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The benthic biological conditions of Los Angeles – Long Beach Harbors: Results of 28 years of investigations and monitoring

D. J. Reish[1], D. F. Soule & J. D. Soule[2]

[1] *Department of Biology, California State University; Long Beach, Long Beach, California, USA 90720*

[2] *Harbors Environmental Projects, Allan Hancock Foundation; University of Southern California, USA 90007*

ABSTRACT: Los Angeles–Long Beach Harbors were a grossly polluted body of water at the time of the initiation of benthic biological studies in 1951. Industrial, domestic and storm wastes were emptied into these waters with little or no treatment. The inner harbor waters contained little or no dissolved oxygen and much of the benthos was azoic or possessed a stressed community. However, the outer harbor water mass contained adequate dissolved oxygen, and the benthos supported a rich fauna dominated by many species of polychaetes. A pollution abatement program was initiated in 1968, and today many former wastes have been eliminated or are being diverted to treatment plants for processing. The benthic fauna changed markedly and rapidly following this environmental clean-up. Peaks in population were reached throughout the harbor in 1973–1974 which was followed by a slight decline then stability. An oil tanker explosion, pre-treatment of fish-cannery wastes then diversion of these wastes to a sewage treatment plant, and a change from primary to secondary treatment of sewage brought about changes in the benthic fauna. In the latter instance, benthic populations of polychaetes, fish populations and the number of birds feeding within the area decreased significantly.

INTRODUCTION

The Los Angeles–Long Beach Harbor area is a single body of water oceanographically, but politically it consists of two harbor departments located in their respective cities. Development of the area into one of the world's leading industrial harbors has been rapid and largely accomplished in this century. The area was initially a marshland with mudflats and extensive areas of marsh grasses (Fig. 1). Development consisted of dredging channels, filling lowlands, constructing a breakwater, and relocating rivers. Changes have been extensive since 1872, as can be seen in Figure 1.

Environmental studies in these harbors were not undertaken until the 1950s, during which time the conditions within this body of water were characterized (Anonymous, 1952; Reish, 1955, 1959a). It was not until the late 1960s that new studies were undertaken which coincided with the initiation of a pollution abatement program (Reish,

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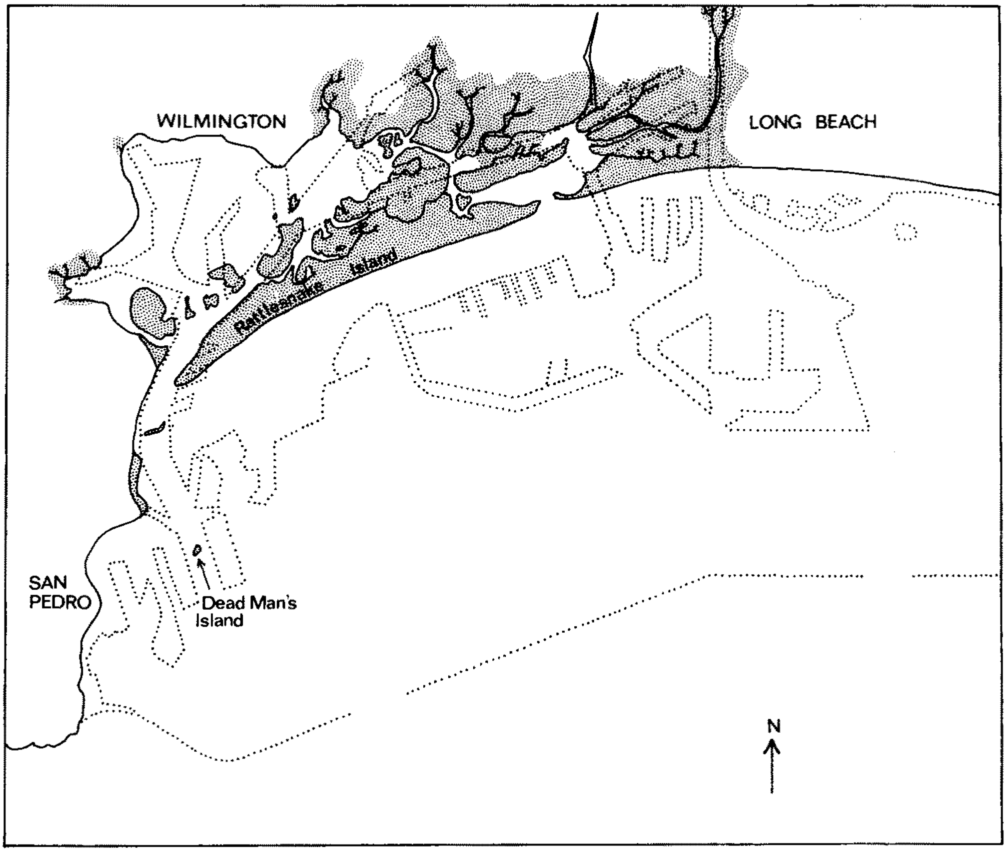

Fig. 1. Map of San Pedro Bay in 1872 with a current map of Los Angeles–Long Beach Harbors superimposed upon it

1971). Additional benthic studies began in 1971 and have continued more or less on a regular basis to the present (Soule & Oguri, 1975, 1976, 1978, 1979).

The importance of the benthos in assessing water-quality conditions has been well documented (Reish, 1973; Pearson & Rosenberg 1978). The purpose of this report is to indicate how the data from benthic studies can be utilized in assessing environmental conditions. The benthic environment during the heavily polluted era of the 1950s will be described as a more or less base-line condition from which it was possible to measure the benefits of the pollution-abatement program. The benthos can then be re-characterized to reflect the changes which have occurred as a result of this clean-up in the late 1960s and early 1970s. Finally, in the mid 1970s, three additional ecological changes occurred, the results of which were reflected in the benthic environment; these were, the explosion of the oil tanker "Sansinena", the diversion of the fish-cannery discharge to the Terminal Island Sewage Treatment Plant, and the change from primary to secondary sewage treatment at the Terminal Island facility.

MATERIALS AND METHODS

Benthic samples through 1971 were taken throughout the harbors with a size 1 Hayward orange-peel bucket (Reish, 1959b). Most of these samples were washed through a 1.0-mm mesh sieve except those within the Long Beach Naval Shipyard which were washed through a 0.5-mm sieve. Samples from the harbor in the 1970s were taken either with a Campbell grab which samples 0.1 m^2 of surface or a Reinecke box core, which samples 0.06 m^2 to a depth of 0.5 m. Samples were washed through a 0.5-mm sieve. All samples were preserved in the field with 10 percent formalin in seawater and brought to the laboratory for processing and identification. See Reish (1959a) and Soule & Oguri (1975, 1978, 1979) for additional details on collection and processing of samples. These benthic studies were a part of a more extensive ecosystem program carried out in the harbors especially in the 1970s.

RESULTS

Benthic conditions 1951–1968

Benthic samples were taken in selected harbor locations in 1951, 1954, 1955, and 1967–68. The conditions in June 1954 (Fig. 2) were used to construct a representative description of the benthic environment during this 17-year period. In addition, the data from samples taken in 1970–71 from the Long Beach Naval Shipyard are incorporated in Figure 2 (Hill & Reish, 1975) since no previous samples had been taken within the naval base and they were taken prior to the initiation of the pollution abatement program by the U.S. Navy at this facility.

Fifty-five stations were sampled in June 1954 and five distinct zones were noted on the basis of the presence or absence of polychaete species (Fig. 2). In general, the polluted zone, characterized by the presence of the polychaete *Capitella capitata*, and the very polluted zone, which lacked animals, were present within the majority of the blind-ending slips or basins of the inner harbor area, inner Long Beach Naval Base, Fish Harbor, and at the discharge point of the Terminal Island Sewage Treatment Plant. The healthy zone, characterized by the polychaetes *Tharyx parvus*, *Cossura candida*, and *Nereis procera*, was present in the outer harbor and main channels. The semi-healthy zones, one characterized by *Dorvillea articulata*, (= *Stauronereis rudolphi* or *Schistomeringos longicornis*) and *Polydora paucibranchiata* (= *Pseudopolydora paucibranchiata)* and the other by *Cirriformia luxuriosa*, were located in the inner harbor areas between the healthy and polluted zones.

Sediment characteristics followed similar patterns in distribution. The black sulfide muds, which had a high organic carbon content, were present in the inner harbors, whereas the cleaner sediments with low organic carbon content were present in the outer harbors.

While there were over 240 companies or agencies discharging wastes into the harbors, industrial wastes constituted the largest fraction of these discharges, with the oil companies being the single most important contributor. Oil-refinery wastes were discharged into Consolidated Slip – East Basin and West Basin areas of Los Angeles Harbor (Fig. 2). Domestic waste from the area was discharged into the outer harbor near Fish

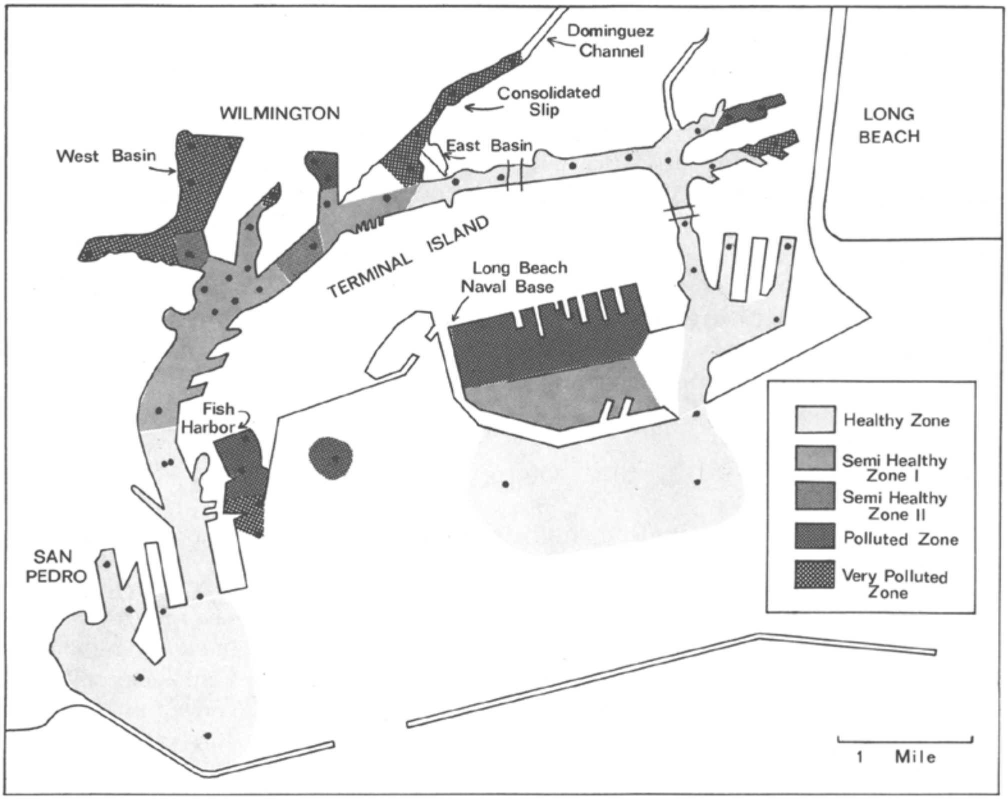

Fig. 2. Benthic biological conditions in Los Angeles–Long Beach Harbors in 1954 with conditions in Long Beach Naval Facility in 1971

Harbor, and fish-cannery waste was discharged into Fish Harbor itself. Dockside facilities discharged raw sewage directly into the water.

Some areas of the inner harbors did not receive major discharges directly, but because of limited water circulation in the blind-ending slips (especially in Long Beach Harbor including the naval base), water exchange was limited which resulted in reduced dissolved oxygen conditions.

Pollution abatement 1968–1970

Ecological conditions remained the same for the ensuing 10–15 years with no appreciable change in the nature or amount of wastes emptied into the harbors. In early 1968, the State of California issued an order prohibiting the discharge of oil-refinery wastes into Dominguez Channel which flowed into the Consolidated Slip – East Basin region of Los Angeles Harbor and elsewhere. The amount of oil-refinery wastes at that time had reached 7.5×10^7 1/day. It took nearly 20 months for all 18 oil companies to comply with this order. A month later, October 1970, the dissolved oxygen in the water mass ranged from 3.8 to 5.2 mg/l where it had formerly ranged from 0.0 to 1.0 mg/l in the

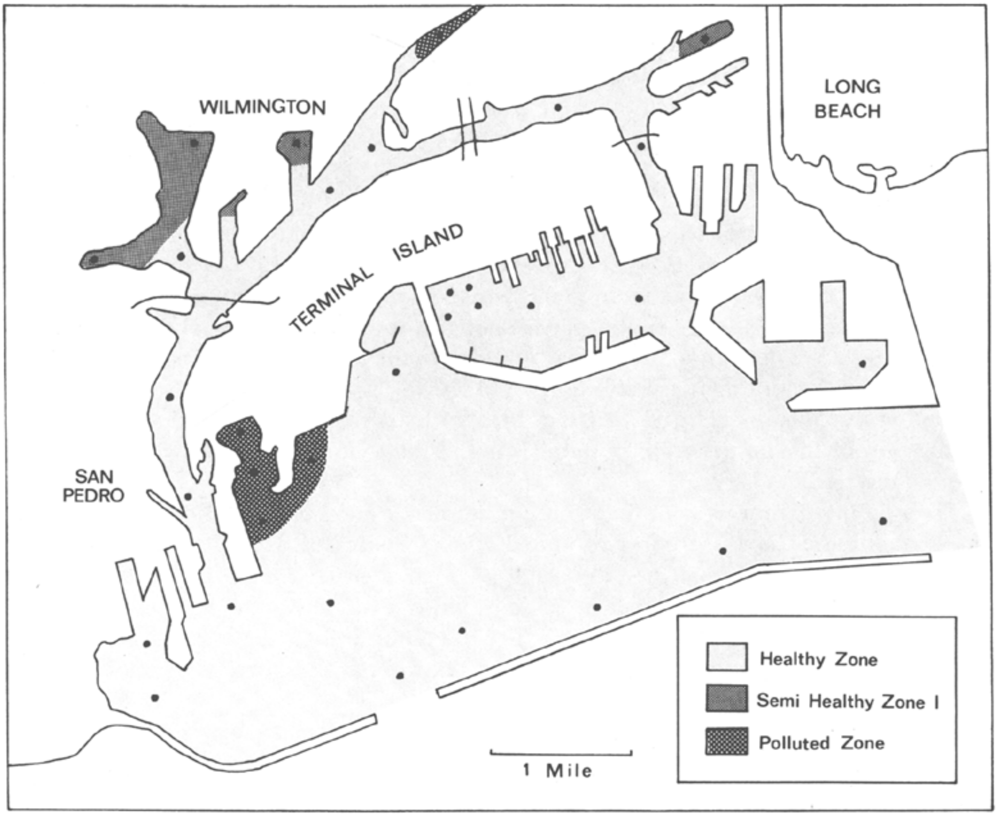

Fig. 3. Benthic biological conditions in Los Angeles–Long Beach Harbors in 1973 with conditions in Long Beach Naval Facility in 1978

mid-1950s. Benthic organisms did not occur in this area prior to pollution abatement but up to 11 species were present at some stations by October 1970 (Reish, 1971). Polychaetes dominant of the polluted and semi-healthy zones characterized this area of the harbor following the abatement program. These conditions remained stabilized in Consolidated Slip (Fig. 3) through 1978. However, in East Basin, which is just down current from Consolidated, benthic species of polychaetes, such as *Euchone limnicola* and *Nephtys cornuta franciscana,* which previously were known only from the outer harbor, were present as dominant species. Fouling organisms, which had been virtually absent previously, were abundant with the mussel *Mytilus edulis* dominating (Reish, 1971). The Consolidated wharf, built of creosoted wood pilings, collapsed shortly after controls were implemented, due to the wood borer *Limnoria tripunctata,* which had previously been absent from the area.

The pollution-abatement program within the U.S. Naval Base (Fig. 2) was not initiated until the mid-1970s. Wastes discharged within the base consisted of petroleum products, waste waters of various types from naval ships, and storm run-off, but now all of these wastes, except storm waters, are collected and discharged elsewhere. In the

1970–71 period much of the benthos in the naval base was dominated by *Capitella capitata* (Fig. 2; Hill & Reish, 1975), but following the completion of the abatement program this species was virtually absent and the benthos was dominated by a wide variety of species with the healthy zone indicators dominating (Fig. 3; Reish, 1978).

Post-pollution-abatement period: 1973–1978

All major industrial wastes were either diverted elsewhere or eliminated by the early 1970s. The fish-cannery wastes were diverted in October 1977–January 1978 to the Terminal Island Sewage Treatment Plant, which changed from a primary to a secondary facility in April 1977. As a result of these changes, the benthic fauna at a given locality also changed in composition. Benthic conditions in the 1973–74 period can be taken as a new base line for judging possible recent and future changes (Fig. 3; Anonymous, 1975). By comparing the results given in Figure 2 with those in Figure 3, one can see the elimination of the former very polluted zone. Benthic animals are now present in all areas of the harbors.

The polluted zone is confined to the innermost region of Consolidated Slip and to the area around Fish Harbor and the discharge point of Terminal Island Sewage Treatment Plant. The semi-healthy zones, which were formerly in the inner main channels, are now confined to some of the innermost regions of the slips or basins. The healthy zone is present throughout much of the outer harbor, Long Beach Naval Base, and the main channels of the harbor (Fig. 3). The very polluted zone, which was azoic, ceased to exist within the harbors.

The number of benthic species more than doubled from 1954 to 1973 largely as a result of invasion into the harbor of offshore species. With this invasion of additional species the healthy zone became more diverse in its composition and was divided into additional associations (Table 2; Anonymous, 1975).

"Sansinena" explosion December 1976

On December 17, 1976, the 70,000 ton tanker "Sansinena" exploded and burned in Los Angeles outer harbor (Fig. 4). Approximately 32,000 barrels of Bunker C fuel were spilled as a result of this explosion. An unknown amount of the lighter oils burned with the heavier components sinking to the bottom.

Benthic samples, together with other biological, chemical and physical measurements, were taken in the surrounding area a few days after the explosion. They were from the vicinity of the explosion (Fig. 4) but not next to the "Sansinena" because the debris from the wreckage of the ship prevented ships from entering the area. However, scuba dive transects from the ship were made immediately after the explosion and monthly for one year. Approximately 2.5 m of oil-tarry residue pooled beneath the wreck, and a layer of oil covered the benthos around the "Sansinena"; a year later the layer had been reduced to 2 cm by salvage operations and was not detected two months later following severe storms (Soule & Oguri, 1978). Clean-up operations of the "Sansinena" prevented box coring on the immediate site of the wreckage for the year following the explosion, but samples were taken initially at 23 stations in the beginning some 50 m from the wreck, and at 12 stations quarterly through November 1977.

Table 1. Range and mean of the number of species and specimens of benthic animals in the vicinity of the "Sansinena" explosion 1976–1977

Date	Number of species Range	Mean	Number of specimens Range	Mean
December 1976	20–46	31.7	298–1815	929
January 1977	6–18	12.4	168–2320	1130
April 1977	15–31	24.3	41– 341	242
July 1977	18–33	24.5	190–2836	751
November 1977	23–35	29.0	450–2874	1237

The harbor area near the "Sansinena" site was characterized by about 40 species and 40,000 specimens/m^2 in 1974, the date of the last published benthic sampling in the area. The results of the benthic studies are summarized in Table 1 as to the number of species and specimens present near the explosion (Fig. 4). with respect to time. The number of species dropped dramatically from a mean of 31.7 in December 1976 (apparently insufficient time had elapsed from the time of the explosion to the date of collection of samples a few days later to have affected the benthic fauna) to a low of 12.4 a month later. However, the number of individuals had actually increased, suggesting a biostimulatory effect on those species not eliminated by acute toxicity. The number of species increased in April but the number of individuals declined by an order of

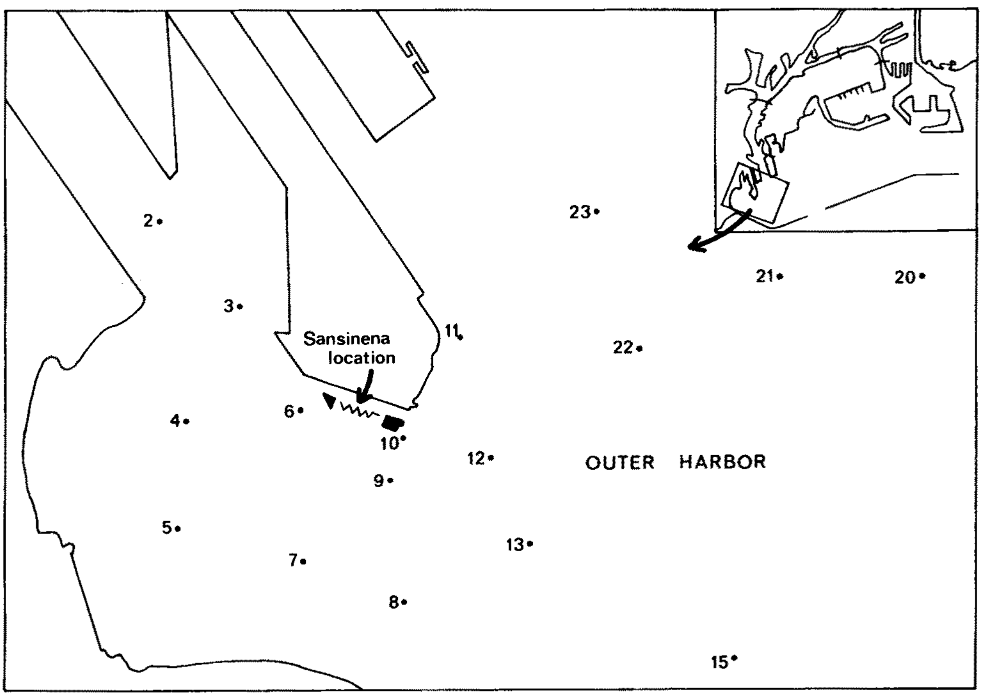

Fig. 4. Location of "Sansinena" explosion in 1976 and station locations of benthic surveys

Table 2. Dominant species composition of the three healthy zones in Los Angeles – Long Beach Harbors 1971–1978

Healthy zone*	Group 1	Group 2	Group 3
Tharyx parvus	*Macoma acolasta*	*Tharyx ? parvus*	*Euchone limnicola*
Cossura candida	*Notomastus c. tenuis*	*Cossura candida*	*Callianassa* sp.
Nereis procera	*Prionsopio pygmaeus*	*Halposcoloplos elongatus*	*Cryptomya californica*
	Tellina modesta	*Prionospio pinnata*	*Nephtys c. franciscanus*

*As defined by Reish (1959a)

magnitude. Partial recovery could be seen by July, and population levels appeared normal by November 1977, although total numbers have not equaled the 1974 levels in recent years.

Analysis of the species composition indicates that all stations sampled were composed of one of the three healthy sub-zones as defined in 1975 (Table 2). While there was a decided reduction in the number of species a month after the explosion, the species present were those characteristic of the healthy environment. Specimens of *Schistomeringos longicornis* and *Pseudopolydora paucibranchiata*,both characteristic of the semi-healthy zone, and *Capitella capitata*, characteristic of the polluted or stressed zone, were taken in small numbers from some of the stations. None of these species was dominant at any of the stations at any time. The area directly beneath the spill was covered by 2–3 m of oil. Following salvage and clean-up of the residual oil, the area was dredged. Therefore, no evidence could be gathered on whether a stressed community might have developed, which would have been dominated by *Capitella capitata*, as noted by Grassle and Grassle (1974) following the West Falmouth oil spill.

Diversion of fish-cannery wastes and conversion of the Terminal Island Sewage Treatment Plant to secondary treatment 1977–1978

Organic wastes from two sources were discharged near one another into outer Los Angeles Harbor; there were two outfalls for fish-cannery wastes and one for primary treated sewage from Terminal Island Sewage Treatment Plant (Fig. 5) in a shallow (4–5 m) area. In 1974–75, fish canneries installed pretreatment equipment (dissolved air flotation). This removed major amounts of proteins, amino acids and fats from the effluent. Under a pollution-abatement program of the Environmental Protection Agency and the State of California Water Quality Control Board, the wastes from the fish canneries were diverted to the Terminal Island Sewage Treatment Plant (October 1977–January 1978). This treatment plant had been converted from primary to secondary sewage treatment in April 1977. Cannery wastes were largely liquid since most of the solid material had been removed prior to discharge into harbor waters. Biological conditions in the vicinity of the discharges vary; from a low of 7 species and 1680 individuals/m^2 in 1971, counts increased to 14 species and 12,256 individuals/m^2 in 1973. In 1974 there were 17 species and 7930 individuals. Following installation of dissolved air flotation, counts dropped in 1976 to 8 species and 808 individuals/m^2 but by

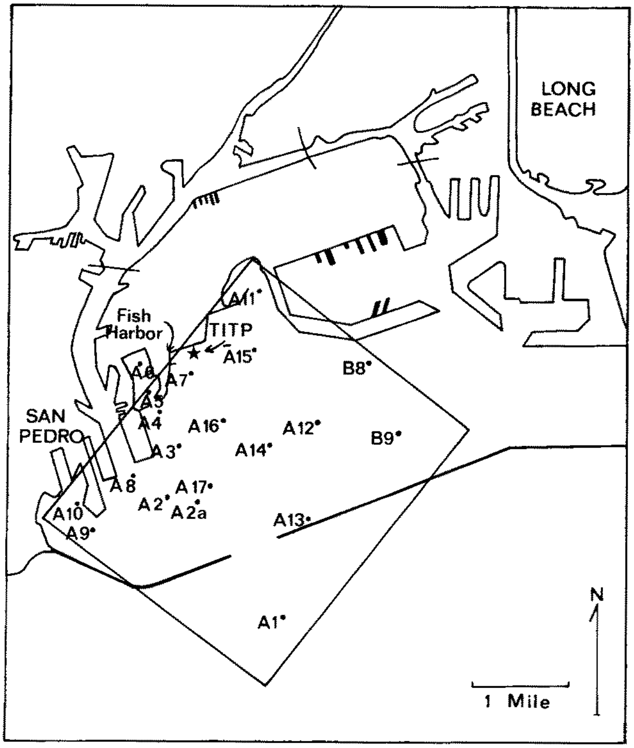

Fig. 5. Location of the discharge sewers for fish harbor and Terminal Island Sewage Treatment Plant (TITR = Terminal Island Sewage Treatment Plant)

1978 the site had recovered. While conditions improved from the capitellid populations of 1976 at the outfalls, formerly rich adjacent areas declined in species and in numbers in 1978 following full secondary treatment (Soule & Oguri, 1979).

The effluents from the fish canneries presented several problems in the operation of the sewage-treatment plant. The cannery wastes are of variable salinity, high in BOD with an average of 1000 mg/l, and intermittent in flow during the day, week and year. Varying amounts of sea water were added to the cannery effluents in an attempt to stabilize salinity and give a combined flow of cannery, domestic and industrial wastes totaling about 56.8 million liters per day, except during times of high storm runoff. In July 1978, treatment plant operations were disrupted by a loss of the bacterial floc, which resulted in discharges with exceedingly high BOD and suspended solids levels, higher than those occurring prior to conversion to secondary treatment. Aeration was increased in September 1978 which resulted in reduction of BOD and suspended solids. Ammonia-N dropped from 20–30 mg/l to about 5 mg/l after conversion to secondary treatment in April 1977, but after diversion of the fish-cannery wastes in late 1977, the values rose to 45 mg/l. Ammonia-N values in 1978 fluctuated but were generally lower than in 1977 until the disruption of plant operations in July 1978 after which the values rose to over 50 mg/l. Values dropped to less than 5 mg/l after resumption of normal plant operations in September 1978. Intermittent violations of the effluent permit continue and a cease and desist order has now been issued.

These changes in the methods of waste disposal and disruption of plant operations brought about immediate changes in the benthic communities which in turn resulted in changes in the fish and bird populations in the vicinity. The general results of 22 benthic surveys in outer Los Angeles Harbor from 1971–1978 are summarized graphically as yearly means in Figure 6. The data for A7, the station located near the discharge pipe of the Terminal Island Sewage Treatment Plant, are plotted separately from the other data. The large increases in the number of species and specimens in the 1972–1974 period were probably the result of the general harbor pollution-abatement program (Reish, 1971) which allowed for extensive new colonizations to occur. The population decreased following the peak in 1973 to a point of relative stability in the 1976–1978 period. The sharp decrease in the number of individuals since 1974 following the sharp rise was probably the result of extensive larval settlement in 1972–1974 following an environmental change but as competition for food and space began to occur during the growth period of these animals, many specimens either died or were eaten by others (Reish, 1961).

Following the changes in the methods of waste disposal and sewage treatment, a drop was noted in the number of species present; however, the number of specimens was not altered. In contrast, the number of species and specimens at Station A7, near the outfall, more than doubled following the changes in waste disposal methods. *Capitella*

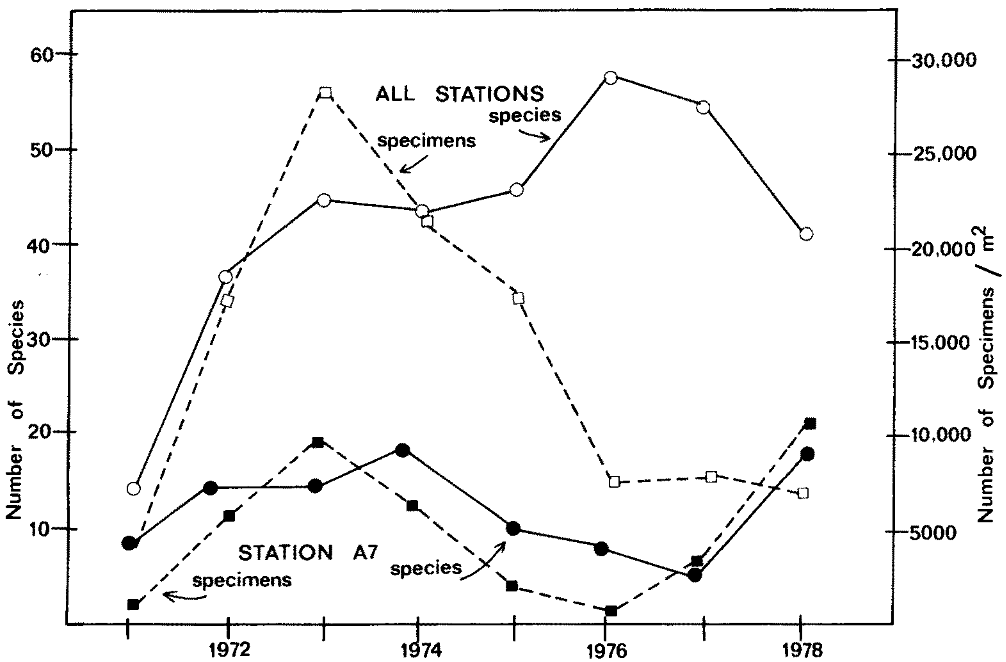

Fig. 6. Annual means of benthic species and number of specimens in the outer harbor (all stations) and near the vicinity of the discharge of the Terminal Island Sewage Treatment Plant (Station A7)

capitata continued to dominate the benthic community at Station A7 into 1978, but with a greater number of species present. *Mediomastus californiensis* (= *Capitita ambiseta*) became the dominant species and faunal composition came to resemble those stations farthest from the discharge point of which the principal components were *M. californiensis*, *Tharyx* sp. (= *Tharyx parvus*), and *Cossura candida*, characteristic of the healthy zone.

Populations of fish and marine birds decreased following the cessation of cannery discharges in late 1977. The mean number of fish per trawl in the outer harbor area experienced a four-fold decrease between 1973 and 1978. The white croakers and the anchovies were particularly affected. The white croaker (*Genyonemus lineatus*), which is the principal fish caught by low income shore anglers dropped 10- to 20-fold during this period. The population of anchovy (*Engraulis mordax*), which is used as a live bait, dropped nearly a hundred-fold between 1973 and 1978 (Soule & Oguri, 1979).

Populations of birds were determined quarterly throughout the harbor in 1978 and compared with similar data collected in 1973–1974. The overall population showed a 2.5-fold decrease in 1978 compared with the 1973–1974 period. The greatest decreases were found in the common marine birds, such as surf scoter, black-bellied plover, sanderling, seven species of gulls, and Forester's tern. However, the western grebe and endangered brown pelican showed an increase in 1978. The fish-cannery sewer site was a common bird feeding site before the diversion of the fish-cannery wastes to the sewage plant. Birds formerly fed near the boil of the sewage-plant discharge but no longer do so (Soule & Oguri, 1979).

DISCUSSION

Generalized results are presented to indicate the effects of environmental changes on benthic fauna in Los Angeles–Long Beach Harbors during the past 28 years. While benthic samples were not taken during all of these years, sufficient data are available to indicate that the benthic fauna responds rapidly to any change in environmental conditions either beneficial or detrimental. Improvement in water quality as the result of the elimination of discharging of oil-refinery wastes into the harbor resulted in an invasion of benthic species into areas formerly azoic. Prior to 1971, canneries discharged fish scales, heads and particulates into Fish Harbor, creating anoxic and azoic conditions. Reduction plants removed the solid wastes and effluents were diverted to the sewer outfall area in 1971, after which the peak outer harbor ecosystem was reached in 1973–1974. Diversion of the fish-cannery waste to the Terminal Island Sewage Treatment Plant and its subsequent conversion to secondary treatment brought about the upgrading of species composition from a polluted to semi-healthy species composition in the immediate area. However, the environmental changes in the outer harbor, with the elimination of the nutrient source of the fish-cannery wastes and the conversion from primary to secondary treatment, have resulted in a drop in benthic species and populations in the adjacent outer harbor area, with a resultant significant drop in fish and bird populations. A 30-fold decrease in microheterotrophs (bacteria, etc.) significantly reduced the detrital food supply to the benthic organisms.

One of the benefits of a monitoring program is that you know what is present prior to some ecological mishap such as the "Sansinena" explosion. Populations near the ship were reduced, reaching their lowest level four months later, but the species composition was always composed of those polychaetes characteristic of the healthy zone. Normal benthic conditions were noted a year after the explosion.

While benthic monitoring problems may appear time-consuming, expensive and perhaps unnecessary, a knowledge of the benthic fauna is an accurate barometer of what has recently happened. Monitoring programs which have been conducted over a long period of time can give us insight into natural variabilities of the environment since it is important to be able to distinguish between them and some man-caused event (Sharp et al., 1979).

A broad spectrum monitoring program was maintained along with quarterly benthic sampling. Temperature, salinity, dissolved oxygen, pH and turbidity were measured at 1-m intervals in the water column and nutrient salts in surface samples determined on a monthly basis. Also, phytoplankton productivity (^{14}C), chlorophyll *a* and assimilation ratios were determined, zooplankton per m^3 identified and settling rack meroplankton were sampled monthly. Fish trawls were made quarterly. Sediment grain size and trace metal and pesticide analyses were made as well. Microbiological counts, uptake studies, calorie and gut-content investigations have been done periodically. Thus the benthic sample data have been correlated, using weighted discriminant computer analysis (Smith 1979), with a variety of parameters. In this way. the ecosystem has been characterized, and progress toward assimilation capacity modeling has been achieved.

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LITERATURE CITED

Anonymous, 1952. Los Angeles-Long Beach harbor pollution. Los Angeles Regional Water Pollution Control Board, Los Angeles, Calif., 43 pp.

Anonymous, 1975. Environmental investigations and analyses, Los Angeles harbor 1973–1975. Harbor Environmental Project, Allan Hancock Foundation, Univ. of Southern California, Los Angeles, Calif., 582 pp.

Grassle, J. F. & Grassle, J. P., 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. – J. mar. Res. *32*, 253–284.

Hill, L. R. & Reish, D.J., 1975. Seasonal occurrence and distribution of benthic and fouling species of polychaetes in Long Beach naval station and shipyard, California. Mar. Stud. San Pedro Bay, Calif. *8*, 57–74.

Pearson, T. H. & Rosenberg, R., 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. – Oceanogr. mar. Biol. *16*, 229–311.

Reish, D. J., 1955. The relation of polychaetous annelids to harbor pollution. – Pub. Hlth Rep., Wash. *70*, 1168–1174.

Reish, D. J., 1959a. An ecological study of pollution in Los Angeles-Long Beach Harbors, California. – Occ. Pap. Allan Hancock Fdn. *22*, 1–119.

Reish, D. J., 1959b. Modification of the Hayward orange-peel bucket for bottom sampling. – Ecology *40*, 502–503.

Reish, D. J., 1961. A study of benthic fauna in a recently constructed boat harbor in southern California. – Ecology *42*, 84–91.

Reish, D. J., 1971. The effect of pollution abatement in Los Angeles Harbor, California. – Mar. Pollut. Bull. *2,* 71–74.

Reish, D.J., 1973. The use of benthic animals in monitoring the marine environment. J. envir.Plann. Pollut. Control *1,* 32–38.

Reish, D. J., 1978. Long Beach naval base and sea plane anchorage, environmental impact report, marine biology. In: Environmental impact statement for the re-establishment of Long Beach naval station for Pacific fleet homeporting. Atlantis Scientific, Beverly Hills, Calif. 27 pp.

Sharp, J. M., Appan, S. G., Bender, M. E., Linton, T. L., Reish, D. J. & Ward, C. H., 1979. Natural variability of biological community structure as a quantitative basis for ecological impact assessment. In: Proceedings of the 2nd annual meeting, petroleum industry biologist, Arlington, Virginia, 257–284.

Smith, R. W., 1979. Ecological analysis package, methods section, discriminate analysis. – Mar. Stud. San Pedro Bay, Calif. *16,* 547–597.

Soule, D. F. & Oguri, M., (Eds) 1975. Environmental biology. – Mar. Stud. San Pedro Bay, Calif. *8,* 1–119.

Soule, D. F. & Oguri, M., (Eds) 1976. Potential effects of dredging on the biota of outer Los Angeles harbor. Mar. Stud. San Pedro Bay, Calif. *11,* 1–325.

Soule, D. F. & Oguri, M., (Eds) 1978. The impact of the Sansinena explosion and Bunker C spill on the marine environment of outer Los Angeles Harbor. – Mar. Stud. San Pedro Bay, Calif. *15,* 1–258.

Soule, D. F. & Oguri, M., (Eds) 1979. Ecological changes in outer Los Angeles-Long Beach harbors following initiation of secondary waste treatment and cessation of fish cannery waste effluent. – Mar. Stud. San Pedro Bay, Calif. *16,* 1–598.