

*Deserving of wider recognition is the relationship between marine animal life and water conditions in harbors, bays, and estuaries into which industrial wastes and domestic sewage are discharged. A step in this direction is this study of the Los Angeles and Long Beach Harbors.*

# The Relation of Polychaetous Annelids to Harbor Pollution

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NO EXTENSIVE investigations of the role of animals in areas of marine pollution have been carried out in waters of the United States, although there have been a few European studies of interest (1-3). Blegvad (3) has stated that some species of polychaetes flourish well near domestic outfall sewers in Copenhagen Harbor. Filice (4) was able to divide the bottom fauna into three zones in a polluted arm of San Francisco Bay.

The seasonal and quantitative aspects of the relationship between bottom-dwelling animals and pollution in a bay or harbor has not been studied previously. This study, which was undertaken in 1954, examines these seasonal and quantitative aspects and seeks possible indicator organisms or animal associations.

At this time only representative material is published to indicate some of the general findings about the relationship of benthic polychae-

tous annelids to zones of pollution in Los Angeles-Long Beach Harbors. Emphasis has been placed upon the polychaetous annelids since they were the bottom-dwelling animal forms most commonly encountered in the 1951 harbor pollution survey conducted by the Los Angeles Regional Water Pollution Control Board (5).

## Materials and Methods

Los Angeles and Long Beach Harbors are one harbor oceanographically. For convenience of discussion in this study, the harbors have been divided into inner and outer harbors. The outer harbors are considered generally to be the area south of Terminal Island (see map).

Many types of wastes are discharged into these harbors. The sources of these discharges have been described in the report (5) of the Los Angeles Regional Water Pollution Control Board No. 4. They may be grouped into the following seven general categories: fish canneries; oil refineries; chemical plants; vegetable oil plants; creosoting and pile-treating plants; metalworking shops, repair shops, and shipbuilding yards; domestic sewage.

It is important to distinguish between the dictionary definition of the word "pollution" and the California legislative definition of pollution. The dictionary definition, which is em-

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*Dr. Reish, research associate, department of biology, University of Southern California, has been studying the biology of estuaries, bays, and harbors since 1950. Because the complete data of the 1954 survey of Los Angeles-Long Beach Harbors are too voluminous to be included in this general summary, they will be published in monograph form.*

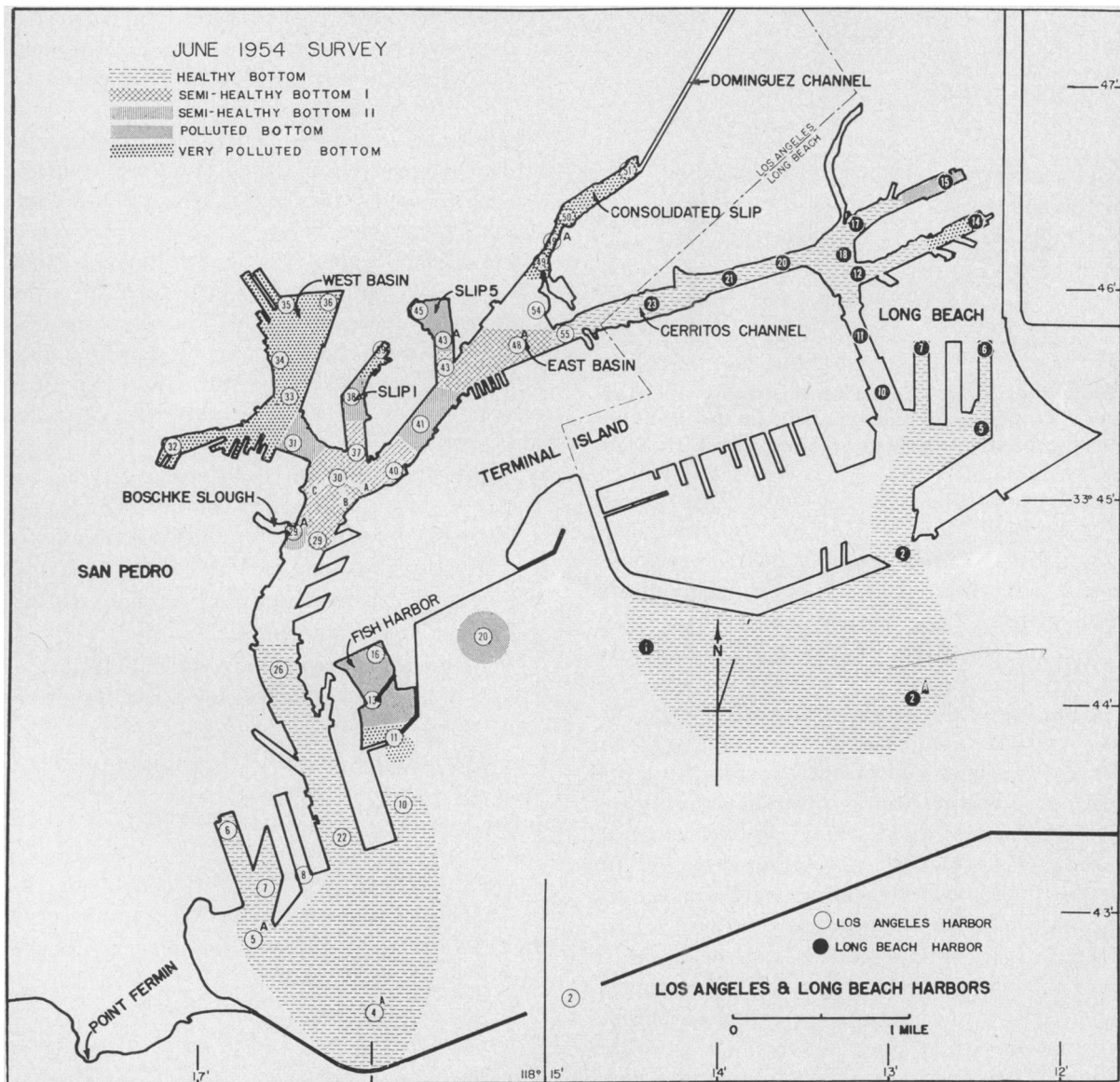
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ployed in this study, is the act of making or rendering unclean, whereas in division 7 of the water code of the State of California, under which the State and regional water pollution control boards operate, pollution means "an impairment of the quality of the waters of the State by sewage or industrial waste to a degree which does not create an actual hazard to the public health but which does adversely and unreasonably affect such waters for domestic, agricultural, navigational, recreational or other beneficial use."

Three surveys of the harbors were made dur-

ing 1954; the first was on January 6-7, the second on June 14-15, and the third on November 18-19. In each survey the water mass and substrate at 55 stations in the harbors were sampled as to physical, chemical, and biological characteristics, with the assistance of the Los Angeles Harbor Department and the California State Department of Fish and Game. The sampling stations were in much the same location as the stations described in the 1951 survey (5). The station numbering system used in 1954 follows that of the earlier survey; however, not all of the 1951 stations were used and

**Bottom conditions in Los Angeles-Long Beach Harbors, June 1954.**





Courtesy of Dr. John L. Mohr.

**The trigger (arrow) is set on this No. 1 size Hayward orange-peel bucket used in the pollution surveys of Los Angeles and Long Beach Harbors.**

some new stations were added. The stations within Los Angeles Harbor are designated LA-2, LA-4A, and so on (shown as stations 2 and 4A in white circles on the map), and stations within Long Beach Harbor are LB-1, LB-2, and so on (shown as 1 and 2 in black circles).

Samples of the water mass taken at the surface and at a 20-foot depth were analyzed for dissolved oxygen concentration, chlorinity, and pH. One bottom sample was taken at each station with a Hayward orange-peel bucket (pictured). The bucket samples an area of 100 square inches and, depending on the nature of the material, holds as much as a gallon.

Part of the sample material was set aside for later determination of carbon and nitrogen content. The remainder was screened through a wire mesh with 20 openings to the inch. This size of screen was convenient to use since it re-

tains the animals and enables screening to be done in the work boats at the station. The material retained on the screen was preserved in formaldehyde. More details about methods are described in the pollution study Reish and Winter (6) made of Alamitos Bay, Calif.

### Distribution of Animal Species

Insofar as possible, identification of the bottom-dwelling animals has been completed for the January and June 1954 surveys. Seventy different animal species have been identified: 45 species were polychaetes, 10 were pelecypods, and 5 were gastropods; and the remaining 10 species included coelenterates, turbellarians, nemerteans, oligochaetes, crustaceans, phoronids, and echinoderms.

The distribution of the polychaetes was plotted and correlated with bottom conditions in Los Angeles-Long Beach Harbors. On this basis the harbors can be divided into 5 ecologic areas, categorized below as healthy bottom, 2 types of semihealthy bottom, polluted bottom, and very polluted bottom. The zones of pollution, which of course varied for the three surveys, are shown on the map of the June 1954 survey. The physical, chemical, and biological characteristics of samples taken from the five areas are shown in table 1.

The white areas in the channel and harbor portions shown on the map did not fall into the categories of pollution for varying reasons:

Most of the outer harbors and that part of the channel between sampling stations LA-26 and LA-29 were not sampled.

Although the areas at stations LB-10 and LB-11 were sampled, dredging operations were recently completed.

The animals found in the sample from station LA-54 were atypical with reference to other sampling stations.

#### *Healthy Bottom*

The healthy bottom zone was characterized by the polychaete species *Tharyx parvus* Berkeley, *Cossura* sp., and *Nereis procera* Ehlers. The zone was found in both Los Angeles and Long Beach Harbors and in much of the inner harbor of Long Beach.

**Table 1. Physical, chemical, and biological characteristics of samples of each of the 5 ecologic areas based on surveys of bottom conditions in Los Angeles and Long Beach Harbors**

| Characteristic                      | Healthy bottom <sup>1</sup>   | Semihealthy bottom I <sup>2</sup>  | Semihealthy bottom II <sup>3</sup>   | Polluted bottom <sup>4</sup>   | Very polluted bottom <sup>5</sup> |
|-------------------------------------|---|--|--|--|-----------------------------------|
| <i>Dissolved oxygen</i><br>(p.p.m.) |   |  |  |  |                                   |
| Surface                             | 7.3   | 3.6  | 4.5  | 8.4  | 0.0                               |
| Deep                                | 7.4   | 4.4  | 3.6  | 6.6  | 2.3                               |
| <i>Chlorinity</i> (0/00)            |   |  |  |  |                                   |
| Surface                             | 19.4  | 19.2   | 19.4   | 19.3   | 19.0                              |
| Deep                                | 19.5  | 19.3   | 19.2   | 19.6   | 19.7                              |
| <i>pH</i>                           |   |  |  |  |                                   |
| Surface                             | Not taken   | 7.5  | 7.4  | 7.6  | 7.7                               |
| Deep                                | do  | 7.5  | 7.6  | 7.6  | 7.6                               |
| Substrate                           | do  | 7.0  | 7.5  | 7.5  | 7.1                               |
| Nature of substrate                 | Gray mud  | Black sulfide mud.   | Black sulfide mud.   | Black sulfide mud; 3 qts. fish scales.   | Black mud; petroleum odor.        |
| <i>Animals</i> <sup>6</sup>         |   |  |  |  |                                   |
| Polychaetes                         | <i>Tharyx parvus</i> (18)<br><i>Cossura</i> sp. (11)<br><i>Nereis procerca</i> (2)<br><i>Scalibregma inflatum</i> (1)<br><i>Prionospio pinnata</i> (2)<br><i>Lumbrineris minima</i> (3)<br><i>Amphicteis scaphobranchiata</i> (2) | <i>Polydora paucibranchiata</i> (13)<br><i>Neanthes caudata</i> (9)<br><i>Dorvillea articulata</i> (7)<br><i>Lumbrineris erecta</i> (1)<br><i>Capitella capitata</i> (2) | <i>Cirriformia luxuriosa</i> (272)<br><i>Polydora paucibranchiata</i> (7)<br><i>Dorvillea articulata</i> (4)<br><i>Neanthes caudata</i> (1)<br><i>Capitella capitata</i> (1) | <i>Capitella capitata</i> (53)<br><i>Dorvillea articulata</i> (8)<br><i>Podarke pugetensis</i> (1) | None present.                     |
| Pelecypods                          | <i>Tellina buttoni</i> (3)  | <i>Tellina buttoni</i> (5)   | <i>Macoma nasuta</i> (3)   |  |                                   |
| Coelenterate                        | <i>Stylatula elongata</i> (1)   |  |  |  |                                   |
| Crustacean                          |   | <i>Epinebalia</i> sp. (1)  |  |  |                                   |
| Unidentified                        | {Nemertean (1)<br>Ophiuroid (1)}  | Oligochaetes (4)   | Phoronid (1)   |  |                                   |

<sup>1</sup> Station LB-1, January 1954. <sup>2</sup> Station LA-30B, June 1954. <sup>3</sup> Station LA-29A, June 1954. <sup>4</sup> Station LA-16, June 1954. <sup>5</sup> Station LA-49A, June 1954. <sup>6</sup> Figures within parentheses indicate number of specimens present in 1 sample.

An average of 10 animal species were present; 7 were polychaetes.

The dissolved oxygen content of the surface water and of the water at 20 feet averaged more than 6.0 p.p.m.

The substrate was typically a fine, gray-colored mud.

#### *Semihealthy Bottom I*

Two apparently distinct semihealthy zones exist principally in the main channels of Los Angeles Harbor. The main difference is in the type of animal life found; the differences in the physical and chemical characteristics of these zones were minor. The first of these semi-

healthy bottom areas was marked by the presence of *Polydora* (*Carazzia*) *paucibranchiata* Okuda and *Dorvillea articulata* (Hartman).

An average of 7 animal species were found; 5 were polychaetes.

The average dissolved oxygen reading of the water was 2.5 p.p.m. at the surface and 3.2 at 20 feet.

Fine mud, shell fragments, sand, fish scales, or black mud possessing a sulfide odor were among the variety of substrate types observed.

#### *Semihealthy Bottom II*

The recognition of a second semihealthy zone was occasioned by the presence of large num-

bers of the polychaete *Cirriformia luxuriosa* (Moore). This species of polychaete is particularly noticeable since it frequently attains a length of 15 centimeters, as measured in preserved condition. Otherwise, the number of animal species present, the chemical and physical characteristics, and the nature of the substrate were essentially the same in this second semihealthy zone as in the other semihealthy bottom area.

Sampling station LA-29A is given in table 1 as an example of this zone, which was found only within a portion of Los Angeles inner harbor. However, the 272 specimens of *C. luxuriosa* listed for semihealthy bottom II is unusually high. A more typical number would be around 80.

#### *Polluted Bottom*

The areas of polluted bottom were characterized by an average of 3 animal species, 2 of which were polychaetes. One of the polychaete species, *Capitella capitata* (Fabricius), was always present and frequently in large numbers. Fishery wastes or domestic sewage was being discharged near the sampling stations where the largest numbers of *C. capitata* were found. The polluted bottom zone was found usually within the slips except in the outer harbors where it was found on two occasions about the Terminal Island outfall sewer and on one occasion near the Fish Harbor outfall sewer.

Both at the surface and at 20 feet, the average dissolved oxygen content of the water was 3.5 p.p.m. This concentration was higher than that observed for the two semihealthy zones.

The substrate was a black mud with a sulfide odor.

#### *Very Polluted Bottom*

No animal life was present in the very polluted bottom areas, which are characterized by sludge beds. Sludge beds are an accumulation of toxic waste discharges to such an extent as to have killed the organisms living in the bottom and to exclude the introduction of organisms from other areas.

The inner reaches of some of the slips in the harbors had a very polluted bottom, but the areas in which no life existed were not observed in the main channels or in the outer harbors ex-

cept once during the November 1954 survey near the Terminal Island outfall sewer. The sources of pollution may be of domestic origin or of industrial origin, from oil refinery wastes for example.

The dissolved oxygen content was an average 1.6 p.p.m. at the surface and 2.2 p.p.m. at 20 feet below the surface.

The substrate consisted of black mud which had either a sulfide or petroleum odor.

#### **Descriptive of Actual Conditions**

While the general designation of the harbor bottom zones as healthy bottom, semihealthy bottom, polluted bottom, and very polluted bottom is based in part on the distribution of the different species of bottom-dwelling animals, notably the polychaetes, this terminology, adapted from Patrick (7), is employed because it is more descriptive of the actual conditions than are the scientific names of the principal species. Each type of bottom is characterized by one or more species of polychaetes, which, within limits, may serve as indicator organisms.

The division into zones may suggest well-defined demarcations, but frequently this is not the case with regard to animal distribution. Species characteristic of the healthy bottom are found in smaller numbers within the two semihealthy bottom zones but not within the polluted bottom area. *C. capitata*, the characteristic organism of the polluted bottom, may be present in the semihealthy bottom, but it has not been found in the healthy area. Animals common in the semihealthy bottom may occur in the healthy or polluted areas but again only in smaller numbers.

The most common areas of overlap occur either near the junction of two bottom types or at stations that were not well defined as to type of bottom from survey to survey. The area in slip 5 is an example of overlapping zones. The zone surrounding station LA-45 was classified "polluted" in the January and June surveys and "semihealthy I" in the November survey.

Since a relationship exists between the polychaete population and the degree of pollution in the waters they inhabit, a knowledge of the more prevalent species of polychaetes is desirable. Comparative lengths and ecologic char-

acters of the principal bottom-dwelling species of polychaetes of Long Angeles-Long Beach Harbors are given in table 2, which also includes geographic distribution and references to published material describing the species.

### Seasonal Distribution

Little seasonal variation in the distribution of the animals was found during the three 1954 surveys. In general, the results of this aspect of the study are similar to the findings of the 1951 survey. Some variations are worthy of mention, however.

In 1951 the very polluted bottom zone extended into the East Basin of Los Angeles Harbor to about the level of station LA-54. The sludge beds characterizing this area in 1951 were removed in 1953 when the East Basin and a portion of the consolidated slip were dredged in order to deepen the Dominguez Channel for shipping. Although animals were found in the bottom area around stations LA-49, LA-49A, and LA-50 in the January 1954 survey, no animals were taken from these stations in the June survey. By November the sludge beds had again advanced into the East Basin to include station LA-54.

Checking upon the encroachment of sludge beds into previously productive biological beds is of particular importance to water pollution control. *C. capitata*, which was particularly

abundant near regions of pollution of biological origin in the Los Angeles-Long Beach Harbors, has been found elsewhere in southern California bay areas:

Reish and Winter (6) found the animal in two different areas of Alamitos Bay. One area is in the vicinity of a public dump, but the other is not near any known source of pollution.

Unpublished data yields the information that *C. capitata* is also present in the lower San Gabriel River, which receives waste discharges of both industrial and domestic origin, and in Newport Bay, too, where it has been found only near fish cannery outfall sewers.

Additional data relating *C. capitata* to pollution is given by Filice (4), who found the animal near industrial and waste discharges in San Pablo Bay, an arm of San Francisco Bay. The further correlation of *C. capitata* with sources of pollution, particularly of biological origin, would be of value.

Comparisons of the fauna and bottom of the Los Angeles-Long Beach Harbors with those of Alamitos Bay (6) and Newport Bay are of interest since these bays are essentially unpolluted bodies of water in southern California, except as noted. The animals in Alamitos Bay and Newport Bay are diversified and similar to those found in the outer harbors of Los Angeles and Long Beach.

Recently, Hartman (8) published the preliminary results of a quantitative survey of the

**Table 2. Comparison of the ecology, length, and geographic distribution of the principal benthic polychaetes in Los Angeles and Long Beach Harbors**

| Species  | Type of bottom <sup>1</sup> | Length <sup>2</sup> (cm.) | Habitat   | Geographic distribution                                   | Reference list       |
|--|-----------------------------|---------------------------|---|---|----------------------|
| <i>Tharyx parvus</i> .....                       | Healthy.....                | 2.5                       | Burrows in substrate.                                   | Vancouver Island, San Francisco Bay, Southern California. | 8, 9, 10.            |
| <i>Cossura</i> sp.....                           | do.....                     | 1.5                       | do.....   | Southern California.                                      | Undescribed species. |
| <i>Nereis procerca</i> .....                     | do.....                     | 9.0                       | do.....   | British Columbia to California.                           | 11.                  |
| <i>Polydora (Carazzia) paucibranchiata</i> ..... | Semihealthy..               | 1.5                       | Builds mud tubes...                                     | Japan, California...                                      | 6, 12.               |
| <i>Dorvillea articulata</i> .....                | do.....                     | 2.0                       | Crawls on surface of substrate or burrows in substrate. | Oregon to western Mexico.                                 | 13, 14.              |
| <i>Cirriformia luxuriosa</i> .....               | do.....                     | 15.0                      | Burrows in substrate.                                   | California.....   | 10.                  |
| <i>Capitella capitata</i> .....                  | Polluted.....               | 3.0                       | do.....   | Cosmopolitan.....   | 9.                   |

<sup>1</sup> In Los Angeles and Long Beach Harbors.

<sup>2</sup> Maximum observed length of preserved specimens.

benthos of the San Pedro Basin—the area between Los Angeles-Long Beach Harbors and Santa Catalina Island. Two of the 5 stations sampled within the 2 harbors have been analyzed. These two stations were located near stations LA-4A and LB-1. A Hayward orange-peel bucket was used to sample an area of 2.8 square feet. Although the number of specimens and species was greater, as reported by Hartman, the results indicated a healthy bottom condition with *T. parvus* predominating.

### Summary

A physical, chemical, and biological study of 55 sampling stations made 3 times during 1954 in Los Angeles-Long Beach Harbors, Calif., placed emphasis upon bottom organisms, particularly the polychaetous annelids. As a result of the survey, the harbors can be divided into five zones on the basis of bottom conditions and distribution of polychaetes. The zones are:

A healthy bottom area characterized by a large number of polychaete species, with *Tharyx parvus*, *Cossura* sp., and *Nereis procera* predominating.

A semihealthy bottom area, with *Polydora* (Carazzia) *paucibranchiata* and *Dorvillea articulata* predominating.

A second semihealthy bottom area in which *Cirriiformia luxuriosa* predominates.

A polluted bottom area, with *Capitella capitata* predominating.

A very polluted bottom area in which there is no animal life.

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