over the composition and extent of each floral zone, particularly the influences of tide, salinity, drainage, and temperature. In the littoral zone normal tidal flooding produces salinities ranging from 20-40 O/oo and temperature fluctuations of 10 C per day. In general the east coast marshes have a gentle slope with a wide littoral zone. Peat is frequently the substrate and occasionally silt mixed with plant debris. There is a great interdependence between the tidal marsh and adjacent estuarine waters. The tidal flow distributes important nutrients and tends to flush the marsh of smothering plant debris. Spartina alterniflora, the dominant species in the littoral zones, appears extremely well adapted to the prevailing conditions. It is the most tolerant of all the' grasses to tidal fluctuation and associated oxygen stress (Cooper, 1973). It covers nearly two thirds of the upper portion of the littoral zone in the New England marsh. It requires a stable substrate and a minimum of wave action (Redfield, 1972).

The most significant factor in the segregation of salt marsh vegetation is regular tidal flooding. Periodic flooding of the high marsh prevents invasion by upland vegetation (Redfield, 1972). Species in the upper or high marsh have a lower salt tolerance than S. alterniflora. Juncus gerardi, Distichlis spicata, Salicornia sp., and Spartina patens are all generally restricted to the flattened areas above the normal high tide line (Cooper, 1973). These usually occupy the barrier zone between the aquatic and terrestrial communities.

In the rocky shore habitat tides, wave action, exposure, salinity, temperature, and seasonal events are the major environmental influences in determining zone composition and structure. The supralittoral zone under-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PRIMARY DUNES
SECONDARY DUNES
foredunes
backdunes
foredunes
hollows
backdunes
VEGETATION
dunegrass
beach heather

goes periods of intense heating and drying. Only those species such as Calothrix are able to tolerate the intense dessication above the high tide line. The wave exposure has a direct effect on the width of each zone. On high exposure rocky shores, the zones tend to be broader and extend higher than those on more protected coves and harbors (Villalard, 1971). Fucus and Ascophyllum dominate in the intertidal zone where wave action and dessication, though less severe than in the supralittoral zone, still present great hazards to more delicate species. These two species are firmly attached to the rocky surfaces and show a dense growth pattern which reduces dessication. At the lower end of the tidal zone where rock formations often create protected pools, a band of Chondrus crispus (Irish moss) forms a subtidal zone adjacent to the subtidal band of Laminaria typical of northern rocky shores. These species are tough, resilient, and firmly attached, but require more continuous exposure to water (Halvorson and Dawson, 1974). Mathiessen and Burns (1971) noted that Chondrus crispus growth increases in areas of swift currents. In the lower littoral and subtidal zones the effect of the breaking surf is less pronounced. Other species which are frequently found intermixed and often as epiphytes in these zones appear to benefit from the protection afforded by the more well-attached species. Other factors which influence the uniformity and composition of a zone are exposure and attitude of the rocky surfaces as well as the level of light intensity.

The salt pond habitat exhibits some vertical species distributional a result of decreasing light intensity with increasing depth. In addition, there is often a distinct local distribution geographically in the pond from salinity variations. Fresh water flowing into the ponds may produce extremes of 35 O/oo to 2 O/oo in adjacent areas. Wright, Cheadle, and Palmatier (1949) have described the general distribution of algae in coastal ponds of Rhode Island in relation to their salinity tolerance. They identified 65 percent of the species as marine and 35 percent as fresh water species. These include Ulva lactuca which is a euryhaline species and Ceramium rubrum, a red algae which is limited to the high salinity areas near the ocean access to the pond.

11.3 EFFECTS OF MAN-INDUCED STRESS

In some parts of the world coastal vegetation has long been regarded as an important natural resource. Plant materials have been harvested for a variety of purposes. In Europe the dried fibers of eelgrass, Zostera marina, have been harvested for use in explosives of the gun cotton type. It has been used as fuel, as a source of salt and soda, in packing and upholstery, and as compost. In the United States from 1913 to 1927 production reached 5000 tons per year at a value of .$20-$30 per ton. In 1955 Nova Scotia produced 2 million square feet (Phillips, 1969).

Several species of algae common to rocky shores have been utilized by

man. Chondrus crispus, also known as "Irish moss" is the most important commercial seaweed. In some areas it is harvested at a rate of 1200 lbs. per tide. It is used as a food as well as a source of agar, carrageenin, and other extracts. Materials obtained from this species are used in dairy and bakery products, processed meats, fabric and leather finishing, lotions, medicinal products, and fertilizers. Marine Colloids, Inc. of Rockland, Maine, is a principal producer of GELCARIN used by other industries (Round, 1966 and Dawson, 1966). The harvest of Chondrus in Nova Scotia has increased from 50,000 lbs. in 1941 to over 17.1 million lbs. in 1958.

Laminaria, Ascophyllum, and Fucus are used by coastal farmers as fodder for cattle, pigs, sheep, and poultry in 5-10 percent feed mixtures. Plants are also collected for use as fertilizers by local residents in many coastal communities. In addition, these species are especially rich in the alganites, fucin and algin, which are commonly used as emulsifiers and jelling agents (Round, 1966).

The coralline algaes Chara and Lithothamnion have been used as sources of lime by coastal farmers, and Ulva lactuca is used as both a food and a fertilizer in certain regions (Round, 1966). Marsh grasses, especially salt hay and meadow hay, have been harvested for hay, bedding, and garden mulch for centuries.

The extent of man's exploitation of these coastal species is difficult to assess because many harvesting activities are limited to local communities. The impact of commercial operations has not yet been evaluated. A more serious threat to the integrity of these plant communities involves other types of man-induced stress. These include mechanical disturbances such as dredging, ditching, filling, or spoiling, catastrophic events such as an oil spill , and finally, long-term sewage or pesticide contamination.

Mechanical disturbances have probably been the most destructive processes to date. Salt marshes have undergone the greatest permanent damage. Between 1954 and 1965, 47,000 acres of salt marsh from Delaware to Maine were permanently destroyed by dredging and filling activities. In Connecticut since 1959, 45 percent of the total 36.5 square miles of marsh in the state have been destroyed (Cooper, 1969). Dredging frequently results in silting of the marsh and almost immediate death of the fauna. The damage to vegetation is sometimes partially alleviated by tidal flushing, and some recovery may occur. Mosquito control practices frequently employ ditching or "drying" techniques. Bourn and Cottam (1950) reported that in a marsh with a coverage of 90 percent Spartina alterniflora, ditching in 1936 resulted in its almost complete replacement with Baccharis halimifolia (sea myrtle) and Iva frutescent (marsh elder) within five years. This phenomenon is attributed to the reduction in tidal penetration because of the ditches. Diking programs in salt marshes in Florida and

New Jersey have significantly altered the flora of the upper marsh by impounding fresh water above the high tide line. This practice has led to a surge in the growth of Typha and Scirpus, both considered more productive in wildlife management practices (Cooper, 1973).

In some states, land reclamation programs have led to the filling of marsh land for residential or commercial use in densely populated areas. Other marshes have been permanently altered by over-enrichment from sewage runoff. Salt ponds like Moriches Bay on Long Island have suffered heavy sewage and agricultural waste pollution, resulting in a steady decline in productivity as anaerobic conditions intensify. Recently some studies have been made on controlled enrichment of marshland with treated sewage. Valiela, Teal and Sass (1973) report some success in stimulating growth of marsh grass with applications of 25 g per meter^2 of commercially treated sludge at hi-weekly intervals. They found that about 28 percent nitrogen and 45 percent P_2O_5 is readily available. The remainder is slowly decomposed and released. Tidal washing further reduced the effective fertilization by about 20 percent nitrogen and .9 percent P_2O_5. Their studies indicate that as much as 110 g N per m^2 per year could be applied to produce maximum growth of Spartina (Teal and Valiela, 1973). Possible detrimental effects such as the concentration of heavy metals, insecticides, and modification of the species of microscopic algae in the marsh should be evaluated before such enrichment programs are used on a large scale.

An oil spill also remains a potentially damaging event to any coastal vegetation. As Gilbert points out in her discussion of salt marshes in this volume, an oil spill in Chedabucto Bay, Nova Scotia, virtually eliminated Spartina alterniflora in the very heavily oiled areas. The oil from this spill persisted on flats adjacent, to the marsh for two years causing repeated oilings of the rhizomes and eventual death of the grass.

While it is difficult to evaluate all possible sources and effects of man-induced stress on coastal vegetation, it seems evident that any activities which disturb the environment in a marine community are likely to modify the species composition.

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11.5 LIFE HISTORY DESCRIPTION OF KEY SPECIES

11.5,1 Ascophyllum

Ascophyllum, one of the rockweeds, is a member of the Phaeophyceae or brown algae, the order Fucales, and together with Fucus constitutes the family Fucaceae along the northeastern coast of North America.

Taylor (1966) lists Ascophyllum nodosumm (Linnaeus) LeJolis, and forma scorpoides (Hornemann) Reinke as well as A. mackaii (Turner) Helms and Batters. A. nodosum grows essentially In the intertidal zone from New Jersey to Hudson Straight and is a major component of the algal flora on rocky shores. The plants may reach a length of ten feet under favorable conditions, They are attached by a large disciform holdfast from which arise one or more strap-like cartilaginous axes which branch in an irregularly pinnate manner.

In contrast to Fucus it has no midrib but produces a number of large, irregularly placed float bladders. Like Fucus, Ascophyllum has a high degree of histological differentiation. A large number of short branchlets arise near the tips of the major branches and give rise to oval yellow receptacles 1-2 cm long and 5-12 mm wide. The plants are dioecious. Within the male conceptacle numerous antheridia develop. Each mother cell carries on meiosis and eventually produces a number of biflagellated sperm cells. Plants bearing female conceptacles produce mother cells, each of which carry on meiosis and give rise to four large egg cells. The conceptacles are shed into the waters in the spring and release the sperm and eggs which unite, and the zygotes settle on solid substrates. Here they develop into normal diploid plants. The first cell division gives rise to two cells. One cell, by further division, forms the basal multicellular holdfast. The second cell gives rise to the remainder of the plant. New cells are cut off from the apical cells and differentiate to form the histologically complex tissues. Chapman (1962) illustrates the sequences of cells developed from the apical cells.

Ascophyllum nodosum forma scorpoides is known along the coast from New Jersey to Nova Scotia. Found on mudflats, in salt marshes, along tidal ditches, and more often entangled in plants in marine wetlands, the plants are thin, highly branching, without an evident main axis. Very few receptacles are developed.

Along the coast of Maine, scorpoides is utilized as packing material for shipping marine worms and lobsters to market.

A. mackaii has a rather narrow distribution in Connecticut and southern Mas sachusetts. They are floating or creeping plants of the tidal flats and marsh edges. The plants have no holdfasts, the branching is rather irregular, and blades are small. The receptacles are forked, thin, and usually curved. Fruiting is in late winter or early spring.

Ascophyllum nodosum harbors several epiphytes. Taylor lists the following species:

Ectocarpus tomentosoides Farlow
Elachistea lubrica Ruprecht
Lithophyllum macrocarpon (Rosanoff) Foslie
Porphyra umbilicali (L.) Agardh
var. epiphytica Collins
Spongomorpha spinescens Ruprecht

Almost every plant bears the red alga, Polysiphonia lanosa (L.) Tandy. It has been regarded as an epiphyte although some observers believed it to be a parasite. Electron microscope studies by Rawlence and Taylor (1972) appear to give clear evidence that P. lanosa is parasitic.

Scraping the surfaces of Ascophyllum yields a diatom flora, but little attention has been paid to it. A considerable number of invertebrate animals such as arthropods, molluscs, and worms are present on and among the vegetative materials.

Although Ascophyllum is firmly anchored to the substrate, great masses of the alga are detached by winds, storms, high tides, and ice cover. Much of the algal mass is washed ashore along with other sea weeds. Random observation indicates that Ascophyllum contributes the larger fraction of the mass. Untangling the mass reveals that a large number of marine animals, including arthropods, molluscs, worms, birds, small mammals; and even domestic animals sometimes feed upon this debris. Remains of fragmented plant material may be washed into the waters giving sustenance to many marine animals. No quantitative estimate of this contribution has been made.

Vadas (1972) and his assistants studying the marine algae of the Montsweag-Back River area over a three-year period have made the most complete ecological assessment ever made on the coast of Maine, and perhaps in the whole area covered by Taylor. Although a large number of species were studied, Ascophyllum was the dominant member of the assemblage.

Chief attention was concentrated on the distribution, percent of cover, growth rates, and mortality. Without going into detail, it was noted

that growth of appreciable amounts occur in late April. In May-June growth rates were in the order of 2-6 percent and in July-August 1-3 percent, and lower rates occurred during the winter months. Temperature, light, and salinity were the most important factors involved in the growth patterns.

Annual growth in terms of length of branches fluctuated from 100-175 millimeters. Plants may survive for eight years and occasionally longer. In the upper and middle tidal zones, dry weight ranged from several hundred grams to several thousand grams per square meter.

Ascophyllum survives better and is more productive in the estuaries than along the open seacoast. The actual coastline of Maine is very long as a result of the presence of hundreds of irregular estuaries, bays, coves, and inlets. The dominance of Ascophyllum in the Montsweag-Back River estuary suggests that it may be the most productive alga all along the coast.

Chapman (1970), Duddington (1966), Round (1965), and Stephenson (1968) discuss the chemical makeup of the species. It has the capacity to concentrate iodine up to 220 times the amount in sea water. Sodium and potassium are also concentrated to a high degree. Vitamins B_1, B_2, B_{12}, C, D3, E, K, pantothenic acid, and niacin are present also.

Like Fucus the plant has been used as a food for livestock and poultry, as bedding for domestic animals, and as a mulch or fertilizer in many parts of the world.

Walker and Smith (1948), growing Ascophyllum in pure culture and with various other algae, observed that the gametophytes of Laminaria did not flourish. They suggested that the production of an antibiotic by Ascophyllum might explain the lack of overlap of the two genera.

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11.5.2 Fucus

The genus Fucus is a member of the Phaeophyceae or brown algae, the order Fucales, and together with Ascophyllum constitutes the family Fucaceae along the northeastern coast of North America.

Taylor (1966) lists the following species:

F . filiformis Gmelin
F. spiralis L.
F.. vesiculosus L.
F. evanescent C. Agardh
F. edentatus Dela Pylaie

He also recognizes some varieties in each of the species except filiformis.

The plants are essentially found in the intertidal region where they generally occur in abundance on rocky shores, F. edentatus occurs at the lower level and filiformis at the very top of the tidal range. The others occur in the order shown above. F. filiformis is not abundant in the United States. The other species-are usually prominent.

Recently some Canadian algologists have proposed a rearrangement of the species. South suggests the following:

F. distichus L.
subsp. distichus
subsp. edentatus (Pyl.) Powel 1
subsp. evanescent (C. Hg.) Powell
F. spiralis L.
F. vesiculosus L.

The plants are closely attached to a solid substrate, usually rocky ledges, by a strong holdfast. The main body is a dichotomously flattened, dichotomously branched growth. Prominent midribs occur in some species. Growth in length proceeds by divisions of apical cells whose derivatives enlarge and differentiate to form a complex histological body. Under favorable conditions some species may" attain a length of two meters.

Enlarged tips of branches called receptacles contain a large number of scattered protuberances. These are known as conceptacles and are really cavities within the receptacle, which has a small opening, the ostiole. Within the globular conceptacle a number of bushlike branching filaments arise from the wall cells of the conceptacle. Certain cells at the tips of the filaments form antheridea, or male gamete-producing bodies. A diploid nucleus within the antheridium undergoes meiosis followed by mitotic divisions until 64 laterally biflagellated sperm cells are formed. Other cells in the conceptacle may form oogonia within which the diploid nucleus undergoes meiosis followed by mitotic division until eight egg cells are formed. The antheridea and oogonia are discharged through the ostiole. The gametes are set free in the water. The large, spherical eggs are not motile. The sperm cells swarm about the egg and one penetrates the nuclei until forming a zygote which has the diploid number of chromosomes. The zygote divides mitotically and gives rise to a new plant.

Fucus vesiculosis and F. spiralis produce both antheridia and oogonia in the same conceptacle. The other species referred to have separate male and female plants.

After fertilization the zygote quickly develops a gelatinous cell wall which causes it to stick to any object on which it happens to land. The zygote undergoes mitosis. One cell gives rise to the holdfast by a series of cell divisions. The other cells eventually form the remainder of the plant body.

There does not seem to be any detailed published account of organisms epiphytic on Fucus or which graze upon it. Elachista fuciola (Velley) Aresch is a very prominent brown algae epiphyte. In addition, Taylor (1966) lists Spnaceiaria fusca (Hudson) C. Agardh and Lithophyllum pustulatum (Lamouroux) Foslie. A considerable population of diatoms may be obtained by scraping the surface of Fucus but little attention has been paid to these. A goodly number of species of small arthropods, molluscs, and worms may easily be gathered by shaking Fucus plants in a pail of water. Presumably they receive both protection and food in this habitat.

Plants are torn from the sites by winds, storms, and high tides. One may find considerable deposits of Fucus, Ascophyllum, Ulva, and a variety of other species of marine algae piled up on the beaches. This detritus may be consumed by such large animals as' moose, deer, rabbits, and even domestic animals. In addition, molluscs, arthropods, and worms may be

seen feeding on the stranded algae. In an earlier day coastal farmers used some of this material as a mulch or as a fertilizer. This practice still prevails in many parts of the world. In many foreign countries farmers feed pigs, cattle, and chickens directly with this material, or they may utilize meal by mixing the algae with other types of food.

Much of this material does not reach the beaches and lies in shallow waters where, presumably, a variety of marine animals feed upon it. In so doing many fragments are formed which may be used by a whole series of smaller animals.

Fucus, Ascophyllum, and a variety of kelps have been used as fertilizers for centuries in many parts of the world. Gathered from the shores they were ploughed in as a green manure. In European countries a variety of domestic animals have been fed diets including ground up seaweeds. This practice was also utilized by early settlers in New England and Canada: The proteins, vitamins, especially A and B, and antibiotics and the high concentrations of iodine as compared to that of sea water have made Fucus and its relatives very useful. Chapman's "Seaweeds and Their Uses" summarizes their many contributions to health, medicine, and the economy.

Relatively few studies of productivity have been made but some data from Nova Scotia indicate a high rate. MacFarlane (1952) shows the fresh weight may be as high as 32 kg/m^2, a rate comparable to the situation in kelps. Westlake (1963) estimated productivity of 640-840 grams/C/m^2/year. Kanwischer (1966) notes that intertidal seaweeds such as Fucus and Ascophyllum may occasionally have rates of production comparable with kelps. Fucus may double its weight in 5-10 days in certain seasons. Under conditions of rapid removal by wave action or browsing by animals, production rates as high as 1000 grams/C/m^2/year may occur.

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11 .5.3 Chondrus crispus

The species is usually placed in the following categories, Division Rhodophyta, Class Rhodophyceae, Subclass Florideophycidae, Order Gigartinales, and Family Gigartinaceae. It is commonly known as Irish moss. Some refer to it as carrageenan, although this really is the name of a chemical common to a number of genera of algae. It has long been known that it is a highly variable species and several formae have been named but there is uncertainty whether these variations are ecological or genetic.

The species ranges from New Jersey'to Nova Scotia, Prince Edward Island, and Newfoundland, as well as from Spain to Norway, including the British Isles. It grows attached to solid objects such as rocks, woodwork, and marine shells. On exposed coastal areas it grows throughout the intertidal. It is more abundant from the low water mark to depths of about sixty feet. Water transparency appears to govern the depth of the growths. In general it has a broad tolerance of different intensities of light, salinity, and temperature.

A number of observers refer to the competition for space by such genera as Ahnfeltia, Corallina, Furcellaria, Gigartina, and Phyllophora. In addition, a number of species of red, brown, and green algae are epiphytic on Chondrus. Several species of bacteria and fungi have been observed as parasites on the species.

At least fifty species of animals have been found on the fronds of Chondrus. Bryozoans, echinoderms, polychaetes, snails, and a variety of arthropods are among the most abundant of the smaller organisms. Crabs, sea stars, mussels, and especially sea urchins take a heavy toll.

Plants attach very firmly to the substrate by means of a disc-like crustose holdfast. Numerous fronds in various stages of development arise from the holdfast. As the young blades increase in length they branch dichotomously and become flattened with widths of 3-6 mm. Mature plants may reach a length of 15 cm. The fronds are very variable in width, and variously curled, twisted, fan-shaped, or stellate. The dense clumps are generally a dark purple-red, although they may become yellow-green in the summer. Rates of growth vary considerably, both seasonally and geographically.

The internal anatomy of a frond is rather complex and is made up of colorless cells. An inner cortex surrounds the central region and is a storage area for the floridean starch grains. The outer cortex is made up of densely branched filaments composed of small cells containing pigmented plastids. Photosynthesis takes place in this assimilatory tissue. An outer sheath covers the surface of the frond. Each of the layers shows a considerable amount of differentiation.

The life cycle is rather complicated and has attracted the attention of many field investigators, In addition, Chen and McLachlan (1972) have demonstrated the life cycle in culture and confirm the observations which have been made by a variety of students of the red algae.

Involved in the life cycle are isomorphic plants known as tetrasporophytes, male gametophytes, female gametophytes and carposporophytes. Fertilization and meiosis occur in the cycle. Magne (1964.). reports the haploid chromosome number is 30 and the diploid number is 60.

The tetrasporophytic plant produces dark red sori borne on both sides of the frond. The diploid cells within a sorus undergo meiosis and pro-" duce four haploid tetraspores.

Tetraspores freed from the sporangia produce haploid male and female gametophytes. The male gametophytes produce small, branched, colorless or white sori near the tips of the branches. These contain antheridial cells enclosing a tiny single male gamete (spermatium). Strangely enough for an aquatic group, none of the red algae have either cilia or flagellae in their life cycles. Male plants appear to be rare in some regions and where present occur at different seasons in various geographic areas. The female organ which develops from an apical cell of a filament in the female plant is known as a procarp. It has the general appearance of a volumetric flask. The swollen basal portions, the carpogonium, contains a single haploid nucleus. The neck of the procarp is the trichogyne. A spermatium in contact with the trichogyne enters the tube, descends to the carpogonium and units with the basal nucleus to form a zygote. This Undergoes nuclear division and each of the diploid products divides many times. Simultaneously a number of filaments arise from the carpogonium. A diploid nucleus moves to the tip of each filament, is cut off by a wall, and becomes a carpospore. Additional carpospores may be formed in a similar manner, Carpospores germinate to form the tetrasporic plant. The cells supporting the procarp, the carposporic filaments, and a number of sterile cells surrounding the carposporic filaments are collectively known as the carposporophyte. Many carposporophytes may develop on each plant and may be present the year round.

HARVESTING CHONDRUS

One of the editors, J. M. McLachlan (1973) of Chondrus crispus, published by the Nova Scotia Institute of Science, make the following statements concerning the harvesting of the Irish moss:

> The cover of this volume serves to illustrate how unevenly the Irish moss field has developed (shows skiffs and rakes of the harvesters). Sophisticated scientific procedures have been deployed in attempting to elucidate the structure of

carrageenans. Yet in parts of the Maritime Provinces the moss is currently harvested by hand-raking from dories, a practice which would have been appropriate several centuries ago. Regretably we still know very little about the effects of harvesting on the Chondrus or the rest of the biological community. There is concern, and quite rightly so, for the natural resource and conservation of this resource.

Generally speaking, this primitive form of harvesting is still practiced all along the northeastern Atlantic Coast. Rather small boats are in use and the harvester has a modified rake with a 12-foot handle by means of which he scoops up the growths.

Most of the harvesting is done in waters down to five or six feet below mean low tide. Experienced harvesters may gather as many as 1200 pounds per tide in the most favorable growing areas. Winds, waves, currents, storms, and exposure may mitigate against frequent harvesting in a goodly number of the highest yielding areas. Yields of 500-600 lbs. per tide are common in many areas while others yield as little as 100-200 lbs. The experience, skill, and strength of the harvester are important factors in determining the quantity harvested.

Chondrus is the most important commercial seaweed on both sides of the Atlantic Ocean. It has a great variety of uses. Especially in France and the British Isles the Irish moss has been user! as a food for ages. Immigrants from Ireland to the United States in the eighteen thirties introduced its use along the Massachusetts coast. The waters in the Scituate-Plymouth area were especially productive and provided a fine source of income for the inhabitants. Maine has been an important producer also. Canadians, especially in Nova Scotia and Prince Edward Island, have studied it and utilized it in many ways over a long period of time. Marine Colloids located in Rockland, Maine, has been the principal exploiter of this versatile organism.

Chapman (1970) lists some 88 uses of chemicals derived from Chondrus which are used in foods for man. Their versatility is suggested by the following major headings: dairy, beverages, bakery, confectionery, dressings and sauces, dietetic foods, meat and fish, and miscellaneous. In addition, Chondrus and other algae have been utilized in feeding a variety of domestic and farm animals.

Chondrus has quite a number of other uses also. It is important in the textile industry as a stiffening and binding material and to provide a gloss finish to leather goods. Many toothpastes, hand lotions, shaving soaps, and hair creams contain materials from the moss. It is used to some extent in medicine as an anti-coagulant for blood, poultices, irritations of the alimentary canal, a vermifuge, urinary disorders, and in cases of diarrhea and dysentery. Coastal people have used it as a fertilizer for it provides both humus and a variety of chemicals necessary for the growth of plants.

Harvey and McLachlan (1973) include a chapter on the physiology and biochemistry of the species. This is too detailed to review here but it is clear that a great deal of valuable information has been accumulated. A list of the major categories studied in detail includes lipids, nitrogen constituents, organic acids, pigments, proteins, steroids, sugars, vitamins, and cellulose and ash constituents? This data is of great importance in commercial applications and in studies of aquiculture and ecology.

Lamb and Zimmerman (1964) surveying the marine seaweeds at Cape Ann, Massachusetts, observed beds of Chondrus extending to a depth of 60 feet. Matthiessen and Burns (1971), observing the algal flora of the New Hampshire coast, noted more abundant growths in areas in which currents were swiftest.

Foster (1954-56) and co-workers in a series of comprehensive studies over a period of several summers along the coast of Maine from Orr's Island to Washington County have contributed a great deal of important information to our understanding of this valuable species. While primarily concerned with the practical aspects, such as availability, distribution, harvesting, and productivity, these matters do involve such factors as substrates, light, temperatures, winds, waves, tides, currents, and the organisms associated with Chondrus.

Samples were taken from June through September. Growth was measured by pounds (wet weight) per square yard. In all areas greatest growth occurred during June and July. Growth was very variable throughout" the harvesting season and in every area studied. Re-harvesting in some of the areas later in the season indicated re-growth ranging from 15 to 50 percent.

Some limited studies on the germination of spores and the growth of sporelings have been published by a variety of investigators.

In addition, Neish and Fox (1971) in Halifax, Nova Scotia, have made a most interesting and significant study of the growth of detached plants under controlled conditions. It involves both ecological and genetic factors.

Detached plants without holdfasts were grown in culture tanks in a greenhouse from February to mid-December of 1970. They were supplied with running sea water at nearly the same temperature as water in the ocean and exposed daily to light for the same length of time as natural populations. Nitrogen was required to prevent bleaching to a yellow color. Calcium or sodium nitrate and ammonium nitrate prevented the loss of pigment and stimulated growth. Phosphates were supplied by diamonium phosphate or 20 percent superphosphate.

The authors conclude that in view of the current price Chondrus is not promising as a greenhouse crop where and when artificial illumination is needed.

However, natural light is sufficiently available for a five-month period (May-September). If the plants could-be grown in an area with water temperature at about 10 C and fertilized to a lesser extent, a 30-fold increase might be attained in a single season.

The Neish-Fox studies included dividing some plants and observing their growth rates over a period of almost a year. Some of the cuttings grew very much more rapidly than others under the same environmental conditions. Clone T-4 showed a 1,000-fold increase in slightly less than a year.

Proper control of environmental conditions together with the development of high yielding genetic strains combined with more efficient methods of harvesting could greatly increase the crop.

R. P. Choate (1970), acting as the coordinator of a research team, has summarized the result of a four-year study of Chondrus carried out largely in Casco Bay, Maine. Experimentation with underwater photography for surveying moss beds was conducted. Chondrus could not be distinguished from Phyllophora by the methods employed. Further experimentation might solve this and other problems encountered.

Using line-transect methods, nearly eight miles of coastline were surveyed along the east side of Bailey and Orr's Islands. An area of 490,000 square yards was sampled and estimated to contain 952,000 pounds of Irish moss. The lowest value per square yard was nine ounces, the highest 5.73 per square yard, with an average of 1.70 lbs. per square yard. Estimates indicated only 1/6 of the crop would be harvestable by raking. Probably less than 50 percent of this resource will ever be harvested, utilizing current techniques. This data points dramatically to the need for some sort of more efficient subtidal harvester.

In 1969, using plot size of 25 square feet, re-growth areas were studied. One plot yielded a re-harvest of 53 percent of the original harvest, a second produced 36 percent of the original harvest, and a third produced 149 percent of the original.

Much of the available data on both original productivity and renewal production, whether it be in Nova Scotia, Maine, or other areas, is based on small samples which show considerable variation. This suggests both the need for better sampling and better means of harvesting.

Choate's team found 37 drift holes in Casco Bay and a few in other areas. They were located by depth recorders and examined using scuba gear. They

are 25-40 feet deep-below the mean low tide base and may contain large quantities of algae, including Chondrus.

The Choate team has experimented for three years with an airlift system for. pumping drift moss. This kind of a system was utilized very successfully by the Department.of Sea and Shore Fisheries during the 1950's for transplanting huge masses of quahogs from one location to another. This technique along with scuba diving has great possibilities for harvesting Chrondrus. The Choate team found that under the crudest conditions, a diver may send up 600 pounds in an hour. Recall this amount as presently harvested using rakes requires a full tidal interval. With experience and improved equipment, a diver might double this quantity. Scuba diving combined with a. pumping operation would enable a team to reach large areas of the moss which have not been exploited.

Ricker (1969) compiled a useful bibliography on Chondrus crispus containing some 130 references. Campbell in Harvey and McLachlam (1973) lists more than 500 references in her bibliography. She observes that the list is not comprehensive inasmuch as some journals were not available.

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11.5.4 Laminaria

Laminaria is a member of the Phaeophyceae or brown algae, the order Larminariales, and the family Laminariaceae. Commonly known as kelps, the family also includes the common genera Agarum, Alaria, Chorda, and Sacchoriza.

Taylor (1966) lists the species L. cuneiformis, groenlandicum, and nigripes as growing in areas north Of the United States. L. agardhii occurs from New Jersey north to south Cape Cod, and is dominant south of Cape Cod and occasional in Maine and northern Labrador. In addition. forma" angustissina Collins is found to a limited extent in Casco Bay, Maine, and forma vittata Setchell occurs in Connecticut and southern Massachusetts. L. saccharin has been reported from northern Massachusetts to Canada, and forma caperta and phyllitis have been collected in Maine. L. longicruris De la Pylaie occurs from Connecticut to

Canadian waters. L. platymeris De la Pylaie is known from northern Massachusetts to Canada. L. intermedia occurs in Connecticut and southern Massachusetts and forma cucullata Foslie is known in New Hampshire, and forma ovata Foslie occurs in Connecticut. Laminaria digitata (Linnaeus) Lamouroux has been found on Long Island, Connecticut to southern Cape Cod, very commonly north of Cape Cod, and into the Canadian provinces, and forma complanata Kjellman is known from northern Massachusetts to Maine, and forma ensifolia is known from Long Island Sound to eastern Maine. L. stenophylla J. Agardh occurs from northern Massachusetts to Maine and Newfoundland.

Laminaria is a conspicuous cold water genus of the sublittoral area. The plants attach tenaciously to rocks or other solid surfaces. They often occur in large dense forests and, generally speaking, their sizes increase as they occur in more northerly areas. In some areas they are the dominant subtidal marine plants.

A plant consists essentially of three parts. The basal holdfast is a many-branched root-like growth which attaches so firmly that it is not easily dislodged. Arising from the holdfast is a stem-like portion known as the stipe which varies greatly in length in the several species. The uppermost section is referred to as the blade, In some species such as L. agardhii and L. longicruris the blade is one undivided unit whereas in a number of other species such as L. digitata and L. stenophylla the blades are cleft to a greater or lesser degree into numerous flat segments. Some species, including L. stenophylla (Kutzing) J. Agardh are annuals, while most species are perennials which may live as long as twelve years.

Unlike most seaweeds, they do not grow at the ends of their branches (Boney, 1966), but instead they have a cambium-like area which lies at the junction of the stipe and the blade. This produces new cells by mitosis and renews the blade in front and the stipe behind, and thus its position continually becomes more remote from the holdfast. As the blade is renewed from behind, the outer region of the blade is cast off, leaving a somewhat ragged edge.

Laminaria has a complex histological system. As new cells are added to the stipe, three areas are delineated. An epidermis is the outermost area and reminds one of the epidermis of higher plants. The central area, the medulla, is made up of unbranched filaments running lengthwise with connecting filaments running crossways. The cortex lies between the epidermis and the medulla and its cells remind one of those in the cortex of land plants. The cells of the medulla serve to conduct dissolved materials. Cells of the cortex contain numerous chloroplastids and are photosynthetic.

The cells of the plant we have described are diploid and thus the plant is the sporophytic stage in the life cycle. At certain seasons, depend-

ing on the species and the geographic location, large, dark, raised patches are recognizable on both surfaces of the blade. These are referred to as sori. A profusion of enlarged sub-epidermal cells now known as sporangia are responsible for this condition. In the early development of a sporangium, the diploid nucleus undergoes meiosis followed by a series of mitotic divisions producing 32-64 haploid nuclei. Cytoplasm surround each nucleus, a cell membrane develops, and each becomes a biflagellated zoospore. The zoospores are discharged into the water, undergo mitotic division, and become very tiny microscopic gametophytes. These bear lateral branches on which unicellular antheridia are formed. Each antheridium produces a single male gamete bearing a pair of flagellae. Other zoospores produce female gametophytes even smaller than the males, and any of its cells may develop into an oogonium containing a single egg. When ripe it is partially extruded through a pore in the wall of the oogonium. A male gamete fuses with the egg and the resulting zygote develops into a new sporophyte. At first it produces a uniseriate filament but with further cell division it forms a flat plate. Rhizoids arise from the plate and form the holdfast while other cells give rise to the stipe and the blade.

According to Kain (1969) both L. digitata and L. saccharin are capable of reproducing the year round. The former is especially fertile between May and November and the latter between October and March, Parke (1948) in Chapman found L. saccharin produced both zoospores and gametophytes reproducing all year round although they varied considerably with respect to the areas in which they grew.

Parke also noted the greatest cause of mortalities is by detachment of young sporophytes. Their survival depends both on the habitat and the time of germination. In the sublittoral zone in exposed situations the winter sporelings had 100 percent mortality during the first month. Spring sporophytes because of higher temperatures and the more rapid development of holdfasts had the highest survival rate. Summer and autumn sporelings survived only in the most sheltered habitats.

Walker and Smith (1948), growing Ascophyllum nodosum in pure culture and with various other algae, observed that the gametophytes of Laminaria did not flourish. They suggested the production of an antibiotic by Ascophyllum might explain the lack of overlap of the two genera.

Kanwischer (1966) and a number of other investigators in various parts of the world have made short-term studies of standing crops of seaweeds. They clearly indicate a high rate of photosynthesis during certain times of the year. For example, MacFarlane's pioneer work along the coast of Nova Scotia has shown standing crops of 20-29 kilograms of carbon per square meter.

Mann (1973) and his team carried out the first year-round study of productivity in kelps. The studies were made in St. Margaret's Bay, Nova

Scotia, utilizing a research submarine and scuba gear. A series of 24 kilometers of the bay were examined over a two-year period. Records were kept of the rate of growth at the bases of the blades of a large number of plants. Laminaria longicruris, L. digitata, and Agarum cribosum were utilized for they accounted for more than 80 percent of the total mass of seaweeds in the bay;

The kelps grow in dense forests to a depth of as much as 30 meters. They extend from low tide level for as much as six or seven miles on the gently sloping shores of the bay. The blades were in constant motion due to tides and wave action, resulting in great exposure to sunlight and a constant renewal of the necessary nutrients.

All three species completely renewed the tissue in their blades between one and five times a year. In addition, the plants grew wider and thicker as they aged. The increase in biomass was roughly proportional to the square of the increase in length. Thus, the biomass of new tissue produced annually was up to twenty times the initial biomass of the blade. Growth in length was rapid throughout the winter and reached a peak in late winter or early spring when the water temperature was close to zero degrees centigrade.

The ratio of annual production to initial biomass was greatest in young plants and for those nearer the sea surface. Weighted values of the ratio of production to biomass were calculated for each species, taking into account the relative proportions of young and old plants and the depth at which each species occurred. In the seaweed zone primary production averaged 1750 grams of carbon per square meter per year.

The total area of St. Margaret's Bay is 138 square kilometers. The average production of seaweeds over the whole bay was 600 grams of carbon per square meter per year. This is about three times the total production of phytoplankton of 191 grams of carbon per square meter according to Platt (1971).

Mann (1973). makes graphic comparisons of several marine genera in terms of net primary production. Listed in order of increasing productivity are (1) plankton of the open sea, plankton of the coastal zone, (2) Zostera in Alaska, Denmark, and the State of Washington, (3) mangroves in Florida and Puerto Rico, (4) Macrocystis in California, (5) Spartina in Atlantic North America, (6) Thalassia in the Caribbean and the Indian Ocean, (7) Laminaria in Atlantic Canada, and (8) Macrocystis in the Indian Ocean.

Odum (1959) presents a table of net 'primary production in grams per square meter per year for a number of cultivated crops and non-cultivated ecosystems. Considering the cultivated crops, wheat, oats, corn, rice, hay, potatoes, sugar beets, and sugar cane, values are given for the world

average and the averages in areas of highest yields. Mann's results with *Laminaria* indicated a higher yield than all but the Hawaiian results. In the non-cultivated group only the tall *Spartina* in Georgia and a stand of pine in England during its years of most rapid growth surpassed *Laminaria*.

Laminaria and other brown algae have been used in many parts of the world as food for domestic animals such as cattle, pigs, sheep, and poultry. Using them alone or as a 5-10 percent mixture with other plant products to form a meal have been the traditional methods. Rich in alganites, such as fucin and algin, they also concentrate a number of chemical substances including potassium, sodium, iodine, and nanitol. These substances have had numerous commercial uses. Chapman (1970), Duddington (1966), Stephenson (1968), Round (1965), and Zajic (1970) discuss these at some length. They also note the presence of vitamins including niacin, pantothenic acid, riboflavin, thiamine, and B_{12}, C, D_3, E, and F.

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11.5.5 Zostera marina var. stenophylla

Hartog (1970) in "Sea Grasses of the World" describes 12 genera with 49 species of marine seed plants. None of these belong to the Graminae but all are members of the Monocotyledonae in rather closely related families. Zostera marina, the "eel grass," is the only species represented on the. eastern coast of North America and ranges from North Carolina to Hudson Bay. Gray's Manual (1950) places it in the Najadales and the family Zosteraceae. Its general appearance is similar to that of some members of the grass family and thus the common names eel grass or grasswrack have been applied to this species, which is without doubt the best known of all the marine monocotyledons. Phillips (1964) listed 374 published papers concerned 'with the species and in 1974 that number might well be at least doubled.

It is the dominant vegetation of the soft bottoms of the intertidal zone and also occurs on firm sand and in a mixture of sand and gravel. Here it forms "meadows" which may also be extended into the subtidal area to depths of fifty meters according to Setchell (1929).

The plants are anchored in the substrate by means of creeping branching rhizomes up to a fourth of an inch in diameter. Year by year the interwoven rhizomes may extend into new areas. Internodes range up to a half inch in length. Small unbranched roots develop at the nodes, as do some basal leaves. Also, from the nodal region a shoot develops, bearing 6-8 tapering leaves up to half an inch in width and up to a meter or more in length.

The small highly reduced perianthelessunisexual flowers are borne in two rows on a stem within a leaflike spathe. The,staminate flower is reduced to one sessile anther bearing filamentous pollen. The pistillate flower is reduced to a single ovary bearing a short style and two slender stigma and encloses a single ovule. The fruit is 3 to 4 mm long, barrel-

shaped, and longitudinally ribbed. Dawson (1966) states that from 500-1000 fruits may be produced on a luxuriant plant in a season. Most of these are eaten by fish and waterfowl. Surviving seeds require 1 to 2 years to produce a healthy plant according to Dawson.

The fertile shoots are ephemeral and perish at the end of the season, while the prostrate shoots persist. The latter may become fragmented to some extent. Some fragments may settle in new areas and thus extend the beds.

The upright shoots which are shed may also be washed to other areas and consumed by a variety of animals. They may also be carried by tides and currents to the shores where they often occur in dense mats. These are disintegrated over a period of time. People living near or on the shores of estuaries gather the detritus and use it as a mulch or a fertilizer.

Conover (1958) in a study of growth on Great Pond, Falmouth, Massachusetts, indicates that growth begins in March, reaches a maximum in July, and ceases in November. He estimated Zostera biomass as 93-136 grams wet wt./m^2. Nixon and Oviatt (1972) estimate Zostera dry weight as 65 g/m2 in Rhode Island waters. There are many difficulties in acquiring consistent, accurate data on productivity in Zostera and other aquatic plants. Furthermore, conditions and results may well differ markedly in various geographic areas of the range of the species along the Atlantic Coast of North America,

Zostera is especially noted for the very large number of species of epiphytic algae and animals which grow upon it. Hartog (1970) states that the number of algal species has never been completely listed but may be as many as 200. All of these may not necessarily be found in our waters, for the species is abundant in many parts of the world's oceans. Included are members of the blue-green, red, green, and brown algae, as well as many species of diatoms and some fungi. Numerous species of small animals such as an assortment of fish, molluscs, and arthropods seek both shelter and food in the Zostera beds. Amos (1966) presents an interesting description, together with fine, colored illustrations of a number of these interesting organisms. Relatively few of the many epiphytics have been studied carefully on our eastern coast.

Prior to 1931 Zostera grew so abundantly along our coast in river mouths and shallow bays that it interfered with navigation of small boats. In 1931 an epidemic occurred on the eastern seaboard and about 95 percent of the Zostera beds were wiped out. Lorus and Margery Milne's "The Eelgrass Catastrophe" (1951) is a fascinating account of the tremendous ecological changes resulting from the epidemic.

A number of organisms were regarded as the probable cause of the disaster. There now is general agreement that the slime mold Labrinthula was the

culprit.

The photosynthetic process of the eelgrass gives rise to prodigious masses of organic materials. A very large number of species of animals depended on this material either directly or indirectly. The pyramid of productivity figured in Milne (1951) indicates the relationships of various groups of organisms in this respect.

Martin, Zin and Nelson (1961) list twelve species of waterfowl which utilize portions of the eel grass as food. They state, "Doubtless the benefit of eelgrass to marine fisheries is very considerable, but the greatest evident value is to waterfowl. Brant, since time immemorial, have relied on the 'stems and leaves of eelgrass as their staple food."

Numerous streams discharging into the coves, bays, and estuaries carried great quantities of soil, factory wastes, and sewage. The eelgrass served to temper the erosion which otherwise might result. The loss of the eelgrass had dramatic and disastrous effects on the inshore waters, and thus on the plant and animal life of the region, and on the livelihood of men harvesting the resources of the sea.

Fortunately, the eelgrass has increased in amount in recent years. Professor Milne (personal communication) estimates that the volume of Zostera in Great Bay, New Hampshire, is about 25 percent of the status prior to the great epidemic.

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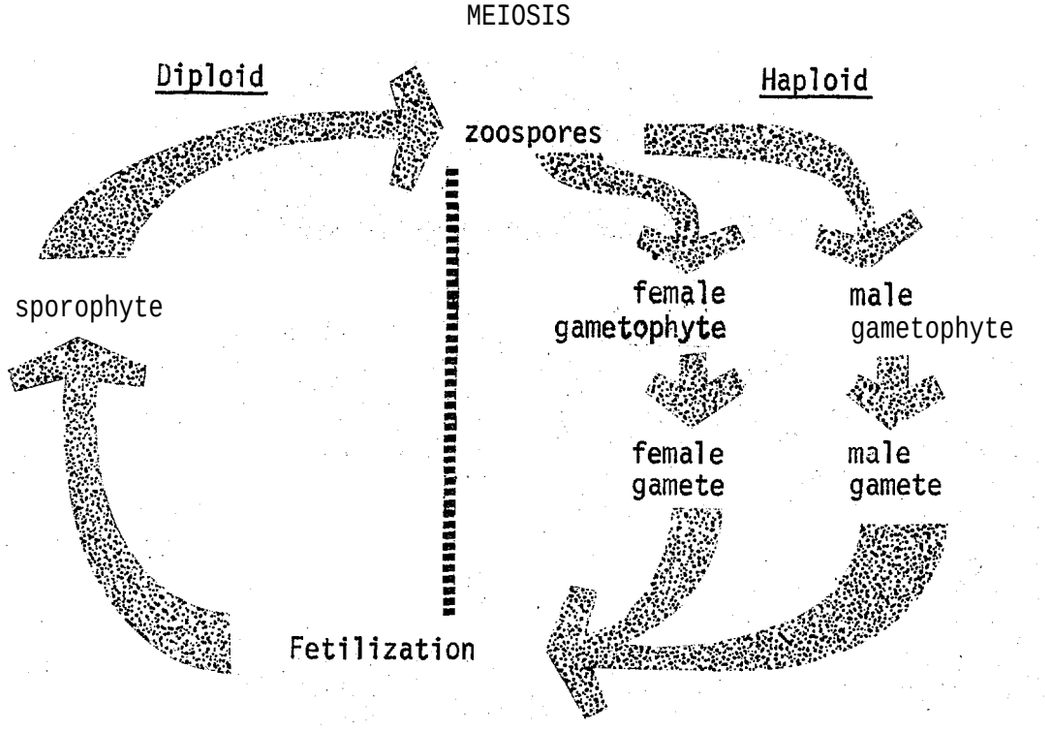
11.5.6 Ulva lactuca

Taylor (1966) places Ulva in the Division Chlorophyta, the Class Chlorophyceae, Order Ulothricales, and Family Ulvaceae. Commonly known as sea lettuce, it occurs all along the eastern coast of North America from Florida to Hudson Bay. Taylor recognizes several varieties.

Each plant is attached tenuously to some solid object such as rocks, mollusc shells, wood, or other marine plants by means of a system of rhizoidal cells. Blade-like growth arises from the holdfast and is often lobed and undulate. Although the plants may attain a diameter of as much as a meter, the blades are only two cells thick. The cellulose cell walls are rather thick. While holdfast cells may contain more than one nucleus the cells of the blades are uninucleate and contain a single laminate chloroplast with one or more pyrenoids.

The life cycle of Ulva is isomorphic and diplobiontic; that is, it has an alternation of generations in which the sporophyte and the gametophyte look alike, although the sporophyte is diploid and the gametophytes are haploids. The outer cells of the blade undergo meiosis at the proper season and the process moves inward. Each cell may produce quadriflagellated haploid zoospores which are released into the water. Ultimately they settle down on some object, and each may develop a haploid plant which is much like the sporophyte, although the cells are smaller. In the course of time cells of the gametophyte produce biflagellated gametes. There are two kinds of gametophytes in spite of the fact that they look alike. One type produces larger gametes than the other, or, in more technical terms, the gametes are anisogamous. The union of a macrogamete and a microgamete produce a diploid zygote, from which a new sporophyte is produced. At times gametes which do not unite may grow into gametophytes which in turn produce gametes.



LIFE CYCLE OF ULVA

Conover (1958) reports that growth occurs the year round in Falmouth, Massachusetts, but grows more rapidly during the warm months under high insolation. At temperatures of 18-20 C beds may produce as much as 500 gram cal/cm^2/day.

Chapman (1964) notes that Ulva has been used as a food in many parts of the world, including such locations as both eastern and western coasts of the United States, Japan, Hawaii, Jamaica, and Trinidad. It is used as a green, in salads, or as a garnish for meats and fish. In Cuba the plant is used as an additive in poultry meal. In various parts of the world, including New England, it has been used as a fertilizer, for it is rich in nitrogen, iodine, and vitamins A_1 and B_1.

Ranwell (1972) observes that in southern England over the past twenty years a great increase in the growth of Ulva and its close relative Enteromorpha has occurred. The growths occur especially in sheltered bays where sewage, industrial effluents and runoff from highly fertilized farmlands accumulate.' In some areas the growth is heavy enough to smother salt marsh plants. Wood and Palmatier (1954), studying coastal ponds in Rhode Island, also noticed considerable quantities of Ulva. In Maine a similar situation exists in certain areas. In all these areas many plants exceed three feet in diameter.

Although marine animals of various kinds doubtless utilize Ulva, no specific studies have been published. Quantities of several species of snails are found in the vegetable debris and one assumes that they feed on this bountiful material.

Udell, Zarudsky, Doheny, and Burkolder (1969) measured the annual crops of marsh plants in the estuary at Hempstead, Long Island. Ulva produced 3.50 tons per acre dry weight and outranked all the other non-planktonic plants except the tall form of Spartina alterniflora which produced 3.68 tons per acre. Ulva contributed nearly 10 percent of the total mass generated by non-planktonic species.

Ulva, with a protein content of 20.8 percent, outranked all the non-planktonic species studied. Spartina averaged 13.9 percent or roughly the content of coastal Bermuda grass, a species utilized in agricultural practices. Ulva was lowest with a fat content of 0.5 percent as opposed to the highest producer, the short form of S. alterniflora, with a value of 2.9 percent. The carbohydrate content for Ulva at 18.2 percent was greatly exceeded by the 63.9 percent for the spartinas. Ash content varied widely with 58.2 percent for Ulva which greatly outproduced all the other species.

Adequate amounts of four B vitamins were present in all the species studied. In the flowering plants B_{12} occurred in small amounts (0.008 to 0.022 micrograms/gram) but Ulva yielded 0.26 micrograms per gram of dry matter.

Dawson (1966) calls attention to the interesting situation in which in certain algae such as Ulva, Prasiola, and Cladophora the tissues contain fungi. These lichen-like growths have been called "composites" in view of their uncertain relationships. In Ulva the mycelium of the ascomycetous fungus Guignardia grows around the cells but does not penetrate them. Perithecia are produced in dark, wart-like structures.

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11.5.7 Spartina

Gray's Manual (Fernald, 1950) classifies Spartina as a genus of the class Angiospermae, the sub-class Monocotyledonae, order Graminales, and family Gramineae.

Although there are several species of Spartina along the northeast coast. of North America, only S. alterniflora Loisel and S. patens (Ait) Muhl are of great consequence in marine marshlands. A number of investigators refer to tall. and short forms of S. alterniflora. The spartinas cover 90 percent or more of the area of the marshlands. S. alterniflora occupies the lower areas and is especially noticeable along the edges of the various streams and ditches which ramify through the marshes. 'The belt it covers depends on the slope of the marsh surface. S. patens covers the next higher belt of the intertidal area. The line between the two species is quite distinct. In the upper reaches of the marshes 30-40 angiospermous species may be found and some of these encroach into the patens belt to some degree. Van Reine's (1962) "Plants and Animals of the Seashore" contains excellent figures of most of these, together with brief descriptions.

The spartinas are perennial grasses with erect stems arising from sturdy underground rhizomes which also bear roots. These rhizomes are so tightly interwoven and packed that considerable effort is needed to dig up a sample for inspection. As growth occurs the rhizomes bore into adjacent areas. Pieces which separate from a parent plant aid in disseminating the species. Leaves are long, tough, and involute. Spikelets are sessile, tightly packed on one side of the stem, forming a spike according to Gray's Manual (Fernald, 1950) and Muenscher (1944).

The two species are easily distinguished from one another. S. alterniflora is much taller and may attain a height of five feet, is stouter than patens, its leaves are much broader, and the influorescence is much larger. S. patens attains less than half the height of alterniflora, its leaves are shorter and narrower, and the much smaller influorescence is reddish-purple in mid to late summer. Growth begins in late April and continues

until October along the northeast coast. In more southerly regions the season is longer.

In an earlier day the only economic crop produced by the salt marshes was salt hay, produced by the spartinas. The right to cut salt hay was an important part of the deeds to shore property. It was in great demand as a mulch for garden crops and as bedding for animals.

The area of the eastern coast between northern New Jersey and the Canadian border has a relatively small but important acreage of salt marsh in comparison to the more southerly states. Professor Eugene Odum has headed a large group of research workers exploring various facets of the vast coastal wetlands in Georgia. They, as well as other investigators along the southern coastline, have made significant contributions to our knowledge of the biology and the economic value of these extensive areas.

Marshlands have been regarded as wastelands rather than as highly productive wetlands by the majority of people. A large percentage of the marshlands in New England have been destroyed. Teal (1969) and many others have called attention to the rapid loss of the wetlands in recent years. According to Teal (1969), Maine has been the most fortunate of the New England states in this respect. The rate of loss has been growing in New Hampshire. A goodly portion of the original wetlands in Massachusetts, Rhode Island, and Connecticut, as well as in New York, Long Island, and northern New Jersey, have ceased to exist. Their place has been taken by a variety of developments, including roads, housing developments, parking areas, marinas, waste disposal, industry, and the general spread of the urban complex. Clark (1967) presents a general, interesting, and valuable discussion of the sport and commercial fisheries as related to the predicament of the coastal wetlands. He then comments on the conditions in each of the fourteen states from Maine to Florida. Fortunately, most of these states and also the Federal Government have taken measures to protect the remaining marshlands.

Teal (1969) observes that S. alterniflora and S. patens are the only species which thrive in the greater portion of the coastal marshlands of the east coast of North America. They have special structures and methods for coping with the lack of oxygen in the soil as well as the presence of salt. Teal devotes a chapter to explaining the physiology involved.

Several species of mammals are associated with the spartenium. Included are deer, mice, mink, otters, muskrats, black rates, Norway rats, rabbits, squirrels, and voles. Some do not live in the marsh but obtain some of their food from the vegetation and from the abundant small animals. Several burrow for food or catch fish, insects, molluscs, crabs, clams, and other small animals found in the grass or in the creeks traversing the marsh.

Birds are an important aspect of the salt marshes. Amos (1966), Barske (1961), Niering (1961), Stuckey (1970), and Teal (1969) are among the

many observers of their presence and activities. By combining their observations, it is evident that well over 100 species dwell in or visit the marshes. Some are present regularly, some are seasonal, and others utilize both marsh and other habitats. The number of individuals vary greatly from season to season. In some cases hundreds may be seen at any one time. In toto they consume considerable amounts of the animal life which is present. Others eat the seeds, fruits, and vegetative portions of Spartina and other marsh plants. Some species, such as the rails and some sparrows, are completely dependent on the marsh for their food. Other birds nesting in the marshes include the black duck, blue-winged teal, common bittern, marsh hawks, short-eared owl, red-winged blackbird, meadowlark, and marsh wren, and all utilize Spartina to some extent.

The reptiles are poorly represented in the northeastern marshes. The mud turtle is an insect eater, the diamond terrapin consumes both animals and plants, and the painted turtle forages for plants, insects, molluscs and probably other common small animals. The loggerhead turtle is really a marine dweller but is occasionally seen in the marshes.

Teal (1969) estimates that two-thirds of the commercial catch of fish and shellfish landed on the east coast of the United States comes from species which live at least part of their life cycle in the marsh estuaries. Living in the tidal creeks they have a wealth of plant detritus as well as a considerable number of species of algae which live in the tidal creeks to feed upon. As the tide rises they may swim into the spartineum and browse on the algae which grow attached to the plant life as well as on other animals.

Ursin (1972) notes that "there is no overstating the importance of vertebrate life in the salt marsh, particularly fish and birds. Their roles in the marsh are indispensable to the ecology." The vegetation provides spawning grounds, protection for the young, and food for many species. The most abundant appear to be the alewife, striped bass, blue fish, flounders, banded killifish, menhaden, mumichug, scup, sea trout, shad, sheepshead minnow, mullet, silversides, sticklebacks, and the top minnow. Their mobility enables them to forage over the whole range of the plant life or to retreat to the tidal creeks and consume the vegetable detritus generated in tidal marshes.

Representative members of almost every animal phylum occur in the coastal marshes. Some occur only in the marshes, others may be found in both the grasslands and in the tidal creeks. A few spend only a short period of their life cycles in the marsh vegetation and develop to maturity elsewhere. Many of the small specimens serve as food for other invertebrates or are consumed by fish, birds, or mammals which live in the marshes or visit them from time to time. As an example, more than 400 species of insects have been collected in the marshlands. Of these, about 50 species spend all or most of their lives in the marshlands.

The single-celled animals, the Protozoa, may occur in large numbers. They consume large amounts of vegetable detritus and many are utilized as food by larger organisms.

Hydroids, members of the coelenterates, attach to vegetable material and consume tiny protozoans, algae, and detritus from the higher plants. Some coelenterates spend their juvenile lives in and on the plants of the marsh and move into the marsh creeks and on out to open water.

Keeton (1967) states "Nematodes found on the rhizomes of the spartinas consume endless quantities of bacteria and small protozoans. Flagellates, ciliates, amoeboid types, and dinoflagellates are notable examples."

The echinoderms are exclusively marine, motile at some time in their life cycle, mostly bottom-dwelling animals and are numerous in all seas and at all depths from the intertidal zone to the ocean depths. The green and purple sea urchins and the green basket stars as well as sea squirts may be found in the marshes but more commonly in seaweed beds, muddy creek bottoms, and in deeper waters. They consume a goodly quantity of plant debris which comes from the marine wetlands.

Among the annelid worms are some that swim or crawl about actively and others that browse in the marsh or sea bottoms and spread their branching tentacles. Small animals on vegetable detritus enmeshed in the tentacles are carried into the body for digestion. Common examples are leeches, polychaetes, worms, sand worms, and blood worms.

The phylum Mollusca is the second largest in the animal kingdom and many thousands of species occur in all sorts of marine and fresh water habitats. A large number of species inhabit the tidal wetlands, the marshland creeks, mudflats, and shallow water. Common examples are angel wings, boat shells, chitons, cockles, false angel wings, limpets, moonshells, mussels (blue, mud and ribbed) oyster, oyster drills, periwinkles, quahogs, scallops and mud snails.

In addition to consuming planktonic food, most of the species utilize vegetable debris produced from the spartinas. A number of snails crawl along the stems and leaves of the spartinas where they feed upon small algae, especially the diatoms, which often occur in great abundance.

The arthropoda is the largest phylum of animals. They occur in almost every habitat and geographic area of the world. Among the marine species associated to some degree with the coastal marshes are insects such as beetles, bees, butterflies, dragonflies, grasshoppers, mosquitoes, spring tails, and wasps. Included also are amphepods, barnacles, centipedes, decapods, isopods, millipedes, mites, and spiders. Lobsters, shrimps, such as the common grass, edible mantis, and scud, and a variety of crabs such as the blue, fiddler, green, hermit, horseshoe, lady, mantis,

skeleton, and spider are associated with life in the spartenium and the tidal creeks. Many of these feed on detritus from the plants. Some pass juvenile stages in the grasses before moving out to deeper waters.

Gordon and Oppenheimer (1969) utilize a diagram from Wass and Wright designated as "Ultimate Utilization of Smooth Cordgrass on the Eastern Shore." The diagram indicates the use of Spartina as a habitat, a source of food for a considerable variety of animals, and a source of nesting material for animals in marshes of Virginia. Presumably a similar chart could be made for the northeast coastal area, although to be complete many more species would be included.

A large number of species of macroscopic algae grow in the tidal creeks, in the pannes, and on and around the Spartina beds. Algae growing in the creeks may be carried by tidal flow to the rooted vegetation. Many of these decompose rapidly and form a considerable amount of detritus utilized by a variety of organisms. Others settle in and grow on and around the spartinas. The most conspicuous genera of the green algae are Cladophora, Enteromorpha, Monostroma, Percusaria, Pilinia, Rhizoclonium, Stichococcus, and Ulva. The xanthophycean genus Vaucheria is a very important member of this flora and often forms large felt-like masses which supply food for many small invertebrates. Among-the prominent members of the red algae are Ceramium, Chondrus, Polysiphonia, and Porphyra. The blue-green algae are represented by such genera as Anabaena, Anacystis, Lyngbya, Oscillatoria, Phormidium, and Rivularia. Some of the blue-greens are capable of nitrogen fixation. Dexter (1947), Jerome, Chesmore, and Anderson (1969), and Webber and Wilce (1971) list a large number of representative species of these and other genera.

Among the microscopic algae are greens, blue-greens, and dinoflagellates, either as plankton or attached to some solid object including the surfaces of the larger members of the vegetation.

Diatoms constitute a major part of the phytoplankton of the sea, occur as sessile communities on a wide variety of plants and animals, or grow on rocks, debris, sand, and mud. Inasmuch as they carry on photosynthesis, they serve as vital links in food chains. Hendey (1964) notes that either directly or indirectly they serve as food for almost every animal in the sea. Although a hundred or more species have been observed in European salt marshes, there is no precise knowledge available for the northeastern marshes in America. They do occur, often in prodigious quantities, on sand and muddy surfaces of the marshlands and on the surfaces of the spartinas and other plants. A number of small invertebrates, notably arthropods and molluscs, browse on these pastures. Many diatoms are detached by wave and tidal activities and may then be consumed by a variety of animals living in the tidal creeks.

Bacteria are present in great numbers living on the surfaces of plants,

in the soil, and on most solid objects in the marsh. They are most conspicuous in the small puddles (pannes) which occur in the marshlands, for the purple and green sulfur bacteria are especially abundant here. The pannes are very interesting, especially because of the wide variety of forms of life which inhabit them.

Teal (1969) devotes considerable attention to productivity and observes that Spartina alterniflora and the algae are the important producers. The data in Table 11-5 indicates the need for additional study of Spartina patens. The 1973 yield in Maine is no doubt caused by sewage pouring into the marsh.

According to Bishop and Billard (1958) "The tonnage of vegetation that marshes produce per acre is unrivaled by any other natural soil and difficult to equal even in intensive agriculture using commercial fertilizer."

Table 11-4 lists the more prominent productivity studies of Spartina alterniflora along the Atlantic Coast. Table 11-5 refers to S. patens.

Table 11-4

Authors	Locality	Yield, (tons per acre dry weight)
Smalley (1959)	Georgia	4.8
Shuster (1959)	Delaware	2.6
Good (1965)	New Jersey	1.3- 2.2
Udell, et al. (1969)	Long Island, N. Y. tall form	3.68
	Long Island, N. Y. short form	2.27
Gross (1966)	Connecticut	2.2
Steerer (1969)	Connecticut	3.4
Stuckey (1970)	Rhode Island	1.87 -4.6
Nixon, et al. (1973)	Rhode Island	6.06
Neiring (1871)	Maine	7.8
Gustafson (1973 unpublished)	Maine	4.1

Table 11-5

Udell, et al. (1969)	Long Island, N. Y.	2.24
Neiring (1971)	Maine	7.8
Gustafson (1973 unpublished)	Maine	8.2

Pomeroy (1959) in his study of productivity of algae on the surface layers of Georgia salt marshes estimated the mean annual net production was 1,000 pounds of carbon per acre per year.

The coastal wetlands are effective barriers protecting the more inland areas from the force of high waves, high tides, and severe storms. Without such barriers severe erosion would take place unless expensive man-made controlling devices were to be constructed. The spartinas hold the soil in place and slowly build new land.

Recently Garbisch, Weller, Bostian, and McCallum (1973) in Chesapeake Bay and Woodhouse, Seneca, and Broome (1972) in North Carolina and their colleagues have been experimenting with utilizing Spartina and. other grasses as a means of stabilizing exposed land areas and constructing additional wetlands.

Rivers discharging waters into estuaries also deposit great quantities of soil. As a consequence, ship channels must be dredged regularly to compensate. The problem is disposing of this material as well as other "spoils" is serious and costly. The investigators have suggested that this material be placed in areas adjacent to the wetlands and thus provide a base for Spartina and other highly productive plants.

Spartina seeds may be harvested and broadcast over new land fill, or they may be harvested and planted in protected seedbeds. The plants which are produced may then be transplanted at favorable times in new areas. In addition, pieces of rhizomes may be taken from thick growths and transplanted. Also, soil plugs from natural growths or from nursery stock may be transplanted.

Techniques for harvesting and storing seeds, for planting and transplanting shoots, and for general care of plants have been developed. Special machinery has been developed for harvesting seed, for planting, and for care of plants. A considerable amount of quantitative biological, chemical and physical data has been accumulated.

Papers by Heath (1974) and Woodhouse and Garbish (1973) resulting from a conference held in Maine in 1973 contain valuable information concerning this form of aquiculture.

The dominance of Spartina in the coastal wetlands has been clearly demonstrated. In addition to the strictly biological data, great economic and social aspects have been assembled by various investigators. As an example, Gosselink, Dum and Pope (n.d.) in "The Value of the Tidal Marsh" call attention to "four levels . ..selected for monetary evaluation of marshlands and estuaries of the South Atlantic and Gulf coasts: (1) by-product production (fisheries, etc.); (2) potential for aquacultural development; (3) waste assimilation; and (4) total 'life support' value in terms of the work of nature as a function of primary production."

In "The Economic and Social Importance of Estuaries, " (Sweet, 1971) relatively little attention was paid to the importance of the coastal marine vegetation. However, the tremendous importance of the very numerous kinds of activities dependent on the estuaries is very revealing. They put enormous pressure on the remaining marshlands.

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12.1 INTRODUCTION

The continental shelf waters from the New Jersey coast to the Bay of Fundy provide the conditions for an abundant fish fauna. The relatively shallow water over. extensive coastal and bank areas, combined with strong tidal mixing in the northern waters, result in the production of large quantities of planktonic and benthic food organisms which support abundant fish populations.

The offing of Cape Cod and the Nantucket Shoals separate the coastline into two geographically distinct areas; the oceanic bight bounded by Cape Cod in the west and Cape Sable in the east, and the area from Cape Cod to Cape Hatteras. These two areas have somewhat different fish fauna (Colton, 1964); the cold, rapidly mixing water of the Gulf of Maine is dominated by boreal species, while the warmer, more sluggish water of the Mid-Atlantic Bight is dominated by warm water species. The offing of Cape Cod which separates the two areas is a transition zone that marks the northern or southern boundary for many species of fish (Colton, 1972; Lux and Grosslien, 1970; Fritz, 1965, Parr, 1933). The New Jersey coast at the southern extreme of the study area and the beginning of the Scotian Shelf at the northern extreme are less definite transition zones, with the continuation of warmer, temperate water species to the south and boreal species to the north. The middle of the study area, then., is more of a natural division with respect to the species composition of fishes than are its northern or southern boundaries.

Because there is no natural biological division at the boundaries of the study area, it is difficult to give the precise number of fish species that are found within it. Based on the compilation in this report we consider 196 species to have their normal range within this area (Bigelow and Schroeder, 1953; Leim and Scott, 1966; Nichols and Breder, 1927).' A full listing is presented in Sections 3.5, 4.6, 5.2, 15.3.2 Habitat Check Lists. This excludes fishes that stray into the area from their normal range. In many cases, particularly at the boundaries of the study area, the difference between fishes that are occasionally found in our areas as a normal part of their range and those that stray in is difficult to determine. The fact that 196 species represent only 20 percent of the total number of species on the Atlantic coast (Bailey, Fitch, Herald, Lachner, Lindsay, Robbins and Scott, 1970) agrees with the generally accepted principle that the flora and fauna of northern latitudes are composed of fewer species, but more abundant individuals of each species.

The fishes as a group are less confined to single habitats than most other marine animals. This allows them to respond to changes in the environment by moving quickly from less favorable to more favorable areas. Mobility, coupled with the extreme seasonal changes in the latitude of the study area, creates a continually shifting and overlapping situation in the species composition of any particular location.

It is convenient, for the purposes of discussion, to classify fishes according to their principal mode of existence. They can be generally grouped as follows:

(1) Pelagic fishes. Range widely throughout the water column, feeding on plankton and other fishes, i.e., herrings, mackerels.

(2) Demersal fishes. Closely associated with the bottom, feeding on bottom invertebrates and fishes; relatively more restricted in their movements than pelagic species, i.e., flatfishes and codfishes.

(3) Nearshore fishes. Usually small species and juveniles found in the shallow waters abutting the coast line; generally tolerant of wide temperature changes, i.e., seasnails, sculpins, rock gunnels, young winter flounder.

(4) Estuarine fishes. Either transient, diadromous species moving to or from spawning areas, or fishes able to tolerate the lower and fluctuating salinity conditions of upper estuaries, i.e., killifishes, sticklebacks.

A more complete classification can be found in the species checklists for the various habitats (Section 3.5, 4.5, 5.1 and 5.2).

Because of their mobility, many species cannot be considered completely pelagic or demersal and in many cases the choice is arbitrary. Some flounder (Olla, Somet ana Studholme, 1972), cod, haddock, and redfish (Beamish, 1966) all carry out diurnal or feeding migrations up into the water column, and cod and redfish in particular spend considerable time pelagically. Many species can be considered semi-demersal in that they remain associated with the bottom or the water column slightly above the bottom. On the other hand, some species, considered here as pelagic, spend considerable time near the bottom. Thus, spiny dogfish, pollock, and silver hake are sometimes called groundfish in the sense that they are taken regularly in groundfish catches of fishermen. It is obvious that a large part of the lives of these species are associated with the bottom. Fishes of a demersal or semi-demersal habit are particularly dominant in the study area because of the large expanse of relatively shallow water.

Over the years a wide variety of fishery investigations have been conducted in the study area. Currently, most work is being done by either federal (National Marine Fisheries Service), state, or college or university sponsored research programs. In the study area the National Marine Fisheries Laboratory at Woods Hole, responsible for most of the offshore investigations, is involved in such programs as groundfish

surveys, Marine Monitoring and Assessment Program (MARMAP), and population dynamics studies of commercially important species. Much of the work at this laboratory is concerned with the international regulation of the fishing effort. in our shelf waters. The National Marine Fisheries' Sandy Hook, New Jersey laboratory has the responsibility for federal fisheries programs of the inshore areas. These include the study of the dependence of fishes on estuarine and inshore environments. All. of the states bordering the study area have ongoing fisheries programs, most of them concerned with local, inshore problems connected with the fishery resources of the particular state. A number of universities and colleges, notably the University of Rhode Island and the University of Maine as well as private research institutes at Woods Hole also participate in fisheries studies, in many. cases doing more basic research than the state or federal agencies.

Most of the research that has been done, particularly at the federal and state level has dealt with single, commercially important species and has been related to problems connected with their exploitation. The life history and population information that has been gathered has been largely for use in the management of the fisheries. While there is still much to be known about any species, a few such as Atlantic herring, haddock, Atlantic cod, winter flounder, and striped bass have considerable literature. In some cases the material is compiled in bibliographic form (Scattergood, 1957; Wise, 1963; Topp, 1965). For most species, particularly those that are not commercially valuable, there has been relatively little life history information gathered.

The examination of fish populations as part of the biological community and how they relate to their physical and biological environment has been less studied. Recent papers by Tyler (1971, 1972), Colton (1972), Wigley (1965), and Pearcy and Richards (1962) have dealt with certain aspects of the problem, while other studies have provided information on the species composition of fishes in some areas by means of surveys. Many of these surveys, however, are heavily biased toward the demersal and semi-demersal fishes because of the extensive use of the otter trawl, which is not effective in sampling pelagic fishes. Because of the sampling problem, the systematic survey of pelagic fishes, particularly in offshore waters, is very incomplete. The total number of species, approximately 196, known to normally inhabit the study area has been consistently undersampled in these surveys. Most of the missing species were either pelagic or for some other reason inaccessible to the sampling gear. Also, with the exception of the offshore groundfish studies, these surveys were not synoptic and were limited to small areas, resulting in a discontinuity of data along the coast.

This chapter has two broad divisions. The first deals with fish populations as a whole and presents their distribution, reproduction, and

ecology. The second deals with the life history of a number of key species. These species have been selected because they are either a primary constituent of their habitat, are of primary commercial importance or, as in one case, a rare and endangered species. The scientific names used are those recommended by Bailey et al., (1970). For uniformity, outdated names appearing in various publications have been changed, where possible, to those recommended by the American Fisheries Society.

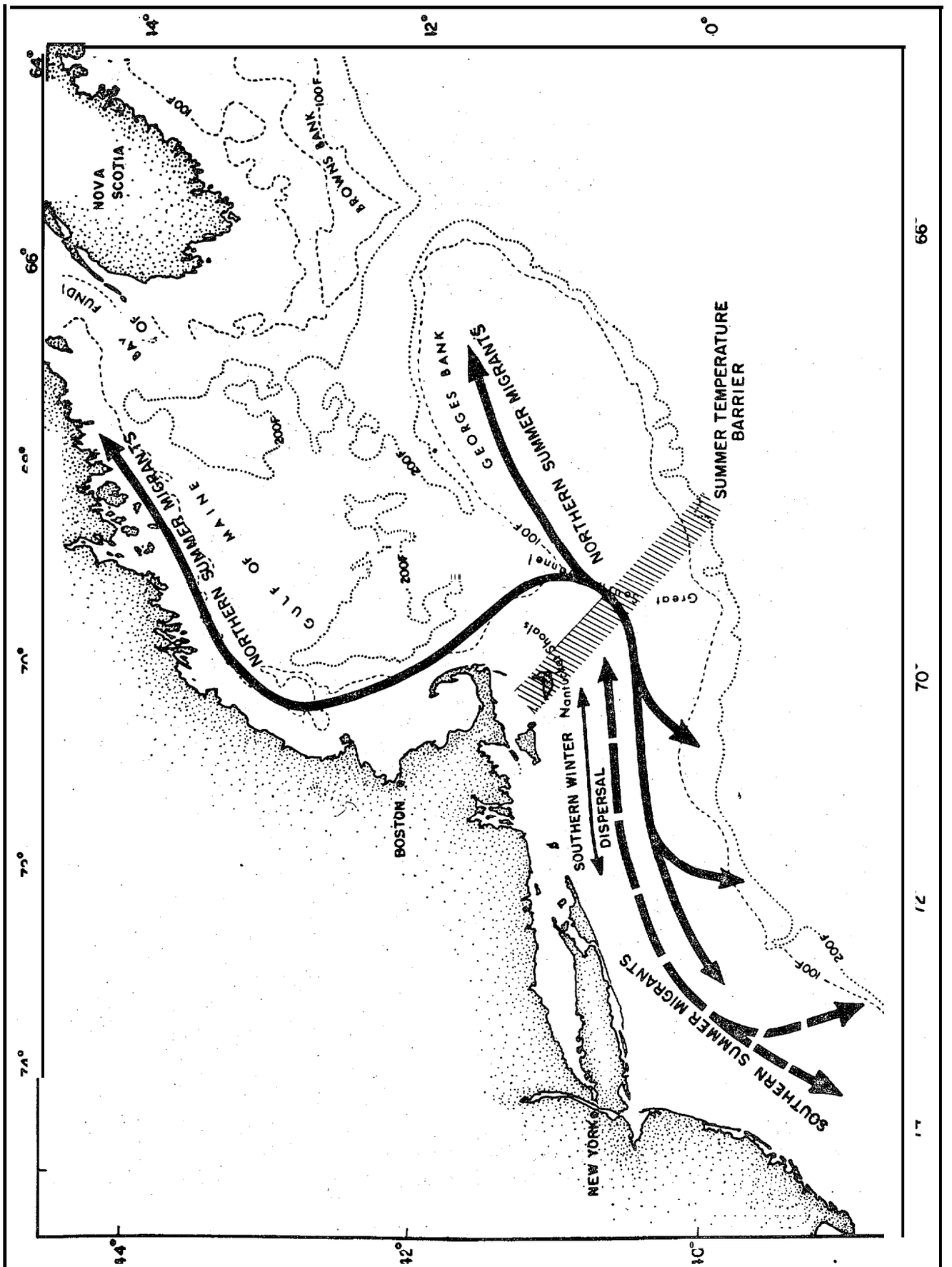
12.2 ZOOGEOGRAPHY

12.2.1 SEASONAL MOVEMENTS AND MIGRATIONS

Investigations by Stickney (1967), Doudoroff (1938) and Hutchins (1947) have shown that many fishes have preferred temperature ranges which they seek. This necessitates movement on the part of most fishes in response to seasonal and local variations in temperature. The range of temperatures that fishes can tolerate varies from species to species and therefore the degree of seasonal movement will vary also. Since, as Hutchins (1947) points out, the temperate latitudes of the western North Atlantic have the greatest temperature extremes, it would be expected that seasonal temperature would have an overriding influence on the seasonal abundance, distribution, and species composition of the fish fauna in the study area.

The cold water barrier at Cape Cod, caused by a surface pool of upwelled water between June and September, separates the Gulf of Maine from the mid-Atlantic Bight by means of a sharp temperature differential (Colton, 1972; Parr, 1933; Hutchins, 1947). The rest of the year there is temperature continuity between these areas. To the north of the barrier, the Gulf of Maine waters are relatively homothermal seasonally, while the Mid-Atlantic Bight waters are heterothermal.

Parr (1933) and Colton (1972) discuss the effect of these temperature characteristics on the period and extent of the migratory activities of fish population of the shelf waters. The Mid-Atlantic Bight contains very few permanent residents, and is composed of continuously shifting populations. The Gulf of Maine, on the other hand, contains mostly endemic species with little seasonal alteration in species composition. In the Mid-Atlantic Bight, a rich population of southern migratory fishes follows the northern dispersal of isotherms to Cape Cod. (Figure 12-1 and Table 12-1). Many of these species enter the Gulf of Maine and remain there throughout the summer-. Winter temperatures cause them to retreat either southward or to the warmer waters of the continental slope. These populations in the Mid-Atlantic Bight are poorly replaced by a seasonal diffusion of a few species that are



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC | FIGURE 12-1 | General Movement of Migratory Fish Species

Table 12-1 Seasonal migration characteristics of some important fish species

I. Southern summer migrants (north to Cape Cod)

Summer flounder	*Paralichthys dentatus*
Scup	*Stenotomus chrysops*
Weakfish	*Cynoscion regalis*
Kingfish	*Menticirrhus saxatilis*
Mullets	*Mugil sp*
Black seabass	*Centropristes striata*
Filefishes	*Aluterus sp., Monacanthus sp.*
Pompanos	*Caranx hippos* and other species
Northern puffer	*Sphaeroides maculatus*

II. Northern summer migrants (north into the Gulf of Maine)

Spiny dogfish	*Squalus acanthias*
Silver hake	*Merluccius bilinearis*
Red hake	*Urophysis chuss*
White hake	*Urophysis tenuis*
American shad	*Alosa sapidissima*
Striped bass	*Morone saxatilis*
Menhaden	*Brevoortia tyrannus*
Bluefish	*Pomatomus saltatrix*
Atlantic mackerel	*Scomber scombrus*
Butterfish	*Peprilus triacanthus*
Bluefin tuna	*Thynnus tynnus*

III. Southern winter dispersal

Atlantic herring	*Clupea harengus*
Atlantic cod	*Gadus morhua*
Pollock	*Pollachius virens*

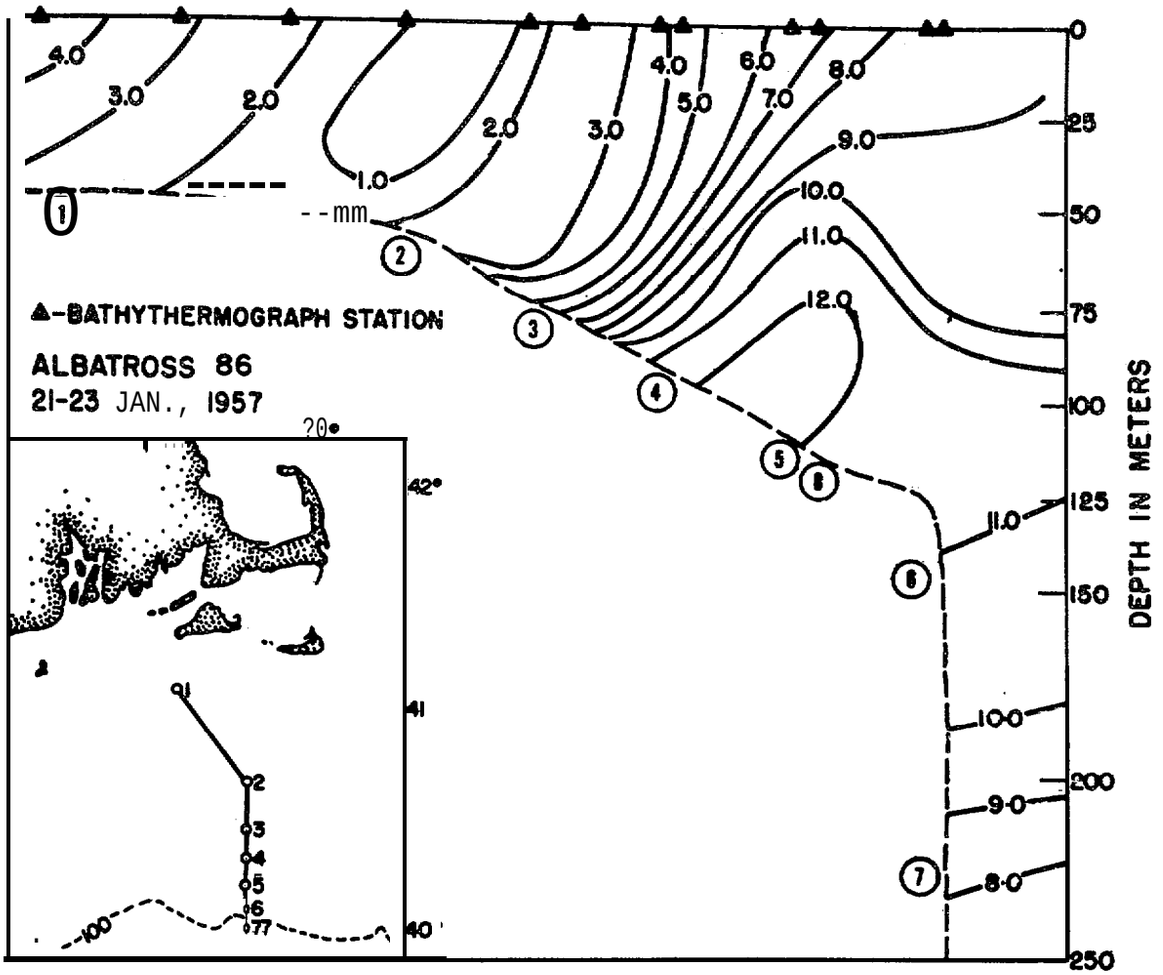
endemic to the Gulf of Maine, but which spill over into the mid-Atlantic Bight during the winter. Whereas the spring and summer movement of fish north is a temperature migration as a result of thermal compulsion, the winter movement south by northern species is a diffusion southward-resulting from the breakdown of the temperature barrier at Cape Cod. The mid-Atlantic Bight, then, has a rich migratory summer population and a poor winter population. The Gulf of Maine has a stable resident population plus a summer migrant population.

During the cold months, many species of the summer migratory component do not move a great distance south and west of Cape Cod, but retreat to the warm winter slope water of southern New England. Edwards (1965) noted that temperatures on the slope at a depth of 100, to 125 m were 12 to 14 C during the winter (Figure 12-2) and that many species common to the inshore summer trawl fishery of southern New England retreated to this offshore warm water zone during the winter. These species included: red hake, silver hake, scup, butterfish, summer flounder, goosefish, and about 20 other less important species. The winter component of fishes moving in from the north and east consisted of: cod, yellowtail flounder, and longhorn sculpin. Generally, the fishes of the summer component tended to be most abundant on inshore grounds when the water temperatures were the same as those in which they occurred most abundantly offshore.

Almost all non-migratory species show some form of seasonal movement, particularly those living in the shallow waters of flats and marshes where the most extreme temperature fluctuations occur. Along the nearshore areas of the Gulf of Maine there is a general paucity of fishes during the winter months (Read, 1969). Until March, only sea raven or longhorn sculpin are found in shallow waters. In March when temperatures reach about 1.7 C eelpout, sculpin, little skate, and winter flounder appear. Later, when temperatures reach about 8.3 C cunner, alewives, and lumpfishes show up. In the fall the process is reversed until by winter most of the fishes have moved into deeper water. In the region south of Cape Cod some boreal species such as winter flounder, which remain in cooler offshore waters during the warmer months, move in to the nearshore areas during the winter.

Tyler (1971) in studying seasonal changes in relative abundance of fishes in Passamaquoddy Bay, Maine, distinguished four groups of fishes from the species composition of his otter trawl catches:

(1) a group present during the winter only - winter periodics



NUMBERS OF SELECTED SPECIES CAUGHT AT STATIONS SHOWN ON FIG. ASTERISK INDICATES YOUNG-OF-THE-YEAR.

	STATION NUMBER							
	1	2	3	4	5	8	6	7
Bottom temperature °C	2.8	2.2	6,7	11.1	11.9	11.6	11.0	8.4
Depth (m)	50	60	70	85	110	115	145	230
Fluke				12	5			
Scup				19	1			
Butterfish				695	21			
Red hake		18	102	1				
Silver hake	*6	*560	223	11		1		28
Angler	2	6	7	1		1		6
Cod		9						
Ocean pout	1	2						

(2) a group present during the summer only - summer periodics

(3) a group present throughout the year - residents

(4) a number of species that were only occasionally present at irregular times and in small numbers

The composition of his catch is given in Table 12-4 which presents species by survey in various parts of the study area.

Tyler compares his assemblage of fishes with those taken in other latitudes (Figure 12-3): those of Merriman and Warfel (1948) in Block Island Sound, Richards (1963) in Long Island Sound and others in tropical waters. He concluded that in temperate regions the inshore, deepwater fish communities are made up of the above components during the winter and summer months with a transitional period in the spring and fall. At latitudes with relatively greater temperature fluctuations there were proportionately more species in the temporal component. Thus, there were more temporal species in Block Island and Long Island Sounds than in Passamaquoddy Bay. In a sense, the stability of the fish community was directly related to the stability of the temperature regime. Recksiek and McCleave's (1973) assemblage of fishes in the Sheepscot-Back River Estuary in central Maine were also in line with Tyler's conclusions.

12.2.2 TEMPERATURE, SALINITY, AND FISH DISTRIBUTION

In the open ocean, where salinities are rather constant and well within the tolerance range of fishes, temperature primarily controls distribution. In coastal and estuarine waters distribution depends increasingly on both temperature and salinity (Kinne, 1964; Gunter, 1961).

Generally, fishes have a range of temperatures that they can tolerate. Those that are subject to temperatures outside of their normal tolerance can exhibit a number of reactions: direct mortality, abnormal changes in metabolism, abnormal changes in growth and longevity, interference in the reproductive process, or changes in movement patterns. For fishes that are found near the boundaries of their thermal tolerances, abnormal temperatures of only a few degrees can cause changes in their habit, particularly if the changes occur suddenly, without prior acclimation (McCleave, 1974).

Sensitivity to temperatures differs according to major life-stages of fish. Eggs and larvae are probably the most vulnerable because of their greater sensitivity and their relative lack of mobility. Juveniles are the most tolerant and the adults are somewhere in between. There are numerous examples of the reactions of the various life-stages of fishes to temperature extremes. Laboratory studies on menhaden

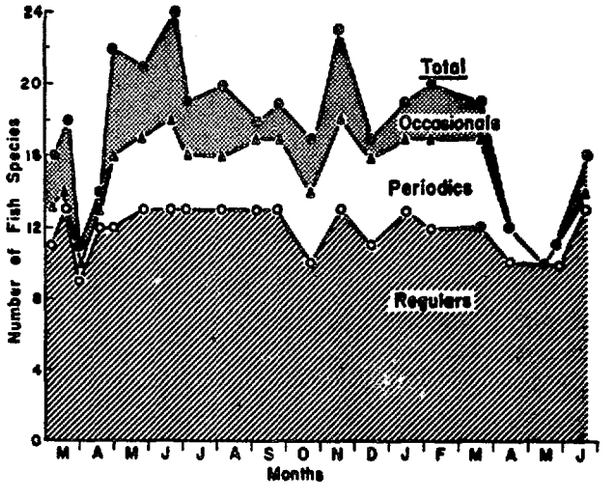


FIG. 7. Number of fish species collected on each sampling date. The height of the diagonally shaded area represents the number of species of the regular community component; the height of the middle unshaded area, the number of periodic species of both winter or summer components; the width of the stippled area, the number of species of the occasional component; the top line of points, the total number of species present on each sampling date.

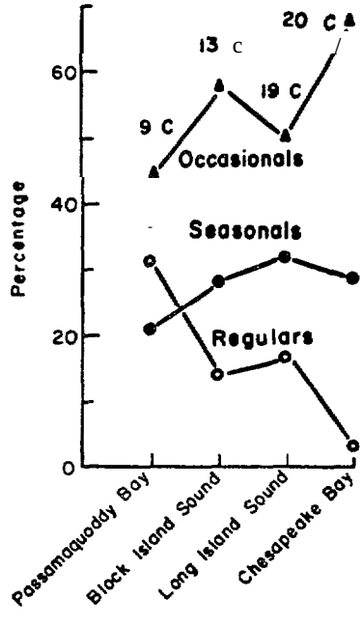


FIG. 11. Percentages of fish fauna that comprise the temporal community components at different latitudes in eastern North America. Annual temperature ranges are at top.

larvae indicate a low temperature tolerance of 3 to 4.5 C (Saila and Pratt, 1973), and for Atlantic herring larvae -1.8 to 0.75 C (Blaxter, 1960). Chenoweth (1970) found abnormally low water temperatures of -1.0 probably contributed to field observations of poor condition of herring larvae.

In the other extreme, Colton (1959) observed mortalities of larval yellowtail flounder and silver hake due to abnormally high temperatures. Rollefsen (1949) found immature cod tolerating lower temperatures than mature cod, and Colton (1955) found that older haddock moved off Georges Bank during the summer into cooler waters. Hoff (1971) found mass mortalities of adult crevalle jack in Massachusetts 'waters (close to the northern limit of their range) as a result of abnormally rapid cooling of estuarine waters to 7.4 to 9.0 C.

In general, pelagic species are more sensitive to temperature than demersal species (Colton, 1972). In the Sheepscot River-Back River estuary, Maine, pelagic species distributed themselves more as a result of temperature than salinity differences (Recksiel and McCleave, 1973); alewife, blueback herring, and menhaden were most abundant in the warm Back River estuary, while Atlantic herring, Atlantic mackerel, and spiny dogfish were most abundant in the cooler, more oceanic Sheepscot River estuary.

The preferential temperatures that are known for pelagic species indicate a rather narrow range. Juvenile Atlantic herring in the Gulf of Maine appear to have a final temperature preferendumof12 to 13 C (Stickney, 1967). The continual attempts to maintain themselves within preferred temperatures has been proposed by Stickney as the reason for erratic movements of juvenile herring in the coastal areas of Maine during the warm months.

Relatively narrow temperature preferendums are likely for other pelagic species as well. American shad follow paths associated with temperatures of 12 to 18 C (Legget and Whitney, 1972). Butterfish are sensitive to small changes in temperature and their minimum temperature tolerance can be generalized at 10 to 15 C (Colton, 1972). The inshore-offshore movement of bluefish appear to result in maintaining the fish in water above 10 C (Miller, 1969).

The demersal fishes are less sensitive to temperature change; such species as yellowtail flounder and winter flounder are well known for their wide temperature tolerances. The distribution of demersal fishes within the broad limits of their temperature tolerance is controlled to some extent by food supply and substrate conditions (Colton, 1972). The quarterly average bottom temperatures for Nantucket Shoals, Georges Bank, the Gulf of Maine, and the Nova Scotia shelf

show distinct. hydrographic zones (Table 12-2) which result from cold oceanic water circulating over the Nova Scotia shelf and Browns Bank, through the Gulf of Maine and then to Georges Bank, warming as it goes (Schopf and Colton, 1966). These temperature regimes are considered as faunal zones in relation to the distribution of demersal fishes (Lux and Grosslien, 1970).

Table 12-2 Quarterly average bottom temperatures from Nantucket Shoals to the Nova Scotia Shelf (C)

	Nantucket. Shoals	Georges Bank	Gulf of Maine	Browns Bank	Nova Scotia Shelf
March	3.6	4.2	4.8	2.5	2.2
June	7.5	8.6	5.9	4.5	4.6
September	11.3	13.0	6.7	7.3	7.0
December	9.5	8.3	6.1	5.0	4.6

The effect of long-term cycles in water temperatures does not appear to have a very significant effect on the distribution of demersal fishes. Taylor, Bigelow, and Graham (1957) examined the changes in distribution of marine animals in relation to the warming trend of 0.5 to 2.5 C throughout the water column from 1912-26 to 1953-54 and concluded that, although there was some northward extension of Atlantic mackerel, Atlantic menhaden, silver hake, and yellowtail flounder, there was no alteration of the composition of fish fauna in the Gulf of Maine. Colton (1972) examined the distribution changes of four species in relation to a cooling trend commencing in 1953-54. He found a change, but not an extensive one, in American plaice and butterfish distributions coincident with the downward trend. There was no change in the general distribution of haddock and yellowtail flounder.

Salinity has a less important influence on the distribution of fishes because most fish are tolerant of a wider range of salinities than is normally found in coastal and offshore waters. It is probably only in the estuaries, where gradients between salt and freshwater occur that fish fauna will change as a result of changes in salinity, and even here the boundaries will be ill-defined because of the fluctuating salinity gradients in response to tidal movements of oceanic water. In the larger, deep, fiord-like estuaries of the northeast coast, true estuarine conditions of reduced salinity may occur fairly far inland. In these cases fishes characteristic of the coastal zone will occur correspondingly deep within the estuary.

12.2.3. SPECIES COMPOSITION

The study area has been divided into a number of faunal zones for the purpose of describing the species composition of fishes. These are:

(1) North coastal . Includes the immediate coastline out to about 36 m, embayments and estuaries up to brackish water, from the Bay of Fundy to Cape Cod.

(2) South coastal. Includes the same areas from Cape Cod to Sandy Hook, N. J.

(3) offshore. Including the continental shelf from about 36 m to the edge of the continental slope. This area is subdivided into western Nova Scotia, Gulf of Maine, Georges Bank, and southern New England after Schopf and Colton (1966) and Lux and Grosslien (1970).

Within these zones, the fish surveys listed in Table 12-3 and located in Figure 12-4 are used to describe the species composition of fishes. As previously pointed out, those surveys that employed only the otter trawl did not effectively sample the pelagic fishes. In many cases the differences in the number of species taken between surveyed areas results more from the type of sampling gear used than from actual differences in fish distribution. This makes it difficult to describe these areas completely as to their characteristic fish fauna.

NORTH COASTAL ZONE

The fish species taken in each survey of the North Coastal Zone are indicated in Table 12-4. The most common or dominant species are noted with an asterisk. Seven of the surveys-conducted on the northern Massachusetts coast have been combined.

The fishes of Passamaquoddy Bay, Maine (Tyler, 1971) were composed of 38 species taken by otter trawl. Twelve species were year-round residents that only showed a slight seasonal inshore-offshore movement. The most common of this group were longhorn sculpin, Atlantic cod, winter flounder, ocean pout, and haddock. Seasonal migrants were four summer migrant species, of which the white hake was the most common, and four winter migrant species, of which the little skate was the most common. The remainder of the species were only occasionally taken in small numbers. Most of the species were resident, boreal fishes of the Gulf of Maine with only the butterfish representing a more southern species, and the capelin and arctic hooker sculpin representing more northern fishes.

The species composition of the central Maine coast was from two surveys. The upper Sheepscot and Back River estuaries were sampled using a

variety of sampling gear and this survey gives a good representation of the fishes there. The lower Sheepscot and Damariscotta estuaries and the coastal area out four miles were sampled by otter trawl by the U. S. Fish and Wildlife Service (unpublished, 1961-62). A total of52 species were reported in the Sheepscot-Back River area, the most common species being spiny dogfish, blueback herring, alewife, Atlantic menhaden, Atlantic herring, rainbow smelt, red hake, white hake, long-horn sculpin, tomcod, winter flounder, and smooth flounder. A total of 39 species were reported for the lower estuary and coastal area. The most common were silver hake, red hake, white hake, redfish, snake blenny, winter flounder, and smooth flounder.

Seasonally, the Sheepscot-Back River areas support essentially summer faunas of pelagic fishes, i.e., alewife, blueback herring, menhaden, mackerel and striped bass. For demersal 'fishes the seasonal trends are less pronounced. However, portions of the populations of important species - tomcod, winter flounder, and smooth flounder, migrate out of the bays in the winter. The most abundant period in lower estuary and coastal areas was during the warmer months, with peaks in the early summer and again in the early fall which resulted from the influx of red hake, white hake, silver hake, and the herrings.

The species composition of central Maine indicates that a number of southern species extend their range at least half way up the Maine coast into the warmer summer waters of the nearshore environment. These fishes include: cravelle jack, scup, hickory shad, northern searobin, bluefish, and striped bass. Some of these, however, should probably not be considered more than strays.

The differences in the species composition between the two surveys can be partly attributed to the limited sampling methods of the more coastal survey and also partly to the difference in fish fauna between upper estuarine and coastal situations.

Collections of fish at the Isle of Shoals (Table 12-4) were made with a variety of sampling gear (Anderson, Borror, Bush, Hewitt and Kingsbury, 1973). The most abundant species were not indicated. Most of the species were endemic to the Gulf of Maine and the more southern fishes were limited to the tautog and fourspot flounder.

The estuarine, nearshore and coastal areas of Massachusetts north of Cape Cod (Table 12-4) have been extensively sampled for fishes by the Massachusetts Department of Natural Resources (Jerome, Chesmore, Anderson and Grice, 1965; Fiske, Matson and Coates, 1966; Jerome, et al., 1968; Jerome, et al., 1969; Chesmore, Testaverde and Richards, 1971; Curley, Lawton, Whittaker and Hickey, 1972), using a variety of conventional sampling gear (trawls and seines) and also in the Cape Cod canal, using diver observation (Fairbanks, Collins and Sides, 1971). The most

Table 12-3 Selected surveys of fish populations in the study area

Faunal Zone	Survey Location	No. Species	Sampling Gear	Reference
North Coastal	Passamaquoddy Bay, Me.	38	trawl	Tyler (1971)
	Sheepscot-Back River, Me.	52	trawl, seine, gill net	McCleave (1972)
	Boothbay Region, Me.	39	trawl	USFWS unpublished
	Isles of Shoals, N.H.	49	trawl, seine, gill net	Anderson, et al., (1973)
	Northern Mass.	67	trawl, seine	Jerome, et al., (1965) Fiske, et al., (1966) Jerome, et al., (1968) Jerome, et al., (1969) Chesmore, et al., (1971) Fairbanks, et al., (1971) Curley, et al., (1972)
South Coastal	Southern Mass.	54	trawl, seine	Fiske, et al., (1968) Curley, et al., (1970)
			trawl	Lux and Nichy (1971)
	Block Island Sound	43	trawl ,	Merriman and Warfel (1948)
	Mystic Estuary, Corm.	50	trawl, seine, trap net	Pearcy & Richards (1962)
	Long Island Sound	37	trawl	Richards (1963)
	Long Island South Shore	71	seine	Schaefer (1967)
Offshore	Western Nova Scotia	49	trawl	Lux and Grosslien (1970)
	Gulf of Maine	67	trawl	Lux and Grosslien (1970)
	Georges Bank	68	trawl	Lux and Grosslien (1970)
	Southern New England	90	trawl	Lux and Grosslien (1970)

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FIGURE 12-4

Location of Fish Population Surveys in the Study Area

Table 12-4 Species taken in surveys in the north coastal zone. The most common species are indicated by an asterisk.

		Passamaquoddy Bay Maine	Sheepscot, Back River, Maine	Boothbay Region Maine	Isles of Shoals N.H.	Northern Mass.
Atlantic hagfish	Myxine glutinosa	X		X		
Sea lamprey	Petromyzon marinus					X
Spiny dogfish	Squalus acanthias		X*	X	X	X
Smooth dogfish	Mustelus canis					
Atlantic torpedo	Torpedo nobiliano					X
Smooth skate	Raja senta	X				
Winter skate	Raja ocellata	X	X		X	
Thorny skate	Raja radiata	X	X		X	
Little skate	Raja erinacea	X*	X	X	X	X
Barndoor skate	Raja laevis	X		X	X	X
Clearnose skate	Raja eglanteria				X	
Shortnose sturgeon	Acipenser brevirostrum		X			
Atlantic sturgeon	Acipenser oxyrhincus		X			
American eel	Anguilla rostrata		X	X	X	X
Conger eel	Conger oceanica					
Blueback herring	Alosa aestivalis		X*	X	X	X*
Alewife	Alosa pseudoharengus		X*!	X	X	X*
American shad	Alosa sapidissima		X		X	X
Hickory shad	Alosa mediocris		X		X	
Atlantic menhaden	Brevoortia tyrannus		X*	X		X
Atlantic herring	Clupea harengus	X	X*	X	X	X
Atlantic salmon	Salmo salar		X			
Capelin	Millotus villos us	X	X			
Rainbow smelt	Osmerus mordax	X	X*	X		X
Striped anchoxy	Anchoa hepsetus					X
Goosefish	Lophius americanus	X	X	X	X	X
Mummichog	Fundulus heteroclitus		X		X	X*
Striped killifish	Fundulus majalis				X	
Silver hake	Merluccius bilinearis	X	X	X*	X	X
Atlantic tomcod	Microgadus tomcod	X	X	X		X
Pollock	Pollachius virens	X	X	X	X	X*
Atlantic cod	Gadus morhua	X*		X	X	X*
Haddock	Melanogrammus aeglefinis	X*		X	X	X
Red hake	Urophycis chuss		X*	X*	X	X
White hake	Urophycis tenuis	X*	X*	X*	X	X
Blue hake	Antimora rostrata				X	
Fourbeard rockling	Enchelyopus cimbrius	X		X	X	X
Cusk	Brosme brosme				X	

Table 12-4 (Continued)
Species taken in surveys in the north coastal zone. The most common species are indicated by an asterisk.

		Passamaquoddy Bay Maine	Sheepscot, Back River, Maine	Boothbay Region Maine	Isles of Shoals N.H.	Northern Mass.
Ocean pout	Macrosoarces americanus	x*	x	x	x	x
Atlantic silverside	Menidia menidia		x			x*
Fourspine sticklebacks	Apeltes quadracus		x			x
Threespine sticklebacks	Gasterosteus aculeatus		x	x	x	x
Blackspotted sticklebacks	Gasterosteus wheatlandi		x			x
Ninespine sticklebacks	Pungitus pungitus		x			x*
Northern pipefish	Syngnathus fuscus		x	x		x
Striped bass	Morone saxatilis		x			x
White perch	Morone americanus					x
Bluefish	Pomatomus saltatrix		x			x
Crevelle jack	Caranx hippos		x			x
Blue runner	Caranx crysos					x
Banded rudderfish	Seriola zonata					x
Scup	Stenotomus chrysops		x			x
Black sea bass	Centropristes striata					x
Mackerel, scad	Decapterus macarellus					x
Northern kingfish	Menticirrhus saxatilis					x
Tautog	Tautoga onitis				x	x*
Cunner	Tautogolabrus adspersus		x	x	x	x*
Redfish	Sebastes marinus	x	x	x*	x	
American sand launce	Ammodytes americanus					x
Atlantic mackerel	Scomber scombrus		x		x	x
Chub mackerel	Scomber japonicus					x
Butterfish	Peprilus triacanthus	x	x		x	
Barrelfish	Hyperglyphe perciformis					x
Snake blenny	Lumpenus lumpretaeformis	x		x*	x	
Daubed shanny	Lumpenus maculatus	x	x		x	
Radiated shanny	Ulvaria subbifurcata	x		x	x	x
Rock gunnel	Pholis gunnellus	x	x	x	x	x
Northern searobin	Prionotus carolinus		x			x
Striped searobin	Prionotus evolans					x
Longhorn sculpin	Myoxocephalus octodecimspinosus	x*	x*	x	x	x
Shorthorn sculpin	Myoxocephalus scorpius		x	x	x	x
Grubby	Myoxocephalus aeneus	x	x		x	x
Atlantic hookear sculpin	Artediellus atlanticus	x				x
Moustache sculpin	Triglops murryi	x				
Sea raven	Hemitripterus americanus	x	x	x	x	x
Mailed sculpin	Triglops nybelini		x	x		

Table 12-4 (Continued)
Species taken in surveys in the north coastal zone The most common species are indicated by an asterisk.

		Passamaquoddy Bay Maine	Sheepscot, Back River, Maine	Boothbay Region Maine	Isles of Shoals N.H.	Northern Mass.
Alligatorfish	Aspidophoroides monopterygius	x	x	x		
Lumpfish	Cyclopterus lumpus	x		x	x	x
Seasnail	Liparis atlanticus				x	x
Atlantic spiny lumpsucker	Eumicrostomus spinosus					x
Wrymouth	Cryptacanthodes maculatus	x	x			
Atlantic wolffish	Anarhichus lupus				x	x
Windowpane flounder	Scophthalmus aquosus		x	x	x	x
Atlantic halibut	Hippoglossus hippoglossus	x				
Winter flounder	Pseudopleuronectes americanus	x*	x*	x*	x	x*
American plaice	Hippoglossoides platessoides	x	x	x	x	
Yellowtail flounder	Limanda ferruginea	x	x	x	x	x*
Smooth flounder	Liopsetta putnami		x*	x*		
Witch flounder	Glyptocephalus cynoglossus	x		x	x	
Northern puffer	Sphaeroides maculatus					x
Ocean sunfish	Mola mola					x
Fourspot flounder	Paralichthys oblongus				x	x

common species taken by conventional gear at the inshore stations were: mummichog, Atlantic silversides, American sand lance, blueback herring, alewife, and ninespined sticklebacks. Much of this area was salt marsh complex. Coastal stations yielded: winter flounder, yellowtail flounder, little and winter skate, alewife, longhorn sculpin, and tomcod as common species. Diver observation in the Cape Cod canal showed the most common species to be: Atlantic cod, pollock, cunner, tautog, winter flounder, and Atlantic silversides.

Seasonal abundance in all areas of the north Massachusetts coast was characterized by high catches of fish during the warmer months and low catches during the cold months, particularly January to March. This indicates a general retreat of fish from the shallow, coastal areas during the winter. In the Cape Cod canal during the winter, Atlantic cod and winter flounder, characteristically cold water fishes, were the only important species encountered.

A total of 74 species were taken in these surveys. The relatively large number of species taken in this section of the coast, relative to the more northern areas, reflects both the intensity of sampling and the fact that the Massachusetts coast represents a major transition zone for many fish species. A large number of fishes common to the southern waters of the study area are found along the northern Massachusetts coast in the warmer months.

SOUTH COASTAL ZONE

The fish species taken in each survey of the south coastal zone is shown in Table 12-5. Three surveys of the southern Massachusetts coast have been combined.

Two Massachusetts Department of Natural Resources surveys using trawl and seine (Fiske, Curley and Lawton, 1968; Curley, Lawton, Hickey and Fiske, 1970) and a survey by otter trawl at Woods Hole (Lux and Nichy, 1971) yielded 53 species of fish.

The most common species at the Waquoit Bay-Eel Pond estuary and the Westport River were: Atlantic silversides, tidewater silversides, American sand lance, mummichog, and fourspined sticklebacks. The most common species at Woods Hole were: cunner, tautog, fourspined sticklebacks, grubby, winter flounder, scup, Atlantic silversides, and northern searobin. Seasonally, the fishes of this area showed the same pattern of abundance as the northern Massachusetts coast. The greatest diversity of species occurred during August and was due to the addition of some southern species. The species diversity in the two southern estuaries was the greatest of any of the Massachusetts surveys.

Table 12-5 Species taken in surveys in the south coastal zone. The most common species are indicated by an asterisk.

		Southern Mass.	Block Island Sound	Mystic Estuary Conn.	Long Island Sound N.Y.	Long Island South Shore, N.Y.
Sand bar shark	Carcharinus mulberti					x
Sand shark	Carcharius taurus					x
Smooth dogfish	Mustelus canis	x	x			x
Dusky shark	Carcharinus obscurus					x
Spiny dogfish	Squalus acanthias		x			x
Cownosed ray	Rhinoptera bonasus					x
Roughtail stingray	Dasyatis centroura					x
Little skate	Raja erinacea	x	x*	x	x	x
Winter skate	Raja ocellata	x	x			x
Barndoor skate	Raja laevis		x			
Clearnose skate	Raja eglanteria					x
Atlantic sturgeon	Acipenser oxyrhinchus					x
Shortnose "sturgeon	Acipenser brevirostrum					x
American eel	Anguilla rostrata	x		x*		
Conger eel	Conger oceanicus				x	
Blueback herring	Alosa aestivalis				x	x*
Alewife	Alosa pseudoharengus	x	x	x	x	x*
Menhaden	Brevoortia tyrannus	x	x		x	x
American shad	Alosa sapidissima					x*
Hickory shad	Alosa mediocris					x*
Atlantic herring	Clupea harengus		x		x	x
Atlantic round herring	Etrumeus teres					x
Bay anchovy	Anchoa mitchelli			x	x	x
Rainbow smelt	Osmerus mordax					
Inshore lizardfish	Synodus foetens. . . .			x		
Goosefish	Lophius americanus	x	x		x	x
Snakefish	Trachinocephales myops	x				
Oyster toadfish	Opsanus tau			x		x
Silver hake	Merluccius bilinearis	x	x*		x*	x
Atlantic tomcod	Microgadus tomcod	x	x	x		
Pollock	Pollachius virens	x	x	x	x	x
Red hake	Urophysis chuss	x	x	x	x	x
White hake	Urophysis tenuis	x	x			
Spotted hake	Urophysis regius		x*	x	x	
"Atlantic cod	Gadus morhua		x			
Haddock	Melanogrammus aeglefinis		x			

Table 12-5 (Continued)
Species taken in surveys in the south coastal zone. The most common species are indicated by an asterisk.

		Southern Mass.	Block Island Sound	Mystic Estuary Conn.	Long Island Sound N.Y.	Long Island South Shore, N.Y.
Fourbeard rockling	Enchelyopus cimbrius				X	
Ocean pout	Macrozoarces americanus		X			
Atlantic needlefish	Strongylura marina	X		X		X
Sheepshead minnow	Cyprinodon variegates	X		X		
Mummichog	Fundulus heteroclitus	X*		x*		
Striped killifish	Fundulus majalis	x*		X		
Banded killifish	Fundulus diaphanus	X				
Rainwater killifish	Lucania parva	X				
Atlantic silverside	Menidia menidia	x*		X*	X	X
Tidewater silverside	Menidia beryllina	x*		X		
Fourspine sticklebacks	Apeltes quadracus	x*		x*	X	
Threespine sticklebacks	Gasterosteus aculeatus	X		x*		
Blackspotted sticklebacks	Gasterosteus wheatlandi	X				
Ninespine sticklebacks	Pungitus pungitus	X		X		
Northern pipefish	Syngnathus fuscus	X		X	X	X
Lined seahorse	Hippocampus erectus				X	X
Bluespotted cornetfish	Fistularia tobacaria					X
White perch	Morone americanus	X				X
Striped bass	Morone saxatilis	X				x*
Black seabass	Centropristes striatia	X	X		X	
Bluefish	Pomatomus saltatrix	X		X		x*
Sharksucker	Echeneis naucrates			X		
African pompano	Alectis crinitus			X		X
Cravelle jack	Caranx hippos					X
Short bigeye	Pristigenys alta	X				
Bigeye scad	Selar crumenophthalmus					X
Blue runner	Caranx crysos					X
Mackerel scad	Decapterus macarellus					X
Round scad	Decapterus punctatus					X
Lookdown	Selene vomer					X
Leather jacket	Oligophites saurus					X
Banded rudderfish	Seriola zonata			X		X
Pompano	Trachinotus carolinus					X
Rough scad	Trachurus lathami					X
Atlantic moonfish	Vomer setapinnis					X
Scup	Stenotomus chrysops	x*	x	x	x*	x
Weakfish	Cynoscion regalis	x	x			x

Table 12-5 (Continued)
Species taken in surveys in the south coastal zone. The most common species are indicated by an asterisk.

		Southern Mass.	Block Island Sound	Mystic Estuary Conn.	Long Island Sound N.Y.	Long Island South Shore, N.Y.
Atlantic croaker	Micropodon undulatus					x
Silver perch	Bairdiella chrysura			x		x
spot	Leiostomus xanthuras		x	x		x
Northern kingfish	Menticirrhus saxatilis	x	x	x		x
Red goatfish	Mullus auratus	x		x		
Tautog	Tautoga onitis	x*	x	x	x	x
Cunner	Tautogolabrus adspersus	x*	x	x*	x	x
Striped mullet	Mugil cephalus			x		x
White mullet	Mugil curema					x
Northern sennet	Sphyraena borealis			x		x
Rock Gunnel	Pholis gunnellus	x	x	x*	x	
American sand launce	Ammodytes americanus	x*			x	
Naked goby	Gobiosoma bosci			x		
Seaboard goby	Gobiosoma ginsbergi	x		x	x	
Atlantic cutlassfish	Trichiurus lepturus					x
Atlantic bonito	Sarda sarda					x
Atlantic mackerel	Scomber scombrus		x			x
Butterfish	Peprilus triacanthus	x	x		x	x
Northern searobin	Prionotus carolinus	x*	x	x	x	x
Striped searobin	Prionotus evolans	x	x		x	x
Longhorn sculpin	Myoxocephalus octodecimspinosus	x	x*	x	x	x
Grubby	Myoxocephalus aeneus	x*	.	x*	x	x
Sea raven	Hemitripterus americanus		x			
Lumpfish	Cyclopterus lumpus	x		x		
Sea snail	Liparis atlanticus		x	x		
Flying gurnard	Dactylopterus volitans	x				
Fourspot flounder	Paralichthys oblongus		x*	x	x	
Summer flounder	Paralichthys dentatus	x	x	x		x
Windowpane	Scophthalmus aquosus	x	x*	x	x*	x
Winter flounder	Pseudopleuronectes americanus	x*	x*	x*	x*	x
Yellowtail flounder	Limanda ferruginea		x			
Witch flounder	Glyptocephalus cynoglossus		x			
Smallmouth flounder	Etropus microstomus			x	x	
Hogchoker	Trinectes maculatus				x	
Orange filefish	Aluterus schoepfi		x	x		x
Grey triggerfish	Balistes capriscus			x		
Planehead filefish	Monacanthus hispidus	x	x			x

Tab e 12-5 (Continued)
Species taken in surveys in the south coastal zone The most common species are indicated by an asterisk.

		Southern Mass.	Block Island Sound	Mystic Estuary Corm.	Long Island Sound N.Y.	Long Island South Shore, N.Y.
Northern puffer	Sphaeroides maculatus	X	X	X	X	X*
Smooth puffer	Lagocephalus laevigtus					x
Striped burrfish	Chilomycterus schoepfi			X	X	X
Striped sea snail	Liparis liparis		X			

Merriman and Warfel (1948) surveyed the fish population of Block Island Sound. The six most abundant species were: winter flounder, little skate, winter skate, longhorn sculpin, silver hake, windowpane flounder. These species made up 82.9 percent of the catch by weight and 91 percent by number. Their catch can be broken down into population components as was Tyler's (1971). The most common residents were little skate, winter flounder, windowpane flounder, and longhorn sculpin. The most common winter seasonal" was Atlantic cod and the most common summer seasonals were silver hake and fourspotted flounder. The 42 species that were taken in the survey were considerably less than the number of species that are known to inhabit the southern New England coastal waters (Nichols and Breder, 1927). The authors point out that not only was the commercial trawl effective in capturing only demersal species, but the areas fished were also restricted to those commercially profitable.

Pearcy and Richards (1962) provide a general treatment of the communities of fishes in the Mystic River estuary, Connecticut. Their use of varied sampling gear (trawls, seines, trap nets) yielded 50 species of adult and juvenile fishes. The total number of species and the greatest catch of fish occurred during the warm months, with about four times as many juveniles and adults found in the estuary in the summer as in the winter. Their species can be generally grouped into 28 resident species, 19 summer migrant species, and 3 diadromous species. Their most common species were: winter flounder (by far the dominant species), fourspined sticklebacks, grubby, mummichog, threespined sticklebacks, rock gunnel, American eel, cunner, oyster toadfish, and Atlantic silversides.

Richards (1963) surveyed the fish populations of two locations in Long Island Sound, one on mud bottom and one on sand bottom, using an otter trawl. She recorded a total of 37 species, ten of which constituted 93 percent of the standing crop of fishes. The winter flounder accounted for 67 percent of the standing crop. Three population components can be. distinguished from the catch: residents, winter seasonals, and summer seasonals (Tyler, 1971). The most common resident species were the winter flounder and silver hake which is a somewhat seasonal species; the most common summer seasonal was the scup, and the most common winter seasonal was the Atlantic herring. Surprisingly, the period of lowest abundance in Long Island Sound was the summer, with an increase in the fall due to the arrival of juveniles. Many of the southern migrating fishes were not present in the catches during the summer. This is unusual considering the rich diversity of fishes on the southern shore of Long Island.

Richards suggests that Long Island Sound was generally not a productive area for fish populations and its fish fauna consisted largely of small juveniles. The standing crop of fishes was less than that recorded for Block Island Sound (Merriman and Warfel, 1948) or for the English Channel,

even though the production of plankton was high. Richards attributed this to the high organic content of the mud which failed to produce food organisms for larger fish, and also competition for food and space with the starfish Asterias forbesi. High primary production, then, is not necessarily an indicator of high fish production.

Schaefer (1967) studied the species composition of fishes on the south shore of Long Island using a commercial sized beach seine. He collected 71 species of fish, a large number of which were southern migratory forms. The more common species were northern puffer (the most abundant) blueback herring, butterfish, alewife, hickory shad, striped bass, bluefish, and American shad. Less than 10 species made up 90 percent of the catch. The large number of migratory species found along the exposed shoreline suggests that the southern coast of Long Island is a major route for the seasonal movements of southern migratory species.

OFFSHORE

The offshore area from western Nova Scotia to Long Island and from 27 m to about the 360 m isobath has been sampled for demersal fishes with an otter trawl by the National Marine Fisheries Service (Lux and Grosslien, 1970).

The survey covered four faunal zones (Figure 12-4), each with somewhat distinct hydrographic conditions (Table 12-2) and animal populations: western Nova Scotia, Gulf of Maine, Georges Bank, and southern New England. The surveys took a total of 110 species which are listed by faunal zones in Table 12-6.

Western Nova Scotia yielded 48 species where the dominant fishes were haddock, Atlantic cod, pollock, and spiny dogfish. Most of the cod and haddock were taken in the vicinity of Browns Bank.

The total number of species for the Gulf of Maine was 67. The principal fish was redfish followed by haddock, spiny dogfish, thorny skate, Atlantic cod, silver hake, pollock, and American plaice.

A total of 68 species were taken on Georges Bank, with haddock the most abundant followed by Atlantic cod, yellowtail flounder, winter skate, little skate, and eel pout.

Southern New England yielded a total of 90 species. The principal species was spiny dogfish followed by yellowtail flounder, red hake, silver hake, little skate, and eel pout. In the southern New England and Georges Bank zones there occurred the greatest variation in seasonal abundance and availability of fishes. Bottom temperatures showed the most variation in these zones, which probably contributed to the greater

Table .12-6 Species taken in surveys in offshore areas. The most common species are indicated by an asterisk.

		Western Nova Scotia	Gulf of Maine	Georges Bank	Southern New England
Atlantic hagfish	Myxine glutinosa	x	x		
Sea lamprey	Petromyzon marinus	x	x		
Spiny dogfish	Squalus acanthias	x*	x*		*
Smooth dogfish	Mustelus canis				
Chain dogfish	Scyliorhinus retifer				
Atlantic torpedo	Torpedo nobiliana				
Barndoor skate	Raja laevis	x	x		
Winter skate	Raja ocellata	x	x	*	
Little skate	Raja erinacea	x	x.	*	*
Smooth skate	Raja senta	x	x		
Thorny skate	Raja radiata	x	x*		
Clearnose skate	Raja eglanteria	x	x		
Rosette skate	Raja garmani	x"	x		
Conger eel	Conger oceanicus				
Atlantic herring	Clupea harengus	x	x		
Alewife	Alosa pseudoharengus	x	x		
Round herring	Etrumeus teres		x		
Blueback herring	Alosa aestivalis	x	x		
American shad	Alosa sapidissima	x	x		
Hickory shad	Alosa mediocris				
Menhaden	Brevoortia tyrannus				
Rainbow smelt	Osmerus mordax	x	x		
Capelin	Mallotus villosus	x			
Striped anchovy	Anchoa hepsetus				
Atlantic argentine	Argentina silas	x	x		
Viperfish	Chauliodus sloani		x		
Hatchetfish	Argyropelecus aculeatus				
Slime eel	Simenichelys cruentifer		x		
Snake eel	Onochelys cruentifer				
Snipe eel	Nemichthys scolopaceus				
---------	Chloropthalmus chalybeius		x		
---------	Paralepis borealis		x		
Pearlsides	Maurolicus pennanti	x	x		
Lanternfish	(several species)	x	x		

Table 12-6 (Continued)
Species taken in surveys in offshore areas. The most common species are indicated by an asterisk.

		Western Nova Scotia	Gulf of Maine	Georges Bank	Southern New England
Longnose batfish	Ogcocephalus vespertilio			X	
Silver hake	Merluccius bilinearis	X	X*	X	X*
Offshore hake	Merluccius albidus			X	X
Atlantic cod	Gadus morhua	X*	X*	X*	X
Haddock	Melanogrammus aeglefinis	X*	X*	X*	X
Pollock	Pollachius virens	X*	X*	X	X
White hake	Urophysis tenuis	X	X	X	X
Red hake	Urophysis chuss	X	X	X	X*
Spotted hake	Urophysis regius				X
Threebeard rockling	Gaidropsarus ensis	X			
Longfin hake	Physis chesteri		X	X	X
Cusk	Brosme brosme	X	X	X	
Blue hake	Antimora rostrata			X	X
Snipefish	Macrorhamphosus scolopax				X
Ocean pout	Macrozoarces americanus	X	X	X	X*
Marlin-spike	Nezumia bairdi		X	X	X
Longnosed grenadier	Coelorhynchus carminiatus				X
Goosefish	Lophius americanus	X	X	X	X
Arctic eelpout	Lycodes reticulatus				X
Wolf eelpout	Lycenchelys verrilli	X	X		
Fawn tusk eel	Lepophidium cervinium		X	X	X
Flat needlefish	Ablennies hians				X
Atlantic saury	Scomberesox saurus			X	X
Halfbeak	Hyporhamphus unifasciatus			X	
Atlantic silversides	Menidia menidia		X		X
American john dory	Zenopsis ocellata				X
Threespine sticklebacks	Gasterosteus aculeatus				X
Northern pipefish	Syngnathus fuscus		X		
Black seabass	Centropristes striatus				X
Mackerel scad	Decapterus macarellus				X
Bigeye scad	Selar crumenophthalmus				X
Bluefish	Pomatomus saltatrix				X
Weakfish	Cynoscion regalis				X
Scup	Stenotomus chrysops		X	X	X
Cunner	Tautogolabrus adspersus		X	X	X

Table 12-6 (Continued)
Species taken in surveys in offshore areas. The most common species are indicated by an asterisk.

		Western Nova Scotia	Gulf of Maine	Georges Bank	Southern New England
Tautog	Tautoga onitis				X
Snake blenny	Lumpenus lumpretaeformis		X	X	
Daubed shanny	Lumpenus maculatus	X	X	X	
Radiated shanny	Ulvaria subbifurcata	X	X	X	
Rock gunnel	Pholis gunnellus			X	
Atlantic wolffish	Anarhichus lupus	X	X	X	
Wrymouth	Cryptacanthodes maculatus		X		X
American sand launce	Ammodytes americanus	X	X	X	X
Atlantic mackerel	Scomber scombrus		X	X	X
Fourbeard rockling	Enchelyopus cimbrius	X	X	X	X
Saurel	Trachurus trachurus				X
Tilefish	Lopholatilus chamaeleonticeps				X
---------	Careproctus ranulus		X		
Frogfish	Antennarius sp.				X
Butterfish	Peprilus triacanthus		X	X	X
Barrel fish	Hyperoglyphe perciformes				X
Redfish	Sebastes marinus	X	X*	X	X
Blackbelly rosefish	Helicolenus dactylopterus		X	X	X
Longspine scorpionfish	Pontinus longispinus				X
Northern searobin	Prionotus carolinus				X
Striped searobin	Prionotus evolans				X
Armored searobin	Peristedion miniatum				X
Longhorned sculpin	Myoxocephalus octodecimspinosus	X	X	X	X
Sea raven	Hemitripterus americanus	X	X	X	X
Hookear sculpin	Artediellus uncinatus	X	X	X	
Shorthorn sculpin	Myoxocephalus scorpius		X	X	
Mailed sculpin	Triglops nybelini	X	X	X	X
Grubby	Myoxocephalus aenaeus			X	
Alligatorfish	Aspidophoroides monopterygius	X	X	X	X
Lumpfish	Cyclopterus lumpus	X	X	X	
Seasnail	Liparis atlanticus	X	X	X	X
Windowpane	Scophthalmus aquosus		X	X	X
Summer flounder	Paralichthys dentatus			X	X
Fourspot flounder	Paralichthys oblongus	X	X	X	X
Winter flounder	Pseudopleuronectes americanus	X	X	X	X

Table 12-6 (Continued)
Species taken in surveys in offshore areas. The most common species are indicated by an asterisk.

		Western Nova Scotia	Gulf of Maine	Georges Bank	Southern New England
Witch flounder	Glyptocephalus cynoglossus	x	x	x	x
American plaice	Hippoglossoides platessoides	x	x*	x	x
Hal ibut	Hippoglossus hippoglossus	x	x	x	
Gulf stream flounder	Citharichthys arctifrons			x	x
Yellowtail flounder	Limanda ferruginea	x	x	x*	x*
Tonguefish	Symphurus sp.				x
Planehead filefish	Monacanthus hispidus				x
Northern puffer	Sphaeroides maculatus				x

movement of fishes.

Although the total catch per haul varied widely from season to season, the average catch per haul for all seasons combined was relatively uniform from zone to zone. Productivity, as measured by the average fish catch per haul, was highest on Georges Bank (152 kg/haul) followed by the Gulf of Maine (128 kg/haul), southern New England (126 kg/haul) and western Nova Scotia (122 kg/haul).

The fish fauna of the deep waters of the Gulf of Maine basin has been the subject of several investigations. Bigelow and Schroeder (1939) made trawl tows in the deep mud bottoms of the western and northern Gulf and found a monotonous faunal community just above the bottom. The principal fishes were silver hake yearlings, redfish, American plaice, witch flounder, and red hake.

Musick (1973a) using otter and midwater trawls found that a number of the mesopelagic fishes of the open ocean are permanent residents in the deep water of the Gulf of Maine basin. Species from such genera as Benthosema, Ceratoscopelus, Myctophum, and Maurolicus occurred below 135 m throughout the year and provided a food source for some of the larger predacious fishes.

12.2.4 ESTUARIES AND NEARSHORE AREAS

The estuaries and the areas adjacent to the coastline provide a varied and demanding environment for fishes, resulting in a fauna that is adapted to live under more extreme conditions of temperature and salinity than is found in water farther offshore. Generally speaking, the fish fauna of these areas are either small, euryhaline species that are adapted to continuous residence, juvenile fishes that use the areas as nursery grounds, or diadromous species that use the estuaries as pathways to and from spawning grounds. Fishery scientists generally agree that the estuaries, sounds, and embayments along the eastern seaboard provide essential habitats for many marine species (Smith, 1973). Clark, et al., (1969) estimate that60 to 70 percent of the economically important Atlantic species inhabit estuarine environments at some time during their life.

Gunter (1961) points out that estuaries are important as nursery grounds for the young of many fish species, but are not as productive of adult populations. The number of fish species declines progressively with the distance up the estuary. Because the greatest number of marine plants and animals are found in the photic zone of shallow waters, estuaries do not generally produce as much marine life as open waters.

The fish fauna of a number of estuaries in the study area have been grouped into several categories (McHugh, 1967; Pearcy and Richards, 1962; Lebida, 1969) which can be summarized as follows:

(1) Fresh water fishes that stray into brackish and salt water. These include brook trout, Salvelinus fontinalis, brown trout Salmo trutta, and members of the perch and sunfish families.

(2) True estuarine fishes that are able to adapt to wide changes in salinity that are characteristic of upper estuarine waters. These fishes include small forage species such as killifishes, silversides, and the sticklebacks; larger euryhaline fishes such as the winter flounder, smooth flounder, and tomcod; and juvenile stages of many species that later reside in open waters as adults.

(3) Diadromous species that use the estuaries as pathways to and from spawning grounds. These include Atlantic salmon, rainbow smelt, alewife, blueback herring, American eel, American shad, sea lamprey, and Atlantic sturgeon.

(4) Resident marine species that are common to open waters as well and which are usually only found in the lower estuarine areas of relatively high salinity. These include little skate, spiny dogfish, sculpins, cunner, tautog, searobins, lumpfish, windowpane flounder, winter flounder and smooth flounder. This also includes summer migrants that enter the estuaries seasonally such as striped bass, bluefish, northern puffer, northern kingfish, scup, and weakfish. All the species in this category show, to some degree, characteristic seasonal movements in and out of the estuary corresponding to the annual fluctuation of temperature.

Gibson (1969) reviewed the fishes that are found in the littoral zone between the tide marks. He found the more stable the shore and the more cover it provided, the greater the population of nearshore fishes. Rocky shores had more resident populations while sandy and muddy shores had fluctuating populations that move in and out with the tide.

In northern shores, sculpins, winter flounder, smooth flounder, and rock gunnel are common shore fishes. The rock gunnel is able to remain in the intertidal zone throughout the tidal cycle (Sawyer, 1967) by remaining in tide pools and under rocks. Tyler (1971b) observed winter flounder, and to a lesser extent longhorn sculpin, sea raven, tomcod, and young Atlantic cod moving into the intertidal zone to feed during the flood tide and retreating on the ebb. Winter flounder entered in a surge and occupied the intertidal zone for 6 to 8 hours before moving out. He concluded that the intertidal zone was a major feeding area

for winter flounder.

In southern shores, Merriman (1947) notes that fishes that entered the intertidal zone on Connecticut beaches were mostly small pelagic and semi-demersal plankton feeders and were juvenile stages of fishes that live in the deeper water as adults. In the shallow, protected areas of the Massachusetts coast (Jerome, et al., 1965; Fiske, et al ., 1966; Jerome, et al., 1968; Jerome, et al., 1969; Chesmore, et al., 1971; and Curley, et al., 1972) and the inner, shallow waters of Great South Bay, Long Island (Briggs, 1973) such small species as Atlantic silversides, sticklebacks, American sand lance, and killifishes are dominant, along with larger fishes such as northern puffer, winter flounder, yellowtail flounder.

In the study area, the estuaries and the intertidal and subtidal regions close to shore have somewhat unique roles in that they:

(1) Provide a habitat for a somewhat specialized group of neritic fish species

(2) Provide a nursery area for juvenile fishes of numerous species

(3) Provide intertidal feeding grounds for a number of species of fish :

(4) Provide a pathway for spawning, di adromous fishes.

12.3 REPRODUCTION

It is generally accepted by biologists that the reproductive phase of the fish's life history is its most sensitive. Saville (1965), Gulland (1965), Marr (1956) and Hempel (1963) all point out that the success of a year class during its early stages governs the productivity of any species of fish, and that for-most fishes the size of a year class is established by the end of the planktonic phase. However, very little is known about the factors that influence reproductive success. The hazards to successful reproduction are many. Most fishes require somewhat specific times, temperatures, and locations for spawning, which, in many cases, are during brief periods and are in limited and vulnerable areas. Many species have planktonic eggs and almost all species have planktonic larvae which drift passively in the water column as part of the meroplankton, subject to unfavorable currents and winds as well as predation. The planktonic phase is terminated when the larvae metamorphose into young adults, or juveniles, and in this state also many species have specific requirements for survival, such as shallow, protected coastlines or estuaries.

12.3.1 SPAWNING

For the majority of fishes the spawning act involves the external fertilization of an enormous quantity of eggs, very few of which will survive to become adults (Sette, 1943). For a few species such as redfish, northern pipefish, and spiny dogfish the eggs develop in the oviduct or in a brood pouch and the young are born in an advanced stage.

For these fishes the number of eggs that are produced is considerably less than for species whose eggs are released and fertilized externally.

There are two types of eggs produced by externally spawning fishes, demersal eggs which sink and either lie loosely or attach themselves to some bottom substrate, and planktonic eggs which float freely in the water column near the surface. Generally, demersal eggs are laid by those species whose life history is closely associated with the shallow, inshore areas of estuaries and embayments (Gibson, 1969; Pearcy and Richards, 1962; Chenoweth, 1973), thus insuring that the spawning products during the egg stage will not be swept away into unfavorable areas. In open waters, fishes that lay demersal eggs do so on relatively shallow coast and bank areas. Notable among these is the Atlantic herring, a pelagic fish that lays demersal eggs in sheets that adhere to the bottom. This species spawns in dense concentrations over limited areas of specific bottom type in the north coastal zone and offshore banks (Caddy and Iles, 1973; Drapeau, 1973). At this point the herring is extremely vulnerable to commercial fishing and the eggs are susceptible to damage from bottom trawling as well as natural causes.

Planktonic eggs are usually laid by fishes that range widely over the continental shelf waters. Many of these species spawn over a large area and over a relatively long period of time, i.e., yellowtail flounder, American plaice, silver hake, Atlantic mackerel, and red hake. The spawning areas of these species are not well defined.

For many species, spawning results in an aggregation of fishes in relatively small, well-defined areas to insure that the spawning products are adequately fertilized. This requires migrations to and from spawning grounds, often under adverse conditions. Anadromous fishes such as Atlantic salmon, rainbow smelt, alewife, blueback herring, the sturgeons, and the shads move into estuarine and river systems on their way to fresh water spawning sites. Successful reproduction for these species depends on free passage into fresh water and suitable spawning beds on which to lay their eggs. In the open waters, spawning migrations also take place while fish move into limited, well-defined spawning areas, i. e., Atlantic cod, Atlantic herring, haddock, and pollock.

Probably the region that is most important for spawning in the study

area is the southern Gulf of Maine, from the coastal belt of Massachusetts, Rhode Island, and Connecticut out to Georges Bank. To the south of this region, many of the summer seasonal fishes have their major spawning outside. the study area. To the north of this region, particularly the Bay of Fundy, the waters are not suitable for reproduction of many species (hake, haddock, cod, mackerel, rockling, plaice, cunner). The suggested reasons for this have been low surface water temperature and mechanical shocks due to the turbulence of the water (Steele, 1963).

Most fish in the study area spawn from late winter to midsummer (Bigelow and Schroeder, 1953). For these species, spawning usually commences first in the southern part of the study area and progresses gradually northward as the seasonal water temperature rises. For fishes that spawn over wide areas, as much as several months may be involved to complete spawning from the southern to the northern extremes.

For a few species, notably the Atlantic herring and the summer flounder, spawning commences in late summer and progresses through the fall as seasonal water temperatures fall. In this case, spawning commences, in the northern part of the study area and progresses south. Spawning information, condensed from Bigelow and Schroeder (1953), is given in Table 12-7 for some of the more important species.

12.3.2 EGGS AND LARVAE

The planktonic period for most fishes occurs during the spring and summer and lasts on an average of 3 to 5 months (Bigelow and Schroeder, 1953; Colton and Temple, 1961). During this time, the eggs and larvae are an important part of the seasonal plankton in the estuaries and the relatively shallow coast and bank areas. The length of time. that any particular species remains in the planktonic stage varies. At one extreme, the winter flounder, which spawns well up in the estuaries, has only a brief semi-demersal existence of about 50 days (Pearcy, 1962) suitable for the maintenance of the larvae well up in the estuaries. At the other extreme, Atlantic herring remain in the larval stage for 5 to 7 months (Graham, Chenoweth and Davis, 1972; Tibbo, Legare, Scattergood and Temple, 1958). The length of a fish's planktonic life is a function of temperature as well as the characteristic of the species. The higher the water temperature, the faster the development of the eggs and larvae. For example, there is several months difference in the time of metamorphosis between Gulf of Maine herring larvae and those from some spawning stocks in European waters due to the differences in surface water temperature. (Tibbo, et al., 1958).

Table 12-7 The spawning characteristics of some of the important species that reproduce in the study area. Primary source was Bigelow and Schroeder (1953) and other sources as listed under life history descriptions of key species.

	Spawning Type	Spawning Time	Spawning Areas
Spiny dogfish *Squalus acanthias*	Ovoviviporous.	Young born in Nov.-Jan. 2nd year.	Offshore wintering grounds.
Little skate *Raja erinacea*	Fertilization is internal; lays eggs.	All year.	Not deeper than 27m on sandy bottoms.
Short-nosed sturgeon *Acipenser brevirostrum*	Anadromous.	Late April (in lower Hudson).	Spawns in rivers.
Alewife *Alosa pseudoharengus*	Anadromous. Eggs demersal.	Spring.	Ponds and sluggish streams. 13-16 C.
Blueback herring *Alosa aestival is*	Anadromous. Eggs demersal.	Late spring.	Nearer tidewater than alewife. 20-23 C.
Atlantic herring *Clupea harengus*	Eggs adhesive, demersal. Larvae pelagic.	Sept.-Nov.	Shallow coast & banks, particularly Georges Bank, less than 90m. Rocky-gravelly bottom.
Menhaden *Brevoortia tyrannus*	Eggs and larvae pelagic.	May-July and Sept-Ott.	15-18 C. coastal waters. Rarely above Cape Cod.
Smelt *Osmerus mordax*	Anadromous. Eggs adhesive, demersal; larvae pelagic.	Once a year. March-May.	Fresh or barely brackish coastal streams. 4-12 C.
Atlantic salmon *Salmo salar*	Anadromous. Eggs demersal.	Late Oct.-early Nov.	Streams, level gravelly bottom.

Table 12-7 (Continued)

	Spawning Type	Spawning Time	Spawning Areas
American shad *Alosa sapidissima*	Anadromous. Eggs semi-buoyant, not sticky.	Spring or early summer. 10-13 C	Sandy or pebbly shallows.
Mummichog *Fundulus Heteroclitus*	Eggs demersal, adhesive.	April-early August.	In a few inches of water, close to shore.
Silver hake *Merluccius bilinearis*	Eggs and larvae pelagic.	June-Sept. Principally in July & August.	Entire coastal zone from Long Is. to Sable Is. Sandy slopes shoaler than 90m. Most important N & E of Cape Cod. 7-12 C.
Atlantic cod *Gadus morhua*	Eggs and larvae pelagic. Seek bottom at 4cm.	Chiefly in winter.	Not below 90m Eastern Georges Bank, Browns Bank, Mass. Bay 3-10 miles offshore, Ipswich Bay.
Haddock *Melanogrammus aeglefinis*	Eggs and larvae pelagic.	Feb.-May Peak in March-Apri 1.	Broken bottom of mixed rock, gravel, mud and sand. 4-7 c.
Pollock *Pollachius virens*	Eggs and larvae pelagic.	Nov.-March Peak, late Dec.	Chiefly region of Mass. Bay. 27-90m. 6-8 C.
Red hake *Urophycis chuss*	Eggs and larvae pelagic.	Sumner.	Relatively shoal water, within 100m isobath.
White hake *Urophycis tenuis*	Eggs and larvae pelagic.	Summer.	Same as red hake.
Atlantic silverside *Menidia menidia*	Eggs demersal, adhesive. Larvae pelagic.	May-July. Primarily May and early June.	Shallow bays and marshes, 15-22 C, over sandy bottoms.

Table 12-7 (Continued)

	Spawning Type	Spawning Time	Spawning Areas
American sand launce *Ammodytes americanus*	Eggs-demersal, adhesive.	Autumn and early winter, late Nov. -late March.	Inshore and offshore above 27m. Sandy bottom.
Atlantic mackerel *Scomber scombrus*	Eggs and larvae are pelagic.	Spring-early summer. Peak May-June.	Primarily Chesapeake Bay to Cape Cod, 9-13 C, no spawning grounds.
Butterfish *Peprilus triacanthus*	Eggs and larvae are pelagic.	June-August. Peak in July.	Within a few miles of shore over most of their range.
Bluefish *Pomatomus saltatrix*	Eggs and larvae are pelagic.	May-June.	Offshore, 18m to edge of continental shelf, waters warmer than 15 c. Not above Cape Cod.
Striped bass *Morone saxatilis*	Anadromous. Eggs and larvae are pelagic. Eggs semi-buoyant.	May-early June.	Brackish to fresh water of Hudson River 14-15 C, as high as 20 C.
Scup *Stenotomus chrysops*	Eggs and larvae are pelagic.	May-August. Peak May-mid-July.	Estuaries, bays and inshore waters, 18-20 C. Not above Cape Cod.
Weakfish *Cynoscion regalis*	Eggs-buoyant.	May-Oct. Peak mid-May to mid-June.	Large estuaries or near their mouths. Not above Cape Cod.
Kingfish *Menticirrhus saxatilis*		June-August.	Bays and sounds. Not above Cape Cod.
Longhorn sculpin *Myoxocephalus octodecimspinosus*	Eggs-demersal, adhesive.	Nov.-Feb. Peak late Dec.-Jan.	Throughout their range.

Table 12-7 (Continued)

	Spawning Type	Spawning Time	Spawning Areas
Cunner *Tautogolabrus adspersus*	Eggs and larvae are pelagic.	May-Oct.	Throughout their range, coastal, 10-11 c.
Tautog *Tautoga onitis*	Eggs and larvae are pelagic.	Early to mid-summer. May-August.	Lower estuaries and shallow coastal areas. Chiefly below Cape Cod.
Summer flounder *Paralichthys dentatus*	Eggs and larvae are pelagic.	Sept.-Feb. in a north to south progression. Early Sept. for the Gulf of Me.	Deep water within 46km of shore, 12-19 c.
Winter flounder *Pseudopleuronectes americanus*	Eggs sink and adhere (demersal, non-buoyant). Larvae have mixed planktonic-benthic behavior.	Jan.-May.	In shoal water, 7m in backwaters of bays and estuaries and on Georges Bank at 45m-72m. 5 C. Sandy bottom.
Yellowtail flounder *Limanda ferruginea*	Eggs and larvae are pelagic.	March-August.	Water 46 to 64 meters deep, over sand bottom.
American plaice *Hippoglossoides platessoides*	Eggs and larvae are pelagic.	March-June. Peak April-May.	From inshore to the 180m contour. 3-5 C. Throughout its range.
Witch flounder *Glyptocephalus cynoglossus*	Eggs buoyant, Larvae pelagic for 4-6 months.	Late spring-summer. Peak July-August.	Throughout the Gulf of Maine and the offshore banks.
Atlantic halibut *Hippoglossus hippoglossus*	Eggs and larvae are pelagic.	Jan.-June. Peak March-May.	Spawn on bottom.
Redfish *Sebastes marinus*	Eggs develop and hatch within the oviduct. Larvae pelagic.	Peak late June to early July.	Both inshore and offshore. Rocky and hard grounds. 2-9 C.

Table 12-7 (Continued)

	Spawning Type	Spawning Time	Spawning Areas
Ocean pout *Macrozoarces americanus*	Eggs laid in gelatinous masses. Larvae demersal.	Sept.-Ott.	Rocky bottoms. Congregate for spawning.
Northern puffer *Sphaeroides maculatus*	Eggs demersal and adhesive.	Mid-May through summer.	Shoal water, close to shore. Not above Cape Cod.

Planktonic fish eggs drift passively in the water column near the surface, usually in the upper 20 m (Williams, 1968). Most-fish larvae also drift near the surface. Gadoid larvae and 10-25 mm redfish larvae are usually in the upper 40 m (Miller, Colton and Marak, 1963; Colton and Temple, 1961; Kelley and Barker, 1961); flatfish larvae tend to be abundant below 20 m while herring larvae carry out diurnal vertical movements in the water column (Colton and Temple, 1961).

At hatching, fish larvae are weak swimmers but pelagic marine larvae show the ability to orient towards currents and carry out limited movements (Bashai, 1960). The ability of the larvae to move independently increases with size until by metamorphosis many species are capable of schooling and undertaking fairly extensive migrations. The larval stage is terminated at metamorphosis at which time the fish assumes the adult body form and habit.

SPECIES COMPOSITION

The species composition and the seasonal abundance of planktonic fish eggs and larvae have been reported from a number of surveys throughout. the study area. These surveys are grouped into two categories: coastal-offshore and estuarine. The composition. and relative abundance of fish larvae from the surveys are shown in Tables 12-8 and 12-9. The seasonal abundance, where available, is shown in Figure 12-5.

As would be expected, the species composition of eggs and larvae in any region reflects, in a general way, the composition of the fish species that are common to that region.

The offshore Gulf of Maine and Georges Bank waters were sampled for eggs and larvae by Marak and Colton, (1961); Colton and Foster, (1962a); and Colton, Foster and Miller, (1962b). These surve y took a total of forty-one species of larvae. The most common were those species who as adults are found in the coastal' and offshore waters i.e., haddock, cod, yellowtail flounder and American plaice. The lack of abundant herring larvae in these surveys is probably because the sampling dates did not coincide with the peak abundance of herring larvae.

Fish and Johnson (1937) surveyed the Bay of Fundy and Gulf of Maine waters in a slightly more northern survey than that of Marak, et al. Some of their dominant species were typical of more northern species: redfish, Atlantic herring, American plaice, and witch flounder.

There have been a number of surveys of the coastal areas of southern New England and Long Island Sound (Merriman and Sclar, 1952; Wheatland, 1956; Perlmutter, 1939) which show larvae of the fishes more common to

Table 12-8 Species composition and relative abundance (percent) of fish larvae from coastal and offshore surveys

		PERCENT OCCURRENCE			
		Marak, et al. 1961, 1962a, 1962b	Wheat and 1956	Merriman & Sclar 1952	Fish and Johnson 1937
American plaice	Hippoglossoides platessoides	5.33			0.26
Alligatorfish	Aspidophoroides monopterygius	0.01			0.08
American sand launce	Ammodytes americanus	7.49	34.40		0.08
Anchovy	Anchoa mitchilli mitchilli		45.68		
Butterfish	Poronotus triacanthus	0.02		0.49	
Atlantic cod	Gadus morhua	9.22		1.71	0.06
Cunner	Tautogolabrus adspersus	2.87	1.09	22.44	
Cusk	Brosme brosme	2.43			0.23
American eel	Anguilla rostrata	0.31	0.07		0.04
Goosefish	Lophius americanus	0.11			
Haddock	Melanogrammus aeglefinus	31.47			1.51
Atlantic herring	Clupea harengus harengus	4,31	0.07	3.90	48.32
Lanternfish	Myctophum affine	0.05			
Lumpfish	Cyclopterus lumpus	0.06		3.90	
Atlantic mackerel	Scomber scombrus	0.47		1.71	
Atlantic menhaden	Brevoortia tyrannus	0.04	10.20		
Striped mullet	Mugil cephalus	0.06			
Atlantic saury	Scomberesox saurus	0.01			
Pollock	Pollachius virens	2.42			
Puffer	Tetraodontidae (Family)	0.01			
Redfish	Sebastes marinus	0.13			47.84
Squirrel hake	Urophycis chuss	3.33		17.80	
Fourbeard rockling	Enchelyopus cimbrius	4.97	0.54		0.04
Banded rudderfish	Seriola zonata	0.02			
Scup (porgy)	Stenotomus chrysops	1.51	0.27	0.24	
Threespine sticklebacks	Gasterosteus aculeatus	0.08			
Longhorn sculpin	Myoxocephalus octodecimspinosus	0.09	0.68	4.15	0.01

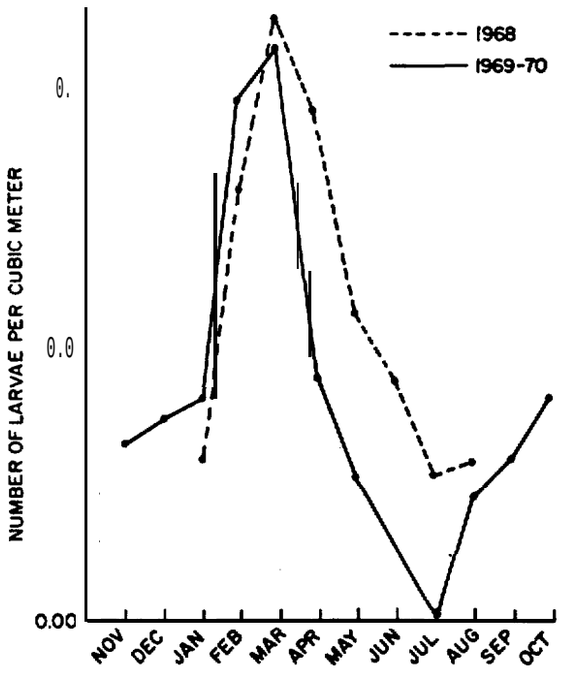
		PERCENT OCCURRENCE			
		Marak, et al. 1961, 1962a, 1962b	Wheatland 1956	Merriman & Sclar 1952	Fish and Johnson 1937
Silver hake	Merluccius bilinearis	6.26		3.90	0.01
Spotted hake	Urophycis regius	0.01			
Northern searobin	Prionotus carolinus	0.02	0.14		
Striped seasnail	Liparis liparis	0.01			
Rough scad	Trachurus lathami	0.01			
Shanny	Stichaeidae (Family)	0.90			
Unidentified		3.54			
Wrymouth	Cryptacanthodes maculatus	0.41		0.49	
Weakfish	Cynoscion regalis	0.06	0.95	23.66	
Witch flounder	Glyptocephalus cynoglossus	1.15			0.40
White hake	Urophycis tenuis	1.26			
Windowpane	Scophthalmus aquosus	0.05	1.16	0.98	
Winter flounder	Pseudopleuronectes americanus	0.01	4.28		
Atlantic wolffish	Anarhichas lupus	0.21			
Yellowtail flounder	Limanda ferruginea	9.25	0.07	10.73	
Northern pipefish	Syngnathus peckianus		0.07	0.24	
Silverside	Menidia menidia		0.07		
Northern kingfish	Menticirrhus saxatilis		0.07		
Tautog	Tautoga onitis		0.07	0.73	
Fourspot flounder	Paralichthys oblongus		0.07		
Northern puffer	Sphaeroides maculatus		0.07		
Lined seahorse	Hippocampus erectus			0.24	
Grubby	Myoxocephalus aeneus			1.71	
Summer flounder	Paralichthys dentatus			0.98	
Atlantic argentine	Argentina silus				0.02
Snake blenny	Lumpenus lumpretaeformis				0.16
Shorthorn sculpin	Myoxocephalus scorpius				0.17
Seasnail	Liparis atlanticus				0.12
Rock gunnel	Pholis gunnellus				0.65

Table 12-9 Species composition and relative abundance (%) of fish larvae from Estuarine surveys.

		Herman 1963	Croaker 1965	Pearcy and Richards 1962	Lebida 1969	Chenoweth 1972	Hauser 1973
Atlantic herring	Clupea harengus harengus	0.03	12.14			6.19	20.65
Atlantic menhaden	Brevoortia tyrannus	4.73	0.21	0.02	6.14		
Bay anchovy	Anchoa mitchilli	3.88	6.57	1.48	0.10		
American eel	Anguilla rostrata	0.09	45.74			0.13	1.79
Silver hake	Merluccius bilinearis	0.42				0.02	< 0.01
Atlantic cod	Gadus morhua	3.50					0.02
Haddock	Melanogrammus aeglefinus	0.34					
Hakes	Urophycis spp.	1.18					
Fourbeard rockling	Enchelyopus cimbrius	0.01	0.12			0.11	< 0.01
Summer flounder	Paralichthys dentatus	0.22		0.01			
Fourspot flounder	Paralichthys oblongus	0.28					
Winter flounder	Pseudopleuronectes americanus	2.05	9.27	72.88	21.01		
Windowpane	Scophthalmus aquosus	1.63	0.58	0.01	0.30	0.14	0.09
Hogchoker	Trinectes maculatus	0.01			0.50		
Atlantic silverside	Menidia menidia	5.83	4.57	0.06	12.19		
Threespine sticklebacks	Gasterosteus aculeatus	0.01		0.03	0.10		
Northern pipefish	Syngnathus fuscus	3.82	8.32	0.28	0.99	0.07	0.17
Butterfish	Peronotus triacanthus	4.09	0.08				
Bluefish	Pomatomus saltatrix	0.01					
Black sea bass	Centropristes striatus	0.03					
Scup	Stenotomus chrysops	4.14		0.05			
Weakfish	Cynoscion regalis	0.83					
Northern kingfish	Menticirrhus saxatilis	0.32					
Sculpins	Myoxocephalus spp.	27.28	0.25		0.20		
Lumpfish	Cyclopterus lumpus	0.61		0.59	0.10	0.04	0.09
Northern searobin	Prionotus carolinus	3.60		0.02			
Striped searobin	Prionotus evolans						
Cunner	Tautogolabrus adspersus	8.11		0.48	1.49	0.08	0.01
Tautog	Tautoga onitis	2.63	0.04	0.11	0.89		0.01
Goby	Gobiosoma spp.	0.66	0.08	0.02	0.20		
American sand launce	Ammodytes americanus	12.31	11.14	0.24	10.90	0.01	0.01
Rock gunnel	Pholis gunnellus	1.43		1.41	0.10	34.51	31.17
Radiated shanny	Ulvaria subbifurcata	1.05				0.92	0.86
Wrymouth	Cryptacanthodes maculatus	0.01				1.14	0.45
Northern puffer	Sphaeroides maculatus	1.18	0.12	0.01	0.69		
Mummichog	Fundulus heteroclitus		0.33	0.01	0.30		
Pollock	Pollachius virens		0.12	0.01			
Unidentified			0.12			0.63	
Spotted seahorse	Hippocampus erectus		0.08				
Atlantic croaker	Micropogon undulatus		0.08				
	Alosa spp.			0.01			
Rainbow smelt	Osmerus mordax			0.20		0.05	19.16
Inshore lizardfish	Synodus foetens			0.02			

Table 12-9 (Continued)

		Herman 1963	Croaker 1965	Pearcy and Richards 1962	Lebida 1969	Chenoweth 1972	Hauser 1973
Conger eel	Conger oceanicus			0.02			
Tomcod	Microgadus tomcod			16.19	27.45		1.13
Fourspine stickleback	Apeltes quadracus			0.15	1.09		
Grubby	Myoxocephalus aeneus			5.60			
Oyster toadfish	Opsanus tau			0.03			
Unknown Perciform larvae				0.03			
Blueback herring	Alosa aestivalis				0.59		
Atlantic needlefish	Osmerus eperlanus				10.11		
Striped killifish	Strongylura marina				0.50		
White perch	Fundulus majalis				3.07		
Snakeblenny	Morone americana				0.79		
Sculpins	Lumpenus lumpretaeformis				0.20		
Seasnail	Cottidae					2.43	0.28
Codfishes	Liparis sp.					45.07	16.35
Alligatorfish	Gadidae					7.53	1.33
Redfish	Aspidophoroides monopterygius					0.01	
Yellowtail flounder	Sebastes marinus					0.71	0.49
Flounder	Limanda ferruginea					0.02	0.01
Seasnail	Pleuronectidae					0.17	
Stickleback	Liparis atlanticus						5.61
Sea raven	Gasterosteidae						0.16
American plaice	Hemitripterus americanus						0.10
	Hippoglossoides platessoides						0.05
							0.01



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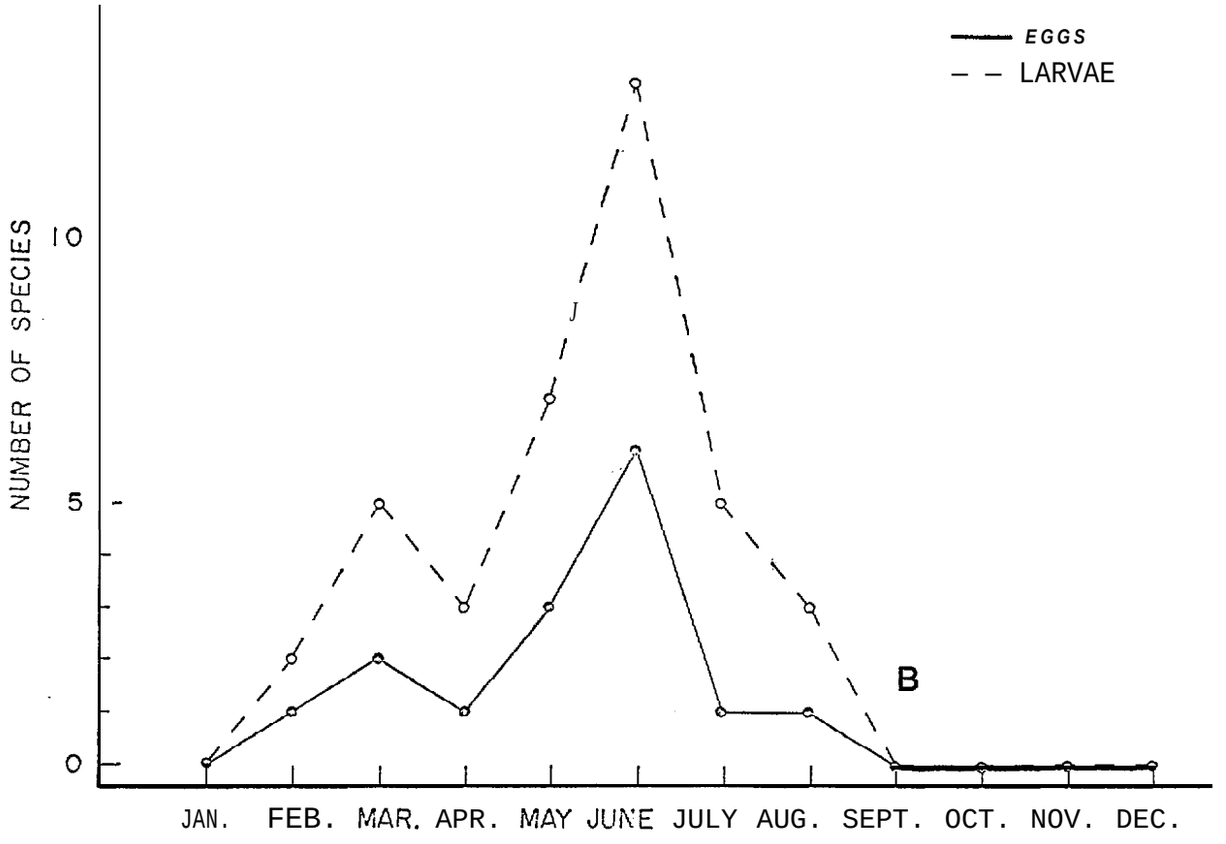
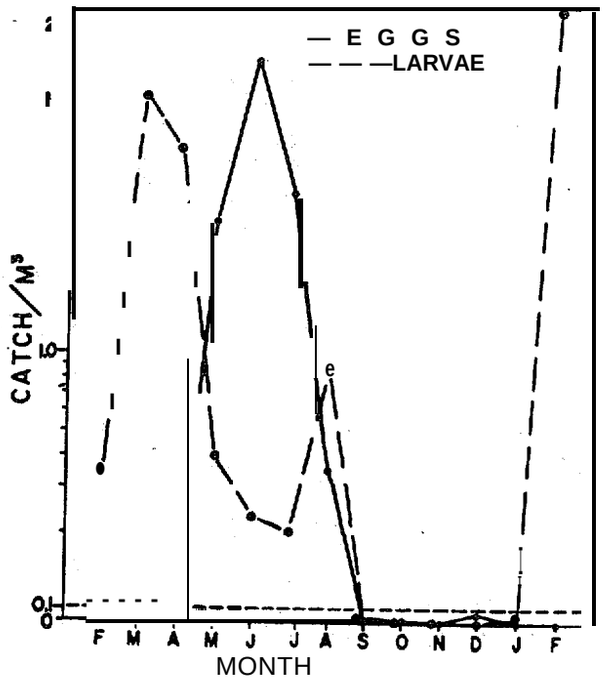


A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 12-5a	Seasonal Abundance of Fish Eggs and Larvae (A. Chenoweth, 1973, B. Lebida, 1969,



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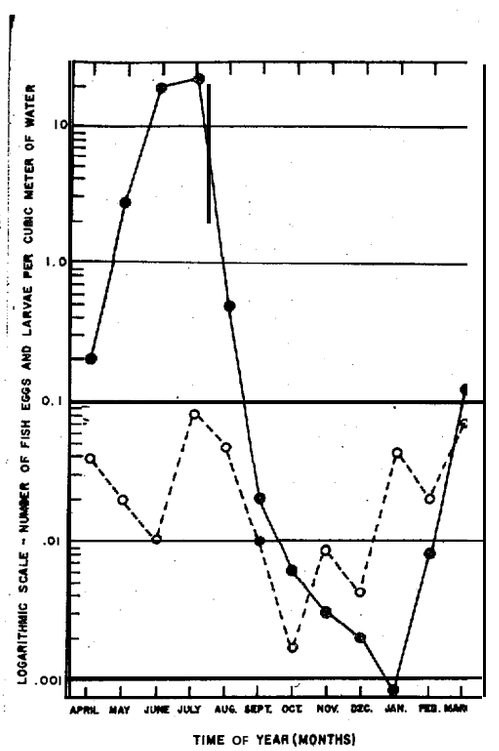

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A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE "NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 12-5b	Seasonal Abundance of Fish Eggs and Larvae C. Pearcy and Richards, 1962, D, Herman, 1963)

the southern part of the study area. The seasonal abundance of larvae (Figure 12-5) in this area peaked during the summer with the contributions from spring and summer spawning southern species.

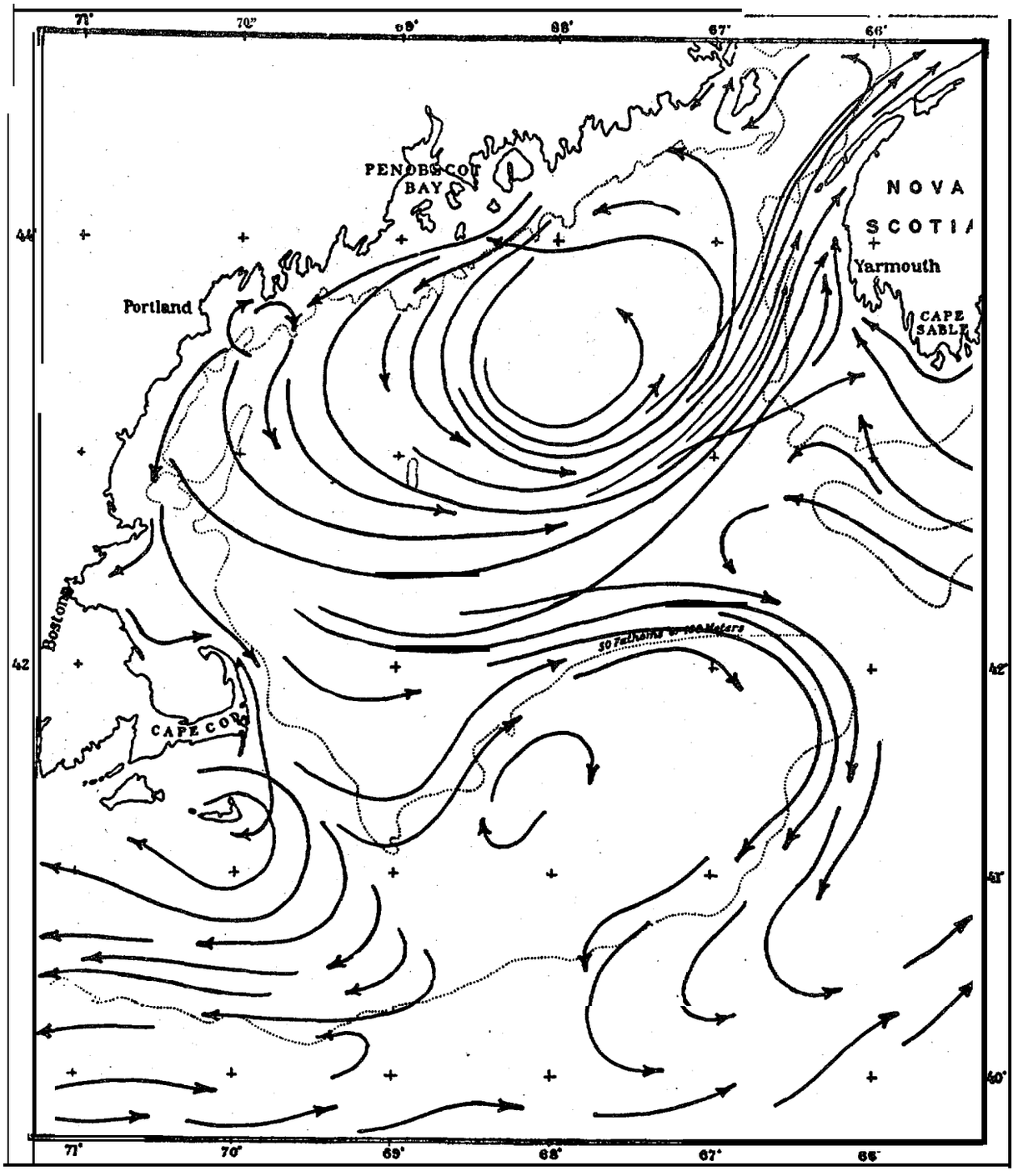
The estuaries of the north coastal zone have been surveyed by Hauser (1973) and Chenoweth (1973). Hauser's survey was in the upper estuarine area of Montsweag Bay and resulted in dominant catches of tomcod, rainbow smelt, winter flounder, American eel, sculpins, and rock gunnel. Chenoweth surveyed the more open lower estuary. He recognized two groups of larvae in his study area, those that used the estuaries as primary spawning and nursery areas, and those that did not. His greatest abundance of larvae occurred in the early spring and consisted of species of the first group: rock gunnel, sculpin, sea snail, and snake blenny, all of which were concentrated in the upper estuaries. Species of the second group of offshore spawned larvae were not numerous enough to show a second summer peak of abundance. The Atlantic herring and the winter flounder were the only abundant, commercially important species found in the area.

The estuaries of the south coastal zone have been surveyed in the Weweantic River, Massachusetts (Lebida, 1969), Narragansett Bay (Herman, 1963), Mystic Estuary, Connecticut (Pearcy and Richards, 1962), and Sandy Hook estuary, New Jersey (Croker, 1965). The Weweantic River and the Mystic River were similar in that they supported dominant estuarine species of larvae that concentrated in the upper estuaries. The Atlantic tomcod, winter flounder, and in the Mystic estuary the rock gunnel, all dominant larval species, had a peak of abundance in the spring (Figure 12-5) . This was followed by a seasonal peak in the summer resulting from the influx of spawning products of the more offshore, later spawning fish. Narragansett Bay was more typically coastal than estuarine in its species composition of fish larvae because of its more open waters.

DISPERSAL

The basic problem that exists for most reproducing fish species in the study area is that of maintaining the spawning products in waters that are suitable for the development of the young (Colton and Temple, 1961; Pearcy and Richards, 1962; Walford, 1938; Chase, 1955). Saville (1965) points out that stocks of fish spawning on shallow banks surrounded by deep waters or on narrow shelves bordering oceanic depths are most vulnerable to mortalities as a result of dispersal. In the study area a variety of ecological situations exist that require somewhat different reproductive adaptations by fishes.

The Gulf of Maine, with its rapidly circulating counterclockwise current, presents an interesting situation (Figure 12-6) . Most spawning occurs



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 12-6	Circulation of Surface Currents in Gulf of" Maine (Bigelow, 1927)

around the periphery of the Gulf, along the coasts of Nova Scotia, Maine, Massachusetts, and out to Georges Bank. The area from the southern Maine coast to Georges Bank is particularly productive. It has been clearly demonstrated that the planktonic spawning products move in a counterclockwise direction around the Gulf of Maine. Along the coast of Maine, larvae of the Atlantic herring move from east to west (Graham, et al., 1972). In Massachusetts Bay, a major spawning area of the Atlantic cod, the planktonic eggs drift out of the Bay and probably supply the Nantucket Shoals and Georges Bank with larvae (Fish, 1929). The larvae of Atlantic herring from the southwestern Nova Scotian spawning grounds drift up into and winter over in the Bay of Fundy (Iles, 1971).

Georges Bank, which is a major spawning ground for many important species - Atlantic herring, haddock, pollock, red hake, silver hake, American plaice, yellowtail flounder, gray sole, and tusk - presents a unique situation (Colton and Temple, 1961). All these species have planktonic larvae and, with the exception of herring, planktonic eggs which drift passively near the surface. With the exception of midsummer, when the Georges Bank eddy is most pronounced, the surface drift is offshore towards the north easterly moving band of slope water. Colton and Temple concluded that under normal conditions, during the 4 to 5 months that the eggs and larvae were planktonic, most of them would drift off Georges Bank and be lost to the fishery. They expressed the hypothesis that, although the egg production of various species on Georges Bank was always sufficient to produce a large year class, the mortalities due to undesirable dispersal was such that only few survived and that only unusual hydrographic conditions would produce a big year class. The importance of wind and currents on the year class strength of haddock has been emphasized by Chase (1955) and Walford (1938).

In the shelf area south of Cape Cod, where there is a sluggish southward movement of water, there is less likelihood of the spawning products drifting offshore. Sette (1943) observed the drift of mackerel eggs and larvae over a two month period from Cape Cod to Cape Hatteras and found both a slow southward and northward drift. The eggs and larvae of many species move inshore to coastal and estuarine areas in southern waters (Merriman and Sclar, 1952), either by current drift or, as in the case of the Atlantic menhaden, active migration.

The estuaries of the study area present a somewhat different situation. The species that reproduce most heavily in the estuaries are those that are resident in the shallow, nearshore areas (Pearcy and Richards, 1962). For these species it is important to maintain their spawning products close to shore. An important characteristic of long, narrow, deepwater estuaries with two layer systems is the net inward flow of relatively

high salinity bottom water and the net outward flow of lower salinity surface water (Rogers, 1940; Ketchum, 1954; Stickney, 1959). It has been shown that the species which use the estuaries as primary spawning areas lay demersal eggs that cannot be swept out into the open waters (Pearcy and Richards, 1962), and their larvae remain concentrated in the upper estuaries (Chenoweth, 1973). It has been suggested that. the maintenance of the larvae within the estuaries results from their use of the net inward flow of bottom water by remaining near the bottom most of the time (Pearcy and Richards, 1962; Lebida, 1969; Chenoweth, 1973).

MORTALITY

Although it is generally accepted that the natural mortality rates of fish larvae are catastrophic, particularly for the more prolific species such as Atlantic herring, Atlantic cod, and haddock, there is very little quantitative data available because of the difficulty in sampling an isolated group of larvae. Some quantitative data are available for the Atlantic mackerel (Sette, 1943), the winter flounder (Pearcy, ?962), and the Atlantic herring (Graham and Davis, 1971; Graham and Chenoweth, 1973).

Whether there is a critical period, that is, a brief period in the early life history in which a differential mortality occurs that influences the strength of a year class, is still an open question and will be until all stages of the early life history of any species can be sampled quantitatively (Saville, 1971; Marr, 1956).

The causes of egg and larval mortality are numerous. In times of heavy concentration, fish eggs and larvae can be a major food source of many adult fishes (Bigelow and Schroeder, 1953). The eggs and larvae can be dispersed offshore into deeper water where they may encounter unfavorable conditions, lack of proper food, or distances that prevent their return migrations (Pearcy and Richards, 1962). Colton (1959) observed a mortality of fish larvae (yellowtail flounder and silver hake) as a result of intrusion of very warm Gulf Stream water into the Georges Bank area. The period at which body reserves of food that are stored in the yolk sac are used up and the larvae learns to feed himself is a particularly sensitive period for larvae of Atlantic herring (Chenoweth, unpublished data).

12.3.3 JUVENILES

The greatest number of juveniles in the study area occurs in the summer and fall after the fish have occupied the waters as spring and summer larvae. After metamorphosis, the juveniles adopt their adult swimming

patterns, seeking out the bottom in the case of demersal species, or swimming freely in the case of pelagic species. At this time they tend to concentrate in more protected environments, probably because of their vulnerability to predation by larger fish. The estuarine and nearshore environments are particularly common habitats of juvenile fishes that are normally found farther offshore as adults. Clark (1967) observed that two out of three species of useful Atlantic fishes depend in some way on tidal lands and shallow bays for survival, and that even oceanic fishes are found in coastal lagoons and tidal rivers at the early stages of their life. Gunter (1961) noted that generally small or young species are more euryhaline than adults and tend to extend farther up the estuaries.

In almost all the surveys of the nearshore environments in the study area, mention is made of the dominance of juvenile fishes. Richards (1963) found only a smal l percentage of her catch in Long Island Sound were adults. Lux and Nichy (1971) at Woods Hole found most of their catch to consist of juveniles of the 0 age group. Jerome, et al., (1965) and Fiske, et al., (1966) noted the use of the Massachusetts estuaries and sounds as nursery grounds of many species, especially winter flounder. McCleave (1972)found that fishes inhabiting the tidal flat coves during the summer in central Maine were primarily juvenile alewives, Atlantic herring, and smooth flounder. During the summer, along the Maine coast, dense shoals of juvenile pollock and Atlantic herring, as well as numerous red and white hake can be observed within a few feet of the shoreline. Observations of professional spotters, that locate schools of small Atlantic herring from the air, indicate that in the late spring dense shoals of small herring move into the coastline and distribute themselves along it, so that by midsummer they are barely distinguishable from the coastline (Personal communi cati on).

The juveniles of some species are difficult to account for. The silver hake disappears after metamorphosis and doesn't reappear until its second year of life. The indications are that during the juvenile stage they seek out the deep water of the Gulf of Maine and perhaps the continental slope (Bigelow and Schroeder, 1939). This maybe the behavior of a number of species of the offshore waters.

The location of juvenile herring that are spawned on Georges Bank is still a mystery. Repeated searches have failed to find the large quantities of juveniles that would be expected from this primary spawning ground.

12.4 FOOD AND FEEDING

Food, feeding behavior, and the competition for food by fishes are important considerations because the survival rate, growth rate, length-weight relations, age composition, sex ratio, fecundity, migrations, and density distribution of fish populations are all affected by nutrition (Wigley, 1965). The feeding activity of fishes, in turn, affects other organisms in the biological community, so that food web relationships are important when considering the marine community as a whole.

With the exception of the menhaden, which is primarily a herbivorous filter feeder and a few species that supplement their diet by browsing on the macroflora or by scavenging material from the detrital food chain (mummichog, silversides, sculpin, and other nearshore fishes), the fishes fill the role of carnivores near the top of the food chain.

Fishes are of three general feeding types: plankton feeders, bottom feeders, and fish eaters (Ricker, 1946). Perhaps this is over-generalized; demersal fishes may feed on infaunal, epifaunal or semi-pelagic organisms that are found close to the bottom; pelagic fishes may feed on plankton organisms or, at times, epifaunal and semi-pelagic organisms. For 18 species of demersal fishes sampled from western Nova Scotia to the Hudson Canyon, the five most abundant prey groups were fish, crustaceans, annelids, molluscs and echinoderms (Arvidson, 1974). Of these, the crustaceans were the most important. The general food habits of the fishes in the study area are given by Bigelow and Schroeder (1953), Nichols and Breder (1927), Leim and Scott (1966). Table 12-10 gives the major food groups of fishes in the study area.

Detailed food studies are available for some of the commercially important species. These will be referred to under the life history descriptions of key species. Most food studies have been done on demersal fishes because they are dominant in the study area (Wigley, 1968) and because the more restricted mobi 1 ity of demersal fishes and their prey makes it easier to study the interrelationships between them.

12.4.1 FOOD RESOURCE DIVISION

Studies of the stomach contents of fishes have disclosed a wide variety of food items (Bigelow and Schroeder, 1953). This has led to the general conclusion that fishes as a group are generalists and opportunistic in their feeding habits, eating whatever food organisms are plentiful at any time or location. There is increasing evidence, however, that boreal marine, fishes have overlapping feeding niches only when food abundance becomes reduced (Tyler, 1972). Anumberof observations

Table 12-10 The Most Common Groups of Food Organisms of Fishes

'elagic fish
Planktonic crustaceans (calanoid copepods, mysids, euphausids, shrimp)
Fish eggs and larvae and other elements of the meroplankton
Small schooling fish (sand lance, herring, young of other pelagic species)
Cephalopods
)emersal fish
Benthic crustaceans (amphipods, shrimp, crabs, lobsters)
Annelid worms
Molluscs
Echinoderms
Small bottom fishes (young flounder, silversides, mummichog)
)emersal fish - scavengers
Any of the above food groups of demersal fish
Organic detritus
Plants (seaweed, eelgrass, diatoms)

of the food intake of various fish species indicate that the bulk of their diet is restricted to a very few species (Tyler, 1972; Richards, 1963; Poole, 1964; Kohler and Fitzgerald, 1969).

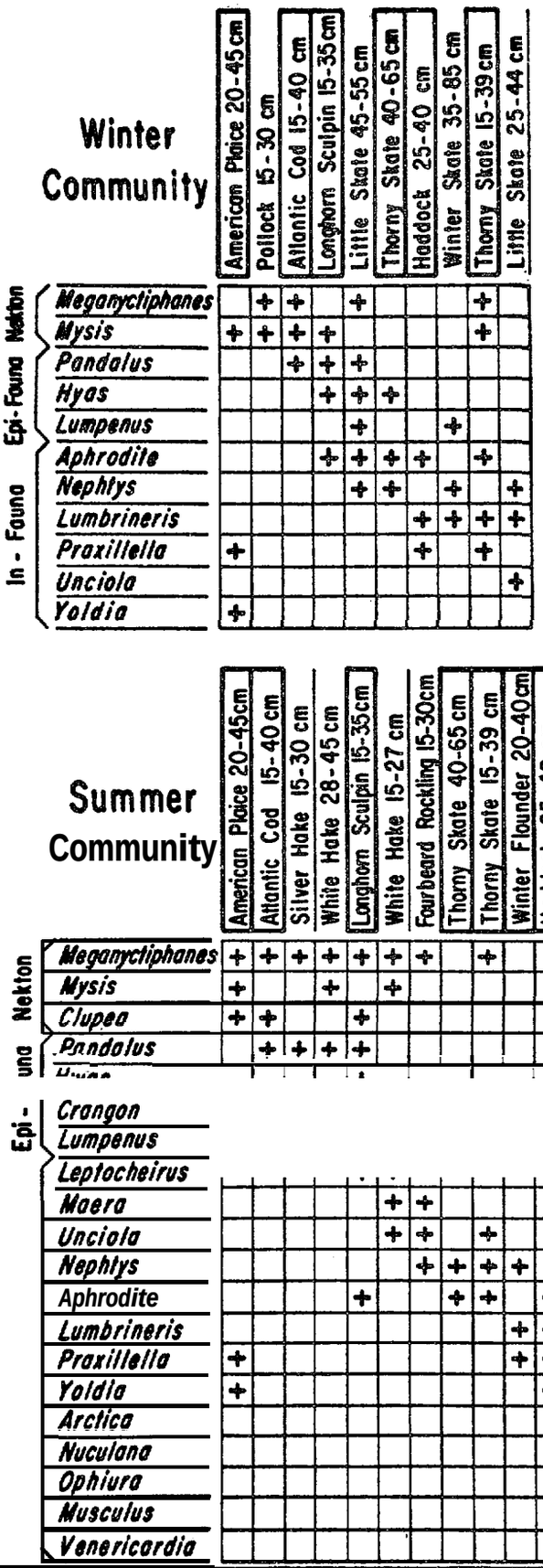
Tyler (1972) considered the division of food species among 13 common fish species in Passamaquoddy Bay, Maine. He demonstrated that, although most of these fishes fed on a fairly wide range of food organisms, only a few food species made up the bulk of their diet (Table 12-11) and that there was very little overlap of food species among the resident fishes (Figure 12-7).

This division of food resources among fishes that live in close association with one another has been reported in other studies also. In the Gulf of St. Lawrence and the Nova Scotia banks, haddock feed on benthic animals and cod feed more on pelagic crustaceans. Richards (1963) found little overlap in food of three resident species of Long Island Sound. The winter flounder fed primarily on polychaetes, while the silver hake and windowpane flounder fed on different species of crustaceans. Merriman and Warfel (1948) noted that competition between the winter flounder and the little skate for the same species of amphipod may have caused the change in relative abundance between the two over a period of years; however, other fish species in the area ate different food organisms. McCleave (1972) found that tomcod and winter flounder were ideally suited to dwell in the same community. The tomcod fed primarily on epifauna early in the morning, while the winter flounder fed on infauna throughout the day.

Competition for food between resident species may not be as common as generally supposed, but may occur more frequently between resident and temporary components. Tyler (?972) investigated the food division between his community components and found that the seasonal fish species did not feed on their own set of prey species, but fed on the same species as the resident fishes. This would imply competition between resident and seasonal fishes during certain times of the year and be of particular significance in the Gulf of Maine which hosts a large summer migratory component.

The food resource division of such pelagic fishes as Atlantic herring, alewife, blueback herring, American shad, and Atlantic mackerel is still largely unknown. These fishes are planktonic feeders whose primary food source is the calanoid copepods and the euphausids. The degree of competition and specialization between schools of these pelagic species has yet to be determined.

In a sense, the division of food resources occurs within a species also. It is generally true that the primary food of fishes varies



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TRIGOM PARC

FIGURE 12-7

Principal Prey for each Feeding Stand Of Fish in Passamaquoddy Bay (Tyler, 1972)

Table 12-11 Percentage by weight of stomach contents comprised by principal prey (after Tyler, *1972)*

Predators	Mar.-Apr. 1965	May-Nov. 1965	Dec.-April 1965-66	May-June 1966
Atlantic cod	81%	80%	68%	36%
Longhorn sculpin	49%	69%	72%	52%
American plaice	--	87%	67%	90%
Winter flounder	*83%*	*85%*	--	*77%*
Haddock	--	82%	61%	70%
Thorny skate 40 cm	84%	79%	95%	--
Thorny skate 40 cm	97%	93%	93%	--
Little skate 45 cm	22%	--	63%	--
Little skate 45 cm	94%	--	89%	--
Pollock	--	--	99%	--
Winter skate	--	--	96%	--
White hake *27* cm	--	94%	--	--
White hake 27 cm	--	95%	--	--
-Silver hake	--	97%	--	--
Fourbeard rockling	--	89%	--	--
Ocean out	76%	75%	_	77%

with age so that fishes of the same species in different growth stages will have entirely different diets (Bigelow and Schroeder, 1953). The particular food organism eaten by fishes at various periods in their life is a function of size. Thus, larval haddock feed chiefly on small and immature members of the zooplankton (Marak, 1960); juvenile haddock on small invertebrates (amphipods, cumaceans, brittlestars), and larger haddock on larger food (decapod, crustaceans, fish) (Wigley and Theroux, 1965). Pollock feed primarily on small copepods as larvae, on small crustaceans, particularly algae inhabiting amphipods as juveniles and on the larger euphausids as adults (Steele, 1963). Parker and Larkin (1959) have termed the lengths at which feeding changes occur as "threshold lengths". The white hake in Passamaquoddy Bay, Maine, changed from a primarily mysid diet to a diet of the larger Pandalus at a threshold length of27 cm (Tyler, 1972). Tyler also observed threshold lengths at 20 to 39 cm and 40 to 65 cm for thorny skate, and at 20 to 44 cm and 45 to 65 cm for little skate.

12.4.2 SEASONAL ASPECTS

Generally, the heaviest feeding activity of fishes occurs during the early summer. At this time, the warm water creates greater metabolic demand. Food is most abundant, particularly in the summer feeding grounds of the Gulf of Maine, and for most fishes this is the post-spawning period when low body reserves have to be replenished. Wigley (1965) found that haddock off Cape Cod, Massachusetts, had a low feeding rate in the late summer, fall , winter and early spring followed by heavy feeding in June.

American shad do not feed during the freshwater spawning migration and consequently the energetic cost of the migration must be met with reserves accumulated during oceanic feeding (Glebe, 1974). Glebe estimated that male shad viscera was depleted 44 to 56 percent and "female viscera depleted 42 to 54 percent during the spawning migration. Shad, then, probably depend on summer feeding to restore these lost body reserves.

For the Atlantic herring, the summer feeding period is extremely important because this is the time in which fat reserves are built up for the winter. Atlantic herring are well noted for their heavy feeding on Calanus finmarchicus during the summer and reduction in the abundance of the calanoid community through competitive grazing of other species such as the ctenophore Pleurobrachia pileus could have significant nutritional effects on herring during the winter (Fraser, 1970).

12.4.3 MIGRATION AND DISTRIBUTION

Two major factors in the distribution and migration of fishes in the study area have already been mentioned; seasonal change in water

temperature, and spawning. A third factor is the distribution of food.

The fact that food is a major element in attracting animals to certain areas contributes to the typically contagious distribution of New England groundfish (Wigley, 1965). Wigley found that groundfish in the New England area of the continental shelf congregate in specific geographic areas, generally the same ones occupied by macrobenthic invertebrates. He showed that areas of high fish and invertebrate density in New England shelf waters were: Great South Channel, the northern periphery of Georges Bank, portions of the Gulf of Maine, and south of Cape Cod-Martha's Vineyard. The areas of low density were in the west central Gulf of Maine and southeast and southwest Georges Bank.

The distribution of pelagic fishes during certain periods of the year is the result of the migration of many species in response to food concentrations. During the warm months, the shelf areas of the Gulf of Maine and Georges Bank are highly productive in pelagic food organisms and these areas are major summer feeding grounds for such pelagic species as Atlantic herring (Bryantsev, 1964), American shad and striped bass (Miller, 1969), and Atlantic mackerel (Redfield, 1941). Bryantsev and Redfield were able to correlate the seasonal occurrence of Atlantic herring and Atlantic mackerel with the occurrence of plankton concentrations.

12.5 MAN-INDUCED STRESS

Stress can be broadly considered as the pressures on a population resulting from adverse conditions that tend to reduce the abundance of the species to a point where the population can no longer sustain itself at its original level. The reaction of fish populations to stress will vary from species to species, depending on the intensity of the stress arid how biologically vulnerable each species is to it.

At present, many fish populations in the study area are subject to three types of stress (Figure 12-10). The first is the result of the natural events such as competitive situations, reproductive failures, or natural alterations of the environment. This type of stress tends to keep the populations in a somewhat fluid state even without man's influence". The second is the result of man's use of fish for sport, food, or industrial products. The study area has long been one of the more intensively fished regions of the Atlantic coast and the increasing demand for fish products, coupled with an increasingly effective fishing technology has put strains on many of the commercially valuable fish species. The third type of stress results from the pressures on fish populations as a side effect to man's industrial and technological development. The

critical situation that exists for many anadromous fishes resulting from the elimination of spawning sites is well known. However, the overall impact on fish populations resulting from the contamination and alteration of the marine environment through man's activities has not yet been fully assessed.

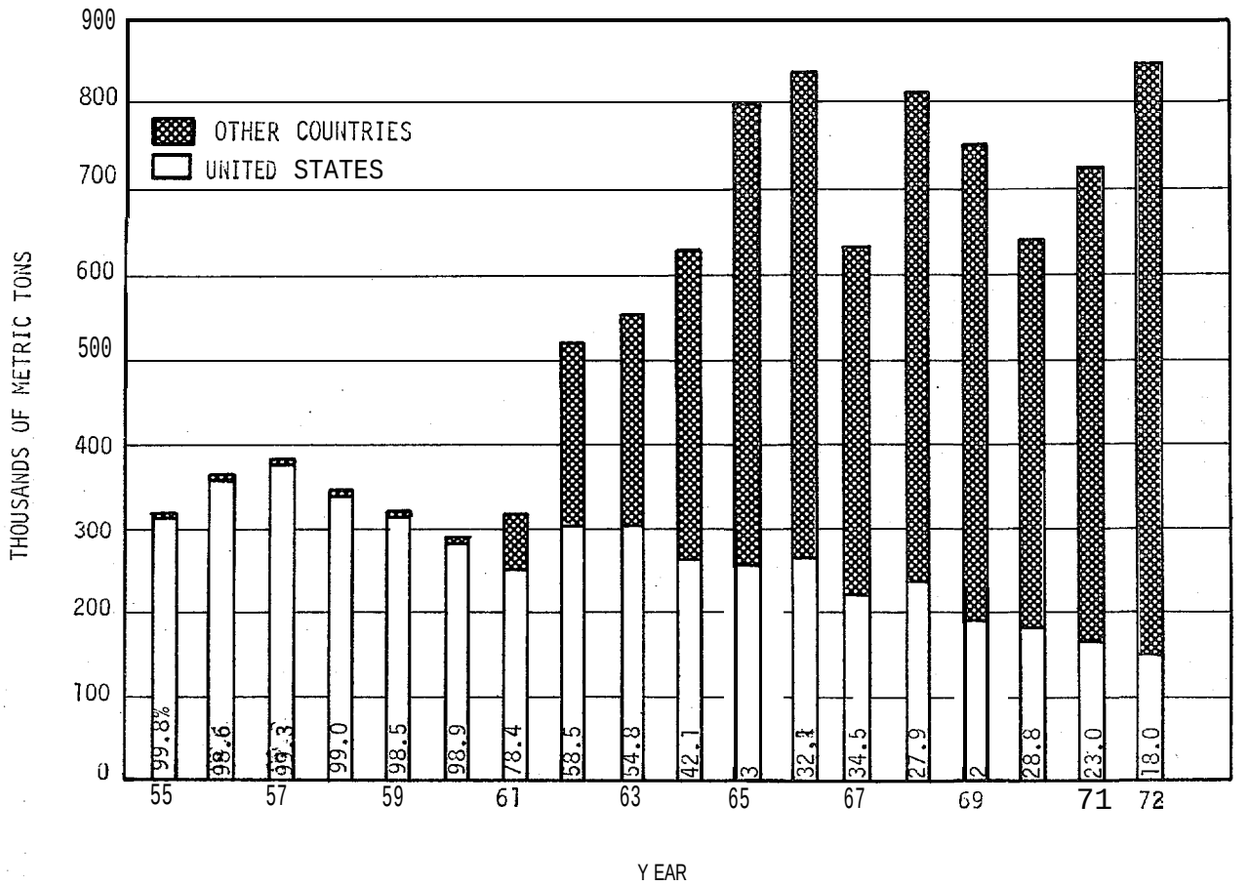
12.5.1 EXPLOITATION

The history of the exploitation of fish stocks in the study area is one of a long upward trend in total landings that has been maintained by shifting the effort to previously unexploited or underexploited species (Graham, 1968). For example, the fisheries of New York State (McHugh, 1972) can be divided into three periods: an early coastal, shallow water fishery which ended about 1930, a second period of expansion to offshore fishing with the newly developed otter trawl ending in the 1950's, and a third period of a steadily declining fishery and a return to inshore fish resources. This fishery was also supported by continually shifting the effort to unexploited stocks. Much of the shifting from species to species can be attributed to declining availability. McHugh suggests that the lack of management and overfishing are important causes of the declining New York fisheries. It is unlikely that the existing fish stocks or any as yet unexploited stocks in the study area can support the present increasing trend much longer (Graham, 1968).

Another important impact on fish stocks has been the advent of foreign fishing in the offshore waters of the study area. Up until the early 1960's the offshore bank areas had been almost totally exploited by U. S. fishing effort. Subsequently, large fleets of foreign vessels have increased the catch of fish even while the U. S. landings have declined (Figure 12-8). The problem of proper management of the fish resources in the study area is complicated by the fact that, while the inshore fishery is within the jurisdiction of the U. S., the offshore fishery is in international waters and management practices require international agreements.

It is likely that we are exploiting the groundfish stocks in the shelf area Browns Bank to the Hudson Canyon at a maximum, or even overexploiting them (Gordon, 1973). Gordon gives the total standing crop for all groundfish species in the area as 5,350,000 metric tons and estimates that at least 45 percent of the available fish harvest is already being made; however, an optimal maximum harvest may be as little as 30 to 35 percent of the standing crop. The optimal harvest varies for each species. For short-lived fishes it could be as high as 90 percent, but for long-lived species or ones with low reproductive potential it would be no higher than 25 to 30 percent.

Edwards (1968) estimated the biomass of finfish in the continental shelf area between the Hudson Canyon and the southern end of Nova Scotia as



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TRIGOM PARC	FIGURE 12-8	Total Landing of Finfish in ICNAF-Sub Area 5 and Percentage Take by the U.S. (Gordon, 1973)

about 5,442,000 metric tons, or 369.6 kg per acre. During the years 1963-64, in excess of 1,179,000 metric tons of finfish, or 81.4 kg per acre, were landed annually, a figure which he considered relatively high for the northern hemisphere. Edwards noted a general decrease in the standing crop of most species with the greatest decrease occurring for those species that were being exploited. However, he pointed out several species that were either unexploited or underexploited because of poor market demand or poor harvest technology.

MAJOR FISHING AREAS

The production of various fisheries is roughly proportional to the amount of shoal water that they are based on (Ackerman, 1941). The wide coastal belt of shoal water stretching from the Nova Scotia banks, around the Gulf of Maine, out onto Georges Bank, and down to Long Island gives the area one of the worlds great fishing grounds. Ackerman estimates the area of the New England fishing grounds (probably not including New York or Nova Scotia] as 299,000 square kilometers of water. shallower than 360 m, and 189,000 km of water shallower than 90 m. The most important fishing grounds are those from the southern New England and Massachusetts coasts out to the northeast grounds of Georges Bank.

The bulk of the catch is made up of cold water species of groundfish that are taken on the hard bottom shoals or banks which are characteristic of the study area. The fishing areas of New England are given by Rich (1930). His data, modified to include the rest of the study area, are shown in Figure 12-9.

These banks range in size from a few square km to larger plateau-like areas such as Browns Bank and Georges Bank, and have abundant bottom food organisms that attract fishes to them (Wigley, 1968). The principal method of fishing is with the otter trawl, a large roughly conical net held open by wooden or steel "doors" and dragged across the bottom. The usefulness of an area for fishing depends on relatively level contours suitable for trawling, as well as the production of fish.

The catch of many species varies with season. Warm water migrants such as silver hake, butterfish, scup, and weakfish are taken during the warm months, while some of the cold water species like haddock move off the banks during the summer and are taken during the cooler months.

Pelagic fishes are taken with a variety of gear, mainly purse seines, weirs, and traps, usually where they become concentrated for spawning or feeding. Thus, the Atlantic menhaden, Atlantic mackerel, and juvenile Atlantic herring are fished on their inshore feeding grounds, while the river herring (alewife, blueback herring) and adult Atlantic herring

TRIGOM PARC | FIGURE 12-9

Major Fishing Grounds in the Study Area (Rich, 1930; Edwards and Lawday, 1960)

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are fished primarily during the times that they are concentrated for spawning.

PRINCIPAL FISHERIES

The Herrings

The most important commercial species of this group is the Atlantic herring. There are two herring fisheries. One is inshore for immature (1 to 3 years old) fish along the coast of Maine and the Canadian provinces. These fish are taken on their inshore summer feeding grounds by purse seines, stop seines, and weirs and are processed chiefly as sardines. Since 1963 this fishery has steadily declined as a result of poor recruitment (Anthony, 1972). The offshore herring fishery is for adult fish and was begun by the Soviet fishing fleet in 1961, but has since been exploited by many other countries. The principal fishery is on Georges Bank during the late summer and fall spawning and is carried out with the midwater and bottom trawls. Anthony (1972) predicts declining catches for this fishery if lower quotas are not imposed.

River herring (alewives, blueback herring) are taken along the immediate coast during the spring at the beginning of their spawning run and are used for industrial products. The menhaden, also an industrial fish, has been of lesser importance in the study area in recent years as a result of weak year classes and over-fishing. It also is a summer fishery along the immediate coast.

Redfi sh

The redfish fishery began in the 1930's. It is a trawl fishery and carried out primarily in the Gulf of Maine. The product is a food fish marketed as "ocean perch". The redfish is vulnerable to heavy fishing pressure because of its slow growth rate. Historically, the fishery is one of continual shifting from stock to stock as each population is depleted.

The Codfishes

All of these species are taken principally with bottom trawls. Cod, haddock, and pollock are taken primarily in the offshore and coastal banks from Georges Bank into the northern Gulf of Maine. Silver hake, red, and white hake are taken throughout the study area and are more of a seasonal fishery.

The cod fishery, one of the earliest, gradually declined until the 1960's because of increasing U. S. market demand for frozen haddock. Since the 1960's, foreign fishing plus the demise of the haddock fishery has again increased the catch of cod (Graham, 1968). The haddock fishery,

because of over-exploitation on several poor year classes, is virtually non-existent at present and the haddock that are being taken are incidental to other species.

The silver hake, better known as "whiting", is the most abundant groundfish on the New England banks (Graham, 1968). It is widely used for both food and industrial products. The fishery has also shown a dramatic increase in the 1960's due to the foreign fishing activities.

The Flounders

The flounder fishery became important in the early 1900's with the advent of the otter trawl. Most of the commercial catch of flounder on the Atlantic coast is from the study area (Graham, 1968). The American plaice and the grey sole are more important in the northern portion of the study area, while the yellowtail flounder and summer flounder fishery are more important in the southern portion. The winter flounder is taken in the more shallow coastal and bank areas throughout. Since the decline of the winter flounder fishery in the 1930's, the yellowtail fishery has become the most important and is concentrated around three somewhat distinct stocks (Lux, 1963) from Long Island to Nantucket and east central Georges Bank (Jensen, 1967).

Seasonal Warm Water Fisheries

These species include scup, weakfish, butterfish, spot, northern puffer and tilefish and are important to the fisheries of southern New England and New York (McHugh, 1972). They are all taken primarily as food fish with bottom trawls. Some of them, such as the scup and weakfish, are important as sport fish also. The catches of all these species have declined in recent years as a result of either low abundance of the populations or reduced market demand.

The Atlantic mackerel, at one time one of the principal commercial species, has been of less importance during the mid 1900's due to lower abundance and reduced market demand. It is a purse seine fishery operating on the fish on their summer feeding grounds. Recently, there has been an increase in the abundance of mackerel and an increased demand created by foreign markets.

Oceanic Fish

Tuna and swordfish are the principal oceanic fishes commercially important in the study area and are taken by harpoon during the warmer months. They are important as both commercial and sport fishes.

The Sport Fisheries

The principal sport fish in the study area is the striped bass. The influence of the sport fishery on the bass population is probably greater than the commercial fishery (McHugh, 1972). Also important are bluefish and tautog. The fishery for these species is carried out along the immediate coast, primarily south of Cape Cod, although the striped bass is an important sport fish north of the Cape. The Atlantic salmon is a highly valued sport fish and attempts are being made through stocking and river improvement to increase the size of the runs. However, at present, salmon runs are limited to a few rivers in eastern Maine and the Canadian provinces.

Industrial Trawl Fishery

There are a number of species that are taken in New England's industrial trawl fishery (Edwards and Lawday, 1960) which are processed into fish meal and oil for protein additives in livestock feed. The principal species are red and white hake, silver hake, and little skate, although a larger number of other bottom fishes are used also. The fish are taken by otter trawl from the grounds around coastal Massachusetts, Rhode Island, and Connecticut.

POPULATION DYNAMICS

The field of population dynamics treats a fish population as a biological entity, examining the parameters that reflect the continuous change within the population rather than the individuals that compose it. What happens to an exploited stock and what the optimum rate of exploitation should be can only be determined after a number of units of information are gathered. Such basic population parameters as fishing and natural mortality, recruitment, growth rate, and fishing effort have to be gathered for each species. The identification of individual stocks of fish and the degree to which they are discrete has to be determined. Finally, the yield relationships, which indicate the optimum amount of fishing a population can withstand, have to be calculated. All this information requires a great amount of complex data gathering for each species under study and which, in many cases, has to be on a continued monitoring basis. The result is information that can be used to rationally manage a fishery in order to obtain a maximum yield without over-exploiting the stock.

the offshore fishing areas are being imposed based on data gathered by the International Commission of the North Atlantic Fisheries (ICNAF), of which the U. S. is a member.

12.5.2 POLLUTION

Fish populations are subject to a variety of man-made stresses that have been increasing during recent years. Most of these are connected with the deterioration or contamination of the environment along the immediate coast. However, as Clark (1967) has observed, a majority of the important fishes are in some way associated with the nearshore areas and therefore affected by any change in the environment there.

The most obvious stress is that of the elimination of the spawning runs of anadromous fishes, principally Atlantic salmon, striped bass, Atlantic sturgeon, and American shad because of blocking structures such as dams or the pollution of river systems. Many parts of the study area once supported heavy spawning runs of anadromous species, which in turn supported important commercial fisheries. Now the runs are either eliminated or reduced to insignificance. Also, fishes that spawn on the bottom in shallow coastal and bank areas are vulnerable to the damage of egg beds through ocean dumping, dredging, and dredge spoil disposal or bottom trawling. For species that are limited to specific spawning areas and bottom types this could have a significant effect.

The impact on fishes of industrial wastes, pesticides, oil and other contaminants has been of increasing concern to fisheries investigators. This has come with the realization that, while contamination of the aquatic environment is widespread and increasing, and therefore a potential threat to fish populations, very little concrete information exists that either biologists or industrial planners can use to assess impacts. Consequently, there is presently an expanding body of literature on the techniques of bioassays as well as the measurement of toxicity on aquatic life. Comprehensive reviews of this can be found in Sprague (1969, 1970, 1971), Alderdice (1967), Edwards and Brown (1967), Doudroff, Anderson, Burdick, Galstoff, Hart, Strong, Surber and Van Horn (1951), and Eisler (1973).

At any life stage two basic reactions of fish to contaminants can be identified. One is the result of lethal exposure, which will cause a certain degree of mortality at a certain level of contamination. In standard bioassays of aquatic organisms the concentration of the toxicant in which 50 percent of the individuals in the test die (LD50) is the standard measure of toxicity. Ideally, bioassay information should be available for each important species and for each type of toxicant, but this is far from reality. There are few standard bioassays of marine fishes completed in the study area.

The second reaction is the result of sublethal exposure and may be identified by behavioral or physiological changes such as the alteration of normal spawning behavior, growth, or respiration. These reactions may occur over a longer period and are more difficult to assess than the lethal effects.

Most of the work in the area of aquatic bioassay has been done on fresh water species and much work needs to be done for the marine fishes of the study area before any firm conclusions can be reached as to the impact of industrial development on fishes.

The effect of oil activities on fish populations is not clear at this point and will undoubtedly vary from species to species. The following potential areas of danger exist and require careful investigation:

(1) Egg and larval mortality due to reduction of oxygen or direct toxicity in areas of oil spills (Eisler, 1968; Moore, Chirlin, Puccia and Schrader, 1974). Eggs and larvae, being the most sensitive and least mobile stages, are likely the most vulnerable.

(2) Damage to the intertidal and shallow water zones (Eisler, 1968; Moore, et al., 1974; Tyler, 1972). This would lead to the elimination of adult feeding grounds, juvenile nursery areas and spawning areas of anadromous, and nearshore spawning fish.

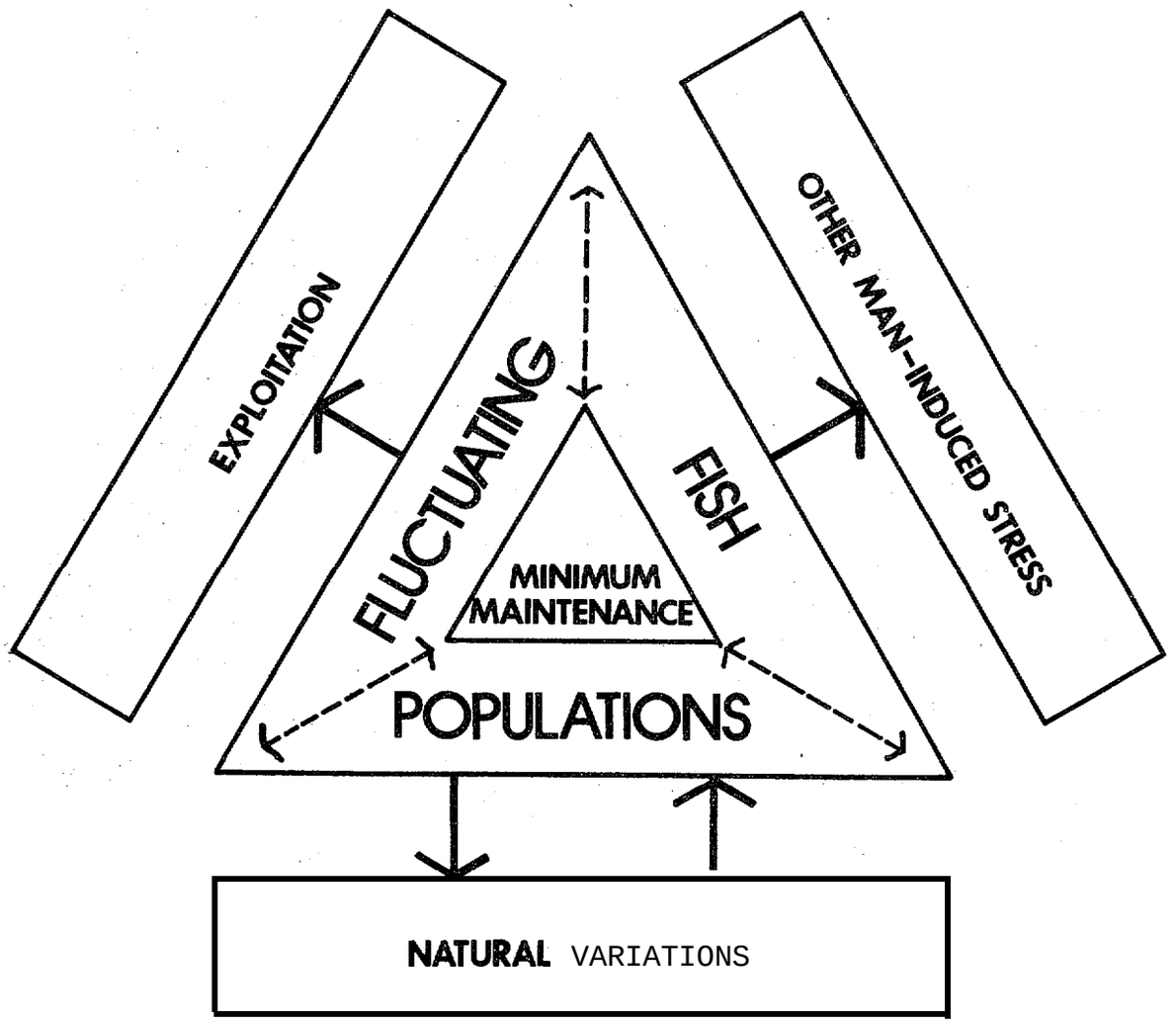
(3) Damage to a population of short-lived fishes through the elimination of a single year class by means of catastrophic egg and larval mortality resulting from a heavy oil spill (Moore, et al., 1974).

(4) Damage to a population of a heavily exploited species through the elimination of a single year class. It has been demonstrated that naturally occurring failures in reproduction can have disastrous effects on a heavily exploited species.

(5) Toxic effects on bottom feeding fishes through the incorporation of petroleum derived hydrocarbons into the food chain. Blumer et al. (1970) observed that petroleum poll ution is incorporated into the food chain and its ecological effect can not easily be determined.

THREE-WAY STRESS

Theoretically, the forces governing the stresses on fish populations can be considered as grouped into three interacting levels that are illustrated schematically in Figure 12-10. The first level are those natural conditions that either increase or decrease the abundance of the stock



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 12-10	Three Types of Stress On Fish Populations

by varying, as a result of natural occurrences, the amount of recruitment to the population. The second level, in a sense superimposed on the first, are the stresses exerted by the exploitation of the fish stocks and its effect depends on the intensity of fishing, coupled with the effects of the first level. The third level are those limitations to the stock resulting from man's alteration of the environment.

At this time, most commercial fish populations in the study area seem to be either barely maintaining themselves or declining as a result of this three-way stress. There are three areas in which increased effort should be considered. These are to:

1. Understand and monitor the natural stresses that influence the important fish species.

2. Regulate the rate of exploitation to a point where fishing will be optimal and in phase with natural fluctuations.

3. Minimize the adverse environmental effects created by man's activities.

12.6 KEY SPECIES

The life histories of a number of important fish species of the study area are described in the pages that follow. These species are listed below.

Squalus acanthias

Raja erinacea

Acipenser brevirostrum

Clupea harengus

Alosa pseudoharengus

Brevoortia tyrannus

Salmo salar

Osmerus mordax

Fundulus heteroclitus

Merluccius bilinearis

Gadus morhua

Melanogrammus aeglefinis

Pollachius virens

Urophycis chuss and *U. tenuis*

Paralichthys dentatus

Limanda ferruginea

Pseudopleuronectes americanus

Menidia menidia

Scomber scombrus

Thunnus thynnus

Peprillus triacanthus

Pomatomus saltatrix

Morone saxatilis

Stenotomus chrysops

Sebastes marinus

Myoxocephalus octodecimspinosus

Tautogolabrus adspersus

Tautoga onitis

Ammodytes sp.

Macrozoarces americanus

12.6 LIFE HISTORY OF KEY SPECIES

12.6.1 Squalus acanthias

The spiny dogfish is a relatively small, predacious shark of pelagic or semi-demersal habit. It rivals in abundance the more common food fish in the Gulf of Maine, but at this time has a limited commercial value.

(1) Reproduction. The" reproductive cycle lasts two years. Ovulation occurs in December or January. Mating occurs in the offshore wintering grounds, probably February or March. Gestation takes 18 to 22 months. Embryos are 10 cm at the end of the first year and 27.5 cm at birth. Young are born in November to January, most of them in the offshore wintering grounds.

The age maturity for dogfish in British waters is given by Holden and Meadows (1964):

Percent Mature	Length (cm)	Age
5	75	8
	80-85	10-11
1%	92-95	17-18

It is evident that complete maturity of a given year class of dogfish does not occur until relatively late in life.

(2) Fecundity and larval life. The dogfish is ovoviviporous so has no external larval stage. Holden and Meadows (1964) give the fecundity relationship-to length as ranging from 3 eggs at 75 cm (8 years of age) to 15 to 110 cm (20+ years of age). The number that are born range between 1 and 11, and is most frequently 4 to 6.

(3) Growth and longevity. The dogfish is a long-lived species, attaining a maximum age of 25 or 30 years. There is some disagreement over the rate of growth. Russian and Pacific coast studies indicate a rate of 3.5 cm per year, while tagging studies indicate 1.4 cm per year. The young are 21.8 to 33 cm at birth and reach a maximum length of about 12 m (Jensen", 1966).

(4) Natural mortality. No specific information; however, natural mortality is low because dogfish have few natural enemies. Also, the fact that dogfish remain extremely abundant with such a low reproductive rate indicates a low rate of natural mortality.

(5) Migration characteristics. Dogfish show two types of movement:

a seasonal inshore-offshore migration, and erratic movements in response to the location of prey. They appear on Georges Bank in March or April and in the inner Gulf by May. By October they have disappeared from the Gulf and are rarely taken in the winter north of Georges Bank. They probably spend the winter in the deeper offshore waters. Temperature seems to govern their seasonal movements. They prefer winter temperatures of 6 to 11 C and appear on the coast when water reaches 6 C, but are not found where it is above 15 C (Bigelow and Schroeder, 1953).

(6) Distribution and niche preference. Dogfish are distributed throughout the study area. Groundfish surveys (Lux and Grosslien, 1970) found them more abundant in southern New England waters than farther north. They travel in loose schools or "packs" and are capable of traveling long distances in search of prey.

(7) Population densities. The only indication of maximum density is from scattered records of commercial catches. In 1904-05 during a peak dogfish year, 27,000,000 were taken off Massachusetts. From 2 to 3 million dogfish were taken in 1938 in Placentia Bay, Newfoundland. There is no doubt from the trouble they cause the fishing industry that they are extremely abundant.

(8) Food. Dogfish are voracious predators, taking anything that is smaller than themselves. Principal species preyed upon include: Atlantic mackerel, herring, Atlantic cod, haddock, squid, shrimp, crabs, and sometimes marine worms. At times ctenophores have been known to be eaten (Bigelow and Schroeder, 1953).

(9) Predators. Dogfish have very few natural enemies. They are preyed upon by larger sharks and bony fishes such as tuna. Man is probably the species' most serious predator. Holden and Meadows (1964) point out that because of the species' low reproductive potential, any heavy predation would reduce the stocks to a point where they could not reproduce themselves.

(10) Competitors. No specific information. Presumably other sharks and large predacious fishes such as silver hake or Atlantic cod would compete with them for food.

(11) Responses to the environment (natural factors, pollutants). No information was gathered.

12.6.2 Raja erinacea

The little skate is the most common skate everywhere along the coast and offshore banks.

(1) Reproduction. The little skate spawns wherever it is found throughout the shoaler parts of the Gulf of Maine and on the offshore banks, and probably prefers a relatively hard bottom substrate. Deposition of the eggs in sand was found to cause clogging of the apertures in the tendrils and the eggs never developed. Maturity is reached at three to four years.

Richards, Merriman and Calhoun (1963) found two high pregnancy-frequency periods, in November-January and June-July, with low periods in March-April and August-October. However, mating occurs throughout the entire year. For more northern areas, spawning occurs in the summer.

The retractile alar spines of mature males are used to hold the female and the rhipidion may serve "to insure effective contact as well as deposition of sperm at the head of the uterus close to the distal' ends of the oviducts". (Richards, Merriman, and Calhoun, 1963). Adult females contain fertilized eggs in both oviducts. The smaller species of skates probably mate with their ventral surfaces opposed. The adult male carries sperm continuously from maturity to death.

(2) Fecundity and larval life. Egg cases are laid in pairs, usually one egg per case. The right case descends and reaches the uterus first and is laid slightly in advance. Cases may be laid immediately or held in utero as long as three weeks. The usual interval between laying of cases is one week or more. A case averaged 14 cm in total length, including the tendrils. Cases decrease slightly in size from north to south. The cases have sticky filaments and adhere firmly to the substrate. Six months may be the minimum time required for hatching and it may take as long as nine months. Length is 9 to 10 cm at hatching.

(3) Growth and longevity. Zero year class fish are 11 to 16 cm; one-year olds, 16 to 26 cm; two-year olds, 22 to 35 cm; three-year olds, 28 to 40 cm. Merriman, Olsen, Wheatland and Calhoun (1953) stated that growth was probably 8 to 10 cm a year for the first three years. After age five, length increased only 2 or 3 cm a year. Few specimens have ever been seen over 50 cm long, and age eight is probably the maximum age ever attained.

(4) Natural mortality. Bigelow and Schroeder (1953) state that the mortality rate appears to be very high after five years.

(5) Migration characteristics. No north-south migrations have been observed; slight offshore movement has been noted during the winter to deeper and therefore warmer water.

(6) Distribution niche preference. The little skate is the most common skate in the Gulf of Maine, and is caught along the coast anywhere and everywhere from the Gulf of St. Lawrence to Virginia. It often frequents shallow water, but lives anywhere from the tide line to 135 m or so. They do not frequent estuarine or brackish environments.

(7) Population densities. In Block Island Sound, trawl haul samples averaged at least a dozen R. erinacea per acre of bottom. No estimate was made of how many escaped the trawl.

(8) Food. The little skate feeds on polychaetes, crustaceans, squid and fish. Bottom invertebrates were-the major food in all seasons with crustaceans 89 percent of the total. Eaten in large amounts were Leptocheirus pinguis, Crangon septemspinosa, Cancer irroratus, and Upogebia affinis. Polychaetes and polycypods were eaten commonly but in small amounts. Squid and fish were eaten occasionally. The young eat copepods first, then amphipods and other pelagic crustaceans.

(9) Predation. No information.

(10) Competition. Possible competitors are Prionotus carolinus, Myoxocephalus octodecimspinosus and Pseudopleuronectes americanus. The latter, in particular, competes with the little skate since the amphipod, Leptocheirus pinguis, is the dominant food item for both. Competition from M. octodecimspinosus is heaviest in the winter.

(11) Responses to environment (natural factors, pollutants). No information was gathered.

12.6.3 Acipenser brevirostrum

The shortnose sturgeon has a "sharklike" tail and a head covered with bony plates. One was caught off Provincetown, Massachusetts, in 1907 and 32 in the Sheepscot River, Maine, in 1971 and 1972. No other recent records exist of their occurrence in the Gulf of Maine. It is a rare and endangered species.

(1) Reproduction. The shortnose sturgeon spawns in rivers. In the lower Hudson it spawns in late April. Males may mature when they are

48 to 51 cm long; females, at about 61 cm. No other information was found.

(2) Fecundity and larval life. No information found.

(3) Growth and longevity. The largest reported by Bigelow and Schroeder (1953) was 91.4 cm, but Fried and McCleave (1973) found one in the Sheepscot River, Maine, that was 118.1 cm, and six of the specimens they took exceeded the length of any previously documented.

(4) Natural mortality. No information found.

(5) Migration characteristics. Some shortnose sturgeons go into the open sea and wander for some distance from the parent stream (Bigelow and Schroeder, 1953).

(6) Distribution and niche preference. The shortnose sturgeon has been found at Provincetown and Waquoit, Massachusetts, the Hudson River, New York, from Delaware Bay and River, and Charleston, South Carolina (Bigelow and Schroeder, 1953).

A population also exists in the Saint John River, N.B., and one in the Sheepscot River, Maine (Fried and McCleave, 1973).

(7) Population densities. No information found except that it is a rare species.

(8) Food. No information found.

(9) Predation. No information found.

(lo) Competition. No information found.

(11) Responses to the environment (natural factors, pollutants). No information found.

12.6.4 Clupea harengus

The Atlantic herring is a relatively small, pelagic, schooling fish of the herring family. The most abundant of the herrings in the study area, it is important as a "forage" fish in the marine food chain as well as a highly prized commercial fish.

(1) Reproduction. The herring in the study area spawn in the autumn (August to December) on falling water temperatures. Spawning occurs in relatively shallow water (less than 90m) all around the periphery of the Gulf of Maine, beginning in late August in the Nova Scotia shelf and occurring progressively later along the coast of Maine and Georges Bank until it reaches Cape Cod by November. Herring spawn on the bottom, laying demersal eggs that adhere in thick sheets to the substrate. On Georges Bank they apparently require gravelly areas of high current, probably for maximum oxygen exchange and minimum siltation, and during this stage they are subject to some predation by bottom organisms (Caddy and Iles, 1973; Drapeau, 1973; Pankratov and Segayev, 1973). Some spawning probably occurs below Cape Cod as herring larvae are taken there in plankton tows. Most herring mature at 4years of age.

(2) Fecundity and larval life. Herring have a moderately high fecundity. A female of 25 cm total length has approximately 17,500 eggs, while a female 33 cm has 141,000 (Perkins and Anthony, 1969).

There have been many investigations of herring larvae in the Gulf of Maine (Boyar, 1966; Chenoweth, 1970; Das, 1968; Graham, Davis and Bickford, 1973; Graham and Chenoweth, 1973; Graham, et al., 1972; Honey and Chenoweth, 1972; Iles, 1971; Tibbo, et al., 1958). The herring has a relatively long larval phase (5 to 8 months) and during that time the larvae are planktonic and concentrated near the surface, although they do show the ability to migrate vertically in the water column. Herring larvae hatch at 5 to 7 mm. During the early stages, the larvae are concentrated near the spawning grounds. The densest concentrations are found in southwestern Nova Scotia, northeastern Georges Bank and the western coast of Maine to Cape Cod. From the density of the larval concentrations it appears that these are the herring's major spawning areas and that Georges Bank is probably the most important During the later larval stage, the herring become more mobile and tend to disperse from the spawning grounds. By October and November along the coast of Maine they concentrate in the estuaries, but disappear by January. The larvae reappear in dense swarms in March and April all around the coastal periphery of the Gulf and remain close inshore during metamorphosis. They metamorphose at approximately 40 mm.

Laboratory experiments on larval herring (Blaxter, 1965; Rosenthal and Hempel, 1970) indicate that the time of yolk sac absorption, during the earliest larval stage, is a particularly sensitive period.

(3) Growth and longevity. A rough estimate of larval growth from 7 to 40 mm (September to May) would be 0.13 mm per day.

Anthony (1972) gives the following growth parameters for the three stocks of Gulf of Maine herring:

	L_∞	K	Tmax
Georges -Bank	34.5	0.34	14.0
Coastal Maine			
Western	35.1	0.335	16
Eastern	38.0	0.227	16
Nova Scotia	39.0	0.179	18

He points out that the growth of Georges Bank herring are different from Nova Scotia and coastal Maine. The Georges Bank herring grow to 43.5 cm in 14 years, while the Nova Scotia herring have a slower rate of growth, but reach 39 cm in 16 to 18 years. Georges Bank herring seem to be faster growing, shorter lived fish than Nova Scotia herring.

(4) Natural mortality. Graham and Chenoweth (1973) estimated 75 percent mortality of larvae less than 10 mm for a 1 to 5 day period on Georges Bank. For adult herring (Anthony, 1972) the rates are generally accepted as:

Age	Mortality (range)
5	0.15-0.32
6	0.30-0.43
7	0.47-0.55
8	0.54-0.82

(5) Distribution and migration characteristics. Juvenile herring (1 to and 3 years old) are found primarily around the coastal periphery of (6) the Gulf and support the coastal sardine fishery. These fish show a seasonal distribution, out on the offshore bottom during the winter (Smith, 1963) and moving inshore during the warmer months. While inshore they do not migrate extensively, but move in and out of coastal areas erratically (McKenzie and Tibbo, 1961). As yet, the significant numbers of juveniles that would be expected on Georges Bank as a result of spawning have not been located. Also, largely unknown is the source of recruitment to the adult stocks. The adults are distributed in schools all around the Gulf according to the distribution of planktonic food (Bryantsev, 1964) during the feeding season, or according to the location of the spawning grounds during the reproductive season. In winter they show a tendency to disperse to the coastal waters south of Cape Cod.

Brawn (1960) found juvenile herring tolerant of a wide range of temperatures. They were caught in temperatures from 0 to 18 C, and could be acclimated to a range of -1.0 to 19.5 - 21.2 C. Stickney (1969), however, experimentally determined temperature preferendum of 12 to 13 C.

(7) Population densities. Herring are found in dense schools or shoals and are particularly concentrated on the spawning grounds where they are taken in large quantities by commercial fishermen. There are at least three separate stocks of herring (Anthony, 1972; Ridgway, Lewis, and Sherburne, 1969) corresponding to the three major spawning areas: Nova Scotia, Coastal Maine and Georges Bank. The degree of separation and where the young fish are recruited from is still not clear.

(8) Food. The herring is a plankton feeder. When first hatched, the larvae feed on larval snails and crustaceans, diatoms and peridinians but soon begin to feed on copepods. As they grow older they feed more and more on the larger copepods, amphipods, pelagic shrimps and decapod crustacean larvae. Copepods and shrimps are the principal food of all herring, large or small. Herring also feed on molluscan larvae, fish eggs, Sagittae, pteropods, annelids and even on microscopic objects as small as tintinnids and Halosphaera. Herring normally are not fish eaters, but sometimes eat small launce, silversides, capelin and the young of their own species (Bigelow and Schroeder, 1953).

Sherman and Honey (1971) report that herring larvae prey principally on five groups of zooplankters - copepods, crustacean eggs and nauplii, cirriped larvae, and tintinnids, with copepods being the predominant food. Parrish and Saville (1965) state that all authors stress the dominant role by Calanus in the food of herring.

(9) Predators. Herring are preyed upon by all kinds of predacious fish, especially cod, pollock, haddock, silver hake, striped bass, mackerel, tuna, salmon, dogfish and mackerel sharks. Finback whales also devour herring in great quantities. The squid (Ilex) destroys many young sardines (Bigelow and Schroeder, 1953).

(10) Competitors. Fraser (1970) states that it might reasonably be expected that herring would be in competition with ctenophores, based on the fact that large numbers of ctenophores would consume much of the plankton, especially copepods, on which herring feed.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.5 Alosa pseudoharengus

The alewife is an anadromous member of the herring family. A pelagic schooling species, it spends much of its life along the coast and is subject to a commercial fishery during its spawning migration.

(1) Reproduction. Throughout their range, alewives are relatively indiscriminate in their choice of spawning sites. They appear to spawn wherever they are afforded unobstructed access from the sea to calm, fresh water, frequently in ponds or sluggish portions of 'streams. They may ascend many miles up large coastal rivers to spawn or no more than a matter of yards in certain coastal creeks.

The timing of spawning is closely linked to water temperature. Spawning occurs in March and April in Chesapeake Bay, March through Play in Rhode Island, March and April in Woods Hole, April and May in the Gulf of Maine and May and June in Nova Scotia. Males become mature in their third year and females in their fourth year.

The spawning act of the alewife follows complex behavior associated with the spawning migration. The beginning of the spawning run starts several weeks before the onset of the actual spawning act. The upstream movements of spawners may extend over a period of one or more months. During the early spring, there is a close association between the temperature of the stream water and the air temperature. Sporadic warmings of air temperature occurring at intervals of approximately 2 to 10 days produce concurrent rises in the stream water temperature. A 'wave' of upstream migrants proceeds to the spawning grounds during each warming period with no upstream movements occurring during the intervening periods of cooler water. In addition to these irregular flurries of migratory activity there are diurnal peaks in activity as well. On days in which upstream movements occur, the peak in migratory activity takes place in the afternoon at a time when the stream water has reached its maximum daily temperature. All entry of fish into the stream ceases when the stream water temperature falls 3.6 to 5.5° C below the daily maximum. Both day length and average daily water temperature increase during the course of the upstream migratory period. It is apparent that the timing of upstream movements is more a function of diurnal and day to day temperature changes-than absolute temperature. Saila, Polgar, Sheehy, and Flowers (1972) noted its close association with incident solar radiation.

Upstream migrants are not fully ripe. The final stages of gonadal maturation take place on the spawning grounds. At the beginning of the spawning run males, which apparently become mature earlier than females, predominate. By the time the run was half over a 50:50 sex ratio was achieved while near the end of the run females made up the bulk of the upstream migrants. The earlier upstream

migrants of both sexes were relatively larger than migrants moving onto the spawning grounds later in the season (Cooper, 1961).

Spawning takes place at temperatures between 10 and 15 C. Spawners may remain on the spawning grounds from 3 to over 80 days. Early migrants were most likely to linger on the spawning grounds. Spawning may occur at any time of day and frequently takes place in water barely deep enough to cover the spawners. Cooper (1961) describes the spawning of alewives in a Rhode Island pond as follows:

> "'Females swim close to shore followed by a number of males. The act of spawning is accomplished in groups of three or in pairs. One or two males will swim side by side with the female. Eggs and sperm are extruded simultaneously".

Greeley (1934) notes regarding the spawning act:

> The act of spawning is characterized by the whirling of a pair of fish in a close spiral, usually ending as they reach the surface with a splash and separate. The whirling is done rapidly and often only a flash of silver is seen .

According to Cooper (1961) the eggs are broadcast at random during the mating act, and then settle and adhere to the available substratum.

(2) Fecundity and larval life. Eggs are pink in color, adhesive, demersal and measure approximately 1.2 mm in diameter. Eggs are released in freshwater where incubation may occupy 6 days at 15.5 C (Bigelow and Schroeder, 1953) or 3 days at 15.5 C (Cooper, 1961). At hatching, larvae are about 4mm long. Larvae undergo metamorphosis by the time they are 15 to 20 mm long, or approximately 40 to 60 days after hatching.

Smith (1907) estimated the average number of eggs produced per female to be 100,000 based on a sample of 600 fish from the Potomac River. Bigelow and Schroeder (1953) give a range of from 60,000 to 100,000 eggs per female according to the size of the fish. Cooper (1961) suggests that fecundity does not increase continuously with size but that a maximum fecundity may occur in fish of a certain size (not specified by Cooper) and decrease in larger females.

(3) Growth and longevity. Since the greater part of the alewives taken commercially and by sportsmen are captured during spring spawning runs, it is reasonable to say that alewives are recruited at the age at which they first take part in spawning migrations.

On this basis, alewives are recruited at an age of 3 to 4 years (Bigelow and Schroeder, 1953) corresponding to lengths of from 90 to 240 mm. Graham (1956) states that among Great Lakes alewives males mature before females at age III. The smallest spawning adults reported by Cooper (1961) for a Rhode Island anadromous population were 247mm and 260 mm for males and females respectively.

Based on data from a number of Atlantic anadromous populations, Hildebrand (1963) summarized early alewife growth in this way:

Growth attained while in fresh water	55 to 109 mm
At one year	65 to 145 mm
At two years	115 to 195 mm
At three years (first maturity)	200 to 250mm

There may be significant differences in growth rate between populations of anadromous alewives.

(4) Natural mortal ity. Based on estimates of the number of adult alewives arriving on the spawning grounds and the number returning to the sea, Cooper estimated that 37.5 percent of spawning adults die during the fresh water phase of the annual spawning migration. Observations by Miller (1930) and Graham (1956) indicate that heavy mortalities among spawning adults may not be uncommon. Cooper's low estimates of the number of juveniles returning to sea in the Pettaquamscutt River in Rhode Island indicate that considerable mortality occurs among juveniles before they reach the sea. His 1:1 spawning adult to returning juvenile estimate must be atypical.

(5) Migration characteristics and distribution. The alewife is found and from the Gulf of St. Lawrence to North Carolina. Its center of
" (6) distribution probably 1 ies between Cape Cod and Chesapeake Bay. The alewife has been introduced into the Great Lakes and a number of other inland bodies of water where land-locked populations have become established. Juveniles leave the spawning grounds sporadically in schools during the summer following the spring they were hatched. The mean length of downstream migrants measured by Cooper (1961) was 65 mm. Downstream migrating juveniles once they have reached the sea, remain in saltwater until they are sexually mature. Juveniles may pass their first winter in the deeper parts of the estuary of their natal stream, others apparently go to sea as do adults after their return from the spawning grounds.

The movements and locations of alewives during their marine phase are not clearly understood. They apparently retain their schooling habit at sea, as evidenced by the large catches sometimes reported.

Bigelow and Schroeder (1953) feel that many adults stay near the coast within the influence of their home estuary. Their appearance in fixed fishing gear along the coast supports this contention. However, the same authors report catches by trawlers from waters 36 to 150 m deep 45 to 144 km off shore.

There is convincing evidence that alewives locate and identify their home (spawning) stream by olfactory means. When gravid adult alewives are transported from their home stream to another stream not already supporting an alewife run, their progeny return, when they become mature, to their adopted 'parent-stream' rather than to the one in which their parents were spawned. This fact has permitted the establishment of alewife runs in streams formerly barren of alewives by merely transplanting spawning adults. Thunberg (?968) demonstrated experimentally that adult alewives could discriminate between water from their parent stream and that from another stream when tested in seawater. His experiments strongly suggested that the basis for this discriminatory ability was olfactory.

(7) Population densities. During the spring spawning season, the entire spawning stock of a given alewife population may, within the course of a few weeks, pass up a coastal stream often no more than a few feet wide. Cooper (1961) estimated that 200,000 adult alewives passed up a small Rhode Island stream between March 20 and May 20, 1959. While reliable numerical counts of alewives ascending given streams are not available, an example of annual commercial catches from small coastal streams gives some indication of the seasonal abundance. Bigelow and Schroeder (1953) report an annual harvest of 1,000 barrels from Herring Brook in Pembroke, Mass. The annual alewife harvest has been much reduced in the past years.

Alewives are a schooling species. Individual schools may contain a large number of individuals. Bigelow and Schroeder (1953) report an instance of 40,000 fish being taken in a single seine haul off Boston (date not given). Trawl hauls of 3,000 to 4,000 individuals have been reported.

(8) Food. The alewife is chiefly a plankton feeder like the herring; copepods, amphipods, shrimps and appendicularians are the chief diet items. However, they also take small fish, such as herring, eels, launce, cunners, and their own species, as well as fish eggs. Unlike herring, alewives often contain diatoms even when adult (Bigelow and Schroeder, 1953).

(9) Predation. No information gathered.

(10) Competition. No information gathered.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.6 Brevoortia tyrannus

The Atlantic menhaden is a large, schooling fish of the herring family whose northern range extends into the Gulf of Maine. An important species for fish meal and fish oil, it supports the largest U. S. commercial fishery in terms of pounds landed along the Atlantic coast and Gulf of Mexico.

(1) Reproduction. Menhaden probably spawn throughout the year over their entire range; however, during their summer sojourn north of Long Island they spawn during May to September (Higham and Nicholson, 1964) when water temperatures are generally between 15 to 18 C. Peak spawning occurs in September as the fish begin to migrate south. The menhaden spawns in oceanic waters and not in inshore areas (Henry, 1971). Most males and females are sexually mature at age 2 and all are mature by age 3.

(2) Fecundity and larval life. Fecundity has been estimated to be 38,000 to 631,000 eggs per female, depending on 'length. Menhaden eggs and larvae are pelagic. The larvae are an average of 4.5 mm long at hatching and metamorphose at 30 to 35 mm in about 2 to 4 months (Reintjes, 1969). After hatching, the larvae enter estuaries and spend several months in tributary streams reaching almost to fresh water, returning to the sounds and bay, and eventually to the ocean, as juveniles. Laboratory studies indicate the larvae suffer mass mortality when temperatures fall below 3 C for several days, or fall rapidly to 4 to 5 C (Saila and Pratt, 1973).

(3) Growth and longevity. The rate of growth varies in different areas. Menhaden are relatively fast growing for the first four years after which growth slows down. Fish taken in the study area are generally older and larger than those taken off the south Atlantic coast (Henry, 1971).

Growth data is as follows:

Age	Length (mm)	Weight (gins)
1	80-100	
2	200-250	160-300
3	250-280	300+

Menhaden reach the maximum age of approximately 8 to 10 years.

(4) Natural mortality. No information on the mortality of early life history stages. The total mortality rate (natural and fishing) as calculated by Henry (1971) was about Z=1.2. Natural mortality (m) was 0.52 (Dry foos, Cheek, and Kroger, 1973).

(5) Migration characteristics. Tagging studies (Dryfoos, et al., 1973) have demonstrated a cyclical pattern of migration for menhaden. The fish move northward in the spring and early summer and southward in the fall. As the fish grow older and larger they migrate farther northward, accounting for the larger, older fish (3+ years) caught in the waters of the study area and also, as the fish are sexually mature at 3 years, for the summer spawning in the waters of the study area. In the fall, the juveniles entering the coastal waters move south also (Kroger, Dryfoos, and Huntsman, 1971).

(6) Distribution and niche preference. During the summer, tight schools of menhaden are found inshore (less than 35 m), particularly in locations with extensive drainage systems. Oviatt, Gull, and Nixon (1972) measured the effect of menhaden schools on the surrounding waters of Narragansett Bay and found that their feeding, respiration, and excretion decreased the concentration of phytoplankton and oxygen and increased that of ammonia in the surrounding water.

(7) Population densities. No information gathered.

(8) Food. Menhaden feed chiefly on microscopic plants, particularly diatoms (Bigelow and Schroeder, 1953) by use of a filter feeding mechanism consisting of successive layers of gill rakers. They feed by swimming with their mouths open and their fill openings spread. No other fish in the study area has a comparable apparatus.

(9) Predation. They are probably preyed on by larger fishes and marine mammals.

(lo) Competition. Probably very little competition for food with other fishes because of its unique type of feeding.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.7 Salmo salar

The Atlantic salmon is a highly prized sport fish in Europe and North America. On this side of the Atlantic it is found from Greenland to Massachusetts, although in the United States regular runs occur in a few rivers in Maine. It must be classed as an endangered species.

(1) Reproduction. Atlantic salmon usually spawn in the same stream that they spent their juvenile life. Areas of level gravelly bottom characterized by an adequate but not violent flow of water are utilized for spawning and egg deposition. Early returning salmon, moving upstream with each freshet, spawn in the upper reaches of the river. If the salmon return late in the season or are held back by low water or obstructions, they may spawn in the lower reaches of the river, even in tidal portions.

The spawning migration begins in early spring. Salmon begin to appear in coastal waters from May through July. Early migrants enter the rivers in late May or June. Later arrivals may linger in the estuaries until fall, unless summer freshets are sufficient to draw them into the rivers. Spawning takes place in late October or early November. The usual age of first spawning is after the second year in the sea, although younger spawners of one sea year (grilse) are not uncommon. In some rivers this age group may predominate. Precocious males are able to produce viable sperm even as parr.

Eggs are laid in nests (redds) hollowed out in the gravel by the female. One male is accepted from numerous suitors attracted by the presence of the female. Male grilse and parr are usually driven away by the female. Lying close beside the female, the male sheds his milt as the eggs are laid. The fertilized eggs are then covered with gravel.

After spawning, the salmon may return immediately to sea, or remain in the stream over winter. Surviving spent salmon (black salmon or kelts) return to the sea the following spring. A few return to spawn once or even twice again, usually at intervals of two years.

(2) Fecundity and larval life. Larval and immature stages (alevin, fry, and parr) are spent in fresh water streams. This period may last from 1 to 6 years, depending on temperature and food supply. In New England the fresh water life usually lasts 2 years, although especially with hatchery reared parr, they may leave the river at one year of age (Stickney, 1960).

Elson (1957a) gives a value for the fecundity of Atlantic salmon of 800 eggs per pound of adult female. In New England the weight of a mature female salmon is about 4 to 6 kg and 3 to 5 kg respectively.

(4) Natural mortality. Although mortality rates vary from stream to stream and from year to year, the following data illustrates the magnitudes to be expected:

	Percent	
From egg to 1 year old parr	94-96	(Elson, 1957a)
From 1 year old parr to smelt	49-66	(Elson 1957b)
From smelt to returning adult	83-98	(Elson 1957c)
5 months old parr to smelt	98	(Stickney, 1960)
Smelt to returning adult	85	(")

(5) Migration characteristics and distribution. Smelts migrate to sea and in late April or May. They may linger a while in estuaries and (6) coastal waters, but many of them migrate to feeding grounds in the West Greenland Sea. In returning to home waters as adults, certain migration routes apparently are taken. Little is known of these routes, but commercial fishing in certain localities year after year indicates that the coast is approached off the mouths of large rivers. Although probably attracted by the dilution spreading seaward, the salmon taken in these localities have been shown by tag returns to have been moving toward rivers other than the one near which they were caught.

Chemical cues are probably important in salmon migration. Pacific salmon have been demonstrated to have highly sensitive chemoreceptors in the nares and can detect differences between water from different rivers. Atlantic salmon undoubtedly have a similar ability, since they also show a strong tendency to return to their home streams.

(7) Population densities. Densities of local populations are limited by the size of the rivers. Elson (1957a) estimates the capacity of a stream as "40-50 pounds of adult female salmon per mile of stream 10 yards wide". For salmon averaging 4.5 kg, male and female, this would amount to 8 to 10 individuals for that area of stream. New England rivers to not have adult salmon runs of much over 500.

(8) Food. Adult salmon feed on small fish and crustacea. Among the fish eaten are herring, capelin, and whiting. Amphipods and shrimp are eaten in quantity and are considered to be responsible for the pink color of salmon muscle tissue. Adults cease feeding after they enter the rivers to spawn, or sometimes even before. Parr in the streams feed on aquatic insects, or on terrestrial insects that fall into the water. They will also feed on the fry of other fish or to some extent on one another. Smelts feed voraciously on the fry of herring, large schools of which are found in bays and estuaries at the time of the smelt migration.

(9) Predation. Fry and parr in the rivers are preyed upon by fish-eating birds (e.g., mergansers, kingfishers, herons) and by other fish (e.g., eels and pickerel). The cormorants a serious predator on migrating smelts. Predators on the large salmon in the sea are not known specifically, but probably include seals and other fish-eating marine mammals, and large predatory fish.

(lo) Competition. Competitors are particularly important in the stream environment. Several species may compete for food, in that a limited supply must be shared more ways. A more direct competition is from other salmonids, especially brown trout, which like the salmon are aggressively territorial in behavior.

.(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6 8 Osmerusmordax

The smelt, a small, silvery fish is very common along the coast and in the streams and estuaries. It is important for recreational activities and is fished from ice "shanties" in the winter on frozen bays, and in the spring it is caught by hand or dipnet while ascending streams to spawn. It is a good food fish.

(1) Reproduction. There are both wholly landlocked and anadromous populations of American smelt. Among anadromous populations, spawning occurs in fresh or barely brackish waters of coastal streams. Eggs may be deposited in thick mats of more than 12,000 eggs per 0.3 m.

Smelt spawn once a year in the late winter or early spring. Spawning may last up to a month, but in most cases peak spawning activity lasts only 2 to 4 days. In some cases there may be multiple peaks. Although spawning may occur under ice, it generally begins within ten days after ice break-up. Spawning takes place between 4 and 12 C, although' the dates vary when these conditions exist. Smelt runs begin during March in Massachusetts Bay and Rhode Island streams, and as late as May in the Gulf of St. Lawrence. Both males and females mature at age 2 or 3.

Spawning activities of the smelt occur at night. In addition to temperature conditions that appear to govern the timing of spawning, it has been reported that spawning may cease during periods of bright moonlight or during stormy or unusually cold conditions.

(2) Fecundity and larval life. Fecundity ranges from 1700 to over 60,000 eggs per female and varies with the size of the female, and between races.

Pelagic larvae emerge from adhesive demersal eggs which are shed in fresh water. Incubation times listed by Carlander (1969) are:

29 days at6 to 7 C
19 to20days at5 to 8 C
10 days at 15 C
11 days at 12 C

Larvae measure 7 mm in length at hatching. Metamorphosis may take up to two months to occur. Newly metamorphosis fry measure 25 to 30 mm.

(3) Growth and longevity. There are significant differences in the rates of growth between different smelt populations (Carlander, 1969). Figures given below are those of McKenzie (1965) (cited in Carlander) for smelt from the Mirimichi River in New Brunswick:

Age	II	III	IV	V	
Males	155	175	193	208	Total length in mm
Fema 1 es	157	183	208	236	

Smelt reach 40 to 80 mm by the end of the summer of the first year they were spawned, and 60 to 200 mm at the end of age 1.

Recruits enter the spawning stock in the spring. Rate of recruitment varies between spawning stocks owing to differences in growth rate, and year class strength.

(4) Natural mortal ity. Natural mortality coefficients have been determined for the European smelt Osmerus operanus (Linnaeus). Natural mortality coefficients cited in Belvanina (1969) were as follows:

Age	1	2	3	4
Natural Mortality Coefficient	0.90	1.08	1.30	1.59

Mortality rates may be very high (over 99 percent) and appear to increase with the density of egg deposition.

(5) and (6) Migration characteristics and distribution. The range of the rainbow smelt extends from the coast of Labrador to Virginia. Its center of abundance lies in the southern Gulf of St. Lawrence. Smelt are year-round residents of the immediate coast. Few have been reported more than smile from shore and many no doubt spend most of their lives under estuarine conditions. Smelt schools range along the coast away from warm streams and shallows in the summer. Adult smelt move into bays and harbors in the autumn and winter in the brackish water near the mouths of their spawning streams. Smelt are known to return to their home stream.

(7) Population densities. The densest aggregations of smelt occur during their spawning runs in coastal streams in the early spring, or in winter in southern New England.

(8) Food. Young smelt feed chiefly on copepods and other minute pelagic crustaceans. The adult smelt feeds on small crustaceans with decapods, mysids and gammarids as its favorite foods. The smelt also feeds on small fish, such as young herring, mummichogs, cunners, anchovies, launce, sticklebacks, silversides, and alewives. The smelt also eats shellfish, squid, annelid worms (Nereis), and crabs (Bigelow and Schroeder, 1953).

(9) Predation. The smelt can be classed as a "forage fish" as it is eaten by all larger predacious fish in its area of abundance.

(lo) Competi.tion. No information gathered.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.9 Fundulus heteroclitus

The mummichog is the most common of a number of species of small, schooling killifishes that are found everywhere in the shallow, nearshore environment of brackish water. It is widely tolerant of temperature and salinity extremes.

(1) Reproduction. The mummichog spawns in the area where it lives in only a few inches of water. It spawns from June to early August in the southern New England coast.

The spawning male clasps the female firmly around the slender portion of the body just back of the dorsal and anal fins. The two fins of the male slip under the homologus fins of the female, which

are raised to admit them, and nearly surround the body of his mate. The ventral fins of the adjacent sides are also locked in similar fashion. The female is usually forced against some perpendicular solid object, such as a stone (Breder and Rosen, 1966).

(2) Fecundity and larval life. A female may produce several batches of eggs during one summer. The number of eggs vary greatly among specimens. The largest number recorded was 460 in a female 98mm in length.

The larvae are 7 to 7.7 mm long at hatching. The yolk sac is absorbed and pectorals and caudal fins already formed at hatching. At 11 mm the dorsal and anal rays are complete in number and first trace of the ventrals is seen. At 16 mm the ventrals are present and at 20 mm the larvae are metamorphosed.

(3) Growth and longevity. The mummichog metamorphoses at 20 mm and are adult at 8.89 to 10.16 cm. Horton (1965) gives the following growth data:

Age	Average length (mm)
0+	62
1+	
2+	1::
3+	111
4+	119

(4) Natural mortality. Horton (1965) gives the survival rate as:

$$S=.3364 < .3684 < .4004$$

with a mean daily natural mortality rate of 0.00173

(5) Migration characteristics and distribute on. Mummichog inhabit ex-
and tremely shallow, brackish water during most of the year. They
(6) exist in groups that have home environments whose boundaries are dependent on bottom topography (Horton, 1965). The groups abandon the shallow environments when the water temperature reaches 9 C and indications are that they may winter over in mouths of rivers or in the mud of tide pools. The size of the home area fluctuates seasonally, being small during spawning time and larger at other times. Horton concludes that the absence of mummichogs in deep water is due to their slope-dependent movements.

(7) Population densities. Maximum densities reported by Horton (1965) were 11, 174 fish along 1,250 feet of shoreline.

(8) Food. Mummichogs are omnivorous, feeding on vegetable matter as well as on animal. They have been found full of diatoms, eelgrass, foraminifera, shrimps, and other small crustacea, small molluscs sometimes small fish, amphipods, carrion, and their own or each other's eggs at spawning time (Bigelow and Schroeder, 1953)..

(9) Predation. Predators on Fundulus include herons, kingfishers, striped bass, white perch, tomcod, and smelt.

(10) Competition. In the southern part of its range, Fundulus shares the habitat with the related species F. majalis and the sheepshead minnow, Cyprinodon variegates. Their food habits are similar, and Cyprinodon in particular is very aggressive (Bigelow and Schroeder, 1953). Other competitors could be juvenile winter flounder and the sand shrimp Crangon.

(11) Responses to the environment (natural factors; pollutants). No information gathered.

12.6,10 Merluccius bilinearis

The silver hake is a swift swimming, wandering fish of the cod family. They are voracious predators, moving in loose bands, rather than tight schools, over wide areas in search of prey. Little is known of the life history of this commercially important species.

(7) "Reproduction. Silver hake spawn along the entire coastal zone from Cape Cod to Grand Manan (Bigelow and Schroeder, 1953) and also the length of the outer shelf from the New Jersey coast to the Scotian shelf (Edwards; NMFS, Woods Hole, Mass.). They spawn less on the offshore banks and not at all on the northern side of the Bay of Fundy. They spawn chiefly in water shoaler than 90 M and the sandy slopes north and east of Cape Cod, being particularly important for reproduction. Silver hake are one of the principal summer spawners in the inshore Gulf of Maine.. They do not spawn north of Cape Cod before June. Egg production is at its height in July and August and spawning continues through September. Offshore, spawning begins earlier and ends earlier - May to August. The evidence suggests an optimum spawning temperature of 7 to 12 C.

(2) Fecundity and larval life. There is no information on the fecundity of the silver hake, except that an individual female probably produces a relatively large number of eggs considering its mode of reproduction. The eggs are buoyant and float in the upper 9 M of water, although spawning may take place in deeper water. Incubation

is rapid,' a little more than 48 hours in the Gulf of Maine. The larvae are pelagic, hatch at 2.8 mm, and metamorphose at 20 to 35mm, after about 2 to 3 months. Probably because of the characteristic counter clockwise drift of eggs and larvae in the Gulf of Maine, most of the larvae are taken in the southwest portion, even though the eggs are found in other parts of the Gulf. The Gulf of Maine is a major nursery area for this species.

(3) Growth and 1 ongevi ty. The growth of the silver hake has not been well studied. Growth is sexually dimorphic, the females growing larger and living longer than the males. Bigelow and Schroeder (1953) give the following:

Time	Length (cm)
End of first summer	2.5 to 8
First February	3 to 13
First April	5 to 17
One Year	14 to 19
Two Years	24 to 28
Three Years	28 to 36

Schaefer (1960) showed dimorphic growth for hake of the New York Bight. Females ranged from 10 to 48 cm and males from 10 to 36 cm. The rate of growth of males slowed rapidly after their third year. Maximum ages were 6years for males and 7years for females. Nichy (1969) found hake in the Gulf of Maine were about 4 cm longer during their first winter than those taken off southern New England.

(4) Natural mortal ity. No information gathered. Greatest rate of mortality is probably in the larval stage, as it is with most fishes with a completely pelagic early life history.

(5) Migration characteristics. Silver hake are wanderers, their movements are governed chiefly by the pursuit of prey and by seasonal changes in water temperature. Most of them migrate from the inshore waters in the late autumn, presumably to warmer offshore wintering grounds, and return in the spring.

(6) Distribution and niche preference. Silver hake are found all over the study area; their chief center of abundance in the Gulf of Maine is in the southwest part. Recent studies" have shown that two distinct races inhabit the Atlantic coast waters. Silver hake range from the tide line to a maximum depth of 279 to 732 m (Saila, 1973). Their optimum temperature range seems to be between 3.3 C and 7.7 C (Bigelow and Schroeder, 1953). Metamorphosed yearling hake move into the waters of the deep basins and probably remain there for ayear or two (Bigelow and Schroeder, 1939). Sarnits and Sauskan (1967) have indicated that in the northern part of their " range, the distribution and probably the strength of the year classes of silver hake is governed by hydrographic conditions, particularly water temperature.

(7) Population densities. There are no good figures for population densities. The main areas of commercial exploitation are in the inshore waters and the commercial catch fluctuates considerably. This could be the result of changes in abundance, fishing effort, or the movements of the fish. The record U. S. catch of silver hake was 60.3 million kg in 1957; subsequently, the catch has fluctuated between 31.7 and 40.8 million kg. The wide ranging habit of the species makes density estimates difficult.

(8) Food. The diet of the silver hake consists mainly of euphausiids and fish. Immatures (less than 28 cm) feed chiefly on euphasiids mature fish on euphausiids, fish, shrimp and squid, while large females (greater than 40 cm) feed exclusively on fish (Vinogradov, 1972). Vinogradov gives the following list of food items found "very often" in hake stomachs (his highest category) in the northwest Atlantic.

Pelagic crustaceans

Calanus finmarchicus
Mysis spp
Themisto compressa
Meganyctiphanes norvegica
Thysanoesia inermis
Pandalus montagui
P. borealis

Pelagic cephalopod

Illex illecebrosus

Fishes

Clupea harengus
Argenti na silus
Myctophum affine
Maurolicus muelleri
Merluccius bilinearis
Scomber scombrus
Ammodytes americanus

Bigelow and Schroeder (1953) state that probably a list of prey of the silver hake in the Gulf of Maine would include the young of practically all the common Gulf of Maine fishes.

(9) Predators. Little information, although larger fishes and marine mammals probably feed on silver hake.

(10) Competitors. Little information, although a potential competitor - the red hake - has a diet that is different enough not to compete with the silver hake for food (Vinogradov, 1972).

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.11 Gadus morhua

The Atlantic cod is a large, boreal, demersal or semi-demersal member of the cod family. In habit it lies between the pelagic pollock and the demersal haddock in that it feeds on epibenthic and pelagic as well as benthic organisms and spends considerable time up in the water column. It is one of the more important commercial species.

(1) Reproduction. The cod has regular, small, well-defined spawning areas. Cod spawn in shoaler waters than haddock and not below 91 m. The following areas are defined by Bigelow and Schroeder (1953):

1. Eastern Georges Bank - 40 to 60 m of water
2. Browns Bank - probably 22 to 46m
3. Massachusetts Bay - 22 to 46 m, 5 to 16 km offshore
4. Ipswich Bay - 9.1 to 46; the most important area of the inner Gulf of Maine, from south of Isles Of Shoals to Merrimack River

The major part of the cod's spawning is limited to these areas and there are heavy concentrations of fish there during the spawning season.

Cod spawn chiefly in the winter, but with no well-defined beginning or end to the season. Peak spawning varies somewhat from spawning ground to spawning ground. The peak spawning periods for the major grounds are given below (Bigelow and Schroeder, 1953):

1. Nantucket Shoals - Early November to mid-February
2. Massachusetts Bay - Same as above
3. Ipswich Bay - March to April
4. Georges Bank - February to April
5. Coast of Maine - Early March to May

Ripe fish have been taken as early as September and as late as June. Most cod are sexually mature at 5 to 6 years, and all are mature by 9 years.

Cod make seasonal migrations to the above small, well-defined spawning areas, although they do not move extensively. Spawning takes place over a wide range of temperatures. In Ipswich Bay spawning is at its height at temperatures of 1.6 to 3 C and in Massachusetts Bay at2 Cto 6 C (Bigelow and Schroeder, 1953).

(2) Fecundity and larval life. The cod is one of the more prolific fish. The average size fish lays about 1,000,000 eggs. The following fecundities are given by Bigelow and Schroeder (1953):

Length (cm)	Number of eggs
99	3,000,000
104	4,000,000
133	9,000,000

The eggs of the cod are planktonic, 1.10 to 1.82 mm in diameter and tend to be larger in colder water. On the average, eggs will drift for 14 to 30 days before hatching.

The following incubation times are given by Bigelow and Schroeder (1953):

Temperature (C)	Days to hatching
8	10 to 11
0	40

From 5 to 8 C appears to be the most favorable for the best condition of the larvae.

Fish (1937) studied egg drift from the inner Gulf spawning grounds (Ipswich Bay and Massachusetts) and found that the eggs were carried counter-clockwise out of both Bays before they were hatched. The eggs drifted east and south and the resultant larvae did not contribute to those inshore stocks. Apparently, the inshore stocks are kept up by immigration of young adults. This was found to be true to some extent also for the Nantucket shoals stock.

The larvae are planktonic and 4mm long at hatching. They are fully developed larvae in 6 to 12 days at 4.5 mm. They metamorphose after about 2 months at 20 mm (Bigelow and Schroeder, 1953). The larvae move around the Gulf from northeast to southeast in accordance with the currents. When they reach 1½ cm long they seek the bottom and not much is known of their life history until they are 25 to 28 cm long and are caught on hook and line. Probably they become distributed all over the Gulf (Bigelow and Schroeder, 1953). The fry and immatures are usually more plentiful on the rough inshore bottoms than the smooth offshore banks.

(3) Growth and longevity. Bigelow and Schroeder, (1953) give the following growth rates for cod.

For young cod - grown in eel pond at Woods Hole:

December	hatched
April 8	32.9 mm
April 25	40 mm
May 13	42.8 mm
May 25	64 mm
June 6	75.5 mm
June 20	75 mm

They are 12.06 to 20.30 cm long by the first autumn. Thereafter there is great variability in growth. Taylor (1958) demonstrated that maximum size and life span is a function of temperature. There was a linear relationship between growth parameters for cod from different areas and water temperature.

Bigelow and Schroeder (1953) give the following growth data for cod from two areas:

Age	Average length (cm) Nantucket Shoals	Bay of Fundy
1	18 to 20	6
2	36 to 43	14

Age	Average length (cm) Nantucket Shoals	Bay of Fundy
3	48 to 56	20
4	58 to 66	26
5	69 to 74	32
6	76 to 81	36
7	84 to 86	39
8		45
9		49

Generally, the average mature shore cod in the Gulf of Maine (15 to 20 kg) are 3 to 8 years old.

(4) Natural mortality. No information gathered.

(5) Migration characteristics and distribution. Wise (1963) distinguished three major stocks in New England: (1) Coastal group along (6) Massachusetts, New Hampshire, and southern Maine, (2) Georges Bank and the Bay of Fundy, (3) Nantucket Shoals and the South Channel.

Cod are distributed, according to commercial catches, as given above, in fairly well-defined grounds. The stocks are fairly discrete, and as a rule the fish do not migrate extensively (Bigelow and Schroeder, 1953). There are two major movements that do take place:

1. Spawning migrations. These do not involve extensive movements.

2. Seasonal movements. This is especially true of the Nantucket Shoals stock, which makes a fall migration to the Rhode Island - North Carolina waters and back in the spring. (Schroeder, 1930). Cod show a slight inshore-offshore seasonal movement.

Cod are found from the surface to 183 m. The young are found in the littoral zone. The larger cod are deeper than 12.8 to 14.6 m. The majority of all cod living in the Gulf are probably within the 9 to 137m contour (Bigelow and Schroeder, 1953).

Cod are bottom fish usually preferring hard bottom rather than soft mud. They usually lie within two meters of the bottom arid are comfortable between the temperature ranges of O to 10 to 13 C.

(7) Population densities. Cod are found in discrete populations in the Gulf of Maine. Bigelow and Schroeder (1953) indicate some relative densities from the commercial catch of cod. The most productive ground is in eastern Georges Bank. The next is the south

channel - Nantucket Shoals area. Then come Seal Island, Nova Scotia, Browns Bank, Lurcher Shoal, Grand Manan Bank, Jeffries Ledge, Ipswich Bay, and the New Hampshire - Maine Coast. Cod are scarce in the Bay of Fundy.

There is little information on specific numbers of cod at any of these fishing grounds. Schroeder (1930) estimated the population in the Nantucket Shoals - South Channel area as approximately 3 to 4½ million adult fish. This was for the period 1923-1928 and is probably not valid today.

(8) Food. Larval and post-larval cod subsist almost exclusively on copepods and on other minute crustacea during the several months while they are drifting in the upper water layers. Copepods, along with amphipods, barnacle larvae and other small crustaceans and small worms are the diet of the small cod as they first seek bottom. As they grow larger they consume invertebrates in great variety and in enormous amounts, mollusks being the largest item in their diet - sea clams (Mactra), cockles (Polynices), sea mussels (Modiolus) - all being swallowed whole. Cod also eat crabs, lobsters, shrimps, brittle stars, sea urchins, sea cucumbers and sea worms (Nereis). Other items in their diet are tunicates, and occasionally hydroids, bryozoans, algae, ctenophores, squid, small fish (particularly herring), their own young, launce and capelin, shad, mackerel, menhaden, silversides, alewives, silver hake, young haddock, flounders, cunners, rock eels, blennies, sculpins, sea ravens, hake, and skates. Fish eggs and even wild ducks are consumed (Bigelow and Schroeder, 1953).

(9) Predation. The worst enemies of the adult cod are large sharks and the spiny dogfish. Small harbor pollock are formidable enemies of young cod. Young cod, up to 18 to 20 cm, are also devoured in large numbers by the larger cod (Bigelow and Schroeder, 1953).

(10) Competition. Rae (1967) reported on the competition for food between cod and other species in Scottish waters. He states that the haddock is mainly a mixed feeder on benthic types, so that competition with the cod is relatively slight. The silver hake resembles the cod quite closely in the type of food taken and in eating habits, although the smaller average size of the silver hake tends to limit the size of the fish it can eat. Stomach analyses of cod and silver hake taken in the same trawl area showed that although they occasionally preyed on the same food types, the remarkable feature was the frequency with which they preyed on different types. Cod and plaice are rarely present on the same grounds in any number. The lemon sole, although predominantly a polychaete feeder, frequently eats the smallest juvenile euphausiids- a type which in their more mature forms provide an appreciable share of the food of cod; and there is a degree of active competition

with the turbot, although it is both seasonal and local. Another important food of the cod, Nephrops norvegicus, is eaten by at least 15 other species of fish. The closest competitor, both in composition of food and sizes of individual organisms eaten, is the chain dogfish (Scyliorhinus).

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.12 Melanogrammus aeglefinis

The haddock is a boreal, demersal member of the cod family, but is more closely associated with the bottom than are the cod or pollock. Once plentiful on Georges Bank and in the Gulf of Maine, its numbers have been severely reduced by a series of poor reproductive seasons and by heavy fishing.

(1) Reproduction. Georges Bank is the primary spawning area for haddock off the east coast of the United States. While haddock may spawn in deep water anywhere on Georges Bank east of Nantucket Shoals, the centers of spawning activity lie on the northeast part and in the Great South Channel.

The spawning season for northwestern Atlantic haddock, including those from Browns and Georges Bank, runs from February to May. Peak spawning activity occurs in March and April. The age at first maturity of Georges Bank haddock is two to three years at a length of from 300 to 500 cm (Clark, 1959).

Courtship and mating behavior have been observed in aquaria (Hawkins, Chapman and Symonds, 1967). A male and female pair off and swimming vertically, belly to belly in close contact, release eggs and milt. In nature, spawning generally occurs near the bottom over a broken bottom of mixed rock, gravel, mud, and sand. It may occur at any time of day.. The spawning season occurs once a year; however, a given female may spawn repetitively over a period of three weeks. The time that haddock spawn appears to be closely related to the temperature on the spawning grounds. Spawning begins a-t the start of the-vernal warming, between the temperatures of 4 and 7 C (Colton, 1968).

(2) Fecundity and larval life. Fecundity has been related to fish length for Grand Banks haddock by the following expression:

$$F = 0.00\ 1391\ xL^{5.110}$$

Where F equals fecundity in thousands
of eggs and L equals fish length in cm.

Both the eggs and the larvae of the haddock are planktonic. The eggs are 1.10 to 1.67 mm (average *1.46 mm)* in diameter and contain no oil globule. Incubation time varies between 9 and 23 days at 3 to 14 C. At hatching, haddock larvae are 3.08 to 4.99 mm (average 4.08 mm) long. Juveniles assume most adult characteristics (metamorphosis) at a length of 45 to 50 mm. The larval phase probably lasts up to six weeks, depending upon a number of conditions, the most important being food availability and temperature. Haddock larvae are concentrated near the surface during February to May (Miller, et al., 1963) and the effect of wind-driven, non-tidal currents on the dispersal of haddock larvae may determine the strength of a year class (Colton and Temple, 196?; Walford, 1938; Chase, 1955).

Fecundity/length and age/fecundity relationships are presented below (Hodder, 1965).

Table 12-12 Relation of fecundity to age (thousands of eggs)

Stock		Age (Years)									Authority
		3	4	5	6	7	8	10	11	12	
NO.	Sea*	31	100	159	224	278	-g	-	-	-	Raitt (1933)
Grand Bank	-	48-154	195-298	198-298	514	481-550	496 514	742	805-?148	846	Hodder (1965)

*Ages adjusted to January 1 birthday

Annual egg production for the Georges Bank spawning stock was estimated at 80 x 10^{11} for 1932. An inverse relationship between the size of the spawning stock and subsequent year-class strength has been suggested for Georges Bank haddock (Herrington, 1944). Georges Bank haddock are recruited into the fishery at Age II. The mean annual recruitment of two year old fish for the period of 1935 to 1963 was calculated by Hennemuth (1969) to be 49 x 10^6. However, the range in calculated recruitment over this period varied from 1 x 10^6 to 502 x 10^6,

(3) Growth and longevity. Young American haddock grow more rapidly than European haddock. However, subsequent growth is relatively less rapid, so that by the time the fish are 7 to 8 years old, both are approximately the same size. Gulf of Maine haddock average 152 mm at the end of their first year (Bigelow and Schroeder, 1953). Age/length relationships for haddock are presented below. Haddock from the northwest Atlantic reach a maximum age of 14 years. The growth rates of haddock from different areas vary considerably. Nantucket Shoals haddock

are among the faster growing stocks (Bigelow and Schroeder, 1953).

Age (years)	Length (cm)
2	31
4	48
6	57
8	64

(4) Natural mortality. The annual mean mortality for adult haddock lies between 40 and 76 percent. Mortality coefficients for Georges Bank haddock, according to Hennemuth (1969) are as follows:

Mortality Coefficients

Years	Natural Mortality (M)	Fishing Mortality (F)	Total Mortality (Z)
1935 to 1963	0.20	0.50	0.70
1965 to 1966	0.20	0.80	1.00

(5) and (6) Migration characteristics and distribution. The haddock is distributed on the continental shelf in the northeast and northwest Atlantic, mostly in water shallower than 200 m. Off the east coast of North America the haddock ranges from the Strait of Belle Isle to Cape May, New Jersey. Its center of abundance stretches from Georges Bank to the southern part of the Grand Bank. The usual depth range is 10 to 450 m. Haddock occur in water temperatures between 1 and 10 C and salinities between 31.5 and 35' O/oo. Haddock may occur in the water column well off the bottom where they feed on pelagic organisms even so they show a preference for broken bottom, gravel, broken shell, smooth, hard sand, clay and in particular areas of smooth bottom between rocky ledges (Bigelow and Schroeder, 1953). Limited seasonal migrations occur to and from spawning grounds. In the winter some haddock move south to Cape Cod.

(7) Population densities. Although not normally a schooling fish, haddock may occasionally form dense schools while spawning or while feeding on sand eels or capelin concentrations. Catch-per-unit-effort data reported by Hennemuth (1969) ranged from 2.9 to 22.6 MT per days fishing. The most important local fishing grounds are the northern edge, and central and southeastern part of Georges Bank, Great South Channel, and Nantucket Shoals.

(8) Food. Haddock fry, living near the surface, feed on copepods. As soon as they settle to the bottom they feed on all kinds of invertebrates including brittle stars, bivalve mollusks, worms, amphipods,

hermit crabs, spider crabs, common crabs, shrimps, gastropod, starfish, sea urchins, sand dollars, sea cucumbers, and squid. Haddock also eat small fish on occasion, but fish do not form an important part of their diet. Herring, sand launce, young eels, small mackerel and small silver hake are rarely taken (Bigelow and Schroeder, 1953).

(9) Predation. No specific information is available, except that young haddock are the prey of larger predacious fishes such as cod and silver hake.

(10) Competition. The haddock would be expected to compete for food with other bottom feeding fish (spiny dogfish, silver hake, red hake), especially south of Cape Cod (Colton, 1972). However, because of different food habits they were found not to compete with cod (Kohler and Fitzgerald, 1969).

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.13 Pollachius virens

The pollock is a member of the cod family, similar in appearance to the Atlantic cod and haddock, but having a more active, pelagic habit. A cold water species, the pollock is more abundant north of Cape Cod. It is an important commercial fish, although not as highly prized as the cod and haddock.

(1) Spawning occurs in the late autumn and early winter (February). From the distribution of ripe adults, spawning seems to be restricted to the region of Massachusetts Bay and between Cape Ann and the Isle of Shoals (Steele, 1963). Pollock spawn on falling temperatures and when the water becomes nearly isothermal to a depth of 90 m. Most of the eggs are produced within a narrow range of temperatures (4 C to 6 C in late December). This is water that is several degrees warmer than that when haddock spawn most intensively. Male pollock mature sexually when 4 to 7years old (55 to 70 cm), according to Steele (1963).

(2) Fecundity and larval life. The pollock is one of the more prolific fish. Its fecundity is reported at 225,000 to 400,000 eggs per female with as many as 4 million eggs for a 10.7 kg female. The eggs and larvae are pelagic and incubate in 9 days at 6 C. The larvae are 4.2 to 4.3 mm at hatching and metamorphosis occurs after about 2 months when the young fish are 20 to 25 mm long (Bigelow and Schroeder, 1953).

Pollock larvae are concentrated in the southern Gulf of Maine and not found in the northern Gulf at all (Steele, 1963). This has led Steele to consider the possibility that pollock larvae are subject to the same offshore dispersal discussed by Colton and Temple (1961). However, the nature of the non-tidal drift over the southern Gulf of Maine during the winter is not well enough known to draw conclusions.

(3) Growth and longevity. The age and growth of Gulf of Maine pollock are given by Hoberman and Jensen (1962) and their data are as follows:

Annuli	Average length (mm)
1	192
2	307
3	410
4	498
5	567
6	625
7	678
8	706
9	726
10	726

Pollock can live at least eleven years,

[4] Natural mortality. No specific information. Probably greatest mortality occurs during the larval stage.

(5) Migration characteristics. Pollock carry out seasonal movements to and from the spawning grounds, which is reflected in the commercial catch. In the northern Gulf of Maine, the catch is largest from June to October and the catch in the southern Gulf is largest from October to February, suggesting that the fish in the northern Gulf migrate to the spawning grounds in the southern Gulf in the winter.

(6) Distribution and niche preference. Pollock are distributed throughout the Gulf of Maine and to a lesser extent below Cape Cod. They

are not reported to occur at the surface when water temperature exceeds 11 C (Bigelow and Schroeder, 1953). Pollock distribution is somewhat determined by size. The small fish (O to 2years old) are found more inshore, especially during the summer and are called "harbor pollock". The 2+ fish are found in deeper coastal water and larger (6 to 11 year olds) fish are found in the deeper colder bank waters; however, even these are segregated to size. The best catches of commercial size are made at temperatures above 1.1 C at depths of 36 to 180 m and on the edges of shoals and banks where there is an abundant food supply.

(7) Population densities. No specific information, except that pollock are most concentrated during the winter on the spawning grounds and during this time are subject to a fairly intensive fishery (Steele, 1963). Thereafter, they are more dispersed as they move out over the Gulf of Maine. Dense schools of pollock can have as many as 60,000 fish.

(8) Food. The offshore pollock are mainly plankton eaters and the euphausiid Meganyctiphanes norvegica is by far the most important food item. Smaller offshore pollock eat planktonic copepods and the largest pollock consume relatively more fish. The small O-class pollock feed mainly on algae-inhabiting organisms (amphipods, insects, harpacticoid copepods) in the summer. Planktonic organisms are less important at this stage (Steele, 1963).

(9) Predation. Young pollock are preyed on by the larger marine fish eaters.

(lo) Competition. Because of their planktonic feeding habits, pollock could compete for food with such fishes as Atlantic mackerel, silver hake and other euphausiid eaters. There is no specific information.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12,6.14 Urophycis chuss & U. tenuis

The white and red hake are cold water bottom fishes of the cod family. They are treated together because they are so similar in appearance and habit that they cannot be easily distinguished. The white hake is slightly larger and has a more northern distribution than the red hake. They are both commercially important.

(1) Reproduction. The spawning behavior of the bakes is not well known. It appears over an extended period during the summer both north and

south of Cape Cod. There is evidence (Nichols and Breder, 1927) that hake from southern grounds spawn somewhat earlier, indicating that temperature probably affects the timing of spawning. South of Cape Cod, spawning occurs from May through August. Hake eggs were collected in Narragansett Bay from May through November and in Block Island Sound from June through September. Red hake probably reach sexual maturity at, Age III. The majority of stations at which hake eggs were collected in the Gulf of Maine were well inside the 100 m isobath. Probably spawning among hake takes place in relatively shoal water.

(2) Fecundity and larval life. The eggs and larvae of the hake are pelagic. Eggs range from 0.63 to 0.97 m in diameter. They are spherical, transparent, and contain one oil globule. At hatching, red hake prolarvae are 1.76 to 2.29 mm long. Newly metamorphosed fry are 40mm long.

(3) Growth and longevity. Hake spawn in the summer. Young-of-the-year taken in November off New York were 49 to 65 mm. Young hake judged to be approaching one year old range from 60 to 110 mm. An analysis of length frequency data for the Bay of Fundy hake presented by Bigelow and Schroeder (1953) revealed the following age-growth data:

	Males	Females
Age I	200 mm	200 mm
Age II	330 mm	360 mm
Age III	405 mm	480 mm

The growth of females outstrips that of males in fish over 2 years old. The white hake is the larger of the two species, attaining a maximum length of four feet and weight of 18 kg. The red hake reaches 75 cm and weight 2.5 to 3.5 kg.

(4) Natural mortality. No information gathered.

(5) and (6) Migration characteristics and distribution. The hake occur along the coast from the Grand Banks to Chesapeake Bay. The red hake's center of distribution extends from Nova Scotia to New York. The white hake is not abundant below Cape Cod (Bigelow and Schroeder, 1953; Fritz, 1965). They are primarily cold water species and are generally found between 4.4 C to 15.0 C (white hake) and 4.4 C to 17.8 C (red hake). They prefer soft. bottom areas and are found in depths up to 1000 m, and are abundant in deeper portions of banks and ledges of the continental shelf. They are closely associated with the bottom and probably seldom swim far above it. Hake move inshore during the spring where spawning occurs. Young hake may spend one or more years along the immediate shoreline and coastal shallows (to 30 m) and these probably serve as nursery

areas for the species. Adults, while appearing in coastal waters, are always more abundant offshore.

(7) Population densities. Trawlers frequently land large catches composed predominately of white and red hake. There is evidence that where they occur they may be present in high concentrations. Large numbers of red hake are caught on soft bottom areas, in depths of from 110 to 130 m on the South Channel, Northwest slope, and Southern slope grounds on Georges Bank, as well as an area south of Nantucket Shoals and on the southwest part of Georges in 50 to 75 m. Fritz (1965) indicates red hake are abundant south of Cape Cod in 30 to 370 m of water. Autumn abundances of hake are shown as over 100 per tow outside 30 m line with most in 100 to 200 m southeast of Long Island and New England. Red hake from inshore grounds contributed 20 percent of the volume of annual landings at Point Judith, Rhode Island, in 1966. Of this amount, one-third were landed from May to July of that year. Red hake are abundant on the continental shelf from Georges Bank to opposite Chesapeake Bay from depths of 10 to approximately 1000 m, depending on the season.

(8) Food. The red hake feeds chiefly on shrimps (Pandalus), amphipods, and other small crustacea that they find on the bottom. They also eat squid and a variety of small fish such as alewives, butterfish, cunners, eels, flatfishes, tautog, herring, mackerel, menhaden, launce, silversides, silver hake, sculpins, sea robins, smelt, and tomcod. Small crabs are also eaten. In the northeastern part of the Gulf of Maine they feed far enough off bottom to capture the pelagic euphausiid shrimps (Meganyctiphanes and Thysanoessa) (Bigelow and Schroeder, 1953).

(9) Predation. No information gathered.

(10) Competition. No information gathered.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.15 Paralichthys dentatus

The summer flounder, or fluke, is a warm water flatfish that is abundant below Cape Cod. It is an active, predacious fish with a seasonal inshore-offshore migration and a dependence on nearshore nursery areas. It is an important commercial and sport fish.

(1) Reproduction. Fluke eggs are buoyant and, according to Smith (1973), it is reasonable to conclude that local concentrations of eggs with

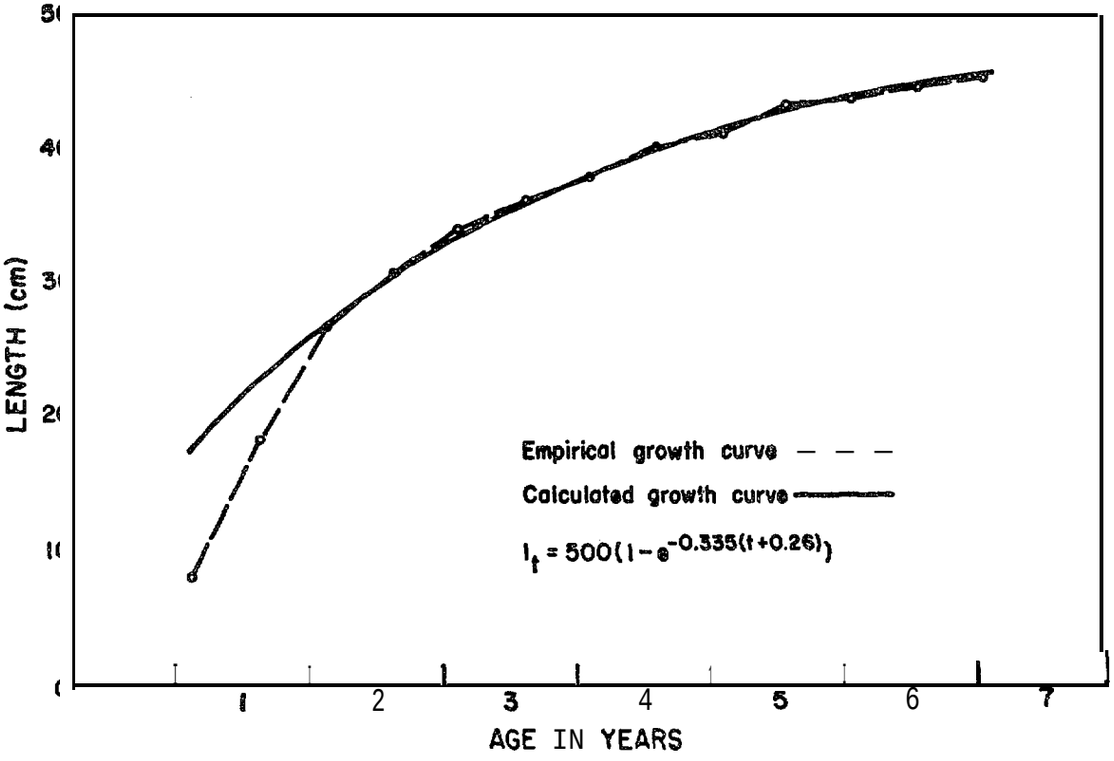
their short incubation periods closely approximate the location of spawning grounds. On this basis, spawning grounds are located generally within 46 km of the shore. Eggs were most abundant at the surface where the bottom temperatures were 12 to 19 C. Although areas of maximum egg abundance varied from year to year, zones of maximum egg abundance occurred in bands paralleling depth contours off Long Island opposite Great South Bay and running south-to the latitude of Barnegat Bay. Isolated concentrations of eggs occurred off Assateague Island and off Oregon Inlet on Cape Hatteras, suggesting the existence of a number of spawning populations. Zones of greatest larval abundance stretched from opposite Montauk Point through the New York Bight to the latitude of Atlantic City, New Jersey in a band between 22 and 83 km offshore. Local concentrations of larvae occurred off Delaware Bay and" Barnegat Bay.

Fluke spawn in autumn in a north to south progression beginning in early September in the northern part of the middle Atlantic->Bight. The peak in spawning activity occurred in October north of Chesspeake Bay and in November south of Chesapeake Bay (1965-1966). The last. spawning occurs off Cape Lookout in February. All of the spawning that normally occurs off southern New England and New York takes place in early September. The minimum size at first maturity is 305 mm for males and 370 mm for females. First maturity for both sexes takes place at an age of just over one year.

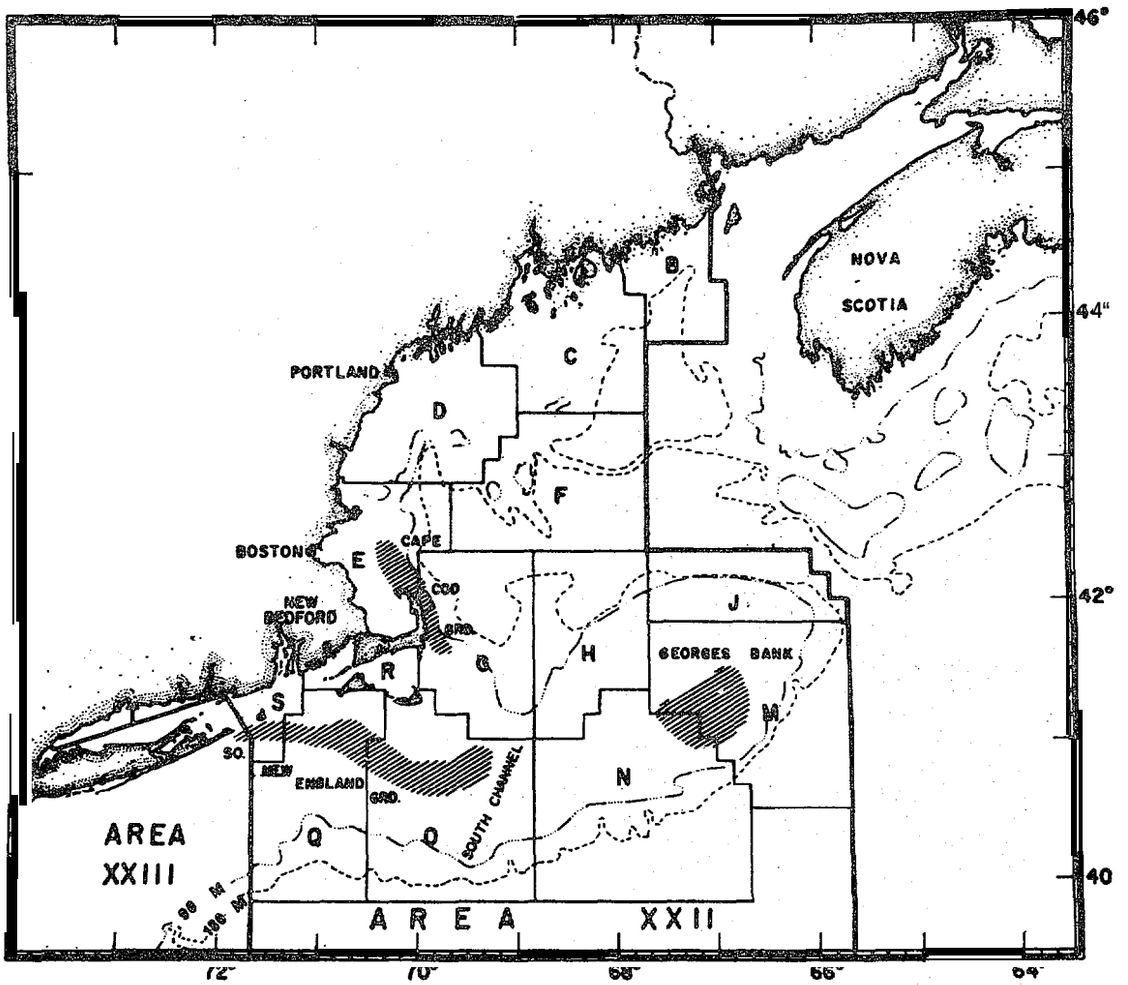
Little is known of the spawning behavior of fluke, except that it probably occurs at the bottom in deep water. There is convincing evidence that the timing of spawning activity is closely related to the bottom temperature on the spawning grounds during the fall. The year to year variation in the location of peaks in egg abundance suggests that bottom temperature may determine the location of spawning grounds as well. Among collections reported by Smith (1973), which were made monthly along the Atlantic Coast from New England to south of Cape Lookout, 77 percent of all eggs collected appeared in waters with bottom temperatures between 12 and 19 C. Taking into account the lateral drift of eggs floating from the bottom to the surface, (Smith) estimates that peak spawning occurs at closer to 19 C than 12 C.

(2) Fecundity and larval life. The small size of fluke eggs and their pelagic habit indicate that it is a high fecundity species. The number of eggs per female probably number at least in the tens of thousands.

Fluke eggs and larvae are pelagic. The eggs are 0.91 to 1.10 mm in diameter and contain one oil globule. Eggs are found at or near the surface. Incubation of eggs takes 72 to 75 hours at 17.5 C. Newly hatched larvae are 3mm in length. Metamorphosis to adult form has occurred by the time the larvae have reached 12 to 13 mm SL.



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 12-29	Growth and Longevity in Yellowtail Flounder (Lux and Nichy, 1969)



A SOCIO-ECONOMIC AND Environmental inventory OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 12-31	Principal Fishing Grounds of Yellowtail Flounder (Bigelow and Schroeder, 1953)

12.6.17 Pseudopleuronectes americanus

The winter flounder is a shallow water member of the right-handed flatfishes, with a wide tolerance of temperature and salinity. It is found from far up estuaries and salt marshes to the shoal areas of Georges Bank and is perhaps the most familiar groundfish in the study area. It is an important commercial and sport fish.

(1) Reproduction. Winter flounder spawn in shoal water 2 to 5 m in the backwaters of bays and estuaries, and on Georges Bank in water 46 to 73 m deep. They spawn in waters no warmer than 40 to 42 C and prefer sandy bottom.

The young produced in a spawning area recruit to the population of winter flounder in that area.

According to Perlmutter (1947), peak spawning varies throughout the winter flounder's range, depending on temperature. The winter flounder is a winter-early spring spawner (January to May). Winter flounder prefer sandy bottom and spawn at night in shoal water. They can spawn in low salinity water (11.4 percent).

Bigelow and Schroeder (1953) give spawning times for several locations:

Boothbay	March 1 - May 10-15 (peak March 30 - April 20)
Georges Bank	April 1 - May
Massachusetts Bay	February - March

The winter flounder is probably sexually mature at 3 years (Bigelow and Schroeder, 1953).

(2) Fecundity and larval life. According to Bigelow and Schroeder (1953), individual females average 50,000 eggs. A large 1.5 kg female produced 1,500,000 eggs.

The eggs sink to the bottom and adhere in clusters. They are 0.74 to 0.85 mm in diameter. Incubation takes 15 to 18 days at 2.7 to 3.3 C (Bigelow and Schroeder, 1953). According to Pearcy (1962), the larvae are found in the Mystic estuary from February through June. They were most abundant in brackish water during March and April. Later in the spring they moved into the lower estuary. In the upper estuaries they were found in extremely high densities.

The larvae are adapted to maintain themselves in the estuary, according to Pearcy, by:

1. Laying demersal eggs
2. Being non-buoyant
3. Having a mixed planktonic-benthic behavior that keeps them in the up-river current pattern. The densities of larvae on the bottom were 6x that on the surface.

The larvae metamorphose at 8 to 9 mm in a little over 53 days. The rate of growth of small larvae is rapid, going from the hatching length of 3 mm to 5 to 6 mm in 20 to 25 days, and it then slows until they reach 8 mm in 53 days.

(3) Growth and longevity. In their studies on growth of winter flounder, Berry, et al. (1965) did not develop a general curve because they did not feel it would be realistic. Winter flounder consist of discrete stocks in which growth will vary depending on conditions. Also, there is considerable difference in the growth of males and females, making it necessary to have sex ratio information on each stock. Again, scales and otoliths of winter flounder are difficult to read beyond age III.

Berry, et. al. give the following growth data from the literature:

Age	Length (cm)	
	Annapolis Bay	Passamaquoddy Bay
I		7.9
II	15.3	11.8
III	22.5	18.7
IV	29.1	23.5
V	33.0	25.7
VI	35.6	28.2
VII	38.0	31.0
VIII	40.2	32.4

Bigelow and Schroeder give the following general growth rates:

1st August	1½ to 3¼ inches
End September	2 to 4 inches
End 1st year	4 to 6 inches
2 years	5 to 7½ inches
3 years	7½ to 9½ inches
4 years	9 1/5 to 10 inches

As a result o-f locally discrete stocks, fishes from different populations grow to different sizes. Georges Bank winter flounder grow much larger than those of the inshore stocks. This and other differences has led to the feeling that certain winter flounder stocks are separate races, and even that the Georges Bank stock is a separate species (P. dignabiles).

(7) Population densities. Pearcy (1962) gives valu e for the density of larvae in the Mystic estuary. This was 10/m^3 in the upper estuary during March and April-, when the larval concentration was at maximum. He gives an average density of 1/m^2 for age group 0 in the spring. The annual juvenile production in the Mystic estuary was 3.7 g/m^2. The maximum density found in Narragansett Bay was a mean of 98/acre (16 to 45 acre usual) and as high as 150/acre (Oviatt and Nixon, Personal Communication).

(8) Food. Diatoms are the first food taken after the yolk of the larval flounder is absorbed. A little later they prey on smaller crustaceans, such as isopods. Young flounders, 2.5 to 11 cm long, from Casco Bay were found to have fed chiefly on isopod crustaceans, with lesser amounts of the stomach content: worms (39 percent), mollusks (2 percent), and various unidentifiable material (22 percent). Other young flounders examined at Woods Hole were feeding chiefly on amphipods and other small crustacea, and annelid worms. The ratio of ingested mollusks to crustacea increases as the fish grow. The adult is limited by its small mouth to a diet of smaller invertebrates and of fish fry. Sometimes they eat shrimps, amphipods, small crabs, or other crustaceans; sometimes ascidians, seaworms (Nereis), or other annelids; or bivalve or univalve mollusks. They also may often bite off clam siphons that protrude from the sand. They will eat squid, holothurians and hydroids; small fish, and sometimes bits of seaweed (Bigelow and Schroeder, 1953).

(9) Predation. The winter flounder is an important food item of the harbor seal Phoca vitulina and of the harp seal, Phoca greenlandica (Fisher and MacKenzie, 1955). Poole (1964) reports that P. americanus is a major food item of the summer flounder.

(10) Competition. Richards, Merriman and Calhoun (1963) mention that Raja erinacea, the little skate, is a competitor for food.

Merriman and Warfel (1948) mention that the little skate is not only a competitor for food, but that there is an inverse relationship between the catches of the two species.

The ocean pout is also a competitor.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.18 Menidiamenidia

The Atlantic silversides is a small, schooling fish of the shallow near-

(4) Natural mortality. Pearcy (1962) gives the following mortality rates for the larval stage:

20 percent per day for small larvae < 6. mm
4 percent per day for larger larvae > 6 mm

The natural mortality rate was very high for small larvae. He found that the total-mortality through the larval and juvenile states was 99.98 to 99.99 percent.

Dickie and McCracken (1955) give natural mortality of over-wintering winter flounder adults as:

October 1949 - May 1950	0.32
November 1954 - April 1953	0.30
Length freq. on virgin population	1.01

(5) Migration characteristics and distribution. The winter flounder is and a shallow water fish and is found from the high tide mark in brack-
(6) ish water to a maximum depth o-f 128 m. Generally, the smaller fish are in shallow water and the larger ones in deeper water. They can stand a wide range of temperatures from close to freezing to 17 to 18 C (Bigelow and Schroeder, 1953).

The winter flounder is a non-migrating fish made up of discrete local populations. They do show a slight seasonal movement offshore in the winter in the northern part of the Gulf of Maine and a gradual dispersion of young fish to deeper water that is characteristic of non-migratory fish species (Perlmutter, 1947).

According to McCracken (1963), 12 to 15 C is the preferred temperature range. They leave the shore zone when temperatures are above 10 C but do not move into areas that are below 12 C in the summer. Flounders along shore in summer are distributed according to size and maturity. The youngest are in shallow zones with high light intensities, the immatures are deeper in zones with low light intensity, and matures are in both regions.

Flounders are restricted to a narrow, shallow depth zone. Therefore, there are not as large populations in the northern areas such as the Bay of Fundy and Nova Scotia which have narrow, shallow depth zones as there are in more southern waters where the shallow depth zone is broader (McCracken, 1963).

Perlmutter (1947) found no mixing between inshore and offshore stocks and that the meristics and size composition of the stocks were different.

shore waters and an extremely abundant species south of Cape Cod. It prefers sandy beaches and salt marshes and, as year-round resident where it is found, is widely tolerant of temperature and salinity extremes.

(1) Reproduction. Menidia spawns in shallow bays and marshes when water temperatures reach 15 to 22 C. Spawning occurs over sandy bottoms.

Spawning occurs during May to July in New England waters, primarily during May and early June. Maturity is probably reached in the first year, or by the time the silverside reaches 50 mm. Larvae are reported in plankton tows from Narragansett Bay, Long Island Sound, and Sandy Hook Bay from May through July.

Spawning behavior which occurs over sandy shallows is marked by the appearance of dense, milling aggregations of spawners, releasing milt and masses of adhesive eggs, which settle into sandy bottom areas or become immeshed in blades of marsh grass. Eggs are frequently shed in intertidal areas. The onset of spawning is no doubt in part controlled by the arrival of suitable temperature conditions (15 to 22 C).

(2) Fecundity and larval life. The eggs of the silversides are demersal while the larvae are pelagic. The eggs which are 1.1 to 1.2 mm in diameter are adhesive and non-buoyant. Hatching occurs after 8 to 9 days at 22 C. The larvae are 4.4 to 5 mm at hatching and 12 to 15 mm at metamorphosis. Menidia larvae grow at least 5 to 6 mm in the first 20 days of hatching.

(3) Growth and longevity. By the end of June, silversides that hatched earlier are about 20 mm. The growth rate of juveniles during July to September ranged from 7 to 14 mm per month in Rhode Island estuaries. At the end of their first year, Menidia are about 45 to 50 mm and can reach upwards of 140 to 150 mm in their third year. They have a three-year life span and many die after the third year's spawning (Bayliff, 1950).

(4) Natural mortality. No information gathered.

(5) and (6) Migration characteristics and distribution. Silversides occur in the shore waters of the western North Atlantic from the Gulf of St. Lawrence to Chesapeake Bay. The center of abundance for this species lies south of Cape Cod. It is tolerant of a wide range in temperatures and salinities and is a year-round resident throughout its range. The silversides prefers protected sandy shores and its occurrence within its range is determined by the presence of this habitat (Bigelow and Schroeder, 1953). They have been reported from depths of 50 m, but generally occur in shallow water

in southern New England.

(7) Population densities. Menidia are found in dense schools in estuaries and bays. Schooling can be observed in juveniles over 25 mm.

(8) Food. The silverside is omnivorous, feeding chiefly on copepods, mysids, shrimps, small decapod shrimps, amphipods, Cladocera, fish eggs (including their own), young squid, annelid worms, and molluscan larvae. They have also been found to ingest insects and algae, and diatoms mixed with mud and sand (Bigelow and Schroeder, 1953).

(9) Predation. The silverside is harried by every predacious fish that comes close inshore, especially by bluefish and striped bass (Bigelow and Schroeder, 1953). They are also an important food of the mackerel.

(10) Competition. No information gathered.

(11) Responses to the environment (natural factors, pollutants]. No information gathered.

12.6.19 Scomber scombrus

The Atlantic mackerel is a swift swimming pelagic fish of the open sea, usually found in dense, constantly moving schools. It is commercially important.

"(1) Reproduction. Mackerel spawn generally from the latitude of Cape Hatteras to the latitude of the Gulf of St. Lawrence. The major spawning areas are between Chesapeake Bay and Cape Cod and secondly, the Gulf of St. Lawrence. The Gulf of Maine is only of lesser importance; the heaviest spawning in that area is in Massachusetts Bay (Bigelow and Schroeder, 1953). They have no particular breeding grounds, but shed their eggs when ripe wherever they happen to be. As the schools are highly mobile and the eggs ripen in successive batches, spawning can occur over a wide area and over a long period of time. The densest concentration of eggs was found by Sette (1943) to occur off Fire Island Light.

Mackerel are spring-early summer spawners (April to July) with peak spawning during May-June. Spawning activities are associated with water temperatures between 9.0 and 13.5 C (Sette, 1943).

Mackerel begin to mature sexually in their second year, and all

are mature by the fourth year.

(2) Fecundity and larval life. Mackerel are moderately prolific. The average size female produces 400,000 to 500,000 eggs. Eggs mature in successive batches and less than 50,000 are released at a time. The eggs are planktonic and incubate in 150 hours at 12 C to 50 hours at 21 C (Bigelow and Schroeder, 1953). The larvae are also planktonic and hatch at 3.1 to 3.3mm. They reach 20 mm after 2 months and are fully metamorphosed at 50 nun.

(3) Natural mortality. Sette (1943) has provided one of the few studies in which the mortality of a fish population in the larval stage could be measured. The greatest mortality occurs during this stage and is probably the cause of periodic changes in abundance. Sette estimated the average mortality rate of the 1932 year class as 11 to 14 percent per day through the larval stage (up to 50 mm). This, according to Sette's calculations, was considerably higher than mortality should have been for successful reproduction. The 1932 year class later proved to be a very weak one. He estimated that it would require a survival of one fish to spawning age per 1,000,000 eggs to keep the population constant. He found a survival of 1 to 10 fish per 1,000,000 eggs to the end of the larval stage (50 mm).

There is no information on the natural mortality of juveniles or adults.

(4) Growth and longevity. Mackerel grow very slowly after the third summer. The following is the rate of growth given by Bigelow and Schroeder (1953).

Time	Length (cm)
Metamorphosis	5
End of first autumn	20 to 23
Following spring	25 to 28
Second autumn	30 to 33
Third autumn	35.5
Fourth autumn	38.5
Fifth autumn	39
Sixth autumn	41

Seventh autumn	41.4
Eighth autumn	42.5

(5) Migration characteristics. The migrations of the mackerel are tied in with the movements of the population as a whole in response to seasonal changes in water temperature. In the late autumn they withdraw from the coast, presumably to spend the winter in the deeper, warmer water of the outer continental shelf. In the spring they move back to the coast and northward, arriving in the western Gulf of Maine the first week in June and the coast of Maine to the Bay of Fundy during June - July. Sette (1950) noted a northern and a southern population of mackerel and believed the southern group was the one that moved into the western Gulf, while the northern one, in part, moved into the western Nova Scotia coast.

(6) Distribution. Mackerel are most abundant along the coastal belt in the summer and in the outer shelf area in the winter. They are found in schools that are usually made up of fish of roughly the same size. Their optimum temperature range seems to be between 7 and 20 C.

(7) Population densities. As with other pelagic, wide ranging fishes, density information is difficult to obtain. There is no information for the Gulf of Maine, although the abundance of the population fluctuates widely from year to year. Sette's (1943) estimate of the spawning stock in the main spawning area (Cape Hatteras to Cape Cod) was from 45,000,000 to 400,000,000 fish. There is yet no satisfactory explanation as to why the abundance of mackerel fluctuates so widely, except that it is probably tied in with reproductive success.

(8) Food. Mackerel generally eat all floating animals of proper size, except coelenterates. They are capable of both filter-feeding on the plankton or selectively feeding. Their diet includes pelagic amphipods and euphausiids, squid, fish eggs and larvae, small herring and sand lance, and even smaller mackerel. They feed little or not at all during the winter and during spawning.

(9) Predators. Most large predacious sea animals: whales, sharks, tuna, bluefish, striped bass. Young mackerel are preyed on by cod, squid, and seabirds.

(10) Competitors. No specific information gathered.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.20 Thunnus thynnus

The bluefin tuna is a large, pelagic, oceanic fish that travels in schools over long distances. It occurs in the study area during the warm months while feeding on schools of pelagic fish, and at this time, it is the subject of a popular sport fishery.

(1) Reproduction. Bluefin of the North Atlantic spawn in the warm waters of the Mediterranean, Gulf of Mexico, and Straits of Florida.

Spawning occurs during May and June in the Straits of Florida. The eggs and larvae of this spawning are carried in the Gulf Stream northward where they feed over the rich banks and coastal waters. Bluefin may mature at an age of 2 to 3 and all have reached maturity by their fourth to fifth year. The average length at maturity is 95 to 105 cm and a weight of 12 to 17 kg.

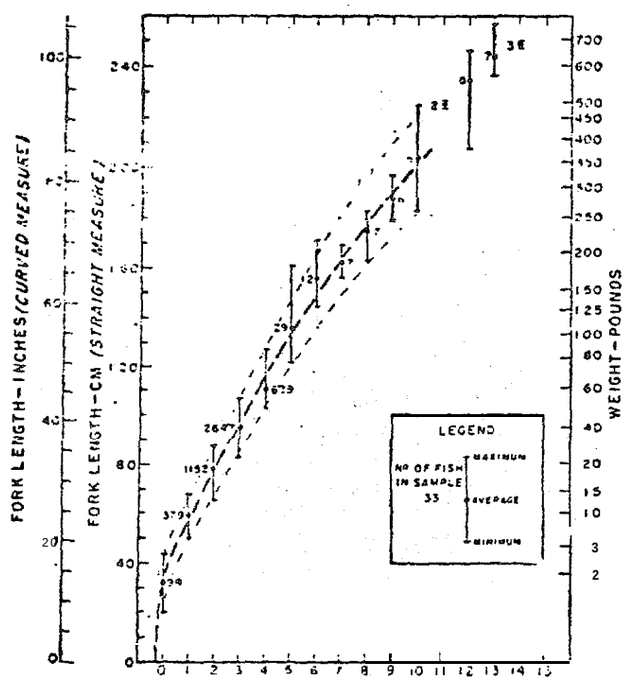
The bluefin's spawning behavior can be described briefly as follows: Following a short courtship, the male and female leave their school. The female swims in a tight circle while extruding her eggs. The male follows her, releasing his milt. The whole spawning process lasts only 1 to 2 minutes.

(2) Fecundity and larval life. A bluefin 130 cm (probably age V) can produce 5,500,000 eggs while one 230 cm produces upwards to 30,000,000 eggs, The fecundity of an average 163 kg (age VI) bluefin is 9.4 x 10^6 eggs.

(3) Growth and longevity. Bluefin growth is rapid, reaching a fork length of 54 to 64 cm (about 4.5 kg) by the end of their first year. By age 2, they reach 76 to 82 cm (about 9.5 kg) and by age 3 are 90 to 100 cm (about 16 kg). An age and growth figure (Figure 12-34) is included here to illustrate later growth. During their northern feeding migrations, bluefin increase their weight by 8.5 to 10 percent per month.

(4) Natural mortality. No information gathered.

(5) and (6) Migration characteristics and distribution. Bluefin are found in all oceans in subtropical and temperate latitudes. They are known to migrate north along the eastern coast of the United States from May and June to September and October. The juveniles move offshore in October to November, spending the winter in the Gulf Stream and Sargasso Sea. The exodus from New England waters generally coincides with decreasing water temperatures below about 20 C. Bluefin are known to migrate across the Atlantic Ocean to Norway and the Mediterranean Sea. The figure included here (Figure 12-35) indicates the locations and probable migration routes of



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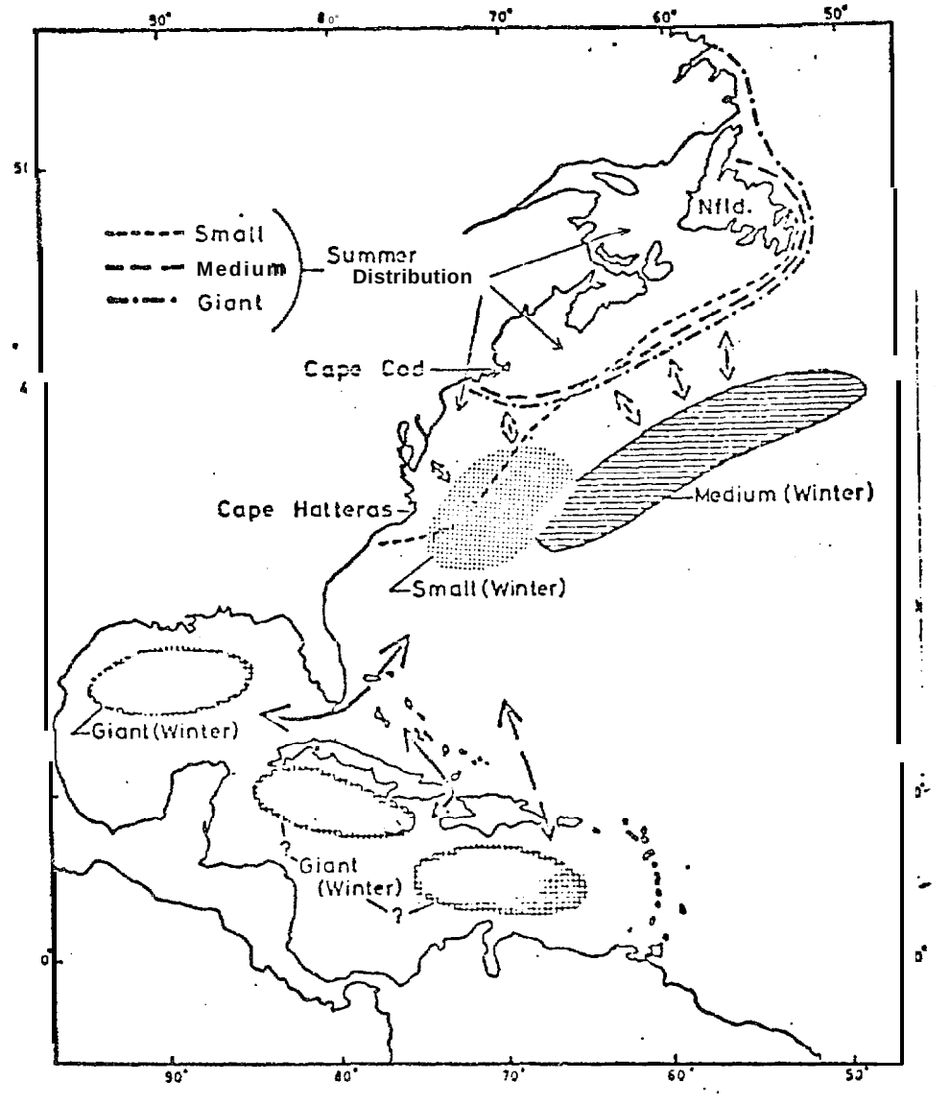
TRIGOM PARC

FIGURE 12-34 Estimated Growth Curve for Bluefin Tuna



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 12-35

Distribution and Migration Routes of Bluefin Tuna

bluefin in the North Atlantic.

(7) Population densities. Maximum densities of bluefin occur from off Cape Hatteras to Newfoundland from April and June through September and October in dense feeding schools. They leave the coastal areas with falling water temperatures.

(8) Food. The principal food supply of the tuna is smaller fish, especially the schooling kind, the particular species depending on the local supply. In the Gulf of Maine they destroy large numbers of herring, large and small; and mackerel. They also take silver hake, rosefish, and dogfish" as large as 3.6 kg. South of Cape Cod they prey on menhaden. They also eat squid and euphausiid shrimps Meganyctiphanes (Bigelow and Schroeder, 1953).

(9) Predation. Tuna have no serious enemies in the Gulf of Maine, but killer whales are a serious predator in Newfoundland waters, usually in September (Bigelow and Schroeder, 1953).

(70) Competition. No information gathered.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.21 Peprillus triacanthus

The butterfish is a small, pelagic fish traveling along the coast in the warm months in loose schools. They are very sensitive to small temperature changes and these largely govern their movements. They are found throughout the study area, although they are more abundant south of Cape Cod.

(1) Reproduction. Butterfish spawn within a few miles of the shore over most of their range. They appear to have a minimum spawning temperature of 15 C (Colton, 1972).

The spawning season, according to the appearance of eggs in plankton tows, extends from June through August in Narragansett Bay, Block Island Sound, and Long Island Sound. Bigelow and Schroeder (1953) give July as the spawning peak in the Gulf of Maine. Nichols and Breder (1972) indicate that the spawning peak occurs in July in southern New England waters. Most York River butterfish are mature by their second summer (Age 1). All Age II butterfish were mature (DuPaul) and McEachran, 1973).

There is no information on the spawning behavior of butterfish.

The near simultaneous spawning peaks from the Gulf of Maine to New Jersey would seem to discredit the role of temperature as a precise determinant of spawning season.

(2) Fecundity and larval life. The eggs and larvae of the butterfish are pelagic. Eggs are buoyant, 0.7 to 0.8 mm in diameter and contain a single oil globule. Incubation time is less than 48 hours at 18 C. Butterfish larvae are 1.68 to 1.75 mm long at hatching. At metamorphosis, postlarvae are 20 mm in length (Bigelow and Schroeder, 1953).

(3) Growth and longevity. Spring spawned butterfish reach from 50 to 100 mm by October of that year in Rhode Island waters (Bigelow and Schroeder, 1953). Age and growth data reported by DuPaul and McEachran (1973) for York River butterfish are included below:

Table 12-13
Observed and back-calculated fork lengths of butterfish in the lower York River in the Fall of 1969

Age Group	Number of Fish	Length extremes (mm)	Observed mean (mm)
0	2	91-95	93
I	56	98-139	119
11	53	142-187	169
III	10	174-200	185

(4) Natural mortal ity. No information gathered.

("5) Migration characteristics and distribution. The butterfish occurs and along the east coast of North America from Newfoundland to Florida. (6) They move inshore in the spring and offshore in the fall to wintering grounds at the edge of the continental shelf. The times of the first appearance of butterfish on their summering grounds varies from location to location. Nichols and Breder (1927) report the following dates:

Woods Hole - Late May to late fall
Orient, N. Y. - April 21 to December 1
New York - May to September

During its summer coastal sojourn the butterfish is particularly common over sandy bottom. A minimum survival temperature of 10 C is indicated (Colton, 1972).

(7) Population densities. Butterfish are gregarious and are commonly found in schools of from a few fish to several hundred. The maximum size of individual schools is unavailable; however, trap fishermen encounter large numbers of butterfish, especially small (I year old) fish. When they appear in otter trawls they are frequently very abundant. The extent of butterfish schools and/or feeding aggregations is no doubt variable. Butterfish are particularly abundant south of Nantucket Shoals from July through November.

(8) Food. The butterfish feeds on small fish, squid, crustacea such as amphipods and shrimp, and annelid worms. Ctenophores have been found in their stomachs but are not thought to be a regular diet item (Bigelow and Schroeder, 1953).

(9) Predation. No specific information gathered, although schools of small butterfish probably serve as forage for the larger predacious fishes.

(lo) Competition. No information gathered.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.22 Pomatomus saltatrix

The bluefish is a swift-swimming, pelagic and oceanic fish that is found in schools both inshore and offshore, primarily south of Cape Cod. The bluefish is a voracious predator on the pelagic schooling fishes (herrings) and is a popular sport fish.

(1) Reproduction. Bluefish spawn in the offshore waters from about 18 m to the edge of the continental shelf in waters warmer than about 15 c. The center of spawning activity may be in the southern part of their range. Water movements transport larvae spawned offshore into inshore nursery areas.

Bluefish spawning occurs in May and June. Although the exact age of maturity of male and female bluefish has not been determined, it is probable that they mature during their third to fifth year of life.

(2) Fecundity and larval life. Bluefish eggs and larvae are pelagic. Eggs are 0.90 to 1.20 mm in diameter and have one oil globule. Incubation takes 46 to 48 hours at 20 C. Bluefish larvae are about 2.0 to 2.2 mm long at hatching. Larvae probably metamorphose at about 20 mm.

(3) Growth and longevity. Bluefish are a fast growing fish. During their first summer they reach 115 to 135 mm by the end of August of the year they were spawned. One year old bluefish average 35 to 42 cm. Two year olds range from 38 to 50 cm in length (Backus, 1962). The largest bluefish recorded (Nichols and Breder, 1927) was a 114 cm and 12.2 kg adult.

(4) Natural mortality. No information gathered.

(5) Migration characteristics and distribution. Bluefish occur regularly and along the eastern Atlantic coast northward to Cape Cod. They undergo
(6) seasonal north-south migrations governed primarily by temperature and food availability. Tag returns (Lund and Maltezos, 1970) indicate that small bluefish move southward along the coast in the late fall, while adults over 45 cm have an inshore-offshore migration. Bluefish first arrive off southern New England when water temperatures reach 12 to 15 C (May) and depart in the fall when temperatures drop back to 13 to 15 c.

(7) Population densities. Bluefish, both the young (snapper blues) and adults, form tight feeding schools during the summer and fall in the waters of southern New England and Long Island. Bluefish schools in this region are composed of one to four year old fish. Bluefish are found in great numbers in the vicinity of concentrations of Atlantic menhaden (Brevoortia). Racial studies (Lund, 1961) indicate that the bluefish in the study area are part of a discrete stock, the most northerly of six groups along the Atlantic coast. This group ranges from New York to Massachusetts.

(8) Food. The young, 15 to 20 cm long, feed chiefly on copepods, crustacean and molluscan larvae, as well as on fish fry smaller than themselves. The adults are perhaps the most ferocious and bloodthirsty fish in the sea, leaving dead and mangled fish behind, in addition to the enormous quantities that they eat. They prey on schooling fish such as mackerel, menhaden, herring, alewives, and on non-schooling fish such as scup, squeteague, hake, butterfish, cunners, and small fish of all kinds; also, squid, various crustacea, and even marine worms (Bigelow and Schroeder, 1953).

(9) Predation. No information gathered.

(10) Competition. No information gathered.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.23 Morone saxatilis

The striped bass is a large, anadromous, migrating fish of coastal waters. Its principal breeding grounds are in Chesapeake Bay, but summer feeding migrations bring substantial numbers in to the study area. It is an important sport fish in these waters.

(1) Reproduction. Striped bass are anadromous, spawning in brackish waters to fresh waters of various rivers. The Hudson River is the only striped bass spawning site of importance in the study area. Here, most spawning activity occurs between Peekskill and Newburg, N. Y. (Clark, 1962). This spawning contributes to the essentially non-migratory stock of bass in Long Island Sound and the New York Bight.

Striped bass ascend the rivers to spawning sites from March to July, depending on latitude, with the majority of spawning taking place between 14.5 C and 21 C, with optimum temperatures 15.5 to 18.5 C (Saila and Pratt, 1973). All males are sexually mature by their third year and all females are mature by their sixth year (Raney, 1952; Merriman, 1950).

(2) Fecundity and larval life. The fecundity of a large bass is estimated at 80,000 to 2,200,000 eggs (Lewis and Bonner, 1966). The eggs are semi-buoyant and require a slightly turbulent current to keep them afloat. The larvae are 3mm at hatching and metamorphosis occurs at about 20mm two to four weeks after hatching. Bass juveniles remain in the estuaries of the rivers in which they were spawned until nearly 2 years old.

(3) Growth and longevity. Striped bass reach 12 cm at the end of their first year. At age 2 they average approximately 23 cm. Thereafter: 3 years - 37 cm, 4years - 45 cm, 5years - 54 cm, 6 years - 61 cm, 7 years - 68 cm, 8 years - 75 cm, 9 years - 83 cm (Bigelow and Schroeder, 1953; Merriman, 1950).

(4) Natural mortality. Merriman (1950) estimated a natural mortality rate of 33 percent per year for fish aged 2 to 5 years of the 1934 year class.

(5) Migration characteristics. The striped bass population in the study area are migratory. Bass move up the coast in the spring when the water temperature approximates 8 C and return in the fall when the temperatures again reach 8 C. They are tolerant of a wide range in environmental conditions and some have been known to winter over in New England waters. In addition to the main migratory population, there are several separate non-migratory

stocks, one in the Long Island Sound - New York Bight area and another originating in Canadian waters (Bay of Fundy to the Gulf of St. Lawrence) which may contribute to the bass populations found along the eastern Maine coast.

Most of the migratory bass are females. The population that enters the Gulf of Maine are 95 to 98 percent females.

(6) Distribution and niche preference. The striped bass spends its entire life along the immediate coast. In the study area they prefer surf-swept beaches, rocky shorelines or shallow bays and estuaries. They are, therefore, affected by changes in coastal conditions. Original spawning areas, particularly in southern New England, have been lost in the past due to obstructions to migrating populations. The study area now depends entirely on spawning stocks from the Chesapeake Bay area.

(7) Population densities. Striped bass begin to exhibit schooling behavior as fry and later may occur in dense schools. The adults form size specific schools. The schools of bass on their summer feeding migration in New England waters are made up primarily of females over two years of age.

(8) Food. Striped bass are voracious feeders, eating principally fishes and invertebrates, both planktonic and benthic. The following is a partial list of food items found in the stomachs of bass caught in the Gulf of Maine (Bigelow and Schroeder, 1953):

Herring	Squid
Smelt	Crab
Sand launce	Lobster
Eels	Sea worms (Nereis)
Silver hake	

(9) Predators. Little information gathered. Man is probably the most serious predator and seals are known to eat bass that are not too large.

(10) Competitors. No information gathered.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.24 Stenotomus chrysops

The scup, or porgy, is a relatively small, schooling fish of the porgy

family that is found principally in coastal waters south of Cape Cod. It is usually found close to the bottom and is an important sport and commercial fish.

(1) Reproduction. Scup spawn in estuaries, bays and inshore waters, primarily below Cape Cod. Eggs and larvae have been observed in Narragansett Bay, Long Island Sound, Peconic Bay and Gardiner's Bay. They mature by or during their third year. In Southern New England scup spawn from May through August, but predominately during May to mid-July. No observations of spawning behavior have been reported. Scup probably do not spawn until water temperature reaches 18 to 20 c.

(2) Fecundity and larval life. The eggs and larvae of the scup are pelagic. The eggs are 0.89 to 0.99 mm in diameter, transparent, and contain one oil globule. At an incubation temperature of 22 C, eggs take 40 hours to hatch. At hatching, larvae are about 2.0 mm and grow to 25 mm before metamorphosis, which probably occurs within two to four weeks after hatching.

(3) Growth and longevity. Juveniles reach at least 100 mm F.L. (29 g) by first year. Two year old scup are an average of 160-170 mm (and 98 g), with an increase to 200-210 mm (194 g) at three when maturity is attained. Von Bertalanffy equations of growth have been calculated based on Long Island fishery for both sexes (Finkelstein, 1969). The resulting equations are:

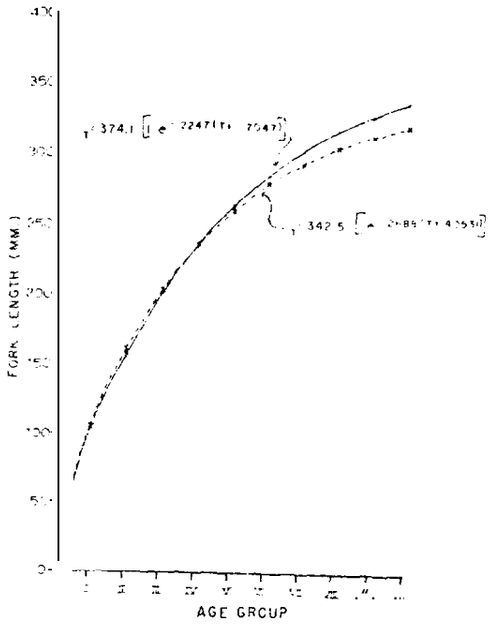
For Males $'t = 342.5\ (1\text{-}e^{-0.2688(t_n + 0.405)})$

For Females $'_t = 374.1\ (1\text{-}e^{-0.2247(t_n + 0.4704)})$

(4) Natural mortality. Annual natural mortality of young adults, based on tagging studies, is estimated at 80 percent. A total annual mortality rate (natural + exploitation) of 95 percent is estimated (Finkelstein, 1971).

(5) and (6) Migration characteristics and distribution. Scup range from Cape Ann to South Carolina and are most commonly found from Cape Cod to Cape Hatteras. Scup are a schooling species, migrating offshore in the fall to 82 to 137 m where they winter. In the spring they return to the area from shore to 37 m. They have a preference of from smooth to rocky bottoms which greatly affects their distribution.

(7) Population densities. The large numbers of scup found in schools in the waters of New England and Long Island are predominately 1 to 3year olds, since the older fish are heavily exploited by the sport and commercial fisheries.



Growth rates of male scup (broken line) and female scup (solid line)

" (8) Food. Young scup feed chiefly on copepods and other small crustacea. Adults are bottom feeders and prey on crustaceans (particularly on amphipods), annelid worms, hydroids, sand-dollars, young squid, and whatever invertebrates are available over the particular bottom over which they Jive. They also eat fish fry, free-floating crustacean and molluscan larvae, appendicularians and copepods (Bigelow and Schroeder, 1953).

(9) Predation. No information gathered. .

(10) Competition. No information gathered.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.25 Sebastes marinus

The redfish is the only prominent member in the study area of the large scorpionfish family. A non-schooling, slow-growing, bottom-dwelling fish, it prefers the deeper colder waters of the Gulf of Maine. It is important commercially, although vulnerable to heavy fishing.

(1) Reproduction. The eggs of the redfish develop and hatch within the oviduct of the mother. In the Gulf of Maine, temperatures of 3 to 4 C are the lowest in which 'redfish are born in any numbers, with 8 to 9 C being the maximum. Production of the young is well under way by late June or early July. Some young may be born as early as late April or early May, and as late as the first week in September.

The redfish matures sexually at 23 to 25 cm in length (about eight years old). Males mature when a bit smaller than the females.

Males mature in the autumn and copulation takes place in areas of summer-autumn feeding. The spermatozoa remain inactive in the ovaries until the eggs ripen (Travin, 1961).

(2) Fecundity and larval life. The number of young produced by large females may run as high as 25,000 to 40,000 yearly. The larvae are about 6 mm long at birth, and are pelagic, drifting in the upper and intermediate water layers until they are about 25 to 30 mm long. After that, they usually live close to the bottom, or are pelagic over deep basins. Fry, living pelagically, have been taken as deep as 494 m in north European waters.

(3) Growth and longevity. The redfish is a slow-growing, long-lived fish. They average about 50 mm in length when one year old. Age

group I averaged 69.7 mm; II, 93.3; III, 112.1; IV, 135.4; V, 160.5; VI, 185.9; VII, 213.0; VIII, 240.3; IX, 254.8; X, 269.8 (Kelly and Wolf, 1959). At age XX, they were 367.5 mm and at XX+ they averaged 351.3 mm. Some of the large fish landed from southeastern Georges Bank may have been in excess of 50 years old. The male grows more slowly than the female after the tenth year.

(4) Natural mortality. Under the slow growth hypothesis, there is a low mortality and Z=0.5 or less, while the fast growth hypothesis gives Z=1.0. With extreme slow growth, K=0.1, M=0.1, t_c=6; fast growth gives a K=0.6, M=0.4, t_c=1 (Gulland, 1961).

(5) Migration characteristics and distribution. The redfish inhabits and both sides of the North Atlantic. Their range extends from Ice-
(6) land, West Greenland, southeastern Labrador, "Newfoundland and ' Gulf of St. Lawrence, southward to the offing of southern New England and as far as the offing of New Jersey in deep water. It lives on the offshore banks, in or over the deep central basin, and along shore, and is plentiful everywhere.

The redfish is primarily a bottom dweller on the slopes of the continental shelf and prefers rocky or hard grounds or mud, seldom sand. They range from living within a few feet of the tide line to at least 641 m, and some live pelagically at intermediate depths over the deep ocean. Most of the commercial catch is taken at 73 to 320 m. Their maximum temperature tolerance is 9 to 10 C, with their minimum tolerance .5 to 1.6 C, or perhaps lower.

Local concentrations may be brought about by light, food, spawning cycles, temperature, type of bottom, etc.

(7) Population densities. The redfish was once an extremely abundant species, but the catch per unit of effort has quickly decreased in each newly fished area.

(8) Food. The redfish eats a great variety of crustaceans, especially mysid, eupahusiid, and decapod shrimps; small mollusks; various other invertebrates, and small fish (Bigelow and Schroeder, 1953).

Lambert (1960) lists the following species and their relative abundance in the diet of the redfish: Abundant - Meganyctiphanes norvegica, Thysanoessa inermis, Thysanoessa raschii (all Euphausiacea; Themisto libellula, Themisto gaudichaudi (Amphipoda); Calanus finmarchicus, Calanus hyperboreus (Copepoda). Common - Paralepis coregonoides boborealis, Cyclopterus lumpus, Benthosema laciale (Fish); Sagitta maxima. Rare - Paraeuchaeta nerve ica Copepoda); Notoscopelus elongates (Fish); Pandalus borealis Shrimps); and Gonatus fabricii.

(9) Predation. The redfish is the prey of all the larger predacious fish and its fry are eaten in quantity by cod, older redfish and

by halibut.

(10) Competition. No information gathered.

(11) Responses to the environment (natural factors, pollutants). No Information gathered.

12.6 26 Myoxocephalus octodecimspinosus

The longhorn sculpin, a demersal scavenger, is the most plentiful and most widely distributed of the sculpins. Because of its abundance and bottom habit, it is an important part of the benthic food web. However, it is only of limited commercial importance.

(1) Reproduction. Off southern New England, the longhorn sculpin spawns from late November to the end of January, with larger fish spawning later than the smaller ones. Peak spawning activity takes place in late December and early January. It spawns on clean, hard bottom substrates and lays its eggs in cavities in sponges, shells, etc. The eggs are strongly adhesive and stick firmly to each other and anything else they touch. Sexual maturity is reached in the third year (Morrow, 1951").

(2) Fecundity and larval life. Each female lays about 8,000 eggs per year. The eggs hatch in not longer than three months, probably less. The larvae are pelagic for a month or so, then become demersal.

(3) Growth and longevity. The average length of the longhorn sculpin is 5.6 cm at one year; 18.2 cm at 2; 24.3 at 3; 26.3 at 4; 27.4 at 5; 28.6 at 6; 29.2 at 7; 29.8 at8; and 30.2 at9. Most of the commercial catch is two to five years old. Fish were aged to 11+ (Morrow, 1951).

(4), Natural mortality. The natural mortality rate is about 0.06 (Morrow, 1951).

(5) and (6) Migration characteristics and distribution. The longhorn sculpin is abundant in shoal harbors and bays, and runs up into estuaries and salt creeks. It is caught in considerable numbers down to 91 m and has been taken as deep at 192 m. It can live in temperatures as high as 19 C. When the water temperature goes higher than this, they go to deeper and cooler water for the summer, and inshore again in the autumn (Bigelow and Schroeder, 1953). Morrow (1951) does not believe that temperature is the controlling factor in this offshore-onshore migration, but thinks it may be a contributing factor. He believes the seasonal movements may be caused by a cycle

of endocrine activity. Its minimum temperature range is 0 to 1.6 C.

The longhorn is found in coastal waters from eastern Newfoundland and the northern Gulf of St. Lawrence to New Jersey.

There are no coast-wise migrations.

(7) Population densities. The longhorn sculpin is neither evenly distributed over the bottom nor schooled into compact groups. It is in loose aggregations which vary from one locality to the next. However, an estimate of 36 kg of sculpins per acre was made by Morrow for one sample (Morrow, 1951).

(8) Food. The longhorn sculpin is an omnivorous carnivore. The dominant food items are the decapod, Cancer irroratus, and the amphipod, Procnerius pinguis. Other items taken are the shrimp, Crago septemspinosus (taken in small amounts); the spider crab, Libinia emarginata (a major item in the fall and winter); small lobsters; annelids; isopods, mysids and cumaceans (eaten rarely). Crustacea formed the majority of the diet in every-sample, with decapods and amphipods dominating. Fish were taken in the winter and spring, and were a fairly large percent of the total (Morrow, 1951) Fish fry eaten include alewives, cunners, eels, mummichogs, herring, mackerel, menhaden, puffers, launce, scup, silversides, smelts, tomcod, silver hake, and sculpins (Bigelow and Schroeder, 1953).

(9) Predation. The ocean pout feeds on longhorn sculpin eggs. The longhorn has been known to eat its own young and eggs.

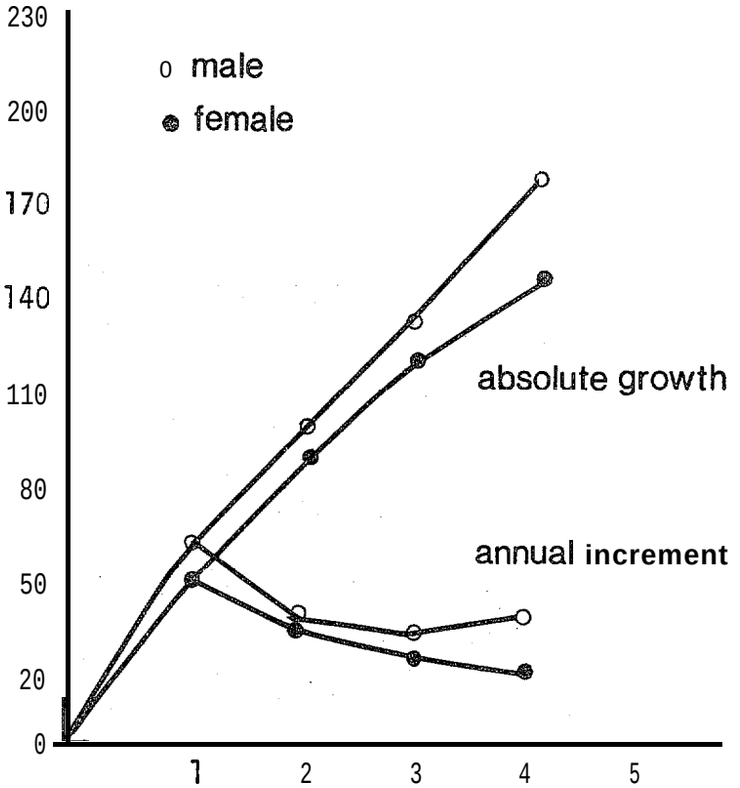
(10) Competition. The abundance of winter flounders, Pseudopleuronectes americanus, and sculpins decreased as the little skate, Raja erinacea, increased. (Merriman and Warfel, 1948)

(11) Responses to the environment (natural factors, pollutants). No information gathered.

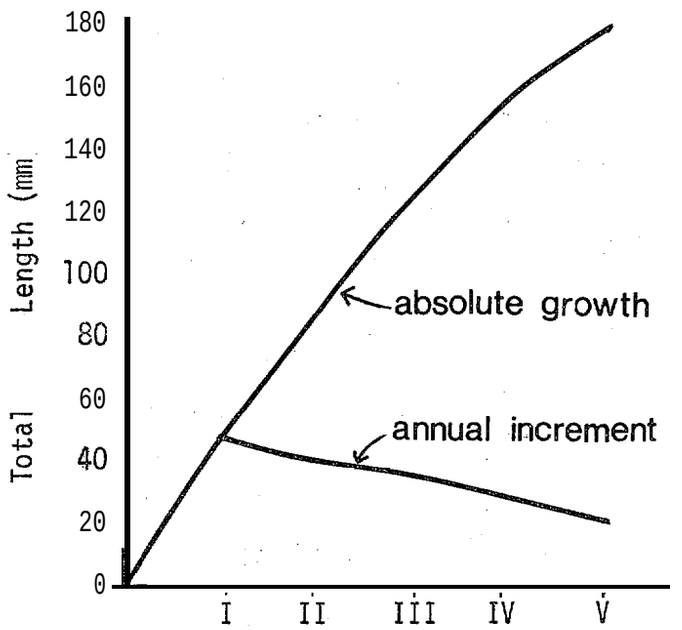
12.6 .27 Tautogolabrus adspersus

The cunner is a non-schooling fish of rocky bottoms throughout the coasts and shallow banks of the study area. They are of no commercial importance, but, because of their abundance are important components of the benthic community.

(1) Reproduction. No distinct spawning migrations are known to occur. Cunner may be expected to spawn along rocky shores throughout its range.



Fisher's Island Sound



Weweantic River

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION		
TRIGOM PARC	FIGURE 12-11	Growth and Longevity of Cunner (Serchuk, 1972 & Dew, 1970)

The peak spawning season south of Cape Cod is in the first two weeks of June. Egg occurrence has been reported from Flay through September in Narragansett Bay, and May through October in Block Island and Long Island Sound. Larvae are abundant in plankton collections from Narragansett Bay and Long Island Sound from June through August. Fishers Island Sound cunner are mature in their first year at a size of 7 to 9 cm (Dew, 1970). There is evidence that cunner from North of Cape Cod are not mature until their second year.

The spawning behavior of the cunner has been described by Wicklund (1970). Spawning described below occurred in the afternoon:

> "Prespawning behavior took place within small aggregations of 3 to 15 cunners which became more active than usual, milling and darting about. Chasing next ensued, one fish pursued by several others, moving in small circular paths in and out of rock crevices and over rises on the bottom. The spawning act took from two to three seconds. In each instance, a group of fish made a quick turn upward, to converge at a point one to two meters off the bottom where the fish either contacted or merely touched each other. Then they immediately swam down and glided in a curved path toward the bottom, away from a white cloud, presumably milt and eggs which they had discharged at the apex of the upward movement."

The timing of the beginning of spawning is probably closely controlled by temperature. Nowhere in its range does the cunner spawn at a temperature below approximately 7 C. The usual spawning temperature is 10 to 11 C. The occurrence of eggs late in August in Long Island Sound indicates that spawning may occur in water as warm as 25 C.

(2) Fecundity and larval life. No specific information on fecundity. The cunner is a high fecundity species. Eggs spawned per gravid female probably number in the tens of thousands, based on observation on the tautog, a related species.

The cunner has planktonic eggs and larvae. The eggs, which are spherical and transparent, measure 0.75 to 1.00 mm in diameter and contain no oil globule. Egg diameters may change during course of spawning season (Williams, 1967). The incubation time for eggs is approximately 2.0 to 2.2 mm in length at hatching. Metamorphosis occurs at the time larvae are 15 mm in length, or approximately 3 to 4 weeks after hatching.

(3) Growth and longevity. Serchuk (1972) has used the Von Bertalanffy growth equation to describe the growth in length of Weweantic River cunner: $L_t = 284.77\ (1-e^{-0.1979\ (t-0.1044)})$

Males grow faster than females at all ages in Fisher's Island Sound (Dew, 1970).

(4) Natural mortality. No information gathered.

(5) and (6) Migration characteristics and distribution. The cunner occurs along rocky shores from Newfoundland to the mouth of Chesapeake Bay. It is most abundant in Massachusetts Bay and in water between Cape Cod and Long Island. Cunner, especially larger individuals, are common on Georges Bank and other offshore rises. The cunner is a year-round resident wherever it occurs and its apparent winter disappearance is associated with a winter lethargy or hibernation during which time cunner retire to rocky crevices or muddy areas during the cold months when the water temperature falls below 5 C (Green and FarWell, 1971).

(7) Population densities. The cunner is a non-schooling species. Although no measurements are available, cunner occur in abundance along rocky shores and offshore banks within their range.

(8) Food. Cunner fry feed chiefly on minute crustacea such as copepods, amphipods, and isopods. Adult cunners are omnivorous and feed on barnacles, small blue mussels, amphipods, shrimps, young lobsters, small crabs, other small crustacea of all kinds; also, univalve mollusks and the smaller bivalves, hydroids, annelid worms. Sometimes they eat small sea urchins, bryozoans, and ascidians. They occasionally eat small fish such as silversides, sticklebacks, pipefish, mummichogs, and the fry of larger species. They also eat eel grass, animal refuse, fish eggs, and no doubt feed on herring spawn (Bigelow and Schroeder, 1953).

(9) Predation. No information gathered.

(lo) Competition. No information gathered.

(11) . Responses to the environment (natural factors, pollutants). No information gathered.

12.6.28 Tautoga onitis

The tautog is a fairly large, solitary fish that is distributed close to the coast; primarily south of Cape Cod. It is demersal in habit and prefers rocky ledges and outcrops, and is a popular sport fish south of the Cape.

(1) Reproduction. Tautog probably spawn throughout much of their range, although spawning within the Gulf of Maine is unusual. The occurrence and/or location of discrete spawning grounds as occur in Narragansett Bay have not been documented from other areas. Spawning may be presumed to occur in areas where mature adults are most abundant, i.e., along rocky shores and bottoms and over nearshore ledges and banks.

In upper Narragansett Bay, the peak in spawning activity occurred between mid-May and mid-June, with a peak during the first week in June in 1961 and 1962. Based on the occurrence of eggs in plankton collections, spawning occurs in Woods Hole primarily in the month of June with some eggs being found as late as July 18. In Narragansett Bay and Long Island Sound, eggs have been taken from May through August. In Sandy Hook Bay, eggs appear between May and July. In no case are larvae reported later than July, indicating that peak spawning is probably of no more than a few weeks duration. Observations in Narragansett Bay indicate that for this population the occurrence of the spawning peak is coincident with a water temperature of between 13 and 14 C. Among fish taken on the spawning grounds in Narragansett Bay, 55 percent of Age II+ males were mature and 90 percent of Age III+ were mature. Among females, no Age II fish were mature, while 80 percent of Age III and 100 percent of Age IV+ fish contained mature ova (Chenoweth, 1963).

In Narragansett Bay, ripe males precede females to the area of the spawning aggregations by several weeks. As the spawning season proceeded, the number of females increased until females outnumbered males. Sex ratio of males to females of 47:53, 46:54 and 43:57 percent were noted at three stations. In each case the predominance of females was statistically significant.

(2) Fecundity and larval life. The fecundity of the tautog may be related to the weight of the gravid female by the following equation (Chenoweth, 1963):

$$Y = 0.31492 + 1.07993\ x$$

Where Y equals fecundity in thousands of eggs and X equals the weight of the female in grams. A 1000 gm female may be expected to produce approximately 90,000 eggs.

Tautog eggs and larvae are pelagic. The eggs are buoyant, transparent, and from 0.84 to 1.0 mm in diameter. The eggs contain no oil globule and closely resemble those of the cunner Tautogolabrus adspersus (Walbaum). At 22 C the time to hatching is approximately 46 hours. Metamorphosis to adult form is complete by the time the fish has reached 30 mm. Although there is no information

available on the time from hatching to metamorphosis, it is probable that metamorphosis is complete from 2 to 4 weeks after hatching in Rhode Island waters.

(3) Growth and longevity. The tautog is a long-lived, slow-growing fish. During the first year of life they grow to a length of from 17 to 200 mm. Thereafter, growth occurs as below (Cooper, 1963):

Age	Length mm (Males)
4	280
8	400
12	480
16	520
20	560
24	595

Older male tautog are slightly larger than females and attain a maximum age of about 30 years.

(4) Natural Mortality. The annual natural mortality rate among Narragansett Bay tautog in 1961 was 18.06 percent. Among fish 275 mm (4 years old) or larger. To this was added a fishing mortality of 14.00 percent to yield a total annual mortality rate of 29.53 percent (Cooper, 1963). As in the case of all high fecundity fish, larval and juvenile mortality rates might be expected to be high. However, no estimates were found on the mortality rates among young tautog.

(5) and (6) Migration characteristics and distribution. The tautog occurs along the east coast of North America from the eastern shore of Nova Scotia to South Carolina. Its center of distribution lies between Cape Cod and the Delaware Capes. Its offshore range seldom exceeds 6.4 to 8 km. It does, however, occur on George Bank, Charles Bank and Seventeen Fathom Bank off New Jersey. Although not a truly migratory species, its movement to and from spawning aggregation in Narragansett Bay indicates that individuals do make some longshore non-spawning journeys.

(7) Population densities. Tautog are a non-schooling species. Juveniles are abundant along rocky shores, eel grass beds, over mussel beds, and among wharf pilings. Juvenile and young tautog appear to stay well inshore. Older tautog are found in deeper water along rocky shores, rocky bottom areas, near wrecks and on offlying banks. Adults seldom occur in concentrations of more than 5 or 10, and then only when associated with a particularly desirable cave or crevice. Tautog spawning in Narragansett Bay form two spawning aggregations near the head of the Bay. The numbers of fish on these aggregations has not. been documented. However, tagging studies. indicate that fish return to the same spawning area year after year. Such spawning aggregations probably occur elsewhere as well among other populations.

(8) Food . Tautog feed on invertebrates, chiefly on mollusks (both univalve and bivalve) and especially on mussels and barnacles. They also feed on crabs and hermit crabs, sand dollars, scallops, amphipods, shrimps, isopods, and lobsters. They may also prey to a considerable extent on sea worms (Nereis) (Bigelow and Schroeder, 1953).

(9) Predation. No information gathered.

(lo) Competition. No information gathered.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.6.29 Ammodytes sp.

The sand launce is a small, schooling fish whose habitat is sandy areas from the littoral zone to the edge of the continental shelf. Of no commercial importance, except as bait fish, they are important in the marine food chain as "forage" for larger fishes. The genus Ammodytes consist of two morphological types provisionally separated into two species, one found inshore, A. hexapterus, and one found offshore, A. dubius (Richards, et. al., 1963b).

(1) Reproduction. Detailed spawning information is not available. What is known is based on larval distribution. There appear to be two groups spawning under different environmental conditions. Spawning probably occurs between December and April along the New England coast to Long Island, and late spring and summer farther north. Sand lance spawn on sandy bottom in shallow water (less than 27 m).

(2) Fecundity and larval life. The fecundity is estimated at 250 to 1400 eggs per fish. The eggs are demersal and the larvae hatch at about 2 months.

On the Scotian shelf A. dubius larvae are found from February to April and grow to 25 mm in about a month. The growth rate of larvae decreases to the north (Scott, 1972).

(3) Growth and longevity. In general, adult sand launce range from 10 to 23 cm in size and A. dubius reaches a maximum age of about 9 years in the Scotian shelf waters (Scott, 1972). Scott gives the following empirical growth for A. dubius:

Age (months)	Length (cm)
6	7
12	13
24	18
36	23
48	26
72	29

(4) Natural mortality. Estimate of instantaneous, or total (Z), mortality has been given at 1.24.

(5) and (6) Migration characteristics and distribution. Usually found in abundance around sandy beaches and offshore banks. Moves into deeper water during mid-summer.

In addition to migrations into, deeper waters during the mid-summer, Ammodytes exhibits diurnal vertical feeding migrations.

(7) Population densities. Ammodytes sp. are found in the Gulf of Maine in densities of 45 to 50 larvae per 10 to 15 minute tow at surface with a meter net. Juveniles and adults are found in schools of thousands.

(8) Food. In Scandinavian waters, sand eels feed on all sorts of small marine animals, chiefly on small crustacea, especially on copepods, and on fish fry, including their own kind. Worms have also been found commonly in their stomachs (Bigelow and Schroeder, 1953).

(9) Predation. Predators include: silver hake, striped bass, mackerel, pollock, porpoise, finback whale, cod, haddock, bluefish, halibut, salmon. The sand eel plays a very important role in the economy of northern seas as food for larger animals and predacious fish (Bigelow and Schroeder, 1953).

(10) Competition. No information gathered.

(11) Responses to the environment (natural factors, pollutants): No information gathered.

12.6.30 Macrozoarces americanus

The ocean pout is a very soft, slimy eel-like fish of demersal habit. There is probably a slower growing race in the Bay of Fundy and northward, and a larger fast growing race from Cape Cod southward. The ocean pout

was becoming a popular food fish in 1943, but the market was spoiled by parasite sores in the flesh, caused by a protozoan.

(1) Reproduction. The ocean pout breeds successfully from the southern side of the Gulf of St. Lawrence to New Jersey. Spawning occurs in September and October and the eggs are laid in gelatinous masses that are guarded by one or both parents until hatching, with the fish coiled around the egg mass. The fish congregate over rocky bottom, and the eggs are laid in crevices and among stones.

Most males mature in their fourth year, some in their third, and some not until their fifth year or later. Females mature in their fifth and sixth year, with all mature by their eighth and ninth (Olsen and Merriman, 1946).

(2) Fecundity and larval life. Egg counts range from 1,306 in a 55 cm female to 4,161 in an 87.5 cm fish. Incubation takes 3 1/2 months in the north and 2 1/2 months in the south. The larvae are 30 mm long at hatching and hold to the bottom immediately.

(3) Growth and longevity. The ocean pout is 3 cm long at hatching. It attains 5 to 8 cm at six months; 11.5 to 15 cm at one year; 16 to 20 at 18 months; 31 at three years; 48 at five; 81 at 10; and 97 cm at age 15. These data were for southern New England. Fish to the north grow considerably slower and do not attain as great a size (Olsen and Merriman, 1946). In a typical commercial catch, four to ten year old fish predominate. Fish have been aged up to 16 or 18 years old.

(4) Natural mortality. No information gathered.

(5) and (6) Migration characteristics and distribution. The ocean pout is distributed from the Gulf of St. Lawrence south to Delaware and is common from the southern Gulf of St. Lawrence and northern Nova Scotia to New Jersey. It is common in water of moderate depth both near shore and on the offshore banks.

(7) Population densities. An abundant species, over 5,000,000 pounds a year were landed from southern New England waters in 1943 and 1944 when a market existed for this fish.

(8) Food. The ocean pout feeds primarily on the sea-urchin Strongylocentrotus drobrachiensis; the whelk, Buccinum undatum; the barnacle, Balanus balanoides; the black mussel, Mytilus edulis and tunicates; and mussels of the genus Modiolaria.

It feeds on a wide variety of shelled mollusks, univalve and bivalve, on crustaceans, both large and small, and on echinoderms

and other invertebrates. Among their diet items are periwinkles (Littorina), scallops (Pecten), brittle stars, spider crabs, small sea scallops (Pecten magellanicus), sand dollars (Echinarachnius), crabs (Cancer), isopod crustaceans (Unicola), and eggs of the longhorn sculpin (Bigelow and Schroeder, 1953)

Olsen and Merriman (1946) listed the most common diet item as the Gammaridae, with the sand dollar (Echinarachnius parma), the crab (Cancer irroratus) and Unicola as close seconds.

(9) Predation. No information gathered.

(10) Competition. No in-Formation gathered.

(11) Responses to the environment (natural factors, pollutants). No information gathered.

12.7 DISTRIBUTION CHARTS

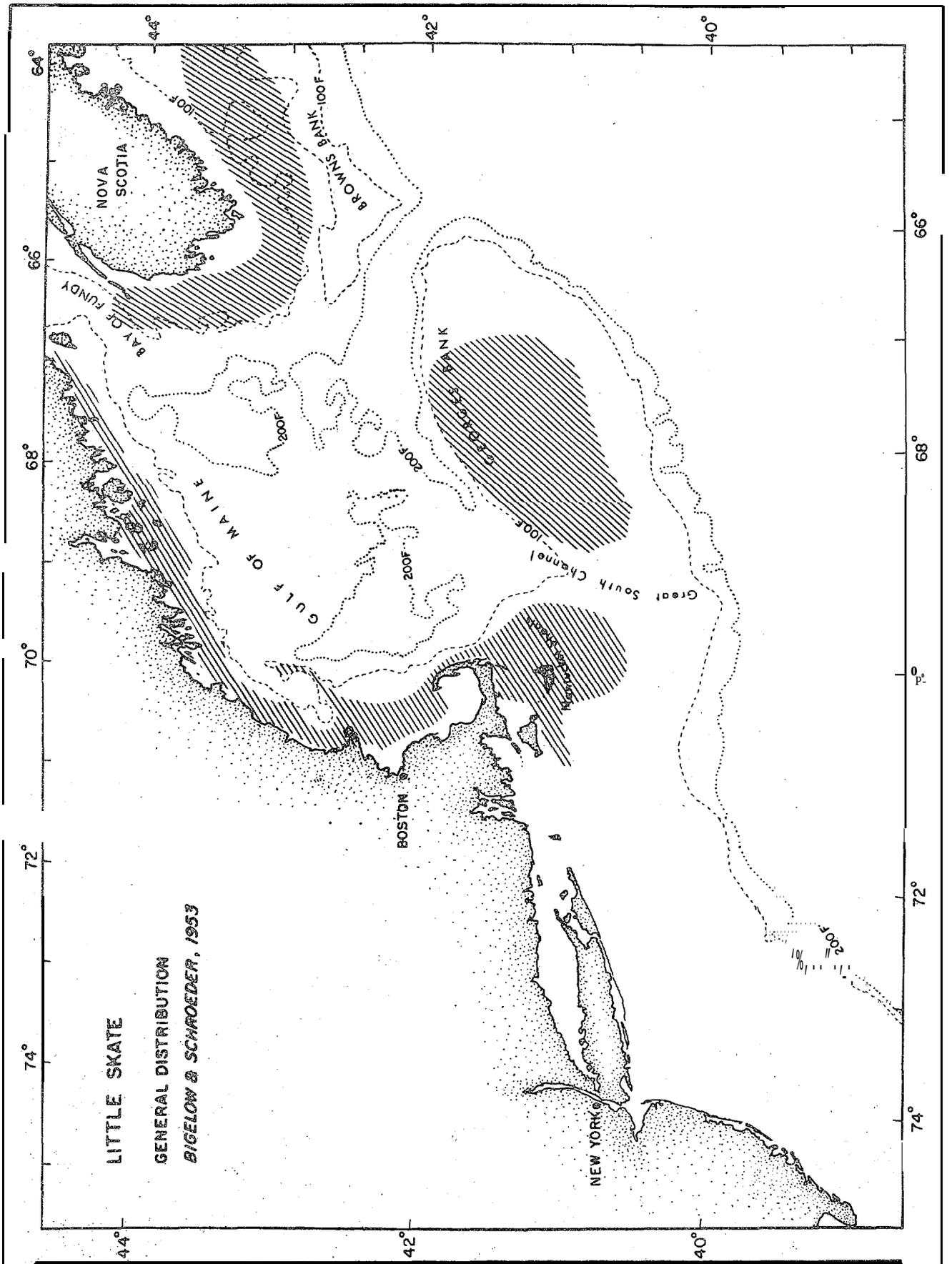
The following are charts showing the distribution of some of the more important species of fish. The charts may be from a single source or composite from several sources, and in some cases only apply to certain times of the year. The charts should only be considered as a general indication of the geographic occurrence of each species.

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 12-12

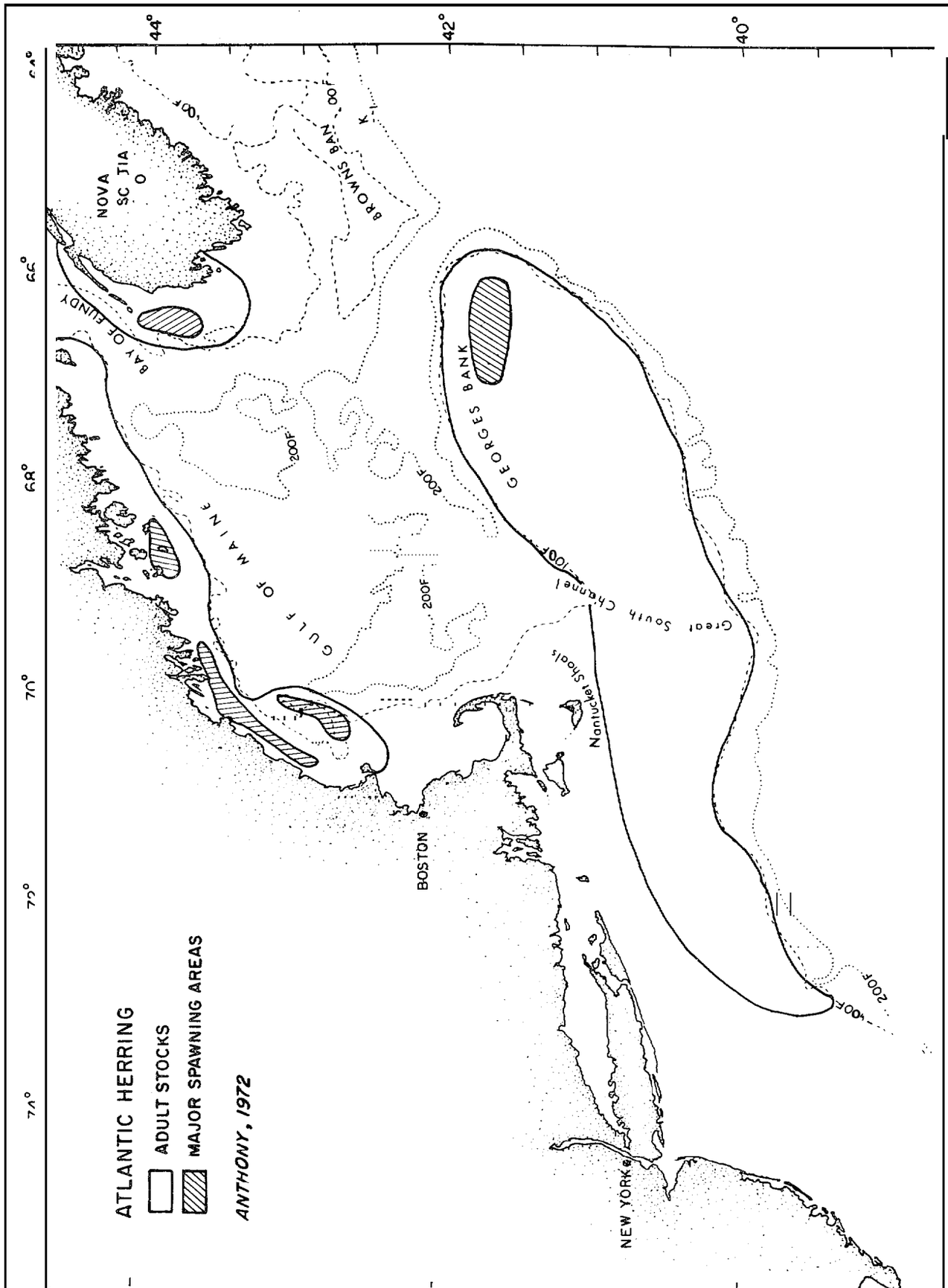
Distribution Charts, Spiny Dogfish (Fritz, 1965)



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE .12-13 Distribution Charts Little Skate (Bigelow & Schroeder, 1953)



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TRIGOM PARC

FIGURE 12-14

Distribution Charts
Atlantic Herring (Anthony, 1972)

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

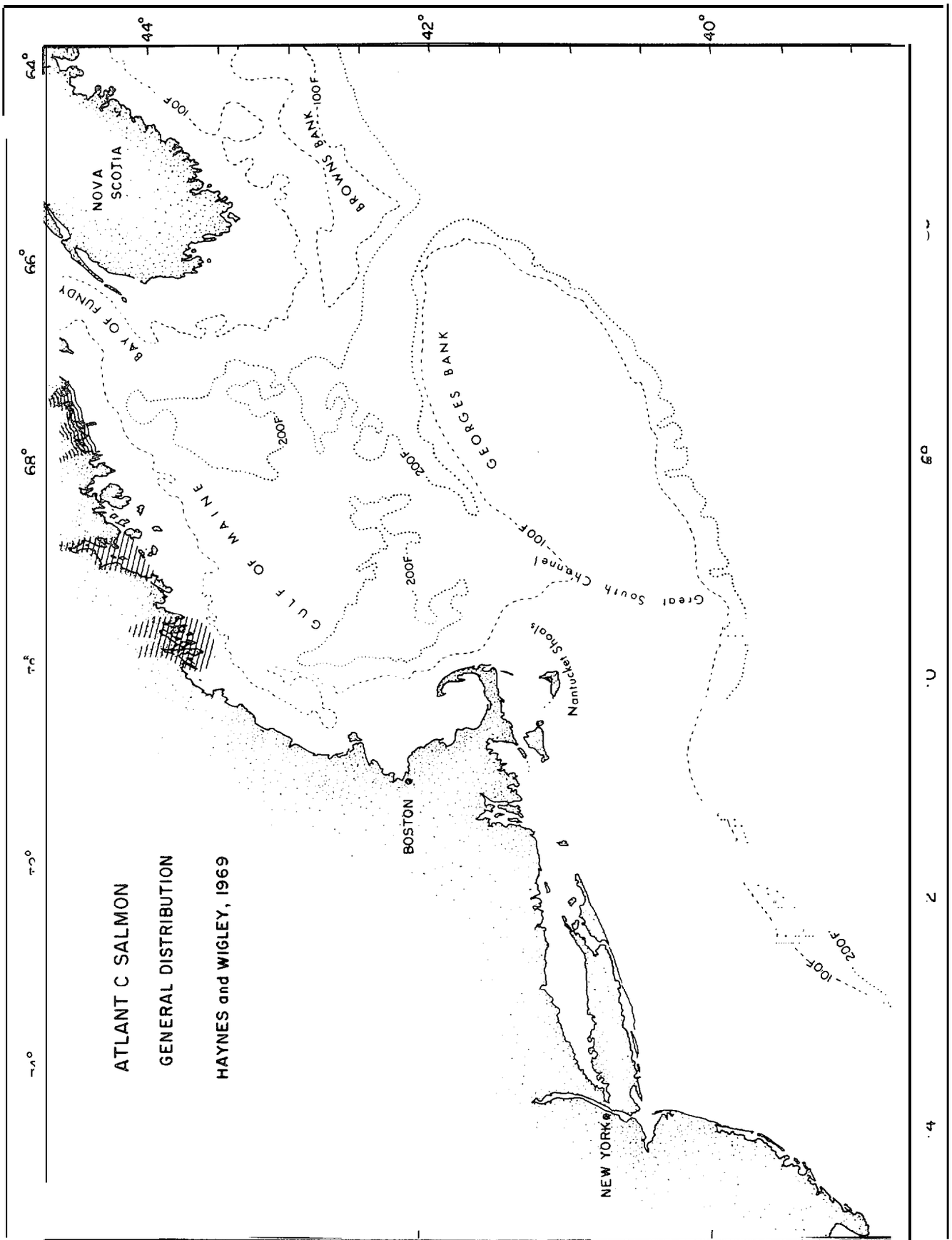
TRIGOM PARC | FIGURE 12-15 | Distribution Charts Blueback Herring (Bigelow & Schroeder, 1953,

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC | FIGURE 12-16 | Distribution Charts
Alewife (Bigelow & Schroeder, 1953)

A SOCIO-ECONOMIC AND Environmental inventory OF THE NORTH ATLANTIC REGION

RIGOM PARC | FIGURE 12-17 | Distribution Charts Menhaden



A SOCIO-ECONOMIC AND ENVIRONMENTAL 1NVENT0R% OF THE NORTH ATLANTIC REGION

TRIGOM PARC | FIGURE 12-18 | Atlantic Salmon Spawning Distribution (Haynes & Wigley, 1969)

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TRIGOM PARC	FIGURE 12-19	Spawning Distribution Shad & Smelt (Bigelow & Schroeder, 1953)

TRIGOM PARC | FIGURE 12-20 | Spawning Distribution Silver Hake (Fritz, 1965)

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 12-21

Spawning Distribution
Atlantic Cod (Bigelow & Schroeder, 1953)

TRIGOM PARC

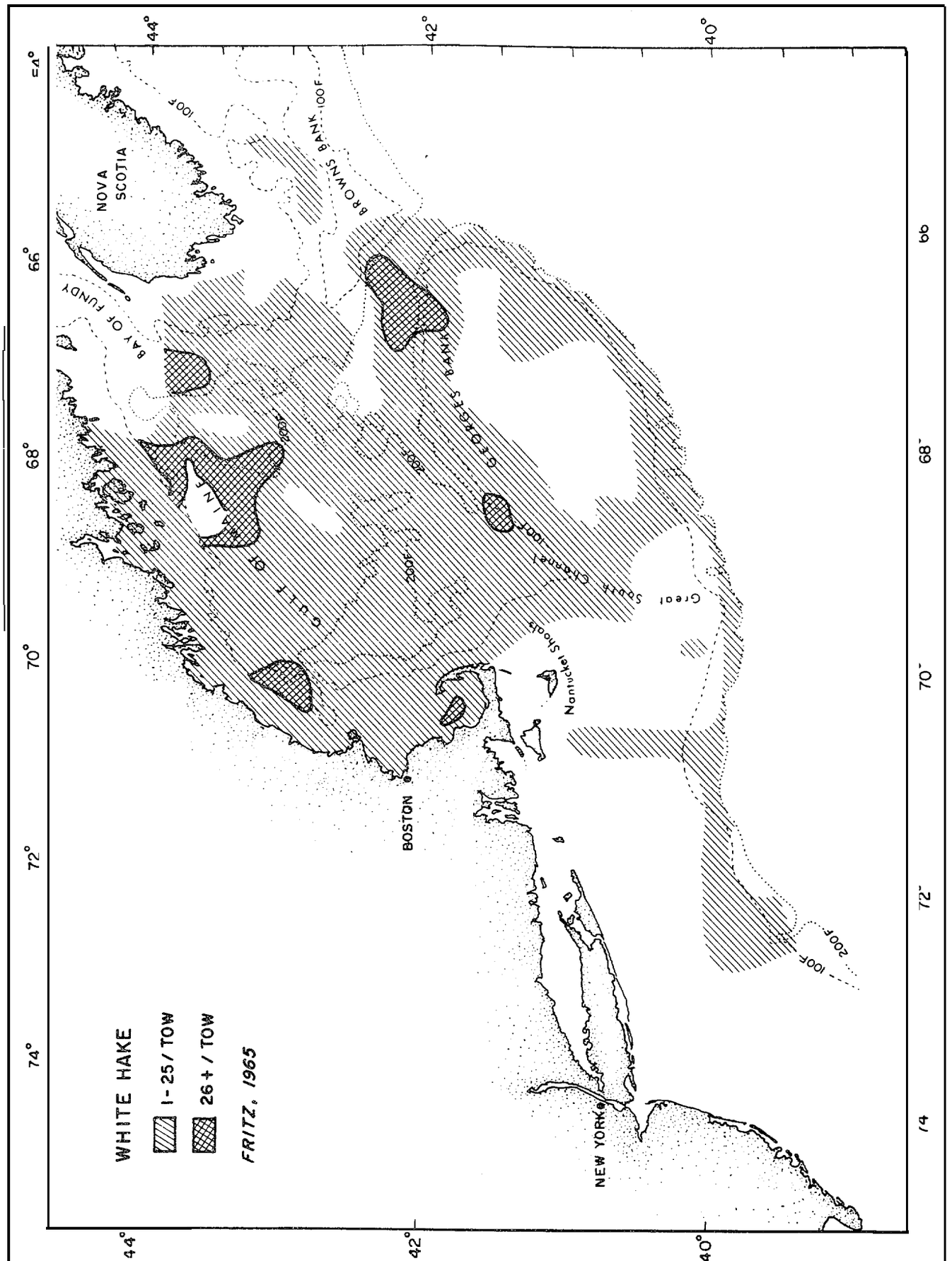
FIGURE 12-22

Spawning Distribution Haddock (Fritz, 1965 & Colton, 1972)

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

RIGOM PARC | FIGURE 12-23 | Spawning Distribution Pollock



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TRIGOM PARC

FIGURE 12-24 Spawning Distribution White Hake (Fritz, 1965)

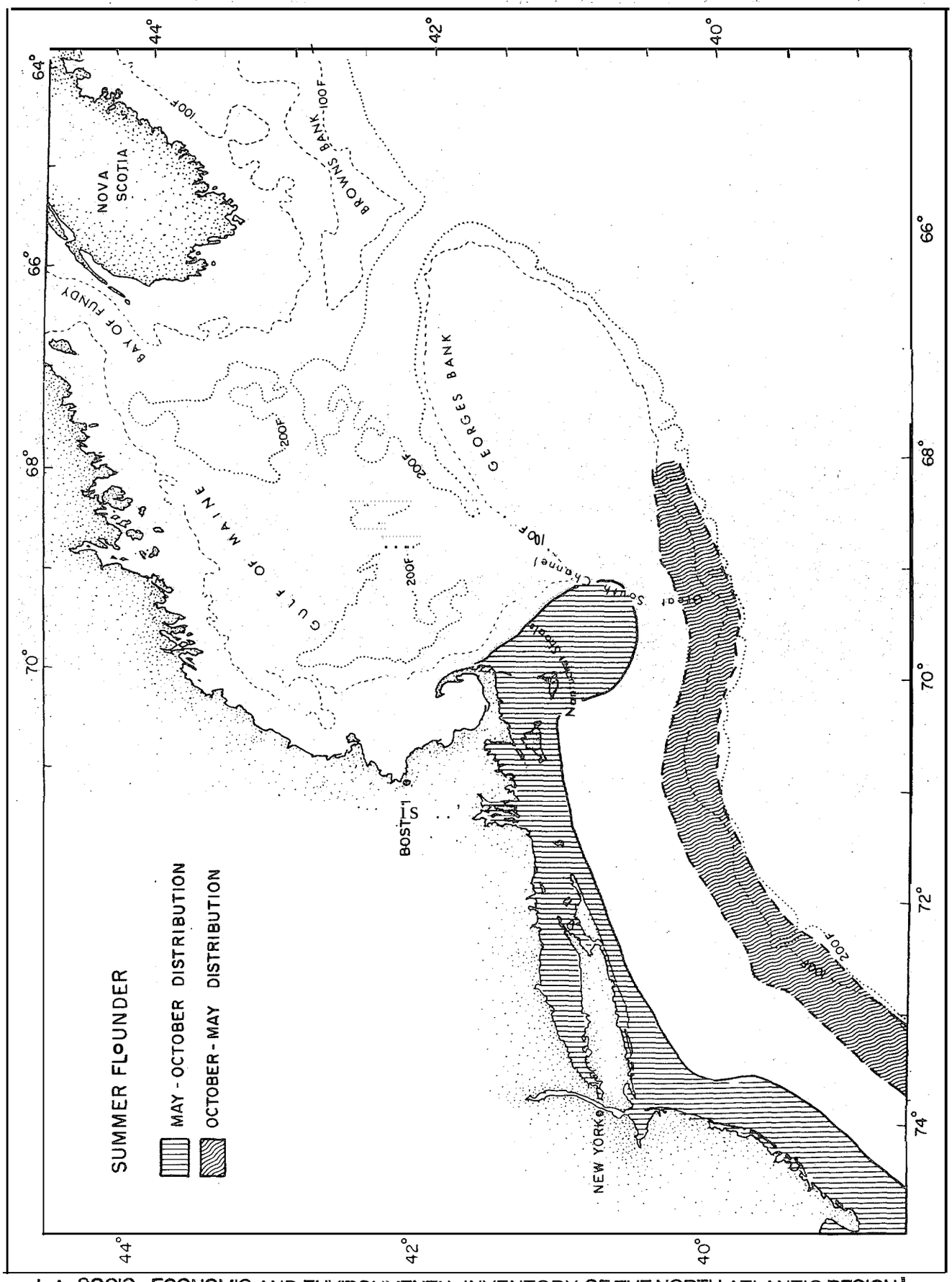
A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 12-25 Spawning Distribution Red. Hake (Fritz, 1965)

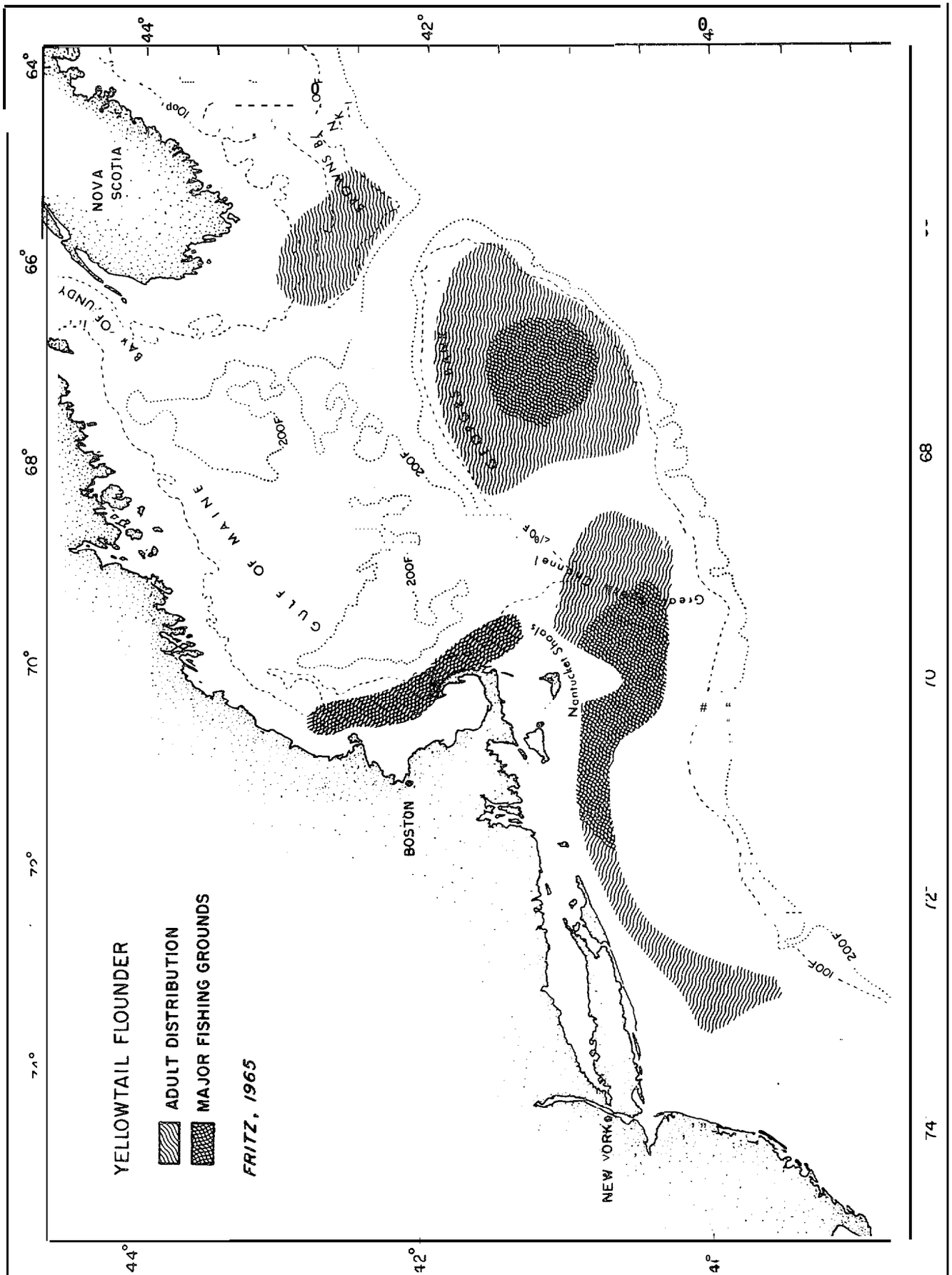
A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC | FIGURE 12-26 | Spawning Distribution American Plaice (Colton, 1972)



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRICOM PARC | FIGURE 12-28 | Distribution Charts Summer Flounder (Fritz, 1965)

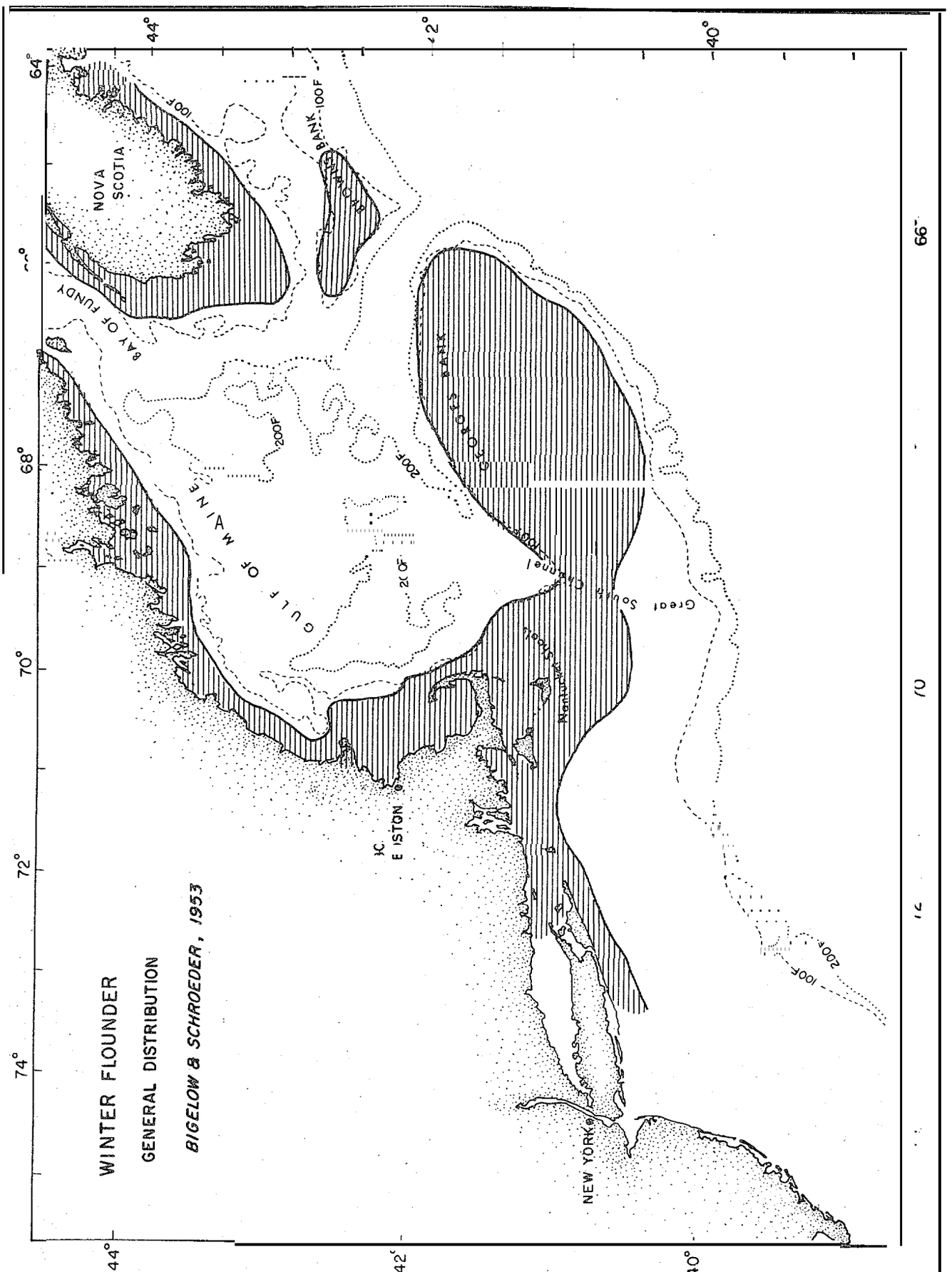


A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 12-30

Distribution Charts
Yellowtail Flounder



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC | FIGURE 12-32 | Distribution Charts
Winter Flounder (Bigelow & Schroeder, 1953)

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 12-33

Distribution Charts
Atlantic Mackerel

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 12-36

Distribution Charts
Butterfish (Fritz, 1965; Bigelow & Schroeder 1953)

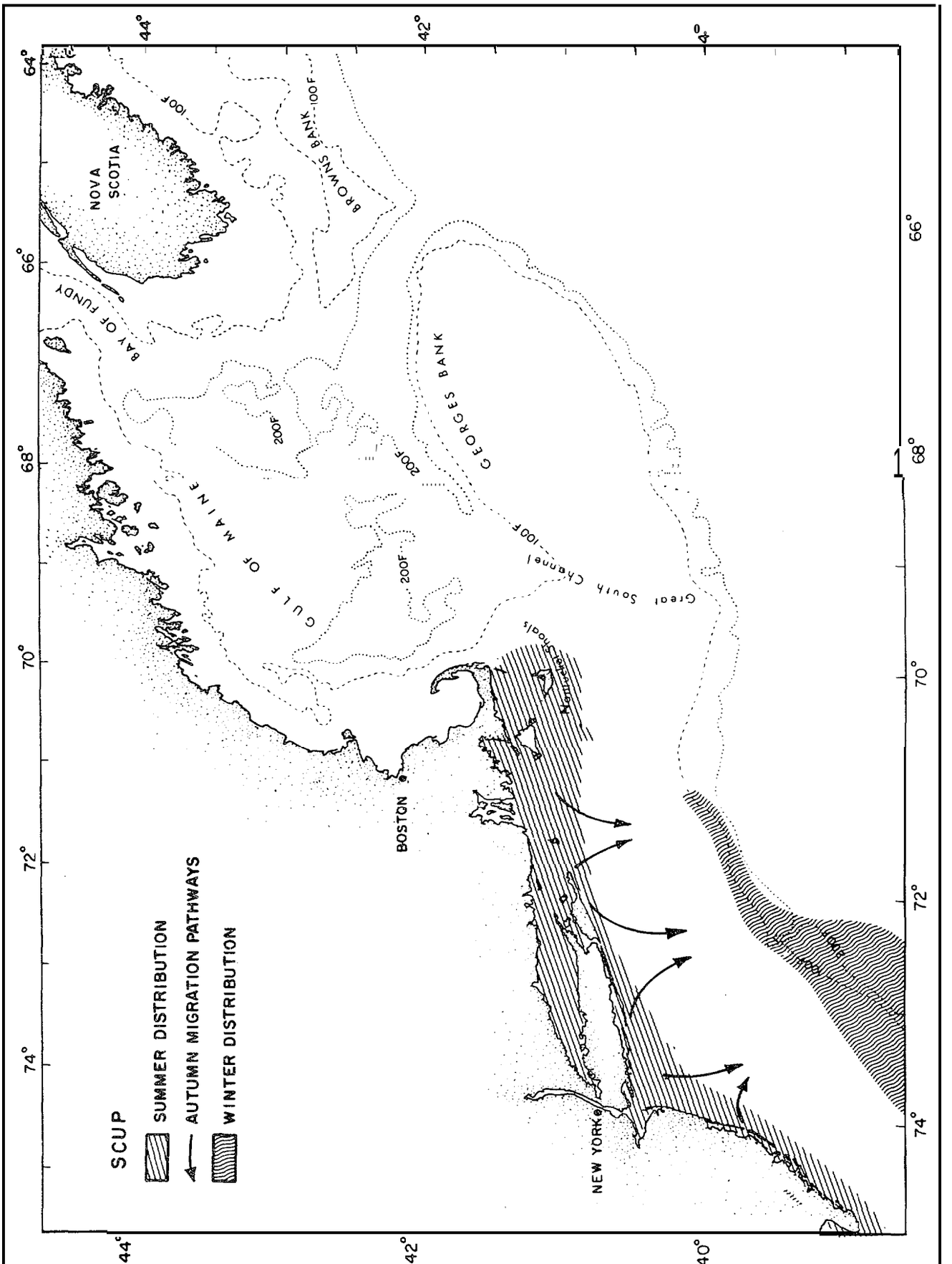
BLUEFISH
SUMMER DISTRIBUTION
WINTER DISTRIBUTION
NOVA SCOTIA
BAY OF FUNDY
BROWNS BANK
GEORGES BANK
GULF OF MAINE
Nantucket Shoals
BOSTON
NEW YORK
100F
200F
Channel
64°
66°
68°
70°
72°
74°
44°
42°
40°

A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 12-38

Distribution Charts
Striped Bass



A SOCIO-ECONOMIC AND ENVIRONMENTAL INVENTORY OF THE NORTH ATLANTIC REGION

TRIGOM PARC | FIGURE 12-40 | Distribution Charts Scup

A SOCIO-ECONOMIC AND ENVIRONMENTAL 1NVENT0R% OF THE NORTH ATLANTIC REGION

TRIGOM PARC

FIGURE 12-41, Distribution Charts Longhorn Sculpin (Fritz , 1965)

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