BIOLOGICAL STUDY OF OIL PLATFORMS HILDA AND HAZEL, SANTA BARBARA CHANNEL, CALIFORNIA

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A final report to the Institute of Marine Resources, Scripps Institution of Oceanography, University of California, San Diego, January 1976.

SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT
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Institute of Marine Resources
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Prepared and Edited by
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Contribution No.65
Southern California Coastal Water Research Project
1500 East Imperial Highway, El Segundo, California

January 1976

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ABSTRACT

During 1975 scientists from the Coastal Water Research Project, Scripps Institution of Oceanography, and International Biological Consultants conducted a series of field surveys to document the diversity, health, and abundance of marine life around oil platforms Hilda and Hazel in the Santa Barbara Channel, California. Scientist-divers equipped with television and 35mm cameras documented the abundance and diversity of fishes and invertebrates at control sites as well as at the platforms. Samples of attached invertebrates, fish, benthic sediments, and infauna were returned to the laboratory for identification and chemical analyses.

The platform fauna was characterized by an abundance of fish (20,000 to 30,000 of over 45 species) and a heavy growth (up to four feet thick) of attached mussels, anemones, corals, starfish, bryozoans and other invertebrates on platform structures and cuttings piles (tailings). Benthic samples taken at one platform revealed a diverse polychaete fauna including a bed of Diopatra tube worms surrounding the cuttings pile. The polychaete fauna was enhanced in the direction of prevailing subsurface currents, suggesting biostimulation resulting from discharge of organic material from the platform organisms.

There were 20 to 50 times more fish under the platforms than at the soft bottom control area of comparable size, and species diversity was similar to a rocky (hard bottom) control site.

Metals and petroleum hydrocarbon levels in platform fish and invertebrates showed no increase over control animals except for vanadium in the rockfish. Petroleum hydrocarbon fractions in sediments were generally high relative to areas with no natural oil seeps, however the hydrocarbons measured were identified as highly weathered natural seep oil indicating no recent contamination. There also were slight elevations in sediment zinc and hydrocarbons below the towers.

No adverse effects on the fauna were observed; the high abundance of fish and the huge mussels suggest that the platforms are beneficial. Future studies should determine the contribution of oil platforms to productivity in local waters.

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ACKNOWLEDGEMENTS

This report was prepared and edited by Dr. Alan Mearns, with Mr. Michael Moore and Willard Bascom, Director, Southern California Coastal Water Research Project. We appreciate the contributions made by various Coastal Water Research Project staff members including: Mr. Harold Stubbs (Marine co-ordinator); Jack Word, Brad Myers, and Leslie Harris (benthic and invertebrate biology); Jim Allen (fish biology); Deirdre McDermott and Dr. David Young (co-ordinators of chemical studies); Henry Schafer, Tsu-Kai Jan, Pat Hershelman, and Ted Heesen (chemical analyses), and Dr. Tareah Hendricks (currents).

We also thank the following individuals for their efforts: Dr. Arthur Wolfson (Marine Biologist, International Biological Consultants), George Alexander (trace metal analyses, University of California, Los Angeles), Glenn Von Blaricom and Noel Davis (Marine biologists, Scripps Institution of Oceanography) and J.S. Warner (Battelle Memorial Institute, Columbus, Ohio).

Special thanks go to Mr. Bob Evans, diver, photographer, and boat operator, for providing exceptionally fine marine life photographs, and to Mr. Jack Carlisle, California Department of Fish and Game, for his interest and concern with this work.

This work was supported by a contract from the Institute of Marine Resources, Scripps Institution of Oceanography, La Jolla, California, through a grant from the American Petroleum Institute.

I. INTRODUCTION

Fishermen and marine scientists alike are quite aware of the abundant marine life associated with natural and artificial structures placed on and above the sea floor. In fact, many state and federal agencies are now spending large sums of money to improve fishing success through manipulation of natural habitats (reefs, kelp beds, etc.), and through installation of artificial structures and reefs. Offshore oil platforms, while not originally designed for the purpose, are also now being reexamined as a multi-use resource (e.g., fishing, mariculture and oil production, Shinn, 1974).

Despite these activities, marine scientists still know relatively little about the real ecological changes associated with submerged oil platforms. How stable are the fish and invertebrate populations that live on and under such structures? Are sea food organisms safe to eat or are they accumulating potentially toxic materials in their tissues? How does the abundance and diversity of the platform fauna compare to similar areas away from the platforms and to other well-studied types of artificial reefs? And, to what extent, if any, do such platforms actually contribute to the productivity of local waters?

Early in 1975, the American Petroleum Institute awarded a grant to the Institute of Marine Resources, Scripps Institution of Oceanography, La Jolla, California, to help answer some of these questions for producing oil platforms in Southern California. This report summarizes the results of a series of field surveys and laboratory analyses made at platforms Hilda and Hazel in the Santa Barbara Channel, during the period February to September, 1975.

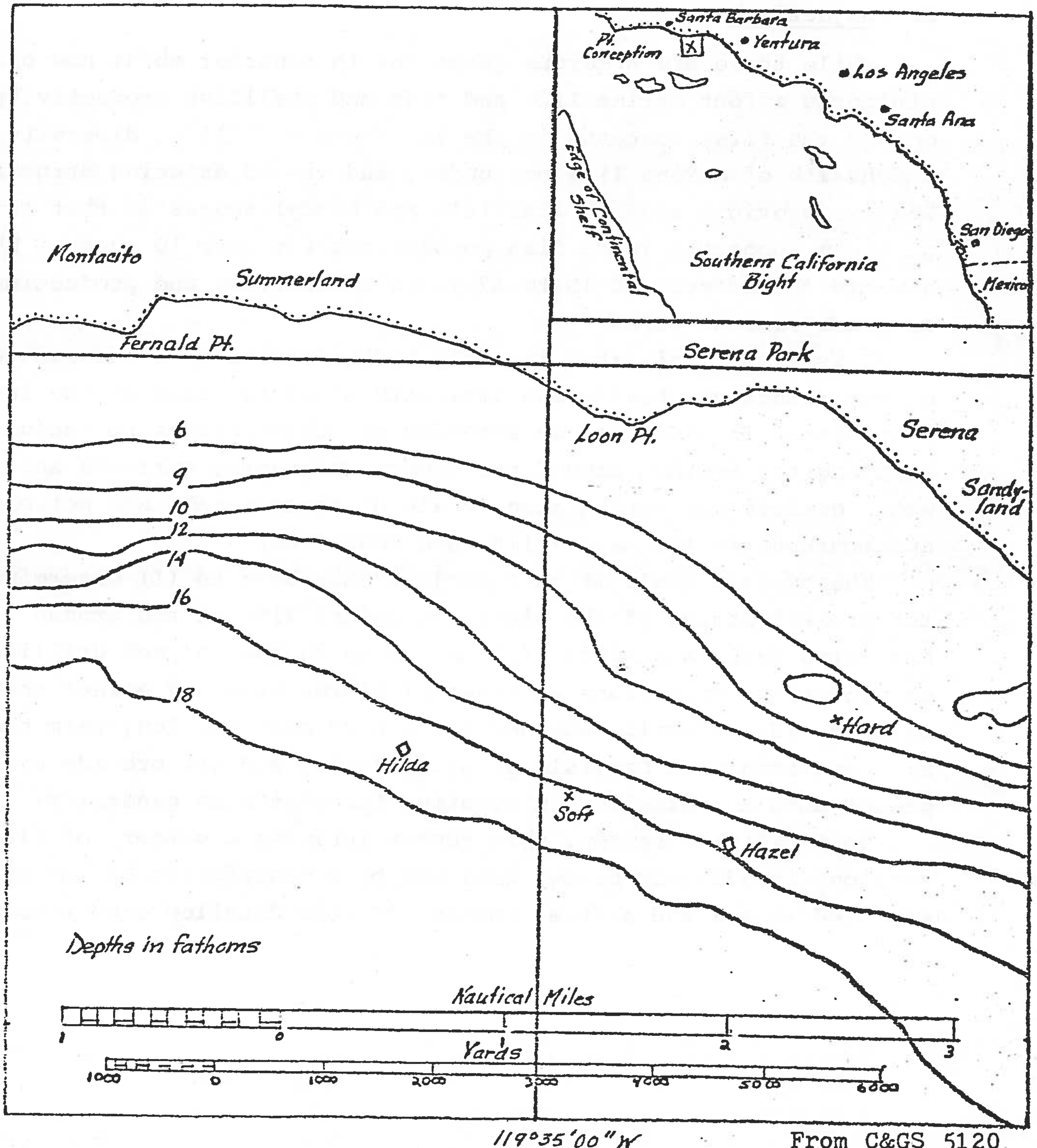
A. Background and History of Hilda and Hazel

Platforms, Hilda and Hazel, were installed by the Standard Oil Company of California in 1958 and 1960, respectively. The platforms are 1½ miles apart, and are about 100 ft. square and constructed of steel tube legs. They are located two miles offshore in about 100 feet of water (Figure I). Drill cuttings and mud formed a pile on the bottom underneath each tower. No special precautions were taken at the time of installment. Twenty-five wells have been drilled from Hazel with eight now producing 290 bbls/day 28-40 API gravity. Twenty-four wells have been drilled at Hilda of which seven are now producing 318 bbls/day 28-40 API gravity.

Shortly after installation of the platforms, a team of biologists of the California Department of Fish and Game, lead by Mr. Jack Carlisle (Carlisle et al., 1964) studied the biological effects of the platforms and the new substrates by diving every month. Fish counts and biological collections were taken over a 29 month period. Carlisle found that the number of fish under platform Hazel stabilized at around 6,000 fish, after a temporary peak at 62,000 caused by an increase in the number of sea perch and schools of transient pelagic fish. He reported 47 species of fish, 40 species of invertebrates and 14 species of algae giving accumulative total of 101 species attached to or adjacent to the platforms. Carlisle also noted that the cuttings piles generally had few marine organisms associated with them.

In a short-term diving survey of platforms Hazel and Hilda (two divers under each platform) in August of 1970, biologists from the California Department of Fish and Game estimated a total number of fish under platform Hilda as over 12,500 and that of platform Hazel as over 18,000 (Robert Hardy, C.D.o.F.& G., pers. comm.,1975), significantly higher than what Carlisle found in 1960.

Despite the numerous and intensive surveys of the 1969 Santa Barbara Oil spill (e.g., National Science Foundation, 1970; Straughan, 1971 and Ebling et al., 1971) or more recent studies (e.g., Dames and Moore, 1974) none of these have substantially addressed the resident platform fauna or changes that may have affected them.



From C&GS 5120
(N.O. 18304)

Figure 1
Location of oil Platforms Hilda and Hazel and control sites (soft and hard) in the Santa Barbara Channel, California.

B. Objectives

While there are numerous questions to consider about how oil platforms affect marine life and fish and shellfish productivity, one of the first concerns is the long-term stability, diversity, and health of marine life on, under, and around existing structures. The two previous studies (Carlisle and Hardy) suggested that the platform supported large fish populations for over 10 years. What now are the effects of 15 to 17 years of drilling and production on nearby marine life?

This study, initiated in early 1975, focused on a reassessment of the abundance, health and diversity of marine life at the two platforms. In addition, we extended our observations to include sampling the benthos around the towers, measuring currents and water quality and determining levels of trace metals and petroleum hydrocarbons in the marine life and sediments.

The overall goals of this project have been to (1) determine the present status of the plant and animal life on and around platforms Hazel and Hilda, (2) determine whether or not drilling or production operations at these platforms have any effect on the animals, (3) determine whether there have been any long-term changes by comparison with Carlisle et al., (1964), and (4) provide background data and baseline information for platforms generally.

To facilitate review, this report includes a summary of findings section (immediately below) followed by a description of the methods employed at sea and a final section of more detailed data results.

II. SUMMARY OF FINDINGS

During 1975, diving and remote sampling surveys were made of life under, on and surrounding the platforms and at several control sites including: (1) A soft mud bottom at the same depth midway between the two towers, (2) a hard-bottom (rocky reef) about one mile inshore of Hazel at a depth of 60 ft, and (3) a well-head at a depth of about 70 ft. Grab samples and cores were taken in and away from the cuttings piles and samples analyzed for polychaete diversity, trace metals, and petroleum hydrocarbons. Fish and invetebrate samples were also collected and analyzed for metals and hydrocarbons. Data on water depth, temperature and dissolved oxygen were taken, along with current measurements, measurements of fallout rate of organic detritus on the bottom, and plankton samples were obtained. Scientist-divers visited the platform and control sites on April 14-30, June 2-5, June 24-25, July 18 and September 19-21, 1975.

A. General Condition of Sea Life.

At least 290 species of invertebrates, fishes, birds and mammals were observed on, under and surrounding the oil platforms (Table 1).

The sealife under and around the towers was abundant and healthy. In general there were 20 to 50 times the number of fish under the towers compared to the soft bottom control, midway between the two towers, and 5 times the number of fish found at the rocky bottom control. There also appeared to be larger-than-normal seastars, mussels, and pile perch. In addition almost every available surface had mussels, aggregate anenomes, or other sealife attached, with fish lying on, hovering outside of, or feeding upon attached and drifting organisms. Thus, the amount and variety of life under the platforms was many times higher than on either the soft or hard bottom controls.

B. Abundance of Fish Populations

The Coastal Water Project's fish census ranged from 10-15,000 total fish (April survey) to 20-30,000 total fish (June and August surveys under each platform; this represents an increase of as much as 500% above the stabilized population of 6,000 that Carlisle et al

Table 1 Summary of plants and animals observed on, below, adjacent to, or within sight of oil platforms Hilda and Hazel, Santa Barbara Channel, California 1975.

	Number of Species Observed in		
Taxonomic Group	Field	Lab	Cumulative Total
Algae	6	4	9
Protozoa (inc. Forams)	0	3	3
Porifera (sponges)	0	4	4
Cnideria (Coelenterates)	16	6	21
Ctenophora (Comb jellies)	1	0	1
Nematoda	0	1+	1+
Nemertea	0	1+	1+
Ectoprocta	5	10	12
Mollusca (snails, clams, nudibranches)	22	10	26
Annelida (Polychaetes)	2	6+77*	8+77
Arthropoda (Barnacles, crabs, etc.)	12	27	37
Echinodermata (Stars, Urchins,etc)	11	0	11
Tunicata (Tunicates)	2	0	2
Elasmobranchs (Sharks)	4	-	4
Fishes	45	-	45
Birds	24	-	24
Mammals	4	-	4
Total			290

* 77 Infaunal polychaetes from Hazel grab samples

Note: The above 156 plants and animal species listed are directly associated with the towers and their tailings piles (8 algae, 110 invertebrates and 46 sharks and fishes)

(1964) found, but only slightly more than the abundance as observed by Hardy in 1970. These estimations were made by averaging the estimates from all divers on all dives from each survey as Carlisle et al., and Hardy et al., had done in their surveys. The Coastal Water Project's biologists also made total population estimates using the 35 mm slides and television footage and these estimates compared quite favorably with the population estimates above. Because no distinct difference was observed between platforms Hazel and Hilda in either species composition or population, the above estimate applies to either one.

Fish abundance was also estimated for the soft bottom control and the hard bottom control by the same methods. Considering an area approximately the same size as the platforms the soft bottom and hard bottom control had an estimated total fish population of 100-500 and 2,000-5,000 respectively.

C. Biological Conditions of Benthic Environment

The soft bottom control site and the bottom area beyond the cuttings pile represent the original bottom before platform installation. The few fish and invertebrates observed at these locations were what would be expected on a silty clay bottom: Ceranthid (burrowing) anenomes, seapens, tube worms and occassional gorgonian corals (attached to rocks and mud clumps). Speckled sanddabs were the most common fish.

Measurements of benthic polychaetes living near Hazel indicate that a bottom area of over 15,000 sq. m (0.015 sq km) had an enhanced abundance of filter feeding polychaetes; this "enriched" zone occurred west by northwest of Hazel in the same direction as prevailing subsurface currents. This observation may indicate that organic wastes produced by Hazel's fish and invertebrate community are enhancing benthic productivity in an area about ten times the area of the platform.

D. Trace Metals and Petroleum Hydrocarbons in Sediments and Marine Life

Nineteen fish, invertebrates and sediment samples were analyzed by Battelle Memorial Institute for petroleum hydrocarbon residues. The fish (white belly rockfish and brown rockfish) samples were collected from the two platforms and from the soft and hard control sites. California mussels from Hazel and Hilda, sediment from Hazel, Hilda, and the soft bottom control, and yellow crabs from all four sites were also analyzed. Petroleum hydrocarbon analyses showed no evident enhancements in animals around the platforms. Sediment hydrocarbons were typical of highly weathered oils including weathered natural seep oil from the Santa Barbara area.

Two hundred and thirty-two tissue samples from a variety of fish and invertebrates were analyzed for trace elements (Ag, Al, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Si, Ti, V, Zn) by Dr. George Alexander, UCLA, using arc emission spectroscopy. These samples yielded 5800 trace element values.

With the exception of vanadium, metals concentrations in the various organs of fish and invertebrates showed no significant increase above background. Likewise, sediments beyond the platform cuttings piles had normal background levels of zinc, copper, volatile solids and hexane extractable material. Immediately below the platform structures, these materials did show increases above background

F. Conclusions and Implications

These platforms appear to act not only as a reef (a hard substrate), but also as an island (extending from the bottom to the surface in the open ocean), and a canopy (providing shade for fish to hide beneath). Whether the towers act mainly as an attractor or a concentrator and/or a breeding habitat remains to be seen, but the structure itself clearly enhances the typical mud bottom by providing these facilities. Thus we believe platform structures are a good place for marine animals to live. They are not damaged by oil activities and probably this concentration of sealife is beneficial to the general marine community. However, until studies are made of animal growth rates, larval productivity, and upstream-downstream effects, we cannot be certain. It would be wise to use this descriptive and numerical study as a foundation for future work that would settle the question of the extent to which platforms are a source of new life or if they merely collect animals from the surrounding waters.

III METHODS

A. How Work was Done at Sea

The M/V Haik, a 33 ft commercial lobster and abalone boat converted for research work (owned and operated by photographer-diver Bob Evans) was used as the support vessel for all field work.

During 1975, diving and remote sampling surveys were made of life under, on and surrounding the platforms and at several control sites including: (1) A soft mud bottom at the same depth (eg; 100 ft) midway between the two towers, (2) a hard-bottom (rocky reef) about one mile inshore of Hazel at depth of 60 ft, and (3) a well-head at a depth of about 70 ft. (Figure 2). Grab samples and cores were taken near and away from the platforms according to the station and transect plan shown in Figure 2. These samples were analyzed for polychaete diversity, trace metals, and petroleum hydrocarbons. Fish and invertebrate samples were also collected and analyzed for metals and hydrocarbons. Data on water depth, temperature and dissolved oxygen were taken, along with current measurements (Figure 2), measurements of fallout rate of organic detritus on the bottom, and plankton samples were obtained. Scientist-divers visited the platform and control sites on April 14-30, June 2-5, June 24-25, July 18, September 19-21, and September 29-30, 1975. Sampling is described in more detail below.

A.1 Water Column Measurements

A.1.a Temperature and Dissolved Oxygen. On 14 April 1975, a preliminary water quality survey was conducted at both platforms and the soft bottom control site to determine if there were any major patterns that might be related to the platforms. One liter water sampling bottles were attached above a 450 ft. bathythermograph (BT) to sample water at 0, 50 and 100 ft. depths. Samples were taken at Hazel and Hilda stations West-1, West-9, East-1 and East-9 (Figure 2) and at the soft bottom control. A previously calibrated YSI D.O. meter was used to measure dissolved oxygen concentrations. Temperatures profiles (at 10 ft. intervals) were plotted from BT slides.

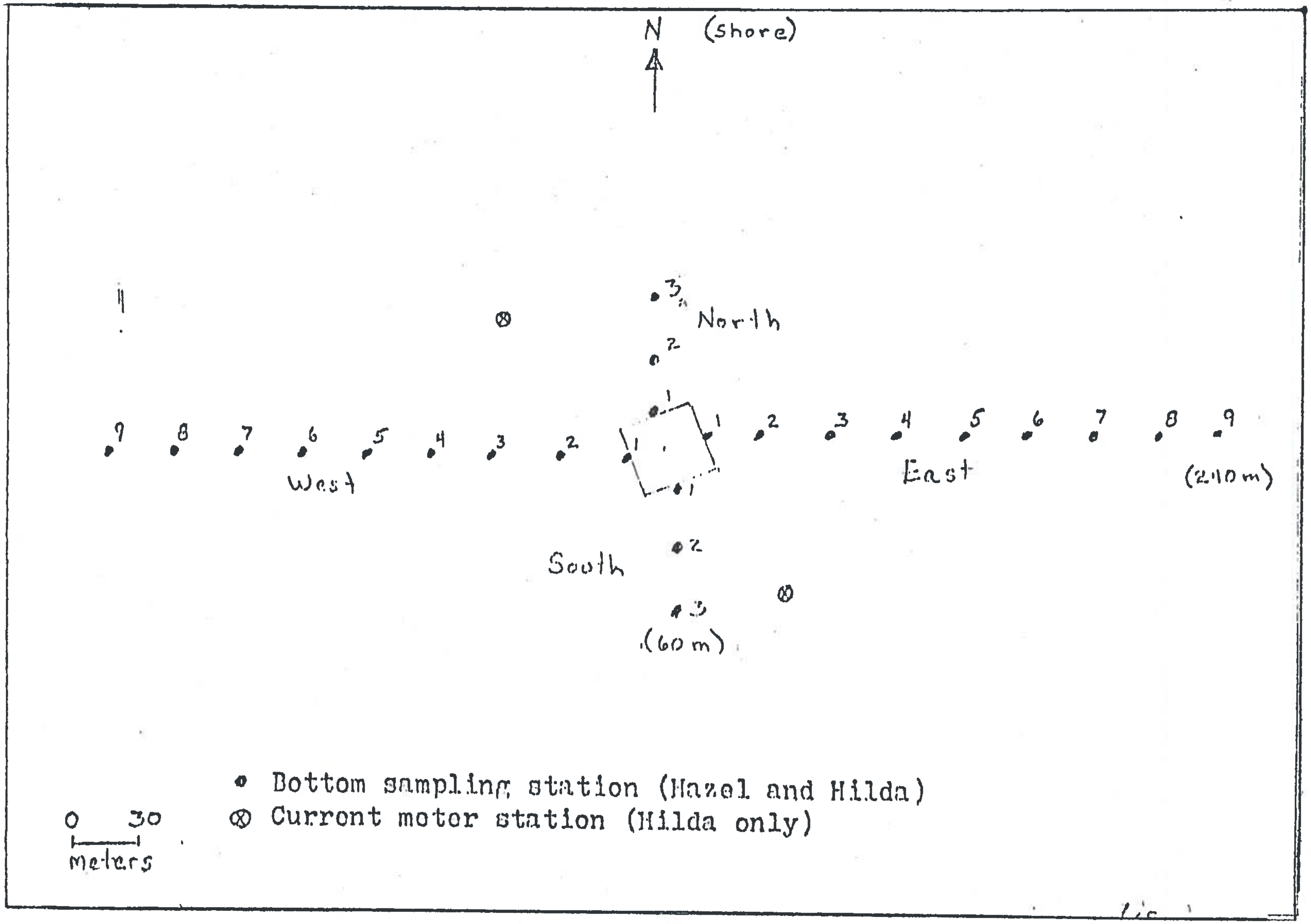


Figure 2. Schematic station plan for water column and bottom sampling around oil platforms Hazel and Hilda. Each platform is approximately 30 x 30 m and not oriented to true north. Stations are oriented to magnetic compass directions and spaced at 30 m intervals to 60 m (North and South) or 240 m (East and West)

A.1.b Plankton Tows. Several plankton samples were taken around platform Hilda and the soft bottom control site on 30 September, 1975, to observe any gross differences. A 153 micron, .25 m net was used to take four vertical tows (100 ft. to the surface) near station Hilda West-2, North-2, East-2 and South-2 (about 100 ft. from the platform, Figure 2), and one tow at the control site. After washing plankton trapped on the net, the contents of the 1 liter collection jar were preserved in 10% borax buffered formalin and returned to the laboratory.

In the laboratory, settled volumes were measured using 10 ml graduated cylinders and subsamples examined under a dissecting microscope for enumeration of dominant organisms and material.

A.1.c. Currents. Platform Hilda was selected as the site for current measurements beginning 18 July, 1975. We used two General Oceanics Model 2011 meters. The meters were set to record flow and direction at 15 min. intervals. They were then tied off to the platform by a diver, one to the northwest of the northwest leg and the other to the southeast of the southeast leg (Figure 2). Once attached, the meters were towed 75 m from the tower; anchors were lowered to the bottom and the meters were held in place by submerged buoys. The meters were finally located 7 m above the bottom.

After 32 days (17 August) the meters were recovered and the films inspected. Film from the southeast meter showed an erratic pattern and were not analyzed. However, 30 days of records were obtained from the northwest meter and this data was analyzed for longshore and onshore-offshore transport at 45 min intervals by Dr. Tareah Hendricks.

A.1.d. Fallout Collectors. Fallout material settling around the towers was measured using sediment collectors with a 0.1 m square surface. These collectors were placed on the bottom at five different sites; 300 m east and west of Hazel; 300 m east and west of Hilda and at the soft bottom control. These sediment collectors had a plastic meshed top with a funnel leading to a one liter jar with the top being approximately four feet off the bottom.

The four sediment collectors around the towers were lowered to the bottom, 300 feet east and west of each tower and tied off to the tower at the 30 feet level. This procedure avoided the use of floats which might be damaged by vessel activity. The five sediment collectors were in place for 23 days at which time the reverse procedure was used to make the recovery.

The one liter jars containing the trapped sediment and larval shrimp were then put in an ice chest for later analysis of volatile solids, total carbon and B.O.D. in our laboratory. The larval shrimp were identified and counted.

A.2 Marine Life Observations

A.2.a. Video Tape Observations. Underwater television equipment designed to operate at depths to 350 m and to present high quality pictures at light levels as low as 10 foot-candles was used to record marine life activity at each site. A hand-held Jaymar 1000 camera was connected to RG-54 coaxial cable and to a Shibaden monitor with a real-time resolution of 600 lines. Taping was done using a Shibaden 1100 half-inch video recorder which effected a drop in resolution to 300 lines.

Diver/photographer Bob Evans descended with the TV camera and recorded several hours of tape of fish and invertebrate activity during both day and night at Hilda and Hazel. Additional footage was made at the soft bottom control and the hard bottom control sites.

Tapes were run and re-run several times at the laboratory with Project biologists taking notes on species, activity and making abundance estimates.

A.2.b. Photography. Robert Evans shot over 240 color slides (Nikon F camera, Nikkor 24 and 55mm lenses) of the topside operation and subsurface structures including closeups of the flora and fauna attached to, and swimming beneath, both Hazel and Hilda. The slides were used to help identify some of the fauna observed while diving. They also proved useful in estimating the number of fish under and around the platforms. An additional 70 color slides of the soft bottom and hard bottom control sites were obtained and were used to compare the flora and fauna with those associated with the towers.

A.2.c. Direct Measurements and Observations by Divers. A total of 92 dives were made by Noel Davis, Glen Von Blaricom, Dr. Arthur Wolfson, photographer Bob Evans, Harold H. Stubbs, and Michael D. Moore.

The diving surveys provided the majority of the biological data for this project. A complete floral and faunal species list from the surface to the bottom and out away from the cutting pile was assembled from field records of all dives. This effort resulted in a depth-related fish species chart and estimates of total number of fish made both by direct observation and by actual counts in hypothetical cubes (30 ft on a side) and extrapolating for the remaining volume beneath each tower. Measurements of the mussels shell depth at the edge of, and overlying, the cutting pile was made by digging until rock chips were found. Estimates of the thickness of growth of marine life on legs of Hazel were made at several depths by pulling away growth and measuring thickness directly. Circumference measurements were also made at intervals of five to ten feet to test what might be a more rapid method of estimating thickness and mass of attached fauna.

In addition to the submerged marine life, biologist Michael Moore also recorded birds, mammals and fish observed within sight of the vessel at the platform and control sites.

A.2.d. Fish and Invertebrate Collections. Samples of fish and invertebrates were collected from both towers and control areas for laboratory analysis of petroleum hydrocarbons (PHC) and trace metals. Hook and line gear was used to capture white belly rockfish (*Sebastes vexillaris*) and the brown rockfish (*S. auriculatus*) from Hazel and Hilda and the hard bottom control area. These species were not present at the soft bottom control site. California mussels (*Mytilus californianus*) were collected from the two platforms and yellow crabs (*Cancer anthonyi*) from all four stations.

The fish and invertebrates were packaged in plastic bags for the trace metals analysis and in aluminum foil for the P.H.C. analysis. These specimens were then immediately frozen and kept frozen until the dissection for the analyses. The trace metals were analyzed by Dr. George Alexander, University of California at Los Angeles, and petroleum hydrocarbons by Battelle Memorial Institute, Columbus Ohio as described in Section III.B., below.

A.3 Benthic Sampling and Sites

The Coastal Water Project's modified Van Veen grab ($0.1m^2$ surface area) was used to sample the bottom at 53 different stations surrounding the two platforms and the soft bottom control. This grab was modified so that the top could be removed to subsample the undisturbed surface sediment to take a sub-core for various chemical tests.

After sub-coring approximately 100 gm sediment and recording color, consistency and odor, a volume measurement of the remaining sample was taken and the sediment was screened through a 1.0 mm mesh. Retained animals and tubes were placed in labeled jars and preserved in 10% borax buffered formalin for sorting and identification in the laboratory.

Single benthic grab samples were taken at 30 meter intervals on transects out to 240 meters from the platforms (Figure 2). A line knotted every 30 meters was tied to the platform and the designated transect course using the boats compass was taken until the 300 meters were run. At this spot an anchored buoy was lowered so that we would have a sight heading. We then returned to the tower and headed for the buoy stopping every 30 meters to take a bottom sample. This method was used on both towers and all transects. Transects were oriented to magnetic compass headings (N, E, S, W) and were therefore not necessarily square with the tower. At the control station we lowered an anchored marker buoy, took a benthic grab and tied the knotted line to the buoy. We then ran the designated course being careful not to drag the buoy, stopping at the 300 meter knot to take a benthic grab sample at each of four stations surrounding the buoy.

In all, 24 sites at each tower plus five sites at the control area were sampled and subsampled as described above. However, not all samples were completely analyzed. Analyses of benthic infauna (polychaetes) and sediment metals, hexane extractables, volatile solids and petroleum hydrocarbons were first done on a few adjacent and distant samples; additional samples were processed and analyzed only if the preliminary analyses revealed trends or gradients which needed further clarification.

B. How Work was Done in the Laboratory

B.1 Chemical Analyses of Marine Animals

B.1.a. Sample preparation. Previously frozen specimens of fish and invertebrates were removed from the freezer and allowed to partially thaw at room temperature. Two animals were dissected and composited for each petroleum hydrocarbon (PHC) sample to insure enough tissue for analysis. Dissections of animals for PHC analyses were performed on acetone-cleaned aluminum foil using carbon steel and stainless steel instruments. Tissues dissected included: The liver tissue from the white belly and brown rockfish collected from Hazel, Hilda and the rocky control; muscle tissue from yellow rock crabs, *Cancer* anthonyi, found at Hazel, Hilda and both the rocky and soft controls; and the whole soft tissues (excluding byssal fibers) of the intertidal mussel, *Mytilus californianus*, collected from Hazel and Hilda. The excised tissues were placed in glass jars with aluminum foil-lined lids. The jars had been heated in a kiln at 538°C (1000°F) overnight to volatilize any interfering organic compounds from their surface. The 12 tissue composites were placed in the freezer until packed in dry ice and shipped to the Battelle-Columbus Laboratories for PHC analysis.

Individual specimens were dissected for trace metal analysis and the muscle, kidney, gonad and liver tissues excised whenever possible. The dissections were performed on partially thawed animals placed on acid-cleaned teflon sheets using carbon steel and plastic instruments. The 232 tissue samples were placed in acid-cleaned plastic jars with plastic lids and stored in the freezer until they were removed for freeze-drying prior to trace metal analysis by George Alexander at the School of Nuclear Medicine and Radiation Biology, University of California, Los Angeles.

B.1.b. Petroleum Hydrocarbon Analyses. (J. Warner, Battelle Columbus Laboratory). The tissue samples were digested with caustic, extracted with ether, and the ether extracts cleaned up and fractionated by silica gel chromatography. Three hydrocarbon fractions were obtained a paraffin hydrocarbon fraction (Fraction 1) and two aromatic hydrocarbon fractions (Fractions 2 and 3). The monoaromatic and most of the diaromatic hydrocarbons occur in Fraction 2. Most of the 3-to 7-ring polycyclic aromatic hydrocarbons occur in Fraction 3. Biogenic olefinic hydrocarbons also occur in Fractions 2 and 3. The biogenic hydrocarbons can generally be distinguished from petroleum hydrocarbons by their GC distribution pattern. Values were obtained for total C_{10} to C_{35} hydrocarbons in each fraction at levels above 5 μg/g (wet weight) and for individual hydrocarbons at levels above 0.1 μg/g provided at least 10 g of sample was available and there were no major interfering compounds.

B.1.c. Trace Metal Analysis (G. Alexander, University of California, Los Angeles). The freeze-dried samples were stored in polystyrene vials until analysis. Graphite electrodes were packed with 10 ± 2 mg of dried tissue and analyzed directly by an optical emission spectrographic procedure capable of the simultaneous determination of 25 elements frequently present in these tissues, (Ag, Al, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Li Mg, Mn, Mo, Na, Ni, P, Pb, Si, Sn, Sr, Ti, V, Zn).

B.2 Chemical Analyses of Sediments

B.2.a. Sample Preparation. The samples for PHC analysis were removed from the freezer, packed in dry ice and shipped with the tissue samples to Battelle-Columbus Laboratories The 29 sediment samples for trace metal analysis were removed from the freezer and allowed to thaw prior to trace metal analysis in the Project's laboratory.

B.2.b. Petroleum Hydrocarbon Analyses (J. Warner, Battelle-Columbus Laboratory). The sediment samples were extracted with carbon tetrachloride and the extract analyzed by a procedure similar to that used for the tissue samples. Elemental sulfur, frequently present in sediment samples, interferes with the analyses and was therefore removed by treatment of the extract with freshly activated electrolytic copper.

In addition to the GC analysis of the sediment samples, the carbon tetrachloride extracts were analyzed by infrared (IR) spectrometry by measuring the methylene absorption to determine the "total carbon tetrachloride extractable organic matter". This method, unlike the GC procedure measures all petroleum components including the asphaltenes. Since the extract also contains any fatty materials present in the sediment as well as hydrocarbons, an indication of the proportion of nonhydrocarbon material present was determined by also measuring the carbonyl absorption. The total carbon tetrachloride extractable organic matter was also determined gravimetrically by evaporating the solvent from an aliquot of the extract and weighing the residue on a microbalance. Similarly the residue from each of the three silica gel fractions were weighed as a check on the total hydrocarbon values found by gas chromatographic analysis.

B.2.c. Trace Metal Analysis (T. K. Jan, SCCWRP). All reagents were AR grade. Commercial deionized water was used for the cleaning of laboratory ware and preparing reagents. The standard solution was prepared by the dilution of 1000 ppm stock solution supplied by Varian-Techtron in deionized water.

Approximately 2 g of wet sediment was weighed into a 150-ml beaker. Ten ml of 1:1 nitric acid solution was added and the sample was digested on a hot plate until there was about 3 ml residue remaining. Another 10 ml of 1:1 nitric acid solution was then added and the digestion was continued. This procedure was repeated until the solution became clear. Then 20 ml of deionized water and about 20 drops of concentracted HCl were added to the residue and the mixture was boiled for 20 minutes and allowed to cool. The sample was filtered through a Whatman #40 filter paper to remove any residues and was diluted to 100 ml.

The digested sample was aspirated into an air-acetylene flame and the concentration of trace metal was determined against standards. A Varian-Techtron atomic absorption spectrophotometer model AA-6 was used for determination of copper and zinc.

B.2.d. Volatile Solids and Hexane Extractables. Measurements of volatile organic matter and hexane extractable matter were made to observe any gross trends in sediment organic content that might be associated with the platforms. Volatile solids were measured by a method modified from Standard Methods (1970). One-gram of wet sediment was placed in a tared beaker and dried to constant weight at 80°C (24 hours). After cooling the beaker was placed in a mufflefurnace at 550°C for 1 hr, cooled and reweighed. The weight differences was expressed as per cent volatile matter on a dry weight basis. A correction for volatile salts was made by subtracting (.035 x % water x 0.14) from the original difference.

Hexane extractable material was analyzed by drying 20 gm sediment at 80°C to constant weight (24 hr), placing material in a soxlet thimble and extracting in condensers with hexane for 3 hrs. (boiling). Hexane was roto-evaporated and the flash weighed. The difference between tare and final weight was expressed as HEM (hexane extractable material) in mg/kg dry weight.

B.3. Biological Analyses

B.3.a. Benthic Grab Animals. Screened material from the fifty-three benthic grabs returned to the lab, sorted to major taxonomic groups by Marine Biological Consultants, Inc., and returned to the Coastal Water Project for indentification and analysis. Due to time and cost restrictions, fifteen of these samples were selected for detailed enumeration of the benthic polychaete fauna; polychaetes were chosen as a first priority since previous experience (SCCWRP, 1973) indicated they were reliable indications of the health of the benthic community. Fourteen stations surrounding Hazel and one control site sample were thus analyzed.

B.3.b. Attached Fauna. Dr. Arthur Wolfson and Terrance Parr of International Biological Consultants identified the fauna associated with mussel clumps obtained from Platforms Hazel and Hilda from 10-30 foot depths.

IV RESULTS

This section presents a detailed account of the conditions of the water and marine life at the oil platforms and control sites. A brief summary of sampling effort and environmental conditions (below) is followed by detailed observations on water quality fish and invertebrate communities and the results of other chemical measurements.

A. Sampling Effort

A total 92 individual dives (almost 32 hours) and 24 ship days were devoted to observing and sampling marine life, sediments and water between mid-February and 30 September, 1975. The number of dives at each site were: Hilda, 50; Hazel, 28; Hard Control, 4; Soft Control, 6; Well-Head, 4. Most of the dives were devoted to biological observations and collections. Dates of specific additional sampling are cited below where appropriate.

B. Characterization of the Water Column

B.1 Sea State and Visibility

Sea state was calm (1-3 ft swell) on most occasions, with west winds ranging from 4 to 20 knots. Water visibility from the surface ranged from 6 to 40 ft. Visibility was lowest during several days in June and highest in April. Seasonal trends were not readily apparent.

B.2 Temperature and Dissolved Oxygen

A detailed series of temperature and oxygen measurements of the two towers and the soft control site on 14 April 1975 revealed a stratification typical for the coastal shelf (Figure 3). Surface temperatures averaged 56°F dropping to 52.8°F at 100 ft. Dissolved oxygen followed a similar trend; averaging 8.9 mg/l at the surface, 8.4 mg/l at 50 ft. and 7.9 mg/l at 100 ft. Surface, 50 ft, and bottom water oxygen values were slightly higher east of the towers than west (variance about 0.1 to 0.2 mg/l).

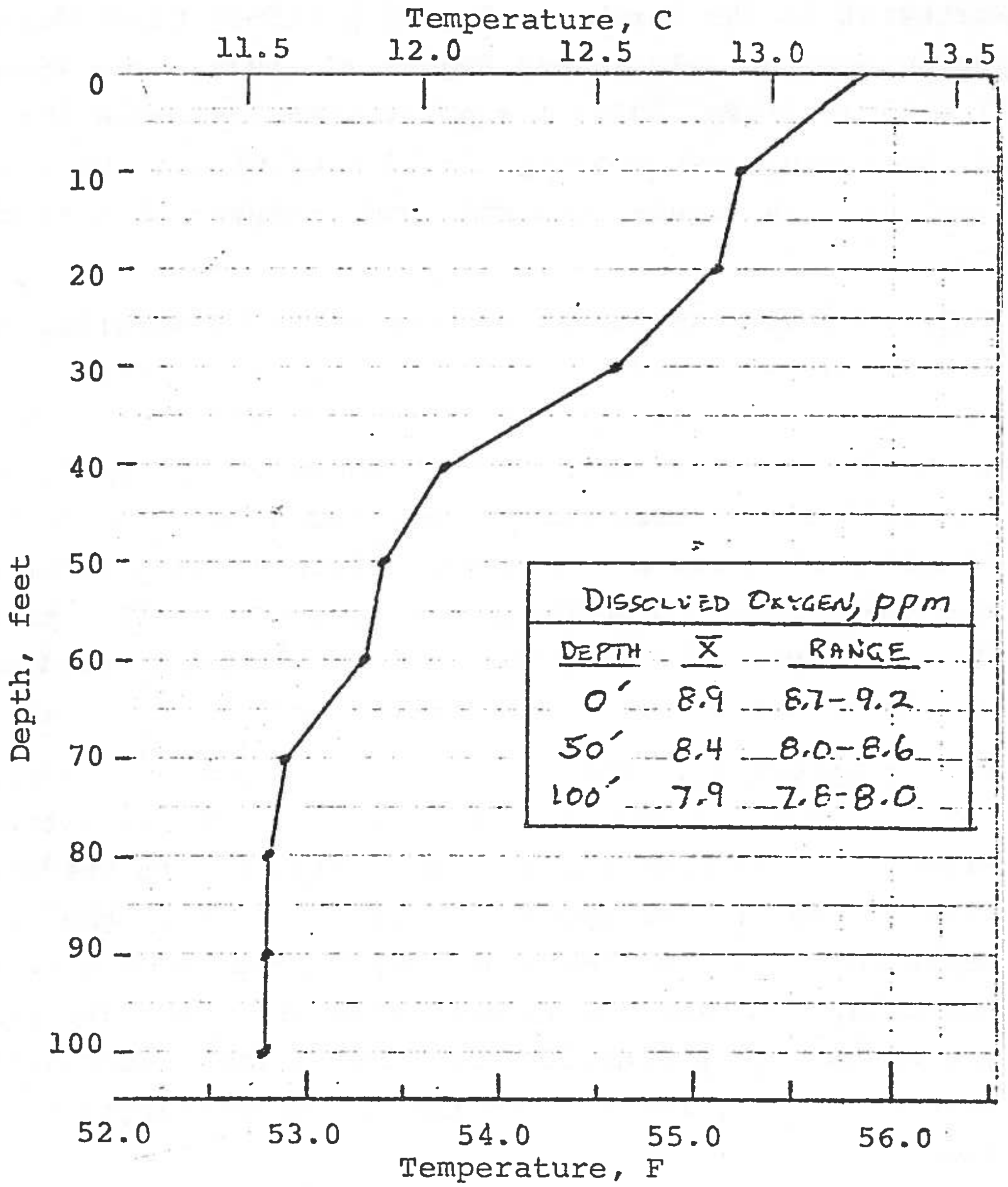


Figure 3. Average temperature profile and dissolved oxygen data for oil platforms Hilda and Hazel, Santa Barbara Channel, 14 April 1975.

B.3 Current Measurements

Current measurements were made at a location 75 m to the Northwest of the Northwest leg of platform Hilda during the period between July 18 and August 17, 1975. The General Oceanics meter (Model 2011) was positioned 7 m above the bottom, on a taut line mooring, in 20 m of water. Data was collected at a 15 minute interval, and analyzed at a 45 minute interval.

B.3.a. Speed. Speeds during the month of sampling ranged from a low of 0 cm/sec., to a high of 21 cm/sec. (0.41 Kt), with an average value of 8.0 cm/sec. (0.15 Kt). The distribution of observed speeds is shown in Figure 4, and Figure 4 illustrates the average speed observed for different directions around the platform. The highest average speeds tend to occur in a direction parallel to shore. The net movement during the entire sampling period corresponds to a speed of 3 cm/sec., along 295° Magnetic.

B.3.b. Direction. The probability of observing a flow in any particular direction for this period is illustrated in Figure 5. The most probable direction was to the West (280° Magnetic), or approximately parallel to the 30 m depth contour. The least probable direction was to the Northeast. A skewness is also present in the distribution, increasing the probability of flow in the Northwest/Southeast direction, relative to the Southwest/Northeast directions.

B.3.c Variability. A spectral analysis was used to examine the data for patterns occuring in the time variability of the observed currents. The smoothed spectra for the alongshore and onshore/offshore directions are shown in Figure 6a and 6b respectively. The horizontal axis is a measure of the frequency of oscillation, measured in cycles/day (CPD), and the vertical axis is a measure of the amount of the observed variability which can be accounted for by each frequency (expressed as the amplitude, in cm/sec., of each "component" current).

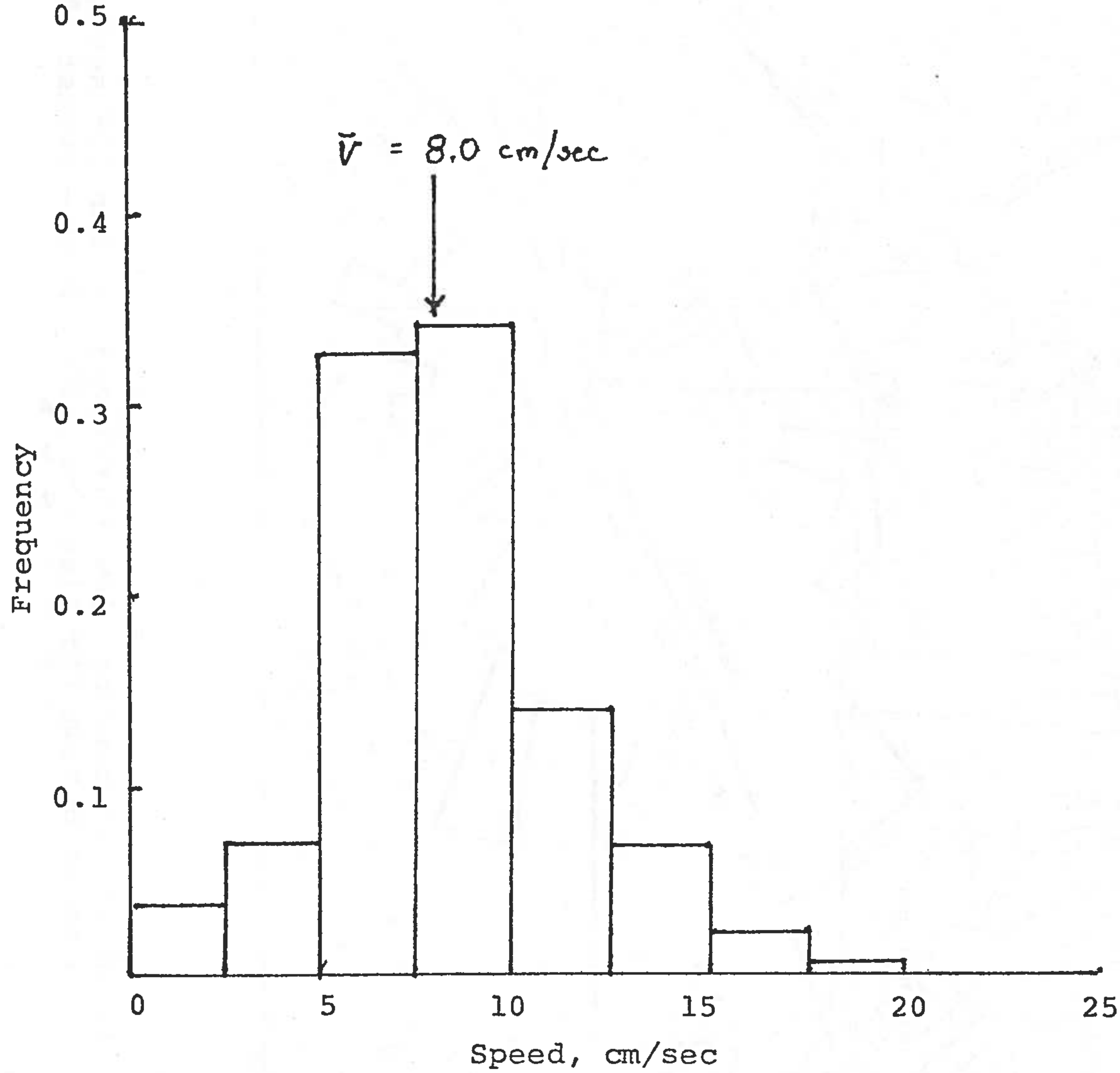


Figure 4. Frequency distribution of current velocities (±2.5 cm/sec) at platform Hilda, July - August 1975.

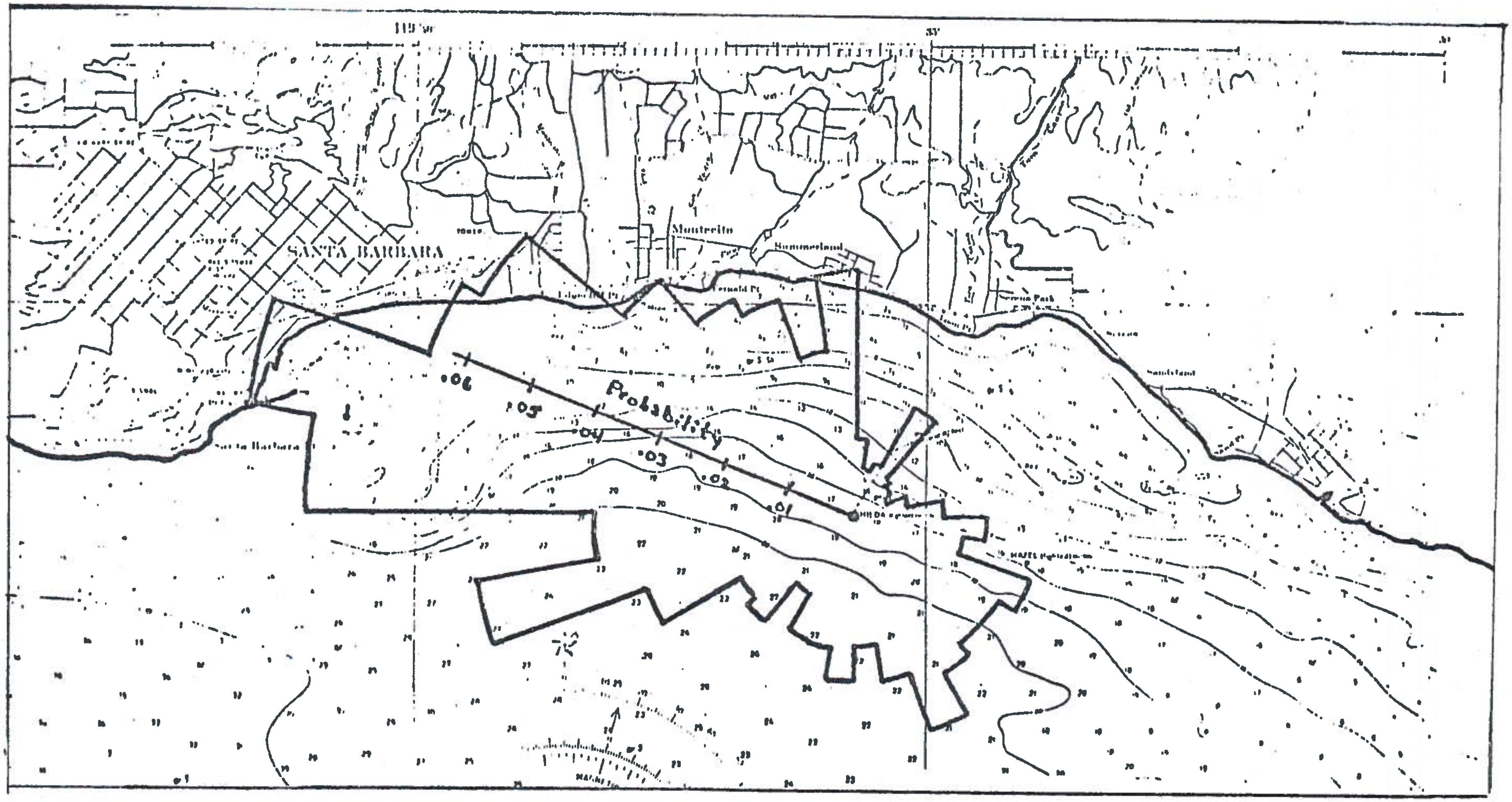


Figure 5. Probability of current flow directions (within 10° sectors) at depth of 7 m above bottom for platform Hilda, July - August 1975.

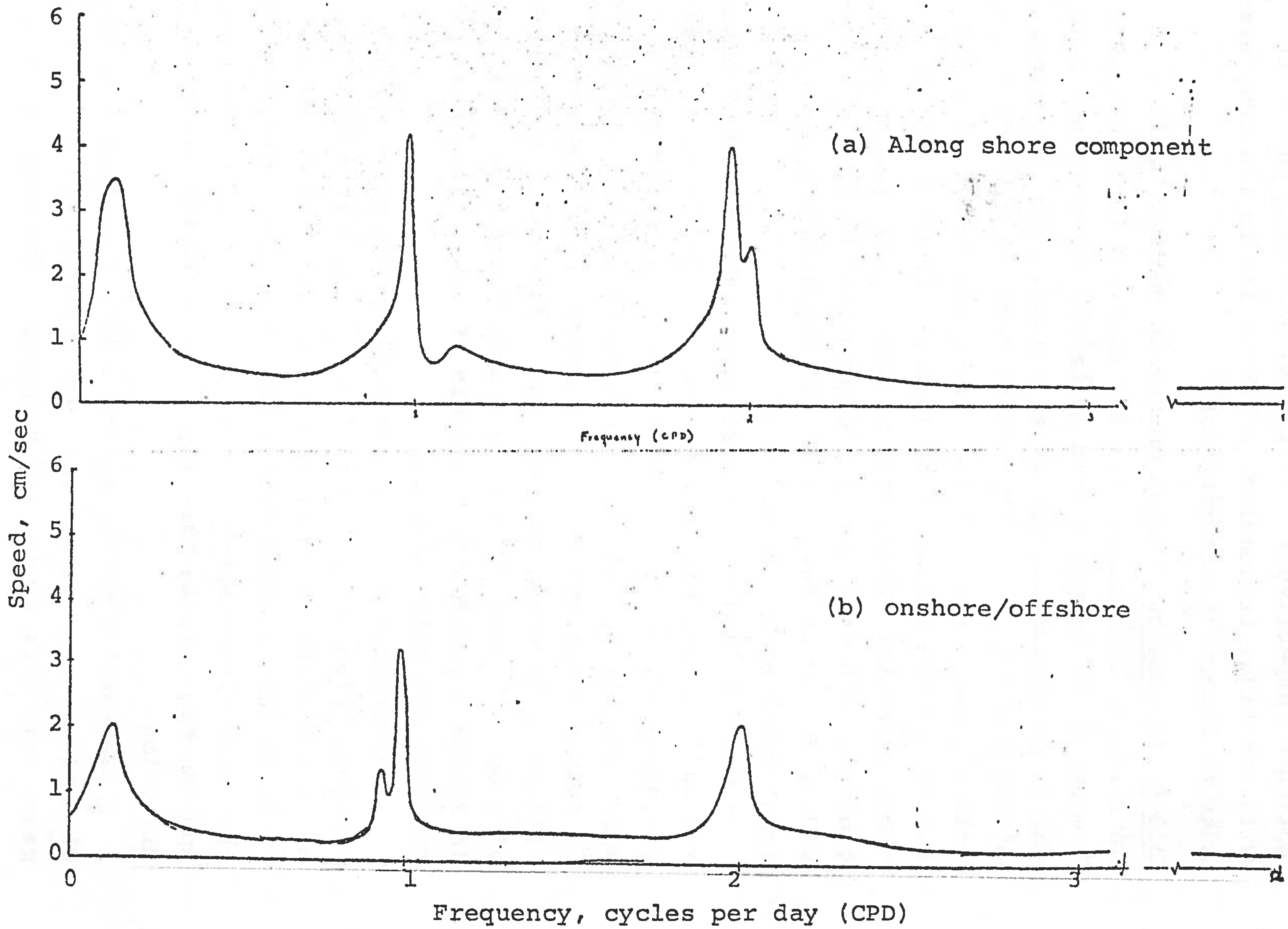


Figure 6. Spectral analysis (smoothed) of current periods (a) alongshore and (b) onshore/offshore.

The enhancements at frequencies of 1 and 2 CPD indicate the presence of diurnal and semi-diurnal tidal currents respectively. It can also be seen that currents with sub-tidal frquencies, of about 1/3 to 1/5 CPD, also make an important contribution.

B.3.d. Discussion. Measurements in another shelf area in Southern California indicate that the flows observed 7 m above the bottom should be fairly representative of the flows throughout the water column, with the exception of the mixed layer at the sea surface. Materials released into the water column below this mixed layer, or which rapidly settle through this layer, will be transported by these currents. Thus, most of the wastes, reproductive products, and other materials generated by the biota residing on, or in the vicinity of the platform should be transported to the west.

The net flow to the West during the period of observation is compatible with the so - called "rule of coastal circulation", which says that the average flow will be approximately parallel to the line of constant depth and in such a direction that an observer facing downstream will have the coast to his right. This trend has generally been observed in numerous other nearshore shelf areas in Southern California, including Pt. La Jolla, Oceanside, Newport, and Palos Verdes.

The distribution and range of speeds observed off Platform Hilda were also similar to those in other shelf areas (in which the average speeds ranged from 6 cm/sec. to 10 cm/sec.). Data from other areas indicates, however, that much higher speeds may occur within the mixed layer, and the flow within this layer can be in the opposite direction.

Examination of the spectral data indicates that the diurnal tidal currents trace out a tidal ellipse whose major axis lies along 310° Magnetic. The peak speed in this direction is 4.5 cm/sec., resulting in a length of 1.2 km., while the flow along the minor axis is only about 0.5 cm/sec. (with a corresponding length of 0.1 km.). This indication of the major axis to the Northwest/Southeast is probably the major factor leading to the skewness observed in the distribution of current directions noted earlier.

The semi-diurnal tidal currents are either aligned with the principal direction of flow (principal semi-diurnal lunar tide) or are barely eccentric (principal solar semi-diurnal tide) so that they do not contribute to the skewness. The speeds associated with the major axis of these two semi-diurnal fluctuations are 3.3 and 2.0 cm/sec. respectively. The tidal currents can exceed 10 cm/sec. on occasions when all the components are in phase.

The long period currents (i.e. with sub-tidal frequencies) are also strongest in the alongshore direction. The driving forces for these currents have not been identified, but their great persistence suggests that they are probably associated with major processes such as the offshore currents or weather patterns.

We have used this data to estimate the alongshore distribution of materials released into the water column below the mixed layer. The distribution of these materials will, of course, depend on the amount of time that has elapsed since their release. To illustrate the dispersion, we have chosen the hypothetical case of a continous release of conservative material (i.e. a material which remains unchanged in the water column). The distributions for this material, after elapsed times of 6, 24, and 72 hours, are shown in Figure 7. Analysis of this model indicates that the rate of dispersion during the first 24 hours is about twice as fast as during subsequent times, reflecting the importance of the tidal currents in distributing materials within the immediate

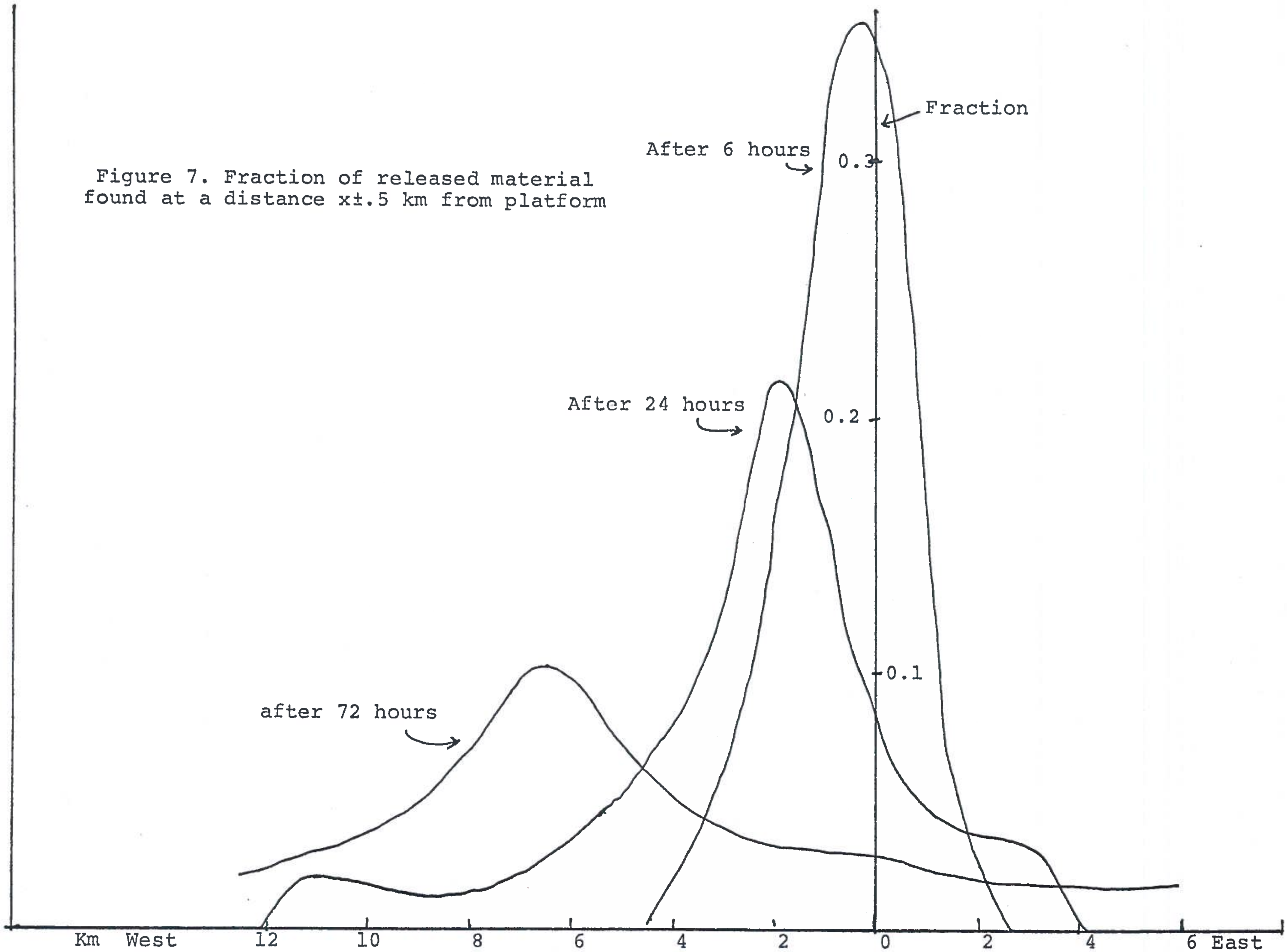


Figure 7. Fraction of released material found at a distance x±.5 km from platform

area (few kilometers) of the platform. This technique can also be used to estimate the dispersion of non-conservative materials if their properties (such as settling rate, etc.) are known.

B.4 Plankton Sampling

The plankton samples collected 100 feet North, South, East, and West of platform Hilda and an additional sample collected from the soft bottom control site proved informative even though we only made a cursory collection and examination of the samples. The volumes (1.2 to 1.6 ml) and species (Table 2) were very similar for all samples except the one obtained west of the tower which contained a significantly higher proportion of hydromedusa and a much larger volume (7.5 ml) which was due to the high abundance of hydromedusa. Most of the organisms observed were normal components of the plankton.

B.5 Fallout Particulates

The fallout collectors were in place for 23 days east and west of platforms Hazel and Hilda and another collector at the soft bottom control. Total solids (TS), volatile solids (VS), biochemical oxygen demand (BOD), fallout rate (FR), and total number of shrimp larvae were measured at all five sites. These data (see Table 3 were well within the normal range and a comparison between the sites showed no significant differences except perhaps in the total number of shrimp larvae which was lower (in general) at the control than at the towers and, possibly, higher east of the platform than west.

Table 2. A preliminary analysis of plankton samples collected by making vertical plankton tows.

Organism	Stations** North	South	East	West	Control
Diatoms	X	X	X	X	X
Dinoflagellates	X	X			
Cnidaria					
Cnidarian, UI		X			
Physonect siphonophore		X			
Hydroid hydromedusae	X	X	X	X+	X
Chaetognatha					
Chaetognaths, UI		X	X		
Sagitta sp.	X				
Cladocera					
Evadne sp	X	X	X	X	X
Podon sp.					X
Copepoda					
Calanoid	X*	X*	X*	X*	X*
Harpacticoid	X				
Corycaeus sp.			X	X	X
Chordata					
Oikopleura sp.	X	X	X	X	X
Larvae					
Nauplius			X		X
Cyphonaut			X		
Polychaete			X		
Fish					X
Volume (ml)	1.4	1.6	1.2	7.5	1.3
ml/m^3 water sampled	0.058	0.067	0.050	0.312	0.054

X = present
* = most abundant numerically
\+ = most abundant biomass (when observed)
** = 100 ft North, South, East, and West of platform Hilda and at the soft bottom control.

Table 3. Concentrations of solids and BOD and fallout rates of materials measured near platform Hilda and Hazel using 1 sq. ft. sediment traps for 23 days.

Station	TS (gm)	VS (%)	BOD (mg/kg)	FR ($g/m^2/day$)	Shrimp Larvae (total number)
Hilda W	183	6.3	2,330	79.5	14
Hilda E	231	5.3	2,690	100.0	18
Control	276	5.9	1,850	120.	4
Hazel W	250	6.7	2,400	109.	0
Hazel E	239	6.7	2,930	104.	12

C. Characterization of Platforms and Control Sites

C.1 Platforms

C.1.a. Condition of the Structure. As described in more detail below, the legs and cross members of both platforms were covered with thousands of mussels, anemones and other invertebrates, but few plants.

Except for a few cross members, no areas had been obviously jet cleaned by divers on either platform Hazel or Hilda. There were small areas that had the normal growth missing; these areas were either eroded from chains suspended from some underwater structure or were due to loss of mussel clumps which had fallen off from its own weight. The cleaned cross members at depths of 20 to 40 feet on both towers and an additional 20 foot section of pipe at a depth of 60 feet on platform Hilda had animal life consisting of encrusting bryozoans, barnacles, hydroids, urchins, and nudibranchs.

C.1.b. General Bottom Conditions. Sediments 100 feet out from directly beneath the edge of the towers appeared to be similar to those of the soft bottom control, midway between the two towers. The sediment consisted of a greenish grey silty clay. The most abundant animals were sea pens, echurids (*Listriolobus* sp.), and tube anenomes. Carlisle's (Carlisle *et al*, 1964) description of the bottom prior to Hazel's construction also appears to be identical to what we found.

Within 100 ft. of the towers the sediment appeared littered with debris (scraps of sheet metal, pieces of cable and chain, and assorted tools) and mussel shells. The animals living here are the same species as those living directly beneath the tower. These include the bat star, live mussels, sea cucumbers, and the colonial anenome *Corynactis*. The fish associated with the debris and living and dead mussel shells are described in more detail below.

C.2 Characterization of Control Sites

The control sites (soft bottom, hard bottom, and well head) were visited by Noel Davis, Glen Von Blaricom, Dr. Arthur Wolfson, and SCCWRP personnel and were characterized as follows:

C.2.a. Soft Bottom Control. The visibility on the bottom (100 ft) was very poor (less than 1½ feet) and was a limiting factor in our observations. A fine silt, which was easily dislodged, covered the bottom, and diver activity suspended this material further reducing visibility.

The distribution of epibenthic animals was very patchy and scattered. Sea pens (*Virgularia* and *Acanthoptilum*), tube anenomes (*Pachycerianthus*), and *Diopatra* or *Trochochaeta* tube worms were probably the most abundant animals, with a rough estimate of 10 animals per square foot (ranging from 0-52).

The few fish species that were observed on the bottom included the speckled (*Citharichthys stigmaeus*) (the most abundant) and English sole (*Parophrys vetulus*). These fish were lying on the mud and as we approached they swam away. Considering an area on the bottom the same size as the tower, it was estimated that there was fewer than 500 total fish. Approximately 100 topsmelt (*Atherinops affinis*) were observed near the surface above the soft bottom control on the one dive.

Three other species of fish were observed near the few scattered rocks found on one dive. These included whitebelly rockfish, lingcod, and a species of blenny. These fish would not normally be found on a soft bottom area in the absence of rocks.

Although the mud bottom just outside the platforms perimeter appeared similar to the soft control it did have a much higher density of polychaete worm tubes. The results of the analysis of benthic grab samples taken at and near platform Hazel also show an increase in numbers of tube dwelling polychaetes approaching the tower.

C.2.b. Hard Bottom Control. The hard bottom control was a rocky reef in 60 feet of water (the top of the reef was 50 feet deep). This reef was located just outside of the kelp line and was covered with purple sea urchins along with scattered red sea urchins. All three species of Pisaster (P. ochraceous, P. giganteus, and P. brevispinus) were found along with a few batstars (Patiria miniata). Probably the most abundant seastar was Pisaster ochaceus.

Other invertebrates included few gorgonian corals, Corynactis, and some Anthopleura anenomes. Unlike the towers, however, there were very few clumps of mussels (mostly Mytilus edulus) on this reef and only one crab (Cancer antenarius) was observed. Chestnut cowrys (Zonaria spadicea) were frequently found along with a few keyhole limpets (Megathura crenulata).

An estimate of between 2000 and 5000 fish was made after the second dive on this reef. There were 19 species of fish identified, seven of which were not found on the towers: these included, Senoritas (Oxyjulius californica), the most abundant fish on the reef; Garabaldi (Hypsypops rubicunda), of which there were a number of juveniles; halfmoons (Medialuna californiensis), giant kelpfish (Heterostichus rostratus), snubnose sculpin (Orthonopias triacis), silver surf perch (Hyperprosopon ellipticum), the second most abundant fish; and the barred sandbass (Paralabrax nebulifer).

One notable species most abundant at the platforms but missing at the reef was olive rockfish (Sebastes serranoides). The blue rockfish (Sebastes mystinus) which ranks second or third in abundance under the platforms was present on the reef in equal abundance with the black and yellow rockfish (Sebastes chrysomelas), ranked third in abundance on the reef.

C.3 Well Head

A well head, situated inshore of Hazel and Hilda on a mud bottom in 70 feet of water was also examined for marine life. The superstructure of metal fittings, pipes, and domes was covered with aggregate anemones, Corynactis californica. There were occasional acorn barnacles, Balanus tintinabulum and Balanus nubilis. In some areas matts of arborescent ectoprocts, mainly Crisia occidentalis and Filicrisia franciscana, and athecate (naked) hydroids (Tubularia sp.), interrupted the otherwise practically continuous cover of aggregate anemones.

There were no mussels on this structure and consequently no mussel pile on the bottom. There was a narrow aggregation of Diopatra tubes around the structure and the bare mud beyond. Pachycerianthus and Virgularia were common in the mud. We did not see Acnthoctilum. The whelk, Kelletia kelleti was common there.

D. Marine Life and Communities at the Platforms

The following section describes in more detail marine life of the major habitats in and around the platforms.

D.1 Surface Community (Birds, Mammals, Fish)

Twenty-four species of birds and four species of marine mammals were observed within visual range of the towers and control sites (Appendix C). Brown pelicans (Pelecanus occidentalis) and western gulls (Larus occidentalis) were present and common on every survey day (total 23 days, (Tables 4 and 5). Brandts cormorants (Phalacrocorax penicillatus) and California gulls (Larus californicus) were seen about half the time and the remaining bird species only occasionally.

California sea lions (Zalophus californianus) were the most common mammals in the area. California grey whales were seen moving north between the oil platforms and the shore on 14 April 1975. The other mammal species were seen on only one occasion each.

Some fish were readily seen from the surface. Schools of northern anchovy (Engraulis mordax) were seen frequently at the

Table 4. Occurrence of mammals, birds and fishes observed from the surface near platform Hilda and Hazel in the Santa Barabara Channel, 14 March to 2 August, 1975. (See appendix for scientific names).

SPECIES	4/14/75	4/15/75	4/16/75	4/17/75	4/18/75	4/21/75	4/22/75	4/23/75	4/24/75	4/25/75	4/28/75	4/29/75	4/30/75	6/2/75	6/3/75	6/4/75	6/5/75	6/24/75	6/25/75	7/18/75	8/19/75	8/20/75	8/21/75	Total
Pelagia pacifica														X	X	X	X							4
Thresher Shark																		X	X	X				3
Northern Anchovy	X	X		X							X													4
Olive Rockfish						X																		1
Kelp Bass						X																		
Halfmoon						X																		1
Pacific Bonito				X																				1
Ocean Sunfish	X											X	X	X	X	X	X	X						8
Arctic Loon											X													1
Western Grebe		X	X					X	X															4
Fulmar						X	X																	2
Pink-footed Shearwater														X	X	X	X							4
Sooty Shearwater				X							X	X	X		X									5
Brown Pelican	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	23
Brandt's Cormorant	X	X	X	X	X	X	X	X	X		X	X	X			X	X	X	X	X				17
American Coot										X							X							2
Black Oystercatcher		X							X															2
Sanderling																	X	x	X	X	X		X	6
Western Sandpiper	X		X	X																				3
Caspian Tern																					X	X	X	3
California Gull	X	X	X	X		X		X			X				X			X					X	10
Ring-billed Gull	X			X								X												3
Heermann's Gull																								2
Western Gull	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	23
Bonaparte's Gull		X		X					X		X		X											5
Black-legged Kittiwake						X	X						X											3
Forster's Tern					X						X	X									X	X	X	6
Elegant Tern																			X					1
Pigeon Guillemot	X							X																2
Cassin's Auklet	X																							1
Wilson's Warbler				X								X												2
House Sparrow				X																				1
California Sea Lion	X	X	X	X		X		X	X		X	X	X	X	X	X	X			X	X	X	X	18
Harbour Seal																							X	1
Pacific White-sided Dolphin								X																1
California Gray Whale	X																							1

Table 5. Most frequently observed birds, mammals and fish.

SPECIES	Number of Occurrences (23 Total)
Brown Pelican	23
Western Gull	23
California Sea Lion	18
Brandt's Cormorant	17
California Gull	10
Ocean Sunfish	8
Sanderling	6
Forster's Tern	6
Sooty Shearwater	5

surface between the platforms in April. On one occasion Pacific bonito (Sarda chiliensis) were observed feeding on anchovies. Thresher sharks (Alopias vulpinus) were observed jumping from the water on four occasions in June and Ocean sunfish (Mola mola) were frequently seen at the surface.

No attempt was made to quantify bird or mammal populations. However, our general impression was that both the abundance and variety of mammals, birds and surface fish schools was quite typical for this coastal area and that pelicans were conspicuously abundant.

D.2 Communities of Submerged Platform Structures

This section presents the results of a detailed marine biological reconaissance of Hilda and Hazel, based on 8 dives, conducted from April 21-24, 1975 by Dr. Arthur Wolfson.

During the subsea reconnaissance at each tower, two adjacent corner pylons were systematically inspected. Diver-biologist, Arthur Wolfson, was accompanied by a professional underwater photographer, Bob Evans, who operated a still or TV camera (the latter was deployed by cable from the support vessel). This team swam directly to the bottom of a selected pylon then slowly ascended through the water column taking pictures and recording observations on underwater writing slates. Any "no decompression" time remaining upon reaching the surface was spent exploring the maze of drill casings, horizontal reinforcement structures, and obliquely slanting guy wires to a depth of 40 feet.

The species composition and relative abundance of marine organisms on Hazel and Hilda appeared quite similar. Consequently, a depth-related description of the general nature of the fouling community for both towers will be given (the few evident differences between the towers are so indicated).

Wave surge precluded close-up scrutiny of the upper intertidal biota on the towers making it impossible to determine whether small marine animals such as periwinkle shells, typical of the highest tide horizon on the adjacent mainland, were present. However, a search with binoculars from the boat, revealed the usual band of green algae, probably species of Ulva and Euteromorpha, at the upper level of marine growth. Within this band were a number of roughly circular patches, devoid of green algae. Each of these plate-sized areas had a 2-3 inch owl limpet, Lottia gigantea, at the periphery. This nocturnal herbivore forages over a circumscribed territory producing the characteristic clearings observed in the Ulva band (Stimpson, 1973). A variety of other limpets, including a number of acmaeid species and volcano limpets were scattered throughout the intertidal zone.

The large, brick-red, thatched barnacle, Tetraclita squamosa, was a conspicuous resident of the mid and low tide zones. Brown buckshot barnacles, Chthamalus sp., smallest of the acorn barnacles (possibly mixed in with the diminutive species of Balanus) extended from the upper intertidal level where it was attached directly to the pylons, through the shallow subtidal, where it mainly encrusted sea mussel shells. One of the most common barnacles, the red and white pin-striped Balanus tintinabulum, ranged from the low tide zone all the way to the bottom. This was also the depth range of the largest barnacle present, Balanus nubilis, which approached 2 inches in basal diameter. Both these species were observed actively feeding at a depth of 85-90 feet attached to mussel shells and other debris covering the cuttings pile at the base of the towers.

Pacific goose-neck barnacles, Pollicipes polymerus, were clustered at about the mid-tide level. Goose-neck barnacles, sea mussels, and starfish of the genus Pisaster constitute the characteristic faunal association (Pollicipes - Mytilus - Pisaster association) of the exposed, rocky coastline of California. (Ricketts and Calvin, 1968). These three genera are also the most immediately evident intertidal organisms on Hazel and Hilda.

Thick clumps of mussels surrounded the pylons from approximately the mid tide line to a depth of 15-20 feet. The bulge of mussels was widest at about the low tide level where its thickness appeared to be on the order of 3-4 feet (radius). There appeared to be a greater biomass of mussels on the towers than any other attached species and within the upper 20 feet of water there is probably more mussel biomass than all other epifaunal species combined. Mussels are a particularly important component of the fouling community because the matrix of shells and byssal threads (chitinous anchoring filaments) provides a protected habitat and ecological niche for a wide variety of associated species (MacGinitte and MacGinitte, 1968). Mussel shells were overgrown with minute species of red and brown algae and a diverse assortment of protozoans, sponges, hydroids, sea anemones, ectoprocts, annelids, mollusks, arthropods, and colonial tunicates.

Both the California mussel, Mytilus californianus, and the "bay mussel", Mytilus edulis, were present although the latter was less abundant and not observed below 20 feet. While the Mytilus californianus population was less dense below 25 feet, individuals were noted at all depths on the towers. The surface of the cuttings pile was littered with Mytilus californianus, many of which were alive. Since Mytilus rarely occurs naturally at this depth (Ricketts and Calvin, 1968), the accumulation is most likely composed of mussels which have fallen from the towers.

The California mussels on the towers were enormous. Many Mytilus californianus exceed 9 inches, the maximum length given for this species (Soot-Ryen, 1955); some specimens were much larger, almost a foot long.

There was a surprising paucity of Pisaster on the towers considering the amount of food available, but those present were unusually large. The Ochre seastar, Pisaster ochraceus, the most common Pisaster along the California coast, reaches a maximum length (diameter) of 14 inches (Ricketts and Calvin, 1968). Most of the ochre seastars on the towers appeared larger than this and one of three specimens actually measured was 22 inches across. Pisaster giganteus was even more spectacularly over-sized. Because this species was originally described from an atypically large specimen, Pisaster giganteus is rather a misnomer. The average individual on the coast is smaller than most Pisaster ochraceus. However, Pisaster giganteus as large as 18 inches have been recorded (Feder, 1969). Many of Pisaster giganteus on the towers exceeded this length and one measured 10 inches across the disk and 30 inches total diameter. The range of Pisaster giganteus and P. ochraceus extended to the ocean bottom. Individuals of both species were scattered over the cuttings pile, some in the characteristic "humped" feeding posture. Carlisle et al. (1964) reported seeing Pisaster brevispinus on the towers but the only two specimens we observed were on the cuttings pile. Two other noteworthy echinoderms were the purple sea urchins, Strongylocentrotus purpuratus and S. franciscanus. The smaller of these species, S. purpuratus, was relatively common from the lower intertidal zone to the bottom and out over the cuttings pile. Only a few S. franciscanus were seen.

Coelenterates were a well-represented component of the subtidal macrofauna of Hazel and Hilda. Large colonies of the ostrichplume hydroid, Aglaophenia struthionides, occurred at all depths on the towers but were particularly numerous in the upper 35 feet where their dense clusters of featherlike branches waved back and forth in the surge. All of the colonies examined were in reporductive condition as evidenced by the presence of corbulae on the branches, within which eggs are brooded.

Five species of sea anemones were noted. The green anemone, Anthopleura elegantissma, and the beaded anemone, Tealia crassicornis, were present in the upper 30 feet but were uncommon. On the other hand, the delicate aggregate anemone, Corynactis californica, is probably the most abundant macroscopic invertebrate on the towers. This colonial anemone occurs in various pastel colors and covers an estimated 70-80% of the available space below 50 feet. Above this depth, Corynactis are still plentiful but are not numerically dominant.

The most striking difference between the two towers was the presence of thousands of the prolific anemone, Epiactis prolifera, on Hilda, while few were observed on Hazel. Epiactis broods its eggs internally rather than discharging them into the water. Young Epiactis break through the parent's body wall near the base where they develop into juveniles, then separate and glide away. This mode of reproduction may have been responsible for the establishment of Hilda's large Epiactis population from a single or a few colonizers carried to the tower on a kelp holdfast (their usual open coast habitat).

Epiactis prolifera was found on platform Hazel by Mike Moore on subsequent diving surveys and later confirmed by Jack Word via 35 mm slides; it was nevertheless much more abundant on Hilda.

The largest anemone on the towers was the giant plumose anemone, Metridium senile. This species has a smooth white trunk capped with a cauliflower-shaped expanse of velvety white tentacles. The largest individuals were about 2 feet tall and 8 inches in diameter. Hundreds of Metridium carpeted basal sections of the pylons and adjacent surfaces of the cuttings pile. Metridium ranged up the tower to a depth of 40 feet. The average size of individuals increased with increasing depth; most patches of Metridium in the shallow end of the depth range were composed of small (less than 1 inch diameter) specimens, probably as a result of repeated basal fragmentation. There was little evidence of this type of asexual reproduction below 70 feet. Carlisle et al. (1964) saw both the white and yellow phases of Metridium. Only white individuals were observed during the present reconnaissance.

Five bivalve mollusk species, in addition to Mytilus, were recorded at the towers. These included the agate chama,

Chama pellucida; the reversed chama, Pseudochama exogyra; the nestling clam, Hiatella artica; the rock scallop, Hinnites multirugosus (which was only found in crevices), and the jingle shell, Pododesmus cepio. Pododesmus was particularly abundant at depths greater than 50 feet. This is another species at the towers which regularly exceeded the maximum size (3.2 inches) stated in the literature (McLean, 1969).

Only four species of nudibranchs were seen: Anisodoris nobilis, Dialula sandiegensis, Doriopsilla albopunctata, and Hermissenda crassicornis. More species of these colorful sea slugs undoubtedly inhabit the multifaceted environment of the submerged platforms. All of the Hermissenda observed were located on the main horizontal cross-members at depths of 20 and 40 feet on both towers. These were the only structures which had obviously been "cleaned off" by oil company divers during past hydraulic jetting operations to remove accumulated marine growth. The biota on the cross-members represented a much earlier successional stage than on the rest of the towers. The occurrence of Hermissenda is a prime example; it was one of the first invertebrates to colonize Hazel and Hilda, (Carlisle et al. 1964). A mixed turf of green, brown, and red algae blanketed the cross-members. A number of small (to two feet long) kelp plants, Macrocystis sp., were growing on the tops of the cross-members. Attached kelp plants were not observed elsewhere on the towers. Carlisle et al. (1964) postulated that the young Macrocystis sporophytes are most likely derived from drift kelp which become snagged on the towers.

The free-living arthropod fauna included three species of cancer crabs, Cancer antennarius, C. Anthonyi, and C. productus, (some of which were gravid), the sheep crab, Loxorhynchus grandis, the striped shore crab, Pachygrapsus crassipes, and various smaller chelate taxa. The only annelid (segmented worm) noted was the feather duster worm, Eudistylia polymorpha, which was most abundant in the upper water column in association with mussel clumps. The sea fan, *Lophogorgia chilensis*; the giant keyhold limpet, *Megathura crenulata*; the starfish, *Henricia leviuscula*; the octopus, *Octopus* sp.; and the stalked tunicate, *Styela montereyensis*, were present but rare (i.e. fewer than five individuals of each species were sighted).

In addition to these direct observations, we also took several clumps of mussels and fouling organisms to the laboratory for identification and verification of small species. At least eighty species were found (Table 6). This examination indicated that additional amphipods, ectoprocts and other small invertebrates probably made important contributions to the diversity of fouling and food organisms on the platforms.

D.3 Characterization of Fish Populations

Enumeration of the abundance and variety of fish species at the platforms and control sites was based primarily on direct diver observations plus confirmation of some species using color slides and video tapes. Table 7 summarizes the number of species and abundance estimates on a number of dive observations between April and August, 1975.

D.3.a Species Diversity and Distribution. A total of a fifty-one species of fishes were observed at the five sites by all participating diver-biologists (Table 8). Most of these have been recorded on video tape and 35 mm slides.

In general, the number of species sighted was proportional to the observation effort and thus more species were recorded from the oil platforms (Hazel, 36; Hilda,44) than from the control sites (soft control 7; hard control, 21; Table 8). However, standardizing the number of species observed per visit to a site did indicate a higher, and quite similar, diversity for the towers (average, 21.0 and 21.6 species per visit, Hazel, and Hilda respectively) than for the controls (7 for soft control, 11 for hard control; Table 8).

TABLE 6. Invertebrates associated with the mussel fouling community at platforms Hazel and Hilda. Mussel clumps from 10 to 30 foot depths examined in the laboratory by Terrence Parr and Arthur Wolfson.

ALGAE

- *Ceramium* sp.
- *Ectocarpus* sp.
- *Pterosiphonia dendroidea*
- unidentified brown alga

PROTOZOA

- *Gromia oviformis*
- *Rosalina columbiensis*
- *Folliculina* sp.

PORIFERA

- *Leucetta losangelensis*
- *Leucosolenia* sp.
- *Rhabdodermella* sp.

CNIDERIA

- Hydrozoa
  - *Aglaophenia struthionides*
  - *Plumularia* sp.
  - *Halecium* sp.
- Anthozoa
  - *Anthopleura elegantissma*
  - *Corynactis californica*
  - *Tealia crassicornis*

NEMATODA - present

NEMERTINA - present

ECTOPROCTA

- *Bowerbankia gracilis*
- *Caulorhamphus spiniferum*
- *Crisia occidentalis*
- *C. serrulata*
- *Callophora horrida*
- *Filicrisia franciscana*

ECTOPROCTA - Continued

Hippotha hyalina

Rhynchozoon sp.

Scruparia ambigua

Tricellaria occidentalis

MOLLUSCA

Gastropoda

Dialula sandiegensis

Diodora aspera

Doriopsilla albopunctata

Pelecypoda

Hiatella arctica

Kellia laperousii

Leptopecten latiauratus

Petricola californiensis

Pododesmus cepio

Mytilus edulis

ANNELIDA

Dexiospira spirillum

Eulalia aviculiseta

Eumida sp.

Neveis mediator

Spirorbis eximius

Syllidae (unidentified)

ARTHROPODA

Crustacea

Cirripedia

Balanus crenatus

B. nubilis

B. tintinabulum

B. trigonus

Chthamalus dalli

Tetraclita squamosa

Malacostraca

Peracardia

Amphiopoda

Aorides columbiae

Caprella californica

C. equilibra

C. verrucosa

C. sp.

Corophilum baconi

Deutella californica

Eurystheus sp.

Elasmopus serricatus

Leucothoe alata

Jassa falcata

Erichthonius brasiliensis

Photis spp.

Podocerus brasiliensis

Stenothoe estacola

Isopoda

Janiralta occidentalis

Jaeropsis dubia

Eucarida

Cancridae (juveniles)

megalops larvae

Pycnogonida - present

Ihsecta

Chironomidae (larvae)

Table 7. Summary of number of fish species and fish abundance estimates from platforms and control sites, April to August 1975.

	Species	Abundance Estimates Lower	Upper
HAZEL			
21 April	15	N.E.	N.E.
30 April	22	8,000	12,000
2-5 June	27	20,000	30,000
24-25 June	25	20,000	25,000
21 August	16	15,000	20,000
HILDA			
21 April	13	N.E.	N.E.
28 April	27	10,000	15,000
2-5 June	31	20,000	30,000
24 June	22	18,000	26,000
18 July	25	N.E.	N.E.
19 August	14	20,000	30,000
21 August	19	20,000	30,000
SOFT CONTROL			
21 April	N.E.	N.E.	N.E.
20 August	7	500	-
HARD CONTROL			
21 April	2	N.E.	N.E.
20 August	20	2,000	5,000

N.E. = No estimates or observations made.

Table 8. Comparison of fish species estimates among platform and control sites.

	Hazel	Hilda	Soft Control	Hard Control	Total
No. Observations	5	7	1	2	
Cum. No. Species	36	44	7	21	51
X species/visit	21	21.6	7	11	
± S. Dev.	5.3	6.7	-	13	

Within the tower area, the greatest diversity of fish species occurred between 30 and 70 feet (18 to 30 species) and the lowest at the surface (11 species) and near bottom (8 to 10 species, Figure 8). The lower variety of fish near the bottom may be due in part to poorer visibility at the bottom, to the occurrence of unobserved small fishes hiding in the bottom debris and/or to a really lower variety.

Depth distributions of platform fishes showed some rather distinct trends; while many species, such as kelp bass (*Paralabrax clathratus*) or brown rockfish (*Sebastes auriculatus*) had a wide depth distribution (Figure 9). Many others were more restricted to the surface or upper water (Northern anchovy, *Engraulis mordax*; topsmelt, *Atherinops affinis*), mid-depth (rubber lip sea perch, *Rhacochilus toxotes*) or the bottom (long-spine combfish, *Zaniolepis latipinnis*, swell shark, *Cephaloscyllium ventriosum*.

D.4.b. Fish Abundances. Fish were 20 to 50 times more abundant at the oil platform than at the soft bottom control site and about five times more abundant than at the hard bottom control site (Table 7). Hilda produced the highest counts ranging from 10,000 to 30,000 fish per visit; Hazel counts ranged from 8,000 to 30,000. Counts were low in April and high in June and August.

The low count at the soft control (less than 500 fish) was possibly due in part to lower diver visibility. The hard bottom count estimate ranged from 2,000 to 5,000 fish.

Our platform estimates are higher than those made by Hardy (*pers. comm.*, in 1975) and considerably higher than those made by Carlisle *et. al.* (1964) during 1958-60.

Carlisle *et al.* (1964) found that the fish fauna consisted of, in the order of abundance, sea perch, rockfish, pelagic species and other fish. They found that on some dives, shiner perch comprised between 6.5 and 79.4% of the total fish population.

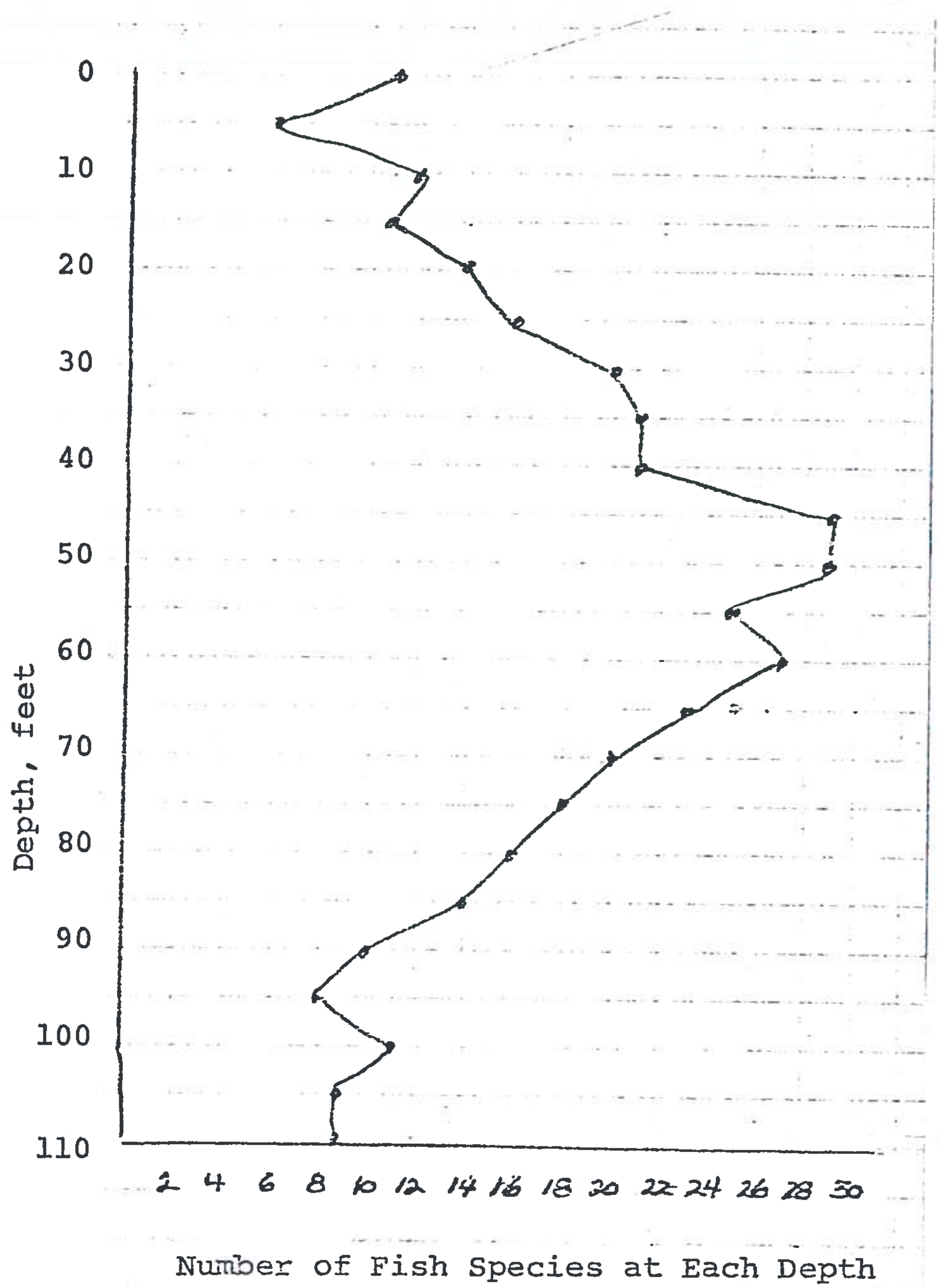
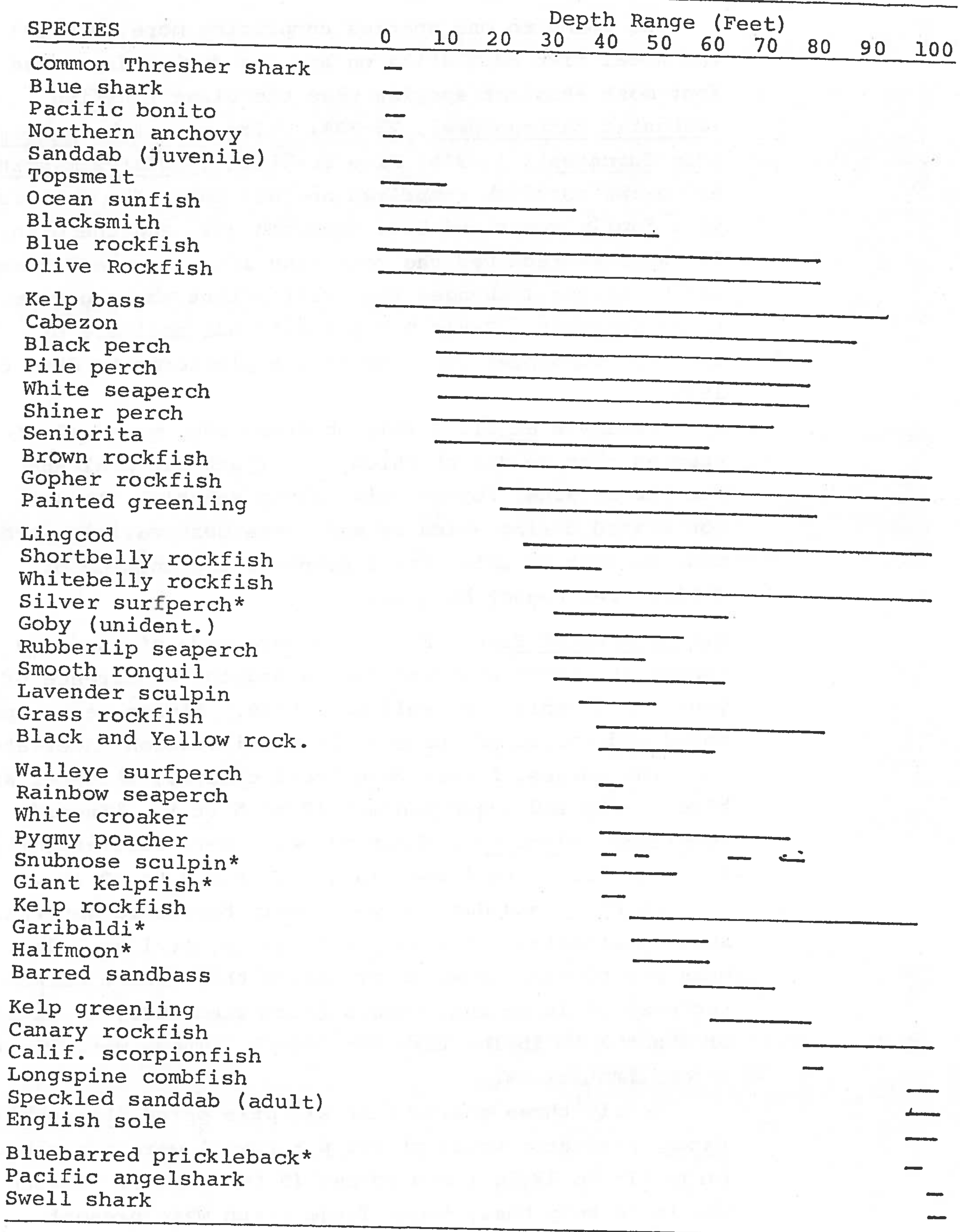


Figure 8. Changes in number of fish species with depth at oil platforms Hilda and Hazel (combined). Highest diversity is at mid-depth (30-70 ft.), lowest at surface and bottom (daytime). At night, some species of rockfish were observed to rest on bottom; other fish (blacksmith, olive rockfish, white seaperch) form dense clusters near pipes.

Depth-ranges of individual fish species at platforms Hazel and Hilda. Based on combined observations from both towers.



*Fishes not found under platforms

We found no one species comprising more than 30% of the total fish population on any one diving day. The four most abundant species were the olive rockfish (Sebastes serranoides), 25-30%; White seaperch (Phanerodon furcatus), 15-20%; Blue rockfish (Sebastes mystinus) and brown rockfish comprised another 15%. The rockfish as a family comprised 50%, seaperch 35%, and the other 19 families received the remaining 15%. However, there may be seasonal changes that will affect these percentages somewhat. Table 9 represents our estimate of species abundances observed at the platforms in June of 1975.

Carlisle et al. (1964) observed many more pelagic species than we did of which some (jack mackerel and Pacific sardine) formed quite large schools. It was not stated during which season these observations were made so that at this time a complete explanation of differences cannot be made.

D.4.c. Size of Fish. Estimates were made of the size ranges of common abundant fishes and the occurrence of young or juveniles as well as adults. Divers were experienced and corrected for the 25% magnification underwater.

The largest fishes were Pacific angel, thresher and blue sharks and ocean sunfish (2 to 5 ft.). Lingcod (Ophiodon elongatus, about 50 per tower) were estimated to range from 2 to 4 feet long and from 8 to 30 lbs.

In April and June surveys, kelp bass were generally small (estimated about 700, 8 to 12 in. or 1 to 2 lbs. bass per tower). However by August there was a marked increase of large individuals (estimated 2000, 14 to 20 in. or about 2 to 15 lb. fish per tower). These were clearly recent immigrants.

Nearly three quarters of all pile perch (Rhacochilus vacca, estimated total of 250 per tower) were noticably large (15 to 18 in.) and robust (5 to 7 lbs.). Unlike the large kelp bass, these large perch were present throughout the survey period.

Table 9. Estimated distribution of abundant fish species among a population of 20,000 fish under either platform in June 1975.

Species	Est. Number	% Population	Cumulative %
Olive rockfish	4,000	20	20
Brown rockfish	2,000	10	30
Blue rockfish	2,000	10	40
White seaperch	2,000	10	50
Kelp bass	1,000	5	55
Blacksmith	1,000	5	60
Black perch	500	2.5	62.5
Painted greenling	500	2.5	65
Cabezon	250	1.25	66.25
Gopher rockfish	250	1.25	67.5
Whitebelly rockfish	250	1.25	68.75
Shiner perch	250	1.25	70
pile perch	250	1.25	71.25
Shortbelly rockfish	50	.25	71.5
Boccacio	50	.25	71.75
Rainbow seaperch	50	.25	72
Lingcod	50	.25	72.25
Subtotal	14,450	72.25	72.25
Balance	5,550	27.75	27.75
Total	20,000	100	100

Olive rockfish, the most abundant species (4000 per tower), generally ranged from 8 to 10 inches (1/2 to 1 lb.). These fish appeared to represent the mean size of the bulk of the fish population in general.

The smallest fishes observed were several species of sculpins, gobies, and ronguils. These, and small fish in general, were not obviously abundant; however, the mussel clumps, cutting piles and debris may well harbor numerous small fishes.

Only six species of fish were obviously represented by juveniles or very young specimens. Blue rockfish juveniles (½ to 2 inches) appeared in August; this influx or appearance of young contributed to the increased dominance of this species. Kelp bass were frequently observed feeding on young of blue rockfish and white seaperch

Unlike the young blue rockfish, young brown rockfish were less visible since they hid among the attached mussels and anemones. The first juveniles of this species appeared in July, were more abundant in August and were absent in September. One juvenile effectively avoided an attack by a kelp bass.

Juvenile white seaperch also appeared in August and were observed hovering close to the tower legs. Young of blacksmith (*Chromis punctipinnis*) were present in June through August, perched on mussels on the tower legs. Young of painted greenling (*Oxylebius pictus*) were present in mussel clumps during all observations. (Finally during all observations). Finally, two larval or post-larval sanddabs (*Citharichthys sp.*) were found hovering beneath a jellyfish (*Pelagia sp.*) near a tower leg during the early June survey.

D.5 Changes from Night to Day

All of the water column fish at night with the exception of the larger pile surfperch were observed lying in close to the structures rather than swimming in the open water column as they did during the daylight hours. Most of the white seaperch were hovering in tight balls at a depth of 50 to 60 feet, clustered next to the drill casings and cross members. The olive rockfish and kelpbass were also seen hovering together in looser schools close to the tower structures.

Blacksmith which normally closely associated with the subsurface structures were, at night, actually perched on those structures and were unresponsive to light and disturbances. The smaller pile surfperch were mixed in with the blacksmith and the larger pile surfperch hovered just off those structures.

Blue, brown and gopher rockfishes were observed sitting on the bottom rubble and only moved when touched. Near the bottom the light exposed numerous rockfish on the outskirts of the tower structure, but they maintained a distance too great to be identified. Also on the bottom clouds of sediment were stirred up by what appeared to be swell sharks; this activity has previously been observed using baited movie cameras off a rocky reef area (SCCWRP, 1973b).

The barnacles didn't appear to filter as frequently as they did during the day and some individuals didn't open at all for periods up to two minutes. There were fewer *Corynactis* anenomes open at night than there were during the day, but the *Metridium* anenomes didn't appear to show any special behavior at night. The feather duster worm *Eudistylia* again apparently was not affected.

In general, night time appeared to be a period of little activity around the structure, but one of moderate activity on the bottom.

D.6 Communities of the Bottom and Bottom Debris

Communities of the bottom debris and cuttings pile were characterized by Dr. Arthur Wolfson, Noel Davis, and Glen Von Blaricom from diving observations at both Hilda and Hazel.

The cuttings pile beneath each tower was covered with debris mostly of biological origin which apparently "rained down" from above. The predominant invertebrates living on the cuttings pile are *Mytilus californianus*; *Corynactis californica*;

Metridium senile; *Pisaster spp.*; *Cancer spp.*; the Southern California sea cucumber, *Parastichopus parvimensis*, and the bat starfish, *Patiria miniata*. A multitude of brightly-colored *Patiria* dotted the cuttings pile; this remarkable, omnivorous sea star with a life span of more than 30 years, is known to feed on living, moribund, and dead animals (Hopkins and Crozier, 1966). Most of the *Patiria* examined on the cuttings pile had their stomachs extruded over rubble which lacked macroscopic life indicating that this species may be also assuming the role of a detritivore on the cuttings pile.

At the base of each of the pilings on the drilling platforms is an extremely deep accumulation of mussel shells ten to twenty-five feet high. As one follows these down and away from the platform, they gradually thin out giving way to an area of debris and scattered mussel shells. Animals associated with this debris include *Parastichopus californicus*, *Patiria miniata*, *Octopus* sp., *Sebastes auriculatus*. This debris extends for about thirty meters away from the platform. Then there is an area of very dense aggregation of a tube worm (*Diopatra* or *Trochochaeta*). This aggregation forms a band about five feet wide surrounding the debris. It ends in very soft mud which is the characteristic bottom in the area. The most abundant animals in the mud are the sea pens, *Acanthootilum* and *Virgularia* and the anemone, *Pachycerianthus*. Perhaps the greatest change since the previous study is the nature of the cuttings pile surface. Carlisle *et al*. (1964) reported that the cuttings pile was "a smooth-surfaced, silty pile without holes for shelter, so it did not attract fish nor did it offer a suitable substrate for the attachment of plants or animals." Apparently, the sediment has been gradually stabilized through incorporation of mussel shells and other animal remains which have fallen from the towers. The surface of the cuttings pile, now mostly hard substrate with low relief, is populated with a flourishing epibenthic assemblage of invertebrates and fish.

E. Benthic Infauna and Sediments around the Platforms

Most of the 53 bottom samples taken by the Van Veen grab on April 16, 1975, contained brown or green clay with a slight silt fraction. The samples were time consuming to screen because of the adhesiveness of the clay. Several samples taken directly underneath the platforms contained mussel shell debris, rock chips and polychaete tubes.

As indicated above, we conducted an analysis of the polychaete community around platform Hazel; many of these and other benthic samples were also analyzed for copper, zinc, volatile solids, and hexane extractable material and seven (three from each platform plus a control) were analyzed for petroleum hydrocarbon fractions.

E.1 Benthic Polychaete Communities

A total of 15 sites were chosen for anlysis of benthic polychaete communities. These included Hazel West No. 1,2,3, 4,5,9; East No. 1,2,5,9: North No. 1 & 2; South No. 1 & 2; and the soft bottom control. All samples were subsequently sorted to major taxonomic groups by Marine Biological Consultants, Inc. and returned to SCCWRP for identification and analysis.

During August, 10 samples from platform Hazel, (West and East 1,2,5, and 9 and North and South 2) and the control sample were examined for abundances and species of polychaete. The results on polychaete species diversity and abundance suggested that platform Hazel affected benthic polychaetes to a distance of 120 m to the west and 30 m to the north of the platform. Additional samples were therefore analyzed to confirm these initial observations. A total of 947 specimens representing at least 77 species and 34 families of polychaetes were identified from the 15 samples (Appendix D). The most abundant species were Trochochaeta franciscanum (103), Sigambria tentaculata((58), (58), Diopatra ornata (53), a maldanid (49), Arabella iricolor (41), Glycinde armigera (38), Lumbrinereis "californiensis" (36), juvenile Lumbrinereis sp. (36), Pectinaria californiensis (35), and Nephtys ferruginea (34).

While these species accounted for over 50 percent of the specimens, several characterized specific sites adjacent to, and to the west of, Hazel. Diopatra ornata, a tube-dwelling filter feeding polychaete dominated stations West-1, and East-1, immediately below the platform. This confirmed, in part, divers observations of a dense bed of tube-dwelling polychaetes surrounding the platform. A commensal scale-worm, Hylosydna latior, was associated with this Diopatra community".

To the west, north, and south, the Diopatra association appeared to be replace by another filter-feeding tube dwelling polychaete, Trochochaeta franciscanum. Trochochaeta franciscanum apparently maintained high populations 30 to 120 meters to the west of Hazel we well as under the platform to the north and south, where it may have been mistaken for Diopatra by divers.

The distribution of these two tube worms is shown in Figure 10together with a plot of polychaete abundance along the west-east axis of Hazel. These plots seem to indicate that platform Hazel directly or indirectly is influencing the benthic community structure immediately below the tower, and to a least 120 meters to the west and 30 meters to the north.

A simple analysis of species similarities among the samples also reflected these trends. The number of species common between any two samples averaged 10.2 ± 3.6 (S.D.), or over 40 percent average similarity among the samples (mean species per sample = 20.4). Hazel West-1 averaged 5.6 ± 2.4, indicating other species as well as Diopatra were making the site significantly different from those beyond. In contrast, Hazel sites West -2, -3, and -4, while dominated by Trochochaeta maintained moderately high similarities to more outlying sites suggesting the filter-feeding infauna of this region was simply enhanced without significant changes in species composition.

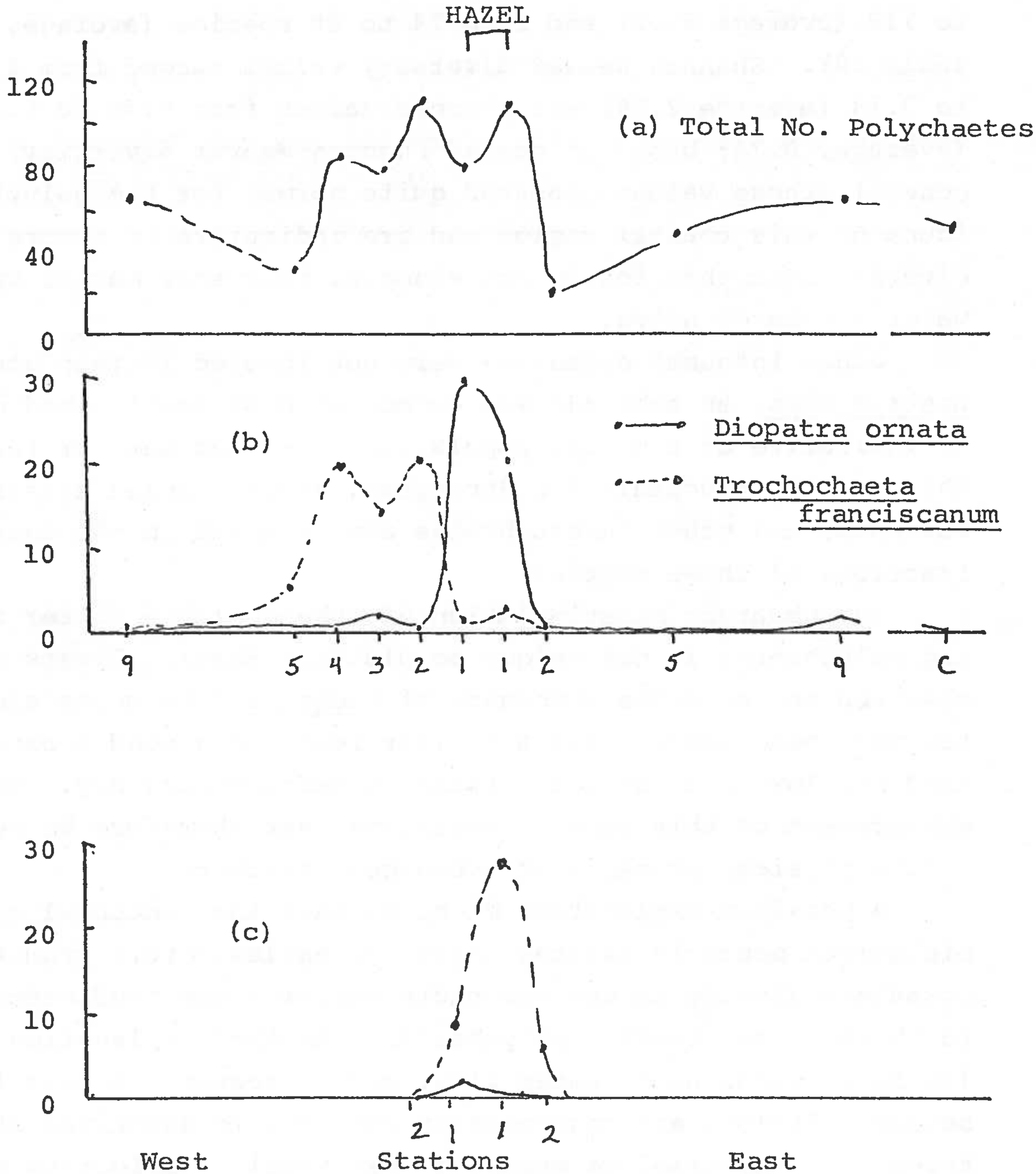


Figure 10. (a) Abundance of polychaetes in samples along the west-east transect through Hazel;

(b) Abundance of two filter-feeding polychaetes on same transect and;

(c) Abundance of the two species along the south-north transect.

Polychaetes in the samples ranged in abundance from 20 to 112 (average 63.2) and from 14 to 28 species (average, 20.5; Table 10). Shannon-Weaver diversity values ranged from 2.04 to 3.13 (average 2.70) and eveness values from 0.46 to 0.83 (average, 0.74; based on scaled Shannon-Weaver diversity). In general, these values appeared quite normal for the polychaete fauna of this coastal region and are indicative of a more diverse fauna than found, for example, near some marine waste-water discharge sites.

Other infaunal organisms were not ignored in this study. Listriolobus, an echuroid was common in most samples and may be indicative of a unique population described earlier for this area by Fauchauld (in Straughan, 1971). Small crustaceans, mollusks, and other invertebrates are abundant in the unanalyzed fractions of these samples.

The apparent biostimulation of tube-dwelling filter feeding polychaetes is not unique to platform Hazel. Divers also observed an increased abundance of Diopatra-like worms around the well head and we have a similar response around a rarely used shallow water sewage outfall in Santa Monica Bay. The enhancement of this type of organisms must therefore be related to the physical presence of submerged structures.

A possible explanation might be that the continual rain of biological products (wastes, eggs, juveniles, etc.) from the organisms already on the structure supplies the food necessary to these filter feeding polychaetes. Another explanation may lie in disturbance of water flow, and consequent changes in sediment fallout and resuspension adjacent to submerged structures. In any case, we estimate that Hazel is affecting the bottom over an area of 15,000 to 30,000 sq. ft. (1396-2792 m^2) slightly north of west of the tower, (Figure 11). As indicated earlier, this is the predominant direction of water transport.

Table 10. Summary of catch statistics on polychaetes from 15 benthic samples taken near platform Hazel in the Santa Barbara Channel.

	WEST						EAST				SOUTH		NORTH			
	9	5	4	3	2	1	1	2	5	9	2	1	1	2	(C)	X ± S.D.
Number of Individuals	61	28	82	79	111	74	112	20	49	66	43	56	60	54	52	63.1±25.9
Number of Species	28	14	16	21	28	15	30	16	26	25	19	21	18	22	24	20.5±4.9
S. W. Diversity	3.13	2.42	2.39	2.70	2.89	2.04	2.95	2.72	3.06	2.80	2.77	2.73	2.09	2.86	2.90	2.70±.33
Eveness2	.83	.72	.79	.80	.78	.62	.77	.70	.79	.70	.84	.76	.46	.81	.76	.74±.10

[1]Shannon-Weaver Diversity, $H' = -\Sigma \frac{n1}{N} \ln \frac{n}{N}$ where N = total individuals,

n_1 = number of specimens in first and each succeding species.

[2]Scaled Shannon-Weaver index, H' (s) = (H' calc. - H' min/H' max - H' min).

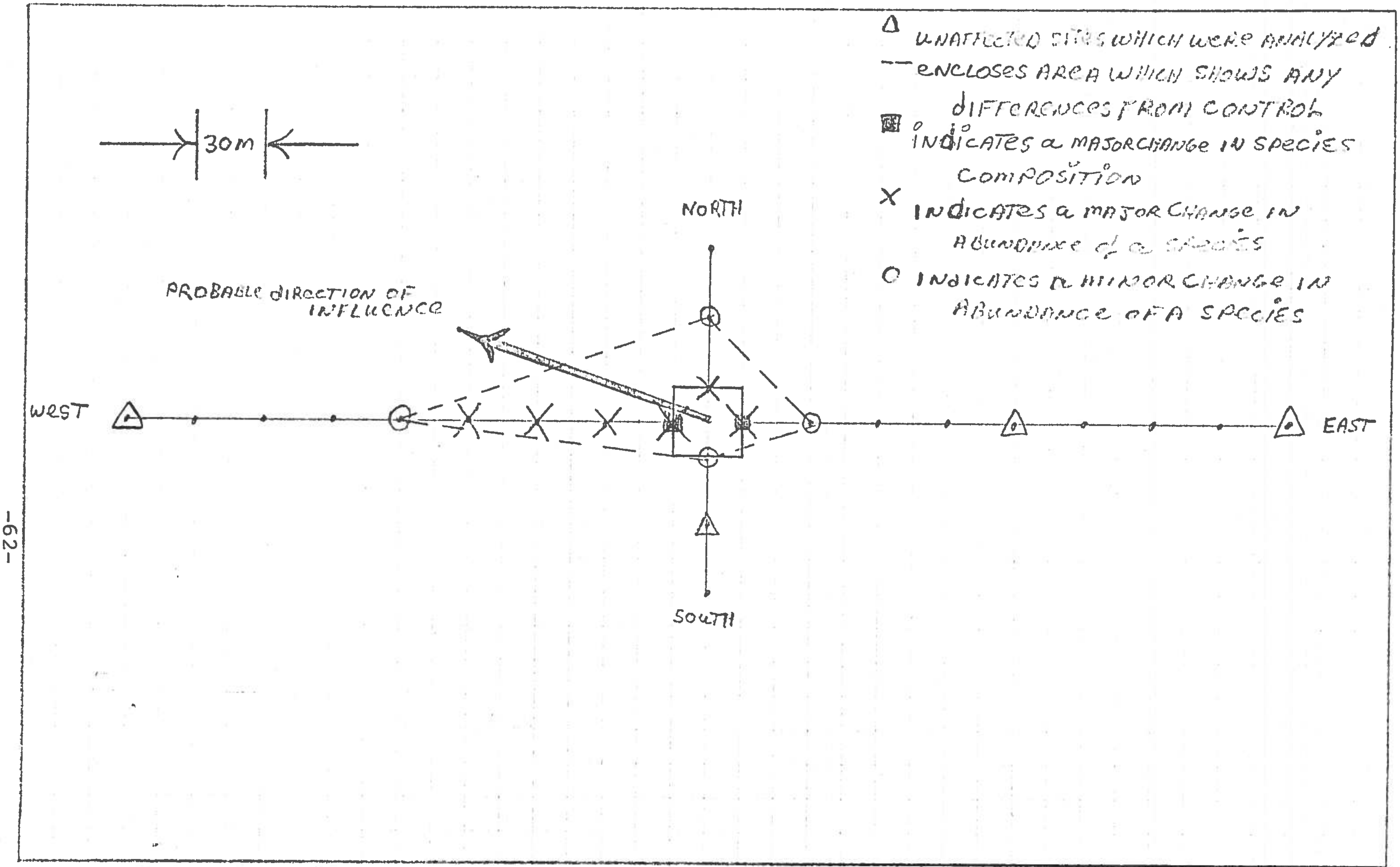


Figure 11. Probable direction and area of influence on polychaete communities (Hazel).

E.2 Sediment Quality

Sediment values of hexane extractable materials, volatile solids, copper and zinc generally appeared normal in most samples surrounding the platforms (Tables 11 and 12). However, immediately below the platforms, all four materials were elevated; the most obvious increases occured for zinc (1500 mg/kg compared to a median of 61 mg/kg) and hexane extractables (4400 mg/kg compared to a median of 665 mg/kg) at site West-1 under platform Hazel. The high zinc level may have resulted from sediment contamination by metal flakes from the platform or from metal debris scattered around the tower. Likewise, the high hexane extractable material may be due to inclusion of animals in the sample or may reflect a high fallout of fecal material from the biota of the structure. In any case, such anomalous values were limited to the biological and cuttings debris piled under the towers.

Examination of Table 12 indicates that median levels of these constituents fell within or near average coastal background levels and well below levels in sediments contaminated by sewage waste discharges.

Petroleum hydrocarbons were analyzed from sediment samples taken along the east transect of each platform and at the soft-bottom control site. The near-platform samples tended to be higher than the control sample (Table 13). The infrared analysis (IR) showed that the extractable material was primarily petroleum hydrocarbon in nature. It also showed that a considerable amount of aromatic hydrocarbon was present which may explain why the IR values are significantly lower than the gravimetric values. The agreement between the IR and gravimetric values is quite satisfactory, however.

The values for total hydrocarbons determined by gas chromatographic (GC) analysis are only 10 to 20 percent as high as the IR and gravimetric results. This is typical for highly weathered natural seep oil from the Santa Barbara area. These oils are relatively high in asphaltenes and polar components which are included in the IR and gravimetric values

Table 11. Summary of sediment concentrations of hexane extractable material (HEM), volatile solids (VS), zinc (Zn) and copper (Cu) near platform Hilda and Hazel and at control site (C)

	West				East				South			North			Median	(C)
	9	3	2	1	1	2	3	9	3	2	1	1	2	3		
HILDA																
VS, %	4.7	4.3	4.9	4.8	5.7	4.8	4.8	4.5	4.9	5.0	5.2	3.9	4.2	3.9	4.8	3.3
Zn, mg/dry kg	64	65	84	110	140	69	67	62	70	67	100	69	64	59	68	61
Cu, mg/dry kg	12	12	14	15	16	14	14	12	14	13	15	11	12	11	14	9.8
HAZEL																
HEM, mg/dry kg	70	950	-	4400	1300	-	340	110	840	-	510	820	-	390	665	470
VS, %	3.7	3.4	4.0	5.2	5.3	3.9	3.1	3.2	4.0	4.9	4.1	3.9	-	2.8	3.9	3.3
Zn, mg/dry kg	65	60	58	1500	99	60	55	54	62	60	71	67	56	53	61	61
Cu, mg/dry kg	13	11	14	39	17	12	11	10	12	12	14	13	11	9.8	12	9.8

Table 12. Comparison of median sediment values of hexane extractables (HEM), volatile solids (VS), Copper (Cu) and Zinc (Zn) with other coastal environments (mg/dry kg; % for VS).

	HEM	VS	Cu	Zn
Control	470	3.3	9.8	61
Hazel	665	3.9	12	61
Hilda	-	4.8	14	68
Coastal Background	∿1000	3-5	16	63
Near Sewage outfall, Santa Monica Bay	to 39,000	10-50	45	110

Table 13. Hydrocarbon content of sediment samples in mg/L.

Station	Infrared absorption at 2920 cm^{-1}	Gravimetric	Gas Chromatograph Range in Given Fraction, mg/liter[a].			
			1	2	3	Total
Hazel E1	730	1200	65	60	2	125
Hazel E3	620	1050	90	75	4	170
Hazel E5	630	1230	95	65	3	165
Hilda E1	980	1870	70	60	3	135
Hilda E3	1230	1670	105	60	2	165
Hilda E5	660	1200	130	110	5	265
Soft Control	550[b]	980	75	70	3	150

a. Determined by gas chromatographic analysis. Fraction 1 consists of time saturated hydrocarbons; Fraction 2 consists of the mono-and diaromatic hydrocarbons and most of the biogenic olefinic hydrocarbons; Fraction 3 consists of the tri- and polyaromatic hydrocarbons, and some of the biogenic olefinic hydrocarbons. No indentifinable individual hydrocarbons were detected. The gas chromatographic fingerprints were typical of those of highly weathered oil.

b. Comprised of approximately 10% carbonyl-containing compounds as indicated by absorption in the 1750 1650 cm^{-1} range. All other samples contained less than 5% carbonyl-containing compounds.

but not in GC values. Also, the higher molecular weight components (above C_{35}) are not included in the GC values. The gas chromatographic fingerprints showed a broad envelope with no significant individual peaks; this again is typical of a highly weathered oil and of the hydrocarbons from Coal Oil Point sediments.

The petroleum hydrocarbon content of all sediment samples collected was higher than values observed in areas with no natural seeps. While the platform levels were higher than the level measured at the control site, the GC fingerprints for all samples were indicative of highly weathered oil indicating no present day contamination of the sediments.

F. Trace Metals and Petroleum Hydrocarbons in Marine Animals

During Spring 1975, specimens of the brown rockfish (*Sebastes auriculatus*), the white belly rockfish (*S. vexillaris*), the yellow rock crab (*Cancer anthonyi*), and an intertidal mussel (*Mytilus californianus*) were collected for trace metal and petroleum hydrocarbon analysis. Tissues excised from these animals were analyzed for 25 elements (see technique section). Eleven elements of interest were selected for statistical analysis and comparison for this report. The 11 metals which will be discussed are: Silver, Cadmium, chromium, copper, iron, molybdenum, nickel, lead, silicon, vanadium, and zinc. Of these, only the vanadium levels were significantly different in rockfish from different locations: Rockfish from Hazel had statistically significant higher vanadium levels than fish from either Hilda or the rocky control site; rockfish from Hilda also had higher levels than control specimens. No statistically significant differences were observed between yellow rock crabs collected from the oil platforms and the control sites. There appeared to be no significant enhancement of trace metal levels in mussels collected from the platforms relative to values reported by other investigators in mussels collected along the California coast. No detectable amount of petroleum hydrocarbons were observed in any of the animals analyzed. The following sections provide a discussion of the trace metal and petroleum hydrocarbon results.

F.1 Trace Metals

Three tissues (muscle, liver, and kidney) were excised from the rockfish and analyzed for their trace metal content. (These data appear in Appendix E). The Wilcoxon rank-sum test was utilized to determine if there were any statistically significant species differences in the levels of these metals in the brown rockfish and the white belly rockfish. The Wilcoxon rank-sum test is a nonparametric statistical method comparable to the parametric Student-t test. Each tissue from the rockfish was analyzed for species differences on an individual station basis to eliminate possible station variations. Two of the results for the 99 statistical tests run (3 locations x 3 tissues x 11 elements) were statistically significant: Brown rockfish were found to have higher levels of iron than the white belly rockfish in kidney tissue at Hazel, and the white belly rockfish had higher levels of zinc in kidney tissue at the rocky control. One would expect, however, for 99 tests, up to 5 statistically significant results to appear as a random result of multiple testing. It was therefore concluded that there was no statistically significant difference between the two species trace element levels.

The data for the two species of rockfish were combined for each tissue since no statistically significant difference was observed. Representative trace metal concentrations in three tissues of rockfish are presented in Table 14. The Wilcoxon rank-sum test was again utilized to determine statistically significant location differences for trace metal levels in rockfish collected from Hazel, Hilda and a rocky control site. Table 15 presents the results of these analyses. The only statistically significant differences ($P \leq 0.05$) observed were for cadmium in the liver where levels were higher in rockfish from Hazel (2.9 mg/dry kg) than in rockfish from Hilda (1.7 mg/dry kg), and for vanadium in the liver where the trend of levels in rockfish was Hazel > Hilda > Rocky control (1.3, 0.8 and 0.08 mg/dry kg, respectively); and vanadium in kidney tissue where rockfish from Hazel (1.2 mg/dry kg) had higher levels than rockfish from the rocky control site (0.2 mg/dry kg). Again, 99 statistical tests were performed and the results observed might be expected to have occurred as a random result of multiple testing; however, since four of these five results all occurred for vanadium, it seems unlikely that these occurred purely by chance. There does appear to be vanadium contamination of rockfish in the vicinity of the platforms. The ecological and biological significance of this contamination is not known.

Reviewing Table 14, there appears to be other elements which could be statistically different with values varying up to a factor of 20 from location to location. Examples of these appear in Table 16. Although the median values do

Table 14. Trace element concentrations (mg/dry kg) in tissues of rockfish* collected near the oil platforms and a control site, Spring 1975. (Detailed data appear in Appendix E.)

	Muscle			Liver			Kidney		
Element	Hazel	Hilda	Rocky Control	Hazel	Hilda	Rocky Control	Hazel	Hilda	Rocky Control
Silver	ND**	ND	ND	0.6	0.5	0.6	0.6	0.8	0.8
Cadmium	ND	0.8	2.0	2.9	1.7	2.0	2.0	0.1	2.1
Chromium	ND	ND	ND	0.2	0.3	1.0	ND	ND	ND
Copper	ND	ND	ND	9.4	5.0	7.8	3.2	3.0	4.2
Iron	3.0	7.1	9.0	550	230	260	550	640	560
Molybdenum	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2
Nickel	2.5	2.4	2.1	2.0	1.4	1.5	2.1	2.6	2.4
Lead	1.2	1.2	1.0	0.9	ND	0.2	0.2	0.6	0.8
Silicon	11	6.6	5.4	9.7	5.9	8.8	6.6	10	6.0
Vanadium	1.2	1.0	0.9	1.3	0.8	0.08	1.2	1.4	0.2
Zinc	12	11	13	54	42	42	66	61	77

* Brown rockfish (<u>Sebastes auriculatus</u>) and white belly rockfish (<u>Sebastes vexillaris</u>)

** ND: Not detected

Table 15. Trace element concentrations (mg/dry kg) in tissues of rockfish* collected from different locations significantly different at the 95% confidence level ($p \leq 0.05$).

Element	Muscle			Liver			Kidney		
	Hazel vs Hilda	Hazel vs Ro Co	Hilda vs Ro Co	Hazel vs Hilda	Hazel vs Ro Co	Hilda vs Ro Co	Hazel vs Hilda	Hazel vs Ro Co	Hilda vs Ro Co
Silver	-	-	-	-	-	-	-	-	-
Cadmium	-	-	-	Ha>Hi (2.9)(1.7)	Ha>R** (2.9)(2.0)	-	-	-	-
Chromium	-	-	-	-	-	-	-	-	-
Copper	-	-	-	-	-	-	-	-	-
Iron	-	-	-	-	-	-	-	-	-
Molybdenum	-	-	-	-	-	-	-	-	-
Nickel	-	-	-	-	-	-	-	-	-
Lead	-	-	-	-	-	-	-	-	-
Silicon	-	-	-	-	-	-	Ha<Hi** (6.6)(10)	-	-
Vanadium	-	-	-	Ha>Hi (1.3)(0.8)	Ha>R (1.3)(0.08)	Hi>R (0.8)(0.08)	-	Ha>R (1.2)(0.2)	Hi>R** (1.4)(0.2)
Zinc	Ha>Hi** (12)(11)	-	-	Ha>Hi** (54)(42)	-	-	-	-	-

*Brown rockfish (Sebastes auriculatus) and white belly rockfish (Sebastes vexillaris)

**Significant at the 90% confidence level ($0.05<p \leq 0.10$).

Table 16. Selected median and ranges of trace element concentrations (mg/dry kg) in tissues of rockfish* collected near the oil platforms and a rocky control site, Spring, 1975.

TISSUE Element	Hazel		Hilda		Rocky Control	
	Median	Range	Median	Range	Median	Range
MUSCLE						
Cadmium	ND**	ND-3.8	0.8	ND-3.1	2.0	ND-3.4
Iron	3.0	ND-9.1	7.1	ND-27	9.0	ND-23
Silicon	11	4.0-26	6.6	4.1-14	5.4	1.0-36
LIVER						
Chromium	0.2	ND-2.4	0.3	ND-10	1.0	ND-8.0
Iron	550	92-3,500	230	80-880	260	12-800
Lead	0.9	ND-2.1	ND	ND-1.1	0.2	ND-1.2
KIDNEY						
Cadmium	2.0	ND-5.8	0.1	ND-4.8	2.1	ND-5.0
Lead	0.2	ND-2.9	0.6	ND-1.7	0.8	ND-1.7

*Brown rockfish (*Sebastes auriculatus*) and white belly rockfish (*Sebastes vexillaris*)

**ND = Not detected

vary by factors of 2 to 20, the range of values and degree of variability generally agree for all three locations resulting in no statistically significant differences for these data.

Two tissues (muscle and gonad) were excised from the yellow rock crab and analyzed for their trace element content. These results are presented in Table 17. There were too few data points from Hilda and the rocky control to do statistical comparisons between each location sampled. The Wilcoxon rank-sum test was utilized, however, to compare trace metal levels in tissues of crabs collected from platform Hazel and a soft control site. The results indicated that there were no statistically significant differences between the trace metal levels in gonad or muscle tissue from crabs collected at these sites.

The whole soft tissues of mussels collected from the oil platforms were analyzed for their trace element content (Table 18); no control samples were available. Reported values from the literature were utilized to compare these data. The values measured for silver, cadmium, and chromium were all comparable to those reported by Graham (1972). The copper and zinc values were lower by factors of 2 and 4, respectively. The lead values were lower by a factor of approximately 8, this is typical of the onshore-offshore gradient for lead previously observed by this Project for intertidal mussels. These results indicate no trace metal contamination of the whole soft tissues of oil platform mussels.

F.2 Petroleum Hydrocarbons

The hydrocarbon content of tissue samples determined by gas chromatographic (GC) analysis show no detectable hydrocarbons (petroleum or biogenic) in the mussels and crabs regardless of collection site but very high levels in the rockfish (Table 19). The GC fingerprints show no indication of any petroleum hydrocarbons in the rockfish: All of the peaks can be reasonably attributed to biogenic hydrocarbons.

The amounts of the more prevalent individual components most of which are unidentified olefinic hydrocarbons are presented in Appendix Table F-2. One component, tentatively indentified as squalene on the basis of GC retention time, accounts for over half of the total hydrocarbon content. Squalene is commonly found in many marine organisms, especially in fish.

Because of the overwhelming quantity of biogenic hydrocarbons found in the rockfish, it would not be possible to detect trace amounts of petroleum hydrocarbons. Since mussels are generally good accumulators of petroleum hydrocarbons and no detectable amounts of petroleum hydrocarbons were found in the mussels, it is unlikely that the rockfish from the same site would contain significant amounts of petroleum hydrocarbons.

Table 17. Median trace element concentrations (mg/dry kg) in muscle and gonard tissue of the yellow rock crab* collected from oil platforms, Spring 1975.

TISSUE	Hazel		Hilda		Rocky Control		Soft Control	
Element	Median	Range	Median	Range	Median	Range	Median	Range
MUSCLE		n**=6		n=2		n=4		n=9
Silver	3.9	2.4-6.7	1.4	1.3-1.6	1.9	†ND-3.2	3.5	2.7-7.9
Cadmium	2.1	1.4-2.6	3.0	2.4-3.5	1.8	ND-3.3	2.5	1.8-12
Chromium	0.6	ND -3.8	ND	ND	0.1	ND-3.4	1.1	ND-7.3
Copper	41	32 -58	33	30-36	35	14-53	41	24-130
Iron	22	7.7-110	21	12-30	15	11-28	22	12-68
Molybdenum	0.1	0.1-0.2	0.2	0.2	0.2	ND-0.2	0.1	ND-0.2
Nickel	1.4	0.9-1.8	2.0	1.6-2.3	2.0	1.2-3.0	1.5	1.2-3.3
Lead	0.7	0.5-0.9	1.0	0.8-1.2	0.8	0.6-1.1	0.7	ND-0.9
Silicon	65	12-400	63	20-110	46	8.0-89	97	4.4-430
Vanadium	0.6	ND-0.9	1.0	0.8-1.2	0.7	ND-1.1	ND	ND-0.9
Zinc	65	40-97	82	77-87	72	67-79	88	45-120
GONAD		n=3		n=2		n=4		n=8
Silver	3.8	3.6-4.6	3.6	1.8-5.3	1.6	1.5-2.1	6.4	1.5-12
Cadmium	4.7	3.9-5.7	4.8	4.5-5.2	4.3	1.3-8.0	6.0	1.2-10
Chromium	1.1	0.7-1.2	0.4	ND-0.7	2.4	0.6-7.0	3.0	ND-7.3
Copper	30	24-30	43	14-71	17	13-33	45	10-140
Iron	67	34-81	73	47-100	62	35-94	43	4.6-90
Molybdenum	0.2	0.07-0.3	0.1	0.1	0.2	0.08-0.5	0.1	0.08-0.2
Nickel	1.6	0.7-3.5	3.6	3.5-3.6	3.0	0.8-5.8	2.4	1.0-9.9
Lead	0.4	ND-0.8	0.7	0.7	0.6	0.4-0.8	0.5	ND-0.8
Silicon	12	3.3-16	9.8	9.1-10	6.2	2.5-8.2	9.4	2.4-54
Vanadium	0.5	0.4-0.8	1.1	0.7-1.4	0.3	ND -0.7	0.3	ND -0.8
Zinc	81	38-110	90	89-92	100	89 -140	91	63 -220

*Cancer anthonyi

**n = number of samples

† ND = not detected

Table 18. Trace element concentrations (mg/dry kg) in the whole soft tissues of intertidal mussels* collected from the oil platforms, Spring 1975.

Element	Hazel		Hilda		Coastal**	
	Median	Range	Median	Range	Median	Range
Silver	2.9	0.7-4.8	1.4	0.9-2.3	<1.0	<1.0-5.5
Cadmium	3.1	2.2-3.3	2.6	ND†-3.2	2.2	2.0-4.9
Chrominum	5.4	4.1-5.9	5.1	2.7-5.8	6.1	<1.5-7.8
Copper	4.0	3.3-6.8	5.7	3.5-6.6	11	9.0-30
Iron	76	53-510	86	36-150	-	-
Molybdenum	0.3	0.2-0.9	0.2	0.2	-	-
Nickel	2.1	0.7-4.4	2.1	1.5-5.7	-	-
Lead	1.0	ND-1.1	0.8	ND-2.1	7.8	<2.2-23
Silicon	240	140-2,100	490	230-920	-	-
Vanadium	0.3	ND-1.1	0.9	ND-1.1	-	-
Zinc	50	33-69	52	21-70	200	160-310

* <u>Mytilus californianus</u>

** Coastal values are the medians of data (D. L. Graham, 1972) from three California locations: Half-Moon Bay, Carmel Bay, and Whites Point

ND = Not detected

Table 19. Hydrocarbon concentrations (mg/wet kg) in tissues of marine organisms collected near the oil platforms and control sites, Spring 1975.*

Animal (tissue)	Hazel	Hilda	Rocky Control	Soft Control
White belly rockfish (liver)	320	270	580	-
Brown rock-fish (liver)	420	1000	1100	-
Mussel (whole soft tissues)	<5**	<5**	-	-
Crab (muscle)	<5**	<5**	<5**	<5**

* Detailed data appear in Appendix Table F-1.

** Limit of detection

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APPENDICES

APPENDIX A

Scientific names of plants and invertebrates observed from oil platforms Hilda and Hazel and control sites, Santa Barbara Channel, California, 1975.

Codes for species locations: a=Hazel piling; b=Hilda piling; c=Hazel mussel clump; d=Hilda mussel clump; e=Hazel bottom debris; f=Hilda bottom debris; g= soft control bottom debris; h=hard control bottom debris; i=well head bottom debris; j=Hazel slides; k=Hilda slides; l=soft control slides; m=hard control slides; n=water column.

Species	Common name	Code
ALGAE		
Ulva sp.	Green alga	a,b
Enteromorpha sp.	Green alga	a,b
Unident. green	Green alga	a,b
Ectocarpus sp.	Brown alga	c,d
Unident. brown	Brown alga	a,b
Macrocystis sp.	Giant kelp	a,b
Ceramium sp.	Red alga	c,b
Pterosiphonia dendroidea	Red alga	c,d
Unident. red	Red alga	a,b
PROTOZOA		
Gromia oviformis	Sarcodina	c,d
Rosalina columbiensis	Protozoa	c,d
Folliculina sp.	Protozoa	c,d
PORIFERA		
Leucetta losangelensis	Sponge	c,d
Leucosolenia sp.	Sponge	c,d
Rhabdodermella sp.	Sponge	c,d
Unident. porifera	Sponge	l,m
CNIDARIA (COLENTERATES)		
Hydrozoa		
Aglaophenia struthionides	Colonial hydroid	a,b,c, d,j,k
Plumularia sp.	Colonial hydroid	c,d
Halecium sp.	Colonial hydroid	c,d
Tubularia sp.	Colonial hydroid	i
Unident. siphonophores		n
Unident. hydroid		j,k
Anthozoa		
Virgularid unid.	Sea pen	e,f,i *
Acanthoptilum sp.	Sea pen	e,f,g *
Stylatula elongata	Sea pen	e,f,g,i *
Lophogorgia chilensis	Gorgonian	a,b,e, g,k,l

*Collected in mud at all locations listed.

Species	Common name	Code
Anthozoa (continued)		
Eugorgia rubens	Gorgonian	g,l
Muricea sp.	Gorgonian	g
Tealia crassicornis	Anemone	a,b
Corynactis californica	Anemone	a,b,c,d,e, f,h,i,j,k
Anthopleura elegantissima	Anemone	a,b,c, d,j,k
Epiactis prolifera	Anemone	a,b,j,k
Metridium senile	Anemone	a,b,e, f,j,k
Pachycerianthus sp.	Anemone	e,f,g *
Anthopleura sp.	Anemone	m
Unident. anemone	Anemone	k
Paracyathus sp.	Hard coral	g,l
Scyphozoa		
Pelagia colorata	Jellyfish	n
CTENOPHORA		
Unident. combjelly	Combjelly	n
NEMERTEA		
Unident. nemertean	Ribbon worm	e
ECTOPROCTA (BRYZOANS)		
Bowerbankia gracilis	Bryzoan	c,d
Caulorhampus spiniferum	Bryzoan	c,d
Crisia occidentalis	Bryzoan	c,d,i
Crisia serrulata	Bryzoan	c,d
Callopora horrida	Bryzoan	c,d
Filicrisia franciscana	Bryzoan	c,d,i
Hippothoa hyalina	Bryzoan	c,d
Rhynchozoon sp.	Bryzoan	c,d
Scruparia ambigua	Bryzoan	c,d
Tricellaria occidentalis	Bryzoan	c,d
Unident. Ectoproct	Bryzoan	j
Unident. Ectoproct	"Lacy" Bryzoan	j,l
MOLLUSCA		
Gastropoda (nudibranchs and snails)		
Anisodoris nobilis	Nudibranch	a,b,c,d
Dialula sandiegensis	Nudibranch	a,b,c,d
Doriopsilla albopunctata	Nudibranch	a,b,c,d
Hermissenda crassicornis	Nudibranch	a,b,c, d,j,k
Doriopsilla albopunctata	Nudibranch	a,b
Cadlina sp. (?)	Nudibranch	j

*Collected in mud at all locations listed.

Appendix A - Continued

Species	Common name	Code
ARTHROPODA		
Cirripedia (barnacles)		
Balanus crenatus	Acorn barnacle	c,d
Balanus nubilus	Acorn barnacle	a,b,c,d, e,f,h,i
Balanus tintinnabulum	Acorn barnacle	a,b,c,d,e, f,h,i,j,k
Balanus trigonus	Acorn barnacle	c,d
Chthamalus dalli	Acorn barnacle	a,b,c,d
Tetraclita squamosa	Acorn barnacle	c,d
Balanus sp.	Acorn barnacle	a,b,c,d
Pollicipes polymerus	Gooseneck barnacle	c,d,j,k
Amphipoda		
Aoroides columbiae	Amphipod	c,d
Caprella californica	Skeleton Shrimp	c,d
Caprella equilibra	Skeleton Shrimp	c,d
Caprella verrucosa	Skeleton Shrimp	c,d
Caprella sp.	Skeleton Shrimp	c,d
Corophium baconi	Amphipod	c,d
Deutella californica	Skeleton Shrimp	c,d
Eurystheus sp.	Amphipod	c,d
Elasmopus serricatus	Amphipod	c,d
Leucothoe alata	Amphipod	c,d
Jassa falcata	Amphipod	c,d
Ericthonius brasiliensis	Amphipod	c,d
Photis sp.	Amphipod	c,d
Podocercus brosiliensis	Amphipod	c,d
Stenothoe estacola	Amphipod	c,d
Isopoda		
Janiralta occidentalis	Isopod	c,d
Jaeropsis dubia	Isopod	c,d
Eucardia (crabs, shrimp)		
Cancer sp.	Crab	c,d
Megalops larvae	Crab	c,d
Cancer antenarius	Crab	a,b
Cancer anthonyi	Crab	a,b,c,d, e,f,j,k
Cancer productus	Crab	a,b
Pachygrapsus crassipes	Shore crab	a,b*
Loxorhynchus grandis	Crab	a,b,j,k
Oxyrhynchid unident.	Crab	k
Alpheus bellimanus	Snapping Shrimp	a*
Pachycheles rudis	Crab	d
Pycnogonida		
Unident. pyncnogonid	Sea spider	c,d,e,f

*Found in stomach contents at all locations listed.

Appendix A - Continued

Species	Common name	Code
Gastropoda (continued)		
Archidoris montereyensis	Nudibranch	a,b,c,d,k
Tritonia diomedia	Nudibranch	g
Unident. dorid	Nudibranch	k
Diodora aspera	Keyhole limpet	c,d,e,f
Megathura crenulata	Giant keyhole limpet	j,k
Lottia gigantea	Limpet	a,b
Cypraea spadicea	Cowery	h
Kelletia kelleti	Kellet's whelk	h,i
Calliostoma sp.	Snail	g
Conus californicus	Cone snail	g
Mopalia muscosa	Chiton	a,b,c,d
Pelecypoda (clams)		
Mytilus californianus	California sea mussel	a,b,c,d, h,j,k,l
Mytilus edulis	Bay mussel	a,b,c,d, h,j,k
Hinnites multirugosus	Purple hinge scallop	a,b,c,d, j,k
Leptopectin latiauratus	Pectin scallop	c,d
Unident. pholad	Burrowing clam	g
Chama pellucida	Clam	c,d
Pseudochama exogyra	Clam	c,d
Hiatella arctica	Clam	c,d
Pododesmus cepio	Clam	c,d
Kellia laperousii	Clam	c,d
Petricola californiensis	Clam	c,d
Unident. siphon	Clam	g
Scaphopoda		
Dentalium neohexagonum	Tusk shell	g
Cephalopoda		
Octopus sp.	Octopus	a,b,c,d
ANNELIDA		
Polychaeta (additional benthic polychaeta - Appendix D)		
Dexiospira spirillum	Polychaete worm	c,d
Eulalia aviculiseta	Polychaete worm	c,d
Eumida sp.	Polychaete worm	c,d
Nereis mediator	Polychaete worm	c,d
Spirorbis eximius	Polychaete worm	c,d
Unident. Syllidae	Polychaete worm	c,d
Eudistylia polymorpha	Feather duster worm	a,b,c,d,j
Diopatra sp.	Tube worm	e,f,i
Haldsydna ? *tuberculifera*		c,d
ECHIURA		
Listriolobus pelodes	Spoon worm (Sea grape)	g *

*Found in stomach contents at all locations listed.

Appendix A - Continued

Species	Common name	Code
ARTHROPODA (continued)		
Insecta		
Chironomid larvae		c,d
ECHINODERMATA		
Asteroidea (sea star)		
Pisaster ochraceus	Sea star	a,b,c,d,e, f,h,j,k,m
Pisaster giganteus	Sea star	a,b,c,d,e, f,h,j,k,m
Pisaster brevispinus	Sea star	a,b,c,d,e, f,g,h,i,k, l,m
Patiria miniata	Bat star	a,b,c,d,e, f,g,h,i,j, k,l,m
Dermasterias imbricata	Leather star	b
Pycnopodia helianthoides	Sea star	e,g
Henricia leviscula	Sea star	a,b,g
Echinoidea (sea urchin)		
Strongylocentrotus purpuratus	Purple urchin	a,b,c,d,e, f,h,j,k,m
Strongylocentrotus franciscanus	Urchin	a,b,c,d,e, f,j,k,m
Holothuroidea (sea cucumber)		
Parastichopus californicus	Sea cucumber	a,b,c,d,e, f,h,i,k,m
Parastichopus parvimensis	Sea cucumber	b,e,f,k
Parastichopus sp.	Sea cucumber	g
Ophiuroidea		
Ophiothrix spiculata	Brittle star	c,d
Ophiopteris papillosa	Brittle star	c,d
CHORDATA		
Tunicata (tunicate)		
Styella montereyensis	Sea squirt	a,b,i

APPENDIX B

List of scientific and common names of fishes observed at oil platforms "Hazel" and "Hilda", and control stations, April - August, 1975.

Species	Common Name
Alopiidae	
Alopias vulpinus	Thresher Shark
Scyliorhinidae	
Cephaloscyllium ventriosum	Swell Shark
Carcharhinidae	
Prionace glauca	Blue Shark
Squatinidae	
Squatina californica	Pacific Angel Shark
Engraulidae	
Engraulis mordax	Northern Anchovy
Atherinidae	
Atherinops affinis	Topsmelt
Scorpaenidae	
Scorpaena guttata	California Scorpionfish
Sebastes atrovirens	Kelp Rockfish
Sebastes auriculatus	Brown Rockfish
Sebastes carnatus	Gopher Rockfish
Sebastes chrysomelas	Black-and-yellow Rockfish
Sebastes dalli	Calico Rockfish
Sebastes jordani	Shortbelly Rockfish
Sebastes mystinus	Blue Rockfish
Sebastes paucispinis	Bocaccio
Sebastes pinniger	Canary Rockfish
Sebastes rastrelliger	Grass Rockfish
Sebastes rubrivinctus	Flag Rockfish
Sebastes serranoides	Olive Rockfish
Sebastes serriceps	Treefish
Sebastes vexillaris	Whitebelly Rockfish
Hexagrammidae	
Hexagrammos decagrammus	Kelp Greenling
Ophiodon elongatus	Lingcod
Oxylebius pictus	Painted Greenling
Zaniolepis latipinnis	Longspine Combfish
Cottidae	
Leiocottus hirundo	Lavender Sculpin
Orthonopias triacis	Snubnose Sculpin
Scorpaenichthys marmoratus	Cabezon

Appendix B - Continued

Species	Common Name
Agonidae	
Agonidae sp., unidentified	Poacher
Serranidae	
Paralabrax clathratus	Kelp Bass
Paralabrax nebulifer	Barred Sand Bass
Sciaenidae	
Genyonemus lineatus	White Croaker
Kyphosidae	
Medialuna californiensis	Halfmoon
Embiotocidae	
Cymatogaster aggregata	Shiner Perch
Embiotoca jacksoni	Black Perch
Hyperprosopon argenteum	Walleye Surfperch
Hyperprosopon ellipticum	Silver Surfperch
Hypsurus caryi	Rainbow Seaperch
Phanerodon furcatus	White Seaperch
Rhacochilus toxotes	Rubberlip Seaperch
Rhacochilus vacca	Pile Perch
Pomacentridae	
Chromis punctipinnis	Blacksmith
Hypsypops rubicunda	Garibaldi
Labridae	
Oxyjulis californica	Señorita
Bathymasteridae	
Rathbunella hypoplecta	Smooth Ronquil
Clinidae	
Heterostichus rostratus	Giant Kelpfish
?Neoclinus uninotatus	Onespot Fringehead
Gobiidae	
Gobiidae sp., unidentified	Goby
Scombridae	
Sarda chiliensis	Pacific Bonito
Bothidae	
Citharichthys stigmaeus	Speckled Sanddabs
Pleuronectidae	
Parophrys vetulus	English Sole
Molidae	
Mola mola	Ocean Sunfish

APPENDIX C

List of scientific and common names of birds and mammals observed near oil platforms "Hazel" and "Hilda" and control stations, April - August, 1975 by Michael Moore. Compiled by Jim Allen.

Species	Common Name
BIRDS	
Gaviidae	
Gavia arctica	Arctic Loon
Podicipedidae	
Aechmophorus occidentalis	Western Grebe
Procellariidae	
Fulmarus glacialis	Fulmar
Puffinus creatapus	Pink-footed Shearwater
Puffinus griseus	Sooty Shearwater
Pelecanidae	
Pelecanus occidentalis	Brown Pelican
Phalacrocoracidae	
Phalacrocorax penicillatus	Brandt's Cormorant
Rallidae	
Fulica americanus	American Coot
Haematopodidae	
Haematopus bachmani	Black Oystercatcher
Scolopacidae	
Crocethia alba	Sanderling
Ereunetes mauri	Western Sandpiper
Laridae	
Hydroprogne caspia	Caspian Tern
Larus californicus	California Gull
Larus delawarensis	Ring-billed Gull
Larus heermanni	Heermann's Gull
Larus occidentalis	Western Gull
Larus philadelphia	Bonaparte's Gull
Rissa tridactyla	Black-legged Kittiwake
Sterna forsteri	Forester's Tern
Thalasseus elegans	Elegant Tern
Alcidae	
Cepphus columba	Pigeon Guillemot
Ptychoramphus aleutica	Cassin's Auklet

Appendix C - Continued

Species	Common Name
Parulidae	
Wilsonia pusilla	Wilson's Warbler
Ploceidae	
Passer domesticus	House Sparrow
MAMMALS	
Otariidae	
Zalophus californianus	California Sea Lion
Phocidae	
Phoca vitulina	Harbor Seal
Delphinidae	
Lagenorhynchus obliquidens	Pacific White-sided Dolphin
Eschrichtidae	
Eschrichtius gibbosus	California Gray Whale

APPENDIX D

Abundance and distribution of benthic polychaetes from stations near platform Hazel, 16 April 1975. Number of specimens of each species from a single 0.1 m^2 Van Veen grab at each station are indicated.

Family	West						East				North		South			
Species	9	5	4	3	2	1	1	2	5	9	2	1	1	2	C	Total
SEDENTERIATE POLYCHAETES																
Orbiniidae																
Haploscopus elongatus	1			2	2	1	6					1			1	14
Paraonidae																
Paraonis gracilis oculata	1						3		1	1						6
Spionidae																
Boccardia bassilaria											2		1			3
Boccardia redeki	1														1	2
Laonice cirrata							1									1
Polydora limnicola															2	2
Prionospio cirrifera	4			3	1					1						9
Prionospio pinnata	2	1		2	3	1	2	1	2		3	1	2	3		23
Prionospio pygmaeus	1		4		4				2				1		1	13
Spiophanes fimbriata							2					1				3
Spiophanes missionensis						2			3					1		6
Prionospio sp. (Frag.)															1	1
Magelonidae																
Magelona pacifica		1						1	1							3
Magelona sacculata									1							1
Trochochaetidae																
Trochochaeta franciscunum		5	20	14	21		2	1			5	27	8			103
Poecilochaetidae																
Poecilochaetus johnsoni	1							1	1		2					5

Appendix D - Continued

Family Species	West 9	5	4	3	2	1	East 1	2	5	9	North 2	1	South 1	2	C	Total
Cirratulidae																
Caulleriella alata															1	1
Caetezone setosa										1						1
Tharyx sp.						2	4							1		7
Cossaridae																
Cossura brunnea	6	3	1	1	4		2			1	5			1	2	26
Flabelligeridae																
Pherusa neopapillata							1									1
Sternaspidae																
Sternaspis fussor										2					1	3
Capitellidae																
Notomastus sp.							1		1							2
N. tenuis	2		2		2		1		1			1	1	2		12
Capitellidae UI						3		1								4
Maldanidae	3		5	11	1		5	2	1	4	9	1	1	2	4	49
Sabellariidae																
Sabellaria mentaria						2	1				1					4
Pectinariidae																
Pectinaria californiensis	5	1	3	3	2			1	7	4		1		4	4	35
Ampharetidae																
Amphicteis scaphobran chiata					1		2		2							5
Ampharete labrops			3							12						15
Samythella interrupta													1			1
Terebellidae																
Pista cristata							1				1					2
P. disjuncta					2				1							3
P. moorei	2				1				2							5
Streblosoma crassibranchiata	1		3	7	5						1		3	2	7	29
Amaena sp.	1				1					1						3
Terebellidae, UI						3										3

Appendix D - Continued

Family Species	West 9	West 5	West 4	West 3	West 2	West 1	East 1	East 2	East 5	East 9	North 2	North 1	South 1	South 2	C	Total
Trichobranchidae																
Terebellides stroemi	1		2	2	6			1	1	1						14
Sabellidae																
Chone mollis									1	2				1		4
Serpulidae																
Protula superbae							1									1
Chaetopteridae																
Phylochaetopterus sp.			1													1
ERRANTIATE POLYCHAETES																
Polynoidae																
Halosydna latior						8	12									20
Polynoid, UI	1	3						2		11	4			5	6	32
?*Malmgrenia*											1					1
Polyodontidae																
Panthalais sp.															1	1
Sigalionidae																
Stenelenella uniformis			4		6	2	6		4			3	7			32
Lepidasthenia braicirrata	1															1
Scaleworm, UI (fragment)				5	1							1	1			8
Phyllodocidae																
Anaitides mutiseriata										1	1		1			3
A. sp.															1	1
Eteone dilitae							1									1
Hesionidae																
Ophiodremus pugettensis															1	1

Appendix D - Continued

Family / Species	West 9	West 5	West 4	West 3	West 2	West 1	East 1	East 2	East 5	East 9	North 2	North 1	South 1	South 2	C	Total
Pilargidae																
Pilargis maculata	3	5		1	2				3	2			4	1	1	22
Sigambra tentaculata	6	2	10	6	8		2	2	2	1	2	3	7	5	2	58
Synelmis albini											1					1
Parandelia fauveli									1					1		2
Nereidae																
Ceratocephale crosslandi							3									3
Nereis sp.	1	1			2	3	1						1			9
Nephtyidae																
Aglaophamas erectens								1								1
Nephtys californiensis								1		2	1				1	5
N. ferruginea	2	1	2	5	7			1	3	3	3		4	3		34
Glyceridae																
Glycera americana		1		1	2	3	2		2		1	3		2	4	21
G. "capitata"								1								1
G. gigantea										1						1
G. sp. (Juvenile)	3		3	1	6	1	5		1	1	1	1	5	1		29
G. robusta				1												1
Goniadidae																
Glycinde armigera		2	4	2	1	1	3	1	1	6	2	7	2		5	38
G. littorea	2	1			2		4				2			1	1	13
Onuphidae																
Diopatra ornata				1		30	20			1			1			53
Nothria "elegans"					1		1					1	1			4
Onuphis eremita	1															1
Nothria sp. (Juvenile)													1			1
Eunicidae																
Marphysa disjuncta	1		1						1	2					1	6

Appendix D - Continued

Family / Species	West 9	West 5	West 4	West 3	West 2	West 1	East 1	East 2	East 5	East 9	North 2	North 1	South 1	South 2	C	Total
Lumbrineridae																
Lumbrineris "*californiensis*"	3		15	6				2			2		3	4	1	36
L. japonica												1				1
L. sps. (Juveniles)	3				15		3		3	1	2	5		1	3	36
Arabellidae																
Arabella iricolor	2	1			2	12	14		1	3	3			3		41

APPENDIX TABLE E-1. Median trace element concentrations (mg/dry kg) in muscle tissue of Brown and White belly rockfish collected near the oil platforms and a control site, Spring 1975.

ent	Species	HAZEL		HILDA		ROCKY CONTROL	
		Median	Range	Median	Range	Median	Range
er	B*	ND**	ND	ND	ND	ND	ND
	W+	ND	ND	ND	ND	ND	ND
mium	B	ND	ND-2.1	0.4	ND-3.3	2.8	ND-3.4
	W	ND	ND-3.8	1.2	ND-3.8	1.2	ND-2.8
romium	B	ND	ND-1.1	ND	ND-2.6	ND	ND-0.7
	W	ND	ND-0.6	ND	ND-1.4	ND	ND-1.2
opper	B	ND	ND	ND	ND	ND	ND
	W	ND	ND	ND	ND-0.5	ND	ND-1.1
ron	B	5.1	3.9-8.5	4.4	ND-27	8.0	ND-23
	W	1.0	ND-9.1	9.8	ND-14	9.9	ND-17
Molybdenum	B	0.3	0.1-0.3	0.2	0.2-0.3	0.2	0.2-0.4
	W	0.2	0.2-0.3	0.2	ND-0.3	0.2	0.2
Nickel	B	2.8	1.4-3.0	2.2	1.5-2.8	2.2	1.8-4.2
	W	2.2	1.6-2.7	2.5	1.6-2.9	2.0	1.7-3.2
Lead	B	1.4	0.7-3.0	1.1	0.7-1.4	1.0	0.9-2.1
	W	1.1	0.8-1.4	1.2	0.8-1.5	0.9	0.8-1.2
Silicon	B	7.2	4.0-9.2	6.3	4.1-14	5.4	4.6-36
	W	14	6.4-26	7.0	4.8-11	5.4	1.0-7.5
Vanadium	B	1.4	0.7-1.5	1.1	0.7-1.4	0.9	ND-1.2
	W	1.1	ND-1.4	0.8	ND-1.3	0.9	0.5-1.2
Zinc	B	12	7.6-18	10	6.8-12	13	5.8-17
	W	12	6.0-20	12	2.9-28	13	6.1-23

*B: Brown rockfish, Sebastes auriculatus. # of samples: Hazel, 5; Hilda, 6; and rocky control, 6.

**ND: Not Detected

+W: White belly rockfish, Sebastes vexillaris. # Of samples: Hazel, 6; Hilda, 6; and Rocky control, 6.

APPENDIX TABLE E-2. Median trace element concentrations (mg/dry kg) in liver tissue of Brown and White belly rockfish collected near the oil platforms and a control site. Spring 1975.

Element	Species	HAZEL		HILDA		ROCKY CONTROL	
		Median	Range	Median	Range	Median	Range
Silver	B*	0.6	ND**-4.4	0.6	0.4-1.0	0.7	ND-1.0
	W+	0.6	ND-1.5	0.4	0.3-1.0	0.4	ND-1.5
Cadmium	B	2.9	1.9-6.8	1.8	1.1-2.5	1.8	ND-2.3
	W	2.9	ND-6.0	1.6	0.5-2.4	2.3	ND-5.2
Chromium	B	ND	ND-2.4	0.08	ND-0.5	2.0	ND-8.0
	W	0.5	ND-1.0	0.5	ND-10	ND	ND-4.1
Copper	B	14	1.8-120	5.4	4.2-17	9.4	4.7-18
	W	4.9	1.9-16	4.6	2.3-5.6	6.2	1.5-16
Iron	B	880	190-3,500	200	80-880	210	12-800
	W	230	92-670	260	240-640	320	59-360
Molybdenum	B	0.2	0.1-0.5	ND	ND-0.2	0.1	ND-0.2
	W	0.04	ND-0.4	0.1	ND-0.2	0.1	ND-0.2
Nickel	B	2.2	1.3-4.6	1.6	1.2-2.2	1.4	0.7-3.0
	W	1.9	1.3-3.2	1.2	ND-5.4	1.6	0.8-3.4
Lead	B	1.4	ND-2.1	ND	ND-1.1	0.3	ND-1.2
	W	0.4	ND-1.2	ND	ND-0.8	ND	ND-0.8
Silicon	B	15	2.4-280	6.5	3.4-12	15	0.7-19
	W	4.4	1.5-23	5.3	0.8-7.5	2.7	0.8-7.8
Vanadium	B	1.4	0.6-5.5	0.9	0.6-2.2	0.07	0.04-1.4
	W	1.2	0.4-4.1	0.7	0.5-0.8	0.08	0.04-3.8
Zinc	B	63	31-280	43	26-55	45	26-49
	W	45	27-100	41	26-44	39	25-71

*B: Brown rockfish, Sebastes auriculatus. # of samples: Hazel, 6; Hilda, 6; and Rocky control, 6.
**ND: Not Detected
+W: White belly rockfish, Sebastes vexillaris. # of samples: Hazel, 8; Hilda, 5; and Rocky control, 5.

APPENDIX TABLE E-3. Median trace element concentrations (mg/dry kg) in kidney tissue of Brown and White belly rockfish collected near the oil platforms and a control site. Spring 1975.

Element	Species	HAZEL		HILDA		ROCKY CONTROL	
		Median	Range	Median	Range	Median	Range
Silver	B*	0.7	ND**-1.1	0.8	0.4-1.0	0.7	0.5-1.2
	W+	0.6	0.2-1.1	0.7	0.5-1.4	0.8	ND-1.2
Cadmium	B	2.9	ND-5.8	0.2	ND-4.8	2.4	ND-5.0
	W	1.2	ND-3.8	ND	ND-4.5	1.8	ND-5.0
Chromium	B	ND	ND-0.7	ND	ND-1.9	ND	ND-1.9
	W	ND	ND	ND	ND-0.2	ND	ND-5.1
Copper	B	3.4	1.7-9.0	2.6	0.8-5.6	4.6	2.7-6.6
	W	3.0	1.3-4.0	3.4	3.0-3.7	3.8	0.6-5.1
Iron	B	730	650-1,100	780	510-1,200	670	510-820
	W	370	290-600	500	280-690	450	380-630
Molybdenum	B	0.1	ND-0.2	ND	ND-0.2	0.2	ND-0.3
	W	0.08	ND-2.2	0.2	ND-0.2	0.2	ND-0.3
Nickel	B	2.0	1.4-3.8	2.5	ND-3.2	1.8	1.6-3.3
	W	2.2	ND-3.3	2.6	2.1-3.3	3.1	2.4-7.5
Lead	B	0.5	ND-2.9	ND	ND-1.0	ND	ND-1.7
	W	ND	ND-1.7	1.3	1.0-1.7	1.6	1.2-1.7
Silicon	B	6.1	5.4-12	8.0	ND-11	7.5	4.6-58
	W	7.2	4.7-10	12	4.8-24	4.6	3.3-9.7
Vanadium	B	1.0	0.7-4.3	1.4	ND-3.8	0.1	0.08-3.5
	W	1.4	0.8-2.5	1.5	1.2-2.2	0.2	ND-3.7
Zinc	B	57	54-90	67	49-75	64	50-69
	W	76	48-83	55	54-69	91	65-120

*B: Brown rockfish, Sebastes auriculatus. # of samples: Hazel, 5; Hilda, 6; and Rocky control, 5.

**ND: Not Detected

+W: White belly rockfish, Sebastes vexillaris. # of samples: Hazel, 8; Hilda, 5; and Rocky Control, 6.

APPENDIX F

v

Table 1.— Hydrocarbon concentrations* (mg/wet kg) in tissues of marine organisms collected near the oil platforms and control sites, Spring 1975.

Sample Designation	Hydrocarbon Content in C_{10}-C_{35} Range in Given Fraction			
	1	2	3	Total
Hazel white belly rockfish	50	250	25	325
Hilda white belly rockfish	50	200	20	270
Rocky control white belly rockfish	70	500	15	585
Hazel brown rockfish	50	350	15	415
Hilda brown rockfish	80	900	20	1000
Rocky control brown rockfish	80	950	25	1055
Hazel mussel	< 2**	< 2**	< 2**	< 5**
Hilda mussel	< 2**	< 2**	< 2**	< 5**
Hazel crab	< 2**	< 2**	< 2**	< 5**
Hilda crab	< 2**	< 2**	< 2**	< 5**
Rocky control crab	< 2**	< 2**	< 2**	< 5**
Soft control crab	< 2**	< 2**	< 2**	< 5**

* Hydrocarbon content was determined by GC analysis. Fraction 1 contains saturated hydrocarbons; Fraction 2 contains mono-and diaromatic and olefinic hydrocarbons, Fraction 3 contains tri-and polyaromatic hydrocarbons and some of the olefinic hydrocarbons. The amounts of some of the more prevalent individual components are given in Table 3.

**Limit of detection.

APPENDIX F

Table 2. Individual biogenic hydrocarbons (mg/wet kg) in rockfish[a] collected near the oil platforms and a control site, Spring 1975.

	Amount of Biogenic Hydrocarbon with Given n-Paraffin Number Retention Time[b]												
	15.0[c]	17.0[d]	17.1[e]	21.1[f]	22.4[f]	23.1[f]	28.1[g]	28.4[f]	28.9[f]	30.6[f]	30.9[f]	32.6[f]	32.9[f]
HAZEL													
white belly rockfish	0.2	0.1	2.7	5.6	4.9	1.2	200	2.1	0.4	1.9	15.6	10.7	6.8
HILDA													
white belly rockfish	1.9	0.1	4.1	4.6	0.7	1.8	190	3.4	6.6	5.3	12.3	14.2	6.6
ROCKY CONTROL													
white belly rockfish	1.5	4.5	5.0	6.4	7.3	0.6	360	30.7	0.4	49.0	31.4	7.2	2.6
HAZEL													
brown rockfish	1.7	0.1	5.4	2.3	1.4	2.0	290	8.9	1.8	18.8	12.0	15.3	3.1
HILDA													
brown rockfish	1.5	0.1	4.8	9.5	8.6	2.4	560	21.0	4.2	79.1	89.4	23.6	9.6
ROCKY CONTROL													
brown rockfish	1.3	0.1	4.3	10.5	160.	3.6	550	19.0	3.3	85.8	87.2	29.4	11.0

a. Brown rockfish (Sebastes auriculatus) and white belly rockfish (Sebastes vexillaris)
b. For example, an n-paraffin number retention time of 23.5 means that the component has a retention time that is half way between that of the C_{23} n-paraffin and that of the C_{24} n-paraffin.
c. n-Pentadecane.
d. n-Heptadecane.
e. Pristane
f. An olefinic hydrocarbon,
g. Probably squalene.