SUMMARY OF FINDINGS

The Annual Report for 1978 is a little different from those of the past in that we are presenting the results of fewer but larger scientific projects and are dealing with each of these in more depth. This year brought to a successful conclusion several pieces of work on which we had previously made progress reports. As before, a considerable effort has been made to make each technical presentation understandable to readers without training in that specific area of science.

The problem of identifying specific areas of pollution in coastal waters is a very common one, both around the U.S. and around the world. The question is: How or where should one draw the line between normal and changed or between pollution and no pollution. This task necessitates the following: (1) A means of assigning precise numerical values to the benthic communities at any location so that various samples or areas can be compared; (2) a knowledge of what normal conditions in any coastal area should be; (3) many measurements covering possibly polluted areas and extending into undisturbed regions. After the methods have been devised, the samples taken, and the data examined and plotted, the most difficult part remains. That is (4) the development of a data-based system of logic for selecting the boundaries between areas that are normal, changed, and degraded.

We believe we have solved the problem of identifying polluted areas of the bottom by using the condition of the bottom and the benthic infauna. Our first four papers cover the four points just enumerated. With the Infaunal Trophic Index, a simple number can be used to describe the condition of the community of small animals that live in the bottom. This number, which is relatively easy to obtain, describes the mix of feeding strategies of the benthic infauna. Index values range from 0 to 100, being high in regions where the animals feed on suspended material in the water, intermediate where they feed on the surface of the bottom, and low if they feed on subsurface materials.

The virtues of the Index are numerous. Each sample can be assigned a value in a few hours, replicates are not needed, and all species in a sample need not be identified. In addition, equal results can be obtained by different biologists using a wide variety of equipment, old data can often be compared with new data, and the results are readily plotted on a chart. Finally, there is a clear relationship between the Index animals and organic materials in the sediments.

The Infaunal Index method greatly reduces the effort that must be made at any one station, thus permitting many more stations to be covered with the same effort. Complex reports, involving long lists of organisms and complicated analyses, can be replaced with simple numbers on a synoptic chart. The 60-meter control survey was devised to answer the question: What is the normal number of species, number of animals, and biomass of animals in regions relatively unaffected by man? In this survey, we took samples every 10 km along the coast from Point Conception to the Mexican border at a depth of 60 meters (the average depth of the large municipal wastewater outfalls). A total of 71 stations were sampled; after all those near outfalls, harbors, or other possible sources of pollutants were eliminated, 29 stations were found to represent undisturbed bottom conditions.

These 29 stations are our "controls;" they furnish the standards against which other measurements can be compared. Each is slightly different from the others; as a group, they show the natural range of variations from place to place. Any station whose characteristics fall within the range of control values can be said to be normal.

At control sites, the Infaunal Index numbers range from 83 to 100; in a tenth of a square meter of muddy bottom, the average number of species is 71, the average biomass is 7 grams, the average number of animals is 423, volatile solids average 2.8 percent, and biochemical oxygen demand is 632 milligrams of oxygen per kilogram of sediment. The largest effort of the year went into a survey of bottom conditions on the coastal shelf from Point Dume at the western end of Santa Monica Bay to Dana Point, south of Newport Beach. Water depths ranged from 10 to 300 meters. Also surveyed was a detailed grid around Los Angeles City's Hyperion outfalls and an area off Point Loma at San Diego. Samples of the bottom for biology and for chemistry were taken at 300 sites in accordance with a plan in which stations were located where they would yield maximum information.

The Project and other groups had taken many samples in this region in the past, but there had never been enough data collected in a short period of time so that a meaningful chart of a large area could be made. By making use of LORAN-C navigation, modern grab sampling techniques, and the Infaunal Index assessment method, it was possible for a small group of scientists to precisely locate, sample, and analyze data from 300 stations in a year. The charts produced are an explicit statement of the present situation to which past measurements and future changes can be compared. Lines at equal levels of Infaunal Index and biomass have been drawn for samples taken between 20 and 200 meters, the zone where our control data are valid. These isolines clearly show the effects of the outfalls on the bottom and its animals. The previous three papers gave us a scale for measuring benthic community structure (the Infaunal Index), a knowledge of normal conditions on the southern California coastal shelf, and charts showing conditions in the regions most affected by man. The data are presented as factual statements without comment as to how they should be interpreted by those interested in pollution matters. In this piece, a logic is established for separating three zones of bottom conditions described as "normal," "changed," and "degraded."

Marine biologists have several criteria for describing the condition of a marine community. These include the number and dominance of species or classes of animals pre-sent, the number of individual animals present per square meter, and the biomass or total weight of animals per square meter. We have used all of these to establish the boundaries between zones.

The Infaunal Index is based on the feeding characteristics of four classes of benthic infauna. The animals in Classes I and II are dominated by suspension-feeders that are characteristic of control areas. Classes III and IV are dominated by surface- and subsurface-feeding animals. If one plots feeding characteristics against Infaunal Index numbers, the suspension-feeding animals dominate until the index drops below 60. This gives an indication of the lower boundary of normality, at least in this region.

The other three criteria are simpler to understand, and we have relied primarily on them to select the Infaunal Index numbers that bound the zones of bottom conditions. If the number of species, number of individuals, and biomass in a sample are all equal to or greater than those in control samples, the bottom is "normal." If only two of the three criteria are equal to or greater than control conditions, the area is "changed." If less than two of the three criteria are equal to or greater than control conditions, the area is "degraded."

By examination of the graphical presentation, it is easy to see that the Infaunal Index number at which "normal" goes to "changed" is 60; the number that separates "changed" from "degraded" is 30. Accordingly, we have made charts using Infaunal Index isolines of 30 and 60 to delineate the areas that fit these descriptions. The "degraded" area off Palos Verdes is 8.4 sq km, that off the 7-mile outfall in Santa Monica Bay is 3.3 sq km; there are no "de-graded" areas at Orange County or San Diego, and no "changed" area near the Oxnard outfall. Each year, we summarize the characteristics of the waste-water discharged during the previous year from the five major treatment plants in southern California. In 1977, the average flow for all five was 966 million gallons (3,658 million liters) per day and 650 metric tons of solids per day. These figures show a decrease in total discharge of 6 percent and an 18 percent reduction in suspended solids relative to 1976.

Oil and grease emissions were down 31 percent; copper and lead were down 20 percent each. Chlorinated hydrocarbons were also down (DDT by 28 percent and PCB by 34 percent) . Only one of the pollutant constituents considered increased dramatically: The mass emission value for silver in 1977 was 170 percent of the 1976 value. Data on this metal have fluctuated considerably for the last few years, possibly because silver is a difficult trace element to analyze. Municipal wastewater contains many substances that can be toxic if present in sufficient quantities. We have long been concerned that some very toxic compounds never measured might be reaching the ocean unnoticed. Therefore, we were pleased when the various dischargers were required by the EPA waiver regulations to scan the wastes for possible pollutants that heretofore had been missed. Project personnel took most of the samples and distributed them to various chemical laboratories for analysis of the EPA's 134 "Priority Pollutants."

We found that, on the average, less than 10 percent of the trace organics named by EPA were present in wastewaters at concentrations above the lower limit set by the agency--10 parts per billion. Many of these substances are highly volatile and would, under ordinary circumstances, probably escape into the atmosphere.

As an additional benefit, we were able to use these data to compare the effectiveness of primary and secondary treatment. We found that, relative to primary, secondary treatment produced only modest reductions in trace metals, but it did achieve substantial reductions in suspended solids, BOD, oil, and coliforms. No data was obtained on the reduction of the chlorinated hydrocarbons, DDT and PCB, because, in all cases, the levels of these were below the EPA's quantification limit. The principal effect of most outfalls is a deposit of organic particles on the bottom in the region of the discharge point. This mass of material may cause degradation of the bottom in two ways: Although it contributes to food for bottom animals, too much of it in one area greatly changes the marine life. Attached to these particulates are possible pollutants, which accumulate as the particles do.

The objectives of these experiments were to (1) deter-mine the amount of particulates from each outfall that fell faster than a hundredth of a centimeter per second and consequently would settle relatively near the release point; (2) discover the amount of trace metals and chlorinated hydrocarbons attached to those rapid-settling particles; (3)

compare the relative settling velocities and potential pollution of various existing or proposed effluents; (4) combine the above measurements with knowledge of the currents to predict the size and shape of the area that would receive the particles; and (5) directly measure the fallout locations of discharged particles by tagging an effluent with fluorescent particles.

This work produced a series of new kinds of measurements that can be used to predict where effluents of various kinds will cause deposition and what pollutants these deposits will contain. If one understands the relationship between the material discharged and the physical/chemical nature of the sediments, it is possible to forecast the effects that a proposed change in the character of an effluent will have on the bottom. The Project has used numerical simulation models to make such forecasts, and these give results that are well supported by biological forecasts based on entirely different kinds of data. The model reported here consists of two parts: The first part uses time, current velocity, and particulate settling rates to estimate the amount of material deposited at various distances from an outfall. The second part combines the effluent deposition figure with that for natural particulates, taking into account the reworking of sediments by waves and currents, to estimate the thickness and composition of outfall-influenced bottom sediments.

Applying this model to possible effluents for an idealized simplified case indicates that, if the problem is to reduce the levels of trace contaminants in the surface sediments, any of three proposed systems are helpful. However, because burial in the sediments is an important process, source control with primary discharge is most effective. Although it reduces the amount of pollutants, secondary treatment does not furnish cover material. Typically, 6 to 7 years would be required for a 90 percent reduction to take place using source control; 10 to 12 years is needed to reach the same level with secondary treatment. If both are used, the most rapid reduction occurs when source control is used alone at the start and secondary treatment is added at a later date. This kind of model can be a useful tool for estimating the changes that will take place on the sea floor if various treatment processes are employed. Natural changes in coastal waters affect marine life more than is generally appreciated. Variations in temperature, currents, or storm patterns can cause major changes in the survival of young fish. This review of some of the biological and physical conditions shows that coastal water temperatures and clarity have increased over the last 10 years. Neither increase seems to be related to waste discharge. The upwelling of deeper waters, generally believed to be a source of nutrients for coastal animals, increases and decreases in alternate years.

In the last decade, some fishes, such as Pacific mackerel, have increased greatly in abundance in southern California; others, such as the northern anchovy, have decreased. The middle years, 1972-76, were marked by the invasion into coastal waters of squid, pelagic red crabs, and jelly fish. The abundance of bottom fish is strongly correlated with changing ocean conditions. In the 1930's, the Palos Verdes Peninsula was bordered by lush kelp beds, which were home for substantial communities of fish and invertebrates. During the 1950's, these beds and the associated animals began a steady decline: By 1969, very little of the kelp remained. Although no specific association can be made, the decline seems to be related to some combination of effects from the nearby outfall discharges.

In 1969, Dr. Richard Grigg of the University of Hawaii participated in a study of the ecological conditions at six stations off Palos Verdes in water depths of 6 and 15 meters. Thus, when he proposed to the Project that these same sites be resurveyed in 1977 to determine how conditions had changed with time, we gladly agreed to support him. He found that, in the interval between 1969 and 1977, the number of species of algae had increased from 3 to 13 at stations near the outfalls, and the number of fish at 15-meter stations within 6 km of the outfalls had increased by 240 percent. The increase in invertebrates was less significant. He also found enhanced levels (greater than control values) of species of algae, invertebrates, and fish at his stations 11 km northwest of the outfalls, another indicator of the general recovery.

A condition of reduced species diversity and abundance still prevails in the vicinity of the outfalls. Since the outfall discharge has not greatly changed (except for the reduction of DDT), the reasons for these changes are still unknown. It has long been assumed that pollutants move upward through the marine food chain or web and accumulate in higher organisms as they do in freshwater or terrestrial ecosystems. That is, when invertebrates are eaten by small fish that are eaten by larger fish, there is an amplification of the amount of pollutant in the large fish relative to the invertebrate. This research, sponsored by the National Science Foundation, is expected to determine whether such amplification does exist in the sea, and if marine food webs are "structured" (layered in neat trophic levels as diagrammed in some ecology books).

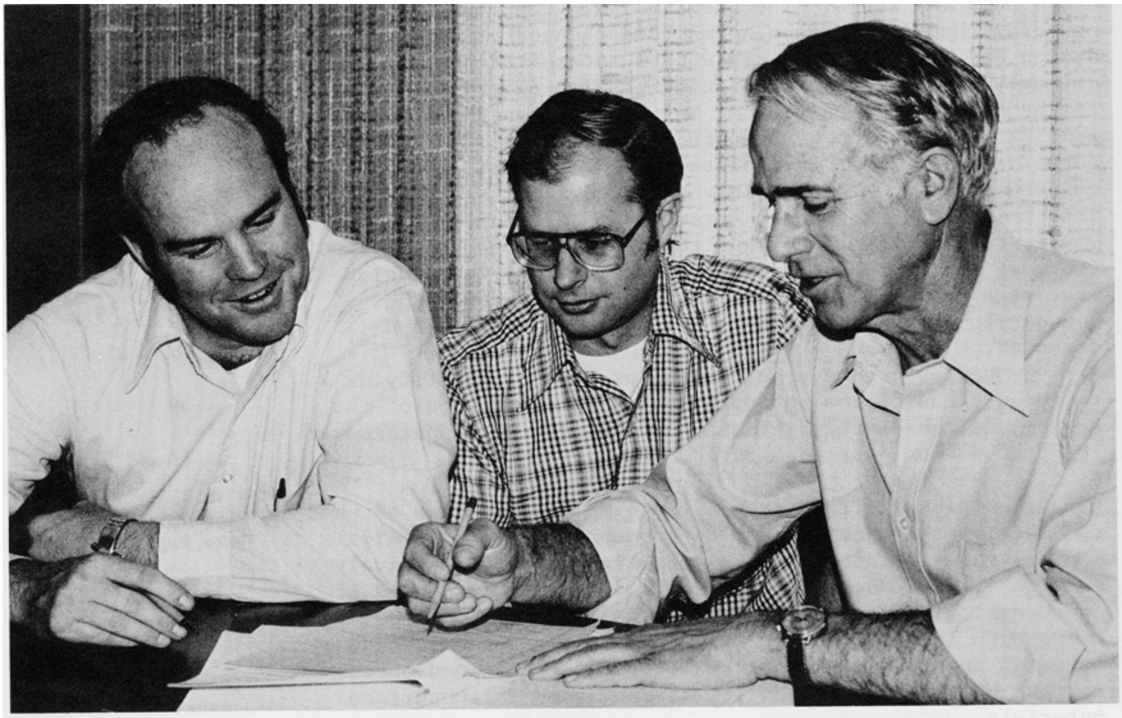
The work consists of sampling a large variety of sea animals, assigning each an estimated trophic level, and measuring the cesium-to-potassium ratio in the animals' tissues to see if there is an increase at higher trophic levels. The logic of this is that, owing to a longer biological half-life in tissue, cesium--a widely distributed normal trace constituent of seawater--tends to concentrate relative to potassium at successively higher levels in a true food chain. Measurements by Dr. David Young of our staff during 1970 showed a cesium amplification of about six times in the rigid trophic structure of the Salton Sea, but no amplification in the same animals in the Gulf of California, where feeding opportunities are much greater and the food web is apparently unstructured.

To date, we have found an approximate doubling of the cesium/potassium ratio in certain pelagic fishes over levels in their prey, indicating a limited degree of "structure" that might lead to amplification of certain pollutants through feeding. However, we also find that most trace metals decrease in fish as the presumed trophic level in- creases. An important exception is organic mercury (generated within the fish or its food), which—along with DDT and some PCB residues—generally increases with trophic position.

The available information about fin erosion disease is summarized so that other scientists interested in the subject can consider the evidence we have found and the conclusions that were reached. Fin erosion disease is most likely to be found in flatfish living on the sea bottom in areas where toxic wastes have been discharged. It has been reported off New York, Seattle, and Boston, as well as in sites off the Japanese and British coasts.

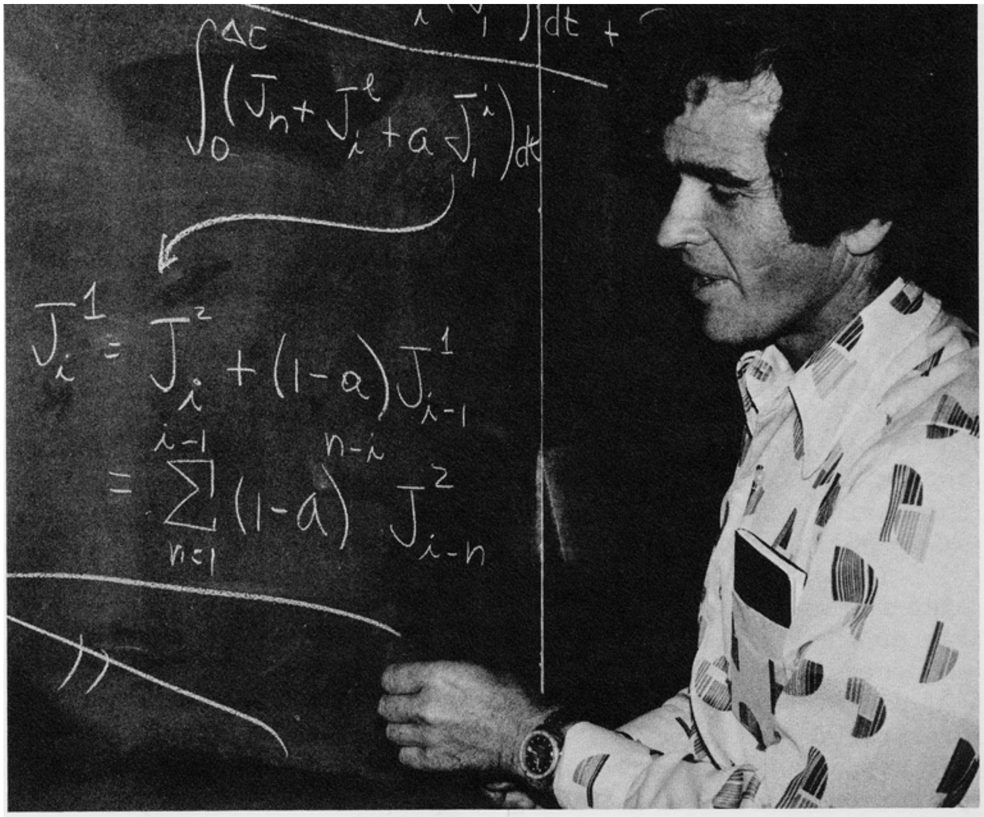
In our investigation, over 290,000 fishes representing 151 species were examined over a 7-year period. About 5 percent of these had external diseases or abnormalities, such as tumors, macroparasites, or fin erosion. Of these, fin erosion--mainly in the Dover sole--was the only con-dition that appeared to be directly associated with waste-water. In trying to identify the cause of this disease, we considered and rejected microbial infection, abrasion, and fin-nipping as the primary agent. We noted that the fins contacting the bottom most frequently were most affected. Extensive chemical studies were made of various possible toxicants on the sea bottom and in the fish.

Although the precise cause of the disease remains un-known, elevated levels of PCB's may be a factor in its development. This material seems to be responsible for liver enlargement, which is found in Dover sole with and without fin erosion. The liver-somatic index (liver weight to total body weight) described in a past Annual Report is a useful indicator of fish health in areas of possible PCB contamination.



Jack Mardesich

Jack Word, Dr. Alan Mearns, and Willard Bascom discuss the data in their Annual Report paper.



Willard Bascom

Dr. Terry Hendricks, the Project's expert on initial dilution, explains the equations he uses to predict rates of deposition and resuspension of particulates near an outfall.

Willard Bascom

Philip Oshida determines the toxicity of water samples by means of sea urchin fertilization and embryo development.