Coastal Zone and Estuarine Studies Division

Organization and Activities

COASTAL ZONE
INFORMATION CENTER

National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Blvd. E.
Seattle, WA 98112

November 1988

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COASTAL ZONE AND ESTUARINE STUDIES DIVISION

ORGANIZATION AND ACTIVITIES

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National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112

November 1988

NORTHWEST REGION FISHERIES RESEARCH MISSION STATEMENT

Under the National Marine Fisheries Service mission of "Achieve a continued optimum utilization of living resources for the benefit of the Nation," it is the responsibility of the regional research to support planning, developing, and managing of multi-disciplinary programs of basic and applied research designed to:

1) better understand the living marine resources (including marine mammals) of the northeast Pacific Ocean and the environmental quality essential for their existence and continued productivity;

2) describe and provide to management, industry, and the public options for the utilization and conservation of living marine resources and maintenance of environmental quality which are consistent with national and regional goals and needs and international commitments.

To fulfill this mission we shall: (1) develop the scientific basis to determine and provide information on the status of stocks/populations of living marine resources, the status of fisheries for exploited species, the effects of pollution and human alterations on the habitats of the resources, the effects of environmental variability, the quality and safety of fishery products, and the enhancement of anadromous fishery resources; (2) collect, document, and interpret scientific and economic data as technical support for management plans, international negotiations, and fishery development programs; (3) provide technical advice on, review, and monitor fishery plans and grant programs; (4) pursue fundamental research on specified topics; and (5) maintain strong relations with the academic community and industry (through grants, contracts, and cooperative programs as appropriate) and with users and the general public. We cooperate with the other Fisheries Regions of the National Marine Fisheries Service in the sharing of expertise and in multi-regional programs consistent with national goals and needs and international commitments.

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DIVISION OVERVIEW

Objective and Role

Two of the most important water resource complexes in the western United States are the Columbia River watershed and Puget Sound. These are habitats for many important living aquatic resources--salmon, steelhead, shad, smelt, sturgeon, oysters, clams, shrimps, crabs, plants, and others.

The overall objective of the Coastal Zone and Estuarine Studies Division (CZES), National Marine Fisheries Service (NMFS), is to provide information leading to the protection, development, and balanced growth of the above aquatic resources in concert with other socially desirable uses of the waters. Specific objectives of the individual research efforts are given in subsequent sections describing the Division's Tasks.

A fishery represents a complex of interactions between organisms, environment, social values underlying the harvesting and processing systems, and habitat uses. The role of the Division is to carry out the research necessary to understand these interactions and to identify and solve problems within this complex.

Problem Setting

The Division's research is carried out within three Tasks: **Ecological Effects of Dams, Habitat Investigations, and Fisheries Enhancement**.

The **Ecological Effects of Dams Task** is focused on the Columbia River watershed which covers 259,000 square miles in Idaho, Montana, Nevada, Oregon, Washington, Wyoming, and Canada (Fig. 1). More than 100 dams were built or authorized in the basin for power, irrigation, navigation, and water storage. These structures severely changed ecological conditions in the downstream areas and caused the loss of over 50% of the spawning and nursery habitats of important fishery resources, namely those of the salmon and steelhead. The Division's research is part of a coordinated comprehensive plan which is intended to double the fishery within the next 10 to 15 years despite the loss of spawning nursery habitat.

The Ecological Effects of Dams Task undertakes applied research relating to migration of anadromous fish between spawning areas and the sea. Studies are carried out on the effects of

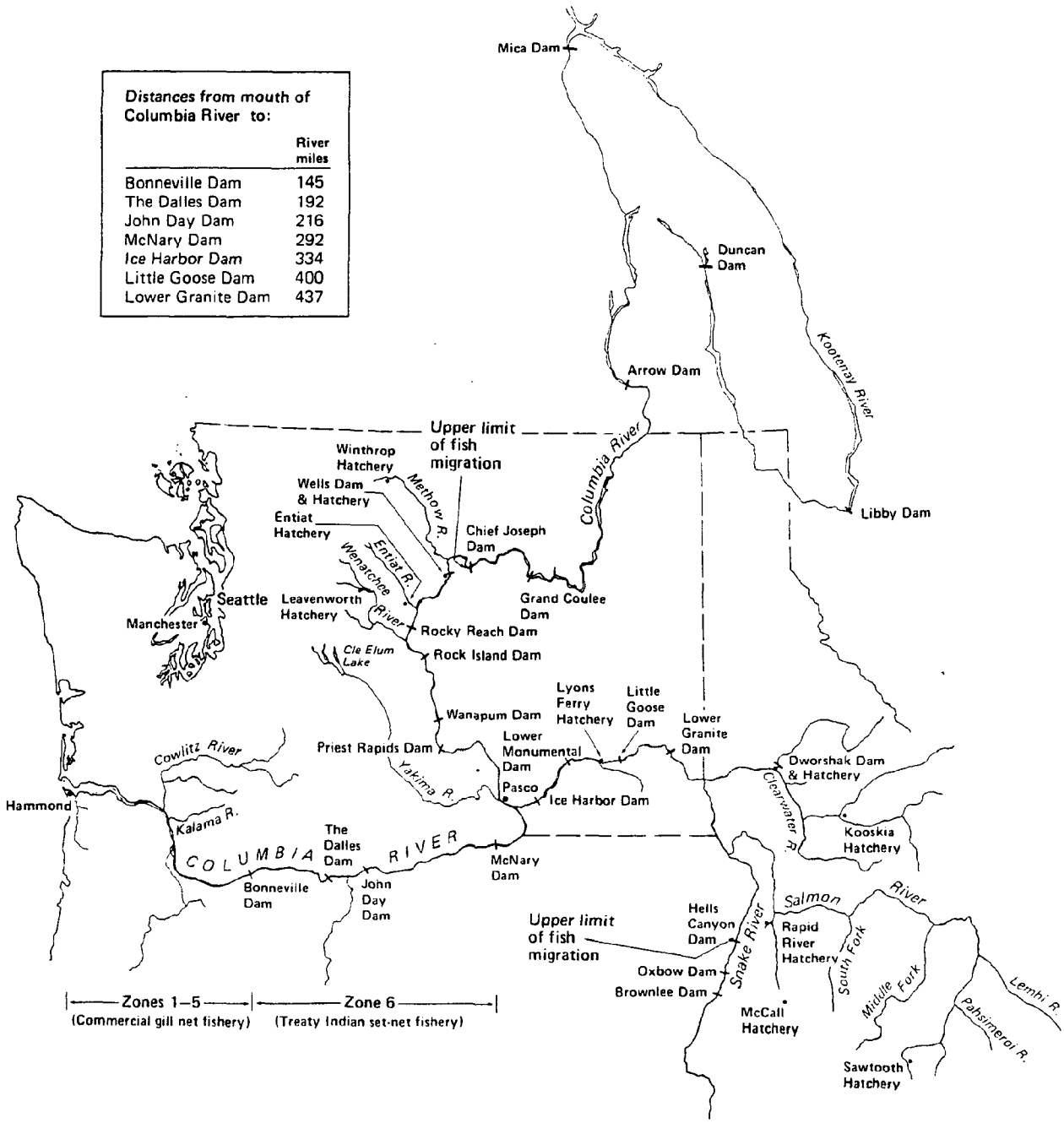


Figure 1.--The Columbia River Basin, showing the location of major mainstem dams on the Columbia and Snake Rivers. Important field sites, field stations, and Puget Sound are also shown.

water resource developments on river ecosystems, fish passage, survival of various stocks of anadromous fish, and the development of systems for alleviating adverse effects. For example, the rapid acceleration of powerhouse construction in the Columbia Basin in response to the energy crisis created a river situation in which a greater percentage of juvenile migrants passed through turbines. The time available to develop and refine solutions to fish passage problems was severely shortened. Fortunately, our research already pointed the way to several important practical steps to reduce salmon and steelhead losses due to dams. The passage of the Pacific Northwest Electric Power Planning and Conservation Act of 1980 and its accompanying Fish and Wildlife Program further accelerated the goal of enhancing the production of Columbia River salmonids. Information obtained from the study of the Columbia Basin problem has application to anadromous fish resources from Alaska to California, the Great Lakes, and the east coast.

The focal point for research activities of the **Habitat Investigations Task** is the Columbia River estuary. This unique body of water covers about 150 square miles and extends from the Pacific Ocean to about River Mile 46. The estuary is an extremely important and complex area involving a variety of biological and physical interactions. It is an important link in the life cycle of some of the Northwest's most important food and sport fishes (e.g., salmon and steelhead). It is also an area subject to subtle as well as drastic changes brought about by man's activities.

The activities of the Habitat Investigations Task fall under four broad fisheries-resources research areas: (1) background studies of the environment, (2) studies on the impacts of dredging and dredge-disposal, (3) studies on the impacts of discharged materials or heat, and (4) lower river and estuarine salmonid studies. Recent Task projects included several surveys in the Columbia River estuary and other strategic areas on the Oregon and Washington coast, a study of white sturgeon below Bonneville Dam, and a survival study of juvenile salmon through the Second Powerhouse at Bonneville Dam. Emphasis is on salmonids, sturgeon, and other important fish and on benthos, particularly Dungeness crabs. Behavioral studies led to important observations concerning the effects of industrial discharges on salmon migrations. The Task is also carrying out, in cooperation with NOAA's National Ocean Service, Ocean

Assessment Division, the compilation of a data base on living marine resources for selected estuaries on the Pacific coast.

Through the Habitat Investigations Task, the Division monitors the biological effects of changes and predicts the consequences of contemplated actions through evaluation of pilot programs. Research information from this Task is used by many federal, state, and private agencies having major activities or responsibilities in the estuary and along the adjacent coasts. These agencies include, among others, the NMFS Northwest Region; Bonneville Power Administration (BPA); U.S. Army Corps of Engineers (COE); Environmental Protection Agency (EPA); U.S. Fish and Wildlife Service (USFWS); state fish, game, and environmental departments; Columbia Basin Fish and Wildlife Authority (CBFWA); port authorities; and utility systems.

The **Fisheries Enhancement Task** is located in Puget Sound, an inland sea with over 2,300 miles of shoreline (Fig. 1). Its deep and sheltered waters are used for many purposes. As a life support system, it has considerable potential for producing fish, shellfish, and aquatic plants. It is recognized that these resources need to be further developed in balance with other socially desirable uses of the Sound. Through its Fisheries Enhancement Task, the Division provides leadership in research directed toward the emerging applications of enhanced production of aquatic organisms for commercial and recreational uses.

The salmon technology developed by the Fisheries Enhancement Task has many applications. Salmon farmers are actively engaged in aquaculture in Washington, with a production of more than 2.8 million pounds of salmon in 1985, valued at the wholesale level at $6.7 million. The information obtained by this Task on development and improvement of freshwater and seawater rearing systems and on detection and prevention of fish diseases can enable public and private growers to substantially increase production and reduce costs.

Current research emphasizes development of technology to improve the quality and production of juvenile salmonids at public hatcheries. Research information obtained by this Task regarding delayed release and extended rearing of various stocks of salmon is being applied in Puget Sound by NMFS and the Washington Departments of Fisheries and Wildlife. As a result, a much more viable fishery now exists. Increased production can also partially ease

the problem of allocation of fish to Indian and non-Indian fishermen. Along this line, a major experiment to restore anadromous sockeye salmon to the Yakima Basin is well underway.

Other research in this Task is designed to assess the status of smoltification and fitness for ocean survival of chinook and coho salmon and steelhead. The information obtained will be invaluable to hatchery managers of the Northwest and will aid in evaluating research conducted by the Ecological Effects of Dams Task to determine requirements for homing imprinting in relation to various methods of collection, bypass, or transportation.

Techniques for maintenance of brood stocks of Pacific and Atlantic salmon and cutthroat trout were developed by the Fisheries Enhancement Task. Current effort is centered on improvement of techniques for maintenance of threatened stocks of spring and fall chinook salmon with special emphasis on marine disease.

An important research development and application by this Task has been the successful demonstration of a genetic method to identify salmonid stocks in domestic and international mixed fisheries. The method is being successfully applied to the management of the troll-fishery off the Oregon and Washington coasts and promises to be an important tool in management of fisheries under the U.S.-Canada Salmon Treaty.

The development of the revolutionary Passive Integrated Transponder (PIT) tag by this Task has opened many new avenues of research. Other new and exciting research findings emerge each year from this Task, and they are applied by the fish cultural and management community which is continually in need of information to improve the effectiveness of their operations.

Organization, Facilities, and Funds

The Coastal Zone and Estuarine Studies Division has a professional staff of fishery scientists, engineers, electronic specialists, and various support personnel. Requests for their expertise and sharing of their techniques are national and international in scope. The Division's table of organization is presented in Figure 2.

The staff of the Division Director's office brings capabilities of managing, bioengineering, budgeting, and computer analysis to bear on the operations of the Division. The core technology

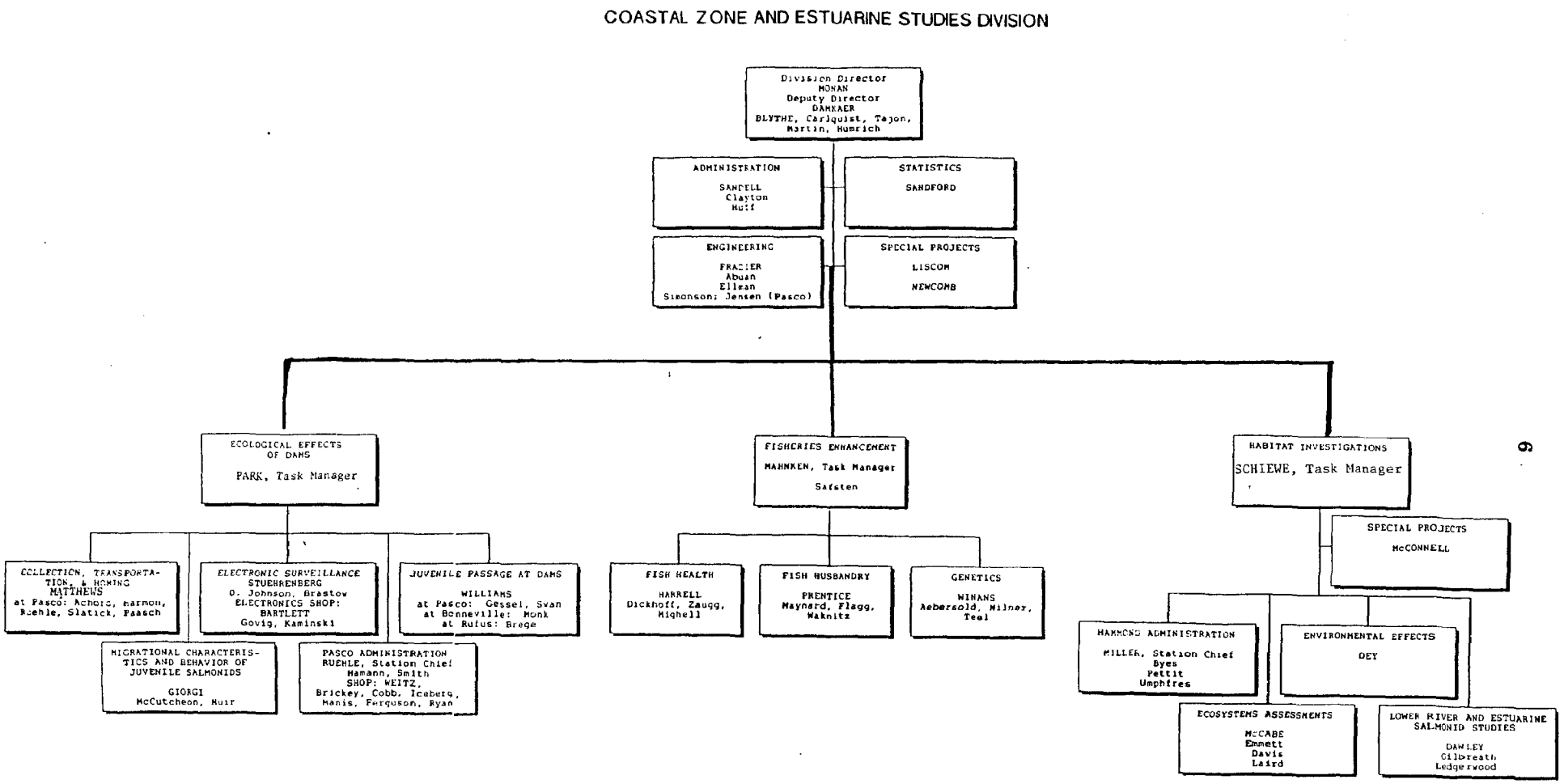


Figure 2.--Coastal Zone and Estuarine Studies Division's table of organization.

of the Division consists of three tasks staffed by professionals and technicians who carry out the applied research necessary to understand and solve problems in two major areas: (1) effects of water and related land resource development projects on the ecosystems, habitats, passage, and survival of fish and (2) development of means for improving management of resources through enhancement and stock identification techniques. The staff directly related to each of the three tasks is identified in Figure 2.

Major field stations for research on Columbia River resources are located at Pasco, Washington, and Hammond, Oregon. Other important on-site field facilities are at major dams on the Columbia and Snake Rivers or on tributary streams: Lower Monumental, Little Goose, Lower Granite, McNary, John Day, The Dalles, and Bonneville Dams and sites at Clatskanie, Oregon, and Cook, Washington. The principal station for research on fisheries enhancement is located on Puget Sound at Manchester, Washington. The Division has office, shop, and laboratory space and hatchery and holding facilities at the NMFS, Seattle.

For the past several years, about two-thirds of the operational funds required for Division research activities has come from reimbursable contracts. In 1987, about $4.6 M were provided via reimbursable contracts with other agencies and about $1.9 M were provided via NMFS appropriated funds. The main sources of reimbursable funds are the COE and BPA because of their responsibility and desire to restore fish runs lost through hydroelectric development in the Columbia Basin. Reliance to this degree on contracts from other agencies to carry out high priority research, however, creates problems within the Division, particularly in long range planning, organization, and staffing. Fluctuations from year to year in the amount of and types of research contracts have resulted in large shifts in research emphasis and reassignments of many of the field research staff. Fortunately, we have developed a talented and flexible staff to accommodate these fluctuations. Significant requirements for travel to carry out the changing research emphasis without corresponding changes in travel allocation also cause serious problems. Generally, the trend is to reduce travel allocations without consideration of travel needed to address research contracts.

Funding summaries for FYs 1984-1988 are presented in Table 1; reimbursable contracts for FY1988 are also shown.

Table 1.--Coastal Zone and Estuarine Studies Division, 1984-1988 funding summary and 1988 reimbursable contracts.

COASTAL ZONE AND ESTUARINE STUDIES FUNDING SUMMARY, 1984-1988

FY	Reg. funds $K	U.S./Canada	REIMBURSABLES TO CZES	To Center	To NOAA/NMFS	To DOC	Total contract	Total FY $K
84	1713.1		2449.8	448.5	701.4	18.0	3617.7	5330.8
85	1728.8		2976.5	243.1	366.4	18.0	3604.0	5332.8
86	1698.3	272.4	3392.5	256.6	369.3	19.1	4037.5	6008.2
87	1697.0	284.5	3123.7	231.6	394.4	18.1	3767.8	5749.3
88	1690.7	306.8	4012.3	225.5	383.9	23.3	4645.0	6537.5

Table 1.--Continued

COASTAL ZONE AND ESTUARINE STUDIES - FY88 FUNDING

Task number	Task title	Direct cost	Center support (14.2%)	National support (24.6%)	DOC support (0.5%)	Total in contract
REIMBURSABLE CONTRACTS - ECOLOGICAL EFFECTS OF DAMS (EED)						
	Funds received from Corps of Engineers					
R-LIA-IE	Perform a Measurement of the Physiological Status of Fish in Relation to Fish Guiding Efficiency at Bonneville Dam (Smoltification)	76.3	5.8	9.8	0.5	92.4
R-LIA-IH	Continuing Studies to Evaluate Improved Collection, Handling, and Transport Techniques Designed to Increase Survival of Juvenile Salmon and Steelhead	263.3	18.6	31.7	1.4	288.0
R-LIA-A7	Fabricate Equipment to Facilitate the Evaluation of the Juvenile Bypass System at Bonneville Dam Second Powerhouse	199.9	10.2	17.5	1.1	228.7
R-LIA-MA	Evaluate Improved Collection, Handling, and Transport Techniques Designed to Increase Survival of Juvenile Salmon and Steelhead	56.7	4.9	8.2	0.4	70.2
R-LIA-MB	Continuing Studies to Improve and Evaluate the Juvenile Bypass System at Bonneville Dam	288.5	26.2	44.7	1.8	361.2
R-LIA-MD	Continuing Studies to Improve and Evaluate Juvenile Fish Collection at Lower Granite and Little Goose Dams	40.4	3.9	6.7	0.3	51.3
R-LIA-ME	Research at McNary Dam to Improve Fish Guiding Efficiency of Yearling and Subyearling Chinook Salmon	13.6	1.4	2.3	0.1	17.4
R-LIA-MG	Evaluate the Prototype Juvenile Bypass System at Ice Harbor	18.3	1.7	3.0	0.1	23.1
	Funds received from Bonneville Power Administration					
R-LIA-IQ	Collection Efficiency - McNary Dam	98.6	9.6	16.4	0.6	125.2
R-LIA-IR	Biological Manipulation of Migration Rate and FGE: The Use of Advance Photoperiod to Accelerate Smoltification in Yearling Chinook Salmon	35.3	3.0	5.2	0.2	43.7
R-LIA-C6	Evaluation of Idaho Wild Stock Contribution Through The Use of PIT Tags	52.9	1.7	2.9	0.3	57.8
R-LIA-HS	Effects of Flow on the Migratory Behavior and Survival of Juvenile Salmon in the John Day Reservoir	3.2	0.2	0.3	0.0	3.7

Table 1.--Continued

COASTAL ZONE AND ESTUARINE STUDIES - FY88 FUNDING

Task number	Task title	Direct cost	Center support (14.2%)	National support (24.6%)	DOC support (0.5%)	Total in contract
REIMBURSABLE CONTRACTS - ECOLOGICAL EFFECTS OF DAMS (EED)						
	Funds received from Bonneville Power Administration (Cont'd)					
R-LIA-HW	Use of a Fish Transportation Barge for Increasing Return of Steelhead Trout	39.2	3.8	6.5	0.2	49.7
R-LIA-ND	Lower Granite Pool Survival Study Using PIT Tagged Rapid River Hatchery Fish	12.6	1.3	2.1	0.1	16.1
R-LIA-NE	McNary Sampling Study Using PIT Tagged Fish From Various Hatcheries	92.5	8.5	14.6	0.6	116.2
	Funds received from Public Utility District No. 2 of Grant County					
R-LIA-20	Priest Rapids Marking	304.0	17.2	29.3	1.8	352.3
	Funds received from U.S. Fish and Wildlife Service					
R-LIA-C9	Marking of Fish at the Leavenworth National Fish Hatchery	3.5	0.0	0.0	0.0	3.5
	Funds received from Washington Department of Fisheries					
R-LIA-41	Construction of Double Brand (Head) Pots	2.0	0.1	0.3	0.0	2.4
REIMBURSABLE CONTRACTS - FISHERIES ENHANCEMENT (FE)						
	Funds received from Bonneville Power Administration					
R-LIA-09	A Study to Determine the Biological Feasibility of a New Fish Tagging System	1042.3	34.6	58.8	5.7	1141.4
R-LIA-83	Yakima Hatchery Pre-Design - Cle Elem Project	424.8	19.6	33.3	2.4	480.1
	Funds received from Brigham Young University					
R-LIA-41	Laboratory Expenses for Mitochondrial DNA Work	1.0	0.0	0.0	0.0	1.0

Table 1.--Continued

COASTAL ZONE AND ESTUARINE STUDIES - FY88 FUNDING (Cont'd)

Task number	Task title	Direct cost	Center support (14.2%)	National support (24.6%)	DOC support (0.5%)	Total in contract
REIMBURSABLE CONTRACTS - FISHERIES ENHANCEMENT (FE) (Cont'd)						
	Funds received from Grays Harbor County Commission					
R-LIA-86	Chehalis River Salmon Survival Study	7.8	0.3	0.4	0.0	8.5
	Funds received from Oregon Department of Fish and Wildlife					
R-LIA-41	Examine Two Groups of Chinook Fingerlings Using Electrophoretic Analysis	5.4	0.2	0.4	0.0	6.0
	Funds received from the Smithsonian Institute					
R-LIA-C9	Processing Fish MTDNA	0.5	0.0	0.0	0.0	0.5
	Funds received from the University of Alberta, Canada					
R-LIA-41	Intertidal Snail Mitochondrial DNA	2.0	0.0	0.0	0.0	2.0
	Funds received from the Washington Department of Fisheries					
R-LIA-1J	Grays Harbor Salmon Survival Study	76.3	5.9	10.1	0.5	92.8
R-LIA-SF	White River Chinook Salmon Study	34.9	0.0	0.0	0.2	35.1
REIMBURSABLE CONTRACTS - HABITAT INVESTIGATIONS (HI)						
	Funds received from the Corps of Engineers					
R-LIA-1M	Continuing Study to Describe the Distribution and Abundance of Dungeness Crabs at the Mouth of the Columbia River	42.1	3.3	5.6	0.3	51.3
R-LIA-9G	Collect Two Sets and Analyze 30 Benthic Invertebrate Samples	11.2	0.2	0.3	0.1	11.8
R-LIA-C4	Collection of Biological and Sediment Samples Prior to and After Disposal of Material from the Mouth of Winchester Bay (Umpqua Dredging Disposal)	15.6	0.6	1.1	0.1	17.4

Table 1.--Continued

COASTAL ZONE AND ESTUARINE STUDIES - FY88 FUNDING

Task number	Task title	Direct cost	Center support (14.2%)	National support (24.6%)	DOC support (0.5%)	Total in contract
REIMBURSABLE CONTRACTS - HABITAT INVESTIGATIONS (HI) (Cont'd)						
	Funds received from the Corps of Engineers (Cont'd)					
R-LIA-MC	Evaluation of Juvenile Salmonid Survival Through Downstream Migrant Bypass Systems, Spillways, and Turbines (Bonneville Dam)	596.4	28.2	47.9	3.4	675.9
R-LIA-SE	Technical Assistance and Physical Monitoring of Sediment Transport During Disposal of Fine Grained Material from Chinook Channel	12.1	0.7	1.1	0.1	14.0
	Funds received from the Oregon Department of Fish and Wildlife					
R-LIA-99	Sturgeon Habitat Study	166.1	13.8	23.4	1.0	204.3

Operations and Goals

A generalized representation of research related to Columbia River resource problems is presented in Figure 3. Details are included in the Task sections. Generally, the research goals are to obtain information on status of populations, patterns of fish behavior, environmental factors, and enhancement systems and to develop alternative protection or enhancement systems related to specific problems. The application of this information by management agencies results in capital savings in fish passage facilities, increased fish production, and maintenance of environmental quality and promotes optimum multiple uses of resources. As shown in Figure 3, inputs from administrative and technical support take place throughout all operations. Implied in the support-operation flow relationship are the various types and degrees of interface with other federal and state agencies; industry; and interest groups on problem identification and definition, planning, programming, budgeting, evaluation, and application of information. The CZES activities are coordinated with other Divisions within the Region primarily by the Deputy and Division Directors; however, scientist to scientist interaction is also encouraged. One important area where planning and coordination of research will continue to be emphasized relates to the goals of the Environmental and Technical Services Division (ETSD), Northwest Region, and CBFWA. Although not shown, evaluation and feedback processes are an inherent part of the operation.

A similar representation of the research related to fisheries enhancement is presented in Figure 4. Details are presented in the Task section. Research goals are to obtain information on production, behavior patterns in fish, environmental factors, and information on husbandry systems appropriate to the Pacific Northwest as related to specific fish (salmon) and companion crops such as shellfish. The application of the information by growers, management agencies, and the food industry results in increased seafood production, enhancement of recreational fisheries, and maintenance of environmental quality.

Figure 3.--Generalized representation of the operation, goals, and impact of research related to the Columbia River fishery resource problem.

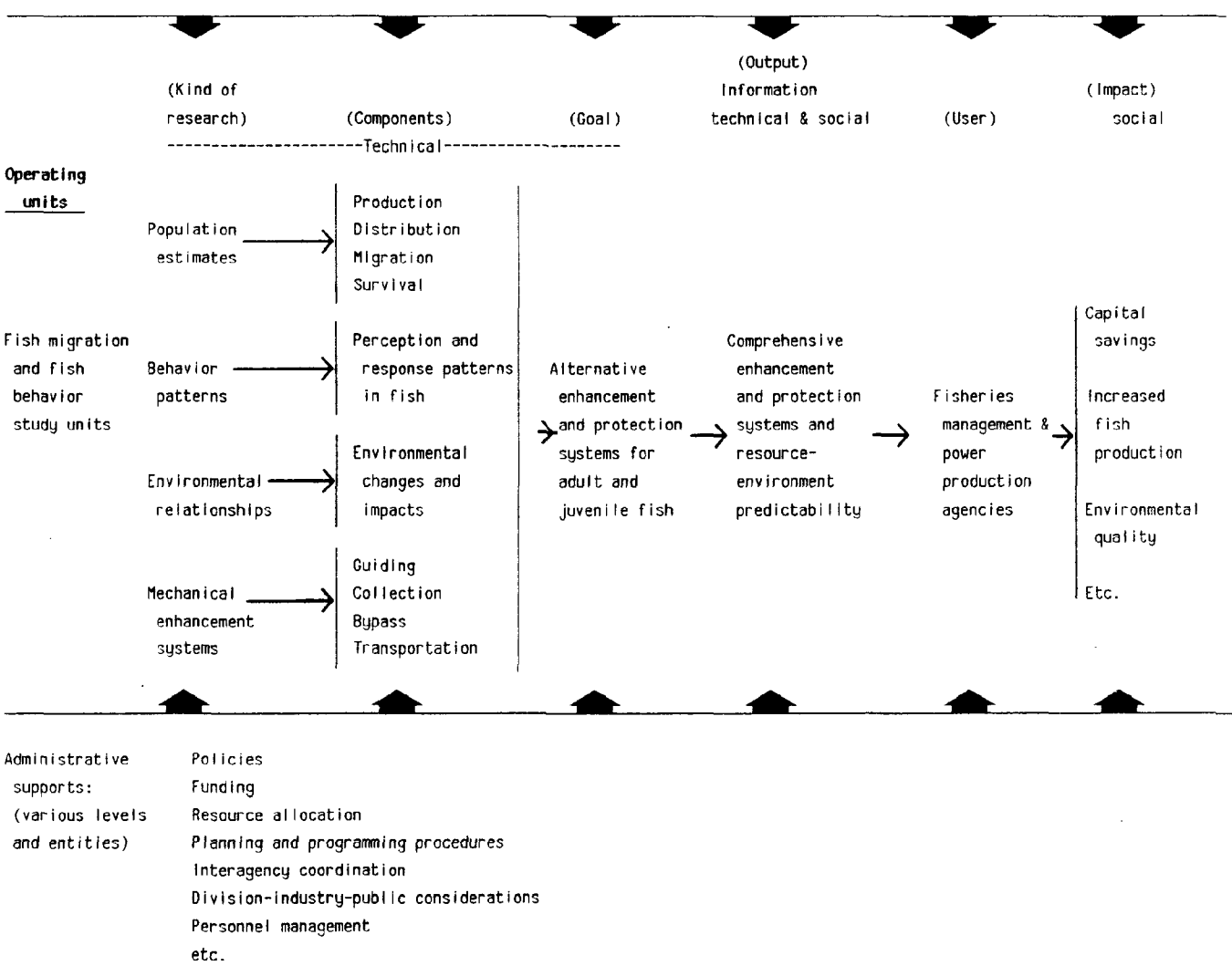
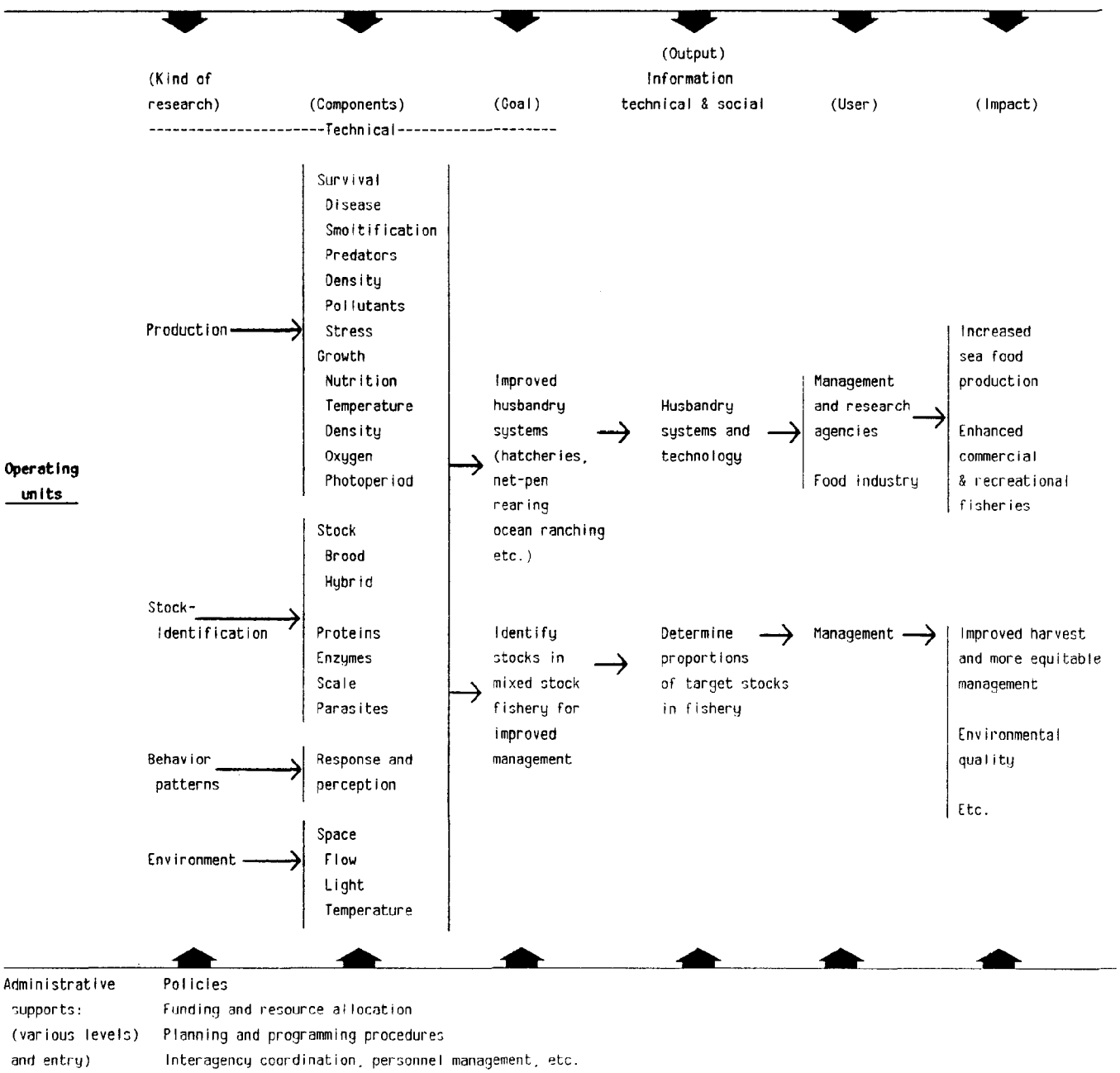


Figure 4.--Generalized representation of the operation, goals, and impact of research related to fisheries enhancement and other fishery research in Puget Sound.



ECOLOGICAL EFFECTS OF DAMS TASK

Background

The construction of dams and other water resource developments brought about dramatic environmental changes in the Columbia River system. Dams altered flow patterns, temperature regimes, competitor-predator relationships, and flooded spawning areas and became physical barriers to migrating anadromous fish. These developments were major factors in the decline in production of salmonids from a peak of about 50 million pounds in 1911 to about half that amount now. With the continuing development of the Columbia River system in the United States and Canada, river flows are now more controlled and the volume of spilling at dams is substantially reduced. More than doubling the turbine capacity of the dams since 1974 has further reduced the volume of water spilled, even with implementation of a water budget under the Pacific Northwest Electric Power Planning and Conservation Act of 1980.

Large investments were made in fishways to provide upstream migrants access to spawning areas and in propagation facilities to increase production of salmonids. Nevertheless, many adult fish migrating upstream are lost each year, and a high percentage of native and hatchery-reared juveniles succumb from a variety of causes during their seaward migration. If past investments are to result in the most efficient production of salmonids, responsible agencies must be aware of the impact of existing environmental conditions on the fishery resources and be cognizant of the consequences of projected changes so that appropriate corrective or mitigative actions can be taken.

Research programs by NMFS and its predecessor organization, the Bureau of Commercial Fisheries, provide a broad base of information on the effects of in-river changes on salmonids. Management agencies use this information and develop techniques to improve survival of salmonids migrating between spawning areas and the sea. The problems created in the fishery resources by the continuing development of the Columbia River system are under observation by the Ecological Effects of Dams Task, with the following objectives:

1) Determine effects of dams and other resource developments on fish migration and survival.
2) Assess detrimental effects of changes on fishery resources.
3) Develop systems for protection of fish from hazardous conditions.

4) Evaluate effectiveness of protective actions.
5) Provide information to improve enhancement, rehabilitation, and redistribution of stocks of salmonids in currently depleted areas.
6) Provide information on survival and behavior of stocks and species of juvenile migrants at dams where various methods are used to bypass downstream migrants.

Specific research projects for the Task are either developed independently by program personnel on the basis of critical needs or research proposals are prepared in response to requests from outside agencies (e.g., state agencies, COE, BPA, etc.) who are responsible for providing safe and effective fish facilities, but lack the technical capability for development and evaluation of fish protection devices. Research proposals are coordinated with and reviewed by the member agencies of CBFWA, through a number of advisory and technical committees.

Research consists of highly cooperative efforts between four subtasks:

1) Migrational Characteristics and Behavior of Juvenile Salmon.
2) Collection, Transportation, and Homing.
3) Juvenile Passage at Dams.
4) Electronic Surveillance.

Within this framework, studies are aimed at obtaining information in major research areas which include the following:

1) Adaptability of juvenile salmonids to changing environments created by dams.
2) Collection and transportation of juvenile salmonids.
3) Migrant passage (juveniles and adults) at dams.
4) Enhancement and redistribution of stocks.

The relationships between Task organization and major areas of research are shown in Table 2. Most of the work is done at field sites extending from the upper reaches of the Salmon River (tributary of the Snake River) downstream about 700 miles through the Snake and Columbia Rivers.

Most experiments are conducted at dams; however, some are conducted at the NMFS in Seattle or at other laboratories. Although the program provides the expertise for a vigorous

Table 2.--Relation of organizational phases to major areas of research in the Ecological Effects of Dams Task.

ECOLOGICAL EFFECTS OF DAMS

Migrational characteristics & behavior of juvenile salmon	Collection, transportation and homing	Juvenile passage at dams	Electronic surveillance
Describe dam passage patterns, and impacts, including survival between dams	Developed techniques for determining quality of fish migrating to sea each year (extended seawater rearing)	Measured fish guidance at Lower Granite, McNary, John Day, The Dalles, and Bonneville Dams	Developed improved techniques for monitoring behavior of juvenile & adult salmon
Assess the integrity of mark-recovery data	Continue evaluating benefits of transporting smolts from Snake River dams, McNary Dam, and Priest Rapids Dam using CWT technology	Develop techniques for improving fish guidance at Bonneville Second Powerhouse	Monitor fish behavior and provide measures of survival
Identify behavioral changes associated with smolt development	Develop imprint techniques for returning fish to specific sites after direct transport from hatcheries	Develop techniques for improving guidance of subyearling chinook salmon	Provide measures of fallback at dams
Assess the feasibility of manipulating smolt development and its associated behavior relative to migration and passage	Initiate new transportation studies on wild spring/summer chinook	Determine importance of smoltification on fish guidance at Lower Granite and Little Goose Dams	Develop acoustic tag for use in seawater
		Continue evaluating fingerling bypass at dams: Lower Granite Little Goose Lower Monumental McNary John Day The Dalles Bonneville	

field effort, the majority of funds for field operations are obtained through contracts with federal agencies such as BPA, COE, and EPA or with Public Utility Districts (PUD).

Data on juvenile salmonid migrations have been obtained from release and recovery of marked fish for several years. Initial population estimates of native and hatchery-reared fish were made in the upper Snake River, and additional estimates were made as the migrants were subsequently recovered in gatewells of dams or in traps and seines along the route of fish migration to the sea. In 1983, this annual routine monitoring of migrational behavior, including daily estimates of populations of juveniles arriving at key locations, was turned over to the Fish Passage Center which was formed as a result of the Pacific Northwest Electric Power Planning and Conservation Act. Routine annual estimates of survival and migrational timing of various populations of juvenile migrants are now computed by the Fish Passage Center based on techniques developed earlier by CZES.

CZES efforts now center on development of new techniques to better refine these and other estimates with less handling and marking of juvenile migrants. Recent development of the juvenile radio-tag and the passive integrated transponder (PIT) tag for fish promises to revolutionize the estimation of passage and survival of the salmonid populations passing dams.

Other research on juvenile migrants is centered on measuring stress, injury, and long-term survival of experimental groups subjected to newly developed bypass systems such as those recently constructed at John Day and Bonneville Dams.

Fish diverted from turbine intakes into gatewells are collected and marked at Lower Granite or McNary Dams; some of these fish are transported (treatment groups) about 200 to 350 miles downstream and others are released at the dam (controls). The recovery of marked fish at different points downstream provides data on survival, timing, and rates of movement toward the sea. Evaluation of the collection and transportation system is based on the recovery of marked adults in the ocean fishery and during their spawning migration at Little Goose, Lower Granite, or McNary Dams. Recoveries in the river fisheries and on the spawning grounds provide further information on the return of marked fish and the effects of transport on homing ability.

Radio-tracking techniques are used to observe movements of adult and juvenile salmonids in relation to physical and operational features at dams and in impoundments. Adults and juveniles tagged with radio tags are observed with radio direction finders from shore and boat stations, locations of fish are plotted on a chart of the area by triangulation, and fish movement is related to flow conditions and operation of adult and juvenile passage facilities.

Most field activities peak in the spring during the downstream migration of juvenile salmonids when fish are collected, marked, and released for future recovery. The recovery effort on marked juveniles extends into the summer and for marked returning adults into the fall. Between major periods of activity, personnel analyze data, prepare reports, and make modifications to equipment and procedures to improve operations in the next field season. A review of Task research progress is held in the winter--usually late December or early January. When it is apparent that additional studies should be initiated, proposals are prepared and submitted for consideration.

Accomplishments (1985-1988)

Collection, Transportation, and Homing

Since 1983, this Subtask has focused on studies to isolate and eliminate areas of stress and injury in the collection and transportation systems. It has also conducted marking and transport research since 1986 at Lower Granite and McNary Dams and barge transport index marking since 1983 at Lower Granite Dam.

Adult returns from the research transportation studies have just begun. A comprehensive summary report of 1968-1980 transportation research was completed.

Field studies were completed to determine the effects of barging steelhead directly from Dworshak National Fish Hatchery (NFH) to release locations downstream from Bonneville Dam (Fig. 5). Final analysis of data awaits adult returns from 1985 releases; the final report will be available in 1988.

Another transportation study, to evaluate the effects of transporting sockeye and spring chinook salmon from Wanapum and Priest Rapids Dams to below Bonneville Dam, has

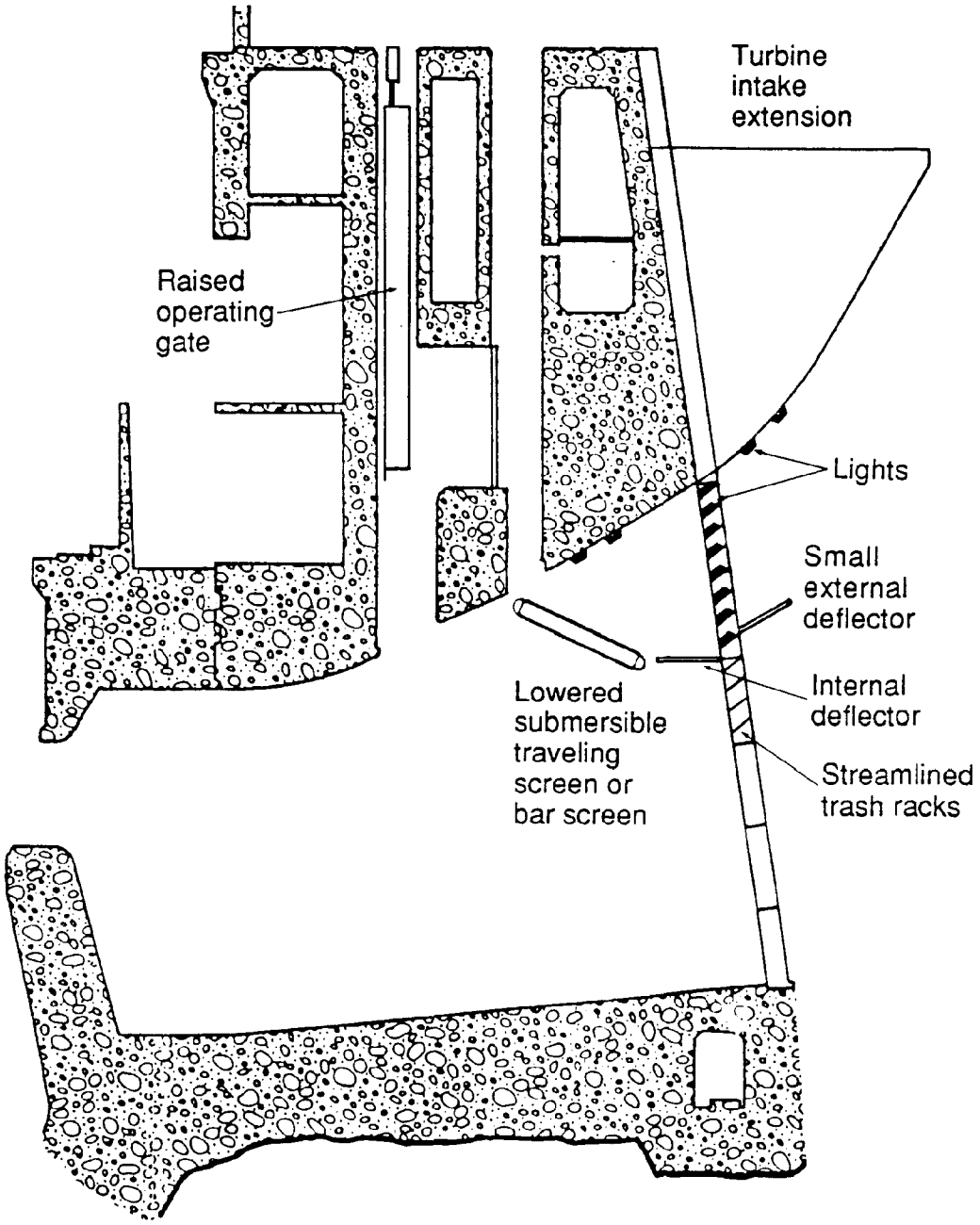


Figure 5.--Schematic cross-section through Bonneville Dam Second Powerhouse showing modifications tested to improve juvenile salmonid guidance at hydroelectric projects on the Columbia and Snake Rivers.

continued since 1983. This study involves the cooperative efforts of Grant County PUD, private consultants, and CZES.

A significant accomplishment of the Subtask in relation to research on stress was the development of a seawater challenge technique for rapid measurement of comparative stress among treatment groups of juvenile salmonids. This system has the advantage over conventional measurements of stress using blood cortisol or electrolytes in that conclusive data can be obtained within 48 h for most test situations, whereas blood chemistry analysis usually takes weeks before analyses can be completed. Several studies using this technique were completed to isolate areas of stress in bypass, marking, and transportation systems. Several modifications to the system were recommended and implemented. Some of the most important results from this work are as follows:

1) Determined that pre-anesthetizing juvenile salmon before handling and marking significantly reduced stress.
2) Isolated stress areas in the bypass system at Lower Granite Dam and recommended successful correction.
3) Provided stress measurements to assist in evaluating traveling screens, vertical barrier screens, and orifice configurations.
4) Determined that juvenile spring chinook salmon, when confined with juvenile steelhead, exhibited specific stress. When possible, steelhead are now separated from chinook salmon in holding raceways and transport vehicles.
5) Determined that load densities of 0.5 pound/gallon were not significantly more stressful than lower densities--confirming this density as safe for general operating procedures.

In addition to implementing the seawater challenge technique to measure stress, long-term artificial seawater rearing in a closed recirculation system was employed in 1984, 1985, and 1986 to measure subtle effects caused by stress or disease in chinook salmon collected at Lower Granite Dam. Treatment groups were reared for 120 days or longer to determine effects on growth and survival. Results suggested that bacterial kidney disease (BKD) was the primary factor impacting long-term survival of hatchery spring chinook salmon. BKD may be the major

limiting factor in the early ocean survival of hatchery spring chinook salmon whether collected and transported or not.

Analyses of adult return data from past and present transportation experiments continue to show the benefit of collecting migrants at upstream dams for transportation to release locations below Bonneville Dam. The data are especially strong for steelhead and fall chinook salmon. Data on spring chinook salmon are highly variable from year to year, but generally indicate benefits. Preliminary analysis of returning adult steelhead data obtained from the direct barging of Dworshak NFH stocks indicates that barging can substantially increase returns to the fishery as well as to the hatchery. Steelhead barged in the middle of the migration (25 April and 19 May) returned at a higher rate than those barged early (19 April) or late (31 May). Rate of return appears related to the level of smoltification at the time of barging. The Na^+-K^+ ATPase profiles from samples of treatment groups appeared to support this observation.

Migrational Characteristics and Behavior of Juvenile Salmonids

The primary activities of this Subtask were to describe the migrational characteristics and to estimate survival of downstream migrants in the Columbia-Snake River System. Beginning in 1983, the Fish Passage Center adopted many of these activities. Consequently, the research emphasis of the Subtask changed. Present research focuses on determining how and to what extent fish behavior is important in the design and implementation of fingerling passage devices and passage strategies employed by fisheries managers. To accomplish this, a variety of tools including PIT tags, miniaturized radio tags, and freeze brands are used.

In 1985-1986, the miniaturized radio tag was used to estimate the proportion of the yearling chinook salmon population passing through a spillway at Lower Granite Dam. Results indicated that fish passed through the spillway in greater proportion than the amount of water spilled.

During that same period, we initiated research relating behavioral changes associated with smolt development to the guidability of yearling chinook salmon into bypass systems. There was a correlation between fish guidance efficiency and the physiological status of the migrant

population. The more developmentally advanced individuals within the population (i.e., those further along in the parr-smolt transformation) guided more readily. We attributed this to behavioral changes which occurred as benthic oriented parr transformed into pelagic downstream-migrants. These results led to a request by fisheries agencies for expanded research on behavior and bypass-system effectiveness. To date, physiological/behavioral research has been conducted in conjunction with bypass evaluations at Lower Granite, Little Goose, and Bonneville Dams.

In 1988, research was initiated to determine if the fish guidance or seaward migration rate could be increased by manipulating smolt development and associated migratory behavior. At Dworshak NFH, treatment fish were exposed to an advanced photoperiod regime for 3 months prior to release. A corresponding control group was released at the same time. Two thousand individuals within each group were PIT-tagged to provide detailed migratory data as the fish traversed the system. Treatment fish migrated to and passed Lower Granite Dam faster than the controls, and they were recovered at higher rates. Physiological data collected over the course of this study confirmed that the photoperiod treatment did indeed accelerate smolt development.

The Subtask has conducted survival estimation experiments at the fisheries community's request. In 1987 we assessed the feasibility of using PIT-tagged fish to estimate smolt survival through reservoirs and turbines. Results showed that the tag offers great promise in more accurately estimating mortality associated with dam passage; however, its utility for estimating reservoir survival is still uncertain and is the topic of much discussion in the Columbia Basin fishery community.

Juvenile Passage at Dams

Research to evaluate and improve juvenile collection/bypass systems was conducted at Lower Granite, Little Goose, McNary, John Day, and Bonneville Dams (Fig. 6). The CBFWA has an interim goal of 50 and 70% fish guidance efficiency (FGE) at hydroelectric projects for subyearling and yearling migrants, respectively, and a long-term goal of 70 and 80%. None of the projects currently meet the long-term standards. Research efforts are directed toward developing means to meet the long-term goals.

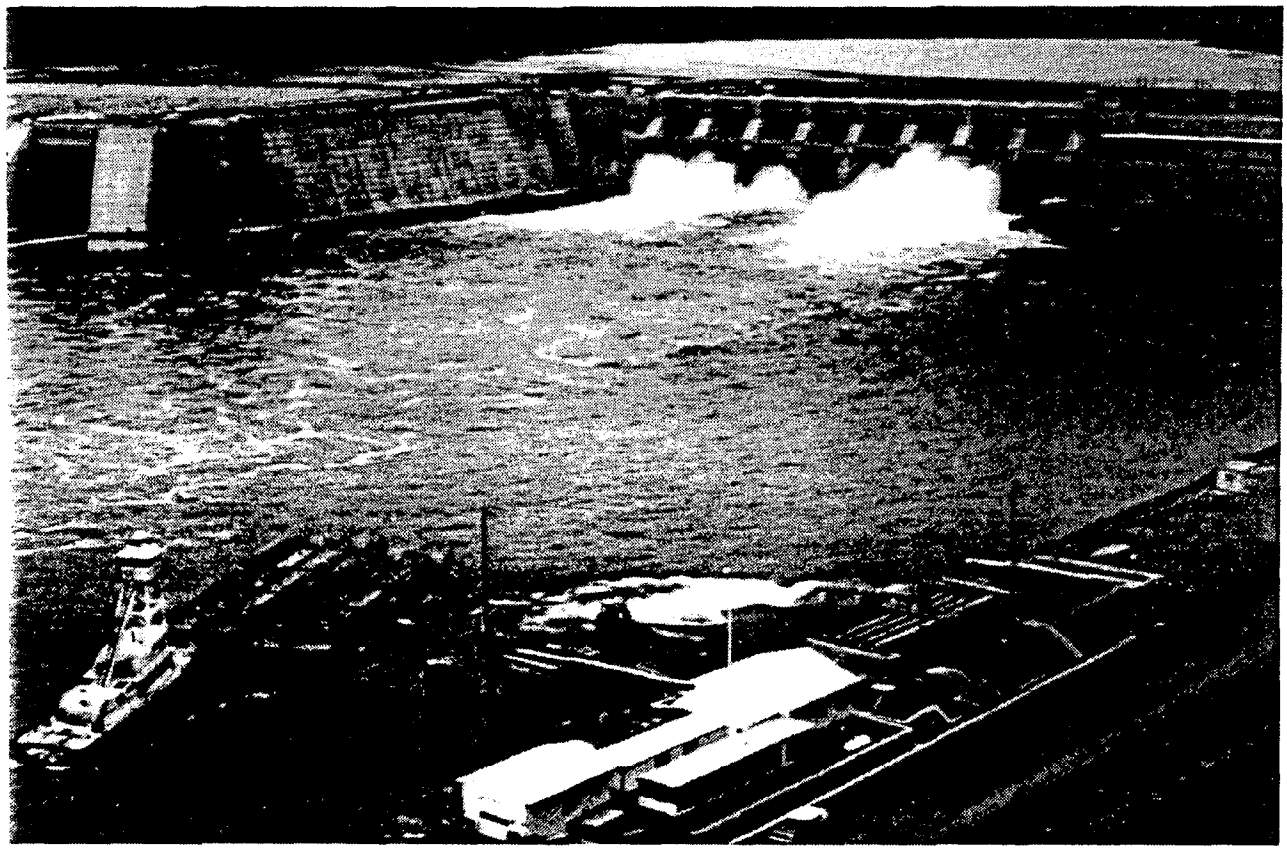


Figure 6.--Transportation barge at Lower Granite Dam.

With the current guidance systems, FGEs at Lower Granite and Little Goose Dams for yearling chinook salmon and steelhead are approximately 60 and 70%, respectively. In 1985 a raised operating gate was tested at Lower Granite Dam and in 1986 at Little Goose Dam as a means to improve FGE. At both projects, significant FGE increases of 8 to 10% were obtained for chinook salmon and steelhead, but even with the increases, the FGE did not meet the long-term CBFWA goals. In 1987, a bar screen deflector was placed in the fish screen slot at Lower Granite Dam to test the concept of an extended submersible traveling screen (STS). The extended STS concept provided overall guidance exceeding 80% for steelhead and, at times, guidance for yearling chinook salmon approached 80%, although an overall 80% average was not obtained. The depth distribution of juvenile yearling chinook salmon at the turbine intakes during the early part of the migration was too great for the guidance device to intercept 80% of the fish. The current hypothesis is that the vertical distribution is biologically based. In view of these results, the COE will raise the operating gates at Lower Granite and Little Goose Dams.

In 1987, raised operating gates were tested at McNary Dam. The FGEs for yearling chinook salmon and steelhead were increased to greater than 80%. Based upon these results, the COE is studying the feasibility of raising the operating gates at McNary Dam. Research was also conducted during the summers of 1986 and 1987 on migrating subyearling chinook salmon. In addition to the raised operating gate used with yearling migrants in the spring, a deflector was added to the trashrack to increase the percentage of intercepted fish. Neither of these two modifications to the project substantially improved FGEs, which ranged from 25 to 45%.

In 1985-86, the new juvenile bypass system at John Day Dam was evaluated. Guidance of steelhead exceeded 80%, yearling chinook salmon FGE was 72%, and subyearling chinook salmon FGE ranged from 25 to 45%.

In 1988, Bonneville First Powerhouse FGE was evaluated for the first time on summer subyearling chinook salmon migrants. Guidance averaged 11%. This was similar to the FGEs obtained in prototype tests at The Dalles Dam in 1985 with standard and lowered STSs (range 8 to 14%, respectively). Bonneville Second Powerhouse FGEs for summer subyearling chinook

salmon migrants under standard powerhouse conditions were less than 20%, but have been as high as 35% with a number of research modifications.

Research efforts during summer have been unsuccessful in meeting the minimum CBFWA guidance levels for subyearling chinook salmon migrants at any project.

No STS bypass facilities exist at Lower Monumental, Ice Harbor, or The Dalles Dams; however, between 1985 and 1987 prototype studies were conducted at each with a lowered STS and raised operating gate (where appropriate) to determine potential guidance levels. Steelhead FGEs exceeded 80% at Lower Monumental and Ice Harbor Dams, but were only 70% at The Dalles Dam. Yearling chinook salmon guidance levels were between 73 and 77% at the former two, but only 60% at the latter.

At Bonneville Second Powerhouse, modifications to the project for research have shown the potential to increase spring guidance of yearling chinook salmon from approximately 20 to 70% through the use of lowered STSs, turbine intake extensions, streamlined trashracks, and lights in the turbine intake.

Research efforts at all of the projects showed that each project is unique and solutions that might be viable at one may not be appropriate at another. Furthermore, fish behavior and physiology apparently play a large role in successful fish guidance and even the most mechanically up-to-date bypass systems may not be successful at guiding fish.

Recently, research was completed on the Hanford Reach of the Columbia River near Richland, Washington, in an effort not related to juvenile fish passage studies. The objectives of the study were to map the distribution of fall chinook salmon redds, types of bottom materials, depth profiles, and water velocities in eight representative areas of the reach. The work was significant in that no previous survey included data on spawning activity in deep water (>10 ft). To survey deep water, the staff modified a two-diver sled patterned after one used by NMFS at Pascagoula, Mississippi. The sled was towed by a boat, and redds were mapped by the triangulation methods illustrated in Figure 7.

Substantial spawning was observed at depths >15 ft, and some spawning occurred to depths of 30 ft. It was concluded that spawning occurred in virtually all areas of the reach from shallow to deep water and that activities such as dredging could adversely affect spawning

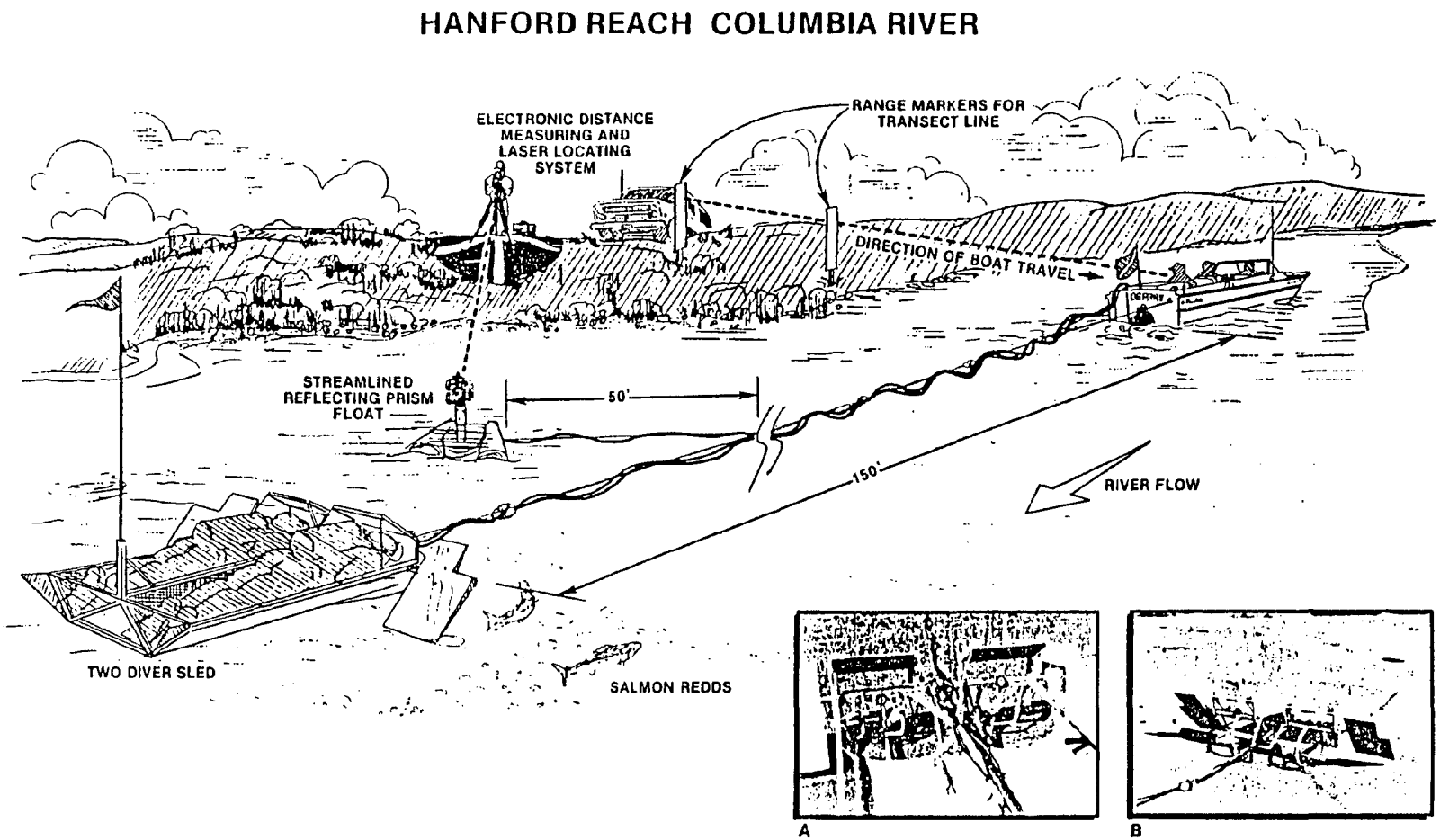


Figure 7.--Depiction of operational procedures during the 1986 deepwater survey of fall chinook salmon spawning in the Hanford Reach of the Columbia River. Inset "A" shows the water shields which deflect flow above and below the divers and the flight controls on the port side. Inset "B" is a front view of the 2-diver sled.

activity and production. More research is required to properly define the spawning potential within the reach.

Electronic Surveillance

Studies centered primarily on behavior and survival of smolts passing dams on the Columbia River. A juvenile radio tag developed by the Subtask's electronics shop was used to determine passage location and behavior of chinook salmon smolts at John Day and Lower Granite Dams. By utilizing the pulse coding capabilities of the tag and associated monitoring equipment, simultaneous releases of over 100 radio-tagged smolts were made to assess the effectiveness of the spillway for passage at Lower Granite Dam. Based upon the proportion of the river flow passing through the spillway and the proportion of the radio- tagged smolts released that passed through the spillway, a spill effectiveness model was derived. Concurrent studies of the tag's effect on smolt behavior indicated that the juvenile radio tag was not appropriate for fish guidance efficiency studies.

In 1986, the emphasis of the Subtask turned to the development and utilization of PIT tag equipment and research. PIT tags were used to estimate survival of hatchery yearling chinook salmon migrants in the Lower Granite reservoir. The study raised questions on mixing of test groups before recapture and problems with varying sampling rates at the recovery dams. This led to the current 2-year study of factors affecting collection efficiency at bypass systems.

Field Facilities

Personnel are based at field stations in Pasco and North Bonneville, Washington. The Pasco Field Station (Fig. 8) is the largest of the Division's stations and includes a complete machine-shop. Facilities are available to overhaul vehicles, cranes, outboard motors, and boats. Metal-shop activities provide for fabrication, construction, or modification of a variety of research gear from small, portable fish tanks to large, submersible traveling screens used in turbine intakes at dams. There are also riverside facilities for behavior and performance tests using either adult or juvenile salmon. These include permanent experimental raceways capable of holding more than 100,000 smolts.

Figure 8.--CZES Pasco Field Station (Pasco, Washington).

Future Projects

Task plans will address research leading to increased protection for downstream migrant salmonids at dams. The following activities will play a significant part in attaining the Northwest Power Planning Council's (NWPPC) goal of doubling Columbia River fish runs:

1) Continue evaluation of adult return data from previous and new experiments.
2) Initiate new transport evaluations from Lower Granite and McNary Dams utilizing state-of-the-art techniques with coded wire tags and brands.
3) Initiate new transport evaluations on wild spring chinook salmon at Lower Granite Dam. These fish will have been tagged with PIT tags as parr in natal areas well in advance of the smolt outmigration.
4) Define how and to what extent physiological changes associated with smolt development affect migratory behavior. Incorporate this knowledge into the design and evaluation of bypass systems, as well as the implementation of management programs like the Water Budget.
5) Determine to what extent we can biologically manipulate smolt development and associated behaviors.
6) Participate in the development and execution of NWPPC Reservoir Mortality/Water Budget Effectiveness TWG work plan.
7) Continue research on the extended STS concept utilizing a bar screen in the fish screen slot at Lower Granite Dam.
8) Evaluate extended STS prototypes at McNary Dam.
9) Continue research on bar screens as alternatives to STSs and as means to improve fish guidance.
10) Continue research on non-mechanical means, such as lights or sound, to influence fish behavior and improve guidance.
11) Refine the PIT-tag receiving equipment for use in defining juvenile fish behavior and passage at dams.

12) Conduct research with PIT tags to estimate salmonid survival within the Columbia River hydroelectric system.

13) Continue work on development of an extended-range monitoring system to detect PIT tags in returning adult salmonids.

14) Continue work on development of a juvenile acoustic tag for seawater tracking.

HABITAT INVESTIGATIONS TASK

Background

The goals of the Habitat Investigations Task are to provide information for the protection and enhancement of fisheries habitat and for predictions of effects of alterations and contaminants in the lower Columbia River, the Columbia River estuary, and along the Washington and Oregon coasts. The Task studies the relationships between organisms in freshwater and marine environments and conducts research on which management and regulatory decisions can be based.

Information from Habitat Investigations Task research is used by many federal, state, and private agencies having major activities or responsibilities in the lower Columbia River and along the adjacent coast. These agencies include COE, EPA, BPA, NMFS/ETSD, NWPPC, Columbia River Inter-Tribal Fish Commission (CRITFC), USFWS, CBFWA, Columbia River Estuary Study Taskforce (CREST), state fish, game, and environmental departments, port authorities, and utility systems. Data products and services from this Task are used to assess research results, management proposals, and permit requests; to prepare environmental impact statements; to determine optimum methods and times of maintenance dredging; to determine optimum dredge disposal methods and localities; to provide information on the survival and timing of juvenile salmonids to the estuary, which relates to the management of water and power at hydroelectric dams; and to provide environmental information leading to the protection, restoration, and enhancement of habitat and fisheries resources.

Present field work and research in the Columbia River estuary and adjacent coastal waters are largely responses to contract-supported projects for the COE and BPA. Most projects are related to the survival of juvenile salmonids through the Columbia River to the estuary and ocean or are assessments related to habitat, dredging, and dredge-disposal. Natural impacts, such as seawater intrusions, dilutions, in-river suspended matter, and sedimentation, are also studied. Assessments are made through observations of diversity, abundance, ecosystem relationships, and bioassay tests. While the projects are important in evaluating effects of various activities on the habitat, they often do not allow the flexibility to focus sufficient effort in time and space on many high priority goals or regional issues. Some limited ecosystem

information (on finfish, shellfish, and benthos) for a number of separate sites has been obtained through outside-agency support.

Accomplishments (1985-1988)

Recent Task activities are refinements or extensions of the first CZES projects in the lower Columbia River and estuary beginning in the mid-1960s. Projects continue to fall under four broad research areas: (1) background studies of the environment, (2) studies on the impacts of dredging and dredge- disposal, (3) studies on the impacts of discharged materials or heat, and (4) lower river and estuarine salmonid studies.

General Habitat/Environmental Studies

Columbia River white sturgeon--Research to determine the impact of development and operation of the hydropower system on white sturgeon (*Acipenser transmontanus*, Fig. 9) in the Columbia River Basin corresponds to the study objectives of the "White Sturgeon Research Program Implementation Plan" developed by BPA and approved by NWPPC in 1985. In response to this plan, the Task, the Oregon Department of Fish and Wildlife (ODFW), the Washington Department of Fisheries (WDF), and USFWS cooperatively developed a 5-year research proposal which addressed the following four high-priority work elements in two reaches of the Columbia River -- the estuary to Bonneville Dam and Bonneville Dam to McNary Dam:

1) Describe the reproduction and early life-history characteristics of white sturgeon populations.
2) Describe the life history and population dynamics of subadult and adult white sturgeon.
3) Define habitat requirements for all life stages of white sturgeon and quantify the extent of available habitat.
4) Evaluate the need and identify potential methods for protecting, mitigating for losses, and enhancing white sturgeon populations.

The study proposal was reviewed and approved by the regional steering committee for white sturgeon research; the research is funded by BPA.

The Task is presently responsible for parts of Work Elements 1 and 3 downstream from Bonneville Dam. This is the only reach in the Columbia River system known to support all

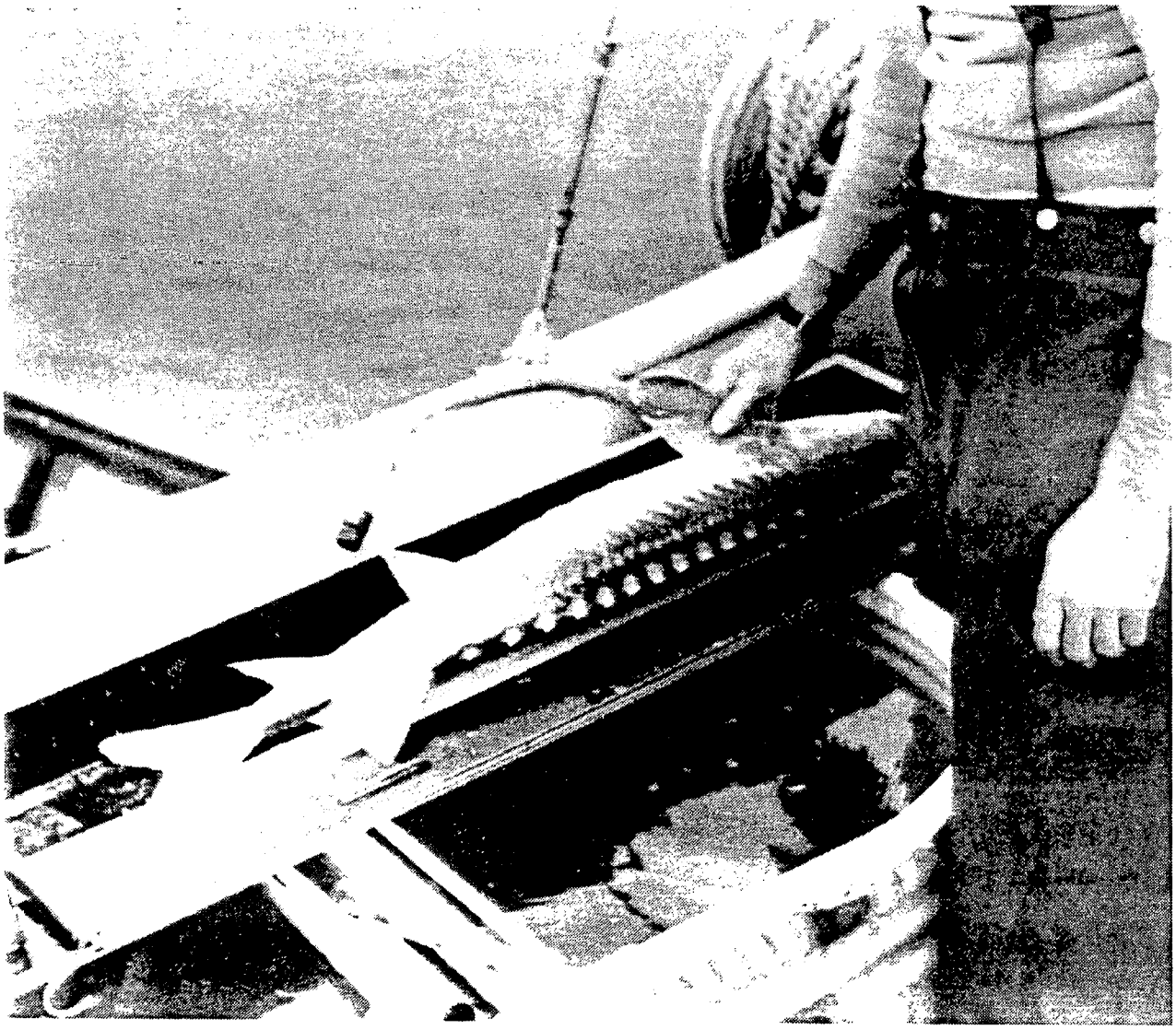


Figure 9.--White sturgeon collected for marking and release during sturgeon-habitat evaluations in the lower Columbia River.

developmental stages of white sturgeon in sufficient numbers to provide a baseline for comparison of habitat availability and utilization upstream from Bonneville Dam. Sturgeon downstream from Bonneville Dam have unrestricted access to the ocean and therefore may exhibit characteristics of sturgeon stocks prior to dam construction. This reach now supports relatively large sport and commercial white sturgeon fisheries.

Initial activities included a literature review and the testing and modification of sampling gear. Field work began in 1987 to accomplish the following: 1) determine the most suitable method for collecting white sturgeon eggs, larvae, and juveniles; 2) make a preliminary determination of the downstream distribution of white sturgeon larvae; and 3) establish index sampling sites that could be used to define the habitat preferences or requirements of juvenile white sturgeon.

During the initial year, white sturgeon eggs were first collected in a plankton net (Fig. 10) near Ives Island (Columbia River Mile (RM) 143) on 21 April. No eggs were collected downstream from Ives Island, and the last eggs collected were taken at this site on 19 June. Larvae (Fig. 11) were collected in plankton nets from 5 May to 2 June between Ives Island and the I-205 Bridge (RM 113).

Current velocities affect the behavior of white sturgeon larvae. Laboratory tests indicated an inverse relationship between water velocity and the time larvae spend in the water column. Columbia River flows are controlled or regulated by an extensive hydroelectric dam system. How these flows are manipulated may be a major factor in assuring the continuation of a productive white sturgeon population downstream from Bonneville Dam.

In 1987, a total of 1,954 juvenile white sturgeon were collected from RM 29 to 140; 1,689 of these were tagged with a numbered monel metal bird-band which was placed around the anterior ray of the right pectoral fin (Fig. 12). Distribution of white sturgeon in the Columbia River downstream from Bonneville Dam was patchy. Not only were there differences in catches among different areas, but also differences in catches among parallel transects within the same area. Relatively high catches were consistently made near RMs 131, 101, 95, and 79. Based on the 1987 field-work, five index sampling sites were established to define the habitat preferences or requirements of juvenile white sturgeon during subsequent years.

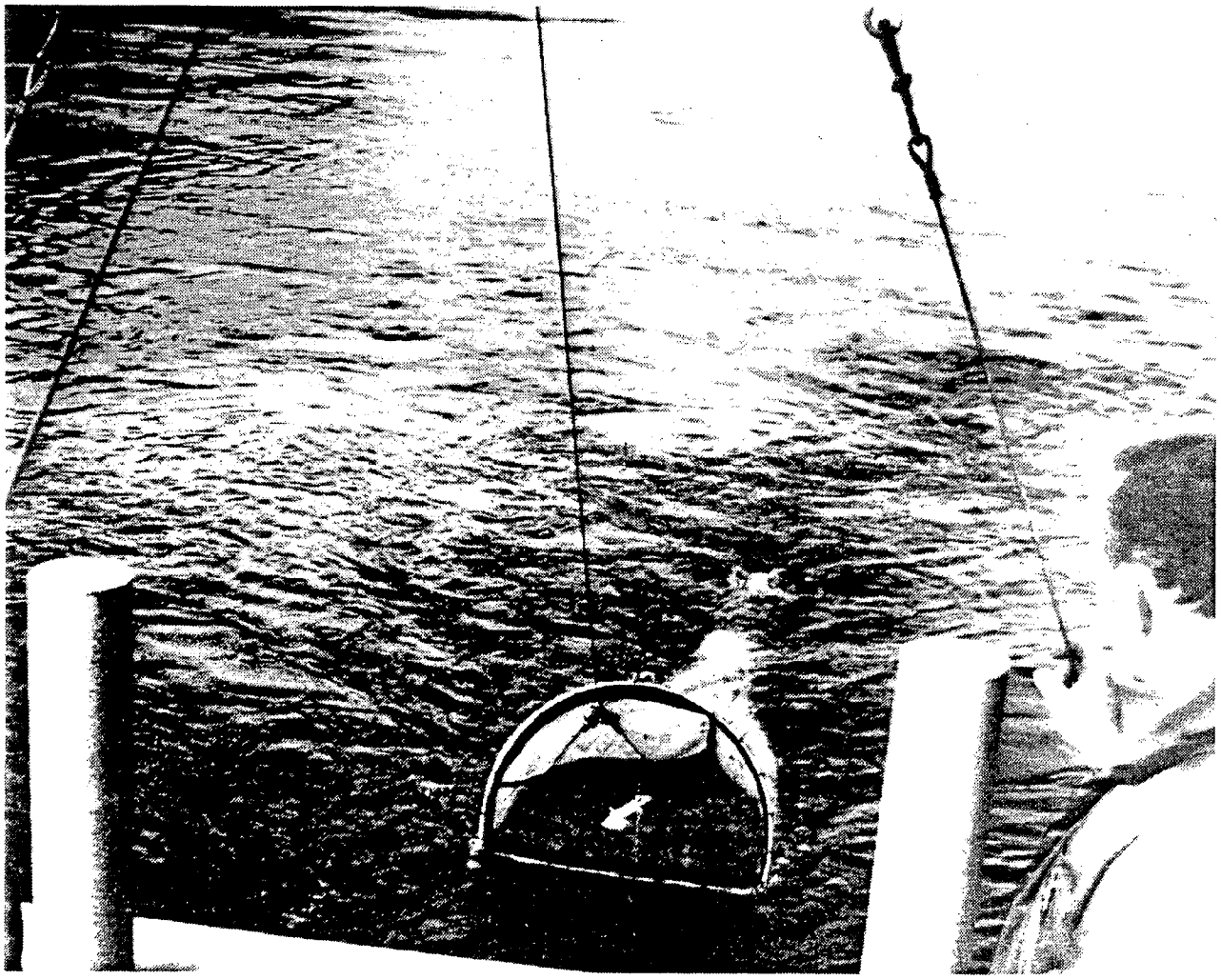


Figure 10.--Plankton net used in collecting white sturgeon eggs and larvae in the lower Columbia River.

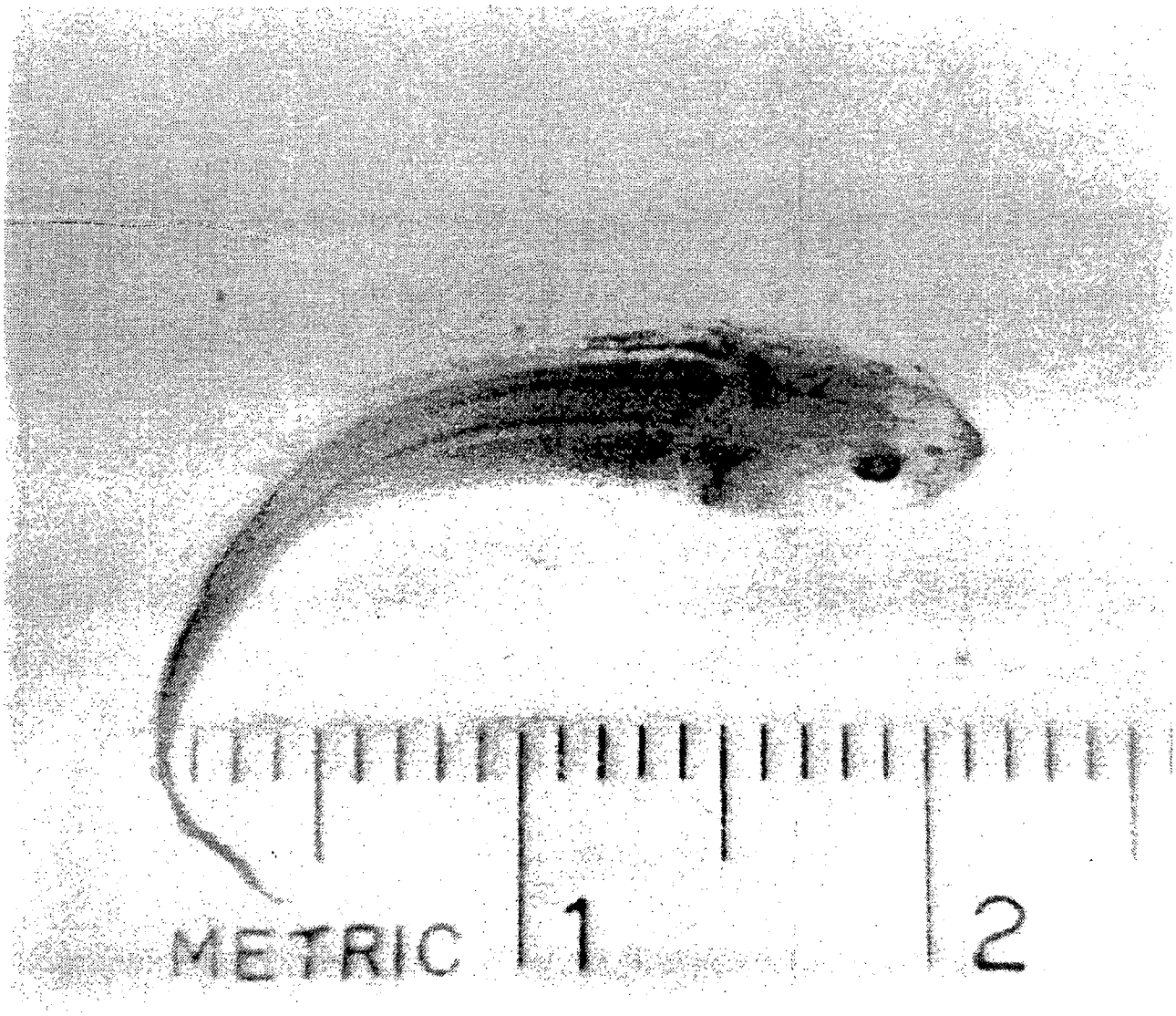


Figure 11.--White sturgeon larva from the lower Columbia River, the river's only reach where all life stages are commonly found.

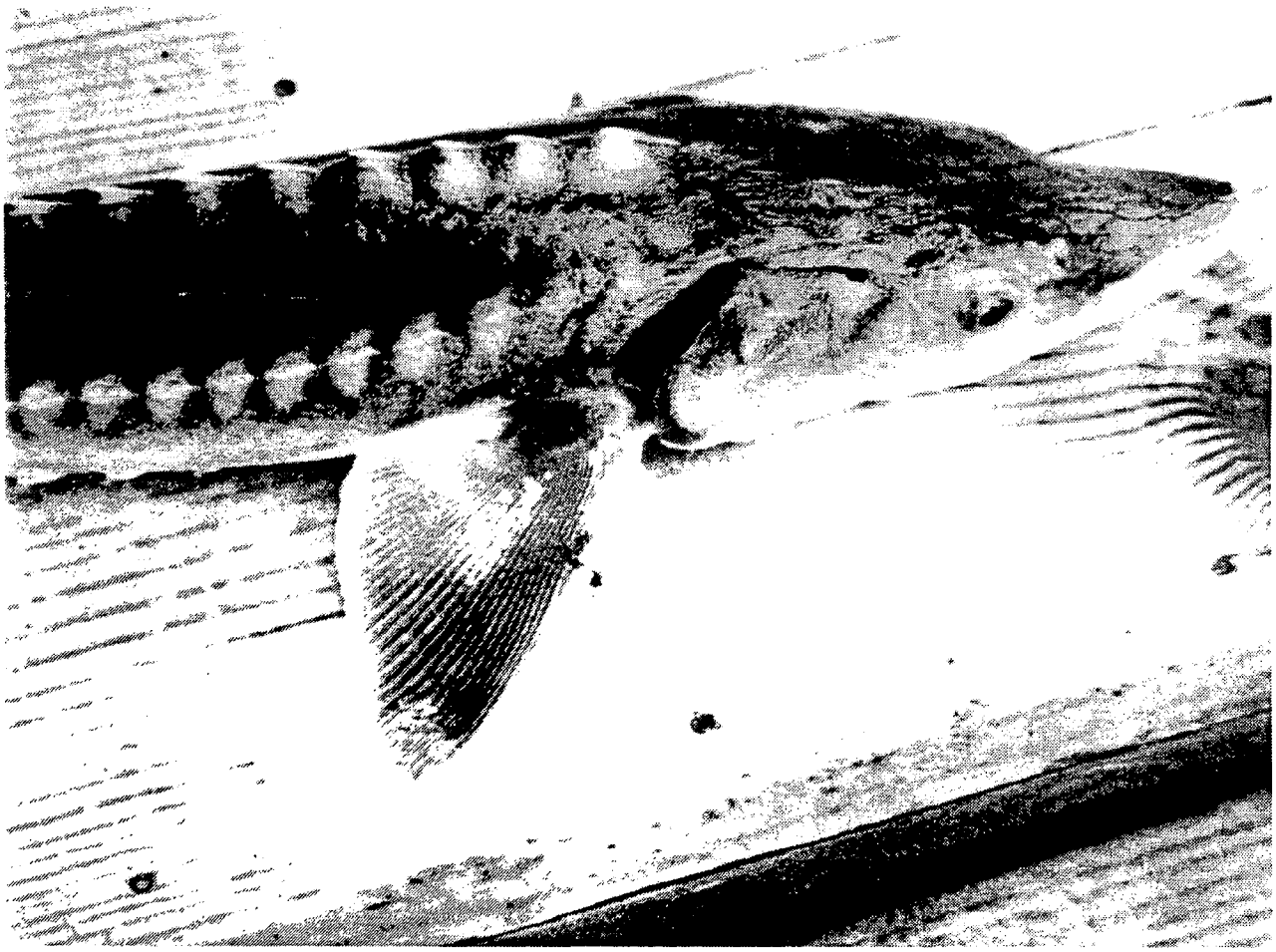


Figure 12.--A juvenile white sturgeon tagged with a bird-band tag placed around the anterior ray of the right pectoral fin.

Objectives for the 1988 field season (March through September 1988) are 1) to determine if additional spawning areas exist in the lower Columbia River, 2) to further investigate the relationship between river flow and egg and larval distribution, and 3) to use biological and physical data to focus on the habitat preferences or requirements of juvenile white sturgeon.

In 1988, we increased the catch of white sturgeon eggs and larvae by simultaneously fishing two plankton nets. Eggs first appeared in the samples on 25 April, again at Ives Island. Larvae first appeared at the same date and place as in 1987. Artificial substrate placed on the bottom of the river was also successful in capturing additional white sturgeon eggs. Through a comparison of physical (depth, temperature, turbidity, and substrate composition) and biological (fish, benthic invertebrates, and stomach analyses) factors observed at the index sites, a data base will be constructed to help determine habitat preferences and requirements.

West Coast Estuarine Inventory--In cooperation with NOAA's National Ocean Service's Ocean Assessment Division, the Task is compiling a summary data base on living marine resources for selected estuaries of Washington, Oregon, and California (Table 3). This summary will become the west coast component of NOAA's National Estuarine Inventory. The final inventory, in atlas form, will review available data on distribution, abundance, and life-history of 47 economically and ecologically important species from 32 west coast estuaries. The completed and computerized data base will enable comparisons between species, groups of species, specific life-stages, estuaries, and geographic regions.

This inventory is a necessary early step in providing documentation which will lead to coordinated regional management strategies. This report will provide a ready reference to key organisms and their distributions, and it should direct researchers and managers toward fields where new data are required. It should now be clear that considerably more information is needed, even on temporal abundances for many organisms. The fields of physiology and ecology and responses to environmental stresses have necessarily been omitted at this stage, but are the next obvious considerations.

The report reflects much effort and thought in gathering vital unpublished data and "gray literature" from a variety of groups and individuals. This is especially true for the life-history

Table 3.--Estuaries in the West Coast Living Marine Resources Inventory.

Washington	Oregon	California
Puget Sound	Columbia River	Klamath River
Hood Canal	Nehalem River	Humboldt Bay
Skagit Bay	Tillamook Bay	Eel River
Grays Harbor	Netarts River	Tomales Bay
Willapa Bay	Siletz River	Central San Francisco/ San Pablo/Suisun Bay
	Yaquina Bay	South San Francisco Bay
	Alsea River	Elkhorn Slough
	Siuslaw River	Morro Bay
	Umpqua River	Santa Monica Bay
	Coos Bay	San Pedro Bay
	Rogue River	Alamitos Bay
		Anaheim Bay
		Newport Bay
		Mission Bay
		San Diego Bay
		Tijuana River

stages that are dependent on estuaries. The included list of sources for unpublished data will be useful for clarifying and updating information.

Impacts of Dredging and Dredge-Disposal

Columbia River Estuary Long Term Management Strategy--Long Term Management Strategy (LTMS) is a recent policy initiative by the COE. To meet their future needs, the Portland District COE initiated a 2-year program to develop a LTMS for maintaining the deep-draft channel in the Columbia River estuary. The program goal is to develop a 50-year operation and maintenance plan for dredging and dredged-material disposal for the estuary portion of the channel. The Columbia River estuary is to serve as one of two national demonstration projects for the COE. The study area is the 40-ft deep-draft navigation channel from RMs 4.4 to 28.0. At present, four estuarine disposal sites --Miller Sands, Rice Island, Pillar Rock Island, and Area D (an in-water disposal site)--annually receive approximately 2.2 million cubic yards of relatively clean sand from this reach (1983-1987 average). At the current rate of dredging, it is estimated that an additional island will be created from this material every 25 to 30 years.

Miller Sands, a 234-acre horseshoe-shaped island (Fig. 13) between RM 21.4 and 25.2, was first formed from dredged materials in 1932. Since then, dredged material has been deposited on the island about every 2.5 years. It is estimated that Miller Sands has a remaining disposal site capacity of only 6-8 years. In 1974, Miller Sands was one of six sites selected by the COE Waterways Experimental Station to test the feasibility of developing marsh and upland habitats on dredged material disposal sites. Task personnel from the Prescott Field Station (now merged with the Hammond Field Station) inventoried and assessed predisposal- and postdisposal-episode aquatic habitat development at Miller Sands from March 1975 to July 1977. This study revealed little influence by the created habitat on the predisposal aquatic biological community.

The Task will soon conduct four field surveys of the fish and benthic invertebrate communities at five locations (Miller Sands, Jim Crow Sands, Taylor Sands, Desdemona Sands, and Rice Island) in the Columbia River estuary. Results from the reevaluation of the Miller Sands aquatic community (14 years after the formal habitat-creation project) will facilitate the assessment of other potential habitat-creation projects considered under the COE LTMS plan.

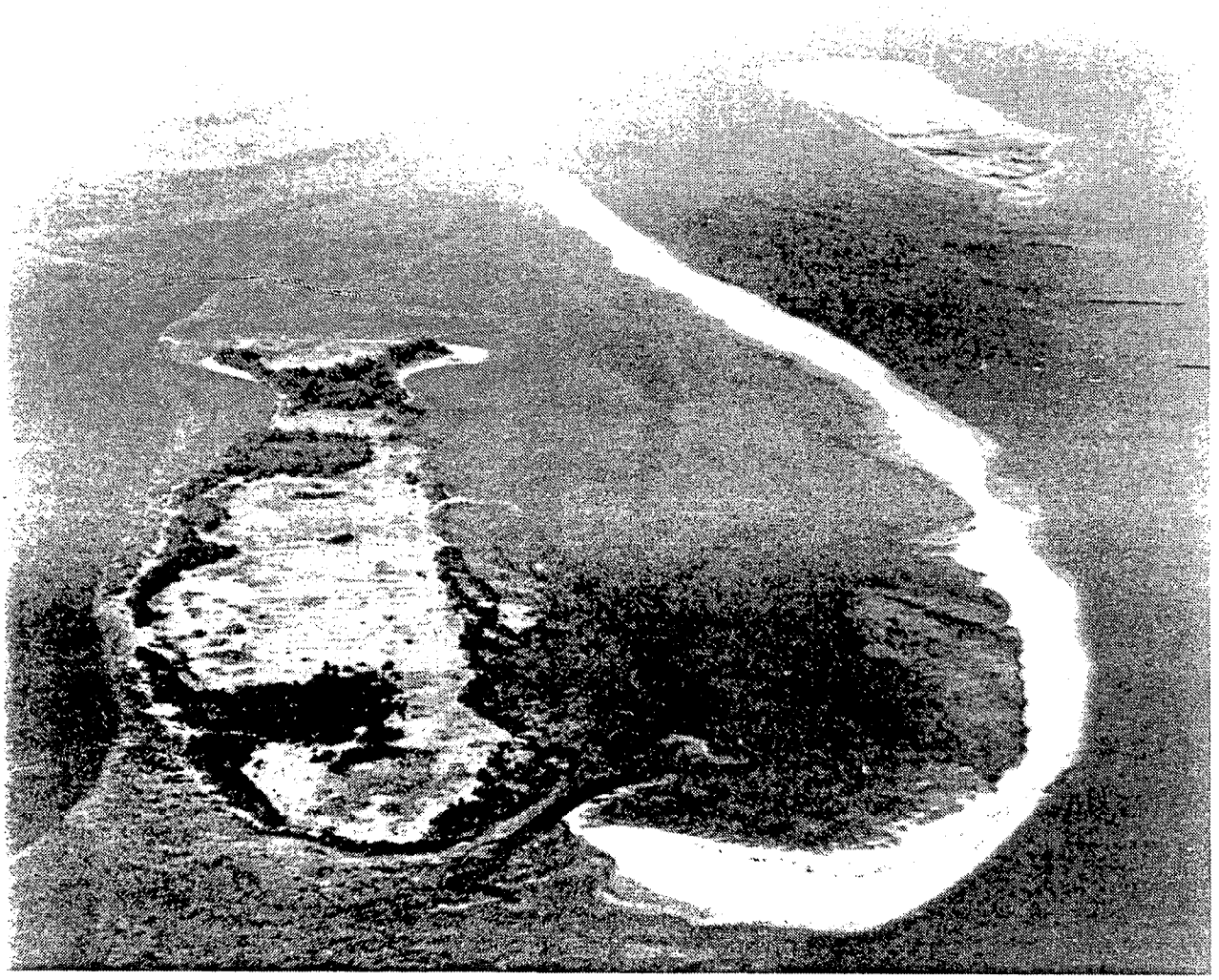


Figure 13.--Miller Sands, a 234-acre island in the Columbia River estuary, formed since 1932 from material dredged from the navigation channel.

Dungeness crab--In September 1988, the Task will complete a 5-year study of Dungeness crabs in or near frequently dredged areas of the Columbia River estuary. The study, in cooperation with the COE, was initiated primarily to investigate the impact of the 1984 deepening of the Columbia River entrance channel. Information was obtained about the estuarine and nearshore distribution, relative abundance, and size-class structure of Dungeness crabs (Fig. 14). The estuary is an important nursery area for juvenile crabs. Juvenile crabs are particularly vulnerable to hopper- and pipeline-dredging. Based on these studies, recommendations were made and accepted regarding optimum dredging times to minimize harmful effects. Because of annual population fluctuations and the commercial and recreational values of Dungeness crab, NMFS plans to continue this study.

Willapa Bay ocean dredged material disposal site--In July 1985, the Task cooperated with EPA and the Seattle District COE to conduct an ecological survey at a proposed interim ocean dredged material disposal (ODMD) site off Willapa Bay, Washington (Fig. 15). Previous studies at the proposed site indicated high benthic invertebrate densities similar to those found in Task studies off Tillamook Bay, Oregon. As a result of this survey, EPA requested additional benthic sampling prior to final site designation.

The relative abundances of demersal fishes and the largest epibenthic organisms within the Willapa Bay study area were determined from trawl samples. However, to adequately describe the fish and crab fauna, replicate samples would be needed from each depth contour.

The benthic invertebrate community, sampled with a box corer, was high in both numbers of species and densities of individuals. Benthic invertebrate densities off Willapa Bay were much higher than typically found in the Washington-Oregon nearshore environment and resembled those from the adjacent Grays Harbor, Washington, and Tillamook Bay ODMD sites. These three estuaries have extensive mud flats with microalgae and eelgrass. The cause of the high invertebrate densities is unknown, but the contribution of primary production from the adjacent estuary is a probable factor. The areal extent of the high invertebrate densities off Willapa Bay, Grays Harbor, and Tillamook Bay is not known and should be defined. Our recommendation was that these areas not be used for the disposal of dredged materials until

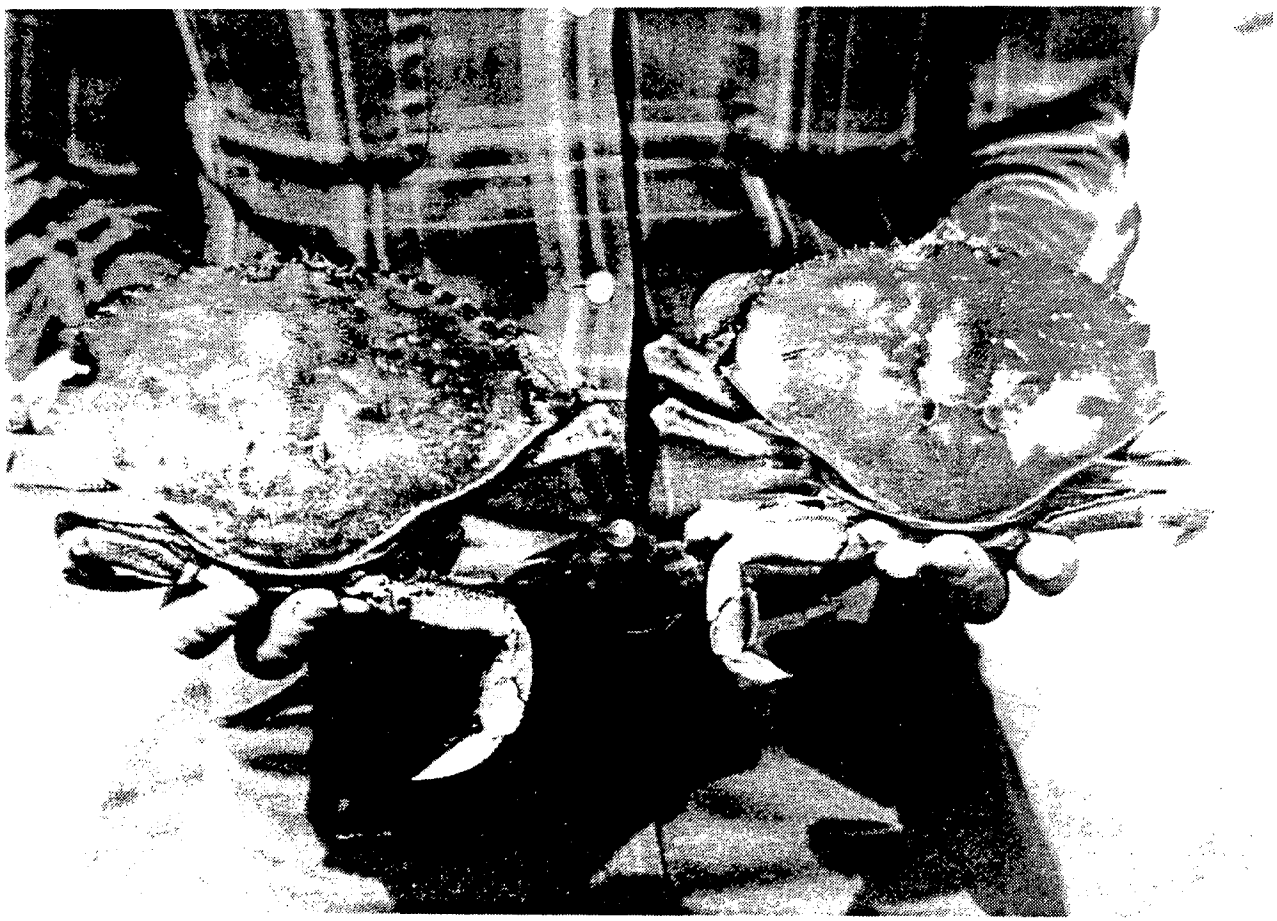


Figure 14.--Dungeness crabs are valuable commercial and recreational shellfish in the Columbia River estuary and on the adjacent coast.

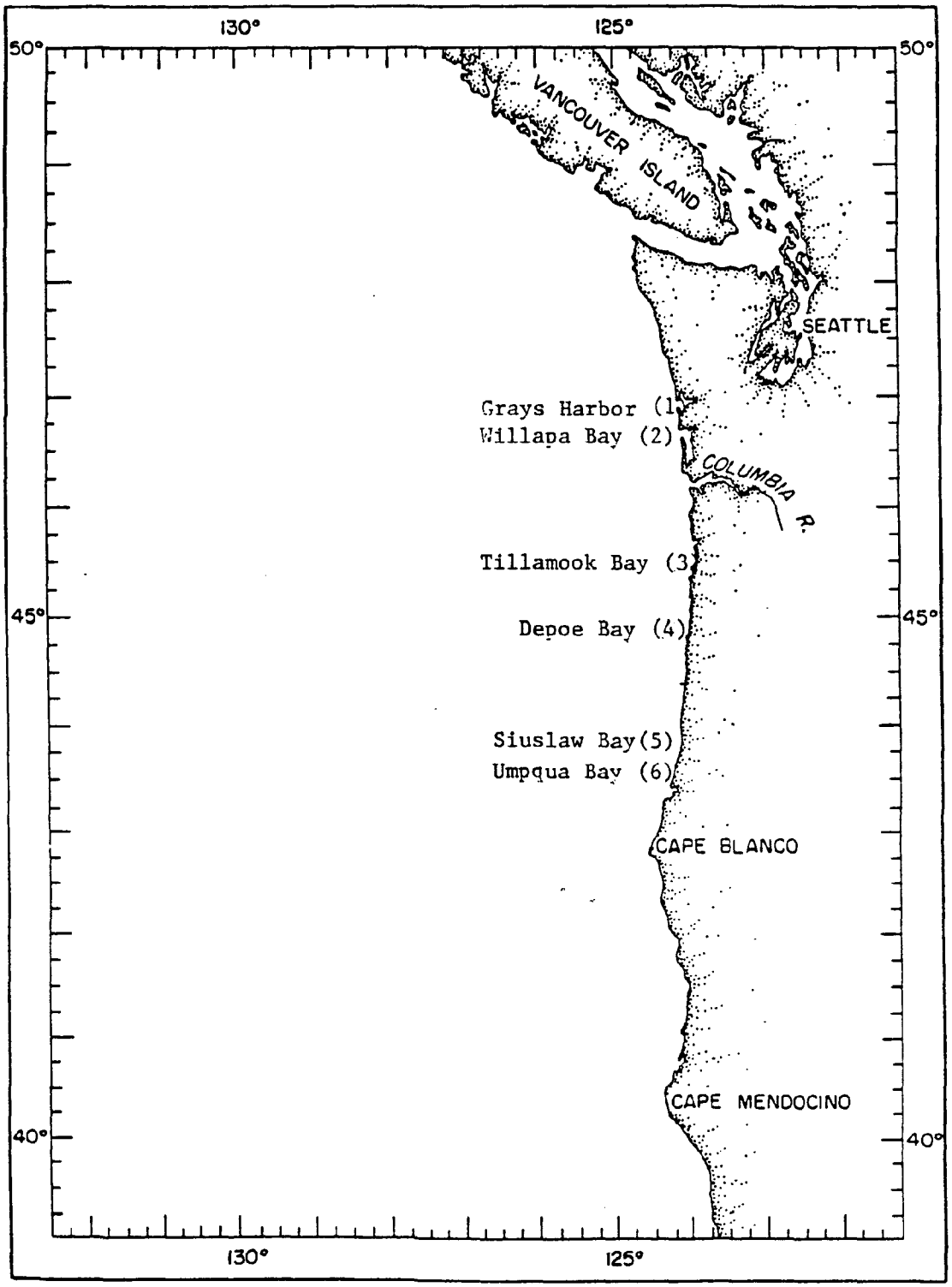


Figure 15.--Washington and Oregon coastal survey sites for interim dredge-disposal (1-4) and dredge-effects (5-6) areas.

after more intensive studies, and then only if it could be shown that there would be no severe impacts to the estuarine and marine fisheries.

Tillamook Bay ocean dredged material disposal site--The Task and the Portland District COE cooperated in a study of the demersal fish and benthic invertebrate communities at four interim ODMD sites along the Oregon coast (Fig. 15). One site was offshore from Tillamook Bay, Oregon. Two surveys (September 1984 and January 1985) showed that the benthic invertebrate population was greater at Tillamook than at the other three sites. The high populations of demersal fishes and benthic invertebrates off Tillamook Bay led to a third survey in July 1985. These three surveys suggested that very high densities of fishes, crabs, and benthic invertebrates occur annually at the Tillamook ODMD site.

The Tillamook offshore site has not received dredge spoils since 1977. It has recently been suggested that this site be used for the disposal of fine-grain material dredged from the federal portion of the bay's entrance navigation channel. There is concern over the existing site because of the high numbers of benthic invertebrates; concerns are magnified when disposal of fine-grain material is considered. The Portland District COE accompanied by Task personnel conducted a field sediment survey in May 1988. Sediments were collected along a transect extending offshore from the existing disposal site. Preliminary examination of the sediment samples indicated a possible reduction in benthic invertebrates 2.4 miles offshore at an approximate depth of 200 ft. The Task will conduct a fourth survey at the extended Tillamook offshore dredge-disposal site in September 1988 to determine its suitability as a disposal site for the bay sediments and to establish baseline data for future monitoring.

Umpqua River in-bay dredged material disposal site--In August and October 1987, the Task, in cooperation with the Portland District COE, conducted a study on benthic invertebrate distribution and habitat in the Umpqua River estuary (southern Oregon coast) at an interim in-bay dredged-material disposal site. The analysis and report of this project are not yet complete. These data will supplement Task data from two surveys each off Depoe, Siuslaw, and Umpqua Bays in 1985 (Fig. 15).

Passage Survival of Juvenile Salmonids at Bonneville Dam

In 1987, the Task and the Portland District COE began a multi-year study to evaluate survival of 0-age chinook salmon passing through the second powerhouse turbines, juvenile bypass system, and spillway at Bonneville Dam. Groups of 20,000 or 30,000 fish (annual total 1.8 - 2.0 million) were coded wire tagged (CWT) and freeze branded, then released at various sites above and below the dam during June and July.

Assessment of results is by comparison of percentages of treatment-group brands recovered at Jones Beach (Columbia River estuary, RM 47) in the year of release and from CWTs recovered from adult returns (on-going sampling programs conducted by state and federal fishery agencies).

Preliminary results obtained from the first 2 years of marked-fish releases at the dam and recoveries at Jones Beach indicate the following:

1) Turbine mortality is about 12%, similar to that from studies done at other dams in past years.
2) Survival of fish traveling through the bypass system was poorer than expected; visual examination of the system has not provided clues to the problem. Additional fish releases, with purse seine sampling just below the bypass outfall, are planned for assessing types and rates of injury specifically from the bypass.
3) Greater than expected mortality occurred in marked fish released at a shore site downstream from the dam. This site was used frequently in prior years for release of transported fish from Columbia River and Snake River collection facilities.

Unfortunately, flows were not high enough in 1987-1988 to provide for assessment of spillway passage survival.

Adult-return tag recoveries will be the final assessment criterion, but preliminary recovery data from Jones Beach provided observations of two potentially serious problems in fish passage through and near Bonneville Dam.

Field Facilities and Vessels

Hammond, Oregon (RM 8.7)

The location of CZES staff at Hammond, just west of Astoria, was in response to increased and broader responsibilities in mandated environmental research. The waterfront Hammond Field Station (Fig. 16) is ideally suited for estuarine and coastal studies. The Task occupies the former Point Adams Coast Guard Rescue Station. The main building dates from the 1930s, but is sound and solidly built. Although not designed as a research facility, the building provides excellent service. Together with the main building, there is a garage/shop, a storage building, and a fourth building which will eventually be converted into a bioassay laboratory with flow-through fresh water/seawater. We are using this as a wet lab with a minimum amount of refurbishing and cost.

There are no onsite structures for vessel moorage, although we have estuarine access on our pier. The station's smaller vessels are kept at the Hammond boat basin, about 1/2 mile to the west. The largest vessel, the Sea Otter, is moored at the Warrenton boat basin, approximately 4 miles to the east.

The station has its main shop and warehouse at Tongue Point, east of Astoria, 12 miles from the station. This property is now owned by Oregon as an industrial site. Negotiations are underway for us to vacate the present location. Under the property-use agreement, the state is obligated to provide NMFS with equivalent facilities elsewhere.

Clatskanie, Oregon (RM 47)

The Clatskanie Field Station, with several portable buildings, is on leased property at Jones Beach. After extensive exploratory sampling, on both Oregon and Washington shores, Jones Beach was chosen in 1968 as the principal location for capturing downstream migrant salmonids entering the estuary. The constricted site permits effective and optimal sampling by beach- and purse-seines of an estimated 0.1-0.6% of all migrating salmonids from the upriver basin. Operations began at Jones Beach in 1966 and, except for 1973-1976 and 1984-86, have been continuous during outmigrations. The facilities are also used by other agencies in cooperative studies.

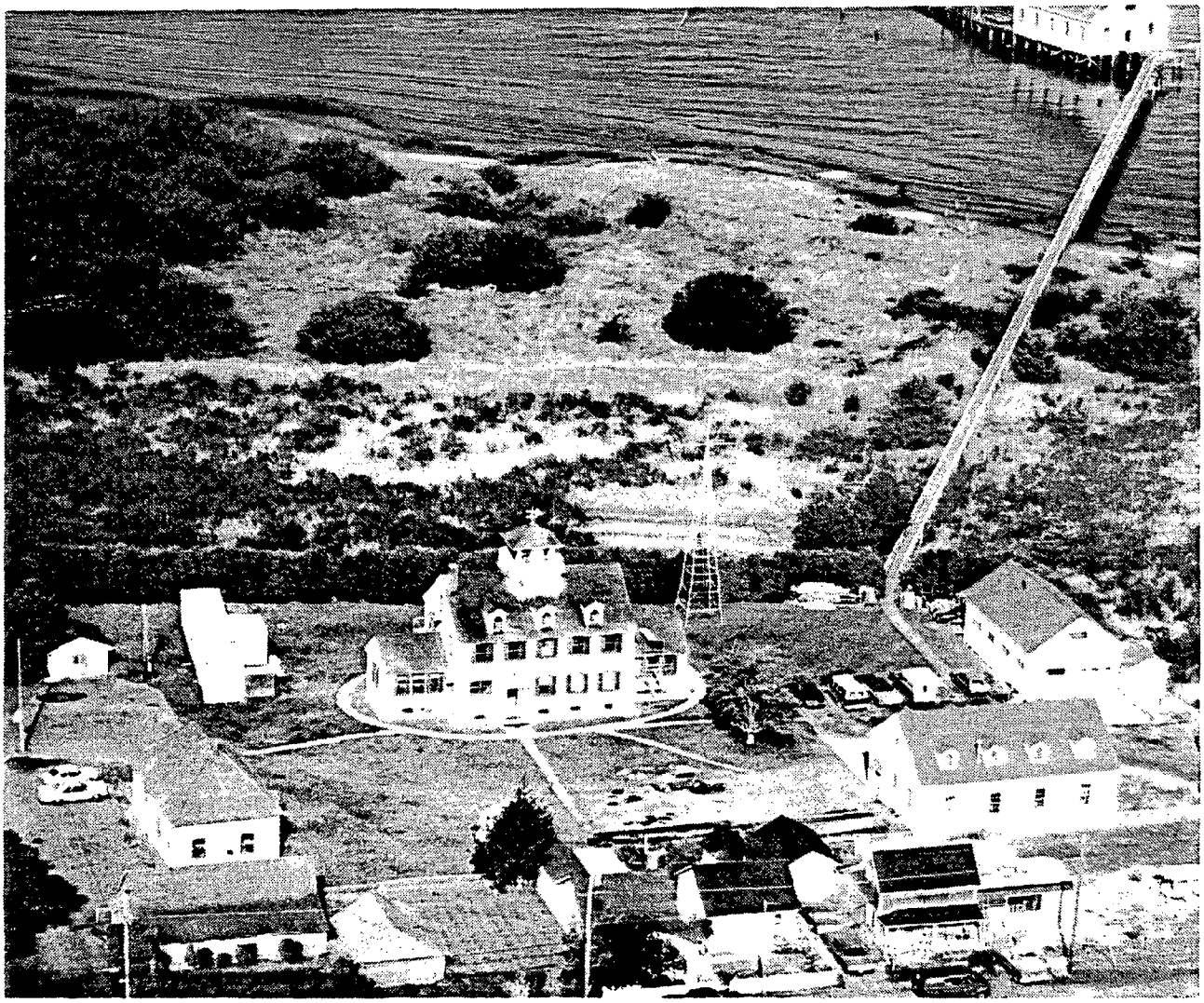


Figure 16.--CZES Hammond Field Station (Hammond, Oregon), former Point Adams U.S. Coast Guard Rescue Station.

Research Vessels

Our principal vessel is the 57-ft Sea Otter, built in 1975 (Fig. 17). Her present capabilities are trawling (8-m shrimp trawl), benthic sampling (box corer, epibenthic sled, etc.), plankton tows, and water sampling. Two large hydraulic winches will soon replace a single small winch to increase trawling capabilities to commercial-sized nets or two 8-m trawls. Electronics include VHF and single-side-band radios, 24-mile radar, Loran-C, RDF, and depth sounders. Cruising range is 1,000 miles, and a minimum sampling crew of four is required. Sea Otter is primarily used for Columbia River mouth and ocean/coastal studies.

Other vessels include the Columbia (Fig. 18), twin gasoline-powered 36-ft fiberglass hull built in 1977; Egret, twin diesel-powered 40-ft wooden hull; and Nerka, twin diesel-powered 40-ft steel hull. The latter two are converted Coast Guard utility/rescue boats that are fast but due to the narrow beam are relatively unsuitable for nearshore ocean studies; they are used in the estuary and in the river. Columbia is a more-stable work platform and has been used for purse-seine studies in the nearshore surf-zone but is too small for everyday offshore work. Capabilities of these vessels are trawling, purse seining, pot fishing, and benthic/epibenthic sampling. Electronics include VHF radios, depth sounders, and radars. Crew requirements, depending upon project, are two to four. The Clatskanie Field Station has an inboard-outboard 26-ft purse- seine barge and four outboard-powered dories from 20 to 22 ft. The Hammond Field Station has two 17-ft Boston Whalers and a 23-ft inboard-outboard dory.

Future Projects

There are several research areas that may logically and fruitfully be expanded or intensified. Most of the potential projects are tied to outside funding and therefore the likelihood of developing any particular project is uncertain. Task efforts in the next 2-3 years will focus on projects which apply directly or indirectly to high-priority regional issues, such as the following:

1) The ecology and survival of juvenile salmonids in the critical transition from fresh water to the marine environment.
2) Seasonal ecosystem studies within the Columbia River estuary.
3) Effects of specific dredging activities in the Columbia River.

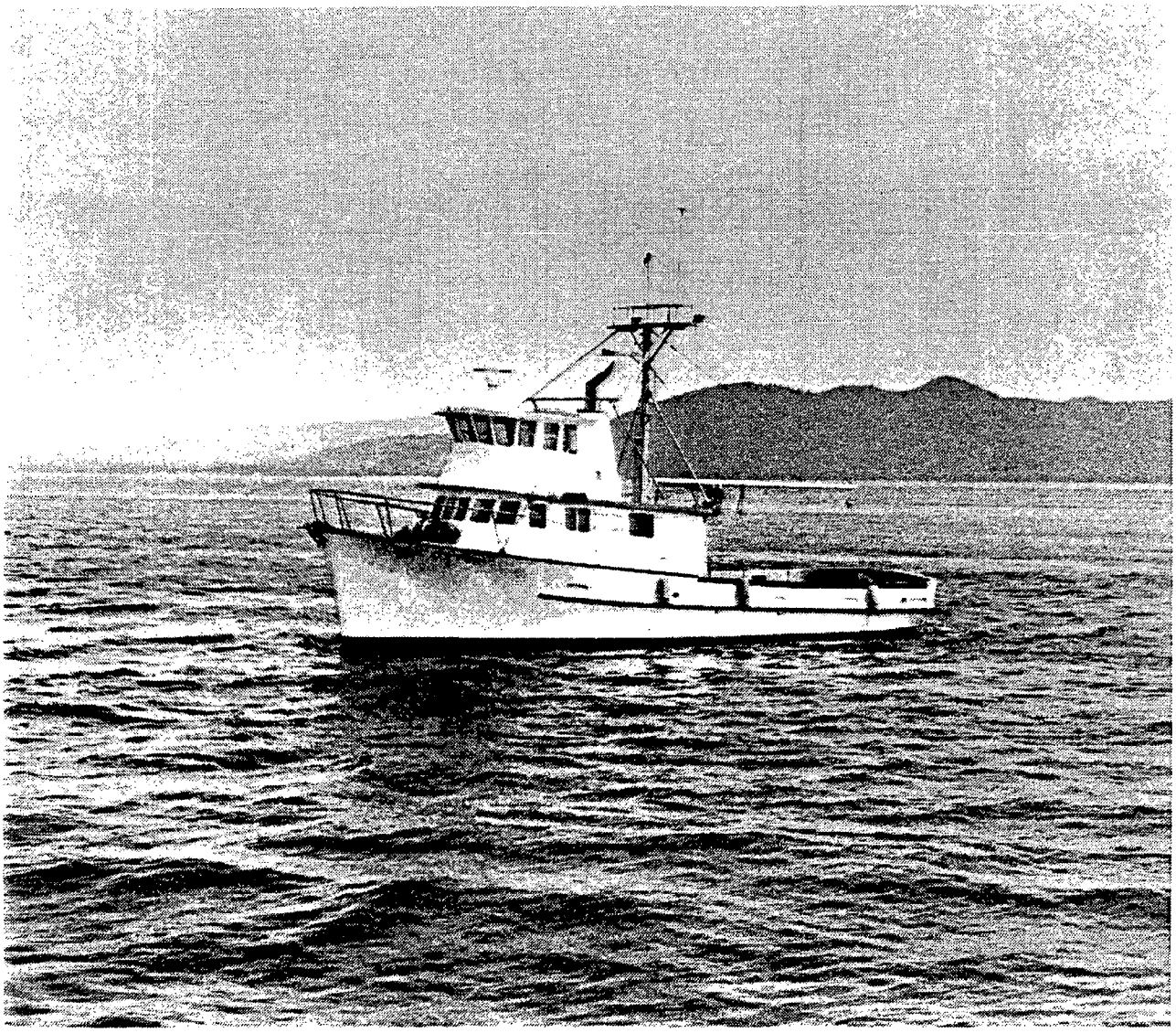


Figure 17.--Habitat Investigations Task's 57-foot Sea Otter, used primarily for fisheries-resource impact studies along the Washington and Oregon coasts.

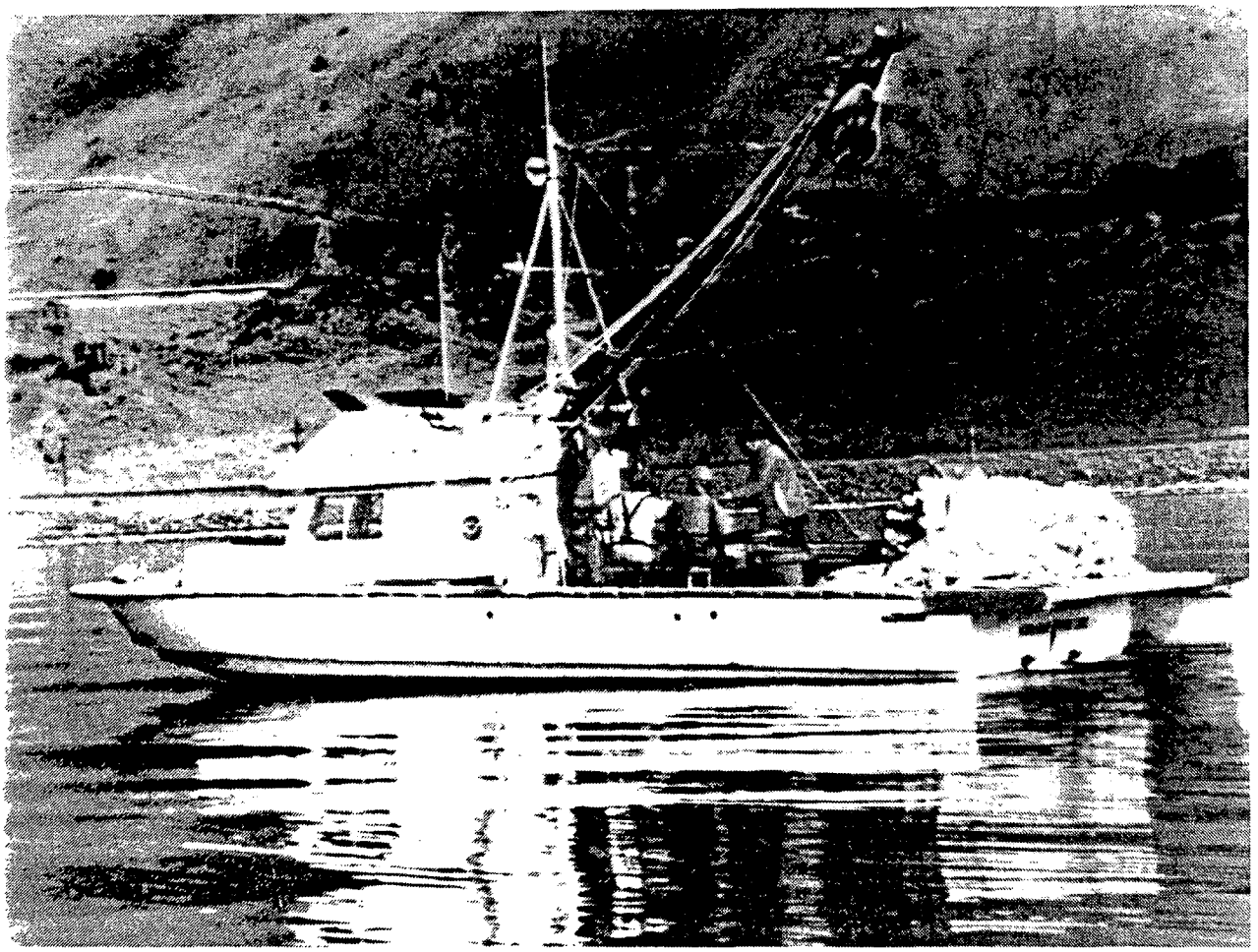


Figure 18.--The 36-foot Columbia, used mainly for purse-seining in the Columbia River estuary.

4) Seasonal ecosystem studies at coastal dredge-disposal sites.

5) The survival of juvenile salmon using known passage routes at hydroelectric dams.

The Task will also encourage the development of, and solicit funding for, the following research projects:

1) To study juvenile salmonids in the Columbia River estuary and provide early evaluations and more-precise interpretations for experimental hatchery releases and to monitor smolt quality and incidence of disease.

2) To establish a long-term habitat database for the lower Columbia River and the Columbia River estuary.

3) To establish a long-term benthic habitat database for the marine waters adjacent to the Columbia River.

4) To investigate the effects of dredging and commercial trawling on coastal Dungeness crab populations.

5) To study the anchovy population and its relationship to salmonid survival and growth off the Columbia River.

6) To study the lingcod population off Grays Harbor.

7) To evaluate the extent of industrially-polluted sediments in the Columbia River.

8) To determine a "fluoride budget" for the Columbia River system.

9) To investigate the effects on production of trace inorganic and organic materials in salmonid hatchery water.

FISHERIES ENHANCEMENT TASK

Background

The goals of the Fisheries Enhancement Task are to develop and test methods for restoring and enhancing depressed salmon runs. The very nature of these runs, which are captured in common-property fisheries as they migrate across a complex of international, federal, and state-managed jurisdictions, necessitates a strong federal role. The mandate for NMFS participation in fisheries enhancement activities is included in several federal legislative acts and treaties and is expressed in congressional authority establishing the Columbia River Development Program of NMFS (Mitchell Act) which funds the majority of hatcheries on the Columbia River system. In 1985, these hatcheries released 110 million chinook and coho salmon and steelhead smolts. Our research programs are aimed at developing new information to enhance anadromous salmon runs by (1) improving the operational efficiency and contribution of federally-funded public hatcheries; (2) developing biochemical genetic methods for identification of salmon stocks in the international mixed-stock fisheries off Oregon, Washington, Canada, and Alaska; and (3) developing marine husbandry techniques for maintaining captive brood-stocks of severely depleted wild runs.

Improved Productivity of Mitigation Hatcheries

The hatchery enhancement of salmon and steelhead is a major part of regional salmonid management strategy--hatcheries produce more than one-half of the salmon caught in Washington, Oregon, and California. In 1987, more than one-half of all Pacific coast salmon and steelhead releases were made from Columbia River hatcheries. However, a 20-year decline in survival of Columbia River chinook and coho salmon has generated many questions about changes in ocean productivity, quality of riverine and estuarine habitat, and hatchery smolt quality. Increased hatchery releases in recent years have not resulted in increased harvest. The improved efficiency of operation of these public-sector hatcheries is considered by many to be the most economical means of improving the contribution to ocean and river fisheries. Releasing juveniles better fitted for marine survival can produce the same results as increasing production through new hatchery construction, but at lower cost.

The Task is developing methods for producing quality smolts that will migrate more rapidly down river, adjust quickly to the ocean environment, survive better at sea, and thus contribute more adult fish to the fishery. Specific objectives of the program are to develop physiological measures of smolt development in hatchery fish, determine environmental/husbandry factors affecting smoltification in hatchery fish, develop low cost methods to control the timing of smoltification, and devise new rearing/release strategies to improve the contribution of adults to the fisheries. When fully developed, these new methods will allow federal and state managers to optimize the time of release. Techniques for altering the timing of smoltification will provide management agencies with tools to program releases to coincide with or avoid environmental events in the river, estuary, and ocean (e.g., to avoid periods of low flow at Columbia River hydroelectric dams, to match releases with high productivity in the ocean, or to avoid a massive single pulse of outmigrants from hatcheries).

Genetic Stock Identification of Pacific Salmon in Ocean Mixed Fisheries

Genetic Stock Identification (GSI) and the maximum likelihood model for analyzing mixed-stock fisheries were developed in CZES. With funding from BPA and the Pacific Salmon Treaty, we have developed a coastwide baseline of data to test the GSI technique in actual mixed-stock chinook salmon fisheries off the Washington coast. The GSI has proven to be a valuable tool to fill the evaluation and accounting void for U.S./Canada managers.

This method of stock identification uses electrophoretically detectable differences between stocks to estimate their contributions to mixed-stock fisheries. The GSI is unique in providing a comprehensive view of the contributions of both hatchery and wild stocks and makes feasible in-season management of mixed fisheries.

The allocation of chinook salmon stocks to the nation of origin is a major goal of the 1985 U.S./Canada Treaty. Allocation is dependent on rapid identification of component stocks in mixed-stock fisheries for in-season management. The ability to rapidly identify migratory chinook salmon stocks by nation of origin is a powerful tool and would allow the passage of threatened wild U.S. stocks through limited closures and focusing the fishery on more abundant hatchery stocks.

The U.S./Canada Treaty outlines a number of ocean fishery management commitments in Annex IV which require the development and use of GSI and other new stock identification tools. Key U.S./Canada management needs for developing coastwide chinook salmon management require the following: (1) the evaluation of harvest limitation programs designed to minimize impacts on weak stocks and (2) annual U.S./Canadian interception estimates based on actual fishery sampling rather than simulated or theoretical approaches. Annex IV further provides for specific evaluation of the potential for in-season management.

The present goals of the GSI program are to expand the collection of chinook salmon baseline data into rivers of British Columbia and southeastern Alaska; provide the Pacific Fisheries Management Council (PFMC) and the U.S./Canada Commission with detailed analyses of chinook salmon stocks comprising mixed fisheries of Washington, Oregon, and British Columbia; and improve the operational efficiency of laboratory and computer analysis methods.

Captive Brood-stock Programs for Restoration of Depleted Wild Stocks

Some unique genetic races of wild salmon and steelhead of the Pacific Northwest are severely depleted or nearly extinct. One method for preserving these remaining wild stocks until natural habitats are restored is to maintain them in total culture, increasing their numbers through successive generations until large numbers can be returned to their streams of origin. The goal of our captive brood-stock program is to develop marine husbandry programs that ensure good health and high survival of certain races of chinook and Atlantic salmon while maintaining genetic integrity and variability.

The maintenance of chinook salmon brood-stocks and associated research will provide cost-effective methods to maintain egg banks of depleted populations of Puget Sound and Columbia River stocks. The White River spring chinook salmon stock has historically made significant contributions to ocean and lower Puget Sound fisheries and is uniquely adapted to the White River environment. This distinct genetic race is extinct in the wild, with only a few transplanted individuals returning to WDF's Minter Creek Hatchery. The largest single gene pool of this stock exists as a totally cultured population in our captive brood-stock program at the Manchester Marine Experimental Station. Task research continues to attempt to solve the

difficult problems of disease control, nutritional requirements, and environmental requirements for maintaining captive chinook salmon brood-stocks.

The specific goals of this project are to develop experimental fish-farming techniques for threatened spring and fall chinook salmon races; develop methods for diagnosis, treatment, and prevention of infectious and nutritional diseases; develop techniques for synchronous maturation and ovulation of marine cultured salmon; and to return selected native fish to viable self-sustaining levels.

Accomplishments (1985-1988)

Improved Productivity of Hatcheries

The phenomenon of parr-smolt transformation in anadromous salmonids has been studied for many years. It is universally recognized that much of the success in freshwater restoration and enhancement programs, sea ranching, and seawater net-pen culture is dependent upon the production of high quality smolts. It is also recognized that environmental factors and fish cultural practices have important effects on the process of smoltification. Therefore, to be consistently successful in producing high quality smolts, cultural practices that retard smoltification must be identified and eliminated and those that enhance smoltification must be incorporated.

Since smolt development is crucial to the survival of cultured salmonids, it is imperative that managers have available some objective measures of smolt development to correlate with survival and with which attempts to improve success can be evaluated. One of our major goals is the development of objective biochemical and physiological indicators of the smoltification process that are unbiased by the subjectivity of the evaluator.

The pursuit of methods to measure smolt development has led to an increase in understanding of some of the basic biochemical and physiological changes and some of the environmental factors, both favorable and adverse, that influence parr-smolt transformation. The following narratives describe some of the results of our recent studies:

1. Developmental physiology and biochemistry

° We have found that the net production of high-energy compounds (ATP and GTP) increases in red blood cells during smoltification in coho salmon.

° We have observed that migration greatly increases gill Na^+-K^+ ATPase activities and decreases blood thyroid hormone levels and that this is accomplished in a highly correlative way in chinook salmon. These results suggest that a period of migration is required to complete smoltification which is not usually achieved in the hatchery environment.

° In a cooperative study with Oregon State University, we observed a dramatic drop in immune response (as measured by the production of plaque-forming cells) corresponding to gill Na^+-K^+ ATPase increases in coho salmon.

° Smoltification, as measured by gill Na^+-K^+ ATPase activities and by seawater challenge, is suppressed in coho salmon under conditions of high density and reduced water flow in rearing ponds. Adult returns of coho salmon to the hatchery were likewise reduced.

° In a cooperative study with USFWS, unusual smoltification was observed in 0-age spring chinook salmon that were progeny of adults induced to spawn early by subjection to reduced day length. Tagged 0-age salmon were released in May and June to compare survival with controls held for normal release 1 year later, at age 1+. Adult return results are being evaluated.

2. Endocrinology of smoltification

° The parr to smolt transformation (smoltification) of juvenile salmon involves morphological, physiological, and behavioral adaptations for downstream migration and residence in the sea. Smoltification proceeds according to an endogenous developmental rhythm that is mediated by photoperiod and temperature among other environmental factors. The

endocrine system plays a pivotal role in controlling the rate and completeness of smoltification. Our studies and those of other investigators show that many endocrine glands and hormones are involved. We have observed that blood levels of insulin show a distinct peak at the beginning of the transformation. Increased activity of the thyroid gland during smoltification is associated with increases in blood plasma concentration of thyroxine (T_4) and (depending on the species) triiodothyronine (T_3). Plasma cortisol levels increase subsequent to the increase in circulating T_4. In some cases, plasma estradiol has been shown to follow a pattern of increase and decrease similar to that of T_4. These hormones function in the control of growth and metabolism, morphological change, homing imprinting, migratory behavior, immune response, and seawater adaptability.

° Changes in the levels of the hormones, thyroid hormones in particular, can be used as indicators of the timing and duration of smoltification. These indicators, combined with others like Na^+-K^+ ATPase, may be an index to determine appropriate times for release of fish from hatcheries or for transfer of fish from fresh water to seawater. Since the process of smoltification in each hatchery is affected by ambient environmental conditions and nutritional status of the fish, these endocrine indicators are precise objective measures that can be used in developing techniques for maximizing and controlling smoltification.

3. Smolt indices and patterns of smoltification at hatcheries

° One of our primary goals is to relate measurements of smolt development (indices) in hatchery fish to postrelease performance. Patterns of gill Na^+-K^+ ATPase activities in 0-age fall chinook salmon at Spring Creek NFH often differ from year to year. Starting in 1978, we related postrelease migratory performance of serially released tagged groups of Spring Creek salmon to patterns of gill Na^+-K^+ ATPase. Migration data strongly suggest that when released, poorly smolted 0-age chinook salmon tend to migrate more slowly and closer to the shoreline than fully smolted fish that move rapidly seaward in the center of the Columbia River. These ongoing studies have shown a significant correlation between adult contribution and smolt development as measured by gill Na^+-K^+ ATPase.

° Recent studies suggest that reduced efficiency of fish bypass guidance systems at Columbia River dams may be related to the lack of complete smoltification of the migrants. Spring chinook salmon taken from the lower portions of turbine entrances had significantly lower gill Na^+-K^+ ATPase activities (poor smolts) than guided salmon (better smolts). For fish released into the Columbia River from hatcheries just above hydroelectric dams, the status of smoltification at release may be important to how efficiently they can be diverted from the turbines.

4. New rearing/release strategies

° Present methods used at the Little White Salmon NFH to rear spring chinook salmon are excellent examples of how cultural techniques can affect smoltification. Upon entering a covered hatchery holding pond, returning adult spring chinook salmon are placed under decreasing day lengths using controlled electric lighting. This results in early spawning (about 1 month) and, consequently, early hatching. We have found that the resulting progeny, which are larger than those from normally spawned adults, exhibit signs of smoltification in their first spring at age 0. A study is now underway to assess the feasibility of releasing 0-age spring chinook salmon smolts. If successful, the number of smolts released from this facility could be about 4-fold greater than at present, with rearing time reduced by about 11 months.

° Yearling spring chinook and coho salmon and steelhead respond to advanced photoperiods by accelerating smoltification. In some instances, accelerated smoltification may provide a solution to problems generally encountered with early releases. We have been cooperating with BPA in a study of spring chinook salmon at Dworshak Hatchery. In 1988, a tagged group of yearling spring chinook salmon was placed on an advanced photoperiod schedule which caused early smoltification (measured by gill Na^+-K^+ ATPase activity). This group was released with a control group to evaluate the effect of accelerated smoltification on downstream migration.

° Gonadal development in salmon can be blocked either by induction of a triploid condition or by the early treatment of embryos and alevins with androgenic steroid hormones. The resulting sterile or neutered salmon cannot mature at the normal time (3 years of age for coho salmon). Canadian studies of sterile Pacific salmon suggest that the sterile adults will not show the normal homing response of returning to fresh water to spawn. Instead, the sterile fish will remain in seawater and continue to grow or be caught in the fishery. Studies are completed with the collaboration of the WDF on the potential use of sterile salmon for enhancement of the Puget Sound fishery. Coded-wire-tagged, sterile coho salmon were released in May and July 1985 from the Puyallup Hatchery. The distribution and appearance of these fish in the fishery were monitored and results are being analyzed. Initial results indicate that some sterile fish remain in the fishery at least 1 year longer than normal fish, and the 4-year-old steriles are caught primarily in the ocean sport fishery. The use of sterile salmon in fisheries enhancement programs could represent a new management strategy for reducing excess returning adults at particularly successful hatcheries and for the development of trophy-sized hatchery fish.

Genetics

Genetic Stock Identification (GSI) has been the major focus of the Genetics Subtask for the last 8 years. This program is aimed at obtaining detailed genetic profiles (baseline data) of distinct breeding stocks of Pacific salmon species to permit the accurate estimation of stock contributions in various mixed-stock fisheries. This goal has been achieved for ocean and terminal harvests of chinook salmon from northern British Columbia through California, and similar studies have been initiated for coho salmon.

Detailed data are available for chinook salmon to identify major population groups within the areas of intense sampling (northern British Columbia through California). The current set of baseline data includes gene frequencies estimated from as many as 30 genetically variable protein systems (or loci), based on samples averaging over 100 individuals from nearly 200 populations. Eight major genetically based regions were identified: (1) the Fraser River tributaries east of the Cascade Crest, (2) Strait of Georgia, (3) Puget Sound, (4) a broad coastal

region ranging from the west coast of Vancouver Island southward through northern California, (5) the Columbia River below The Dalles Dam, (6) the Columbia River above The Dalles Dam, (7) the Snake River, and (8) the Sacramento River. Genetic differences between stocks within a region are typically smaller than between stocks of different regions. Nevertheless, genetic differences between stocks within a region often permit their identification in mixed-stock fisheries. Groups from differently timed spawning migrations within a region tended to conform to the general genetic pattern of the region. Transfers appear to have rendered some hatchery populations indistinguishable (e.g., Carson-Leavenworth-Kooskia, Spring Creek-Big Creek-Bonneville). Nevertheless, the general persistence of genetically distinct geographical regions suggests (1) that genetically adapted groups within regions have largely resisted assimilation of genes from differently adapted populations and (2) that interbreeding of genetically distinct groups is inadvisable. Resampling of populations indicated that their genetic characteristics remain stable between generations and among year classes; thus, the effort to acquire baseline data does not require regular repetition.

The GSI directly addresses needs of major management plans (e.g., NWPPC, Pacific Salmon Treaty, PFMC) by providing stock composition information both in-season and post-season. Beginning in 1982, the GSI has been used to provide and accumulate information on the temporal and spatial distribution of chinook salmon stocks in mixed-stock fisheries. These fisheries have included recreational, commercial, and Indian Treaty fisheries off the coast of Washington, Strait of Georgia, West Vancouver Island, and the Fraser River and in terminal fisheries of the Columbia River. This type of information was the basis for setting Washington coast chinook salmon quotas for the last 4 years.

A promising beginning has been made toward obtaining a usable set of genetic profiles to estimate compositions of stock mixtures of coho salmon. These data dispel concerns about using the GSI approach for coho salmon because of minimal levels of genetic variation previously observed in this species. An intense screening of 100 protein-coding loci revealed 20 loci with sufficient genetic variation to clearly distinguish eight stocks sampled from British Columbia through California. Composition estimates of simulated mixtures of these stocks were accurate and precise. Separation of Canadian and American stocks was particularly good. These

findings suggest that distinct regional population units exist in coho salmon as well as in chinook salmon, and that, with an expanded set of baseline data, GSI will provide accurate and precise estimates of stock mixtures of coho salmon.

The genetics unit remains at the forefront of technology regarding stock identification. New procedures for gathering and analyzing data are regularly assimilated into the methods used. A reflection of this activity is the recent work comparing patterns of variation of mitochondrial DNA with those observed for protein variants.

Captive Brood-stock Programs

Since 1979, the Task has been involved with brood-stock egg production for restoration of threatened runs of Atlantic and Pacific salmon. The captive brood-stock concept involves the transfer of smolts into marine net-pens where they are reared until maturity.

Captive marine rearing offers the unique opportunity to document developmental factors (like growth and health) during an otherwise unobservable period of the fish's life-cycle. The closed-culture rearing of chinook salmon resulted in the accumulation of information and development technology that can best be described under the separate categories of husbandry/egg production, fish health, and induced ovulation.

Husbandry/egg production--The marine culture of chinook salmon has been problematic. The chinook salmon populations we have observed at the Manchester Marine Experimental Station suffer chronic mortality that accelerates with age of the fish, resulting in less than 10% overall survival. These seawater mortalities are primarily due to bacterial kidney disease (BKD) and to adult-phase marine pathogens (recently documented by Task pathologists and described in the Fish Health section). Our investigations indicate that chinook salmon in seawater must be cultured at low density (under 8.0 kg/m^3) and under darkened (covered) conditions. However, even the best culture techniques now available cannot alleviate the marine disease problems of chinook salmon.

The chinook salmon egg-bank program conducted at Manchester is an on-going cooperative effort with the WDF for restoring the White River spring chinook salmon run. Although, this stock of chinook salmon is susceptible to marine diseases, the program is currently able to

supply up to 50,000 eggs per year for restoration--about one-half of all White River spring chinook salmon eggs available for this purpose. The program has, therefore, been instrumental in the maintenance of this stock. However, further investigations of marine diseases are also necessary before this program can supply sufficient numbers of eggs to fully rehabilitate the White River run.

Fish health--Most literature pertaining to salmonid disease deals with pathogens and parasites affecting juvenile fish in hatchery situations. The remaining approximately 85% of the salmon life-cycle remains for the most part a "black hole" insofar as fish health is concerned. Basic defense mechanisms against infectious disease may be compromised in fish held captive and fed artificial diets. This premise is demonstrated by the relative severity of some epizootics that occur in marine net-pens. Nevertheless, we feel that these exaggerated situations will provide an excellent opportunity for the development of new information regarding wild-fish health.

The following synopsis resulted from several years of observations and experimentation at Manchester:

° Task personnel have documented two new, previously undescribed protozoan parasites of marine cultured salmon:

(a) *Parvicapsula* sp. a myxozoan parasite, was diagnosed as the cause of significant mortality in coho salmon cultured in commercial marine net-pens.

(b) *Kudoa thyrsitis*, a common protozoan parasite of Pacific hake and many other indigenous species, appears to exist in symbiosis with these hosts. However, when unnaturalized stocks of Atlantic salmon are cultured in Puget Sound, they can be parasitized by *K. thyrsitis* and mortality may occur.

° Chinook salmon brood-stock programs at Manchester have been compromised by systemic infections of adults by a previously undescribed organism designated the Rosette pathogen. Taxonomy of the agent has proven difficult, but the eukaryotic organism is probably a fungus or colorless alga. The organism was successfully cultured on a chinook salmon embryo. Tests

demonstrated that the antifungal drug Amphoteracin-B inhibited growth of the pathogen in vitro. The disease caused by the Rosette pathogen affects primarily Snake River fall chinook salmon; however, White River spring chinook salmon are also infected, usually to a lesser degree.

° White River spring chinook salmon are susceptible to another adult disease that is manifest as a severe anemia, with hematocrits of 10% packed cell volume (35% is normal) or less. This condition was designated Marine Infectious Anemia (MIA) since injection of blood from infected adults produced the condition in naive chinook salmon in fresh water. The causative agent has been identified as a microsporean parasite.

° BKD is considered by Pacific Northwest fishery pathologists as one of the major causes of poor survival of chinook salmon stocks. In addition to the Rosette pathogen, BKD has been responsible for significant losses in the chinook salmon brood-stocks held in marine net-pens. Mortality usually begins 6 months after transfer to seawater and may continue to maturity. Recent trials with BKD-free smolts transferred to seawater suggest that the disease is either transmitted horizontally in seawater or exacerbated by the stress of seawater entry.

Induced ovulation and spawning--Difficulties in the spawning of adult salmon include prespawning mortality that is either natural or associated with diseases (especially furunculosis and fungus). Considerable asynchrony in the timing of spawning of a large population of brood stock may lead to problems, since it may take several months between the spawning of the first and the last fish.

Induction of ovulation through the injection of hormones allows a greater egg-take since prespawning mortality may be reduced or eliminated. Furthermore, synchronizing the spawning of the population offers a more efficient use of staff and resources. Also, the resulting eggs and fry can develop at the same rate.

Although spawning of fish through the use of pituitary gland extract has been practiced for over 50 years, the recent use of a brain hormone, gonadotropin-releasing hormone (GnRH), will

greatly enhance the effectiveness of inducing spawning. GnRH is a small (10 amino acid) peptide that acts by stimulating the release of the fish's own pituitary gonadotropin. A synthetic analogue, des Gly^{10}, D-Ala^{6} GnRH ethylanide (GnRHa), is a more potent form of the naturally occurring hormone and is the peptide of choice for spawning fish. Salmonids are particularly sensitive to GnRHa and usually spawn within 6 to 10 days after the first of two injections (3 days apart) at a dose of 5 to 10 mg/kg body weight.

New studies have been proposed using a novel technology for the manipulation of fish reproductive cycles. Fish are implanted with inert plastic capsules that slowly release gonadotropic hormones. It is hoped that these techniques can be used to induce vitellogenesis and ovulation in a more rapid and synchronous manner.

Passive Integrated Transponder Tag

In 1983, the Task began to evaluate the technical and biological feasibility of adapting a new miniature identification system, known as a Passive Integrated Transponder (PIT) tag, to salmonids. The PIT tag is proving to have broad application to fisheries science in monitoring movement and behavior of test organisms. The project has been funded primarily by BPA.

The tag consists of an antenna and a 42-bit preprogrammed computer chip. The tag is a cylinder measuring 12 mm long by 2.1 mm in diameter. Each tag is uniquely coded with one of about 34 billion codes. The tag is passive, having no power of its own, and thus must rely upon an external source of energy to operate. A 400-kHz signal is sent from an exciter, received by the tag antenna, and converted to power which operates the tag electronics. A 40- and 50-kHz signal is then transmitted from the tag antenna to the monitor system where the signal is processed. The tags can be read through soft and hard tissue, liquid, glass, and plastic but not through metal. Extreme heat or cold does not influence the detection and reading of the tag. The small tag is now mass produced and is commercially available.

Our research is divided between laboratory and field studies. The laboratory work is directed at developing tagging techniques for juvenile and adult salmonids; finding the best anatomical areas for tag placement; documenting effects of the tag on growth, survival, and behavior; and testing tag retention and tissue response.

Results of the laboratory tests show that the body cavity is a good area for tag placement in both juvenile and adult salmon ranging in weight from less than 3 to 9,000 g. The tag has no significant affects on growth, survival, or swimming performance of juvenile salmon. Tests were conducted to determine the minimum size salmon that can be PIT tagged and maintain 100% survival and 95% tag retention over an extended time. Tag retention appears related to fish size. We believe that the minimum size limit will be between 1.5 and 4 g.

Tissue response to the tag is minimal. The tag is injected using a modified hypodermic needle and syringe. The tagging wound is closed within a day, and at 60 to 70 days the wound is invisible. Necropsies have shown the majority of the tags are not attached by mesentery and are located within the body cavity just posterior to the pyloric caeca and near the spleen.

Field studies are directed at determining the tag-reading efficiency of PIT-tag monitors at dams. Juvenile PIT-tag monitors have been installed at Lower Granite, Little Goose, and McNary Dams on the Columbia-Snake River System. At present, the only adult monitor is at Lower Granite Dam. Results of tag-reading efficiency tests using 0-age and yearling chinook salmon and steelhead showed a minimum of 95% of the tagged fish released into the wet separators at Lower Granite and McNary Dams were recorded. Tag-reading accuracy (correct decoding of the tag) was greater than 99% for all tests.

Although further laboratory and field tests will be conducted this year, it appears that the PIT tag has the potential of becoming a useful tool for fishery biologists for both juvenile and adult salmonids.

Yakima River Basin Sockeye Salmon Restoration Program

In 1987, CZES began a BPA-funded study of the feasibility of restoring sockeye salmon to Cle Elum Lake (the largest reservoir in the Yakima River Basin). Donor stock smolts will be used in studies to assess outmigration potential from the lake and downstream survival through the Yakima River. Acquisition of donor stock involves the collection of adult sockeye salmon from the Wenatchee River system for brood egg supply. Returning adults are captured at a fishway, moved to floating pens in Lake Wenatchee, and held through spawning in September and early October. All spawners are examined for health status, and the gametes are reared in isolation at a quarantine station at the NMFS Montlake facility.

The purpose of the adult collection program is to provide disease-free juvenile sockeye salmon for outmigration and enhancement studies in 1989 and 1990. A major concern is infectious hematopoietic necrosis (IHN) virus which is problematic in sockeye salmon. The results of 1987 work were very encouraging; over 95% of the 263 adults collected survived to spawning, and certification procedures showed 100% of the spawners to be IHN free. This resulted in nearly 130,000 IHN-free fingerlings that are currently being reared for outmigration studies in spring 1989. An additional 520 adults were collected from the Wenatchee River in late July 1988 to provide progeny for outmigration studies in 1990. Prespawning survival to mid-September 1988 has been over 95%; the fish are apparently healthy, suggesting that this year's spawning will also be successful.

Coho Salmon Survival in Grays Harbor

The Fisheries Enhancement Task is involved in cooperative research with WDF in the Grays Harbor area of western Washington. Two major rivers, the Chehalis River (the second largest river system in Washington) and the smaller Humptulips River, flow into Grays Harbor. Coho salmon from the Chehalis River have significantly lower survival and contribute fewer adults to the fishery than salmon from the Humptulips River. As part of an investigation to determine the cause of the differential survival, wild and hatchery fish from both rivers were sampled biweekly from early March to June 1987 and 1988.

Task biologists conducted intensive investigations into the status of smoltification and general health of the Grays Harbor area coho salmon. The following factors were evaluated: 1) gill Na^+-K^+ ATPase changes, which indicate the development of seawater tolerance and reflect how well the fish are smolting; 2) concentration of two thyroid hormones, triiodothyronine (T3) and thyroxine (T4), which indicate the success of the early stages of smoltification; 3) body shape (morphometrics), which progressively alters through smoltification; 4) fish condition (K) and body coloration, which also change during the smoltification cycle; and 5) fish health status.

Over 800 coho salmon fingerlings and smolts were examined for grossly detectable disease and microscopically for incidence of nanophyetiasis, a disease caused by a digenean fluke that is indigenous to the Grays Harbor area. In 1988, coho salmon smolts from the Humptulips Hatchery were transported via barge through the inner harbor (Chehalis watershed) and the

Humptulips estuary in an effort to mimic the natural meanderings of downstream migrants. After barging, these fish were transported to marine net-pens at the Manchester Marine Experimental Station to test effects of this exposure on ability to survive in seawater.

Data generated from investigations of smoltification and fish health are being analyzed and will be the subject of a multi-agency publication. Humptulips Hatchery smolts that were barged to the inner harbor (Chehalis) did not survive seawater challenge at Manchester as well as smolts barged in the Humptulips estuary.

Field Facilities

The Fisheries Enhancement Task maintains three facilities: the Manchester Marine Experimental Station (Fig. 19) near Manchester, Washington, on Clam Bay, a small bay adjoining the central basin of Puget Sound; another station at a USFWS facility near Cook, Washington, in the Columbia River Gorge; and a freshwater station at the University of Washington's (UW) Big Beef Creek Station near Seabeck, Washington.

The Manchester Marine Experimental Station is housed in a refurbished naval fire school on 22 acres of land surplused to NOAA in the late 1960s. The building contains five laboratories, six offices, and computer and conference rooms. Adjoining the main building is a smaller disease diagnostic laboratory containing a pathology lab, two offices, a darkroom, and a small experimental hatchery.

A major advantage of the site is the excellent quality seawater. Clam Bay is a major tidal mixing zone between Sinclair and Dyes Inlets to the west and waters of central Puget Sound to the east. Excellent water quality combined with an 800-ft pier made available to us by our next door neighbor, the EPA Region X Laboratory, make Manchester an excellent site for experimentation/culture of a variety of finfish and shellfish.

At the end of the pier there are two small laboratories supplied with pumped seawater and an adjoining experimental salmon-farm (Fig. 20) consisting of a staging float and 35 net-pens of various sizes. Total combined rearing space is 4,100 m^3.

The Cook Field Station is in the USFWS laboratory adjacent to the Willard NFH. The station is located in the heart of hatchery country and is within easy distance of most of the NMFS Columbia River Development Program hatcheries. The USFWS makes available to us

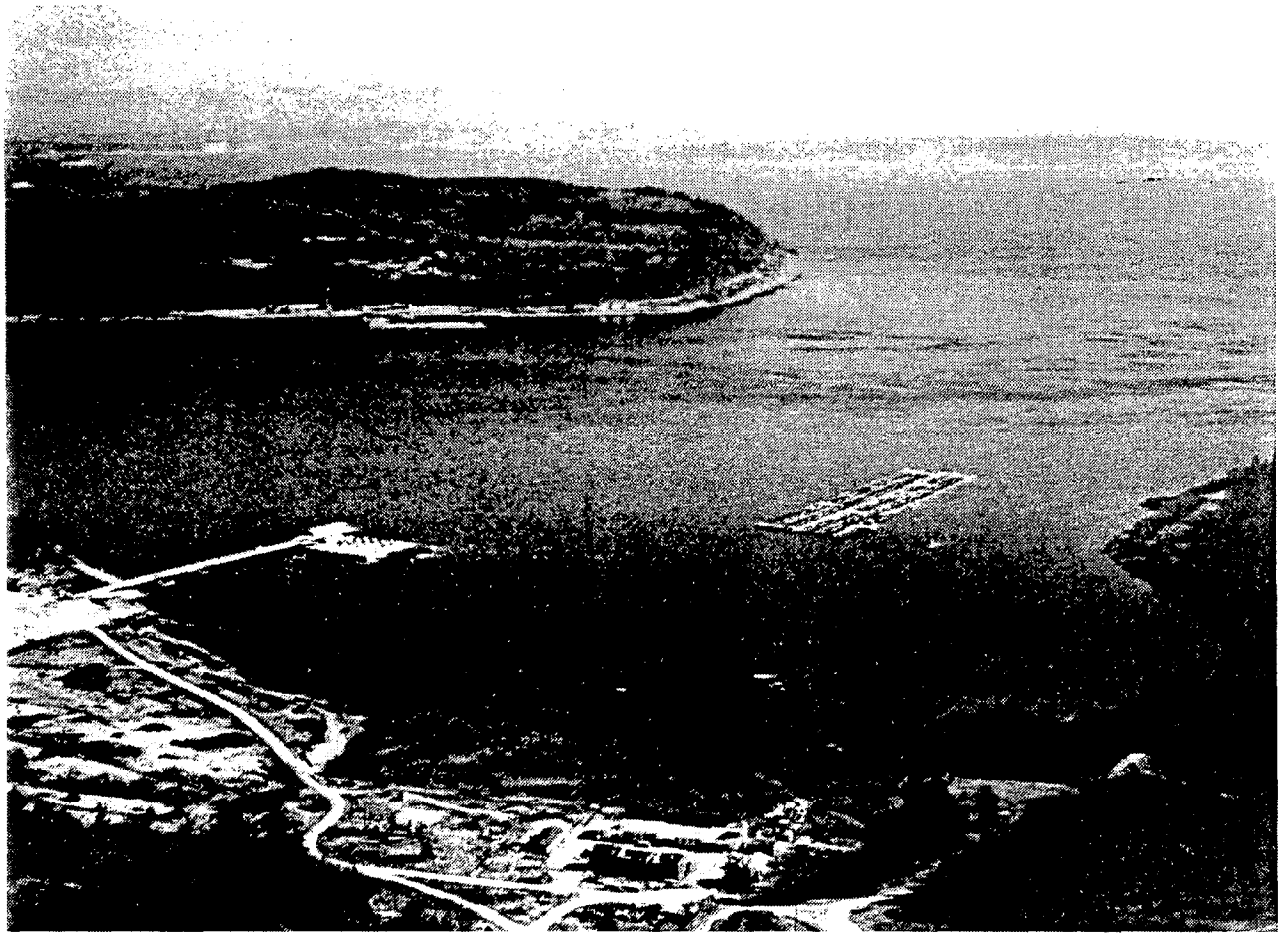


Figure 19.--CZES Manchester Marine Experimental Station (Manchester, Washington), on Clam Bay, western shore of Puget Sound; Seattle in background.

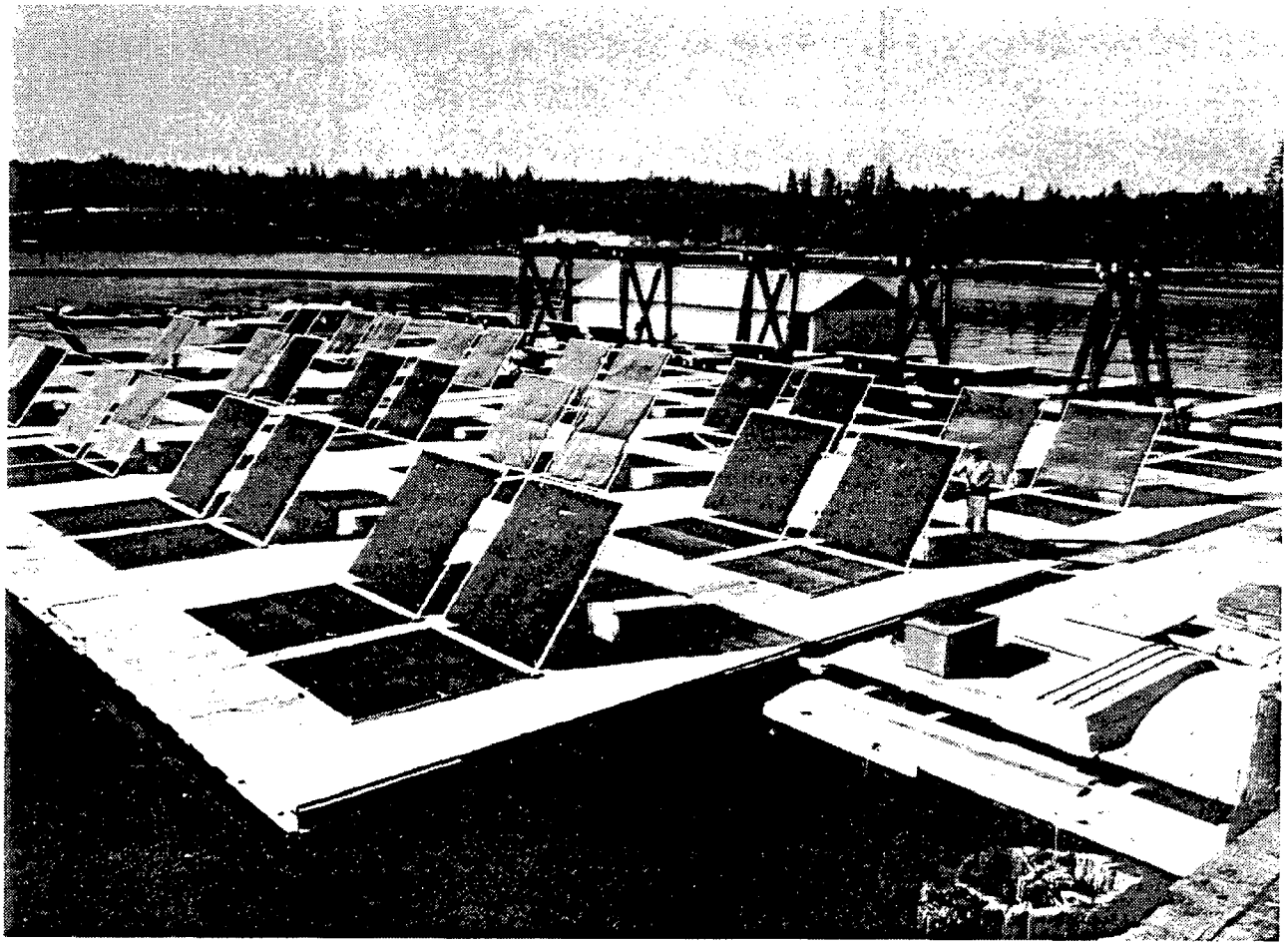


Figure 20.--Floating net-pen complex at Manchester Marine Experimental Station.

one chemistry laboratory and office and limited experimental rearing facilities. However, most of our work is conducted at the state and federal hatcheries themselves.

The Task also maintains an experimental hatchery facility the UW Big Beef Creek Station near Seabeck on Hood Canal. Excellent quality artesian water of constant 10°C is supplied to 20 circular rearing containers (1-3 m diameter).

Future Projects

Future research in the Fisheries Enhancement Task will depend in part on the development of research proposals that are acceptable to cooperating agencies. Areas of research that deserve attention and effort are as follows:

1. Investigations of the endocrine mechanisms controlling the development of precocious maturation in chinook and Atlantic salmon.
2. Research on the effects of nutrition on the endocrine control of growth.
3. Investigations on the horizontal transmission of infectious hematopoietic necrosis (IHN) virus in seawater.
4. Research and development of freshwater rearing strategies for endangered chinook salmon brood-stocks.
5. Research into the causes of "summer kill" in Atlantic salmon.
6. Develop a PIT-tag monitor with increased reading-range so that adult salmonids can be passively monitored in fishways.
7. Develop a miniature combination sonic/radio tag that can be implanted in juvenile fish, that has at least a 1/8-mile range, and which remains functional through the life of the fish.
8. Develop PIT-tag monitoring systems capable of interrogating PIT-tagged fish that are pumped, crowded, or volitionally released from fish hatcheries.
9. Develop a genetic monitoring program for hatchery and wild chinook salmon in the Columbia River.
10. Using genetic techniques based on DNA and protein variability, examine the feasibility of identifying continent-of-origin of salmon caught in high seas fisheries.

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