ECOLOGICAL PROBLEMS AND FINDINGS

This project is studying the relationship between plant and animal life and the condition of the coastal waters of southern California. To understand ecological changes, it is helpful to begin with an inventory of the plants and animals that live in the area; of the precise chemical characteristics of the seawater that flows past; and of the materials that are added to the sea by streams, aerial fallout, harbors, and wastewater outfalls. Our project is measuring all of these characteristics, but even if we were in possession of complete figures now and could readily take into account the motions of the water and the dilutions of the chemicals, still we might not be sure why the populations of plants and animals change as they do.

The problem is that there are such great natural changes in the biota caused by normal fluctuations in sea temperature, currents, and storms that it is difficult to determine the extent of the changes caused by man. Whatever the reasons, sea organisms constantly adapt or redistribute themselves as their communities adjust to a changing environment.

This project has made progress in identifying the animals that live along our coast; we have studied tides and currents, measured the amounts of trace contaminants in incoming seawater, and made a detailed analysis of the "inputs" into the sea from major wastewater discharges as well as streams, harbors, and aerial fallout.

Each scientist on this project is working on a small piece of this large complicated puzzle. We have ideas or hypotheses; we test them by means of observations and measurements; we discover new facts. As the ideas evolve into theories and the facts become better documented, we report them. But we note with humility that absolute facts that apply to all times and places are hard to find. Progress in understanding the sea is slow and expensive.

In this section of our annual report for 1973-74, we will attempt to give an overall picture of the problems and of our findings to date, both past and recent. We believe that they will be useful to anyone concerned with the ocean disposal of man's wastes.

CHEMISTRY

This project reported last year on the kinds and quantities of material discharged in municipal wastewater in 1971, and on material reaching the sea via stream runoff and aerial fallout. The wastewater summary has now been updated to include 1972 and 1973. Much new data on aerial fallout, ship bottom and harbor inputs has been added. Generally, we see a significant decrease in the amounts of metals and chemicals reaching the sea. For example, at the Los Angeles County outfalls off Palos Verdes the input of DDT, a major chlorinated hydrocarbon, decreased about 83 percent, and inputs of 9 of 12 metals decreased on the average by 26 per-cent. Ten of 13 other constituents measured (including total suspended solids, oil and grease, BOD, 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 (see section on municipal wastewater inputs, Part II).

DDT is one of the most important contaminants reaching the local marine environment, and our studies of it continue. Although municipal wastewater discharge of this toxicant has been greatly reduced, wastewaters are still the dominant source. We have found that the next most important coastal source is aerial fallout, which contributes about 25 percent of the total known input of DDT to the nearshore waters.

An analysis of DDT concentrations measured in Palos Verdes sediments indicates that over 200 metric tons of this pesticide and its residues are contained in the upper 20 cm (8 in.) of a 60 sq km (20 sq mi) area around the outfall system. The principal residue observed was p,p'-DDE, which constituted 55 to 75 percent of the total DDT measured in these sediments. This is also the principal DDT compound found in organisms in the discharge region. We observed a thousandfold difference between median DDT concentrations in the Palos Verdes area and those in the Point Loma area; intermediate values characterized the other discharge sites, although concentrations fell rapidly with distance from the Palos Verdes region.

Measurements of dated sediment layers from Santa Barbara Basin revealed that the first detectable concentrations of PCB occurred on sediments deposited about 1945, and the first detectable DDT, in 1952. By 1967, a tenfold increase had occurred. More recent depositions will be analyzed during the coming year.

Analysis of 1973 monitoring data indicates that DDT concentrations in the flesh of fish from the Palos Verdes shelf often exceeded the Federal limit of 5 ppm. Measurements of DDT and PCB in flesh of crabs collected during 1971-72 between Point Dume and Newport Bay revealed relatively low concentrations. However, the highest DDT concentrations were found in specimens caught off Palos Verdes, and highest PCB levels (none of which approached Federal limits) occurred in crabs caught near the City of Los Angeles Hyperion 7-mile outfall in Santa Monica Bay. In general, the distributions of PCB were much more uniform along the southern California coast than were those of DDT compounds.

DDT and PCB concentrations found in intertidal mussels from the Palos Verdes Peninsula have decreased to about one-fourth of the 1971 values, reflecting the decreasing amounts discharged. Mussels collected from Whites Point in 1973 contained 1 ppm DDT and 0.1 ppm PCB. Corresponding analyses of specimens collected inshore of the major outfalls in Orange County and San Diego City generally revealed lower concentrations.

PCB levels in bay mussels from San Pedro, Newport, and San Diego Harbors were higher than those found in specimens of the same species from just outside these harbors. Although we found relatively low PCB inputs (including those from antifouling paints) to all three harbors during 1973, highest concentrations were observed in mussels living near regions of greatest vessel activity.

An experiment to determine the rate at which mussels contaminated with DDT cleanse themselves when they are moved to a clean environment showed that body content of DDT is reduced by about 50 percent every 2 weeks.

One of our significant findings in the past was that fish living on sediments highly contaminated with potentially toxic metals showed somewhat lower concentrations of certain metals in their livers than fish living on uncontaminated sediments far from outfalls. We have since examined additional metals in the flesh, livers, and gonads of such fish. These results confirm the previous finding that there is little enhancement of these contaminants in fish from around the outfalls, and that some of the metal concentrations are lower than normal. Chromium is the exception: Concentrations of this metal in fish near outfalls were twice back-ground levels on the average (but were still extremely low). In addition, at one outfall station, diseased and apparently healthy specimens contained significantly different concentrations of this element; concentrations in the heart and gonads of the diseased fishes were lower than those in healthy specimens but kidney and liver concentrations were higher.

Certain volatile elements are potentially toxic, and these have been studied around the site of the largest discharge, the Whites Point outfall system. Enhanced concentrations of arsenic, antimony, and selenium—three potential contaminants that have received little attention to date—have been found in bottom sediments around the outfalls. Levels of these trace elements in the surface layer are roughly ten times natural values; the distribution of arsenic and antimony around the outfalls generally follows the same elongated oval pattern found in earlier studies of sediment contaminants.

During 1972-73, we analyzed the amount of total mercury, another volatile element, in the upper 5 cm (2 in.) of bottom sediments collected within the Palos Verdes outfall monitoring zone. We found that the greatest enrichment is centered around the 60-m depth contour and that concentrations many times above background exist up to 12 km (7 mi) to the north-west of the outfall diffusers. Efforts to detect organomercurials in these sediments are in progress.

Our early work revealed a high concentration of trace metals on wastewater solids and in bottom sediments around outfalls, suggesting that particulates are important to the distribution and eventual fate of these contaminants following marine discharge. Thus we set about studying several aspects of this matter.

Trace metal profiles in sediments near outfalls indicate sedimentation rates as much as thirty or more times the natural rates. This is a much greater rate than that predicted by using field observations on currents and laboratory measurements of the settling velocities of effluent/seawater mixtures.

Trace metal distribution in the sediments can be explained on the basis of mobilization (release) from the bottom, but other processes besides purely chemical release and physical mixing may also be at work. Mobilization of the metals from effluent particles in the water column does not explain the observed results.

In the Whites Point outfall area, there are two sediment regions—one where the trace metals concentrations are approximately constant, and a second where metals concentrations decrease with increasing distance from the outfall. The boundary between these regions correlates well with subjective measurements of the physical/chemical properties of the sediments, and with changes in benthic invertebrate community structures. A model of trace metal distribution suggests that this may be a boundary between aerobic and anaerobic surface sediments.

OCEANOGRAPHY

A knowledge of the degree to which metals in effluent attach to particulates and the rate of their release following discharge to the sea is important to understanding of their fate. We have therefore performed experiments in the laboratory to provide data for the construction of predictive models of the distribution of metals.

We found that the ratio of the amount of lead in solution to that attached to particulates is widely different in different effluents. For example, 80 percent of the lead in Hyperion effluent is in soluble form, while less than 10 per-cent of the JWPCP lead is in soluble form.

Rapid mobilization of some trace metals may take place when primary effluent particulates are mixed with seawater. Hence, the soluble fraction (particularly for cadmium and manganese) can be increased following discharge into the ocean.

Although the addition of an activated sludge process to primary treatment can reduce the concentration of suspended solids in the effluent by as much as 93 percent, the removal efficiency for the trace metals can be significantly lower (30-85 percent). In addition, the concentrations of the soluble fraction of some trace metals such as cadmium, or the amount associated with the particulates for others such as mercury, may actually increase.

During dry weather, the concentrations of some metals (cadmium, nickel, lead, etc.) on particulates in runoff from urbanized areas can be significantly higher than the amounts on typical primary effluent particulates.

Most primary effluent particulates will pass through a 44-micron filter; the concentration of trace metals on these particulates is independent of particle size. The direction and velocity of new, clean seawater moving past the end of each outfall is obviously of great significance to any study of the concentration of pollutants in the water and sediments. We therefore initiated a series of current studies, which have already produced some data.

We find that the typical amplitude of currents with tidal period fluctuations in the Whites Point and Point Loma out-fall areas is about 9 to 15 cm/sec and produces displacement/ dispersion of the effluent over an area from 1.2 to 4.0 km from the outfall.

Preliminary evidence indicates that flushing of the out-fall area may be due to long-period oscillating currents with speeds on the order of 6 to 7 cm/sec.

BIOLOGY

Our biology program is much concerned with the effects of pollutants on marine animals and plants. It is very difficult to demonstrate cause and effect, in which some specific animal can be shown to be damaged or annoyed by a specific pollutant. Some animals leave; others ignore the changes or adapt to them; some prefer the new conditions. Many possible pollutants are below the threshold concentration that would cause a problem. Fish diseases that are prevalent near out-falls give us a clue as to how to begin these investigations.

We have recently seen evidence of fin erosion in 31 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 specimens with eroded fins have been collected at depths beyond those sampled in routine monitoring surveys (to 200 m).

The only species from southern California coastal waters consistently affected with skin tumors is the Dover sole. There are no geographical gradients in the frequency of tumor—bearing Dover sole off Los Angeles and Orange Counties. The cause of the tumors remains unknown, but collections made in 1972 and 1973 confirm that the disease is seasonal and develops in recently settled juveniles. Although white croaker with lip papillomas were relatively abundant in 1970, few have been collected since then. Studies of Dover sole planktonic larvae confirm that they are abundant offshore and live in the water column for at least 1 year before they settle to the bottom, primarily in late winter and early spring.

Marine animals come and go for many reasons, and it is difficult to distinguish population variations caused by natural influences from those due to human activities. We know that bottom sediment type has changed from sand to mud as streams have been dammed, and that this has caused fish to shift their habitats. We also find that bottom water temperature and dissolved oxygen can change dramatically in a short period of time, and these seem to have a profound effect on the distribution of demersal and benthic populations. The deep waters of Santa Monica Basin, which have low oxygen levels and low temperature, are sometimes moved by currents into the areas of waste discharge, where they completely change the benthic environment.

Our studies of wild fish in the ocean are supported by related studies conducted in laboratory aquaria filled with cool flowing seawater. We have found that it is possible to maintain wild marine benthic fishes (such as speckled sand-dab, yellowchin sculpin, and hornyhead turbot) in the laboratory and use them for toxicity tests. The free-swimming fishes (such as croaker, perch, and rockfish) are more difficult to collect and transport to the laboratory in good condition.

In dealing with marine animals, it is necessary to deter-mine the species and populations in each area. These must be resampled periodically to determine if changes have occurred.

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.

A number of faunal differences previously thought to exist between adjacent coastal areas were caused by misidentification of specimens and nonstandardized recording of data rather than by pollution. When the species names are reconciled, the variation between areas is less than previously thought.

Baited cameras reveal 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.

Modern statistical tools are available for the study of marine community structures. Data from trawls and grabs are punched onto cards and fed to a computer. By varying the program, one can simulate natural effects and determine what conditions are associated with population shifts. For example, cluster analysis techniques of the benthic communities off Palos Verdes indicate that sites associated with the highest concentration of pollutants are readily distinguished from adjacent sites by their species composition. There are major seasonal changes in the communities of organisms living on or in the benthic sediments, especially near the outfalls, which 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 seems to lower the diversity and alter the species-composition.

Chromium is a toxic metal whose effect on marine animals has been little studied. It is present in most wastewaters in concentrations higher than permitted by the State standards. Apparently it will be very difficult to meet those standards, so we have initiated a program to determine the actual toxicity of this metal. We have found that the' threshold for direct toxicity of chromium, as potassium dichromate, to a marine worm (*Neanthes arenaceodentata*) is about 0.8 ppm. However, concentrations as low as 0.08 ppm significantly affect the ability of these animals to build, maintain and inhabit mucous tubes necessary for reproduction and protection from predators.

We have reviewed recent research by others on the sea life along the Palos Verdes shores, and we are about to initiate a program to investigate some aspects of the plant and invertebrate community. We find that since the mid-1960's, there has been a substantial increase in the area where fine clay particles are deposited.

Inshore and intertidal marine communities along Palos Verdes outfall area differ substantially from those in other outfall areas and those in the offshore benthic environment. Holothurians (sea cucumbers) are rare or absent, large numbers of *Patiria miniata* (bat star) occur, and macroalgae is drastically reduced in abundance and diversity. The natural kelp beds remain absent except at one locality where natural recruitment of *Macrocystis* has occurred this year. Grazers such as urchins are abundant inshore but rare in deeper waters. Kelp beds in the Point Loma area are increasingly healthy, however.

Recently, the project has been sponsoring new work in microbiology to try and discover the concentrations and survival times of various pathogens in seawater and bottom sediments. We found that pathogenic microorganisms such as *Salmonella typasa* and *Shigelta dysenteriae* that can be cultured from raw sewage have not been detected in Santa Monica Bay. There are, however, abundant populations of fecal coliforms and streptococci in water and sediment samples near the outfalls. The highest concentrations of bacteria and fungi are in sediments; floating particulates and surface waters have lower concentrations and the lowest are found in mid-water samples.

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 are more abundant near waste discharge sites than away from them and are more abundant than micro-organisms 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.