SUMMARY OF FINDINGS

This annual report contains 28 professional papers prepared by individual scientists. Each covers a piece of the re- search that was outlined in our Research Plan for 1977 and describes when, where, and how the scientific work was done, as well as what was discovered. Although an effort has been made to make the writing generally understandable, we appreciate that not all of our readers are interested in all the details of the research or in all the numbers generated.

Therefore, this summary was been prepared for the benefit of those who wish to have the substance of our findings in a short simplified form. It covers the following topics:

- Recent data on possible pollutants contributed to southern California's open coastal waters by various sources, especially including details about municipal wastewaters.
- New information about how the discharged material is distributed by water motions.
- New findings about animal and plant populations.
- Studies of the levels of pollutant materials in animals,
- The levels at which metals and chlorinated hydrocarbon pollutants become toxic to marine life as determined by tests.
- Evidence of actual effects on animals in the ocean.

Possible pollutants added by municipal wastewater discharges

Each year we report the kinds and quantities of material discharged into southern California coastal waters via the six largest municipal outfalls. We use the data prepared by each of the dischargers for the State Water Resources Control Board, sometimes reorganizing it into our units and format. The object is not only to make the concentrations and totals more readily available but to determine the extent of the changes resulting from various pollution reduction programs.

The 1976 flow from the six large outfalls averaged 1,026 million gallons/day. This is an increase of about 10 percent in the amount of wastewater discharged over the last 5 years. In that same time, although there have been yearly ups and downs of many of the possible pollutants, none have increased significantly, and there have been notable declines in the emissions of lead, zinc, and chromium. The greatest decreases have come in the most toxic substances, DDT and PCB. Emissions of DDT and PCB (independently sampled and analyzed in the Project's laboratory as a check) have fallen by 80 to 90 percent since 1972. There has been a general decrease in suspended solids, which is expected to continue as new treatment facilities are added.

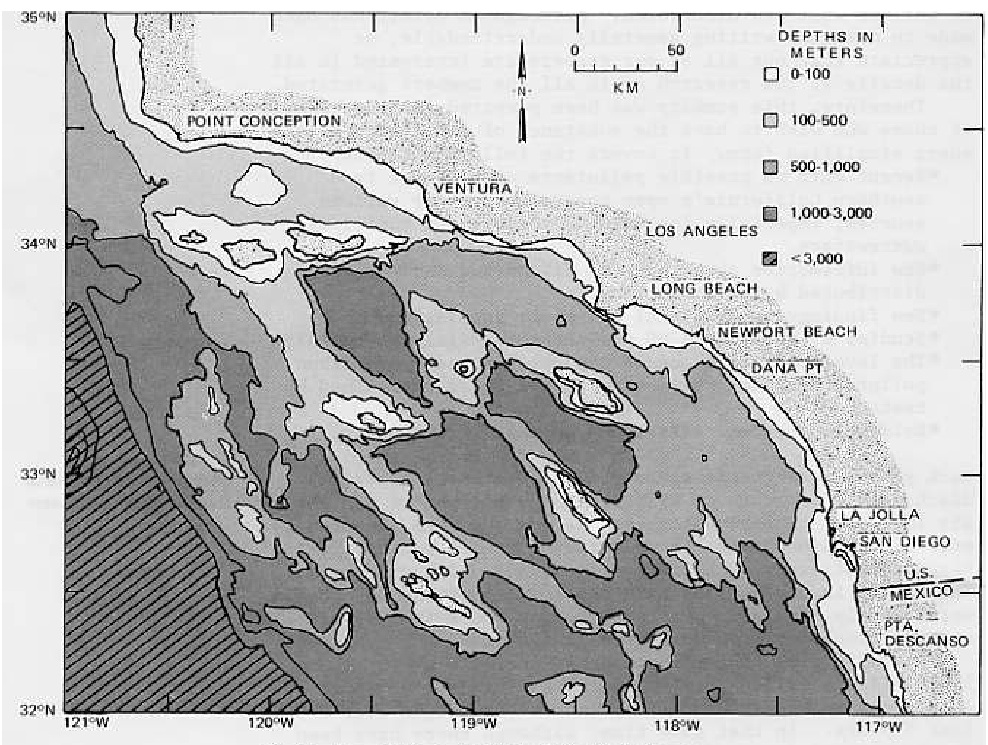
Coastal currents

Studies to determine the complex nature of the flow of water along our coast continue. The surface waters, which are moved mostly by the wind and surface currents, are relatively easy to measure. We are most interested in the motion of the subsurface waters into which municipal wastes are released. To understand the ultimate fate of pollutants, it is necessary to know the average speed and direction of these currents, the distance along the coast for which current measurements at one point are valid, and the variability of the flow.

By means of drogues (underwater parachutes towing surface floats) and current meters, we have determined that in the San Diego region and for 60 km to the north, the subsurface water moves up coast at about 3 cm/sec (6 feet/minute). These and other measurements, plus the distribution of effluent-related materials to the north and west in the Orange County and Palos Verdes discharge areas, confirms that this is the general direction of subsurface flow. Often it is opposite to that of the surface water, which, usually moves down coast at 25 cm/sec (about 50 feet/minute). If this condition is more or less continuous from the Mexican border to Point Conception, as it seems to be, the travel time of a subsurface water particle over that distance is about 150 days. This gives an indication of the maximum residence time of water off southern California.

Initial dilution of wastes

In collaboration with the University of California at San Diego, we have directly measured the dilution of waste-water at four major outfalls immediately after its discharge into the ocean. The objective was to examine the behavior of buoyant plumes and to determine which of several



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

mathematical and physical models most closely approximates actual conditions. Measurements of ammonia, turbidity, fluorescence, and Rhodamine WT determined that the minimal initial dilution (at the equilibrium depth of the wastefield) ranged from 100 to 1 with little current to 300 to 1 at 16.6 cm/sec.

Trawls at 600-meter depths

Project biologists are familiar with the sea life down to 200 meters because in the past we have concentrated our efforts in shallow depths most likely to be influenced by outfalls or other acts of man. This year, the studies of bottom fish and invertebrates were extended down to 600 meters in a few places. In examining the history of scientific trawls at this depth we discovered that although many have been made over the last few decades, the results have been poorly recorded and the data cannot be effectively utilized. Our deeper trawls brought up fewer fish and fewer species of fish as the depth increased. As one would expect, the species making up fish communities changed; on the average, individual fish caught weighed five times as much as those taken in shallow trawls. A few Dover sole with fin erosion disease were caught in a 460-meter trawl directly down slope from Palos Verdes but not elsewhere.

Our studies of invertebrates taken in trawls in the 200- to 600-meter depth range showed that the 200-meter depth is an important biological boundary; only 10 percent of the species collected are present both above and below that depth, indicating distinctly different communities. In the deeper water, there are a remarkable number of echinoderms; 99 percent of the individuals taken were sea urchins. The number of individual animals captured was about 10 times larger than that taken by similar trawls in shallow water, and the average biomass was 11.8 times as great. In spite of this generally high abundance, there is a depression in echinoderm abundance down the slope from Palos Verdes, suggesting some effect of the outfall.

Commercial fish catches

Seafood harvesting causes substantial ecological changes that sometimes are mistaken for the effects of pollution. To obtain data for comparative purposes, we have summarized information on commercial fish catches since 1930 and scientific opinions as to the probable reasons for the changes. The most important change was the great reduction in total tonnage landed between 1950 and 1953, the period when sardines virtually disappeared from our waters. In the opinion of Prof. John Isaacs and others who have care-fully studied the matter, this seems to be a natural long-term change (comparable to other comings and goings of sardines over the last 2,000 years) that may have been speeded up somewhat by overfishing. It was not caused by pollution.

If the sardine catch is excluded, the yearly commercial catch from the Southern California Bight is steadily increasing at a rate of about 1,200 tons/year. In 1975, the total catch was 178,000 tons, of which about 83 percent was landed off Los Angeles. Four "fishing blocks" immediately adjacent to Los Angeles yielded 44.5 percent of the total.

In the laboratory of the marine vessel, VELERO IV, Henry Schafer examines juvenile rockfish for parasites.

Sport fish catches

Because many sport fishermen fish in outfall areas, we have reviewed the 1973 statistics available for the commercial party boat fishery (1973 is the most recent year for which Department of Fish and Game records are available). Their data are reported for 18 km square "blocks" and, although the seven blocks near outfalls are subjected to 10 times as much fishing pressure as all the other 207 blocks of the California Bight, the effort (1.67 fish/angler-hour) is about the same. About one-third of southern California's entire catch of 3.7 million fish were taken from the 3 percent of the Southern California Bight that is adjacent to waste outfalls. The catch per hour is greatest in Santa Monica Bay and off Palos Verdes, but species composition is different there than in areas to the north and south. One problem with the sport fish statistics is that they are given in number of fish instead of weight of fish and so cannot be compared accurately either with the past (the present fish may be smaller or larger) or with the commercial catch data, which are given in tons.

New control sites

Defining pollution as a damaging excess suggests that one must know what is normal or what the conditions are in areas not influenced by man. Thus it has been customary for each outfall area to have a "control" or "reference" site with which its impact on sea life can be compared. Generally, these sites have been located in the closest coastal area believed to be in a natural condition or off Santa Catalina Island, at the same depth as the outfall. Some of the control sites used are not very similar to each other or to the impacted area and do not take into account substantial natural variations in the sea life or impacts caused by non-outfall factors.

Therefore we made an extensive survey to provide better and more logical control values. At a depth of 60 meters (200 feet), which is about the average discharge depth of the large outfalls, we sampled the entire southern California coast. At 10-kilometer intervals between Point Conception and the Mexican border, we trawled, sampled the bottom, and measured water-column characteristics. The result of having taken about a thousand samples is that we now feel we have a much better scientific data base that can be used for comparison with similar measurements in outfall areas. If the outfall area value falls within the natural range of uninfluenced areas, one can feel confident that it has not been impacted. Eight years of quarterly trawl data from the coastal shelf off Orange County were reexamined in hopes of determining the normal variability of fish abundance. A total of 112 species and over 113,000 individual fish, sharks, and rays had been collected, and information on temperature, water clarity, and currents recorded. The number of fish caught varied about four-fold between trawls, but much of that variation was due to major increases and decreases in the abundance of small fish, only a few months old. The periods of "recruitment" of new fish to this area often occurred during the onset of increasing turbidity and following the lowest temperatures of the year.

Eight years of trawling off Orange County

Status of giant kelp at Palos Verdes

The large beds of *Macrocystis pyrifera* (giant kelp) formerly existing at Palos Verdes, which were almost entirely missing from 1968 to 1971, have now partially recovered. The principal loss began in the 1940's and has been attributed to many factors, including the discharge of municipal wastes off Whites Point. This Project has not been directly involved in the kelp-related research there but has observed the kelp reestablishment work of Dr. Wheeler North and California Department of Fish and Game personnel, who have transplanted many thousands of adult plants into the area and protected them against predatory fish and urchins. By January 1977, there were at least 11 beds of giant kelp, some of which seem to have seeded themselves, with a total canopy area of 34 hectares (85 acres). The growth of these beds has been somewhat erratic and has been slowed by large storms and unusually warm water. Many other species of kelp are present in the area in dense beds, and Dr. North believes these other beds may be an important precursor to the establishment of the giant kelp. No clear relationship is apparent between outfall discharge and the growth of kelp; beds close to outfalls can flourish and those far distant from outfalls can suddenly disappear. However, we will continue our observations because there is the possibility that some specific chemical or size of particle may issue from an outfall or that sewage nutrients will enhance the kelp predators and cause a problem.

Chlorinated benzenes in fish

Some municipal wastewaters contain ten times as much chlorinated benzenes (CB) as they do polychlorinated biphenyls (PCB). Both are known to be very toxic under some circumstances, and we were concerned that there might be some substantial but previously unmeasured effect on sea animals. Therefore we determined the CB and PCB levels in the liver and muscle of Dover sole, a fish believed to be a good indicator of organic pollutant uptake. We found that, despite the relatively large input of chlorinated benzenes into the sea, the amount detected in the fish was less than a hundredth of the amount of PCB present in the same organs.

Metals in seafoods

Municipal wastes are the largest single source of metals entering the coastal waters of southern California as a result of the acts of man (the natural input by the California Current is much larger). Under a contract from the State Water Resources Control Board, we carefully investigated the amounts of various metals in fish and invertebrates both near outfalls and at distant control sites. No increase of metals in the edible muscle tissue of six popular species of fish was found. There were, however, increases in the levels of some metals in some invertebrates. For example, scallops taken near the JWPCP outfall contained two to three times as much cadmium, copper, nickel, silver, and mercury as those from Santa Catalina Island. Even so, the level of mercury was still only a tenth of the acceptable level established by U.S. Food and Drug Administration. There was also a ten-fold increase in chromium in the muscle of abalone and scallops (1 ppm and 0.3 ppm, respectively), but this should not reduce their values as a seafood resource, especially considering the opinion of the National Academy of Sciences that there is a general deficiency of chromium in the national diet.

Metals from harbors

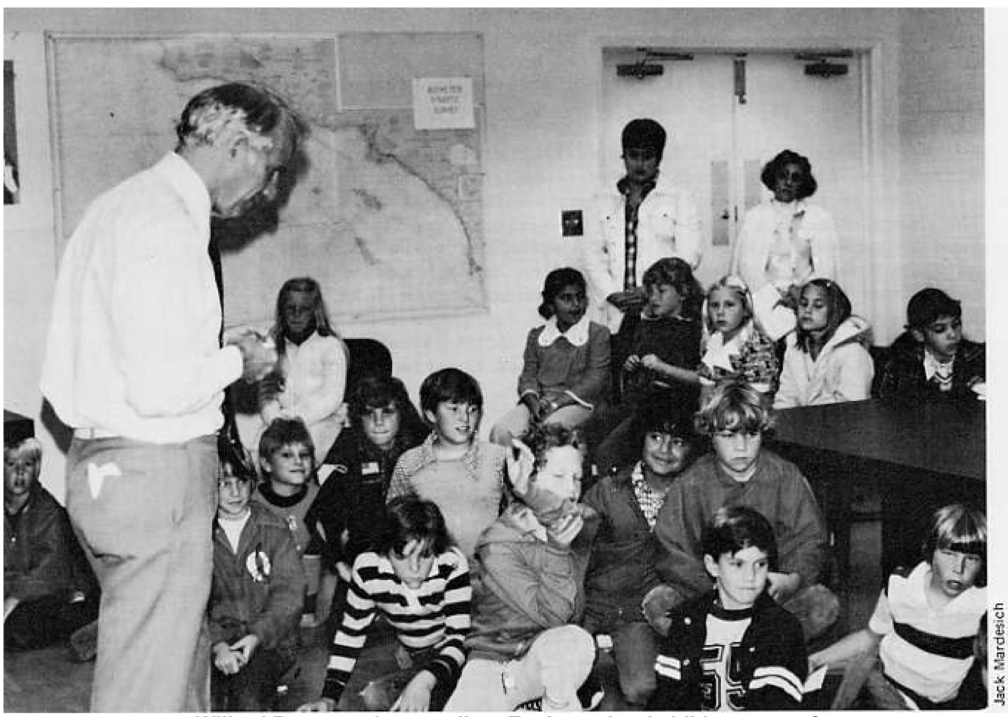
Another source of metals for coastal waters is the tidal flushing of harbors, which brings copper, zinc, mercury, and tin (used to protect boats from corrosion and sea growth) to the ocean. Because metal levels in seawater are low and hard to measure accurately, it is convenient to use mussels as bioindicators. These filter-feeding animals concentrate metals and can magnify increases in contamination levels. We have determined the ratios of metal concentrations between the levels in mussels collected inside three harbors (Newport, San Diego, and Los Angeles) and mussels taken from open coastal waters nearby. For example, the copper concentration in one area inside Newport harbor was 9 times that of the open coast. Cadmium, lead, and zinc generally were up by factors of 2 to 3. However, we do not believe that the amounts of metals brought to the sea by tidal flushing from harbors cause any environmental problems.

Zoo birds and DDT

In early 1976, a collection of gulls and cormorants at the Los Angeles Zoo died after exhibiting signs of pesticide poisoning. A zoo veterinarian, who believed the deaths might be linked to municipal waste discharge, called the Project and said the birds had, for several years, been fed exclusively on queenfish caught in the Palos Verdes area. Pelicans in adjacent cages were fed surf smelt caught north of Point Conception and were not affected. We obtained some accidentally killed wild birds and ran comparative analyses of breast, liver, and brain tissues for DDT, PCB, and mercury. The brain and liver tissues of the dead zoo birds contained concentrations of DDT residues that were 100 times greater than those of the wild (control) birds. We also ran samples of the queenfish and found that they contained about 3.6 ppm of total DDT. This compares with 0.018 ppm in surf smelt fed to the unharmed pelicans. It is quite clear that a long-continued and exclusive diet of fish containing DDT residues can damage certain animals.

Safe levels of chromium

Experiments to discover the maximum concentration of hexavalent chromium in seawater that is safe for a sensitive marine worm (*Neanthes avenaoeodentata*) were completed. In the past, we noted that very little of the total chromium in primary treated wastewater reaches the sea in its hexavalent (toxic) state, apparently because passage through a sewerage system converts it to the totally non-toxic trivalent state. In the past we have reported that the natural level of chromium in the sea is about 0.2 parts per billion, of which about 75 percent is in the hexavalent form.



Willard Bascom gives a talk to Encino school children, one of many groups to visit the Project in the past year.

Our intention in these experiments was to determine the threshold of toxicity so that realistic toxicity standards can be established. We found that a level of 30 ppb of hexavalent chromium causes no change in the reproduction rate of *N. arenaceodentata* over three generations. There was also a rise in the concentration of chromium in body tissues.

Benzenes as mitotic poisons

Last year, we reported that samples of wastewater contained several kinds of chlorinated benzenes, one of which is known to act as a mitotic poison. Using recently fertilized sea urchin eggs, we made a preliminary investigation of ortho-dichlorobenzene (o-DCB) to determine its toxic potential. This consisted of exposing the eggs to the relatively high concentration of 21 ppm and observing their development for the next 52 hours. The result was that some grossly abnormal sea urchin embryos were seen after 28 hours. Although it is very unlikely that this concentration could be reached in the ocean, the experiment determined one aspect of o-DCB toxicity and confirmed the usefulness of sea urchin eggs as indicators of certain toxins.

Indicator species

Any kind of change in the marine environment causes an adjustment of the animal community that is exposed to that change. The ones that are best adapted to the new situation increase in numbers; those that are less tolerant to the change, or to the population pressure of the better adapted animals, decrease. The process of identifying and counting the thousands of animals, which is ordinarily required to show such distributional patterns, is costly and time consuming. Therefore, we have assembled data on various animals to determine whether a few that are especially responsive can be used to indicate the changed conditions with less effort. We find that four groups of indicator species containing a total of nine benthic invertebrate species can be used to define the areas of impact around the major outfalls. If standard sampling and reporting techniques are adopted, this brief list could be used to greatly simplify monitoring.

Trends in fin erosion disease

There are few clear instances in which a relationship between wastes and damage to animals can be established. One of these few is fin erosion disease in bottom fishes, and we are continuing to study its progress and look for long-term changes. In late 1976 and early 1977, the overall prevalence of fin erosion in Dover sole at Palos Verdes was about 25 percent or about half of that measured a year earlier. Analysis of the trend since 1972 indicates a long-term decrease in overall prevalence. A similar decrease in the disease in rex sole is noted. However, considering only juvenile Dover sole, the prevalence of fin erosion disease remains unchanged.

Repair and regeneration of damaged fins in Dover sole

A small percentage of the Dover sole collected in past years have had bent fin rays—a possible sign of fin repair and regeneration. This year we investigated the ability of this species to regenerate portions of fins that were excised. We found that, within a few weeks, new tissue had begun to grow and that, in 4 to 5 months, fin repair appeared complete. In some cases, the fin rays appeared bent at the point where the new growth began; this produced fins that were similar in appearance to those of some fish found in the sea, suggesting that natural fin erosion repair occurs on some occasions.

Liver size as a health indicator

Flatfishes with similar fin erosion diseases are found in the New York Bight and Seattle's Duwamish River Estuary as well as off Palos Verdes. The species, characteristics, and circumstances are different, but all seem to have been exposed to toxic wastes. Our comparative studies of the three areas are still underway, but we have been able to show that, off southern California and Washington, the livers are 2 to 3 times larger in fish from the high-disease-prevalence areas that in those from the control areas. In Dover sole, the levels of lipids (fats) in the enlarged livers were three times higher than in the controls, and studies of tissues from enlarged livers under the micro-scope revealed structural disarray. Fish caught at Palos Verdes with no visible fin damage had notable irregularities in their liver tissues; those with serious fin erosion had very badly degenerated livers. Liver damage may precede fin erosion; the relationship of these two responses deserves further study.

Taxonomic codes

Our work on standardization of the names and identification of marine animals (taxonomy) continues. This is important because, in the past, a number of alleged instances of pollution were found to be misidentification of animals. Bimonthly taxonomic meetings are steadily increasing the species lists and reducing the problems of identifying animals that are only seen occasionally. The proceedings of these meetings reach 200 scientists in 85 different organizations throughout California. A guide to the identification of certain species used as indicators (Ophiuroidea) is being assembled.

Scientists attending a national meeting on taxonomic problems at our laboratory, agreed on a standard format for presenting data on each species; this makes it easier to contribute their knowledge of any species to the pool of material to be published. The attendees of that meeting 14 also concluded that three of the existing computer coding systems are sufficiently close to an "ideal" code for general use. All this is gradually leading to a generally acceptable international system.

Analytical variability

Ecology laboratories are often subject to questions about how much variability in their chemical results is self-generated by sampling procedures, storage methods, processing techniques, and laboratory inaccuracies of one kind or another. Because our findings depend on precise and detailed measurements of pollutants in water, sediments, and animals, we decided to determine the coefficients of variation (CV, expressed as a percentage) of our own organics laboratory. Lower CV's indicate a more repeatable and reliable grade of work. Generally, ours fall in the 10 to 20 percent range for all but the lowest concentrations of organic constituents in seawater.

W.B.