

BIOLOGICAL CHANGES IN LOS ANGELES HARBOR FOLLOWING POLLUTION ABATEMENT

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INTRODUCTION

Los Angeles-Long Beach harbors are an example of a highly industrial body of water which has been modified by construction (Figure 1). Industrial wastes of various types, of which oil refinery wastes constitute the single most important kind, are emptied primarily in the inner harbor areas. Domestic sewage is discharged throughout the region but only the wastes from the Terminal Island sewage treatment plant discharge any large quantity of effluents. Storm drains are located throughout the harbor area. Los Angeles and Long Beach harbors are one harbor oceanographically; the distinction is political, with the administration under two separate city harbor departments. Originally the area was a marshland with meandering channels. The Los Angeles River flowed into the inner harbor near Consolidated Slip (Figure 1). The river was diverted to its present course in 1923. Development of the harbor area began in 1850 and has proceeded to this day (McQuat, 1951; Anon., 1952; Reish, 1959).

The history of pollution in the harbor area has been outlined in the accounts by Anon., 1952; Larson, 1956; Reish, 1959. Biological studies concerned with pollution in the Los Angeles-Long Beach Harbors include these accounts: benthic studies (Anon., 1952; Reish, 1955, 1957a, 1957b, 1959, 1960, 1963, 1964b), fouling organisms (Barnard, 1958; Crippen and Reish, 1969; Reish, 1961a), experimental studies (Reish and Barnard, 1960; Reish, 1961b), and wood-boring organisms (Menzies, Mohr, and Wakeman, 1963). Oil refinery wastes constitute the single most important industrial waste discharged into the harbor. A peak of 16.5 m.g.d. of oil refinery wastes was emptied into Dominguez Channel in 1968. The effect of these wastes on the benthic fauna has been recorded in Reish (1959) and on fouling organisms in Crippen and Reish (1969). Essentially the harbor floor in the area affected by this discharge was devoid of animal life (Figure 2, Table 1). Only a few fouling organisms were observed over a period of years at station LA50; these consisted of blue-green algae, tubificid oligochaetes and rat-tail maggots. Five species of polychaetes, with *Capitella capitata* dominating, were present on boat docks at station LA 54 along with the green alga *Enteromorpha crinita*, chironomid larva, and tubificid oligochaetes. These biological conditions have been similar since I began studying this area in 1950. Elsewhere, the benthos of Los Angeles-Long Beach Harbors was divided into five zones on the basis of the association of poly-

chaete species: a healthy zone characterized by *Tharyx parvus*, *Nereis procera*, and *Cossura candida*; semi-healthy zone I, characterized by *Polydora (Cazzia) paucibranchiata* and *Dorvillea articulata*; semi-healthy zone II, characterized by *Cirriformia luxuriosa*; a polluted zone characterized by *Capitella capitata*; a very polluted zone devoid of macroscopic life (Reish, 1959).

TABLE 1
Number of Species Collected from Boat Docks
and Harbor Floor

| Station Number | Docks | Benthos | |
|----------------|--------------|----------------------------|--------------|
| | October 1970 | November 1954 ¹ | October 1970 |
| LA51..... | 13 | 0 | 10 |
| 50..... | 15 | 0 | 4 |
| 49..... | 16 | 0 | 6 |
| 54..... | 18 | 0 | 11 |
| 26..... | 27 | 15 | -- |
| 7..... | 37 | 11 | -- |

¹ Data from Reish, 1959b.

Pollution Abatement in the Consolidated Slip-East Basin Region

On February 21, 1968, the California Regional Water Quality Control Board, Los Angeles Region, issued an order prohibiting the discharge of oil refinery wastes into the Dominguez Channel. Following this directive, the 18 major companies involved either ceased emptying their wastes into the channel or eliminated the oxygen-depleting fraction of their discharge. The last company to comply with this order did so on September 25, 1970. The average daily volume discharged into this region is now 4 m.g.d. and consists largely of cooling waters or wastes from which the oxygen-depleting portion has been removed. The estimated costs for this clean-up were over 20 million dollars.

Since the termination of collections on January 8, 1968, as reported by Crippen and Reish (1969), I have visited the Consolidated Slip-East Basin region in May 1968 and April 1970. The conditions on the boat floats were identical to the earlier studies. However, during the summer of 1970, I received various reports that biological conditions in this region were changing. I visited the area on October 30, 1970, and saw marked changes in the biological conditions. This report, therefore, constitutes the observations made on that date.

MATERIALS AND METHODS

The biological characteristics were observed at six stations in Los Angeles Harbor on October 30, 1970. These stations (Figure 1) were selected with reference to an increasing distance from the source of oil refinery discharge. The exact location of these stations has been described previously (Reish, 1959; Crippen and Reish, 1969). Biological materials (= fouling organisms) were removed from floating boat docks and placed in pans for field identification; some smaller species were identified later in the laboratory. Subtidal benthic samples were taken at the four inner stations with a size one Hayward orange peel bucket, and the material was washed through a screen with a mesh opening of 0.7 mm. The material retained on the screen was preserved with formalin and brought to the laboratory for identification. Sub-

surface water samples were taken for dissolved oxygen measurements according to the Winkler method.

DATA

Dissolved oxygen. The present dissolved oxygen concentration at all stations is recorded in Table 2 together with some previously published data. It can be seen that the concentration of oxygen has increased markedly in the inner harbor area following pollution abatement.

Fouling organisms. The number of species encountered on the boat docks at the six stations is recorded in the second column of Table 1. It can be seen from these data that the number of species encountered increases from a low of 13 at LA51 to a high of 37 at LA7. For the most part, species present at LA51 were present at the other stations. The bay mussel,

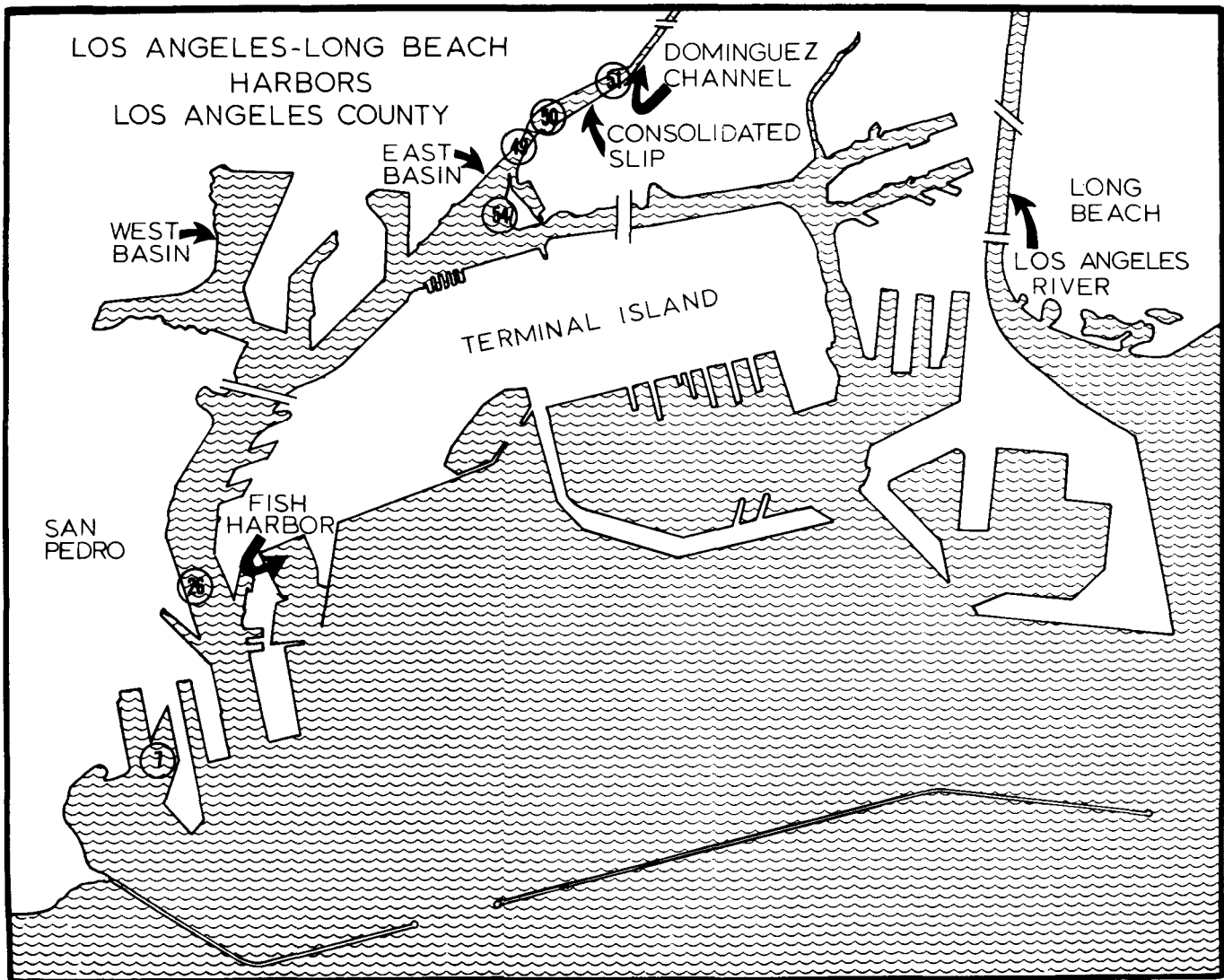


FIGURE 1. Map of Los Angeles-Long Beach Harbors, California, showing station locations and other features mentioned in the text.

Mytilus edulis, was present at all stations, but it was not considered a dominant member of the present community except at the three outer stations (LA54, 26, 7). The green alga *Enteromorpha crinita* and the polychaete *Hydroides pacificus* were dominant species at LA51, 50, 49 and 54. The wood-boring isopod *Limnoria tripunctata* was observed burrowing into wood at LA50 and 54.

Benthic organisms. The number of species encountered in the benthos at the four stations in the Consolidated Slip-East Basin region is given in the third and fourth columns of Table 1. With the exception of LA51, the number of species increased as one proceeded away from the previous source of waste dis-

charge. The polychaete *Dorvillea articulata*, characteristic of semi-healthy zone I, was the most prevalent animal taken along with the pelecypods *Chione undatellum* and *Hiatella arctica*. The polychaete *Capitella capitata*, the characteristic animal of the polluted zone, was the dominant animal at the remaining three stations. The substrate at these four stations was black and possessed a sulfide odor.

DISCUSSION

Comparisons of the data for fouling organisms for October 1970 with those of 1966-67 indicate striking changes in the community structure. The blue-green algae-oligochaete and the *Enteromorpha crinita*-oligochaete associations, which occurred previously at the stations with little or no dissolved oxygen, were no longer present. The *Mytilus edulis* community, with some additional commonly encountered species, apparently is developing at all stations. It is, however, progressing in degrees. The alga *Enteromorpha crinita* is the prominent species at the inner stations and *Ulva lobata* at LA26 and LA7. The large population of *Hydroides pacificus* (= *H. norvegica*) may be the result of warmer water temperatures or the absence of competition for space on floating logs (Reish, 1961a; 1964a). *Limnoria tripunctata* has now moved into regions of the harbor where it has been absent (Menzies, *et al.*, 1963).

TABLE 2
The Dissolved Oxygen Concentration (in mg/l) at Selected Stations in Los Angeles Harbor 1954-1970

| Station | November ¹ 1954 | October ² 1966 | October ² 1967 | October 1970 |
|-----------|-------------------------------|------------------------------|------------------------------|-----------------|
| LA51..... | 0.0 | -- | -- | 3.8 |
| 50..... | 0.0 | 0.4 | 0.2 | 4.4 |
| 49..... | 0.5 | -- | -- | 4.4 |
| 54..... | 1.0 | -- | 0.9 | 5.2 |
| 26..... | 2.3 | 2.4 | 1.7 | -- |
| 7..... | 3.7 | 4.5 | 2.7 | -- |

¹ Data from Reish, 1959.

² Data from Crippen and Reish, 1969.

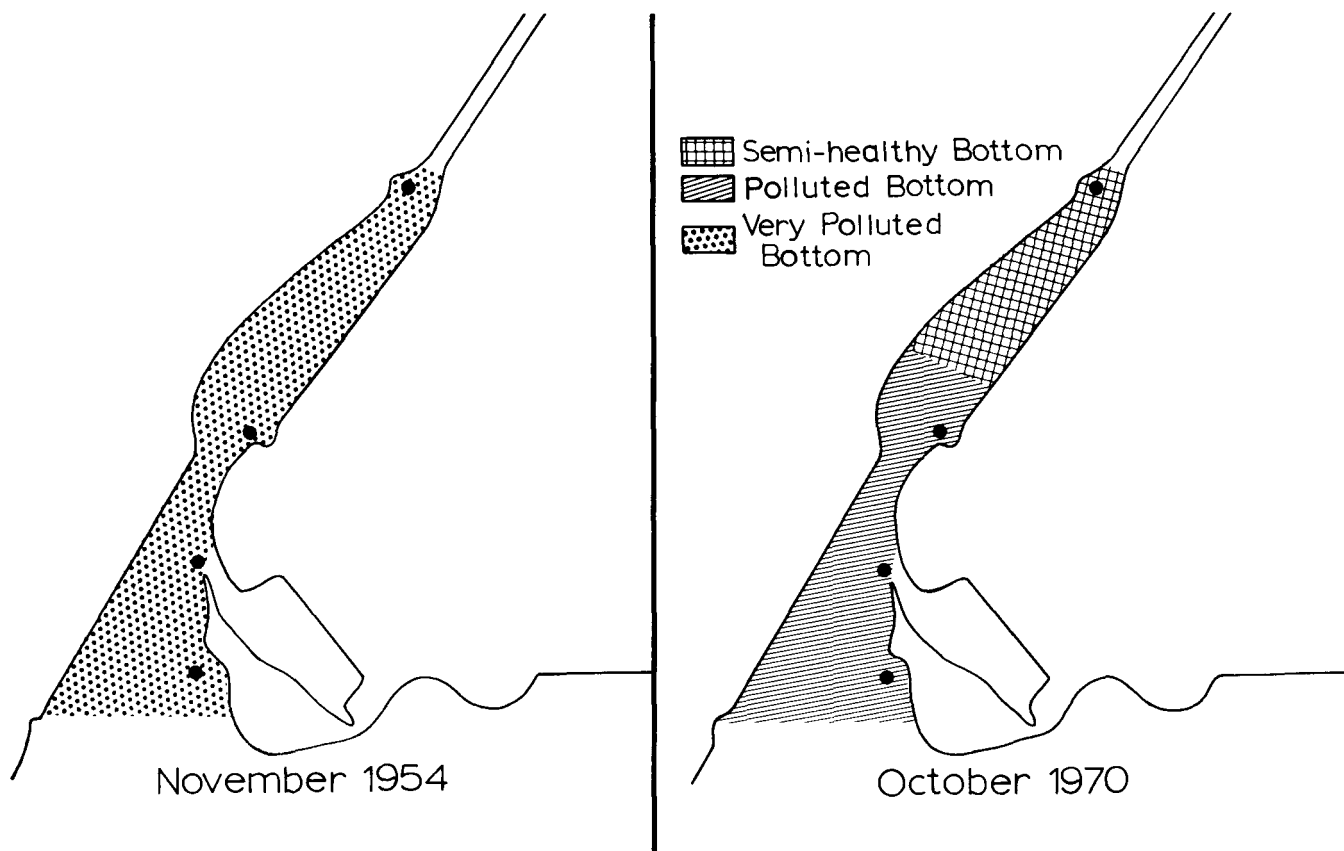


FIGURE 2. Summary of distribution of bottom conditions in the Consolidated Slip-East Basin region of Los Angeles Harbor in November 1954 and October 1970.

Comparisons of the findings for the benthos in 1954 with 1970 (Table 1) are equally striking. Except for the period of one year following dredging activity in 1953 (Reish, 1957b), no macroscopic life was present in this region. All animals collected in 1970 were present in either the main channel or outer harbor area in 1954. The organisms at these four stations have representatives of the polluted zone (*Capitella capitata*), the semi-healthy zone I (*Dorvillea articulata* and *Polydora paucibranchiata*) and semi-healthy zone 2 (*Cirriformia luxuriosa*) (Reish, 1959). It is of interest that no dominant species from the healthy zone was present. It appears from these data that station LA51 has progressed further towards cleaner conditions than either LA50 or 49 and perhaps 54 (Figure 2).

I think that some possible biological predictions may be appropriately stated herein. Initially, with the termination of the oil refinery discharge, water quality improved and dissolved oxygen appeared. Since many of the local species of marine organisms, especially bay and harbor representatives, have either extended reproductive periods or reproduce throughout the year (Reish, 1961b), larvae were able to settle rapidly. Successful settlement and growth of a greater diversity of organisms occurred more rapidly on the boat floats than the benthos because of the lack of the accumulative wastes characteristic of the bottom. Since *Mytilus edulis* reproduces during the winter months in nearby Alamitos Bay (Moore and Reish, 1969) with settlement of larvae extending into the spring months (Reish, 1964a), apparently sufficient water quality improvement had occurred by the end of spring 1970. It seems logical to assume that *M. edulis* will become the dominant organisms on the boat docks in 1971.

Speculation concerning the benthos is more difficult, especially with regard to estimating recovery time. Several variables will influence this rate of recovery. The affected sediments extend to at least a depth of 20 cm; the time required for the oxidative processes to change these sediments is unknown. Dominguez Channel also serves as a flood control channel, and the amount of run-off from rain may influence this rate of recovery. Finally, the role played by the early inhabitants in assisting this oxidative process is unknown. It is also difficult to predict the final community structure at these benthic stations. *Capitella capitata* is the normal dominating organism in similar upper reaches of Alamitos Bay (Stone and Reish, 1965). It is doubtful that the healthy zone from the outer harbor will extend this far; however, it is quite possible that this zone may extend up to the level of LA26 or farther since this abatement.

ACKNOWLEDGMENTS

The author wishes to thank Mr. Raymond M. Hertel and Mr. Roy C. Hampson, Los Angeles Regional Water Quality Control Board, for information on pollution abatement in Dominguez Channel and Mr. Raymond Cripps, Mr. Gary Gillingham and Mr. Thomas Kauwling for their assistance in collecting the samples.

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