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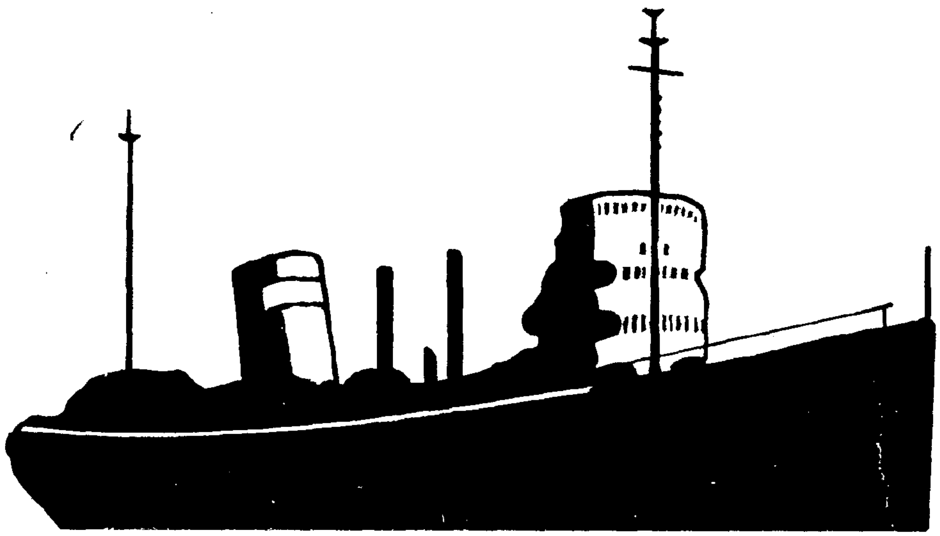
DREDGE DISPOSAL STUDY

SAN FRANCISCO BAY AND ESTUARY



U.S. Army Corps of Engineers

APPENDIX L

OCEAN DISPOSAL

SEPTEMBER 1975

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U.S. Army Corps of Engineers

DREDGE DISPOSAL STUDY, SAN FRANCISCO BAY AND ESTUARY

APPENDIX L

OCEAN DISPOSAL OF DREDGED MATERIAL

SEPTEMBER 1975

U.S. Army Engineer District, San Francisco
Corps of Engineers
100 McAllister Street
San Francisco, California 94102

DREDGE DISPOSAL STUDY, SAN FRANCISCO BAY AND ESTUARY

APPENDIX L

OCEAN DISPOSAL OF DREDGED MATERIAL

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INCLOSURES

FOREWORD

In April 1972, the San Francisco District of the United States Army Corps of Engineers initiated a three and one-half year, $3 million study to quantify the impact of dredging and dredged material disposal operations on the Environment of San Francisco Bay and Estuary. The study is generating factual data, based on field and laboratory studies needed for the Federal, State and local regulatory agencies to evaluate present dredging policies and alternative disposal methods.

The study is set up to isolate the questions regarding the environmental impact of dredging operations and to provide answers at the earliest date. The study is organized to investigate (a) the factors associated with dredging and the present system of aquatic disposal in the Bay, (b) the condition of the pollutants (biogeochemical), (c) alternative disposal methods, and (d) dredging technology. The study elements are intended first, to identify the problems associated with dredging and disposal operations and, second, to address the identified problems in terms of mitigation and/or enhancement. The division into separate but inter-related study elements provides a greater degree of expertise and flexibility in the Study.

This report presents the findings of Appendix L, Ocean Disposal. The overall study will be the basis for preparation of a composite Environmental Impact Statement for Dredging Activities in San Francisco Bay System.

The following is an index of appendices to be published in the Dredge Disposal Study:

APPENDIX	REPORT	DATE PUBLISHED
-	FINAL REPORT	
A	Main Ship Channel (San Francisco Bar)	June 1974
B	Pollutant Distribution	
C	Water Column (Water Column-Oxygen Sag)	
D	Biological Community	August 1975
E	Material Release	
F	Crystalline Matrix	July 1975
G	Physical Impact	July 1975
H	Pollutant Uptake	September 1975
I	Pollutant Availability	
J	Land Disposal	October 1974
K	Marsh Development	
L	Ocean Disposal	September 1975
M	Dredging Technology	September 1975

CONVERSION FACTORS

If conversion from the Metric to the British system is necessary, the following factors apply:

LENGTH

1 kilometer (km)=10^3 meters=0.621 statute miles=0.540 nautical miles
1 meter (m)=10^2 centimeters=39.4 inches=3.28 feet=1.09 yards=0.547 fathoms
1 centimeter (cm)=10 millimeters (mm)=0.394 inches=10^4 microns (μ)
1 micron (μ)=10^{-3} millimeters=0.000394 inches

AREA

1 square centimeter (cm^2)=0.155 square inches
1 square meter (m^2)=10.7 square feet
1 square kilometer (km^2)=0.386 square statute miles=0.292 square nautical miles

VOLUME

1 cubic kilometer (km^3)=10^9 cubic meters=10^{15} cubic centimeters=0.24 cubic statute miles
1 cubic meter (m^3)=10^6 cubic centimeters=10^3 liters=35.3 cubic feet=264 U.S. gallons=1.308 cubic yards
1 liter=10^3 cubic centimeters=1.06 quarts=0.264 U.S. gallons
1 cubic centimeter (cm^3)=0.061 cubic inches

MASS

1 metric ton=10^6 grams=2,205 pounds
1 kilogram (kg)=10^3 grams=2.205 pounds
1 gr (g)=0.035 ounce

SPEED

1 knot (nautical mile per hour)=1.15 statute miles per hour=0.51 meter per second
1 meter per second (m/sec)=2.24 statute miles per hour=1.94 knots
1 centimeter per second (cm/sec)=1.97 feet per second

TEMPERATURE

Conversion Formulas $^oC = \frac{^oF-32}{1.8}$ $^oF = 1.8(^oC) + 32$

DREDGE DISPOSAL STUDY, SAN FRANCISCO BAY AND ESTUARY

APPENDIX L

OCEAN DISPOSAL OF DREDGED MATERIAL

INTRODUCTION

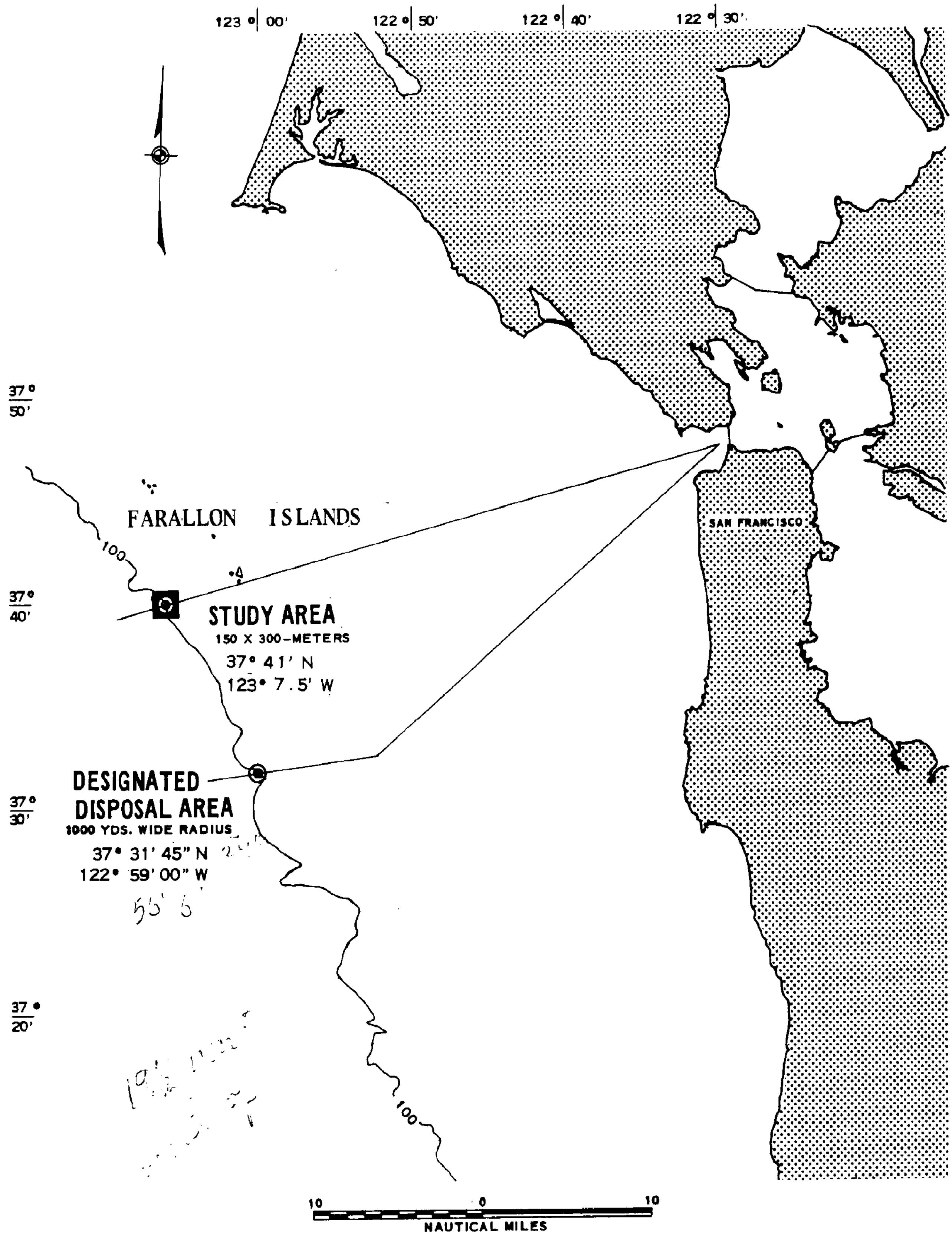
The Ocean Disposal Study is one of three studies which address the feasibility of alternatives to the present system of aquatic disposal in San Francisco Bay waters. The other two alternative studies are concerned with marshland development utilizing dredged sediments, and land disposal. The objectives of the Ocean Disposal Study is (1) to provide a qualitative description of the physical, chemical, and biological environment in one area on the continental shelf break in the vicinity of the Farallon Islands, and (2) to provide a qualitative description of the general release pattern of dredged material placed on the continental shelf break.

In order to fulfill the above objectives a brief literature review was conducted with respect to the continental shelf environment. The information collected in this review is summarized in Inclosure 1, Oceanographic Conditions off the Central California Coast. Field studies at a 100-fathom study area were conducted during 5-7 September 1974 with the Naval Undersea Center, Department of the Navy, by an interagency agreement with the San Francisco District, Corps of Engineers. Details of the field studies and laboratory analysis performed by the Navy are presented in Inclosure 2. Water quality monitoring was conducted by personnel of the San Francisco District in conjunction with the field studies. Water quality data collected are presented in Inclosure 3.

OCEAN DISPOSAL CRITERIA

The discharge of dredged sediments into the territorial sea is governed by the Marine Protection, Research and Sanctuaries Act of 1972, Public Law 92-532 and regulations and criteria issued pursuant thereto. Ocean dumping criteria published in 40 CFR 227 (Federal Register, 15 October 1973, Volume 38, Number 198, Part II, paragraph 227.61) lists guidelines for classifying dredged material. The three elements of the guidelines are (1) the type of sediment such as sand versus clays and organics, (2) adequacy of water quality using state water quality standards and the health of the biota associated with the sediments, and (3) standard elutriate (contaminants released to the water from the sediments using a standard test) within 1.5 times the contaminant levels of the water at the disposal area.

The Environmental Protection Agency in cooperation with the Corps of Engineers has established standard aquatic disposal sites in San Francisco Bay and off the California coast for dredged sediments. The standard sites include three aquatic sites in the Bay, one on the San Francisco Bar and one in the ocean at the 100-fathom line south of the Farallon Islands. The locations of the designated ocean disposal area and the study area are shown in Figure 1.



LOCATION OF TRANSECTS FROM GOLDEN GATE TO 100-FATHOM DISPOSAL AND STUDY AREAS

FIGURE 1

SUMMARY OF FINDINGS

a. Literature Review - Oceanographic Conditions off the Central California Coast (Inclosure 1). The continental shelf forms a broad plain beyond the Golden Gate ranging from 15 to 20 nautical miles in width. The shelf slopes gradually seaward from the Golden Gate with average inclinations of 0.2 to 0.3 percent. At depths from 70 to 80 fathoms the slope steepens to 5 to 6 percent forming the continental shelf break and the continental slope.

Sediments on the continental shelf are predominantly sands while sediments on the continental slope range from fine sands through fine silts. In several locations along the California coast surface sediments are bound into aggregate-sized nodules (phosphatic nodules). These nodules form a surface layer which is a favored habitat of sessile and borrowing marine organisms.

During the summer, prevailing winds and swells are from the northwest with some distant storms from the southwest. In addition to this, two predominant currents influence the central coastal waters: a southward moving current (California Current) and a northward moving current (Davidson Current). With these factors, the California coast exhibits three distinct oceanographic seasons: the Upwelling occurring in spring with an overturning of the upper layers from moderate depths; Oceanic in the fall with southward movement of both surface and deep currents; and Davidson in the winter with northward surface currents near shore.

Central California coastal waters, particularly the Gulf of the Farallones, support an immense recreational and commercial fishery. Most of the important fishes have pelagic eggs which are an integral part of the plankton community and virtually all depths at the continental shelf are used either as feeding, spawning, or nursery areas. There is a subtle biological interrelationship between the Gulf of the Farallones and San Francisco Bay. Salmon, several species of flatfish, the Pacific herring, and many other varieties of fishes are dependent on both the ocean and estuarine (bay) environments. The most productive areas for all commercially important fish (except salmon) are in the Gulf of the Farallones and south of the Farallon Islands at depths greater than 50 fathoms. Some of the most productive areas south of the Farallones are near the designated 100-fathom disposal area.

b. Field Studies - Ocean Disposal of Dredged Material (Inclosure 2. The designated disposal area was not used for the field studies because that area was already disturbed by previous disposal operations. The study area selected, however, very nearly approximates the disposal area in terms of topography. Similarity of the two areas with respect to the continental shelf break is shown in Figures 2a and 2b. The profiles are plotted along two transects from the Golden Gate as shown in Figure 1. Exaggerated and true slope are plotted for both transects. In general, the shelf break along both transects occurs between 70 and 80 fathoms with the 100-fathom contour lying approximately one mile beyond.

TRANSECT FROM GOLDEN GATE TO 100-FATHOM DISPOSAL AREA

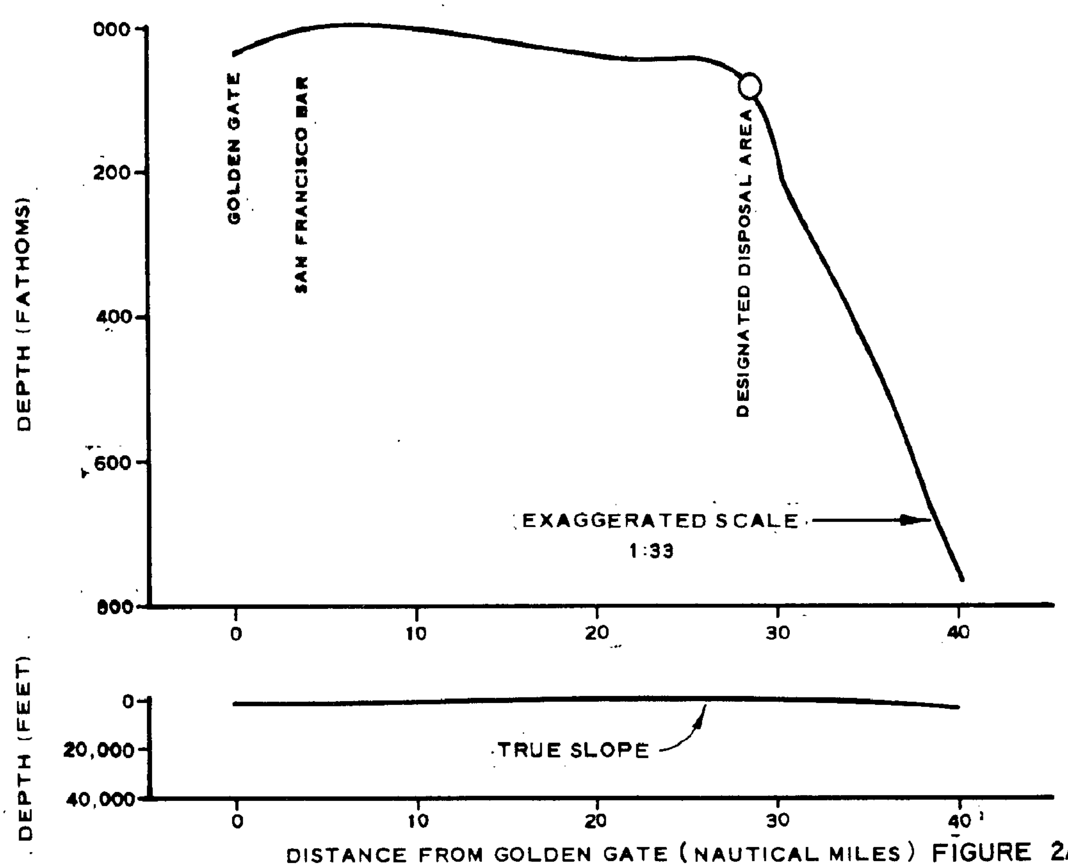


FIGURE 2A

TRANSECT FROM GOLDEN GATE TO 100-FATHOM STUDY AREA

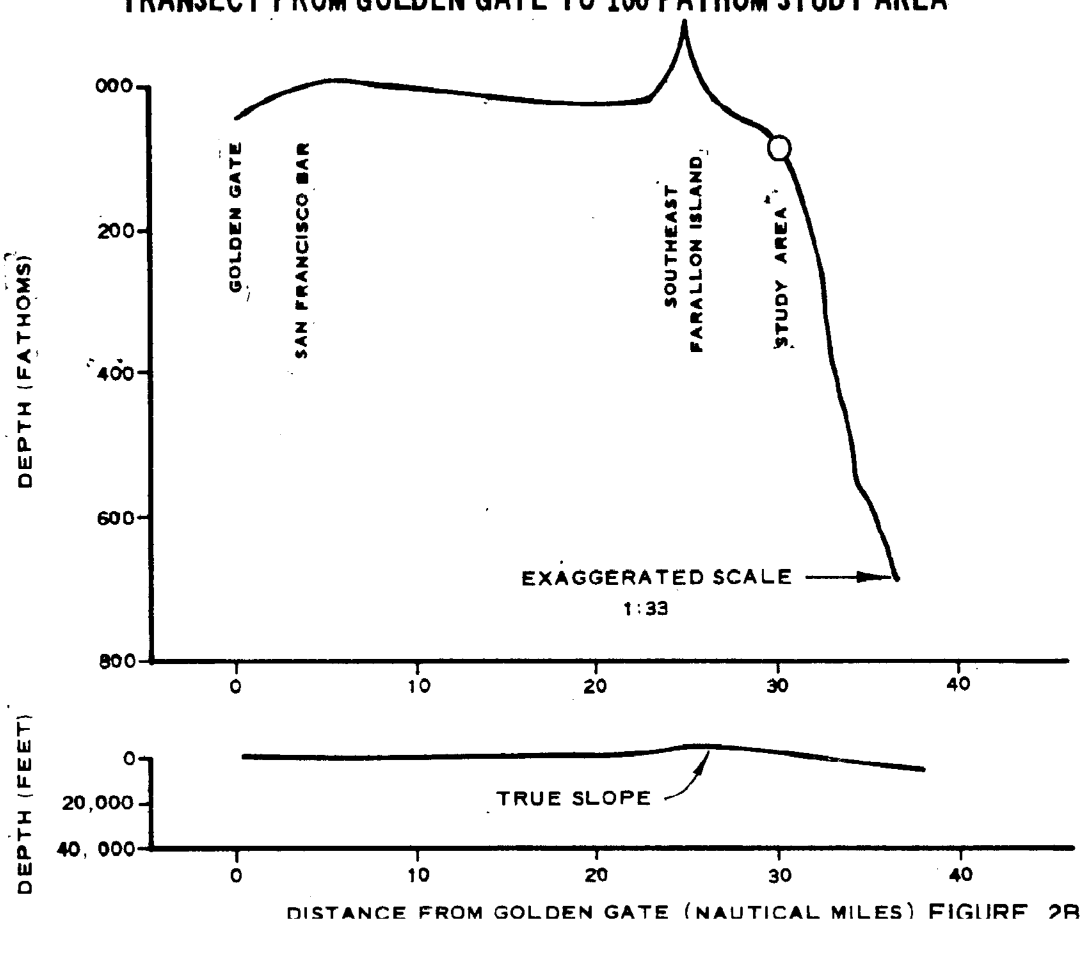


FIGURE 2B

The study area was a 150-meter by 300-meter rectangle with a northwest to southwest orientation. The site was marked at each corner with a sonar reflector placed 2 meters from the bottom and with a surface buoy at the center of the northwest end (Figure 3). Approximately 3,000 cubic meters of dredged material loaded in two bottom-dump barges towed in tandem were released over the study area. Sediment samples were collected prior to release and photographic surveys were made both before and after the release. Sediment sampling sites, path of the barge, and release stations are also shown in Figure 3.

(1) Sediment Sampling. Sediment samples were collected with the use of a Shipek Dredge at five locations along a 300-meter transect which traversed the length of the study area. Dispersed grain size analysis of the samples collected indicated that the sand fraction in the sediments varied from 24 to 88 percent. Table 1 compares the dispersed grain size distribution of ocean sampling stations with sediment collected in dredging project areas in San Francisco Bay.

TABLE 1

COMPARISON OF DISPERSED
GRAIN SIZE DISTRIBUTION IN OCEAN AND BAY
SEDIMENTS

DISPERSED GRAIN SIZE	OCEAN SAMPLING SITES* 1	2	3	4	5	OAKLAND OUTER	PINOLE SHOALS	OAKLAND INNER	MARE ISLAND
SAND	24	58	72	85	88	65	60	47	1
SILT	56	40	21	13	10	18	23	33	50
CLAY	20	2	7	2	2	17	17	20	49

*See Figure 3.

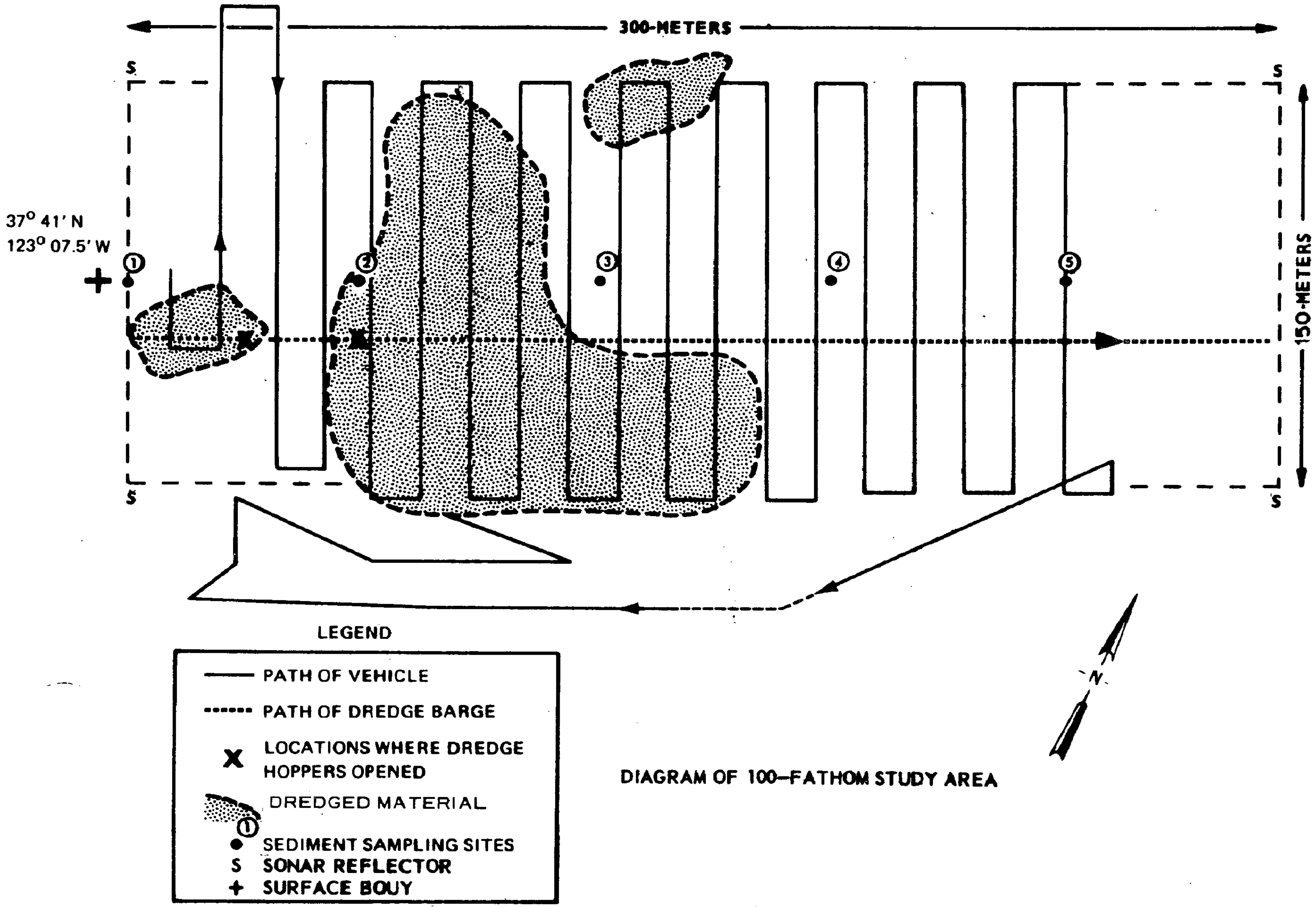


DIAGRAM OF 100–FATHOM STUDY AREA

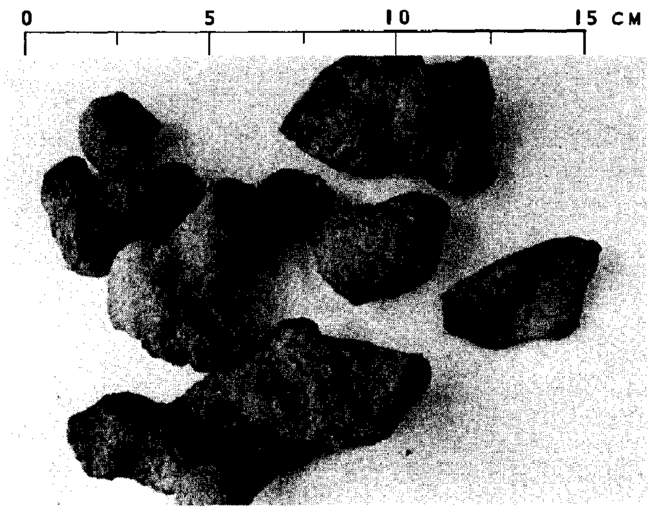
FIGURE 3

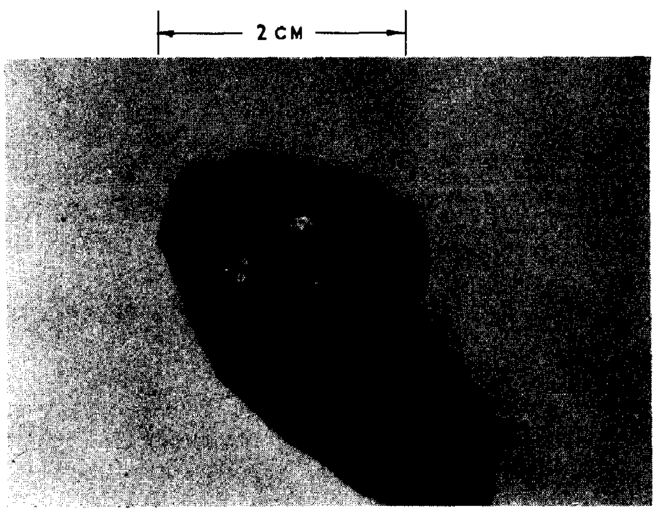
Sites 3, 4, and 5 contained a greater percent sand than found in typical Bay samples. Phosphatic nodules were also recovered from the study area with the use of a basket grab attached to the Naval Undersea Center's CURV III, underwater tethered vehicle. Three photos of the nodules are shown in Figure 4. The top photo shows the physical size and shape of the nodules, the middle photo views a nodule in cross section, and the bottom photo provides a microscopic view of individual particles within the nodule. The nodules are generally less than 6 centimeters in diameter and are comprised of fine sand, shell fragments, and animal tubes bound together with a phosphate cement.

Sediment samples collected in the study area were also analyzed for the presence of various contaminants. Table 2 compares contaminant levels in ocean and Bay sediments. Contaminant levels in Bay sediments are from 2 to 5 times greater than those found in ocean sediments sampled.

OCEAN STUDY AREA SEDIMENTS

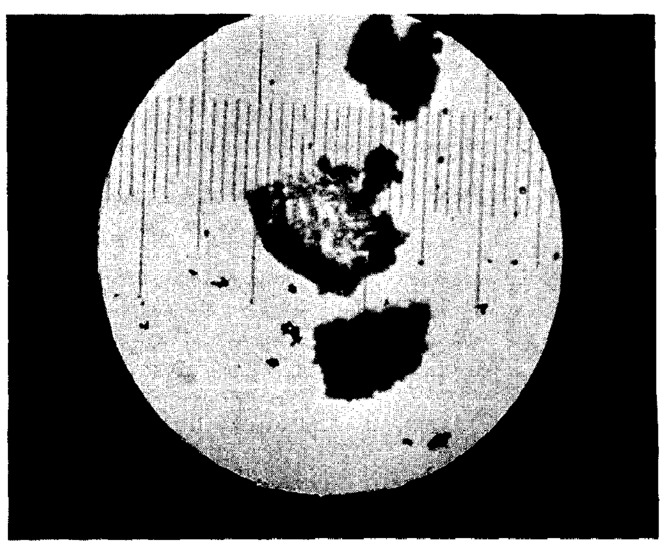
NODULES





NODULE
CROSS SECTION

PARTICLES
FROM NODULE



1 UNIT= 10 MICRONS (.01 mm.)

FIGURE 4

TABLE 2

COMPARISON OF CONTAMINANT LEVELS IN OCEAN AND BAY SEDIMENTS

Parameter	Dredged Channels S.F. Bay Mean Concentration PPM 1/	100-Fathom (Ocean) Mean Concentration PPM
Lead	35.6	7.0
Zinc	108.1	40.5
Mercury	0.55	0.17
Cadmium	1.59	0.41
Copper	41.6	9.6
Volatile Solids	6.03×10^4	2.01×10^4
Chemical Oxygen Demand	4.12×10^4	1.51×10^4

1/ Dredge Disposal Study, Appendix B, Pollutant Distribution (To Be published)

(2) Benthic and Pelagic Faunal Studies. Speciation and enumeration of epibenthic macrofauna were obtained from photographs taken by CURV III prior to dumping. Animal densities were calculated from numerical totals obtained from the photographic survey. In addition, three of macrofauna species were collected with a grasping basket assembly for analysis. A Pisaster starfish, a small fish (*Mesluccius productus*) and a Heart urchin (*Echinocardium*) were collected. Each species was analyzed for mercury, copper, cadmium, lead chromium, and zinc.

The epibenthic macrofauna of the study area was relatively abundant. The dominant group were arthropods which made up about 70 percent of all bottom animals. In order of decreasing abundance the remainder were molluscs (13%), bony fishes (10%), and echinoderms (7%). The density of total animals was relatively high (1801 animals over 1316 m^2 or 1.4 animals/m^2), but the species diversity was relatively low. In the three species of epibenthic macrofauna analyzed (wet weight) copper ranged from 1.74 - 5.87 ppm, cadmium from 0.28 - 1.66 ppm, lead from 2.06 - 7.27 ppm and chromium from 16.7 - 103.3 ppm. Mercury concentrations (dry weight) on replicate samples of the starfish were 259 ppb and 204 ppb.

(3) Dredge Material Release Study. To determine the dispersal of the dredged material a grid pattern was first marked on the bottom at the study area. This was accomplished with the CURV III during the pre-dump, photographic survey using the skids of the vehicle. The pre-dump markings consisted of 300-meter long parallel lines at eight-meter intervals (Figure 3). The dredged material was then released from two barges each containing 1,500 cubic meters of material. The barges were emptied by the time they reached 150 meters into the study area. Approximately 12 hours after the release of dredged material a second photographic survey was made. The vehicle followed a track perpendicular to the pre-dump markings. Interpretation of the post-dump photographs revealed that the released material passed nearly vertically through the water column and landed in clumps in the study area. The average depth

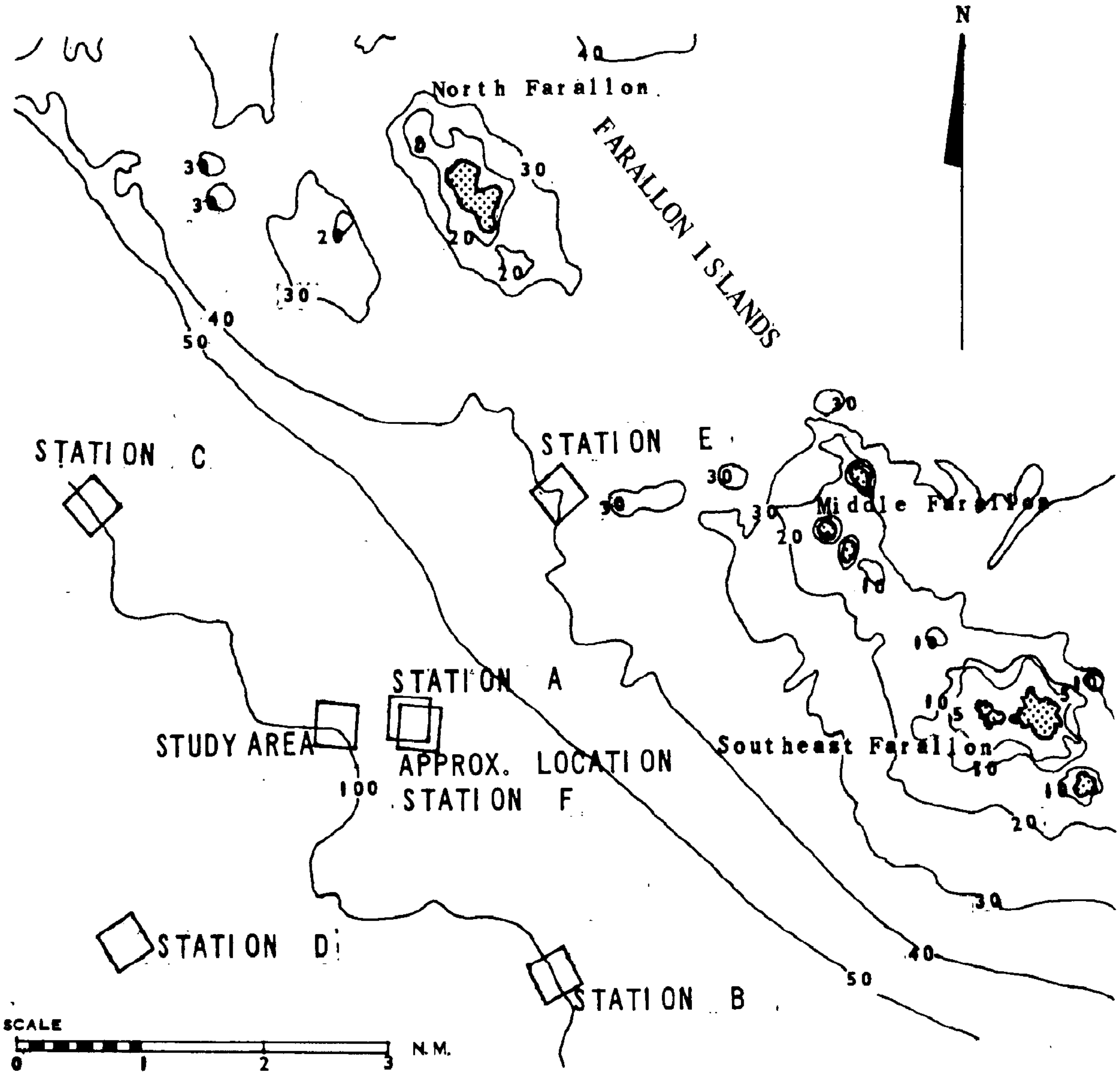
of deposition in the study area was about 0.3 meters and the area impacted was about 10,000 square meters (Figure 3). Based on studies in Appendix M, Dredging Technology, lack of dispersion was due to the low water content of the cohesive sediment.

c. Water Quality Monitoring (Inclosure 3). Water quality monitoring was performed by District personnel in the study area and in four locations approximately three nautical miles outside of and surrounding the study area (Figure 5). Pre-dump monitoring was conducted in the upper 80 meters of the water column with an Inter-Oceans Water Quality Monitoring Probe on 5-6 September 1975. The water quality monitoring was performed to provide baseline information on water quality conditions in the surface waters adjacent to the 100-fathom contour. The parameters measured included conductivity, salinity, turbidity (percent transmission), turbidity (FTU), temperature, and dissolved oxygen. Table 3 summarizes the results of the monitoring.

TABLE 3

WATER QUALITY, STUDY AREA VICINITY

DEPTHS IN METERS	WATER QUALITY PARAMETERS				
	SALINITY 0/00	TURBIDITY % TRANS	TURBIDITY FTU	TEMPERATURE ^{o}C	DISSOLVED OXYGEN mg/l
20	33.4	90.4	1.0	12.6	9.6
40	33.5	91.2	0.7	11.0	7.3
60	33.6	91.0	0.8	10.1	5.5
80	33.7	92.3	0.8	9.5	-



LOCATION FARALLON ISLANDS SAMPLING STATIONS FIGURE 5

RELATIONSHIP WITH OTHER STUDY ELEMENTS

Several other Dredge Disposal Study elements provide additional information pertinent to the consideration of ocean disposal as an alternative for disposing of material dredged from San Francisco Bay.

Land Disposal, Appendix J, provides an analysis of the relative costs of various disposal alternatives. In general, the transport of sediments to the 100-fathom disposal area with theorized systems may increase dredging costs two fold as compared to present practice of in-Bay disposal. Removal of polluted materials to land disposal areas would necessitate a similar cost escalation.

Field work associated with other study elements gives an insight into release patterns which occur under disposal conditions different from those found at the ocean disposal area. During studies on the San Francisco Bar (Main Ship Channel), Appendix A, the sandy sediments were found to react as discrete particles during disposal, depositing in a predictable pattern. The study showed a normal distribution pattern with a maximum deposition of two inches directly beneath the hopper dredge. During the monitoring of oxygen depression associated with the disposal of Bay mud at Carquinez Strait (Water Column, Appendix C), an induced current of one knot perpendicular to the tidal current was observed at the bottom of the water column. Other monitoring at the Carquinez Strait site showed complete transport of sediments from the disposal site during a hopper dredge release within fifteen minutes in the bottom one meter of the water column.

The Dredging Technology Study, Appendix M, included laboratory simulation studies to qualitatively describe immediate release patterns generated under various disposal conditions. These studies provide, within the variability of the prototype system, an evaluation of the loading of the water column, the degree of bottom impact and the rate of transport from the site. This information will be applied to the results of other study elements to define the extent of environmental impact.

The impacts of various levels of suspended sediments in the water column and various depositional depths upon selected marine organism are discussed in Physical Impact, Appendix G. The potential release of heavy metals from sediments, uptake of metals and availability of metals to organisms are discussed in Crystalline Matrix, Appendix F; Pollutant Uptake, Appendix H; and Pollutant Availability Appendix I, respectively.

CONCLUSIONS

a. Areas of greatest productivity for all commercially important fish (except the salmon) along central California waters are in the Gulf of the Farallones and south of the Farallon Islands at depths greater than 50 fathoms.

b. Water conditions in the vicinity of the 100-fathom contour show no signs of degradation.

c. Unlike sediments in San Francisco Bay, sediments in the vicinity of the 100-fathom study area are generally higher in sand content and contain aggregate size nodules.

d. Sediments at the 100-fathom study area are significantly less contaminated than Bay sediments.

e. Cohesive sediments with low water content deposited at 100-fathom study area fall nearly vertically and concentrate in clumps on the bottom.

INCLOSURE ONE

OCEANOGRAPHIC CONDITIONS OFF THE CENTRAL CALIFORNIA COAST

PHYSICAL OCEANOGRAPHIC CONDITONS OFF THE CENTRAL CALIFORNIA COAST

The continental shelf forms a broad plain beyond the Golden Gate ranging from 15 to 20 nautical miles in width. The shelf slopes gradually seaward from the Gate with average inclinations of 0.2 to 0.3 percent. At depths of from 70 to 80 fathoms the slope steepens to 5 to 6 percent forming the shelf break and the continental slope. The 100-fathom contour lies two to three miles beyond the break. Though there are several theories concerning the origin of the continental shelf, it is rather widely accepted that erosion during periods of glacially lowered sea level contributed measurably to its formation.

Sediments upon the continental shelf adjacent to San Francisco Bay are predominantly shell sands, and glauconitic sands while sediments on the continental slope range from fine green sands through coarse silts to fine olive-green silts (Bailey, 1966). Along the Central coast, shelf sediments are generally shallow and are underlain with granitic bedrock (Moore and Shumway, 1959). In many locations along the California coast, surface sediments are bound into phosphatic nodules with diameters up to 6 centimeters (Bailey, 1966). These nodules form a surface layer which is a favored habitat of sessile and borrowing marine organisms (Twenhofel, 1950). Phosphatic nodules have considerable distribution in areas of the ocean bottom which are subject to rapid and large change in temperatures (Twenhofel, 1950). Rapid changes in temperature occur offshore from San Francisco as the result of upwelling. The occurence of the nodular layer in ocean sediments seaward of the Golden Gate has been documented. In 1952 Chesterfield recovered nodules in dredge hauls in water depths between 400 to 600 fathoms west of San Francisco and at depths from 200 to 400 fathoms to the northwest of the Golden Gate (Chesterfield, 1952).

The physical conditions outside the Golden Gate are quite different from that of San Francisco Bay. Certain physical factors of insignificant influence in an estuary become magnified in the great expanse of the ocean. For example, the subtlety of the earth's rotation and the flow of the trade winds normally have a minor effect on an estuary but are important in influencing the surface currents of the ocean. The tides influencing the continental shelf along central California are semi-diurnal. During the summer, prevailing winds and swells are from the northwest with some distant storms from the southwest. In addition to this, two predominant currents influence the Central coastal waters: a southward moving current (California Current) and a northward moving current (Davidson Current).

The California Current is a broad, slow, southward moving, surface current which emanates from the North Pacific Current that crosses the North Pacific from Japan. It moves about 0.2 knots and passes through the Gulf of the Farallones. The width of the current is about 300 nautical miles with a depth of about 180 meters. Eventually it becomes a part of the North Equatorial Current which flows westward toward Japan.

The California Current is the prevailing nearshore current off the central California coast from late winter through fall. From late summer until the beginning of winter, it is particularly close to shore and this is when the surface ocean temperatures are highest for the year, around 15°C, off North Farallon Island. A strong vertical temperature gradient also exists in the upper water column. The surface salinity is slightly higher than the rest of the year. Transparency of the water averages 10 to 12 meters and the dissolved oxygen levels range from 9 mg/l at the surface to 4 mg/l several hundred feet deep (Kaiser Engineers, 1969). The time period which is characterized by these events is known as the Oceanic Period.

Preceding the Oceanic Period is the Upwelling Period from late winter to late summer. This time period is characterized by persistent fog which shrouds the central coast, and by a phenomenon known as upwelling. During the spring and summer prevailing winds are from the north and northwest. Due to the prevailing winds and the rotation of the earth, surface waters at this time move offshore and are replaced by colder, subsurface water from depths of a few hundred feet. The replacement of offshore moving surface water by colder subsurface water is called upwelling, and it is this phenomenon that contributes to the richness of the fisheries off the California coast. The southward moving California Current is not as close to shore as during the Oceanic Period due to upwelling. The nearshore surface water, which moves westward, pushes the California Current further offshore during this time period.

Between the Oceanic Period and the Upwelling Period, from November to February, the fast-moving Davidson Current moves northward pushing the southward California Current offshore. It is this northward moving current that becomes the prevalent nearshore current during the winter season. The Davidson Current has a minimum width of 50 nautical miles and can attain speeds of 0.5 to 0.9 knots over distances of several hundred nautical miles. Since this current occurs during the winter, freshwater runoff from the coast augments the northward flow.

In summary, the three oceanographic seasons are listed below:

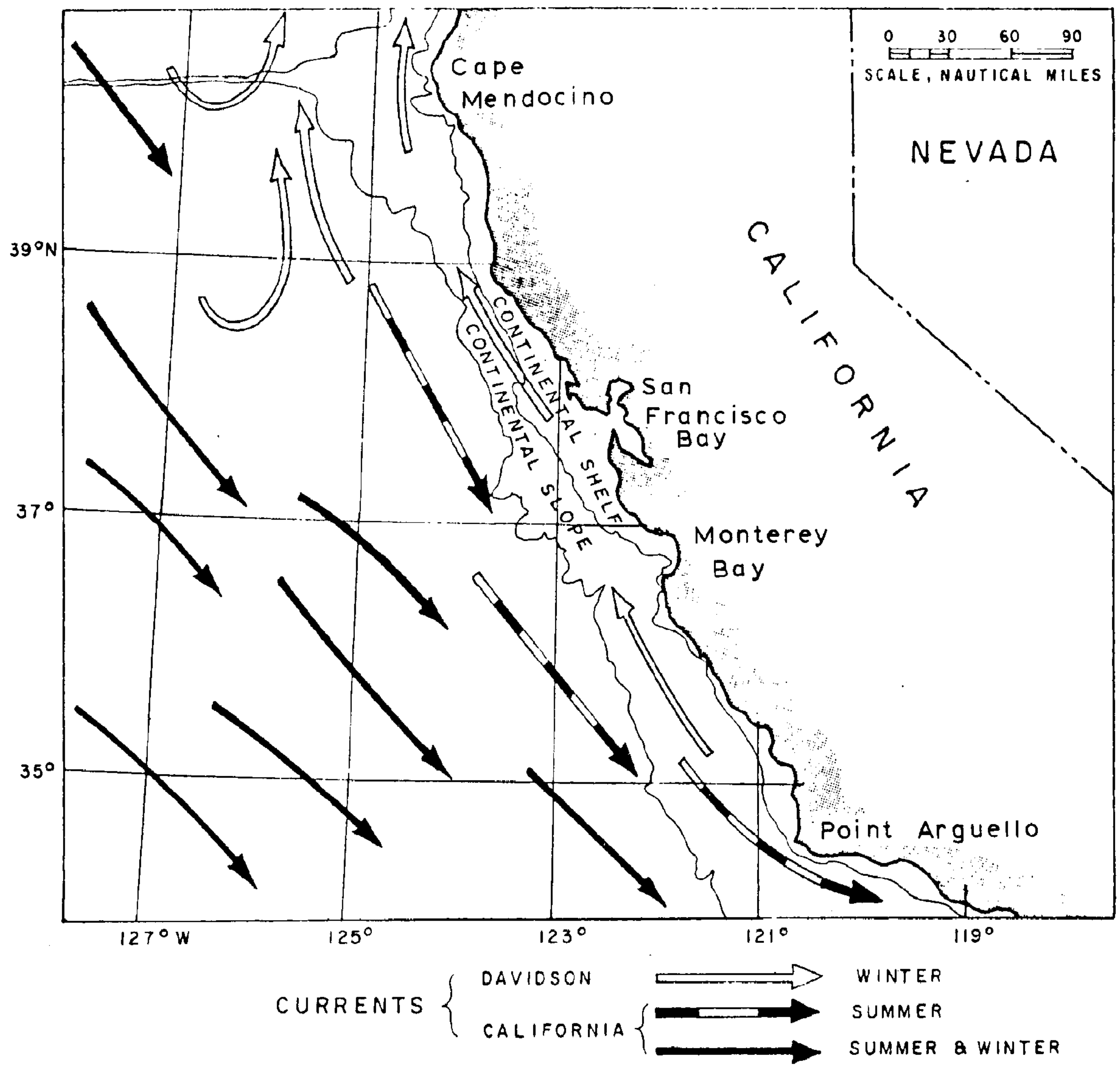
Oceanographic Season	Duration	Median Temperature (°C) Range West of S.F.
Upwelling Period	February-July	12.0 - 13.5
Oceanic Period	July-November	14.1 - 15.2
Davidson Period	November-February	15.0 - 12.0

Figure 1 compositely shows the prevailing California and Davidson Currents off the central California coast (Brown and Caldwell, 1971).

MARINE BIOLOGICAL CHARACTERISTICS OFF THE CENTRAL CALIFORNIA COAST

a. Plankton. Tidal cycles play less of a factor in affecting plankton species composition outside the Bay than in the Bay with the exception of the area shoreward of the sand bar. Seasonal changes, however, are quite important.

Atmospheric seasons are directly related to the three oceanographic seasons and affect sunlight intensity over the water and availability of nutrients to phytoplankon. These, in turn, affect plankton species composition and numbers. Of the three oceanographic seasons, the Upwelling Period has the most pronounced effect on phytoplankton. Abundant nutrients such as phosphates and silicates are brought to the surface from lower



SOURCE: BROWN & CALDWELL, 1971. A PREDESIGN REPORT ON MARINE WASTE DISPOSAL, VOL. 1.

PREVAILING CURRENTS OF THE CENTRAL CALIFORNIA COAST

FIGURE 1

depths of the ocean by the upwelling process, and sufficient sunlight is available during this time of the year to allow optimum phytoplankton photosynthesis. These conditions result in a population explosion of the phytoplankton community known as a "plankton bloom." Not all phytoplankton species bloom during the Upwelling Period. There are species and varieties that find the other two oceanographic seasons more favorable for growth and thus blooms can be detected during each oceanographic season.

As in the Bay, diatoms are the dominant phytoplankton types. Dinoflagellates are less numerous but are, nevertheless, an integral part of the phytoplankton community. All phytoplankton form the nutritional basis upon which all marine animal life are directly or indirectly dependent.

With respect to zooplankton, the animal portion of the plankton that typically feeds on the phytoplankton, the variety found in Central San Francisco Bay is also found in the Gulf of the Farallones. During the winter or Davidson Period, the zooplankton in the Gulf are dominated by salps (pelagic tunicates) and copepods. The variety of types is least during the winter as is also true in the Bay. In spring, when there is an abundance of phytoplankton to feed on, the variety of zooplankton is at its greatest. In addition to salps and copepods (of which there are many species), fish eggs and larvae, cirripeds (young barnacles) and crab larvae are abounding (Brown and Caldwell Consulting Engineers, 1971).

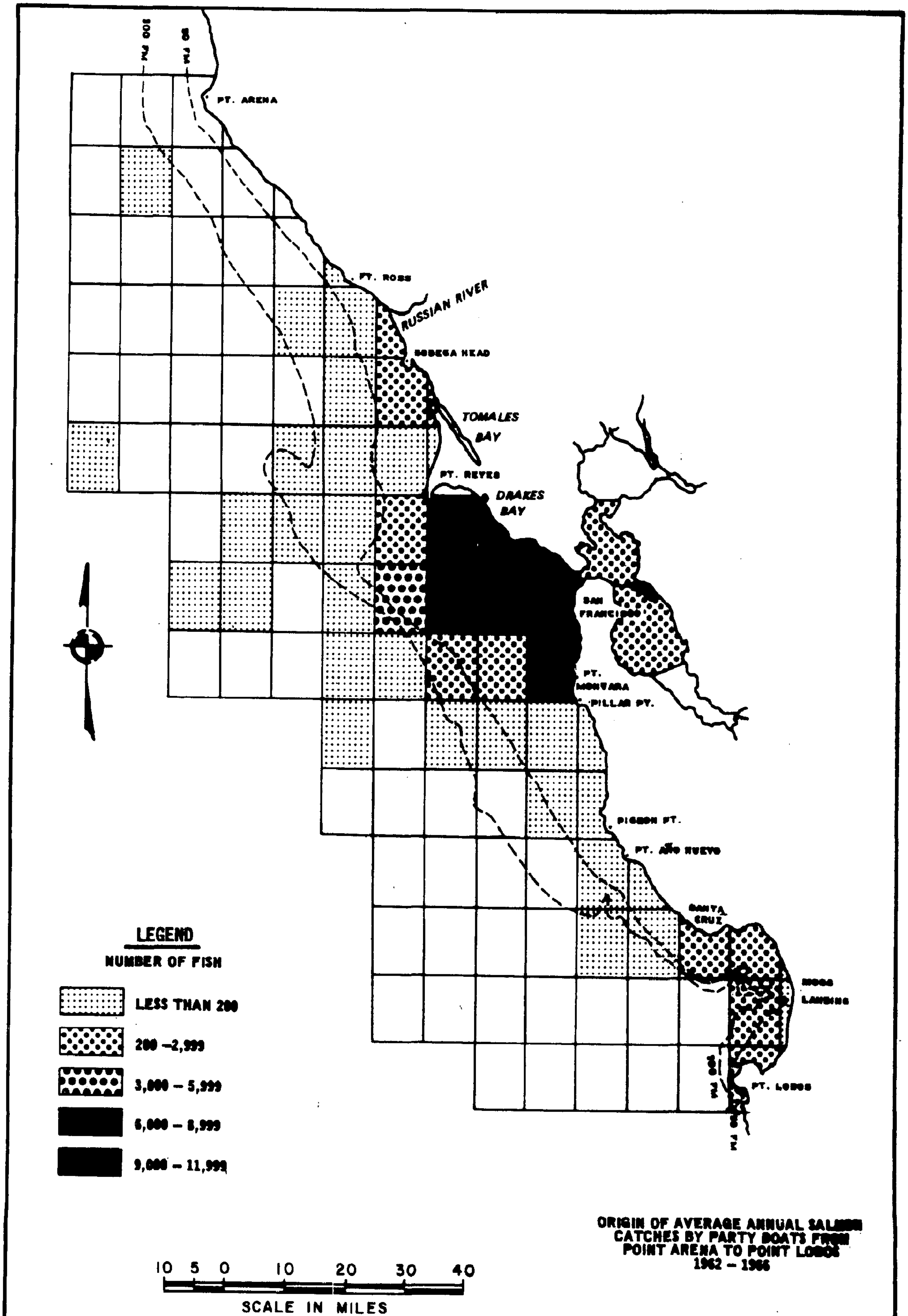
Except for ocean shrimp (*Pandalus*), no zooplankter per se is commercially or recreationally important. Ocean shrimp are commercially caught north of Point Reyes but none are harvested in the Gulf of the Farallones. There are members of the ocean zooplankton community that give rise to commercially and recreationally important species. The most obvious are fishes and crabs.

Because of the dominating nature of ebb-flood currents through the Golden Gate, much of the zooplankton stages of the Dungeness crab are swept into the Bay during winter when they are most abundant. Those seaward of the San Francisco Bar are less influenced by the tides and thus remain a part of the ocean plankton community. Larvae crabs voraciously feed on the plentitude of copepods.

b. *Fish*. Bane and Bane list 172 fish species that are known to frequent the inshore waters of the central California coast (Bane and Bane, 1971). The list includes all the anadromous and marine species within the Bay. Many of these are commercially and recreationally valuable, of which a few will be discussed in greater detail to depict the diversity and importance of coastal marine fishes, and their relationship to the overall ecology of the central California coastal waters. All of the species to be discussed can be found in the general vicinity of the Bar and the 100-fathom disposal area.

(1) Chinook salmon. Chinook salmon fishing (all species of salmon, for that matter) in the Gulf of the Farallones produces the most consistent salmon yields in the State. This area is heavily, commercially fished for chinooks and every year over one-half of the State's sport salmon catch comes from the Gulf (Smith, 1973). This area is productive because it is in the main migratory route between San Francisco Bay and the ocean. Salmon fishing in California is exclusively a troll fishery (hook and line only) regulated by the State. The commercial fishing season is restricted to the period April 15 to September 30 for chinooks and May 15 to September 30 for Coho salmon. Chinooks are mostly caught between 5 to 30-fathom depths at a trolling speed of one to three knots (Odemar et al, 1968). Peak salmon catches occur in early summer off San Francisco. Recreational (party boat) fishing for salmon is extremely popular off the central California coast and landings always rank among the highest of sport fishes. Recreational salmon fishing is allowed year-round north of Tomales Point and in San Francisco Bay but can only be legally taken seaward of the Golden Gate and south of Tomales Point between mid-February and mid-November. Figure 2 depicts where most of the salmon are annually caught off central California. In the ocean, chinooks eat a variety of organisms and show seasonal preferences. They feed heavily on anchovies, juvenile rockfishes, Pacific herrings, euphasids (shrimps) and larval crabs.

(2) Rockfish. This group of fishes, belonging to the genus Sebastes, is extraordinarily diverse in color, habitat, depth preference, and geographical range. The genus consists of the largest



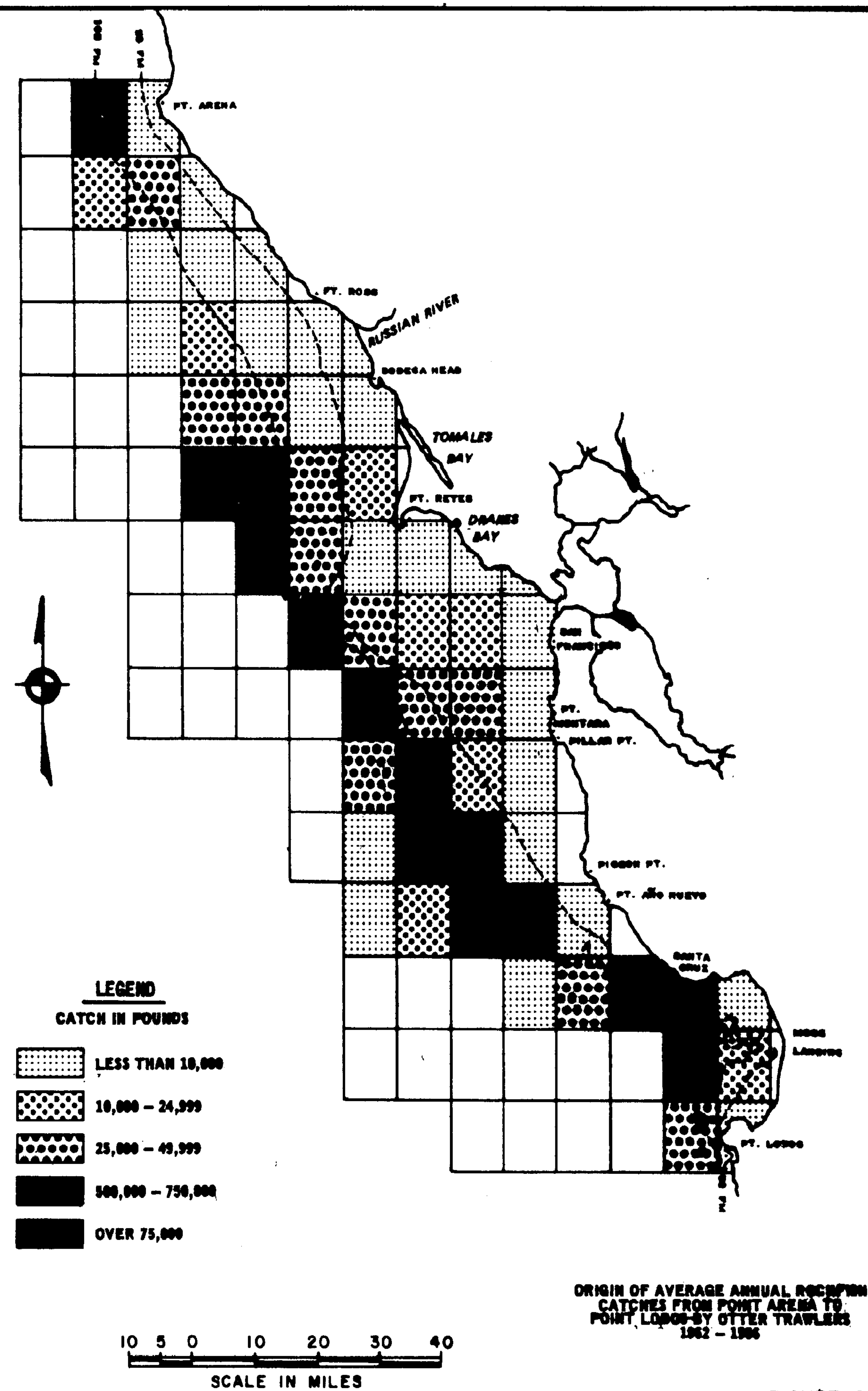
ORIGIN OF AVERAGE ANNUAL SALMON CATCHES BY PARTY BOATS FROM POINT ARENA TO POINT LOBOS 1962 – 1966

FIGURE 2

SOURCE: ODEMAR ET AL, 1968

number of marine fishes off California, constituting 58 recognized species as of 1972 (Miller et al, 1972). Of the 58, 48 are known to occur off central California and most are considered commercial and sport fishes. Most are caught in rather deep water, between 70-350 fathoms, and as their name implies, are associated with rocky reefs. Most spawn during the winter and their eggs are planktonic. Larval rockfish can be found year-round down to 100 fathoms. As adults, they actively feed on anything that can be accommodated within their mouths, including anchovies, lantern fish, young hake, smaller rockfish, sablefish, squid, euphasiids and tunicates. The most commonly caught rockfish species by commercial trawlers and party boats along central California include the Bocaccio (*S. paucispinis*), Chilipepper (*S. goodei*), Splitnose rockfish (*S. diploproa*), Widow rockfish (*S. entomelas*), Speckled rockfish (*S. ovalis*), Blue rockfish (*S. mystinus*), Yellowtail rockfish (*S. flavidus*), Black rockfish (*S. melanops*), and Canary rockfish (*S. pinniger*). High catch areas are centered south of San Francisco but waters around the Farallones also offer excellent fishing for rockfish (Figure 3).

(3) Dover sole. Flatfish as a group (pleuronectiforms) constitutes a very important commercial fisheries in California waters averaging several million pounds annually. The single most important species, poundwise, is the Dover sole (*Microstomus pacificus*) of which 20 percent of the entire California catch of this species originates from the central California coast (Odemar et al, 1968). Dover sole is primarily a deep-water bottom fish, caught at depths between 290-360



ORIGIN OF AVERAGE ANNUAL ROCKFISH CATCHES FROM POINT ARENA TO POINT LOBOS BY OTTER TRAWLERS 1962 – 1966

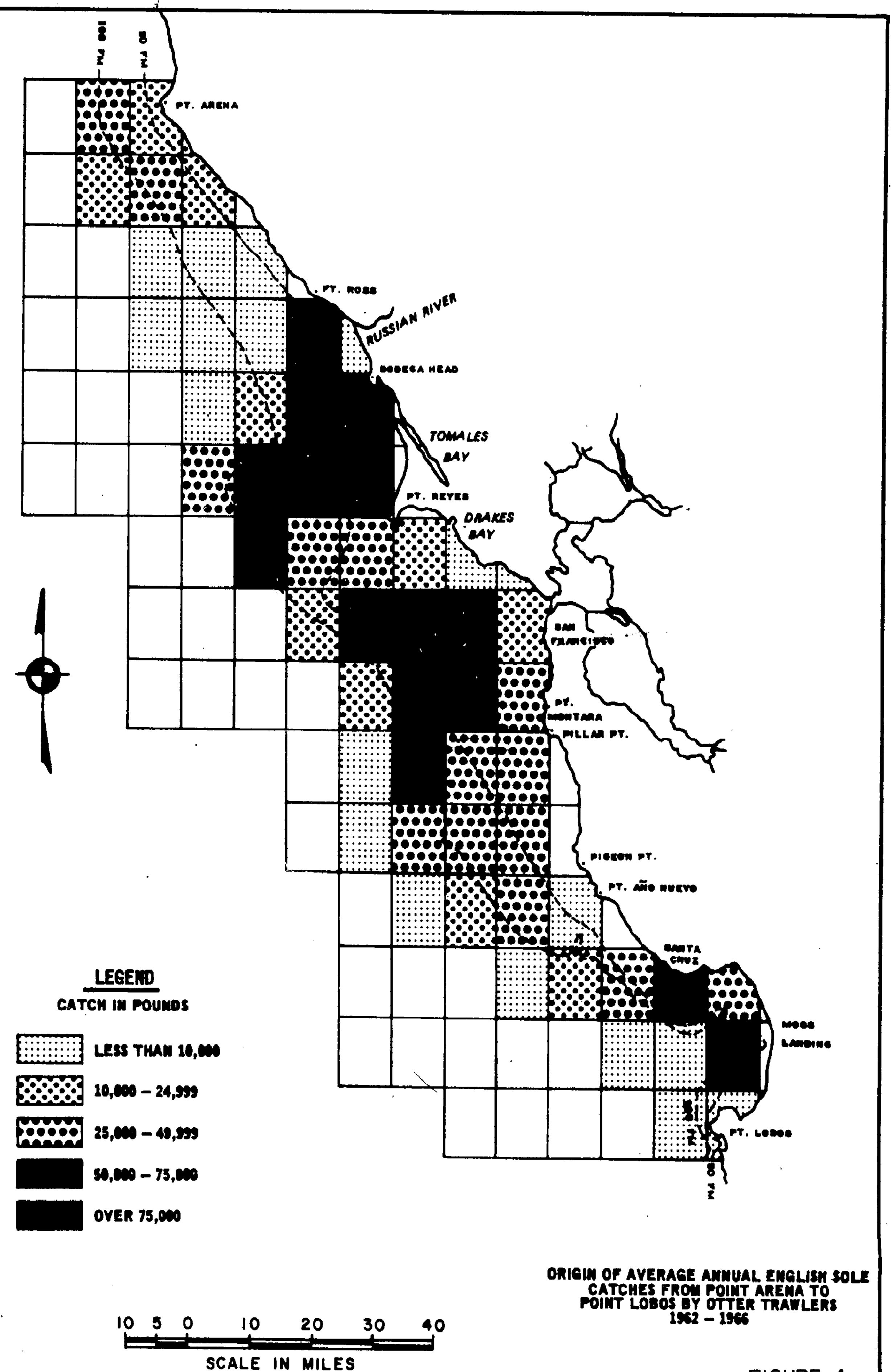
FIGURE 3

SOURCE: ODEMAR ET AL, 1968

fathoms. Peak landings occur during the summer, and for central California, between Point Montara and Point Ano Nuevo. Spawning takes place in winter in deep waters between 350-600 fathoms with the greatest concentrations between points offshore of Bodega Bay and Point Montara (Odemar et al, 1968). After spawning, the adults again move inshore to their summer feeding grounds. The eggs are pelagic. The adults, as would be expected from their bottom nature, feed mainly on the benthos such as snails, clams, annelid and peanut worms, nematodes, scaphopods (tooth shells), and ophiuroids (brittle stars).

(4) English sole. This is another flatfish abundantly taken offshore of San Francisco. In fact, the area between Fort Ross and Point Montara from 20 to 150 fathoms contains California's most productive English sole (Parophrys vetulus) fishing grounds (Odemar et al, 1968). Like the Dover sole, they spawn in the winter but in much shallower waters (20-60 fathoms). Eggs are pelagic and tend to drift into nearby bays and protected areas which serve as nursery grounds. San Francisco Bay and the Gulf of the Farallones are important nursery areas for the English sole. Juveniles and adults primarily feed on the benthos. Their distribution is reflected by where they are commercially caught and heaviest catches occur in the Gulf of the Farallones in less than 100 fathoms and north to Fort Ross (Figure 4).

(5) Petrole sole. The third most important flatfish landing of central California is the Petrole sole (Eopsetta jordani) of which 60 percent are commercially caught from the Gulf of the Farallones



ORIGIN OF AVERAGE ANNUAL ENGLISH SOLE CATCHES FROM POINT ARENA TO POINT LOBOS BY OTTER TRAWLERS 1962 – 1966

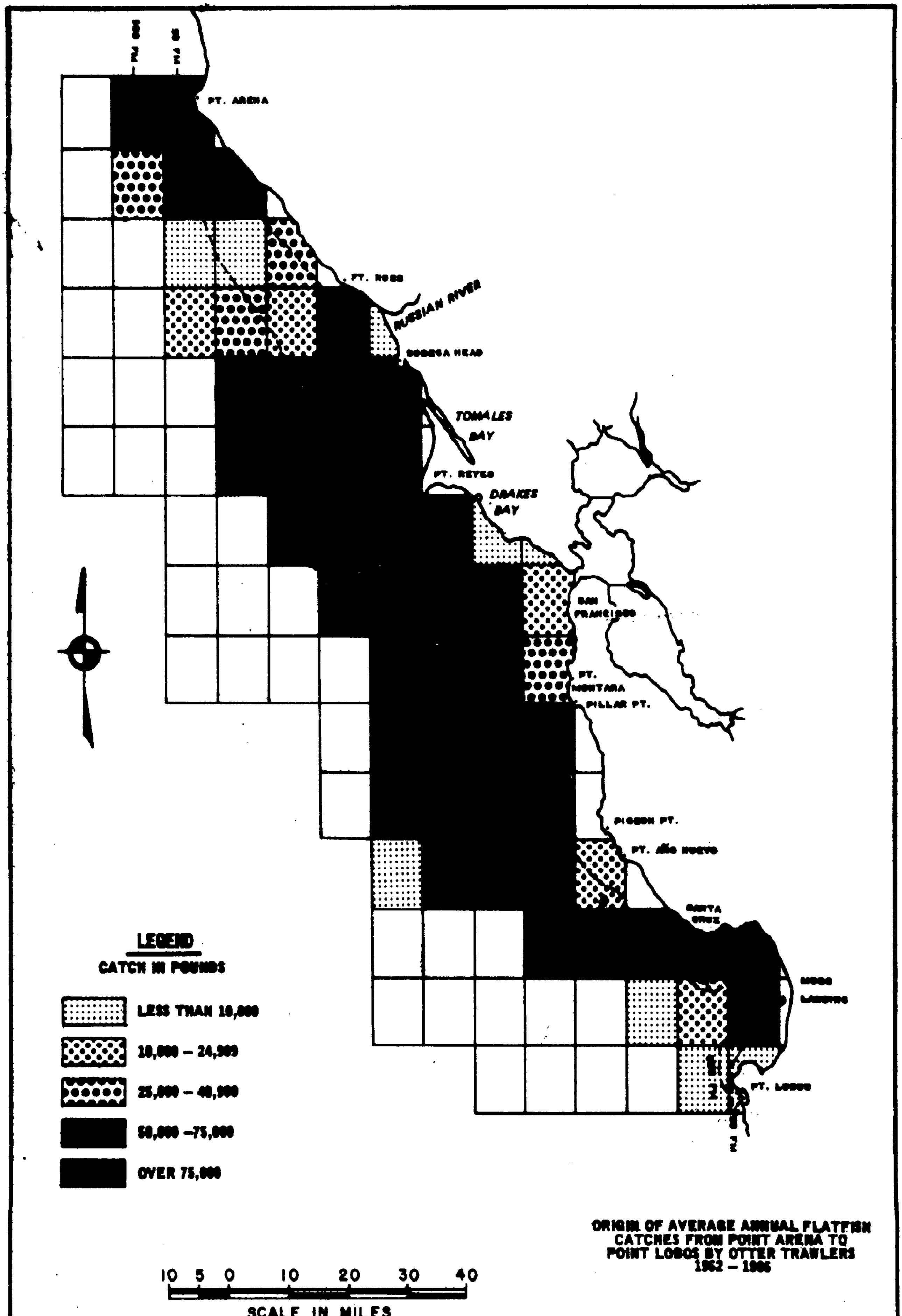
FIGURE 4

SOURCE: ODEMAR ET AL., 1968

between 180-210 fathoms (Odemar et al, 1968). Spawning occurs in winter in deep water. One of the most important spawning areas is situated 30 to 40 miles southwest of the San Francisco Lightship in 180-230 fathoms (Odemar et al, 1968). Adults move back inshore after spawning. Eggs are pelagic. A year-round fishery exists for the Petrole sole but peak landings occur during the summer and winter months.

(6) Other flatfish. There are several other flatfish species of lesser importance but which collectively constitute major annual landings. These species include the Rex sole (Glyptocephalus zachirus), two species of sanddabs (Citharichthys spp.) and the California halibut (Paralichthys californicus); all found in the Gulf of the Farallones. When all the flatfishes are considered, one can see that they are a major resource of the Gulf of the Farallones and support a large segment of the commercial fishing industry. Figure 5 shows a composite picture of their concentrations off central California.

(7) Other commercially and recreationally important fishes. In addition to the above species, many other marine fish are caught by commercial trawlers and party boats off central California. When treated as a group, they constitute a sizeable portion of the annual landings. Many of these species occur in the Gulf of the Farallones, near the sand bar, and at the 100-fathom disposal area vicinity. They include sharks, skates and rays, the Pacific hake, White croaker, Jack mackerel, Pacific mackerel, Pacific bonito, Albacore, surf perches, Cabezon, anchovies, herrings, Sablefish and Lingcod.



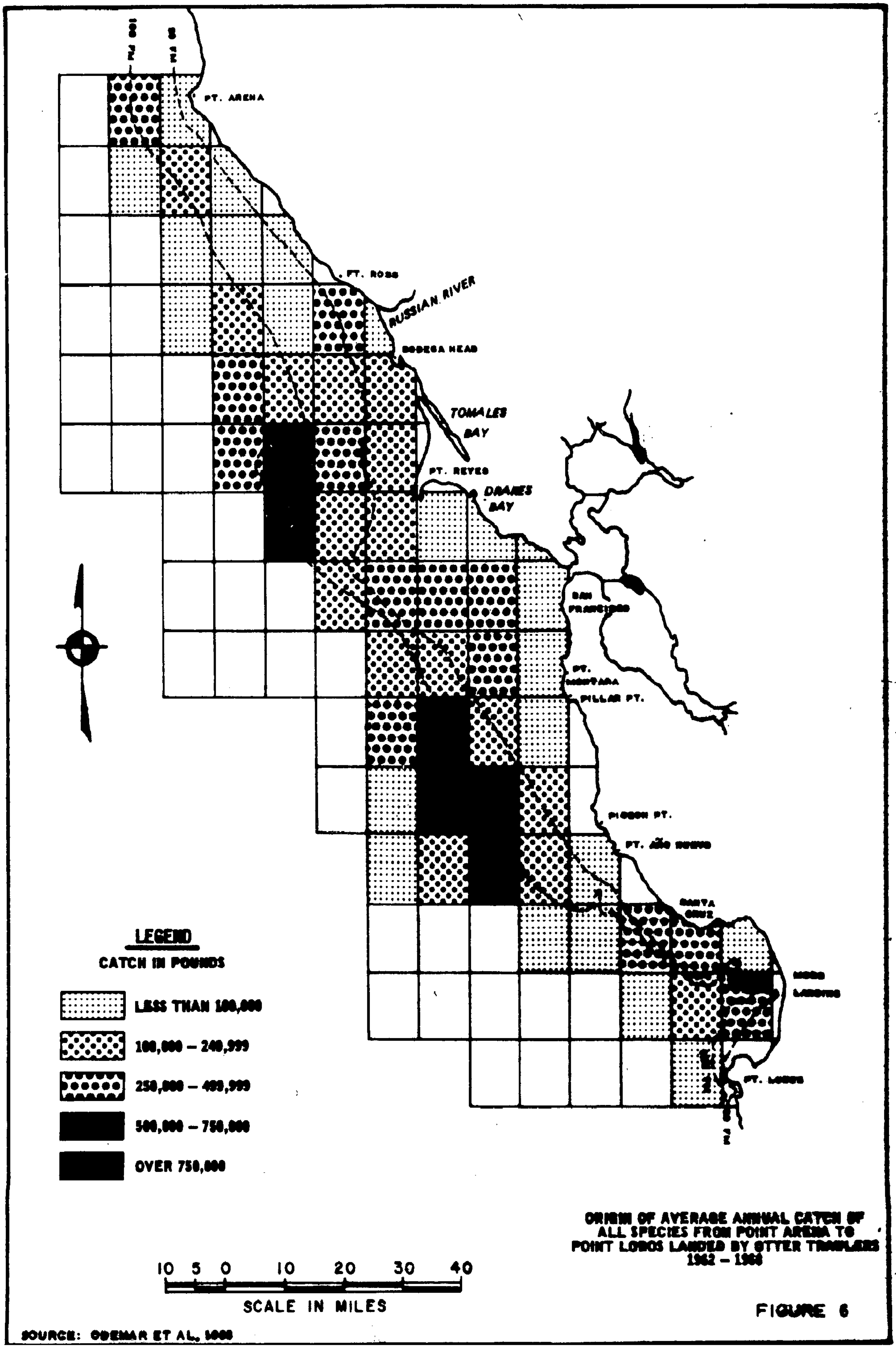
ORIGIN OF AVERAGE ANNUAL FLATFISH CATCHES FROM POINT ARENA TO POINT LOBOS BY OTTER TRAWLERS 1962 – 1966

FIGURE 5

SOURCE: ODEMAR ET AL, 1968

(8) From the fin fisheries data, the immense productivity of the Central California coastal waters, particularly the Gulf of the Farallones, can be seen. Most of the important fishes discussed have pelagic eggs which are an integral part of the plankton community. They use virtually all depths of the Continental Shelf as feeding, spawning or nursery areas. Extensive use of the bottom by flatfish is obvious from the above discussion. The subtle biological interrelationship between the Gulf and San Francisco Bay also becomes apparent from the above discussion. Not only are salmon dependent on both the ocean and estuarine (bay) environments but also several species of flatfish, the Pacific herring and others. Salmon live their adult lives in the ocean but spawn in freshwater; several flatfish species use the bays as nursery grounds for the young; and the Pacific herring lays its sticky eggs in shallow bays and the young feed in those protected waters. The most productive areas for all commercially important fish (except salmon) are in the Gulf of the Farallones and south of the Farallon Islands at depths greater than 50 fathoms (Figure 6). The productive areas south of the Farallones are near the 100-fathom disposal area.

c. Other Pelagic Species. There are open water inhabitants other than fish that are ecologically and commercially important. Ocean shrimp (*Pandalus jordani*), for example, are commercially netted north of Point Reyes (Odemar et al, 1968). They are a part of the plankton community but somewhat larger and more active than typical plankters. They



ORIGIN OF AVERAGE ANNUAL CATCH OF ALL SPECIES FROM POINT ARENA TO POINT LOBOS LANDED BY OTTER TRAWLERS 1962 – 1968

FIGURE 6

can be found near the surface preying on other plankters but are more commonly found in 40 to 65-fathom depths. Squid (Loligo opalescens) is another important fisheries product of Californa. In terms of annual landings, squid rivals the salmon and flatfish, averaging several million pounds per year. Largest landings are at Monterey and peak catches occur during the summer. The distribution of the ocean shrimp and squid extends throughout the Gulf of the Farllones but they are not abundant (at least, not commercially abundant) in these waters. High catch statistics of flatfish and rockfish from this area suggest that the bottom does harbor a rich supply of these smaller animals, and the fact there is a large population of shrimps is suggestive of copious amounts of scavengable food.

d. Marine Mammals. Daugherty lists 34 species of marine mammals in California ocean waters (Daugherty, 1972). The best known of the large whales off California is the California gray whale (Eschrichtius gibbosus) which migrates from the Bering Sea southward to Baja California during the winter. While migrating south, they are fairly close to shore and can be seen near the Farallones. There is debate as to whether they feed while in transit southward. While in the Bering Sea, they largely feed on zooplankton and to a lesser extent on fish.

Two porpoises, which are related to the whales, are occasionally seen close to shore. These are the Harbor porpoise (Phocoena phocoena) and the Dall porpoise (Phocoenoides dalli) and both have been recorded in San Francisco Bay (Daugherty, 1972). They are normally found offshore and actively feed on fish and squid.

out of the surf zone to bask in the sun and sleep. They may be seen together with the Elephant seals and sea lions at the Farallones and other offshore rocks. The Harbor seal feeds on fish, squid, shellfish and octopus.

Although rare in the Gulf of the Farallones, the Sea otter (Enhydra lutris) is a familiar marine mammal of Monterey Bay and south. They were hunted to near extinction in the 1800's, but have been protected since 1911. Like the Elephant seals, they have made a successful comeback. Infact, there is now a controversy as to whether to control its population, particularly in Monterey Bay, because of the alleged competition between sea otters and the abalone fishermen. Besides having a taste for abalone, they have a large appetite for other shellfish, octopus, sea urchins, crabs, and some fish.

Seals and sea lions are more common inshore than whales and porpoises because of their dependence on land - seals and sea lions are born on land. There are several species that inhabit the waters off the central coast as exemplified by the name Seal Rocks seaward of San Francisco. Two species are particularly common: the Steller sea lion (Eumetopias jubata) and the darker and smaller California sea lion (Zalophus californianus). Both occur together except during the summer and can be found at Ano Nuevo Island (San Mateo County), Seal Rocks, the Farallones and Point Reyes. The California sea lions are only found from the Channel Islands south during the summer breeding season. Stellers breed throughout their range from southern California to Alaska. Both feed on squid and fish.

The largest seal is the Northern elephant seal (Mirounga angustirostris) with the bulls attaining a length of 15-16 feet and weighing over two tons. Although more common farther south, there is a breeding population at Ano Nuevo Island during the winter and there are indications that they have started breeding on the Farallones. Before these creatures were hunted to near extinction in the late 1800's, they were abundant as far north as Point Reyes. They are now protected and their comeback has been slow but dramatic over the last century. Elephant seals feed mostly on small sharks, rays, ratfish, rockfish and squid, indicating that they feed in fairly deep waters (Daugherty, 1972).

The Harbor seal (Phoca vitulina) is common outside the Golden Gate. They are frequently seen close to shore and often haul

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INCLOSURE TWO

SAN FRANCISCO BAY AND ESTUARY DREDGE
DISPOSAL STUDY

OCEAN DISPOSAL OF DREDGED MATERIAL

BY

NAVAL UNDERSEA CENTER

San Francisco Bay and Estuary Dredge

Disposal Study

Ocean Disposal of Dredged Material

by

Naval Undersea Center

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Submitted to:

San Francisco District, U.S. Army Corps of Engineers

March 21, 1975

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INTRODUCTION

The San Francisco District of the Army Corps of Engineers is conducting a study of the environmental impact of dredging operations in San Francisco Bay and Estuary. As a part of this program a qualitative study of the ocean disposal of dredged material was conducted. The results of that study are presented in this report.

STATEMENT OF THE PROBLEM

Determination of the environmental impact of ocean disposal requires (1) knowledge of existing information of the ocean environment at the disposal site, (2) evaluation of what conditions should be monitored in assessing environmental impact and (3) evaluation of how the conditions can be monitored. The purpose of this work was to obtain information with respect to some of these requirements.

OBJECTIVES

The objectives of the program were (1) to obtain a qualitative description of the physical, chemical and biological environment at a 100-fathom disposal site in the vicinity of the Farallon Islands and (2) to obtain a qualitative description of the general release pattern of dredge material.

SCOPE OF WORK

The work items included in this study are a literature review, marine sediment studies, benthic and pelagic fauna studies and dredged material release studies.

Literature Review

The literature was reviewed with respect to the physical, chemical and biological components of the marine environment in the vicinity of the Farallon Islands as well as the potential impact of open ocean disposal of dredged material.

Marine Sediment Studies

Samples of marine sediments were taken at five sites within the study area prior to the deposition of dredged material and analyzed for grain size distribution, heavy metals (Pb, Hg, Cd, Cu, and Zn), chemical oxygen demand, and volatile solids. A video tape and 35 mm photographic survey of benthic sediments was made before release of dredged material to formulate a qualitative description of sediment characteristics and bottom topography.

Benthic and Pelagic Fauna Studies

Three species of the benthic community were selected, identified and analyzed for heavy metals (Pb, Hg, Cd, Cr, Cu, and Zn). From the photographic survey the speciation and enumeration of benthic on-fauna and near bottom pelagic fauna were determined and a qualitative description of the community in the disposal area was formulated.

Dredged Material Release Study

A video tape and 35 mm photographic survey of the benthic sediments in the disposal area after the deposition of dredged material was performed to provide a qualitative estimate of the area of disturbance and the depth of deposition.

LITERATURE REVIEW

The literature was reviewed to obtain background information about the environmental conditions in the vicinity of the Farallon Islands and about the potential impact of ocean disposal of dredged material. Information about the former was not readily available and reports on open ocean dredge disposal studies were lacking.

Detailed and extensive information about the ocean environment in the immediate vicinity of the Farallon Islands was not available. Most oceanographic surveys and studies are concerned with gross features of the Coastal Zone of California, e.g., the California Current. However, some physical and chemical data were available from the California Co-operative Oceanic Fisheries Investigations (CALCOFI) atlases (State of California Marine Resources Committee, 1964-1972). A summary of this data is compiled in "Oceanic Observations of the Pacific" by the Scripps Institution of Oceanography (1962). The CALCOFI station closest to the dredge disposal site is located at 35° 47.5'N, 123° 15'W which is about five miles northwest of the site. Water depth at this station is 60 fathoms. Data from this station as reported in "Oceanic Observations of the Pacific" are shown in Table 1. These data are in reasonable agreement with those measured by the U.S. Army Corps of Engineers (1974) at the San Francisco Channel Bar. However, dissolved oxygen values reported by the latter are inordinately high.

A number of reports concerning the disposal of wastes in the open ocean are available (e.g., Interstate Electronics Corporation, 1973a). However, there are very few reports which directly address the problem of ocean disposal of dredged material. In a bibliography on ocean waste disposal (Interstate Electronics Corporation, 1973b) over 400 documents are listed, but fewer than 20 were related to dredged materials. The environmental impact of dredging and the disposal of dredged material has been studied mainly in bays, estuaries and in the vicinity of eroded

TABLE 1. Oceanographic Conditions in the Vicinity of the Farallon Islands.

OBSERVED					INTERPOLATED				COMPUTED		
Z m	T °C	S ‰	O_2 ml/L	δ_T $10^{-5}cm^3/g$	Z m	T °C	S ‰	O_2 ml/L	σ_t g/L	δ_T $10^{-5}cm^3/g$	ΔD dyn. m
BLACK DOUGLAS; October 17, 1955; 1527 GCT; 37°47.5'N, 123°15'W; sounding, 60 fm; wind, 110°, force 2; weather, cloudy; sea, moderate; wire angle, 00°.											
0	12.18	33.72	5.76	241	0	12.18	33.72	5.76	25.58	241	0.00
10	12.18	33.72	5.70	241	10	12.18	33.72	5.70	25.58	241	0.02
14	12.17	33.71	5.77	242	20	12.08	33.72	5.73	25.60	240	0.05
19	12.11	33.72	5.76	240	30	11.72	33.72	5.60	25.67	233	0.07
24	11.95	33.73	5.69	236	50	11.18	33.76	5.44	25.79	221	0.12
29	11.75	33.72	5.58	234	75	9.72	33.86	3.78	26.13	189	0.17
33	11.59	33.73	5.61	230							
43	11.52	33.74	5.55	228							
53	10.94	33.77	5.36	216							
62	10.24	33.83	4.51	200							
77	9.65	33.86	3.72	188							

swimming beaches. The most economically important areas affected by these operations are shellfish beds and fish spawning grounds (Ingle, 1952; Sykes and Hall, 1970).

Biological aspects of concern for coastal waste disposal include assessment of dredged material toxicity, smothering of benthic communities, biostimulation by waste materials, public health concerns from pathogenic bacteria and viruses, and deleterious sublethal responses to toxicants (Cronin, 1969). Reviews are available on the impact of suspended and deposited sediments on estuarine organisms (Sherk, 1971) and the biological impact of offshore dredging to replace eroded beach sand (Thompson, 1973).

Benthic communities are considered the best indicators of environmental insult from dredging and dredged material disposal (Rounsfell, 1972; Sherk, 1971). Smothering may result from suspended solids at the dredge dump site, damaging coral reefs, oyster beds, etc. (Courtney, et al., 1974; Heillier and Kornicher, 1962). Oxygen depletion may result from high biochemical oxygen demands in the sediments (Arnal and Leopold, 1972) or directly from toxic materials contained in the sediments. The dumping of sediment of high biochemical oxygen demand near Santa Cruz, California, caused the destruction of botton-dwelling organisms by completely covering them so that they could not continue their normal and vital respiratory processes (Arnal and Leopold, 1972).

The effects of burial by sediments have been studied for a variety of organisms. The organisms most susceptible to burial by dredged material are the epibenthic species, weak burrowers and suspension feeders. The strong burrowers, infaunal species and deposit feeders appear to be most resistant to harmful effects resulting from burying (Stanley, 1970; Saila, Pratt and Polgar, 1972; Maurer, 1967; Cummington, 1968). Several benthic species were able to reach the sediment surface after burial in

20 cm of dredged material in a disposal study in Rhode Island Sound. Species colonizing the dredged material were members of the surrounding benthic community. Species diversity in the dredged material was high in some samples, suggesting little disturbance, while low diversities were found in other samples, suggesting considerable disturbance (Saila, Pratt and Polger, 1972). Burying of benthic communities by several centimeters of sediment was found to be of no significance in shifting sand environments in San Francisco Bay where strong currents prevailed naturally (Ebert and Cordier, 1966; U.S. Army Corps of Engineers, 1974). These environments favor only organisms which are highly motile, resisting burial by the sediments. Less motile forms such as small clams, snails and amphipods were absent in sediment samples and only a few polychaetes were present.

The impact of dredged material discharge on the benthic community, phyto- and zooplankton, and the nekton was studied in Chesapeake Bay (Cronin, et al., 1970). After release of the dredged material a 71% reduction in the average number of individual animals occurred in addition to a 65% reduction in the biomass. After 1.5 years the site returned to pre-disposal conditions for species diversity, abundance and biomass. In Chesapeake Bay, the potential harm from dredge spoils released in the area of spawning grounds of striped bass and shellfish beds was alleviated by dumping the material in deep areas of the bay (Gunter, Mackin and Ingle, 1964). In England deposition of china clay waste in two bays has eliminated much of the benthic fauna in the vicinity of the discharge (Howell and Shelton, 1970). Macrobenthic invertebrate assemblages were examined in the spoil disposal area and undisturbed control areas near the mouth of the Delaware Bay (Maurer, et al., 1974). A significant reduction in density of benthic animals was found at the disposal site.

Physical transport of released dredged material was studied by the U.S. Army Corps of Engineers (1974) at the San Francisco Bar. The water depth at the Bar was about 30 feet and approximately 3,000 cubic yards of material were dumped in less than 5 minutes. The dredged material did not exceed 2 inches during any one release. Movement of material on the Bar took place in two strata, the fluid sediment layer and the turbid suspension layer. The layers are maintained by surge and wave generated currents and moved by tidal currents. Tidal currents were found to be the main influence on dispersion of dredge material during settling and immediately after deposition on the sea floor. Methods have been developed to predict the fate of discharged dredged materials (Clark et al., 1971). The physical transport is described in four separate steps: convective descent, collapse, long-term dispersion and bottom transport or resuspension.

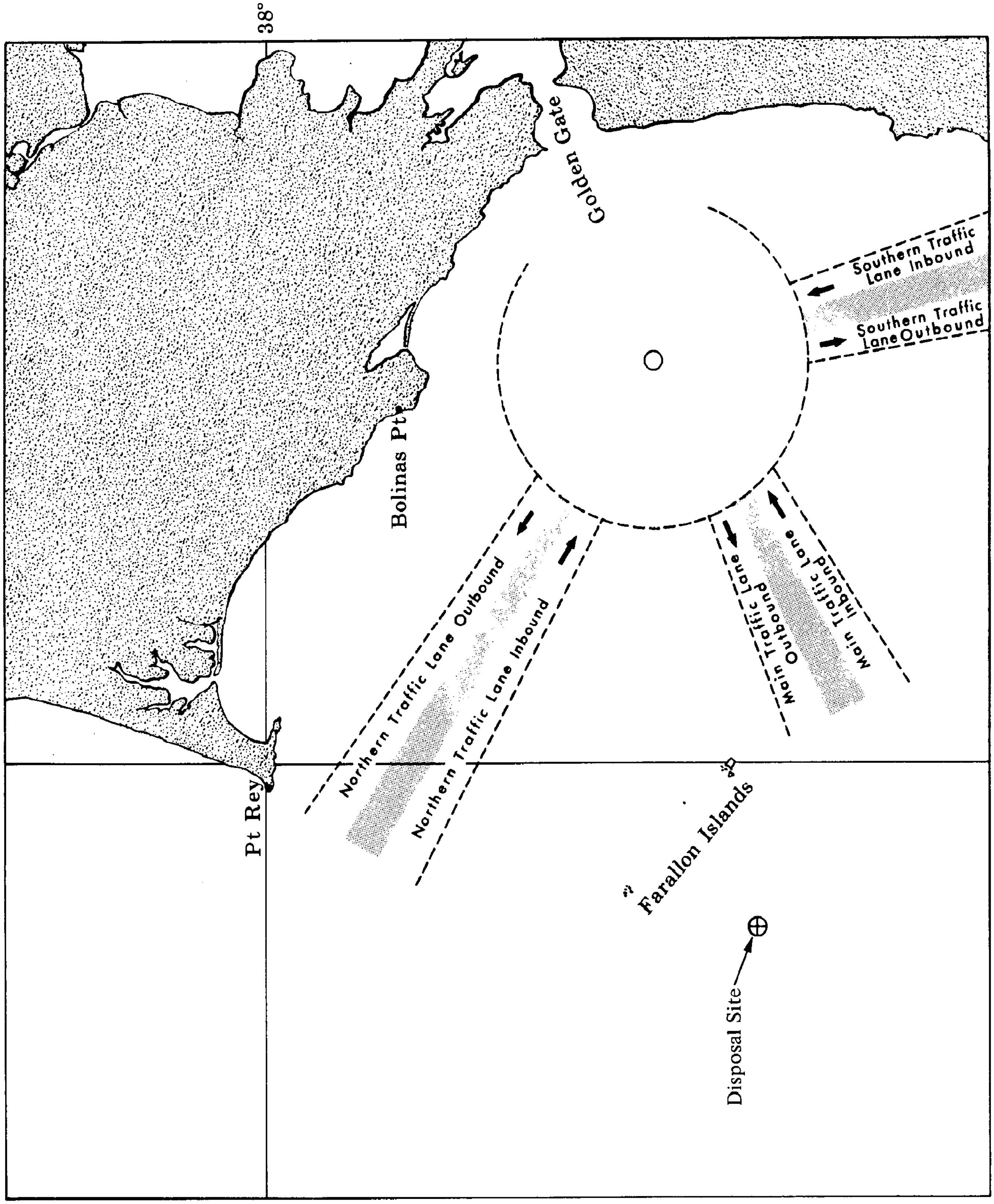
METHODS AND PROCEDURES

General

The disposal site is located along a 100-fathom contour line at 37° 41'N and 123° 07.5'W. The site is approximately 35 nautical miles west of San Francisco, California and 5 nautical miles west of the Farallon Islands (Figure 1). Originally a site located 20 miles northwest of the study area had been selected. However, this site was found to have a sloping bottom making it unsuitable for conducting the planned survey. Therefore, the 100-fathom contour line was followed until a flat area was found. The study area was a 500-foot by 1000-foot rectangle with a northwest to southeast orientation. The site was marked at each corner with a sonar reflector placed 6-feet from the bottom and at the center of the northwest end with a surface buoy (Figure 2).

Approximately 4000 cubic yards of dredged material loaded in two hoppers towed in tandem were released over the study area. Sediment

Figure 1. Location of the Open Ocean Dredge Material Disposal Site West of the Farallon Islands.



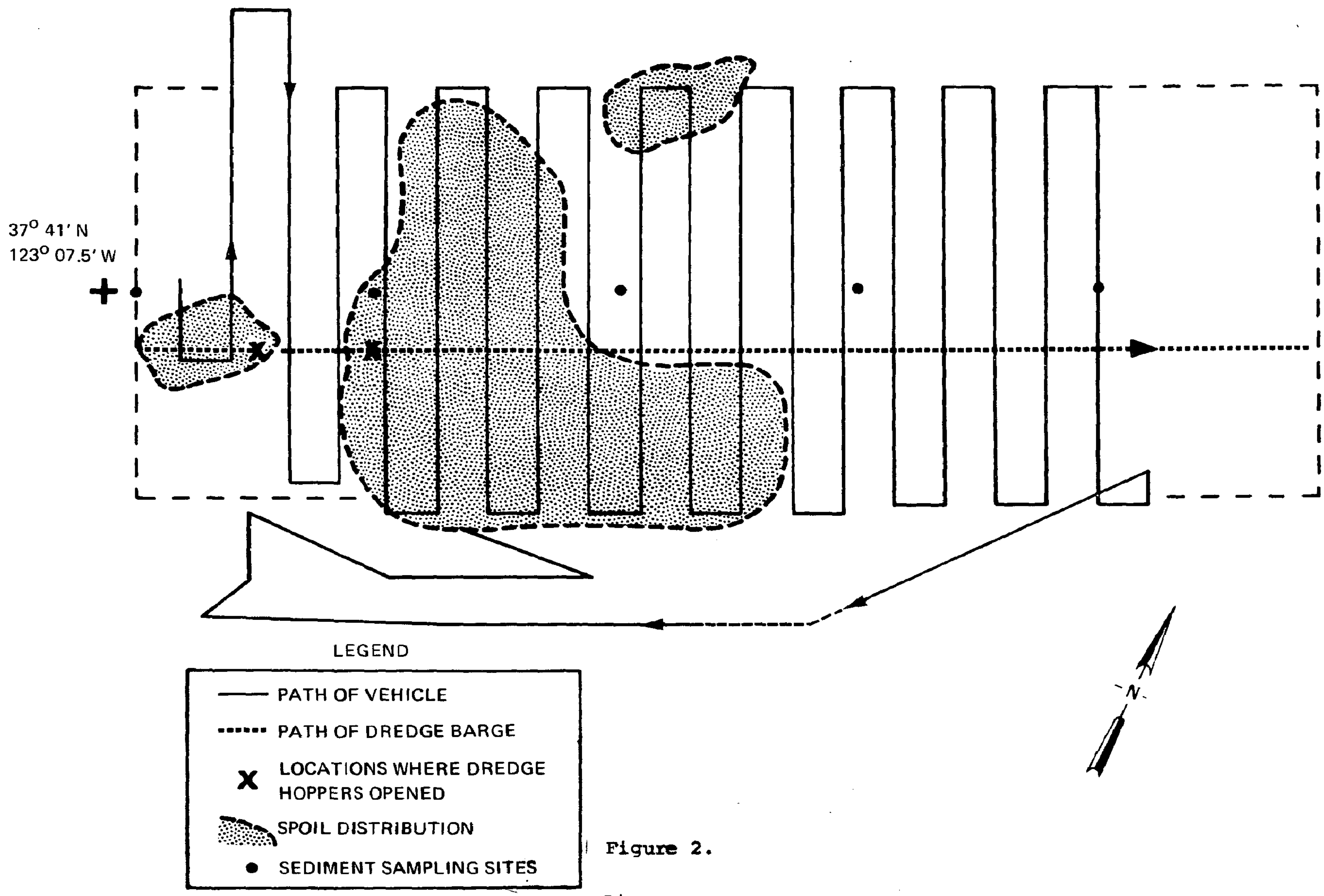


Figure 2.

Diagram of Study Area Showing Path of CURV III During Postdump Survey, Path of Dredge Barge, Distribution of Disposed Material on the Bottom and Predump Sediment Sampling Sites.

and biological samples were collected prior to release and photographic surveys were made both before and after the dump.

The primary vehicle used for the survey was the Naval Undersea Center's (NUC) Cable-Controlled Underwater Recovery Vehicle, CURV III (Figure 3). This vehicle is tethered, unmanned and remotely controlled. Details of the characteristics of CURV III are presented in Appendix A. The vehicle was used to place sonar reflectors on the bottom, to mark a grid pattern on the bottom at the study area and to take photographs. The photographic system consisted of two Vidicon television cameras, four mercury-vapor headlights, two mercury-vapor spotlights, and a 500-exposure 35-mm EG and G color camera with a 250-watt-second strobe. The support vessel for CURV III during this study was the M/V GEAR.

Marine Sediment Studies

Sediment samples were collected prior to the release of dredge materials at five sites located at 200 foot intervals, along a 1000-foot transverse of the disposal study area (Figure 2). Sediment samples were collected with a Shipek rotary bucket sampler, placed in polyethylene bags, and frozen immediately.

Each sediment sample was analyzed for copper, lead, zinc, cadmium and mercury. The sediment samples were also analyzed for chemical oxygen demand, volatile solids and grain size distribution.

For copper, lead, zinc and cadmium determinations, the sample was dried at 110°C for 2 to 3 days. It was then "homogenized" by mixing and stirring in a beaker. A 20-g portion of the sample was refluxed in 100-ml of concentrated nitric acid until evolution of NO_2 gas ceased. The mixture was centrifuged and the liquid decanted into a 100-ml volumetric flask. The residue was rinsed twice with distilled water, centrifuged

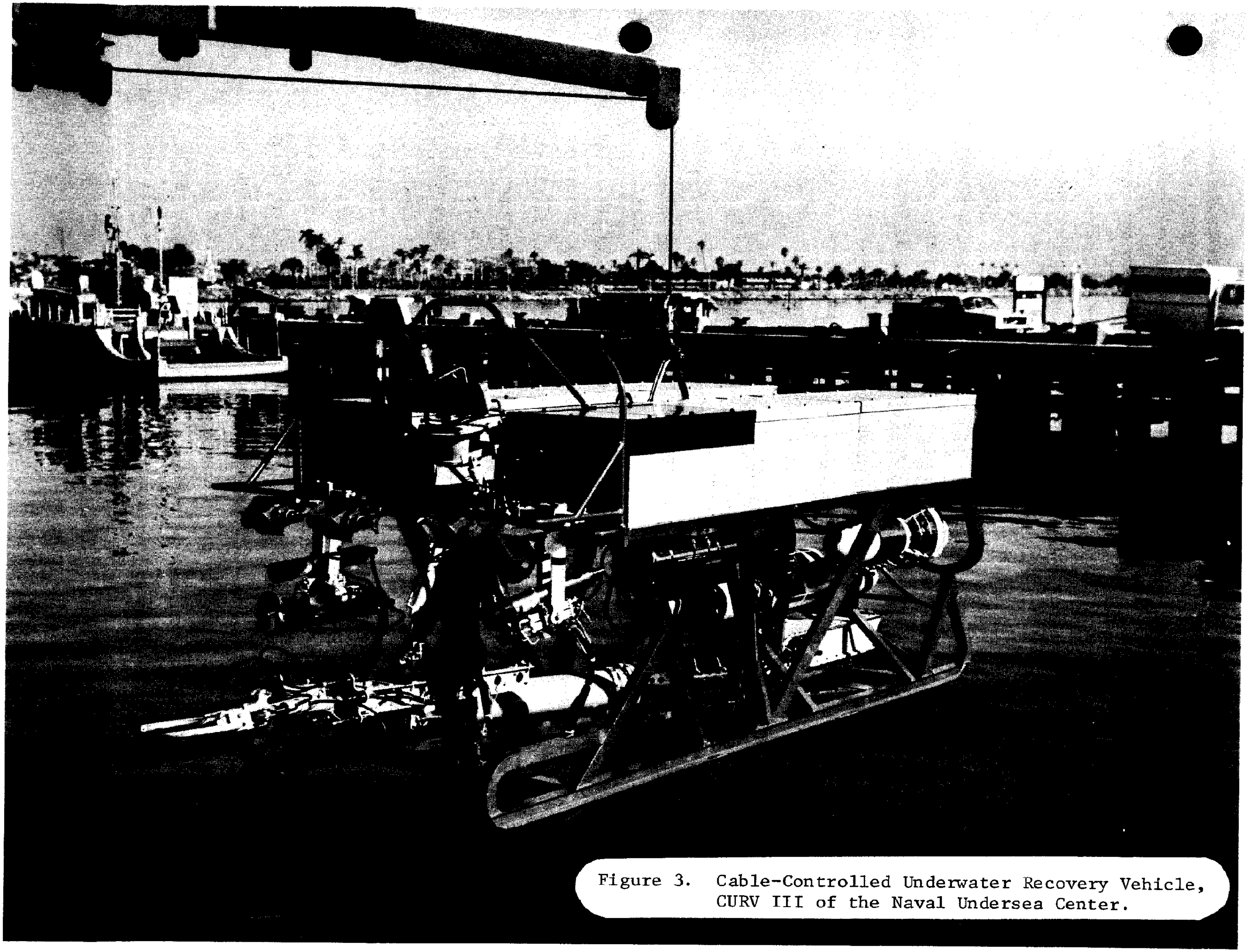


Figure 3. Cable-Controlled Underwater Recovery Vehicle, CURV III of the Naval Undersea Center.

and the rinse water was combined with the extract. The composite solution was diluted to 100 ml and aliquots from this solution were then analyzed by Atomic Absorption Spectrometry with a Perkin-Elmer Model 306 spectrometer. The method of standard additions was used; three additions were made for each sample.

Mercury concentrations were determined by neutron activation analysis (Williams and Weiss, 1973). Approximately 2-3 g of frozen sediment was transferred to irradiation vials prior to irradiation and covered with concentrated nitric acid. A section of frozen sediment that was in juxtaposition to the sample was chipped off and its water content determined by drying at 110°C for 1 hour. The comparator consisted of 10 g of mercury as the nitrate in 10 ml of concentrated nitric acid. The nitric acid blank consisted of three irradiation vials each filled with 14 ml of concentrated nitric acid. Samples, comparators and blanks were irradiated for 1 hour at a flux of 1.8×10^{12} neutrons cm^{-2} sec^{-1} in a "lazy susan" which rotated at 1 rpm about the core of the MARK I TRIGA reactor at General Atomic Co., San Diego, California. Subsequent to irradiation, sediments were digested in a nitric and sulfuric acid mixture as described previously. The sediment was prepared further for radiochemical purification by addition of 25 ml of concentrated ammonium hydroxide to the digest, and the mixture was filtered. If at this stage pebbles were detected in the residual sediment, they were removed and the sample was corrected for their weight. To the filtrate was added 2.5 ml of freshly prepared stannous chloride. The precipitated mercury metal was collected by centrifugation. The precipitate was dissolved in 5 ml *aqua regia*; 5 mg of copper (as nitrate) was added and the solution filtered. The reduction of mercury to the metal was repeated and the solid collected by filtration. The precipitate was again dissolved with 5 ml *aqua regia* and the solution was neutralized with 5 ml of concentrated ammonium hydroxide after the addition of mercury carrier, and the mercuric sulfide was precipitated and collected for measurement. The processed mercury samples as well as mercury carrier standards (10 mg mercury) were reirradiated for 5 seconds.

Through comparison of the activity level of the samples and standards, the carrier yield was computed and the counting rate in the original irradiation was corrected for this factor. The radioactive measurements were made with a sodium iodide detector coupled to a 400-channel pulse-height analyzer. The counts attributable to the 77 keV radiation of ^{197}Hg were integrated by the method of Covell (1959).

Chemical oxygen demand (COD) and volatile solids were determined by procedures described in Standard Methods for the Examination of Water and Wastewater (1971). Sediment samples were first dried overnight at 100° - 105°C. For COD analyses 1-gram (dry weight) aliquots were refluxed in concentrated sulfuric acid solution containing potassium dichromate. Silver sulfate was used as a catalyst and mercuric sulfate was added to remove chloride interference. The excess dichromate was titrated with standard ferrous ammonium sulfate using ferroin as an indicator. Volatile solids were determined by heating approximately 20 grams of the dried sediment at 550°C for 2-hours. The difference in weight before and after heating is a measure of the volatile solids.

Dispersed grain size distribution was determined using the Wentworth (1933) grain size classification (Appendix B) and the Emery settling tube (Emery, 1933). Sand is introduced into the top of the Emery settling tube (a vertical water-filled tube), and the height of the sand column formed at the bottom is measured at predetermined times. The amount of the sample which is larger than a given diameter is obtained using empirical calibration curves.

Benthic and Pelagic Faunal Studies

Speciation and enumeration of epibenthic macrofauna were obtained from photographs taken prior to dumping by CURV III. Animal densities were calculated from numerical totals obtained from the photographic survey. The mean area covered per slide was estimated to be 2.25 m^2; and the total area covered by the photographs was 1316 m^2. The animals on each slide were enumerated by group. The total for each group was divided by the total estimated area to obtain density. Species were also identified from the slides

Three species of macrofauna were collected for analysis with a grasping basket assembly fitted to the CURV vehicle. A Pisaster star fish, a small fish *Mesluccius productus* and a Heart Urchin *Echinocardium* were collected. Each species was analyzed for mercury, copper, cadmium, lead, chromium, and zinc. With the exception of mercury, which was determined by neutron activation, all metals were analyzed by atomic absorption spectrophotometry. These samples were ashed overnight at 470°C and the residue dissolved in concentrated nitric acid. The method of standard additions was used; three additions were made for each sample. Due to the large quantity of material required for the atomic absorption analysis only the Pisaster starfish could be analyzed for mercury.

Dredge Material Release Study

To determine the dispersal of the dredged material a grid pattern was first marked on the bottom at the study area. This was accomplished with CURV III during the predump photographic survey using the skids of the vehicle. The predump markings consisted of 1000-foot-long parallel lines at 25-foot intervals.

The dredged material was then released from two hoppers containing 2000 cubic yards each. The hoppers were towed by a dredge barge starting from a position adjacent to the surface buoy and proceeding through the study area at a speed of 1-2 knots (Figure 2). The hoppers were opened 150 feet and 200 feet southeast of the buoy and the material was released as the vessel proceeded on course. The hoppers were emptied by the time they reached 500 feet into the study area.

Approximately 12-hours after the release of dredged material a second photographic survey was made. The vehicle followed a track perpendicular to the predump markings (Figure 2). As each 35-mm frame was exposed a sequential number was exposed on that frame. This number was related to a number tally in the CURV III control van on board the M/V Gear. The position of the dredged material on the bottom was determined by cross referencing the frame number with the number and position log maintained in the control van.

RESULTS

Marine Sediment Studies

Copper, cadmium, lead, zinc and mercury concentrations in the sediments are tabulated in Table 2. Copper ranged from 4.97 - 7.81 ppm at four stations and was 21.1 ppm at a fifth station, cadmium levels ranged from 0.084-1.03 ppm, lead from 5.53 - 9.05 ppm, zinc from 30.9 - 61.5 ppm and mercury from 51 - 87 ppb at three stations with two stations having values of 267 ppb and 376 ppb.

Chemical oxygen demand and volatile solids are reported in Table 3. COD ranged from 12.85 - 20.34 mg/g and volatile solids ranged from 1.6% to 2.9%.

Dispersed grain size distributions are presented in Table 4 and Figure 4.

Benthic and Pelagic Faunal Studies

The epibenthic macrofauna of the study area was relatively abundant. A species list is given in Table 5. The dominant group were arthropods which made up about 70% of all bottom animals. In order of decreasing abundance the remainder were molluscs (13%), bony fishes (10%), and

TABLE 2. Heavy Metal Concentrations in Sediments Collected September, 1974, in the Vicinity of the Farallon Islands, California (ppm dry weight)

Station No.	Copper	Cadmium	Lead	Zinc	Mercury
1	21.1	0.084	9.05	61.5	0.087
2	7.81	0.18	6.66	35.2	0.376
3	7.72	0.259	6.25	40.4	0.045
4	6.30	0.518	7.29	30.9	0.267
5	4.97	1.02	5.53	34.4	0.051

TABLE 3. Chemical Oxygen Demand and Volatile Solid Concentrations of Sediments Collected in September, 1974, in the Farallon Islands, California

Station No.	Chemical Oxygen Demand % (dry wt.)	Volatile Solids % (dry wt.)
1	2.03	2.93
2	1.42	1.93
3	1.28	1.83
4	1.36	1.62
5	1.44	1.74

TABLE 4. Grain Size Distribution of the Sediments Collected in September, 1974, in the Vicinity of the Farallon Islands, California

Station No.	Median Diameter mm	Median Diameter ϕ	Mean Diameter mm	Mean Diameter ϕ	Composition (%) gravel	sand	silt	clay
1	0.0337	4.89	0.0190	5.72	0	24	56.5	19.5
2	0.0728	3.78	0.0661	3.92	0	58	40.0	2.0
3	0.0661	3.92	0.0791	3.66	0	72.2	21.3	6.5
4	0.1111	3.17	0.1073	3.22	0	85.5	12.5	2.0
5	0.1051	3.25	0.1022	3.29	0	88.5	9.5	2.0

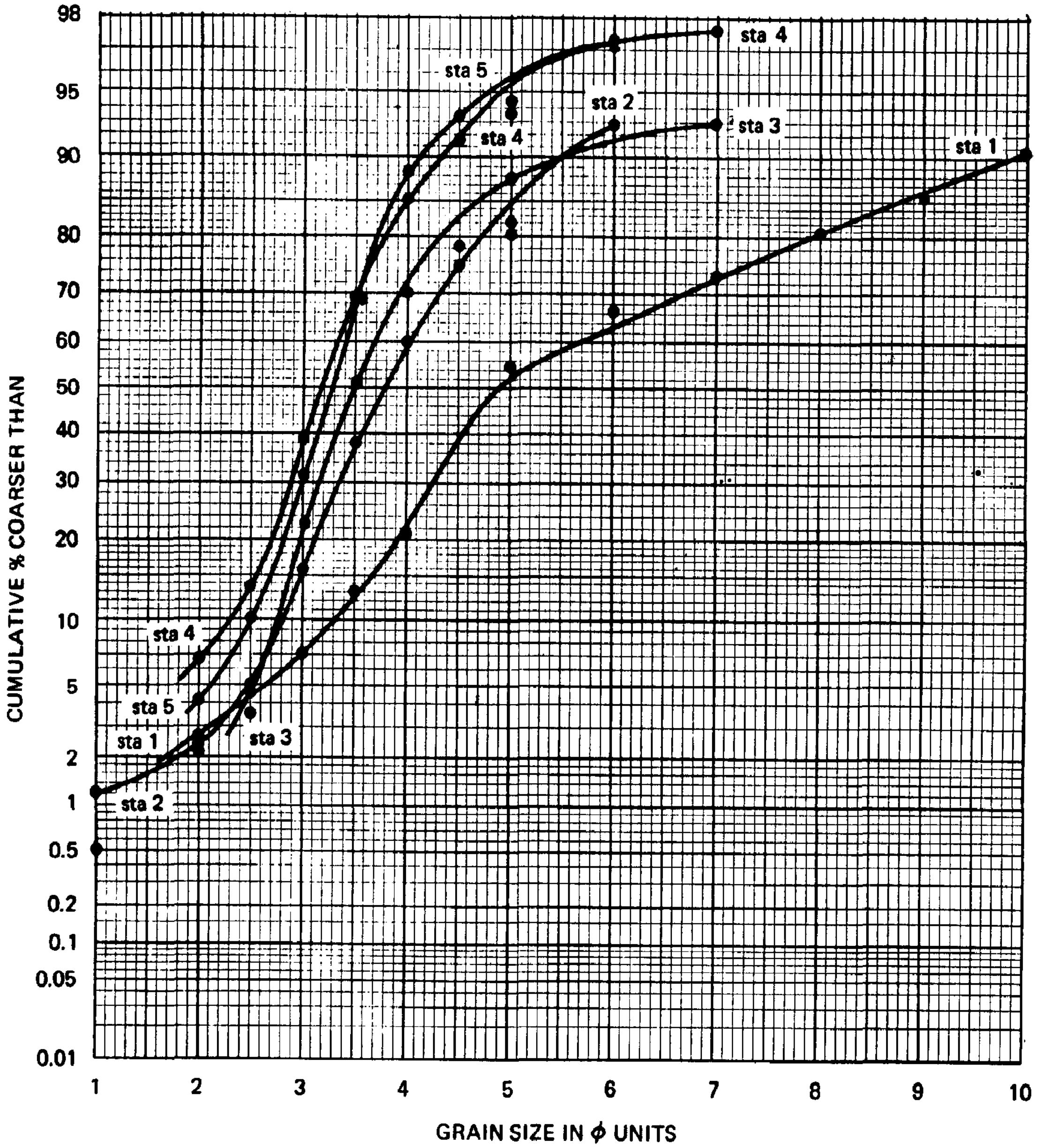


Figure 4. Grain size distribution for sediments collected in September, 1974, in the vicinity of the Farallon Islands, Calfironia.

TABLE 5. List of Species Identified During Predump Survey of Ocean Disposal Site in the Vicinity of the Farallon Islands.

Fishes	Sebastes zacentrus - Sharpchin Rockfish
	Sebastes diploproa - Splitnose Rockfish
	Sebastes elongatus - Greenstriped Rockfish
	Sebastes saxicola - Stripetail Rockfish
	Anaplopoma fimbria - Sablefish
	Eptatretus stoutii - Pacific Hagfish
	Aprodon cortezianus - Bigfin Eelpout
	Unidentified cod - FAMILY GADIDAE
	Unidentified prickleback - FAMILY STICHAEIDAE
	Unidentified flatfish - FAMILY PLEURONECTIDAE
Echinoderms	Allocentrotus fragilis - Pink Urchin
	Parastichopus californicus - Sea Cucumber
	Luidia sp. - Sea Star
	Unidentified sea star - CLASS ASTEROIDEA
Arthropods	Crago sp. - Shrimp
	Cancer sp. - Crab
	Unidentified crab - BRACHYURAN
Mollusks	Pecten sp. - PELECYPOD
	Octopus sp. - CEPHALOPOD

echinoderms (7%). The density of total animals was relatively high (1801 animals over 1316 m^2 or 1.4 animals/m^2), but the species diversity was relatively low. About 13 different species were observed but only four species accounted for 91% of all bottom animals. Most of the arthropods were decapod crustaceans, probably of the genus *Crago* sp. (1235 decapods/1801 animals or 69%) and they were randomly distributed. The molluscs were composed almost entirely of *Octopus* sp. (11% of all animals). Bony fishes were dominated by rockfish, *Sebastes* sp. (7% of all animals) and the echinoderms by *Allocentrotus* (5% of all animals. Figures 5 - 8 are representative photographs of the bottom fauna.

The heavy metal concentration in three species of epibenthic macrofauna are shown in Table 6. Copper ranged from 1.74 - 5.87 ppm, cadmium from 0.28 - 1.66 ppm, lead from 2.06 - 7.27 ppm, and chromium from 16.7 - 103.3 ppm. Mercury concentrations on replicate samples of the starfish were 259 ppb and 204 ppb.

Dredge Material Release Studies

Photographs indicate that the dredged material was deposited somewhat unevenly over the deposition area. Most of the material fell directly below the path of the barge, while some spread laterally to the edge of the study area and some fell slightly beyond its borders. Photographs of the dredged material on the bottom are shown in Figures 9 - 11. Some of the material was deposited in large clumps while the rest was finer and more widely dispersed.

The photographic survey indicated that the average depth of deposited dredged material was approximately 1 foot. Based on the area of deposition this indicates a sediment estimate of 5,000 cubic yards of material which is in reasonable agreement with the 4,000 cubic yards actually dumped.

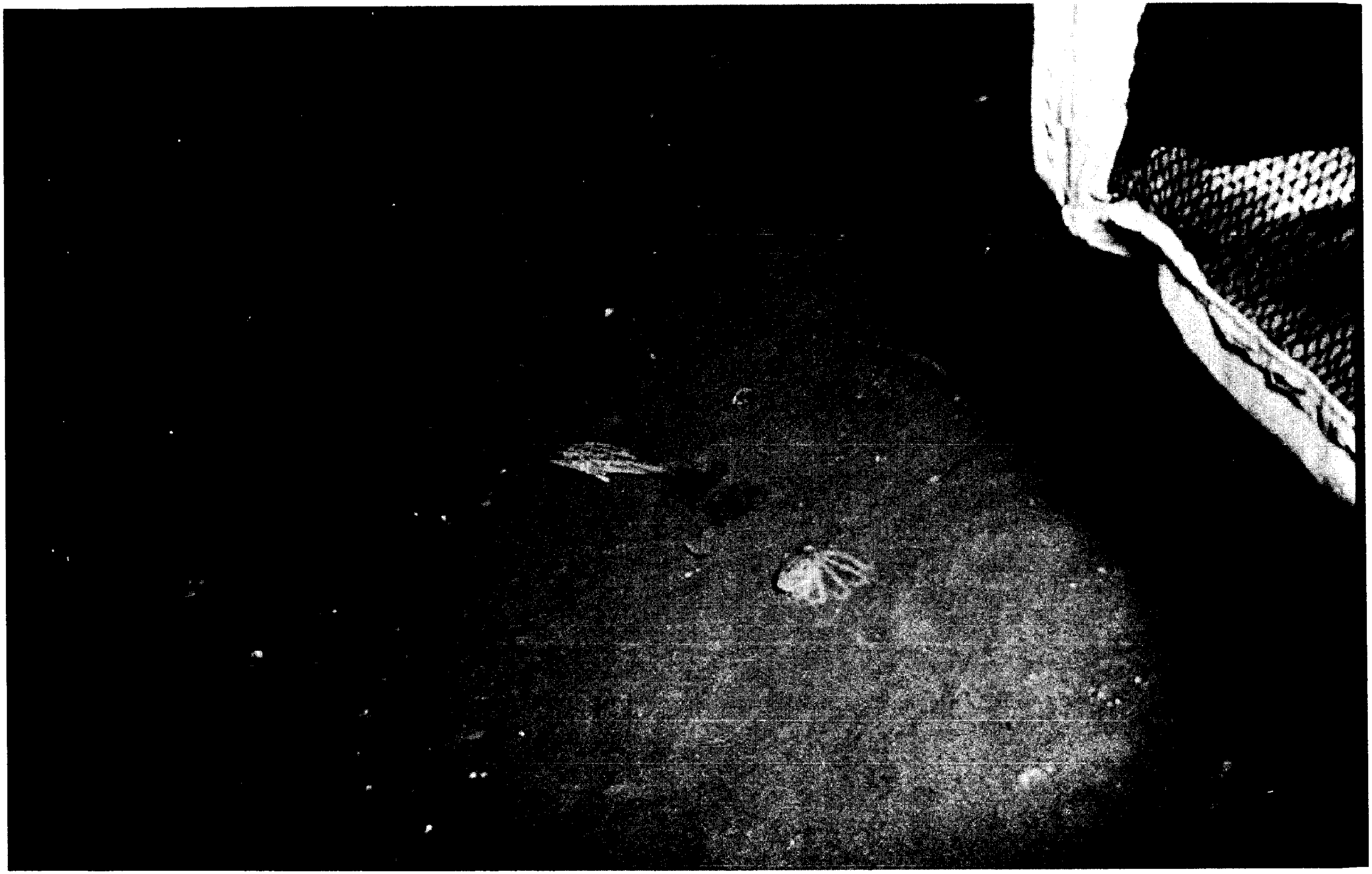


Figure 5. Benthic fauna in the vicinity of the Farallon Islands: Sea cucumbers (Parastichopus californicus), octopi and rockfish. Photograph taken with CURV III during predump survey.

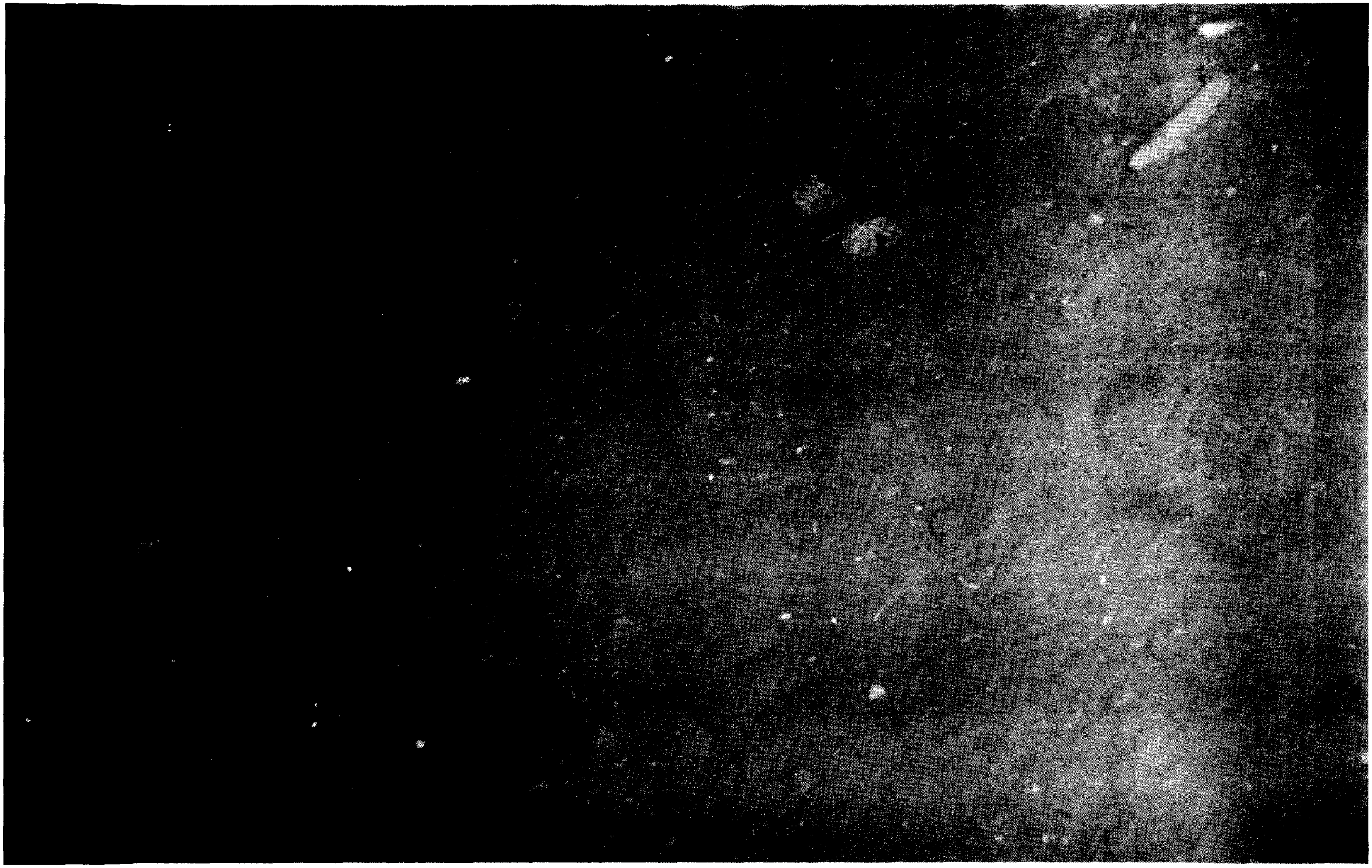


Figure 6. Benthic fauna in the vicinity of the Farallon Islands: Sea cucumbers (Parastichopus californicus), octopi and decapods. Photograph taken with CURV III during predump survey.

Figure 7. Benthic fauna in the vicinity of the Farallon Islands: decapods. Photograph taken with CURV III during predump survey.

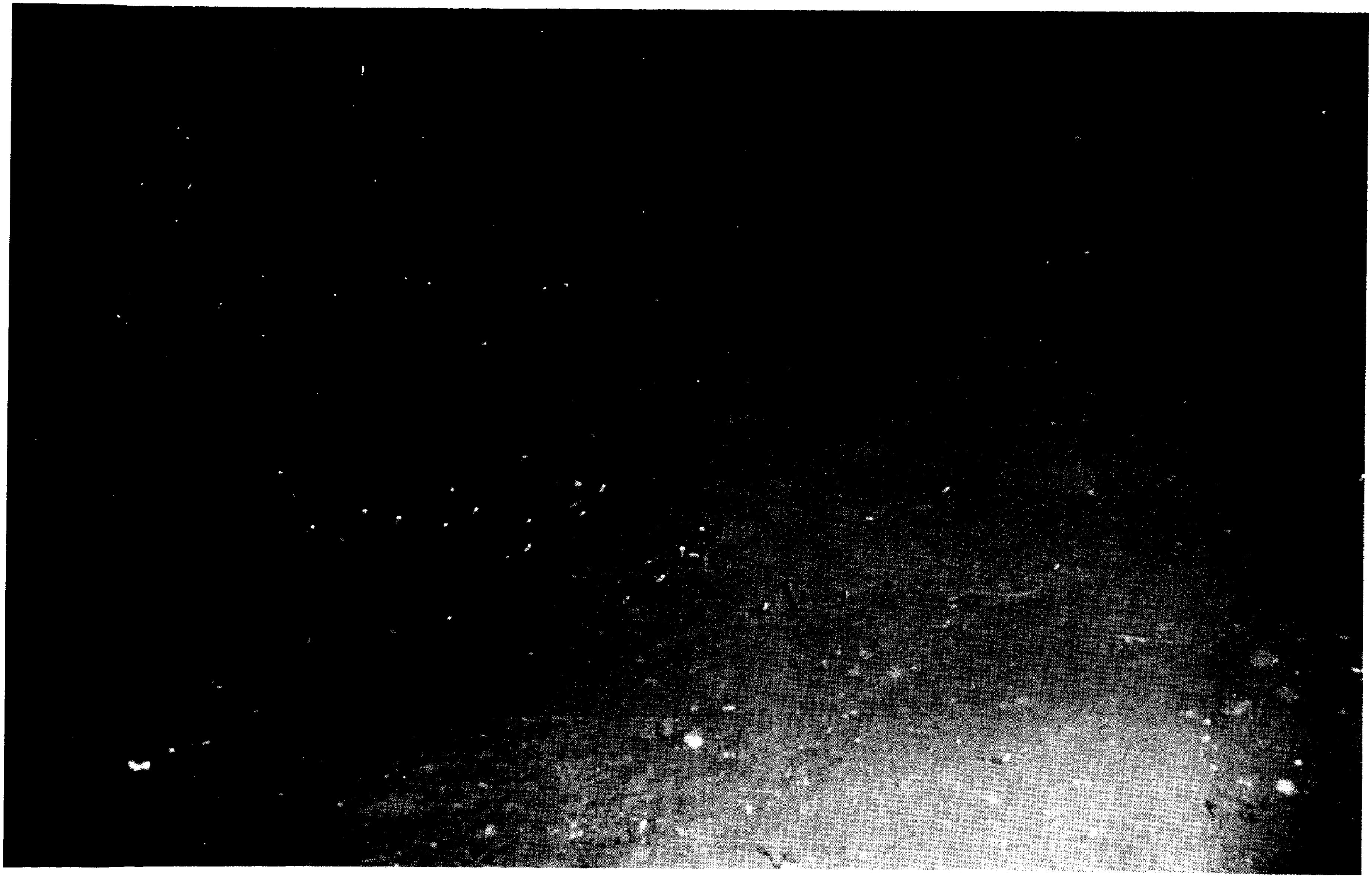


Figure 8. Benthic fauna in the vicinity of the Farallon Islands; decapods. Photograph taken with CURV III during predump survey.

TABLE 6. Heavy Metal Concentrations of Epibenthic Fauna Collected in September, 1974, in the Vicinity of the Farallon Islands, California

	Copper ppm (wet wt)	Cadmium ppm (wet wt)	Lead ppm (wet wt)	Chromium ppm (wet wt)	Zinc ppm (wet wt)	Mercury ppb (dry wt)
Starfish	5.87	1.66	7.27	2.13	103.3	259/204**
Urchin	1.74	0.28	3.25	0.67	16.7	
Fish	2.26	*	2.06	0.95	54.4	

*Concentrations below sensitivity of analytical procedure (0.02 ppm).

**Assumed Hg carrier yield of 90%.

DISCUSSION

The results of this study indicate that the physical, chemical, and biological environment at the 100-fathom disposal site in the vicinity of the Farallon Islands is generally comparable to other nearshore areas along the California coast. However, there were some significant differences.

Data reported in the CALCOFI atlases (Table 2, State of California Marine Resources Committee 1964-1972) show that salinity and dissolved oxygen concentration near the study area are similar to those in other area along the coast and that water temperature is, as expected, slightly lower than those of waters further south.

Heavy metal levels in the sediments collected in the study area are similar to those reported in the literature for natural nearshore sediments. A comparison of metal concentrations found in this work with those cited in the literature is presented in Table 7. "Dredge Disposal Site LA-5" is a 100-fathom disposal site located 7.7 miles west of San Diego. Copper and lead values reported by Riley and Skirrow (1965) are slightly higher than those found by others. Mercury concentrations for the North Slope of Alaska are the range of values reported by Weiss, et al. (1974) for 52 stations in the Beaufort Sea. The mercury values found in this work agree well with those of Weiss. Generally higher levels of mercury in sediments were reported off the coast of Palos Verdes, California, by the Southern California Coastal Water Research Project (SCCWRP, 1974); the values ranged from 0.21 - 4.67 ppm. COD for the sediments ranged from 1.42 - 2.03 % (dry weight), which is considerably higher than the range of 0.17 - 0.68% (with 2.6% at one station) reported by the U.S. Army Corps of Engineers (1974) for the San Francisco Channel Bar. COD values ranging from 0.62 - 6.36% have been reported for San Diego Bay sediments (Peeling, 1975). COD is a measure of the amount of material oxidized by

TABLE 7. Literature Values for Co, Cd, Pb, Zn, Hg in Sediments, ppm, Dry Weight.

Location	Cu	Cd	Pb	Zn	Hg	Reference
Farallon Islands	4.97-21.1	0.084-1.02	5.53-9.05	30.9-61.5	0.045-0.376	This work
Dredge Disposal Site LA-5	15-24		7.16-12.4	49-68	0.059-0.291	
Natural Marine Nearshore Sediment	48		20			Riley & Skirrow (1965)
Southern California Coast	13-25	0.60-1.2	7.1-22	54-76	--	Galloway (1972)
North Slope, Alaska					0.029-0.169	Weiss, et.al. (1974)

potassium dichromate in sulfuric acid at reflux temperature. This includes organic matter, living organisms entrapped in the sediment during sampling, detritus, etc. Reasons for the high values in the study area are not known. However, because of the harsh chemical treatment used in the procedure, COD measurements are of questionable value. Volatile solids ranged from 1.62 - 2.93% (dry weight). These values are slightly higher than the average of 1.41% found at a disposal site in Mayport, Florida (Naval Oceanographic Office, 1973) but lower that the range of 1.4 - 9.0% reported for San Diego Bay (Peeling, 1975) and an order of magnitude lower than that for dredged material at Mayport. Again the reason for the small discrepancy between volatile solids for the study area and for the Mayport disposal site is not clear.

Dispersed grain size distributions (Figure 4) show that 50% or more of sediments at Stations 2 - 5 and 80% at Station 1 are finer than 0.06 mm. These sediments are much finer than those from the San Francisco Channel Bar as reported by the U.S. Army Corps of Engineers (1974). This is not unexpected since bottom currents at the study area are much less than at the Channel Bar (less than 1 knot compared to 2 - 4 knots). It should be noted that the objective of grain size analysis is to characterize the nature of the sediment during deposition or after accumulation. This objective probably is not met, because the grain size distribution is necessarily altered during the analysis. The sediment is separated into two fractions by wet sieving and the fractions are analyzed by different settling methods, which may cause a discontinuity in the cumulative curve at the sand-site break (Griffith 1951). However, many workers believe the discontinuity is real and results from a natural deficiency of fine sand and coarse silt grain (Udden, 1914, Wentworth, 1933, Hough 1942, Tanner, 1958; Folk, 1959). It is necessary to attempt to analyze the size distribution of single grains, which requires the use of a dispersing agent for sieving and pipet analysis. In the marine environment, however, fine grains do not settle individually, but rather as aggregates, bonded electrostatically as a result of ingestion by filter feeding animals (Arrhenius, 1963). Thus, by necessity, fine particles are not in their natural state during analysis. Assuming that the sediment grains were normally distributed when deposited, this would skew the distribution curve toward the fines.

Results of the benthic and pelagic faunal studies showed a high animal density in the study area (1.4 animals/m^2). This apparent high density may be misleading due to the presence of a large number of decapods which were not observed in past work with CURV III in Southern California. They are relatively small in size and near the limit of resolution of the CURV III cameras. At about 9 cm in length they were extremely difficult to see; however, their detection was facilitated by their large eyes, which reflected the light from the vehicle. Another interesting observation was the relative paucity of echinoderms and abundance of cephalopods. Most of our benthic surveys in Southern California have shown the echinoderms to be the dominant group, in most cases constituting 70-90% of the epibenthic macrofauna; whereas in the Farallon Island study area only 7% of the observed animals were echinoderms and no cephalopods were observed. In addition, the density of all animals was considerably lower at LA-5 (0.293 animals/m^2). Some of the biota were analyzed for lead, copper, cadmium, chromium zinc and mercury. With the exception of lead, the observed heavy metal concentrations are similar to those reported in the literature. Copper ranged from 1.74 - 5.87 ppm; Bowen (1966) reports 4 - 50 ppm. Cadmium concentrations of a starfish and urchin were found to be 1.66 ppm and 0.28 ppm, respectively, at the Farallon Island site, while Bowen reports a range of 0.15 - 3 ppm. Lead ranged from 2.06 - 7.27 ppm versus 0.5 ppm in the literature. The apparent high observed values are of questionable significance because they only represent three animals. Zinc was found to be 16.7 - 103.3 ppm which is within the range of 6 - 1500 ppm reported by Bowen. Chromium concentration ranged from 0.67 - 2.13 ppm, while Bowen reports a range of 0.2 - 1 ppm. Two aliquots of the starfish were analyzed for mercury; the observed concentrations of 259 and 204 ppm are comparable to literature values. The many decapods probably play a significant role at the base of the food chain in this area. Although nearly all of the decapods were observed on the bottom during the predump survey, they were in the water column 1 - 3 meters off the bottom during the postdump survey. Since the predump survey was conducted during the day and the postdump survey conducted at night, it is not clear whether this phenomenon was due to the effects of dumping or a natural migration for feeding. Similar animals are known to come off the bottom to feed at night.

The dispersal of dredged material on the bottom was estimated from photographs taken after the dump (Figure 9 - 12). Coverage of the bottom was estimated from the photographs and the track followed by the vehicle by cross referencing the photographic frame number with the position log. Coverage of the grid lines laid out prior to the dump did not prove useful in assessing coverage. Photographs indicated that the dredge material was distributed somewhat unevenly over the deposition area. Most of the material fell directly below the path of the barge while some spread laterally to the edge, and some slightly beyond the borders of the study area (Figure 2). The material was compacted in the barge as it was transported to the disposal site. Such compacting would vary with the sea conditions during transport, the distance to the disposal site and the characteristics of the dredge material, and this would affect the distribution of the material on the bottom. The material released in this study probably had little affect upon the area as a whole because the coverage was limited. If the dredge materials were uniformly distributed over the entire area all of the animals would be affected in some way by smothering or partial covering. With an uneven distribution of the material animals in the covered areas might be severely affected but the community as a whole would be relatively untouched. Photographic evidence indicates that less than 25% of the study area was covered with dredged material. Repeated dumping within the area would increase coverage and ultimately affect the entire area. Frequency of dumping would also be a factor in

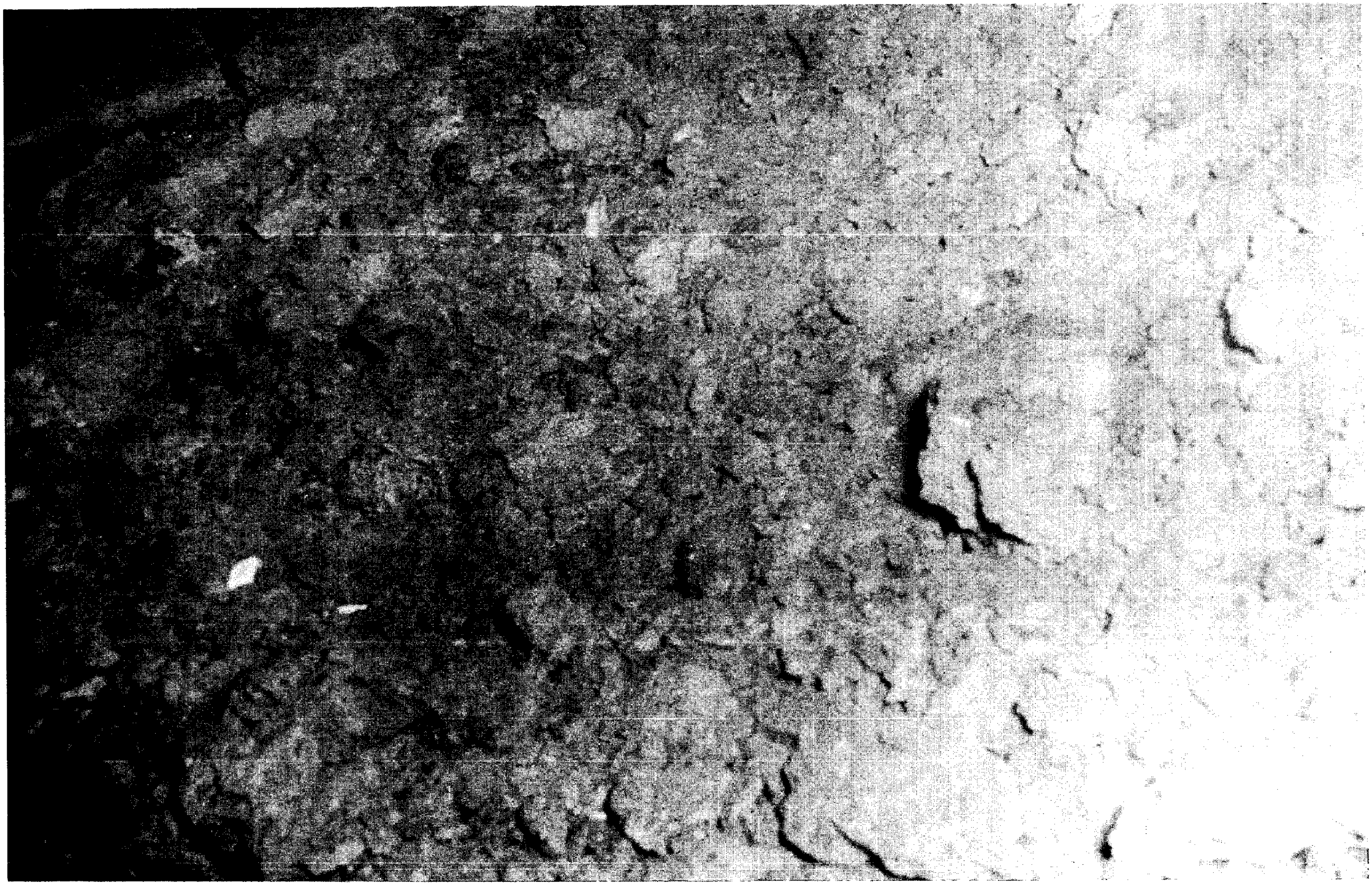


Figure 9. Released dredged material on the bottom.

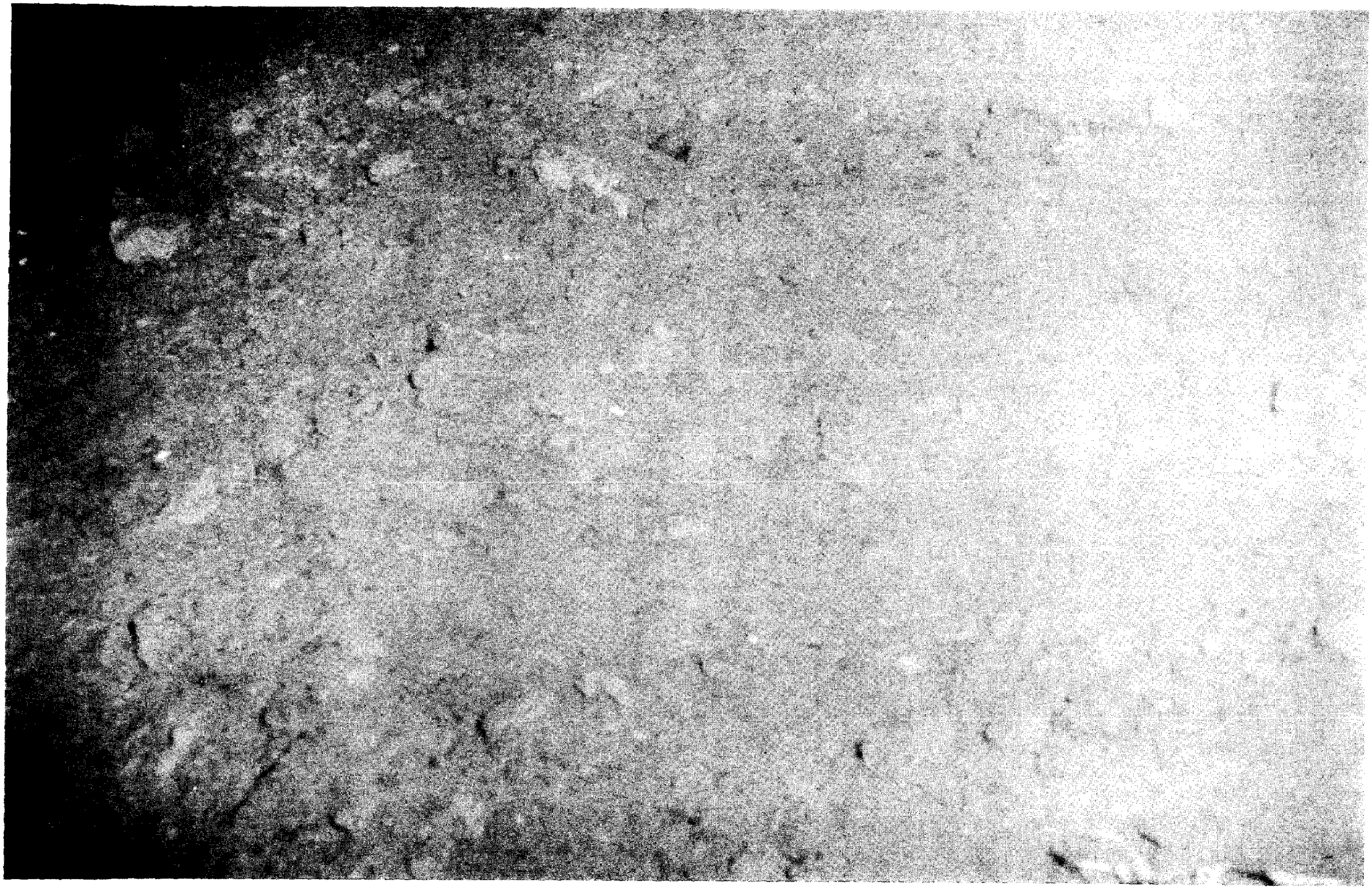


Figure 10. Released dredged material on the bottom.

Figure 11. Released dredged material on the bottom.

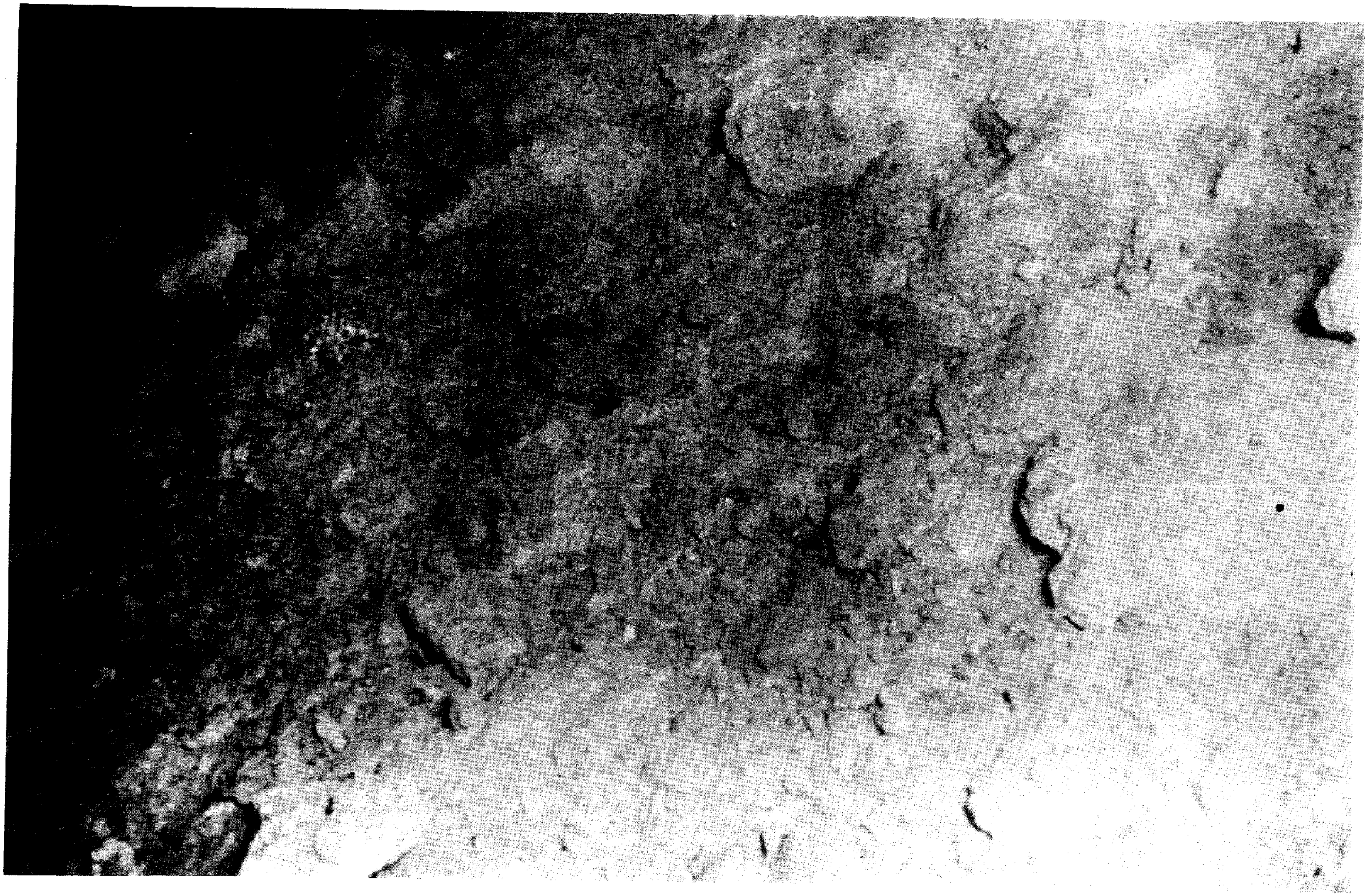


Figure 12. Released dredged material on the bottom.

the covering and smothering and subsequent reestablishment of benthic communities. There is insufficient data to speculate on the point at which dumping would affect the entire benthic community for a specific area. If there were significant pollutants in the dredged material there would probably be a severe effect upon the benthic community whether the material was uniformly distributed or in a clumped distribution pattern. While it is relatively easy to predict the impact from physical covering or smothering it is almost impossible to predict the environmental impact from chemical factors on the biota.

The literature indicates that the most harmful effect of dredge disposal on benthic communities results from smothering or lowered oxygen concentrations caused by high oxygen-demanding sediments. The response of benthic organisms to burial by dredge material depends upon the ability of organisms to move through the material to the sediment surface or respire successfully beneath the deposited material. Dispersion of discharged dredge material and subsequent covering of benthic communities is predicated upon the magnitude and duration of the release, sediment density and grain size, tendency of the spoils to remain in clumps, currents and depth of the water column and movement of the dredge barge during release.

CONCLUSIONS

On the basis of this study the following conclusions can be drawn:

1. The literature indicated a lack of detailed oceanographic information in the vicinity of the Farallon Islands and a paucity of reports dealing with the disposal of dredged material in the open ocean.

2. Sediment analyses showed that the 100-fathom disposal site is not contaminated with respect to heavy metals, volatile solids or chemical oxygen demand (although the last was higher than that reported for bottom sediments at the San Francisco Channel Bar). The sediment in the study area consisted of a large amount of fine material; more than 50% by weight was finer than 0.06 mm.

3. Photographic survey of the bottom prior to the dump showed that the area is biologically active. The density of macrofauna was estimated to be 1.4 animals/m^2. However, species diversity was relatively low. About 13 different species were observed, but only four species accounted for 91% of all bottom animals. These animals were found not to be contaminated with heavy metals.

4. The materials release study demonstrated that most material fell directly below the path of the hoppers, while some spread laterally to the edge of the study area. Some of the material fell in clumps, probably because of compaction during transit to the disposal site.

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APPENDIX A

GENERAL CHARACTERISTICS
OF
CURV III

DESCRIPTION

The Cable-controlled Underwater Recovery Vehicle (CURV) program was begun by NUC for the specific purpose of developing economical systems to recover test ordnance at NUC's Long Beach and San Clemente Island test ranges. CURV III is the latest in this series of tethered, unmanned, remotely controlled vehicles. Originally conceived for use as a search and recovery vehicle, CURV has evolved into a versatile and easily adaptable multipurpose work vehicle capable of performing not only search and recovery tasks but also of pursuing test, evaluation, exploration, and work projects. Basically, CURV is a composite of intergrated subsystems including such items as propulsion, search, and navigation, optics, hydraulics, and tools. Because it is unmanned and does not require life support systems or other complex support systems, CURV is able to perform most undersea tasks more economically and efficiently than manned systems. Also, since it is powered and controlled from the surface, CURV has a continuous, unlimited operating capability. Under emergency conditions, the vehicle can operate to 10,000-foot depths. Another feature of CURV is that it is easily transported to any spot in the world. The vehicle, control van, cable, and support gear can be transported to a work site and mounted on any suitable ship of opportunity.

VEHICLE

General

Size . . . . 6.5 ft x 6.5 ft x 15 ft

Weight	4,500 lbs (approx.)
Operating Depth	7,000 ft
Crew	7
Payload	200 lbs max (vehicle only) 2000 lbs max (with assist on strength member) 10,000+ lbs (with separate surface recovery line)
Submerged Speed (max)	4 kts (estimated)
Operating Endurance	Unlimited
Power Requirements	(self contained)

Vehicle Subsystems and Components

Propulsion	Three 3-phase, 440 VAC, 10 HP, oil-filled, pressure-equalized motors with fixed pitch screws; thrust varied by voltage, max 400 lbs forward, 250 lbs reverse (each)
Seach and Navigation	Straze SLAD-603 -Active Sonar: CTFM 78-82 kHz, ranges 50 yd, 250 yd, 800 yd -Passive Sonar: 45 kHz -Transponder Mode: 50 yd, 250 yd, 800 yd -Sonar Training Mechanism: Projector, hydrophone, receiver, and passive listening hydrophone; automatic scan 120° at 26°/sec, tilt + 15°

Search and Navigation (cont) . .	-Locator: Pinger with 36.5 kHz, 1.5 sec pulse interrupted by 37.2 kHz, 10 msec pulse -Altimeter: Transducer 100 kHz, 100 msec pulse, ranges 0-10 ft and 0-100 ft, accuracy ±0.5 ft -Compass: Gimballed rang-core, flux gate magnetometer
Optics	Television Cameras -Two Hydro Products solid state, standard scan vidicon cameras; water corrected lens, 54° view angle, aluminum housing Lights -Four stationary, pressure balanced mercury vapor 250 watt flood lights at front of vehicle. Two 100 watt pressure-balance mercury vapor spotlights mounted with TV cameras Documentary Camera -One EG&G 35mm color with 200 watt/sec strobe, 1 flash every 8 sec Optical Pan-and-Tilt Units -Hydraulically-actuated 360° pan, 90° tilt
Hydraulics	Actuator -Hydraulic five-function unit. Arm UP-DOWN, Arm rotate:CLOCK-WISE-COUNTER-CLOCKWISE; Arm eject; Wrist:CLOCKWISE-COUNTER-CLOCKWISE (axis 90° to arm); Claw: OPEN-CLOSE

Hydraulics (cont)	Tools -13 in. claw, snare, grapnel hook, noose, marine organism basket, manipulator, Pyronol torch
Structural Components	Buoyancy -50 3M Co. Syntactic foam slabs. Each slab:5-3/4 x 11-3/4 x 22 in. (0.83 cu ft), 38 lbs/cu ft (26 lbs/ cu ft buoyancy) -Hydrostatic crush: 11,000 feet maximum -Water absorbtion: 3% maximum 2.1% average @ 4,500 psi Total Byouancy -With approximately 70 lbs forward lead trim; vehicle 40-50 lbs buoyant Frame -Main structure, exclusive of brackets and bumpers, 6 ft wide 4 ft high, 11 ft long of welded 6061 aluminum structural shapes
Interconnecting Cables . . .	Cables are pressure-balanced immersed in oil inside flexible tygon tubing. Pressure-balanced connectors based on NUC designs.

MAIN CABLE

Length	10,000 ft
Diameter	1-1/2 in. O.D.
Weight	1.25 lb per ft in air, 0.6 lb per ft in water

SUPPORT AND POWER CONVERSION EQUIPMENT

<u>Instrumentation Van</u> . . . . 15 ft long, 9 ft wide, 8 ft high with air conditioner removed

5 Bay electronic control console:

- Display - Sonar, altimeter, depthometer, locator, vehicle tracker, TV monitors, vehicle and ship's compass (with cable twist counter)
- Vehicle Operator Controls - Propulsion, T.V., 35mm camera lights, claw
- Sonar Operator Controls - Sonar mode and range scan frequency, assist on TV on claw
- Communication - Ship intercom, radio remote station

<u>Vehicle & Target Tracking Gear</u> . . . BALD Gear (Directional Hydrophone)

NUC UNLOC

Honeywell Sea-Scannar II-F sonar

<u>Instrument Power Conversion and Isolation Package</u> . . . . One 5 KW motor generator

Three Superior Electric variable transformers for output of 1000V (max)

HANDLING EQUIPMENT

<u>Crane</u> . . . . Hiab Titan articulating crane with manually-telescoping boom; 5,000 lbs at 19 ft.

Cable Storage Bins	. . . .	Two bins 4 ft high, 4 ft wide, 14 ft long
Miscellaneous	. . . .	Spare parts van portable capstan, Boston Whaler

APPENDIX B

Wentworth Grain Size Classification

The Wentworth grain size classification (Table 3) is probably the most widely used sediment grade scale. The sample was first divided into coarse (sand and gravel) and fine (silt and clay) fractions by wet sieving, using 0.062 mm sieve and 1/4 gm/ml sodium hexametaphosphate solution (commercial Calgon water conditioner) as a dispersing agent. Measurement of the amounts of silt- and clay-size grains was done, indirectly, using Stoke's Law of settling velocities (Stokes 1851):

$$v = \frac{2(d_1 - d_2)gr^2}{9m}$$

where: v = settling velocity of a sphere in a fluid,
d_1 = density of the sphere
d_2 = density of the fluid
g = acceleration of gravity
m = viscosity of the fluid.

The assumption is made that all sediment particles are spherical, and that all particles have the same density. The fluid used is Calgon solution of approximately constant temperature, so that the viscosity and density may be considered constant.

With these assumptions and conditions, the velocity of a falling particle is dependent on its size. In other words,

$$v = Cr^2.$$

These assumptions and conditions are, of course, not entirely correct, but this method has the advantage of more closely approximating natural settling and sorting processes than do direct methods of size measurement.

The technique is simply to determine the weight of material which has settled out of suspension after a predetermined amount of time. Settling times are computed for specific grain sized using the above equation.

Grain size analyses are customarily shown as graphs of grain size (in phi units) versus cumulative weight percent (coarser than) on arithmetic probability paper. In general size distributions are approximately log-normal (i.e., the cumulative curve is a straight line or nearly so). Because of the approximately normal distribution of sediment sizes, several standard statistical parameters have been adapted for describing sediments. These include mean grain size, median grain size, standard deviation (called sorting coefficient by sedimentologists), skewness and kurtosis. These statistics are approximated by the following formulas:

$$\text{Median} = \phi 50 \qquad \text{Trask, 1930}$$

$$\text{Mean} = \frac{(\phi 16 + \phi 50 + \phi 84)}{3} \qquad \text{Folk \& Ward, 1957}$$

$$\text{Sorting coefficient} = \frac{(\phi 84 - \phi 16)}{4} + \frac{(\phi 95 - \phi 5)}{6.6} \qquad \text{Folk \& Ward, 1957}$$

$$\text{Skewness} = \frac{(\phi 16 + \phi 84 - 2(\phi 50))}{2(\phi 84 - \phi 16)} + \frac{(\phi 5 + \phi 95 - 2(\phi 50))}{2(\phi 95 - \phi 5)} \qquad \text{Folk \& Ward, 1957}$$

Where: Ø16 indicates the grain size (in phi units) corresponding to the 16th percentile, etc.

Median, and perferably mean, grain size reflect the overall average size of the sediment as influenced by source, transport, and environment of deposition.

Sorting Coefficient, or standard deviation, is a measure of the uniformity of the size distribution. Descriptively, a well sorted sediment has a narrow range of sizes, while a poorly-sorted sediment has a broad range of sizes.

Skewness is a measure of the assymetry of the distribution.

Kurtosis is a measure of the peakedness of the distribution.

WENTWORTH GRAIN SIZE CLASSIFICATION

Diameter in mm		Name	Diameter in Ø units *
64 - 4	(64.00-4.000)	Pebble	-6 to -2
4 - 2	(4.000-2.000)	Granule	-2 to -1
2 - 1	(2.000-1.000)	V. Cse. Sand	-1 to C
1 - 1/2	(1.000-.5000)	Coarse Sand	0 to 1
1/2 - 1/4	(.5000-.2500)	Medium Sand	1 to 2
1/4 - 1/8	(.2500-.1250)	Fine Sand	2 to 3
1/8 - 1/16	(.1250-.0625)	V. Fine Sand	3 to 4
1/16 - 1/32	(10625-.0313)	Coarse Silt	4 to 5
1/32 - 1/64	(.0313-.0156)	Medium Silt	5 to 6
1/64 - 1/128	(.0156-.0078)	Fine Silt	6 to 7
1/128 - 1/256	(.0078-.0039)	V. Fine Silt	7 to 8
1/256 - 1/512	(.0039-.0020)	Coarse Clay	8 to 9
1/512 - 1/1024	(.0020-.0010)	Medium Clay	9 to 10

* Diameter in Ø units = $-\log_2$ of the grain size in mm.

The Ø notation (Krumbein, 1934) is a convenient method for converting geometric size classes to equal intervals. It is analagous to plotting on logarithmic graph paper.

INCLOSURE THREE

WATER QUALITY MONITORING
100-FATHOM OCEAN DISPOSAL STUDY AREA
(5-6 September 1975)

Equipment - Interoceans Water Quality Monitoring Probe - Model 500

WATER QUALITY READINGS
100-FATHOM OCEAN DISPOSAL
STUDY AREA

Station A	Depth (Meters)	Cond. (mmho)	Sal. (0/00)	Tur. (% Trans.)	Tur. (FTU)	Temp. (^{o}C)	D.O. (mg/1)
	5.0	39.90	33.50	91.6	0	13.45	10.40
	10.0	39.90	33.50	91.5	0	13.45	10.35
	15.0	38.85	33.30	92.3	0	12.45	9.65
	20.0	38.45	33.40	92.4	0	11.80	8.70
	25.0	38.20	33.45	92.5	0	11.60	7.97
	30.0	37.85	33.50	92.6	0	11.15	7.35
	35.0	37.70	33.55	92.8	0	11.05	6.82
	40.0	37.50	33.55	92.8	0	10.75	6.60
	45.0	37.30	33.35	92.8	0	10.55	6.30
	50.0	37.10	33.60	92.6	0	10.25	5.92
	55.0	37.05	33.60	92.6	0	10.15	5.90
	60.0	37.05	33.65	92.8	0	10.15	5.90
	65.0	36.72	33.60	92.6	0	9.75	5.35
	70.0	36.60	33.68	92.6	0	9.60	5.80
	75.0	36.50	33.70	92.6	0	9.50	5.80
Station B							
	10.0	39.95	33.50	90.1	0	13.50	10.80
	20.0	39.30	33.40	91.9	0	12.75	9.75
	30.0	37.90	33.35	92.4	0	11.30	7.90
	40.0	37.50	33.50	92.5	0	10.80	7.12
	50.0	37.20	33.55	92.5	0	10.35	6.30
	60.0	36.95	33.60	92.4	0	10.05	5.80
	70.0	36.62	33.60	92.6	0	9.66	5.40
	80.0	36.40	33.70	92.4	0	9.35	5.10
Station C							
	10.0	39.95	33.45	88.0	1	13.55	10.50
	20.0	38.55	33.50	89.6	1	12.20	9.60
	30.0	38.20	33.30	90.0	1	11.70	8.85
	40.0	37.60	33.35	90.5	1	10.98	7.85
	50.0	37.20	33.50	90.7	1	10.52	6.55
	60.0	36.90	33.55	90.7	1	10.05	6.10
	70.0	36.75	33.60	90.8	1	9.85	5.90
	75.0	36.65	33.65	90.6	1	9.70	5.60

WATER QUALITY READINGS
100-FATHOM OCEAN DISPOSAL
STUDY AREA

Station A	Depth (Meters)	Cond. (mmho)	Sal. (0/00)	Tur. (% Trans.)	Tur. (FTU)	Temp. (°C)	D.O. (mg/1)
	5.0	39.90	33.50	91.6	0	13.45	10.40
	10.0	39.90	33.50	91.5	0	13.45	10.35
	15.0	38.85	33.30	92.3	0	12.45	9.65
	20.0	38.45	33.40	92.4	0	11.80	8.70
	25.0	38.20	33.45	92.5	0	11.60	7.97
	30.0	37.85	33.50	92.6	0	11.15	7.35
	35.0	37.70	33.55	92.8	0	11.05	6.82
	40.0	37.50	33.55	92.8	0	10.75	6.60
	45.0	37.30	33.35	92.8	0	10.55	6.30
	50.0	37.10	33.60	92.6	0	10.25	5.92
	55.0	37.05	33.60	92.6	0	10.15	5.90
	60.0	37.05	33.65	92.8	0	10.15	5.90
	65.0	36.72	33.60	92.6	0	9.75	5.35
	70.0	36.60	33.68	92.6	0	9.60	5.80
	75.0	36.50	33.70	92.6	0	9.50	5.80
Station B							
	10.0	39.95	33.50	90.1	0	13.50	10.80
	20.0	39.30	33.40	91.9	0	12.75	9.75
	30.0	37.90	33.35	92.4	0	11.30	7.90
	40.0	37.50	33.50	92.5	0	10.80	7.12
	50.0	37.20	33.55	92.5	0	10.35	6.30
	60.0	36.95	33.60	92.4	0	10.05	5.80
	70.0	36.62	33.60	92.6	0	9.66	5.40
	80.0	36.40	33.70	92.4	0	9.35	5.10
Station C							
	10.0	39.95	33.45	88.0	1	13.55	10.50
	20.0	38.55	33.50	89.6	1	12.20	9.60
	30.0	38.20	33.30	90.0	1	11.70	8.85
	40.0	37.60	33.35	90.5	1	10.98	7.85
	50.0	37.20	33.50	90.7	1	10.52	6.55
	60.0	36.90	33.55	90.7	1	10.05	6.10
	70.0	36.75	33.60	90.8	1	9.85	5.90
	75.0	36.65	33.65	90.6	1	9.70	5.60