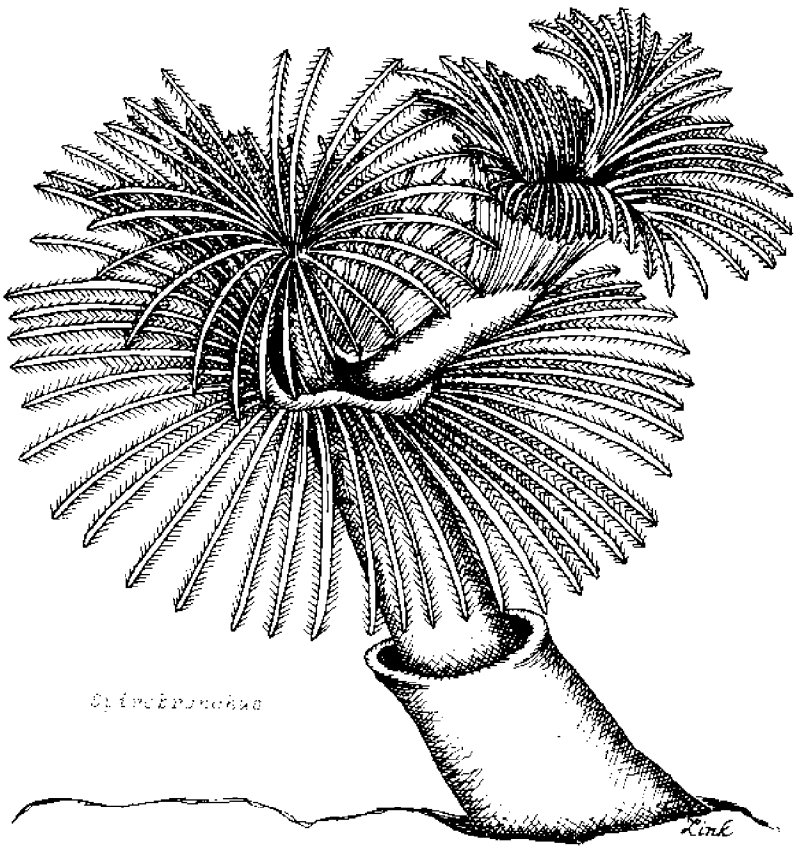
Marine Studies of San Pedro, California

PART 11

POTENTIAL EFFECTS OF DREDGING ON THE BIOTA OF OUTER LOS ANGELES HARBOR

Toxicity, Bioassay and Recolonization Studies



Edited by
Dorothy F. Soule and Mikihiko Oguri

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June, 1976

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On the cover - sketch of polychaete by Catherine Link.

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART 11.

June, 1976

POTENTIAL EFFECTS OF DREDGING ON THE BIOTA OF OUTER LOS ANGELES HARBOR

Toxicity, Bioassay, and Recolonization Studies

FOREWORD

Responsibility for the environmental quality of inshore marine waters is divided among numerous public agencies at federal, state and local levels. In the Port of Los Angeles, the Harbor Department and Board of Harbor Commissioners of the City of Los Angeles are responsible for maintaining existing water quality through supervision and/or management of Port activities, and for planning of Port development to meet projected long range shipping needs. This requires obtaining environmental information on existing local physical, chemical and biological conditions, as well as implementing field and laboratory investigations on the potential environmental effects of development.

To assist in meeting these requirements, the Chief Harbor Engineer, L.L. Whiteneck and Calvin W. Hurst, Environmental Scientist, requested that Harbor Environmental Projects (HEP) of the Allan Hancock Foundation and the Environmental Engineering Program of the University of Southern California undertake certain studies of the effects of dredging on indigenous harbor organisms. Contract number 976, issued in December, 1973 was multi-tasked and the final report is presented herewith to the Board of Harbor Commissioners as Part 11 of Marine Studies of San Pedro Bay, California, by Harbor Environmental Projects published jointly by the Allan Hancock Foundation and the USC-Sea Grant Program through the Institute of Marine and Coastal Studies.

The Marine Studies of San Pedro Bay series represents an unusual cooperative effort of federal and local public agencies as well as private industries, in helping to develop and publish the necessary base of environmental information for planning and management of natural resources and socio-economic concerns. Funding for Parts 1-9 has come, in part, from the Los Angeles Harbor Department Board of Harbor Commissioners, from the USC-Sea Grant Program (NOAA, Department of Commerce), the U.S. Army Corps of Engineers, the Pacific Lighting Service Corporation and other industrial users in the harbor, and the Tuna Research Foundation. Part 10 was funded by the Port of Long Beach, for reference in their General Plan Environmental Impact Report.

The USC tasks in Los Angeles Harbor Department Contract No. 976 were specified as follows:

1. To provide an estimate of the total biomass to be lost as a consequence of dredging and dredge material disposal at seven specified stations and supplemental locations;

2. to determine the potential for recolonization of bottom sediments based on exposure of test samples of similar sediments at five locations;

3. to test the effects of short-term (96 hours) and long-term (life cycle of 28 days) exposure to "elutriates" - seawater contaminated by resuspension of bottom surface sediments - by utilizing toxicity and bioassay experiments, on benthic, planktonic and pelagic species; and

4. to obtain sediment samples from 11 stations for performance of biological and chemical analyses.

The station locations are shown in Figure 1, and the proposed dredge and fill areas are shown in Figure 2.

The contract specified that the Harbor Department would obtain certain sediment core samples and would provide lighted buoys for attachment of racks of jars for recolonization studies by HEP. These buoys, deployed in the outer harbor, were soon run down by large vessels, or destroyed by vandals. To avoid this, a program was instituted by HEP wherein no surface markers were used, and electronic pingers were attached to racks placed on the bottom. Divers set out jars and retrieved samples using a Burnett pinger locator (kindly loaned by Meredith Sessions of the University of California, San Diego) to find the racks in the very turbid water. Even with the pinger system, locating the racks was very difficult because of the suspended sediment and turbidity present in the shallower water. An unexpected problem occurred when the pinger locator apparently received a signal from a torpedo ray (fish), which shocked the diver into unconsciousness when he touched it. Fortunately the diver was wearing full face diving gear and the water was shallow, so no injury occurred.

It must be recognized that the IPA provisional requirements for dredging studies changed several times during the inception and completion of this project (Chen and Wang, 1976). Rather than pursue a standard set of procedures when the merits of these were not known, several variations in methods were undertaken in order to approximate field conditions as closely as possible.

This volume contains a discussion of potential dredging effects, and sections on the major topics outlined above.

Preliminary data reports have been provided to the Port as follows:

I. Biological Impact Investigations, Preliminary Report. April 1, 1974 by D.F. Soule and M. Oguri.

   1. Sediment Toxicity Investigations, by R. Emerson, N. Shields, E. Norse, G. Brewer, and D. Chamberlain.

   2. Species Occurrence in Outer Los Angeles Harbor, by D.F. Soule, J.D. Soule, D.J. Reish, J. Dawson, and N. Condap.

   3. Species-Temperature Associations, by R.W. Smith (for Pacific Lighting Corp.).

   4. Literature Survey of Thermal Distribution Patterns, by D. Soule, M. Yeaman, and N. Condap.

   5. Biomass Investigations, by T. Kauwling and R. Osborn.

   6. Physico-chemical Results of Elutriate Tests of Sediments from the Proposed LNG Route, by K. Chen and C. Wang.

II. Biological Impact Investigations, Six Month Progress Report. July 1, 1974, by D.F. Soule and M. Oguri.

   1. Sediment Toxicity Investigations, by R. Emerson, E. Norse, J. McConaugha, and D. Chamberlain.

   2. Biomass Investigations, by T. Kauwling.

   3. Physico-chemical Results of Elutriate Tests of Sediments from the proposed LNG route, by K. Chen and C. Wang.

III. Biological Impact Investigations, Interim Report. June 30, 1975, by D.F. Soule and M. Oguri.

   1. Effects of Resuspended Sediment from Los Angeles Harbor on Two Species of Polychaetous Annelids, by R. Emerson.

   2. Effects of Resuspended Sediment on Three Species of Crustaceans in Los Angeles Harbor, by J. McConaugha.

   3. Recolonization Studies, by T. Kauwling.

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART 11. June, 1976

POTENTIAL BIOLOGICAL EFFECTS OF HYDRAULIC DREDGING IN LOS ANGELES HARBOR:

An Overview

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INTRODUCTION

Dredging for the maintenance of navigable channels, for the deepening of waterways and for development of new channels and lands has been reduced or virtually halted in the United States due to multiple concerns over the impact of these activities. One of the major issues has been concern for the possible release of contaminants into the water column from resuspension and elution of sediments during dredging.

Little has been said about effects similar to dredging, however, which are due to the resuspension of contaminated sediments, by natural wind and water movements and by mechanical stirring from ship traffic, in shallow streams, harbors and estuaries. These effects are perhaps equal to dredging effects in some cases, and create long term, chronic exposures if pollutants are in a form available for uptake as they are complexed to sediment particles.

In Los Angeles Harbor, the main channel borders the Palos Verdes Hills at the western edge of the estuarine Los Angeles River depositional area, which is part of San Pedro Bay. Areas of the bay sheltered behind the federal breakwater are divided politically into the Port of Los Angeles on the west, the Port of Long Beach in the center along with the U.S.Navy facility, and a City of Long Beach Harbor area lying to the east (Figure 1). Harbor channels were dredged to 35 feet a number of years ago, but subsidence due to pumping of the underlying oil fields caused parts of the Long Beach main channel and Cerritos Channel to sink about 60 foot depths (Allen, 1973). Both ports now require increased channel depths, as well as additional areas capable of handling containerized cargo, and gas and oil tankage or pumping facilities, but the Port of Los Angeles is especially handicapped by its shallow channels. The original estuarine channels and the flood plains draining the Los Angeles basin have long since been channelized, filled or blocked by development, so that recreating a natural estuary would be virtually impossible in the heavily urbanized area.

The history of the harbor water quality (Los Angels Regional Water Quality Control Board, 1969) indicates that pollution, with sulfide problems, was a problem from the 1920's on. Enormous quantities of high organic content wastes were discharged from oil refineries; indistrial wastes and human wastes were freely discharged as well. Efforts to regulate and clean up the harbor were implemented by the National Environmental Policy Act (NEPA, 1969) and the California Environmental Quality Act (CEQA, 1970).

During the 1950's, much of the inner harbor was considered to be devoid of macrofauna - virtually biologically dead - with frequent anoxic conditions (Reish, 1959; Los Angeles RWQCB, 1969). Within a year or two after enforcement began, the effects of reduction in tosic wastes effluents could be seen (Reish, 1971). The studies by Harbor Environmental Projects in 1973 and 1974 (AHF, 1975) showed that inner harbor conditions had improved so that they were similar to earlier outer harbor conditions, while the outer harbor had improved to resemble the diversity and richness of fauna found previously outside the breakwater.

While reduced levels of pollutants continue to reach harbor waters, the residual toxic pollutants remain in quantity in the inner harbor channels, adsorbed mainly from past years on the finer sediments, to be resuspended with each disturbance.

On the shallow main Los Angeles Harbor channel, when cargo container vessels maneuver in the turning basin to dock, clouds of sediment fill the water column. Since most harbor sediments are considered to be contaminated (Chen and Lu, 1974) resuspension occurs on virtually a daily basis. The larger boats of the tuna fleet come close to the bottom when entering Fish Harbor from the outer Los Angeles Harbor to unload at the canneries, and some larger boats must unload frozen catch on the main channel to lighten the cargo. For years, until the 1970's, fish wastes and effluent from the canneries and wastes from boat holds were dumped into Fish Harbor. The bottom "sediment" still consists mainly of blackened fish scales which decay very slowly. These are stirred to some extent each time a larger vessel docks. In other areas of the harbor, oil brine wastes, industrial wastes, and storm drain wastes have accumulated in the sediments. even though enforcement practices have significantly reduced such inputs.

Natural Resuspension

Natural circulation in the outer harbor is strongly influenced by prevailing southwest winds, due to the shallowness of the harbor, the low current rate outside the harbor, and to tidal exchange levels (Robinson and Porath, 1974; Soule and Oguri, 1972). Occasionally, high velocity wind storms, called Santa Anas, from the east or north reverse the normal wind-driven circulation patterns and cause stirring or turnover in the outer harbor. Sediments and organics that are normally anaerobic may be resuspended and may exert a strong oxygen demand before settling out of the water column. Biological sediment stirring by macrofauna can also be extensive in some areas; some fish species ingest sediments to get worms and other microfauna and spit out the debris, processing large quantities during feeding.

There is also a natural turnover of outer harbor waters in the fall, similar to that which occurs in small freshwater lakes, due to the chilling of surface waters after the warm summer months have created a thermocline. In winter months, during the rainy season, runoff from the Los Angels River and other drainage channels causes stirring and resuspension, as well as delivering new loads of pollutants from the drainage basin.

All of these factors cause a resuspension of sediments containing toxic pollutants such ss trace and heavy metals and pesticides, and may also create dissolved oxygen demands which may lower the water quality of the harbor. In addition, aerobic microbial activity and the release of chemical or organic wastes or detritus can cause large increased in immediate oxygen demand (IOD), chemical oxygen demand (COD), or biological (= biochemical) oxygen demand (BOD).

Ecological Richness

The harbor waters, especially in the outer harbor between Terminal Island and the breakwaters, are richer in fish species diversity and in total production than adjacent waters outside the breakwater (Stephens, Terry, Subber, and Allen, 1974). Benthic (bottom dwelling) animals and planktonic water column fauna are also diverse in species and rich in biomass. This serves to indicate that the outer harbor waters are relatively healthy in spite of the many stresses from pollutants

and wastes which have been discharged into them (Allan Hancock Foundation, 1975). However, the total biomass had declined in the outer harbor over the past four years for unknown reasons.

It is important to note that the present faunas of benthic and planktonic invertebrates and fish have been recruited and developed utilizing the nutrient resources provided in large extent by the Terminal Island Treatment Plant primary sewage wastes and the cannery effluents. Better management and processing of cannery wastes in 1974-75 have largely controlled periodic anoxic episodes which resulted in fish kills and die-off of other faunas in previous years, although the nutrient levels have perhaps also been reduced in so doing.

The Effects of Wastes

There are apparently great differences between the release and build-up of toxic wastes, composed of non-natural molecules, and natural wastes which are biodegradable and can be recycled for food and energy in the food web (chain). Although excess levels of natural wastes can impose an enormous oxygen demand on receiving waters, causing temporarily anoxic conditions, high levels of non-natural wastes may be immediately toxic, or they may be sublethal but damaging to the growth and reproduction of the populations.

TOXICITY STUDIES

Some organisms are apparently able to reject toxic substances, either by barriers to uptake, or by actively excreting or eliminating toxicants. Other organisms exist in an equilibrium with the ambient levels of toxicants in the environment. Organisms may require certain heavy metals for metabolism, but these would normally occur in the environment in very small trace quantities. It is possible that they have no mechanism to limit this uptake, and will continue to accumulate such metals, which may be deposited at various sites such as muscle, liver, gonads, or shell in the organisms. Other substances, entirely foreign to the natural environment, such as polychlorinated biphenyls, may be similarly accumulated. The substances may not be toxic to the organism, and may pass through the food chain to be found in increasing levels as larger animals ingest greater quantities of the smaller organisms. Man may be the ultimate consumer affected; or birds, large fish, or marine mammals may be threatened by the concentrations.

There are three important levels of lesser damage to organisms other than immediate death from lethal toxicity:

1. The sustenance of life of the existing individual but without growth or reproduction,

2. the sustenance of life with growth, or

3. the sustenance of life with growth and reproduction.

The inhibition of growth and development, while regarded as sublethal, actually becomes lethal over a larger period of time if the organisms cannot reproduce. In some cases, weakening of the organism causes the behavior patterns essential to feeding, protection, shelter, or reproduction to be abandoned. The impact of toxic substances, temperature stress, or anoxia may not result in death during 96-hour mortality tests, which are commonly used to evaluate toxicity, but if behavioral patterns for habitat, feeding and reproduction are impaired, death will be the end result of the environmental stress. (Brewer, 1974; Norse, 1974; Oshida and Reish, 1974; Hadley and Straughan, 1974).

As reported by McConaugha (1976) in this volume, in the 96-hour toxicity tests with copepod crustaceans, the calanoid species *Acartia tonsa* showed significant reductions in survival in elutriates from stations along the shore of the outer harbor and near the waste outfalls. Stations (Figure 2) in the harbor ship channel area and also Station 26 did not show significant differences in survival from controls. Control mortality rates suggested that all animals involved were stressed by collection, sorting and testing.

In tests of the epibenthic harpacticoid *Tisbe*, sp., only elutriates from near the sewage outfall showed greater mortality than the controls. Survivals in elutriates from LNG-4, 25 and 24 were significantly higher than in the controls, but these showed unusually low survivals of only 56.4% due to undetermined causes. *Tisbe* is normally present in many polluted areas of the harbor, and is continuously cultured in the laboratory, so would not be expected to show such control mortality.

In toxicity/bioassay studies of the two benthic polychaete species, *Ophriotrocha* and *Capitella capitata*, reported in this volume by Emerson (1976), no significant mortality occurred in the 96-hour tests. In the long term (28 day) tests, the numbers of offspring of *Ophriotrocha* were significantly lowered for all stations except for station LNG-1, which had results similar to the controls. Elutriate from

stations on the proposed channel produced offspring numbering from about 15-30% of those from the controls, while the near-shore stations produced offspring in the 2-10% range.

In *Capitella* 28 day sublethal effects were evaluated by successful growth and by development of fertile females. The percent of control organisms that completed development was exceeded by those tested in LNG-2 elutriate. Mean growth of controls was exceeded by those exposed to elutriates from all stations, except 17 and 25. All specimens brooded or showed eggs in the coelomic cavity except those in elutriates from stations LNG-7 and 27, which are polluted areas.

Brewer (1976) in the present study tested the effects of seawater-sediment mixtures from three stations representing different sediment types on juvenile and adult anchovies, *Engraulis mordax*. The percent survival varied according to the sediment type; the 4:1 mixture was 100% lethal in tests of two of the three sediments, and a 10:1 mixture was 100% lethal in one of those. Oxygen depletion may have been a factor. Tissue analysis of test fish showed concentration of cadmium and zinc in particular.

Chamberlain (1976) had tested earlier the California killifish, *Fundulus parvipinnus* and the white croaker, *Genyonemus lineatus* from three stations. Mortalities did not appear to be due to toxicity, and starvation probably accounted for the 22-28 day test mortalities.

The effects of dredging on at least some fish would be due more to BOD and COD than to toxicity of the sediments, as shown in 96-hour tests. However, it is clear that various fish species do accumulate excessive concentrations of heavy metals and pesticides, in part through the resuspension of sediments. Thus, it would seem that dredging which removes some of the accumulated pollutants would help to decrease the long term exposure to excessive levels of potentially harmful substances. Harbor pollutants are mapped in Appendix I.

A survey of the literature on accumulation by fishes is presented by K.Y. Chen and Bert Eichenberger, as Appendix II to the present volume. A survey of the literature on accumulation by invertebrates and vertebrates, by D.J. Reish and K.H. King is given as Appendix III.

RECOLONIZATION

Previous investigations of dredging recolonization and succession have indicated variability in both community structures and in time. These are probably associated with several

factors: the quality of the new substrates exposed, the percentage of the immediate areas disturbed, and the circulation or flushing available to carry in eggs, larvae and juveniles for recolonization and survival. (Reish, 1964 a,b; Allan Hancock Foundation, 1975).

The studies reported in the present volume (Soule, 1976) indicate that establishment of a benthic fauna in the harbor occurs rapidly in newly exposed substrates. After about 12 weeks of successional populations and predation, a juvenile population similar in species composition, but not necessarily in proportion numerically, is established.

Benthic polychaete worms are very important to the food web of the harbor. They are quite small and are numerous in soft bottoms, feeding and recycling organic debris and detritus. They in turn are fed upon extensively by the large populations of benthic fish in the harbor.

Polychaetes need only a thin layer of sediment on the surface to colonize newly exposed substrates. Some species are able to colonize on the thin layer of sediments trapped on glass slides in settling racks, which are suspended at 3 meter depths monthly in the water column (Allan Hancock Foundation, 1975). The precipitating fines from hydraulic dredging would probably be sufficient to furnish the thin layer of sediment necessary for colonization.

DISCUSSION

Dredging may be essential to future energy and commodity needs of the Los Angeles and Orange Counties metropolis. There are few commercial harbors in the United States with sufficient depths to handle large vessels of economically feasible size, disregarding entirely the so-called super-tanker category of 200,000 DWT and above. Furthermore, large areas of some urban harbors have numerous obsolete channels and wharves which constitute a poor usage of valuable and limited coastal zone resources.

The present studies (Brewer, 1976; Chamberlain, 1976; Chen and Wang, 1976; Emerson, 1976; McConaugha, 1976; and Soule and Oguri, 1976) were undertaken in an effort to determine the potential effects of resuspended sediments due to dredging, and to consider the alternative of open water disposal. The studies also suggest the effects of the present shallow water conditions and the bottom stirring due to them.

When considering the alternatives for managing harbor marine environmental quality, some attention must be given to

the possible continuing effects of not dredging, as opposed to the effects of dredging which would temporarily stress the harbor, but which would also clean up much of the historic accumulation of contaminants. It seems possible that if dredging were undertaken during the late fall-early winter months, when benthic animal populations are at lowest seasonal levels, and if the areas of dredging were limited at any given period so that recolonization could occur, dredging might well have positive long term benefits. Fish spawning does occur in January-March, and might be seriously affected for one season by disturbances in the areas frequented by larvae and juveniles.

The current California Coastal Plan by the State Coastal Commission under consideration by the legislature has indicated that dredging should not be permitted in harbors, even for maintenance of existing facilities. However, the estuary cannot be returned to its pristine stage because the Los Angeles Basin watershed has long since been altered by urbanization. Many areas would soon be obsolete if no dredging is permitted. On the other hand, the massive fills of the entire outer harbor, shown on planning maps, would be an environmental disaster, in the opinion of our investigators. Water quality in the inner channels would be degraded, and the rich outer harbor fish and benthic fauna would be lost. Birds that feed on the fish would be seriously affected. The outer harbor presently acts as a nursery for large numbers of juvenile fish in the 0-1 year class, which may subsequently migrate to deeper waters. Should the nursery be destroyed, populations outside the harbor would also be seriously affected. A more moderate course of dredging and improving channels in increments would remove pollutants while helping to modernize the port facilities.

RECOMMENDATIONS

1. The results of tests over the past several years indicate that most 96-hour toxicity experiments with harbor fauna generally showed lethality on only the most severe conditions. The longer term tests, which can include reproductive cycles and larval and juvenile development, are more indicative of possible effects in the environment. No one test organism should be proposed for all areas, but rather a selection of benthic, planktonic and pelagic organisms should be made, which are normal inhabitants of the proposed dredge site or of adjacent waters. The 28 day tests, or a suitable period adjusted to consider size of organisms and life cycles, should be carried out whenever possible. Chemical analyses of sediment, seawater, elutriate and tissue should also accompany any such tests.

2. Biomass and baseline faunal sampling should be performed in the area under consideration for dredging, and monitoring should be mandated both during and after the operations for at least two years.

3. Recolonization studies could be accomplished by settling rack, perhaps more easily than bottom installations tended by divers. Racks suspended below low tide but above sediments evaluate the fauna potentially available to replenish the bottom and water column following disturbances such as dredging.

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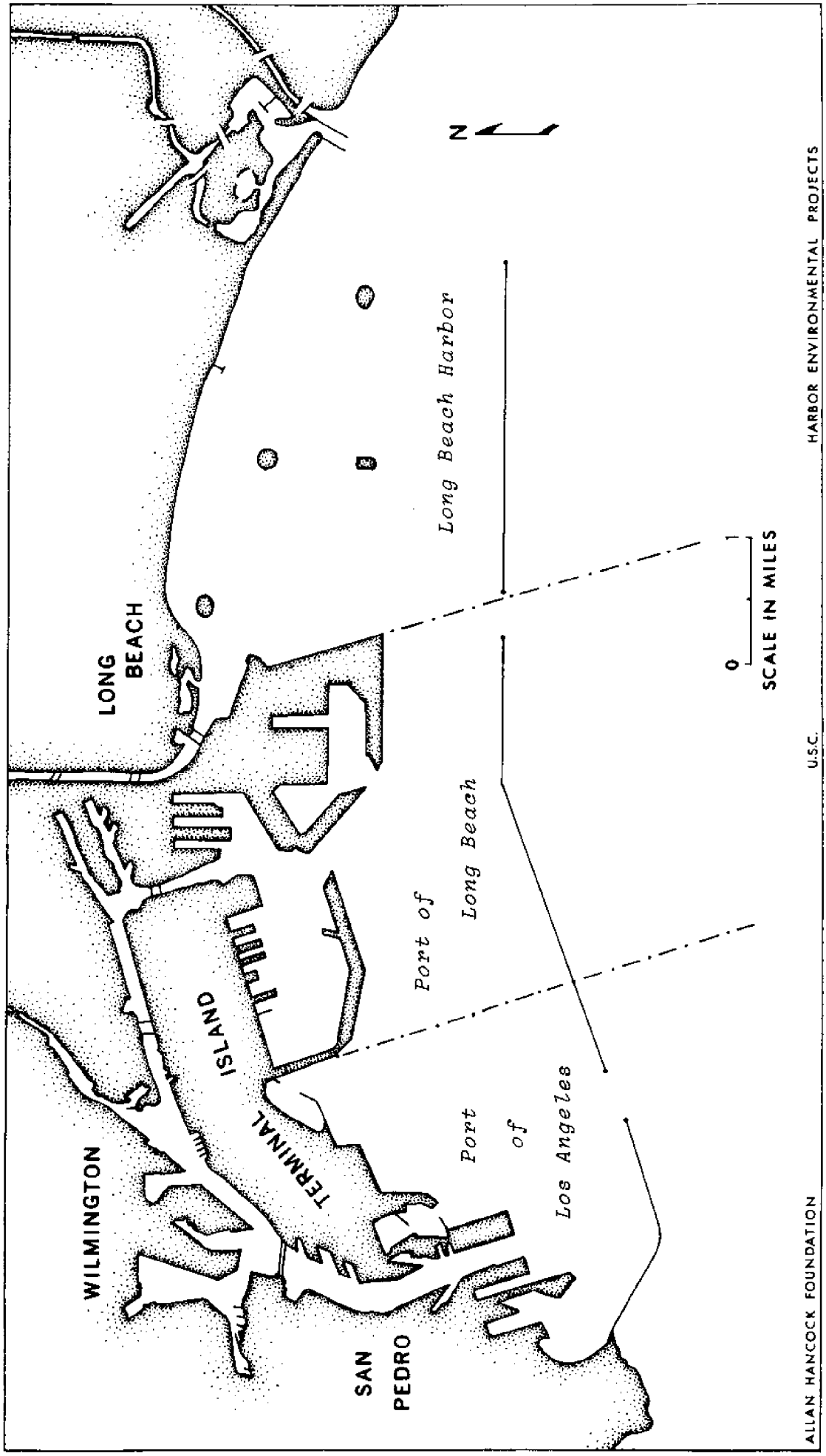

Figure 1. Harbors of San Pedro Bay, California.

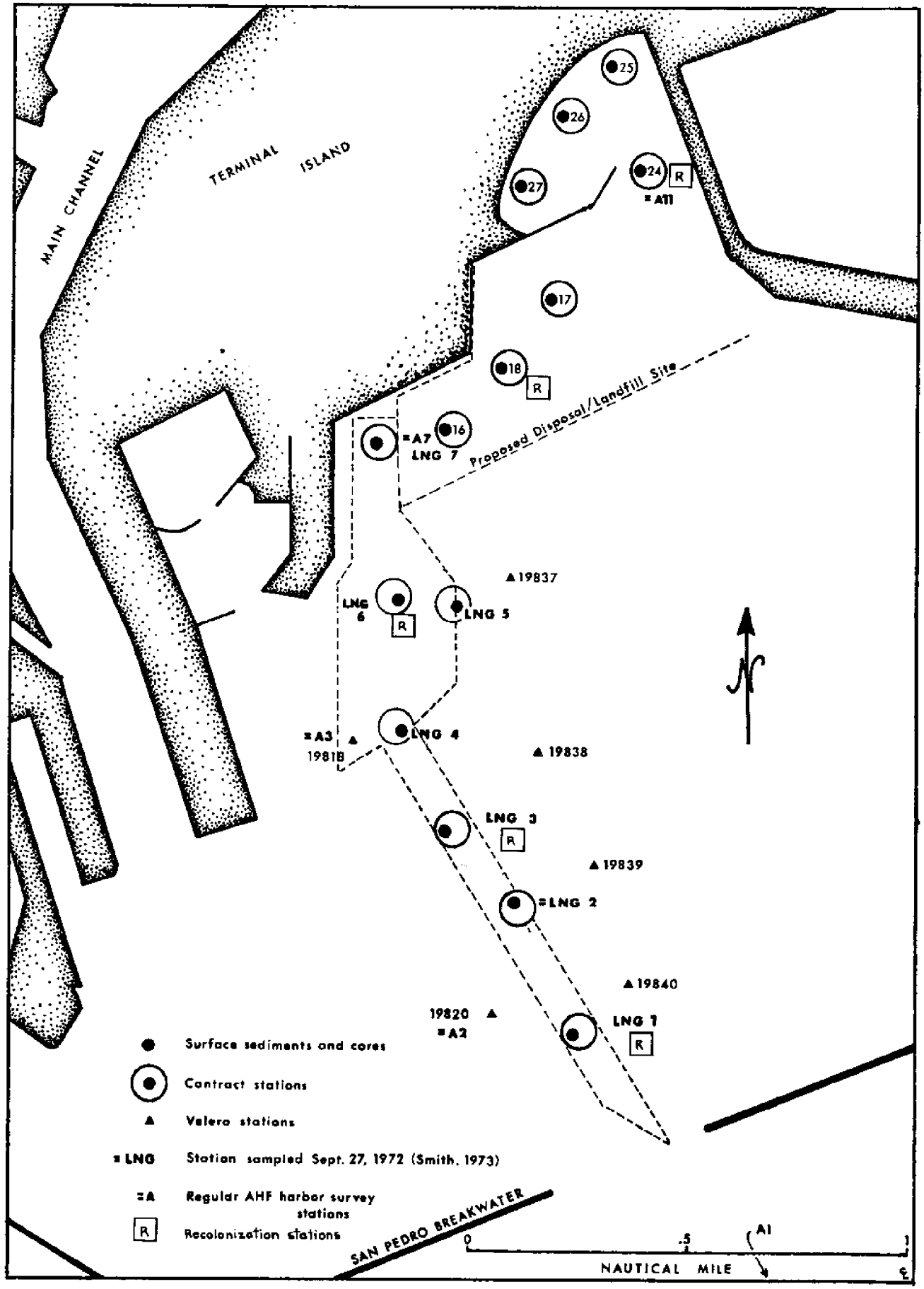

Figure 2. Outer Los Angeles Harbor Dredging Effects Study (Harbor Environmental Projects, 1976).

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART 11.

June, 1976

RESUSPENDED SEDIMENT ELUTRIATE

STUDIES ON THE NORTHERN ANCHOVY

by
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ABSTRACT. Samples of sediment from three locations in the Los Angeles-Long Beach Harbors and elutriates resulting from resuspension were assayed for heavy metals, pesticides, and other pollutants. Juvenile and adult northern anchovy (*Engraulis mordax*) were exposed to sediment elutriates prepared from seawater-sediment ratios between 4:1 and 100:1 for periods up to fourteen days. Toxicity varied between the three sediment samples; acute oxygen depletion was suspected as the cause of mortality. Analyses of muscle, gonad, gill, and liver tissues for silver, cadmium, chromium, copper, iron, manganese, nickel, lead and zinc from control and elutriate-exposed fish showed high levels of cadmium and zinc in fish exposed to the resuspended sediments. However, the small sample size precludes any conclusions regarding the rapid uptake of heavy metals. Sediment elutriate which had been stored for two weeks was not toxic to anchovy embryos and larvae.

ACKNOWLEDGMENTS. This work was supported in part by Contract 976 between the Los Angeles Harbor Department and Board of Harbor Commissioners, and the Harbors Environmental Projects of the Allan Hancock Foundation.

RESUSPENDED SEDIMENT ELUTRIATE STUDIES ON THE NORTHERN ANCHOVY

INTRODUCTION

The dredging and redeposition of harbor sediments during the creation and maintenance of navigable waterways and berthing facilities promotes the release and diffusion of fine particulates, trace metals, organic complexes, and nutrients. The migration and fate of various resuspended sediment constituents involve diverse pathways including adsorption, oxidation, reduction, precipitation, and complex compound formation depending on sediment characteristics and redox conditions (Chen and Lu, 1974). Some trace substances may be incorporated and concentrated in living tissues (Goldberg, 1957; Bryan, 1971). The potential uptake of heavy metals and pesticides by marine organisms and their transfer and amplification through food webs is of special concern (Risenbrough, Menzel, Martin and Olcott, 1967). In addition, marine organisms are potentially susceptible to acute oxygen depletion from sediments with high sulfide and organic loads and to suffocation from suspended particulates.

Highly polluted bottom sediments in Los Angeles-Long Beach Harbor have been characterized by Chen and Lu (1974). In light of proposed harbor dredging activities, laboratory experiments were conducted to determine the effects of exposure to resuspended harbor sediments on the northern anchovy (*Engraulis mordax*). The ecological and economic importance of the northern anchovy in the Los Angeles-Long Beach Harbor and throughout southern California was reviewed by Brewer (1974). Caught as live bait for sport fisheries, the anchovies constitute an important economic resource in the harbor.

METHODS

Juvenile and Adult Fish

Anchovies were obtained from a Long Beach, California live-bait dealer and acclimated for at least two weeks in 950-liter (250 gallon) round, fiberglass aquaria with filtered, running seawater. Photoperiod was maintained at 12 hours light (65 foot-candles) and 12 hours dark (1.5 foot-candles) throughout the acclimation and test periods. The fish were fed four percent of their body weight per day of a dry commercial preparation called Trout Chow. The fish ranged in size from 90 to 130 mm, standard length, and weighed between 10 and 20 grams. Acclimation

temperatures ranged from 12.5 to 14.0°C. Tests were conducted during December and January 1975-76.

Sediment samples from three sites in the Los Angeles Harbor (Figure 1) were obtained by divers, sealed in polyethylene containers and refrigerated until used. Sediment chemistry analysis followed methods described by Chen and Lu (1974). The composition of the sediment elutriate was determined following EPA (1973) guidelines which call for a 4:1 seawater-sediment ratio, mixed vigorously for 30 minutes and then allowed to settle for 60 minutes. The supernatant was carefully poured off and filtered through a 0.45 μ membrane filter to obtain the clear "standard elutriate" which was then analyzed (Allan Hancock Foundation, 1975).

Unfiltered and uncentrifuged elutriate was used for the anchovy bioassay because the large volumes of seawater required for tests on pelagic fish make these techniques impractical. Furthermore, filtration and centrifugation remove the finer sediment particles, to which pollutants may adsorb, and which are likely to remain suspended in the water column during and after actual dredging.

96-Hour Tests. The elutriates were prepared from seawater-sediment ratios of 4:1, 10:1, 40:1, and 100:1, mixed thoroughly for 30 minutes and allowed to settle for 60 minutes. Anchovies were transferred from acclimation tanks to 950 liter test tanks containing 285 liters (75 gallons) of unfiltered elutriate. Air was bubbled through three air stones in each test tank. Test water temperatures ranged from 12.0 to 14.0°C. Mortality, as evidenced by the absence of swimming movements, was strictly monitored during the 96-hour test period.

Seven-day tests. Anchovies were transferred from an acclimation tank to a 950-liter test tank containing 285 liters of seawater. Each day, 2.85 liters (0.75 gallons) of sediment from station 7 were mixed thoroughly with the aquarium seawater containing the sample of anchovies. The direct addition of the sediment sample was continued for seven days. All other test parameters were maintained as above.

Heavy Metal Analysis. After exposure to various elutriate concentrations, live anchovies were sacrificed and stored frozen at -20°C until preparation for chemical analysis, when the material was thawed and tissues dissected. The liver, left gonad, left (second) gill arch, and a section of white dorsal musculature from each fish were halved and weighed to 0.1 mg on an electronic balance after being lightly blotted. The tissues were then dried to a constant weight in an oven at 100°C.

Contamination of teflon, quartz, and polyethylene labware was minimized by scrupulous cleaning with National Bureau of Standards double distilled quality acids and deionized quartz-distilled water. A 2:1:1 solution of water, H_2SO_4, and HNO_3 was used to digest the tissue in teflon or quartz beakers heated to 150°C. The clear digestate was collected in polyethylene vials and concentrations of silver, cadmium, copper, nickel, lead, zinc, iron, manganese and chromium were analyzed by atomic absorption spectrophotometry as detailed by Chen and Lu (1974).

Embryos and Larvae

Elutriate tests on anchovy embryos and larvae used sediment samples from stations 2, 3 and 4 (Figure 1). A 4:1 sea water-sediment ratio was mixed vigorously for 30 minutes, and allowed to settle 60 minutes. The elutriate was stored for two weeks at 4°C until anchovy eggs became available in plankton collections.

Eggs were collected with a standard plankton net (333 μ mesh) during March 1974 at a depth of approximately 4 meters within the Los Angeles-Long Beach Harbor. Plankton samples were decanted into glass vessels and transported to the laboratory in styrofoam insulated containers. The anchovy eggs were sorted by pipette, using a dissection microscope. Anchovy eggs from several plankton samples were pooled into a single glass vessel for subsequent distribution to samples of resuspended sediment elutriate.

Fifteen anchovy eggs, approximately 32-36 hours old and at the same stage of development (blastopore closure stage) were placed directly into 1 liter glass jars containing 400 ml of elutriate from stations 2, 3 and 4, respectively. Anchovy eggs were similarly placed into a 1 liter jar of standard (control) seawater. Replicate samples for each station and for the seawater standard were prepared; hence, 30 anchovy eggs were incubated in each elutriate sample as well as the sea water standard.

Eggs were collected at water temperatures of 16°C; sorting and incubation temperatures were maintained at 16.5°C (plus or minus 0.5°C). Photoperiod was maintained as above.

RESULTS

96-Hour Tests. The results of 96-hour bioassays of resuspended sediment elutriates for stations 1, 4 and 7 are given in Table 1. Acute sediment toxicity apparently varied considerably

among the sediment samples tested. While a 4:1 seawater-sediment ratio for station 1 was tolerated by the fish, a similar elutriate concentration for station 7 was lethal to all the test fish within one hour. Sediment elutriate from station 7 required dilution with more than 40 parts of seawater before survival of the anchovies would equal survival of the control sample.

The mortality rates in Table 1 indicate a sudden initial stress occurred as the fish were placed in the elutriate. Low levels of oxygen may be responsible for the observed mortality. The Allan Hancock Foundation (1975) has shown that oxygen is rapidly depleted as sulfide and organic rich sediments are added to seawater. Dissolved oxygen measurements taken immediately before anchovies were introduced into the 40:1 elutriate from station 7 showed the oxygen level to be 2.1 ppm.

One might anticipate that mortality would gradually increase with exposure time if toxin accumulation was responsible for the lethal effect. Such a condition was not apparent. After the initial 96-hour test on station 7 sediment, using a 40:1 ratio, the fish were maintained an additional 10 days in the elutriate; no additional mortality occurred.

Seven-day Tests. Sediment samples from station 7 were tested by direct addition to seawater containing anchovies. Repeated exposure to low concentrations (100:1 ratio) of resuspended sediments over a seven-day period was not lethal to the test fish (Table 2). Mortality among the fish exposed to the elutriate differed little from the control sample. Mechanical damage to the fish from the daily routine of mixing the seawater and sediment would account for the slightly higher death rate among the test fish.

Occurrence of Heavy Metals. The chemical composition of the sediments and the concentrations of metals in the standard elutriate (filtered) preparations are given in Tables 3, 4, 5 and 6 . Increasing levels of sediment contaminants are evident between the outermost (station 1) and innermost (station 7) locations tested. Metals, pesticides, nitrogen, phosphorous, sulfide, oil and grease, total volatile solids, and oxygen demands are highest at station 7 and decrease through stations 4 and 1. However, there appears to be an inverse relationship between the concentration of the sand fraction and increasing concentrations of pollutants (Allan Hancock Foundation, 1975) rather than a direct relationship to the distance from the harbor entrance. Sediments from stations 1 and 4 are characterized as sandy, while station 7 is predominantly sandy silt.

Conversely, the concentrations of metals in the standard elutriate preparations show a reverse trend when compared to the concentration of metals in the sediments. The station 7 elutriate contained lower concentrations of heavy metals than did elutriate samples from stations 1 and 4. Apparently the fine sediment fraction at station 7 effectively "scavenges" the metals by adsorption, thereby removing them from solution (AHF, 1975). Filtration of the elutriate removes these fine particles, as well as the adsorbed metal complexes and their potential toxic effects. Unfiltered elutriate, as used here, would be expected to contain concentrations of metal residues in proportion to concentrations found in the sediments themselves, although this needs to be substantiated. Furthermore, exposure of animals to unfiltered elutriate in the laboratory would better simulate conditions that these organisms might encounter during dredging operations.

Since the sediments at station 7 were the most highly polluted, anchovies exposed to station 7 sediment elutriate were analyzed for metals and compared to control fish. Samples of anchovy tissues from fish exposed to sediment concentrations of 40:1 (96-hour test) and 100:1 (seven-day test; sediment added daily) were analyzed. Results are summarized below. Metal concentrations in tissues and sediments are expressed as mg/kg dry weight; metal concentrations in the filtered elutriates are in mg/l.

Silver. Silver levels were variable but showed no consistently high concentration in any tissue. Values for test and control fish were similar.

	Liver	Gonad	Gill	Muscle
Concentration range in tissue	0.19-2.26	0.21-1.39	0.47-2.13	0.15-1.61
Mean	1.18	0.96	0.96	1.78

Elutriate concentration: undetectable

Cadmium. High concentrations of cadmium were found in livers of fish exposed to the sediment elutriate when compared to cadmium concentrations in liver controls and other tissues.

	Liver	Gonad	Gill	Muscle
Concentration range in tissue:				
test	2.42-38.3	0.14-1.26	0.03-0.38	0.01-0.62
control	0.69-1.15			
Mean: test	17.0	0.88	0.21	0.23
control	0.92			

Elutriate concentration: undetectable
Sediment concentration: 2.87

Chromium. Highest mean concentrations of chromium were found in livers and gills. Concentrations in test and control samples were comparable.

	Liver	Gonad	Gill	Muscle
Concentration range in tissue	0.69-9.61	0.82-8.29	2.62-10.7	0.61-3.36
Mean	5.41	4.57	5.12	1.93

Elutriate concentration: 0.5
Sediment concentration: 61.8

Copper. The highest copper concentrations were found in liver tissue. Concentrations in control and test fish were similar.

	Liver	Gonad	Gill	Muscle
Concentration range in tissue	6.45-61.0	3.82-8.37	3.10-24.2	1.07-11.5
Mean	17.3	6.67	8.56	3.67

Elutriate concentration: undetectable
Sediment concentration: 69.7

Iron. Iron was concentrated in liver and gill tissues of both control and test fish.

	Liver	Gonad	Gill	Muscle
Concentration range in tissue	908-2130	97.5-1250	378-3680	26.9-215
Mean	1695	641	1440	80.3

Elutriate concentration: 6.0
Sediment concentration: 38,200.0

Manganese. High levels of manganese were found in the gills of control and test fish.

	Liver	Gonad	Gill	Muscle
Concentration range in tissue	0.23-5.88	0.39-6.19	17.2-40.5	0.01-1.53
Mean	2.13	1.58	26.6	0.72

Elutriate concentration: 17.5
Sediment concentration: 410.0

Nickel. Although variability in the concentrations of nickel was great, no accumulation in any one tissue was apparent.

	Liver	Gonad	Gill	Muscle
Concentration range in tissue	0.28-29.6	0.0-50.9	0.46-21.7	0.0-87.5
Mean	12.3	8.4	8.4	12.6

Elutriate concentration: 1.0
Sediment concentration: 47.2

Lead. Lead was distributed uniformly in the tissues analyzed.

	Liver	Gonad	Gill	Muscle
Concentration range in tissue	5.33-22.7	9.59-21.7	9.53-19.2	10.7-23.7
Mean	15.1	16.9	14.8	17.9

Elutriate concentration: 0.2
Sediment concentration: 74.1

Zinc. Excessively high zinc concentrations were recorded from the gonads of three of the four fish exposed to the sediment elutriate and assayed.

	Liver	Gonad	Gill	Muscle
Concentration range in tissue	111-348	test: 107-1100 control: 168-187	143-342	44.4-586
Mean	209	test: 690 control: 177	216	128

Elutriate concentration: 0.0
Sediment concentration: 242.0

The analyses of heavy metals were based on halved samples of tissue from only one or two fish for each control and elutriate test. In some cases the reported values of halved samples varied considerably. A few extreme values are suspect; yet general trends, as indicated by mean values, should be considered with confidence.

The data reflect a high degree of variability in the heavy metal content of different tissues, which is consistent with the literature (Vinogradov, 1953). High levels of manganese in gill tissue, cadmium in liver, iron in liver and gills, and excessive levels of zinc in some gonad tissue are noteworthy. In general silver, chromium, nickel and lead were uniformly distributed in the tissues analyzed. Copper was concentrated in the liver. With the possible exception of cadmium and zinc, short term exposure to resuspended sediments, highly polluted with heavy metals, does not result in a direct rapid uptake of metals. However, the small sample size and large variability in the data obviate statistical analysis for possible significance.

The values reported here for silver, copper, iron, and manganese are comparable to concentrations found in other fishes (Halcrow, Mackay and Thornton, 1973; Leatherland and Burton, 1974; Hardisty, 1974; Brooks and Rumsey, 1975; and Stenner and Nickless, 1975). Mean values for cadmium, chromium, nickel, lead and zinc, as reported here, equal or exceed the highest values reported by the above authors.

DISCUSSION

A significant disturbance of polluted sediment from the Los Angeles-Long Beach Harbors during proposed dredging and landfill projects may be detrimental to existing fish populations unless precautions are taken to minimize sediment disturbance. Acute mortality of juvenile and adult fish occurred in laboratory experiments when exposure was of short duration. Whether lethal concentrations of sediments would be resuspended during dredging operations must await future analyses. Mixing and flushing in the natural system might disperse sediment resuspension sufficiently to preclude any fish mortality.

Anchovies exposed to clouds of resuspended sediment in laboratory aquaria are repelled by the turbid waters. As the sediment diffuses through the aquaria, the fish actively avoid the material until it completely encompasses them. A similar situation will occur during harbor dredging operations if turbidity is excessive and is not controlled. Anchovies and

other fishes would presumably flee temporarily from disturbed areas.

The direct uptake of heavy metals by anchovies during short exposure to polluted, resuspended sediments seem of little concern, with the possible exception of cadmium. Although extreme levels of zinc were reported in the gonads of some test fish, the uptake and transport of high zinc concentrations to the gonads in four days seems unlikely. Long-term exposure may show quite different results. The uptake and concentration of metals by green plants (Bryan and Hummerstone, 1973) and organisms on lower levels of the food web (Alexander and Young, 1976) may result in the amplification of toxic materials in anchovies, other fishes, and their predators.

Experiments on embryos and larvae utilized elutriates which had been stored for two weeks before use. This procedure apparently eliminated a large part of the BOD fraction; the embryos and larvae were, therefore, not susceptible to the elutriate's potentially toxic effects. Additional experiments on these early developmental stages, including heavy metal uptake analyses, are warranted.

This study must be considered preliminary; a much larger sample size is necessary to insure statistical reliability. The excessive levels of some metals in anchovy tissues require substantiation. Control samples of anchovy should be compared from relatively unpolluted areas to the north and south. The relationship of fish size, sex, and season (i.e., spawning cycle) should be tested for correlation with metal concentrations. Finally, sediment elutriate bioassays should be standardized to reflect the actual sediment disturbance expected from dredging operations, not only in sediment and pollutant characteristics and quantities, but also duration of exposure. Long-term, continuous-flow bioassays (i.e., one month or longer) combined with histological and histo-chemical studies would provide insights into subtle, yet potentially damaging effects of the exposure of fishes to heavy metals and pesticides. Heavy metals in moderate concentrations inhibit enzyme systems (Bryan, 1971). Hence, normal development, growth, behavior, and reproductive functions may be upset. Damage to gill, liver, and kidney tissues may not be apparent during short term tests.

Only the gross effects of acute exposure to polluted sediments have been examined here. It is clear that this study is not sufficient.

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Table 1. Results of Resuspended Sediment Elutriate Tests on Anchovy Mortality -- 96-hour.

Station No.	Seawater Sediment Ratio	N	Cumulative Mortality After 24 (HOURS)	48 (HOURS)	72 (HOURS)	96 (HOURS)	Percent Survival
1	4:1	18	0	0	0	0	100.0
4	4:1	10	8	10	10	10	0.0
	10:1	12	3	3	3	3	75.0
	40:1	16	0	0	0	1	93.8
7	4:1	16	16*	16	16	16	0.0
	10:1	26	26	26	26	26	0.0
	40:1	20	0	0	1	3**	85.0
	100:1	15	0	0	1	1	93.3
Control	no sediment	36	0	2	2	2	94.5

* Mortality within one hour.
** No additional mortality after 14 days.

Table 2. Results of Resuspended Sediment Elutriate Tests on Anchovy Mortality -- Seven Day Test.

Station No.	Seawater Sediment Ratio	N	Cumulative Mortality After 24 (HOURS)	48 (HOURS)	72 (HOURS)	96 (HOURS)	120 (HOURS)	144 (HOURS)	168 (HOURS)	Percent Survival
7	100:1*	38	0	0	2	4	5	5	5	86.8
Control	No sediment	30	0	0	1	2	2	2	2	93.3

* Direct addition of sediment daily.

Table 3. Sediment Characteristics of LNG Stations.

Sediment types	Sand	Sandy silt	Silty sand	Sand	Sandy silt
LNG stns. Parameters	#1	#2	#3	#4	#7
Moisture content (%)	24.09	43.75	38.70	28.64	49.76
Total organic carbon (%)	0.47	0.60	0.53	0.61	2.06
Total volatile solids (%)	0.92	4.59	2.80	1.71	2.77
Immediate Oxygen Demand*	140	538.7	383.2	682	4,150
Chemical Oxygen Demand*	15,100	52,590	29,210	21,500	71,800
Organic nitrogen*	317	357	689	418	1,984
Kjeldahl nitrogen*	326	357	706	439	2,010
Phosphorus*	737	886	679	1,010	1,990
Sulfide*	38	258	163	121	828
Oil and grease*	195			289	1,477

* All units in mg/kg per dry weight unless specified.

Table 4. Sediment Characteristics of LNG Stations. Trace Metals Concentrations.

Sediment types	Sand	Sandy silt	Silty sand	Sand	Sandy silt
LNG stns. Elements *	#1	#2 **	#3 **	#4 **	#7
As	2.74	9.2	8.5	0.69	4.62
Cd	0.98	6.55	4.65	1.47	2.87
Cr	34.2	229.4	94.0	34.3	61.8
Cu	14.0	78.65	50.70	32.7	69.7
Fe	18,900	31,680	28,980	26,300	38,200
Hg	0.219	0.685	0.277	0.224	0.588
Mn	248	114.7	440.2	376	410
Ni	18.6	131.1	45.2	27.1	47.2
Pb	40.7	185.7	64.8	47.4	74.1
Zn	55.4	111.4	125.2	78.4	242

* Trace metals concentration expressed in mg/kg dry weight.
** Sampled February 1974, others sampled September 1975.

Table 5. Sediment Characteristics of LNG Stations. Chlorinated Hydrocarbons.

Sediment types	Sand	Sandy silt	Silty sand	Sand	Sandy silt
LNG stns. Parameters	#1	#2	#3	#4	#7
pp' DDE	0.126	2.394	0.694	0.220	0.740
op' DDE	0.059	0.036	0.131	0.062	0.246
pp' DDD	0.076	0.004	0.066	0.160	0.496
op' DDD	0.030			0.054	0.170
op' DDT*	--	--	--	--	--
pp' DDT*	--	--	--	--	--
Total DDT	0.294			0.497	1.652
pcB 1254	0.063	0.252	0.110	0.070	0.200
pcB 1260	0.006	0.025	0.011	0.007	0.020
pcB 1242	0.080	0.192	0.121	0.094	0.250
Total pcB	0.149	0.469	0.242	0.171	0.470
Dieldrin*	--	--	--	--	--
Heptachlor epoxide*	--	--	--	--	--

* These chlorinated hydrocarbons were below detection limit

Table 6. Trace Metals Concentration in Elutriates (from Standard Elutriate Test).*

	LNG 1	LNG 4	LNG 7
(Sediment type)	Sand	Sand	Sandy silt
Elements			
Cr	0.50	0.60	0.50
Fe	8.5	1.9	6.0
Mn	19.5	30.0	17.5
Ni	2.2	2.0	1.0
Pb	0.8	0.0	0.2
Zn	0.13	0.26	0.0

* The concentrations of Cd, Hg, Ag and Cu in the elutriates were undetectable.
All concentrations in ug/l.
All samples were filtered through 0.45 um membrane filters.

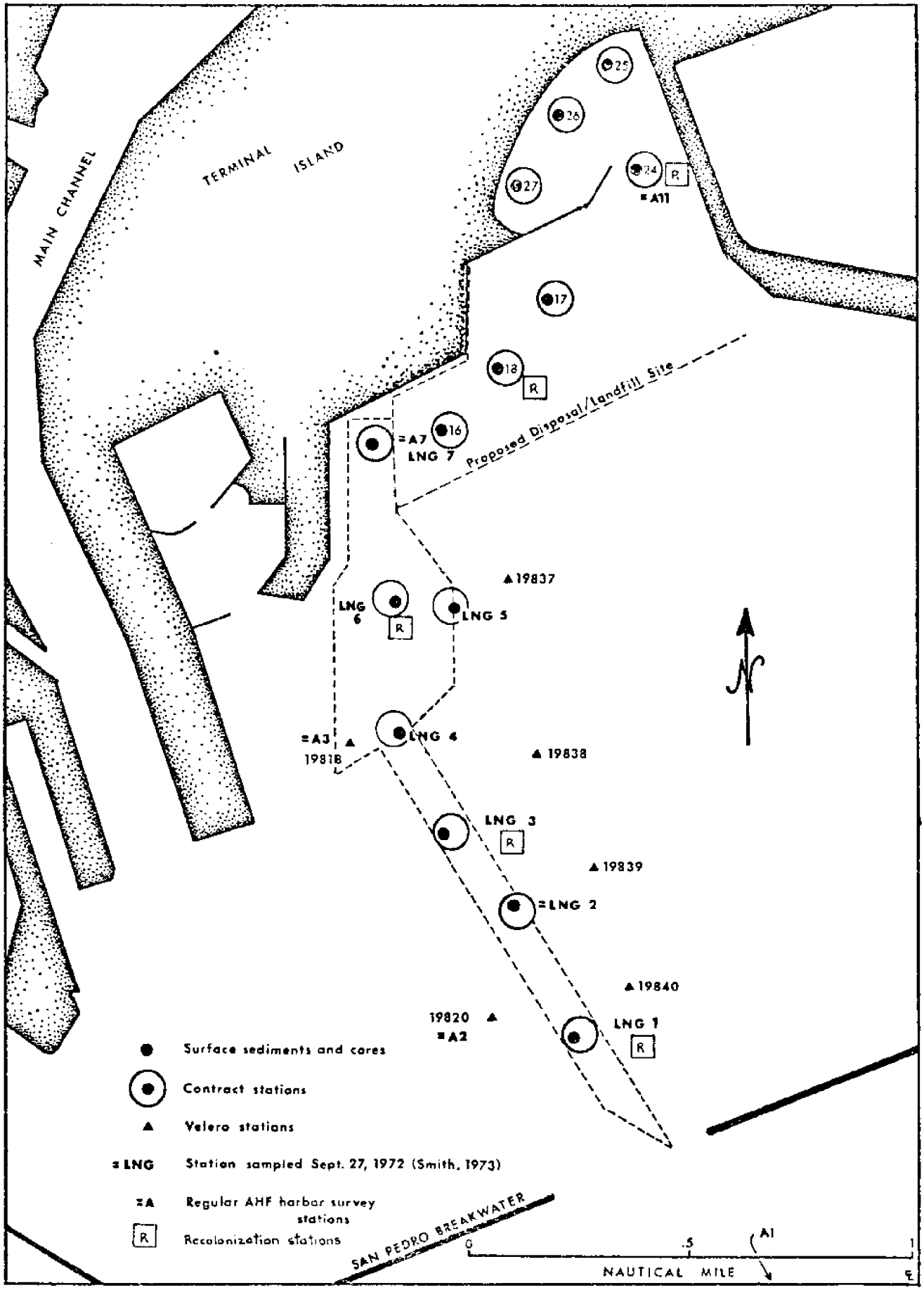

Figure 1. Outer Los Angeles Harbor Dredging Effects Study (Harbor Environmental Projects, 1976).

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART 11

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EFFECTS OF LOS ANGELES HARBOR SEDIMENT ELUTRIATE ON THE CALIFORNIA KILLIFISH, *FUNDULUS PARVIPINNIS* AND WHITE CROAKER, *GENYONEMUS LINEATUS*

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ABSTRACT. California killifish, *Fundulus parvipinnis*, were held in 5-gallon aquaria for a period of 96 hours to test toxic effects of elutriate from sediments from three stations. One fish died during the 96 hours. Ten fish died in the subsequent 22 days of observation. Dissolved oxygen, pH, specific gravity, temperature and nitrite-nitrogen parameters in the water were monitored periodically. Fish were not fed during the experiment. Deaths were probably related to lack of food rather than to the presence of any toxic substances in the elutriate.

The white croaker, *Genyonemus lineatus*, showed no toxic effects in 96-hour elutriate tests from one station. Deaths in the 28-day tests seemed attributable to primary or secondary effects of starvation. Tissue analysis after the 14-day exposure to elutriate indicated increases of 1.5-2 times over control fish levels of eight trace metals.

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EFFECTS OF LOS ANGELES HARBOR SEDIMENT ELUTRIATE ON THE CALIFORNIA KILLIFISH, *Fundulus parvipinnus* AND WHITE CROAKER, *Genyonemus lineatus*

INTRODUCTION

This study is one of a series of toxicity experiments bearing on the possible effects of a proposed dredge and fill operation to deepen channels and basins creating additional docking facilities within Los Angeles Harbor. In the first set of experiments the killifish, *Fundulus parvipinnis*, was used because of its small size, abundance, hardiness, ease of laboratory maintenance and its occurrence in the harbor.

The California killifish ranges from Almejas Bay, Baja California to Morro Bay, California and is common in bays of southern California. It is a common resident of Los Angeles-Long Beach Harbor and they are equally at home in fresh, brackish or marine waters. Because of their abundance, low cost, small size (to 4.25 inches) and wide tolerance to various water conditions they have been used extensively in laboratory experimentation.

For the second experiments, a less hardy fish, the white croaker, *Genyonemus lineatus*, was chosen in an attempt to elicit acute effects of exposure to sediment elutriate which probably would not be apparent in more resistant species such as the killifish.

The white croaker is one of the most abundant fish in Los Angeles-Long Beach Harbor (Stephens, Terry, Subber and Allan, 1974) and is readily obtained. There is considerable evidence that this species is more responsive to environmental stress factors than many of its contemporary species in ways that can be easily assessed as illustrated by the incidence of caudal fin rot and liver disease (Phillips, MS, 1973); lip papilloma (Russell and Kotin, 1956) and vertebral anomalies (author's unpublished data) that have been observed.

METHODS

California killifish. Forty-four killifish, *Fundulus parvipinnus*, were divided evenly among four 5-gallon glass and stainless steel aquaria. Initially all aquaria contained regular filtered seawater obtained from an experimental facility located on pier "J" in Long Beach Harbor. Fish were observed in these tanks for nine days prior to the start of the experimental procedure. Three of the 44 fish died during

this time and a fourth was sacrified on the first day to provide control tissue for later histological examination. Three different foods were offered during the holding period, Tetra Conditioning Food for marine fish, Purina Trout Chow, and live tubifex worms. The prepared foods were rejected and the worms were eaten more or less readily. Individuals purchased from a local supplier for this experiment were captured in the Grand Canal, Venice, California on February 13, 1974.

Elutriate used with the killifish was obtained following EPA preliminary dredge spoil disposal criteria procedures, from sediments at LNG Stations 2, 3 and 4. It was necessary to prepare the elutriate from each sediment station in three to four batches because of the volume of mixture needed to obtain enough elutriate test water to fill each 5-gallon aquarium. After 30 minutes of shaking and two hours of settling for the large volumes a great deal of water remained mixed with the sediment. Two liters (0.52 gal.) of sediment were mixed with 8 liters (2.1 gal.) of seawater in each batch. The 3-4 batches for each sediment station were then combined and allowed to settle for two hours. Approximately 9.5 to 10.4 liters (2.5 - 3.0 gal.) of elutriate were obtained from each batch total of 25 liters (6.6 gal.). It was necessary to leave the last batch, from station LNG 4, settling over night to obtain sufficient elutriate. About 17.0 liters (4.5 gal.) from 25.0 liters of sediment-seawater mixture was obtained. (See Table 1 for sediment analyses).

All stages of elutriate preparation (hand mixing of sediment and site water, shaking, settling and centrifuging) were done at remperatures below 10^{o} C.

The holding tanks were housed in a refrigerated walk-in room held at a temperature of 14.5^{o}C with constant (24 hour) fluorescent illumination at a distance of 6 to 8 feet furnished by three General Electric F40CW, Mainlighter, Cool White Lights, 46". The elutriate was allowed to reach the ambient temperature of 14.5^{o} C. (58.1^{o} F.). Water for the control aquarium was obtained from the same source as that used for elutriation. Ten killifish were placed in each of the four aquaria (LNG Stations 2, 3 and 4 and Control) with aeration supplied, and covered with a glass plate. No water filtration system was used and food was withheld during the experiment. A constant temperature of 14.5^{o} C. (58.1^{o} F.) was maintained.

Dissolved oxygen, specific gravity (expressed as salinity in Figure 3), nitrite-nitrogen, pH and water temperature in each aquarium were monitored initially and every 24 hours for the 96-hour period. After 96 hours water chemistry was tested at about 48-hour intervals.

White Croaker. Fish for this experiment were collected by a local bait dealer incidentally along with northern anchovy, *Engraulis mordax*, on 11 May 1974. They were acclimated for 72 hours in 50-gallon (189.5 liter) aquaria at a temperature of 14.5° C (58.1° F), then transferred to 5-gallon (18.9 liter) aquaria for the test. Replicate aquaria were used, two containing seawater only. Water to prepare the elutriate and that used in the control aquaria, plus sediments, were all from the same station, at LNG 5. Each aquarium was provided with weak aeration by a small air stone. Five fish were placed in each aquarium. Food was withheld during the period of acclimation and during the 96-hour experimental period. Fish in each aquarium were checked at 3, 6, 12, 24, 36, 48, 72 and 96 hours. After 96 hours fish were checked at 24-hour intervals. Dissolved oxygen, pH, nitrite-nitrogen and temperature were monitored initially and periodically thereafter. Criteria for acute toxicity effects were loss of equilibrium (LeGore and DesVoigne, 1973), mucous on gills (Hourston and Herlineaux, 1957), and rate of opercular movement (Belding, 1929). Sediment for the preparation of the elutriate was collected with a box corer and placed in 6-gallon (22.7 liter) plastic buckets, then sealed and transported to the laboratory without refrigeration, where it was held at 4° C. (39.2°F.) until used. The location of station LNG 5, where water and sediment were collected is near the Fish Harbor breakwater, outer Los Angeles Harbor, at a depth of 20 feet (6.1 m). (See Figure 5 for station locations).

Elutriate was prepared in the following manner: A 1-gallon (3.79 liter) aliquot of sediment was added to 4 gallons (15.2 liter) of seawater in a 6-gallon (22.7 liter) plastic pail. The mixture was stirred by hand until all large lumps were broken up, a process usually taking ½ to 1 minute. The bucket was then sealed and placed on a shaker table and shaken for 30 minutes at a rate of 120 shakes per minute. This mixture was then allowed to settle for 1 hour. The resulting cloudy supernatant was passed through a continuous flow refrigerated centrifuge cooled to 0° C and spun at 10,000 rpm. The clear supernatant was collected over ice and stored in clean, sealed white plastic buckets until used. Elutriate yield by this method was approximately 10 gallon (37.9 liter) from 30 gallons (113.7 liter) of sediment/seawater mixture. Fish were exposed to the elutriate for 14 days.

Tissue samples from test and control fish were analyzed for heavy metals and pesticides. These were carefully removed from the fish so as to keep contamination as low as possible. Fish were removed from the aquaria, the side from which the tissue was to be removed was dried with clean paper toweling and the overlying scales removed by rubbing with additional clean toweling. When a sufficient area was cleansed

of scales and mucous the tissue samples were removed by excising with the aid of cleaned glass microtome knives, used instead of a metal knife to lessen metal contamination. Tissues were then blotted on clean toweling to remove excess moisture and then weighed to the nearest 0.01 mg. The tissue for analysis consisted of dermis and muscle; the epidermis is removed with the scales in the cleaning process.

Tissues were then digested according to the method of Emerson (MS, 1974) in a 1:1 solution of H_2SO_4 and HNO_3 over steam until a clear, yellow liquid was obtained on which the analysis was performed.

To assure minimum contamination, preparation of the tissue was done with glassware and instruments cleaned by the method of McConaugha and Norse (MS, 1974). Super-clean water ("Q" water) for washing and rinsing and tissue digestion was obtained from the laboratory of Dr. Patterson, California Institute of Technology, Pasadena, California. To provide for future "Q" water needs, an arrangement of glass stills and a demineralizer were set up in our laboratory. Commercially available demineralized water from a 5-gallon glass carboy was passed through a Corning model LD-3 cation-anion demineralizer fitted with an ultra high purity mixed resin cartridge. Water flow into the demineralizer was regulated by an adjustable flowmeter. From the demineralizer the water dripped into the first of two Corning Mega-pure 1-liter Pyrex glass stills. The condensate from this still flowed by gravity through a Tygon plastic tube to the second Mega-pure still. Condensate from the second still then flowed again by gravity to an Amersil bi-distillation apparatus model Bi4 of clear fused quartz.

RESULTS

Killifish. In the killifish experiments one fish (Aquarium 3) was dead at the end of 96 hours, leaving a total of 39 living, as shown in Figures 1 through 4. The 96-hour percent mortality and toxicity concentration are shown in text table 1 on page 6. Fish behavior was essentially the same during the entire 96 hours, i.e., a loose schooling aggregation, with the fish facing into the water current set up by the air stone. Occasionally one or two individual fish were seen swimming at the surface.

Brownish flocculent material slowly became evident suspended in the water of all tanks and by 72 hours all tanks were clouded with this material, probably consisting of feces and coagulated mucus.

Text Table 1. 96 Hour Toxicity. Percent mortality and toxicity concentration units for California killifish held in Los Angeles Harbor sediment elutriate.

Aquarium	Control	LNG-2	LNG-3	LNG-4
96-hr % Mortality	0	0	2.5	0
Toxicity concentration	0	0	40	0

Data presented in Figures 1 through 4 summarize those variables monitored during the 96-hour test and subsequent time period. In the lower graph of each figure each symbol in the curve represents the death of one fish. A total of 12 fish died in the 26 days of observation. One died in aquarium LNG-3 within the first 96 hours. Eleven died between 96 hours and 26 days, three in LNG-3, three in LNG-2, one in LNG-4, and one fish died in the control aquarium. Temperature remained constant during the entire test period at 14.5° C. (58.1° F.) in all aquaria. Nitrite nitrogen increased slowly in all aquaria from less than 1.0 ppm to 15.0 ppm (BIF 6) introduced by the fish as waste products. Dissolved oxygen fluctuated somewhat in all aquaria in the first seven days and then rose slowly but never went below 7.0 ppm (BIF 7). Salinity ($S^{o}/_{oo}$) was stable after an initial rise of 1 part per thousand between the 4th and 8th days (BIF 8). The change in hydrogen ion concentration (pH) of the water fluctuated between pH 7.9 and pH 8.4 (BIF 9). Normal seawater range is pH 8.0 to 8.4

Isopod parasites were found on one or two killifish during the holding period and others were seen swimming in the aquaria after the test began. All were removed and any influence from these was discounted.

White Croaker. In white croaker experiments, no fish showed evidence of acute toxic effects during the 96 hours. One control fish died of fin rot, a rather common occurrence in laboratory maintained white croaker. One fish in the second control aquarium developed buoyancy problems 3 hours after the test began but by 24 hours this condition had passed. The next death occurred at 192 hours with one fish in a control aquarium. Gross examination revealed no cause of death. Water in all four aquaria developed a slight hazy appearance at the end of 192 hours. The first fish in a test aquarium died between 192 hours and 216 hours. Following

this, two test fish died at 288 hours and one control at 336 hours. One fish from each aquarium was sacrificed at 336 hours for tissue analysis. At 384 hours one test fish was dead; at 504 hours another; at 528 hours one test and one control fish were dead; at 620 hours another test fish died and at 668 hours the experiment was terminated with one test fish and three control fish remaining alive. These were frozen for future tissue analysis. The pH values in test and control aquaria rose from 7.6 and 7.4 respectively, at the beginning to a high of 9.1 at 552 hours. Dissolved oxygen values dropped after the first day from 6.0 and 6.7 parts per million(ppm) in test aquaria and 6.4 and 5.6 in the control aquaria to below 4.5 ppm and then rose slowly to values of 5.8-6.9 at 552 hours. Nitrites were below 10 ppm at all times in all aquaria. Water temperatures fluctuated very little, 14.5^{o} C $\pm$ 0.5^{o}C, in all aquaria.

Tissue analyses for trace metals showed small differences in levels between control fish from the harbor and elutriate-treated fish from the harbor. Increases were from about 1.2 times for silver to 2X for zinc, lead, chromium and cadmium. This may have been due to the fact that the elutriate was centrifuged but was not filtered, leaving the smallest particulates in the water.

DISCUSSION

Killifish. Killifish mortalities encountered during 96-hour toxicity tests and during the subsequent observation period were probably the result of starvation and not due to any toxicity of substances eluted from the sediments.

The pH of the test waters fluctuated but remained very near or within the range for normal seawater; and fish mortality did not increase sharply after the lower levels were reached. Fish generally can tolerate pH in the range of 5 to about 9. Fish may be less tolerant to changes in pH if they are subjected to other environmental stress. Dissolved oxygen concentrations ranged between 7.2 and 9.2 ppm, well within the acceptable limits. Salinity values in this test were between 32.8 and 33.8 parts per thousand which are also near normal values.

Nitrites from the fish waste products rose slowly, which is expected in small enclosed aquarium systems, especially where there is no filtration and no biological populations present to utilize nitrites. Most fish tolerate a nitrite level of 1 to 10 ppm and, as all but two deaths occurred at levels below 10 ppm, this factor would not be significant to mortalities.

The elutriate, as prepared for this test, probably had little, if any, gross physical or behavioral effects on the test fish. Sediment particles suspended in the water by dredging activities could conceivably cause damage by mechanical action to certain delicate exposed tissues such as gill membrances. Mucous secretions would also increase within the gill cavity due to irritation by sediment particles. Both situations would reduce the efficiency of gas exchange across the gill membranes. The magnitude of these effects would generally be related to particle size, particle configuration, settling rates, water temperature and fish behavior.

The fish did not show signs of distress or toxic reaction, except for one in aquarium LNG-3 which was removed for histological studies on the 10th day. Increase in the rate of opercular (gill cover) movement, usually a sign of distress, was not observed. There is no indication that this elutriate might not have some adverse effect on more delicate fish species, embryos or larvae, which have not been tested.

According to acute toxicity criteria set for the white croaker experiments, the sediment elutriate from collection site LNG-5 was non-toxic. Fish mortalities during the course of the experiment are deemed the result of other causes; one from fin rot and the others probably from the primary or secondary effects (lowered resistance) of starvation.

There was no gross evidence as to the cause of death in these other fish. In addition to starvation, death could have occurred from chronic effects of pollutants in the elutriate water, since 30 per cent of the control fish survived and only 10 per cent of the test fish. Generally pH values of 5 to 9 are not directly lethal to fish but synergistic effects with other substances and/or chemical or phyical conditions might, working together, cause mortalities. The pH range 5 to 6.5 is harmful if free carbon dioxide or iron salts precipitated as ferric hydroxide are present in sufficient amounts. Such conditions, however, were absent during this experiment.

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Table 1. Sediment Constituents, Outer Los Angeles Harbor, 1974.

Parameters	Sta. #1	Sandy silt Sta. #2	Silty sand Sta. #3	Silty sand Sta. #4	Sta. #5	Silty clay Sta. #6
TOC %	1.09	1.90	2.0	0.84	1.11	2.12
COD	--	52,590	29,210	21,450	22,874	116,840
IOD	--	538.7	383.2	350.3	181.0	1567.0
TVS %	--	4.59	2.80	1.97	2.10	10.13
$\Sigma S^{=}$	--	258	163	102	269	1673
Organic N	--	357	689	588	459	2822
Total N	--	357	706	636	493	2923
Total P	--	886	679	644	787	1465
Ag	4.48	16.9	7.1	3.5	5.4	10.2
Cd	2.42	1.90	0.66	0.66	2.45	2.20
Cr	89	175	94	67	77	178
Cu	45.2	119	51	35	47.5	568
Fe	31,610	40,830	28,980	28,560	33,620	45,180
Hg	--	0.685	0.28	0.27	0.33	1.43
Mn	502	429	422	381	487	493
Ni	21.6	35.3	23.0	18.2	21.9	47.2
Pb	39.2	67	47	32	35.6	332
Zn	115	205	106	94	112	612

-- not determined

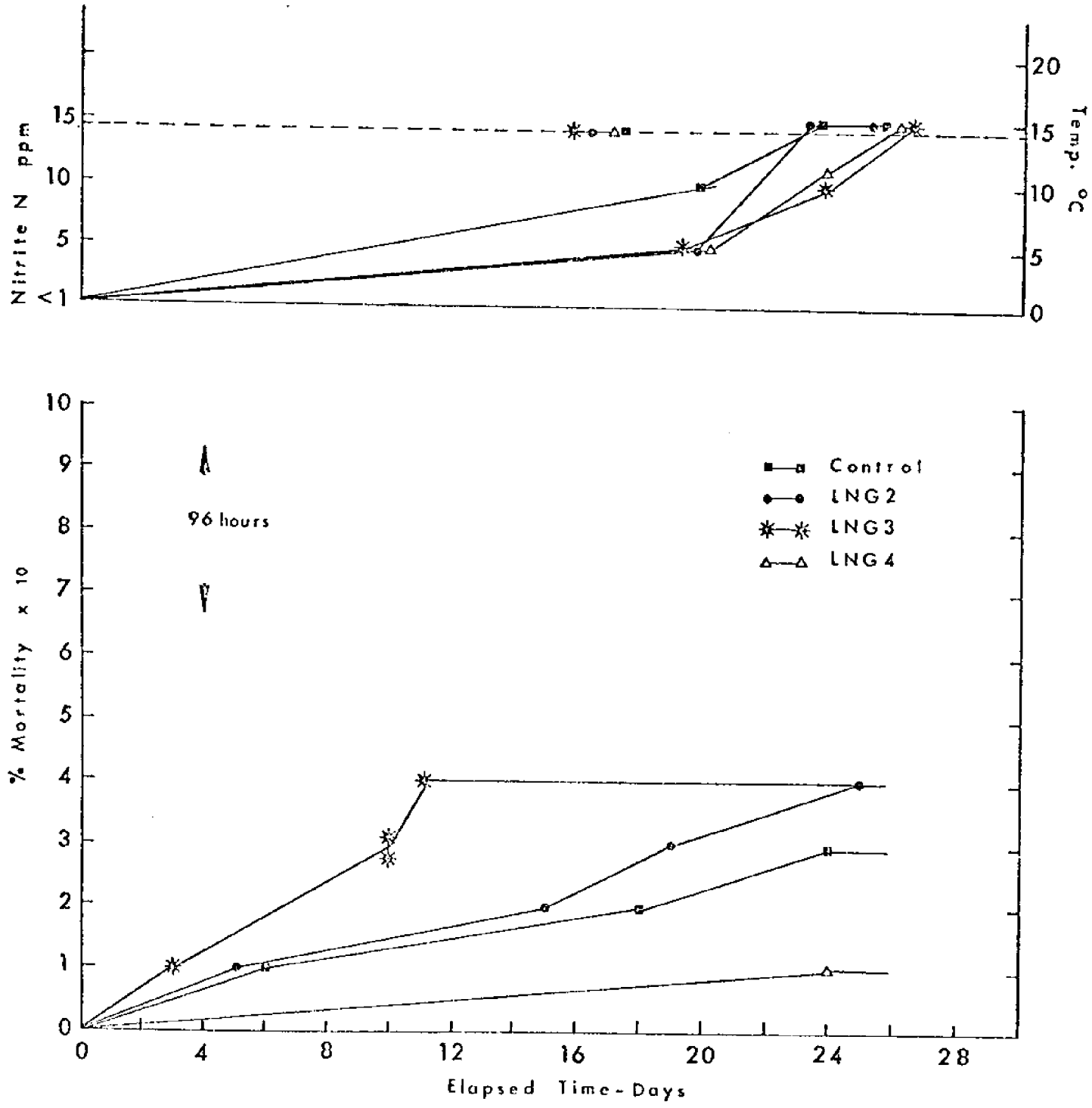

Figure 1. Percent mortality of F. parvipinnis held in harbor sediment elutriate, nitrate nitrogen level in parts per million and termperature during the 96-hour toxicity test and at the end of 26 days.

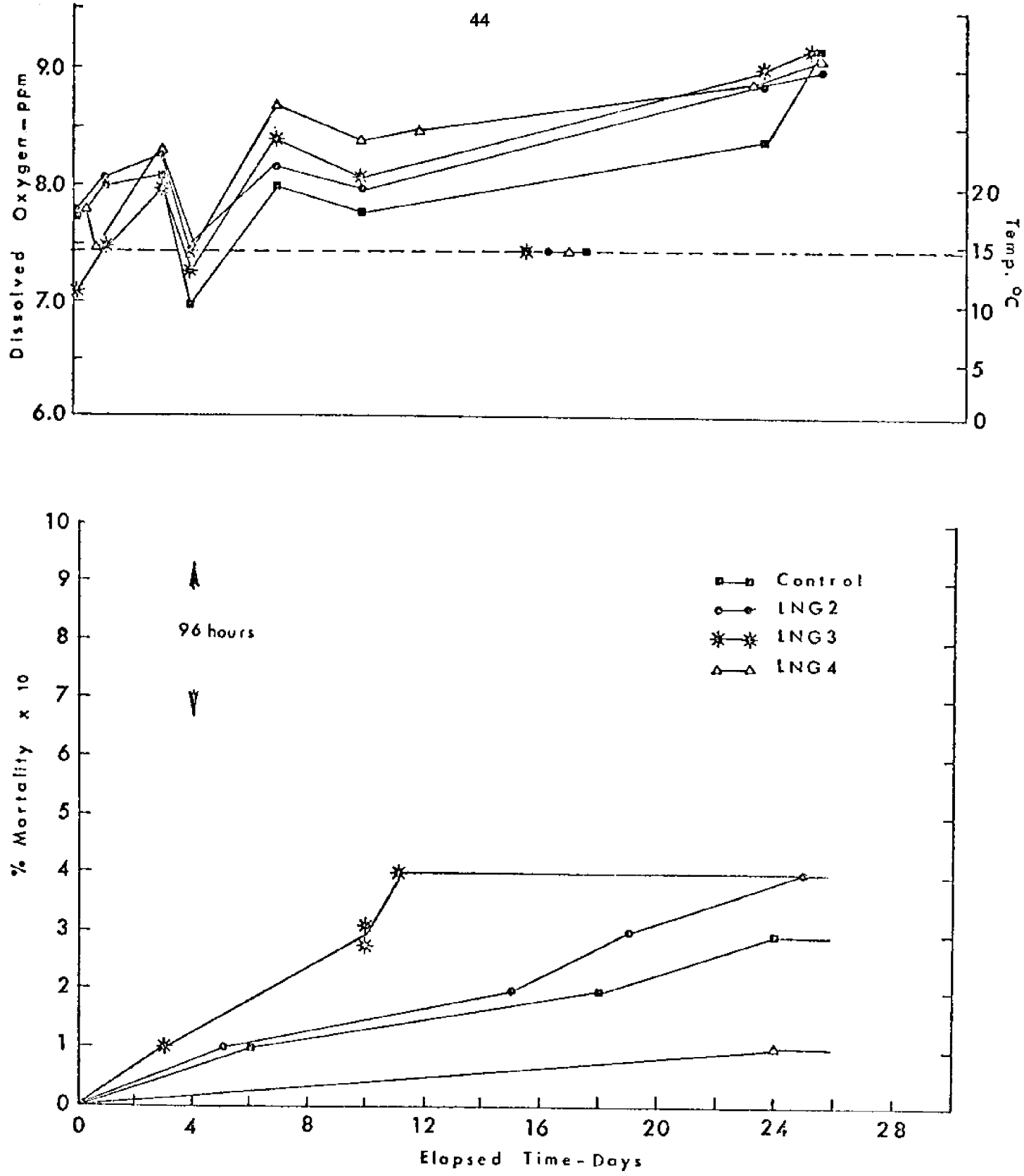

Figure 2. Percent mortality of *F. parvipinnis* held in harbor sediment elutriate, dissolved oxygen in parts per million and temperature during the 96-hour toxicity test and at the end of 26 days.

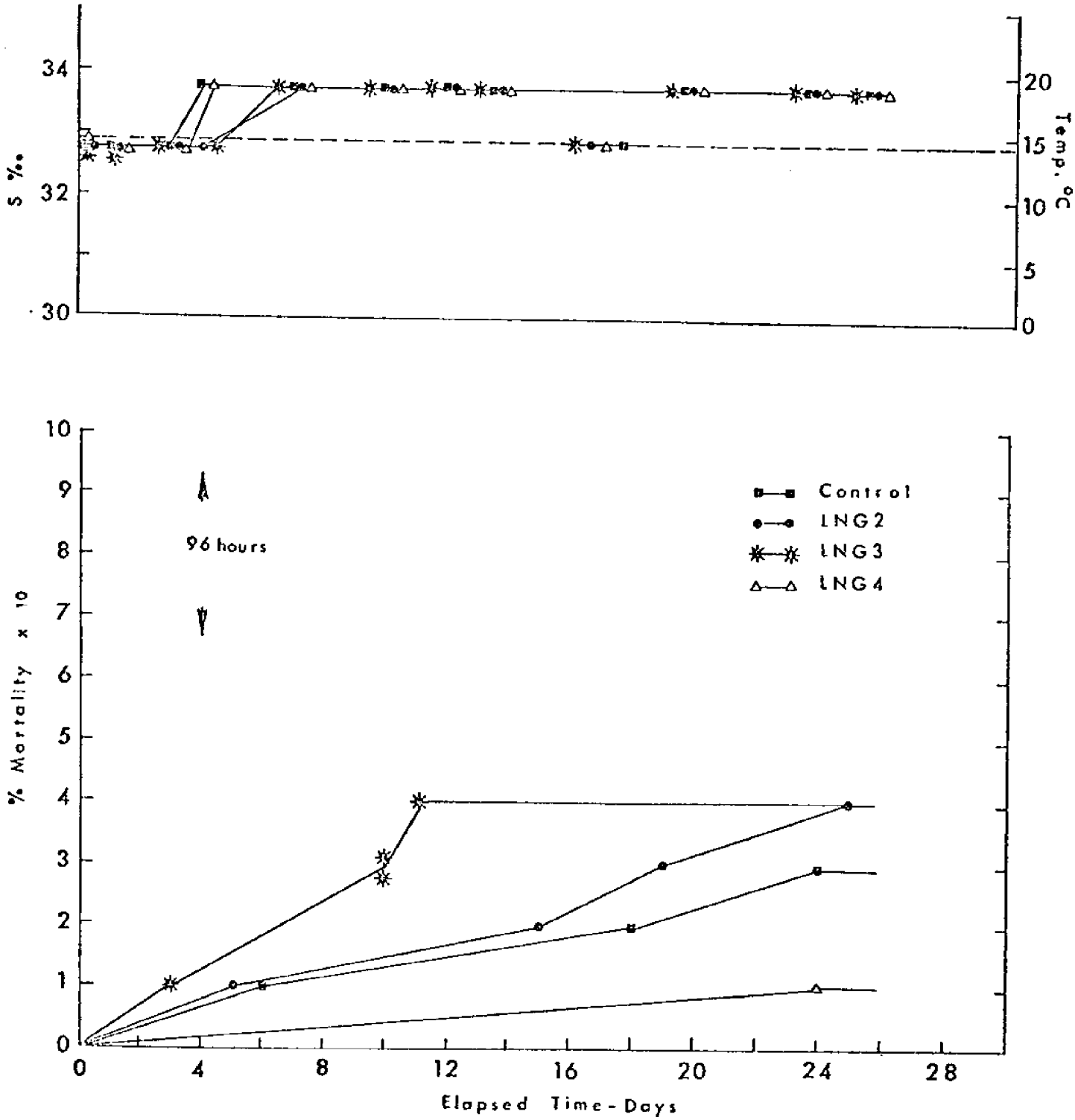

Figure 3. Percent mortality of F. parvipinnis held in harbor sediment elutriate from three different sites, salinity in parts per thousand and temperature during the 96-hour toxicity test and at the end of 26 days.

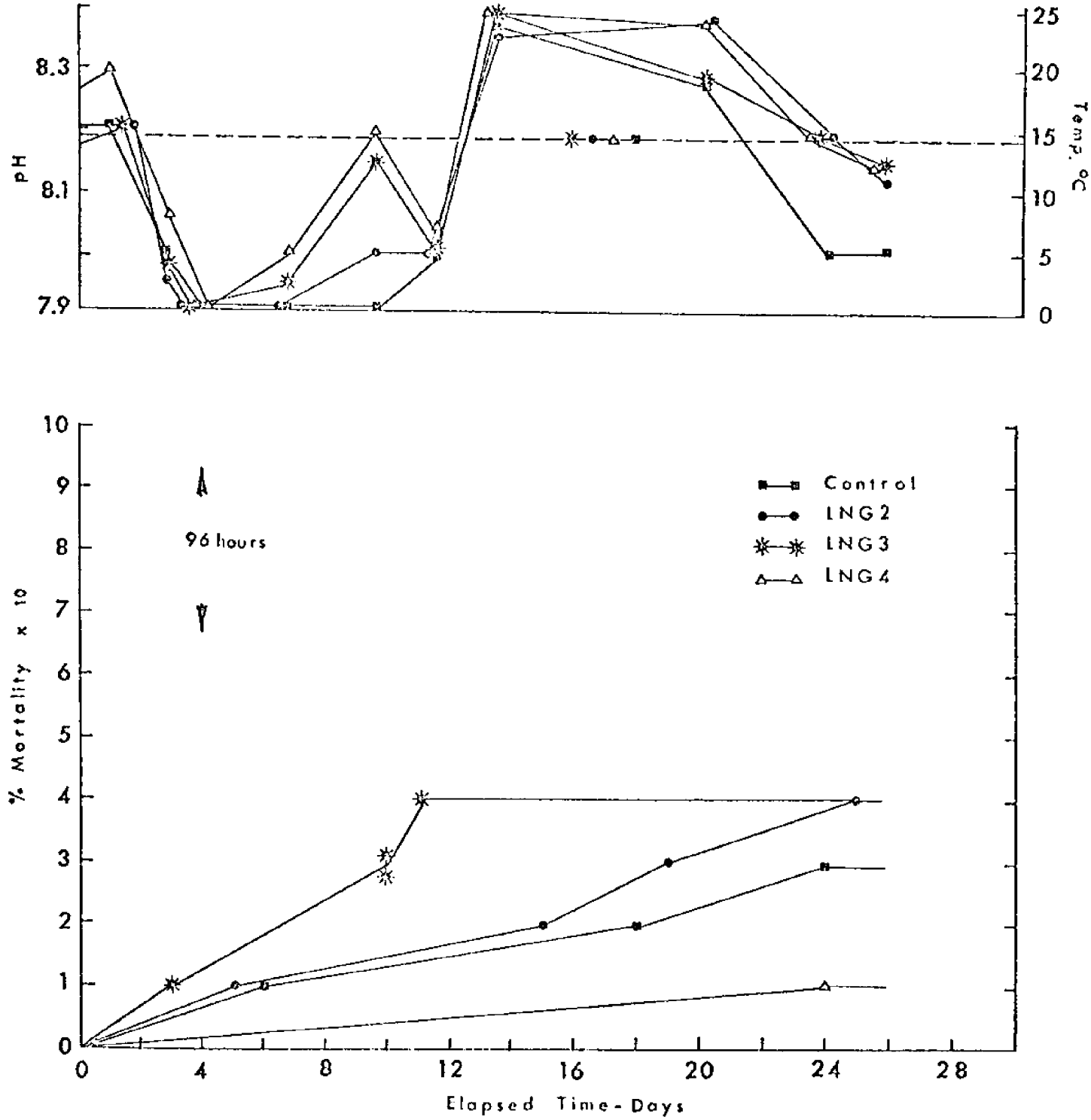

Figure 4. Percent mortality of *F. parvipinnis* held in harbor sediment elutriate, hydrogen ion concentration (pH) and temperature during the 96-hour toxicity test and at the end of 26 days.

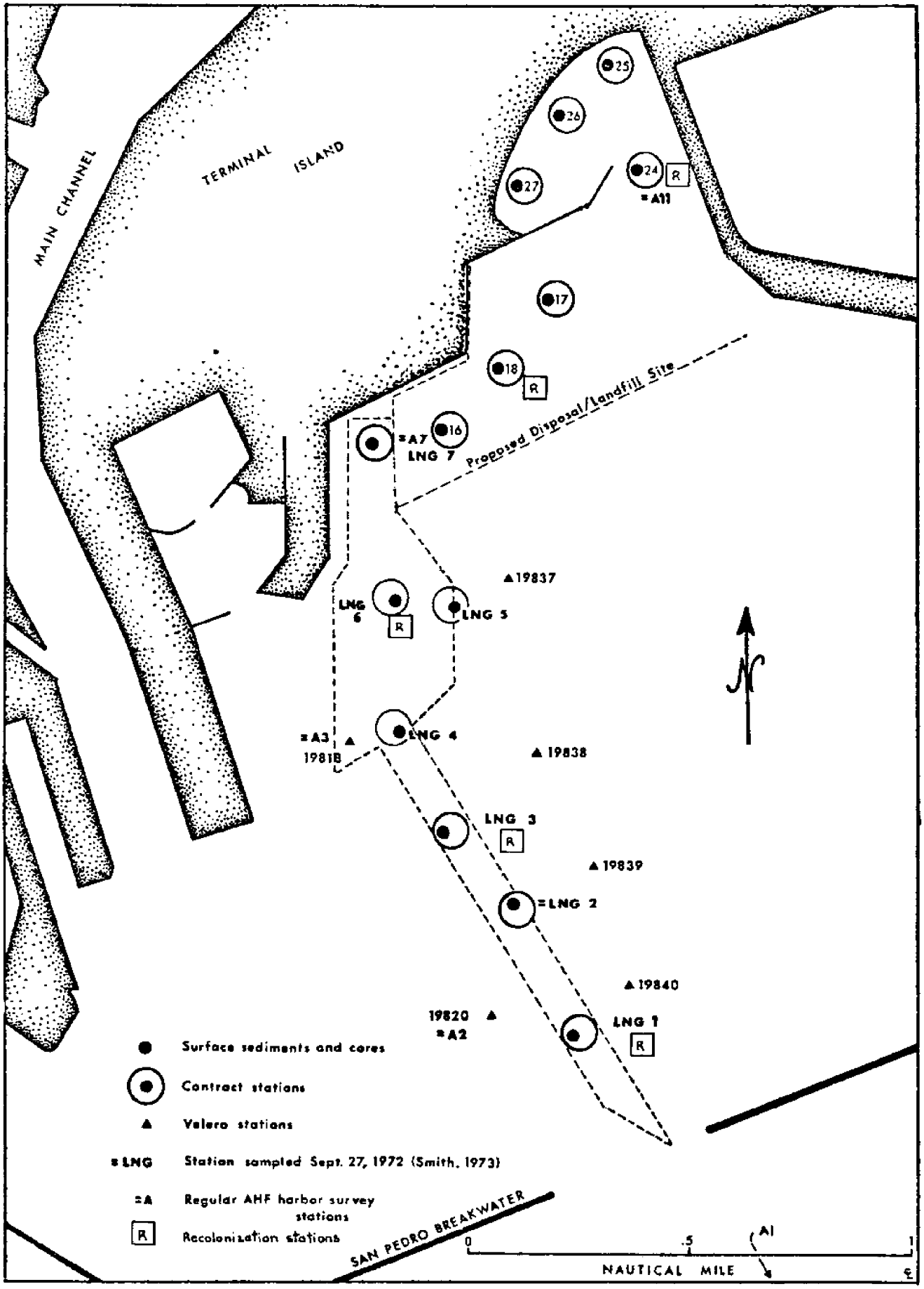

Figure 5. Outer Los Angeles Harbor Dredging Effects Study (Harbor Environmental Projects, 1976).

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TOXICITY AND HEAVY METALS UPTAKE IN THREE SPECIES OF CRUSTACEA FROM LOS ANGELES HARBOR SEDIMENTS

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ABSTRACT. Two species of crustaceans, *Acartia tonsa* and *Tisbe* sp., were subjected to the filtrate fraction (< 0.45μ) of resuspended sediments from 12 stations in the Los Angeles Harbor. The 96 hour bioassays for *A. tonsa* produced significant reductions in the survival rates of test groups at stations LNG-6, LNG-7, 16, 17, 18, 24 and 27. In the *Tisbe* bioassays only station LNG-7 had significantly lower survival in the test group than in controls, while test group survival at stations LNG-4, -25 and -27 were significantly higher than control survival. This data suggests that dredging operations could have an adverse effect on the *A. tonsa* population and consequently an effect on the plankton composition and food chain in the Los Angeles Harbor. However, the stations with poorest quality are in the area to be filled.

Additional experiments were conducted to determine if the lined shore crab, *Pachygrapsus crassipes*, was capable of accumulating heavy metals from resuspended sediments. Following a 7 day exposure to the sediment elutriate the gill tissue was examined for 9 heavy metals. Because of extreme variations in the data no discernible trends were observed.

ACKNOWLEDGMENTS. I would like to thank the Harbors Environmental Projects technicians for supplying both organisms and sediment samples used in these studies. This research was supported in part by Contract No. 976 between the Los Angeles Harbor Department Board of Harbor Commissioners, and the University of Southern California Harbors Environmental Projects.

TOXICITY AND HEAVY METALS UPTAKE IN THREE SPECIES OF CRUSTACEA FROM LOS ANGELES HARBOR SEDIMENTS

INTRODUCTION

Nearshore waters, especially those in heavily populated or industrialized areas, receive considerable quantities of pollutants through run-off, industrial outfalls and other human activities. These pollutants, especially heavy metals and pesticides, can accumulate to toxic levels in the sediment. Once in the environment these compounds often undergo complex chemical transitions, due to both abiotic and biotic conditions, which can alter their toxicity (Steeman-Neilsen and Wium-Andersen, 1970; Lewis, Whitfield and Ramnarine, 1972).

It has been postulated that these compounds represent a potential danger to the local flora and fauna in the event that the sediment becomes resuspended in the water column following dredging operations (Gibbs, 1973; Allan Hancock Foundation, 1975). Should sediments become resuspended it is possible that the concentrations of heavy metals could reach toxic levels, at least temporarily. However, heavy metals released from resuspended sediments may undergo a multitude of complex interactions which can alter their toxicity (Lewis, Whitfield and Ramnarine, 1972). These interactions include readsorption to organic matter, adsorption to other metallic oxides, precipitation and co-precipitation, formation of complex compounds, or be incorporated into living organisms (Harbor Environmental Projects, 1975; Gibbs, 1973).

Most studies that have investigated the biological impact of dredging have been concerned with the effects on benthic organisms (Kaplan, Welker, Karus and McCourt, 1975; O'Connor, 1972; Taylor and Saloman, 1968; Harrison, Lynch and Altschaeffl, 1964; and Emerson, 1974). There is a paucity of data concerning the effects of dredging on epibenthic and planktonic organisms Kaplan, Welker, Kraus and McCourt (1975) state that one of the initial effects of dredging is the removal of plankton. The removal of plankton can presumably be related to an increase in turbidity, changes in water chemistry, or reduced dissolved oxygen concentration (Allan Hancock Foundation, 1975; N. Shields, personal communication; Kaplan, et al. (1975).

Furthermore, on one hand metals are an integral part of vital organic molecules such as enzymes and respiratory pigments (Williams, 1952) and often play leading roles in

osmotic regulation (Lockwood, 1962). On the other hand, heavy metals in large amounts can quickly become toxic. It has been shown that crustaceans can concentrate heavy metals from water and food sources (Renfro, Fowler, Heyraud, and La Rosa, 1975; Martin, 1973, 1974; Vernberg and Vernberg, 1972; Benayoun, Fowler and Oregioni, 1974). Although the percent body burden accumulated through these sources varies among crustaceans, uptake from water represents a significant contribution to the total body burden in all cases studied (Renfro, Fowler, Heyraud and La Rosa, 1975; Benayoun, Fowler and Oregioni, 1974). The accumulation of heavy metals from the surrounding water is presumably accomplished by the gills since gill tissue contains the highest concentrations of metals in the organism (Vernberg and Vernberg, 1972; Martin, 1973) and is involved in osmo-regulation. Thus the gill tissue should be representative of changes occurring in heavy metal uptake from water sources.

The purposes of this study were to examine for toxic effects and heavy metal uptake from the filtrate fraction (p.45μm) of resuspended sediments from proposed dredge sites in the Los Angeles Harbor. By using only the filtrate portion of the resuspended material it was hoped that the laboratory conditions would simulate field conditions following settlement of resuspended sediments. In the first set of experiments, 96 hour toxicity tests were performed on the crustaceans, *Acartia tonsa* and *Tisbe* sp. *Acartia tonsa* is a holoplanktonic (calanoid) copepod, which constitutes 50% of the plankton in the harbor and *Tisbe* sp. is an epibenthic harpacticoid copepod which can be found in the water column.

In a second set of experiments, the decapod crustacean (rock crab) *Pachygrapsus crassipes* was utilized to determine whether heavy metal uptake occurs from resuspended sediment (elutriate). Because of the very small size of *Acartia* (2 mm) and *Tisbe* (1 mm), the larger organism was required for tissue analysis.

96 Hour Tests. For the first series of tests, on *Acartia* and *Tisbe*, sediment was collected from 13 stations in the Los Angeles Harbor (Fig. 1). Collected with a $0.1m^2$ surface modified Campbell grab, sediments were placed in 5 gallon polyethylene containers, sealed and returned to the laboratory where they were stored at $4^{o}C$ to inhibit bacterial action. Standard elutriate was prepared by mixing unfiltered seawater and sediment in a ratio of 4:1 in a 2 liter glass erlenmeyer flask to give a final volume of 1 liter. This mixture was then shaken at maximum speed on a variable speed shaker table for 30 minutes, followed by a one-hour settling period. After settling the supernatant was decanted, with care being taken

not to disturb the underlying sediment, and filtered under pressure to 0.45µm with a standard millipore filter apparatus. Control experiments utilized seawater only, filtered to 0.45 µm.

Tisbe sp. were obtained from stock cultures maintained in the laboratory at room temperature and fed the unicellular alga *Dunaliella tertiolecta*. *Tisbe* stock cultures were initiated with organisms collected from pilings in the Los Angeles Harbor. Both adults and copepodite stages were utilized in the toxicity studies.

Acartia tonsa were obtained from plankton tows taken in the Los Angeles Harbor. The crude plankton was returned to the laboratory and sorted. *Acartia* were placed in 2 liters of 0.45µ filtered seawater in 1 gallon jars. Only organisms that survived and appeared in good condition on the following day were utilized in the toxicity studies.

All experiments were based on the mortality of organisms during a 96-hour exposure to the elutriate. All experiments utilized a static volume of fluid containing the test organism and an appropriate food supply. Aeration was not utilized.

All *Tisbe* experiments were conducted in covered Stendor dishes containing 10 ml of either elutriate or control seawater. Station LNG-2 utilized 32 organisms per dish. All other experiments utilized approximately 10 organisms per dish. The exact number varied due to the addition of small nauplii which molted to copepodites during the test period and were counted in the final analysis. Each dish received 1 ml of *Dunaliella tertiolecta* suspension (approx. 100,000 cells/ml) as food. Cultures were checked daily for mortality, molts and freshly hatched nauplii. The data represent the combined results of five replicates per station.

Acartia tonsa adults and copepodites were placed in 1 liter of elutriate in 8" stacking dishes at a density of 1 per 30 ml of elutriate. In the initial experiments *Dunaliella tertiolecta* was supplied as food. Later experiments utilized *Isochrysis galbonia* and *Rhodomonas* sp. as a food source. Algal densities were approximately 40,000 cells/ml. All experiments utilized a minimum of 3 replicates per station. Data were combined prior to analysis.

Sediments were analyzed for total organic carbon (TOC), total volatile solids (TVS), immediate oxygen demand (IOD), chemical oxygen demand (COD), heavy metals, chlorinated hydrocarbons, and sediment grain size (ø). Elutriates were analyzed for heavy metals and chlorinated hydrocarbon content. All analyses were conducted by Dr. K. Y. Chen, Environmental Engineering, University of Southern California.

Heavy Metal Uptake Tests. In the experiments using *Pachygrapsus crassipes*, sediments from Harbor Environmental Projects stations LNG 1, LNG 4, LNG7, 17 and 27 were resuspended by mixing sediments and unfiltered seawater in a ratio of 1:4 to give a final volume of 1 liter. The flask containing the water-sediment mixture was shaken vigorously on a variable speed shaker table for 30 minutes. After a 1-hour settling period the supernatant was decanted with care being taken not to disturb the underlying sediment. Controls consisted of unfiltered seawater.

Male specimens of the decapod crustacean *Pachygrapsus crassipes* were collected at a rocky groin 1 mile north of Manhattan Beach, California. Individual animals were placed in 1 gallon glass jars containing 2 liters of either elutriate or seawater and aerated. Although heavy metal uptake and metabolism varies with the stage of the molting cycle (Martin, 1973) this was not a factor in the present study, since *P. crassipes* was in a period of molt inhibition (C_4) during the time the study was conducted (Hiatt, 1948).

Following a seven day exposure the animals were sacrificed and the gill tissue removed, briefly rinsed in distilled water and placed in tarred plastic petri dishes. The gills from each side of the organism were treated as separate samples. Following determination of wet weights the tissue was dried at 40°C for 72 hours and stored in a dessicator. Tissues were digested according to the procedure of Emerson (1976) and analyzed by Dr. K.Y. Chen and C.C. Wong of the Environmental Engineering Program, University of Southern California, using an atomic absorption spectrophotometer.

RESULTS

96 Hour Toxicity Tests on *Tisbe* and *Acartia tonsa*. The results of the *Tisbe* bioassays are summarized in Table 1. Only station LNG 7 showed a significantly lower survival rate when compared to controls ($P < .01$). Assays for stations LNG 4, 25 and 27 resulted in a significantly higher survival rate ($P < .05$) for the test organisms. This was undoubtedly due to the low survival levels of the control series for these tests. The unusually low percent survival can not be adequately explained. In all assays except for station LNG 2, for which data are not available, freshly hatched nauplii were present and appeared to be in relatively good condition. Since these nauplii hatched from eggs carried by females that were ovigerous prior to their introduction to the test solutions, this data indicated only that hatching and survival of the early naupliar stages could be achieved in the elutriates tested, but did not provide sufficient information to determine whether or not this organism can successfully complete a full reproductive cycle under the test conditions.

Comparison of the mean percent survival between the controls and experimental groups in the *Acartia tonsa* bioassays (Table 2) showed significant reductions ($P \leq .05$) in the survival of test groups LNG 6, LNG 7, 16, 17, 18, 24 and 27. All of these stations are characterized by either silty sand (17, 18, 24), sandy silt (6, 7,16) or clay silt (27) sediments. Assays for stations LNG 1, LNG 2, LNG 3, LNG 4 and 26 did not result in any significant difference when compared with the controls. Sediment composition of LNG 1, LNG 4 and 26 is classified as sand. The relatively low survival rate for the controls indicates that all organisms used in the study were probably stressed. This stress may be related to the conditions of their collection and subsequent handling prior to the initiation of the experiments.

Because of the extremely small size (1-2 mm) of the copepod individuals, analysis of tissues to measure possible uptake, or concentration, of trace metals was not undertaken for *Acartia* and *Tisbe*. In order to obtain such information the large crustacean *Pachygrapsus crassipes* was used as the experimental animal. (Table 3).

Heavy Metals uptake. Station LNG 7 sediments proved to be toxic to *P. crassipes*, killing all animals within 48 hours. Mortality also claimed two organisms from station LNG 4 and one each from LNG 1, 27 and the control. Table 3 shows the mean and standard deviation for the concentrations of nine metals in the remaining organisms. Due to large variations in metal concentrations between individuals of the same test series and within tissue samples from the same organism no discernible trends in heavy metal uptake can be seen. However, gill tissue in some individuals exposed to the test solutions showed an obvious greenish color. Thurberg, Dawson and Collier (1973) reported similar observations in crabs exposed to cupric chloride and suggested a possible correlation with tissue damage. Copper-induced damage to gill tissue of marine organisms has been previously reported (Baker, 1969).

DISCUSSION

One of the major problems with conducting toxicity studies of the type employed in this report is that it is nearly impossible to determine the exact cause of mortality. It was initially felt that the heavy metals and chlorinated hydrocarbon concentrations of the sediments would be a major contributing factor to the toxicity of the substrate. Although there were substantial amounts of heavy metals and chlorinated hydrocarbons in the sediments (Tables 4, 5, and 6), analysis of the standard elutriates indicated that only small amounts of heavy metals could be detected and no chlorinated hydrocarbons

were detectable (Table 7). Although the concentration for any given heavy metal in the elutriate was below the levels known to be toxic to crustaceans, it is possible that synergistic effects may have contributed to the observed mortalities (Vernberg and Vernberg, 1972; Vernberg, DeCoursey and Padgett, 1973; Roesijiadi, Petrocelli, Anderson, Presley and Sims, 1974; Thurberg, Dawson and Collier, 1973; and DeCoursey and Vernberg, 1972).

In some instances the concentrations of Fe, Cu, Ni, Pb and Zn were below the background levels found in seawater, thus indicating that scavenging of these metals by the sediments has occurred (K.Y. Chen, pers. comm.). The reduction of trace metals by filtration of the elutriate might actually have contributed to the observed mortalities since metals may limit survival of an organism when they occur in concentrations insufficient for the needs of the organism (Lewis, Whitfield and Ramnarine, 1972). Martin (1973) investigated iron metabolism in the crab *Cancer irroratus* and found that all tissues studied were capable of a constitutive element or an internal metabolite. Copper is also essential in crustaceans since it is an integral part of the oxygen bearing respiratory pigment, haemocyanin. Therefore, it seems probable that the alteration of the heavy metal concentrations in the elutriate may have contributed to the observed mortalities.

Other factors that may have contributed to the toxicity of the elutriate are the release of organic compounds, the reduction of dissolved oxygen and sediment type. Dissolved organics have been shown to be inhibitive to organisms in closed systems (King, 1975). The resuspension of Los Angeles Harbor sediments caused a drastic reduction in dissolved oxygen (Allan Hancock Foundation, 1975). However, due to the method of filtration (i.e., under compressed air) this was probably not a factor. Sediment type seems to have influenced the resultant mortalities in the *Acartia tonsa* assays. All stations that showed significant reductions in survival are composed of either silty sand, sandy silt or clay silt. Stations 1, 4 and 26, which are composed of sandy sediments, were non-toxic even though station 26 has a relatively high concentration of heavy metals and chlorinated hydrocarbons. The exact relationship between grain size and toxicity is not known but might be related to the increased surface to volume ratio of the finer grain sizes which might allow for greater release or adsorption of toxic molecules.

CONCLUSIONS

The proposed dredging operations will probably have little long-term effect on the epibenthic harpacticoid copepod

population. These organisms are relatively tolerant to adverse environmental conditions and have a high reproductive rate (Battaglia, 1970). As indicated in this study only the area around station LNG 7 might be expected to have a reduced population due to the release of toxic substances.

In contrast to the harpacticoid copepods, dredging could have adverse effects on the planktonic calanoid copepod population and consequently an effect on the plankton composition and food chain. Results of this study indicate that a substantial reduction in the *Acartia* population might be expected for the outfall area and those stations to the north, following sediment resuspension. The period in which this area might remain toxic cannot be determined from the available data, but might be lengthy since circulation is reduced in the area. Since *Acartia* is planktonic, rapid recolonization would probably occur following the loss of toxicity in the water column.

In the second set of tests there did not appear to be any clear trend toward concentration of heavy metals by *P. crassipes* above ambient levels when exposed to resuspended sediment from the Los Angeles Harbor. However, due to the wide variations in the data, a greater number of organisms would be needed to validate this conclusion statistically.

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Table 1. Percent Survival of Tisbe sp. in 96-hour Toxicity Tests.

STATION	CONTROL	TEST	NAUPLIAR STAGES PRESENT	x^2
LNG 1	98.5	92.7	Y	NS
LNG 2**	100%	100%	NA	NS
LNG 4	56.4	92.3	Y	10.57 P < .05
LNG 6	98.5	98.2	Y	NS
LNG 7	98.5	69.1	Y	18.21 P < .01
LNG 16	98.5	90.7	Y	NS
LNG 17	56.4	68.8	Y	NS
LNG 18	56.4	75	Y	NS
LNG 24	56.4	75.5	Y	NS
LNG 25	56.4	92.5	Y	11.76 P< .05
LNG 26	56.4	67.5	Y	NS
LNG 27	56.4	92.3	Y	11.36 P < .05

** Test conducted by Elliot Norse

NS - Not significant for P < .05
NA - Data not available

Table 2. Percent Survival of Acartia tonsa in 96-hour Toxicity Tests

STATION	CONTROL	TEST	x^2	
LNG 1	80	70.6	NS	
LNG 2*	60%	60%	NS	
LNG 3*	57.5	52.5	NS	
LNG 4*	62.5%	67.5%	NS	
LNG 6	70	52.9	9.18	$P < .01$
LNG 7	70	0	71.76	$P < .001$
LNG 16	70	30	10.41	$P < .001$
LNG 17	61	54.7	4.28	$P < .05$
LNG 18	48.2	17.4	31.54	$P < .001$
LNG 24	48.2	19.5	27.5	$P < .001$
LNG 26	49%	53.3	NS	
LNG 27	49%	28.6	7.98	$P < .01$

*Tests conducted by Norman Shields

Table 3. Concentrations of Heavy Metals Found in Pachygrapsus crassipes Expressed in mg/kg Dry Weight.

	Ag	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Control	1.66±1.07	2.98±.61	3.04±.34	147.45±32.8	148.8±39.5	1.27±.40	5.53±5.69	2.06±.59	85.78±14.1
LNG-1	1.44±.26	1.47±.37	3.55±.94	100.3±8.2	216.98±61.1	2.29±.84	10.01±5.5	2.72±.76	30.81±4.8
LNG-4	1.70±.19	1.33±.61	5.77±1.65	135.25±27.8	334.18±12.1	2.08±2.6	11.77±10.2	2.23±1.2	27.11±3.27
LNG-17	1.27±.59	2.65±1.73	6.42±2.17	97.85±54.0	428.82±190.1	3.06±1.4	3.99±2.44	2.79±.86	50.40±20.5
LNG-27	1.79±.95	1.23±.13	2.18±.73	138.58±43.83	209.66±67.1	1.82±1.1	9.66±2.21	1.62±.47	59.54±19.4

Table 4. Sediment Characteristics of the LNG Stations.

Sediment types / LNG stns. / Parameters	Sand			Silty Sand				Sandy Silt			Silty Clay
	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
MC (%)	24.09	28.64	30.88	31.22	36.09	24.87	19.32	48.47	49.76	38.11	65.12
TOC (%)	0.47	0.61	0.82	0.82	1.14	0.62	0.57	1.68	2.06	1.10	3.49
TVS (%)	0.92	1.71	1.61	2.07	2.65	1.45	0.70	4.28	2.77	2.33	6.90
IOD (mg/kg)	140	682	2030	996	3770	1090	283	3150	4150	1820	8550
COD (mg/kg)	15100	21500	24100	25600	39300	15300	10400	62800	71800	40600	105400
Organic N(mg/kg)	317	418	562	646	858	457	135	628	1984	904	2656
Kjeldahl N (")	326	439	583	663	879	461	138	656	2010	923	2696
P (mg/kg)	737	1010	1330	1030	1120	1040	910	1390	1990	1610	1820
Sulfide (mg/kg)	38	121	65	259	241	58	35	549	828	151	1530
Oil & Grease (mg/kg)	195	289	369	598	777	338	301	1323	1477	810	2094

MC = Moisture Content; TOC = Total Organic Carbon; TVC = Total Volatile Solids;

IOD = Immediate Oxygen Demand; COD = Chemical Oxygen Demand.

Table 5. Sediment Trace Metals Concentrations at LNG Stations.

Sediment types / LNG stns / Elements	Sand			Silty Sand				Sandy Silt			Clay Silt
	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
As	2.74	0.69	1.16	0.22	3.02	0.35	0.31	3.28	4.62	2.57	5.46
Cd	0.98	1.47	1.49	1.69	1.55	1.48	1.16	3.77	2.87	2.60	4.19
Cr	34.2	34.3	46.3	43.1	35.7	32.9	27.0	77.7	61.8	43.9	77.7
Cu	14.0	32.7	38.7	42.4	35.7	30.3	20.4	149	69.7	53.1	194
Fe	18900	26300	30400	34200	34100	30300	22000	43100	38200	36400	49600
Hg	0.219	0.224	0.518	0.575	0.397	0.692	0.211	1.260	0.588	0.493	0.937
Mn	248	376	433	407	378	425	308	452	410	312	395
Ni	18.6	27.1	29.8	25.9	25.4	28.4	17.9	55.5	47.2	35.2	59.8
Pb	40.7	47.4	49.6	36.2	34.1	39.9	40.8	120	74.1	55.1	117
Zn	55.4	78.4	116	103	114	92.3	69.1	262	242	140	317

- Trace Metals concentrations expressed in mg/kg dry weight.

Table 6. Sediment Chlorinated Hydrocarbon Concentrations at LNG Stations.

Sediment types / LNG stns. / Parameters	Sand			Silty Sand				Sandy Silt			Clay Silt
	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
pp'-DDE	0.126	0.220	0.291	0.334	0.438	0.243	0.073	0.321	0.740	0.485	0.984
op'-DDE	0.059	0.062	0.100	0.110	0.144	0.084	0.023	0.104	0.246	0.164	0.329
pp'-DDD	0.076	0.160	0.162	0.196	0.231	0.139	0.059	0.184	0.496	0.282	0.586
op'-DDD	0.030	0.054	0.053	0.069	0.078	0.044	0.020	0.061	0.170	0.090	0.189
Total DDT	0.294	0.497	0.606	0.708	0.892	0.510	0.176	0.670	1.652	1.021	2.088
PCB-1254	0.063	0.070	0.085	0.090	0.122	0.082	0.023	0.092	0.200	0.131	0.740
PCB-1260	0.006	0.007	0.008	0.009	0.012	0.008	0.002	0.009	0.020	0.013	0.024
PCB-1242	0.080	0.094	0.098	0.090	0.110	0.097	0.043	0.009	0.250	0.150	0.270
Total PCB	0.149	0.171	0.191	0.189	0.244	0.187	0.068	0.200	0.470	0.294	0.534

- Other chlorinated hydrocarbons are below detection limit

Table 7. Trace Metals Concentration in Elutriates (from Standard Elutriate Test).

Sediment Type / LNG stations / Elements	Sand			Silty Sand				Sandy Silt			Clay Silt
	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
Cr	0.50	0.60	0.50	0.50	0.50	2.0	0.70	0.55	0.50	1.80	0.55
Fe	8.5	1.9	0.4	1.9	0.9	148.0	0.6	5.5	6.0	365.7	2.3
Mn	19.5	30.0	17.7	18.0	16.0	17.7	3.6	7.2	17.5	14.2	1.70
Ni	2.2	2.0	2.0	2.5	1.0	4.0	2.5	0.50	1.0	0.50	0.0
Pb	0.8	0.0	0.4	0.2	0.0	4.0	0.0	0.2	0.2	1.3	0.4
Zn	0.13	0.26	0.0	0.0	0.0	0.0	0.0	0.15	0.0	0.26	0.0

- The concentrations of Cd, Hg, Ag and Cu in the elutriates were undetectable.
- All concentrations are in ug/l
- All samples were filtered through 0.45 um membrane filters.

Table 8. Trace Metals in Seawater* used for Elutriate Test.

Elements / Parameters	Ag	Cd	Cu	Cr	Fe	Hg	Mn	Ni	Pb	Zn
Mean**	0.02	0.24	0.23	0.55	2.97	0.06	1.03	0.75	0.17	0.27
Standard Deviation	0.027	0.16	0.04	0.07	1.41	0.0007	0.11	0.21	0.04	0.09
Coef. of Variance	0.28	0.69	0.18	0.13	0.47	0.01	0.10	0.28	0.25	0.34

* Passed through 0.45 μ membrane filter.

** Average of two independent determinations.

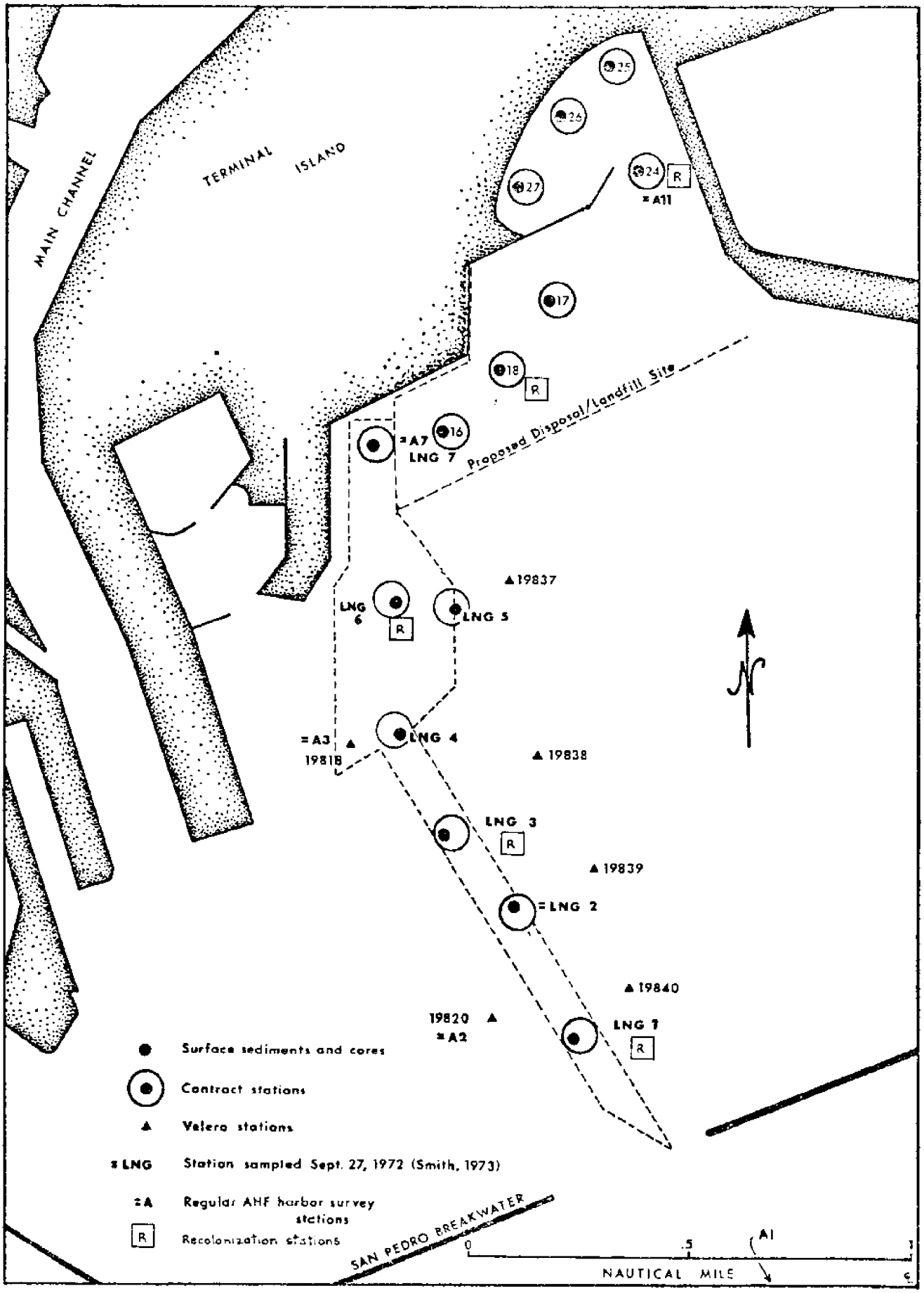

Figure 1. Outer Los Angeles Harbor Dredging Effects Study (Harbor Environmental Projects, 1976).

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART 11.

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BIOASSAY AND HEAVY METAL UPTAKE INVESTIGATIONS OF RESUSPENDED SEDIMENT ON TWO SPECIES OF POLYCHAETOUS ANNELIDS

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ABSTRACT. Two species of polychaetous annelids (*Capitella capitata* and *Ophryotrocha* sp) were used in a series of bioassays to determine the toxicity of resuspended sediments from fourteen stations in Los Angeles Harbor. Significant mortality did not occur in either short-term (96-hour) or long-term (28-day) bioassays using *Ophryotrocha* sp. Numbers of offspring were significantly reduced in all sediments except the outermost harbor station (LNG-1), indicating sublethal effects. Development success of *Capitella capitata* larvae ranged from 40% to 95%. The more grossly contaminated sediments yielded lower numbers of successfully developing larvae but higher growth rates in the surviving larvae. Contamination levels of the sediments correlated more closely with sediment particle size than with distance from the outside harbor.

Heavy metal concentrations in the tissues of *Capitella capitata* did not correspond with sediment contamination levels. Resuspended sediment may result in "scavenging" which lowers the concentration of some heavy metals in the seawater.

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BIOASSAY AND HEAVY METAL UPTAKE INVESTIGATIONS OF RESUSPENDED SEDIMENT ON TWO SPECIES OF POLYCHAETOUS ANNELIDS

INTRODUCTION

The ecological effects of resuspended sediments can be separated generally into those effects that are caused by physical factors and those caused by chemical changes. The potential adverse physical effects of resuspended sediment may result in smothering of the bottom communities. The amount of damage is usually related to the quantity of silt redeposited and filter feeding organisms are usually the most sensitive to this (Hoss, Coston and Schaaf, 1974). Silt deposits create a "fluff zone" at the sediment-water interface which has been shown to have a smothering effect (Wakeman, Peddicord, and Sustar, 1975). The chemical effects of resuspended sediments include the impacts of constituents such as heavy metals and pesticides. Heavy metals and pesticides adsorb onto the sediments and complex with organic components, forming a sink for the contaminants. This can provide a long standing source of contamination to estuarine or harbor sediment ecosystems (Groot and Allersma, 1973).

Differences in the levels of contaminants such as heavy metals taken up from the environment by marine organisms may be due to a variety of biotic factors such as feeding strategies, age, habitat and environmental conditioning or tolerance (Bryan and Hummerstone, 1973; Leatherland and Burton, 1974; Phelps, Santiago, Luciano, and Irizarry, 1969). The concentrations of contaminants are also dependent upon the concentration levels and dynamics of the physical environment (Goldberg, 1957).

Concentration of heavy metals is more readily evidenced by populations exposed to low levels of environmental contamination (Brooks and Rumsby, 1965). Regulation of heavy metals is more likely to be found in those organisms that live in highly contaminated environments such as part of Los Angeles Harbor. The ability to regulate may in fact be a controlling factor, determining to some extent the species composition of the community.

Because dredging is an activity that may take place in contaminated areas, questions have been raised as the possibility of increased toxicity or of food chain amplification due to dredging. In the United States, most dredging has been halted in recent years, pending the outcome of studies on the environmental effects of dredging.

Previous studies to predict the effect of dredging in Los Angeles Harbor have been conducted, in which baseline biotic surveys were made. One approach has been to place test organisms in and around the dredge site for a field bioassay (Reish and Barnard, 1960). This method produced significant findings; however, comparative results can be obtained only after dredging operations have been completed.

In the present studies, the first set of experiments were designed to test 96 hour toxicity effects and 28 day long-term effects of simulated dredging activities on two species of benthic polychaetes.

The Environmental Protection Agency (EPA, 1973) formulated bioassay techniques to provide an indication of the potential chemical toxicity of the resuspended sediment before the dredging operation takes place. These techniques were utilized in the present study in an attempt to determine the potential toxicity of sediments collected from a series of stations along the proposed LNG construction site. Some modifications of techniques were also tested, and EPA procedures were also modified during the project period.

In the second portion of the study, investigations were designed to determine whether benthic polychaete species, *Capitella capitata*, which occurs naturally in polluted sediments, would be affected by dredging operations in the outer Los Angeles Harbor. These studies were part of a larger study dealing with the effects of dredging on planktonic, pelagic, and benthic organisms, and the potential of areas to recolonize following dredging.

MATERIALS AND METHODS

Toxicity-Bioassay Tests.

Sediment was collected with a +0.10 m^2 modified Campbell grap along the proposed dredge site (Fig.1). Sediment samples were placed in one gallon jars and returned to the laboratory and stored at 4°C. Seawater for these tests was collected in 5 gallon polyethylene carboys from near the sea buoy at station A1, located outside the Los Angeles Harbor Angels Gate, and stored at 12°C. The "standard elutriate" was prepared by mixing a volumetric 1:4 ratio of sediment and seawater. The container of sediment and seawater was capped tightly and shaken vigorously on a mechanical shaker for 30 minutes. After shaking, the suspension was allowed to settle for one hour and the supernatant was carefully decanted. Both the supernatant

and control seawater were filtered through a .45μ Millipore filter in a filtration device mounted between two 50 cc syringes. Filtration through the syringes minimizes oxidation of the supernatant. The filtrate of "standard elutriate" was apportioned equally to the test containers. Control chambers were filled with an equal volume of seawater.

Female polychaete worms bearing fertile eggs were isolated from *Capitella capitata* stock cultures. The eggs were removed and allowed to develop into active swimming metatroch larvae. Only the metatroch larval stages were used, as previous studies have shown that, in the trochophore state, controls undergo an excessively high mortality (Emerson, 1974). Replicate tests were conducted, in which ten metatrochs were placed in each of a series of 16 ounce jars. Minimal aeration and a small quantity of *Enteromorpha* was provided as food in each jar. Survival after 28 days of exposure was determined. Sublethal effects on *Capitella capitata* were also determined in respect to growth, presence of eggs and brooding activity. Mortality was expressed in toxicity units as suggested by the California State Water Resources Control Board as follows:

$$Tc\ (tc) = \frac{\log\ (100 - S)}{1.7}$$

S = percentage survival in 100% waste.

Ophryotrocha sp. stock cultures are maintained in one gallon jars at room temperature. Experimental procedures consisted of placing the stock culture in a "cold room" at 12°C. for four days, which synchronized reproductive development (Akesson, 1970), so that numerous offspring of uniform size and age are available. One specimen was placed in each of a series of small stendor dishes filled with 16 ml of solution. Each chamber was provided with a trace amount of "Tetra," a tropical fish food. Four replicates were prepared for each station. Tests were conducted for 96 hours and for 28 days, at which time mortality and survival numbers of individuals was recorded. Aeration is not required for this species under these conditions.

Heavy metal uptake.

The methods were designed to test for transfer of pollutants from the sediments to either the suspensate (elutriate) or to the tissues of the animals themselves.

Six females of the benthic polychaete worm *Capitella capitata* that were brooding larvae within their membranous tubes were selected from stock cultures. Cultures, originally

obtained from Dr. D. J. Reish, have been maintained for approximately 28 months in our laboratory. Individuals were placed in test and control 1-gallon jars for a 28 day exposure period. Dried *Enteromorpha* was provided for food and minimal aeration was supplied.

Sediment was collected from station LNG-1, LNG-4, LNG-7, 17 and 27 with a .10m^2 modified Campbell grab (Figure 1). These sites were selected as representative of a range of sediment grades which include sand (LNG-1, LNG-4), silty sand (LNG-17), sandy silt (LNG-7) and silty clay (LNG-27). Sediment samples were placed in 1-gallong jars and returned to the laboratory and stored at 12°C. Seawater for these tests was collected in 5-gallon polyethylene carboys from near Sea Buoy Station A-1, located outside the Los Angeles Harbor Angel's Gate, and stores at 12°C.

The "standard elutriate" was prepared by mixing in a volumetric 1:4 ratio of sediment and seawater. The container of sediment and seawater was capped tightly and shaken vigorously on a mechanical shaker for 30 minutes. After shaking, the suspension was allowed to settle for one hour and carefully decanted (EPA, 1973). Approximately 1,000 ml of elutriate were prepared from the sediment of each station and added to 1-gallon jars.

Clean Laboratory Technique: In preparation for the analysis of sediments and tissues it is essential that all labware undergo established cleaning procedures to control background contamination levels (Patterson, 1974). The labware was cleaned in one of three 1000-ml teflon beakers which had been previously cleaned with two changes of concentrated analytical reagent-grade HNO_3 for two periods of three days each at a temperature of about 80°C. Following the acid wash the beakers were thoroughly rinsed in deionized, quartz-distilled water.

All teflon and quartz glass labware was cleaned in the manner outlined for the 1000-ml beakers. All subsequent cleanings consisted of subjecting the labware to two changes of concentrated HNO_3 and a single change of 1% NBS-double distilled HNO_3 (National Bureau of Standards double distilled quality). After cleaning, the labware was rinsed in deionized quartz-distilled water and wrapped wet in Saran Wrap. All clean labware was handled only with clean non-talced polyethylene gloves. Polyethylene vials were cleaned with 6N HCl instead of concentrated HNO_3 which degrades polyethylene. All procedures were performed in a standard laboratory fume hood.

Heavy Metals Analysis: Tissue sample size ranged from 25-50 mg wet weight and consisted of 8-12 specimens. Replicate samples were prepared from each test and control jar. Tissue

samples were dried at 103°C for 24 hours and allowed to cool in a dessicator. Each sample was weighed and transferred to a 20 ml teflon beaker into which was pipetted 2 ml of a 2:1:1 solution of deionized quartz-distilled water, H_2SO_4 and HNO_3 (NBS quality) and heated at about 150°C. The digestion was monitored for a clear solution, which indicates total digestion. The sample was collected in a tared 20 ml polyethylene vial and diluted to 10 ml for each 0.5 gms. of tissue. Samples were analyzed by atomic absorption spectroscopy (Perkin-Elmer Model 305B and HGA 2100). Working conditions for atomic absorption are shown in Table 9. Reagent blanks were run with each group of samples. Elutriate was prepared and analyzed for heavy metal as detailed by Chen and Lu (1974).

RESULTS

Toxicity-Bioassay Studies.

The short term (96-hour) toxicity bioassays conducted with *Ophryotrocha* sp. did not produce significant mortality in any of the "standard elutriates" from the fourteen stations. The long term (28-day) exposure period produced minor mortality in tests from several stations, although none of these tests differed significantly from the control groups. Sublethal effects in terms of the number of offspring produced in each station elutriate after a 28-day exposure period were significantly lowered in each station elutriate with the exception of LNG-1, which was similar to the control groups (Table 1).

Three general areas of response in number of *Ophryotrocha* offspring produced were noted in the elutriates from fourteen stations included in this study. The outermost station (LNG-1) was similar to the control groups and may be considered as having the least toxic sediment. The second group, showing intermediate toxicity included stations LNG-2, LNG-3, LNG-4, LNG-5. The third group included the innermost stations within the study area. Elutriates from these stations (LNG-6, LNG-7, 16, 17, 18, 24, 25, 26 and 27) yielded the fewest offspring and could be considered as potentially the most toxic sites in respect to reproduction.

Sublethal effects on *Capitella capitata* were determined according to the growth of successfully developing specimens and to the presence of fertile females. The mean growth of the control groups was exceeded by specimens exposed to some of the station elutriates which had the lowest percentage of successfully developing specimens.

Development success of the *Capitella capitata* larvae exposed to station elutriates for a 28-day period ranged from 40% in LNG-7 elutriate to 95% in stations LNG-2, LNG-4 and 25 elutriates (Table 2). Larval settlement was most successful in elutriates from stations LNG-1, LNG-2, LNG-4 and 25, all of which exceeded two of the control groups, and least successful in elutriates from stations LNG-7, LNG-6, 24 and 27, with only 40-60% of the larvae undergoing successful development.

The mean growth of the control groups was exceeded by specimens exposed to elutriates from stations LNG-3, LNG-6, LNG-7, 16 and 27. Specimens brooding eggs or evidencing the presence of eggs in the coelomic cavity occurred in all elutriates with the exception of LNG-7 and 27.

The heavy metal and pesticide content of the sediments did not show a direct trend of increasing contamination levels with increasing distance from the outer harbor but were related more closely with similarities in sediment particle size (Tables 3, 4 and 5). Sandy sediments at stations LNG-1, LNG-4 and 26 were the least contaminated. Sediments characterized as mostly silty sand were generally most contaminated and included stations 17, 18, 24 and 25. The stations characterized as sandy silt were the most highly contaminated and consisted of stations LNG-6, LNG-7 and 16. The most contaminated stations consisted primarily of silty clay. Increasing levels of sulfide content were also evident.

The release of most heavy metals in the elutriate preparation did not correspond with the contamination levels of the sediment (Chen and Wang, 1976). The significance of lack of correlation suggests a more complex interaction of the constituents than can be demonstrated with present EPA prescribed procedures. The more contaminated stations in terms of the elutriate test are listed according to the concentration of each consituent in Table 6. The difficulty in predicting potentially toxic sediments based on concentrations of individual constituents in the elutriates is very complex due to synergistic and antagonistic interactions of these constituents, which may not presently be known.

Heavy Metals Uptake.

Heavy metal concentrations in the elutriate did not correlate well with sediment grain size. It is of interest that the heavy metal content of the elutriates from the sandy sediments (LNG-1 and 4) were higher in Mn, Ni, and Zn than those from the finer sediments (7 and 27).

The concentration of heavy metals found in the seawater used in the elutriate preparation was higher than those in the elutriate in some cases (Table 3 and 4). When the heavy metals in the elutriates are less than that of the seawater used in the preparation of the elutriate, the phenomenon of "scavenging" is said to occur (Chen & Wong, 1976).

The trace metal concentrations in the tissues of *Capitella capitata* specimens (Table 10) did not correspond significantly with the concentration of trace metals in the elutriate preparations (Table 6). The control group was higher in at least one of the test groups with the exception of manganese. Tissue concentrations were lowest from in silver, copper, iron, nickel and lead from station 7 elutriate. Tissue concentrations of chromium and zinc were lowest in station 17 elutriate. Tissue concentrations of cadmium were lowest in elutriate from station 1.

Tissue concentrations of heavy metals were highest in elutriates from stations LNG-1, LNG-4 and 27. Silver, chromium and nickel were highest in specimens exposed to LNG-1 elutriate. Tissue concentrations of copper, iron, manganese, lead and zinc were highest in LNG-4 elutriates, while cadmium was highest in those organisms exposed to station 27 elutriate.

CONCLUSIONS

The soluble constituents in the sediments collected along the proposed dredge and fill site within the outer Los Angeles Harbor area are potentially toxic as determined within the limits of this study. The results give a conservative estimate of the "potential toxicity" and must be interpreted with caution. Such critical factors as the effect of the resuspended sediment on the dissolved oxygen content of the water and the physical effect of turbidity to filter feeding organisms were not considered. Dredging activities during the summer months of increased water temperature have been shown to produce a more toxic effect because of decreased dissolved oxygen levels (Wakeman, et al., 1975).

The effect of resuspended sediments on the biota within the harbor depends in part on the location of the organisms within the study area. The polychaete *Ophryotrocha* sp. is a member of the harbor fouling community and has been collected successfully in the upper levels of the water column from the pilings and docking facilities. The species may also occur at deeper levels. The abundance of *Ophryotrocha* and other species in the upper reaches of the water column lessens the effect of depressed dissolved oxygen levels that result from

the resuspension of sediment.

The benthic polychaete *Capitella capitata*, which occurs in abundance throughout the harbor area has been considered an indicator of environmental disturbance by some investigators (Grassle and Grassle, 1974). The existence of a pelagic larval stage and the ability of this species to withstand minimal dissolved oxygen levels insure recruitment and recolonization of the area following the dredging activity.

It is of interest that results were somewhat contradictory in evaluating toxicity of the sediments (elutriates) with successful development and growth rates. Low development success did not coincide with reduced growth rates in the surviving specimens. Those tests with the greatest amount of larval mortality also showed the greatest amount of growth for the developing specimens. It is suggested that the larval stage of *Capitella capitata* is the most sensitive stage in the life cycle, but those larvae which survive the elutriate tests undergo biostimulation, as evidenced by increased growth (Emerson, 1974).

The effects of the dissolved fraction in the elutriate were most distinctly evidenced by sublethal effects upon the reproductive potential of *Ophryotrocha*. Sublethal effects on the growth of the developing *Capitella capitata* specimens were not as well defined due to the effect of "biostimulation." In general, the results of the bioassays and sediment contamination levels suggest a gradient of increasing contamination from the outermost harbor station with increasing levels of potential toxicity within the more inner reaches of the study area, but the sediment grain size also shows a general trend toward decreasing in the inner harbor or in areas of reduced flushing. The trend of increasing contamination levels with decreasing grain size related to the increased surface area of the smaller particles for the adsorption of both heavy metal and pesticide contaminants. The decrease in particle size is also correlated with an increase in the organic carbon content which also provides adsorption sites for the variety of contaminants.

The poor relationship of the release of contaminants in the elutriate preparation with the levels of sediment contamination and the bioassay results suggests that this method may require some revisions if meaningful applications are to be made. The present procedure requires that the organic fraction be removed from the elutriate by "appropriate" filtration. The suspended fraction has been shown to concentrate 80 to 90 percent of the trace metals in the sediment fraction (Chen and Lu, 1974). This suggests that the present bioassay results represent a conservative measure of the potential

toxicity of the resuspended sediment fraction within the study area.

The uptake levels of heavy metals in *Capitella capitata* specimens exposed to a range of sediment contamination levels did not yield agreement with the sediment contamination levels (Table 10 and Table 4). The lack of correlation may be attributed to the purification effect of the suspended organic fraction on the elutriated preparation and the biological process of regulation by the organisms.

Resettlement of the suspended fraction may have a "purification effect" on the test solution or elutriate. It has been shown that 80 to 90 percent of the pesticide and heavy metal constituents are removed by filtration of the particular suspended fraction (Chen and Lu, 1974). The silt fraction was highest in the more contaminated sediments, which may provide a greater number of adsorption sites for soluble contaminants in the medium in the preparation of the elutriate. The elutriates prepared from sandy sediments in some cases were higher than in the elutriates prepared from silty sediments, which may indicate that the greater amount of resuspended particulation in the silty sediments is serving to remove soluble contaminants.

The concentrations of heavy metals in the tissues of the organisms could also be modified through the process of internal regulation. Regulation of the uptake levels in the tissues is a phenomenon that would contribute to the success of an organism in contaminated environments.

An additional aspect to consider is the process of "biostimulation" which has been demonstrated in respect to increased growth rates of specimens in more contaminated sediment elutriates (Emerson, 1974). When considering that similar sized tissue samples were used in these analyses, those organisms growing at an increased rate may represent a lower unit mass of heavy metal concentration than those organisms which did not undergo an increased rate of growth.

Additional factors may be involved which have obscured a clearer interpretation of the data. In any case it is concluded from this limited approach that the uptake of heavy metals by *Capitella capitata* is not a major problem in assessing a projected dredging impact. The transfer of high heavy metal concentrations to subsequent generations would be considered to be even less of a concern. The concentration of heavy metals in subsequent generations is herein suggested as similar to those concentrations found in the parental organisms initially exposed to the dredging activity.

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Table 1. *Ophryotrocha* sp. Produced within a 28-day Period.

Station	#1	#2	#3	#4	Total Number	$\bar{X}$	P
Control 4	4	7	9	9	29		
Control 3	13	10	10	5	38	9.50	
Control 1	10	10	9	10	39		
Control 2	9	7	10				
LNG 1*	6	20	5	10	41	10.25	-
LNG 2*	3	3	2	2	10	2.50	.01
LNG 3*	3	3	2	1	9	2.25	.01
LNG 4*	2	2	1	1	6	1.50	.01
LNG 5*	5	1	2	4	12	3.00	.05
LNG 6*	0	0	0	1	1	0.25	.001
LNG 7*	0	0	0	0	0	0	-
16	0	0	2	0	2	0.50	.001
17	1	0	0	1	2	0.50	.001
18	0	2	0	1	3	0.75	.01
24	0	1	0	2	3	0.75	.01
25	0	2	1	1	4	1.00	.01
26	1	0	0	3	4	1.00	.01
27	0	0	0	0	0	0	-

* Sediment collected in 1974; all others collected 1975.

Table 2. Survival and growth of *Capitella capitata* within a 28-day Period.

Station	Total No. Metatrochs	Successful Development(%)	Toxicity Units	Mean Growth(mm)	Fertile Females
Control 1	20	100	-	11.6	yes
Control 2	20	100	-	11.2	yes
Control 3	20	80	.77	7.0	yes
Control 4	20	85			
LNG-1*	20	90	.59	10.6	yes
LNG-2*	20	95	.41	11.3	yes
LNG-3*	20	85	.69	12.3	yes
LNG-4*	20	90	.59	11.3	yes
LNG-5*	20	80	.77	10.1	yes
LNG-6	20	60	.94	17.0	yes
LNG-7	20	40	1.05	16.5	no
16	20	80	.77	13.0	yes
17	20	80	.77	9.1	yes
18	20	70		10.2	yes
24	20	60	.94	12.1	yes
25	20	90	.59	9.7	yes
26	20	70		11.4	yes
27	20	50		15.9	no

* Sediments collected in 1974; all others collected 1975.

Table 3. Sediment Characteristics of the LNG Stations (ppm)

Sediment types / LNG stns. / Parameters	Sand			Silty Sand				Sandy Silt			Silty Clay
	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
MC (%)	24.09	28.64	30.88	31.22	36.09	24.87	19.32	48.47	49.76	38.11	65.12
TOC (%)	0.47	0.61	0.82	0.82	1.14	0.62	0.57	1.68	2.06	1.10	3.49
TVS (%)	0.92	1.71	1.61	2.07	2.65	1.45	0.70	4.28	2.77	2.33	6.90
IOD (mg/kg)	140	682	2030	996	3770	1090	283	3150	4150	1820	8550
COD (mg/kg)	15100	21500	24100	25600	39300	15300	10400	62800	71800	40600	105400
Organic N(mg/kg)	317	418	562	646	858	457	135	628	1984	904	2656
Kjeldahl N (")	326	439	583	663	879	461	138	656	2010	923	2696
P (mg/kg)	737	1010	1330	1030	1120	1040	910	1390	1990	1610	1820
Sulfide (mg/kg)	38	121	65	259	241	58	35	549	828	151	1530
Oil & Grease (mg/kg)	195	289	369	598	777	338	301	1323	1477	810	2094

MC = Moisture Content; TOC = Total Organic Carbon; TVC = Total Volatile Solids;

IOD = Immediate Oxygen Demand; COD = Chemical Oxygen Demand.

Table 4. Sediment Trace Metals Concentrations at LNG Stations (ppm)

Sediment types / LNG stns / Elements	Sand			Silty Sand				Sandy Silt			Clay Silt
	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
As	2.74	0.69	1.16	0.22	3.02	0.35	0.31	3.28	4.62	2.57	5.46
Cd	0.98	1.47	1.49	1.69	1.55	1.48	1.16	3.77	2.87	2.60	4.19
Cr	34.2	34.3	46.3	43.1	35.7	32.9	27.0	77.7	61.8	43.9	77.7
Cu	14.0	32.7	38.7	42.4	35.7	30.3	20.4	149	69.7	53.1	194
Fe	18900	26300	30400	34200	34100	30300	22000	43100	38200	36400	49600
Hg	0.219	0.224	0.518	0.575	0.397	0.692	0.211	1.260	0.588	0.493	0.937
Mn	248	376	433	407	378	425	308	452	410	312	395
Ni	18.6	27.1	29.8	25.9	25.4	28.4	17.9	55.5	47.2	35.2	59.8
Pb	40.7	47.4	49.6	36.2	34.1	39.9	40.8	120	74.1	55.1	117
Zn	55.4	78.4	116	103	114	92.3	69.1	262	242	140	317

- Trace Metals concentrations expressed in mg/kg dry weight.

Table 5. Sediment Chlorinated Hydrocarbon Concentrations at LNG Stations.

Sediment types	Sand			Silty Sand				Sandy Silt			Clay Silt
LNG stns. / Parameters	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
pp'-DDE	0.126	0.220	0.291	0.334	0.438	0.243	0.073	0.321	0.740	0.485	0.984
op'-DDE	0.059	0.062	0.100	0.110	0.144	0.084	0.023	0.104	0.246	0.164	0.329
pp'-DDD	0.076	0.160	0.162	0.196	0.231	0.139	0.059	0.184	0.496	0.282	0.586
op'-DDD	0.030	0.054	0.053	0.069	0.078	0.044	0.020	0.061	0.170	0.090	0.189
Total DDT	0.294	0.497	0.606	0.708	0.892	0.510	0.176	0.670	1.652	1.021	2.088
PCB-1254	0.063	0.070	0.085	0.090	0.122	0.082	0.023	0.092	0.200	0.131	0.740
PCB-1260	0.006	0.007	0.008	0.009	0.012	0.008	0.002	0.009	0.020	0.013	0.024
PCB-1242	0.080	0.094	0.098	0.090	0.110	0.097	0.043	0.009	0.250	0.150	0.270
Total PCB	0.149	0.171	0.191	0.189	0.244	0.187	0.068	0.200	0.470	0.294	0.534

- Other chlorinated hydrocarbons are below detection limit

Table 6. Trace Metals Concentration in Elutriates (from Standard Elutriate Test) (ppb)

Sediment Type / LNG stations / Elements	Sand			Silty Sand				Sandy Silt			Clay Silt
	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
Cr	0.50	0.60	0.50	0.50	0.50	2.0	0.70	0.55	0.50	1.80	0.55
Fe	8.5	1.9	0.4	1.9	0.9	148.0	0.6	5.5	6.0	365.7	2.3
Mn	19.5	30.0	17.7	18.0	16.0	17.7	3.6	7.2	17.5	14.2	1.70
Ni	2.2	2.0	2.0	2.5	1.0	4.0	2.5	0.50	1.0	0.50	0.0
Pb	0.8	0.0	0.4	0.2	0.0	4.0	0.0	0.2	0.2	1.3	0.4
Zn	0.13	0.26	0.0	0.0	0.0	0.0	0.0	0.15	0.0	0.26	0.0

- The concentrations of Cd, Hg, Ag and Cu in the elutriates were undetectable.
- All concentrations are in µg/l
- All samples were filtered through 0.45 um membrane filters.

Table 7. Trace Metals in Seawater* used for Elutriate Test. (ppb)

Elements / Parameters	Ag	Cd	Cu	Cr	Fe	Hg	Mn	Ni	Pb	Zn
Mean**	0.02	0.24	0.23	0.55	2.97	0.06	1.03	0.75	0.17	0.27
Standard Deviation	0.027	0.16	0.04	0.07	1.41	0.0007	0.11	0.21	0.04	0.09
Coef. of Variance	0.28	0.69	0.18	0.13	0.47	0.01	0.10	0.28	0.25	0.34

* Passed through 0.45 µ membrane filter.

** Average of two independent determinations.

Table 8. Ratio of Trace Metals in Elutriate/Seawater (ppb)

Sediment types / LNG stns. / Elements	Sand			Silty Sand				Sandy Silt			Clay Silt
	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
Cr	1.0	1.1	1.0	1.0	1.0	3.6	1.3	1.0	1.0	3.3	1.0
Fe	2.8	-0.64	-0.13	-0.64	-0.30	49.3	-0.20	1.8	2.0	121.0	-0.77
Mn	19.0	30.0	17.7	18.0	16.0	17.7	3.6	7.2	17.5	14.2	1.70
Ni	2.9	2.7	2.7	3.3	1.3	5.3	3.3	-0.67	1.3	-0.67	-0
Pb	4.7	-0.0	2.4	1.2	-0.0	23.5	-0.0	1.2	1.2	7.7	2.4
Zn	-0.5	1.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.5	-0.0	1.0	-0.0

- Dash (-) indicates that the concentration of trace metals and elutriates is less than that of the concentration in background seawater; therefore, "scavenging" occurs.

Table 9. Working Conditions for Atomic Absorption Spectroscopy (Perkin-Elmer Model 305B with HGA 2100).

Parameter / Elements	Wavelength (nm)	Slit No.	Drying Temp.(°C) / Time (sec)		Charring Temp.(°C) / Time (sec)		Atom. Temp.(°C) / Time (sec)		Background Corrector		Purge Gas Flow	
			(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Silver	328.1	4	125/20	125/20	650/30	650/30	2450/7	2400/8	w/o	w/o	N	N
Cadmium	228.8	4	115/30	125/20	400/30	400/30	1500/8	1500/7	w/o	w/o	I	I
Copper	324.7	4	115/30	125/30	1000/30	950/30	2500/8	2550/8	w/o	w/o	N	N
Nickel	232.0	3	115/30	125/20	1200/20	1200/20	2500/7	2550/7	w/o	w/o	N	N
Lead	283.3	4	115/30	125/30	500/40	550/40	2000/6	2000/7	w/o	w/o	N	N
Zinc	231.9	4	125/30	125/30	650/30	650/30	2000/8	2000/7	w/o	w/o	N	N
Iron	248.3	3	120/20	120/20	1000/20	1000/50	2400/5	2400/7	w/	w/	N	N
Manganese	279.5	3	115/30	120/30	1000/30	1150/40	2500/8	2500/8	w/	w/	I	I
Chromium	357.9	4	115/30	115/30	1250/20	1250/35	2600/5	2600/8	w/	w/	N	N

(A) - Working Conditions for Double Distilled Water Solution

(B) - Working Conditions for MIBK Solution. (Except the elements of Iron, Manganese and Chromium in Seawater for which direct injection methods were applied).

Table 10. Concentrations of Heavy Metals in *Capitella capitata* Exposed to "Standard Elutriate" Prepared from Sediment Samples. (ppm)

Element / Station	Ag	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Control	0.32±.25	0.78±.48	5.74±5.03	25.07±7.59	2375.35±1866.41	11.8±7.78	16.42±3.32	8.85±2.07	236.05±138.95
LNG-1	0.69±.19	0.50±.24	22.59±14.23	35.41±9.64	6175.50±5520.52	34.7±30.5	30.53±6.51	10.90±3.94	245.44±27.63
LNG-4	0.57±.27	1.26±1.14	15.34±8.85	39.68±0.18	8457.10±4603.97	57.19±31	21.69±10.2	17.68±4.51	248.94±13.13
LNG-7	0.18±.01	0.76±0.59	4.91±1.84	14.85±0.57	1984.80±156.41	16.31±3.65	7.90±0.03	5.65±0.74	203.47±6.72
LNG-17	0.28±.05	0.54±.05	4.84±2.97	16.30±6.58	2762.0±1055.99	20.33±6.06	10.06±8.93	16.22±1.24	138.21±46.34
LNG-27	0.65±.42	1.55±1.11	7.46±.37	38.95±8.55	3252.8±769.19	32.25±8.39	15.15±1.73	14.31±13.62	214.01±22.37

- Analyses are means of duplicate determinations.

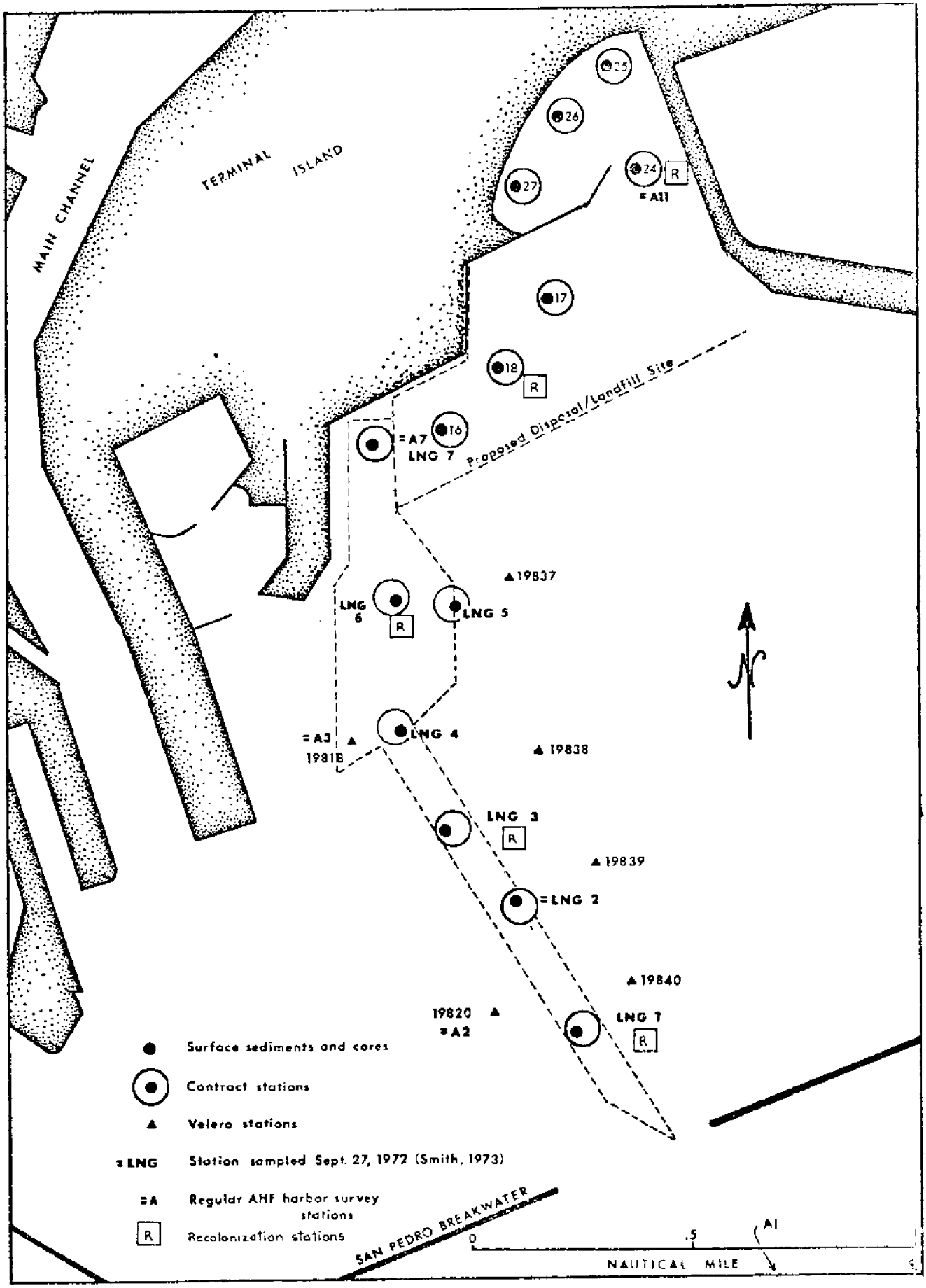

Figure 1. Outer Los Angeles Harbor Dredging Effects Study (Harbor Environmental Projects, 1976).

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART 11

June, 1976

BIOMASS AND RECOLONIZATION STUDIES IN THE OUTER LOS ANGELES HARBOR

by

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ABSTRACT. Benthic biomass sampling in areas of proposed dredging of a new ship channel and adjacent underwater landfill showed a zone near the shoreline and waste outfalls of low biomass and outer areas of higher standing stock. These data were compared with five years of monthly water column biomass sampling with settling racks. Recolonization studies were carried out using jars supplied with newly exposed sediments or existing site sediments. Few significant differences were found between the two types of sediments, but spatial and seasonal differences in species and biomass were observed. The dominant species in recolonizing were less prominent in mature communities at the sites. However, most species that dominate mature communities were present as early as within the six week exposure periods.

ACKNOWLEDGMENT. These studies report the efforts of many people: Thomas Kauwling initiated the recolonization investigations and the field biomass studies. Robert Osborn directed their completion, assisting in identifications. Dr. D. J. Reish and his students at California State University, Long Beach carried out identifications. Dr. John Soule designed and assisted in the settling rack studies summarized. Dr. Robert W. Smith carried out computer analyses. Divers included Dr. Robert Given, James McSweeney, Gene Mummert, David Schomisch and Steven Kimmel during recolonization retrieval. Funding was provided in part by the Los Angeles Harbor Department and Board of Harbor Commissioners. Cooperation was provided by the Allan Hancock Foundation and USC Sea Grant Program. Appreciation is expressed to all of these people and organizations.

BIOMASS AND RECOLONIZATION STUDIES IN THE OUTER LOS ANGELES HARBOR

BENTHIC BIOMASS INVESTIGATIONS

One method of quantifying the ecological richness of a given area is to measure the wet weights of organisms sampled throughout that area. Certain biases are inherent in limiting the importance of the biomass technique alone: 1) the implication is that any weight of living tissue is as representative of ecological quality as any other; 2) the weight of certain animals such as molluscs, with relatively heavy shells, can dominate the numbers when compared to the very small, soft-bodied invertebrates such as polychaetes or hydroids; 3) species diversity is not reflected by weights and should be considered; 4) the degree to which the organisms are necessary to the food web may be ignored.

These biases can be alleviated in part by various additional studies such as identifying at least to higher category, and to species level where feasible, so that diversity is apparent, or adjusted biomass weights can be presented; that is, when a single larger animal dominates a sample, weights with and without that organism can be determined. Differing sampling techniques can also be tested and the results compared. Biomass can then become a more useful indicator of the biological richness of a given area. In areas of proposed dredging or other significant alteration to the environment, estimates can be made of the potential loss of living organisms.

Several approaches were used in estimating the potential loss in biomass from dredging the proposed LNG channel in the outer Los Angeles Harbor and in filling the seaplane base and adjacent area. A field sampling program was begun on the R.V. Velero IV in December 1973, taking duplicate boxcorer samples in the channel locality. Continuing through April 1974, Campbell grab samples were taken by the R.V. Golden West at a total of 20 stations (Figure 1), including stations too shallow to be reached by the Velero IV.

The Reinecke boxcorer samples a .06m^2 surface and has a capacity of .028m^3. The Campbell grab samples a surface area of 0.1m^2 and has a capacity of .02m^3. Differences in substrate composition may prevent the sampling device from filling completely, however. Samples taken were immediately sieved by washing through a 0.25mm mesh screen; the material retained was preserved in 10% formalin in seawater and later transferred to 70% isopropyl alcohol.

Animals were picked from debris under at least 10X magnification, sorted, and drained on absorbent towels for 10 minutes before weighing by taxonomic group on a Mettler analytical balance to the nearest 0.01 gm. Weights were measured as "preserved wet weights" because drying would prevent further identification of species. Biomass per square meter was determined by multiplying boxcorer samples by 16 and Campbell grab samples by 10.

As indicated in Figure 2, the biomass patterns indicated two rather distinct benthic areas. Within about 500m of the existing shore, the biomass ranged from 0.3gm/m^2 inside the seaplane base, to 27.3gm/m^2 near the Fish Harbor entrance , with an average of 11.5gm/m^2. These patterns may reflect differences in sediment types, water circulation, dissolved oxygen levels, and pollutants, or they may be influenced by the sampling device, since the inshore samples were collected by Campbell grab and the others by boxcorer. The boxcorer closes with a spade mechanism that retains most organisms undisturbed in situ, while some organisms capable of moving fairly rapidly can escape the Campbell grab, at times leaving only their burrow in the sample.

In the outer harbor area farther from the shoreline and waste discharges and toward the breakwater, biomasses are generally greater. Tidal flushing in the main ship channel would be better in that area, and the major circulation gyre (Soule and Oguri, 1972; Robinson and Porath, 1974) occurs in roughly the same area as the higher biomass.

Benthic species diversity seems to increase from station LNG 1 to LNG 4, and then decreases at LNG 5, 6 and 7. Although the biomass is lower in the area of station 16, the diversity is higher, although the station is very close to the Terminal Island treatment plant sewer outfall. Diversity seems to drop again at 17 and 18.

The biomass is quite small at station 24, but diversity is very much increased, particularly in the non-polychaetes. The bottom is somewhat scoured in this area, and fine sediments are not accumulated to any extent. The low biomass but higher diversity is consistent in the seaplane base area.

The duplicate samples appear to be reasonably consistent, but no statistical conclusions were made due to the variabilities in sampling technique dictated by the shallowness of the inshore waters.

BIOMASS OF MIDWATER (FOULING) FAUNA

Benthic faunal patterns are influenced by factors such as sediment grain size, organics, and pollutant content. In order to eliminate some of these variables, settling racks have been used to evaluate the water quality and colonization potential of the water column. The organisms that are only temporarily in the plankton as eggs, larvae or juveniles (meroplankton) must find suitable substrate to settle on, or attach, within a few hours or days, or they will perish.

Settling racks composed of wooden boxes containing glass microscope slides, and covered with Saran plastic screening have been suspended throughout the harbor at the 3 meter depth and changed monthly. At the A stations, the records extend from March, 1971 to the present for biomass (wet weight) and species numbers. These data offer longer term comparisons of biomass than the biomass and recolonization studies reported herein. The monthly records reflect seasonal trends more closely than the quarterly benthic sampling by HEP at the A stations.

Biomass in the A station area has shown a gradual drop since 1971, for unknown reasons. This may relate to changing salinities in the harbor, which have decreased due to reinjection of oil brines, or to decreasing nutrients, or to general changes in the southern California coastal waters. Pollution control enforcement has apparently improved the average dissolved oxygen conditions and decreased levels of toxic effluents during that time.

As shown in Figure 3 , the biomass average for the A stations for the year was 101.28 grams in 1971 (April to December), 48.37 gram 1972, 47.46 gram in 1973, 37.12 gram in 1974 and 32.99 gram in 1975.

Seasonality

In most years, the typical outer harbor seasonal pattern appeared to consist of a small spring peak in April, and a very strong late summer-early fall peak between September and November. This varied from year to year, and some years there was a midsummer peak as well, or instead of, the spring peak.

These variations are perhaps keyed to the coastal area temperatures which vary considerably from year to year. Low faunal periods appeared in each year in December, February and May, keeping in mind that the month, as graphed in Figure 3 , represents the previous four week exposure period.

In comparing the biomass settling rack data in Tables 21 and 22, the richness indicated at Station A3 is in keeping with that found in the benthic study reported above (Figure 2). Average monthly biomass was plotted against temperature (Figures 4, 5 and 6).

In computer plots of the monthly temperature (Soule and Oguri, 1974) the curves for the Sea Buoy, Station A1, and A3 in the outer harbor show differences from 1971 through 1974. The curves are similar to some extent to the biomass data. The inner stations in the harbor show less temperature variation, with more of a smoothed curve for the summer. Biomasses and species diversity are more strongly influenced there by effluents, reduced water circulation and other shore-related impacts.

Impacts of Dredge and Fill

The process of dredging, by whatever means, will remove all benthic organisms from the surface of the channel site. The degree to which siltation during dredging affects adjacent benthic organisms depends upon the kind of dredge used and the pace at which the area is dredged. If the rain of fines is minimal, as in hydraulic dredging, adjacent organisms may work their way up through the sediment.

As much as an estimated 3 hundred million grams (damp weight) of animal tissue may be lost by dredging and filling for the proposed LNG terminal, as it was designed and shown in Figure 7. About 10% of that biomass would be irretrievably lost due to the fill, but in all, some 35 tons of animals would probably be eliminated at least temporarily. Since individual weights are often in the ranged of 0.01-0.5gm, some 60-300 million individual organisms could be eliminated. More recent planning configurations, showing a large landmass in the outer harbor connected to the Navy mole, would have more serious impact because it is in a more productive area and has a much larger fill. It also would seriously affect water quality and circulation, upon which recovery is dependent.

The standing stock of worms has not been considered in the past to be extensively seasonal, but peak reproductive periods seem typically to occur in the spring and in late summer or early fall (Figure 3). These peaks are typical also of many other faunal patterns, except possibly certain fishes. Thus, the season selected for dredging will probably affect the quantities of organisms lost or temporarily impaired.

RECOLONIZATION INVESTIGATIONS

The rate at which faunas will become reestablished in newly dredged areas is dependent upon a number of factors; sediment grain size of the exposed substrate, pollutants entering the area, water circulation, dissolved oxygen content, temperature, and adjacent reproductive populations, for example.

Reish (1957) studied effects of dredging on benthic species in East Basin and Consolidated Slip. Five species existed there prior to dredging; 10 species were present 2.5 years after dredging, but only 2 species were there 4 years after dredging. However, these areas were still subjected to heavy inputs of pollutants at that time, so that the temporary improvement was soon nullified.

In Alamitos Bay, Reish (1961) found maximum recruitment within one year, followed by a steady decline in the next two years as sulfide muds accumulated. Reish (1956) observed a similar sequence in an area of the lower San Gabriel River.

Because all of these studies were carried out in areas with limited circulation and pollutant accumulation, the results cannot necessarily be extrapolated to the harbor, with wider circulation. However, the trends are in keeping with known ecological principles wherein a newly available niche may exhibit increased numbers of species and populations, but diversity tends to decrease as niches are filled and competition increased with time.

Field biomass investigations can provide information on existing species, abundance and distribution and can indicate the extent of loss in the area to be dredged or filled. However, few if any, field tests have been carried on sequentially before, during and after dredging operations in an extensive area.

Methods.

In order to simulate recolonization of newly exposed surfaces in outer Los Angeles Harbor, five sites were selected (Figure 1) that represented 1) different sediment types, 2) different exposures to pollutants, and 3) varied circulation or flushing.

Samples of sediment were taken from each location, homogenized, and frozen to render them azoic (free of macrofauna; sterilization would alter the organics). These served as

"control" sediments. The "experimental" sediment samples were taken at Berth 235 after maintenance dredging had been carried out, which exposed cleaner, sandier soils similar to those that might be found after dredging of the proposed channel. These were also homogenized and frozen.

Lighted marker buoys were built by the Harbor Department Testing Laboratory, and were deployed by the USC RV Golden West, at the request of Harbor Department personnel. Lengthy delay in initiating this portion of the program was encountered due to problems in constructing the buoys and in obtaining permission from the U.S. Army Corps of Engineers to deploy. The buoys were soon run down by vessels or vandalized, causing loss of a number of experiments.

Racks, constructed by the USC Marine Facility, were placed on the bottom at the five sites, anchored by 75 lb concrete weights and marked first by the buoys and next by floats at the water surface. Each rack supported two plastic crates, each in turn containing 12 wide mouth quart jars. One crate of bottles served as the "experimental" set, and the other, the "control". Each jar had 150 cc of sediment from the pre-treated experimental sediments at Berth 235, or a similar amount of pre-treated sediment from each recolonization site. Jars had surface water added at each site and were capped for transport to the bottom by divers. When jars were deployed, and sediments settled, caps were removed to begin exposure. Vandalism of surface floats then forced the use of electronic pingers for divers to locate the bottom sampling racks in the turbid waters. The large number of bottles deployed at a few sites permitted retrieval of jars exposed for different time periods, rather than exposing jars at many sites for a single time period.

Retrieval. Six weeks after the initial exposures, three jars from each rack were capped by divers and brought to the surface, where the contents were mixed with formalin. In the laboratory, the material was transferred to 70% isopropyl alchohol and washed through a 0.25mm mesh screen. Sorting and identification were carried out using at least 10X magnification.

New jars of sediment replaced those removed, for a different six-week period, while the others were in place for 12, 18 or 24 week periods. The purposes were to observe differences in reproductive periods, if any, to observe changes in species composition of the "community" over a longer period of time, and to compare the "experimental" and "control" sediments, if possible.

RESULTS

During the recolonization study, more than 100 polychaete taxa and over 40 other invertebrate taxa were identified; 62,075 individual animals were identified and counted. Due to the limited periods of exposure, large numbers of juveniles were present, which were retained on the fine mesh (0.25mm) screen. Many of these cannot be identified to species level as juveniles, and had to be placed in higher categories, tending to bias the faunal lists.

Newly dredged soils. The fauna from the "experimental" sediments taken from the newly dredged Berth 235 area was compared with that from the "control" sediments at the LNG sites. Statistical analyses were performed using 62 taxa, from which questionable identifications were eliminated or raised to higher categories.

In the non-prarmetric "U" Test, values were arranged in station and time matrices in which significant differences were identified. The number of significant differenced was surprisingly low, well below the 20% value expected due to random change using the "U" test. This indicates that there was little difference overall between the newly exposed sediment and older sediment from the LNG sites. It is possible that sufficient finer sediment and organic debris entered the test jars from turbidity stirred up either during the diver placement operations in situ or thereafter, to minimize initial grain size differences. According to Reish (pers. comm.) only after a very thin layer of fine material is needed for colonization.

Few significant differences were discernible between the sediments in the occurrences of benthic species, as shown in Table 23. So few instances out of the total numbers of samples, coupled with the difficulties in experimental procedures, probably lends weight to the conclusion that there was little difference between the newly dredged sediment and that occurring at the other sites.

The newly exposed sediment was a coarser grain size but several postulations may be made, that 1) sediment deposition of fines soon covered over the coarser material, or 2) other abiotic parameters were more important in limiting species and populations than grain size, or 3) grain size differences are important but the more tolerant species are not as limited by that factor, or 4) predation of the captive populations had a more decisive effect than sediment size.

"Communities". The recolonization procedures using jars that stood above the normal substrate affected the species/population composition. Some species normally associated with hard substrates (fouling organisms) colonized on the interior glass whereas they would not have survived on open, soft bottoms. Thus the species present can be grouped into two categories:

Group I - animals associated with hard and soft substrates

Group II - animals exclusive to soft substrates

The graphs (Figures 8 to 13) show seasonal data on those taxa prominent at each station and exposure period, in Groups I and II. Group I fauna dominated the colonizers by far; those species are graphed at one-half the scale used for Group II fauna. For comparison of the recolonization fauna with the usual "mature" community or population at each site, a list of species found in box corer or Campbell grab samples is presented with each station figure. As might be expected, the "mature" species sampled are more similar to the soft bottom Group II colonizers. The numbers of the individuals, however, indicate that the proportions of the species occurrences in the mature populations differ (Table 24) from those of the colonizing populations. The actual numbers also differed, of course, because the Campbell grab samples $0.1m^2$ surface, the box corer samples $0.06m^2$ and the jars have only about $0.006\ m^2$ of surface.

The colonizing communities were dominated by four Group I taxa; cyclopoid and harpacticoid copepods, the polychaete Armandia bioculata and nematodes. These data are more comparable to settling rack data.

In Group II (soft substrate) taxa, the polychaete Capitita ambiseta was consistently most abundant. Tharyx was well represented at outer harbor sites but was virtually absent at stations 18 and 24. Conversely, Prionospio cirrifera was present at all stations but was more abundant at stations 18 and 24.

Because of the differing sampling periods and gaps due to loss of field samples and buoys, seasonal trends are not definitively indicated. However, Table 25 shows clearly that the May-June period was less productive than February-March. Those sampling periods that ended in August had the largest biomasses, regardless of the length of exposure time. Biomasses in some cases decreased over the longer exposure period; this may be due to the space limitations imposed by growth and reproduction in the jars, or to predation. Large epibenthic

crustaceans were frequently present; the shrimp Heptacarpus was abundant. Cancer crabs also were frequent, either as ovigerous females or small juveniles, suggesting that the jars furnished convenient shelter. The guts of two individuals examined were empty.

Tables 26 and 27 summarize the biotic measurements of total taxa, individuals and biomass for each station and period. Table 28 lists the species identified by numbers, stations and recolonization times.

CONCLUSIONS

In general, the following observations can be made:

1) The animals most dominant in recolonizing were less important in numbers in mature communities, and were sometimes absent.

2) Most animals that dominate mature communites were present in the recolonizing populations as early as the six weeks samples, but not necessarily in dominating proportions.

3) Many animals that are abundant in mature communities were absent in the colonizing populations.

4) Colonizing populations were less diverse than mature populations, with more individuals and fewer taxa.

This suggests that considerable change, over time, would occur before the colonizing population would resemble the present mature population; perhaps in 2-3 years. However if abiotic conditions are changed appreciably the mature colonizing population would probably not be like the present mature community.

Table 1.

L.A. Harbor Biomass Study
Velero Station 20071
Jan. 28, 1974 - Gear: Boxcorer

Station LNG 1

Count	Replicate A	Wt. (g.)
	Polychaeta	
2	*Lumbrineris* sp.	0.16
2	*Pista* sp.	0.08
3	*Goniada brunnea*	0.08
3	*Amphicteis* sp.	0.01
3	*Laonice* sp.	0.09
3	*Prionospio* nr. *pinnata*	0.04
	Misc. (no dominant)	0.50
	Mollusca	
4	*Macoma* sp.	0.15
10	*Tellina (?carpenteri)*	
	Crustacea	
5	Pinnotherid crabs	0.78
1	Enteropneust(head only)	0.22
2	Nemerteans	0.09
	Echiuroidea	
1	*Listriolobus pelodes*	0.23
	Misc.: *Tellina* sp. juv. dominant	0.30
Total		2.73

Count	Replicate B	Wt. (g.)
	Polychaeta	
3	*Lumbrineris* sp.	0.59
1	*Pista* sp.	0.11
1	*Goniada* sp.	0.04
2	*Marphysa* sp.	1.30
2	*Polydora* sp.	0.09
1	*Nothria* sp.	0.10
	Miscellaneous (polychaetes plus all others)	1.65
Total		3.78

Average Biomass = 52.08 g/m^2

Table 2.

L.A. Harbor Biomass Study
N East of LNG 1
Nov.-Dec., 1973 - Gear: Boxcorer

Velero Station 19840

Count	Replicate A	Wt.(g.)	Count	Replicate B	Wt.(g.)
	Polychaeta			Polychaeta	
4	*Lumbrineris* sp.	0.38	2	*Lumbrineris* sp.	0.27
13	lg. *Tharyx* sp.	0.25	1	*Pista* sp.	0.03
			2	*Nothria* sp.	0.17
			5	*Laonice* sp.	0.12
			6	lg. *Tharyx* sp.	0.32
	Misc.: most numerous	3.13		Misc.: no dominant, many larger animals	2.90
	Mollusca			Mollusca	
	Gastropods	1.03	4	Gastropods(2 *Ajalia* sp.)	0.09
			40	Pelecypods	0.45
	Crustacea			Crustacea	
	Pinnotherids	0.72			
			18	Amphipods	0.08
	Coelenterata				
1	Sea pen	0.48		Misc.: juv. pelecypods	0.17
	Nemerteans	0.01	Total		4.60
	Misc.: juv. pelecypods	1.62			
Total		7.62			

Average Biomass = 97.76 g/m^2

Table 3.

L.A. Harbor Biomass Study
Station A2
Nov.-Dec., 1973 - Gear: Boxcorer

Velero Station 19820

Count	Replicate A	Wt.(g.)	Count	Replicate B	Wt. (g.)
	Polychaeta			Polychaeta	
1	*Glycera* sp.	0.84	5	*Marphysa* sp.	1.90
3	*Marphysa* sp.	1.66	7	*Lumbrineris* sp.	0.90
1	*Lumbrineris* sp.	0.12	12	lg. *Tharyx* sp.	0.50
	Misc.: *Tharyx* dominant	5.80		Misc.: *Tharyx, Capitita ambiseta, Cossura* dominant	6.36
	Mollusca			Crustacea	0.08
many	sm.-med. pelecypods	1.10		Nemertea	0.81
10	gastropods	0.11		Misc.: juv. pelecypods	0.38
	Crustacea	0.01			11.03
2	Phoronids	0.001			
6	Nemertea	0.001			
		9.642			

Average Biomass = 165.3 g/m^2

Table 4.

L.A Harbor Biomass Study
Velero Station 20069
January 28, 1974 - Gear: Boxcorer

Station LNG 2

Count	Replicate A	Wt. (g.)	Count	Replicate B	Wt. (g.)
	Polychaeta			Polychaeta	
5	*Marphysa* sp.	1.37	3	*Marphysa* sp.	0.81
3	*Glycera* sp.	0.68	2	*Lumbrineris* sp.	0.29
1	*Diopatra* sp.	0.70	2	*Glycera* sp.	0.10
4	*Lumbrineris* sp.	0.22	1	*Amphicteis* sp.	0.01
1	*Amaeana occidentalis*	0.02	1	*Tharyx* sp.	0.01
1	*Laonice cirrata*	0.01	1	*Laonice* sp.	0.01
	Misc.: *Tharyx* dominant; *Sigambra, Capitita ambiseta* numerous.	5.35		Misc.: *Tharyx* dominant, *Haploscoloplos*.	1.02
	Non-Polychaeta			Non-Polychaeta	
1	lg. ophiuroid arm	0.33	1	*Callianassa* sp.	0.10
1½	*Callianassa*	0.30	1	*Cancer* sp. (juv.)	0.11
1	Pinnotherid	0.03	8	*Tellina* sp.	0.27
6	lg. *Thyasira*	0.25	7	*Acteon punc. cael.*	0.12
6	lg. *Tellina*	0.11	9	*Axinopsida* sp.	0.34
8	lg. *Axinopsida*	0.25	1	*Lucia* sp.	0.02
4	Nemerteans	0.01	1	*Macoma* sp.	0.04
	Misc.: juv. pelecypods	0.40		Misc.: juv. pelecypods	0.46
Total		9.78	Total		3.71

Average Biomass = 6.75 g/m^2

Table 5.

L.A. Harbor Biomass Study
ENEast of LNG 2
Nov.-Dec., 1973 - Gear: Boxcorer

Velero Station 19839

Count	Replicate A	Wt.(g.)	Count	Replicate B	Wt.(g.)
	Polychaeta			Polychaeta	
3	*Marphysa* sp.	1.35	4	*Marphysa* sp.	0.83
4	*Lumbrineris* sp.	0.23	1	*Nereis* sp.	~0.005
2	*Pista* sp.	0.54	1	*Pista* sp.	0.09
3	*Prionospio pinnata*	0.02	1	*Polydora* sp.	~0.005
2	*Spiophanes* sp.	0.03	3	*Streblosoma* sp.	0.18
6	*Chaetozone* sp.	0.05	1	*Glycera* sp.	0.06
9	*Tharyx* sp.	0.13	1	*Tharyx* sp.	0.03
	Nereis sp.	0.06	2	*Notomastus* sp.	0.07
	Ampharetids	0.03			
	Polydora sp.	0.04			
	Misc.: *Tharyx* dominant	5.55		Misc.: *Tharyx* dominant	4.90
	Mollusca			Mollusca	
1	lg. clam	0.22	24	lg. pelecypods	0.46
	Crustacea		2	Crustacea (amphipod and isopod)	0.01
	Pinnotherids	0.15			
			1	Phoronid	0.22
	Misc.: juv. pelecypods and nemerteans	1.10		Misc.: juv. pelecypods	0.45
Total		9.50	Total		7.30

Average Biomass = 134.49 g/m^2

Table 6.

L.A. Harbor Biomass Study
Velero Station 20068
Jan. 28, 1974 - Gear: Boxcorer

Station LNG 3

Count	Replicate A	Wt.(g.)
	Polychaeta	
1	*Pista* sp.	1.16
3	*Marphysa* sp.	0.79
6	*Lumbrineris* sp.	0.50
3	*Tharyx* sp.	0.09
1	*Spiophanes* sp.	0.01
2	*Nereis* sp.	0.02
1	*Chaetozone* sp.	0.01
3	*Glycera* sp.	0.16
2	*Polydora* sp.	0.02
1	*Streblosoma* sp.	0.02
1	*Laonice* sp.	0.01
	Misc.: *Tharyx* dominant, over 2000 animals	6.20
	Non-Polychaeta	
3	*Callianassa* sp.	1.30
2	Pinnotherids	0.50
5	Gammarid amphipods	0.01
8	*Tellina* sp.	0.02
2	*Macoma* sp.	0.01
2	*Tagelus* sp.	0.05
2	*?Thyrasira* sp.	0.10
2	*?Axinopsida* sp.	0.04
6	*Protothaca* sp.	0.09
	Misc.: juv. pelecypods	0.41
Total		11.52

Count	Replicate B	Wt.(g.)
	Polychaeta	
3	*Glycera* sp.	14.84
1	*Lumbrineris* sp.	0.12
1	*Poecilochaetus* sp.	0.04
2	*Marphysa* sp.	0.53
1	*Nereis procera*	0.03
1	*Notomastus* sp.	0.01
	Misc.: *Tharyx* dominant	3.25
Total		18.82

Average Biomass = 242.72 g/m^2

Table 7.

L.A. Harbor Biomass Study
West of LNG 4
Nov.-Dec., 1973 - Gear: Boxcorer

Velero Station 19818

Count	Replicate A	Wt. (g.)
	Polychaeta	
1	*Lumbrineris* sp.	0.27
2	Nereids	0.05
6	*Notomastus* sp.	0.16
1	*Laonice* sp.	0.02
1	*Haploscoloplos* sp.	0.01
	Misc. Polychaeta: *Capitita ambiseta* dominant; very few *Tharyx* sp.	1.66
	Mollusca	
1	*Tresus nuttallii* (siphons)	14.69
1	*Macoma* sp.	7.63
3	*Macoma* sp.	2.38
30	small clams	0.40
	many juvenile clams	0.02
	Misc.: nematodes, nemerteans, and oligochaetes; 1 crustacean (copepod)	0.40
Total		27.69 g.

Count	Replicate B	Wt. (g.)
	Polychaeta	
2	*Lumbrineris* sp.	3.19
2	Arabellids	3.25
1	Maldanid	0.33
2	*Prionospio pinnata*	0.07
2	*Notomastus* sp.	0.49
1	*Haploscoloplos* sp.	0.04
1	*Pectinaria* sp.	0.10
	Misc. Polychaeta: *Capitita ambiseta* and *Capitella capitata* dominant	5.45
	Mollusca	
3	*Macoma* sp.	1.74
18	med. pelecypods	0.21
20	small pelecypods	0.02
1	*Olivella* sp.	0.03
	Crustacea	
1	lg. *Callianassa* sp.	7.25
1	med. *Callianassa* sp.	0.95
2	sm. *Callianassa* sp.	0.11
2	lg. *Upogebia* sp.	16.81
11	Pinnotherids	0.55
1	Hemichordate	3.78
	Misc.: juv. clams/nemerteans	1.00
Total		45.37 g.

Average Biomass = 584.5 g/m^2

Table 8.

L.A. Harbor Biomass Study
Velero Station 20067
Jan. 28, 1974 - Gear: Boxcorer

Station LNG 4

Count	Replicate A	Wt. (g.)
	Polychaeta	
1	*Glycera* sp.	0.73
1	*Goniada brunnea*	0.13
1	*Marphysa* sp.	0.28
2	*Lumbrineris* sp.	0.40
7	*Tharyx* sp.	0.30
1	*Pista* sp.	0.27
1	*Laonice* sp.	0.01
7	*Polydora* sp.	0.18
1	*Diopatra* sp.	0.05
	Misc.: *Tharyx* dominant	3.75
	Non-Polychaeta	
6	Nemerteans	1.70
1	*Solen* sp.	0.06
2	*Tagelus* sp.	0.01
4	*Tellina* sp.	0.11
1	*Macoma* sp.	0.01
3	*Protothaca* sp.	0.02
1	*?Thyrasira* sp.	0.01
1	*?Axinopsida* sp.	0.01
	Misc.: juv. pelecypods, nematodes, oligochaetes	0.01
Total		8.01

Count	Replicate B	Wt. (g.)
	Polychaeta	
1	*Marphysa* sp.	0.11
1	*Lumbrineris* sp.	0.27
1	*Pista* sp.	0.47
2	*Polydora* sp.	0.10
5	misc. fragments	0.50
	Non-Polychaeta Misc.	3.06
Total		4.51

Average Biomass = 94.4 g/m^2

Table 9.

L.A. Harbor Biomass Study
ESEast of LNG 4
Nov.-Dec., 1973 - Gear: Boxcorer

Velero Station 19838

Count	Replicate A	Wt.(g.)
	Polychaeta	
4	*Marphysa* sp.	0.98
16	*Polydora* sp.	0.35
2	*Lumbrineris* sp.	0.08
3	*Laonice* sp.	0.04
2	*Pista* sp.	0.11
7	lg. *Tharyx* sp.	0.21
	Misc.: *Tharyx, Cossura, Capitita ambiseta* probably most abundant; no dominant.	2.00
	Mollusca	
	Gastropods	0.10
2	Razor clams	0.18
many	misc. pelecypods	0.45
	Crustacea	0.18
	Miscellaneous	0.11
Total		4.79 g.

Count	Replicate B	Wt.(g.)
	Polychaeta	
2	*Marphysa* sp.	0.41
8	*Polydora* sp.	0.24
4	*Lumbrineris* sp.	0.29
1	*Notomastus* sp.	0.02
1	*Pista* sp.	0.15
1	*Spiophanes missionensis*	0.05
2	*Prionospio pinnata*	0.18
	Misc.: *Capitita ambiseta* perhaps most numerous; bulk of wt. is large misc. spp.	2.12
	Mollusca	
22	Pelecypods	0.43
7	Gastropods	0.08
	Crustacea	
1	*Callianassa* sp.	0.21
2	Pinnotherids	0.10
2	Amphipods	0.01
1	Barnacle	0.01
1	Isopod	0.01
3	Nemerteans	0.01
1	Phoronid	0.01
	Miscellaneous	0.40
Total		4.93 g.

Average Biomass = 77.4 g/m^2

Table 10.

L.A. Harbor Biomass Study
Velero Station 20066
Jan.28, 1974 - Gear: Boxcorer

Station LNG 5

Count	Replicate A	Wt. (g.)
	Polychaeta	
2	*Lumbrineris* sp.	1.2
1	*Glycera* sp.	0.001
1	*Prionospio pinnata*	0.001
1	*Tharyx* sp.	0.001
1	*Sigambra* sp.	0.001
3	*Notomastus tenuis*	0.11
2	*Polydora* sp.	0.001
1	*Laonice* sp.	0.001
1	Scaleworm	0.001
	Non-Polychaeta	
2½	*Callianassa* sp.	28.7
2	Pinotherids	0.11
1	*Listrilobus* sp.	4.39
8	*Macoma* sp.	3.51
4	*Tellina* sp.	0.29
6	Nemerteans	0.29
	Misc. Polychaeta	1.51
	Misc. Non-Polychaeta (juv. pelecypods)	0.09
Total		40.21

Count	Replicate B	Wt. (g.)
	Polychaeta	
2	*Notomastus* sp.	0.25
1	Cirratulid	0.02
3	*Tharyx* sp.	0.01
	Miscellaneous Non-Polych.	1.74
Total		2.02

Average Biomass = 337.76 g/m^2

Table 11.

L.A. Harbor Biomass Study
ENEast of LNG 5
Nov.-Dec., 1973 - Gear: Boxcorer

Velero Station 19837

Count	Replicate A	Wt.(g.)	Count	Replicate B	Wt.(g.)
	Polychaeta			Polychaeta	
1	*Prionospio pinnata*	0.04	5	*Prionospio pinnata*	0.22
4	lg. *Tharyx* sp.	0.04			
	Misc.: *Tharyx* and *Cossura* dominant	2.28		Misc.: *Cossura* dominant, *Tharyx* next dominant	5.10
	Mollusca			Mollusca	
6	*Macoma*-like pelecypods	2.77	6	*Macoma* sp.	2.17
			13	sm. pelecypods	0.11
	Crustacea			Crustacea	
5	lg. *Callianassa* sp.	18.42	9	lg. *Callianassa* sp.	34.90
3	sm. *Callianassa* sp.	1.33	7	sm. *Callianassa* sp.	1.72
7	pinnotherid crabs	0.34	4	pinnotherid crabs	0.04
			11	Amphipods	0.01
			1	lg. Isopod (gravid)	0.07
	Miscellaneous	0.16		Misc.: primarily *Callianassa* eggs	1.38
Total		25.38 g.	Total		45.72 g.

Average Biomass = 568.6 g/m^2

Table 12.

L.A. Harbor Biomass Study
Velero Station 20070
Jan. 28, 1974 - Gear: Boxcorer

Station LNG 6

Count	Replicate A	Wt.(g.)
	Polychaeta	
2	*Sigambra* sp.	0.12
100+	lg. *Capitella capitata*	1.81
	Misc.: very few others	
	Non-Polychaeta	
20	Nematodes	0.001
4	Harpacticoid copepods	0.001
4	Zoea larvae	0.001
Total		1.933

Count	Replicate B	Wt.(g.)
many	Polychaeta *Capitella capitata*	1.18
	Non-Polychaeta	0.11
Total		1.29

Average Biomass = 1.611 g/m^2

Table 13.

L.A. Harbor Biomass Study
Gear: Campbell Grab
February, 1974

Station LNG 7

Count	Replicate A	Wt. (g.)	Count	Replicate B	Wt. (g.)
63	Polychaeta *Capitella capitata* Misc.: *Capitella capitata* dominant, *Armandia bioculata & Polydora* common	0.96 0.89	77	Polychaeta *Capitella capitata* Misc.: *Capitella capitata* dominant, *Armandia* and Polydorids common; a few *Nereis*.	0.87 0.96
50 4 1	Non-Polychaeta Nematodes juv. pelecypods Gammaridean amphipod	0.01	70 1 1 3	Non-Polychaeta Nematodes juv. *Protothaca* sp. juv. *Saxidomus nuttalli* juv. pelecypods	0.10
Total		1.86	Total		1.93

Average Biomass = 18.9 g/m^2

Table 14.

Sea-Plane Anchorage Benthic Study
U.S. Naval Area of LA Harbor
March 1973, gear: Boxcore

STATION LNG 16

Counts	Replicate A	Wt. (g)
	Polychaetes:	
2	*Prionospio pinnata*	0.03
1	*Nereis* sp.	0.02
1	*Diopatra* sp.	.01
2	*Northria* sp.	.01
1	*Glycera* sp.	.24
	Miscellaneous Polychaetes:	
	Capitella capitata, *Capitita ambiseta* dominate	1.50
	Non-Polychaetes:	
6	large Pelecypods (c/ssp)	0.19
1	Nemertean	0.15
	Misc. Non-Polychaetes: incl. over 100 Nematodes, many juv. clams, a few Cumaceans, Amphipods (both caprellid and gamm.), cyclopoid Copepod and juv. *Callianassa* sp.	0.02
		2.17 g

Biomass = 34.72 g/m^2

Counts	Replicate B	Wt. (g)
	Polychaetes:	
1	*Pholoe glabra*	
1	*Gyptis brunnea* (large)	
1	*Nephtys* sp.	
26	*Polydora ligni*	
268	*Prionospio cirrifera*	0.09
2	*Prionospio pinnata*	
1	*Pseudopolydora paucibranchia*	
1	*Tharyx* sp.	
2	*Cossura candita*	
223	*Capitella capitata*	0.12
161	*Capitita ambiseta*	0.03
1	*Pectinaria californiensis newportensis*	
6	*Stauronereis rudolphi*	
72	*Armandia bioculata*	
	Non-Polychaetes:	
2	Pinnotherids	0.01
1	Platyhelminth	
3	Pelecypods	0.02
1	Amphipod (gamm.)	
1	Nemertean	
		0.27 g

Biomass = 4.32 g/m^2

Biomass Average of Replicates = 19.52 g/m^2

Table 15.

Sea-Plane Anchorage Benthic Study
U.S. Naval Area of LA Harbor
April 1974, gear: Campbell Grab

STATION LNG 17

Counts	Replicate A		Counts	Replicate B	
	Polychaetes, in order of abundance: *Capitella capitata, Armandia bioculata, Capitita ambiseta, Prionospio* sp. *Nephtys sp.*	Wt. (g)		Polychaetes: *Capitella capitata* (dominant) *Capitita ambiseta* *Armandia* *Nephtys* spp.	Wt. (g) 0.08
	Total wt.	1.54		Misc. Spionids, etc.	
	Non-Polychaetes:			Non-Polychaetes:	
24	Caprellids		3	Caprellids	
1	lg. Pelecypod *Lucinia*-like	0.03	5	larval *Callianassa* spp.	
50	Nematodes		1	Pinnotherid	0.01
20	Oligochaetes		2	Gammarids	
8	larval *Callianassa*		3	Nemerteans	
2	gamm. Amphipods		7	juv. Pelecypods (at least 3 spp.)	
7	juv. Pelecypods				
1	Pinotherid		3	lg. Pelecypods	
	Total wt.	1.57 g.		Total wt.	0.81 g

Average wt. = 1.19 g

Average biomass = 11.9 g/m^2

Table 16.

Sea-Plane Anchorage Benthic Study
U.S. Naval Area of LA Harbor
April 1974, gear: Campbell Grab

STATION LNG 18

Counts	Replicate A	
	Total Polychaetes,	Wt. (g)
	incl.:	
	Armandia	
	Capitella capitata, etc.	1.31
	Non-Polychaetes	
1	juv. Pelecypod	
1	juv. Gastropod	
1	Sipunculid	
	many Nematodes	
	Total wt.	1.31 g

Counts	Replicate B	
	Polychaetes:	Wt. (g)
402	*Capitella capitata*	1.22
687	*Armandia bioculata*	0.08
22	*Pectinaria californiensis newportensis*	0.02
	Misc. Polychaetes:	
	incl. *Prionospio cirrifera*, *Nephtys cornuta-franciscana*, *Polydora*	0.08
	Non-Polychaetes:	
1	Caprellid	
9	larval *Callianassa*	
1	Nemertean	
3	juv. Pelecypods	
	many Nematodes	
	Total wt.	1.4 g

Average wt. = 1.355

Average biomass = 13.55 g/m^2

Table 17.

Sea-Plane Anchorage Benthic Study
U.S. Naval Area of LA Harbor
Feb. 1974, gear: Campbell Grab

STATION LNG 24

Counts	Replicate A		Counts	Replicate B	
	Polychaetes:	Wt. (g)		Polychaetes:	Wt. (g)
414	*Capitita ambiseta*	0.30	444	*Capitita ambiseta*	0.20
174	*Cossura candita*		17	*Haploscoloplos elongatus*	0.01
18	*Haploscoloplos elongatus*		46	*Armandia bioculata*	
32	*Tharyx* sp.		72	*Cossura candita*	
7	*Chaetozone corona*		6	*Lumbrineris*	
35	*Armandia bioculata*		22	*Magelona* sp.	
3	*Prionospio* nr. *malmgreni*		2	*Nephtys cornuta franciscana*	
4	*Prionospio cirrifera*		4	*Nephtys caecoides*	
9	*Prionospio pygmaeus*		2	*Rhynchospio* sp.	0.01
7	*Lumbrineris* sp.		2	*Prionospio heterobranchia newportensis*	
4	*Nephtys caecoides*		3	*Prionospio cirrifera*	
2	*Nephtys cornuta franciscana*		10	*Prionospio pygmaeus*	
3	*Phyllodoce* sp.		3	*Polydora brachycephala*	
3	*Euchone limnicola*		3	*Pseudopolydora paucibranchiata*	
2	*Chone* sp.		8	*Spiophanes berkeleyorum*	
9	*Polydora brachycephala*		13	*Euchone limnicola*	
1	*Polydora ligni*	0.10	11	*Pista* sp., juv.	
1	*Gyptis arenicola glabra*		4	*Pectinaria californiensis newportensis*	
1	*Prionospio pinnata*		1	*Chone* sp.	
3	*Rhynchospio* sp.		7	*Chaetozone corona*	0.05
8	*Magelona* sp.		37	*Tharyx* sp.	
5	*Euchone incolor*		8	*Ampharete labrops*	
3	*Pectinaria californiensis newportensis*		5	*Amphicteis scaphobranchiata*	
5	*Pista* sp., juv.		2	*Poecilochaetus johnsoni*	0.00
2	*Capitella capitata*		3	*Harmothoe priops*	
2	*C. capitata tripartita*		3	*Phyllodoce* sp.	
2	*Sphaerodoropsis biserialis*		13	*Sphaerodorpsis biserialis*	
5	*Amphicteis scaphobranchiata*				
2	*Ampharete labrops*				
1	*Telepsavus costarum*				

Table 17 (cont'd)

STATION LNG 24 (cont.)

Counts	Replicate A		Counts	Replicate B	
	Non-Polychaetes:	Wt. (g)		Non-Polychaetes	Wt. (g)
43	Oligochaetes		2	*Macoma yoldiformis*	
7	Ostracods		4	*Tellina* sp.	
7	Caprellid Amphipods		2	*Prototheca* sp.	
2	Cumaceans	0.00	2	*? Olivella* sp.	
6	megalops larvae		1	*Aglaja* sp.	
1	Isopod (*Gnathia*-like)		16	Pelecypod sp. 4	
1	Gammaridean Amphipod		8	Pelecypod sp. 1	
4	Nemerteans		5	Cumaceans	
14	Nematodes		4	Ostracods	0.11
2	*Aglaja* sp.		4	Caprellid Amphipods	
1	*? Olivella* sp.		3	Gammaridean "	
1	*? Cylichna* sp.		2	Phoronids	
47	Pelecypod sp. 1	0.05	3	Nemerteans	
17	*Tellina* sp.		57	Oligochaetes	
1	*Prototheca* sp.		42	Nematodes	
2	Pelecypod sp. 2				0.38
10	*Macoma yoldiformis*				
5	Pelecypod sp. 3				
		0.45			

Biomass = 0.45 g./0.1 m^2

938 individuals, at least 48 spp.

Sample volume 0.0005 m^3

Biomass = 0.38 g./0.1 m^2

906 individuals, at least 42 spp.

Sample volume 0.0005 m^3

Average Biomass = 4.2 g/m^2

Table 18.

L.A. Harbor Biomass Study
U.S. Naval Area - Seaplane Anchorage
Feb., 1974 - Gear: Campbell Grab

Station LNG 25

Count	Replicate A	Wt.(g.)
	Polychaeta	
23	*Platynereis bicanaliculata*	0.03
2	*Haploscoloplos elongatus*	0.04
3	*Nephtys caecoides*	
26	*Armandia bioculata*	
60	*Capitita ambiseta*	
1	*Prionospio pygameus*	
2	*P. heterobranchia newpt.*	
4	*Pectinaria californiensis*	
3	*Rhynchospio* sp.	
3	*Spiophanes* sp.	
1	*Phyllodoce* sp.	
1	*Pseudopoly. paucibranchiata*	
1	Sabellid (frag.)	
1	*Diopatra* sp.	
	Mollusca	0.34
2	*Olivella baetica*	
1	*Nassarius* sp.	
1	*Odostoma* sp.	
2	*Tellina* sp.	
4	unid. Molluscs	
2	unid. *Cooperella*-like	
1	Nudibranch	
	Crustacea	0.05
40	Caprellids	
79	Gammaridean amphipods	
1	Tanaid	
5	Ostracods	
10	Cumaceans	
1	Larval *Callianassa*	
Total		5.58*

Count	Replicate B	Wt.(g.)
	Polychaeta	
1	*Nephtys caecoides*	0.01
1	*Platynereis bicanaliculata*	0.01
	Misc.: *Capitita ambiseta* dominant	0.04
75	Non-Polychaeta Caprellids Misc.(gammarid amphipods, cumaceans)	0.01
	Gracilariopsis sp. (with unid. hydroid)	1.92
Total		1.99

Average Biomass = 60.48 g/m^2

* Includes *Gracilariopsis* sp. (with red epiphytes) and *Ulva* sp.....0.21

Table 19.

Sea-Plane Anchorage Benthic Study
U.S. Naval Area of LA Harbor
Feb. 1974, gear: Campbell Grab

STATION LNG 26

Counts	Replicate A		Counts	Replicate B	
	Polychaetes:	Wt. (g)		Polychaetes:	Wt. (g)
3	*Haploscoloplos elongatus*		18	*Armandia bioculata*	
103	*Capitita ambiseta*		1	*Platynereis bicaniculata*	
1	*Nephtys caecoides*		1	*Haploscoloplos elongatus*	0.01
1	*Lumbrineris* sp.		1	*Nephtys caecoides*	
26	*Armandia bioculata*		2	*Pectinaria californiensis newportensis*	
4	*Pseudopolydora paucibranchiata*		1	*Phyllodoce* sp.	
4	*Prionospio pygmaeus*		55	*Capitita ambiseta*	
2	*Prionospio heterobranchia newportensis*	0.44	1	*Prionospio heterobranchia newportensis*	0.01
2	*Phyllodoce* sp.		1	*Euchone limnicola*	
10	*Rhynchospio* sp.		20	*Rhynchospio* sp.	
			4	*Prionospio pygmaeus*	

Continued ---

Table 19 (cont'd) STATION LNG 26 (cont.)

Counts	Replicate A	
	Non-Polychaetes:	Wt. (g)
4	Caprellid Amphipods	
10	Gammaridean "	
6	Ostracods	
1	Copepod	0.02
1	Nematods	
67	Oligochaete	
16	Pelecypod sp. 1	
1	*Nassarius* sp.	1.11
1	*Mitrella* sp.	0.06
1	? *Olivella* sp.	0.09
1	*Tellina* sp.	--
	Algae:	
	? *Gracilariopsis* sp.	6.47
	(drift?)	8.19

Counts	Replicate B	
	Non-Polychaetes	Wt. (g)
30	Cumaceans	
10	Gammaridean Amphipods	
4	Caprellid	
1	zoea larvae	0.00
1	Megalops larvae	
4	Ostracods	
14	Oligochaetes	
1	Nemertean	
1	*Olivella* ? juv.	0.08
1	unid. juv. gastropod	
11	Pelecypod sp. 1	
1	*Tellina* sp.	0.00
1	*Modiolus ?capax*	
Col.	*Membranipora tuberculata*	
Col.	Unid. hydroid	0.31
1	unid. alga	
		0.41

Biomass = 8.19 g./0.1 m^2

275 individuals, at least 22 spp.

Sample volume 0.0005 m^3

Biomass = 0.41 g./0.1 m^2

188 individuals, at least 27 spp.

Sample volume 0.0005 m^3

Average Biomass = 43 g/m^2

Table 20.

Sea-Plane Anchorage Benthic Study
U.S. Naval Area of LA Harbor
Feb. 1974, gear: Campbell Grab

STATION LNG 27

Counts	Replicate A	
	Polychaetes:	Wt. (g)
12	*Stauronereis rudolphi*	0.01
15	*Capitella capitata*	0.01
1	*Capitita ambiseta*	-
2	*Tharyx* sp.	-
2	*Chone* sp.	-
1	*Nephtys cornuta franciscana*	-
1	*Prionospio cirrifera*	-
2	*Prionospio heterobranchia newportensis*	-
2	*Platynereis bicanaliculata*	0.01
1	Syllids, unident. juven.	-
	Non-Polychaetes:	
8	Nematodes	-
2	zoea larvae	-
1	? *Crepidula* sp. (no shell)	-
1	Tanaid	-
	Algae:	
	? *Gracilariopsis* (? drift)	13.60
		13.63

Counts	Replicate B	
	Polychaetes:	Wt. (g)
13	*Capitella capitata*	
4	*C. capitata tripartita*	
2	*Armandia bioculata*	
4	*Stauronereis rudolphi*	
7	*Tharyx* sp.	0.01
3	*Prionospio heterobranchia newportensis*	
1	Syllid, unidentified	
1	*Haploscoloplos elongatus*	
1	*Capitita ambiseta*	
	Non-Polychaetes:	
1	zoea larva	
2	Caprellid amphipods	
2	*Protothaca*, juv.	
1	*Macoma yoldiformis*	0.01
3	Nematodes	
2	unid. juv. pelecypods	
1	Oligochaete	
	Algae:	
	? *Gracilariopsis* (drift?)	0.85
		0.87

Biomass= 13.63 g./ 0.1 m.^{2}

53 individuals, at least 16 species

Sample volume 0.0137 m^3

Biomass= 0.87 g./ 0.1 m^2

48 individuals, at least 17 species

Sample volume 0.013 m^3

Average Biomass = 72.5 g/m^2

Table 21. Settling Rack Biomass Annual Averages, by station.

Station	1971	1972	1973	1974	1975
A1	68.4	42.45	30.68	46.11	44.09
A2	150.9	57.99	60.97	46.42	39.73
A3	180.8	66.71	49.67	45.66	20.75
A6	75.8	58.35	29.65	19.21	21.46
A7	131.0	52.97	60.68	32.21	41.27
A8			64.4	45.71	37.30
A9	75.7	45.97	54.23	37.82	49.63
A10	63.5	30.32	29.43	23.88	9.71
Total	746.1	354.76	379.71	297.02	263.94
Total Annual Average	106.59	50.68	47.46	37.12	32.99

Table 22. Biomass of Organisms on Settling Racks in the Outer Los Angeles Harbor. (Numbers represent wet weights, in grams.)*

1971 Stations	Jan.	Feb.	Mar.	4/12	5/13	6/4	7/1	8/3	9/2	10/6	11/4	12/8
A1						18.85	32.05	159.2	73.7	73.1	24.9	97.3
A2						121.1	48.4		200.7	191.8	274.6	68.8
A3						137.9	181.6	52.3	324.8	237.9	258.4	72.9
A6				6.95	15.0	16.5	17.4	113.0	89.7	398.1	14.4	11.2
A7				180.3	44.7	106.3	145.3	58.0	312.1	120.8	126.0	86.6
A8												
A9				60.85	5.0	38.5	77.4	178.0	123.2	131.1	51.7	15.9
A10						24.7	11.45	120.9	173.6	80.8	25.2	7.9
Monthly Average				82.7	21.6	66.3	73.4	113.6	185.4	176.2	110.7	51.5

1972 Stations	1/5	2/2	3/7	4/4	5/2	6/6	7/11	8/9	9/6	10/4	11/8	12/6
A1	3.5	12.6	7.45	12.3	8.15	49.5	123.1	13.5	34.8	74.4	127.9	
A2	6.6	25.3	10.0	28.7	6.6	31.8	146.7	26.6	110.2	193.7	169.9	39.9
A3	9.3	34.1	16.6	52.5	15.6		136.6	18.1	98.7	167.7	145.5	39.2
A6	3.8	6.8	18.2	9.6	12.3	19.7	44.8	62.9	300.5	64.99	133.1	23.7
A7	9.8	11.5	35.2		12.9	22.5	187.5	41.2		14.3	170.2	24.7
A8												
A9	4.2	7.1	3.2	11.2	11.5	71.2	201.8				57.8	
A10	1.4	1.9	2.35	4.45	5.1	22.7	97.1	28.3	48.2	87.4	55.8	9.5
Monthly Average	5.5	14.2	13.3	16.9	10.3	36.2	128.7	31.7	118.5	83.8	40.5	27.4

* Dates represent panel exposure for previous 4 weeks.

Table 22. (cont'd)

1973 Stations	1/10	2/7	3/7	4/6	5/2	6/6	7/5	8/1	9/4	10/3	11/7	12/5
A1	38.71	19.3	40.2	32.18	36.86	59.3	36.13	35.2		9.84	14.6	15.2
A2	62.56	58.25	56.0	60.41	53.51	92.9	50.66	59.9	112.04	27.16	63.3	35.0
A3	67.87			108.3		79.6	30.22	36.1	57.98	23.33	23.4	20.3
A6	7.85	5.9	22.3	25.7	22.31	30.8	80.03	85.0	44.8	13.51	6.7	10.9
A7	32.81	44.89	75.2	121.9	58.2	80.0	50.76	70.1				12.4
A8			22.9	58.3	46.3		105.3	99.1	59.7	95.8	93.6	55.7
A9	30.79	14.02	13.56	12.2		46.9	78.2	52.3	126.73		121.9	45.8
A10	6.0	7.23	11.26	18.23	4.08	16.8	75.8		92.87	26.01	55.0	10.5
Monthly Average	35.2	21.4	34.5	54.6	36.9	58.0	63.4	62.5	82.4	32.6	54.1	25.7

1974 Stations	1/9	2/6	3/7	4/3	5/1	6/6	7/3	8/7	9/4	10/9	11/6	12/4
A1		38.1	41.9	63.7		68.5		43.9	36.1	57.8	18.9	
A2	41.6	26.1	43.7	50.3	42.6	72.0	18.4	56.9	49.5	120.3	23.4	12.3
A3	43.1	18.4	34.7	84.0	95.2	69.3	6.7	44.3	53.4	49.9	28.4	20.6
A6	14.5	7.1	12.2	20.0	9.2	22.7	8.2	28.5	44.2	10.5	37.6	15.9
A7	2.9	21.7	24.3		66.6			51.2	35.2		49.2	6.6
A8		18.1	21.1	20.6		23.2	14.3	93.0	70.9	137.9	47.1	10.9
A9		13.4	39.3	21.8	26.6	37.8	10.2	75.0	77.8	56.1	44.1	13.9
A10		3.3	4.7	1.8	4.6	2.3	8.1	102.2	34.1	78.1	19.2	4.3
Monthly Average	25.5	18.3	27.7	37.5	34.6	42.3	11.0	61.9	50.2	72.9	33.5	12.1

Table 22. (cont'd)

1975 Stations	1/8	2/5	3/5	4/2	5/7	6/11	7/2	8/6	9/3	10/8	11/12	12/9
A1	45.5					20.7	31.3	41.5	132.23	46.95	26.23	8.33
A2	44.0	26.2	36.0	26.5	33.8	29.5	25.5	126.1	48.86	71.41	4.43	4.47
A3			44.3	36.2	29.8	37.1	11.3	2.2	2.66		9.71	13.47
A6	14.3	10.3	19.4	12.7	23.4	33.2				61.85	12.41	5.60
A7	18.8	8.9		50.3		41.7	23.0	122.2	47.15	56.59		2.80
A8	22.7	12.8	13.5	18.8	62.5	60.1	11.1	131.1	47.44		18.49	11.79
A9		16.7	10.0		17.8		17.8	140.5		91.98		
A10	4.9	3.3	3.7	6.9	10.6	28.9						
Monthy Average	25.0	13.0	21.1	25.2	29.6	35.9	20.0	94.0	55.67	65.75	14.25	7.74

Table 23. Taxa with significantly higher values for recolonization occurrences in control or experimental sediment samples.

Station and Species	Feb. - March	May- June	June - August	Feb.- May	April- June	Feb.- June	Feb.- August
	6 weeks			12 weeks		18 weeks	24 weeks
LNG 5							
*Capitita ambiseta**	+	*	*	*	+	+	*
Cossura candida	+	●	●	+	+	+	●
Tharyx sp.				●	●	+	
Oligochaeta	+			+		+	
LNG 18							
Mactridae		+					+
LNG 24							
Nematoda		+				●	+

* Non-significant higher value.

\+ Significantly higher value in "Control" sediment.

● Significantly higher value in "Experimental" sediment.

Table 24. Species Abundant in "Mature Communities."

	LNG 1	No.	LNG 3	No.
September, 1972 (average of 3 Campbell grabs per station.)	*Prionospio pygmaeus*	38	*Tharyx* sp.	1236
	Spiophanes bombyx	30	*Capitita ambiseta*	148
	Lumbrineris spp.	27	*Paraonis g. oculata*	33
	Chaetozone ? corona	23	*Cossura candida*	27
	Chone sp.	20	*Nephtys c. franciscana*	14
	Capitita ambiseta	15	*Pectinaria c. newportensis*	10
	Tharyx sp.	14	*Haploscoloplos elongatus*	9
			Amphicteis scaphobranchiata	8
Total Polychaete species: 18			37	
Average No. Polychaetes: 637			1513	

	LNG 1	LNG 3
November, 1973 - Boxcorer	*Tharyx* sp. most numerous; no clear dominance.	*Tharyx, Capitita ambiseta,* and *Cossura candida* numerous, but no clear dominance.

	LNG 1	No.	LNG 3	No.
January, 1974 - All taxa identified - Boxcorer	*Capitita ambiseta*	248	*Tharyx* sp.	497
	Tharyx sp.	122	*Capitita ambiseta*	151
	Tellina sp. (juv.)	80	*Paraonis g. oculata*	45
	Lumbrineris spp.	40	*Chaetozone corona*	39
	Prionospio pygmaeus	25	*Lumbrineris* spp.	34
	Ostracoda	22	*Haploscoloplos elongatus*	30
	Nematoda	18	*Nereis procera*	29
	Parvilucina sp.	18	*Tellina* sp. (juv.)	29
	Paraonis g. oculata	14	*Protothaca* sp. (juv.)	29
	Chaetozone corona	14	*Sigambra tentaculata*	28
	Euchone incolor	14	*Cossura candida*	27
	Nereis procera	12	*Euchone incolor*	17
			Notomastus tenuis	17
Total Polychaete species: 41			41	
Total taxa: 63			68	
Total No. Individuals . .802			1397	
Total No. Polychaetes . .586			1003	

Note: Campbell grab: Surface area sampled = 0.100 m^2

Boxcorer: Surface area sampled = 0.0625 m^2

Table 24. (cont'd)

September, 1972 (average of 3 Campbell grabs/stn.)

LNG 5	No.
Tharyx sp.	1016
Cossura candida	553
Capitita ambiseta	404
Prionospio cirrifera	68
Paraonis g. oculata	53
Prionospio pygmaeus	47
Chaetozone corona	15
Amphicteis scaphobranch	15
Nephtys c. franciscana	15
Diopatra sp. (juv.)	13
Spiophanes missionensis	13
Haploscoloplos elongatus	13

Total Polychaete species: 36
Average No. Polychaetes: 2104

Nov., 1973 Boxcorer

LNG 5	No.
Tharyx, Cossura candida, Capitita ambiseta all numerous.	

January, 1974 - Boxcorer

LNG 5	No.
Capitita ambiseta	369
Cossura candida	309
Tharyx sp.	181
Oligochaeta	100
Prionospio cirrifera	66
Cyclopoid copepoda	56
Capitella capitata	17
Paraonis g. oculata	15
Chaetozone corona	12

April, 1974-Rough estimates (Campbell)

LNG 18	No.
Armandia bioculata	700
Capitella capitata	200
Pectinaria c. newport.	20
Others occurring (most first)	
Prionospio cirrifera	
Nephtys cornuta franciscana	
Polydora spp.	

February, 1974-average of 2 Campbell grabs.

LNG 24	No.
Capitita ambiseta	429
Cossura candida	123
Oligochaeta	50
Armandia bioculata	41
Tharyx sp.	35
Nematoda	28
Magelona sp.	15
Tellina sp. (juv.)	11
Prionospio pygmaeus	10
Euchone limicola	8
Pista sp. (juv.)	8

Total Polychaete species: 36
Average No. Polychaetes: 759
Totoal taxa:..... 56
Average No. individuals: 922

Note: Campbell grab: Surface area sampled: 0.100 m^2
Boxcorer: Surface area sampled: 0.0625 m^2

Table 25. Recolonization Biomasses with Seasonal Abundances Indicated.

1975 Stations		6 weeks				12 weeks			18 weeks		24 weeks
		Feb.-March	May-June	June-August	*Aug.-Sept.	Feb.-May	April-June	May-August	Feb.-June	*May-Sept.	Feb.-August
LNG 1	C		○ 1.8	◯ 25.6	○ .205			◪ 46.1			
Recol 1	E		○ 3.5	◯ 16.9	○ .175			◯ 14.4			
LNG 3	C		○ 2.9	◔ 32.3	○ .30			◯ 27.0			
Recol 2	E		○ 2.3	● 73.4	○ .62			◪ 50.5			
LNG 5	C	◯ 11.8	○ 4.7	◔ 35.0		◯ 14.1	○ 2.6		○ 2.9	○ 0.2	◯ 12.0
Recol 3	E	◯ 24.7	○ 6.6	◔ 37.6		◯ 14.1	○ 0.9		○ 3.5	○ 0.35	◯ 26.7
LNG 18	C	◪ 57.6	○ 8.8	■ 131.9		◔ 35.2	○ 0.6		◯ 23.5	■ 139	■ 161.6
Recol 4	E	◪ 48.1	◯ 16.4	◯ 22.9		◯ 10.6	○ 5.9		◯ 17.6	■ 162.4	■ 135.0
LNG 24	C	◯ 16.5	◯ 10.6	● 60.8		◯ 15.3	○ 7.1		○ 8.8		◔ 36.7
Recol 5	E	◯ 17.0	○ 6.2	● 80.2		○ 7.6	○ 5.3		○ 8.8		■ 162.4
Average		29.28	16.4	51.6		16.5	3.73	34.5	10.85		89.6

○ 0 - 9 ◔ 30 - 39 ● 60 - 69 ■ 90 - 99

◯ 10 - 19 ◪ 40 - 49 ● 70 - 79 ■ 100 (* One sample only)

◯ 20 - 29 ◪ 50 - 59 ● 80 - 89

Table 26.

Los Angeles Harbor Department
Recolonization Study

Summary of Biotic Measurements

Station LNG 1

Exposure	6 Weeks				12 Weeks	
	May-June '75		June-August '75		May-August '75	
Sediment Type	C	E	C	E	C	E
Total Taxa	28	29	63	52*	79**	59**
Total Individuals	304	317	1274	492*	2249	1580
Adjusted Biomass (g/m^2)	1.8	3.5	25.6	16.9	45.8	14.4
Total Biomass (g/m^2)	1.8	3.5	25.6	16.9	46.1	14.4

Station LNG 3

Exposure	6 Weeks				12 Weeks	
	May-June '75		June-Aug. '75		May-Aug. '75	
Sediment Type	C	E	C	E	C	E
Total Taxa	25	28	37	52	45**	31**
Total Individuals	622	665	1456	1671	2020	1919
Adjusted Biomass (g/m^2)	2.9	2.3	29.4	33.5	23.5	44.9
Total Biomass (g/m^2)	2.9	2.3	32.3	73.4	27.0	50.5

Totals represent the sum of 3 replicate samples.
* Less than 3 replicates compared.
** Adjusted to exclude animals not previously identified to generic level.
C= Control sediment.
E= Experimental (dredged) sediment.
Adjusted Biomass= Total Biomass less the biomass of *Heptacarpus* sp.

Table 26 (cont.)

Los Angeles Harbor Department
Recolonization Study

Summary of Biotic Measurements

Station LNG 5

Exposure	6 Weeks					
	February-March '75		May-June '75		June-August '75	
Sediment Type	C	E	C	E	C	E
Total Taxa	31	30	31	36	44**	43**
Total Individuals	355	397	879	908	1335	1613
Adjusted Biomass (g/m^2)	5.3	22.9	4.7	1.2	33.5	35.5
Total Biomass (g/m^2)	11.8	24.7	4.7	6.6	35.0	37.6

Exposure	12 Weeks				18 Weeks		24 Weeks	
	Feb.-May '75		Apr.-June '75		Feb.-June '75		Feb.-Aug.'75	
Sediment Type	C	E	C	E	C	E	C	E
Total Taxa	12*	21*	22*	22*	35	33	42**	43**
Total Individuals	388*	536*	443*	368*	687	618	1222	1254
Adjusted Biomass (g/m^2)	2.64	7.9	1.8	0.9	2.3	3.5	10.9	23.2
Total Biomass (g/m^2)	14.1	14.1	2.6	0.9	2.9	3.5	12.0	26.7

Totals represent the sum of 3 replicate samples.
* Less than 3 replicates compared.
** Adjusted to exclude animals not previously identified to generic level.
C= Control sediment.
E= Experimental (dredged) sediment.
Adjusted Biomass= Total Biomass less the biomass of *Heptacarpus* sp.

Table 26 (cont.)

Los Angeles Harbor Department
Recolonization Study

Summary of Biotic Measurements

Station LNG 18

Exposure	6 Weeks					
	February-March '75		May-June '75		June-August '75	
Sediment Type	C	E	C	E	C	E
Total Taxa	23	24	30	32	42**	36**
Total Individuals	1375	961	1230	1246	1851	2431
Adjusted Biomass (g/m^2)	53.5	37.0	2.4	15.9	131.6	22.9
Total Biomass (g/m^2)	57.6	48.1	8.8	16.4	131.9	22.9

Exposure	12 Weeks				18 Weeks		24 Weeks	
	Feb.-May '75		Apr.-June '75		Feb.-June '75		Feb.-Aug. '75	
Sediment Type	C	E	C	E	C	E	C	E
Total Taxa	20	17	20	21	35	27	42**	35**
Total Individuals	609	736	836	655	1139	1052	2670	2557
Adjusted Biomass (g/m^2)	2.9	9.4	0.6	1.8	22.3	17.6	160.4	135.0
Total Biomass (g/m^2)	35.2	10.6	0.6	5.9	23.5	17.6	161.6	135.0

Totals represent the sum of 3 replicate samples.
* Less than 3 replicates compared.
** Adjusted to exclude animals not previously identified to generic level.
C= Control sediment.
E= Experimental (dredged) sediment.
Adjusted Biomass= Total Biomass less the biomass of *Neptacarpus* sp.

Table 26 (cont.)

Los Angeles Harbor Department
Recolonization Study

Summary of Biotic Measurements

Station LNG 24

	6 Weeks					
Exposure	February-March '75		May-June '75		June-August '75	
Sediment Type	C	E	C	E	C	E
Total Taxa	33	37	30	23*	51**	41**
Total Individuals	822	864	1815	1270*	1828	2173
Adjusted Biomass (g/m^2)	5.9	17.0	9.4	4.4	54.0	27.3
Total Biomass (g/m^2)	16.5	17.0	10.6	6.2	60.8	80.2

	12 Weeks				18 Weeks		24 Weeks	
Exposure	Feb.-May '75		Apr.-June '75		Feb.-June '75		Feb.-Aug. '75	
Sediment Type	C	E	C	E	C	E	C	E
Total Taxa	26	27	16*	20*	26*	20*	42**	41**
Total Individuals	1634	1184	686*	511*	1108*	534*	1175	1551
Adjusted Biomass (g/m^2)	14.7	4.7	5.3	3.5	7.9	5.3	7.6	78.4
Total Biomass (g/m^2)	15.3	7.6	7.1	5.3	8.8	8.8	36.7	162.4

Totals represent the sum of 3 replicate samples.
* Less than 3 replicates compared.
** Adjusted to exclude animals not previously identified to generic level.
C= Control sediment.
E= Experimental (dredged) sediment.
Adjusted Biomass= Total Biomass less the biomass of *Heptacarpus* sp.

Table 27.

Los Angeles Harbor Department
Recolonization Study

Summary of Biotic Measurements

6-Week Exposure - May-June 1975

Station Sediment Type	LNG 1 C	 E	LNG 3 C	 E	LNG 5 C	 E	LNG 18 C	 E	LNG 24 C	 E*
Total # Species	28	29	25	28	31	36	30	32	30	23*
Total # Individuals	304	317	622	665	879	908	1230	1246	1815	1270*
Adjusted Biomass (g/m^2)	1.8	3.5	2.9	2.3	4.7	1.2	2.4	15.9	9.4	4.4
Total Biomass (g/m^2)	1.8	3.5	2.9	2.3	4.7	6.6	8.8	16.4	10.6	6.2

12-Week Exposure - April-June 1975

Station Sediment Type	LNG 5* C	 E	LNG 18 C	 E	LNG 24* C	 E
Total # Species	22*	22*	20	21	16*	20*
Total # Individuals	443*	368*	836	655	686*	511*
Adjusted Biomass (g/m^2)	1.8	0.9	0.6	1.8	5.3	3.5
Total Biomass (g/m^2)	2.6	0.9	0.6	5.9	7.1	5.3

18-Week Exposure - February-June 1975

Station Sediment Type	LNG 5 C	 E	LNG 18 C	 E	LNG 24* C	 E
Total # Species	35	33	35	27	26*	20*
Total # Individuals	687	618	1139	1052	1108*	534*
Adjusted Biomass (g/m^2)	2.3	3.5	22.3	17.6	7.9	5.3
Total Biomass (g/m^2)	2.9	3.5	23.5	17.6	8.8	8.8

* Less than 3 replicates compared

Table 28a . Benthic Recolonization Tables: Data Summary by Station and Time.

	LNG 1						LNG 3						LNG 5								LNG 18								LNG 24							
Weeks	6		6		12		6		6		12		18		6		24		6		12		24		6		6		12		17		6		24		6		18		12	
	May - June		June - August		May - August		May - June		June - August		May - August		Feb. - June		June - August		Feb. - August		May - June		April - June		Feb. - August		May - June		June - August		April - June		Feb. - June		June - August		Feb. - August		May - June		Feb. - June		April - June	
SPECIES	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E
Annelida																																										
Polychaeta, unid.(juv.)							4	0																																		
Amaeana occidentalis			3	0	2	2									3	0									1	0									0	1						
Ampharetidae, unid.(juv.)					0	4																													0	1						
Amphicteis scaphobranchiata	3	4	2	1	10	4	3	3	5	10	9	4	0	1	3	4	2	2	2	0															2	2	2	0				
Amphitrite sp.			4	3	4	6			2	0																																
Anaitides williamsi					1	1			0	1					1	0																										
Anaitides sp.																																										
Anaitidestroyllis hamata																																										
Arabella sp.															0	1																										
Aricidea wassi			1	0																					1	0																
Armandia bioculata	122	90	262	118	317	300	92	95	467	447	556	555	104	98	461	501	281	217	257	287	112	37	290	381	571	397	481	653	95	165	149	230	513	304	542	443	505	360	177	38	189	104
Autolytus cornutus					1	0							1	1			2	1	0	3					10	7			5	8	10	6									0	2
Barmaria hamata	22	7	26	2	23	27	56	30	116	115	112	27	3	2	33	22	2	1	128	13	1	5	57	79	8	126	57	111	1	3	25	37	172	78	0	151	75	56	10	13	6	14
Boccardia sp. (juv.)			0	1			0	2													0	1	2	17	6	0									26	0						
Capitella capitata	2	0	1	0	1	0	0	2	11	32	3	1	4	0	16	4	7	0	2	1	1	1	7	19	7	5	6	13	26	7	27	35	6	0	1	1	10	1	3	2		
Capitella capitata	0	3	82	31	179	91	5	14	70	127	62	43	20	4	138	157	43	74	10	35	15	3	44	69	13	6	91	100	1	0	3	3	458	360	147	252	16	7	15	12	27	19
Capitellidae, unid. (juv.)																	0	1	1	0			0	1											0	2						
Caulleriella sp.											0	1					0	2					4	6																		
Caulleriella hamata	1	0																																								
Chaetozone setosa					8	0									0	1	3	1	0	1			1	3			0	2														
Chaetozone setosa	1	1	12	2	22	29	1	0	0	1	1	0																														
Chaetozone sp.	0	1													2	1																										
Chone sp.			5	0	13	20											1	0			0	1					1	5														
Cirratulidae, unid. (juv.)			0	1	2	0									0	2											2	0					7	0								
Cossura candida													29	4	0	6	3	17	0	21	30	0																				
Diopatra sp.																																					0	1				
Dorvilleidae, unid.(juv.)	1	0	3	0							1	0			0	2			1	1					0	1	1	0					0	1								
Eteone dilata	6	8	1	0					0	1							1	1															0	2			1	0				
Eteone pacifica									0	11					1	0																	2	0							0	1
Eteone sp.									0	1							0	1															1	0	1	0						
Euchone incolor	2	5	6	0			2	1			3	2			0	1									0	1							2	0								
Euchone limnicola	6	8	16	4	3	9	1	0			1	0			1	1			0	1													1	2	1	0						
Euchone sp.							0	4																									1	0								
Eulalia sp.									0	3																																
Eumida bifilata			2	0					1	1																																
Eumida sanguinea			0	3	1	0																	0	2			1	0					2	2								
Eumida sp.																																			1	1						
Exogone lourei					9	0					1	0													0	1					1	2										
Exogone verugera					9	0																											11	2	0	2						
Exogone sp.	1	0	1	0	1	3	0	4	3	5	6	0																														
Exogonella brunnea			0	3																													2	0	0	1	1	1	2	2	0	1
Flabelligeridae, unid.(juv.)																																	1	0								
Flabelligerma sp. ?	0	1																																								

C = Control Bottles; sediment collected from that station. E = Experimental Bottles; sediment from newly dredged area.

Table 28b . Benthic Recolonization Tables: Data Summary by Station and Time.

SPECIES	LNG 1						LNG 3						LNG 5								LNG 18										LNG 24									
Weeks →	6		6		12		6		6		12		18		6		24		6		12		24		6		6		12		17		6		24		6		18		12	
	May - June		June - August		May - August		May - June		June - August		May - August		Feb. - June		June - August		Feb. - August		May - June		April - June		Feb. - August		May - June		June - August		April - June		Feb. - June		June - August		Feb. - August		May - June		Feb. - June		April - June	
	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E
Glycera americana											0	1	0	1			0	1																						
Goniada brunnea	2	0			1	0							1	0					0	1																				
Cyptis brevipalpa	1	1	71	18	30	4							1	0																	2	6	17	0	6	0	1	0		
Cyptis brunnea			0	1	0	2																													0	2				
Sphaerosyllis elongatus	1	0	7	1	15	18			5	5			1	0	1	1	0	2	1	1	0	1	1	0	1	0	3	1												
Haplosyllis sp.			0	2	1	0																																		
Harmothoe priops					4	2													2	0																				
Hesionidae, unid. (juv.)	0	1			1	0							0	2					2	0	1	0	1	2			1	0	1	0							2	1	0	1	1	0
Leonice cirrata													0	1	1	0																			2	0				
Lumbrineris sp.			3	2	1	3							1	1			0	1	2	1	3	1											4	2	0	1			0	1		
Maldanidae, unid. (juv.)					0	2			0	1																														
Mediomastus acutus																																	2	12						
Nephtys californiensis																																			1	0				
Nephtys cornuta franciscana	2	1	2	5	4	3	3	2	0	1	0	2	10	7	0	1	3	10	3	6	1	1	2	0													1	0		
Nereidae, unid. (juv.)			2	0	1	1			0	1	1	2	4	4	1	1	0	2	0	1					5	8			10	0	4	8								
Nereis procera	0	1			1	0					0	1																									1	0		
Nerinides acuta									0	1																							0	2						
Onuphidae, unid. (juv.)			1	0	3	5			1	0													1	1	1	0	0	1											0	1
Onuphidromus tigrinensis	5	14	29	25	60	51	20	8	4	7	1	1			19	31	13	11	2	0	1	0	13	5	0	2	23	25			2	0	4	10	3	0	0	2	1	0
Paraonis gracilis oculata							0	2	0	1	1	0																					1	0						
Pectinaria californiensis			4	2	4	3			0	1			0	1											1	0													1	0
P. californiensis newportensis																			1	0																				
Pherusa neopapillata			0	1	3	5							1	0	0	1																								
Pholoe glabra			1	0	2	0																	1	1					2	0	0	3							0	1
Phyllodocidae, unid. (juv.)			2	0	1	0											1	0					0	1	2	1	0	2	1	2	8	0	2	0						
Phyllodoce sp.																																	1	0						
Pista sp.	1	5	1	0							0	1					1	0					1	0																
Pista fasciata			1	2	10	0																																		
Platynereis bicanaliculata													2	0	2	1							0	1																
Spionidae, Polydorid-complex	0	4	6	0	1	0	20	39	10	2	17	11	6	9	5	8	12	44	4	11	1	6	15	18	11	24	1	19	7	12	13	22					45	37	13	5	4	7
Polydora sp.	3	1							0	8																	4	0			0	6								
Polydora brachycephala	0	4	3	0	1	0	6	3	1	0	2	0	2	2			4	0	9	2	0	7	3	0	0	1					1	0								
Polydora ligni									2	2					1	2	6	0					4	0	1	7	17	37			7	0	1	0	1	0				
Polydora limicola			1	1	0	3					4	0					3	0					3	0			1	0					2	0	4	0				
Polydora quadrilobata			0	1																																				
Polydora socialis			8	14	10	4			19	30	1	0			2	2							1	0			1	19					27	354	12	3				
Prionospio sp.			1	1					0	1													1	3	1	0	0	1			0	1					9	23	1	2	5	1
Prionospio cirrifera	0	2	13	5	12	15	1	6	17	22	16	27	17	9	17	22	12	18	4	17	15	10	15	18	23	13	11	15	20	13	17	16	70	88	110	233	220	73	102	175	124	58
Prionospio heterobranchia newportensis					0	1	1	0	4	4	1	0			11	7	1	2					5	11			8	7					38	40	1	15				
Prionospio cf. *malmgreni*																																	10	0	11	6				
Prionospio pygmaeus	0	2					0	3	1	1	0	1	1	0	2	0	0	1	0	2	1	0			0	1	1	1			1	0			4	4	0	4		
Pseudopolydora paucibranch.									0	2	1	0	2	1	4	0					0	1	1	1	1	0	6	3			1	0	3	0						
Sabellidae, unid. (juv.)			0	2																																		

C = Control Bottles; sediment from that station. E = Experimental Bottles; sediment from newly dredged area.

Table 28c . Benthic Recolonization Tables: Data Summary by Station and Time.

SPECIES	LNG 1						LNG 3								LNG 5								LNG 18										LNG 24									
Weeks →	6		6		12		6		6		12		16		6		24		6		12		24		6		6		12		17		6		24		6		18		12	
	May - June		June - August		May - August		May - June		June - August		May - August		Feb.- June		June - August		Feb.- August		May- June		April- June		Feb.- August		May- June		June- August		April- June		Feb.- June		June- August		Feb. - August		May- June		Feb.- June		April- June	
	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E
Sabellaria alcocki					2	0																																			
Scaleworm, unid. (juv.)			1	1	1	0							0	2											1	4			0	3	3	7					1	0	1	1		
Heteromastus filiformis					1	0																							0	3												
Schistomeringos sp.													1	0																												
Schistomeringos longicornis	0	1	3	1	19	24			1	0	0	2			5	0	3	18					134	158			10	5			6	2	6	2	11	7						
Stigmbes tentaculata					2	0	1	0																																		
Sphaerodorum sphaerulifera					1	0																																				
Sphaerosyllis sp.			7	0							1	5			1	2																										
Sphaerosyllis californiensis	2	3					2	3											0	1																						
Spiochaetopterus costarum	1	0	0	1	0	1																																				
Spionidae, unid. (juv.)																			1	0			1	0					3	0							1	0				
Spiophanes berkeleyorum							1	0																																		
Spiophanes bombyx																	1	9																								
Spiophanes missionensis			1	0	0	1			3	2	1	0	1	1	2	0	2	1	1	0			1	0									2	3								
Streblosoma crassibranchia					2	2																											1	0								
Syllidae, unid. (juv.)			1	0															0	1																						
Terebellidae, unid. (juv.)			1	1	4	2																																				
*Thary*x spp.	4	12	4	6	43	16	88	79	25	16	35	27	44	15	11	23	35	28	44	34	23	27	4	0			2	0			0	2	1	0					1	0		
Thaulapus sp.																																	1	0								
Typosyllis sp.			0	6																																						
Oligochaeta, unid.			1	0					0	2	1	0	21	2	3	4	1	18	1	5	9	1					1	0							0	14			0	1	0	3
Arthropoda																																										
Amphipoda, gammaridean	23	31	5	4	12	27	2	3	1	1	5	9	14	12	11	4	32	15	4	3	1	1	11	39	109	64	13	5	72	56	67	77	46	4	110	32	310	172	86	74	130	94
Amphilochus sp.			3	0	6	16			28	13	5	4			2	11							10	2			11	4					68	151	0	66						
Anatanais normani																															1	0			2	0						
Aoridae, unid.																	0	21					1	0																		
Callianassa sp.																			0	1	1	1	0.	1	1	0			0	1			0	1	2	2	1	0	1	0		
Cancer sp.							1	0					1	0																												
Cancer antennarius							0	1			1	0															1	0														
Cancer antennarius																									0	1			0	2												
Copepoda, calanoid			18	6	58	18			0	8	4	0			0	2	1	0															12	164	0	2						
Copepoda, cyclopoid	79	99	182	52	219	101	255	185	291	325	791	981	305	353	239	291	403	378	297	308	161	82	308	560	373	358	221	310	473	343	408	301	60	63	59	127	299	309	275	208	148	99
Copepoda, harpacticoid	2	3	164	3	172	95	0	7	85	99	78	143	13	21	153	176	129	140	29	20	9	11	1221	590	51	98	661	847	75	3	273	227	66	162	20	23	71	32	12	7	12	0
Corophium sp.					1	0																	0	1											0	2						
Corophium crassicorne									5	0					0	4	1	1					39	1									24	2								
Cumacea, unid.	0	1	0	3					0	1			1	1											0	2					1	0			1	0						
Cumella sp.			1	0	1	4			0	2	0	1															5	0					0	11	1	2						
Cylindroleberis sp.																																	8	10	25	14						
Decapoda, unid. (larvae)																			0	1											1	0			5	0	2	0	1	0		
Dexamella sp.																	16	0																								
Eurystheus thompsoni																	2	0					2	1			3	0					10	5	0	2						
Harpinia sp.	6	0			1	0	47	35	24	29	21	25	2	1	7	24	10	12			1	1	4	0	4	9	1	2	1	16	4	3	3	32	23	22	25	17	13	13	17	6

C = Control Bottles; sediment from that station. E = Experimental Bottles; sediment from newly dredged area.

Table 28d . Benthic Recolonization Tables: Data Summary by Station and Time.

SPECIES	LNG 1						LNG 3						LNG 5								LNG 18								LNG 24							
Weeks	6		6		12		6		6		12		18		6		24		6	12	24		6		12		17		6		24		6		18		12	
	May - June		June - August		May - August		May - June		June - August		May - August		Feb.- June		June - August		Feb.- August		May- June	April- June	Feb.- August		May- June		June- August		April- June		Feb.- June		June- August		Feb. - August		May- June		Feb.- June		April- June	
	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E
Ischyrocerus sp.			24	24	233	186			1	3	9	24			10	5	62	6					171	170			16	18					11	9	5	5						
Isopoda, unid.					9	0					0	1					0	1	0	1															0	2						
Jassa falcata	5	0			4	1											2	1					4	3			3	2					0	3						
Leptochelia dubia			1	0	0	1			0	1																														
Lorormynchus sp.			1	0																																				
Mysidacea, unid.																																			1	3	20	0	20	0		
Ostracoda	1	0	2	3	17	32			1	3	8	7	0	1	16	7	12	20					2	16			0	3					13	27	2	19						
Ostracoda, Cylindroleberididae													0	2						1			1	0			2	0		10	0		2	0			36	10	8	5	2	1
Photis sp.															1	0																	2	7	0	1						
Photis bifurcata																							1	4									0	2	0	1						
Podocerus brasiliensis																							0	4																		
Stenothoe sp.																																	2	1								
Stenothoe valida																																									
Synchelidium shoemakeri					0	1																																		
Unciola sp.													1	2					3	1			1	0					0	1	2	1								
Mollusca																																								
Astyris astricata															1	0	0	1																						
Cooperella subdiaphana			7	5					0	1													0	2	0	2	1	4												
Cryptomya californica																	1	0					2	0																
Cumingia sp.					1	1			1	1																							3	1						
Cumingia californica																																								
Gastropoda, unid.													1	0																										
Lacuna subviridis			1	0																															1	1				
Leptochiton mucosus															1	0																								
Leptopecten sp.			2	0									0	0			0	3					1	0	0	1	1	0												
Leptopecten latiauratus					2	0																																		
Lyonsia californica					5	0																																		
Mactridae, unid. (juv.)			2	6	1	7	3	0	4	5	7	0			36	19	8	6	6	0			5	50	10	84	78	11			4	2	5	1	0	1	0	1		
Macoma sp.			1	0	2	4			1	0	4	8			0	1	3	2			0	4	2	1	1	1	1	0			1	0								
Macoma asolasia					1	1							1	0																			0	1						
Mitrella carinata																			11	0			0	2	1	0	0	26					0	1	0	1	2	1	1	0	2	1
Myadella sp.			0	1	0	2			6	2	3	0			5	0																			0	2				
Myadella nedroana					3	1					1	0																												
Nassarius sp.				1	0																																			
Nassarius mendicus					0	1																													1	0			1	1
Odostomia sp.																					1	0																		
Olivella baetica																																								
Parvilucina sp.							0	1			2	0	2	0	0	2			26	5	0	2	6	26	6	7	24	69	3	3	6	4	30	8	7	6	2	2	1	0	0	2
Pectenidae, unid. (juv.)															0	1											0	1												
Pelecypoda, unid. (juv.)	1	0	91	53	107	21	1	1	44	66	101	23	12	9	18	26	22	8									0	1												
Petricola tellimyalis															0	1							8	9	0	3	22	15					12	9	1	2				
Protothaca sp.			17	5	6	0			2	1	1	0			13	0	3	0					0	3			2	1					0	2	3	2			1	0
Saxidomus sp.			4	2	6	1			0	1																														

C = Control Bottles; sediment from that station. E = Experimental Bottles; sediment from newly dredged area.

Table 28c . Benthic Recolonization Tables: Data Summary by Station and Time.

SPECIES	LNG 1						LNG 3						LNG 5										LNG 18										LNG 24									
Weeks	6 May - June		6 June - August		12 May - August		6 May - June		6 June - August		12 May - August		18 Feb.- June		6 June - August		24 Feb.- August		6 May- June		12 April- June		24 Feb.- August		6 May- June		6 June- August		12 April- June		17 Feb.- June		6 June- August		24 Feb. - August		6 May- June		18 Feb.- June		12 April- June	
	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E
Solen sp.			1	0													1	0																								
Tellina sp.			1	0					6	1	1	0			1	0	1	0							0	2	2	1					9	6	3	5	1	0	2	1		
Tellina modesta													3	0			1	0																			2	0	0	1		
Tellinidae, unid. (juv.)																	0	2																								
Thyracia curta									1	0																																
Tresus nuttallii					1	0									0	1							15	13																		
Turbonella sp.																			0	1																						
Miscellaneous Taxa																																										
Anthozoa					1	6							0	1																												
Echinoidea					0	1																																				
Foraminifera			0	3					*	*	*	*			*	*	*	*	6	0	0	*	*	*	*	0	*	*	0	1												
Nematoda	8	10	109	39	461	329	6	131	180	223	133	378	55	46	70	228	61	158	22	117	0	16	240	257	16	0	47	73	23	4	77	47	51+	54+	*	59+	66	158	352	72	10	92
Nemertea			7	6	7	5	0	1	4	6	1	0	1	0	3	1	3	0	1	0	63	1	2	4	0	5	2	0			2	1	2	3								
Ophiuroidea			0	1			0	1											0	1																						
Platyhelminthes			0	1	0	1																											1	0								
Phoronida					5	3									2	0																										
Phoronis pallida	2	0											0	1																	1	0										
Phoronopsis sp.							0	3					0	1					0	1	1	0			0	2			0	1	0	2										
Sipunculida					5	0																																				
Total Animals	315	323	246	488	2149	1532	622	679	1871	1656	2019	1919	686	617	1334	1612	1223	1251	878	907	404	272	2670	2555	1228	1051	1845	1869	835	636	1124	1954	1814	2167	1070	1549	1814	1692	1118	534	686	510
Total Species	30	29	64	54	76	60	25	29	39	52	45	32	34	32	44	44	48	45	26	35	22	24	52	42	29	33	44	38	20	21	32	27	56	47	40	45	29	21	26	20	16	19

* Present, but not counted.

C = Control Bottles; sediment from that station. E = Experimental Bottles; sediment from newly dredged area.

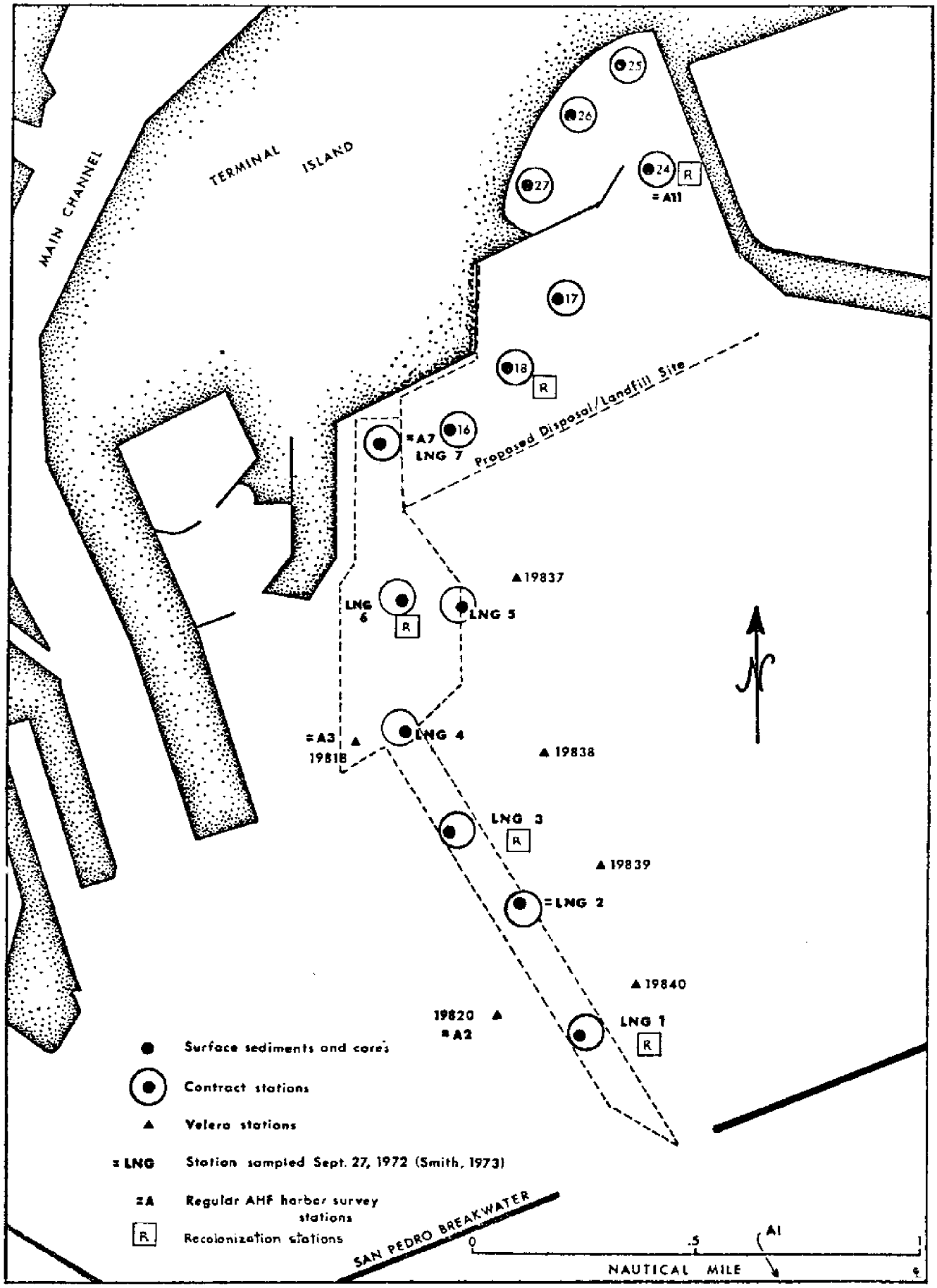


Figure 1. Outer Los Angeles Harbor Dredging Effects Study (Harbor Environmental Projects, 1976).

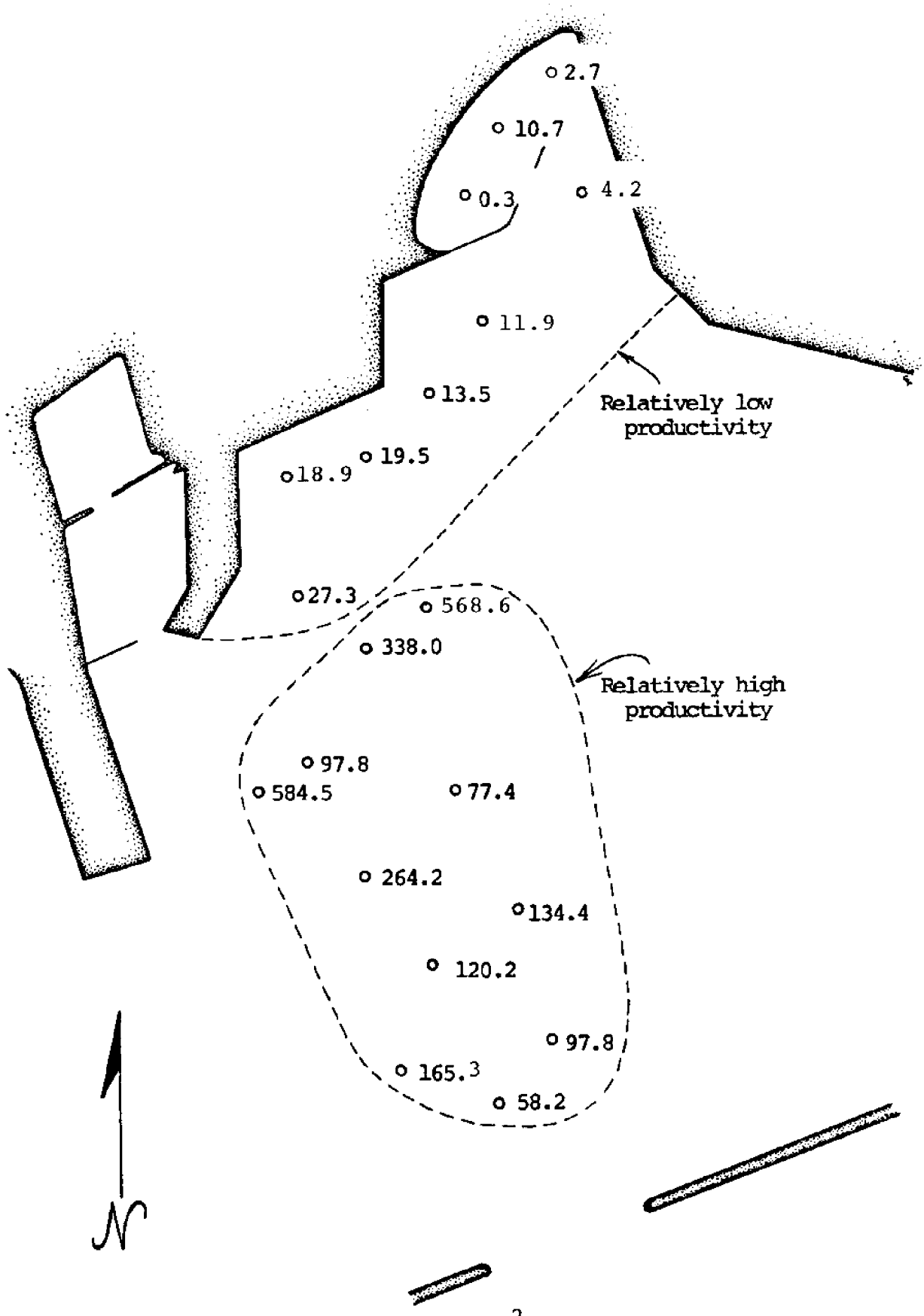


Figure 2. Animal Biomass in g/m^2 at the Benthic Stations.

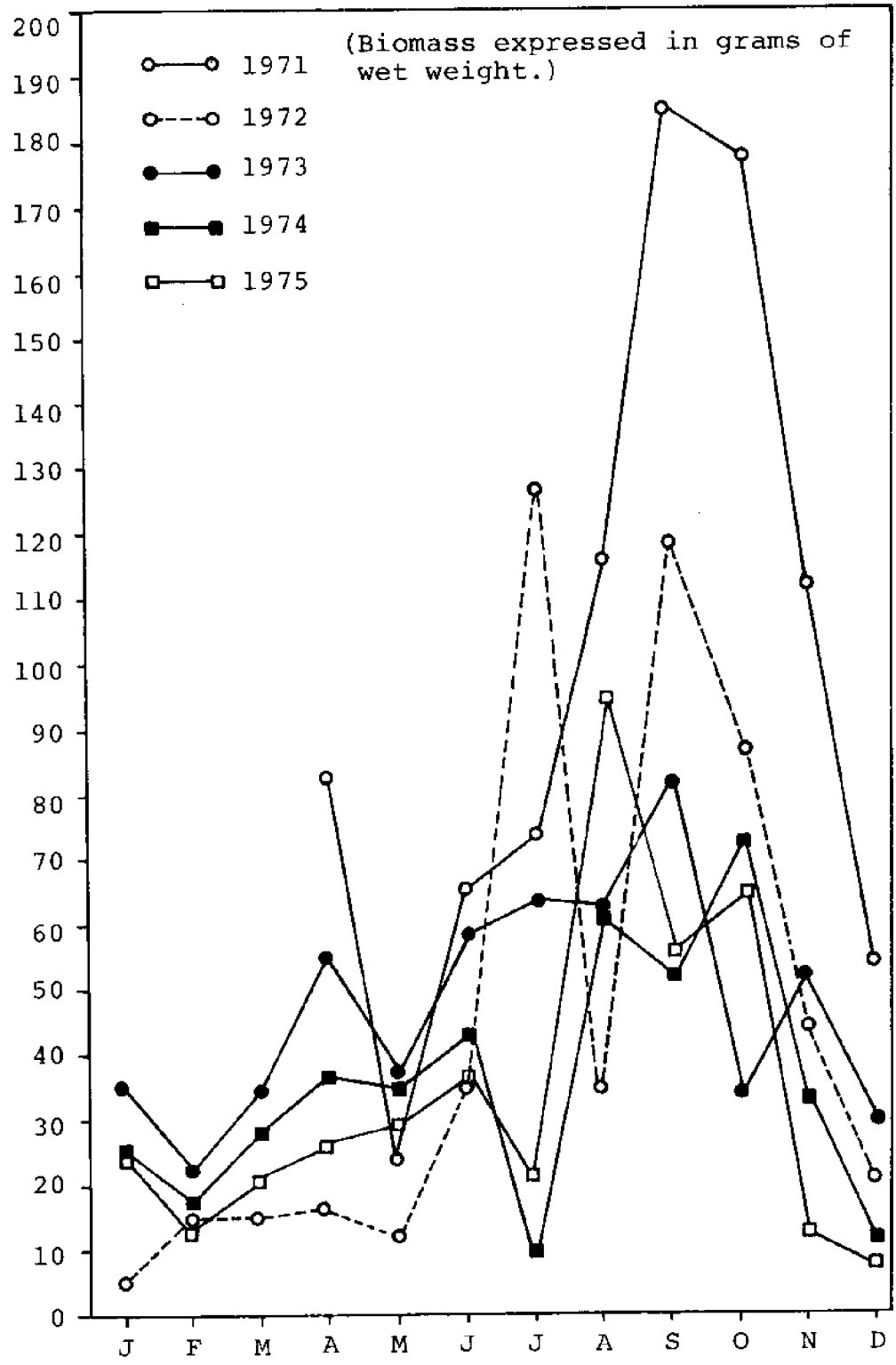


Figure 3. Monthly* averages of biomass from all A station settling racks in the outer harbor.

* Month symbol is for previous 4 weeks exposure.

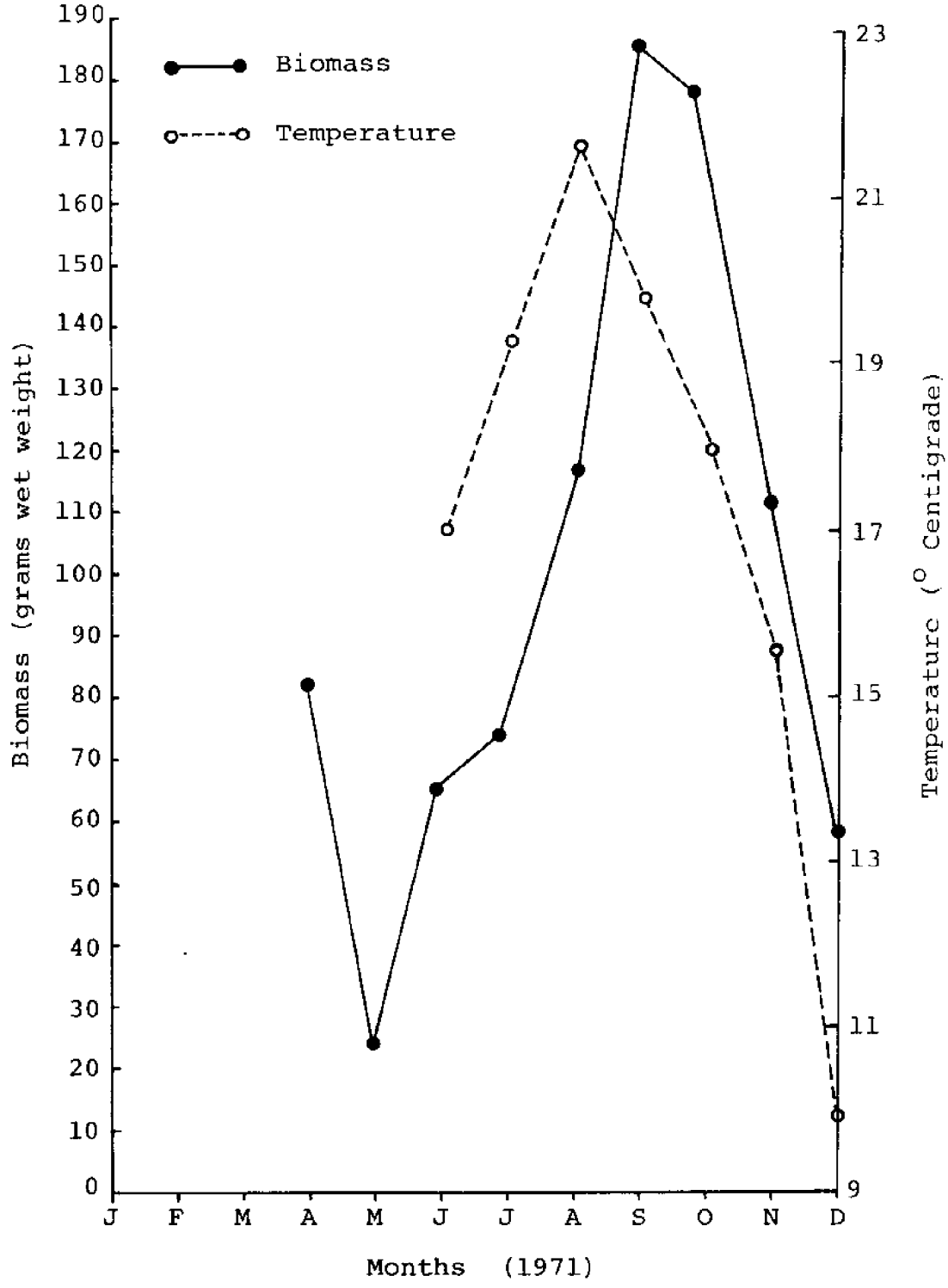


Figure 4. Seasonal Average Settling Biomass and Temperature at Station A3, 1971.

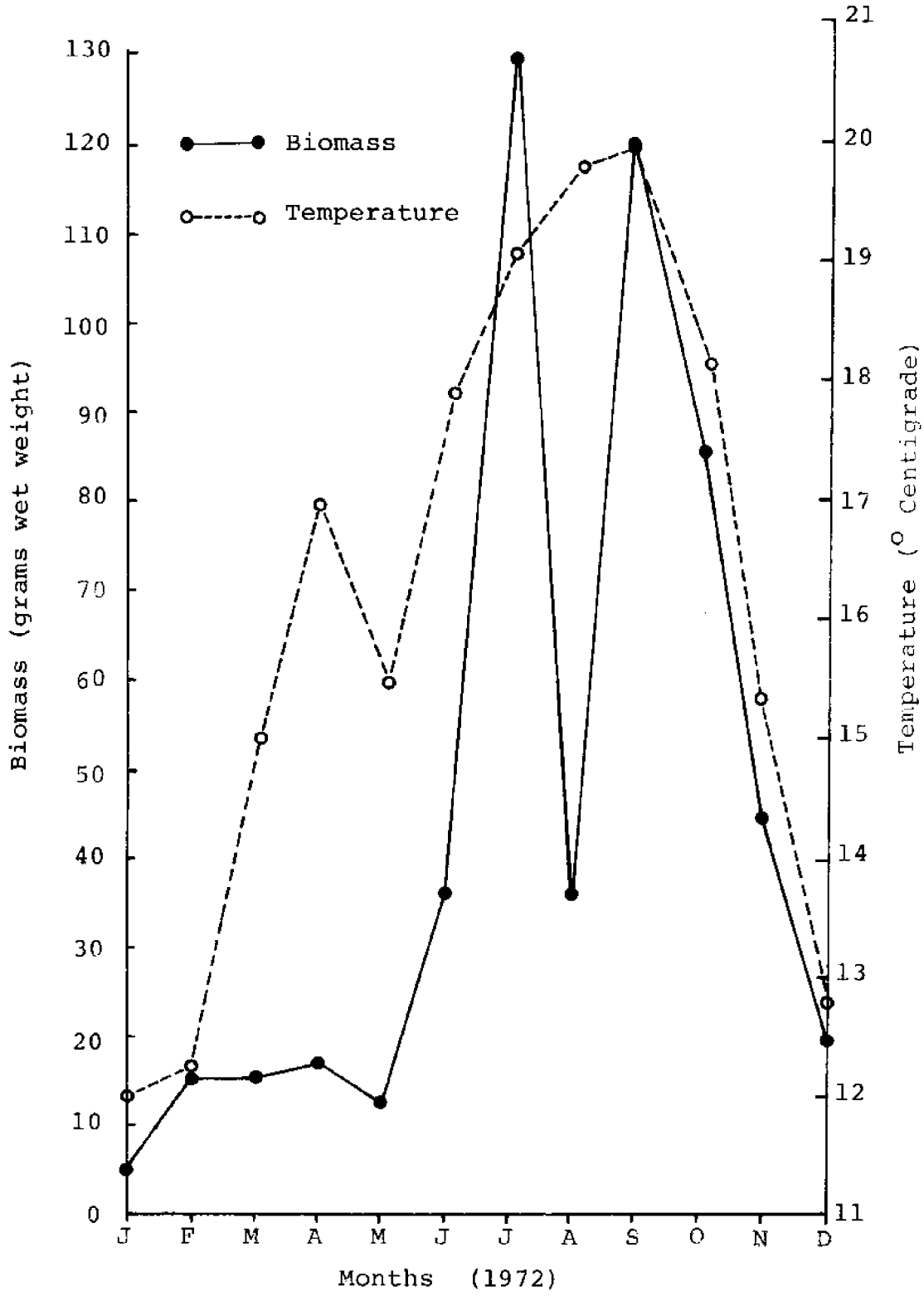


Figure 5. Seasonal Average Settling Biomass and Temperature at Station A3, 1972.

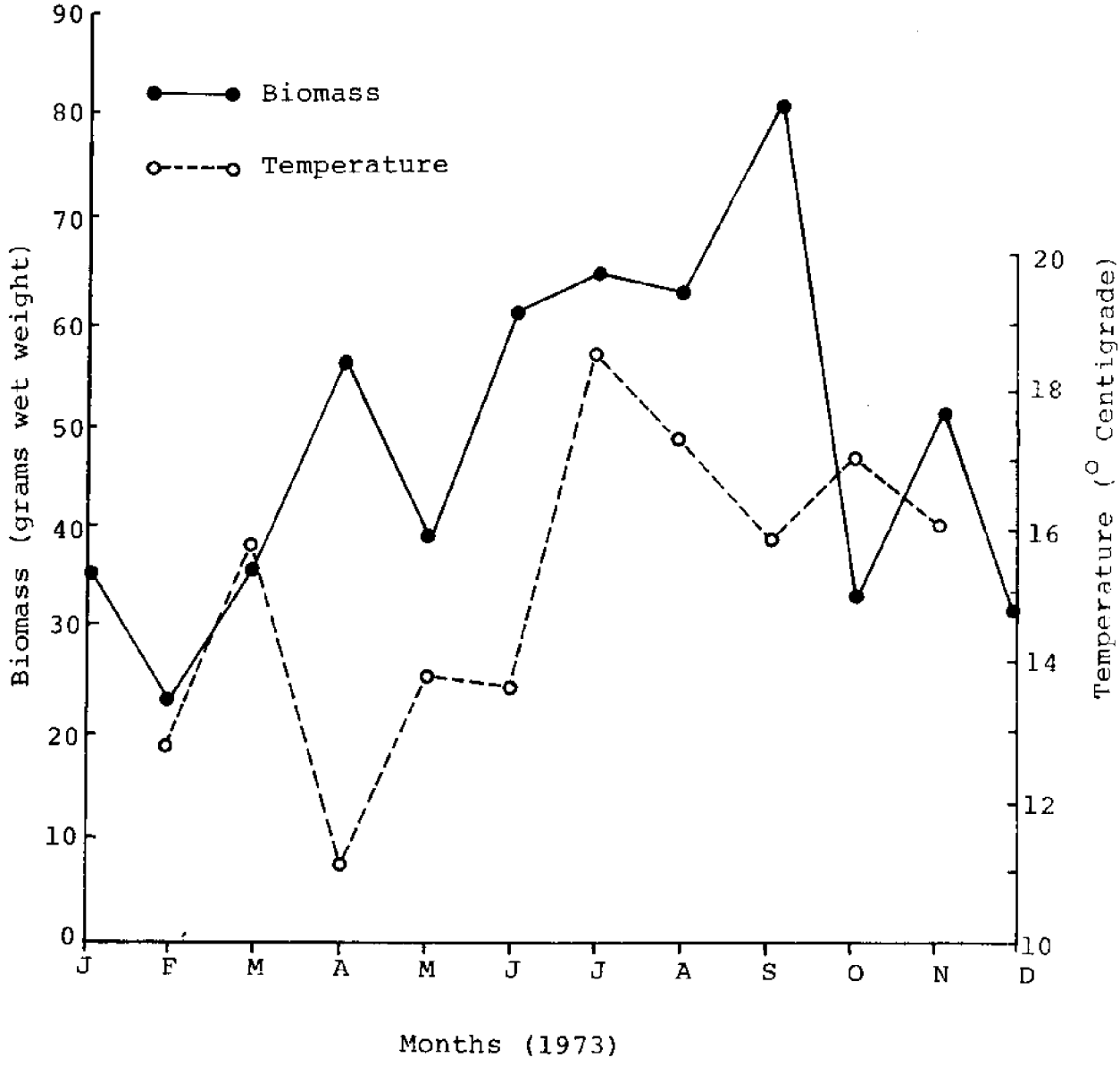


Figure 6. Seasonal Average Settling Biomass and Temperature at Station A3, 1973.

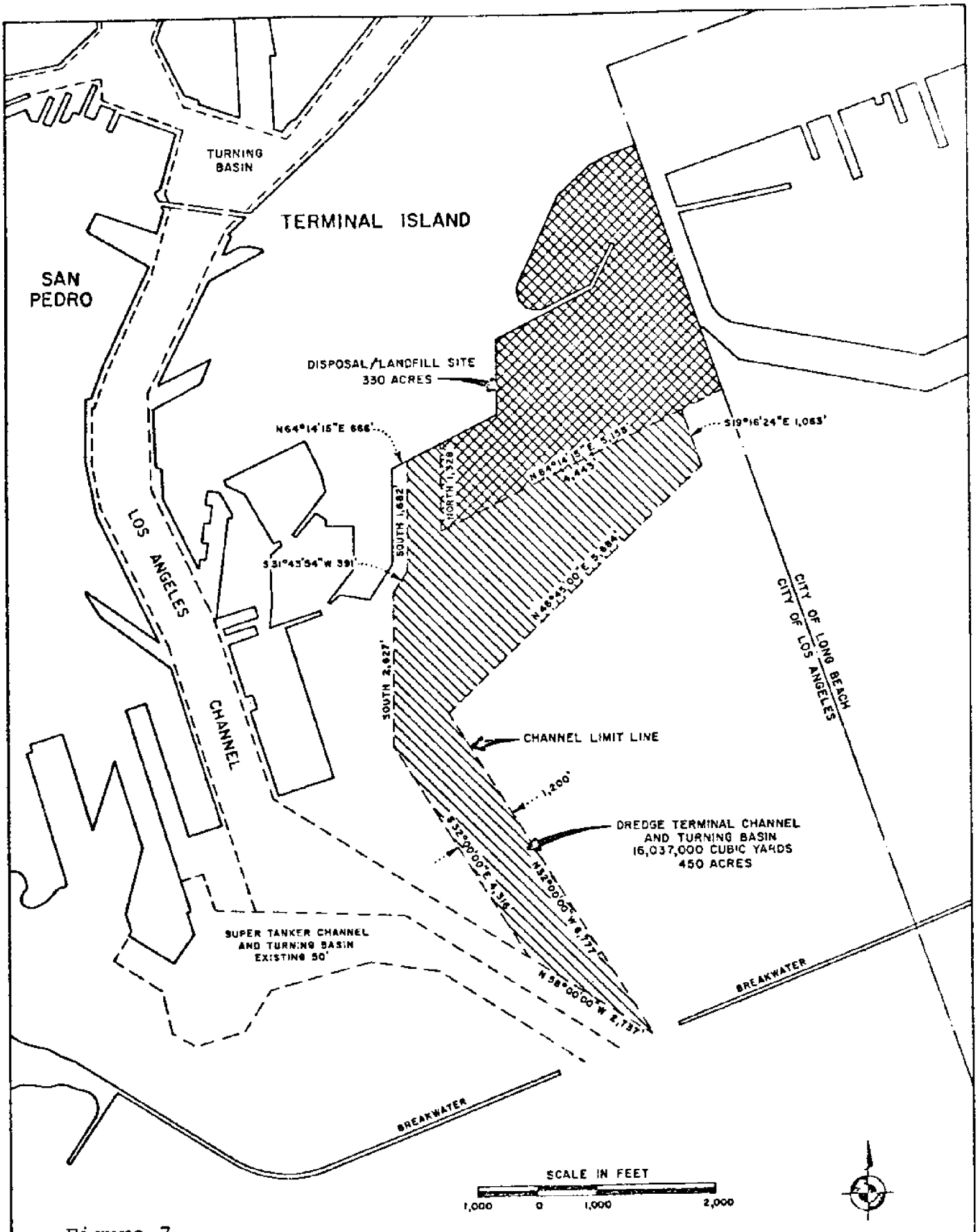
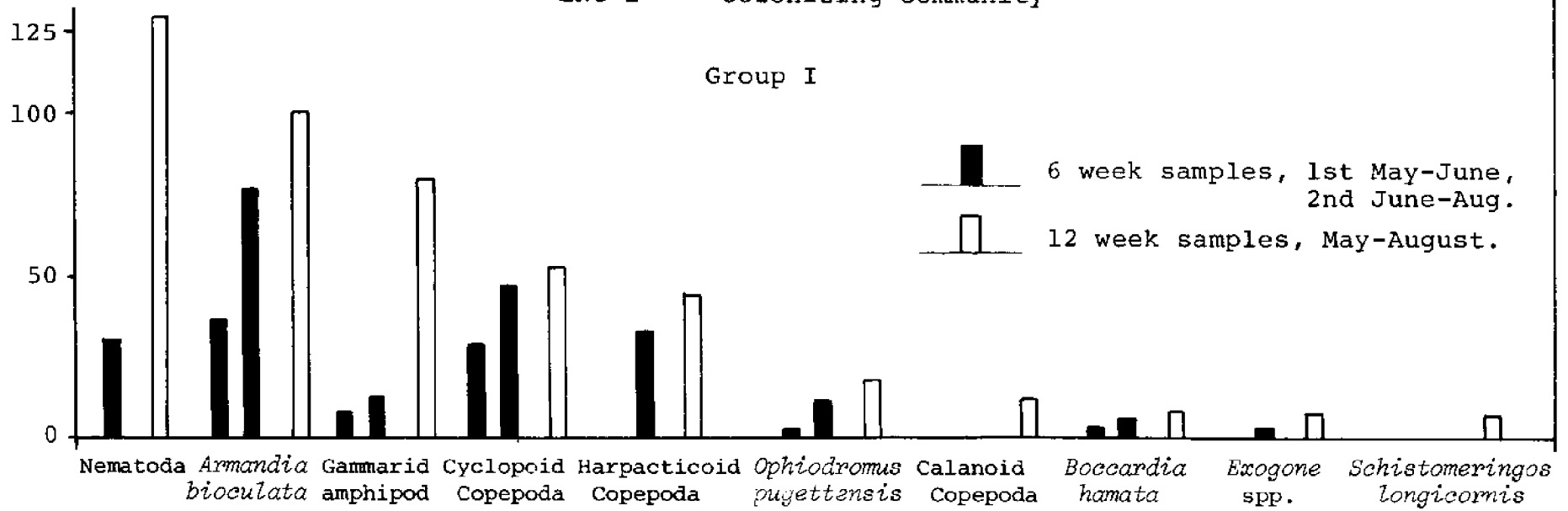


Figure 7.

SCALE SHOWN	DATE	PLAN - LNG TERMINAL	
DRAWN ML	2/74	DREDGE & DISPOSAL SITES	
CHECKED			
ENGINEER L.H. Anderson	ASSISTANT CHIEF HARBOR ENGINEER	APPROVED CHIEF HARBOR ENGINEER	PORT OF LOS ANGELES ENGINEERING DIVISION P.O. BOX 151 SAN PEDRO CALIF.
			DRAWING NUMBER 5-4348

Figure 8

LNG 1 - Colonizing Community



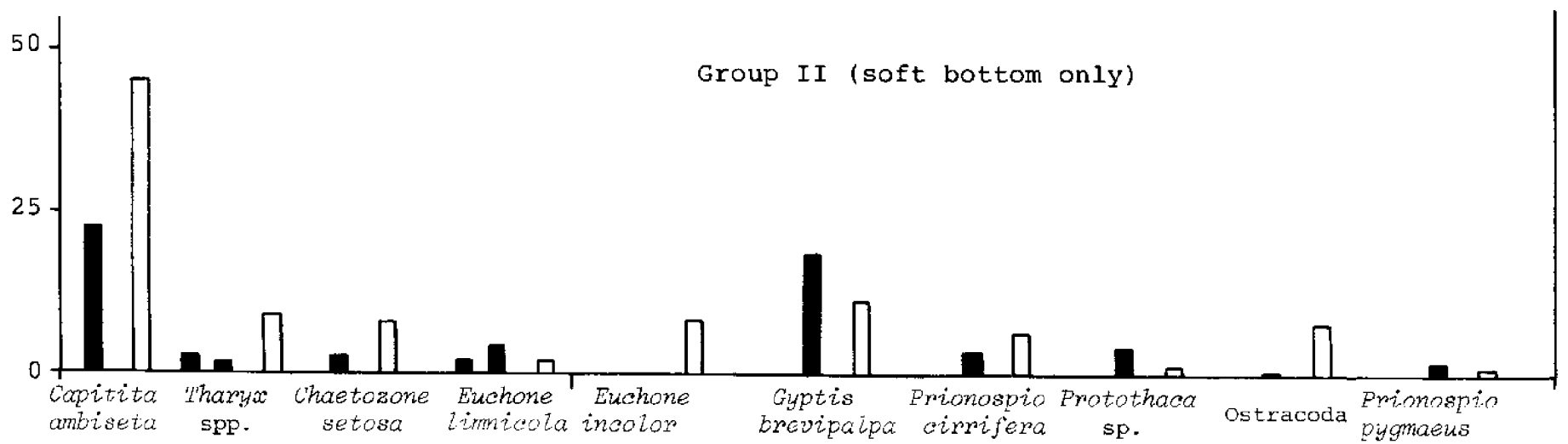


Figure 9

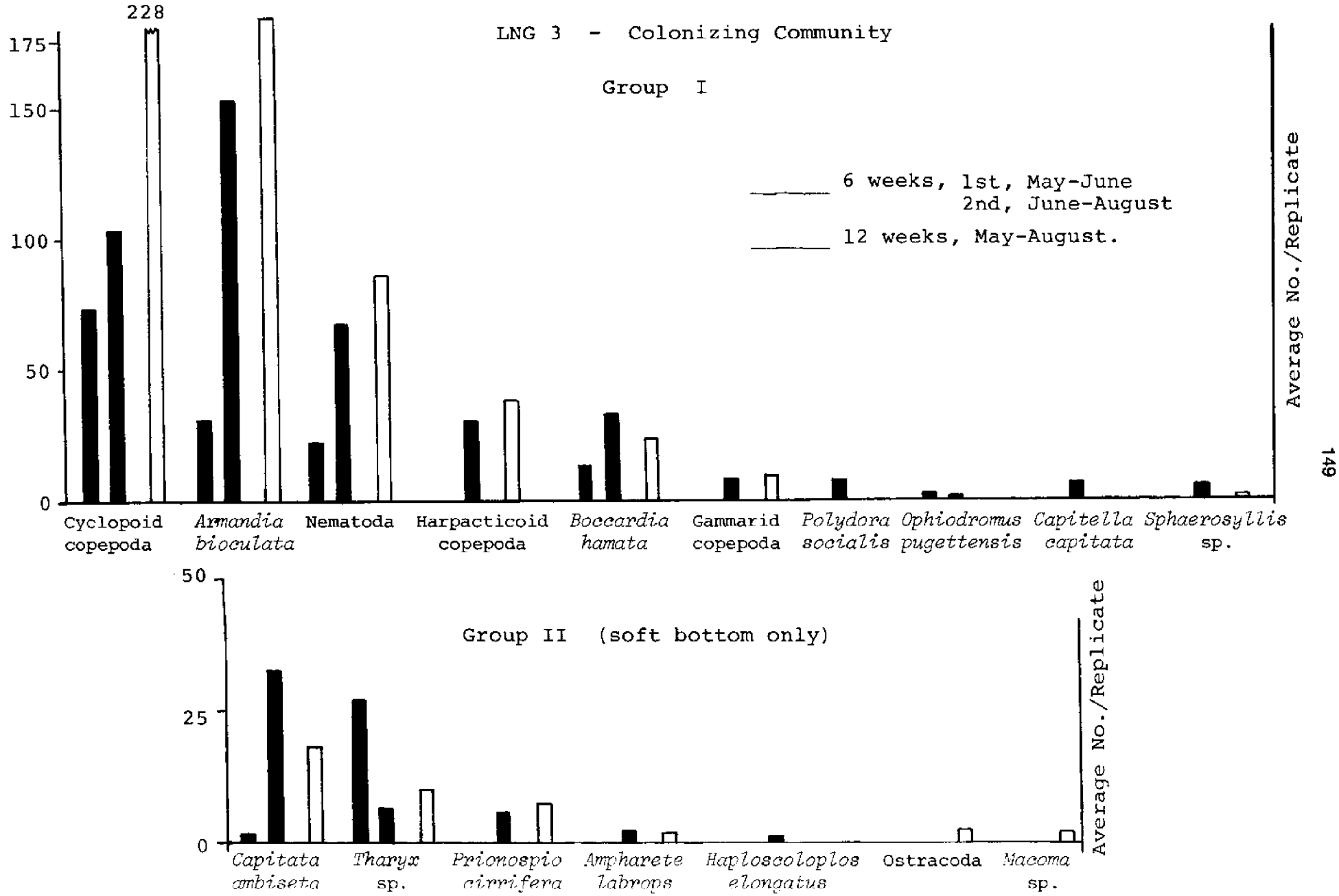

LNG 3 - Colonizing Community
Group I
6 weeks, 1st, May-June
2nd, June-August
12 weeks, May-August.
228
175
150
100
50
0
Average No./Replicate
Cyclopoid copepoda
Armandia bioculata
Nematoda
Harpacticoid copepoda
Boccardia hamata
Gammarid copepoda
Polydora socialis
Ophiodromus pugettensis
Capitella capitata
Sphaerosyllis sp.
Group II (soft bottom only)
50
25
0
Average No./Replicate
Capitata ambiseta
Tharyx sp.
Prionospio cirrifera
Ampharete labrops
Haploscoloplos elongatus
Ostracoda
Macoma sp.

Figure 10

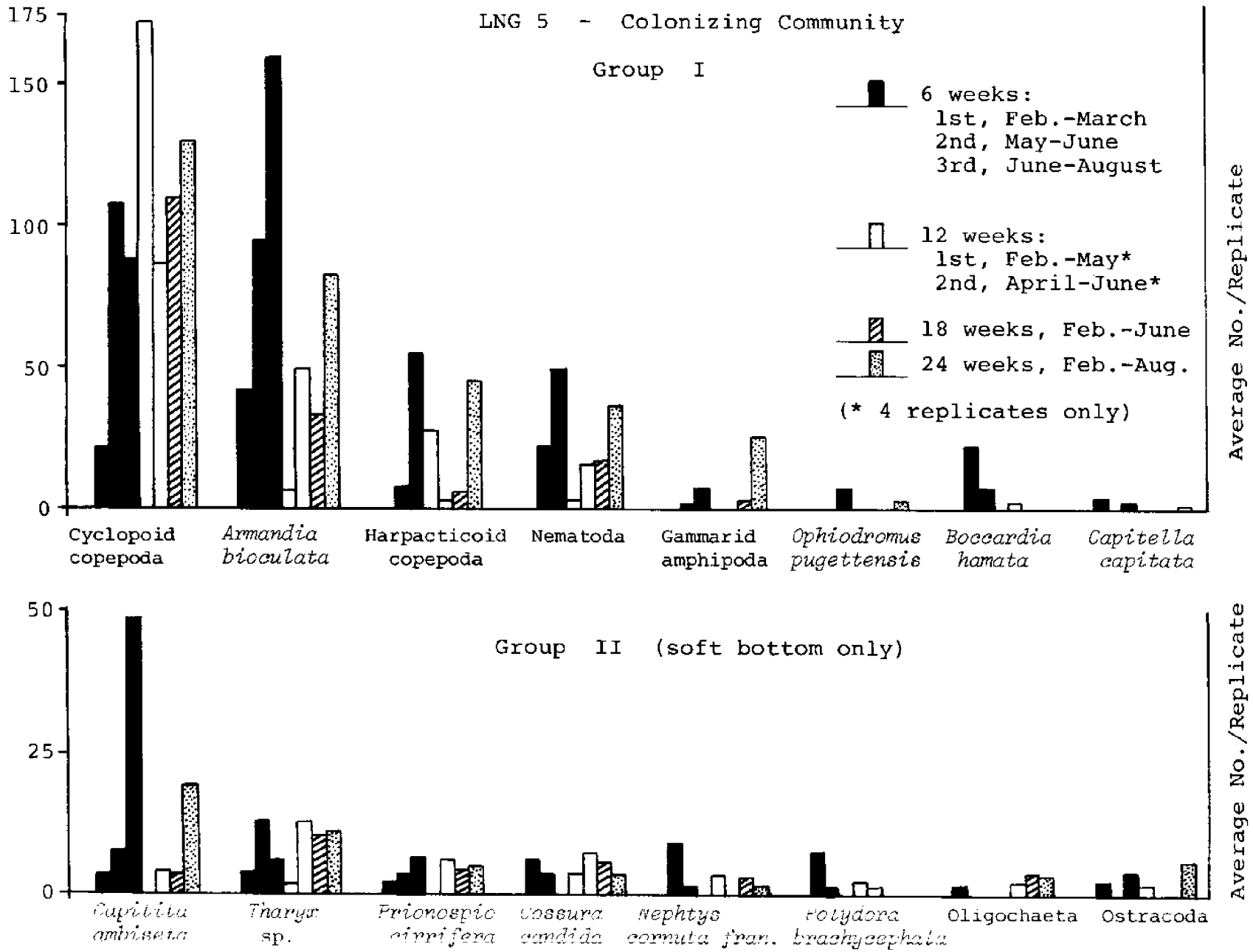

LNG 5 - Colonizing Community
Group I
6 weeks:
1st, Feb.-March
2nd, May-June
3rd, June-August
12 weeks:
1st, Feb.-May*
2nd, April-June*
18 weeks, Feb.-June
24 weeks, Feb.-Aug.
(* 4 replicates only)
Average No./Replicate
175
150
100
50
0
Cyclopoid copepoda
Armandia bioculata
Harpacticoid copepoda
Nematoda
Gammarid amphipoda
Ophiodromus pugettensis
Boccardia hamata
Capitella capitata
Group II (soft bottom only)
Average No./Replicate
50
25
0
Capitella ambiseta
Tharyx sp.
Prionospio cirrifera
Cossura candida
Nephtys cornuta fran.
Polydora brachycephala
Oligochaeta
Ostracoda

Figure 11

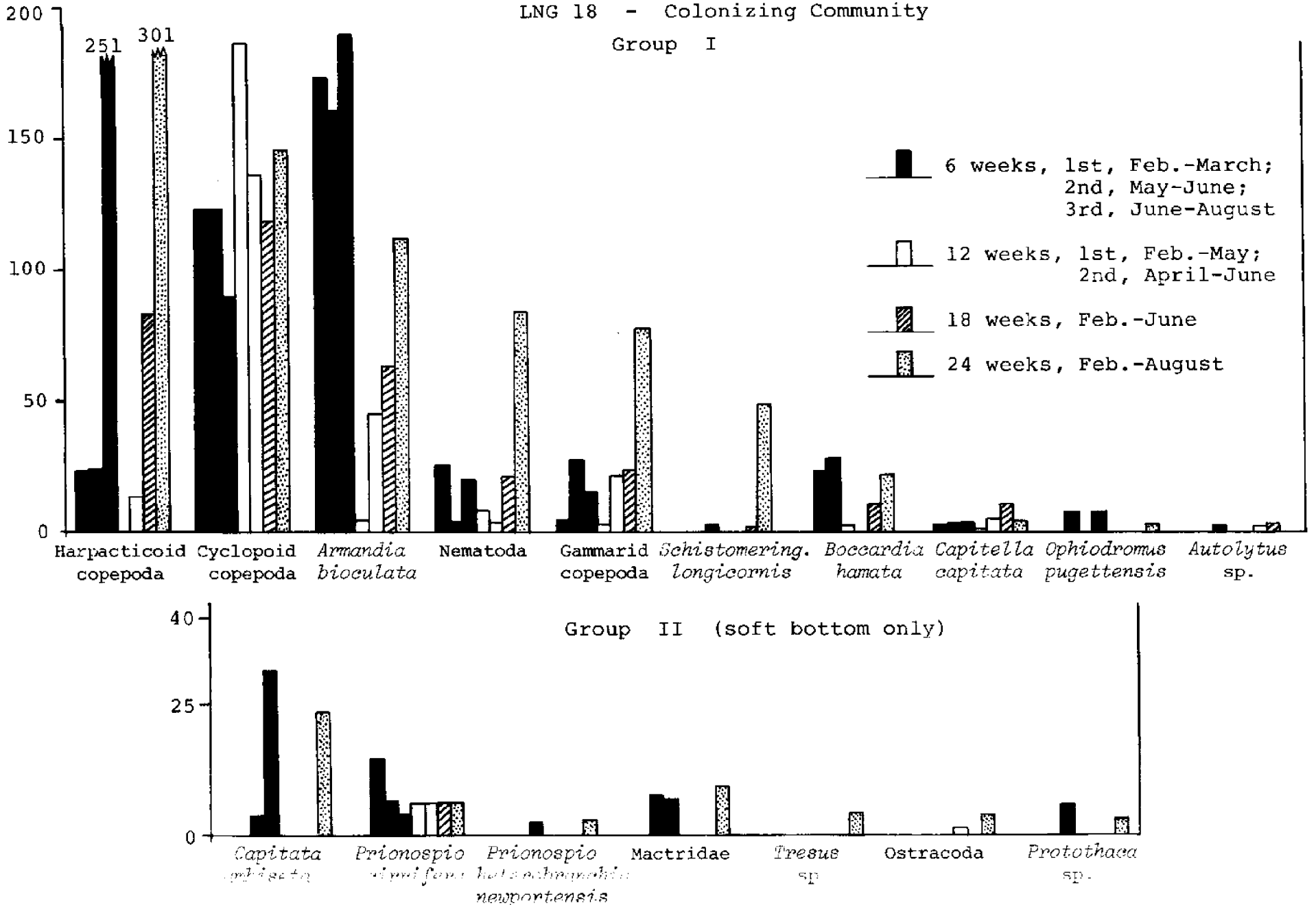

LNG 18 - Colonizing Community
Group I
200
150
100
50
0
251
301
6 weeks, 1st, Feb.-March;
2nd, May-June;
3rd, June-August
12 weeks, 1st, Feb.-May;
2nd, April-June
18 weeks, Feb.-June
24 weeks, Feb.-August
Harpacticoid copepoda
Cyclopoid copepoda
Armandia bioculata
Nematoda
Gammarid copepoda
Schistomering. longicornis
Boccardia hamata
Capitella capitata
Ophiodromus pugettensis
Autolytus sp.
Group II (soft bottom only)
40
25
0
Capitata
Prionospio
Prionospio
newportensis
Mactridae
Tresus sp
Ostracoda
Protothaca sp.

Figure 12

LNG 24 - Colonizing Community

Group I

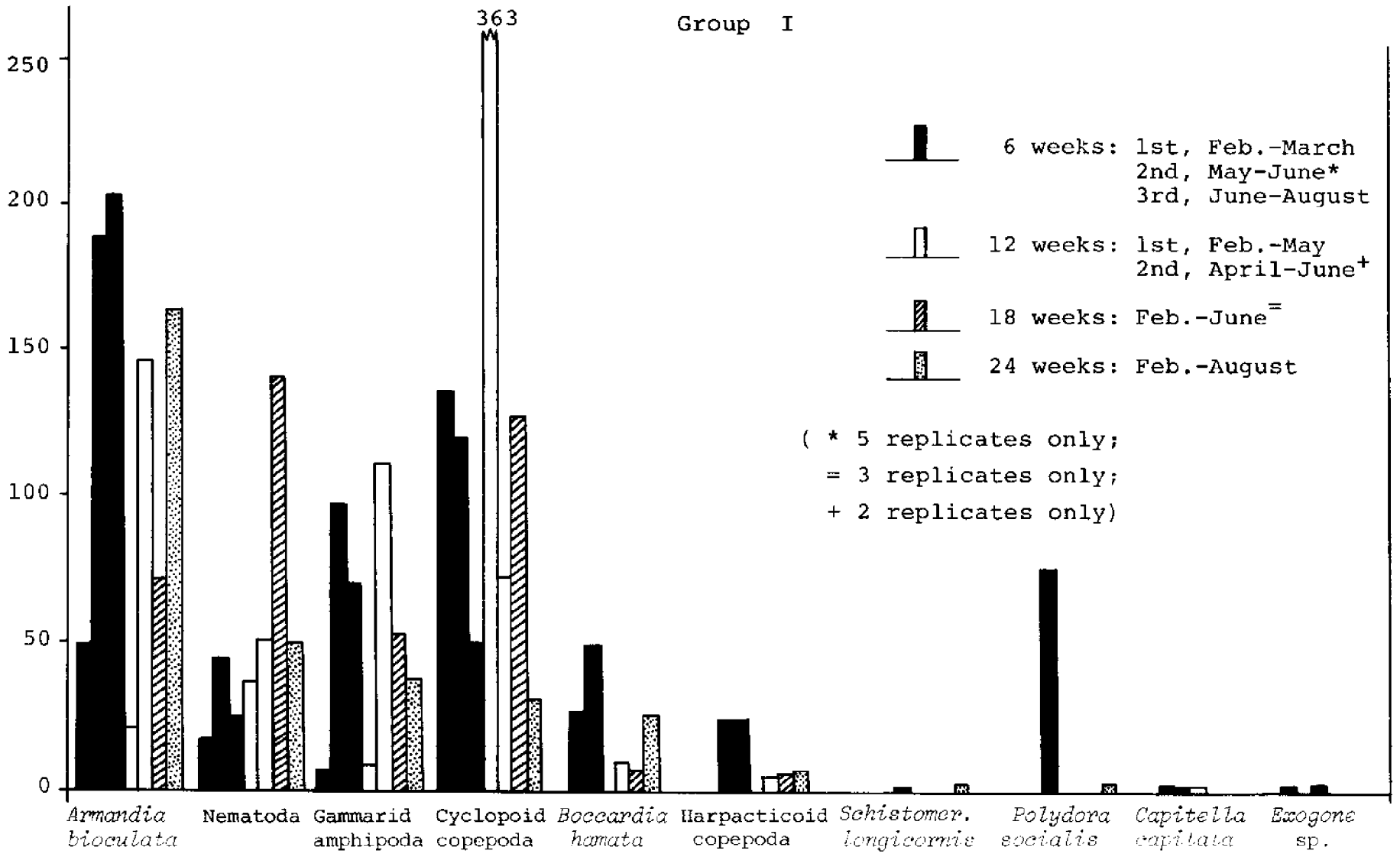
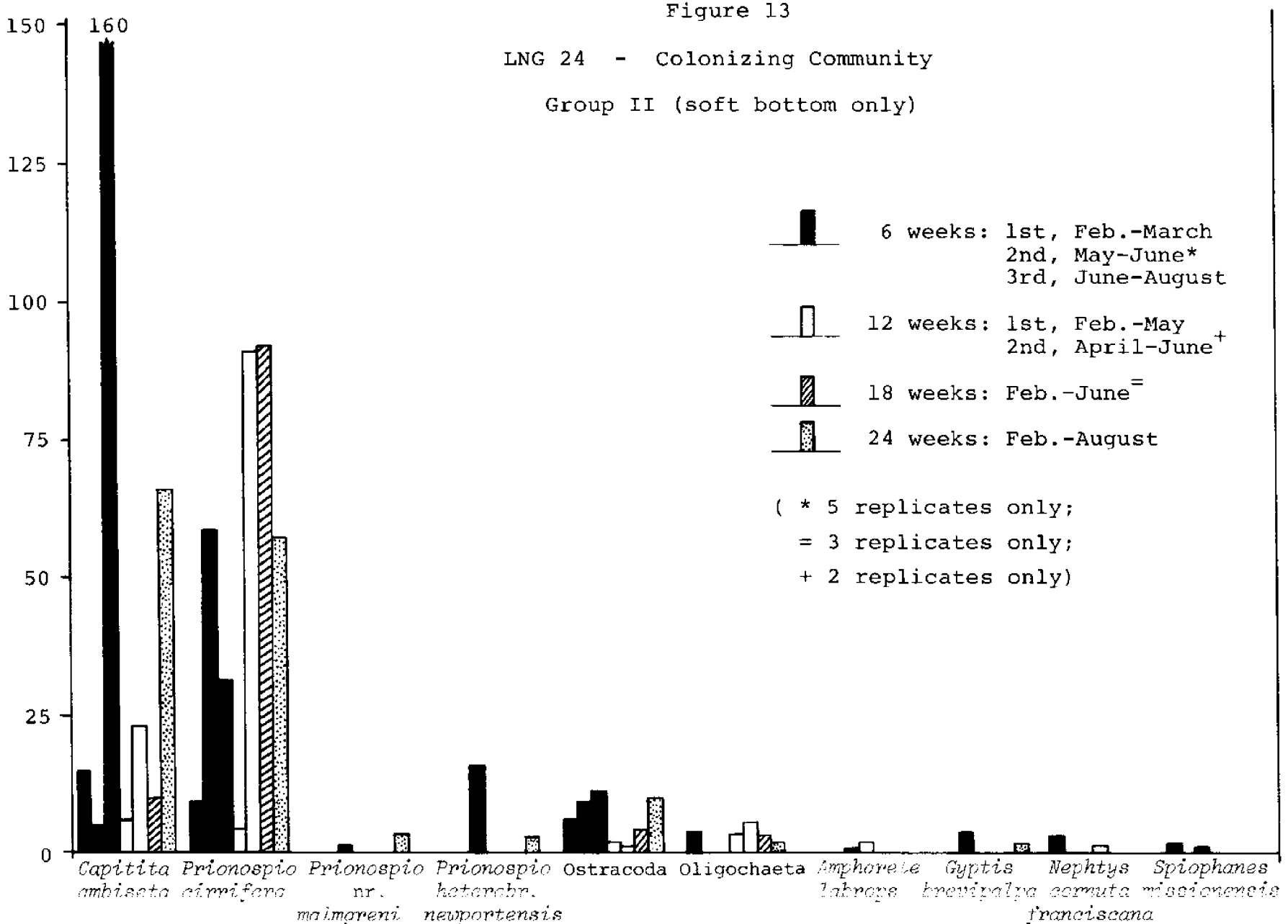


Figure 13

LNG 24 - Colonizing Community

Group II (soft bottom only)



MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART 11

June, 1976

WATER QUALITY EVALUATION OF DREDGED MATERIAL DISPOSAL FROM LOS ANGELES HARBOR

by

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ABSTRACT. An intensive physico-chemical characterization of seawater and sediments from the Los Angeles Harbor was conducted for the evaluation of potential water quality impact of future dredging activities.

The EPA Standard Elutriate Test as well as short-term and long-term experiments were performed to simulate hydraulic dredging operations for both open water and dike disposal of polluted sediments. The results show that redissolution of trace metals and the release of chlorinated hydrocarbons were insignificant in comparison with established ocean water criteria. Trace contaminants associated with suspended particulates may present a potential water quality problem. One possible solution to this problem is the treatment of sediment-seawater mixtures by the addition of selected flocculants to improve the settling characteristics of those particles.

The disposal of fill material in a confined area with proper treatment, for example, flocculation, can effectively reduce the transport of suspended contaminants to the receiving water course. With a detention time of 1-2 hours, the concentration of trace metals, suspended solids, and turbidity can easily meet both CSWRCB and EPA water quality standards.

In open water disposal, very low levels of contaminants are released. The dilution that would normally occur would be expected to rapidly reduce any released contaminants to essentially ambient water column levels. As a result, no long-term water quality problems are expected from the release of contaminants to the water column at the disposal site.

WATER QUALITY EVALUATION OF DREDGED MATERIAL DISPOSAL FROM LOS ANGELES HARBOR

INTRODUCTION

The continuing rapid population and industrial growth of the southern California area plus the planned import of large quantities of oil and natural gas in deep draft supertankers and LNG carriers have dictated the need for expanded port facilities in San Pedro Bay harbors. The Port of Los Angeles is scheduled to undertake many major dredging and marine construction projects within the next decade.

Due to the scarcity of reliable data, many concerns have been expressed over the possible degradation of water quality resulting from these activities.

Sediments are known to contain the major fraction of trace metals, chlorinated hydrocarbons, and nutrients in aquatic environments. The question of whether sediments are a source or a sink for trace metals has been a subject of controversy. During dredging operations, migration of chemical species may take place depending on the existing environmental conditions. After resettlement of dredged material, new sediment-water interfaces are formed. Changes in the environmental condition of the overlying water will influence the migration of chemical constituents between the sediment and surrounding waters.

Due to a scarcity of definitive information on the bioavailability of contaminants and nutrients, national and regional EPA guidelines for the discharge of dredged material have been very conservative. Many investigators have questioned the rationale and relevancy of these guidelines as an adequate indicator of the pollution potential of dredged or fill material.

This study was initiated in December 1973 with special emphasis on the physico-chemical characterization of sediments from the Los Angeles Harbor area, and the evaluation of potential water quality degradation resulting from the disposal of dredged and fill material. The short-term and long-term effects on water quality were investigated in conjunction with several treatment procedures.

CRITERIA AND GUIDELINES FOR EVALUATING THE DISCHARGE OF DREDGED MATERIAL IN NAVIGABLE WATERS

GUIDELINES FOR FEDERAL PERMITS

Guidelines published by the Environmental Protection Agency, in conjunction with the U.S. Army Corps of Engineers, are utilized by Corps District Engineers in the review of permit applications for the discharge of dredged or fill material in navigable waters (Corps of Engineers, 1975). These guidelines are applicable to any project or activity involving a discharge of dredged or fill material (EPA, 1975). Navigable waters are defined in Section 404 of the Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500, to mean "the waters of the United States, including the territorial seas" (EPA, 1975).

A brief history and analysis of national and regional EPA guidelines is presented to illustrate some of the problems and uncertainties confronting proposed dredging operations.

History and Analysis

May, 1971. The early EPA "Criteria for Determining Acceptability of Dredged Spoil Disposal to the Nation's Waters" were based entirely upon gross concentrations (EPA, 1971). These criteria were developed as guidelines for the evaluation of proposals and applications for permits to dredge sediments from fresh and marine waters. When one or more of the following pollution parameters exceeded the numerical limits expressed below, the sediment would be considered polluted in all cases and, therefore, would be unacceptable for open water disposal.

Chemical Constituent	Concentration, %, dry weight basis
Volatile solids*	6.0
Chemical oxygen demand (COD)	5.0
Total Kjeldahl nitrogen	0.10
Oil and grease	0.15
Mercury	0.0001
Lead	0.005
Zinc	0.005

* TVS % (dry) = 1.32 + 0.98 (COD%)

The term "open waters" was not specifically defined and is subject to interpretation; however, it is generally accepted that it applied to:

(1) all open ocean areas, bays, estuaries, lakes, and rivers

(2) all landfill projects in which the dredge spoil return waters are permitted to drain directly in such areas (Macfarlane, 1974).

May, 1973. Pursuant to the Marine Protection Research and Sanctuaries Act of 1972, Pub. L 92-532, the following "Standard Elutriate Test" was developed by the EPA in conjunction with the Corps of Engineers to determine the pollution potential of dredged materials prior to ocean disposal (EPA, 1973).

> Dredged material will be considered unpolluted if it produces a standard elutriate in which the concentration of no major constituent is more than 1.5 times the concentration of the same constituent in the water from the proposed disposal site used for the testing. The "standard elutriate" is the supernatant resulting from the vigorous 30-minute shaking of 1 part bottom sediment with 4 parts water from the proposed disposal site followed by 1 hour of letting the mixture settle and appropriate filtration or centrifugation. "Major constituents" are those water quality parameters deemed critical for the proposed dredging and disposal sites taking into account known point or area source discharges in the area, and the possible presence in their waste of the materials.

These criteria apply to "waters of the territorial sea, the contiguous zone, and the oceans" (EPA, 1973), and have been used to determine whether or not a particular sediment may be discharged in open waters or must be disposed of in diked areas or on land (Lee and Plumb, 1974).

October, 1973. The Region IX Office of the EPA, in consideration of the need for criteria applicable to the discharge of dredge spoil into navigable and ocean waters and based upon data representative of local environmental conditions, developed Regional Interim Dredge Spoil Disposal Criteria (DSDC). The Regional Office began application of the DSDC for review of dredge spoil disposal projects in October of 1973 (EPA, Region IX, 1973).

The resulting criteria represent the interpretation and implementation of the 1973 national guidelines for dredging projects in California by the Regional EPA office. The DSDC specified the "Standard Elutriate Test" plus the following additional analyses and numerical limits:

(1) Elutriate analysis. The following tests were required on the elutriate and water from the disposal site for all projects:
   (a) Immediate oxygen demand (prior to settling, on elutriate only)
   (b) Biochemical oxygen demand (5-day, 20°C)
   (c) Suspended solids
   (d) Organohalogens

   On disposal proposed for inland navigable waters, the following tests were required for projects greater than 50,000 cu yds:

   (a) Phosphorus (total)
   (b) Total Kjeldahl nitrogen
   (c) Nitrate

(2) Bottom sediment analysis. The following bottom sediment analyses (dry weight basis) were required for all projects:

Parameter	Limit (ppm)
Mercury	1
Cadmium	2
Lead	50
Zinc	130
Oil and grease	1500

October, 1974. The DSDC of October 1973 were revised in consideration of (1) guidance from Headquarters on national policy for discharge of dredge spoil into navigable waters, (2) review comments on the DSDC submitted by local, State, and Federal agencies and industries, and (3) additional information. Regional Interim Dredge Spoil Disposal Criteria were revised, based on these inputs (DSDC-R1; EPA, Region IX, 1974).

DSDC-R1 did not include the "Standard Elutriate Test" and established new limits for bottom sediment concentrations for shallow marine and estuarine waters. Development of the DSDC-R1 for toxic substances was limited to mercury, cadmium, lead, zinc, and oil and grease. The DSDC-R1 could be amended or revised to reflect new information or to include additional toxic pollutants where the findings of investigations or research so warrant. Development of numerical criteria

applicable to organic matter, nutrients, and suspended matter contained in dredge spoil is not anticipated at this time.

DSDC-R1 requirements are as follows:

Marine (Shallow) and Estuarine Water

Pollutant	Maximum Spoil Concentration, ppm (dry weight basis)
Mercury	1.5
Cadmium	3.0
Lead	180
Zinc	300
Oil and grease	4000

In DSDC-R1, Region IX of the EPA proposed restrictions for the discharge of fill material as follows:

(1) No permit shall be issued for the discharge of fill material without evaluation of (a) the need for the preparation of an environmental impact statement, and (b) the probable environmental impact of the fill discharge, of the activities on the fill site, and of further development on the fill site.

(2) No permit shall be issued for the discharge of fill material when the Regional Administrator determines that the material contains unacceptable quantities, concentrations, or forms of heavy metals, nutrients, pesticides, polychlorinated biphenyls, petroleum and non-petroleum oil and grease, oxygen-demanding substances, or materials designated as toxic pollutants, in accord with Section 307 of the FWPC Act, unless such material is effectively confined so as to prevent leaching, discharge, or erosion of the material outside of the confinement.

It is concluded from the foregoing statements that fill material may be confined in a diked area provided the effluent outflow meets applicable water quality standards.

May, 1975. On May 6, 1975, the EPA issued proposed guidelines to be used in controlling the discharge of dredged or fill material into navigable waters (EPA, 1975, "Navigable Waters--Discharge of Dredged or Fill Material"). Dredged material and fill material are defined as follows:

Dredged material--Any material in excess of one cubic meter when used in a single or incidental operation, excavated or dredged from navigable waters, including without limitation, runoff or overflow which occurs during a dredging operation or from a contained land or water disposal area.

Fill material--Any material discharged into navigable waters for a purpose other than disposal, including without limitation, the creation of fast land, or the production of intended elevation of land beneath the water.

Three interim test procedures were stipulated in the proposed guidelines: (1) elutriate test, (2) sediment analysis, and (3) total suspended solids. A brief description of the requirements follows.

Elutriate test. The elutriate test was initially specified by the EPA in May 1973. The following changes were incorporated into the proposed guidelines of May 1975.

(1) The test is required for both dredged and fill material.

(2) In cases where confined disposal is proposed, the elutriate test is used to determine if return flow will require restricted discharge conditions. The discharge site will be that area receiving return flows from the confined disposal area.

(3) The standard elutriate is prepared with water from the dredging site instead of using water from the proposed disposal site as previously required (EPA, 1973).

(4) A dilution factor of 10 is permitted to determine compliance with the 1.5 concentration requirement, based on the proposed disposal site.

(5) A final 0.45 μm filtration is required.

(6) Major constituents are those parameters deemed critical by the District Engineer and the Regional Administrator.

Sediment analysis. Extraction of total concentrations of parameters from a weighed portion of dredged or fill material will be accomplished by concentrated strong acid action for

inorganic parameters and solvent extraction for organic parameters. The resultant extracts will be individually analyzed by standard EPA procedures for major constituents.

Suspended solids. In the event that suspended solids (mg/l) are identified as a major constituent, one part of the 1:4 sediment-seawater slurry shall be withdrawn immediately upon completion of the 30-minute shaking period and dispersed within 10 parts (v/v) of water from the proposed discharge site, allowed to settle for 1 hour, and the uppermost layer analyzed gravimetrically for suspended solids. This result will then be compared to 1.5 times the ambient suspended solids concentration at the proposed discharge site.

Dredged or fill material will require restricted disposal conditions, if upon evaluation the results of the tests specified are deemed unacceptable by the Regional Administrator and the District Engineer.

Considerations for restricted disposal conditions include the following:

(1) Appropriate scientific literature, such as the National Water Quality Criteria developed by the Administrator, EPA, pursuant to Section 304(a) of the FWPC Act.

(2) Alternatives to open water disposal such as upland or confined disposal.

(3) Disposal sites where physical environmental characteristics are most amenable to the type of dispersion desired.

(4) Disposal seaward of the baseline.

(5) Covering contaminated dredged material with cleaner material.

(6) Conditions to minimize the effect of runoff from confined areas on the aquatic environment.

September, 1975. On September 5, 1975, the EPA issued interim final guidelines in order to provide immediate guidance in the implementation of the permit program under Section 404 of the Water Pollution Control Act Amendments of 1972 (EPA, 1975, "Navigable Waters--Discharge of Dredged or Fill Material"). Interim guidance to applicants concerning the applicability

of specific approaches or procedures will be furnished by the District Engineer.

These interim final guidelines are essentially a clarification of the May 6, 1975, proposed guidelines. Some of the changes made were based on comments received on various sections of the proposed guidelines of May 1975. The elutriate test, sediment analysis, and bioevaluation will be used, where appropriate, to determine the suitability of proposed disposal sites. One important change was the removal of 1.5 factor in the elutriate test in determining the potential effect of disposal of dredged materials. The EPA also acknowledges that no single test can be applied in all cases to evaluate the effects of proposed discharges of dredged or fill material. Technical evaluations will be required only when a case-by-case review indicates that the results will provide information necessary to reach a final decision. The results of an appropriate technical evaluation will serve as one of many factors involved in the decision-making process.

The national EPA guidelines of May 6 and September 5, 1975, indicate the elutriate test and sediment analysis may be required for both open water and confined disposal of dredged and fill material. The interpretation and implementation of the national guidelines by the Region IX office of the EPA is not available at the time of this publication.

There are strong reservations within the scientific community over the rationale and relevancy of the elutriate test and bulk sediment analysis as indicators of the pollution status of dredged or fill material. Critical comments by various investigators are presented in the following paragraphs.

Sediment analysis. Rationale: Suitability of the proposed disposal sites may be evaluated by the use of sediment analysis. Markedly different concentrations of critical constituents between the excavation and disposal sites may aid in making an environmental assessment of the proposed disposal operation (EPA, 1975).

Comments:

(1) Little is known about the relationship between the concentrations of various chemical constituents within sediments subject to dredging and disposal operations, and the consequent effects on water quality (Boyd, 1972).

(2) The presence of a constituent (toxin, biostimulant, etc.) in the sediment does not indicate or predict the nature and significance of adverse effects following disposal. This is because many chemical constituents found in sediments are

not bioavailable and do not react as pollutants (Keeley and Engler, 1974).

(3) A review of the literature on the release of chemical contaminants from dredge material and natural water sediments has shown that the bulk chemical composition is not a useful index of potential environmental quality problems for waters coming in contact with these sediments (Lee and Plumb, 1974).

(4) Gross sediment concentrations may not bear direct or linear relationship to biological potentials (Chen and Lu, 1974).

Obviously, most studies show that no direct correlation exists between the amounts of release/removal of metals and the gross metal content in the bulk sediment; therefore, the bulk chemical composition of the dredged sediment is not a proper index for indicating the potential polluting status of the sediments.

Elutriate test. Rationale: The elutriate test is used to predict the effect on water quality due to the release of contaminants from the sediment to the water column (EPA, 1975).

Comments:

(1) The elutriate test is a poor simulation of the environment affecting the availability of heavy metals in fresh and estuarine waters, or in marine waters, where the benthic community is a major concern (EPA, Region IX, 1974).

(2) The elutriate analysis points to a short-term water quality effect. However, such a procedure presents tremendous difficulties in practice. At present, the most serious problem in establishing such criteria is the extreme difficulty in evaluating the validity of data from seawater studies. The analysis of trace metals in seawater generally requires a highly sophisticated and elaborate laboratory setup with meticulous cleaning procedures. Even so, the variation of data from one laboratory to another is tremendous (Patterson, 1974). To create a new test such as the "Standard Elutriate Test" without thoroughly testing it prior to adoption certainly creates serious problems for the enforcement of regulations. The cost of setting up the necessary equipment to perform a meaningful study is generally beyond the reach of most laboratories. Additionally, the standard elutriate test as outlined in the EPA guidelines does not take into consideration the possible changes of environmental variables which may alter the availability of toxicants and nutrients for biota (Chen and Lu, 1974).

(3) It has been questioned whether water from the proposed project site (dredging site) should be mixed with the sediments or whether water from the proposed disposal site should be used. It can be argued that dredging site water should be used, since the test is designed to simulate the hydraulic dredging process. The ratio of sediment to water approximates the normal hydraulic pumping ratio; the vigorous shaking simulates the actual hydraulic dredging process; and during this process, net changes in dissolved concentrations may occur. On the other hand, this does not necessarily take into account changes that may occur at the disposal site due to environmental conditions different from those at the dredging site (Keeley and Engler, 1974).

It should be noted that national EPA guidelines have vacillated on this point. On May 16, 1973, the EPA specified water from the disposal site for preparation of the standard elutriate; on May 6, 1975, the requirement was changed to the use of water from the dredging site.

(4) The 1.5 factor has no toxicological or any other ecological basis. It is meant instead to serve as a guide to the amount of increase in dissolved chemical concentrations that should be allowed before taking into account dilution at the disposal site. However, if dissolved concentrations using project site water do not exceed the 1.5 factor, it is thought that dilution at the disposal site will reduce dissolved concentrations below any harmful levels (Keeley and Engler, 1974).

(5) It is possible that a disposal site might be selected, based on the 1.5 factor, which would allow a greater deterioration of water quality than would occur if this factor was not utilized. A key part in the 1.5 factor is the ambient concentration of selected chemical species in the disposal site water. It is possible that, by selecting a water with a high ambient background of a particular chemical species released in the elutriate test, disposal of dredge material would cause the waters in the disposal region to exceed the critical concentration for certain forms of aquatic life but not 1.5 times the ambient concentration. It is clear that the 1.5 factor should not be used as a rigid standard, but to detect potential problems. The proper interpretation of the amount of release that occurs requires consideration of the contaminant assimilative capacity in the disposal site water column relative to the critical concentration for this contaminant to selected organisms in the water column (Lee and Plumb, 1974).

(6) The arbitrary application of the 1.5 factor to determine whether a particular sediment is "polluted" is no

more technically sound than using bulk analysis. The proper interpretation of the elutriate test results requires consideration of the existing concentrations of each of the water quality parameters of concern in relationship to the amount of increase in concentrations that would occur in the disposal area. The sum of these two must be examined in light of the critical concentrations of the parameter for aquatic life of the receiving water (Lee and Plumb, 1974).

(7) It should be emphasized that the elutriate test is designed primarily to detect potential problems that could occur in the water columns of the respective areas during dredging and disposal. This test should also detect any potential problems occurring due to resuspension of the dredge material at the disposal site. It will not readily detect problems associated with dredging which are related to the physical effects of solids deposition on aquatic organisms, nor will it detect, to any significant extent, problems associated with dredging that may arise from the presence of chemical contaminants to benthic organisms. The environment that exists in the dredged sediments of the disposal site will probably be markedly different from the environment existing in the water columns at the dredging and disposal sites.

A review of the literature on the leaching of contaminants from dredge material and sediments shows that a wide variety of factors could affect the results of the elutriate test, including solid-liquid ratio, time of contact, pH, dissolved oxygen concentration, agitation, particle size, handling of solids, characteristics of water and sediments, and solid-liquid separation. It is apparent that a considerable amount of research is needed to establish the significance of these factors to the elutriate test results, for the many types of sediments that are likely to be dredged (Lee and Plumb, 1974).

The EPA acknowledges that many questions remain to be answered regarding means of evaluating the effects of dredged or fill material discharged in navigable waters (EPA, 1975).

Functionally, the elutriate test will measure the amount of trace contaminants and nutrients in the interstitial water and exchangeable phases of the sediments. However, any release factor should only be considered as an indicator as to whether the sediment involved will release chemical constituents from the solid phase into the solution phase. It may carry no ecological implication that any biota will be significantly affected or that water quality is impaired.

It is concluded, based on the foregoing comments, that the elutriate test and sediment analysis are not adequate for determining the potential water quality impact resulting from the disposal of dredged or fill materials. Sediment analyses and elutriate tests for Los Angeles Harbor sediments are presented for comparison with the current guidelines.

This study was conducted under the assumption that the proposed dredging project will utilize either one of two methods of disposal: (1) confined disposal in a diked area, or (2) open water disposal. In the case of confined disposal, any degradation of water quality would be that caused by the effluent return from the diked area. Since this represents a source of discharge into ocean waters, the effluent quality requirements established by the California State Water Resources Control Board (CSWRCB) should be the applicable criteria in the absence of other relevant regulations. The requirements are given in Table 11 (CSWRCB, 1972). The same rationale for applicable criteria for open water disposal is applied.

Since each discharge of dredged or fill material into a navigable water is, in effect, the discharge of a pollutant into the water, a State water quality certification is required under Section 401 of the FWPC Act of 1972. Thus, any state may cause the denial of a Section 404 permit if it chooses to deny a water quality certification. Where a state denies a permit, the Corps of Engineers will not issue a Section 404 permit. On the other hand, if a state issues a permit, the Corps would not deny its permit unless there are overriding environmental factors, as reflected in the EPA guidelines (EPA, 1975).

In California, dredging of marine or freshwater sediments and subsequent disposal of the spoils are subject to a variety of existing, proposed, or inferred criteria, standards, and policies. These have been formulated by the EPA (national and Region IX), the California Coastal Zone Commission, the Regional California Coastal Zone Commissions, the Bureau of Fisheries and Wildlife, the California State Water Resources Control Board, the California Regional Water Quality Control Boards, and the California Department of Fish and Game (Macfarlane, 1974).

Nine California Regional Water Quality Control Boards are responsible for maintaining water quality in the State's inland and coastal waters. Any project which might affect water quality must comply with discharge requirements set by the governing regional board following a formal public hearing. The regional boards have at times required several

additional tests or procedures not required by other agencies, including:

(a) analysis of composite samples from entire cores
(b) fish bioassays
(c) limited monitoring procedures for approved dredging operations
(d) chemical analysis of interstitial waters extracted from sediment samples.

The Bureau of Sport Fisheries and Wildlife has, in the past, specified that additional coring and analysis, beyond that required by the EPA and the California Regional Water Quality Control Boards, must be carried out for harbor dredging projects involving the disposal of polluted spoils. The California Department of Fish and Game also has an interest in the ecological impacts of spoils in areas where substantial habitat damage is possible. But the department has not specified any requirements for analyzing dredge spoils (Macfarlane, 1974).

Additional marine water quality criteria have been proposed during the past two years (EPA, 1973 and 1975). The applicability of these criteria for open water and confined disposal has not been established. The proposed criteria are given in Table 11.

COMPARISON OF SEDIMENT ANALYSIS AND STANDARD ELUTRIATE TEST WITH NATIONAL AND REGIONAL EPA REQUIREMENTS

In this study physical-chemical properties of sediment samples from the Los Angeles Harbor area have been characterized with respect to trace metals, nutrients, and other chemical constituents. Sediment samples from the Los Angeles Harbor were collected by stainless steel Reinecke or Campbell grab sampler from the Velero IV and Golden West, ocean-going research vessels operated by the Hancock Foundation of the University of Southern California. The location of sampling stations is shown in Figure 1. Efforts were made to eliminate all possible contamination during the sampling process. Cores or grabs were sliced open with Teflon knives and samples were taken from the interior to avoid surficial contamination. Sediment samples were sealed in plastic bags and stored in ice at 4°C for transport to the laboratory, where the well-mixed subsamples were transferred into an airtight plastic container in a glove bag under nitrogen atmosphere. The samples were stored in a refrigeration unit at approximately 4°C until used. At no time were the sediment samples frozen. Analytical methods are detailed in other publications (Chen and Lu,

1974; Chen et al., 1976).

For each constituent, the reported number is the average of three separate analyses determined on three sediment samples from the same location. Sediment compositions are given in Tables 1 and 2. Complete particle size distribution analyses by pipette methods were carried out for the textural composition of LNG sediment samples. The data are listed in Table 3 (Chen and Wang, 1974); classification and size distribution in Figures 2-7a. The sediments can be classified into the following comparative groups according to particle size distribution: sandy, sandy silt, silty sand, silty clay, and clay silt (Tables 3 and 4).

Bulk Sediment Analysis. Summarized results of the sediment analyses for trace elements and oil and grease are given in Table 5. The natural background level of trace elements in the San Pedro Basin are given in Table 6 (Chen and Lu, 1974). A comparison of the referenced data indicates that most surface sediments in the Los Angeles Harbor are grossly contaminated with respect to the natural background levels. It should be realized that many sediments may have substantially higher values than those presented in the table. In addition, the so-called natural background levels are not uniform throughout the area. It simply represents the lowest concentration that can be found.

Sediment concentrations of cadmium, lead, mercury, zinc, and oil and grease are compared with the current EPA Region IX Interim Dredge Spoil Disposal Criteria, Revision 1 (DSDC-R1) of October 1974 (Table 5). The data indicate that many stations exceed the maximum allowable concentrations. Cadmium presents the greatest difficulty; approximately 44% of the Los Angeles Harbor stations exceed the allowable limit.

As stated previously, it has been concluded from a comprehensive literature review and analysis of available data, that the sediment analysis and elutriate test criteria are not relevant or adequate for predicting the water quality impact resulting from the disposal of dredged or fill material.

Standard Elutriate Test. The latest procedure for the Standard Elutriate Test is presented in the EPA interim Final Guidelines of September 5, 1975, as follows.

Elutriate Test. The elutriate is the supernatant resulting from the vigorous 30-minute shaking of one part bottom

sediment from the dredging site with four parts water (v/v) collected from the dredging site (representing the dredge slurry) followed by a one-hour settling period and appropriate centrifugation and 0.45 μm filtration. A schematic diagram for the Standard Elutriate Test is shown in Figure 8. Major constituents are those parameters deemed critical by the District Engineer and the Regional Administrator for the proposed dredging and disposal site, taking into account known sources of discharge in the area and known characteristics of the dredging and disposal sites.

Sediments normally contain constituents that exist in different chemical forms and are found in various concentrations in several locations within the sediment. The potentially bioavailable fraction of a sediment is dissolved in the sediment interstitial water or in a loosely-bound form that is present in the sediment. The short-term bioavailable fraction of a sediment is determined by the elutriate test.

A comprehensive analysis of sediment elutriate tests for the Los Angeles Harbor area was conducted. Seawater from the reference station (.5 miles outside the breakwater of the harbor, 33° 41.5'N, 118° 14.5'W) was used in all of the elutriate tests. Each five-gallon polyethylene container was thoroughly cleaned with acid and rinsed with demineralized redistilled water. Water samples were used within 24 hours of collection. Concentrations of trace metals in the referenced station are given in Table 7.

The elutriate test procedure in the referenced studies was established by the University of Southern California investigators and the environmental management group of the Los Angeles Harbor Department prior to December 1973. It should be pointed out that at the time these experiments were conducted, there was no knowledge of whether disposal would be permitted inside the harbor or at EPA-designated dump sites. Therefore, seawater from a standard reference station was selected and used throughout the investigations.

Summarized results from the sediment elutriate tests are given in Tables 8 - 10. The data indicate different release factors for different metal species.

Release of soluble trace metals can be divided into three broad categories based on the number of stations which meet the 1.5 concentration factor (May 6, 1975 EPA guideline).

(1) 0% compliance: manganese

(2) 50-75% compliance: chromium, iron, lead, nickel

(3) 90-100% compliance: cadmium, copper, mercury, silver, zinc.

The elutriate test was designed to represent the pipeline effluent (dredge slurry) from hydraulic dredging (Keeley and Engler, 1974; EPA, May 6, 1975). The relevancy of the elutriate test for predicting the water quality impact of dredge or fill material disposal has not been established. In fact, the 1-5 factor was not included in the most recent EPA criteria (Sept. 5, 1975) dealing with discharge of dredged or fill material in navigable waters.

In the present study the data indicate that there is no directly correlated relationship existing between the amounts of release/removal of metals and the gross metal content in the bulk sediment (Figures 10-12). For all the elutriates in which release of metals occurred, only the readily available fraction, either the metals in the interstitial water or in ion-exchangeable form, can be expected to be released from sediment to the elutriates. The scavenging effect and the complexity of the sediment itself make it impossible to derive a simple relationship between the metals release and the gross metals concentration in the sediment. It is concluded, therefore, that the bulk chemical composition of the dredged sediment is not a proper index for indicating the potential polluting status of the sediments.

CONFINED DISPOSAL OR FILL MATERIAL

The effluent return from a diked disposal area represents a potential source of contaminants transported into ocean waters. In the absence of other relevant regulations, the effluent requirements established by the California State Water Resources Control Board (CSWRCB) are used in this study for evaluating effective disposal procedures. The CSWRCB requirements are given in Table 11.

A summary of experimental data relative to the release of soluble and suspended trace metals and nutrients is presented in the following section.

Release of Soluble Trace Metals and Nutrients. If the release of soluble constituents is significant compared to the total transport (soluble and suspended) to the water column, then a treatment scheme in addition to coagulation and sedimentation may be required. Several studies on the release of soluble trace contaminants and nutrients indicate that in most cases the release is insignificant (Windom, 1972; May, 1973; Chen, et al., 1976). Recent studies by Chen and Wang (Jan. 1974;

Jan. 1975; Feb. 1975) confirm the negligible release of soluble trace metals, chlorinated hydrocarbons, and nutrients under simulated conditions for the disposal of fill material in a confined area.

A grossly polluted station (LNG 6) in the Los Angeles Harbor area was selected for the referenced investigations. The concentrations of trace metals and nutrients in the LNG 6 station are given in Tables 12 and 13. If water quality degradation resulting from the disposal of LNG 6 sediment is insignificant, then negligible impact should result from the disposal of less contaminated sediments.

The column design and flow chart for the simulated release of soluble contaminants and nutrients are shown in Figure 9. The basic procedures are as follows:

(1) Mix sediment and seawater at a 1:4 ratio in a 2-liter polyethylene container.

(2) Shake vigorously for 5 minutes and pour immediately into the water column, to a final sediment-seawater ratio of approximately 1:100.

(3) Withdraw the samples from the sampling post with 50 ml plastic syringes at regular intervals.

(4) Pass through 0.45 μm Millipore membrane filter to remove colloidal and suspended particles.

(5) Collect samples in pre-cleaned bottles.

Samples were taken at intervals of 5 minutes and at ½, 1, 2, 4, 8, 12, 24, and 48 hours, and collected in clean plastic bottles, after which the necessary reagents were added immediately to preserve the samples. Analytical procedures are detailed by Chen, et al., (1976).

A summary of the experimental data as given in Table 14 indicates that the release of soluble constituents is insignificant in comparison with the CSWRCB ocean water effluent requirements. Chlorinated hydrocarbons were not detected in the soluble phase. The analytical sensitivity can detect constituents on an order of magnitude below the CSWRCB requirement of total identifiable chlorinated hydrocarbon concentration of 2 ppb for 50% of the time.

Total Concentration of Trace Metals in the Water Column. The total trace metal concentration (soluble and particulates) in

the water column is an important parameter because treatment of the dredge material or returned effluent may be required if the discharge causes significant degradation of water quality in the receiving water.

The resuspension and redissolution of trace metals in a water column under simulated disposal conditions was conducted. The previously described procedures for the release of soluble constituents were used in this study. Samples taken at intervals of 5 minutes and ½, 1, 2, 8, 24, 48, and 72 hours were analyzed for total trace metal concentrations, suspended solids, turbidity, and dissolved sulfide.

A summary of the experimental data in Table 14 is compared with the CSWRCB ocean water discharge standards of 1972 and criteria recently proposed by the National Academy of Science and the EPA (1975). The data indicate that all of the criteria with the exception of CSWRCB limits for chromium and suspended solids to an acceptable level could be obtained with a detention time of 2 to 8 hours. Total sulfide concentrations were below the detection limit.

The CSWRCB, NAS, and EPA water quality criteria given in Table 14 do not differentiate between soluble and particulate concentrations. It is apparent that confined disposal will require either a long detention time or treatment in order to meet the effluent water quality requirements. It is concluded that treatment would seem inevitable for the effective reduction of contaminants, suspended solids, and turbidity in the effluent.

Treatment Studies. The disposal of fill material in a confined area with proper treatment can effectively reduce the transport of soluble and suspended contaminants to the receiving watercourse. The effectiveness and economics of two treatment procedures were investigated: (1) direct treatment of dredged spoil, and (2) treatment of returned effluent from confined disposal areas. The general procedures for the two treatment processes are shown in Figure 9.

A summary of the experimental data for the two treatment procedures (Tables 15 to 17) is compared with the CSWRCB ocean water discharge requirements. Conclusions based on the results of this study are presented:

(1) Coagulation and sedimentation of the dredge spoil prior to its disposal into the receiving water will result in substantial improvement in water quality compared with the disposal of dredged spoil without treatment.

(2) Treatment of the effluent from the confined area results in slightly better improvement in water quality than that obtained by direct treatment of dredged spoils.

(3) No significant difference in water quality resulted from the use of either selected coagulant, cationic polymer CAT-FLOC T or anionic polymer WT-3000.

(4) The direct treatment of dredged spoils requires only two-thirds the amount of polymer required for effluent treatment.

(5) The direct treatment of dredge spoils with a detention time of one hour results in concentrations of trace metals, suspended solids, and turbidity limits well below the CSWRCB ocean water discharge requirements.

(6) Total sulfide and chlorinated hydrocarbons are below the detection limits for both types of treatment.

(7) No significant problem regarding water quality in the receiving watercourse will result if proper attention is given to the design and use of dredging equipment and construction of a confined disposal area to provide sufficient settling time.

Open Water Disposal of Dredge Materials

An extensive laboratory study and analytical characterization of the water quality effects from large-scale open water disposal of contaminated dredged sediments have been carried out (Chen, et al., 1975).

Water and sediment samples for simulated studies from marine environments were obtained from the Los Angeles Harbor area (Figure 1). Sediment samples of silty sand, sandy silt, and silty clay types were characterized with respect to physicochemical properties, including particle size distribution. The sediments were also analyzed for concentrations of metal species in total sediments and in the interstitial water (Tables 18,19).

The main approach of this study involved the use of simulated laboratory experiments to evaluate the impact on water quality of the open water disposal of dredged sediments. Special efforts were devoted to quantifying the migration of trace contaminants and nutrients under various conditions.

Specific areas of investigation encompassed by the referenced study are as follows:

(1) Sediments subject to dredging were evaluated as to the short-term and long-term effects on water quality due to aquatic disposal of dredged materials. The migration to or from the water column of trace contaminants and nutrients was thoroughly characterized by the use of settling column studies. The settling column studies were used to evaluate the amounts of contaminants and nutrients that leach from a disturbed sediment as it disperses and settles through the water column in both freshwater and marine systems. The capability of a dredged sediment to scavenge or deplete a water column enriched in contaminants or nutrients was also completely evaluated. These studies are of particular importance in impounded areas where the effect of water currents would be minimal. The sediments under investigation were thoroughly characterized as to ion exchange capacity, form and location of ions, grain size distribution, and predominant clay types. This laboratory evaluation also thoroughly characterized sorption-desorption reactions and kinetics of reaction of various contaminants and chemical constituents of the resuspended dredged material.

(2) After a dredged sediment is disposed of in open water, it eventually settles and forms a new sediment-water interfacial zone, where a series of migrations and transformations takes place. Several factors will influence the occurrence of the reactions. Among the more important are the total organic carbon content of the sediment, the amount and type of sediment, and the concentration and fractionation of chemical constituents. A laboratory evaluation was conducted where simulated sediment-water columns are created by aquatic disposal of dredged material with a resultant newly-formed sediment-water interfacial zone. A thorough evaluation of the migration of chemical constituents from the sediment of the simulated dredged material disposal site into the overlying water column was also conducted.

(3) All of the sediment samples used in this study were characterized for the following indigenous properties: pH, percent solids by weight and volume, grain size distribution, total organic carbon, total organic nitrogen, nitrate, ammonium nitrogen, total phosphorus, type of sediment, cation exchange capacity, sulfide content, and salinity. This data is required for predicting the water quality impact from physicochemical characteristics of the sediments.

Experimental procedures, summary of pertinent experimental data, and conclusions for the short-term and long-term

column studies are presented.

Short-Term Column Settling Studies. In order to evaluate the release of chemical species upon disposal of dredged materials, sediment-water mixtures were resuspended in the water column under different redox and agitation conditions, and observed for the migration of chemical species over a period of 48 hours (Table 21). The short-term column test is essentially an extension of the EPA Standard Elutriate Test (EPA, 1975) and simulates more closely the release of soluble constituents under different environmental conditions during open water disposal of dredge materials.

Experimental procedure. The two columns used in the experiments were specially designed in two sections: an upper section fabricated from a 5' length of 9½" I.D. plexiglass cylinder, ¼" thick; and a lower section, a regular commercial 5-gallon plastic pail provided with a hermetically sealed lid so that the sediment and seawater contained in it could be saved for continued long-term studies. A plastic collar bolts onto the column flange to connect the two sections. Gas bubbling units were located near the base of the column.

Basically, the column test consisted of the dispersion of the sediment in seawater at a ratio of 1:20. Using a glove bag purged with nitrogen gas, 4 liters of sediment were measured and thoroughly mixed with 16 liters of seawater. The well stirred mixture was then poured into the column holding the remainder of the seawater to make a total volume of 34 liters.

To simulate dredging conditions as closely as possible, the column studies were performed under various conditions. Some of the parameters varied during the test were: (a) type of sediment, (b) type of water, (c) dissolved oxygen content of water, and (d) degree of agitation. Samples were withdrawn from the mid-column with 50 ml plastic syringes and filtered through 0.2 μm Millipore membrane filter. 250 ml of filtrate were collected each time in pre-cleaned plastic bottles and 200 μl ultrapurified HNO_3 was added to prevent precipitation and adsorption on the container wall. Samples were taken at 0, ½, 1, 2, 4, 8, 12, 24, and 48-hour intervals.

The samples were analyzed for pH, temperature, DO, total sulfide, nitrogen (Kjeldahl, ammonia, and organic), phosphate (total and orthophosphate), silica, and heavy metals (Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn). All of the analytical procedures adopted, except those for heavy metals which are found in the Appendix, are described in the Standard Methods for the Examination of Water and Wastewater, 13th ed. (1971).

The untreated seawater was used in several tests. To vary the dissolved oxygen content, nitrogen was pre-bubbled into the seawater to simulate a slightly oxidizing condition, while the compressed air or oxygen was pre-bubbled into the seawater for aerobic conditions. All column tests were performed under ambient conditions.

Summarized test results for a grossly contaminated organic-sulfide-rich sediment (LNG 6) and a relatively unpolluted silty sand sediment (LNG 3) are presented for comparison and for demonstration of the potential release of soluble constituents under various environmental conditions (Tables 21-30; Figures 13-17).

Summary and Conclusions

(1) From the data presented, it is obvious that the release of trace metals from dispersion, settling, and resedimentation of sediment are generally in the ppb or sub-ppb range. These concentrations are well below the proposed numerical criteria for ocean water established by Federal and State regulatory agencies (Table 11).

(2) Most of the trace metals displayed a release pattern immediately after the addition of the sediment mixture to the seawater. A sudden release of metal to the seawater during the first hour was followed by subsequent removal from solution; either gradually, as often found in slightly reducing environments, or immediately, under slightly oxidizing to oxidizing environments. The initial release is most likely due to the dilution of interstitial waters, dissolution of the solid phase through complex formation, and release from the exchangeable phase.

(3) It is apparent from the data presented in Tables 21-33 that the release from interstitial waters alone is not enough to account for most of the release. Complex formation and ion exchange seem to explain the bulk of the release.

(4) In the short-term study (48-hr period), the concentration factor for each metal species calculated from the areas on the time-concentration graphs enables the comparison of the relative degree of release for each metal. Table 31 tabulates the metal release factor for each metal and test type relative to the seawater background. The release phenomena may be classified as:

(a) metals most significantly released (factor range 10-160): Fe, Mn, and Ni

(b) metals moderately released (factor 3.4-17.5): Cr, Cu, Pb, and Zn

(c) metals showing negligible release: Ag, Cd, Hg

(5) Most soluble nutrients were found to be more readily released under reducing conditions than under oxidizing conditions.

(6) The three metals showing the most significant change in concentration with change in redox condition are Fe, Mn, and Ni. Their transport phenomena behaved similarly, and the order of metal release followed:

reducing slightly oxidizing oxidizing

Concentrations of soluble iron and manganese, which are non-toxic, may range up to several hundred ppb under anaerobic conditions; however, in an oxidizing environment, these concentrations are greatly reduced.

(7) Cr, Cu, Pb, and Zn exhibited moderate release (< 20 times seawater concentration).

(8) Cr and Cu, although moderately released (6.5 to 10.9 factor), demonstrated very little variation with change in redox condition.

(9) The concentration of Cr remained steady under both oxidizing and reducing condition.

(10) Ag, Cd, and Hg showed very little change under all test conditions.

(11) Changes in Cd concentrations were very slight under the various types of test conditions. The concentrations showed lower values with agitation, and were very near the concentrations of the original seawater.

(12) Since the concentrations of these metal species in the water column are mostly in the sub-ppb to ppb ranges (with the exception of iron) after the disposal of dredged materials, the short-term release of metal species is considered to be ecologically insignificant.

(13) A major deficiency of this type of laboratory study is that dilution which could occur at an open-water site cannot be properly reflected in the laboratory setup. It should be realized that such a dilution is extremely difficult and perhaps impossible to model under laboratory conditions. The

measured concentrations therefore represent the maximum conditions, and actual concentrations should be substantially lower than those from laboratory measurements.

(14) The concentration of nutrients after the initial release remains more or less constant (Table 32).

(15) Most of the nutrients are released in the sub-ppm to ppm range, which would create little problem in open-water disposal.

(16) The DO content and redox condition determine, to a large extent, the amount and species of soluble metal ions and nutrients.

(17) Upon the addition of the seawater-sediment mixture (1:4 ratio) to the seawater column, the DO immediately drops to a much lower level with organic and sulfide-rich sediment (Table 33).

(18) Aside from turbidity, the depletion of oxygen can also pose serious problems for organisms in both fresh and marine waters. The magnitude and duration of the short-term effects depend very much on the characteristics of the sediment and the existing water quality of the receiving waters. An increase in the sediment:seawater ratio (open-water disposal) should prevent the abrupt initial DO drop to a substantial degree.

(19) Column tests using silty clay sediment (Stn. 6) gave the highest release of sulfide, with the quiescent tests releasing more than the agitated tests, possibly due to the loss of hydrogen sulfide to the atmosphere under agitated conditions. The presence of sulfide would create a reducing environment; open oxidation, the conversion to sulfate, results in lowering the pH of the solution.

(20) Test results relative to standards. The results of the column test simulating dredging conditions show with certainty that certain trace metals and nutrients are released. However, comparison of the numerical values of the test data with those of the different governmental standards as tabulated in Table 34 show that most of the magnitudes are insignificant. The trace metal contents meet the Ocean Discharge Standards of California (CSWRCB, 1972) and the more recent guidelines suggested by the National Academy of Science and the United States Environmental Protection Agency (1975).

Long-Term Sediment-Water Interfacial Studies. After a dredged sediment is disposed of in open water, it eventually settles and forms a new sediment-water interfacial zone, where a series of migrations and transformations takes place. A thorough evaluation of the migration of chemical constituents from the sediment of the simulated dredged material disposal site into the overlying water column was also conducted.

Two different types of long-term experimental tests were set up in a dark temperature chamber (10-14°C): first, disturbed sediment without resettling; and second, disturbed sediment with resettling in a water column.

Disturbed, non-resettled test with redox control. Before contacting with sediment, the seawater was passed through 0.05 μm membrane filter and bubbled with different ultrapurified gases (air, nitrogen, and hydrogen sulfide) to render the seawater in oxidizing, slightly oxidizing, or reducing conditions. After contacting, the ultrapurified gases were still connected with the experimental systems under the appropriate partial pressure. Dissolved oxygen (DO) and total dissolved sulfide (ΣS_D) were checked every two days to maintain the systems in the desired condition:

(a) Oxidizing condition: DO = 5 - 8 mg/l; ΣS_D = 0 mg/l

(b) Slightly oxidizing condition: DO = 0 - 1 mg/l; $\Sigma S_D < 0.05$ mg/l

(c) Reducing condition: DO = 0 mg/l; ΣS_D = 15 - 30 mg/l

The pH values were found to stabilize gradually to an equilibrium condition under different redox conditions. For oxidizing and slightly oxidizing conditions, pH decreased from approximately 8.3 to 7 after about 15 days of contact time, and remained at pH 7 thereafter. Under reducing conditions, pH remained steady at about 7 during the experimental period.

Disturbed, resettled test without redox control. The sediments were mixed with unfiltered seawater at a 1:4 volume in a glove bag and shaken vigorously for about 10 minutes, then dumped into a 6-ft tall plexiglass cylinder containing 60 liters of original seawater. After two days of resettling, the lowest part of the column was removed with its contents, the sediment and seawater with an approximate ratio of 1:4. This reactor was sealed and placed in a constant-temperature, constant-humidity room at 10-14°C for a long-term experiment as a closed system.

After resettling, the interfacial water associated with silty clay sediment was in:

(a) Oxidizing condition from 0 to ¼ day:
DO > 0.5 mg/l; $\Sigma S_D = 0$

(b) Slightly oxidizing condition from ¼ to 3 days:
$0 < DO \leq 0.5$ mg/l; $\Sigma S_D < 0.05$ mg/l

(c) Reducing condition after 3 days:
DO = 0 mg/l; $\Sigma S_D > 0.05$ mg/l

No external control was attempted.

All the interfacial water samples were taken from 1 inch above the surface of the sediment. In order to keep air from contaminating the sample, a syringe pressurized filtration technique and glove bag setup were used. Samples for trace metals analysis were passed through 0.05 μm membrane filter. In the column study tests, 0.2 μm membrane filters were used due to high loading of suspended solids. For nutrient analysis 0.45 um membrane filter was used. For chlorinated hydrocarbons glass filter paper was used.

Test results for the long-term sediment-water interfacial study on the migration of chemical species in the sediment-water interface under different environmental conditions are shown in Figures 13-16 (Chen, et al., 1976). Major findings are summarized as follows:

(1) In the long-term study, the organic-rich, sulfide-rich type of sediment with a high clay and silt content showed a comparatively low soluble trace metal concentration and a higher nutrient release.

(2) After sediments are resettled, the direction of transport of trace metals between the sediment-seawater interface is controlled mainly by the environmental conditions of the overlying seawater.

(3) Under oxidizing conditions, with the exception of Ag, Cr, and Hg, all other observed trace metals were found to be released into the sediment-water interfaces. In comparison with background seawater, Cd, Mn, Ni, and Zn were significantly released, with Cu, Fe, Mn, and Pb only moderately released. It is suggested that the release effect is mainly the result of carbonate, chloride, and organo-complexes formation.

(4) Under reducing conditions, Fe and Mn were released to a very high level, up to the ppm range. The concentrations

of other trace metals were decreased to extremely low values in the initial contact period. As time passed, the concentrations of Cd, Cu, Hg, Ni, Pb, and Zn were again increased. The deposition effect is a result of metallic sulfide formation. The subsequent increase in metal concentrations after the initial release is probably due to complex formation.

(5) Under slightly oxidizing conditions, the concentrations of trace metals were between those of the oxidizing and reducing environments.

(6) The flux of metal transport across a sediment-water interface is primarily governed by the type of sediment and the overlying seawater conditions and the chemistry of the individual elements.

(7) No significant difference was found between the resettled and non-resettled tests. The releasing pattern of trace metals in the resettled tests was close to that obtained under similar redox conditions in the non-resettled tests.

(8) The flux of metals transport in the sediment-water interfaces is independent of the gross concentration of sediments.

(9) Due to the extremely low levels of metal concentrations in most seawaters, the relative factors of release in comparison with seawater backgrounds are very misleading. For example, a ten-fold increase in the soluble fraction of lead in most seawater will result in a concentration ranging from 0.3 to 1.0 ppb, which is insignificant even from the standpoint of most restrictive water quality standards. The release of other metal species can be described in the same manner.

(10) During the entire study, no soluble form of chlorinated hydrocarbons was ever observed. Most of the chlorinated hydrocarbons are found to be associated with fine particles and macromolecular organic compounds.

(11) Nitrogen and phosphorus compounds were found to release in the sub-ppm range in the water column, while the concentration of soluble silicate increases to the level of 10-20 ppm. The silty clay-type sediment was found to release higher concentrations of nutrients and lower concentrations of trace metals. It is obvious that at such levels of release, autotrophic activity can be greatly increased. This should benefit increasing productivity in open waters, but might be harmful in semi-enclosed waters for a short time.

(12) The only potential problem is the release of ammonia under anaerobic conditions in a confined area with very little dilution from overlying water. Under these conditions, ammonia concentration may increase to over 10 ppm, which would create some physiological problems for more delicate organisms. However, with some circulation, this type of problem should disappear.

CONCLUSION

(1) From the data presented, it is obvious that the release of trace metals from dispersion, settling, and resedimentation of sediments is generally in the ppb or sub-ppb range, both short and long term. These concentrations are well below proposed numerical criteria for ocean water established by Federal and State regulatory agencies (CSWRCB, 1972; EPA, 1975).

(2) The results show that concerns regarding the release of a significant quantity of toxic materials into solution phase during dredging operations and disposal are unfounded. No soluble chlorinated hydrocarbons were detected in the solution phase from either short term or long term study.

(3) Even though a certain fraction of sediment samples from Los Angeles Harbor may exceed EPA criteria on the basis of gross concentrations, there is no evidence from extensive laboratory studies that any significant degradation of water quality will ensue upon disposal of such sediments in open waters.

(4) One potential problem regarding the water quality impact of the open water disposal of dredged sediment is the association of trace contaminants with suspended particulates. Even though there is no direct evidence of adverse ecological impact from such operations, the potential of increasing uptake of contaminants by filter-feeding organisms and certain species of algae cannot be minimized. One possible solution to minimize this problem is the direct treatment of sediment-water mixtures by the addition of flocculants to improve the settling characteristics of suspended particulates, as described in the section on treatment studies.

(5) Disposal of dredged material behind dikes or in other confined areas will require addition of flocculants to improve the quality of returned effluent for discharge to ocean waters.

(6) There will be a complete compliance of water quality standards of both CSWRCB and EPA for dike disposal of dredged material with proper addition of flocculant either directly to dredged slurry or returned effluent with one hour retention time for sedimentation.

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Table 1

Sediment Constituents of LNG Stations

I. General Characteristics

LNG Station	Moisture Content %	Total Organic Carbon %	Total Volatile Solids %	Immed. Oxygen Demand mg/kg	Chem. Oxygen Demand mg/kg	Organic Nitrogen mg/kg	Kjeldahl Nitrogen mg/kg	Phosphorus mg/kg	Sulfide mg/kg
2	43.75	0.60	4.59	538.7	52,590	357	357	886	258
3	38.70	0.53	2.80	383.2	29,210	689	706	679	163
4	31.56	0.50	1.97	350.3	21,450	588	636	644	102
5	35.72	0.60	2.10	181.0	22,874	459	493	787	269
6	57.38	3.64	10.13	1567.0	116,840	2822	2923	1465	1673

Samples collected February, 1974.

Table 1

Sediment Constituents of LNG Stations

II. Trace Metals

LNG Station	As	Cu	Cd	Cr	Fe	Mn	Ni	Pb	Zn	Hg
2	9.2	78.65	6.55	229.4	31,680	114.7	131.1	185.7	111.4	0.685
3	8.5	50.70	4.65	94.0	28,980	440.2	45.2	64.8	125.2	0.227
4	5.6	61.12	9.48	147.5	49,531	231.9	126.5	221.3	130.7	0.27
5	3.7	20.30	3.10	60.3	15,110	238.0	15.9	36.2	72.5	0.33
6	27.9	255.06	7.27	144.2	45,180	512.8	73.3	214.4	504.6	1.43

All units in ppm (ml/kg)

Samples collected February, 1974

Table 1

Sediment Constituents of LNG Stations

III. Chlorinated Hydrocarbons

	PCB's (ppm)			Organochlorine Pesticides (ppm)		
LNG Stations	PCB 1254	PCB 1260	PCB 1242	p,p'DDE	o,p'DDE	p,p'DDD
2	0.2521	0.0252	0.1920	2.1943	0.0360	0.0043
3	0.1103	0.0110	0.1213	0.6935	0.1311	0.0662
4	0.0704	0.0070	0.0960	0.2384	0.0102	---
5	0.2370	0.0240	0.2620	1.0953	0.0513	0.0366
6	0.3660	0.0340	0.3040	1.3712	0.0550	0.3370

Samples collected February, 1974.

Table 2

Sediment Constituents of LNG Stations

I. General Characteristics

(mg/kg dry weight, except as noted)

Samples / Parameters	Sand			Silty Sand				Sandy Silt			Clay Silt
	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
Moisture content (%)	24.09	28.64	30.88	31.22	36.09	24.87	19.32	48.47	49.76	38.11	65.12
Total org. carbon (%)	0.47	0.61	0.82	0.82	1.14	0.62	0.57	1.68	2.06	1.10	3.49
Total volatile solids (%)	0.92	1.71	1.61	2.07	2.65	1.45	0.70	4.28	2.77	2.33	6.90
Immed. O_2 demand	140	682	2030	996	3770	1090	283	3150	4150	1820	8550
Chem. O_2 demand	15100	21500	24100	25600	39300	15300	10400	62800	71800	40600	105400
Organic N	317	418	562	646	858	457	135	628	1984	904	2656
Kjeldahl N	326	439	583	663	879	461	138	656	2020	923	2696
Phosphorus	737	1010	1330	1030	1120	1040	910	1390	1990	1610	1820
Sulfide	38	121	65	259	241	58	35	549	828	151	1530
Oil & Grease	195	289	369	598	777	338	301	1323	1477	810	2094
Phenols	0.46	0.56	0.69	0.64	0.77	0.72	0.55	0.76	1.33	0.63	1.4
Cyanide	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil

Samples collected September, 1975.

Table 2

Sediment Constituents of LNG Stations

II. Trace Metals Concentration

Samples	Sand			Silty Sand				Sandy Silt			Clay Silt
Parameters	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
Arsenic	2.74	0.69	1.16	0.22	3.02	0.35	0.31	3.28	4.62	2.57	5.46
Cadmium	0.98	1.47	1.49	1.69	1.55	1.48	1.16	3.77	2.87	2.60	4.19
Chromium	34.2	34.3	46.3	43.1	35.7	32.9	27.0	77.7	61.8	43.9	77.7
Copper	14.0	32.7	38.7	42.4	35.7	30.3	20.4	149	69.7	53.1	194
Iron	18900	26300	30400	34200	34100	30300	22000	43100	38200	36400	49600
Mercury	0.219	0.224	0.518	0.575	0.397	0.692	0.211	1.260	0.588	0.493	0.937
Org. Hg	0.057	0.190	0.24	0.10	0.08	0.17	0.08	0.13	0.12	0.10	0.07
Manganese	248	376	433	407	378	425	308	452	410	312	395
Nickel	18.6	27.1	29.8	25.9	25.4	28.4	17.9	55.5	47.2	35.2	59.8
Lead	40.7	47.4	49.6	36.2	34.1	39.9	40.8	120	74.1	55.1	117
Zinc	55.4	78.4	116	103	114	92.3	69.1	262	242	140	317

mg/kg dry weight.
Samples collected September, 1975.

Table 2

Sediment Constituents of LNG Stations

III. Chlorinated Hydrocarbons

Samples / Parameters	Sand			Silty Sand				Sandy Silt			Clay Silt
	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#27
p,p'DDE	0.1258	0.2201	0.2908	0.3338	0.4384	0.2433	0.073	0.3211	0.7397	0.4853	0.9835
o,p'DDE	0.0594	0.0623	0.1003	0.1095	0.1438	0.0836	0.0228	0.1044	0.2459	0.1638	0.3294
p,p'DDD	0.0759	0.1603	0.1619	0.1956	0.2314	0.1392	0.0596	0.1839	0.4956	0.2819	0.5857
Total DDT	0.2939	0.4965	0.6055	0.7078	0.8919	0.5099	0.1755	0.6699	1.6515	1.0214	2.0876
PCB 1254	0.063	0.070	0.085	0.090	0.122	0.082	0.023	0.092	0.200	0.131	0.240
PCB 1260	0.006	0.007	0.008	0.009	0.012	0.008	0.002	0.009	0.020	0.013	0.024
PCB 1242	0.080	0.094	0.098	0.090	0.110	0.097	0.043	0.009	0.250	0.150	0.270
Total PCB	0.149	0.171	0.191	0.189	0.244	0.187	0.068	0.200	0.470	0.294	0.534

Other chlorinated hydrocarbons are below detection limit.

(units in mg/kg dry weight.)

Samples collected September, 1975.

Table 3. Sediment Composition of LNG Stations: Physical Descriptions.

LNG Station	Sediment Type	% Moisture	% sand >50μm	% silt 50-5μm	% clay <5μm
2	sandy silt	43.75	48.5	31.5	20.0
3	silty sand	38.70	71.0	17.5	11.5
4	silty sand	31.56	80.0	8.0	12.0
5	sandy silt	35.72	----	----	----
6	silty clay	57.38	12.0	56.0	32.0

Samples - February, 1974.

Table 4. Composition* of LNG Sediment Samples.

Composition / Station No.	% of Sand	% of Silt	% of Clay	Sediment Type
LNG 1	94	3	3	Sand
LNG 4	81	11	8	Sand
LNG 6	36	48	16	Sandy Silt
LNG 7	24	59	17	Sandy Silt
LNG 16	28	59	13	Sandy Silt
LNG 17	68	23	9	Silty Sand
LNG 18	51	41	8	Silty Sand
LNG 24	70	22	8	Silty Sand
LNG 25	60	35	5	Silty Sand
LNG 26	91	5	4	Sand
LNG 27	16	61	23	Clay Silt

*Size limits:

Sand - >0.05mm

Silt - 0.05 to 0.005mm

Clay - Less than 0.005mm

Samples collected Sept., 1975

Table 5. Trace Metal Concentrations in Los Angeles Harbor Sediments Compared with Region IX Dredge Spoil Disposal Criteria Revision 1 (DSDC-R1), October, 1974.

Constituent	mg/kg 16 stations Low	High	DSDC-R1 mg/kg	Percent of Stations exceeding DSDC-R1
Arsenic	0.22	5.46		
Cadmium	0.98	9.48	3.0	43.8
Chromium	27.0	229.4		
Copper	14.0	255.1		
Iron	15,110	49,600.00		
Lead	34.1	221.3	180	18.8
Mercury	0.21	2.74	1.5	6.3
Nickel	15.9	131.1		
Zinc	55.4	504.6	300	12.5
Oil & grease*	195	2,094.00	4,000	0

*11 stations

Samples collected 1974-1975

Table 6. Natural Background Levels of Trace Metals in San Pedro Channel*

Element	Natural Background Level (mg/kg)
Arsenic	1 - 1.5
Cadmium	1 - 1.5
Chromium	20 - 30
Copper	5 - 10
Iron	12,000 - 15,000
Lead	20 - 25
Mercury	0.025 - 0.050
Nickel	15 - 20
Zinc	30 - 35

*Data from Chen and Lu, 1974

Table 7. Trace Metals in Seawater* used for Elutriate Test

Elements / Parameters	Ag	Cd	Cu	Cr	Fe	Hg***	Mn	Ni	Pb	Zn
Mean **	0.02	0.24	0.23	0.55	2.97	0.06	1.03	0.75	0.17	0.27
Standard Deviation	0.027	0.16	0.04	0.07	1.41	0.0007	0.11	0.21	0.04	0.09
Coef. of Variance	0.28	0.69	0.18	0.13	0.47	0.01	0.10	0.28	0.25	0.34

* Pass through 0.45 μ membrane filter

** Above is the average of two independent determinations.

*** No methyl mercury was detected in seawater

Table 8. Trace Metals Concentration in Elutriates (from Standard Elutriate Test) (µg/l)

	Sand			Silty sand				Sandy silt			Silty** clay	Clay silt
	#1	#4	#26	#17	#18	#24	#25	#6*	#7	#16	#6	#27
Silver	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0
Cadmium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.49	0.0
Copper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.18	0.0
Chromium	0.50	0.60	0.50	0.50	0.50	2.0	0.70	0.55	0.50	1.80	0.85	0.55
Iron	8.5	1.9	0.4	1.9	0.9	148.0	0.6	5.5	6.0	365.7	16.0	2.3
Manganese	19.5	30.0	17.7	18.0	16.0	17.7	3.6	7.2	17.5	14.2	10.9	1.70
Nickel	2.2	2.0	2.0	2.5	1.0	4.0	2.5	0.50	1.0	0.50	0.20	0.0
Lead	0.8	0.0	0.4	0.2	0.0	4.0	0.0	0.2	0.2	1.3	0.35	0.4
Zinc	0.13	0.26	0.0	0.0	0.0	0.0	0.0	0.15	0.0	0.26	0.20	0.0

*Sample was collected in Sept. 1975.
**Sample was collected in Feb. 1974.

Concentrations of Hg in the elutriates were undetectable.

All samples filtered through 0.45 µm membrane filter.

Table 9. Ratio of Trace Metals in Elutriate/Seawater (µg/l)

	Sand			Silty sand				Sandy silt			Silty clay	Clay silt
	#1	#4	#26	#17	#18	#24	#25	#6	#7	#16	#6	#27
Silver	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0
Cadmium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
Copper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.78	0.0
Chromium	1.0	1.1	1.0	1.0	1.0	3.6	1.3	1.0	1.0	3.3	1.6	1.0
Iron	2.8	-0.64	-0.13	-0.64	-0.30	49.3	-0.20	1.8	2.0	121.0	-0.77	5.4
Manganese	19.0	30.0	17.7	18.0	16.0	17.7	3.6	7.2	17.5	14.2	1.70	10.6
Nickel	2.9	2.7	2.7	3.3	1.3	5.3	3.3	-0.67	1.3	-0.67	-0.27	0.0
Lead	4.7	0.0	2.4	1.2	0.0	23.5	0.0	1.2	1.2	7.7	2.1	2.4
Zinc	-0.5	1.0	0.0	0.0	0.0	0.0	0.0	-0.5	0.0	1.0	-0.74	0.0

Dash (-) indicates that the concentration of trace metal in elutriate is less than that in background seawater; therefore, "scavenging" occurs.

Table 10. Standard Elutriate Test--Los Angeles Harbor Sediments

ND--not detectable

Constituent	Composition (ppb)*	Elutriate composition (ppb)* 12 stations		1.5 times seawater composition**	% of stations meeting 1.5 concentration factor
		Low	High		
Cadmium	0.24	ND	0.49	0.36	91.7
Chromium	0.55	0.50	2.0	0.83	75.0
Copper	0.23	ND	0.18	0.35	100
Iron**	2.97	0.40	366.	4.46	50.0
Lead	0.17	ND	4.0	0.26	50.0
Manganese***	1.03	3.6	30.0	1.55	0.0
Mercury	0.06	ND	ND	0.09	100
Nickel	0.75	ND	4.0	1.13	50.0
Silver	0.02	ND	0.03	0.03	100
Zinc	0.27	ND	0.26	0.41	100

* 0.45μm filtration

** 1.5 factor is not included in Sept. 5, 1975 EPA national Guideline

***not required

Table 11. Comparison of Marine Water Quality Criteria (mg/l)

Constituent	California ocean discharge requirements (1972) 50% of time	50% of time	EPA Proposed water quality criteria (1973)	EPA, NAS proposed water quality criteria (1975) EPA	NAS
Arsenic	0.01	0.02	0.05	0.2	0.2
Cadmium	0.02	0.03	0.01	0.1	0.01
Chromium	0.005	0.01	0.1	0.1	0.05
Copper	0.2	0.3	0.05	--	--
Lead	0.1	0.2	0.05	0.05	0.05
Mercury	0.001	0.002	0.1	0.1	0.1
Nickel	0.1	0.2	0.1	0.1	1.0
Silver	0.02	0.04	0.005	5.0	5.0
Zinc	0.3	0.5	0.1	0.2	--

Source: CSWRCB, 1972.

Table 12. Characteristics of Sediments from Sampling Stations* in Los Angeles Harbor

(units in ppm unless specified)

Parameters	Silty Sand Sta.#1	Silty Silt Sta.#2	Silty Sand Sta.#3	Silty Sand Sta.#4	Silty Sand Sta.#5	Silty Clay Sta.#6
TOC**	1.09	1.90	2.0	0.84	1.11	2.12
COD	--	52,590	29,210	21,450	22,870	116,800
IOD	--	538	383	350	181	1,570
TVS**	--	4.59	2.80	1.97	2.10	10.1
$S^{=}$	--	258	163	102	269	1,670
Organic Nitrogen	--	357	689	588	459	2,820
Total Nitrogen	--	357	706	636	493	2,920
Total Phosphorus	--	886	679	644	787	1,470
Ag	4.48	16.9	7.1	3.5	5.4	10.2
Cd	2.42	1.90	0.66	0.66	2.45	2.20
Cr	89	175	94	67	77	178
Cu	45.2	119	51.0	35.0	47.5	568
Fe	31,610	40,830	28,980	28,560	33,520	45,180
Hg	--	0.685	0.28	0.27	0.33	1.43
Mn	502	429	422	381	487	493
Ni	21.6	35.3	23.0	18.2	21.9	47.2
Pb	39.2	67	47	32	35.6	332
Zn	115	205	106	94	112	612

--not determined
*Stations shown in Figure 1
**In percent
Samples collected February, 1974

Table 13. Concentrations of Chlorinated Hydrocarbons in Los Angeles Harbor Marine Sediments

Station	Moisture Content (%)	p,p'DDE / t-DDT (%)	o,p'DDE / t-DDT (%)	p,p'DDD / t-DDT (%)	o,p'DDD / t-DDT (%)	p,p'DDT / t-DDT (%)	o,p'DDT / t-DDT (%)	Total DDT (ppm)	Dieldrin (ppm)	Total PCB's (ppm)	Total Chlorinated Hydrocarbons (ppm)
1	22.3	71.0	6.3	10.6	6.0	2.8	3.2	0.321	0.9	0.046	0.368
2	45.5	69.6	7.1	10.0	5.2	5.0	3.1	3.212	1.3	0.285	3.498
3	33.6	65.9	9.1	10.8	6.4	3.1	4.6	0.831	0.9	0.123	0.955
4	28.9	68.6	8.2	10.2	6.2	2.8	4.0	0.353	0.6	0.05	0.403
5	33.6	62.0	8.4	14.5	3.4	7.7	4.0	0.297	2.2	0.071	0.370
6	19.0	61.7	8.7	12.2	7.8	7.0	2.6	0.115	2.1	0.190	0.307
7	36.4	60.7	6.1	16.6	6.1	6.5	4.0	0.247	4.5	0.214	0.466

Samples collected February, 1974.

Table 14. Total Trace Metals Concentration in Water Column Without Polymer Treatment, Sta. 6 Sediment

Units in ppb unless specified

	5 min	0.5 hr	1 hr	2 hr	8 hr	24 hr	48 hr	72 hr	CSWRCB Limit 50% time	1975 Criteria EPA	1975 Criteria NAS
Cadmium	4.9	2.0	1.9	1.7	1.5	1.3	1.3	1.3	20	100	10
Copper	33.0	31.5	18.6	10.7	2.2	1.9	1.9	2.2	200	--	--
Chromium	41.8	20.0	12.2	6.5	1.43	1.4	1.2	0.4	5	100	50
Iron	700	614	470	470	350	--	39	42	--	300	300
Manganese	61.7	40.0	38.3	26.2	7.8	7.5	7.0	7.0	--	100	100
Lead	27.4	17.0	10.7	6.5	2.4	--	1.7	1.4	100	50	50
Zinc	16.5	11.9	10.9	8.2	6.0	4.6	1.5	1.5	100	200	--
Silver	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20	5000	5000
Nickel	<----------				trace	----------		---------->	100	100	1000
Suspended Solids, ppm	1026.5	146	114	64.7	38	37.4	35.4	35.6	50	--	--
Turbidity, JTU	115	70	60	44	20	7	6	6	50	--	--

Table 15. Total Trace Metals Concentration in Water Column with Polymer Treatment (Effluent Treatment), Sta. 6 Sediment

Cationic polymer--CAT-Floc T, dosage 1.5ppm Units in ppb unless specified

	5 min	0.5 hr	1 hr	2 hr	8 hr	24 hr	48 hr	72 hr	CSWRCB Limit 50% time
Cadmium	2.9	2.8	1.8	1.7	1.6	1.6	1.6	1.6	20
Copper	19.4	6.0	1.9	1.9	1.8	1.7	--	2.1	200
Chromium	7.2	2.2	1.4	2.0	0.8	0.8	0.8	0.8	5
Iron	465	323	307	206	94.0	--	24.5	25.0	--
Manganese	33.0	23.0	19.8	11.8	12.0	--	11.5	10.0	--
Lead	8.1	3.4	1.0	1.1	1.1	--	1.2	1.4	100
Zinc	5.9	4.6	3.5	3.7	1.7	--	0.7	0.7	300
Silver	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20
Nickel	<---------- trace ---------->								100
Suspended solids, ppm	78.7	28.7	21.4	25.4	20.0	19.3	18.6	18.3	50
Turbidity, JTU	40	6.0	5.2	2.5	2.0	2.0	2.0	2.0	50

Table 16. Total Trace Metals Concentration in Water Column after Treatment of 1:4 Sediment-Water Mixture with Polymer (Direct Treatment), Sta. 6 Sediment

Units in ppb unless specified

	5 min	0.5 hr	1 hr	2 hr	24 hr	48 hr	CSWRCB Limit 50% time
Cadmium	4.2	3.7	2.6	2.0	2.0	1.5	20
Copper	90	40	19	16	12	12	200
Chromium	5.7	5.2	3.5	1.6	0.7	0.7	5
Iron	630	630	530	480	410	180	--
Manganese	63	25	14	10	9.5	9.0	--
Lead	21	4.6	1.9	1.3	1.0	1.0	100
Zinc	19	14	12	7.6	4.6	4.2	300
Silver	0.0	0.0	0.0	0.0	0.0	0.0	20
Nickel	10	3.0	1.5	1.0	0.5	trace	100
Suspended solids, ppm	280	84	62	44	28	29	50
Turbidity, JTU	80	35	25	12	6	6	50

Cationic polymer: CAT-Floc T
Polymer dosage: 10 ppm

Table 17. Water Quality of Soluble Phase in the Mixture of Compressed Air Aerated Seawater and Sta. 6 Sediment under Agitated Settling Conditions (Sediment/Seawater ~ 1/100 by volume)

--not determined

Time (hrs) Elapsed	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	D.O. mg/l	pH	S^- mg/l	NH_3-N
0	--	0.011	0.55	0.15	10.0	0.048	0.4	0.002	0.33	0.3	6.7	7.78	0.029	0.015
0.5	--	0.002	1.3	0.07	10.0	0.079	1.5	0.07	0.00	2.13	0.0	7.86	0.00	0.85
1	--	0.006	0.25	0.0	88.0	0.088	9.0	0.09	0.03	1.99	0.4	7.84	0.004	--
2	--	0.008	0.25	0.05	11.0	0.056	6.15	0.03	0.05	1.81	3.45	7.80	0.006	0.091
4	--	0.013	0.27	0.0	11.0	0.053	5.16	0.035	0.10	1.73	5.10	7.86	0.00	0.090
8	--	0.014	0.26	0.2	10.0	0.055	4.15	0.04	0.13	1.83	6.28	7.92	0.002	0.085
12	--	0.016	0.25	0.33	10.0	0.02	3.40	0.08	0.23	2.0	6.4	8.22	0.01	0.063
24	--	0.018	0.23	0.48	10.0	0.023	2.68	0.12	0.23	2.06	6.6	8.31	0.006	0.074
48	--	0.08	0.2	0.41	10.0	0.041	2.55	0.12	0.38	2.56	6.7	8.13	0.015	0.061
Original seawater	0.00-0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00	--
CSWRCB requirements, 50% time, gross conc.	20	20	5	200	--	1	--	100	100	300	--	6 - 9	--	40

Units in ppb unless indicated

Table 18. Interstitial Water Analysis for Trace Metals* of Sediments from Sampling Stations** in Los Angeles Harbor

Element	Sandy Silt Sta. #2	Silty Sand Sta. #3	Silty Sand Sta. #4	Silty Sand Sta. #5	Silty Clay Sta. #6
Cd	0.2	0.3	0.1	0.25	0.5
Cr	0.9	0.9	0.8	0.4	0.7
Cu	0.4	1.3	0.9	1.3	0.4
Fe	980	985	360	2,000	120
Mn	74	92	100	75	6.0
Ni	1.3	2.5	1.3	1.8	0.6
Pb	0.4	0.3	0.4	4.5	0.45
Zn	19	21	21	24	10

* In µg/l
** Stations shown in Figure 1
Samples collected February, 1974

Table 19. Moisture Content and Particle Size Distribution of Sediments from Sampling Stations* in Los Angeles Harbor

Parameter	Silty Sand Sta #1	Sandy Silt Sta #2	Silty Sand Sta #3	Silty Sand Sta #4	Silty Sand Sta #5	Silty Clay Sta #6
Moisture Content, %	30.5	43.5	31.0	26.0	29.2	43.0
Sand, % > 50 um	77.0	48.5	71.0	80.0	71.0	12.0
Silt, % 50-5 um	12.3	31.5	17.5	8.0	18.0	56.0
Clay, % < 5 um	10.7	20.0	11.5	12.0	11.0	32.0

*Stations shown in Figure 1
Samples collected February, 1974

Table 20. Column Test Runs

Col. Test Series	Date	Sta. No.	Seawater Preloading	Initial D.O.	pH	Condition after addition of mixture
I	6/17/74	6	none	6.2	--	quiescent
II	6/27	3	none	5.75	--	quiescent
III	7/8	3	nitrogen	2.75	7.66	cont. bubbling (canc.)
IV	7/16	3	nitrogen	0.4	8.61	quiescent
V	7/16	3	nitrogen	0.6	8.82	cont. agitation
VI	7/23	6	oxygen	7.1	8.02	quiescent
VII	7/23	6	nitrogen	0.4	7.78	quiescent
VIII	7/30	6	none	7.0	7.59	quiescent
IX	7/30	6	comp. air	6.7	7.78	cont. agitation
X	8/6	3	none	6.6	7.71	quiescent
XI	8/6	3	comp. air	7.3	7.88	cont. agitation
XII	8/21	1	none	6.6	8.0	quiescent
XIII	8/21	1	nitrogen	0.5	8.35	cont. agitation
XIV	8/31	2	none	6.54	8.2	quiescent
XV	8/31	2	nitrogen	0.56	8.34	cont. agitation
XVI	9/4	2	nitrogen	0.35	8.33	quiescent
XVII	9/4	2	comp. air	6.8	8.25	cont. agitation
XVIII	9/23	Morris Dam	none	6.6	8.32	quiescent
XIX	9/23	"	nitrogen	0.2	8.43	quiescent
XXII	10/29	6	nitrogen	0.2	8.52	cont. agitation
XXIII	10/29	3	comp. air	7.8	8.66	quiescent
XXIV	11/4	2	comp. air	7.2	8.6	quiescent
			Freshwater Preloading			
XX	10/1	Morris Dam	none	2.3	8.6	quiescent
XXI	10/1	"	nitrogen	0.2	7.59	quiescent

Table 21. Water Quality of Soluble Phase in the Mixture of Seawater and Silty Clay Sediment (LNG 6) under Quiescent Settling Conditions.

Time elapsed (hrs)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Dissolved oxygen (mg/1)	pH	Total sulfide (mg/1)	Total phosphorus (mg/1)	Phos-phate (mg/1)	Kjeldahl nitrogen (mg/1)	Ammonia nitrogen (mg/1)	Organic nitrogen (mg/1)	Sili-cate (mg/1)	Temp. °C
0	0.033	0.035	0.00	0.65	0.00	0.04	0.1	0.1	0.47	0.38	6.2	---	---	0.01	0.01	0.22	-0.02	-.20	1.5	---
0.5	0.063	0.021	0.00	0.25	31.2	0.08	10.1	0.24	0.43	0.00	---	---	---	---	---	---	---	---	---	---
2	---	---	---	---	---	---	---	---	---	---	---	---	---	0.14	0.13	0.39	0.068	0.32	2.3	---
4	0.00	0.004	0.4	0.00	44.4	0.04	11.7	0.04	0.03	0.00	0.48	---	---	---	---	---	---	---	---	---
24	0.00	0.025	0.00	0.35	2.0	0.03	10.4	0.12	0.16	0.1	0.48	---	---	0.27	0.25	0.61	0.081	0.53	8.5	---
48	---	---	---	---	---	---	---	---	---	---	---	---	---	0.25	0.23	0.80	0.12	0.68	1.2	---
72	0.00	0.008	0.00	0.00	7.0	<0.02	10.8	0.09	4.0	0.00	0.21	---	---	---	---	---	---	---	---	---
Original Sea-water	<0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.0-8.0	0.00	---	---	---	---	---	---	---

Trace metals in ppb

Sediment: seawater - 1:30 by volume

-- not determined

Phenol, cyanide, and methyl mercury were below detection limit in solution phase.

Table 22. Water Quality of Soluble Phase in the Mixture of Deaerated Seawater and Silty Clay Sediment (LNG 6) under Quiescent Settling Conditions.

Time elapsed (hrs)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Dissolved oxygen (mg/l)	pH	Total sulfide (mg/l)	Total phosphorus (mg/l)	Phos-phate (mg/l)	Kjeldahl nitrogen (mg/l)	Ammonia nitrogen (mg/l)	Organic nitrogen (mg/l)	Sili-cate (mg/l)	Temp. °C
0	0.02	0.315	0.35	3.65	5.1	0.064	0.08	5.38	2.04	5.45	0.40	7.78	0.05	0.01	0.013	0.120	0.015	0.105	1.05	---
0.5	0.018	0.137	0.95	2.0	9.5	<0.02	0.35	4.78	1.13	6.6	0.0	8.01	4.02	0.65	0.555	0.864	0.365	0.499	15.3	---
1	0.018	0.095	0.95	0.25	43.0	0.008	0.83	4.38	0.78	5.6	0.0	7.34	4.72	0.605	0.535	0.674	0.253	0.421	14.1	---
2	0.018	0.075	1.0	0.02	8.0	0.040	0.60	4.9	0.45	5.3	0.0	7.32	2.76	0.61	0.613	0.779	0.288	0.491	13.0	---
4	0.017	0.020	0.95	0.02	10.0	0.028	0.52	4.9	0.45	3.5	0.0	7.18	4.34	0.61	0.540	0.846	0.223	0.623	13.6	---
8	0.018	0.001	0.65	0.0	27.0	0.031	3.25	4.9	0.45	2.8	0.0	7.41	5.50	0.60	0.540	0.835	0.213	0.622	13.3	---
12	0.018	0.001	0.35	0.0	8.0	0.030	0.32	2.98	0.44	2.2	0.0	---	---	0.60	0.580	0.896	0.275	0.621	10.1	---
24	0.018	0.001	0.35	0.25	10.0	0.029	0.70	2.72	0.44	0.3	0.0	7.73	4.76	0.57	0.550	0.882	0.239	0.643	12.2	---
48	0.017	0.001	0.35	1.77	7.5	0.029	0.65	4.8	0.43	0.3	0.0	7.56	4.28	0.58	0.550	0.926	0.216	0.710	13.1	---
Original Sea-water	<0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	---	---	---	---	---	---	---	---

Trace metals in ppb

Sediment: seawater - 1:20 by volume

--not determined

Phenol, cyanide, and methyl mercury were below detection limit in solution phase.

Table 23. Water Quality of Soluble Phase in the Mixture of Oxygen Aerated Seawater and Silty Clay Sediment (LNG 6) under Quiescent Settling Conditions.

Time elapsed (hrs)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Dissolved oxygen (mg/l)	pH	Total sulfide (mg/l)	Total phosphorus (mg/l)	Phos-phate (mg/l)	Kjeldahl nitrogen (mg/l)	Ammonia nitrogen (mg/l)	Organic nitrogen (mg/l)	Sili-cate (mg/l)	Temp. °C
0	0.01	0.62	0.35	3.6	5.0	0.157	0.12	2.9	4.0	9.5	7.1	8.02	0.09	0.02	0.013	0.231	0.021	0.210	1.80	---
0.5	0.0	0.55	0.35	1.25	25	<0.02	2.40	3.6	1.25	8.4	0.0	7.93	0.112	0.47	0.455	0.652	0.200	0.452	12.2	---
1	0.0	0.14	0.22	1.0	132	0.145	1.77	0.6	0.2	10.1	0.0	7.94	0.073	0.41	0.380	0.496	0.154	0.342	13.45	---
2	0.0	0.35	0.18	1.45	128	<0.02	0.85	1.0	3.1	5.72	0.1	7.82	0.002	0.45	0.463	---	---	---	10.8	---
4	0.0	0.15	0.0	0.97	87	0.126	0.80	0.8	0.4	10.1	0.0	7.92	0.06	0.435	0.430	0.776	0.156	0.620	10.2	---
8	0.0	0.12	0.78	1.75	102	0.126	0.85	0.4	0.95	2.9	0.0	7.52	0.061	0.48	0.480	0.685	0.142	0.543	8.10	---
12	0.0	0.02	0.35	0.38	107	0.110	1.00	0.5	1.82	0.9	0.0	7.71	0.062	0.48	0.470	---	0.123	---	7.65	---
24	0.0	0.06	0.55	0.42	80	0.020	1.67	0.4	0.87	5.3	0.0	7.90	0.105	0.46	0.450	0.754	0.133	0.621	12.4	---
48	0.0	0.09	0.35	0.51	128	---	0.42	0.3	0.3	1.35	0.0	7.56	0.106	0.47	0.450	0.695	0.135	0.560	14.2	---
Original Sea-water	<0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00	---	---	---	---	---	---	---

Trace metals in ppb

Sediment: seawater - 1:20 by volume

--not determined

Phenol, cyanide, and methyl mercury were below detection limit in solution phase.

Table 24. Water Quality of Soluble Phase in the Mixture of Deaerated Seawater and Silty Clay Sediment (LNG 6) under Agitated Settling Conditions.

Time elapsed (hrs)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Dissolved oxygen (mg/1)	pH	Total sulfide (mg/1)	Total phosphorus (mg/1)	Phos-phate (mg/1)	Kjeldahl nitrogen (mg/1)	Ammonia nitrogen (mg/1)	Organic nitrogen (mg/1)	Sili-cate (mg/1)	Temp. °C
0	--	0.09	0.47	5.45	10.0	0.224	0.47	2.6	2.4	6.0	0.2	8.52	0.05	0.125	0.093	0.172	0.012	0.160	1.90	18.0
0.5	--	0.05	0.47	1.10	1950	0.033	1.2	3.3	2.75	5.8	0.1	8.50	0.06	0.224	0.188	0.242	0.012	0.230	20.05	18.0
1	--	0.07	0.42	0.70	190	0.023	1.4	1.2	3.6	6.0	0.1	8.60	0.055	0.319	0.294	0.162	0.012	0.150	17.50	17.5
2	--	0.1	0.47	1.50	155	0.209	0.9	1.35	3.3	5.9	0.1	8.64	0.07	0.350	0.332	0.262	0.012	0.250	15.40	18.1
4	--	0.02	0.47	1.30	170	0.17	1.6	0.7	4.2	5.8	0.1	8.70	0.074	0.239	0.199	0.552	0.012	0.540	16.30	17.9
8	--	0.15	0.5	1.20	30.0	0.038	1.0	0.67	1.5	6.2	0.15	8.81	0.088	0.335	0.301	0.643	0.023	0.620	13.30	17.5
12	--	0.10	0.48	1.52	20.0	0.07	1.1	1.15	1.43	6.2	0.1	8.87	0.05	0.314	0.312	0.828	0.058	0.770	16.40	17.0
24	--	0.10	0.47	1.61	17.0	0.064	1.05	0.5	1.8	6.2	0.2	8.98	0.048	0.343	0.324	0.755	0.035	0.720	16.80	17.6
48	--	0.09	0.47	1.10	40.0	--	1.4	1.7	1.7	6.2	0.2	8.99	0.054	0.302	0.290	0.730	0.070	0.660	17.70	17.5
Original Sea-water	<0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.0-8.0	7.8-8.0	0.00	---	---	---	---	---	---	---

Trace metals in ppb

Sediment: seawater - 1:20 by volume

--not determined

Phenol, cyanide, and methyl mercury were below detection limit in solution phase.

Table 25. Water Quality of Soluble Phase in the Mixture of Compressed Air Aerated Seawater and Silty Clay Sediment (LNG 6) under Agitated Settling Conditions.

Time elapsed (hrs)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Dissolved oxygen (mg/1)	pH	Total sulfide (mg/1)	Total phosphorus (mg/1)	Phos-phate (mg/1)	Kjeldahl nitrogen (mg/1)	Ammonia nitrogen (mg/1)	Organic nitrogen (mg/1)	Sili-cate (mg/1)	Temp. °C
0	---	0.011	0.55	0.15	10.0	0.048	0.4	0.002	0.33	0.3	6.7	7.78	0.029	0.035	0.030	0.116	0.015	0.101	2.05	25.0
0.5	---	0.002	1.3	0.07	10.0	0.079	1.5	0.07	0.0	2.13	0.0	7.86	0.0	0.290	0.205	0.548	0.95	0.453	8.75	25.0
1	---	0.006	0.25	0.0	88.0	0.088	9.0	0.09	0.03	1.99	0.4	7.84	0.004	0.140	0.135	---	---	---	9.20	25.5
2	---	0.008	0.25	0.05	11.0	0.056	6.15	0.03	0.05	1.81	3.45	7.80	0.006	0.045	0.045	0.379	0.091	0.288	10.40	25.2
4	---	0.013	0.27	0.0	11.0	0.053	5.16	0.035	0.10	1.73	5.10	7.86	0.0	0.035	0.030	0.482	0.090	0.392	8.25	25.0
8	---	0.014	0.26	0.2	10.0	0.055	4.15	0.04	0.13	1.83	6.28	7.92	0.007	0.030	0.020	---	0.005	---	7.65	25.0
12	---	0.016	0.25	0.33	10.0	0.02	3.40	0.08	0.23	2.0	6.4	8.22	0.01	0.030	0.020	0.547	0.063	0.484	9.75	25.5
24	---	0.018	0.23	0.48	10.0	0.023	2.68	0.12	0.23	2.06	6.6	8.31	0.006	0.050	0.045	0.655	0.074	0.581	11.10	24.5
48	---	0.08	0.2	0.41	10.0	0.041	2.55	0.12	0.38	2.56	6.7	8.13	0.015	0.040	0.035	0.715	0.061	0.654	12.20	25.0
Original Sea-water	<0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03 0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00	---	---	---	---	---	---	---

Trace metals in ppb

Sediment: seawater - 1:20 by volume

--not determined

Phenol, cyanide, and methyl mercury were below detection limit in solution phase.

Table 26. Water Quality of Soluble Phase in the Mixture of Seawater and Silty Sand Sediment (LNG 3) under Quiescent Settling Conditions.

Time elapsed (hrs)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Dissolved oxygen (mg/1)	pH	Total sulfide (mg/1)	Total phosphorus (mg/1)	Phos-phate (mg/1)	Kjeldahl nitrogen (mg/1)	Ammonia nitrogen (mg/1)	Organic nitrogen (mg/1)	Sili-cate (mg/1)	Temp. °C
0	---	0.31	0.05	3.1	11.0	0.118	2.2	2.0	2.91	4.0	6.6	7.71	0.007	0.040	0.035	0.132	0.010	0.122	2.00	---
0.5	---	0.40	0.05	2.17	178	0.093	15.2	3.24	1.15	6.1	0.3	7.57	0.01	0.285	0.280	0.249	0.092	0.157	8.65	---
1	---	0.06	0.18	0.2	81.5	0.11	12.1	1.08	0.08	2.1	0.4	7.64	0.018	0.210	0.205	0.260	0.081	0.179	7.05	22.5
2	---	0.0	0.05	0.25	87.5	0.11	13.1	1.3	0.1	0.0	1.1	7.62	0.001	0.215	0.215	0.332	0.065	0.267	4.50	21.0
4	---	0.0	0.15	0.8	15.5	0.103	13.6	1.1	0.1	0.1	0.7	7.60	0.009	0.225	0.230	0.285	0.066	0.219	4.50	21.5
8	---	0.1	0.15	0.38	112	0.088	14.1	1.1	0.6	3.44	0.8	7.53	0.002	0.250	0.270	0.345	0.080	0.265	6.70	22.5
12	---	0.0	0.27	0.74	192	0.105	11.6	1.22	0.09	0.0	0.4	7.51	0.002	0.265	0.260	0.419	0.077	0.342	8.65	22.5
24	---	0.01	0.15	0.4	49.0	---	14.4	1.2	0.0	0.0	0.3	7.21	0.0	0.280	0.270	0.428	0.074	0.354	10.05	22.5
48	---	0.14	0.16	1.4	102	---	12.7	1.1	0.52	3.0	0.15	7.89	0.0	0.235	0.230	0.436	0.073	0.363	11.15	22.5
Original Sea-water	<0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00	---	---	---	---	---	---	---

Trace metals in ppb

Sediment: seawater - 1:20 by volume

--not determined

Phenol, cyanide, and methyl mercury were below detection limit in solution phase.

Table 27. Water Quality of Soluble Phase in the Mixture of Deaerated Seawater and Silty Sand Sediment (LNG 3) under Quiescent Settling Conditions.

Time elapsed (hrs)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Dissolved oxygen (mg/1)	pH	Total sulfide (mg/1)	Total phosphorus (mg/1)	Phos-phate (mg/1)	Kjeldahl nitrogen (mg/1)	Ammonia nitrogen (mg/1)	Organic nitrogen (mg/1)	Sili-cate (mg/1)	Temp. °C
0	0.01	0.213	0.15	1.03	0.0	---	1.6	0.08	0.44	2.0	0.4	8.61	0.0	0.020	0.015	0.120	0.020	0.100	1.00	---
0.5	0.03	0.002	0.0	0.65	1070	<0.02	11.2	0.07	0.32	0.5	0.5	7.94	0.003	0.440	0.430	0.498	0.132	0.366	10.50	---
1	0.0	0.0	0.30	2.48	1050	---	23.2	0.24	0.0	0.5	0.2	7.56	0.004	0.430	0.415	0.343	0.129	0.214	2.65	---
2	---	0.006	0.0	1.18	1045	0.036	26.4	0.03	0.10	1.6	0.9	8.39	0.006	0.430	0.430	0.379	0.091	0.288	2.60	---
4	---	0.008	0.0	1.23	1075	0.041	22.8	0.22	0.0	1.4	0.3	8.45	0.008	0.460	0.455	0.320	0.088	0.232	2.90	---
8	0.01	0.010	0.0	0.90	1050	0.050	14.8	0.04	0.0	1.0	0.6	8.35	0.0	0.490	0.470	0.482	0.066	0.416	5.35	---
12	---	0.0	0.31	1.02	1070	0.065	14.0	0.05	0.0	0.4	0.1	8.36	0.017	0.490	0.470	0.497	0.073	0.424	8.20	---
24	0.0	0.0	0.0	0.43	970	0.165	18.4	0.04	0.0	0.2	0.0	8.27	0.062	0.470	0.470	0.484	0.074	0.410	13.20	---
48	0.0	0.007	0.0	0.13	908	0.190	20.4	0.03	0.0	0.3	0.1	7.38	0.0	0.440	0.430	0.503	0.079	0.424	15.15	---
Original Sea-water	<0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00	---	---	---	---	---	---	---

Trace metals in ppb

Sediment: seawater - 1:20 by volume

--not determined

Phenol, cyanide, and methyl mercury were below detection limit in solution phase.

Table 28. Water Quality of Soluble Phase in the Mixture of Compressed Air Aerated Seawater and Silty Sand Sediment (LNG 3) under Quiescent Settling Conditions.

Time elapsed (hrs)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Dissolved oxygen (mg/1)	pH	Total sulfide (mg/1)	Total phosphorus (mg/1)	Phos-phate (mg/1)	Kjeldahl nitrogen (mg/1)	Ammonia nitrogen (mg/1)	Organic nitrogen (mg/1)	Sili-cate (mg/1)	Temp. °C
0	---	0.5	0.47	3.75	0.0	0.39	1.1	1.4	1.3	5.6	7.8	8.66	0.001	0.105	0.092	0.28	0.041	0.239	1.70	19.8
0.5	---	0.0	0.4	1.2	75.0	1.33	2.4	0.9	0.4	4.5	1.84	8.77	0.015	0.110	0.087	0.584	0.197	0.387	10.50	20.3
1	---	0.0	0.4	0.5	75.0	0.5	2.7	0.6	0.5	6.4	1.90	8.81	0.01	0.065	0.055	0.513	0.163	0.350	12.60	20.0
2	---	0.1	0.45	0.6	35.0	2.18	2.55	0.9	0.7	4.8	1.1	8.00	0.012	0.040	0.030	0.535	0.155	0.38	10.80	20.0
4	---	0.12	0.37	0.8	40.0	1.33	2.7	0.9	0.4	5.5	1.9	8.50	0.012	0.045	0.033	0.695	0.160	0.535	10.20	20.1
8	---	0.1	0.43	0.9	0.0	0.02	2.3	0.8	1.0	4.6	1.6	8.56	0.009	0.042	0.032	0.697	0.143	0.554	8.6	21.0
12	---	0.13	0.37	0.65	0.0	0.209	2.35	0.65	0.6	6.8	1.5	8.70	0.00	0.08	0.066	0.866	0.135	0.731	7.8	20.0
24	---	0.1	0.5	1.25	0.0	0.033	3.1	1.1	0.6	5.5	1.5	8.69	0.016	0.065	0.042	0.820	0.130	0.690	12.90	20.8
48	---	0.08	0.45	0.9	0.0	---	2.4	1.1	0.4	5.7	1.5	8.62	0.015	0.055	0.029	0.650	0.129	0.521	13.9	21.0
Original Sea-water		<0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00	---	---	---	---	---	---	---

Trace metals in ppb

Sediment: seawater - 1:20 by volume

--not determined

Phenol, cyanide, and methyl mercury were below detection limit in solution phase.

Table 29. Water Quality of Soluble Phase in the Mixture of Deaerated Seawater and Silty Sand Sediment (LNG 3) under Agitated Settling Conditions.

Time elapsed (hrs)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Dissolved oxygen (mg/l)	pH	Total sulfide (mg/l)	Total phosphorus (mg/l)	Phos-phate (mg/l)	Kjeldahl nitrogen (mg/l)	Ammonia nitrogen (mg/l)	Organic nitrogen (mg/l)	Sili-cate (mg/l)	Temp. °C
0	0.01	0.213	0.15	1.03	0.0	--	1.6	0.08	0.44	2.0	0.6	8.02	0.0	0.02	0.015	0.120	0.020	0.100	1.00	---
0.5	0.02	0.086	0.45	0.90	790	0.062	26.6	0.16	0.08	3.1	0.0	8.56	0.002	0.41	0.405	0.522	0.120	0.402	10.3	---
1	0.0	0.0	0.26	0.89	822	< 0.02	25.6	0.20	0.30	0.4	0.0	8.57	0.022	0.34	0.330	0.372	0.122	0.250	2.70	---
2	0.0	0.005	0.15	0.60	550	0.032	22.6	0.01	0.0	0.4	0.0	0.54	0.0	0.38	0.380	0.405	0.081	0.324	2.70	---
4	0.05	0.032	2.80	1.48	980	0.021	31.6	0.14	1.32	1.6	0.0	8.62	0.050	0.37	0.373	0.464	0.064	0.400	2.70	---
8	0.03	0.053	1.30	1.48	515	0.041	28.0	0.13	1.26	3.8	0.0	8.73	0.037	0.38	0.373	0.482	0.079	0.403	5.10	---
12	---	0.0	0.15	0.95	72	0.061	23.1	0.06	0.0	0.2	0.0	8.10	---	0.42	0.415	0.482	0.080	0.402	7.40	---
24	0.01	0.075	0.32	1.04	190	0.019	20.4	0.22	0.0	0.8	0.0	8.08	0.022	0.43	0.410	0.511	0.079	0.432	12.30	---
48	---	0.007	0.0	0.65	62	0.020	20.5	0.04	0.15	0.3	0.0	8.10	0.001	0.43	0.415	0.538	0.076	0.462	14.10	
Original Sea-water	< 0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.25	0.03-0.12	0.2-0.12	6.8-8.0	7.8-8.0	0.00	---	---	---	---	---	---	---

Trace metals in ppb

Sediment: seawater - 1:20 by volume

--not determined

Phenol, cyanide, and methyl mercury were below detection limit in solution phase.

Table 30. Water Quality of Soluble Phase in the Mixture of Compressed Air Aerated Seawater and Silty Sand Sediment (LNG 3) under Agitated Settling Conditions.

Time elapsed (hrs)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Dissolved oxygen (mg/l)	pH	Total sulfide (mg/l)	Total phosphorus (mg/l)	Phos-phate (mg/l)	Kjeldahl nitrogen (mg/l)	Ammonia nitrogen (mg/l)	Organic nitrogen (mg/l)	Sili-cate (mg/l)	Temp. °C
0	---	0.03	0.3	3.85	5.05	0.513	0.9	1.25	1.05	2.5	7.3	7.88	0.004	0.035	0.030	0.135	0.010	0.125	2.10	23.0
0.5	---	0.1	0.7	1.3	12.5	---	14.5	1.7	0.6	2.9	0.05	7.73	0.002	0.170	0.170	0.249	0.044	0.205	10.20	21.8
1	---	0.14	0.15	0.9	2.95	---	9.5	1.1	0.5	2.35	3.4	7.64	0.018	0.080	0.073	0.238	0.033	0.205	8.75	21.5
2	---	0.19	0.1	0.8	9.5	0.055	9.1	0.52	0.28	1.8	5.2	7.62	0.075	0.115	0.110	---	0.036	---	6.20	21.4
4	---	0.05	0.27	0.7	35.5	0.130	11.1	0.31	0.35	1.5	6.7	7.88	0.002	0.055	0.065	0.240	0.035	0.205	7.65	22.2
8	---	0.07	0.08	0.5	1.5	---	2.1	0.48	0.2	2.52	6.8	7.81	0.007	0.100	0.085	0.246	0.037	0.209	11.45	22.5
12	---	0.27	0.1	4.8	5.05	0.048	2.3	1.7	0.3	2.2	6.8	7.96	0.016	0.070	0.065	---	0.039	---	10.20	22.2
24	---	0.2	0.2	2.15	4.5	0.083	0.4	0.48	0.25	1.1	6.4	8.01	0.01	0.050	0.053	0.336	0.042	0.294	8.90	22.4
48	---	0.055	0.05	3.0	17.5	0.030	0.1	0.5	0.31	2.7	7.3	8.60	0.01	0.043	0.040	0.367	0.047	0.320	9.75	22.5
Original Sea-water	0.01	0.03-0.24	0.05-0.8	0.1-0.8	0.4-310	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00	---	---	---	---	---	---	---

Trace metals in ppb

Sediment: seawater = 1:20 by volume

--not determined

Phenol, cyanide, and methyl mercury were below detection limit in solution phase.

Table 31. Comparative Metal Release Factor

Individual element in seawater background = 1

Column Test Type	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
A	1.1	1.0	7.4	7.5	29.4	1.5	13.7	38.7	3.4	7.9
B	1.1	1.0	8.8	8.4	165.4	2.0	16.2	88.6	4.8	11.5
C	(0.4)	1.0	8.3	9.7	27.6	4.4	14.6	52.6	12.4	14.6
D	(0.5)	(0.7)	8.0	10.6	52.4	1.6	14.9	54.0	8.9	17.1
E	(0.4)	(0.7)	6.5	10.9	15.9	2.1	10.4	48.3	6.5	17.5
Actual Ranges of seawater background, ppb	0.00-0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5

A = untreated seawater

B = nitrogen prebubbled, quiescent

C = oxygen prebubbled, quiescent

D = continued bubbling with nitrogen

E = continued bubbling with compressed air

__ peak released (relative release see page 22)

( ) less than ambient

Table 32. General Characteristics of Nutrient Release

Nutrient	Initial Concentration, ppm	Reak Release ppm	After 8 hrs.
NH_3-N	0.04	0.15-0.36	steady or slightly up
Org-N	0.15	0.40-0.86	slightly up
PO_4^{-3}	0.025	0.30-0.88	steady or slightly down
SiO_2	1.5	10.5-22.8	slight to medium rise

Table 33. Dissolved Oxygen in the Settling Column (mg/l)

Station	Type A Init.	Type A Range	Type B Init	Type B Range	Type C Init.	Type C Range	Type D Init.	Type D Range	Type E Init.	Type E Range
#1--Silty Sand	6.6	3.4-4.0	--	--	--	--	0.5	nil	--	--
#2--Sandy Silt	6.54	0.4-1.4	0.4	0.0-0.5	7.2	1.9-2.7	0.56	nil	6.8	0.0-6.8
#3--Silty Sand	5.7-6.6	0.15-2.5	0.35	0.0-0.55	7.8	1.1-1.9	0.6	nil	7.3	0.05-7.3
#6--Silty Clay	6.2-7.0	0.0-0.48	0.4	nil	7.1	0.0-0.1	0.2	0.1-0.2	6.7	0.6-6.7
Morris Dam	2.3-6.6	0.8-2.3	0.2	0.1-0.2	--	--	--	--	--	--

A = untreated seawater

B = nitrogen prebubbled, quiescent

C = oxygen prebubbled, quiescent

D = continued bubbling with nitrogen

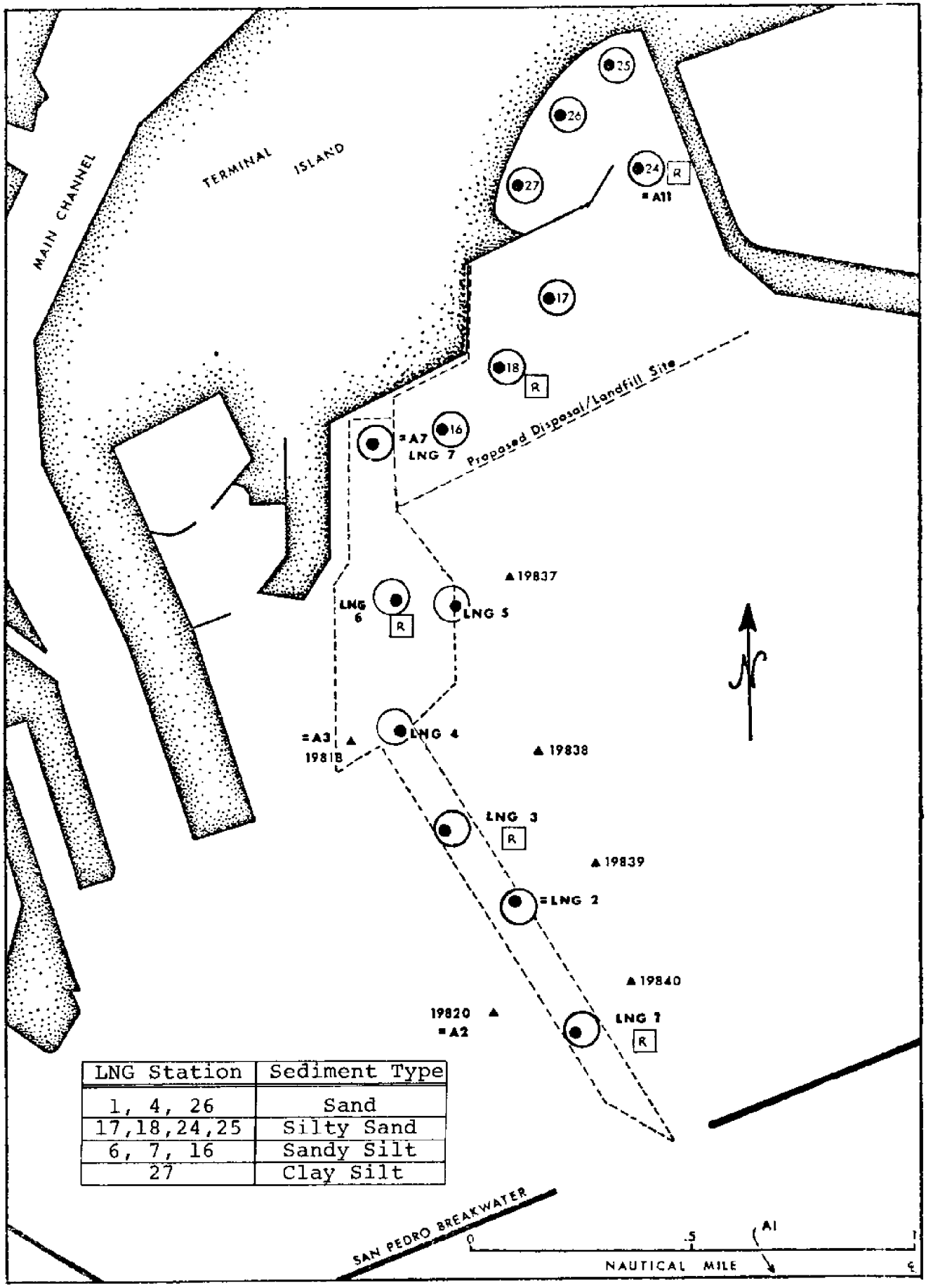
E = continued bubbling with compressed air

-- not determined

Table 34. Metal Release Compared with Standards
All values in ppb

Element	Avg. Column test value (48hr) at 1:20 dilution		Proposed EPA criteria (1975) Marine Aquatic life	CSWRCB Stds. Ocean Discharge (1972)		Drinking water Standards (1962)	
	Low	High		50% of time	100% time	Max	Recv.
Ag	0.007	0.022	5000	20	40	50	--
Cd	0.105	0.155	100	20	30	10	--
Cr	0.325	0.441	100	5	10	50	--
Cu	0.15	0.746	--	200	300	*	1000
Fe	42.8	447.9	300	--	--	--	300
Hg	0.045	0.1311	100	1	2	--	--
Mn	0.830	1.298	100	--	--	--	--
Ni	0.774	1.772	100	--	--	--	--
Pb	0.272	0.994	50	100	200	--	--
Zn	1.586	3.490	1-200	300	500	*	5000

*same as recommended



LNG Station	Sediment Type
1, 4, 26	Sand
17,18,24,25	Silty Sand
6, 7, 16	Sandy Silt
27	Clay Silt

Figure 1. Outer Los Angeles Harbor Dredging Effects Study (Harbor Environmental Projects, 1976).

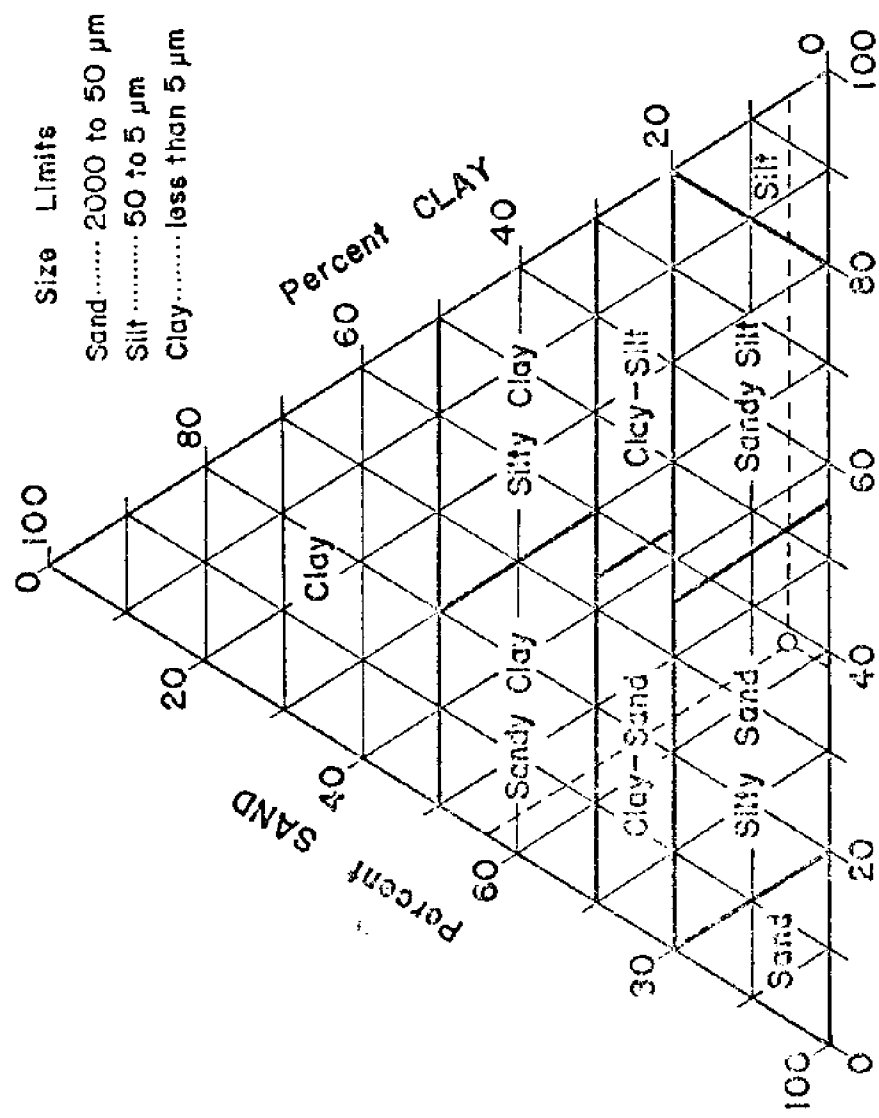


Figure 2. Triangular Classificiation Chart (Lower Mississippi Valley Division, Corps of Engineers, U.S.Army).

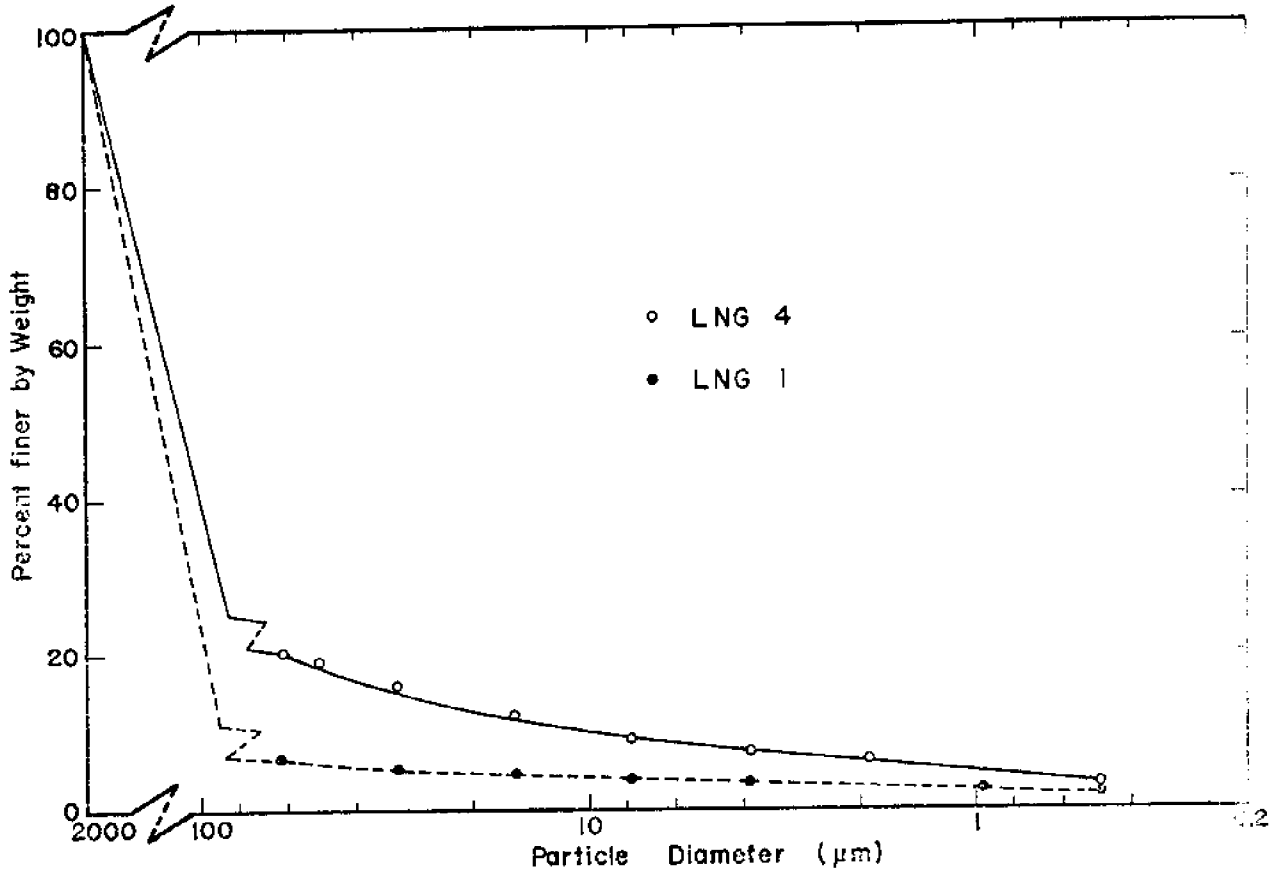


Figure 3. Particle Size Distribution Curves for the Sediments, LNG 1 and 4.

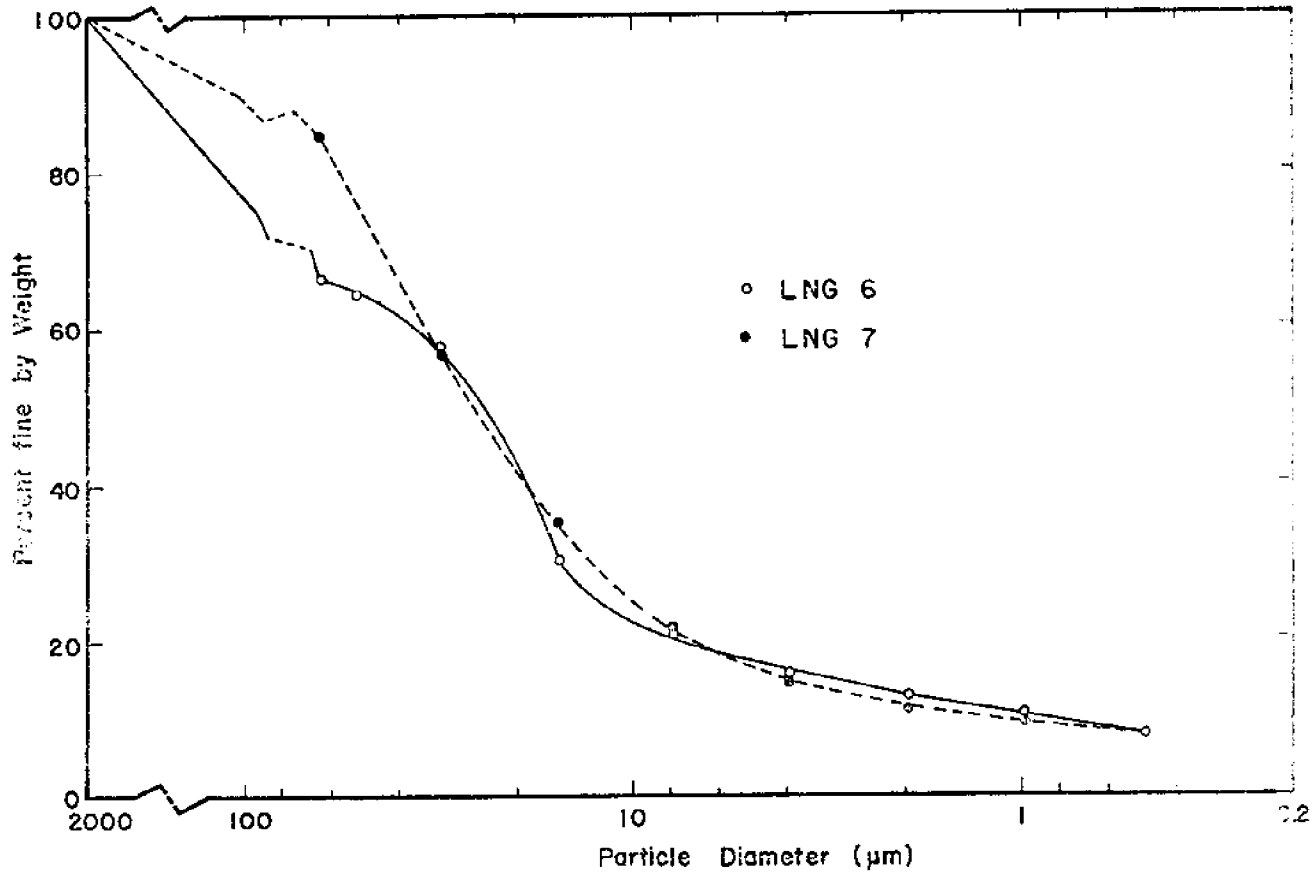


Figure 4. Particle Size Distribution Curves for the Sediments, LNG 6 and 7.

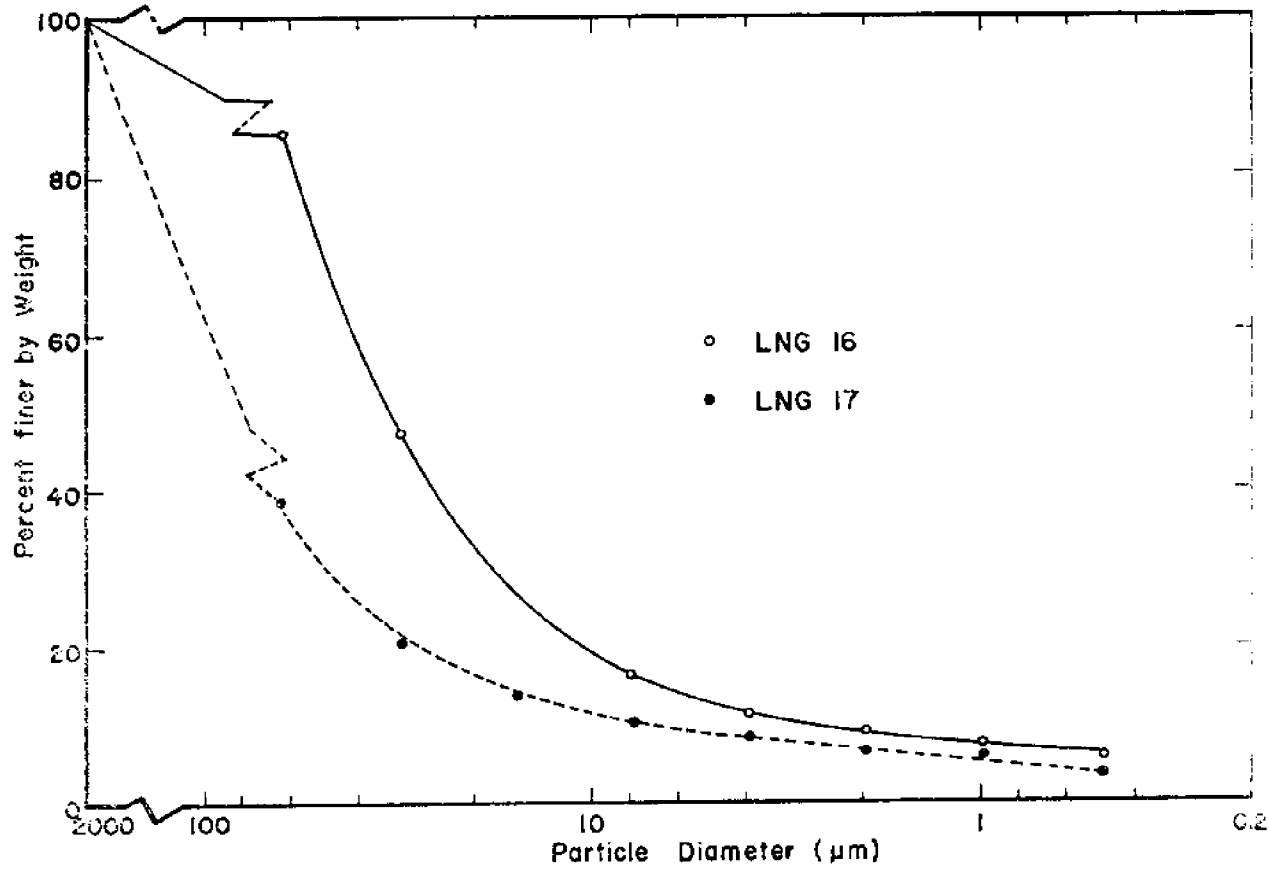


Figure 5. Particle Size Distribution Curves for the Sediments, LNG 16 and 17

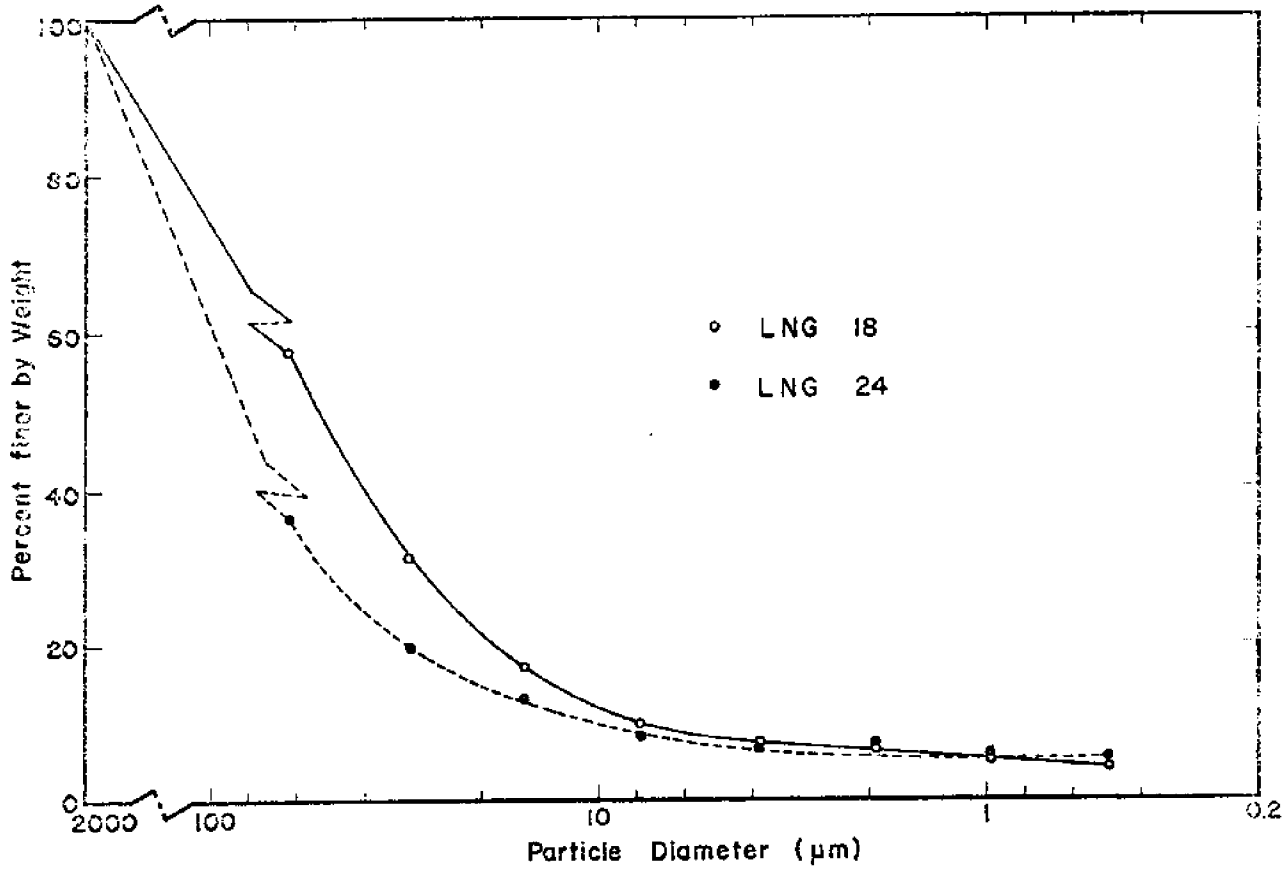


Figure 6. Particle Size Distribution Curves for the Sediments, LNG 18 and 24.

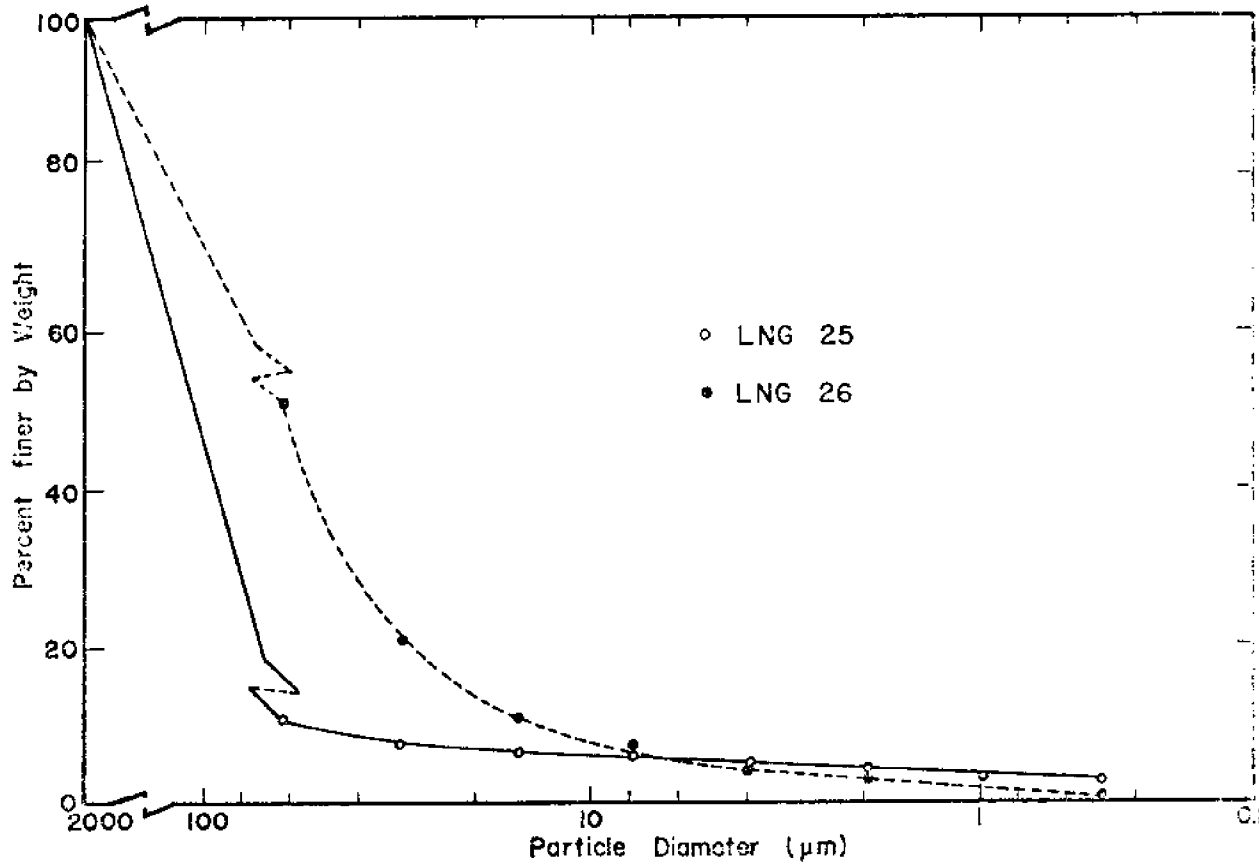


Figure 7. Particle Size Distribution Curves for the Sediments, LNG 25 and 26.

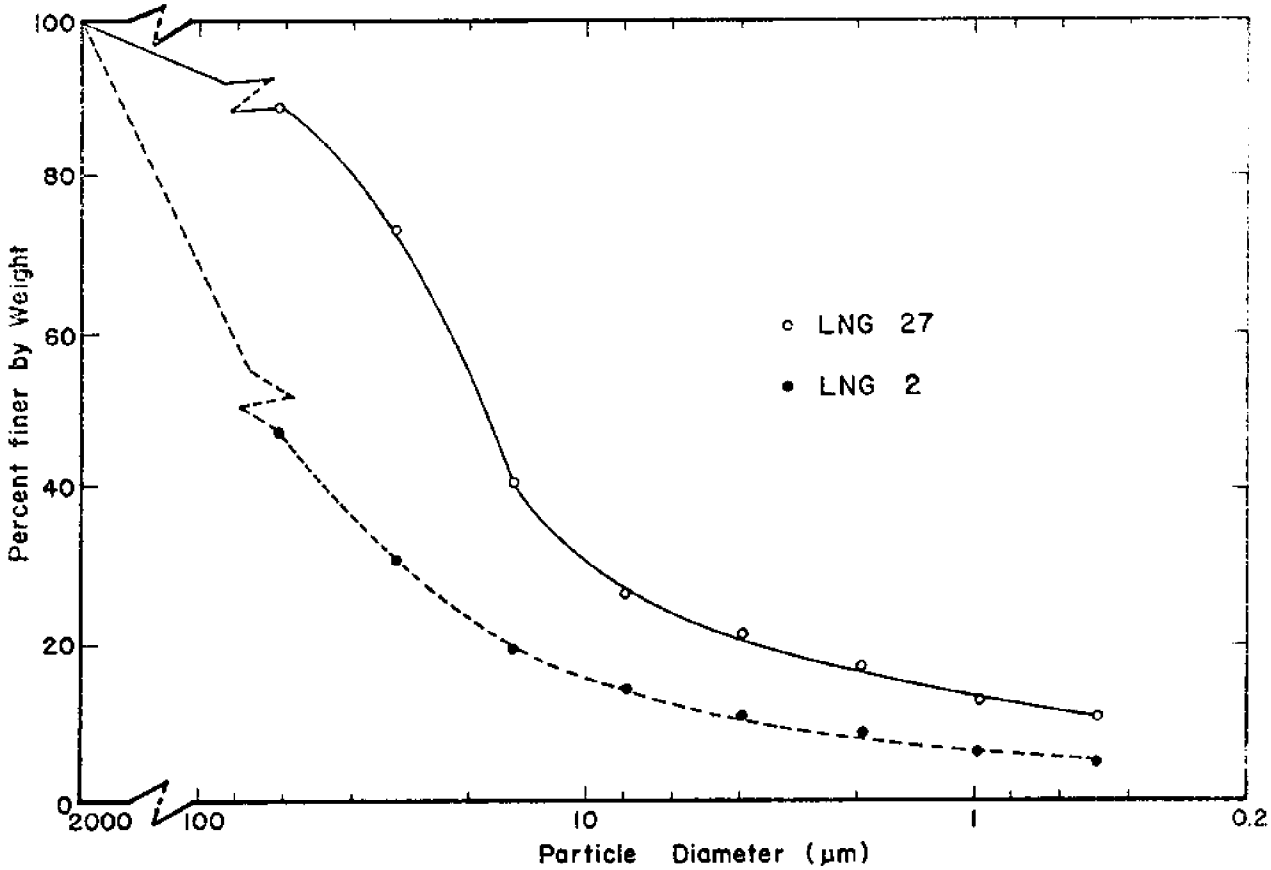


Figure 7a. Particle Size Distribution Curves for the Sediments, LNG 27 and 2.

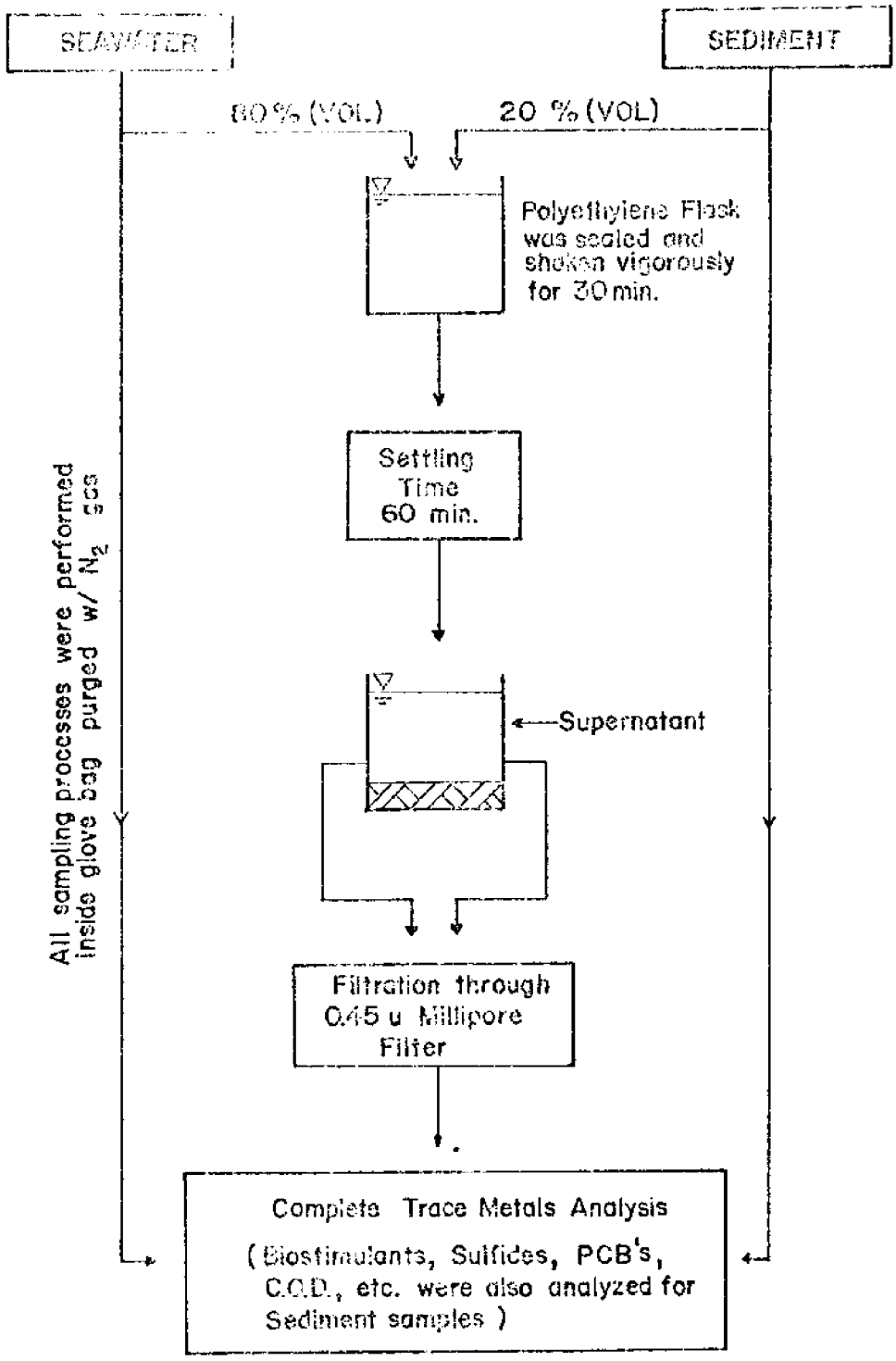
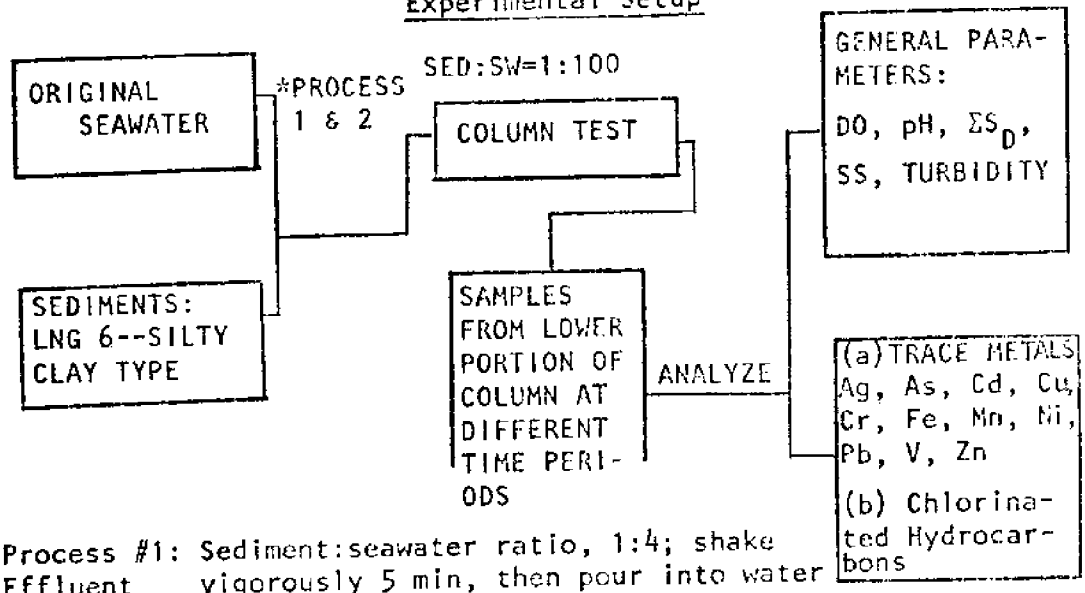


Figure 8. Schematic Diagram of the Standard Elutriate Test (Modified after Keeley and Engler, 1974).

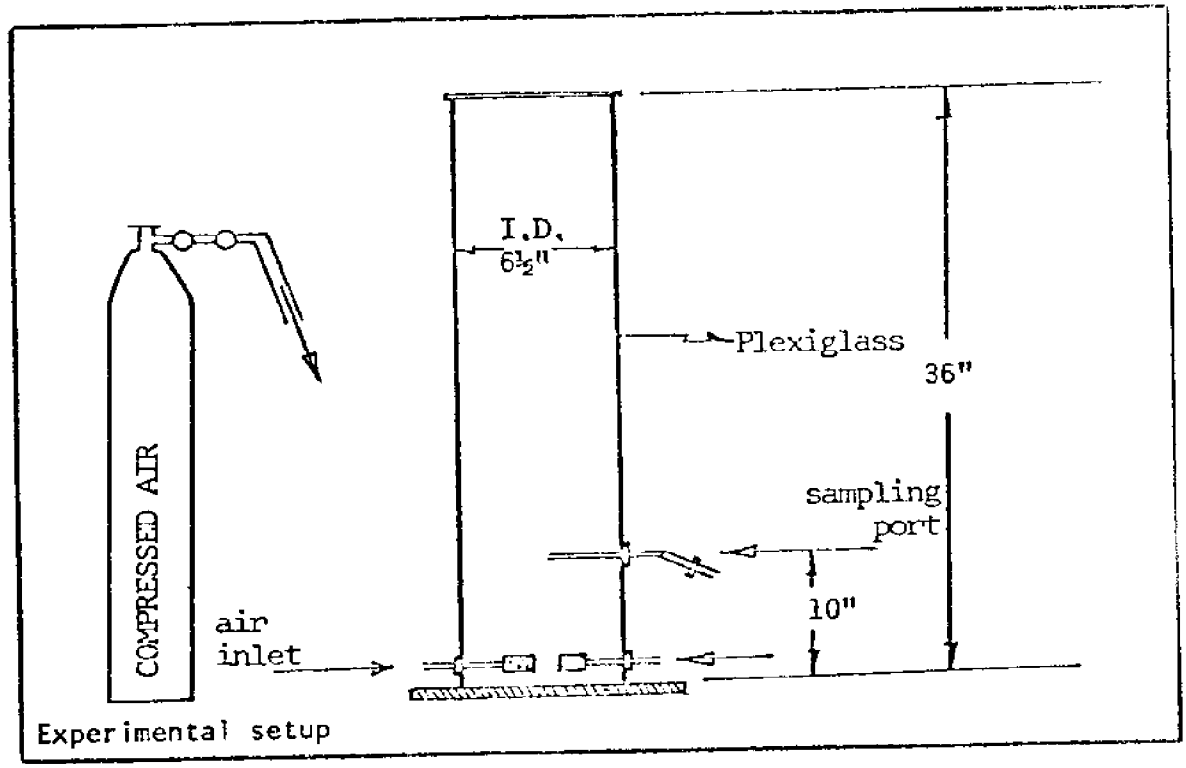
FIGURE 9.

Flow Chart of Column Test and Experimental Setup



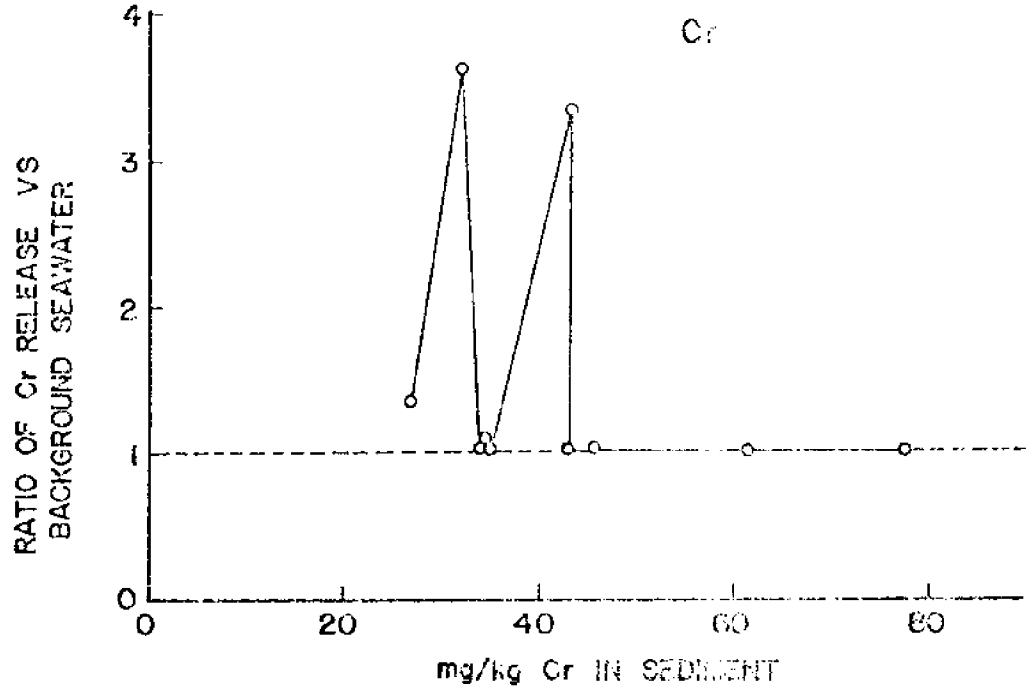
* **Process #1: Effluent treatment** Sediment:seawater ratio, 1:4; shake vigorously 5 min, then pour into water column. Add optimum dosage of polymer. Bubble with compressed air for 5 min.

Process #2: Direct treatment Sediment:seawater ratio, 1:4; add polymer; vigorously shake for 5 min. Pour mixture into water column.



Experimental setup

Figure 10. Cr and Fe Release Ratio in Elutriate Test as a Function of Total Cr and Fe Sediment Content.



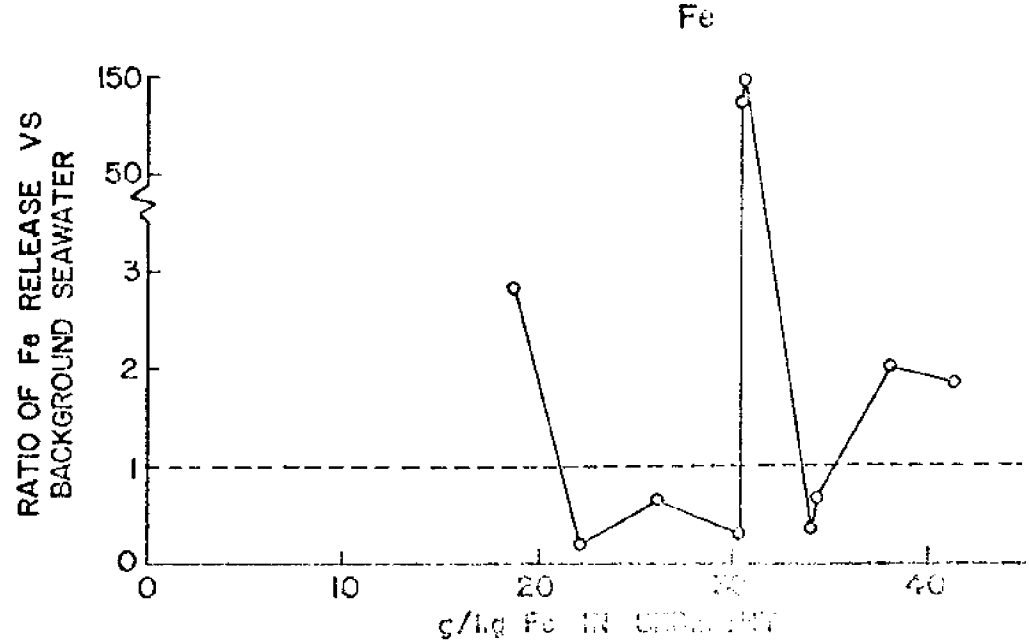
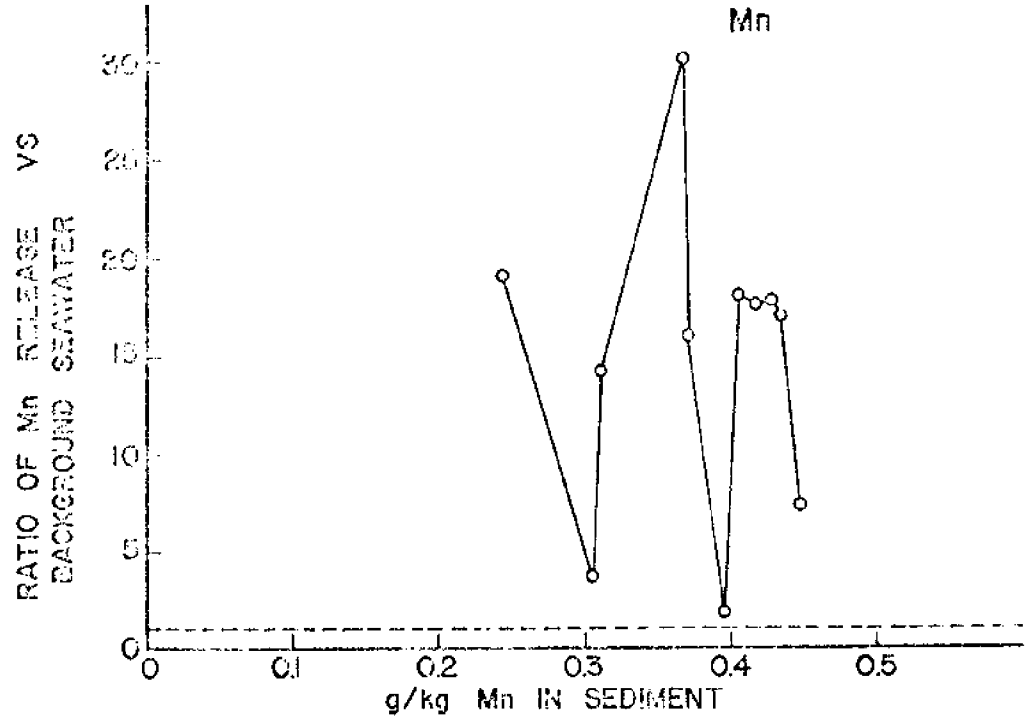


Figure 11. Mn and Ni Release Ratio in Elutriate Tests as a Function of Total Mn and Ni Sediment Content.



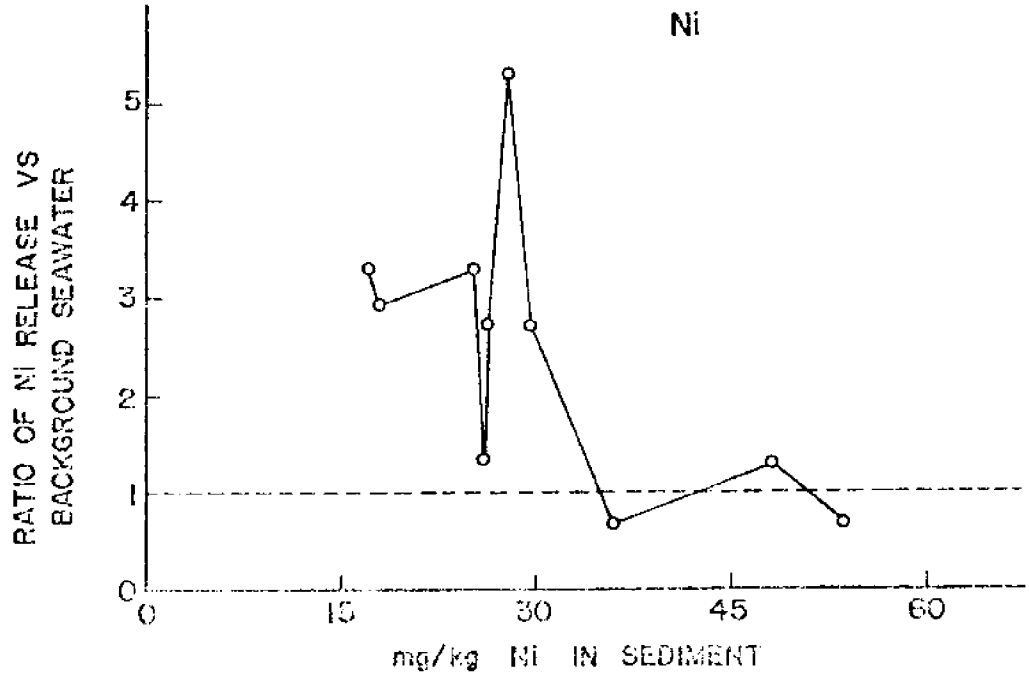
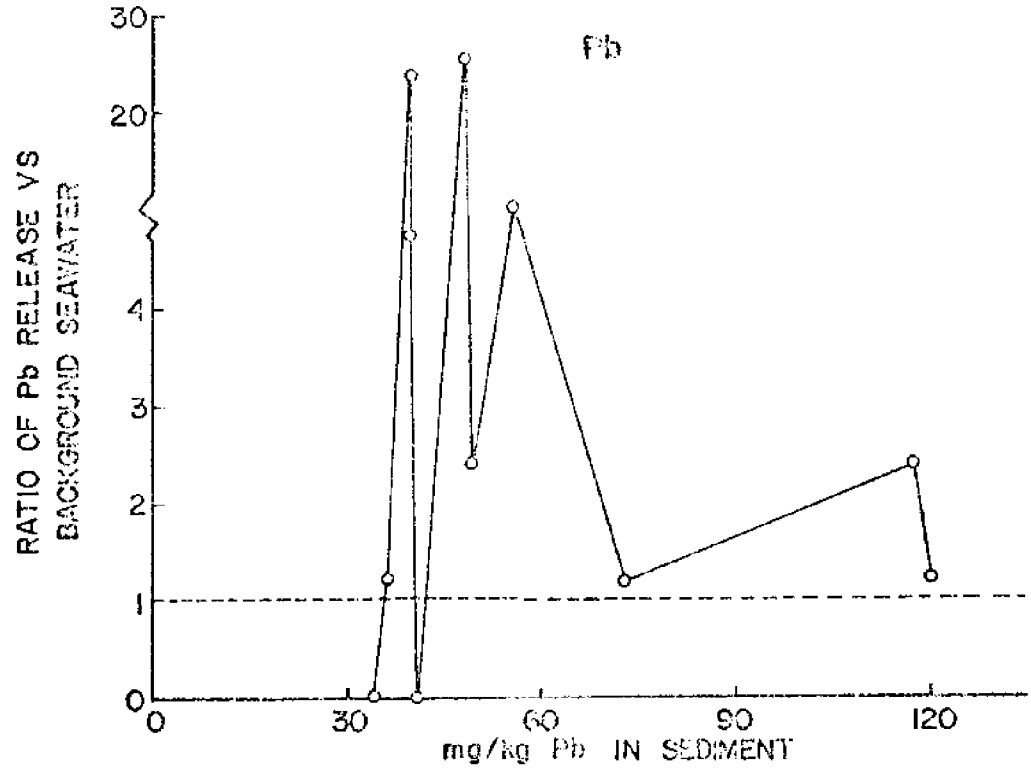


Figure 12. Pb and Zn Release Ratio in Elutriate Tests as a Function of Total Pb and Zn Sediment Content.



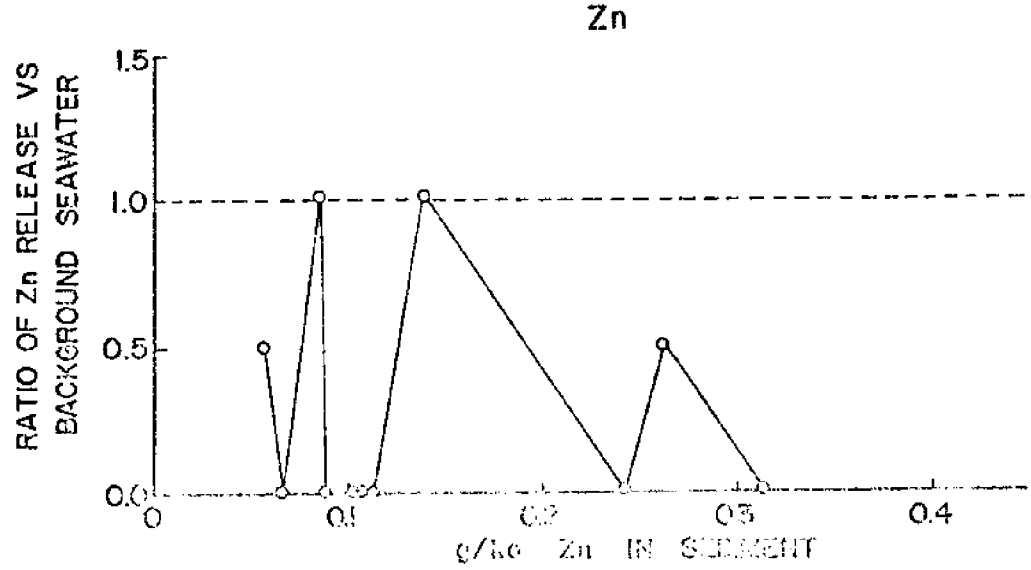


FIGURE 13. TRANSPORT OF TRACE CONTAMINANTS AND NUTRIENTS FROM SEDIMENTS (OXIDIZING CONDITION)

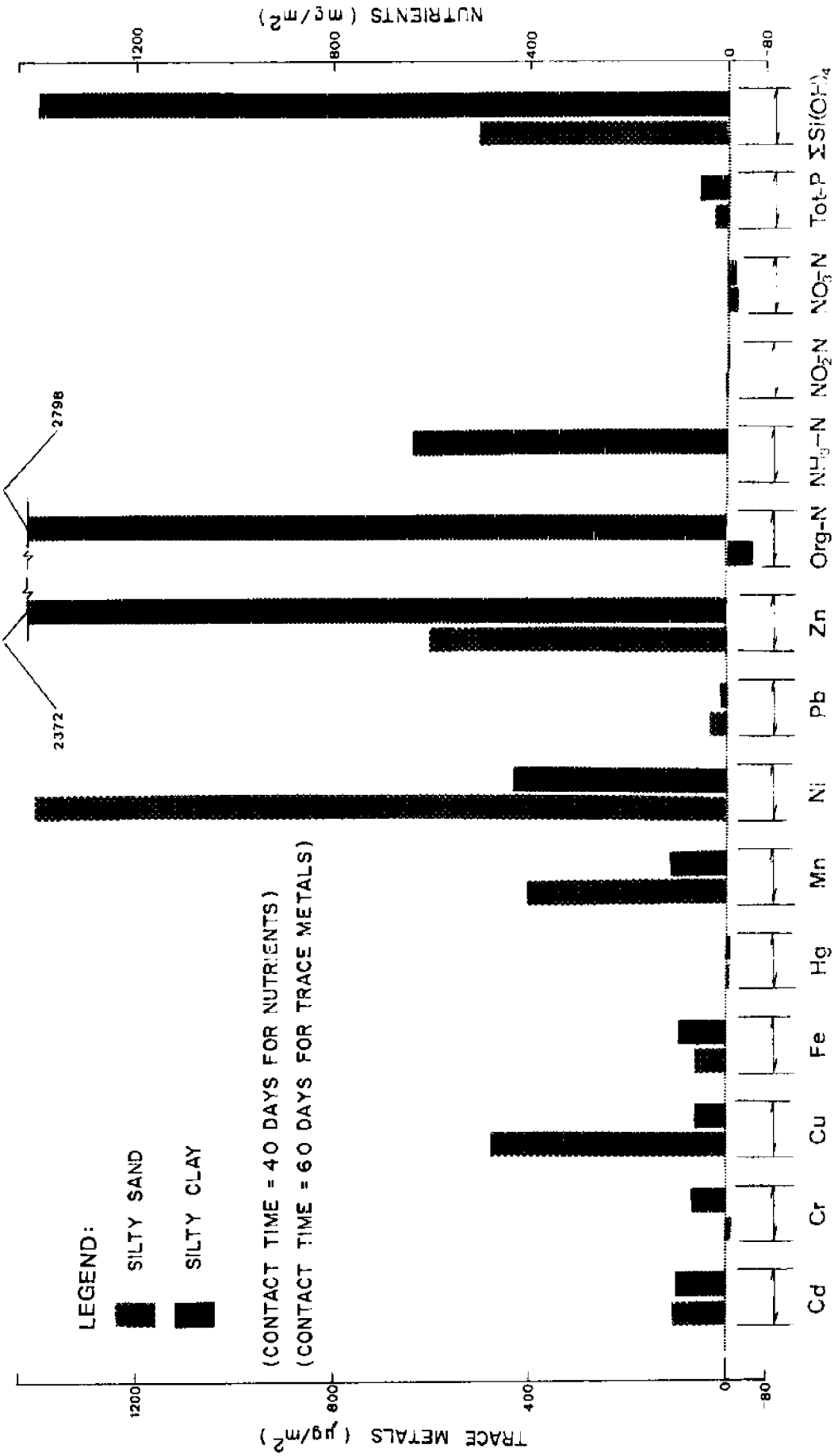
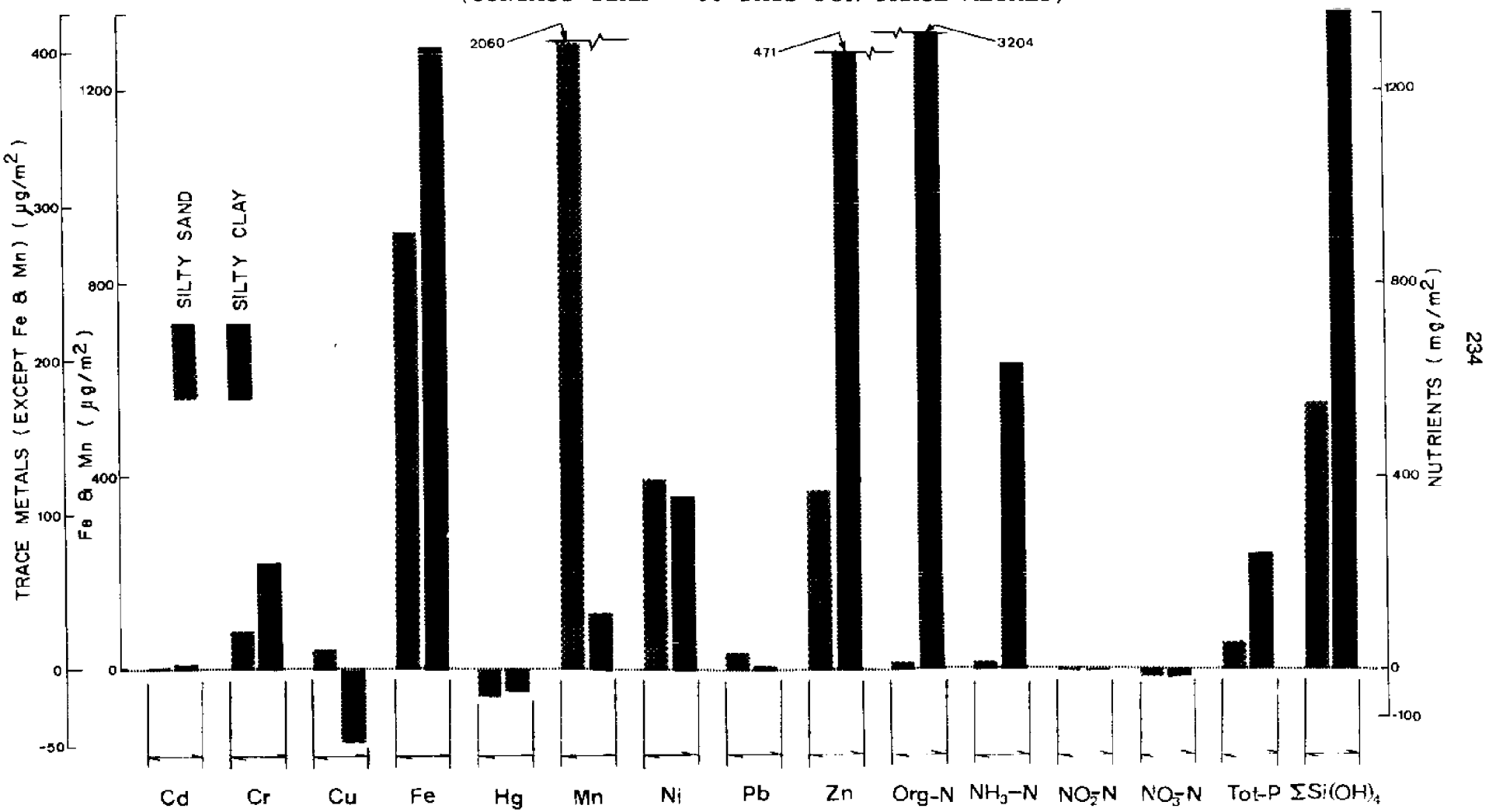


FIGURE 14. TRANSPORT OF TRACE CONTAMINANTS AND NUTRIENTS FROM SEDIMENTS

(SLIGHTLY OXIDIZING CONDITION)
(CONTACT TIME = 40 DAYS FOR NUTRIENTS)
(CONTACT TIME = 60 DAYS FOR TRACE METALS)



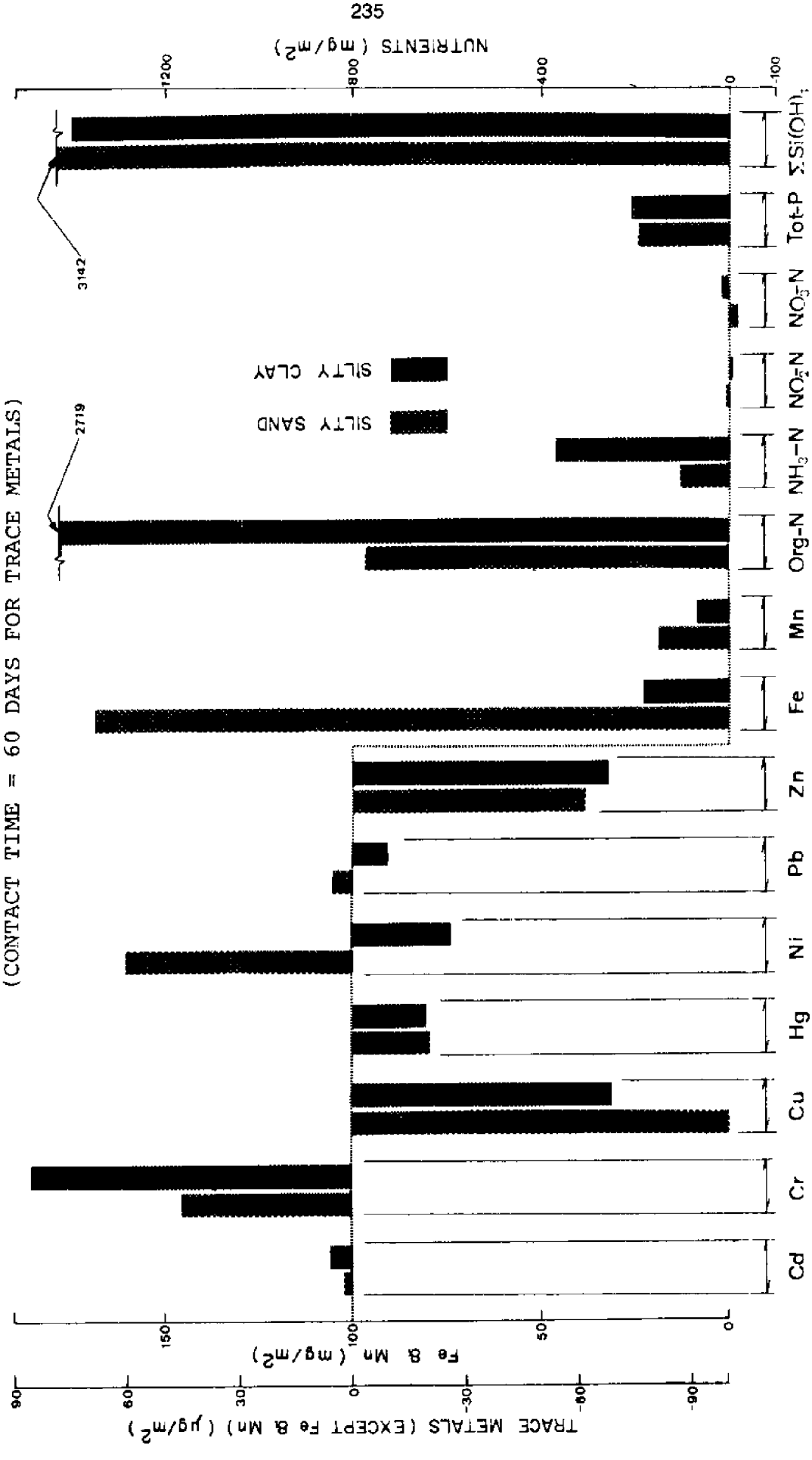
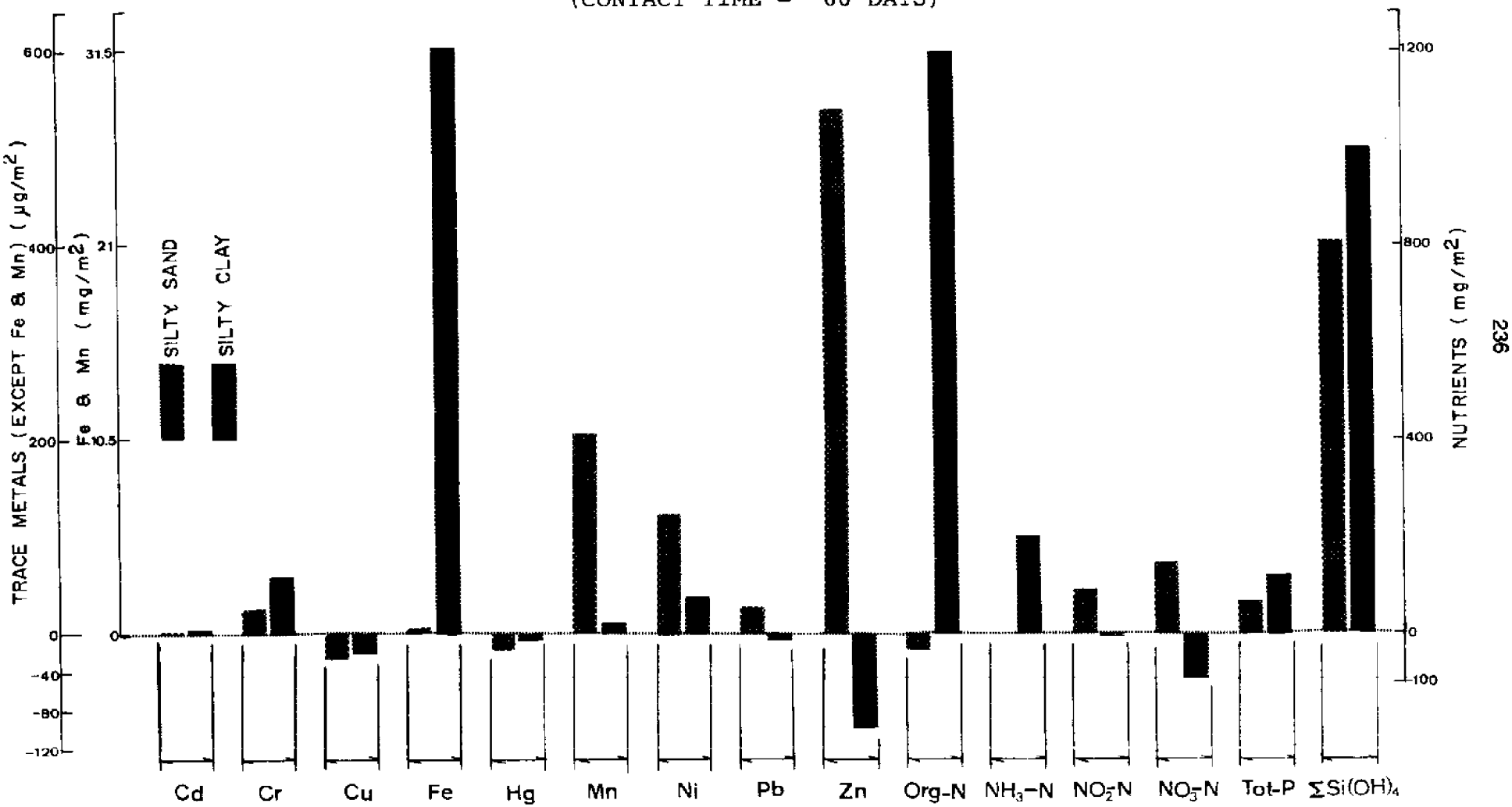


FIGURE 15. TRANSPORT OF TRACE CONTAMINANTS AND NUTRIENTS FROM SEDIMENTS (REDUCING CONDITION) (CONTACT TIME = 40 DAYS FOR NUTRIENTS) (CONTACT TIME = 60 DAYS FOR TRACE METALS)

FIGURE 16. TRANSPORT OF TRACE CONTAMINANTS AND NUTRIENTS FROM SEDIMENTS (RESETTLED TEST) (CONTACT TIME = 60 DAYS)

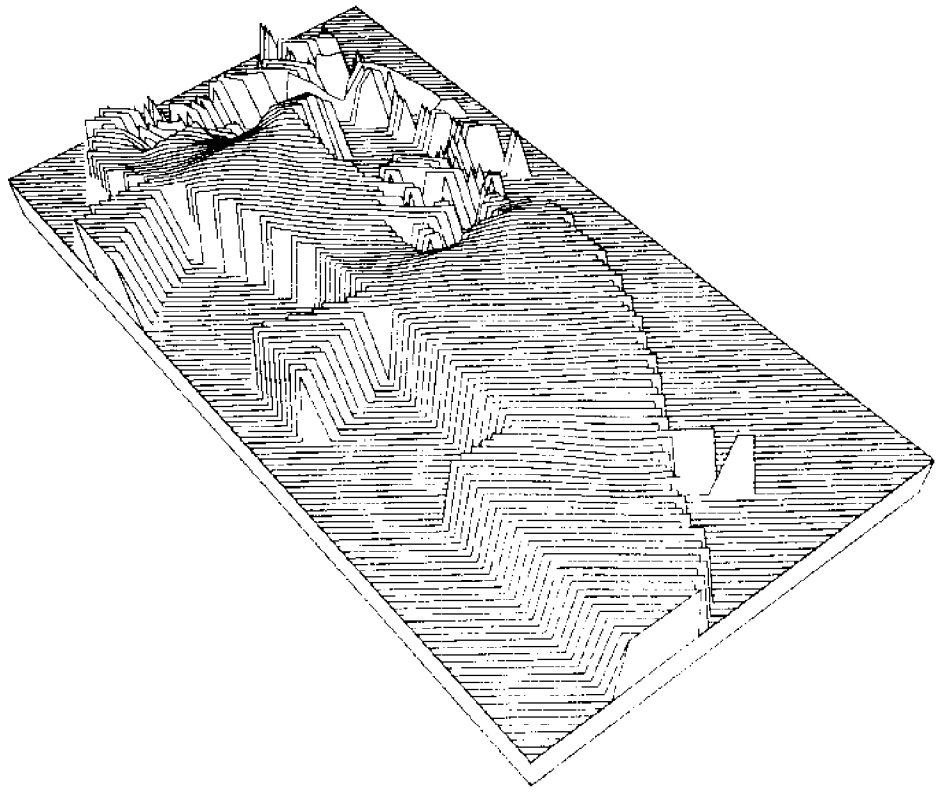


MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART 11. June, 1976

Appendix I

COMPUTER MAPPING OF POLLUTANTS IN LOS ANGELES HARBOR

by
John W. McDonald
Geography Department
University of Southern California
Los Angeles, California 90007



Minimum oxygen - 1973

Azimuth = 309 Altitude = 65
*Width = 10.00 *Height = 1.00

*Before foreshortening

Range 0.42 - 7.00 ppm

The Pollutant graphics and accompanying legends are from field data prepared for the Port of Los Angeles and the U.S. Army Corps of Engineers in 1973-1974 by Harbor Environmental Projects.

Figure 1a. Mean Phi Sediment. Legend.

DATA VALUE EXTREMES ARE 3.35 6.47

TOTAL MISSING DATA POINTS IS 1

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	3.35	3.66	3.97	4.29	4.60	4.91	5.22	5.53	5.85	6.16
MAXIMUM	3.66	3.97	4.29	4.60	4.91	5.22	5.53	5.85	6.16	6.47

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	'	-	=	+	X	C	@	&	#
FREQ.	2	2	0	3	3	4	2	3	2	6
1	I..I..I	I'.2.'I		I==4==I	I++5++I	IXX6XXI	ICC7CCI	I@@8@@I	I&&9&&I	I##*##I
2	I..I..I	I'.2.'I		I==4==I	I++5++I	IXX6XXI	ICC7CCI	I@@8@@I	I&&9&&I	I##*##I
3				I==4==I	I++5++I	IXX6XXI		I@@8@@I		I##*##I
4						IXX6XXI				I##*##I
5										I##*##I
6										I##*##I

Figure 1b. MEAN PHI SEDIMENT

Figure 2a. Total Organic Carbon. Legend.

```
DATA VALUE EXTREMES ARE          0.33          2.66


TOTAL MISSING DATA POINTS IS          2


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.33       0.58       0.84       1.09       1.34       1.60       1.85       2.10       2.36       2.61
  MAXIMUM       0.58       0.84       1.09       1.34       1.60       1.85       2.10       2.36       2.61       2.86


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4          5          6          7          8          9         10
         =========================================================================================================
         .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  CCCCCCCCC  @@@@@@@@@  &&&&&&&&&  ##########
         .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  CCCCCCCCC  @@@@@@@@@  &&&&&&&&&  ##########
  SYMBOLS ....1....  ''''2''''  ----3----  ====4====  ++++5++++  XXXX6XXXX  CCCC7CCCC  @@@@8@@@@  &&&&9&&&&  ####*#####
         .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  CCCCCCCCC  @@@@@@@@@  &&&&&&&&&  ##########
         .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  CCCCCCCCC  @@@@@@@@@  &&&&&&&&&  ##########
         =========================================================================================================
  FREQ.          3          3          4          3          3          6          2          1          0          1
       1  I..1..I  I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI  ICC7CCI  I@@8@@I                  I##*##I
       2  I..1..I  I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI  ICC7CCI
       3  I..1..I  I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI
       4                    I--3--I                    IXX6XXI
       5                                               IXX6XXI
       6                                               IXX6XXI
```

Figure 2b. TOTAL ORGANIC CARBON

Figure 3a. Sediment - Immediate Oxygen Demand (IOD). Legend.

DATA VALUE EXTREMES ARE 276.00 2511.50

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
("MAXIMUM" INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	276.00	499.55	723.10	946.65	1170.20	1393.75	1617.30	1840.85	2064.40	2287.95
MAXIMUM	499.55	723.10	946.65	1170.20	1393.75	1617.30	1840.85	2064.40	2287.95	2511.50

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	*	-	=	+	X	0	@	#	#
FREQ.	8	6	5	3	1	1	1	0	0	1

```
1  I..1..I  I**2**I  I--3--I  I==4==I  I++5++I  IXX6XXI  I00700I                 I##*##I
2  I..1..I  I**2**I  I--3--I  I==4==I
3  I..1..I  I**2**I  I--3--I  I==4==I
4  I..1..I  I**2**I  I--3--I
5  I..1..I  I**2**I  I--3--I
6  I..1..I  I**2**I
7  I..1..I
8  I..1..I
```

Figure 3b. SEDIMENT - IOD

Figure 4a. Log Sediment - Chemical Oxygen Demand (COD). Legend.

DATA VALUE EXTREMES ARE 9.77 11.93

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	9.77	9.99	10.20	10.42	10.63	10.85	11.06	11.28	11.50	11.71
MAXIMUM	9.99	10.20	10.42	10.63	10.85	11.06	11.28	11.50	11.71	11.93

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	'	-	=	+	X	0	@	#	*
FREQ.	4	2	1	4	3	6	3	2	0	1
1	. . 1 . .	' ' 2 ' '	- - 3 - -	= = 4 = =	+ + 5 + +	X X 6 X X	0 0 7 0 0	@ @ 8 @ @		# # * # #
2	. . 1 . .	' ' 2 ' '		= = 4 = =	+ + 5 + +	X X 6 X X	0 0 7 0 0	@ @ 8 @ @		
3	. . 1 . .			= = 4 = =	+ + 5 + +	X X 6 X X	0 0 7 0 0			
4	. . 1 . .			= = 4 = =		X X 6 X X				
5						X X 6 X X				
6						X X 6 X X				

Figure 4b. LOG SEDIMENT - COD

Figure 5a. Log Sediment - Organic Nitrogen. Legend.

DATA VALUE EXTREMES ARE 4.29 8.91

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
("MAXIMUM" INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	4.29	4.75	5.21	5.68	6.14	6.60	7.06	7.52	7.98	8.44
MAXIMUM	4.75	5.21	5.68	6.14	6.60	7.06	7.52	7.98	8.44	8.91

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	'	-	=	+	X	0	8	■	■
FREQ.	1	3	7	7	4	3	0	0	0	1

```
1  I..1..I  I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI                    I■■*■■I
2           I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI
3           I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI
4                    I--3--I  I==4==I  I++5++I
5                    I--3--I  I==4==I
6                    I--3--I  I==4==I
7                    I--3--I  I==4==I
```

Figure 5b. LOG SEDIMENT - ORGANIC NITROGEN

Figure 6a. Log Sediment - Sulfide. Legend.

DATA VALUE EXTREMES ARE 4.08 8.22

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
("MAXIMUM" INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	4.08	4.49	4.91	5.32	5.73	6.15	6.56	6.98	7.39	7.81
MAXIMUM	4.49	4.91	5.32	5.73	6.15	6.56	6.98	7.39	7.81	8.22

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	*	-	=	+	X	0	8	■	■
FREQ.	4	1	4	5	3	3	2	2	1	1

1	I..1..I	I*2*I	I--3--I	I==4==I	I++5++I	IXX6XXI	I07 0 7I	I88 8 8I	I■9■■I	I■■*■■I
2	I..1..I		I--3--I	I==4==I	I++5++I	IXX6XXI	I07 0 7I	I88 8 8I		
3	I..1..I		I--3--I	I==4==I	I++5++I	IXX6XXI				
4	I..1..I		I--3--I	I==4==I						
5				I==4==I						

Figure 6b. LOG SEDIMENT - SULFIDE

Figure 7a. Oil and Grease. Legend.

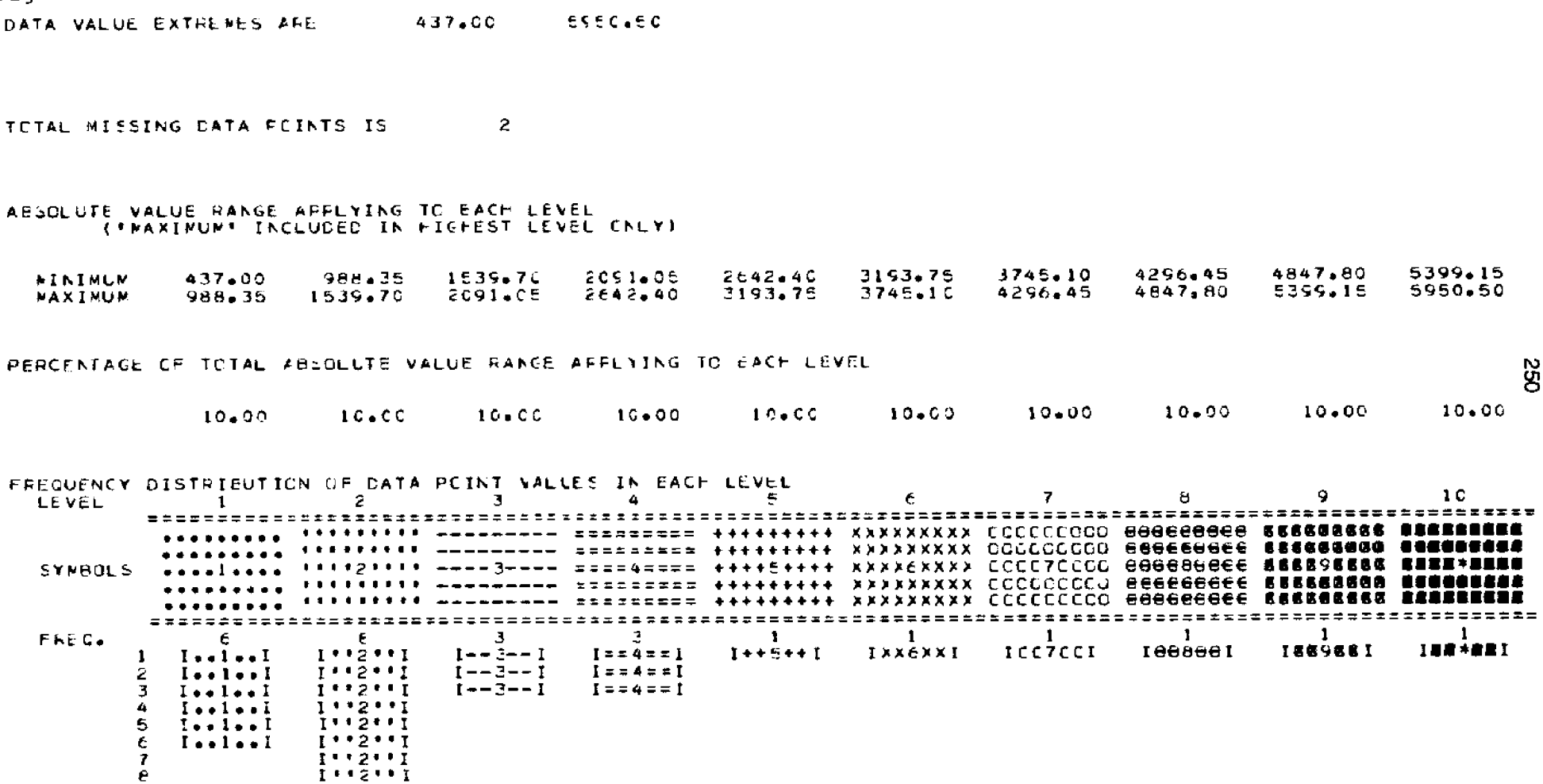


Figure 7b. OIL AND GREASE

Figure 8a. Mean Bottom Oxygen. Legend.

DATA VALUE EXTREMES ARE 4.34 6.67

TOTAL MISSING DATA POINTS IS 1

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
("MAXIMUM" INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	4.34	4.57	4.80	5.04	5.27	5.50	5.74	5.97	6.20	6.43
MAXIMUM	4.57	4.80	5.04	5.27	5.50	5.74	5.97	6.20	6.43	6.67

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	'	-	=	+	X	C	@	%	#
FREQ.	2	4	1	2	0	5	2	6	3	2
1	I..I..I	I''2''I	I--3--I	I==4==I		IXX6XXI	ICC7CCI	I@@8@@I	I@@9%%I	I##*##I
2	I..I..I	I''2''I		I==4==I		IXX6XXI	ICC7CCI	I@@8@@I	I%%9@@I	I##*##I
3		I''2''I				IXX6XXI		I@@8@@I	I%%9%%I	
4		I''2''I				IXX6XXI		I@@8@@I		
5						IXX6XXI		I@@8@@I		
6								I@@8@@I		

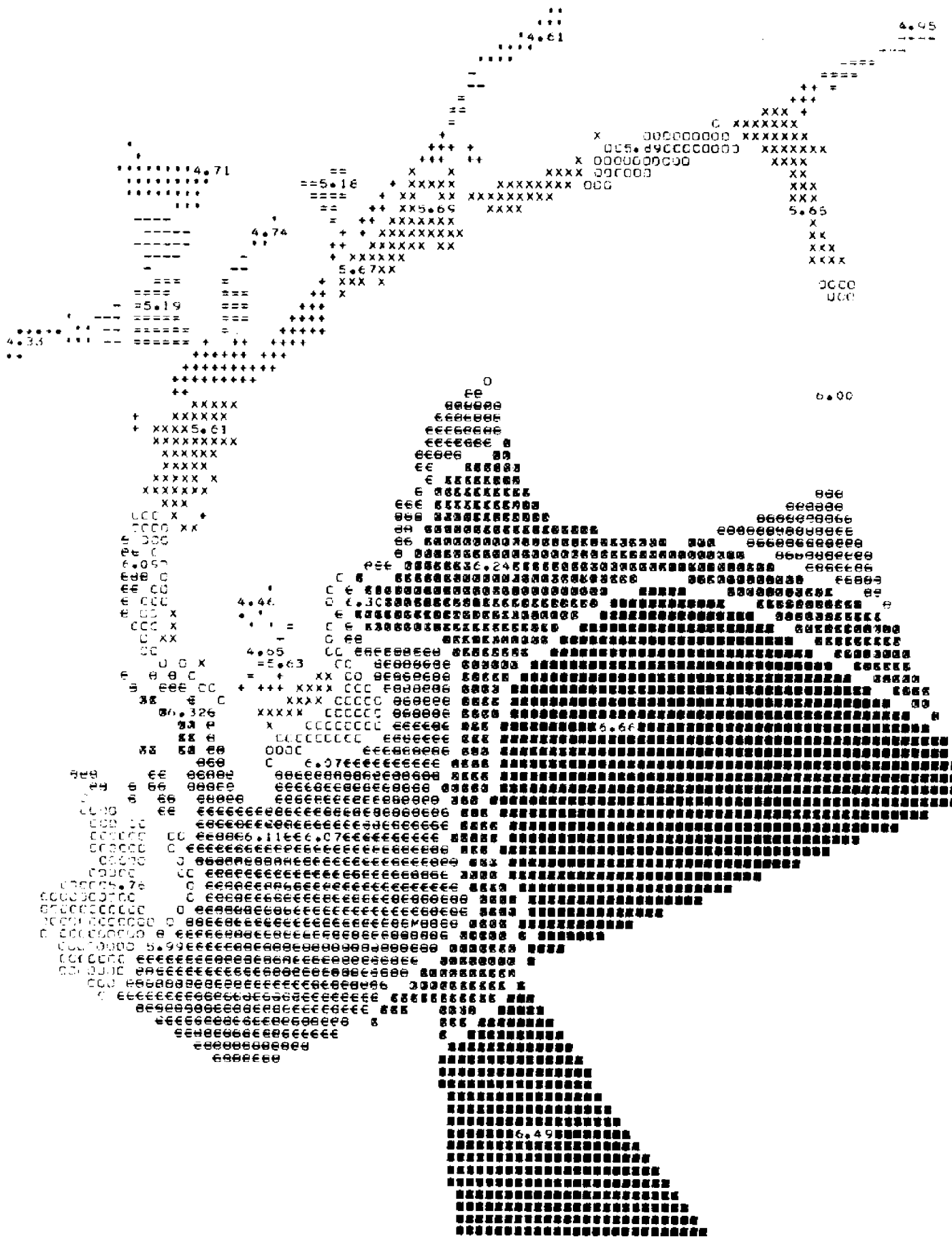


Figure 8b. MEAN BOTTOM OXYGEN

Figure 9a. Minimum Bottom Oxygen. Legend.

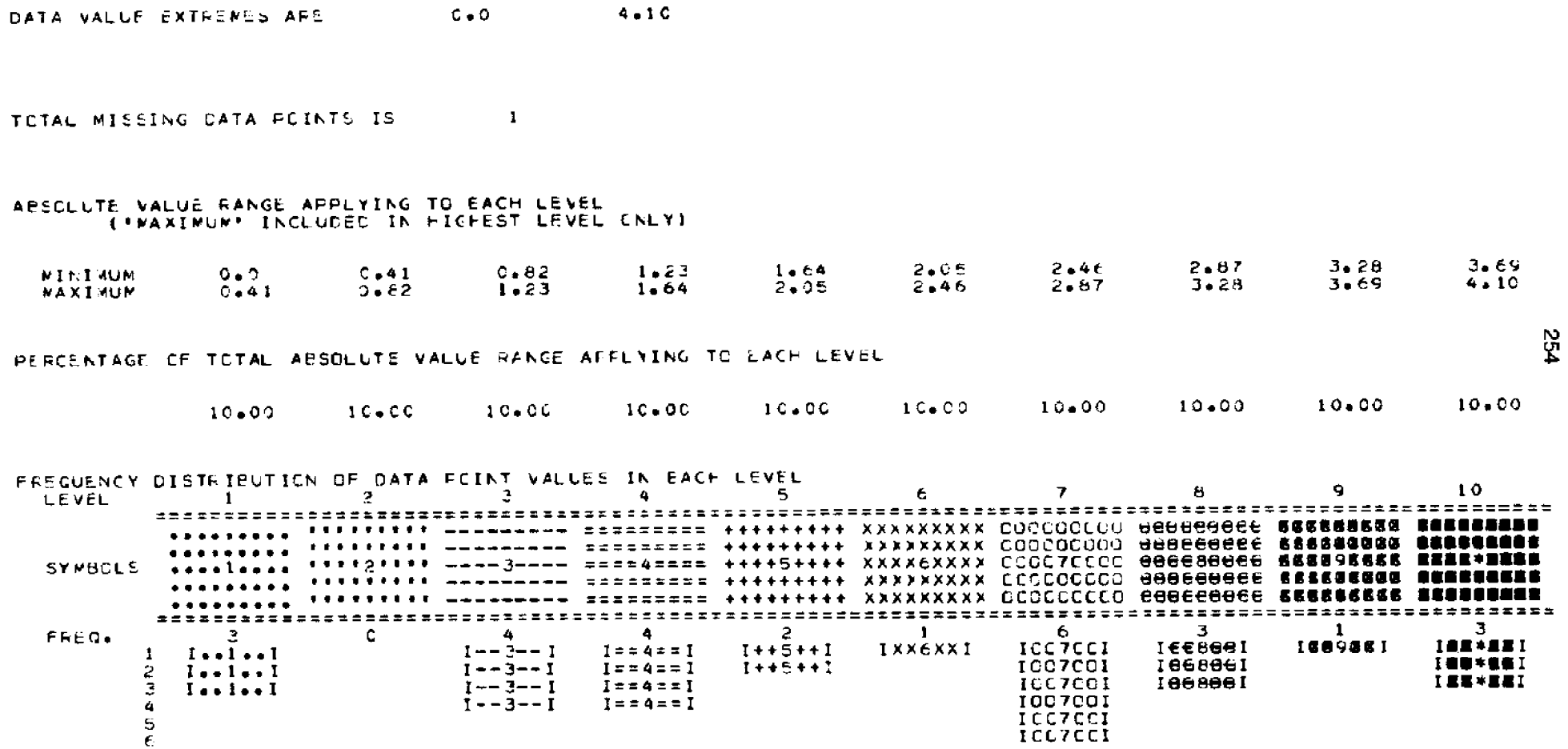


Figure 9b. MINIMUM BOTTOM OXYGEN

Figure 10a. Minimum Oxygen (Water Column) - 1974. Legend.

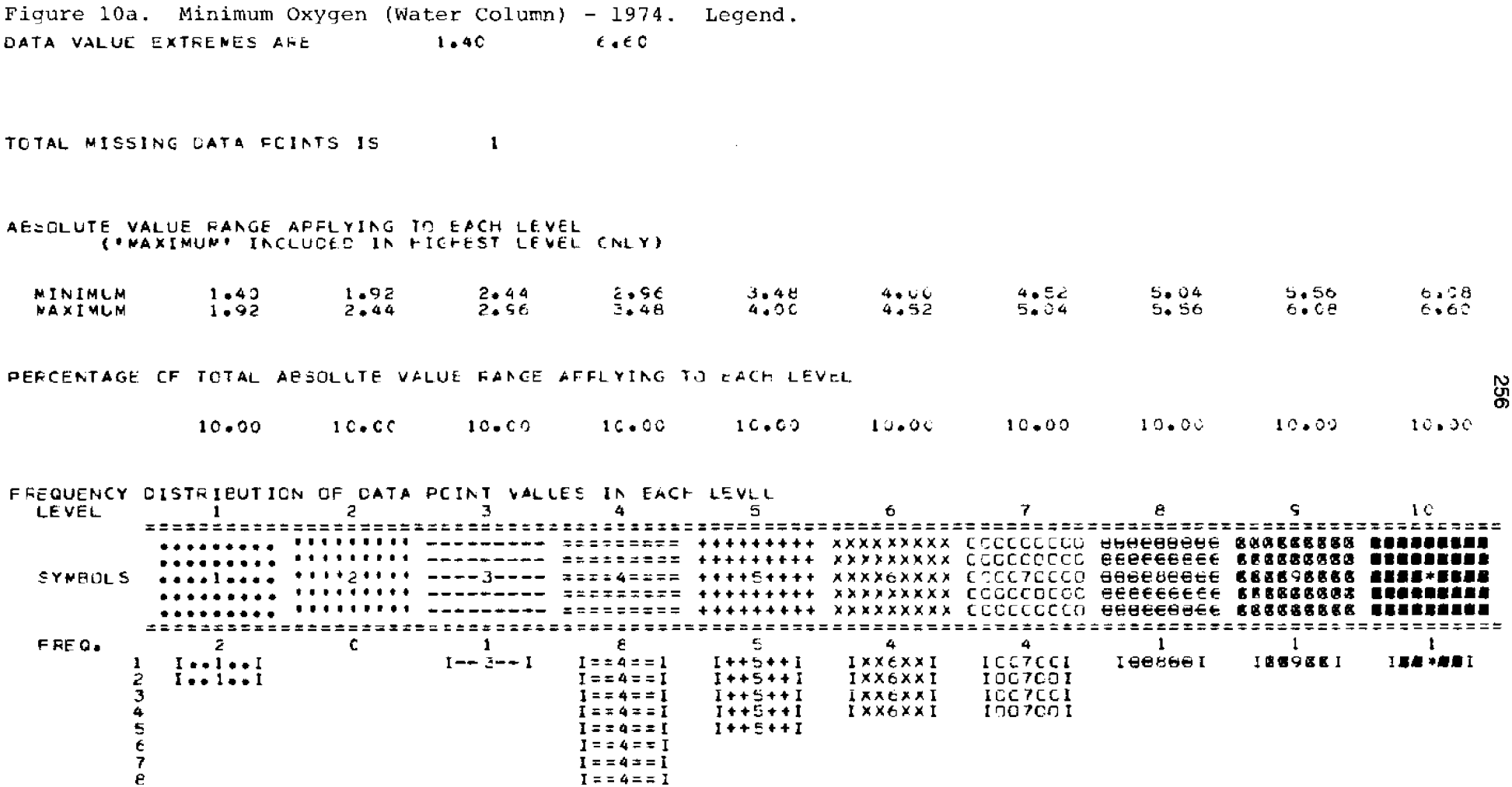


Figure 10b. MINIMUM OXYGEN (WATER COLUMN) - 1974.

Figure 11a. Sediment - Arsenic. Legend.

DATA VALUE EXTREMES ARE 2.22 20.80

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
("MAXIMUM" INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	2.22	4.08	5.94	7.80	9.65	11.51	13.37	15.23	17.08	18.94
MAXIMUM	4.08	5.94	7.80	9.65	11.51	13.37	15.23	17.08	18.94	20.80

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

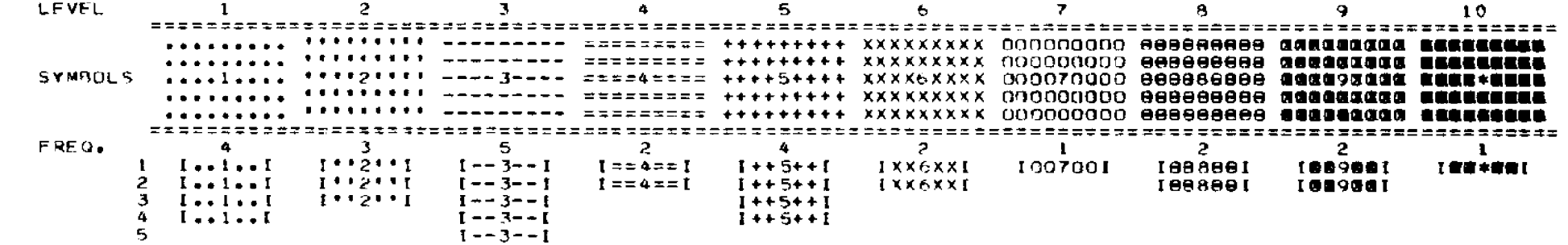


Figure 11b. SEDIMENT - ARSENIC

Figure 12a. Sediment - Cadmium. Legend.

DATA VALUE EXTREMES ARE 0.70 8.51

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	0.70	1.48	2.26	3.04	3.83	4.61	5.39	6.17	6.95	7.73
MAXIMUM	1.48	2.26	3.04	3.83	4.61	5.39	6.17	6.95	7.73	8.51

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	'	-	=	+	X	0	@	&	*
FREQ.	2	4	4	4	4	5	1	1	0	1
1	1 . . 1 . .	' ' 2 ' '	- - 3 - -	= = 4 = =	+ + 5 + +	X X 6 X X	0 0 7 0 0	@ @ 8 @ @		& * & &
2	1 . . 1 . .	' ' 2 ' '	- - 3 - -	= = 4 = =	+ + 5 + +	X X 6 X X				
3		' ' 2 ' '	- - 3 - -	= = 4 = =	+ + 5 + +	X X 6 X X				
4		' ' 2 ' '	- - 3 - -	= = 4 = =	+ + 5 + +	X X 6 X X				
5						X X 6 X X				

Figure 12b. SEDIMENT - CADMIUM

Figure 13a. Sediment - Chromium. Legend.

DATA VALUE EXTREMES ARE 14.00 360.00

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	14.00	48.60	83.20	117.80	152.40	187.00	221.60	256.20	290.80	325.40
MAXIMUM	48.60	83.20	117.80	152.40	187.00	221.60	256.20	290.80	325.40	360.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....1.....	.....2.....	----3----	====4====	+++++5+++++	XXXX6XXXX	000070000	88888888	■■■■9■■■■	■■■■*■■■■
FREQ.	7	9	2	3	2	0	1	1	0	1

```
1   I..1..I   I..2..I   I--3--I   I==4==I   I++5++I                 I007001I   I88888I                 I■■*■■I
2   I..1..I   I..2..I   I--3--I   I==4==I   I++5++I
3   I..1..I   I..2..I             I==4==I
4   I..1..I   I..2..I
5   I..1..I   I..2..I
6   I..1..I   I..2..I
7   I..1..I   I..2..I
8             I..2..I
9             I..2..I
```

Figure 13b.SEDIMENT - CHROMIUM

Figure 14a. Sediment - Copper. Legend.

DATA VALUE EXTREMES ARE 17.80 415.30

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	17.80	57.55	97.30	137.05	176.80	216.55	256.30	296.05	335.80	375.55
MAXIMUM	57.55	97.30	137.05	176.80	216.55	256.30	296.05	335.80	375.55	415.30

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	'	-	=	+	X	0	@	a	#
FREQ.	5	9	3	2	1	3	0	0	2	1

Figure 14b. SEDIMENT - COPPER

Figure 15a. Sediment - Iron. Legend.

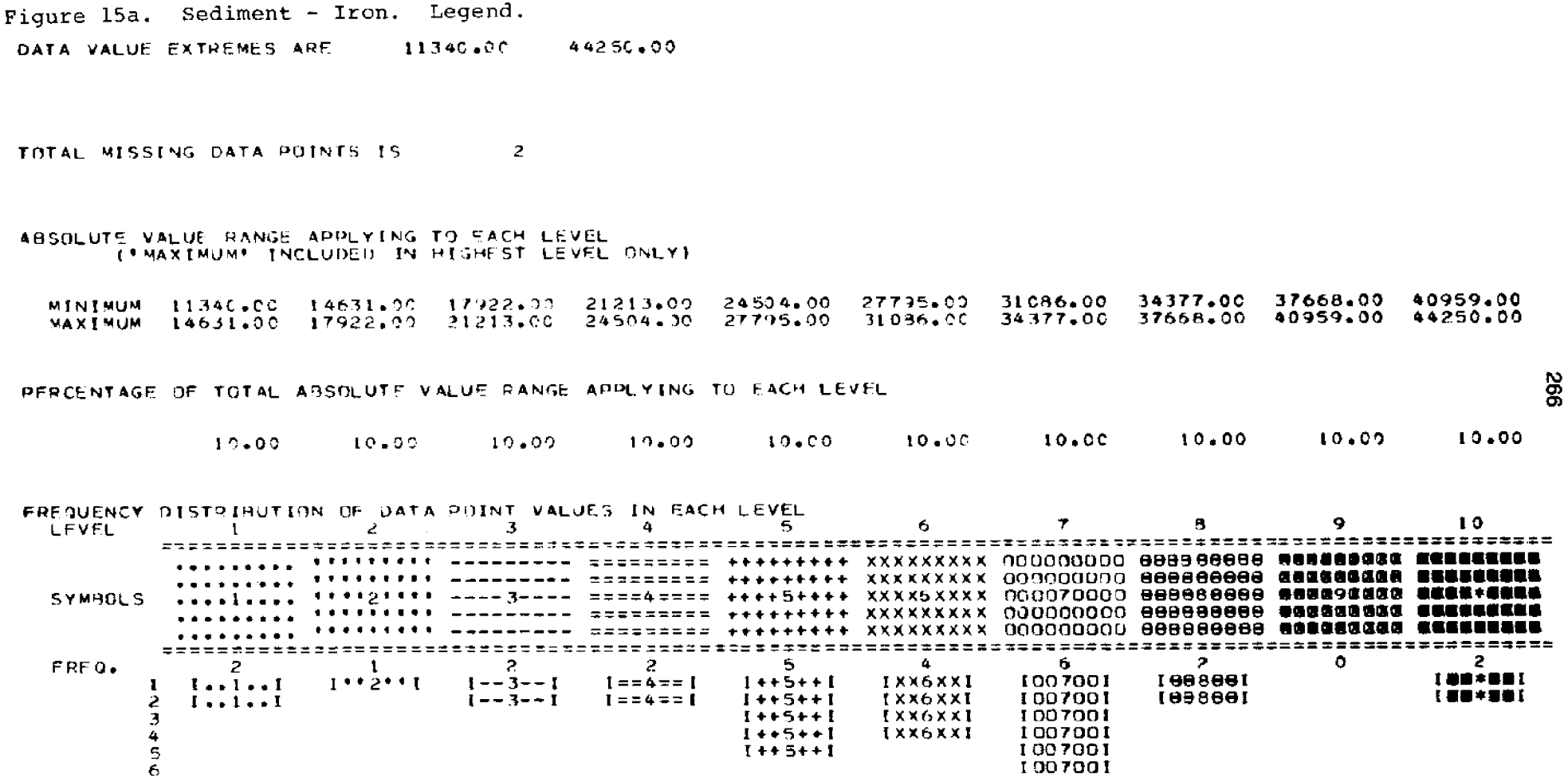


Figure 15b. SEDIMENT - IRON

Figure 16a. Log Sediment - Lead. Legend.

DATA VALUE EXTREMES ARE 3.56 6.21

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
("MAXIMUM" INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	3.56	3.82	4.09	4.35	4.62	4.88	5.15	5.41	5.68	5.94
MAXIMUM	3.82	4.09	4.35	4.62	4.88	5.15	5.41	5.68	5.94	6.21

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	*	-	=	+	X	0	#	@	*
FREQ.	1	3	5	4	5	6	1	0	0	1
1	I..1..I	I*2*I	I--3--I	I==4==I	I++5++I	IXX6XXI	I007001			I##*##I
2		I*2*I	I--3--I	I==4==I	I++5++I	IXX6XXI				
3		I*2*I	I--3--I	I==4==I	I++5++I	IXX6XXI				
4			I--3--I	I==4==I	I++5++I	IXX6XXI				
5			I--3--I		I++5++I	IXX6XXI				
6						IXX6XXI				

Figure 16b. LOG SEDIMENT - LEAD

Figure 17a. Mercury. Legend.

DATA VALUE EXTREMES ARE 0.22 4.18

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
("MAXIMUM" INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.22	0.62	1.01	1.41	1.81	2.20	2.60	2.99	3.39	3.78
MAXIMUM	0.62	1.01	1.41	1.81	2.20	2.60	2.99	3.39	3.78	4.18

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	'	-	=	+	X	O	@	#	*
FREQ.	8	7	6	2	2	0	0	0	0	1

```
1  I..1..I   I''2''I   I--3--I   I==4==I   I++5++I                        I##*##I
2  I..1..I   I''2''I   I--3--I   I==4==I   I++5++I
3  I..1..I   I''2''I   I--3--I
4  I..1..I   I''2''I   I--3--I
5  I..1..I   I''2''I   I--3--I
6  I..1..I   I''2''I   I--3--I
7  I..1..I   I''2''I
8  I..1..I
```

Figure 17b. MERCURY

Figure 18a. Sediment - Nickel. Legend.

DATA VALUE EXTREMES ARE 22.00 83.10

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	22.00	28.11	34.22	40.33	46.44	52.55	58.66	64.77	70.88	76.99
MAXIMUM	28.11	34.22	40.33	46.44	52.55	58.66	64.77	70.88	76.99	83.10

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	'	-	=	+	X	0	@	■	■
FREQ.	3	3	6	6	3	0	2	2	0	1
1	I..1..I	I''2''I	I--3--I	I==4==I	I++5++I		I007001	I088801		I■■+■■I
2	I..1..I	I''2''I	I--3--I	I==4==I	I++5++I		I007001	I088801		
3	I..1..I	I''2''I	I--3--I	I==4==I	I++5++I					
4			I--3--I	I==4==I						
5			I--3--I	I==4==I						
6			I--3--I	I==4==I						

Figure 18b. SEDIMENT - NICKEL

Figure 19a. Sediment - Phosphorus. Legend.

```
DATA VALUE EXTREMES ARE        818.00      1891.00


TOTAL MISSING DATA POINTS IS         2


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       (*MAXIMUM* INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM     818.00     925.30    1032.60    1139.90    1247.20    1354.50    1461.80    1569.10    1676.40    1783.70
  MAXIMUM     925.30    1032.60    1139.90    1247.20    1354.50    1461.80    1569.10    1676.40    1783.70    1891.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4          5          6          7          8          9         10
          =========  =========  =========  =========  =========  =========  =========  =========  =========  =========
           .........  *********  ---------  =========  +++++++++  XXXXXXXXX  000000000  000000000  ■■■■■■■■■  ■■■■■■■■■
           .........  *********  ---------  =========  +++++++++  XXXXXXXXX  000000000  000000000  ■■■■■■■■■  ■■■■■■■■■
  SYMBOLS  ....1....  ****2****  ----3----  ====4====  ++++5++++  XXXX6XXXX  000070000  000080000  ■■■■9■■■■  ■■■■*■■■■
           .........  *********  ---------  =========  +++++++++  XXXXXXXXX  000000000  000000000  ■■■■■■■■■  ■■■■■■■■■
           .........  *********  ---------  =========  +++++++++  XXXXXXXXX  000000000  000000000  ■■■■■■■■■  ■■■■■■■■■
          =========  =========  =========  =========  =========  =========  =========  =========  =========  =========
  FREQ.          2          1          5          2          2          6          3          4          0          1
       1  I..1..I    I**2**I    I--3--I    I==4==I    I++5++I    IXX6XXI    I007001I    I00800I                I■■*■■I
       2  I..1..I               I--3--I    I==4==I    I++5++I    IXX6XXI    I007001I    I00800I
       3                        I--3--I               I++5++I    IXX6XXI    I007001I    I00800I
       4                        I--3--I               I++5++I    IXX6XXI                I00800I
       5                        I--3--I               I++5++I    IXX6XXI
       6                                              I++5++I    IXX6XXI
```

Figure 19b. SEDIMENT - PHOSPHORUS

Figure 20a. Log Sediment - Zinc. Legend.

DATA VALUE EXTREMES ARE 3.74 7.05

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	3.74	4.07	4.40	4.73	5.06	5.39	5.72	6.06	6.39	6.72
MAXIMUM	4.07	4.40	4.73	5.06	5.39	5.72	6.06	6.39	6.72	7.05

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	'	-	=	+	X	0	@	■	■
FREQ.	1	2	1	5	9	5	1	1	0	1
1	I..1..I	I''2''I	I--3--I	I==4==I	I++5++I	IXX6XXI	I007001	I@@@@@I		I@@*@@I
2		I''2''I		I==4==I	I++5++I	IXX6XXI				
3				I==4==I	I++5++I	IXX6XXI				
4				I==4==I	I++5++I	IXX6XXI				
5				I==4==I	I++5++I	IXX6XXI				
6					I++5++I					
7					I++5++I					
8					I++5++I					
9					I++5++I					

Figure 20b. LOG SEDIMENT - ZINC

Figure 21a. Total DDT. Legend.

DATA VALUE EXTREMES ARE 0.06 2.46

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.06	0.30	0.54	0.78	1.02	1.26	1.50	1.74	1.98	2.22
MAXIMUM	0.30	0.54	0.78	1.02	1.26	1.50	1.74	1.98	2.22	2.46

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

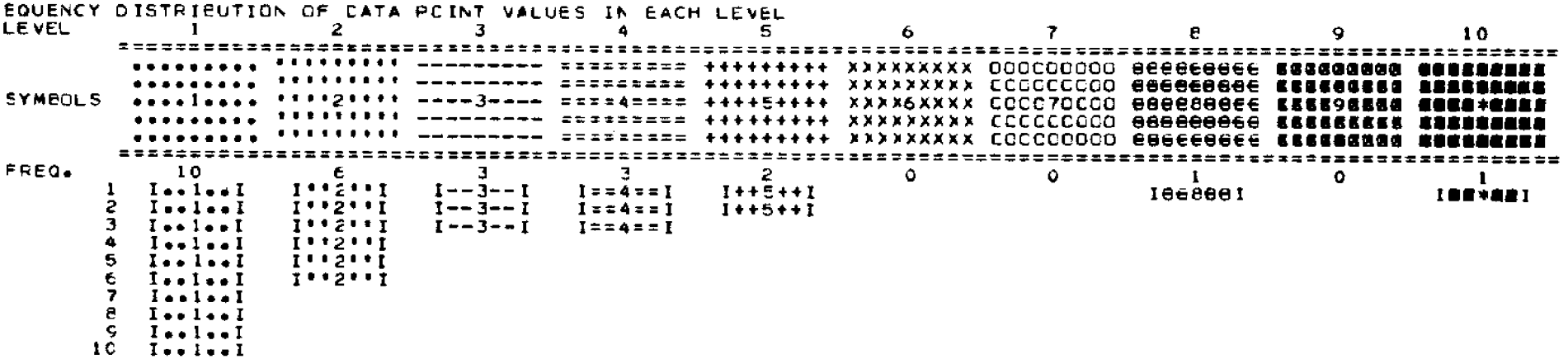


Figure 21b. TOTAL DDT

Figure 22a. Sediment - Total PCB. Legend.

DATA VALUE EXTREMES ARE 0.22 3.47

TOTAL MISSING DATA POINTS IS 2

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
("MAXIMUM" INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	0.22	0.55	0.87	1.20	1.52	1.85	2.17	2.50	2.82	3.15
MAXIMUM	0.55	0.87	1.20	1.52	1.85	2.17	2.50	2.82	3.15	3.47

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

1	2	3	4	5	6	7	8	9	10
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.	'	-	=	+	X	0	■	■	■
FREQ.	9	5	7	1	3	0	0	0	0	1

```
1  I..1..I  I''2''I  I--3--I  I==4==I  I++5++I                        I■■*■■I
2  I..1..I  I''2''I  I--3--I           I++5++I
3  I..1..I  I''2''I  I--3--I           I++5++I
4  I..1..I  I''2''I  I--3--I
5  I..1..I  I''2''I  I--3--I
6  I..1..I           I--3--I
7  I..1..I           I--3--I
8  I..1..I
9  I..1..I
```

Figure 22b. SEDIMENT - TOTAL PCB

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART 11. June 1976

Appendix II

CONCENTRATIONS OF TRACE ELEMENTS AND CHLORINATED HYDROCARBONS IN MARINE FISH

A Bibliography

by

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Approximately 250 references were surveyed for this study, with the subsequent inclusion of 52 references in this report. The primary sources of information were: (1) Environment Index, (2) Pollution Abstracts, (3) Applied Science and Technology Index, and (4) Chemical Abstracts.

The reliability of the data is not known and techniques have advanced rapidly in a relatively short time. Both dry ashing and wet acid digestion techniques were used by the referenced investigators in conjunction with various analytical procedures. The available data indicate that most analyses have been conducted for DDT, PCB, and mercury.

All concentrations in Table 1 are in ppm, wet fish weight, except as noted. Limited data was obtained for fish oils and fish meals.

The concentration factor is obtained by dividing the weight of the constituent in the fish species by the seawater concentration. Seawater concentrations were obtained from the most recent sources and are referenced in this report. Concentrations of methyl mercury, polychlorinated biphenyls, and hexachlorobenzene in seawater could not be obtained. The concentration factors shown in Table 1 are the minimum and maximum values from the referenced data. Single values indicate that only one reference was obtained.

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Table 1a. Concentration of Trace Elements and Chlorinated Hydrocarbons in Marine Fish. (References numbered in parentheses.)

Note: First number in column lists the concentration found in tissue, in ppm wet weight unless specified.
() are referenced in Literature Cited.
Numbers below dotted line indicate the amplification ratio (concentration in fish/concentration in seawater).

FISH (Common Name) Concentration Factor	Total DDT	PCB	HCB C_6Cl_6	As	Ba	Cd	Co	Cr	Cu	Hg	CH_3Hg as Hg	Mn	Mo	Ni	Pb	Sb	Se	Zn
Anchovetta					.8(41)				.0184 (41)			1.03 (41)			1.7 (41)		.84-2.6(29)*	.108 (41)
*meal					20				80			1000			10,000			
Anchovy	.33-14.0 (37) .69(28)	1.0(37)								.07-.22(17) .1(11)								
	9,400 - 400,000									1170-3670								
Atlantic Croaker	.21(22)																	
	6,000																	
Bass	4-138(51)																	
	114,000-3900000																	
Striped Bass			.007-.050(26)							>0.5 (2)								
										8330								
Bigeyed Scad										.07-.11(43)	.07-.11 (43)							
										1170-1830								
Billfish	2.07(51)																	
	59,000																	
Blowfish	.17(51)																	
	4860																	
Bluefish										>0.5 (2)								
										8330								

Table 1b. Concentration of Trace Elements and Chlorinated Hydrocarbons in Marine Fish. (References numbered in parentheses).

Note: First number in column lists the concentration found in tissue, in ppm wet weight unless specified.
() are referenced in Literature Cited.
Numbers below dotted line indicate the amplification ratio (concentration in fish/concentration in seawater.)

FISH (Common Name) Concentration Factor	Total DDT	PCB	HCB C_6Cl_6	As	Ba	Cd	Co	Cr	Cu	Hg	CH_3Hg as Hg	Mn	Mo	Ni	Pb	Sb	Se	Zn
Bonita										.03 (45)								
										5000								
Capelin * fish oil				12.1* (33) 7.8-8.5* (32)					.03-.40* (39)								.10-.12 (32)	
				(520-807)*					(130-1740)*								(25-30) *	
Cod * oil ** liver	.005-.023(5) 1-300(40) .001-.11(25) .01(52) **.2-135(5)	.006-.057 (25) .02 (52)	.06-38* (26)	.03(30) 8.4-* 9.9(33)						.026-.064 (37) .09(45)	.022-.055 (37)							
	143-8600000 (5710-**3900000)	20 (560-660)**								430-1500								
Lingcod						.009-.224(9)									.036-.070(9)			
						38-930									212-412			
Cuttlefish									23(4)									
									100000									
Dogfish	.028-.33 (25)	.054-.30(25)		1.7-5.6(30)						.5-2.0 (13)								
	800-9430	113-370								8300-33,300								
Dolphin										.17-.31(43)								
										2830-5170								

Table 1c. Concentration of Trace Elements and Chlorinated Hydrocarbons in Marine Fish. (References numbered in parentheses.)

Note: First number in column lists the concentration found in tissue, in ppm wet weight unless specified.
() are referenced in Literature Cited.
Numbers below dotted line indicate the amplification ratio (concentration in fish/concentration in seawater.)

FISH (Common Name) Concentration Factor	Total DDT	PCB	HCB C_6Cl_6	As	Ba	Cd	Co	Cr	Cu	Hg	CH_3Hg as Hg	Mn	Mo	Ni	Pb	Sb	Se	Zn
Eel	.28(50)																	
	8000																	
Flounder * dry weight	1.28(50)					3.4- 7.3* (23)				.08 (45)					13.9- 24.5* (23)			76.3* -176 (23)
	36,600					14170*- 30,420				1330					81800*- 652000		283000- 652000*	
Starry Flounder	.08(38)					.008(9)									.048(9)			
	2290					33									282			
Greenling				0.4(30)														
				27														
Grouper	.001- 1.39(15)	.003- .220(15)																
	29-3970																	
Gurnard						.008- .024(6)		.01- .02(6)	.15- .75(6)			.10- 3.70(6)		.01- .03(6)	.13- .40(6)			2.5- 16.2(6)
						33-100		18-36	650- 3260			97- 3590		13-40	765- 2350			9260 -60,000
Haddock								.07(46)		.04(45)								
								127		670								
Hake	.2-2.0 (42)	.16(37) .02(52)				.014 (9)									.044(9)			
	5140- 57,000					58									260			
Halibut	.59(38)									.15-.7 (45)								
	16,900									2500- 11,700								

Table 1d. Concentration of Trace Elements and Chlorinated Hydrocarbons in Marine Fish. (References numbered in parentheses.)

Note: First number in column lists the concentration found in tissue. in ppm wet weight unless specified.
() are referenced in Literature Cited.
Numbers below dotted line indicate the amplification ratio (concentration in fish/concentration in seawater.)

FISH (Common Name) Concentration Factor	Total DDT	PCB	HCB C_6Cl_6	As	Ba	Cd	Co	Cr	Cu	Hg	CH_3Hg as Hg	Mn	Mo	Ni	Pb	Sb	Se	Zn
Hapuku						.001- .011 (6)		.01- .05 (6)	.20- 1.62 (6)			.05- .95(6)		.01- .04(6)	.04- 1.64 (6)			2.1- 12(6)
						4-46		18-91	670- 7040			49-920		13-53	235- 9650			7780- 44400
Herring * oil ** meal	7-17*(1) .15-.67 (31) .094-2.3 (25) .66(52)	11*(1) .21-.61 (31) .01-1.0 (25) .32-.54 (52)	.003- .006(52)	5.3- 7.6* (32) 13.8- 19.3* (33)					.08- .12* (39)	.07(45) 1.0(37)							1.30- 2.6** (29) .02- .26* (32)	
	2690- 66,000 (200000- 486000)*			350- 1290*					350- 522*	1170- 16700							5-65* 325- 650**	
Kawahai						.002- .003 (6)		.01- .04(6)	.30- 3.24 (6)			.09- .62(6)		.02-.04 (6)	.09- .27(6)			9-46 (6)
						9-13		18-73	1304- 14100			83-602		27-53	529- 1590			33300 -170000
Kingfish						.002- .014 (6)		.01- .03(6)	.2-3.4 (6)			.12- 1.10 (6)		.02-.08 (6)	.2-.97 (6)			2.8- 56 (6)
						8-58		18-55	870- 14800			117- 1.070		27-107	1180- 5710			10370- 207000
Lantern Fish				1-2(16)		.3-1.6 (16)			1.8-23 (16)	.11- .34(16)					.5-3.7 (16)			13-85 (16)
				67-133		1250- 6670			7830- 100000	1830- 5670					2940- 21760			48150- 315000
Mackerel	.16(52) .2-2.0* (42)	.35(52)	.001(52)	4.8-* 9.1(32) 8.2-* 13.0(33)						.12 .5(12)							.05- .21* (32)	
4570-57100		(320-670		320-670*						2000-8330							13-53*	

Table 1e. Concentration of Trace Elements and Chlorinated Hydrocarbons in Marine Fish. (References numbered in parentheses.)

Note: First number in column lists the concentration found in tissue, in ppm wet weight unless specified.
() are referenced in Literature Cited.
Numbers below dotted line indicate the amplification ratio (concentration if fish/concentration in seawater.)

FISH (Common Name) Concentration Factor	Total DDT	PCB	HCB C_6Cl_6	As	Ba	Cd	Co	Cr	Cu	Hg	CH_3Hg as Hg	Mn	Mo	Ni	Pb	Sb	Se	Zn
Jack Mackerel	.56(37)	.02(37)																
	16,000																	
Menhaden * oil ** meal			.11*(26)														.75-4.2**(29)	
																	188-1050*	
Moki						.001-.012(6)		.01-.02(6)	.15-2.8(6)			.02-.36(6)		.03-.09(6)	.08-.39(6)			1.8-20(6)
						4-50		18-36	650-12170			19-350		40-120	471-2290			
Mullet	2.9-37(28)									.05(43) .006-.23(35)	.05(43)							
	28600-1060000									100-3830								
Needlefish	2.07(50)																	
	59,100																	
Perch										.22-3.25(37)	.20-2.99(37)							
										3670-54170								
Shiner Perch	1.0-1.4(37)	.4-1.2(37)																
	28570-40000																	
Silver Perch	1.26(22)																	
	36,000																	

Table 1f. Concentration of Trace Elements and Chlorinated Hydrocarbons in Marine Fish. (References numbered in parentheses.

Note: First number in column lists the concentration found in tissue, in ppm wet weight unless specified.
() are referenced in Literature Cited.
Numbers below dotted line indicate the amplification ratio (concentration in fish/concentration in seawater.)

FISH (Common Name) Concentration Factor	Total DDT	PCB	HCB C_6Cl_6	As	Ba	Cd	Co	Cr	Cu	Hg	CH_3Hg as Hg	Mn	Mo	Ni	Pb	Sb	Se	Zn
Pacific Blue Marlin										.35-14(43)	.23-1.79 (43)							
										5830-233000								
Parrot Fish										.05-.1(43)	.05-.08 (43)							
										833-1670								
Pinfish	.94(22)																	
	26,860																	
Plaice	.01(52)	.03(52)							1.3-6.7 (47)									
	286								5650-29130									
Ratfish				.4-10.3 (30)														
				27-690														
Red Goatfish										.05(43)	.05(43)							
										830								
Rockfish				.30-2.6 (30)		.014-.088 (9)									.069-.092 (9)			
				20-173		58-370									406-540			
Salmon	.67(38) .26-7.1 (25)	.014-.54(25)		.04 (30)						.063-.309 (49) .04 (45)	.055-.256(49)							
7430-203000		3							670-5150									

Table 1g. Concentration of Trace Elements and Chlorinated Hydrocarbons in Marine Fish. (References numbered in parentheses.)

Note: First number in column lists the concentration found in tissue, in ppm wet weight unless specified.
() are referenced in Literature Cited.
Numbers below dotted line indicate the amplification ratio (concentration in fish/concentration in seawater.)

FISH (Common Name) Concentration Factor	Total DDT	PCB	HCB C_6Cl_6	As	Ba	Cd	Co	Cr	Cu	Hg	CH_3Hg as Hg	Mn	Mo	Ni	Pb	Sb	Se	Zn
Atlantic Salmon	.37(52)	.45(52)																
	10,570																	
Coho Salmon	19(48)	5(20)	.01(26)															
	543,000																	
Sardine	15.3-19.4(28)									.02(45) .1(11)								
	440,000-554,000									330-1670								
Sea Trout	.64(28)									.218-.296 (49)	.207-.258 (49)							
	18,290									3630-4930								
Shark				1.9-5.9(30)						>.5 (3)								
				127-393						>8300								
Sheephead	.94(50)																	
	26,860																	
Silverside	.23(50)																	
	6,570																	
Skate				16.2 (30)														
				1,080														
Smelt * meal																	.49-1.23* (29)	
																	123-308*	

Table 1h. Concentration of Trace Elements and Chlorinated Hydrocarbons in Marine Fish. (References numbered in parentheses.)

Note: First number in column lists the concentration found in tissue, in ppm wet weight, unless specified.
() are referenced in Literature Cited.
Numbers below dotted line indicate the amplification ratio (concentration in fish/concentration in seawater.)

FISH (Common Name) Concentration Factor	Total DDT	PCB	HCB C_6Cl_6	As	Ba	Cd	Co	Cr	Cu	Hg	CH_3Hg as Hg	Mn	Mo	Ni	Pb	Sb	Se	Zn
Squirrel Fish										.1-.43 (43)	.1-.4(43)							
										1670-7170								
Steelhead				.4(30)														
				27														
Swordfish										.23-1.27 (36) 1 (21) .49-2.6(27) .5-3.0 (45) .99-2.01 (11)								
										3830-50,000								
Tarakihi						.002-.015 (6)		.01-.03(6)	.11-.91(6)			.04-8 (6)		.02-.06 (6)	.09-.3 (6)			.9-7 (6)
						8-63		18-55	480-3960			39-7770		27-80	529-1770			3330-25900
Toadfish	.17(50)																	
	4860																	
Trevally						.006-.012 (6)		.01-.02(6)	.11-.91(6)			.09-.84(6)		.01-.04(6)	.09-.30(6)			1-35 (6)
						25-30		18-36	480-3960			87-816		13-53	529-1770			3700-130000

Table 1i. Concentration of Trace Elements and Chlorinated Hydrocarbons in Marine Fish. (References numbered in parentheses.)

Note: First number in column lists the concentration found in tissue, in ppm wet weight unless specified.
() are referenced in Literature Cited.
Numbers below dotted line indicate the amplification ratio (concentration in fish/concentration in seawater.)

FISH (Common Name) Concentration Factor	Total DDT	PCB	HCB C_6Cl_6	As	Ba	Cd	Co	Cr	Cu	Hg	CH_3Hg as ^3Hg	Mn	Mo	Ni	Pb	Sb	Se	Zn
Tuna * meal	.2-2(42)									.09-1 (14) .31 (45) .3-.5 (7) .04-.55(27) .46-.91(11)	1 (21) .37-1.2 (44)						3.4-6.2* (29) 1.7-3.4* (14)	
	5700-57100									670-16700							425-1550 *	
Albacore Tuna										.13-.48(36) .31(45)								
										2170-8000								
Bluefin Tuna	.22-.56 (37)	.04(37)																
	6290-16000																	
Skipjack Tuna	.029-.057(37)	.1(37)			.12 (41)				.023 (41)	.18(36) .27-.52(43) .2(45)	.2-.57 (43)	.0412 (41)		.037 (41)				.135 (41)
	830-1630				3				100	3000-8670		40		50				500
Yellowfin Tuna	.07-.62 (37)	.04(37)			.08 (41)				.046 (41)	.24-1.32 (43) .17(45)	.25-1 (43)	.0824 (41)						.189 (41)
	2000-17700				2				200	2830-22000		80						700

Table 1j. Concentration of Trace Elements and Chlorinated Hydrocarbons in Marine Fish. (References numbered in parentheses.)

Note: First number in column lists the concentration found in tissue, in ppm wet weight unless specified.
() are referenced in Literature Cited.
Numbers below dotted line indicate the amplification ratio (concentration in fish/concentration in seawater.)

FISH (Common Name) Concentration Factor	Total DDT	PCB	HCB C_6Cl_6	As	Ba	Cd	Co	Cr	Cu	Hg	CH_3Hg as ^3Hg	Mn	Mo	Ni	Pb	Sb	Se	Zn
Whiting										.06 (45)								
										1000								
Whitefish										1.06-1.40 (37) .05 (45)								
										830-23,300								
Normal Seawater (ppb)	.02(19) .05(50)			15(10)	30(34) 50(10)	.24(8)	.1(10) .1(34)	.55(8)	.23(8)	.06(8)		1.03 (8)	.7(10)	.75(8)	.17(8)	.2(24	4(10)	.27 (8)

Table 1k. Concentration of Trace Elements and Chlorinated Hydrocarbons in Marine Fish. (References numbered in parentheses.)

Note: First number in column lists the concentration found in tissue, in ppm wet weight unless specified.
() are referenced in Literature Cited.
Numbers below dotted line indicate the amplification ratio (concentration in fish/concentration in seawater.)

FISH (Common Name) Concentration Factor	Total DDT	PCB	HCB C_6Cl_6	As	Ba	Cd	Co	Cr	Cu	Hg	CH_3Hg as Hg	Mn	Mo	Ni	Pb	Sb	Se	Zn
Snapper						.012- .19(6)		.02- .04(6)	.03- .5(6)	.31 (45)		.04- .8(6)		.02- .06(6)	.15- .6(6)			2-10 (6)
						50-792		36-73	130- 2170	5170		39-780		27-80	882- 3530			7410- 37040
Sole * liver				.6- 11.5 (30) .07- 4.3* (18)		.06- 6.9* (18)	.017- .1* (18)		1.1- 9.2* (18)	.1(11) .05- .39* (18)			.04-.2 *(18)			.001- .007 *(18)	.23- 1.9* (18)	19- 39* (18)
				40-767 (5-287)*		250- 28,750*	170- 1000*		4780- 40000*	1670 (830- 6500)*			(57- 286)*			5-35*		*70000 -144000
Dover Sole						.011- .014 (9)									.075- .105(9)			
						46-58									441-618			
English Sole	.19-.76 (37)	.04-.11 (37)				.007- .013 (9)									.033- .130(9)			
	5430- 21,700					29-54									194-765			
Petrale Sole						.008- .018 (9)									.044- .091(9)			
						33-75									259-535			
Rex Sole						.012- .026 (9)									.114- .229(9)			
						50-108									671- 1347			
Sand Sole	.133(38)					.014(9)									.047(9)			
	3800					58									277			

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART 11. June 1976

Appendix III

CONCENTRATIONS OF TRACE METALS IN MARINE ORGANISMS

A Bibliography

by

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A literature survey of citations on data of trace metal incidence in marine plankton, plants, invertebrates, and some fish, birds, seals and other mammals selected 99 references. No information can be given on the reliability of the data because techniques and instrumental working conditions vary so widely. Of particular utility in data search is the Annual Literature Review by the Journal of the Water Pollution Control Federation.

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Table 1a. Concentration of Trace Elements in Marine Organisms (References within parentheses () are listed in Literature Cited.

All measurements in ug/dry g. or mg/dry kg unless specified (* wet weight; + ug/g ash-free dry weight).

Group	Al	Sb	As	Cd	Cs	Cr	Co	Cu	F⁻	Ge	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	Zn
Plankton		0-6.8* (6)			0-0.003* (6)	0-18*(6) 3.5(61)	0-0.5(6)				1.7-2900* (6)		0.06-7.8* (6)	0.057-2.745(38) 0.2-5.3 (97) 0.14-0.59(53)				0.6-710 (6)	(cont'd)
Phyto-plankton				0.1-7.0 (49)		41.3-73.3(74)		1.0-50 (49)				0-40(49)	5-32(49)					0-725(49)	
Zooplank-ton														55-388 (95) 2-16(93)					
Green Algae (Chloro-phyta)		0.067 (91) 0.16* (6)		0.0005-0.007 (89) 0.7-13 (88)	0.01*(6)	0.5*(6)	0.038* (6)	5-26(89) 9-170 (88)			39*(6)	< 4-20 (89) 3-1200 (88)	4.1*(6)	<0.001-25.5(45) 0.34-0.7*(78)				62-130(89) 20-1820 (88) 5.6*(6)	
Red Algae (Rhodo-phyta)		0.08-0.19(52) 0.21-0.24*(6)	11-39 (52)	5 (89) 0.7-3 (88)	0.056-0.095* (6)	0.13-0.87*(6)	0.018-0.054* (6)	8 (89) 0-33(88)			37-49*(6)	8 (89) 6-32(88)	2-6.1* (6)	< 0.001-3.03(45) 0.07-0.14(52)				50-150(89) 55-300(88) 5.6-11*(6)	
Brown Algae (Phaeo-phyta)		0.016-0.06 (52) 0.14-0.2* (91)	26-54 (52) 35 (9) 9.8-17.2 (71) 4.2-19.5* (44)	0.15-53 (52) 0.8-4 (89) 3.8-19.5(59) 1-12.5 (88)		1.3(61)		18-19 (10) 9-30(89) 8.82-14.3(59) 4-118 (88)		< 0.003-0.03* (44)	148-158 (10)	5-13(89) 0.7-202 (88)	38.7-89.2(59)	< 0.001-1.15(45) 0.07-0.22(52) < 0.01-0.07* (44)				99-600(52) 644-656 (10) 0.216-0.5 (41) 59-345(89) 88.4-262 (59)	65-3550 (88)
Plants						1.0(61)													
Marine Grass		0.098* (91)		2-5(89) 2.8(88)				27 (89) 9-1350 (88)				6-1800 (89) 22 (81)						100-1480 (89) 170(88)	
Marsh Grass				0.04-0.7 (7)								1.8-12 (7)						11-31(7)	
Mangrove leaves														0.2(54)					

Table Ib. Concentration of Trace Elements in Marine Organisms (References within parentheses () are listed in Literature Cited.

All measurements in ug/dry g. or mg/dry kg unless specified (* wet weight; + ug/g ash-free dry weight).

Group	Al	Sb	As	Cd	Cs	Cr	Co	Cu	F	Ge	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	Zn (cont'd)
Sponges		0.089 (52)	2-8(52)	0.85 (52)										1580 (95) 0.33 (52)					
Coelenterates						< 1(63)													
Sea Anemones (Anthozoa)		0.02(52)	72(52)	0.07(52)										0.86(52)				200 (52)	200(52)
Gorgonians						16.0-20.9* (90)													
Ctenophora						< 1(63)													
Polychaeta		0.031 (52)	5.2(52)	0.08-3.6(16)		8.1-14.7(29) 23.8-34.04 (74)		9-22* (14) 22-1142 (15)			200-4280 (73)	0.7-1.1* (14) 0.7-5.9 (15)	10 (17)	0.35(52)				130-350 (16) 34-36*(14) 155-199 (15)	78-164 (20) 55-2961 (73)
Pteropods						< 1(63)													
Gastropoda	19.8-172.5 (84)	0.007-0.12(52) 0.08* (6)	1-4.7* (70) 8.1-38 (52) 4-11.5 (71)	0.2-4.2 (84) 0.9-118.5* (70) 0.69-178(52) 82-145 (10) 1.1-9 (89) 3.5-1120(87) 0-51(88)	0.001* (6)	0.5*(6) 9.3-23.2(62) 0-13.2 (4) < 1.5-24.2(32) 43.52-68.22* (90) 0.07-0.9(29)	5.5-6.7 (10) 0.025* (6)	3.4-177.3 (84) 2-12* (70) 20-282 (10) 5-50(89) 0-1750 (87) 17-190 (88) 4.6-11.2(62)			16-573.8 (84) 1180-4660 (10) 18* (6)	5-30.4 (84) 0.17-0.75(70) 10-27 (89) 0-39(88)	1.7-27.5(84) 16-20 (10) 0.17*(6) 5.1-22.7 (62)	0.036-1.84(45) 0.02-0.3*(70) 0.1-3.5 (78) 0.07-0.8 (52) 0.61(5) 0-0.34 (62)	1.8-18.5 (84) 8.8-12.3 (10) 5.7-11.9 (62)		0.4-10.7 (84) 1.2-6.7 (62)	1.7-288.2 (84) 9.7-260* (70) 38-414(52) 0.028-1.98 (41) 284-794 (10) 60-120(89) 55-4500 (87) 87-2900 (88) 12*(6) 4.7-86.7 (62)	

Table 1c. Concentration of Trace Elements in Marine Organisms (References within parentheses () are listed in Literature Cited.

All measurements in ug/dry g. or mg/dry kg unless specified (* wet weight; + ug/g ash-free dry weight).

Group	Al	Sb	As	Cd	Cs	Cr	Co	Cu	F	Ge	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn	(cont'd)
Pelecypoda		0.007-0.18(52) 0.5*(91) 0.18-0.2*(6)	1.8-15 (52) 14 (9) 1.6-5.3 (71)	< 0.6-2.5 (39) 0.3-2.5 (52) 4-43(10 0-34.3* (75) 5.5-10.7* (25) 0.09-0.27* (43) <0.5-7.9(89) <1.2-28 (34) 0.1-0.5 *(55) 2-6.7 (7) 1.9-140 (88) 1.6-39** (21)	42-113* (40) 0.007* (6)	0.7-11 (99) 0.1-0.24 *(6) 0.35(51) 1.5-14.2(32) <3-145 (13) 0.5-1.6 (29) 4.6-17.3 (74)	1-3.5 (10) 96-540* (40) 0.038* (6)	0-200 (39) 18-201 (24,68) 200-6480 (10) 4-147.7* (75) 3.6-40 (79) 6.6-37.9 *(43) 3.1-57.9 *(25) 6-505(89) 3.96-2208(34) 7-77(99) 18-55* (55) 10-2100 (80) 3-120 (88)			16-56 (24,68) 158-800 (10) 18-1327 (79) 150-450 (64) 29-59*(6)	1.9-6.4 (82) 7-17(10) 0.008-19.37 (81) 1.2-15.6 (26) 0-2*(43) < 0.7-30(89) 2.45-10 (34) 2.6-3.1 (7) 0-1(64) 2-3100 (88)	3.3-7.1 (24,68) 16-46 (10) 2.5*(25) 1-2.7* (6)	0.64-19.95 (45) 0.25-0.4 (93) 0.16-1.9 (52) <0.02-180*(50) <0.005-0.13*(28) 0-0.04* (43) 0.29-0.84(5) 0.02-0.6 *(22) 0.01-0.2 (77)	2-6.5 (10) 0.1-0.6* (43) 0-14(99)		17-29(67) 1.2-16.4(34)	0-72000 - (39) 52-650(52) 0.25-0.779 (41) 215-950 (24,68) 1830-99200 (10) 318-10019* (75) 12.4-140 (42) 15-24*(40) 45.8-5657* (25) 8.1-10460 (34) 93-244(99) 110-695* (55) 70-8430 (80) 48-52 (7) 0.12-0.75 (50) 7-11 (64)	16-18* (6) 100-920 (89) 105-2370 (88)
Cephalopoda		0.84-0.92(91)	73-198 (52)	<0.05* (25) 8 (89) 22.6-1106(57)		< 1 (63) 0.07-0.12(29)		5.3-7* (25) 47 (89) 17-15160 (57)			19-850 (61)		< 0.5-0.6*(25)	0.4-202 *(78) 0.67-0.9 (52) 0.06-0.11* (28) 280(95)			4.4-83.6 (57)	18.5*(25) 132(89) 93-892(57)	
Copepoda		0.12-0.4*(91)	6 (71)			260(63) 1.5(29)													
Barnacles			0-7.6* (44)	4.5-12 (89)				6.3-600 (89)		0-0.28* (44)		0.2-1.5 (42)	0.09-0.35(42)	0-0.39* (44)				40-3300 (89) 138-3438* (94) 3-33(42)	4.5-23.1 (41)

Table 1d. Concentration of Trace Elements in Marine Organisms (References within parentheses () are listed in Literature Cited.

All measurements in ug/dry g. or mg/dry kg unless specified (* wet weight; + ug/g ash-free dry weight).

Group	Al	Sb	As	Cd	Cs	Cr	Co	Cu	F⁻	Ge	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn
Mysids														406(95)				
Sea Lice														0.22-0.63(48)				
Amphipoda				10-25(8) 5.1-8.8 (88)				10-70(8) 35-94 (88)			25-115(8)	0-10(8) 18-23 (88)	3-6(8)		0-5(8)		0-2(8)	60-120(8) 110-275 (88)
Euphausiids						< 1 (63)												
Decapoda		0.16(52) 0.53* (91) 0.12*(6)	16 (52) 63-80(9) 3.8-7.6 (71) 5.5-12.7* (44)	7 (67) 2.8-33.1* (70) 0.31(52) 0.4-1.2 (10) < 0.05 (25) 0.7-32 (89) 0.5-1.4 (7) 1.9-6.9 (88)	3.5-5.8 *(40) 0.01*(6)	0.08*(6) 0.04-1.1 (29)	3-4(10) 14-36* (40) 0.004* (6)	3.8-150 (67) 38-49 (10) 15.8-31.4* (25) 110-435 (89) 2.1-90 (88)		< 0.002-0.025* (44)	25-30(10) 2.7*(6)	8(10) < 1.2-11(89) 0.7-7.5 (7) 8.31(88)	1.4-1.9 (10) 0.8*(25) 0.27*(6)	0.12-3.7 (67) 332(95) 0.3-4.47 *(78) 0.98(52) 0.06-1.53*(28) 0.31-0.39(5) 0.01-0.67(77) 0.03(89) 0.01-0.09*(44)	1.1-2 (10)			35.5-81.7* (70) 57-58(10) 12-32*(40) 74.3*(25) 79-330(89) 81-110(7) 85-190(88) 17*(6)
Chaeto-gnaths						< 1(63)												
Echinoder-mata		0.6-46.3(84)						2.1-39.6 (84)			33.5-1196(84)	15.9-30.9 (84)	2.4-6.3 (84)	280(95)	12-14 (84)		2.5 (84)	416-619+ (70) 32.9-511.9 (84)
Asteroidea (Sea Star)			5.8-10 (52)	0.6-0.7* (25) 0.6-12 (89) 10-18(88)		0.02(65) 1.2(29)		10.4-31.4* (25) 6-8(89) 18(88)				14-22 (89) 110-460 (88)	6.9-51.7 *(25)					40.6-245* (25) 1(89) 510-1500 (88)
Echinoids			1.4-10.8 (71)															
Sea Urchins		0.01-0.027 (52)			4.2-7.6* (40)	0.02(65) 19.91-43.2*(90)	71-84* (40)	7.6-16.6 (83)				20-58.6 (83)	0.54-86 (83)	0.2*(78) 0.22-0.92(52)	8.4-15.4 (83)			55.6-122 (83) 31-50*(40)

Table 1e. Concentration of Trace Elements in Marine Organisms (References within parentheses () are listed in Literature Cited.

All measurements in ug/dry g. or mg/dry kg unless specified (* wet weight; + ug/g ash-free dry weight).

Group	Al	Sb	As	Cd	Cs	Cr	Co	Cu	F⁻	Ge	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn
Ophiuroids (Brittle Stars)						24.17* (90) 0.8(29)												
Holothuroidea (Sea Cucumber)					2.5-6.1* (40)	0.9(65) 0.3-1.1 (29)	8.2-19* (40)											16-17*(40)
Tunicates		0.15-0.26(52)	4.8-6.6 (52)	0.2*(25)				8.3*(25)					112.6* (25)	0.13-0.57(52)				135(52) 64*(25)
Thaliacean						1 (63)												
Fish		0.006-0.015 (52) 0.05-0.6*(91) 0.002-0.26*(6)	< 1-22 (96) 1.7-8.7 (52) < 0.1-0.79(30) 0.1-2.75* (56) 0.4-0.8 (71) 2.6*(44)	0.07-1.67* (70) < 0.1-5 (96) 0.002-0.033* (36) < 0.1-1.8(30) 10.001-54*(12) < 0.05-0.3*(25) 0-0.15* (43) 1.1-5.2 (35) < 0.3-4.3(89) 0.05-83* (56) 0-0.0006 **(31) 0.12-928 (33) 0.001-54*(12)	1-66* (40) 0.006-0.04*(6)	0.01-6 (12) < 0.1-3.4*(12) 0.1-1.3* (6)	0.3-284 *(40) 0.002-0.03*(6)	< 0.3-44(96) 1.8-280 (30) 0.03-35.2* (12) < 0.25-9* (25) < 0.6-10 (89) 0.5-22* (56) 15.9-29.3(27) 0.6-8.5* (31) 0.03-35.2* (12)	0.98-99.7* (98)	< 0.002* (44)	0.8-20250(12) 3-17*(6)	< 0.5-310(30) 0.04-12.4(12) 0.1-0.8* (43) 0.0002-5.3*(19) 0.6-4.9 (2) 14.1-28.2(35) < 1.2-22 (89) 0.1-1.1* (56) 0-0.007* (31) 0.04-12.4* (12)	0.02-46 (12) < 0.5-15*(25) 0.1-0.9* (6)	122-2800 (95) 0.1-9 (96) 0.8-6.2 (93) 0.1-29.8 *(78) 0.09-1.8 (52) 0.12-0.27*(23) 0.1-0.66 (30) 0.008-14*(72) < 0.05-4.78(69) 0.01-0.73*(18) 0.05-2.3 (47) 1.1-2.19 (47) < 0.005-0.45*(28) 0.0006-0.03(58) 0.006-0.862(92) 0.2-0.45 (86)	0.01-6.5*(12) 0-7.2* (43) 0-0.006* (31)	0.4-13.5* (56)	0-0.0007* (31)	4-52.5(70) 7-397(96) 15 (52) 13-450(30) 0.9-1200* (12) 0.4-198* (40) 4.6-146.7* (25) 125.2-224.5(35) 21-220(89) 4-375*(56) 131-316 (27) 0.9-1200* (14) 3.2-7.2* (6)

Table 1f. Concentration of Trace Elements in Marine Organisms (References within parentheses () are listed in Literature Cited.

All measurements in ug/dry g. or mg/dry kg unless specified (* wet weight; + ug/g ash-free dry weight).

Group	Al	Sb	As	Cd	Cs	Cr	Co	Cu	F⁻	Ge	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn
Fish (cont'd)														0.14-0.71(5) 0-0.17* (43) 0.5(1) 0.05-0.79(89) 0.3-63* (56) 0.1-2 (76) 0.01-0.64(77) 0.01* (44) 0-0.6* (31) 0.06-0.88* (46) 0.001-6.9(45) 0.3-6.9* (78) 1-20(66)				
Birds									0.2-750*(98)									
Seals				0.1-15.6*(3) 2.2-11.6 *(37) Max. 2 (3)								0.3-34.2(11) 0.2-1.8 *(3) Max. 3 (3)		0.7-224.85 (45) 0.0195-5.36(48) 0.1-700* (3) 0.4-113* (37) 0.17-0.7 (3) 0.53-143* (85)				
Mammals														0.01-1.57 (60)			1.06-15.5*(85)	

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART 11. June, 1976

Appendix IV

PRIMARY PRODUCTIVITY, CHLOROPHYLL *A*, AND ASSIMILATION RATIOS IN LOS ANGELES-LONG BEACH HARBOR, 1973 AND 1974

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DATA REPORT AND CORRECTION

Data on phytoplankton productivity and pigments of the Los Angeles-Long Beach Harbor were routinely sampled on a monthly basis at a series of stations shown in Figure 1 during the years 1973 and 1974. These data are presented in Table 1.

The stations were divided into four groups designated as A, B, C and D. The A group was occupied during the first week of each month, and the other groups were occupied in order on consecutive weeks.

At each station a sample of surface water was obtained using a plastic bucket. A known amount of carbon fourteen (^{14}C) was added to replicate subsamples in light and dark bottles. The light bottles were placed in an incubator box lighted by two fluorescent cool white 40w tubes held at sea surface temperature. The dark bottles were stored in the dark. After an incubation period of about three hours the samples were filtered through millipore AA filters. The filters were returned to the laboratory for counting in a Geiger counter and determination of carbon fixed by the phytoplankton retained on the filter. The data are reported as milligrams of carbon fixed per hour per cubic meter of water.

Separate subsamples were filtered with HA millipore filters on board for subsequent determination of the photosynthetic pigment chlorophyll *a*. The dried filters were returned to the laboratory for spectrophotometric measurement of chlorophyll absorbance values. The calculation of chlorophyll content was done using the Parsons and Strickland (1963) equations.

Due to a computer program error, data on chlorophyll values found in the harbor and reported earlier are low by a systematic factor of 2.5. These data have been corrected and are reported as milligrams of chlorophyll *a* per liter of water sampled.

Assimilation ratio, as reported here, is an index number determined by dividing the productivity value by the chlorophyll *a* value. These data should be viewed as minimal estimates, since the pigment values reported do not separate the phaeo-pigments from the chlorophyll values.

LITERATURE CITED

Parsons, T.R. and J.D.H. Strickland. 1943. Discussion of spectrophotometric determination of marine-plant pigments with revised equations for ascertaining chlorophylls and carotenoids. J. Mar. Res. 21(3):155-163.

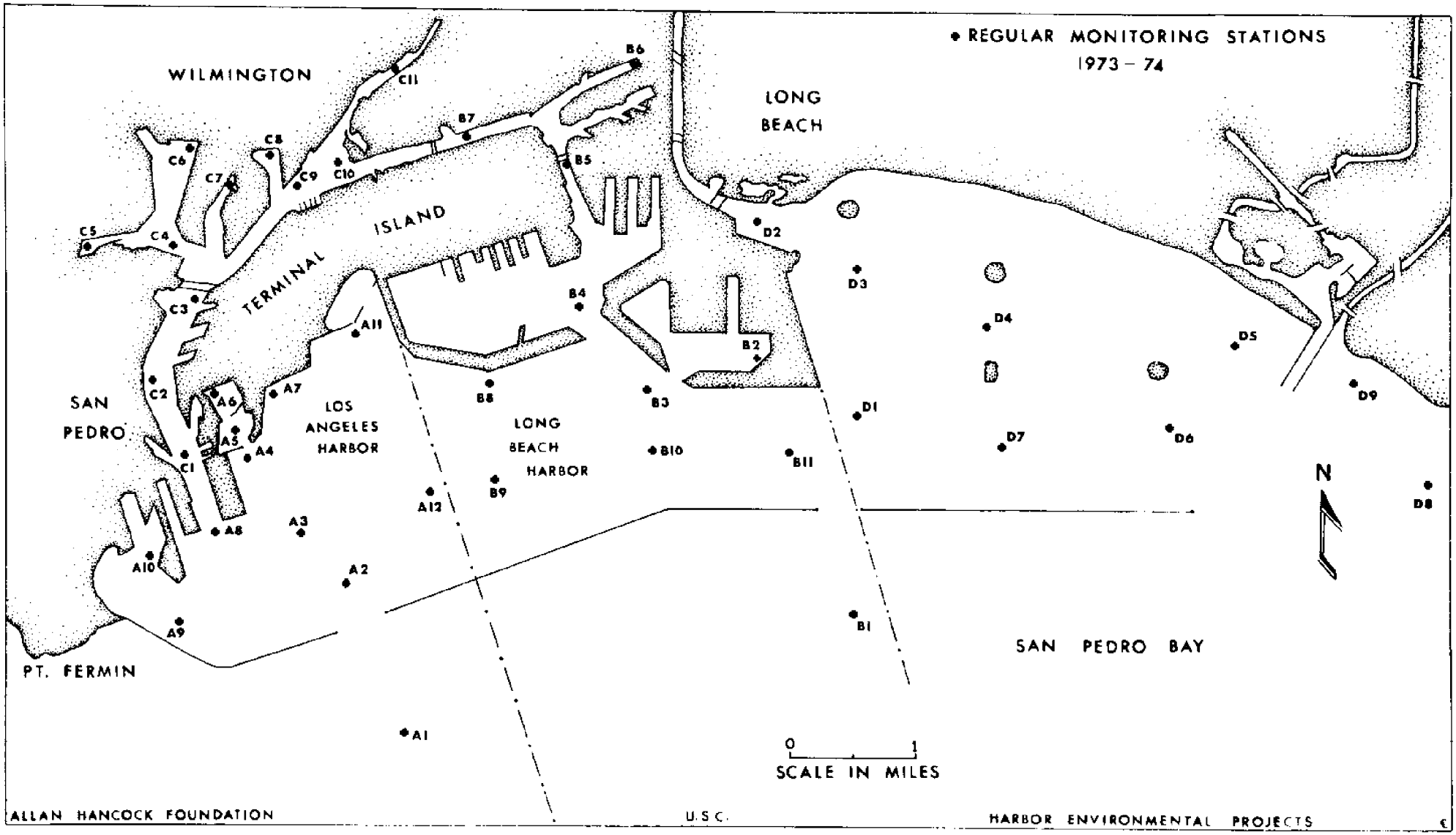

Figure 1. Regular Monitoring Stations, 1973-1974.

Table 1

ABIOTIC TABLE FOR THE YEAR 1973: PRODUCTIVITY, CHLOROPHYLL A, AND ASSIMILATION RATIO A

STATIONS A1 THROUGH D8 BY MONTH

		JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
A1	PROD	******	3.70	4.40	10.30	3.00	3.30	38.20	10.60	9.10	15.30	7.50	29.30
	CHLA	******	1.77	2.10	4.82	******	1.30	6.37	1.07	2.55	2.62	******	7.92
	ASMA	******	2.08	2.10	2.13	******	2.54	5.99	9.86	3.57	5.83	******	3.70
A2	PROD	******	8.40	14.20	10.80	33.10	30.10	81.80	89.10	29.10	12.70	19.80	31.20
	CHLA	******	2.00	5.42	5.05	18.07	12.45	11.97	9.40	5.47	5.07	3.37	6.62
	ASMA	******	4.20	2.62	2.14	1.83	2.42	6.83	9.48	5.32	2.50	5.87	4.71
A3	PROD	******	3.70	18.70	15.60	30.60	21.20	134.90	76.20	131.40	9.60	44.20	50.20
	CHLA	******	1.17	7.92	6.90	18.42	7.95	17.30	10.67	15.32	4.47	6.15	11.00
	ASMA	******	3.15	2.36	2.26	1.66	2.67	7.80	7.14	8.57	2.15	7.19	4.56
A4	PROD	******	2.00	16.70	4.60	20.20	35.90	159.70	76.60	107.60	4.80	14.60	32.90
	CHLA	******	1.25	9.02	2.82	13.75	21.85	18.47	10.90	15.30	3.70	2.30	10.05
	ASMA	******	1.60	1.85	1.63	1.47	1.64	8.64	7.03	7.03	1.30	6.35	3.27
A5	PROD	******	3.30	25.00	11.30	14.70	31.30	138.30	108.60	44.90	1.30	31.00	51.00
	CHLA	******	1.40	8.90	8.00	6.60	20.00	17.32	19.10	6.05	2.32	7.10	11.90
	ASMA	******	2.36	2.81	1.41	2.23	1.56	7.98	5.69	7.42	0.56	4.37	4.29
A6	PROD	******	3.60	19.70	16.50	17.90	56.40	104.60	66.90	38.90	1.30	76.80	43.10
	CHLA	******	1.50	10.70	9.67	3.22	33.13	17.52	13.75	8.35	2.92	10.97	14.15
	ASMA	******	2.40	1.84	1.71	5.55	1.70	5.97	4.87	4.66	0.44	7.00	3.05
A7	PROD	******	1.80	10.50	1.20	1.40	45.20	31.30	15.20	77.20	1.40	14.40	******
	CHLA	******	2.77	6.60	3.35	21.85	29.25	7.77	5.87	8.80	3.20	1.77	******
	ASMA	******	0.65	1.59	0.36	0.06	1.55	4.03	2.59	8.77	0.44	8.11	******
A8	PROD	******	2.80	4.40	7.10	9.20	29.00	105.30	68.10	38.00	1.50	20.30	23.00
	CHLA	******	1.45	2.32	3.22	4.95	9.90	16.10	9.50	5.90	1.42	11.85	5.75
	ASMA	******	1.93	1.89	2.20	1.86	2.93	6.54	7.17	6.44	1.05	1.71	4.00
A9	PROD	******	7.10	13.50	6.50	10.90	******	117.10	48.40	25.30	4.50	23.90	30.20
	CHLA	******	2.17	4.82	2.97	4.50	10.35	18.52	8.92	3.82	2.02	4.00	8.30
	ASMA	******	3.26	2.80	2.18	2.42	******	6.32	5.42	6.61	2.22	5.99	3.64
A10	PROD	******	2.60	5.00	5.50	8.00	13.80	130.70	46.50	29.90	7.20	51.30	38.90
	CHLA	******	0.87	1.35	2.50	3.32	3.67	17.40	10.27	3.92	2.40	9.40	6.70
	ASMA	******	2.97	3.70	2.20	2.41	3.76	7.51	4.53	7.62	3.00	5.46	5.81
A11	PROD	******	1.80	13.90	9.80	20.80	25.60	51.30	74.60	64.50	8.20	150.80	11.60
	CHLA	******	1.07	5.67	5.22	10.22	27.35	10.37	10.82	15.30	******	10.72	10.22
	ASMA	******	1.67	2.45	1.88	2.03	0.94	4.94	6.89	4.22	******	14.06	1.13

VALUES OF ****** REPRESENT DATA NOT AVAILABLE

Table 1 (cont.)

ABIOTIC TABLE FOR THE YEAR 1973: PRODUCTIVITY, CHLOROPHYLL A, AND ASSIMILATION RATIO A

STATIONS A1 THROUGH D8 BY MONTH (CONTINUED)

		JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
A12	PROD	******	4.80	14.00	7.10	18.40	29.30	75.70	27.50	43.60	22.00	******	58.00
	CHLA	******	2.02	8.80	6.22	12.92	11.95	10.82	5.22	13.15	10.97	40.00	11.70
	ASMA	******	2.37	1.59	1.14	1.42	2.45	6.99	5.26	3.32	2.00	******	4.96
31	PROD	13.60	6.60	3.60	5.30	4.30	6.10	5.60	18.30	3.20	3.20	13.90	29.90
	CHLA	3.10	2.25	5.47	9.55	6.17	4.00	1.47	4.12	0.80	1.52	1.85	5.97
	ASMA	4.39	2.93	0.66	0.55	0.70	1.53	3.80	4.44	4.00	2.10	7.51	5.00
B2	PROD	5.50	5.70	6.30	10.60	21.40	16.60	46.50	16.20	334.20	26.10	19.40	11.40
	CHLA	1.70	1.80	3.27	5.90	10.42	6.12	8.32	3.50	155.92	7.20	2.20	1.52
	ASMA	3.24	3.17	1.92	1.80	2.05	2.71	5.59	4.63	2.14	3.62	8.82	7.48
33	PROD	11.90	3.90	6.40	10.50	14.80	23.40	44.40	15.60	94.20	45.80	15.00	30.10
	CHLA	2.60	1.72	5.37	6.67	11.25	8.47	7.82	3.55	12.42	15.50	2.35	4.60
	ASMA	4.58	2.26	1.19	1.57	1.32	2.76	5.67	4.39	7.58	2.95	6.38	6.54
84	PROD	7.60	3.90	7.10	14.00	25.40	28.10	58.50	28.50	138.80	21.50	48.90	38.50
	CHLA	1.50	1.55	4.80	7.57	10.63	12.57	10.20	10.17	26.72	13.15	7.35	5.52
	ASMA	5.07	2.52	1.48	1.85	2.39	2.23	5.74	2.80	5.19	1.63	6.65	6.97
35	PROD	4.40	4.10	4.50	25.60	0.10	20.40	93.30	74.80	142.70	31.90	24.70	25.30
	CHLA	0.90	1.30	2.87	12.67	13.92	8.02	14.07	21.62	28.25	11.60	3.37	4.32
	ASMA	4.89	3.15	1.57	2.02	0.01	2.54	6.63	3.46	5.05	2.75	7.32	5.85
86	PROD	2.10	19.40	6.60	28.40	75.60	25.90	77.00	101.10	301.40	83.10	102.90	35.10
	CHLA	5.70	7.37	2.45	19.12	28.75	11.70	11.77	21.17	87.70	40.37	9.82	3.17
	ASMA	0.37	2.63	2.69	1.48	2.63	2.21	6.54	4.77	3.44	2.06	10.47	11.06
97	PROD	6.50	0.40	2.60	12.20	20.10	18.10	80.60	93.70	87.50	12.00	23.40	11.90
	CHLA	1.22	0.35	1.55	6.90	6.40	9.77	13.37	18.52	18.10	6.60	3.65	1.90
	ASMA	5.31	1.14	1.68	1.77	3.14	1.85	6.03	5.06	4.83	1.82	6.41	6.26
88	PROD	******	5.00	7.20	11.50	19.80	30.80	38.10	25.50	167.40	27.40	29.40	25.80
	CHLA	******	1.07	5.22	3.30	10.87	14.72	5.50	8.72	31.25	10.40	5.20	4.77
	ASMA	******	4.65	1.38	3.48	1.82	2.09	6.93	2.92	5.36	2.63	5.65	5.40
89	PROD	******	******	******	******	******	******	******	******	******	******	******	******
	CHLA	******	******	5.37	******	******	******	******	******	11.90	******	******	******
	ASMA	******	******	******	******	******	******	******	******	******	******	******	******
810	PROD	******	******	11.30	******	******	******	******	******	******	******	******	******
	CHLA	******	******	7.22	******	******	******	******	******	10.42	******	******	******
	ASMA	******	******	1.56	******	******	******	******	******	******	******	******	******

VALUES OF ****** REPRESENT DATA NOT AVAILABLE

Table 1 (cont.)

ABIOTIC TABLE FOR THE YEAR 1973: PRODUCTIVITY, CHLOROPHYLL A, AND ASSIMILATION RATIO A

STATIONS A1 THROUGH D8 BY MONTH (CONTINUED)

		JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
B11	PROD	******	******	9.70	******	******	******	******	******	******	******	******	******
	CHLA	******	******	6.85	******	******	******	******	******	3.32	******	******	******
	ASMA	******	******	1.42	******	******	******	******	******	******	******	******	******
C1	PROD	1.30	5.80	******	11.50	12.80	54.90	128.80	33.80	42.90	40.50	9.20	5.30
	CHLA	0.60	1.88	******	4.85	5.17	13.07	14.82	4.40	11.37	5.85	1.88	1.25
	ASMA	2.17	3.09	******	2.37	2.47	4.20	8.69	7.68	3.77	6.92	4.91	4.24
C2	PROD	0.70	3.50	******	75.70	6.00	0.90	108.90	******	30.60	22.10	4.20	11.40
	CHLA	0.65	1.32	1.30	19.38	2.22	8.97	13.75	3.67	9.00	2.50	0.67	1.55
	ASMA	1.08	2.64	******	3.91	2.70	0.10	7.92	******	3.40	8.84	6.22	7.35
C3	PROD	1.00	5.20	******	101.50	13.00	70.60	98.60	25.50	13.20	18.00	8.40	6.10
	CHLA	0.45	1.52	0.67	25.15	4.82	15.90	13.25	3.07	3.20	17.40	1.55	1.00
	ASMA	2.22	3.41	******	4.04	2.69	4.44	7.44	8.29	4.13	1.03	5.42	6.10
C4	PROD	1.90	2.70	******	195.00	18.80	55.80	97.20	13.90	40.00	39.40	5.90	4.50
	CHLA	0.37	1.22	0.42	******	5.17	20.12	10.17	2.05	10.72	6.67	1.32	0.80
	ASMA	5.07	2.20	******	******	3.63	2.77	9.55	6.78	3.73	5.90	4.45	5.63
C5	PROD	1.80	8.80	******	4.10	21.30	41.70	144.70	132.70	86.70	75.90	6.90	16.20
	CHLA	0.42	2.07	0.32	28.77	15.60	7.22	20.77	15.05	30.30	8.25	1.50	1.85
	ASMA	4.24	4.24	******	0.14	1.37	5.77	6.97	8.82	2.86	9.20	4.60	8.76
C6	PROD	******	2.00	******	16.20	13.30	59.00	90.80	11.50	37.40	6.80	3.90	7.90
	CHLA	******	1.37	1.17	21.05	4.55	12.77	20.07	1.20	5.37	2.00	1.07	1.32
	ASMA	******	1.45	******	0.77	2.92	4.62	4.52	9.58	6.96	3.40	3.63	5.96
C7	PROD	3.70	1.10	******	295.30	12.10	70.60	90.40	21.20	10.60	39.30	12.40	15.00
	CHLA	0.75	1.15	0.75	163.77	3.87	17.77	11.70	3.07	2.17	4.80	2.30	1.60
	ASMA	4.93	0.96	******	1.80	3.12	3.97	7.73	6.89	4.87	8.19	5.39	9.38
C8	PROD	3.50	2.80	******	16.50	8.70	1.40	88.30	40.70	11.50	26.50	7.70	13.80
	CHLA	0.40	2.40	1.55	6.15	2.57	8.42	16.57	5.17	2.47	5.20	1.70	1.52
	ASMA	8.75	1.17	******	2.68	3.38	0.17	5.33	7.86	4.65	5.10	4.53	9.05
C9	PROD	1.60	4.10	******	10.00	16.60	49.70	75.80	50.80	36.70	13.70	5.60	5.30
	CHLA	0.27	1.92	1.82	4.95	3.47	7.35	11.52	4.20	13.95	2.17	1.50	0.90
	ASMA	5.82	2.13	******	2.02	4.78	6.76	6.58	12.10	2.63	6.30	3.73	5.89

VALUES OF ****** REPRESENT DATA NOT AVAILABLE

Table 1 (cont.)

ABIOTIC TABLE FOR THE YEAR 1973: PRODUCTIVITY, CHLOROPHYLL A, AND ASSIMILATION RATIO A

STATIONS A1 THROUGH D8 BY MONTH (CONTINUED)

		JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
C10	PROD	******	9.70	******	9.10	8.80	38.10	75.00	40.20	23.70	11.70	6.70	11.50
	CHLA	0.55	2.25	1.10	5.87	3.00	13.95	8.10	3.45	5.25	1.88	1.77	1.42
	ASMA	******	4.31	******	1.55	2.93	2.73	9.26	11.65	4.51	6.24	3.77	8.07
C11	PROD	******	7.40	******	9.40	25.30	39.70	79.30	64.80	12.30	4.80	3.20	4.00
	CHLA	0.30	2.60	0.77	4.20	5.07	8.92	9.10	6.77	1.92	1.65	0.92	1.25
	ASMA	******	2.85	******	2.24	4.99	4.45	8.71	9.56	6.39	2.91	3.46	3.20
D1	PROD	******	******	10.30	11.90	******	38.20	52.80	******	27.10	48.50	36.90	157.70
	CHLA	******	******	8.10	6.25	******	14.17	10.10	******	6.65	8.60	10.63	19.10
	ASMA	******	******	1.27	1.90	******	2.69	5.23	******	4.08	5.64	3.47	8.26
D2	PROD	******	******	9.60	133.00	******	54.40	181.50	29.50	175.00	25.50	30.60	52.10
	CHLA	******	******	4.50	41.70	******	16.37	27.17	7.40	37.90	6.67	7.67	9.60
	ASMA	******	******	2.13	3.19	******	3.32	6.68	3.99	4.62	3.82	3.99	5.43
D3	PROD	******	******	8.70	126.20	64.70	47.40	135.30	50.90	40.80	51.20	39.40	94.50
	CHLA	******	******	4.42	34.40	17.42	17.20	18.30	7.57	6.07	8.57	10.85	13.40
	ASMA	******	******	1.97	3.67	3.71	2.76	7.39	6.72	6.72	5.97	3.63	7.05
D4	PROD	******	******	7.30	12.50	18.00	22.50	87.10	19.50	72.30	15.10	45.80	187.40
	CHLA	******	******	3.55	3.72	7.57	10.35	10.30	4.47	7.57	3.15	15.25	25.40
	ASMA	******	******	2.06	3.36	2.38	2.17	8.46	4.36	9.42	4.79	3.00	7.38
D5	PROD	******	******	******	4.90	42.60	32.60	60.90	13.20	33.80	24.10	33.60	170.30
	CHLA	******	******	3.50	2.07	15.60	10.27	8.67	2.70	4.35	4.25	8.35	19.07
	ASMA	******	******	******	2.36	2.73	3.17	7.02	4.89	7.77	5.67	4.02	8.93
D6	PROD	******	******	******	6.20	30.00	18.00	63.10	28.00	59.20	41.10	55.20	64.20
	CHLA	******	******	3.17	3.13	12.20	7.95	9.05	4.12	6.45	7.07	15.12	6.25
	ASMA	******	******	******	1.98	2.46	2.26	6.97	6.79	9.18	5.81	3.65	10.27
D7	PROD	******	******	10.10	13.50	******	29.60	35.50	38.00	25.20	57.10	71.50	161.00
	CHLA	******	******	4.67	4.80	******	3.57	6.47	6.62	3.75	10.00	17.95	12.60
	ASMA	******	******	2.16	2.81	******	8.28	5.48	5.74	6.72	5.71	3.98	12.78
D8	PROD	******	******	******	8.50	******	13.80	19.10	15.70	30.20	15.50	28.70	58.30
	CHLA	******	******	2.72	2.32	******	6.60	2.82	2.80	2.82	3.20	6.30	7.45
	ASMA	******	******	******	3.66	******	2.09	6.76	5.61	10.69	4.84	4.56	7.83

VALUES OF ****** REPRESENT DATA NOT AVAILABLE

Table 1 (cont.)

ABIOTIC TABLE FOR THE YEAR 1974: PRODUCTIVITY, CHLOROPHYLL A, AND ASSIMILATION RATIO A

STATIONS A1 THROUGH D8 BY MONTH

		JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
A1	PROD	7.10	7.90	9.80	35.80	6.80	1.90	6.00	6.90	13.60	23.30	3o.50	******
	CHLA	1.27	1.60	1.50	4.25	4.17	1.95	1.22	1.40	4.87	7.07	3.40	******
	ASMA	5.57	4.94	6.53	8.42	1.63	0.97	4.90	4.93	2.79	3.29	10.74	******
A2	PROD	14.70	17.00	24.10	69.40	19.50	15.70	17.40	106.40	31.50	49.20	16.70	41.30
	CHLA	1.70	2.47	6.72	8.05	5.88	20.90	4.42	15.32	9.15	14.40	2.90	6.30
	ASMA	8.65	6.87	3.58	8.62	2.84	0.75	3.93	6.94	3.44	3.42	5.76	6.56
A3	PROD	82.40	17.90	13.00	83.90	13.60	21.30	19.00	19.70	5.70	50.10	57.70	43.10
	CHLA	6.70	2.52	4.82	6.57	7.37	28.80	4.45	2.42	1.62	******	******	11.07
	ASMA	12.30	7.09	2.69	12.76	1.84	0.74	4.27	8.12	3.51	******	******	3.89
A4	PROD	121.80	12.50	73.10	63.30	15.60	19.80	28.60	22.30	3.00	24.30	37.00	19.60
	CHLA	8.65	1.85	6.57	8.40	4.77	15.65	3.92	3.80	5.25	******	******	6.15
	ASMA	14.08	6.76	11.12	7.54	3.27	1.27	7.29	5.87	0.57	******	******	3.19
A5	PROD	157.50	14.10	23.40	59.20	23.30	11.40	17.30	44.90	28.60	9.90	7.00	4.60
	CHLA	10.95	2.35	7.65	10.15	9.70	29.60	4.67	8.27	10.40	1.90	2.62	0.70
	ASMA	14.38	6.00	3.06	5.83	2.40	0.39	3.70	5.43	2.75	5.21	2.67	6.57
A6	PROD	55.40	20.70	17.70	48.00	19.60	26.90	19.20	77.70	7.70	15.30	14.90	2.40
	CHLA	5.20	2.37	6.15	6.42	10.37	47.20	3.35	9.92	3.15	2.32	2.07	0.63
	ASMA	10.65	8.72	2.88	7.47	1.89	0.57	5.73	7.83	2.44	6.58	7.18	3.84
A7	PROD	84.10	13.10	95.70	64.70	9.70	34.10	12.90	9.30	0.50	8.40	10.10	35.80
	CHLA	7.92	1.52	5.05	5.85	4.57	31.52	4.32	4.65	0.20	******	2.92	4.52
	ASMA	10.61	8.59	18.95	11.06	2.12	1.08	2.98	2.00	2.50	******	3.45	7.91
A8	PROD	11.00	12.40	19.40	52.60	23.50	15.30	13.00	26.00	9.60	6.00	26.30	11.80
	CHLA	1.60	2.37	5.90	10.00	7.52	28.22	4.10	4.72	6.05	4.87	5.22	5.47
	ASMA	6.88	5.22	3.29	5.26	3.12	0.54	3.17	5.50	1.59	1.23	5.03	2.16
A9	PROD	25.30	9.90	12.80	45.90	17.20	5.30	9.10	56.30	4.60	22.10	15.20	0.70
	CHLA	1.97	1.27	6.00	7.05	6.37	5.45	3.72	9.47	2.45	5.45	2.72	2.57
	ASMA	12.81	7.76	2.13	6.51	2.70	0.97	2.44	5.94	1.88	4.06	5.58	0.27
A10	PROD	18.80	9.70	5.40	27.30	12.80	9.80	6.30	48.40	1.40	14.80	7.90	8.80
	CHLA	1.60	1.05	2.00	2.70	4.22	13.75	1.60	5.70	0.85	******	0.42	1.80
	ASMA	11.75	9.24	2.70	10.11	3.03	0.71	3.94	8.49	1.65	******	18.59	4.89
A11	PROD	23.20	12.10	41.10	33.60	10.50	36.50	5.80	52.10	0.90	12.20	10.70	66.30
	CHLA	2.90	1.40	7.47	6.70	3.60	50.97	2.17	4.17	0.87	0.57	0.50	18.17
	ASMA	8.00	8.64	5.50	5.01	2.92	0.72	2.67	12.48	1.03	21.22	21.40	3.65

VALUES OF ****** REPRESENT DATA NOT AVAILABLE

Table 1 (cont.)

ABIOTIC TABLE FOR THE YEAR 1974: PRODUCTIVITY, CHLOROPHYLL A, AND ASSIMILATION RATIO A

STATIONS A1 THROUGH B8 BY MONTH (CONTINUED)

		JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
A12	PROD	22.10	12.80	15.00	87.90	10.30	4.70	10.50	19.90	1.80	59.40	30.30	7.50
	CHLA	2.47	1.70	7.82	12.55	5.35	9.25	3.10	2.15	5.52	5.42	3.35	1.72
	ASMA	8.93	7.53	1.92	7.00	1.93	0.51	3.39	9.26	0.33	10.95	9.04	4.35
B1	PROD	9.10	13.70	30.70	11.70	2.40	8.20	14.50	18.70	13.10	5.90	5.50	2.70
	CHLA	1.25	8.55	2.90	2.02	1.05	6.40	4.02	2.17	0.75	0.60	0.70	5.22
	ASMA	7.28	1.60	10.59	5.78	2.29	1.28	3.60	8.60	17.47	9.83	7.86	0.52
B2	PROD	18.30	3.70	17.40	8.10	7.00	71.40	31.10	95.50	24.80	16.90	10.50	5.20
	CHLA	1.52	2.32	1.45	1.45	3.55	104.25	6.37	12.35	4.52	1.57	2.40	0.75
	ASMA	12.00	1.59	12.00	5.59	1.97	0.68	4.88	7.73	5.48	10.73	4.38	6.93
B3	PROD	10.90	12.30	63.70	11.90	8.00	22.50	16.10	27.10	46.50	10.50	24.50	10.70
	CHLA	1.22	9.72	7.67	1.80	3.40	23.57	5.65	2.77	3.70	1.25	1.05	2.42
	ASMA	8.90	1.26	8.30	6.61	2.35	0.95	2.85	9.77	12.57	8.40	23.33	4.41
B4	PROD	19.20	10.00	47.40	5.50	10.60	24.80	22.00	76.80	124.50	15.20	29.00	0.90
	CHLA	1.50	6.77	7.27	1.65	4.27	33.67	6.10	10.40	11.12	3.40	5.12	1.90
	ASMA	12.80	1.48	6.52	3.33	2.48	0.74	3.61	7.38	11.19	4.47	5.65	0.47
B5	PROD	9.60	2.80	30.30	15.60	11.10	114.20	51.90	167.00	101.60	9.40	8.70	0.40
	CHLA	1.20	10.17	5.20	2.32	4.97	191.80	16.45	28.10	5.55	1.67	3.55	0.72
	ASMA	8.00	0.28	5.83	6.71	2.23	0.60	2.81	6.65	18.34	5.61	2.45	0.55
B6	PROD	4.60	2.10	100.80	12.40	21.40	132.40	247.10	390.20	403.30	14.20	17.80	8.70
	CHLA	0.63	1.77	11.85	1.92	12.22	81.67	74.57	13.15	41.67	8.45	10.07	******
	ASMA	7.36	1.18	8.51	6.44	1.75	1.62	3.31	29.67	9.68	1.65	1.77	******
B7	PROD	2.50	3.50	36.40	19.90	11.70	106.80	127.30	167.30	208.60	7.40	5.90	3.60
	CHLA	0.85	2.12	5.47	2.52	4.40	131.05	30.47	22.85	16.60	4.72	6.02	0.40
	ASMA	2.94	1.65	6.65	7.88	2.66	0.81	4.18	7.32	12.57	1.57	0.98	9.00
B8	PROD	23.90	24.20	88.80	5.30	13.80	19.30	26.50	56.90	53.60	12.10	19.90	8.70
	CHLA	2.85	4.27	9.27	1.75	4.55	19.45	5.67	38.67	4.65	2.35	4.32	2.12
	ASMA	8.39	5.66	9.57	3.03	3.03	0.99	4.67	1.46	11.53	5.15	4.60	4.09
B9	PROD	******	******	31.90	******	11.80	27.20	28.50	39.70	59.50	8.20	17.00	9.60
	CHLA	******	******	8.67	******	3.25	36.97	4.97	3.70	4.10	2.37	2.52	3.87
	ASMA	******	******	9.44	******	3.63	0.74	5.73	10.73	13.64	3.45	6.73	2.48
B10	PROD	******	******	******	******	5.00	15.70	20.20	29.70	25.00	9.70	6.10	4.80
	CHLA	******	******	******	******	******	25.15	5.07	2.95	2.87	0.60	0.97	10.55
	ASMA	******	******	******	******	******	0.66	3.98	6.85	8.70	16.17	6.53	0.45

VALUES OF ****** REPRESENT DATA NOT AVAILABLE

Table 1 (cont.)

ABIOTIC TABLE FOR THE YEAR 1974: PRODUCTIVITY, CHLOROPHYLL A, AND ASSIMILATION RATIO A STATIONS A1 THROUGH D8 BY MONTH (CONTINUED)

		JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
B11	PROD	******	******	******	******	7.80	12.10	16.90	21.60	39.00	26.00	18.00	7.90
	CHLA	******	******	******	******	******	20.07	7.35	1.90	1.47	******	0.92	8.27
	ASMA	******	******	******	******	******	0.60	2.30	11.37	26.44	******	19.46	0.95
C1	PROD	6.40	14.10	392.10	59.70	17.30	6.00	5.80	101.40	9.50	6.40	2.90	0.80
	CHLA	1.25	2.22	24.42	6.15	4.57	2.55	3.80	******	******	2.05	0.22	0.37
	ASMA	5.12	6.34	16.05	9.71	3.78	2.35	1.53	******	******	3.12	12.89	2.13
C2	PROD	3.50	16.80	334.50	86.00	12.00	9.70	16.30	46.10	7.50	7.50	5.80	0.90
	CHLA	0.82	2.15	38.77	10.02	5.00	4.17	3.92	4.12	******	3.13	0.55	0.25
	ASMA	4.24	7.81	8.63	8.58	2.40	2.32	4.15	11.18	******	2.40	10.55	3.60
C3	PROD	8.70	8.10	235.10	70.70	26.70	11.30	23.10	20.80	14.30	5.50	5.60	0.90
	CHLA	1.17	1.52	37.27	7.92	6.05	3.20	6.27	2.07	******	1.42	0.52	0.20
	ASMA	7.40	5.31	6.31	8.92	4.41	3.53	3.68	10.02	******	3.86	10.67	4.50
C4	PROD	17.50	13.70	241.70	85.80	45.70	26.10	21.00	19.30	21.30	8.60	11.90	1.60
	CHLA	1.97	2.00	13.52	5.50	12.55	13.13	7.85	2.25	******	1.15	******	0.35
	ASMA	8.86	6.85	17.87	15.60	3.64	1.99	2.68	8.58	******	7.48	******	4.57
C5	PROD	12.80	13.60	272.10	28.90	47.30	36.60	10.50	18.40	28.30	17.40	1.20	8.70
	CHLA	1.62	1.80	29.95	13.60	15.32	33.80	2.42	1.40	******	1.12	0.85	0.63
	ASMA	7.88	7.56	9.09	2.12	3.09	1.08	4.33	13.14	******	15.47	1.41	13.92
C6	PROD	8.30	16.40	177.90	68.60	40.10	11.90	18.40	28.90	3.20	6.20	2.10	0.30
	CHLA	1.25	1.95	26.35	18.20	14.55	3.77	5.15	2.00	******	1.50	0.17	0.42
	ASMA	6.64	8.41	6.75	3.77	2.76	3.15	3.57	14.45	******	4.13	12.00	0.71
C7	PROD	57.90	19.10	257.50	92.90	30.00	26.00	18.10	17.00	8.00	15.30	7.70	1.30
	CHLA	4.75	2.35	33.35	6.00	9.42	14.95	4.02	3.17	******	1.17	******	0.50
	ASMA	12.19	8.13	7.72	15.48	3.18	1.74	4.50	5.35	******	13.02	******	2.60
C8	PROD	5.40	8.10	50.80	44.40	20.40	8.80	6.00	15.50	9.80	6.10	5.90	1.50
	CHLA	1.05	2.05	7.50	4.85	7.15	3.50	5.57	2.27	******	4.25	0.20	2.02
	ASMA	5.14	3.95	6.77	9.15	2.85	2.51	1.08	6.81	******	1.44	29.50	0.74
C9	PROD	5.50	8.30	69.40	65.40	20.40	14.50	8.80	11.80	16.30	7.50	5.40	0.60
	CHLA	0.92	1.80	8.22	4.92	7.45	3.40	2.52	1.50	******	0.97	0.27	0.27
	ASMA	5.95	4.61	8.44	13.28	2.74	4.26	3.49	7.67	******	7.69	19.64	2.16

VALUES OF ****** REPRESENT DATA NOT AVAILABLE

Table 1 (cont.)

ABIOTIC TABLE FOR THE YEAR 1974: PRODUCTIVITY, CHLOROPHYLL A, AND ASSIMILATION RATIO A

STATIONS A1 THROUGH D8 BY MONTH (CONTINUED)

		JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
C10	PROD	1.60	6.50	27.20	47.50	19.50	18.10	8.10	19.70	16.00	5.20	11.10	0.50
	CHLA	0.50	1.50	5.15	5.60	5.97	3.72	2.32	2.45	******	2.75	******	2.15
	ASMA	3.20	4.33	5.28	8.48	3.26	4.86	3.48	8.04	******	1.89	******	0.23
C11	PROD	2.60	6.90	7.30	38.70	20.60	23.90	9.70	5.60	9.50	7.90	1.50	0.40
	CHLA	0.80	1.57	1.25	2.80	4.95	7.17	4.65	1.02	******	1.77	1.90	0.67
	ASMA	3.25	4.38	5.84	13.82	4.16	3.33	2.09	5.40	******	4.45	0.79	0.59
D1	PROD	43.20	19.30	17.40	12.70	28.20	25.10	280.90	42.40	148.20	1.20	1.70	18.90
	CHLA	6.70	4.00	2.77	7.02	12.65	26.45	43.85	4.38	13.72	4.67	6.10	3.32
	ASMA	6.45	4.82	6.27	1.81	2.23	0.95	6.41	9.69	10.80	0.26	0.28	5.68
D2	PROD	37.00	24.60	******	30.70	215.20	155.90	311.30	267.60	362.80	46.30	43.30	4.00
	CHLA	8.92	3.67	******	37.27	77.20	64.77	68.80	46.17	65.40	32.62	5.70	0.60
	ASMA	4.15	6.69	******	0.82	2.79	2.41	4.52	5.80	5.55	1.42	7.60	6.67
D3	PROD	56.90	15.00	15.70	23.40	57.90	87.80	201.70	305.90	441.50	64.20	75.60	2.50
	CHLA	10.95	2.40	2.62	12.57	28.00	30.57	49.40	42.95	89.95	18.80	23.65	0.57
	ASMA	5.20	6.25	5.98	1.86	2.07	2.87	4.08	7.12	4.91	3.41	3.20	4.35
D4	PROD	49.90	23.30	17.70	8.20	110.00	28.60	126.50	3.80	386.90	82.90	79.70	16.20
	CHLA	8.75	4.10	2.62	5.77	53.32	18.52	20.75	9.95	19.97	9.62	57.50	1.82
	ASMA	5.70	5.68	6.74	1.42	2.06	1.54	6.10	0.38	19.37	8.61	1.39	8.88
D5	PROD	112.30	45.90	25.30	15.60	46.40	45.80	55.90	10.30	420.00	22.20	23.00	22.40
	CHLA	16.72	6.02	4.42	9.42	14.50	26.52	9.50	1.15	22.32	6.45	0.97	3.62
	ASMA	6.71	7.62	5.72	1.66	3.20	1.73	5.88	8.96	18.81	3.44	23.59	6.18
D6	PROD	64.30	13.10	23.10	13.00	32.70	20.90	24.60	54.20	437.10	36.90	45.30	35.90
	CHLA	9.02	1.85	2.75	5.55	18.85	16.00	3.67	5.97	24.92	10.82	25.22	3.30
	ASMA	7.12	7.08	8.40	2.34	1.73	1.31	6.69	9.07	17.54	3.41	1.80	10.88
D7	PROD	40.30	17.80	17.00	13.10	24.30	22.00	54.10	79.20	495.10	30.90	37.50	13.90
	CHLA	8.22	2.35	2.22	3.90	13.67	11.30	10.00	9.70	38.50	13.80	5.17	5.10
	ASMA	4.90	7.57	7.64	3.36	1.78	1.95	5.41	8.16	12.86	2.24	7.25	2.73
D8	PROD	62.70	14.30	37.10	14.20	27.60	36.90	4.60	240.20	58.40	8.70	7.60	22.00
	CHLA	9.80	3.13	5.05	7.85	8.15	18.15	0.65	55.65	******	******	34.15	3.25
	ASMA	6.40	4.58	7.35	1.81	3.39	2.03	7.08	4.32	******	******	0.22	6.77

VALUES OF ****** REPRESENT DATA NOT AVAILABLE