SUMMARY OF FINDINGS

Ecology is the study of the relationship between living things and their environment. For 6 years. The Coastal Water Research Project has been striving to understand these relationships in the waters of the Southern California Bight and how they have been altered by the acts of man. The first three year's efforts—baseline studies and reviews of the work of other scientists—are summarized in a report entitled "The Ecology of the Southern California Bight: Implications for Water Quality Management." Since then, the Project has increasingly concentrated on original research, both at sea and in the laboratory, to extend man's knowledge of ecology and shallow-water oceanography.

We continue to study all forms of marine environmental change with particular emphasis on the effects of the daily addition of a thousand million gallons of municipal waste-water. We also try to determine the responses of a number of marine animals to these changes. Our measurements, experiments, and findings are presented in technical memoranda, in papers in the professional journals, and in these annual reports. Our past publications, listed in Appendix C, present the scientific foundation for the work described in this annual report.

In the last year, our understanding of the biological, chemical and physical factors influencing the ecology of southern California waters has increased: Our new findings are summarized in the following paragraphs.

Chromium in seawater and marine sediments.

Our techniques for sampling and analyzing chromium have improved to the point where we can sense variations in seawater of 0.02 µg/liter (parts per billion). Using these methods, we have determined that the average natural back-ground levels of hexavalent and trivalent chromium in the Bight are 0.14 ug/liter and 0.045 µg/liter, respectively. The concentration of chromium in the water near the Palos Verdes submarine outfalls is not significantly greater than elsewhere in the Bight. However, the amount of chromium attached to particulates in that region is 10 to 100 times that in offshore water. Comparison of these values with corresponding effluent concentrations indicates that dilution of 200 is initially achieved by the deep diffuser outfalls. The amount of chromium available in the toxic form (as ionic hexavalent chromium) is less than 1 percent of the total chromium found in municipal wastewater.

Sources of DDT and PCB

This year, we compared 3 years of work for the U.S. Environ- mental Protection Agency on the analysis of chlorinated hydrocarbon inputs to the sea. These include municipal and industrial wastewaters, river runoff, aerial fallout, and harbor discharges. Largely because of effective source control, municipal wastes now contain only 5 percent of the amount of DDT discharged in 1970. Aerial fallout has been the dominant input of DDT to the sea since 1974. Most PCB enters the sea via outfalls, but the 1975 level is only about one-tenth of the 1972 level.

Benzenes in municipal wastewaters.

Our work on chlorinated compounds in the past has been mainly with DDT, PCB, and their derivatives. This year, we began to study the benzene group, partly because a National Academy of Sciences study suggested that hexachlorobenzene (HCB) might be a serious pollutant. We found that HCB is not present in wastewater in significant quantities but that p-DCB (paradichlorobenzene) and two other benzenes are present at levels comparable to the PCB levels believed to be dangerous (the benzene chemicals are used by industry, in pest-killing home products, and in lavatory deodorant cakes). The reliability of our analytical technique has been confirmed by mass spectrometry.

New aerial fallout collection technique.

Our use of the glass plate/mineral oil technique to collect samples of chlorinated hydrocarbons led us to consider the possibility that systematic errors could have been introduced into the findings if some of the components on the plates were revolatilized by solar heating. We therefore tried a new technique involving dry ice, which caused the fallout materials to freeze on contact. No substantial change in values was observed, thus confirming our previous measurements.

Aerial fallout of metals during a brush fire.

In keeping with a long-standing interest in aerial fallout of possible pollutants on the portion of the Bight inside the Channel Islands, we studied the fallout from the smoke of a 65,000-acre brush fire to determine if remobilization of pollutants by fire is an important input. In November \1975, when an east wind sent a smoke plume 100 km wide over the ocean, we collected the falling particles on plates placed along the shore and on several islands. The inputs of metals from this fire turned out to be only about a tenth to a hundredth of the amounts of metals introduced by municipal wastewater in the same length of time.

DDT in sediments and fish.

In the last few years, there have been major reductions in the mass emission of DDT and PCB. However, substantial amounts (perhaps 150 tons) of these pollutants are stored in the effluent-related sediments on the Palos Verdes shelf. Relatively high levels of both DDT and PCB are still found in bottom fish taken in this area because of this persistence in the sediments.

Changes in wastewater composition

Each year, we summarize the reported quantity of flow, concentrations of possible pollutants, and mass emission rates of the large municipal waste discharges into the California Bight for the last calendar year. Comparing 1975 with 1974, the volume of flow is down 1 percent, and the amount of suspended solids is up 10 percent (much of the latter is the result of special, one-time situations). The mass emission rates of all metals except silver was down. Cadmium was reduced 6 percent; mercury 25 percent. Silver apparently increased 17 percent, but this may be a reflection of better measurements rather than actual increase. DDT continued to decline (down 6 percent) as did PCB (down 35 percent) but the latter also may partly be due to better sampling and analytical procedures.

Currents in outfall areas.

Subthermocline outfall wastes mix with deep sea water and generally move with the subthermocline currents. A continuation of our past measurements with current meters and drogues showed that these currents mainly flow alongshore parallel to the contours. The mean speed of currents observed at

outfall depths (independent of direction) is 9.8 cm/sec. Seventy-five percent of the kinetic energy in these currents is associated with driving forces of periods longer than the- tidal periods, such as the California Current. There is good coherence between the records of current meters placed 10 km apart, but poor coherence at 60 km, presumably indicating intermediate points of upwelling and/or horizontal cellular circulation.

Direct measurements of the velocity of water required to move sediments of various types were made by lowering an open-bottomed, clear plastic tunnel to the sea bottom and steadily increasing the water velocity within the tunnel by means of a variable-speed propeller while watching with a television camera. In outfall areas, sediments that are highest in organic material have both the lowest "initiation of motion" velocity and the lowest "resuspension" velocity, suggesting that they are reworked more frequently than natural sediments by waves that disturb the bottom at these depths.

We then estimated the percentage of time that such resuspension of effluent-related sediments by wave action might take place. For example, at a depth of 56 meters off Palos Verdes, resuspension—presumably followed by a slow drift to deeper water—may occur more than one-third of the year.

The sediment field off the end of Los Angeles City's 7-mile sludge outfall was resampled on a 400-meter grid in early 1976. The area we identified as having sludge-like characteristics covered less than 2 sq km. At three stations in the center of the sludge area, the bottom materials smelled strongly of hydrogen sulfide, and the metal and volatile solids levels were high. (On a trip in August 1976, this area seemed to have disappeared.) The number of species of benthic biota was about half those at the control sites, and there were about five times as many individual animals.

The sludge field in Santa Monica Bay.

Various forms of mercury have quite different toxicity, the organic varieties being the most dangerous. Last year, we reported that there are only very small quantities of organic mercury in the Palos Verdes sediments and that the total amount of mercury in the fish and other sea animals in the area is well below U.S. Food and Drug Administration guide-lines. This year, we have found that the major fraction of this low level of mercury in the muscle tissue of these animals is the organic type and that its quantity is in proportion to the amount of total mercury present in the same tissue.

Forms of mercury in marine animals and sediments.

The sediments off Palos Verdes now contain about 4 tons of mercury; this is a slight decrease since 1972, although the level in the effluent remains about the same. The highest level of organic mercury measured in the sediment is 0.021 ppb, dry weight. The quantities of other trace metals in these sediments are similar to those measured in 1972.

Changes in grain size of Palos Verdes sediments.

Studies of the size of the sediment particles in a 40-sq-km area of the Palos Verdes shelf at depths of 60 to 150 meters showed significant change from 1950 to 1973. In 1950, the clay-sized (very fine grained) fraction was less than 20 percent; by 1973, this had risen to more than 40 percent, and it had declined again to about 23 percent by 1975. The large, temporary increase in the clay fraction may have been caused by large quantities of organic

material in the water from both past and present outfalls, which bound clay particles together and caused them to settle in the area.

Survival of viruses in mussels.

We have been able to detect viruses in the ocean, capturing them and the associated coliform bacteria from the water near outfalls by means of filter-feeding mussels suspended from a buoy. The viruses survive three to six times longer in mussels than do the coliforms, which experience a 90 percent mortality in 1 to 5 hours.

Levels of mercury in mussels.

The level of mercury in a mussel's digestive gland changes with the levels in the water, thus reflecting the general environmental level. Analysis of adductor muscle and gonads gives a much more accurate indication of the permanent physiological incorporation in the animal. Chronic exposure to the water near one large outfall resulted in a gradual accumulation of mercury in the adductor muscle tissue of mussels suspended from a buoy.

Levels of metals in scallops.

The digestive glands, gonads, and adductor muscles of scallops that live in areas where the sediments contain high levels of metals generally reflect the levels of contamination Samples of scallops from the Palos Verdes shelf were compared with those from offshore island control stations. Increases in body burden of most metals were minor, but chromium in the muscle tissue of outfall area specimens was ten times greater than that in the control animals, and the gonadal tissue level was six times greater. Cadmium levels in the digestive and gonadal tissues of scallops from polluted sediment areas were depressed, an effect that may be caused by the presence of DDT.

Levels of metals and petroleum hydrocarbons around oil platforms.

Studies of metal levels in the bottom around oil platforms Hazel and Hilda showed these to be similar to average coastal values and well below those found near major municipal waste discharge areas. The only metal found at anomalously high levels in the three species of animals surveyed was vanadium in a rockfish. Ratios of vanadium to nickel are used to identify oils and since the nickel level in the fish was very low, the fish probably got the vanadium by eating small organisms that greatly concentrate vanadium from the water. In the sediments, only weathered oils were detected, indicating no recent spills.

Fin erosion disease in flatfish.

Fin erosion disease primarily affects Dover sole off Palos Verdes, but we now have found indications of the disease in 41 of 151 species examined over the past 3 years. In our laboratory, apparently healthy Dover sole were exposed to sediments contaminated with PCB, DDT, and metals taken from the Palos Verdes shelf; after about 1 year, symptoms of fin erosion disease were observed. Recent samples of fish taken off Palos Verdes showed no reduction in the percentage of disease in young fish (under 120 mm long) in spite of the dramatic reduction of hydrogen sulfide in the sediments. This seems to eliminate hydrogen sulfide as a possible cause of the disease (earlier findings eliminated bacteria and uptake of heavy metals).

Toxicity of chromium to marine life.

In establishing standards of discharge, it is useful to know the lowest level of trace element that causes undesirable effects to the most sensitive animal. In our chromium studies, we use the reproduction of a polychaete worm to explore the toxicity of very low levels of chromium. These small animals can

complete a reproductive cycle in 20°C water in 130 days, thus enabling us to extend an experiment over several generations. We have found no effect whatsoever of 10 parts per billion hexavalent chromium in three generations, and there is some indication that further experimentation may find the level of no effect to be slightly higher. In another study, large amounts of trivalent chromium precipitate, the most likely form of chromium discharged in the ocean, had no observable effects' on two generations of worms.

Subsequent experiments compared possible test organisms to determine the relative sensitivity of each. The polychaetes and brittle stars were the most sensitive animals tested, followed by shrimp and sipunculid worms. Since the number of viable offspring is probably the most meaningful toxicity test, and the polychaete is one of the most sensitive animals yet tested, this suggests that our chromium toxicity findings are realistic and conservative.

Speckled sanddabs were used to measure the reaction and uptake of hexavalent chromium in higher animals. After 44 days of exposure at 0.5 ppm, we could see no abnormalities in feeding behavior, reaction, or growth rate. However, in other experiments, chromium was found to accumulate in three organs of these fish at a rate proportional to the exposure concentrations. The effects of small accumulations of metals in body tissues of an organism is not known.

Undersea photography

Our belief that a great deal can be learned about the sea bottom and the animals that live there by observations with television and color photography has been reinforced by this year's successes. We have learned to "fly" the TV camera a short distance above a rough bottom and to inspect details of the bottom by means of a low-light-level camera with a zoom lens mounted on a pan-and-tilt unit controlled from the surface. Project biologists replay the tapes later to identify and quantify the animals seen. All persons who have viewed the tapes have a much clearer mental image of the operation of diffuser outfalls, the appearance of the bottom, and the nature of the sea life.

High levels of light achieved by a specially built strobe unit make it possible to take underwater color photos at high f-stops and high speeds. This means that even the subtle details of a mud bottom, with its tiny holes and animals that have partly buried themselves, can be recorded. A sequence of high-quality photos makes it possible to assess the marine life in an area and to study their environment in detail.

Life near offshore structures.

Studies on the fauna of two offshore oil platforms in the Santa Barbara Channel were completed. In the summer months, there are 30,000 fish around each platform—one-fourth of which are of suitable size for sport fishing. This number has been steadily increasing since the platforms were installed 15 years ago. These structures function as artificial reefs, providing complex hiding places, an increased variety of environmental niches, and a shady canopy. The vertical legs permit the diver-scientists to descend past several quite different layers of biota from the intertidal plants and animals at the surface to those on the bottom 33 meters below. There is far more life and more varieties of life around these platforms than lived on and above the soft bottom on which they were built.

Benthic grab sampling devices.

The old questions of how many replicates are enough and what depth samples are required were reconsidered for benthic grab samplers since this is one of the best ways of obtaining direct information on the response of animals to pollution. Last year, we reported our comparison of seven types of grab samplers and our finding that the chain-rigged Van Veen best met the established criteria. Since then, we have done additional biological/statistical work on groups of ten replicate samples from various kinds of bottoms; the study showed that 90 percent of the individual animals and 95 per-cent of the species are in the upper 10 cm of sediment. We now believe that--for many monitoring purposes--a single, properly taken Van Veen grab is adequate to account for the important faunal changes.

New key to shrimps.

Our taxonomic standardization group, recognizing that only about one-third of the local invertebrates are adequately described in the literature, has published a second volume of keys; this new book guides the identification of 76 species of shrimp. Some 250 biologists and over 100 organizations are now involved with us or have expressed interest in this work.

Changes in marine life near outfalls.

Since Orange County changed from a short to an extended out-fall a few years ago, we have studied the changes around both discharge sites. When discharge was abandoned at the old site, both the numbers of individuals and the number of species declined immediately; the decline has continued and the area now has the small populations characteristic of unaffected sediments. In the area northwest (down current) of the present discharge, we now find an increased abundance of animals (especially those that prefer organic material and nutrients in the water) and no decline in the number of species (197 taxa known). We have observed changes (but no ill effects) on the biota around this outfall.

Studies of the benthic infauna off Palos Verdes have been repeated along the 60-meter contour where the impact of the outfall is greatest. The change from 10-sq-km of anoxic bottom in 1973 to less than 2-sq-km in 1976 has had some important\effects on marine life. Five of the most pollution-tolerant animals (four kinds of worms and a small clam) have declined in numbers, while one new form (an echiuroid worm commonly called the sea grape) has greatly increased. Most of the other species present have not changed much over the last 7 years; the average number of benthic species found in each sample (30) remains at about two-thirds the number found in samples from control sites.

There are substantial changes in southern California waters from year to year as the currents shift, the kinds and numbers of incoming animals change, and the sea temperatures vary. In an attempt to learn more about the distribution of marine life and the effects of these natural changes, we examined the records of 2,400 trawl samples, mostly taken since 1957 in depths to 659 meters. About 200 species of fish and 400 invertebrates were identified. By far the largest number of individuals, the most species, and the greatest biomass were caught in the Palos Verdes/San Pedro Bay region. The years of 1971 and 1975 produced high catches; 1969, 1970 and 1973

catches were relatively low. The biomass of benthic invertebrate populations shows corresponding adjustments to ocean conditions.

Life history of the Dover sole.

The local life history of the Dover sole was reviewed. This species' main range is off the northern California coast where it is commercially important; southern California conditions are not optimal, and it does not seem to live as long nor grow as rapidly nor as large. The Dover sole spawns in very deep water from November to March, producing larvae that may remain in the planktonic stage for 9 months (and perhaps drift as much as 3,500 km). The growth rate of this fish is somewhat higher in coastal waters than around the Channel Islands, presumably because the nearshore food supply is better. Off Palos Verdes, where Dover sole are most numerous, they have a larger liver-to-body-weight ratio, presumably indicating a response to one or more pollutants.

Other findings are reported in the following papers. We have tried to present our year's work in a form that is understandable to the concerned citizen who is interested in protecting our coastal waters, while giving sufficient detail and documentation to convince the scientific reader of the validity of the work.

W.B.