ECOLOGICAL QUESTIONS AND FINDINGS

The objective of this Project is a broad overall understanding of the ecology of southern California coastal waters. We are trying to find out how the thousands of species of marine organisms live together in this special environment that is influenced by man's activities. The problems are very complex, and it would be virtually impossible to discover all possible reactions of all animals to all possible pollutants. So we look for clues-hints of change in the animals' health or distribution—and we try to quantify these with statistically reliable data. If changes are taking place, we try to determine the cause by generating hypotheses and testing them at sea and in laboratory experiments.

We recognize that scientists are often so close to their work that it is difficult for them to explain in a concise manner how their current research into some specific part of a problem helps to answer a fundamental question. Laymen often want short, simplistic answers to questions that may have far broader implications than they imagine.

Therefore, as a means of bringing these points of view together and summarizing the Project's work for the year ending 30 June 1975, we have asked a number of fundamental questions relating to ocean ecology and partially answered them with brief statements of this year's findings. As our recent work has built upon the studies and findings of previous years, we have then added a brief summary of some of our past findings, which are described in the publications listed in Appendix C.

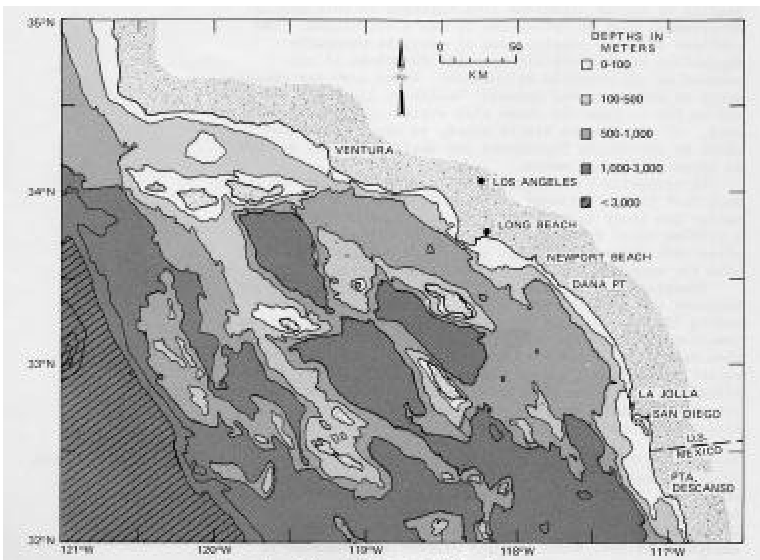
What pollutants enter the sea from municipal wastewaters?

Potential pollutants in municipal wastewaters include suspended solids, organic matter, oil and grease, cyanide, nutrients, trace metals, and chlorinated hydrocarbons. We have compared the effluents from southern California's dischargers for the years 1971 through 1974. With the exception of DDT, which dropped dramatically because of source control, there have been small but steady improvements from year to year.

In several previous reports, we noted this continuing decrease in the amounts of metals and chemicals reaching the sea from the Whites Point outfall system. In 1974, inputs of 9 of 12 metals decreased on the average by 26 percent. Levels of 10 of 13 other constituents measured (including total suspended solids, oil and grease, biological oxygen demand, and nutrients) are down an average of 26 percent. Other substantial decreases were observed at the Los Angeles City outfalls in Santa Monica Bay and at the San Diego City outfalls off Point Loma.

What possible pollutants enter the ocean from the air?

Our past year's work showed that aerial fallout is an important route of entry of DDT and PCB into coastal waters of the entire Bight, especially because the annual input of DDT by municipal wastewaters has decreased until it is about equal to the aerial source (each about 1.5 metric tons per year).



The Southern California Bight, the Project's study area.

What possible pollutants enter the ocean from harbors

In 1975, we measured the levels of copper, chromium, and nickel, as well as chlorinated hydrocarbons, in the outflow of three harbors and found that the input into coastal waters from this source is low by comparison with other sources. However, average levels of dissolved (biologically available) copper were approximately four times those found in the wastewater plume off White Point. Thus, harbor discharges may have a significant effect on the copper uptake of nearshore organisms.

In the past, we showed that PCB levels are higher inside the harbors than in open coastal waters. Although the PCB input to the sea from harbors is low, highest concentrations of PCB in mussels are found near regions of greatest vessel activity.

What motions of the water influence the movement of pollutants?

Our 1975 work on currents showed that, in inshore waters at subthermocline depths comparable to those of most discharges, the water motions closely follow the depth contours, with little onshore or offshore motion. These currents flow at speeds of 7 to 10 cm/sec and often persist for more than a week in each direction. Therefore, measurements of currents must extend over several weeks if they are to characterize even the short-term nearshore water movements.

A revision of our conceptual model of the transport and dispersion of wastewater particulates now takes into account our new findings on water motions. Thus our predictions of sediment quality alterations by wastewater particles now agree well with actual measurements in wastefields.

Our previous reports gave evidence that the typical velocity of currents with tidal period fluctuations in the Whites Point and Point Loma outfall areas is about 9 to 15 cm/sec; this disperses the effluent over an area from 1.2 to 4.0 km from the outfall.

Flushing of the outfall area is primarily due to long-period oscillating currents with speeds on the order of 6 to 7 cm/sec.

What animals live in our coastal water?

The number of animals known to inhabit local waters continues to grow until now the number of kinds of fish is around 500 and the number of invertebrate species exceeds 4,000. Our staff is preparing a set of "taxonomic keys" that will aid in identifying animals taken in monitoring surveys and ensure that biologists at various laboratories use the same names for the same animals.

In previous years, we reported that some faunal differences thought to exist between adjacent coastal areas were caused by misidentification of specimens and non-standardized recording of data rather than by pollution. When the species names were reconciled, the variation between areas was less than previously thought. Certain animals that seemed to be missing from some coastal areas were simply misidentified: In other cases, up to 15 different names were being used to refer to a single species.

What levels of possible pollutants are present in the water column, and where do they go?

The concentrations of DDT in harbor and coastal waters are generally several parts per trillion. In the Whites Point effluent plume (identified by ammonia and turbidity measurements), the level is an order of magnitude higher. Far offshore, the background level of DDT is less than 1 part per trillion.

In 1975, levels of cadmium, copper, chromium, and nickel were measured in the Whites Point plume within 1 km of the outfalls. Concentrations of the metals in the particulate form were 10 to 100 times greater in the plume than at the nearby control station. However, there were much smaller differences between dissolved concentrations in the two regions: Soluble cadmium and chromium levels in the plume were about the same as background; copper and nickel were three to four times higher.

Previously we have reported on the five possible places for waste materials to go after they enter the ocean. They can remain in the water column in solution and be carried away, they can settle to the bottom or float to the surface, they can be taken up by marine animals, or they can decay and change chemically.

We have shown that large amounts of many "pollutants" are naturally present in seawater and that they are needed by many animals. It is useful to distinguish between these and the similar materials added by man.

What happens to pollutants on the bottom

Wastewater particulates that settle to the ocean bottom carry down many pollutants, including organic matter, trace metals, and chlorinated hydrocarbons. In 1975 studies, we measured alterations in the sediment chemical quality resulting from wastewater and sludge discharges in Santa Monica Bay. The data show that, although the organic matter decays slowly on the bottom, the trace metals associated with particulates mobilize even more slowly. The amount of falling particulates caught in sediment traps is much greater than the amount that becomes part of the bottom sediment, leading us to conclude that resuspension is an important mechanism of particulate transport and sediment formation. The evidence indicates that any motion of these sludge-like materials is offshore and down the submarine canyon.

DDT degrades to p,p'-DDE at a rate of about 10 percent per year, but there are about 200 metric tons of this substance in the upper 20 cm of an area of 60 sq km off Palos Verdes.

Past work has shown that metals in an oxygenated bottom slowly mobilize and drift away with the currents at very low concentrations. In reducing bottoms where sulfides are present, there is little change. Measurements of the annual layers in the sediments of Santa Barbara Basin revealed the history of the entrance of pollutants into our coastal waters and their steady increase over the last 100 years.

What effects of various levels of chromium on marine organisms can be seen in the laboratory?

A summary of our 1975 findings relating to the effects of chromium on marine life must be considered in light of the fact that, although hexavalent chromium is a serious toxicant, most of it is reduced to the trivalent state as it passes through a sewage treatment system. Trivalent chromium has a very low toxicity. Approximately 90 percent of the total chromium discharged to the sea is on particulate material and probably is not biologically available; only a small percentage of the dissolved chromium is in the hexavalent form. Upon introduction to seawater, trivalent chromium forms a hydroxide precipitate that settles with the other particulates. Thus, it is important to distinguish between total and hexavalent chromium in wastewaters and between chromium's particulate and dissolved phases.

In the past year's experiments, we found that the levels of hexavalent chromium required to affect feeding behavior of one marine fish in laboratory experiments are substantially above levels of total dissolved chromium in wastewater. We have sought to determine the lowest concentrations of either form at which any effects can be observed.

The ability of one polychaete worm to reproduce is affected by 13 ppb of hexavalent chromium. This level is at least 100 times greater than the level of hexavalent chromium likely to be encountered in the ocean. The precipitated trivalent chromium that predominates in the sea does not seem to affect this animal's reproduction.

Last year we reported that the threshold for direct toxicity of hexavalent chromium, as potassium dichromate, to the same worm is about 0.8 ppm. However, concentrations as low as 80 ppb significantly affect the ability of these animals to build, maintain, and inhabit the mucous tubes they need for reproduction and protection from predators.

How do outfall sediments high in both metals and chlorinated hydrocarbons affect bottom fish?

In the past year, wild Dover sole from "clean" bottom areas were brought into the laboratory and placed on highly contaminated bottom sediments to see if they would develop the fin erosion disease. The test is still in progress; however, after 3 months of exposure, the fish appear healthy, and there is no sign of the disease or other problems.

In past years, we have reported that several species of fish have a fin erosion disease that is related in some way to the pollution of outfall sediments. The Dover sole is most susceptible: In some seasons, prevalence of the fin erosion disease in this species is as high as 80 percent. Other than that, the evidence of effects on fish consists mainly of adjustments in community structure.

How are changes in fish communities determined?

We have developed a model that can be used to predict the species and sizes of benthic fishes that occur at each water depth and bottom condition. Six major feeding roles have been defined; these account for the distribution patterns of about 120 species of fish. There are abnormal distribution patterns of fishes around outfall areas that may be caused by alteration and contamination of bottom sediments or by unusually abundant food organisms.

In previous reports, we have described methods of sampling fish populations and estimating the numbers and depth ranges of various species.

What is known about the uptake of pollutants into marine animals?

In our 1975 studies of the biological effects of pollutants, we concentrated on diseases in fish. Our major findings:

- Dover sole living on contaminated Palos Verdes sediments have approximately twice as much copper in their kidneys and twice as much chromium in their gonads and skin as do specimens from control areas. Copper concentrations in gonads of Dover sole with fin erosion were only about two-thirds those of apparently healthy specimens. Harbor mussels contained up to ten times as much copper as did specimens living in nearby open coastal areas.
- Specimens of Dover sole from Palos Verdes typically have muscle tissue concentrations of DDT of 10 to 15 ppm. However, PCB concentrations in the tissues of fish taken around several large outfalls were only 1 to 2 ppm.
- DDT levels in muscle tissue of Dover sole with fin erosion taken off Palos Verdes and Orange County were statistically the same, at around 10 ppm (possibly because they came from the same population). Diseased Dover sole off Palos Verdes had 1.5 times as much DDT in their muscle tissue as did healthy specimens. PCB was about twice as high in diseased fish. Since 1971, DDT and PCB concentrations in intertidal mussels of the Bight have fallen by factors of six and three, respectively.

In 1975, we also experimented with a system for monitoring biological uptake of pollutants with caged animals. Mussels suspended off the Whites Point outfalls proved to be useful bioindicators of DDT and PCB contamination of the water column. Specimens kept on the bottom survived well but took up 10 times as much of these chlorinated hydrocarbons as did surface specimens.

In past reports, we have summarized the amounts of pollutant materials in various organs of the Dover sole as well as levels in mussels and other invertebrates. Generally, there has been little change in the amount of DDT and PCB in fish muscle tissue. Metal concentrations found in the livers of fish living on the most contaminated sediments are actually lower than those in the livers of fish taken elsewhere.

How can changes in benthic infauna be evaluated?

Seven leading diversity indices have been compared in the past year. Basically these are measures of the number of species present, the evenness of distribution of numbers of individuals for each species, or a combination of the two. The Shannon or Brillouin indices (which mathematically express the combination of the two main criteria) seem to be the most useful for ocean pollution studies or monitoring purposes.

In the past, we found that modern statistical tools are useful in the study of marine community structure. Data from trawls and grabs are punched onto cards and fed to a computer. Cluster analysis of data on the benthic communities off Palos Verdes indicated that sites associated with the highest concentration of pollutants could be readily distinguished from adjacent sites by their species composition. The major seasonal changes in the communities of organisms living on or in the benthic sediments, especially those near the outfalls, are due to fluctuations in the distribution of a few species.

The number and biomass of benthic and demersal marine animals off Palos Verdes is high relative to average southern California coastal conditions for a silt bottom. However, the discharge of wastewater does lower the diversity and alter the species composition.

How can we make the most effective use of the monitoring data on benthic infauna communities?

Cluster analysis, ordination, and regression techniques have been applied to routinely collected data to distinguish patterns in the distribution of benthic life around the Palos Verdes outfalls. Five abiotic factors representing potential causes of community disturbance were found to be significantly correlated with the observed faunal patterns. In addition to depth, which is the major natural factor, free sulfide, total DDT, and organic matter were most important.

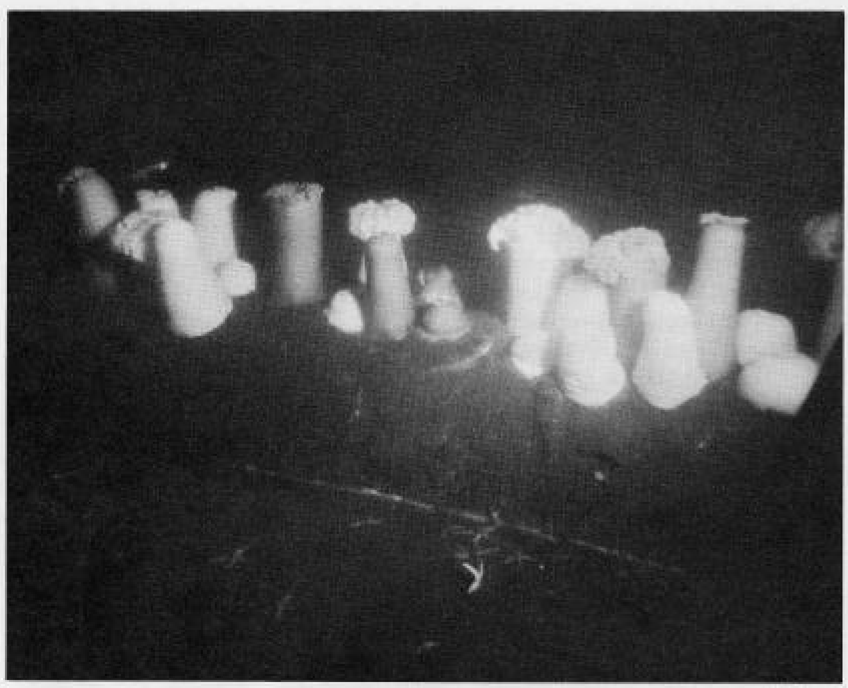
How do fish populations in waste disposal areas compare with those in unaffected areas?

Our 1975 trawls in an unaffected area off Laguna Beach and Dana Point revealed that fish were less abundant in this area than in the bays and near outfalls but that they were slightly more diverse. About one-quarter of one percent of the fish were diseased or deformed: Although this is low compared to some outfall sites, these levels indicate that diseased fishes will be found in coastal areas unaffected by wastewater discharge.

Tumor-bearing Dover sole were identified in museum collections of fish taken off Baja California, indicating the disease is not peculiar to southern California outfall areas.

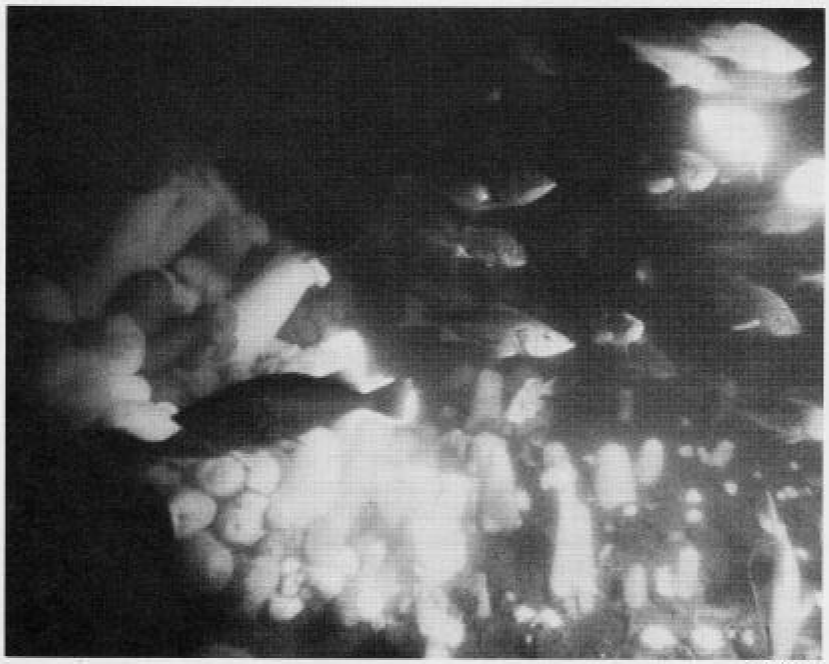
Dover sole appear to be growing at slower rates in southern California than on the northern coast, but faster at Palos Verdes than off Santa Catalina Island, a "control" area. Liver weights, sometimes used as an inverse indicator of general health, are larger in Palos Verdes fish than in fish of similar body weight from other localities. In fish with fin erosion, livers were some 40 percent heavier than livers in apparently healthy fish. Fish with fin erosion also produce less mucus than unaffected fish.

In past reports, we noted that there is evidence of fin erosion in at least 30 species of bottom fish from the coastal waters off Orange and Los Angeles Counties. Dover sole is the species most frequently and severely affected. The prevalence of the disease is highest off the Palos Verdes Peninsula, with a definite decrease to the north and to the South. The seaward limit of the disease is unknown, although



Jack Word

Photograph taken from a submersible shows the sealife congregated near Hyperion's 7-mile sludge pipe (0.6-m dia.) at 60-m. Large sea anenomes and several Dover sole are on the pipe; sand stars move about on the silt near the pipe.



At 60 m near the base of Hyperion's 5-mile effluent pipe, the ballast provides a rocky habitat for several species of rockfish (cow and vermilion rockfish and bocaccio can be seen here) and the sea anenome.

specimens with eroded fins have been collected at depths beyond 200 m, the maximum depth sampled in routine monitoring surveys.

The only species from southern California coastal waters consistently affected with skin tumors is the Dover sole.

What are the best ways of observing or sampling fish populations?

In the past year, we used trawls, hook and line fishing (several methods), towed television, and diver/submersible photography to "sample" fish populations in Santa Monica Bay.

Each method is sensitive to somewhat different segments of the populations. Trawls give the most information because they catch more fish of more species, but the trawl nets are avoided by the larger fish that can be caught on hook and line.

Photographic methods are most useful where fish are concentrated by rocks or structures that make trawling impossible. The combined evidence of all methods seems to give a good overall picture.

In previous years, we reported that variations in sampling gear and procedures—and thus in sampling efficiency—had led earlier workers to erroneous conclusions about regional differences in fish diversity and biomass. We found that, when uniform trawling procedures are used, little difference can be seen in biomass and diversity of demersal organisms in the regions sampled along the coasts of Orange and Los Angeles counties.

Baited cameras revealed a previously unmeasured abundance
of sablefish and dogfish off the Palos Verdes Peninsula and important day/night differences in the activity and species composition of nearshore marine life.

What are the fates of enteric microbes and viruses in the sea?

Human intestinal and pathogenic bacteria are discharged through sewage and runoff water into seawater already containing numerous natural marine microorganisms. Raw or primary treated sewage contains large numbers of the non-pathogenic bacteria that can be used to indicate contamination of marine water. But the pathogenic bacteria, such as Salmonella and Staphylloooccus, in the samples are four to five orders of magnitude lower in abundance.

Our 1975 studies showed that secondary treatment results in a thousand-fold decrease of all bacterial output, and chlorination reduces this amount even further. However, at short distances from outfalls discharging untreated primary effluent, the bacterial count is already down 1,000 times because the die-off rate is very rapid. Bacteria probably survive longer in laboratory tests than they do in nature because such tests cannot take into account the effects of the complex microbiology and chemistry of the ocean and the consumption of microorganisms by plankton.

After a careful search, we found some pathogenic bacteria in outfall sediments and in some ocean water samples, but the levels of these pathogens were lower than often exist on city streets or in natural stream runoff. Shellfish that exceed the health standards for bacteria have been found, but the source of these bacteria may not have been the large outfalls.

In the past, we found abundant populations of fecal coliforms and streptococci in water and sediment samples taken near the outfalls in Santa Monica Bay. The highest concentrations of bacteria and fungi were in sediments; floating particulates and surface waters had intermediate concentrations, and middepth seawater samples had the lowest.

Because of their more prolonged survival in seawater, fecal streptococci may be better indicators of bacterial contamination of coastal waters than either total or fecal coliform.

Marine microbes seem to be more abundant near waste discharge sites than away from them and are more abundant than microorganisms of sewage origin. In the direct influence of chlorinated waste discharges, marine microbial populations appear to be depressed, but when the discharge of chlorine is discontinued, they recover quickly to densities higher than normal.