BIOLOGICAL AND OCEANOGRAPHICAL SURVEY OF THE SANTA BARBARA CHANNEL OIL SPILL 1969—1970

VOLUME I

BIOLOGY AND BACTERIOLOGY

Compiled By

DALE STRAUGHAN

ALLAN HANCOCK FOUNDATION
UNIVERSITY OF SOUTHERN CALIFORNIA
1971

Sea Grant Publication No. 2

BIOLOGICAL AND OCEANOGRAPHICAL

SURVEY OF THE

SANTA BARBARA CHANNEL OIL SPILL

1969-1970

VOLUME I

BIOLOGY AND BACTERIOLOGY

Compiled By

DALE STRAUGHAN

ALLAN HANCOCK FOUNDATION

UNIVERSITY OF SOUTHERN CALIFORNIA

1971

THE WORK HEREIN WAS PARTIALLY SUPPORTED BY A GRANT
(GH-89) FROM THE NATIONAL SEA GRANT PROGRAM
U. S. DEPARTMENT OF COMMERCE TO THE
UNIVERSITY OF SOUTHERN CALIFORNIA

Sea Grant Publication No. 2 December 1970

TABLE OF CONTENTS

PREFACE

On February 20, 1969, the Western Oil and Gas Association awarded a research grant to the Allan Hancock Foundation, University of Southern California, to study the biological and oceanographical effects of oil spillage in the Santa Barbara Channel following the 1969 blowout. The grant was for a twelve month field study so that indications of recovery, as well as damage, could be studied. The results of this research were to be published by the Allan Hancock Foundation and this publication "will be insofar as it can, a compendium of the findings of all persons working either directly within the project, or on the problem". To this end, we have summarized data available to us from government agencies, including the California State Water Quality Control Board, the California Department of Fish and Game, the Federal Water Quality Administration, and the United States Bureau of Commercial Fisheries. Unfortunately not all of their data was available to us, due to restrictions imposed pending several legal suits. We have invited others to publish papers with us, e.g., Robert L. Brownell, Burney Le Boeuf, and Barbara Drinkwater et al. We have referred to papers and reports not published herein and attention is drawn to the preliminary report on ecological effects of the Santa Barbara Oil Spill submitted by E.K. Anderson, L.G. Jones, C.T. Mitchell and W.J. North to the Western Oil and Gas Association, and to the report written for the Federal Water Pollution Control Administration (now FWQA) by M. Neushul entitled "Santa Barbara Oil Pollution, 1969; Final Report Dealing with the Early Stages of the Santa Barbara Oil Spill".

Many oil industry personnel were of considerable assistance throughout this research. We are grateful for this help. By prior agreement, assistance and advice was provided only when requested.

We have also had the benefit of advice and criticism of a Liaison Committee formed of representatives from outside the oil industry. This included one representative each from the Federal Water Quality Administration, the California State Water Quality Control Board, the California Department of Fish and Game, and Dr. Mason L. Hill, who was an active petroleum geologist before retirement. We wish to thank all these gentlemen for their time, consideration, and advice.

The investigations were the responsibility of Dr. Bernard C. Abbott, Director of the Allan Hancock Foundation. Dr. Dale Straughan was the project director. Dr. Ronald L. Kolpack was responsible for the geology and oceanography sections of the program. Dr. O. Bandy and Dr. D.S. Gorsline have provided invaluable assistance in the geology and oceanography work. Dr. J. Foxworthy, Loyola University, was involved in the initial planning stages of the bacteriology program.

Papers in Volume I, Biology and Bacteriology, were compiled by Dr. Dale Straughan and edited by Mrs. D. Halmos, editor of the Allan Hancock Publications. Papers in Volume II, Physical, Chemical and Geological Studies, were compiled and edited by Dr. Ronald L. Kolpack.

CHAPTER 1

INTRODUCTION

On January 28, 1969, there was a blowout at the Union Oil well on Platform A in the Santa Barbara Channel. During the following weeks, as the company struggled to control and contain the flow of oil, large areas of ocean and waterfront were polluted. Efforts to contain the spill and protect beaches were hampered and often destroyed by high winds and seas during the stormy weather. Damage caused by oil was difficult to assess because of the unusually high freshwater runoff both preceding and after the spill. Overall, the period was one of confusion and dire predictions--confusion because people did not grasp the magnitude of the problem and lacked the technology to cope with it, which gave way to dire predictions when the situation was grasped and the people of Santa Barbara felt helpless. Many informed people predicted that the area would be barren and lifeless and no longer a beauty to behold. However, a year later, the outlook is more optimistic. Out of the initial confusion one can piece together the events following the spill, determine at least some of the effects the oil had in the Santa Barbara Channel, and assess what we have learned from this experience.

Fixed drilling Platform A is located about six miles southeast of Santa Barbara and six miles southwest of Carpinteria, California (Fig. 1). This is on tract 402, which is leased jointly to Union Oil, Gulf Oil Corporation, Mobil Oil Corporation and Texaco. Union Oil is the operator of A-21 well. Drilling began on the A-21 well, the fifth well drilled from Platform A, on January 14, 1969. At mid-morning on January 28, mud began to flow from the drill pipe while it was being removed from the hole preparatory to running electric logs and later setting production casing. The events which followed are detailed in the Battelle-Northwest

Report (1969). Fourteen to twenty-five minutes after the blowout, bubbles were noticed in the ocean around the platform and a large boil, several hundred feet in diameter, appeared about 800 feet east of the platform. Next day there was also a smaller boil, 30 feet in diameter, at the northeast leg of the platform, with lesser bubbling between the boils. Bubbles extended to 300 feet west of the platform. Eleven days after the blowout, enough drilling mud was assembled to pump into the well. The boils diminished to a few bubbles. When there was no evidence of leakage at the surface, the well was cemented and filled to the ocean bottom. Only a few small gas bubbles appeared under the edge of the platform. On February 12, 13, seepage increased and extended out to 800 feet from the platform. The slick from this seepage was 30 to 150 feet wide and extended one to two miles. Adjacent wells went into production in an attempt to reduce pressure in the upper sand zone. Attempts were made to cement fissures on the ocean floor. On February 16, Union Oil placed the first steel hood in position. This hood collects oil over a wide area, by accumulating it at the top of the hood, from where it is pumped off. On February 23, the boil at the platform leg predominated, with lesser bubbling 500 feet east and 300 feet west of the platform. At the end of February, the boil at the northwest leg diminished and seepage along the east and west lines was renewed. Subsequent to this, Battelle-Northwest (1969) states that seepage continued at rates up to an estimated fifty barrels per day (1 barrel = 42 gallons oil). Present seepage rate (April, 1970) varies up to ten barrels per day.

After the spill, oil accumulated at sea under the influence of the prevailing north-northwest winds. A storm commencing on February 4 and continuing through February 7 shifted the winds from a southeasterly direction clockwise to the west. Thus, on the night of February 4, large quantities of oil entered the Santa Barbara Harbor and heavy pollution of the mainland beaches began.

Attempts were made to control the oil spread by using booms. When the booms remained in place, they were often ineffective because of the heavy seas; but the weather made it difficult to place them in position and those that were successfully moored soon broke up. Straw was the most widely used sorbent. It repels water and absorbs from five to forty times its own weight in oil. "Limited" use was made of dispersants. Correxit 7664, Polycomplex A-11, and Ara Chem were the most commonly used products. These were used inside Santa Barbara Harbor and in other areas at least a mile offshore (Table 1).

The oil was washed on and off the beaches by the tides. This meant that contamination varied almost continuously and it was impossible to determine accurately the amount of oil that any one area was exposed to. Hence, we are resorting to use of arbitrary terms such as light (iridescent film), moderate (iridescent film and some heavy black oil), heavy (heavy black oil). Our estimates of pollution on a beach could differ from those of observers who visited the beach at different times.

In December, 1969, a second spill occurred on Platform A. On December 15, a small leak was found in the collection pipeline from the tents at Platform A and was repaired. Next day there was still oil in the water and a drop in shipping line pressure. Platforms A and B were shut down to repair the shipping line leak. The spill estimate was 400 barrels. The repair was completed on December 19 and production was resumed on December 20. Seepage from the sand increased due to pressure buildup and no estimate of this loss is available (personal communication, H. Morrison).

Following the January spill, private, government, and university agencies moved into the field in an attempt to determine the effects of oil pollution in the marine environment. Among them were personnel from the California State Water Quality Control Board, the Federal Water Pollution Control Administration, California State Fish and Game, and the U.S. Bureau of Commercial Fisheries. The United States Geological Survey, Coast Guard, and Corps of Engineers also had personnel working in the area. Biologists from the University of California at Santa Barbara worked on immediate effects on nearshore and intertidal communities and private individuals were involved in efforts to save sick birds. The results of this research are referred to in the relevant sections of this report. Battelle-Northwest (1969) and Southern California Academy of Sciences (1969) gave lists of research and development programs that have been promoted as a result of the Santa Barbara Oil Spill. Both lists are incomplete as they do not include projects sponsored by the American Petroleum Institute.

A preliminary evaluation of the ecological effects in the Santa Barbara Channel by a team from the California Institute of Technology headed by Wheeler North was supported by Western Oil and Gas Association. Observations were made at intertidal and subtidal stations on the mainland and Channel Islands between February 14 and 19. This survey was conducted during the most extreme phases of oil pollution of the beaches and kelp beds. In many cases diving conditions were poor and collections were made by feeling for specimens.

"The vast majority of organisms we observed were alive and appeared entirely healthy. Occurrences of moribund and/or dead creatures were so rare that they can be described individually. One moribund pismo clam and two bird corpses were the only affected animals found on the intertidal survey of February 15. A portion of a recently dead urchin test was recovered from forty feet during the diving near Santa Barbara Harbor on February 16. Fifteen recently dead urchins, one sea hare, one chiton, one abalone, and a bird corpse were found in the intertidal at Sandstone Point, Santa Cruz Island. A dead urchin was also found at Blue Bank Anchorage, Santa Cruz Island. A patch of dead coralline algae was noted on a rock forty feet deep off Anacapa Island. Impingement of surrounding sand suggested that these corallines had recently been exposed by sediment movements. It was concluded that they had probably expired long ago due to natural burial. About 20 percent of the barnacle population attached to the undersea portion of Platform A appeared to have died recently. Recent mortalities among kelp pectens were also noted on this structure. No other potential victims of oil pollution were noted.

"Healthy plants and animals of nearly every phylum occurred abundantly at all stations. Except for bird populations, there was not the faintest resemblance to the extensive losses observed after the 'Tampico' spillage. The only circumstances that could be considered suspicious were the barnacle and pecten losses at Platform A and the small accumulation of dead animals in the intertidal at Sandstone Point. Since the underwater structure at Platform A may have been exposed to the most intense and fresh masses of liberated oil as well as noxious gases, losses here are not surprising. The small area and numbers of organisms involved, compared to the entire Channel, indicates that this special instance was not of great significance. The same can be said of the Sandstone Point. It is possible that losses at Sandstone Point may have resulted from excessive dilution of a tidepool by intense rainfall that occurred prior to our visit there. We are somewhat hesitant to ascribe mortality here to oil pollution because deposits of oil substances were relatively light compared to most other areas we studied."[1]

On February 20, Western Oil and Gas Association awarded a research grant to the Allan Hancock Foundation at the University of Southern California to study the biological and oceanographic effects of oil spillage in the Santa Barbara Channel. This research program was drawn up after consultation with other interested parties so that the work would be complementary with that of other groups and would give as complete a coverage of the problem as possible. Under the terms of the grant, the results of the research would be published. This publication would include at least reference to research results obtained by others working in the Santa Barbara Channel. Several papers relevant to the problem but written by scientists funded by other sources are included with the papers presenting the results of the Western Oil and Gas Grant. The papers that follow are, with these exceptions, the results of research conducted under this grant.

This grant was for a twelve month field study in the Santa Barbara Channel. The aims were to determine the initial effects of oil pollution and gain some insight into the longer term effects of oil pollution and rates of recovery and recolonization. The problems associated with determining the damage caused by the oil spill were compounded by two factors. The first is the natural oil seepage in the Santa Barbara Channel. Oil has always appeared on Southern California beaches, so that it was important to obtain some

[1] Anderson, E. K., Jones, L. G., Mitchell, C. T., and North, W.J. Preliminary report on the ecological effects of the Santa Barbara Oil Spill. Part of a report submitted to Western Oil and Gas Association.

measure of which oil came from natural seeps and which came from the area around Platform A. Natural seepage was reported in the area of Platform A about eleven months before the spill. This further complicated the problem. The second resulted from the unusually high winter rains. Peak flooding in rivers occurred on January 25 and February 25. This results in lowered salinities and a high sedimentation rate. There was probably an increase in pesticide levels in the Channel because the citrus orchards were sprayed prior to the rains and large numbers of oranges were washed into the Channel by the floods.

The Santa Barbara oil spill is unique in that volumes of oil both from natural seepage and the January spill are unknown. Estimates of the rate at which oil seeped from the area of Platform A vary by a factor of ten. In the well documented tanker accidents such as "Torrey Canyon" (Smith, 1968) and "Tampico Maru" (North et al., 1964), the vessels carried a known volume of oil. The 1970 Louisiana spill from a drilling platform resulted in the loss of a large unknown volume of oil. However, this did not occur in an area of active oil seepage. The heavy rains and their side effects also complicated the Santa Barbara research. It is important to take these factors into consideration when using this spill as an example on which to base predictions of the effects of spills in other areas.

REFERENCES

Battelle Northwest
1969 Review of Santa Barbara Channel oil pollution incident. Water Pollution Control Research Series, Dast 20.

Emery, K. O.
1960 The sea off Southern California. Wiley and Sons, New York. 366p.

North, W. J., M. Neushul, and K. A. Clendenning
1964 Successive biological changes observed in a marine cove exposed to a large spillage of mineral oil. In Comn. Internatl. Explor. Sci. Mer Méditerr., Symp. Pollut. Mar. par Microorgan. Prod. Pétrol., Monaco. pp. 335-354.

Smith, J. E.
1968 "Torrey Canyon" pollution and marine life. Cambridge Univ. Press, Cambridge, Eng. 196p.

Southern California Academy of Sciences
1969 Scientific news and comments. Santa Barbara oil leak. So. Calif. Acad. Sci., Bull., 68: 262-263.

Wiley, D. R.
1969 Oil seeps: historical background. Union Seventy-Six, 13(5): 18.

Table 1

	Unico	Corexit 7664	Polycomplex A-11	Ara Chem.
1969				
Jan.	5	147	10	-
Feb.		170 (+20)	17 (+20)	16
March			211 1/2	244 1/2
April				64 3/4
May				83 1/2
June				59 1/2
July				39 1/2
Aug.				12
Sept.				20
Oct.				15 1/3
Nov.				19
Dec.				83 1/2
1970				
Jan.				123 1/4
Feb.				25 3/4
Total	5	317 (+20)	238 1/2 (+20)	802 7/12

Note:

Number of drums (1 drum = 55 gallons of dispersant) used by Union Oil, January 29, 1969 to February 28, 1970. (Information supplied by Union Oil Company of California.) All dispersant application was outside the one-mile limit except for the evening of February 4, 1969 when (+20 drums) of Polycomplex A-11 were used to mitigate the fire hazard inside the Santa Barbara Harbor and an equal volume of Corexit was used in the vicinity of the Sterns Wharf and undersea Garden Aquarium.

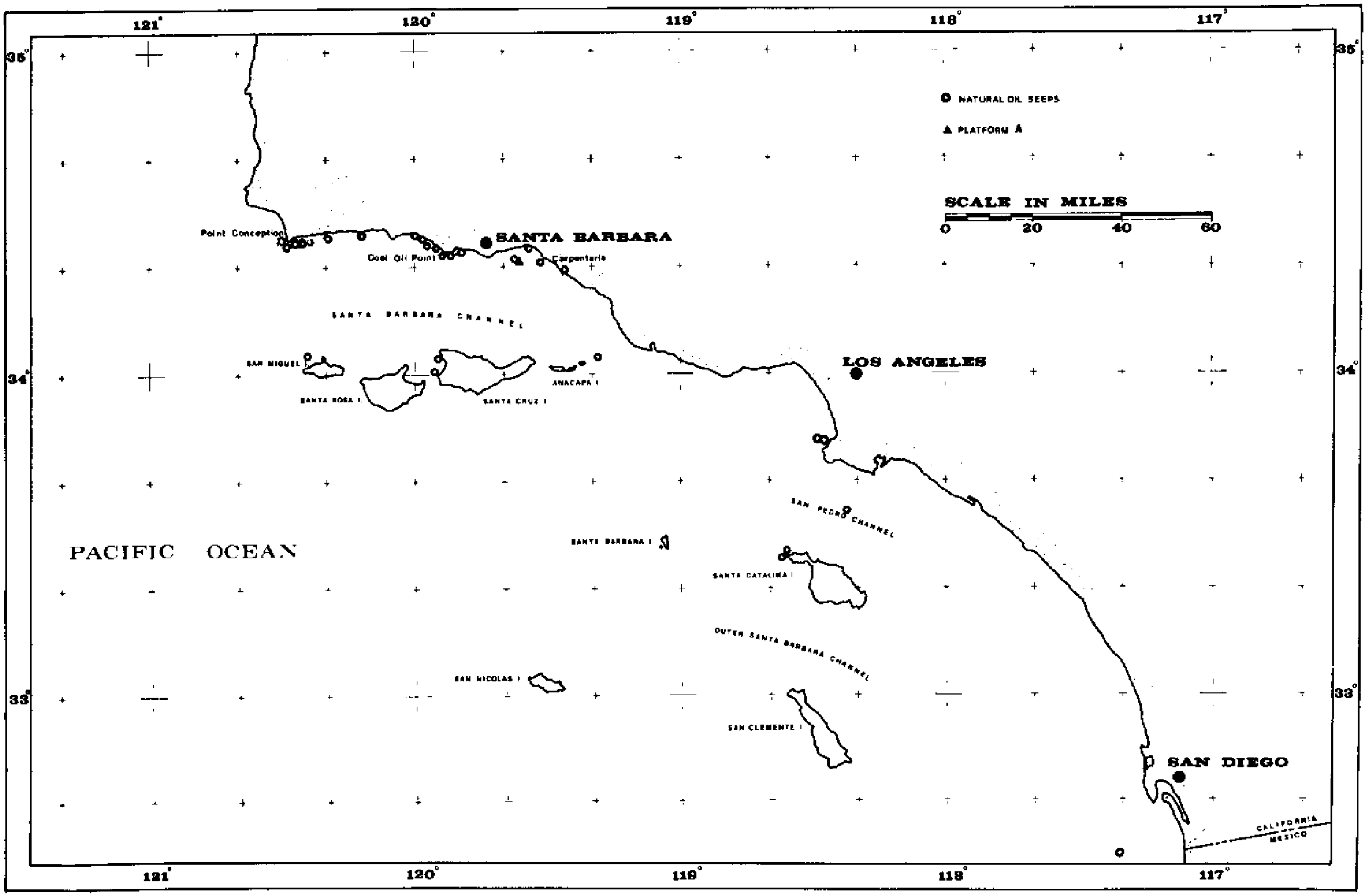


Figure 1. Map of Santa Barbara Channel showing location of Platform A and position of natural oil seeps. (Data on natural seeps compiled from Emery, 1960, and Wiley, 1969.)

CHAPTER 2

NATURAL OIL SEEPS: HISTORICAL BACKGROUND

by C. Ventura and J. Wintz

Colorful, thin slicks of a greasy substance and thick patches of sticky, black material are recorded from the sea and beaches of Southern California for over three centuries. Today a casual beach walker might condemn the petroleum industry for such "unsightly" pollution of America's coastal regions. Man-made oil pollution has occurred since Drake began drilling in Pennsylvania in 1859, but other sources also contribute to the accumulation of tar on California's beaches. These are the natural oil seeps which, although well-known from land to many through the fame of the La Brea Tar Pits, are not so well-known from marine areas. Emery (1960) reviewed some of the historical records of natural oil seeps in the sea off Southern California and also referred to the presence of many well-preserved skeletons of Pleistocene vertebrates in La Brea Tar Pits. Submarine seeps in the Santa Barbara Channel similarly have a long history, including records prior to Spanish settlements in the 1780's, but there is no evidence available comparable to the fossils in the La Brea Tar Pits to indicate their age.

Early Chumash Indians of the Santa Ynez region used the asphalt material washed up on Coal Oil Point for water-proofing and mending their dug-out canoes (Dibblee, 1966). Spanish explorers led by Ferrelo, second in command to Cabrillo, mentioned tarry material in the Santa Barbara Bay area. On Ferrelo's journey past the Santa Barbara area in 1543 he and his men, on a windy day, were able to smell the bitumen off the coast.

In 1776, Father Pedro Font, a Franciscan, journeyed to the Goleta area and recorded "much tar which the sea throws up is found on the shores. Little balls of fresh tar are also found. Perhaps there are springs of it which flow out of the sea" (Wiley, 1969).

Bitumen was reported off Santa Barbara in the logs of Captain George Vancouver in 1792. On his sailing past Santa Barbara, Vancouver noted:

> "The surface of the sea which was perfectly smooth and tranquil, was covered with a thick, slimy substance, which, when separated or disturbed by any little agitation became very luminous, while the light breeze that came principally from the shore brought with it a strong smell of tar or some such resinous substance. The next morning the sea had the appearance of dissolved tar floating upon its surface, which covered the ocean in all directions within the limits of our view, and indicated that in the neighborhood it was not subject to much agitation." (Mason, 1961:449)

Mason (1961:320) also quotes from the log of Sir Edward Belcher, later Arctic explorer, for October, 1839:

> "Off this part of the coast to the westward (of Santa Barbara) we experienced a very extraordinary sensation, as if the ship was on fire, and after a very close investigation attributed it to a scent from the shore, it being more sensible on deck than from below; and the land breeze confirming this, it occurred to me that it might arise from naphtha on the surface. The smell of this asphaltum appears to be occasionally experienced quite far from the land."

Between 1855 and 1865 two geologists, W. P. Blake and J. D. Whitney, noted the results of natural oil seepage. Whitney states, "The slates (shales) are black and highly bituminous where the outcrop strikes the sea three miles to the southeast of Carpinteria, and large quantities of tarry asphaltum flow from them. For a mile or more along the shore the banks abound in it, and it saturates the beach sand and flows into the sea" (Wiley, 1969). J. Walter Fewkes (1889) logged on a trip across the Santa Barbara Channel, in his sail boat, the Angel Dolly, "On the return trip to Santa

Barbara we sailed through a most extraordinary region of the Channel in which there is a submarine petroleum well. The surface for a considerable distance is covered with oil, which oozes up from sources below the water, and its odor is very marked. The oil probably comes from the upturned strata deep below the sea." A fishing expert, A. B. Alexander, wrote in the same year, after his cruise on the Albatross, "About 4 miles to the southward of Santa Barbara light we ran into extensive "slicks" on the surface, caused by petroleum bubbling up through the water. Oil is frequently reported by the fishermen and sea captains in this vicinity" (Alexander, 1892).

The early 1900's brought with them an added interest in the ocean and its properties--yet natural seeps were still not fully understood. In 1913 the California Division of Mines Bulletin contained the statement "Offshore seepages, if there be, have never been seen, but only an oil scum is often visible in the water between Santa Cruz Island and Santa Barbara" (Prutzman, 1913).

Rosen et al. (1958) noted the routine appearance of large amounts of chemically similar petroleum at Coal Oil Point. Merz (1959) studied the deposition and chemical composition of tar on Southern California beaches. "Excluding the fifteen determinations made on Coal Oil Point samples, there were 165 made on all other coastal stations. Ninety per cent of these resulted in quantities less than 1 oz. of tar per 500 square feet. Of these, 69 per cent contained either no tar or just a trace." But on a given day at Coal Oil Point, where the average weight of tarry material was 344 ozs., a maximum 1,520 ozs. was collected. Gaviota, 20 miles north, had the next highest rate of tar deposition with a maximum of 6 ozs. and an average of 2.3 ozs. Vernon and Slater (1963) dived to locate tar mounds off Point Conception in 90-foot depths, 1-1/2 miles offshore. The tar in this area covers 1/4 square mile and forms a 10- to 12-foot scarp at the seaward edge. These mounds are exposed in shale outcroppings. Vernon and Slater describe the mounds as "accumulations of small discrete masses of tar in the form of flows. Tar is extruded slowly from the vent forming a tapered whiplike strand which floats, but remains attached to the vent until it is at least several feet long."

In September, 1969, submarine seeps off Goleta were photographed with a Hydro-Products TC-303 Underwater Video-Television camera system supported by the R/V Golden West. Three types of oil release were observed. Small beads of oil one-quarter to one-half inch in diameter were concentrated over crusty white sediment, as yet unidentified but probably composed of sulphide and heavy nonvolatile oil fractions. The underlying sediment was composed of oil-saturated silty sand. The second type took the form of a tar mound from which teardrops of viscous material with long whiplike tails periodically escaped. The third type were areas of rapid high volume release. One such area of about a square foot had 20-25 point sources from which globules were released at two to three second intervals.

Emery (1960:321, Fig. 244) plotted the positions of known offshore oil seeps. Scott (1969:22) added the positions of several more seeps and tar mounds to data supplied by Emery. Notable among these is the seep that was recorded in the vicinity of Platform A when the platform was being installed (Chapter 1, Fig. 1). The seep stopped producing oil before drilling commenced from the platform. W. Stephens (personal communication) reported seep activity off Carpinteria in March and April, 1969. While tar mounds are known from this area, there are no other records of recent seep activity there. Allen (1969) reported an average loss of 50 to 70 barrels of oil a day for October, 1969, from Coal Oil Point. Maximum and minimum figures of 160 and 11 barrels per day respectively are indicative of the variable nature of seepage. This variable activity is characteristic of the natural seeps in the Santa Barbara Channel and makes it difficult to plot accurately distribution and amount of oil discharged by the seeps.

ACKNOWLEDGMENTS

We are grateful to the following for assistance in making the underwater observations on the oil seeps: Dave Doerner, Doug Chapin, University of California, Santa Barbara; Bill Curcaco, University of California, Los Angeles; Bob Cimberg, Ray Emerson, Bill Jesse, Bob Kanter, Kendall Robinson, Tom Trask, Josie Yudkin, University of Southern California.

REFERENCES

Alexander, A. B.
1892 Coast of Southern California. U.S. Comn. Fish., Report for 1888: 451.

Allan Hancock Foundation, University of Southern California
1965 An oceanographic and biological survey of the Southern California mainland shelf. California State Water Quality Control Board, Publ. 27: 1-232. Appendix Data: 1-445.

Allen, A. A.
1969 Estimates of surface pollution resulting from submarine oil seeps at Platform A and Coal Oil Point. General Research Corporation, Santa Barbara. Techn. Mem. 1230: 1-43.

Dibblee, T. W., Jr.
1950 Geology of southwestern Santa Barbara County, California. California Div. of Mines, Bull., 150: 75.

1966 Geology of the central Santa Ynez Mountains, Santa Barbara County, California. California Div. of Mines, Bull., 186: 84.

Emery, K. O.
1960 The sea off Southern California. Wiley and Sons, New York. 366p.

Fewkes, J. W.
1889 Across the Santa Barbara Channel. American Naturalist, 23: 387-394.

Hamilton, E. L.
1957 The last geographic frontier: the sea floor. Scientific Monthly, 85: 311.

Mason, J. D.
1961 Reproduction of Thompson and West's history of Santa Barbara and Ventura Counties, California. Howell-North, Berkeley, California. 477p.

Merz, R.
1959 Determination of the quantity of oily substances on beaches and in nearshore waters. California State Water Quality Control Board, Publ. 21: 1-45.

Prutzman, P. W.
1913 Petroleum in Southern California. California Div. of Mines, Bull., 63: 396-406.

Rosen, A. A., L. R. Musgrave, and J. J. Lichtenberg
1958 Pollution of California beaches by oil and grease. U.S. Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Progr. Rpts. 1-2.

Scott, C. B.
1969 A visit to San Miguel Island. Union Seventy-Six, 13(5): 19-23.

Vernon, J. W , and R. A. Slater
1963 Submarine tar mounds, Santa Barbara County, California. Amer. Assn. Petrol. Geologists, Bull., 47: 1624-1627.

Wiley, D. R.
1969 Oil seeps: historical background. Union Seventy-Six, 13(5): 18.

Yerkes, R. F., H. C. Wagner, and K. A. Yenne
1969 Petroleum development in the region of the Santa Barbara Channel. U.S. Geol. Survey, Prof. Paper 679: 13-27.

CHAPTER 3

PRIMARY PRODUCTIVITY IN THE SANTA BARBARA CHANNEL

by M. Oguri and R. Kanter

INTRODUCTION

Phytoplankton production by photosynthesis establishes the limit of energy available for most of the organisms in the sea. The limits on production are set by the response of the phytoplankton to the chemical, physical and biological environment in which they live. Alterations, both natural and artificial, in the environment can cause changes in the ability of the organisms to produce.

Many of the environmental changes are due to natural phenomena, such as seasonal alterations in run off from the shore, turbulence and horizontal and vertical currents, which tend to redistribute organisms, and other factors of significance to the phytoplankton in the surface layers of the sea. Superimposed on the "natural" cycles of production are the influences of artificial alterations in the environment, such as the discharge, accidentally or intentionally, of material not normally found in the receiving waters or normally present but at different concentrations.

The blowout at Platform A in January of 1969 represents one such discharge. In this case material released substantially increased the quantity of oil already present from natural oil seeps and resulted in the distribution of this material into areas where it had not previously occurred noticeably. Any resultant alteration in the normal pattern of phytoplankton productivity could be evaluated only if the normal pattern was known. Consequently this study was designed to establish the normal background and to attempt to detect departures from background values that could be associated with the oil spill.

METHODS

Sampling was normally carried out at eleven stations in the eastern part of the Santa Barbara Basin, as shown in Fig. 1, except for the cruise of April, 1969, shown in Fig. 2. This area of the basin was sampled twelve times during the period of the study. As the opportunity arose, more extensive sampling was carried out, covering the entire basin. Five such cruises were made as shown in Figs. 14-18.

At each station a sample of the surface water was collected, using a plastic bucket. This was sub-sampled to obtain water both for pigment analysis and for productivity measurements.

Chlorophyll content of the sample was determined by filtering a liter of the water and extracting the pigments with 90% acetone. The optical density of the extract was then read at appropriate wavelengths in a spectrophotometer. Calculation of pigment concentration was done using the formulae of Richards and Thompson (1952).

Productivity studies were carried out using the method described by Steemann Nielsen (1952) with slight modifications. Aliquots of the sample water were placed in replicate clear bottles for "light" incubation, and opaque bottles for "dark" incubation. The bottles were then stored at ambient temperature in the dark until the following morning. At that time a measured amount of radioactive carbon, C^{14}, was added to each bottle and the bottles were incubated under artificial light of approximately 2000 foot-candles for about three hours. Following incubation the contents of the bottles were filtered through Millipore HA filters and stored in a desiccator for later counting of the radio-carbon taken up by the cells filtered from the water.

Incubation under artificial light gives a measure of productivity rather than production but yields data that reflect the interaction of fewer variables. The data from cruise to cruise are, thus, more directly comparable. Storage of collected samples until a standard time before starting incubation introduces problems of sample change on storage but obviates correction for diurnal periodicity in photosynthetic potential as reported by Doty and Oguri (1957), Shimada (1958) and others. Determination of the magnitude of this effect in these waters showed minimum potential productivity occurred between the hours of 0000 to 0200 and the maximum occurred between 1000 and 1400, rather than in the 0600 to 0800 reported earlier (Doty and Oguri, 1957). Maximum values found in this study were about six times higher than the lowest values.

Storage of the water samples resulted in relatively small variations, plus or minus 10%, if the storage time was held to less than 12-18 hours. Storage for longer periods resulted in variations that could reach 50%. The samples collected for this study were, with few exceptions, stored for less than twelve hours.

RESULTS AND DISCUSSION

The data from the eleven stations in the eastern part of the Santa Barbara Basin are presented in Table 1 and in Figs. 2-13. The data include productivity data as milligrams of carbon fixed per hour per cubic meter of water sampled, pigment concentrations as milligrams of chlorophyll "a" per cubic meter and a value for productivity per unit of chlorophyll "a". This last value is used to reflect the efficiency of the photosynthetic process as it occurs in the immediate sampling area and to permit results to be considered independent of variations in size of populations. Chlorophyll "a" only, rather than total chlorophyll, is used as a measure of standing crop of phytoplankton, to make the information compatible with earlier studies carried out along the Southern California coast (Tibby et al., 1965; Allan Hancock Foundation, 1965b). The use of chlorophyll "a" in preference to total chlorophyll has been generally utilized (Strickland, 1965).

It is worth noting that utilization of any of the three types of data reported does not cause any major variation in the patterns reported.

One of the general patterns apparent in the distribution of the data is the higher productivity found inshore. This has previously been noted as a land mass effect (Doty and Oguri, 1956). It is not always accompanied by an inshore increase in pigments; however, the data for productivity per unit chlorophyll shows that photosynthetic efficiency shows a more consistent pattern of higher values inshore.

Enrichment of the inshore areas by run off and mineralization in the shallow inshore waters could add to the nutrients available. Additionally, sewage discharges, such as those from Santa Barbara and Ventura, have been associated with moderate increases in the ratio of productivity to chlorophyll (Allan Hancock Foundation, 1965b).

The variation in population, as reflected in the chlorophyll data, does not as consistently reflect the changes found in productivity per unit chlorophyll. Average values for the entire period of the study at each station indicate that there is a slight reduction of chlorophyll values found inshore. The zooplankton data also show a pattern of smaller volumes found inshore.

Seasonal variation in productivity (Allan Hancock Foundation, 1965b) and in standing crop of phytoplankton (Allan Hancock Foundation, 1965a) is a normal feature of waters along this coast. The previous study (Allan Hancock Foundation, 1965b) reported values of productivity for spring and summer averaging about double the values of fall and winter along the coast of Orange and San Diego counties.

The presently reported values, shown in the bottom row of Table 1, show a shorter period of high productivity in the spring, about five times higher than the summer values and about ten times higher than winter values. A minor bloom also occurred in August, 1969, with two times the winter productivity. Pigment values, although following the same pattern, do not vary as greatly as productivity, showing a change of two or three fold between maximum and minimum values. Consequently the values of productivity per unit chlorophyll show seasonal variation that is approximately half that mentioned above for productivity alone. It appears that the seasonal bloom represents not only an increase in standing crop, as shown by pigment values, but also shows an increase in the ability of the organisms to photosynthesize.

Results from the cruise of April, 1969, shown in Table 1 and Fig. 2, are anomalously low in productivity, although chlorophyll values are similar to those found in March, 1970. The low overall average of 0.8 mg of carbon fixed per milligram of chlorophyll "a" during this cruise was the lowest value found for any of the cruises.

Eight of the nine stations sampled are in the vicinity of stations 1 and 11 for the other cruises. Averages of the data for the eight stations are:

Productivity = 0.43 mg $C/hr/m^3$
Chlorophyll "a" = 0.58 mg Chl "a"$/m^3$
Productivity/Chlorophyll "a" = 0.8 mg C/mg Chl "a"

Comparison of these values with the tabulated values for stations 1 and 11 during the cruise of March, 1970, indicate that in April, 1969, the productivity was greatly depressed although the standing crop was apparently not materially affected. Similar comparison with the station off Port Hueneme during April, 1969, and stations 6 and 7 of March, 1970, show a like pattern of similar pigment values and lower values for productivity in the earlier cruise.

The similarity in standing crop measurements suggests that the population during the two cruises was not greatly different but that some functional aspect was disrupted in the earlier cruise.

The possibility of the low productivity resulting from the presence of the oil on the surface of the water does not appear to be borne out by the data. At station 11, the one nearest to Platform A, oil was noted in sufficient quantity to be easily detectable during the cruises of April, 1969, May, 1969, January, 1970, and May, 1970. The oil in January, 1970, formed a very thin film on the surface. During the other months it was considerably heavier.

The values for productivity and chlorophyll for May, 1969, and those for May, 1970, are strikingly similar and show no marked reduction in the productivity per unit of chlorophyll.

An oil spill starting December 15, 1969, after the cruise for that month, is possibly the cause for the oil noted in January, 1970. The data for the January cruise are similar to those for December and are not strikingly different from the data for February.

During May, 1970, a sample of the oil from the surface at station 11 was collected. One milliliter aliquots of this oil were added to a replicate set of clear and opaque bottles containing water from station 7, the farthest one from Platform A. At this station there was no evidence of oil. The bottles were then treated routinely for productivity determinations

The oil remained as distinctly separate globules on the upper side of the bottles during incubation. After incubation the samples were decanted into a wide mouth container and the oil was removed prior to filtration. This was done to avoid coating the filter surface with oil.

The data are summarized in Table 2. Productivity was not significantly affected by the presence of the oil during the period of incubation. Also variation in the light and the dark uptake of the radio carbon is not considered excessive between the oil free samples and those with oil.

In view of these results, the explanation for the low values for productivity found in April, 1969, apparently does not rest with the oil itself. A possibility is the use of dispersants in the months immediately prior to this cruise. A summary of the kinds and quantities of material used is contained in Chapter 1. In the months of January through March of 1969, four different types of dispersant were used. Subsequently only one was used. Over 60% of the total quantity of all dispersants used was used in the first three months of the 14 months reported on.

The phytoplankton and their productivity are products of the water in which they live rather than the location at which they are sampled. Consequently some consideration was given to a broader areal coverage of the whole Santa Barbara Basin in an attempt to relate them to water mass distribution. Five cruises covering the western and central parts of the basin as well as the eastern portion were made during the period of this study. The data are shown in Figs. 14-18.

In May of 1969, as shown in Fig. 14, the basin as a whole showed high productivity reflecting the seasonal bloom. Two patterns in distribution of productivity data are apparent.

There is a pattern of higher inshore values, particularly along the northern shore of the eastern part of the basin. This has already been mentioned and briefly discussed.

The water in the southern part of the basin, particularly west of Santa Cruz Island, is notably more productive than water to the north. This suggests that water is entering the basin at both eastern and western ends. The highly productive water from the western end is displaced in a southerly direction by the less productive water entering from the east.

In August of 1969, shown in Fig. 15, the values are substantially lower and the patterns are less clear. However, essentially the same general distribution of data is present, particularly with regard to the productivity per unit chlorophyll. The production along the northern shore to the east of Santa Barbara is higher than offshore values. The phytoplankton to the west and in the central portion are more productive in the south than in the north.

December of 1969, shown in Fig. 16, yielded values of productivity and productivity per unit of chlorophyll lower than in May or August. However, the same general pattern persists, with a marked reduction in the relative productivity of the western end of the basin.

In February of 1970, shown in Fig. 17, the higher values inshore, as on earlier cruises, is present along the northeastern shore. Smaller pockets of high values are found near the northern coast in the central and western parts of the basin. The rest of the basin is relatively less productive.

In June of 1970, shown in Fig. 18, the relatively more productive northeastern region of the basin is apparent as it is for all of the cruises. Although sparsely sampled, the values found in the rest of the basin show no patterns suggestive of the pockets of higher productivity found on earlier cruises.

The data from these five cruises covering the entire basin reflect the patterns of circulation in the area, as discussed elsewhere in this report.

The most constant feature is the more productive northeastern portion. This roughly corresponds with the area in which the current entering from the east eddies northward, contributing to an eastward flowing longshore drift. As mentioned earlier, some artificial enrichment of the water also occurs in this area.

A pocket of higher productivity along the northern side of the basin in the vicinity of El Capitan to Gaviota is found on all cruises except the one of June, 1970. It is roughly in this area that some coastal upwelling has been detected. This would result in some enrichment of the surface waters.

Currents moving into the basin from the west are displaced to the southern side bordered by Santa Barbara Channel Islands. Upwelling along the coast of these islands would explain the higher values found there in May, August, and December of 1969.

CONCLUSIONS

The productivity of the Santa Barbara Basin is the result of a number of factors. Patterns of seasonal enrichment of the waters and the resultant increase in population of phytoplankton and their productivity rely upon currents for distribution. The currents also interact with shores, producing upwelling and currents and eddies that can result in holding a population in fertile areas.

There is no conclusive evidence from this study of any major effect on phytoplankton that can be attributed directly to the presence of oil in the environment. The use of dispersants, however, may result in marked reductions in productivity. The longevity of any such effect would depend on the currents and rate of dilution, as well as the type and quantity of the dispersants.

REFERENCES

Allan Hancock Foundation, University of Southern California

1965a An oceanographic and biological survey of the Southern California mainland shelf. California State Water Quality Control Board, Publ. 27: 1-232.

1965b An investigation on the fate of organic and inorganic wastes discharged into the marine environment and their effects on biological productivity. California State Water Quality Control Board, Publ. 29: 1-117.

Doty, M. S., and M. Oguri

1956 The island mass effect. Internatl. Council for Explor. of Sea, J. Conseil, 22: 33-37.

1957 Evidence for a photosynthetic daily periodicity. Limn. Oceanogr., 2: 37-40.

Richards, F. A., and T. G. Thompson

1952 The estimation and characterization of plankton populations by pigment analysis. II. A spectrophotometric method for the estimation of plankton pigments. J. Mar. Research, 11: 156-172.

Shimada, B. M.

1958 Diurnal fluctuation in photosynthetic rate and chlorophyll "a" content of phytoplankton from eastern Pacific waters. Limn. Oceanogr., 3: 336-339.

Steemann Nielsen, E.

1952 The use of radio-active carbon (C^{14}) for measuring organic production in the sea. Internatl. Council for Explor. of Sea, J. Conseil, 18: 117-140.

Strickland, J. D. H.

1965 Production of organic matter in the primary stages of the marine food chain. In Riley, J. P., and G. Skirrow, eds. Chemical oceanography. Academic Press, New York. Vol. 1: 477-610.

Tibby, R. B., J. E. Foxworthy, M. Oguri, and R. C. Fay
1965 The diffusion of wastes in open coastal waters and their effects on primary biological productivity. In Comn. Internatl. Explor. Sci. Mer Méditerr., Symp. Pollut. Mar. par Microorgan. Prod. Pétrol., Monaco. pp. 95-113.

Table 1

Data from eleven stations in the eastern part of the Santa Barbara Basin, as shown in Figure 1. P is productivity as milligrams of carbon fixed per hour per cubic meter. C is chlorophyll "a" as milligrams per cubic meter. E is the ratio of productivity to chlorophyll "a".

Sta.		1969 IV 2-4	V 5-7	VI 25-26	VII 22-23	VIII 28-30	XI 11-12	XII 12-13	1970 I 13-14	II 6-7	III 30-31	V 1-2	VI 11-13	Avg.
1	P		38.83	5.52	5.91	6.04	3.81	3.39	1.05	3.10	2.65	34.01	9.85	10.38
	C		2.88	0.86		1.05	0.63	1.40	0.73	0.97	0.55	3.14	1.60	1.38
	E		13.5	6.4		5.8	6.0	2.4	1.4	4.1	4.8	10.8	6.2	6.1
2	P		32.92	2.56	4.95	6.58	3.48	3.38	1.48	3.27	1.80	38.02	8.52	8.81
	C		4.33	2.08		1.51	0.79	1.05	0.57	1.00	0.43	3.11	1.33	1.62
	E		7.6	1.2		4.4	4.4	3.2	2.6	3.3	4.2	12.2	6.4	5.0
3	P			6.23	2.48	5.17	1.49	1.50	1.82	2.74	2.21	17.23	15.20	5.61
	C			1.60		1.57	0.52	0.77	0.94	0.92	0.70	1.66		1.09
	E			3.9		3.3	2.9	1.9	1.9	3.0	3.2	10.4		3.8
4	P			3.47	3.58	4.00	3.73	2.89	1.69	2.90	2.32	31.54	9.34	6.55
	C			1.78		1.22	0.76	1.04	0.80	1.15	0.73	3.01	1.19	1.30
	E			1.9		3.3	4.9	2.8	2.1	2.5	3.2	10.5	7.8	4.3
5	P		9.62	4.50	2.16	6.24	2.30	2.03	3.55	2.99	2.09	27.89	18.09	7.41
	C		1.37			2.34	0.78	1.21	1.72	1.22	0.70	2.74	2.34	1.60
	E		7.0			2.7	3.0	1.7	2.1	2.5	3.0	10.2	7.7	4.4
6	P		14.11	2.53	3.18	4.24	5.48	2.99	1.84	2.03	16.18	58.48	24.12	12.29
	C		1.66	1.01		1.31	0.95	1.44	1.18	0.44	1.15		3.12	1.36
	E		8.5	2.5		3.2	5.8	2.1	1.6	4.6	14.1		7.7	5.6

Table 1--Continued

Sta.		1969 IV 2-4	V 5-7	VI 25-26	VII 22-23	VIII 28-30	XI 11-12	XII 12-13	1970 I 13-14	II 6-7	III 30-31	V 1-2	VI 11-13	Avg.
7	P		4.98	3.16	1.80	3.14	1.73	1.24	2.43	1.42	13.12	18.23	18.69	6.36
	C		0.98	0.88		0.88	0.44	0.77	1.40	0.69	1.10	1.95	2.28	1.14
	E		5.1	3.6		3.6	4.0	1.6	1.7	2.1	11.9	9.3	8.2	5.1
8	P			7.08	2.89	3.28	2.21	2.16	2.46	1.65	2.47	2.57	9.04	3.58
	C			1.85		0.84	0.54		0.98	0.67	0.82	0.47	1.72	0.99
	E			3.8		4.0	4.1		2.5	2.5	3.0	5.4	5.3	3.8
9	P			3.61	2.02	3.74	2.46	0.72	1.72	1.24	1.72	8.46	7.41	3.31
	C			1.92		0.87	0.84		0.96	0.64	0.79	1.28	1.44	1.09
	E			1.9		4.3	2.9		1.8	2.0	2.2	6.6	5.2	3.4
10	P		3.58	6.33	2.04	4.99	0.68	1.18	1.79	1.50	1.38	25.33	7.25	5.10
	C		0.94			2.86	0.78	1.28	1.18	1.13	0.69	2.57	1.51	1.44
	E		3.8			1.7	0.9	0.9	1.5	1.3	2.0	9.9	4.8	3.0
11	P		24.93	5.56	2.66	3.48	1.39	1.49	2.05	2.68	2.13	31.55	19.13	8.82
	C		2.08			1.18	0.43	1.32	1.29	0.99	0.62	3.08	3.00	1.55
	E		12.0			2.9	3.3	1.1	1.6	2.7	3.4	10.2	6.4	4.8
Avg.	P	0.49	18.42	4.60	3.02	4.63	2.61	2.09	1.99	2.32	4.37	26.66	13.33	
	C	0.72	2.03	1.50		1.42	0.68	1.14	1.07	0.89	0.75	2.30	1.95	
	E	0.8	8.2	3.2		3.6	3.8	2.0	1.9	2.8	5.0	8.6	6.6	

Table 2

Productivity data for surface samples collected during May 2, 1970. To each bottle of one replicate set of samples was added one ml of oil collected about seven hours earlier at station 11.

	Treatment	cpm per Hour of Incubation	mg C/hr/m^3
Standard--no oil	Light	1251 1011	18.23
	Dark	7 5	
Oil added	Light	1163 1014	17.51
	Dark	7 8	

FIGURES

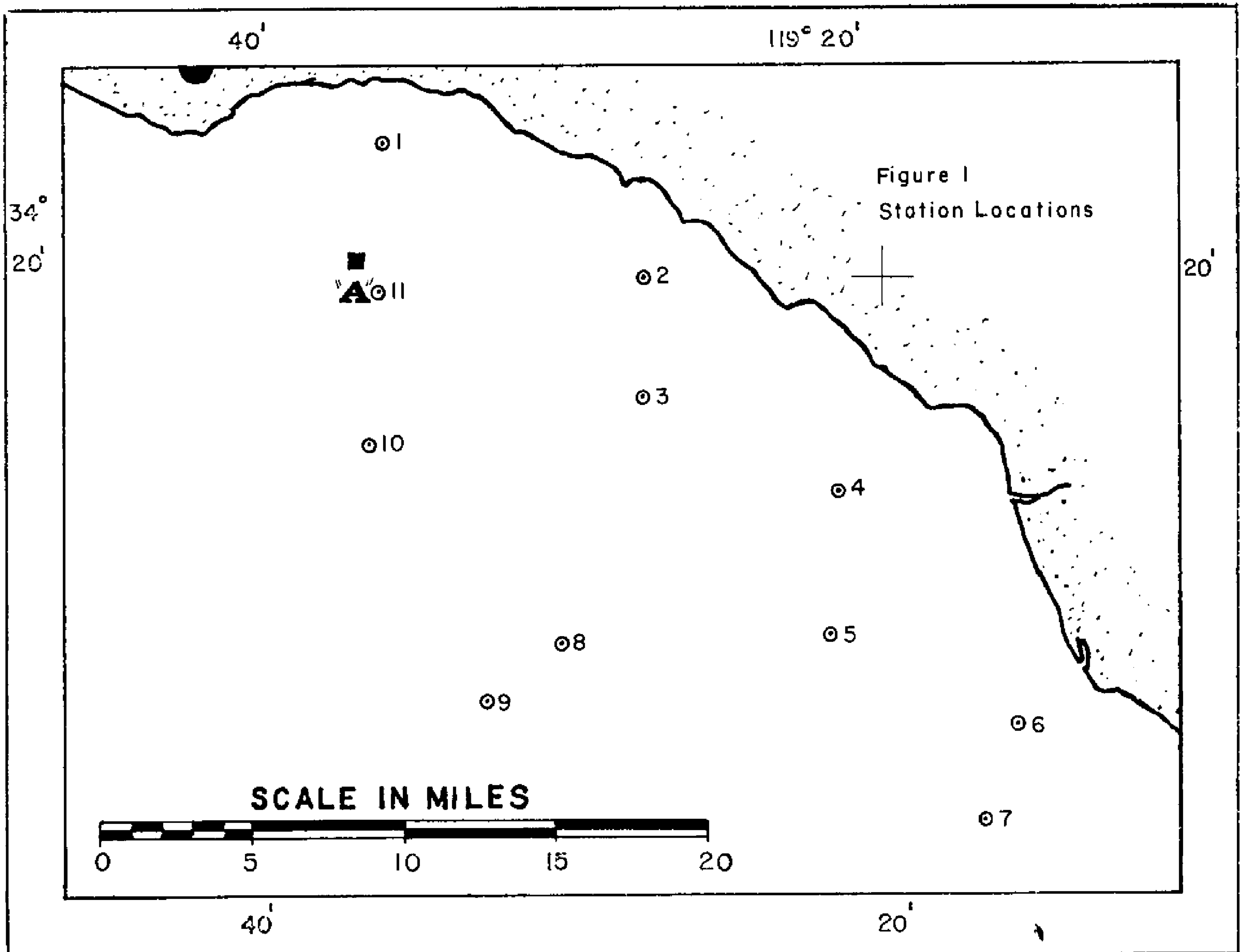
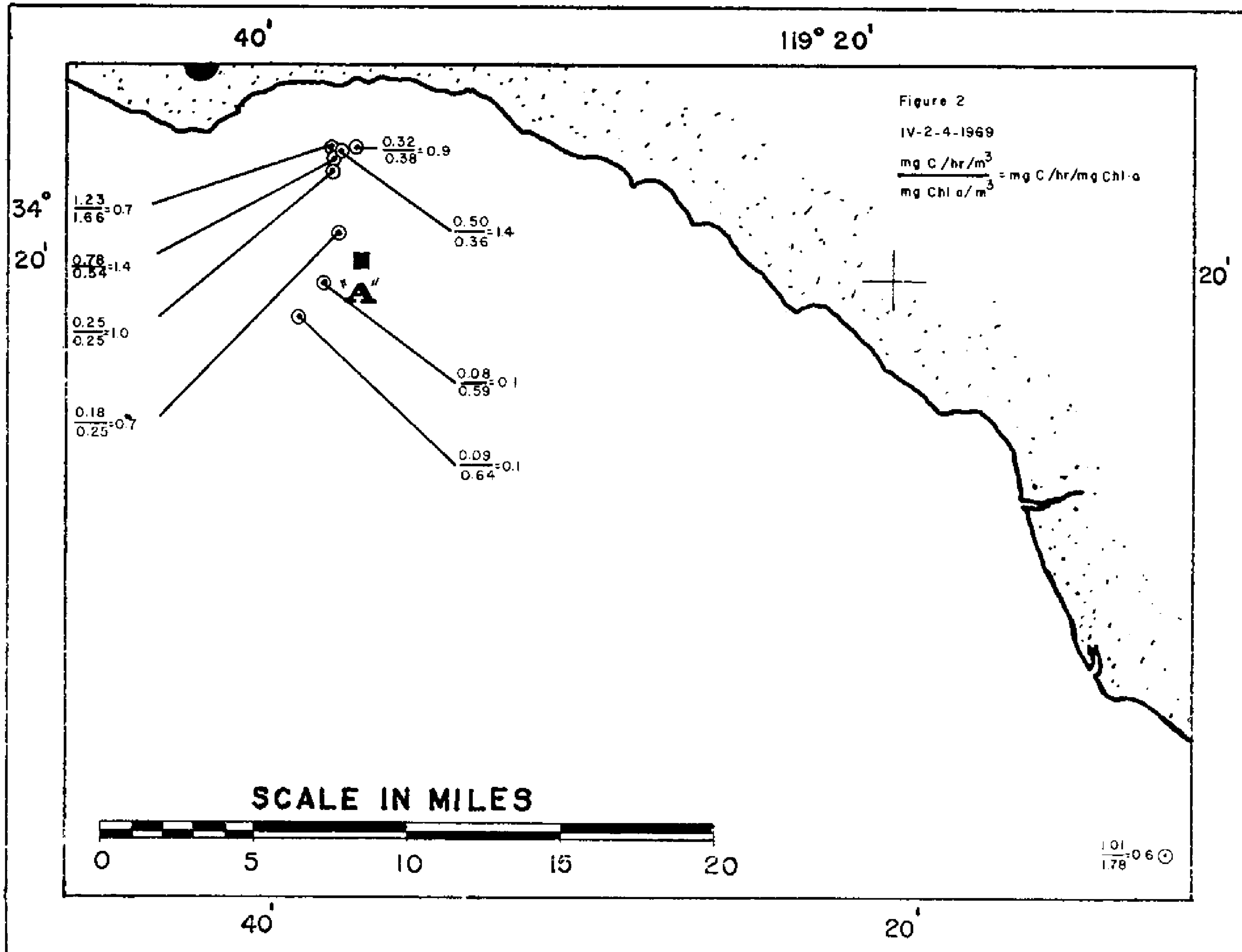


Figure I
Station Locations


40'
119° 20'
34°
20'
Figure 2
IV-2-4-1969
mg C/hr/m³ / mg Chl a/m³ = mg C/hr/mg Chl-a
0.32/0.38 = 0.9
0.50/0.36 = 1.4
1.23/1.66 = 0.7
0.78/0.54 = 1.4
0.25/0.25 = 1.0
0.18/0.25 = 0.7
0.08/0.59 = 0.1
0.09/0.64 = 0.1
"A"
20'
SCALE IN MILES
0
5
10
15
20
1.01/1.78 = 0.6
40'
20'

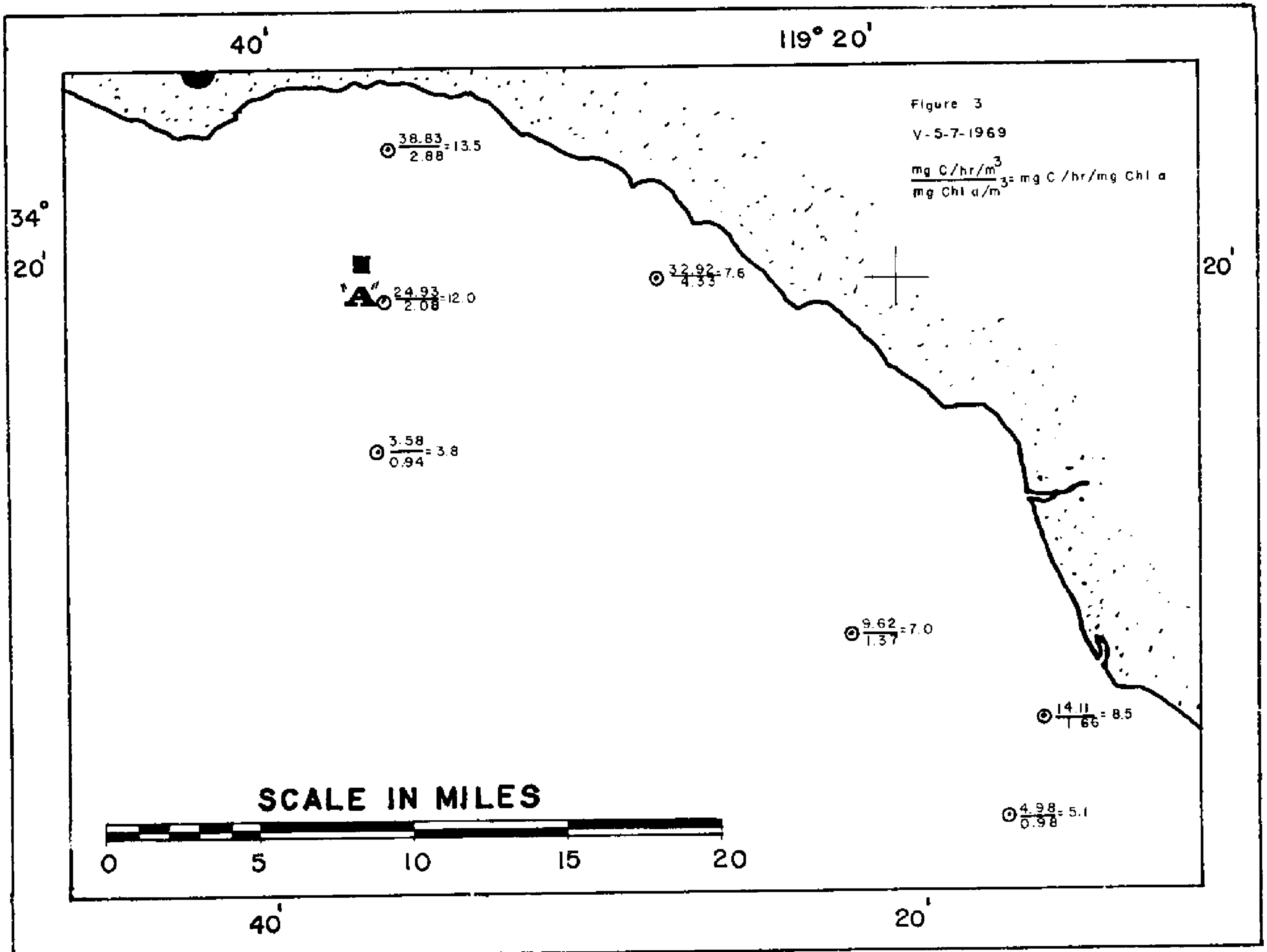


Figure 3
V-5-7-1969
mg C/hr/m³ / mg Chl a/m³ = mg C/hr/mg Chl a
119° 20'
40'
34° 20'
20'
38.83/2.88 = 13.5
24.93/2.08 = 12.0
"A"
32.92/4.33 = 7.6
3.58/0.94 = 3.8
9.62/1.37 = 7.0
14.11/1.66 = 8.5
4.98/0.98 = 5.1
SCALE IN MILES
0
5
10
15
20
40'
20'

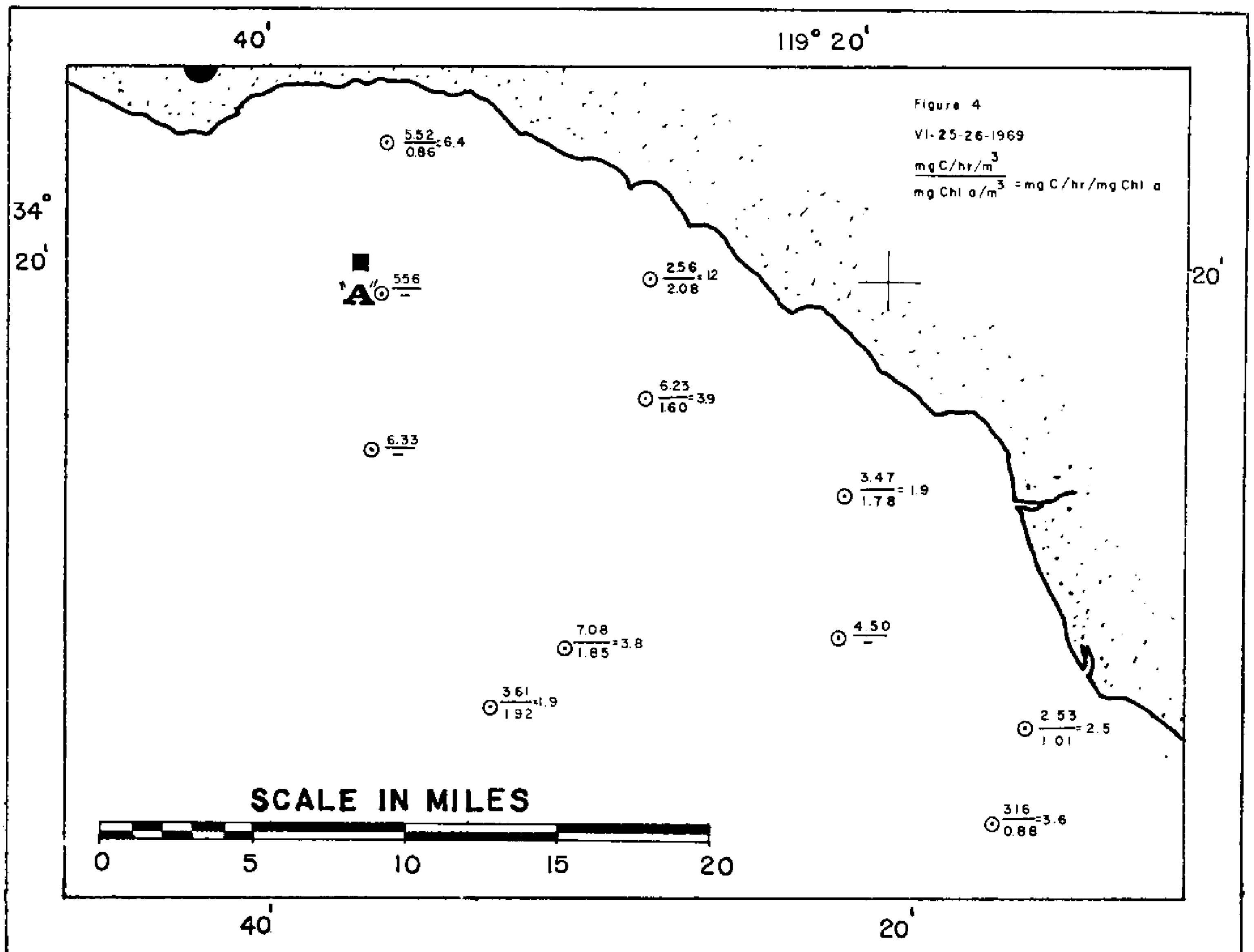
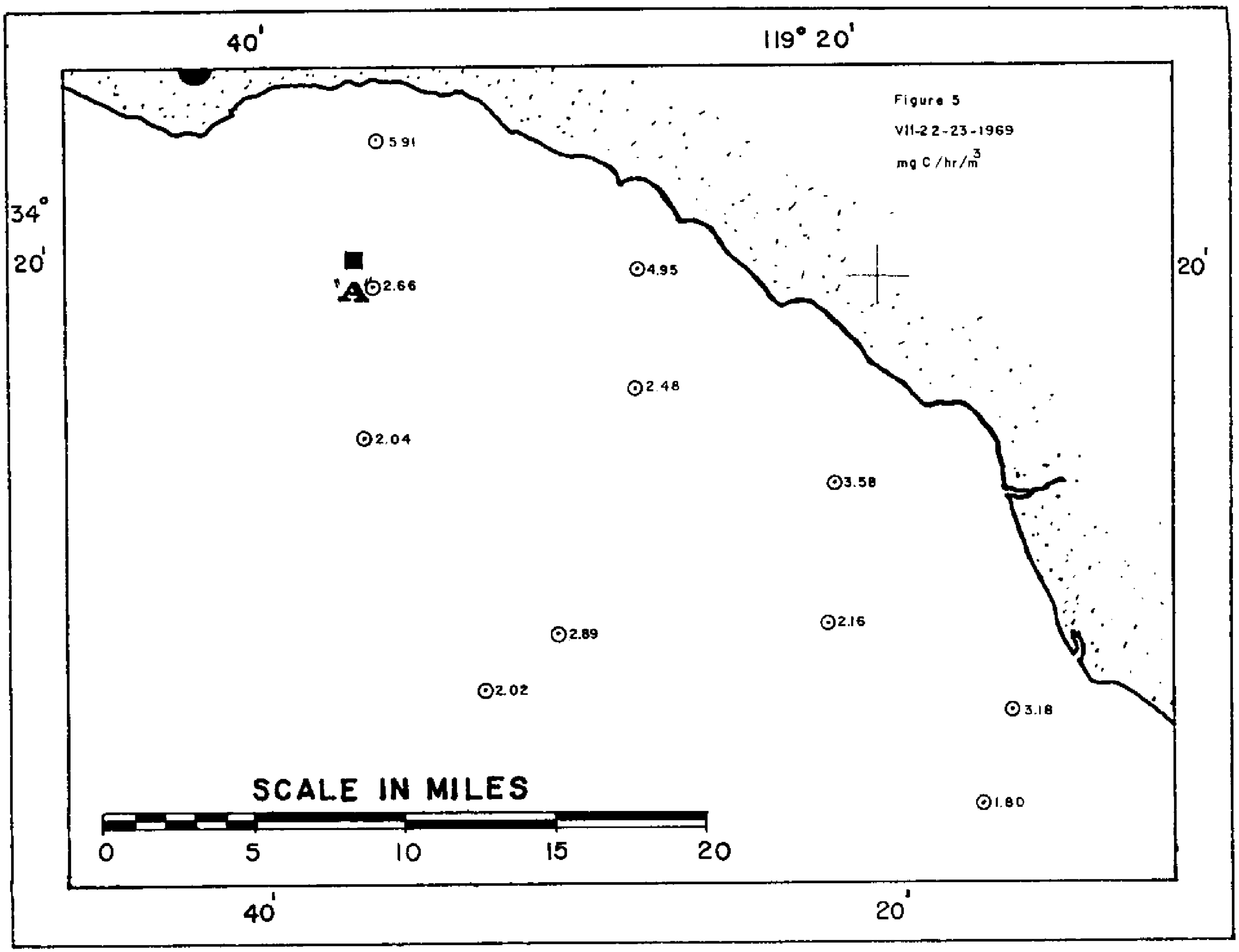


Figure 4

VI-25-26-1969

$\frac{\text{mg C/hr/m}^3}{\text{mg Chl a/m}^3}$ = mg C/hr/mg Chl a



40'
119° 20'
34° 20'
20'
40'
20'
Figure 5
VII-22-23-1969
mg C/hr/m³
5.91
'A'
2.66
4.95
2.48
2.04
3.58
2.89
2.16
2.02
3.18
1.80
SCALE IN MILES
0
5
10
15
20

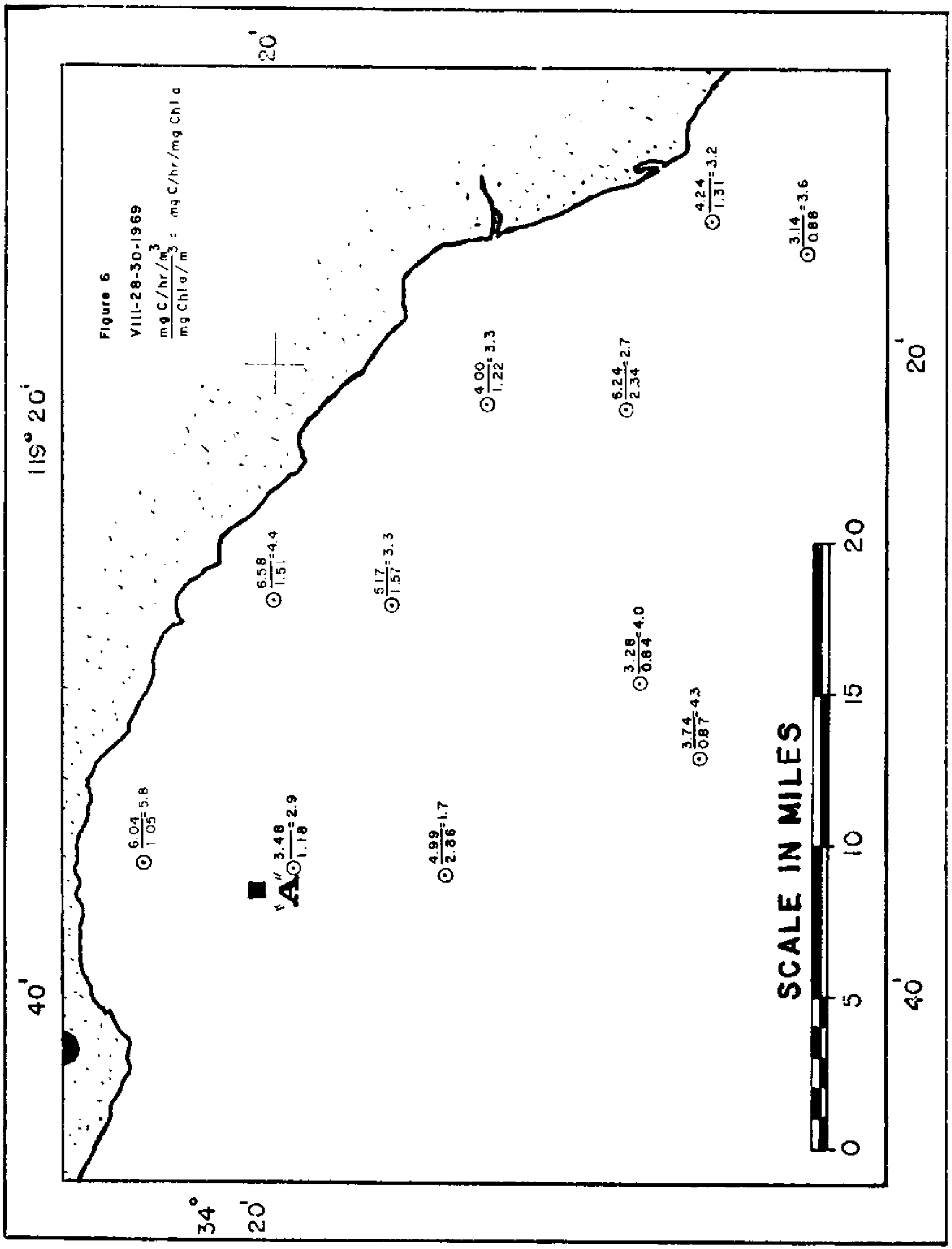


Figure 6
VIII-28-30-1969
mg C/hr/m3 / mg Chl a/m3 = mg C/hr/mg Chl a
119° 20'
34° 20'
40'
20'
40'
20'
6.04/1.05 = 5.8
"A" 3.48/1.18 = 2.9
4.99/2.86 = 1.7
6.58/1.51 = 4.4
5.17/1.57 = 3.3
4.00/1.22 = 3.3
6.24/2.34 = 2.7
3.28/0.84 = 4.0
3.74/0.87 = 4.3
4.24/1.31 = 3.2
3.14/0.88 = 3.6
SCALE IN MILES
0
5
10
15
20

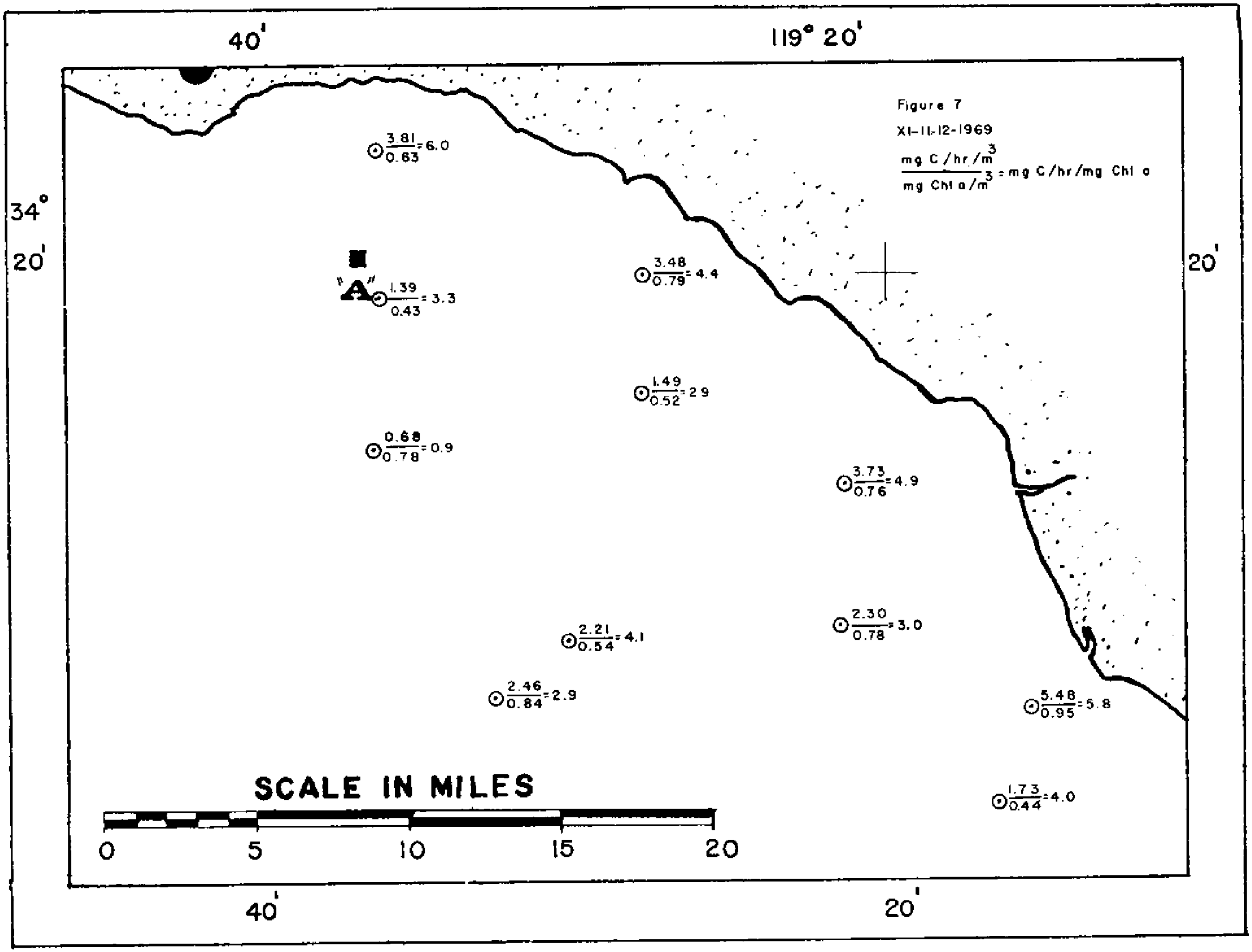


Figure 7
XI-11-12-1969
mg C/hr/m³ / mg Chl a/m³ = mg C/hr/mg Chl a
40'
119° 20'
34°
20'
20'
"A"
3.81/0.63 = 6.0
1.39/0.43 = 3.3
0.68/0.78 = 0.9
3.48/0.79 = 4.4
1.49/0.52 = 2.9
2.21/0.54 = 4.1
2.46/0.84 = 2.9
3.73/0.76 = 4.9
2.30/0.78 = 3.0
5.48/0.95 = 5.8
1.73/0.44 = 4.0
SCALE IN MILES
0
5
10
15
20
40'
20'

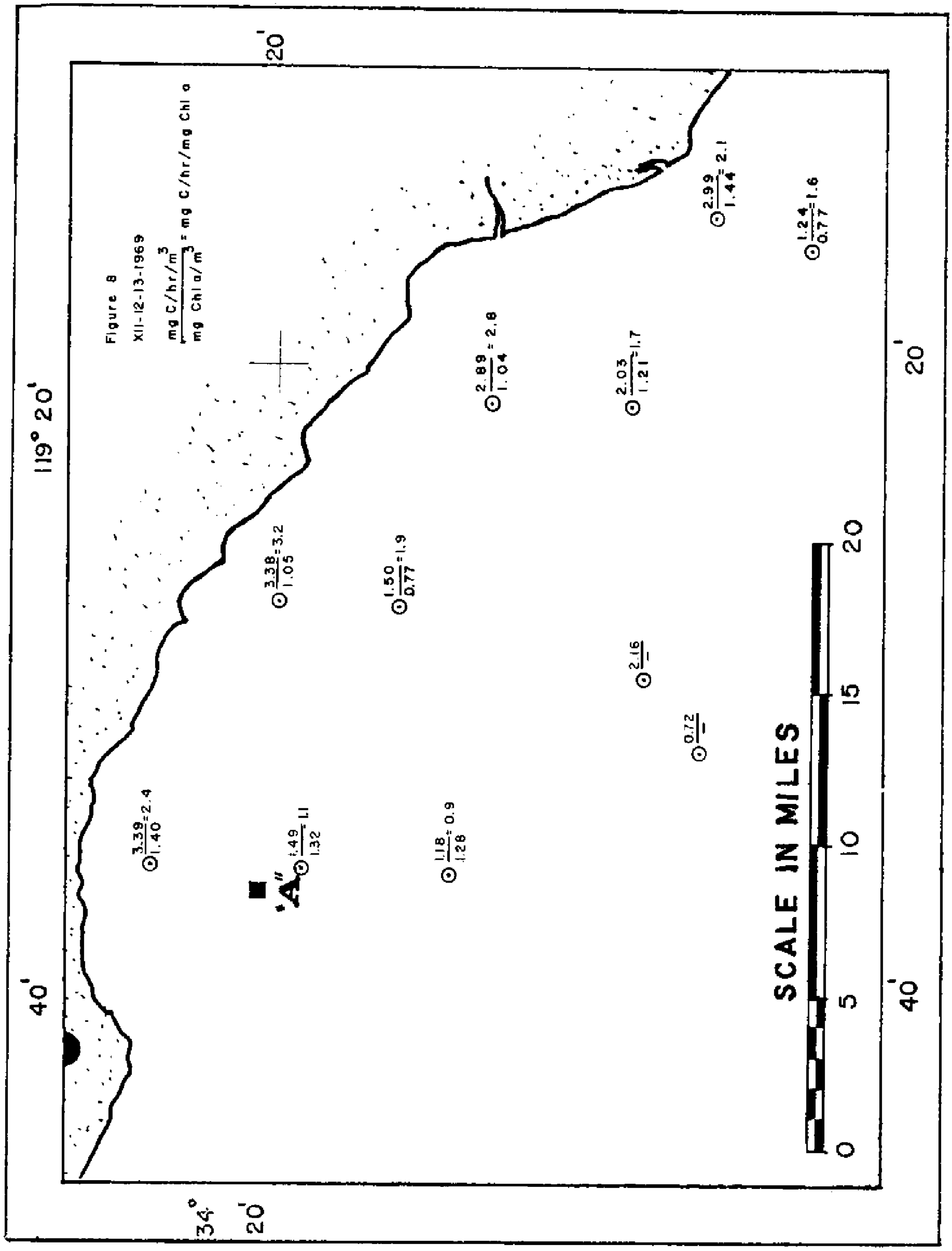


Figure 8
XII-12-13-1969
mg C/hr/m³ / mg Chl a/m³ = mg C/hr/mg Chl a
119° 20'
34° 20'
40'
20'
"A"
3.39/1.40 = 2.4
1.49/1.32 = 1.1
1.18/1.28 = 0.9
3.38/1.05 = 3.2
1.50/0.77 = 1.9
2.16/—
0.72/—
2.89/1.04 = 2.8
2.03/1.21 = 1.7
2.99/1.44 = 2.1
1.24/0.77 = 1.6
SCALE IN MILES
0 5 10 15 20

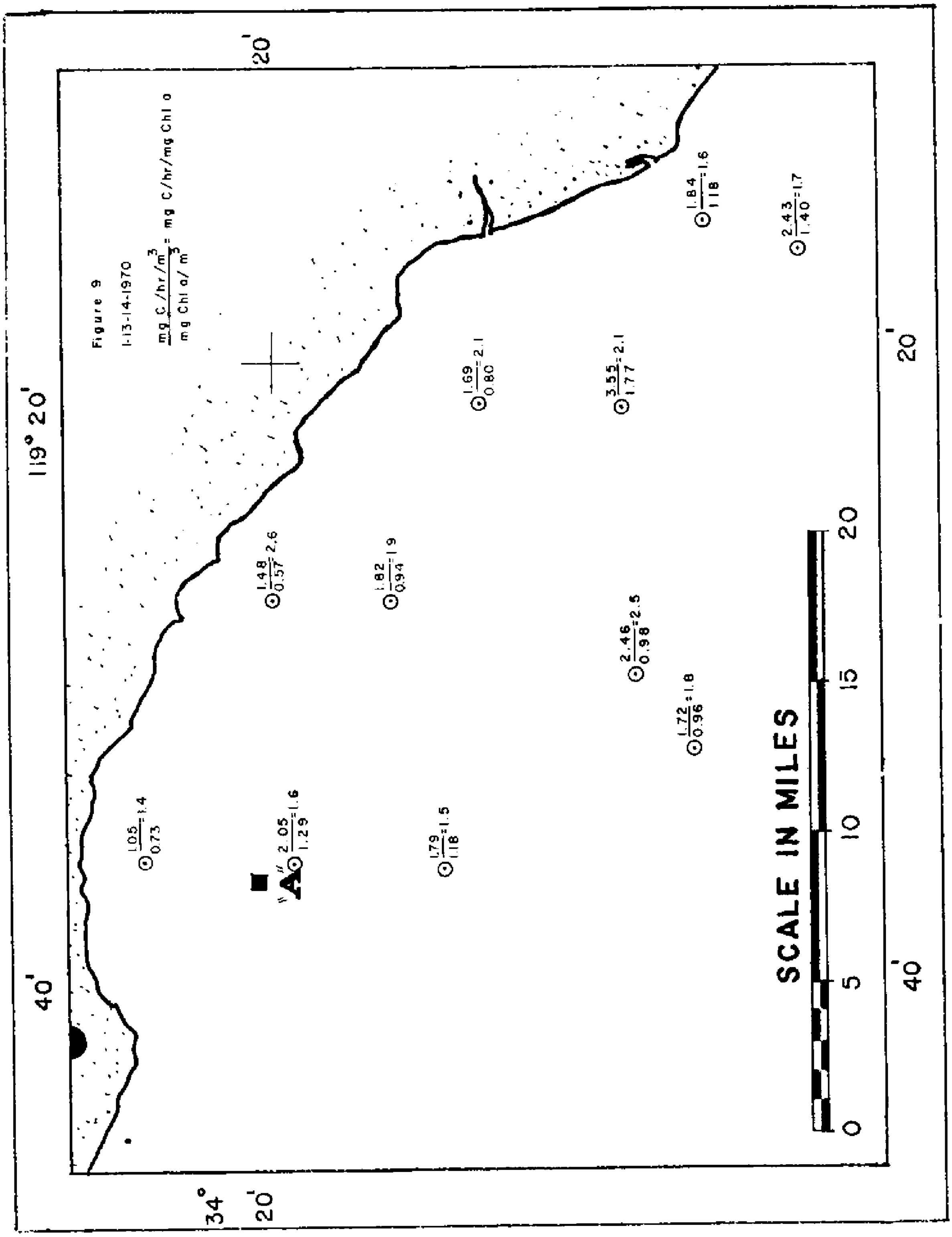


Figure 9

1-13-14-1970

$\frac{mg\ C/hr/m^3}{mg\ Chl\ a/m^3} = mg\ C/hr/mg\ Chl\ a$

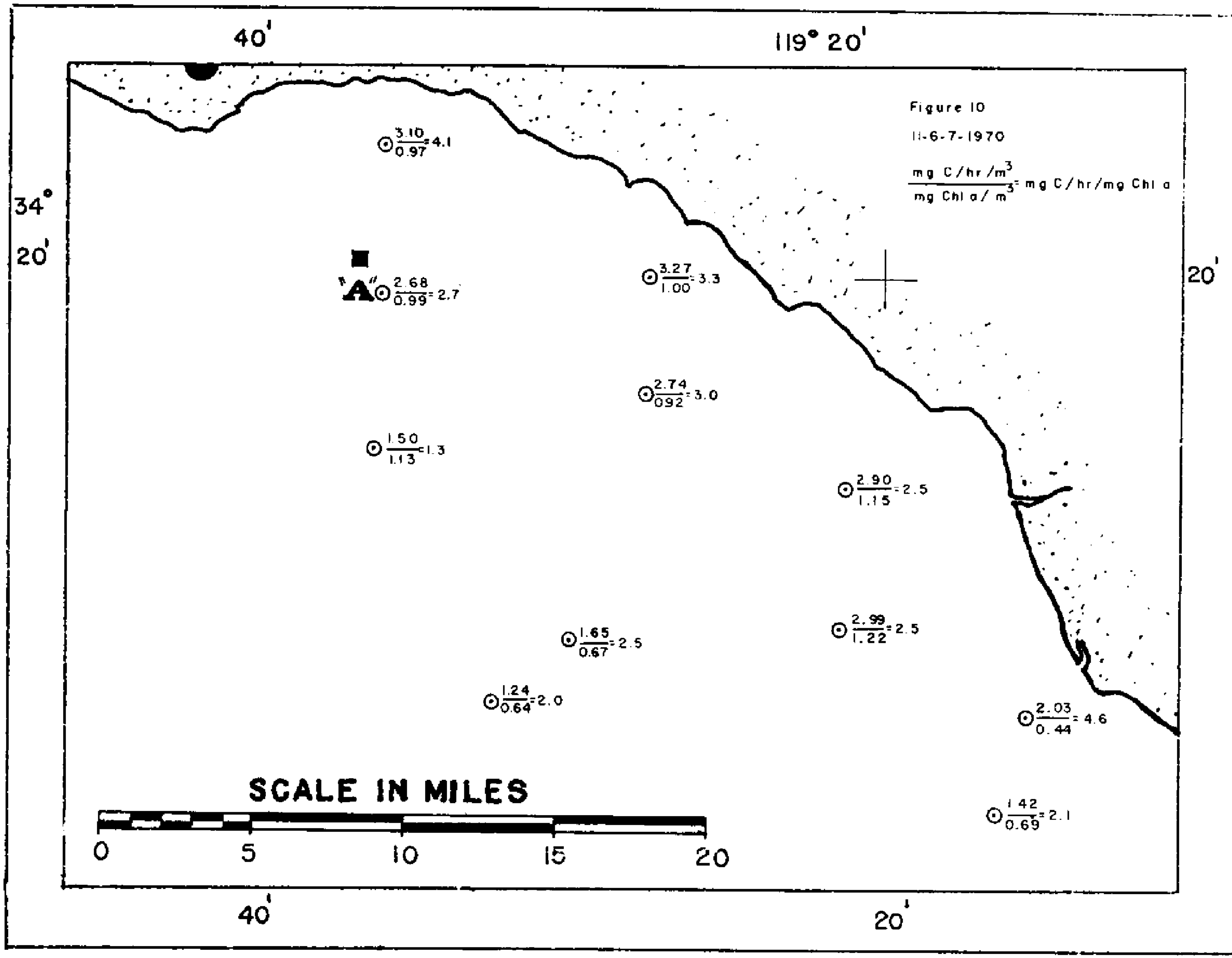
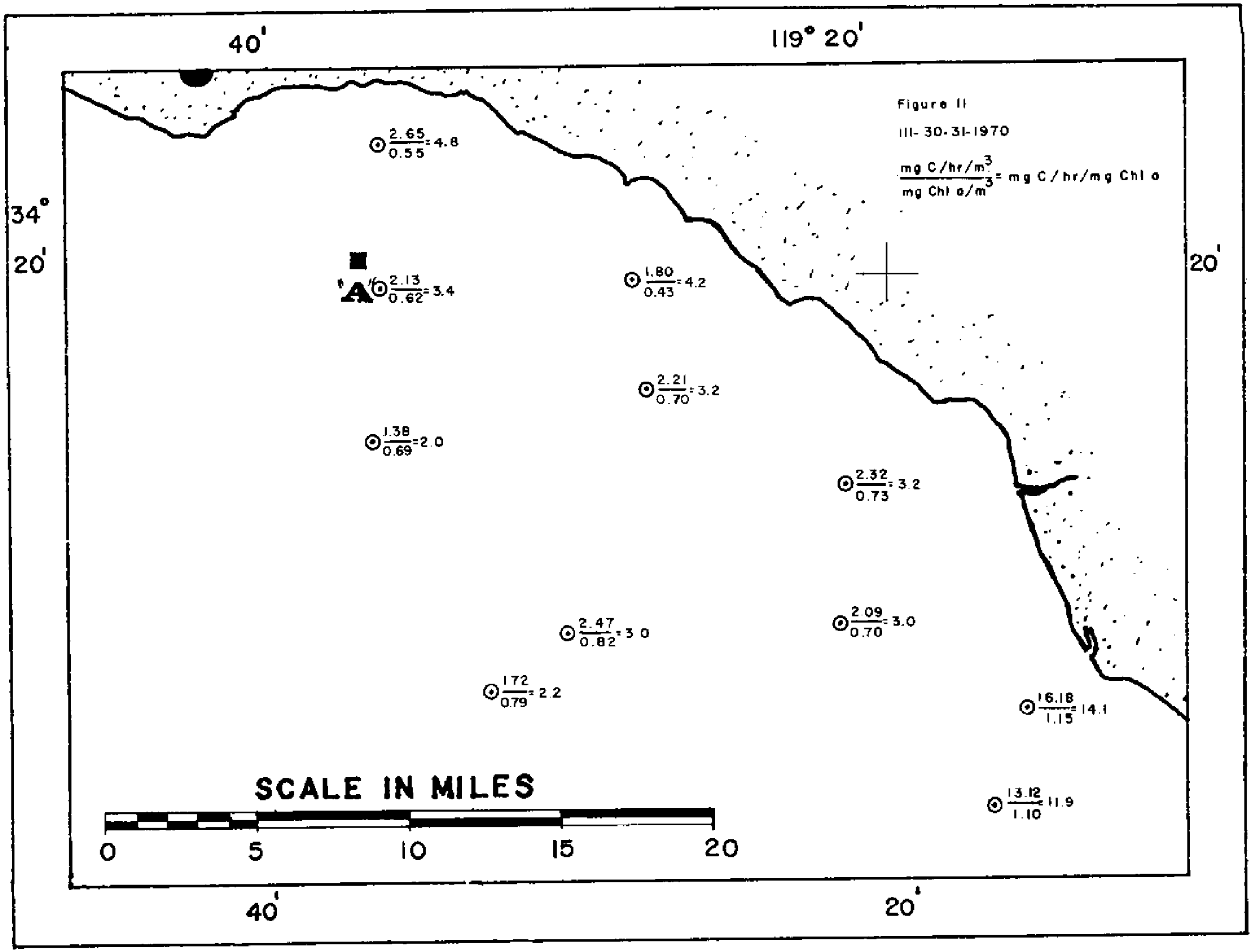


Figure 10

II-6-7-1970

$\frac{\text{mg C/hr/m}^3}{\text{mg Chl a/m}^3}$ = mg C/hr/mg Chl a


40'
119° 20'
Figure 11
III- 30-31-1970
mg C/hr/m³ / mg Chl a/m³ = mg C/hr/mg Chl a
34°
20'
20'
2.65/0.55 = 4.8
A
2.13/0.62 = 3.4
1.80/0.43 = 4.2
2.21/0.70 = 3.2
1.38/0.69 = 2.0
2.32/0.73 = 3.2
2.47/0.82 = 3.0
2.09/0.70 = 3.0
1.72/0.79 = 2.2
16.18/1.15 = 14.1
13.12/1.10 = 11.9
SCALE IN MILES
0
5
10
15
20
40'
20'

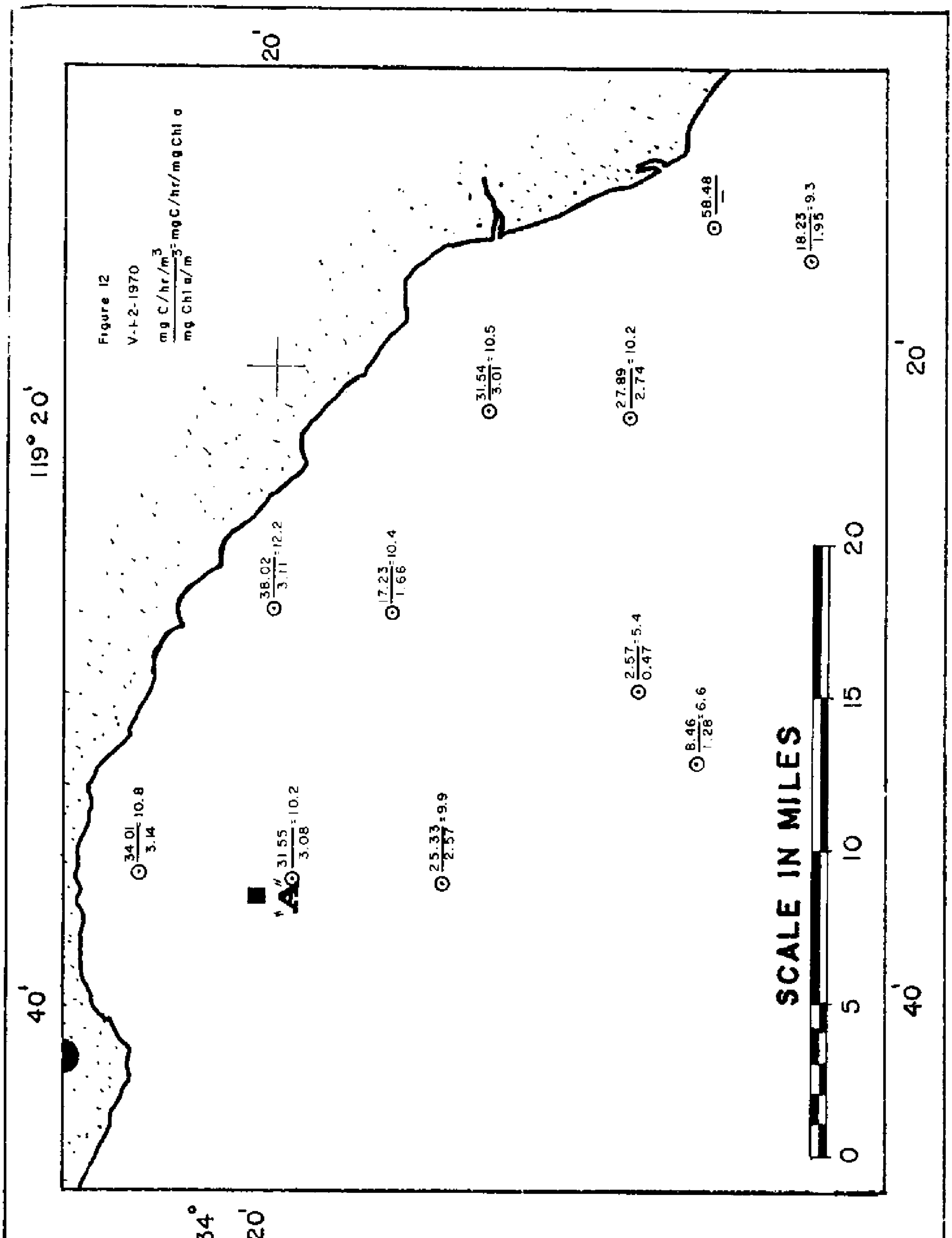


Figure 12
V-1-2-1970
mg C/hr/m³ / mg Chl a/m³ = mgC/hr/mgChl a
119° 20'
40'
20'
34° 20'
34.01/3.14 = 10.8
31.55/3.08 = 10.2
25.33/2.57 = 9.9
38.02/3.11 = 12.2
17.23/1.66 = 10.4
31.54/3.01 = 10.5
27.89/2.74 = 10.2
2.57/0.47 = 5.4
8.46/1.28 = 6.6
58.48
18.23/1.95 = 9.3
A
SCALE IN MILES
0 5 10 15 20

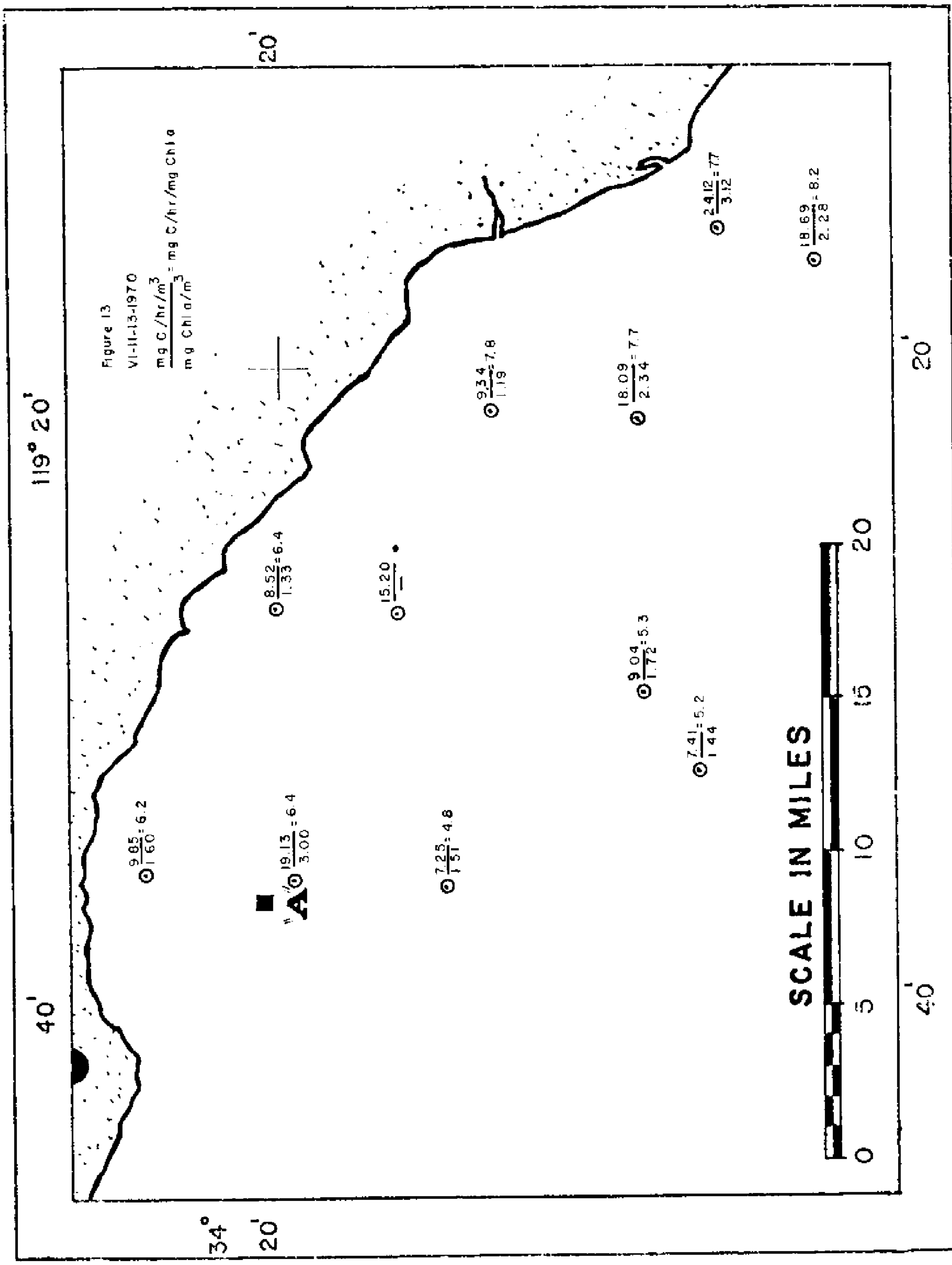


Figure 13
VI-11-13-1970
mg C/hr/m3 / mg Chl a/m3 = mg C/hr/mg Chl a
119° 20'
40'
20'
34° 20'
9.85/1.60 = 6.2
19.13/3.00 = 6.4
7.25/1.51 = 4.8
8.52/1.33 = 6.4
15.20/—
9.04/1.72 = 5.3
7.41/1.44 = 5.2
9.34/1.19 = 7.8
18.09/2.34 = 7.7
24.12/3.12 = 7.7
18.69/2.28 = 8.2
A
SCALE IN MILES
0
5
10
15
20

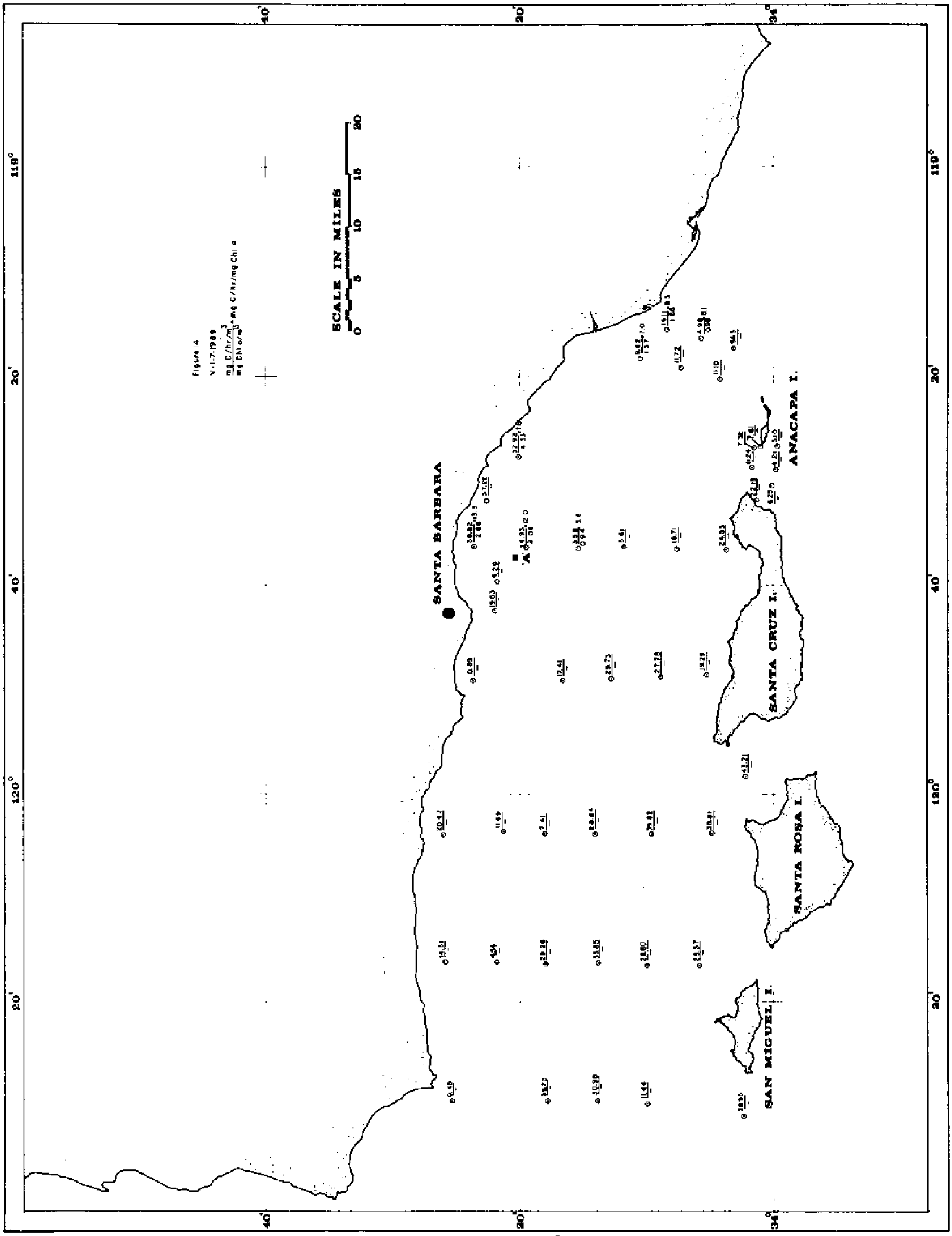


Figure 14
V-1-7-1969
mg C/hr/m3 / mg Chl a/m3 = mg C/hr/mg Chl a
SCALE IN MILES
0 5 10 15 20
SANTA BARBARA
SANTA CRUZ I.
ANACAPA I.
SANTA ROSA I.
SAN MIGUEL I.
119°
120°
34°
40'
20'

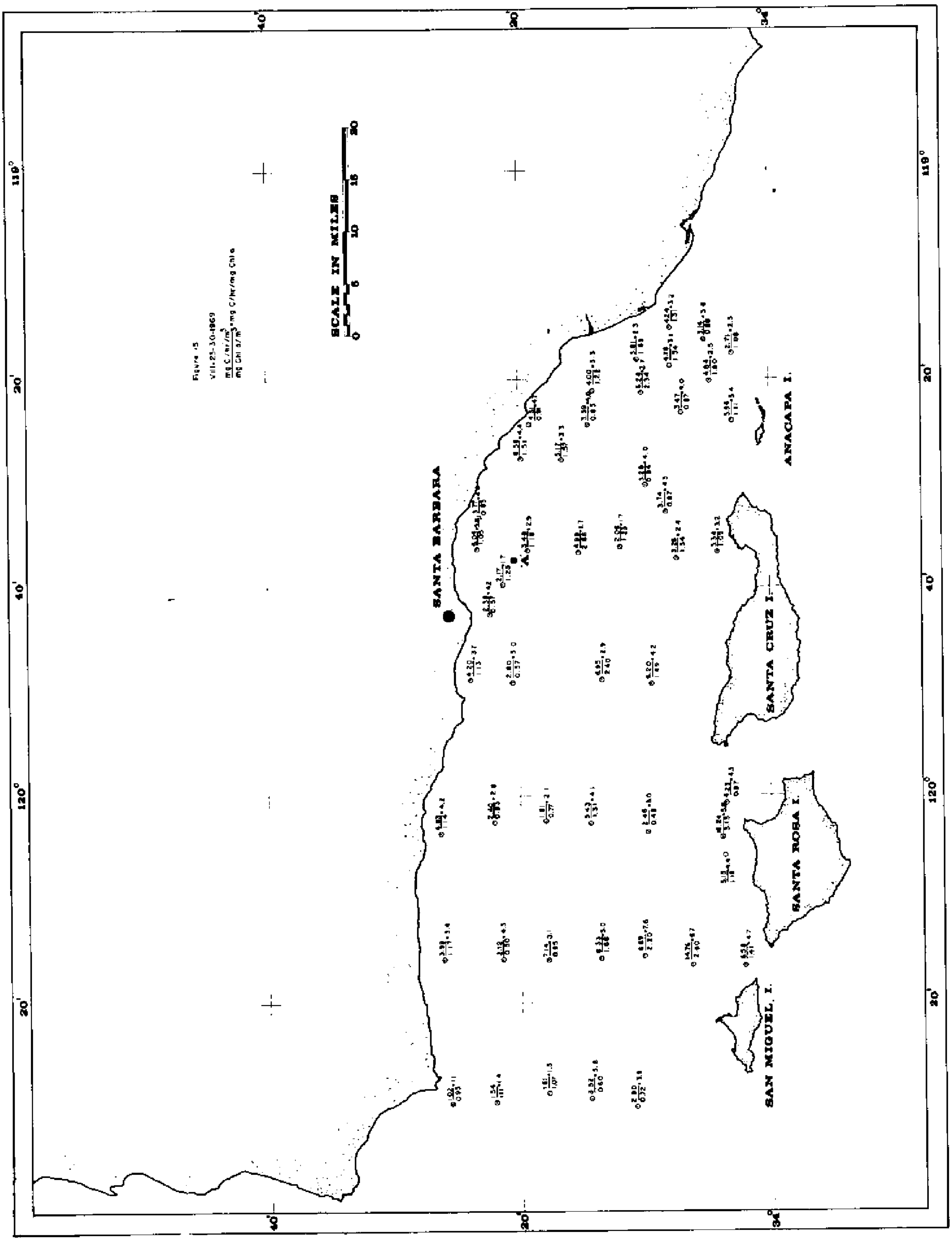
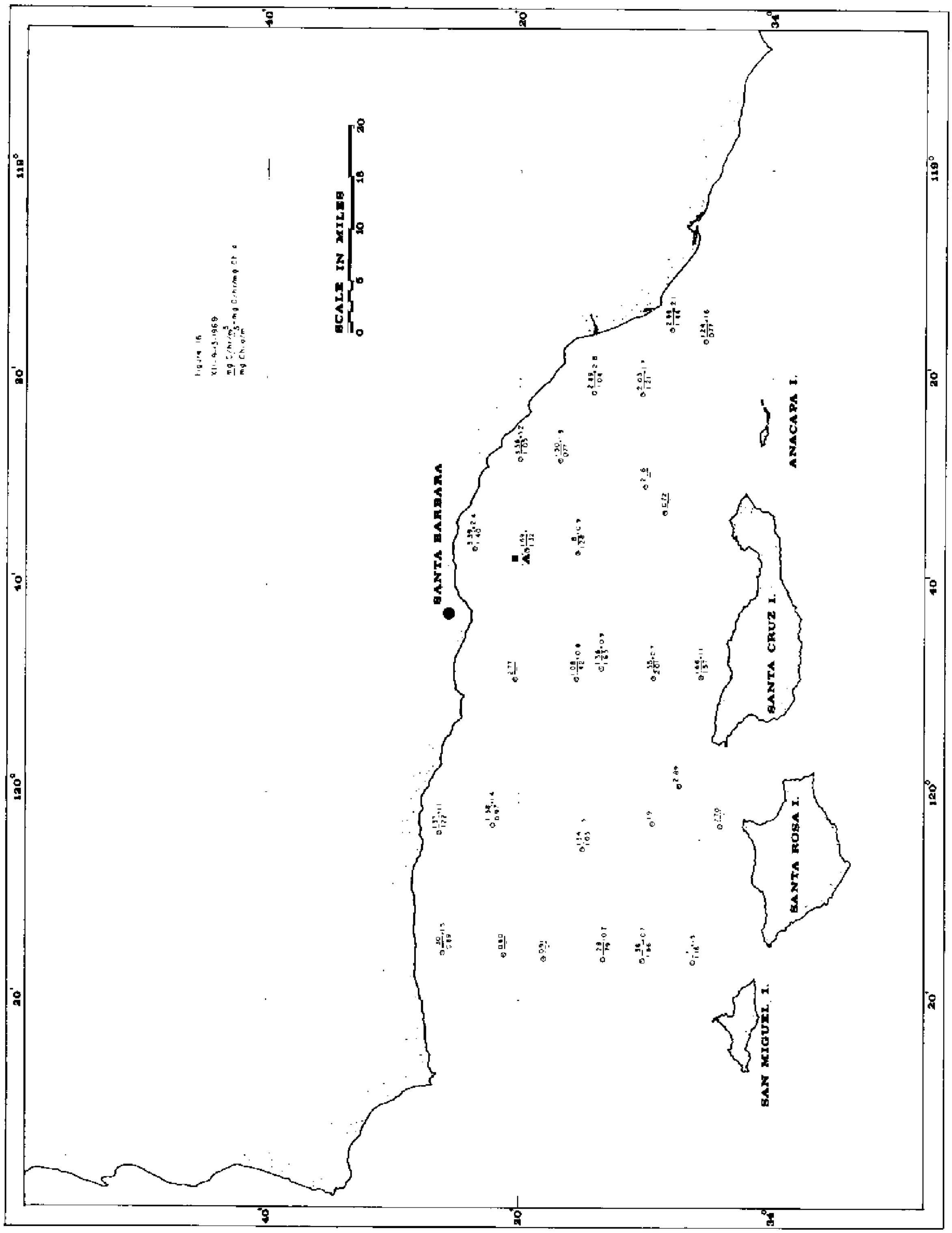


Figure 5
VIII-25-30-1969
mg C/hr/m³ / mg Chl a/m³ = mg C/hr/mg Chl a
SCALE IN MILES
0 5 10 15 20
SANTA BARBARA
SANTA CRUZ I.
SANTA ROSA I.
SAN MIGUEL I.
ANACAPA I.
119°
120°
34°
40'
20'


SANTA BARBARA
SANTA CRUZ I.
SANTA ROSA I.
SAN MIGUEL I.
ANACAPA I.
SCALE IN MILES
0
5
10
15
20
119°
120°
40'
20'
34°

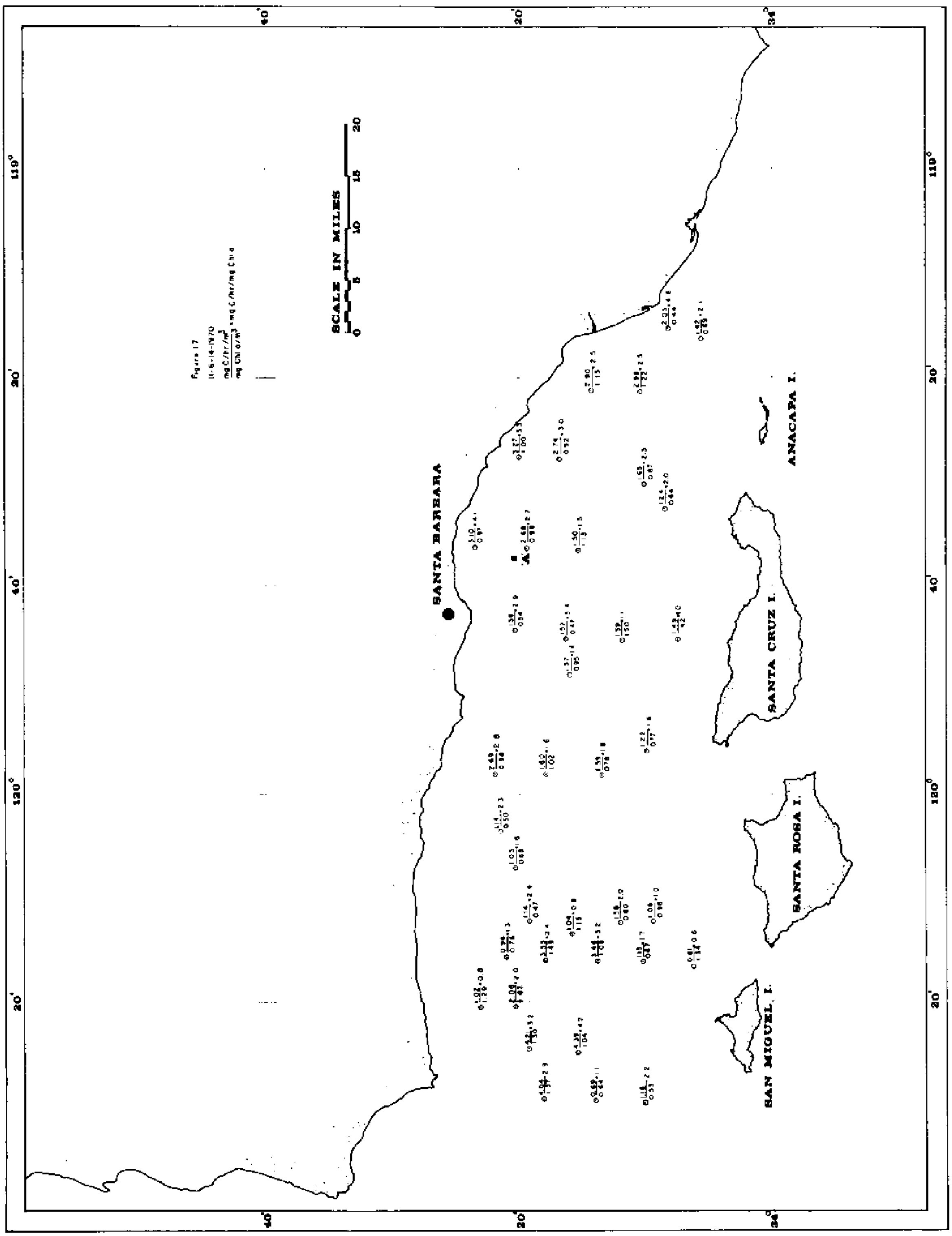
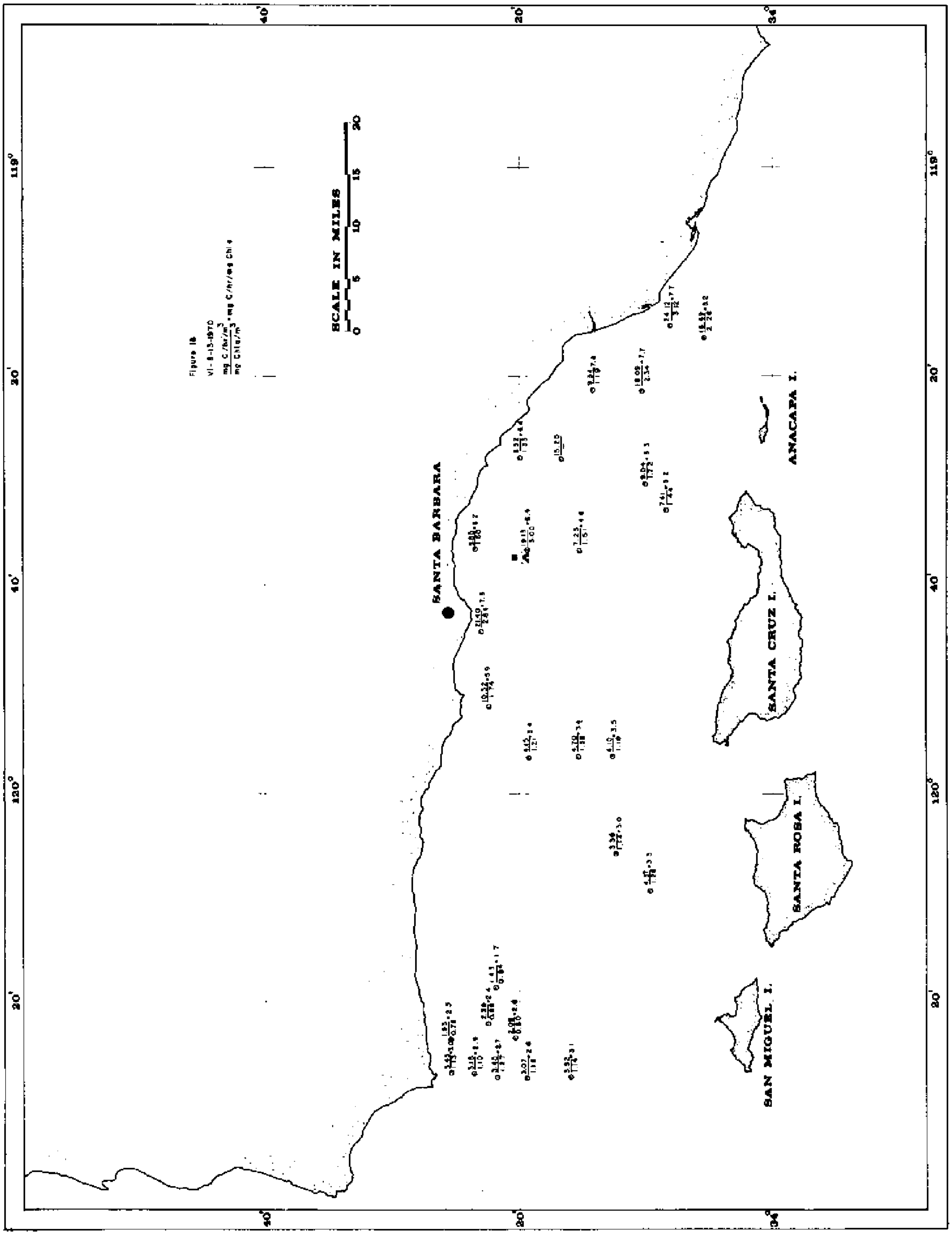


Figure 17
11-6-14-1970
mg C/hr/m³ / mg Chl a/m³ = mg C/hr/mg Chl a
SCALE IN MILES
0 5 10 15 20
SANTA BARBARA
ANACAPA I.
SANTA CRUZ I.
SANTA ROSA I.
SAN MIGUEL I.
40'
20'
34°
119°
120°


SANTA BARBARA
SCALE IN MILES
0
5
10
15
20
SANTA CRUZ I.
SANTA ROSA I.
SAN MIGUEL I.
ANACAPA I.
119°
120°
20'
30'
40'
34°

CHAPTER 4

OBSERVATIONS ON THE ZOOPLANKTON OF THE EASTERN SANTA BARBARA CHANNEL FROM MAY, 1969, TO MARCH, 1970

by Diane Robbins McGinnis

INTRODUCTION

Knowledge of the manner in which zooplankton may be affected by any alien substance is of considerable importance. Zooplankton forms a critical energetic link between phytoplankton and the larger animal species of the nekton and benthos. Zooplankters also provide a "rain" of organic materials to the sea sediments. Temporary plankters, including eggs, larvae and juveniles of benthic and nectonic forms, afford the means for constant replenishment of individuals to many marine habitats.

The assignment to study the influence of an oil spill on the zooplankton ecology of the Santa Barbara Channel initially seemed a feasible task. The individual components of the plankton are well-known (for a preliminary list of references see Isaacs *et al*., 1969). The California Cooperative Oceanic Fisheries Investigations have extensively sampled and summarized data for plankton communities of the upper 140 meters of California coastal waters. The data were collected in oblique hauls and do not separate the components of the zooplankton for different depths within the upper 140 meters of water. As an oil spill is primarily a surface phenomenon, only the surface plankton (0-5 meters) was surveyed in the present study. There are, to my knowledge, no published accounts of surface plankton communities in the study area. Without comparative and comparable pre-oil spill data, the scope of this paper is largely limited to a chronicle of major constituents of the surface zooplankton in the eastern Santa Barbara Channel from May, 1969, to March, 1970. Data were also obtained on zooplankton volumes and presence and absence of oil in the samples.

MATERIALS AND METHODS

Eleven stations in the eastern Santa Barbara Channel (see Chapter 3, Fig. 1) were sampled monthly from May, 1969, to March, 1970. Station data for March and April, 1970, are listed in Appendix 1, data for all other cruises may be found in Volume 2. Additional stations were occupied in April, May and August, 1969, and February and June, 1970. These will be considered in a separate paper. A half meter plankton net (mest 330μ) was fished just below the surface for ten minutes. A flow meter was employed with the net from July, 1969, to April, 1970. It should be noted that the March, 1970, samples were collected on 30, 31 of that month and the April, 1970, samples were collected on April 1 and 2. The specimens were fixed and preserved in 5% formalin and processed at the Allan Hancock Foundation, where the samples are deposited.

A crude quantitative estimate of biomass was established by measuring the settled volume of each sample. The volume of sample per revolution of flow meter was calculated for comparison of different samples. The sample was then stirred well and an aliquot removed. As a rule the aliquot was sorted to major taxonomic groups only, as the brevity of this program did not allow further separation. However, in certain instances it seemed wise to note species displaying unusual blooms. The thalacian *Doliolum denticulatum* and the cladoceran *Penilia avirostris* fall into this category.

A search was made for a species or group of species that could be monitored easily throughout the year's cycle. The species must be easily recognizable, must occur in relatively large numbers, and must inhabit the surface waters of the area. The pontellid copepods *Labidocera trispinosa* and *L. jollae* fit the above description and were systematically removed from the aliquots and counted. Males, females, and females with spermatophores were counted in order to estimate breeding activity.

The number of specimens in each major taxonomic group was counted, and group percentages of the total tabulated. The entire sample was scanned to detect groups not present in the aliquot, presence of oil, or unusual amounts of phytoplankton.

RESULTS

Tables 1 and 2 summarize results of this study. Predictably, copepods comprise the major portion of plankton at most stations. Notable exceptions include the high concentrations of thalacians (particularly *Doliolum denticulatum*) throughout the entire eastern basin in August, 1969, and the appearance of the neritic cladoceran *Penilia avirostris* in the late summer and fall. *P. avirostris*, an inhabitant of most of the world's oceans, has not previously been reported from the eastern North Pacific Ocean (Della Croce, 1964). It appeared at station 3 in August, continued to be present in September (stations 1, 2, 3, 4, 5, 6, 7), November (stations 1, 10), and reached its greatest density in December. At station 4 in December, *P. avirostris* comprised 94% of the sample. It also occurred that month at stations 1, 2, 6 (20%), 7 (4%), 10 (4%), and 11. Small numbers of this species were present at stations 2 and 11 in January, 1970.

Labidocera trispinosa and *L. jollae*, pontellid copepods which inhabit the neritic regions of California and northern Mexico (Fleminger, 1967), were present throughout the year. *L. trispinosa* reached a peak concentration in November, at station 6, where it composed 16% of the sample. Females with attached spermatophores were present in May, June, July and November, 1969, and January, 1970. This indicates that breeding probably occurred throughout the year. Spermatophore-bearing females appeared with the greatest frequency in the summer months.

Labidocera jollae was rarely observed in the samples, and no females bearing spermatophores were found.

Comparative data must be available in order to assess the effects of oil on the composition of plankton in the Santa Barbara Channel. The quantity and quality of a zooplankton community are determined by a large number of biotic and abiotic variables. Intrinsic variability persists in the form of breeding cycles, dormant periods, patchiness, diurnal migrations and other factors not well understood. Zooplankton communities are subject to water movement and influenced by light, temperature, salinity, and other hydrographic factors. Comprehensive and extensive data of several seasons' duration are required for the establishment of normal parameters of zooplankton variability--a feat far beyond the possibilities of this investigation. With these limits in mind the following observations are of significance:

1. Zooplankton was present at all stations at all times of the year.

2. Zooplankton was most abundant in January, 1970, and least abundant in September, 1969.

3. Oil was never recorded in samples from stations 5, 8, 9; stations 5 and 9 were the most productive in the area studied.

4. The epipelagic copepod *Labidocera trispinosa* appeared to be breeding throughout the year.

5. *Penilia avirostris* is recorded for the first time as an inhabitant of neritic waters of Southern California.

RECOMMENDATIONS

Due to the importance of zooplankton in the economy of the sea, the initiation of a monitoring system for delineation of the degree of normal variation in the plankton communities of the Santa Barbara Channel is recommended. A program incorporating comprehensive analysis of regular and consistent samples from Platform A and, less frequently, from a grid of at least 10 stations in the eastern end of the channel would provide information of basic scientific value and could provide a basis for comparison should another spill occur.

ACKNOWLEDGMENTS

I wish to thank M. Oguri and J. Wintz for collecting the plankton samples.

REFERENCES

Della Croce, Norberto
1964 Distribuzione e biologia del cladocero marino *Penilia avirostris* Dana. Institut Oceanogr., Monaco, Bull., 62(1301): 1-16.

Fleminger, Abraham
1967 Taxonomy, distribution, and polymorphism in the *Labidocera jollae* group with remarks on evolution within the group (Copepoda: Calanoida). U.S. Natl. Mus., Proc., 120(3567): 1-61.

Isaacs, J. D., A. Fleminger, and J. K. Miller
1969 Distributional atlas of zooplankton biomass in the California current region: spring and fall 1955-1959. California Cooperative Oceanic Fisheries Investigations, Atlas, 10. xxvp., 252 charts.

APPENDIX
I

Station	Date	Lat. (N)	Long. (W)
14069	3/30/70	34°05'30"	119°16'30"
14070	3/30/70	34°08'10"	119°15'30"
14071	3/30/70	34°10'30"	119°21'35"
14072	3/30/70	34°13'11"	119°21'28"
14073	3/30/70	34°20'00"	119°27'45"
14074	3/30/70	34°16'48"	119°27'50"
14075	3/31/70	34°10'12"	119°30'30"
14094	4/1/70	34°23'39"	119°36'21"
14095	4/1/70	34°19'30"	119°36'18"
14096	4/1/70	34°15'27"	119°36'40"
14097	4/2/70	34°08'45"	119°32'50"
14098	4/2/70	34°10'15"	119°30'30"
14099	4/2/70	34°16'36"	119°27'45"
14100	4/2/70	34°20'00"	119°27'32"
14101	4/2/70	34°14'20"	119°21'30"
14102	4/2/70	34°10'30"	119°21'40"

Table 1

Numerical Percentages of Taxonomic Groups in Sorted Aliquots

Project No.	Velero IV Sta.	Time[b]	Volume[c] (ml.)	Oil	Phytoplankton	Unknown Eggs	Fish Eggs	Larvae: Fish	Larvae: Crustacean[a]	Larvae: Holothuroid	Larvae: Echinoid	Larvae: Ophiuroid	Larvae: Asteroid	Larvae: Brachiopod	Larvae: Cyphonautes	Larvae: Phoronid	Larvae: Cirripede	Larvae: Polychaete	Larvae: Gastropod	Larvae: Pelecypod	Larvae: Euphausids	Larvaceans	Salps	Doliolids	Heteropods	Pteropods	Squid	Isopods	Amphipods	Euphausids	Mysids	Copepods	Ostracods	Cladolerans	Annelids	Chaetognaths	Ctenophores	Coelenterates
1	13013	D					+		+						2						3	4	+		+					+		89		+				+
2	13032	N	210				9		+												+			+					+	+		87				3		+
5	13021	N	12				5		+						+						2	2	+	2								88				+		+
6	13022	N	400						+												+		34									55		+		5		+
7	13023	N							+												+	4	12	+		+			+	+		70		8		3		+
10	13010	N	160				+	+	+												+	67	+	+					+	+		29			+	+	+	+
11	13011	T	60				+	+	+								+				2	15	3	2								73	+			+		+
1	13094	T	40				+		+													+										79		18		+		
2	13104	N	50				6														+	+										74		17		+		+
3	13103	N	110				9		+												+	+										77		10		2		+
4	13102	N	70				2		+										+		3	+										86		7		+		+
5	13099	N	345				+	+	+								+		+		3	+					+		+		+	93			+	+		+
6	13100	N	50				5		+												7	+	+									80	+	4		+		+
8	13098	N	170				4	+	+												9	2							+			81		+		2		
9	13097	N	325				9	+	+						+		+		+		15	+		+			+		18			63			+	6	+	+
10	13096	N	35			+	31														2	+										66		+		+		+
11	13095	N	25				+														+	2										91		+		2		+
1	13220	N	90				+		+												+	+		+								87		10		2		
2	13214	N	145																		+	+		+								93		+		5		
3	13215	N	165																		+	+		+								61		6		30		
4	13213	N	200				+	+	+												+	+	+		+							73		9	+	13		+
5	13212	N	60				+	+	4									+			+	15		+					+	+		65	+	5	+	2	+	+
6	13211	T	50		+			+	+									+			+	2	+	+					+	+		67	6	7		13		+
7	13210	T	150				2		+										+		+	7	2									22		43		20	+	2
8	13216	N	125				+	+	+												+	3		3						+		31	+	21		30		+

Table 1--Continued

								Larvae																														
Volume[c] (ml.)	Time[b]	Velero IV Sta.	Project No.	Oil	Phytoplankton	Unknown Eggs	Fish Eggs	Fish	Crustacean[a]	Holothuroid	Echinoid	Ophiuroid	Asteroid	Brachiopod	Cyphonautes	Phoronid	Cirripede	Polychaete	Gastropod	Pelecypod	Euphausids	Larvaceans	Salps	Doliolids	Heteropods	Pteropods	Squid	Isopods	Amphipods	Euphausids	Mysids	Copepods	Ostracods	Cladolerans	Annelids	Chaetognaths	Ctenophores	Coelenterates
230	N	13217	9				+	+	+												+	+										38	+	33		24		2
220	N	13218	10																		+	2		21								28		19		27		
130	N	13219	11		+																+	+		+								71		16		9		+
70	N	13351	1		+							3		+			+		+		+	+	+	84						+		2		2		2		+
70	N	13364	2				+	+						+			+		+				+	67		+		+		+		9		14		5		+
70	N	13363	3		+	+						+									+		+	15								77		+		5		
40	N	13374	6		+		+		+		+	+									+	+	33	45						+		6	+	3		+		10
50	D	13355	8		+				+		+							+		+		3	3	30					+	+		10		38		10	+	+
	N	13362	8		+		+	+	+				+				+		+		+			50		+				+	+	23		12		8		+
50	D	13356	9		+		+		+												+			54					+			11		27		5	+	+
75	N	13353	12		+							+					+		+		+	4	2	42						+		38				2	+	7
130	N	13352	11		+		+		+		+					+					+	3	2	74								7		10		+		+
50	N		1																				+	3								9	+	4		2		
20	N		2	+	+		+		+		+											+	+	5								82		5		3		+
13	N		3				+										+				+			5								35		51		2		2
15	N		4		+		+	+													15		+	2								68		12		2		
15	N		5		+		+		3									+			2		+	+						12		15		55		5	+	+
10	N		6		+		+		+								6	+			+	+	+	2						3		28		48		3		
20	N		7					7	+						+						8	4		3								44	+	29		4		
25	N		8				2					+			1						21	+	+	2								37	3	25		8		
10	N		9		+		5		2		+				21						+			6					+	6		30		23		4		+
20	N		10				+		+						+				+		+	4	+									25	+	56		9		+
50	N	13599	1					+	+																							98		+		+		
60	N	13605	2				+	+	2						+			+			+								+	+		94				+		
45	N	13604	3		+		4	+						+							+	10		2								72		+		4		+
85	N	13607	5		+		6	+						5							2	13		5								56	4	+		5		+

Table 1--Continued

Volume[c] (ml.)	Time[b]	Velero IV Sta.	Project No.	Oil	Phytoplankton	Unknown Eggs	Fish Eggs	Larvae: Fish	Larvae: Crustacean[a]	Larvae: Holothuroid	Larvae: Echinoid	Larvae: Ophiuroid	Larvae: Asteroid	Larvae: Brachiopod	Larvae: Cyphonautes	Larvae: Phoronid	Larvae: Cirripede	Larvae: Polychaete	Larvae: Gastropod	Larvae: Pelecypod	Larvae: Euphausids	Larvaceans	Salps	Doliolids	Heteropods	Pteropods	Squid	Isopods	Amphipods	Euphausids	Mysids	Copepods	Ostracods	Cladolerans	Annelids	Chaetognaths	Ctenophores	Coelenterates
75	N	13608	6					+	+						12						+	+		3								78				3		+
100	N	13609	7	+	+				+						+						15			10		2				2	+	38	+	16		3	+	5
120	N	13603	8		+			+	+					2					+		5	8		+						+		72		+		3	+	2
230	N	13602	9		+							+							+		7								+			79	+	+	+	2		+
287	N	13601	10		+				+						+				+		+	+	+	+								82				6		1
350	N	13600	11		+		+											+					+			+			+	+	+	7		4		6		
200	N	13688	1				+	+	6						2			+				+							+			75		5		4		+
80	N	13685	2				+		6						+						+	+		+								87		+		5		
350	N	13684	3	+	+		7	+	+									+			+	+		44						+		19		16		3		+
10	N	13683	4		+				+						+															+		5		94		+		+
25	N	13682	5				12	+	19									+			+	+	+	28						2		32		+		3		+
40	N	13696	6	+					37						+			+			+	2		14						+		12		21		6		+
30	N	13695	7				+											+			2			+								45		4		+		+
100	N	13681	8				4	+	11									+				2	2	33						+	+	34		12		+		+
70	N	13680	9				+		+												5			2						4		80	+			3		+
35	N	13686	10	+					5									+				3		50						+		21		6		2	+	6
40	N	13687	11	+			+		3									+				+	+	44						3		29				3		9
220	N		1				+	+	+				+		+							5	+	11								70	+	9	+	+		+
120	N		3		+	27											+	+			+	+	+	22								45		+	+	+		+
190	N		4				7	+	+									+			4	10	+	7		+						66			+	+		2
290	N		5				19	+	+									+			4	10	5	7		+						46		4		+		+
230	N		6			+	+												+		3	11	11	8					+	+		54		+		4		3
300	N		7		+		+	+										+	+		+	35	16	8						+		20		+	+	7	+	3
270	N		8				10		+												+	10	6	6								56		2		5		+
500	N		9				14	+	+						+						4	4	2	4								67				+	+	+
180	N		11				4	+	+									+	+		+	6		2								81	+		+	4		+
100	N	13793	1				5				+		+		+							39	2						+			51						+
40	N	13787	2																			56		+								43						
80	N	13788	3	+					+										+		+	31	+		+					+		62				+		+

Table 1--Continued

Project No.	Velero IV Sta.	Time[b]	Volume[c] (ml.)	Oil	Phytoplankton	Unknown Eggs	Fish Eggs	Larvae: Fish	Larvae: Crustacean[a]	Larvae: Holothuroid	Larvae: Echinoid	Larvae: Ophiuroid	Larvae: Asteroid	Larvae: Brachiopod	Larvae: Cyphonautes	Larvae: Phoronid	Larvae: Cirripede	Larvae: Polychaete	Larvae: Gastropod	Larvae: Pelecypod	Larvae: Euphausids	Larvaceans	Salps	Doliolids	Heteropods	Pteropods	Squid	Isopods	Amphipods	Euphausids	Mysids	Copepods	Ostracods	Cladolerans	Annelids	Chaetognaths	Ctenophores	Coelenterates
4	13786	N	40	+			72	+	+													20		+					+			7		+	+	+		+
5	13785	N	30				55	+	3									+			+	9		+								28		+		2		+
6	13784	N	70				+	+	+				+								+	58	+	6							+	31				+		+
7	13783	N	70				+		+												+	84	+	3								12				+	+	+
8	13789	N	200				+															14	+									84				+		
9	13790	N	40						+						2							8	+									89				+		+
10	13791	N	150	+			10	+	+		+	+			+						+	27	+	7								51				3		
11	13792	N	40				+	+													2	26	+	+								66		+		+		+
1	14079	N	50					+	6						+						+	3										87	+	+		+		+
2	14073	N	60					2	21								+	+			+	+		2								61	2	+		+		8
3	14074	N	75					4	33									+			+	25		+								33		+		+		+
4	14072	N	50					+	6												+	39		19								25		5		+		2
5	14071	N	80					3	+					+							6	6		7					+			63		+		7		+
6	14070	N	140				+	+						+				+			+	+		+		+				+		42	+	+		4	+	+
7	14069	N	100					+	18		+	+		+							4			+								68		+		6	+	+
9	14076	N	430				+	38					+					+			20	5	+	+			+			6		27				+		+
10	14077	N	50				+	6													8	23		18					+	+		41		+		+		3
11	14078	N	80					3	+												7	34		+								54		+		+		+
1	14094	N	20					5	6		5		+	+	10			+	+			+		+								70		+		+		+
2	14100	N	70					+	13		+	+		+	+			+				6		2								70		+	+	+		+
3	14099	N	45						53					+			+				+	5		+		+						39	+	+				+
4	14101	N	180					+	+									+			10	10	+	2								77				5	+	+
5	14102	N	250		+	+		+										+			2	17	+	3						+		70				3	+	+
8	14098	N	50					+						+							4	22	+									61				3	+	+
10	14096	N	55				+	+	+										+		6	26		+			+		+		+	56	+					5
11	14095	N	50					2	5												8	4	+	+							+	77		2				2

[a]Crustacean larvae excluding Euphausids and Cirripedes.

[b]D = day; N = night; T = twilight.

[c]Settled volume.

Table 2

Average Settled Volume (ml)/Flowmeter Revolution in Plankton Samples
Taken from July, 1969 to April, 1970

Project No.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	Station Average
1	.0288	.0202	.0216		.0131	.0508	.0526	.0338		.0069	.0294
2	.0338	.0153	.0096		.0139	.0189		.0108	.0250	.0231	.0188
3	.0339	.0205	.0051		.0177	.0855	.0375	.0234	.0318	.0146	.0300
4	.0451		.0035			.0048	.1055	.0137	.0202	.0565	.0356
5	.0161		.0029		.0294	.0064	.1110	.0095	0340	1160	.0406
6	.0146	0085	.0018			.0139	.0608	0254	.0467		.0245
7	.0471		.0046		.0294	.0097	.0776	.0220	.0286		.0313
8	.0300	.0132	.0057		.0322	.0376	.0703	.0690		.0189	.0311
9	.0515	.0145	.0023		.1270	.0268	.0977	0165	.1370		.0591
10	.0595	.0165	.0042			.0084		.0585	.0188	.0192	.0250
11	.0328	.0336				.0121	.0432	.0116	.0278	.0139	.0267
Monthly average	.035	.0177	.006		.037	.024	.071	.027	.041	.033	

CHAPTER 5

THE BENTHIC FAUNA IN THE SANTA BARBARA CHANNEL FOLLOWING THE JANUARY, 1969, OIL SPILL

by Kristian Fauchald

INTRODUCTION

The benthic fauna off Santa Barbara was studied as part of a large-scale investigation covering the shelf areas of Southern California by scientists from the Allan Hancock Foundation, University of Southern California. The very extensive series of samples taken during the years 1956-1960 formed the basis of several important publications (see inter alia Barnard and Hartman, 1959; Barnard and Ziesenhenne, 1961; Hartman, 1960; and Jones, 1969). The material from this investigation was only partially worked up, due to time limitations and lack of funds, as remarked by Jones (1969:41). The published records of identified organisms were used in the present study as comparative material in an attempt to evaluate the effects of the January, 1969, oil spill from Platform A. In this paper, these published records are referred to as AHF:USC, 1965, Appendix; the 1956-60 survey itself is called the State Survey; and the 1969 study is called the Pollution Study.

The Pollution Study can be separated into three distinct phases:

1. A series of samples taken as soon as possible after the spill (actually in early March) over a large area surrounding Platform A (34° 20' N, 119° 37' W) in order to gain some information on the initial effect of the oil spill.

2. A series of samples taken at two to four month intervals in the *Listriolobus*-bed between Santa Barbara harbor and Platform A to study more chronic effects of the spill on faunal composition, standing crop and, if possible, on recruitment.

3. A series of stations taken during October in an attempt to gain some information on variation in standing crop and faunal composition of the whole shelf area off Santa Barbara.

The results are presented in three separate reports. Two papers deal with common and dominant animal groups of the area, while this paper is an evaluation of the results in terms of changes in standing crop and in species replacements. An attempt was made to relate the observed changes to the oil spill and to all other factors which may have influenced the fauna of the area in the ten years separating the State Survey and the Pollution Study.

As the results of the geological investigations were not available at the time of writing, all evaluations have been made in terms of the distribution of the fauna *per se*.

SAMPLING AND LABORATORY METHODS

Sampling

Eighty-five samples were taken; two were box-cores, two were taken with a six-foot beam trawl, and the remainder of the samples were taken with a Campbell Grab. Durham (1955) and Hartman (1955) described the gear and shipboard arrangements of the *Velero IV*.

Each grab-sample was considered a separate station and treated as such throughout the study. On collection, the volume of material was determined and notes were taken on the kind of sediments collected. These notes were based on the amount of noticeable grittiness and the cohesiveness of the material. This method is inaccurate, but will give a rapid, shorthand characterization of the sediments without the rather laborious process of identifying and quantifying each of the many different fractions of the material. The following notations were used: clay--no discernible grittiness, very high cohesiveness; silty clay--distinct but slight grittiness, high cohesiveness; silt--pronounced grittiness, cohesiveness relatively poor; fine sand--particles visible, poor cohesiveness; coarse sand--large particles, no cohesiveness. As remarked above, the geological results were not available at the time of writing.

Each sample was washed with running sea water on a 0.5 mm mesh screen. The larger and more delicate organisms were sorted out. These and all material left on the screen after washing were preserved separately in 10% formalin in sea water.

Laboratory procedures

Each sample was washed in running water to remove the formalin and the animals were sorted into the major taxonomic groups. Excess water was dried off carefully and each group of organisms was weighed on a Mettler Balance Model B6. Weight determinations were made to 0.01 grams. The standing crop of macro-organisms per square meter of the sample was calculated; as each grab covers one-half square meter of bottom, the summed figures for all animals in a sample were multiplied by two. The standing crop determination in the Pollution Study was thus in terms of formalin weight, as in the State Survey. The percentage representation of each group was also determined. After weighing, the organisms were preserved in 70% isopropyl alcohol.

Station lists

The station list for the Pollution Study is given in Table 1 and Fig. 1, and for the State Survey in Table 2 and Fig. 2. The first four columns in each table give station number, date, location and depth in meters in both lists. The fifth column in Table 2 is the standing crop of macro-organisms in grams per square meter. In Table 1 the percentage of standing crop of each sample identified in detail is given in column 7. In cases where less than 80% of the standing crop was treated taxonomically, the most abundant organism in the untreated fraction is given in column 8. In a few cases no group can be singled out as dominant, but usually a single large holothurian or a sea-pen makes up a major portion of the standing crop not accounted for. In the station list for the State Survey (Table 2), the presence or absence of Listriolobus is noted in column 6; sediment-types were omitted from this latter list, since the terminology differs from the one employed in the present survey and notations are missing from a large number of stations.

Identifications and species lists

Lists of species identified in one or both of the surveys are given in Tables 3 to 5. Time limitations made it impossible to treat all organisms in detail.

Polychaetous annelids were identified only for selected families, primarily chosen to include as high a percentage of the standing crop of polychaetes as possible. Materials from stations 12741-13031 were so treated. The identification of polychaetes, one of the most important groups of animals in these bottoms, is very slow and laborious and the work has been progressing as rapidly as could be expected. The results are detailed in Chapter 6.

Mollusks were identified through station 13424 and the presence of the brachiopod Glottidia albida was noted at these stations.

The ophiuroid echinoderms, reported in Chapter 7, were identified from all but the last eleven samples. The presence of the echiuroid worm Listriolobus pelodes was noted in all samples.

Lists of the identified material from the State Survey covering the same taxa identified in the Pollution Study were abstracted from the published records (AHF:USC, 1965, Appendix). Some names were changed to remove synonyms; such synonyms are indicated in the lists.

The polychaetous annelids were identified by Mr. Raymond Emerson, the mollusks by Mr. Ted Phillips of the Santa Barbara Museum of Natural History, and the ophiuroids by Mr. Jack Wintz.

Diversity indices and statistical treatment

The materials from both the State Survey and the Pollution Study have been only partially sorted and identified. Thus, in effect, the treatment has been qualitative rather than quantitative at the species level. This is especially true of the polychaetous annelids and the smaller groups, generally lumped as "Other groups" in our lists. A species diversity index based on such material could be misleading, so it was decided to wait for more fully identified material before applying any of the many possible diversity indices. Similarly, a complex statistical treatment based on materials so incompletely treated as in the Pollution Study would be no better than a direct interpretation of the results. The material from the State Survey, which was much more fully treated than that from the Pollution Study and thus could be used for statistical treatment, has been so treated by Jones (1969) in considerable detail and the results of the Pollution Study have been compared when possible with his results.

Comparison with the techniques of the State Survey

The methods used during the State Survey were critically analyzed by Jones (1969:24-26, 36-46). Jones discussed in detail the operation of the Hayward Orange Peel Grab used during the State Survey and the various objections different authors have raised to the use of this instrument. The Pollution Study was done with the Campbell Grab, which lacks some of the more objectionable features of the Orange Peel Grab. The Campbell Grab is rather large and takes one-half square meter in a haul; it is very heavy so that good penetration is insured under most circumstances; but it will not function well in hard-packed sands or in very oozy soft muds where the trigger mechanism may fail. The sediments of the Santa Barbara shelf are eminently suitable for investigation with the Campbell Grab and only rarely did the grab fail to come up completely filled. It does have a tendency to kite due to water resistance during lowering and this may cause the uppermost, flocculent layer of mud to be blown away with its fauna just before the grab hits the bottom.

This kiting was countered by mounting a large lead-weight (150 lbs) in each scoop of the grab and no noticeable kiting was then observed, even during very rapid lowering of the grab.

Jones (1969:44) gave a series of figures for converting the catch of the Orange Peel Grab to square meter estimates. These conversion figures were arrived at by comparing the volume of the samples, which is easily measured, with the area of identifiable surface material in the grab. It is possible that the identifiable surface material in a catch was less than the surface actually sampled; thus the conversion factors may have been overestimated somewhat. Under no circumstances can the model of Orange Peel Grab used cover more than one-fourth square meter, so the minimum conversion to square meters is a factor of four. It was decided to use this lowest conversion figure for all estimates of the standing crop from the State Survey for comparison with the results from the Pollution Study; thus the estimated standing crop cited for the State Survey is a minimal figure rather than a maximal one.

The screening procedures, fixative, and laboratory methods were similar in both studies; in fact, the Pollution Study was patterned as much as possible on the earlier study to facilitate comparisons between the two series of samples.

ACKNOWLEDGMENTS

The Captain and crew of the Velero IV were very patient with the group and were a great help to them. Mr. Carl Philippi and Mr. Paul Irving gave us much help with the large, often cumbersome Campbell Grab. The following persons assisted in the sorting and weighing of the material: Janet Lent, John O'Neill, John Sweet, Jack Wintz and Craig Zwizinski. Mr. Craig Zwizinski and Miss Catherine Link drew maps and charts and were generally helpful during the final phase of this study.

Dr. Dale Straughan is thanked for her encouragement and for being available for discussion and advice on all occasions. Dr. Olga Hartman assisted greatly with the identification of the polychaetous annelids and has given much valuable advice in numerous discussions of the problems and concepts involved in this study. Dr. Gilbert F. Jones gave us several helpful ideas and advice on the pitfalls of benthic ecology.

RESULTS

Standing crop of macro-invertebrates

The standing crop of macro-invertebrates, measured in grams per square meter formalin weight, is given for each station in the station lists. Figs. 3 and 4 were drawn with isopleths at 100 grams per square meter intervals to show the general distribution of standing crop in the area of the vicinity of Platform A. It should be noted that these figures may be biologically meaningless in that the isopleths may connect areas which have very little in common other than a similar amount of living material in the bottom. This has been pointed out by Thorson (1957) and should be kept firmly in mind during the discussion of the results.

Series of samples were taken at different times of the year, especially in the areas of the heaviest concentration of standing crop. The observed variations are well within the normal sample to sample variation and no seasonality in the standing crop can be observed. Similarly, there are no indications in the series of samples taken in October of any kind of recuperative process in the area.

The recent series of samples show a concentration of standing crop in an area ESE of Santa Barbara harbor, where approximately 800 grams per square meter was found. This concentration is associated with a bed of *Listriolobus pelodes*; the other two concentrations with standing crops of near 300 grams per square meter are also associated with the presence of this echiuroid worm. The standing crop in the remaining study area varies from 8 to approximately 180 grams per square meter. These variations are probably associated with patchiness in the distribution of the fauna, as described by Hartman (1955) for the San Pedro area, and are here considered trivial. The irregular course of the 100 grams per square meter isopleth reflects this patchy distribution of macro-organisms.

The distribution of standing crop taken during the State Survey is rather dramatically different. The standing crop appears to have been higher in the whole area ten years ago. In general, areas south and west of Platform A have standing crops similar to those found in the area today. The conversion factors used in calculating the standing crop of the State Survey are open to some doubt, for this reason; and because of the general patchiness of the fauna, differences of the order of two- to three-fold are here considered well within the possible limits of error. The 700 gram peak due south of Santa Barbara appears, however, to have disappeared during the intervening ten years.

The most dramatic difference is in the distribution of standing crop in the triangle between Santa Barbara harbor, Platform A and Carpinteria. The standing crop in the dense part of the *Listriolobus*-bed off Santa Barbara reached 2000 grams per square meter at the time of the State Survey and the bed extended southeastward along the coast to Carpinteria, with peaks near 1500 and 1800 grams per square meter. Today the maximum concentration of *Listriolobus* is slightly east of the former high point and the density of the bed appears to have decreased from 2000 to 800 grams per square meter. That part of the bed extending toward Carpinteria has been severely reduced during these ten years, from approximately 1100 grams per square meter to less than 100 grams. The weight of other macro-invertebrates associated with *Listriolobus* is approximately the same as it was ten years ago, so the drop in standing crop appears to be due exclusively to a reduction in the density of the *Listriolobus* population.

Standing crop figures such as presented here demonstrate only the presence of a certain amount of living material of macro-invertebrates in the bottom. The relationship between standing crop and productivity is not necessarily simple and linear (Thorson, 1957) and the figures do not indicate the level of productivity in the area.

Some comments on individual groups of macro-invertebrates

Listriolobus pelodes Fisher (1946). This echiuroid worm, which forms the highly characteristic beds off Santa Barbara, is found along the Californian coast at least from San Diego to Tomales Bay. As far as known, it does not form dense beds except off Santa Barbara, so these beds are unique. Barnard and Hartman (1959:14) related the presence of the beds to the composition of the sediments in the area; and changes in sediment composition may have influenced the size of the beds.

During the summer of 1969, several *Listriolobus pelodes* were kept in aquaria at the Santa Catalina Marine Biological Laboratory. These specimens were collected near Santa Barbara and transported by car and plane to the laboratory. Despite this rather lengthy period in transit, they lived for up to three weeks in aquaria and some observations on their habits were possible. *L. pelodes* digs in the sediments, but does not appear to be a very efficient digger. It primarily pushes its posterior end into the sediment, forming a shallow depression in which it sits. The normal posture of the organism in the sediment is with the narrow, elongated spoon-shaped anterior end projecting free from the sediment. This anterior end is usually held erect in the water and the animal orients with the flat side of the anterior end transverse to the water current. This may indicate that *L. pelodes* filters food from the suspended material in the water, but does not preclude its use of this anterior end to pick up material from the sediments surrounding it. The animals in aquaria did not dig deeper than 5-6 centimeters into the substrate and made no U-shaped tubes as do other echiuroid worms (MacGinitie, 1949). It is possible that the sediments given the worms in the aquaria were unsuitable for deep burrowing by these very soft-bodied animals, and these results must not be considered as definite.

The distribution maps (Figs. 5-6) show that *L. pelodes* is present in approximately the same area as it was ten years ago. There are no indications that it has been totally exterminated or even reduced markedly in the vicinity of Platform A. In fact, in one of the box cores taken in October, 1969, as part of the bacteriological survey, a relatively small, but otherwise normal, L. pelodes was found sitting in its shallow depression surrounded by an inch-thick layer of black mud mixed with crude oil.

It is apparent from the distribution of the standing crop and the geographical distribution of L. pelodes that the population has been thinned out in a spectacular manner over a large area of the beds, but no reason can be given for this drop in numbers. It should be noted that the biology of L. pelodes is very poorly known and no systematic population studies of this organism have been made.

Polychaetous annelids. All the commonly reported polychaetous annelids found in the State Survey have also been found in the Pollution Study with a few notable exceptions. It should, however, be noted that only a few families have been treated and that these temporary results may be reversed when the complete fauna has been worked up. Most of the polychaetes found in only one of the two surveys are characteristically present in one or a few samples only; the populations of these species may thus be too thinly spread out to be caught consistently in the grab.

Chloeia pinnata Moore (1909) was reported as very common during the State Survey; during the present survey another species of Chloeia, presently identified as C. entypa Chamberlin (1919), was very common. A rapid check of some of the material from the State Survey shows that the two records are of different species, but the whole material will have to be re-evaluated before any safe statements can be made. It is presently considered probable that there has been a replacement of C. pinnata with another species of the same genus.

Nereis procera Ehlers (1868) was reported as common in the State Survey; another species of Nereis, presently called Nereis sp. 1, has been found in the present study. This latter species is definitely different from any species of Nereis known from this coast (see Chapter 6). The distribution maps show that this "new" species has the same geographical distribution as N. procera had ten years ago (Figs. 6-7). It should be noted that N. procera was not found in any of the Pollution Study samples from Santa Barbara although studies of other materials show that it is still present in other areas of the Southern California shelf.

Arabella pectinata Fauchald (1970) was recognized as a distinct species only a short time ago; some of the records of A. iricolor Montagu (1808) from the State Survey may refer to this species. The distinction is not critical since both species appear rather similar ecologically.

Most of the other polychaetes identified from both surveys are the same and show little or no difference in numbers of specimens or in geographical distribution on the shelf areas off Santa Barbara in the ten-year span separating the two investigations.

Mollusks. The mollusks from the Pollution Study were studied by Mr. Ted Phillips of the Santa Barbara Museum of Natural History and will be given a detailed treatment later. Below is a survey of the relative frequency of individual species of mollusks in relation to the findings made during the State Survey.

Species present in more than 10% of the samples in both the State Survey and the Pollution Study include Acteocina intermedia, Compsomyax subdiaphana, Macoma yoldiformis, Nemocardia centifilosa, Nucula tenuis, Nuculana taphria, Phacoides tenuisculptus, Saxicavella pacifica, Tellina carpenteri and Venericardia ventricosa.

The following species were common during the State Survey and have been taken, but in low numbers, during the Pollution Study: Acteon punctocoelata, Amygdalum pallidulum, Cylichna attonsa, Mysella aleutica, Olivella baetica, Periploma discus and Tellina buttoni. The genus Cylichna is represented by high numbers of C. diegensis in the Pollution Study; this latter species was found only rarely in the State Survey. Mysella tumida was common in the Pollution Study, but present only in low numbers during the State Survey.

The following mollusks were found in 10% or more of the State Survey samples but have not been found in the Pollution Study at all: Acila castriensis, Adontorhina cyclia, Axinopsida serricatus, Bittium subplanatum, Pseudopythina chacei and Siliqua lucida. In the Pollution Study the genus Axinopsida was represented by A. viridis in more than 10% of the samples; the genus Bittium was represented by several species, none of which were particularly common; and, finally, fragments of a species of Siliqua were present on some stations.

Conversely, a few mollusks that were not reported from the State Survey were found to be common in the Pollution Study; these include Phacoides approximatus and Psephidia cymata. The genus Psephidia was represented in the State Survey by relatively low numbers of P. lordi.

It is possible that some of the differences between the two surveys come from the fact that the material from the two collections was identified by different persons; but this does not appear to be the case, since in most instances the changes observed are in the relative frequencies of the different taxa.

The differences in the mollusk-fauna over the ten years appear to be due to a rather extended replacement of the fauna similar to that indicated for the polychaetes. Most of the mollusks that seem to be missing or have been reduced in numbers over the last ten-year period probably live several years (cfr. Thorson, 1957). This suggests that recuperation of the fauna may take several years, if it will take place at all.

It is also possible that the relative numbers of the different species may fluctuate from year to year and that the differences we are seeing are due to long-term cyclical fluctuations.

Ophiuroidea. Amphiodia urtica (Lyman) is present in nearly all samples, as it was ten years ago. The numbers of specimens and the distribution of this species seem the same. The other, rarer, species of brittle-stars appear to be less common than they were ten years ago, but no distinct patterns of geographical restriction or replacement can be noted.

DISCUSSION

The approach here has been to discuss the geographical distribution of species present in a large percentage of the samples and responsible for a major proportion of the standing crop. This may be unfortunate in that it places emphasis on organisms that are able to survive under varying conditions. The brittle-star Amphiodia urtica, for example, which is obviously biologically very important in the shelf areas off Southern California (Jones, 1969), may be able to survive in areas where less tolerant species would be missing. On the other hand, this species has not been reported from Los Angeles-Long Beach harbors in a series of investigations by Reish (1965). This may indicate that the species is unable to survive in polluted waters, but may also mean that it generally tends to avoid living in semi-enclosed bays and sloughs. Furthermore, other kinds of pollutants apart from oil are present in the harbor areas and may restrict the distribution of all animals severely.

The survey technique in itself may not be able to show elimination or reduction of sensitive and delicate organisms due to oil pollution, since this technique nearly automatically places the emphasis on common or large or otherwise obviously important organisms. A study of the smaller, lesser known organisms such as polychaetous annelids or amphipod crustaceans might be of more value in estimating the effects of pollutants in the water than a survey of the large, common organisms. This in turn implies that other, more detailed techniques may have to be applied to the problem of determining whether or not the benthic environment has been partially or wholly destroyed by pollutants. Probably the only solution to the problem is to undertake continual, long-term monitoring in areas where pollution might be expected to be concentrated. For such a monitoring program it would not be sufficient to get only the large organisms identified. The effort will have to be concentrated on what are now considered the lesser known and taxonomically often very difficult groups to work with.

Prior to all pronouncements about the level of pollution in the benthos, some knowledge will have to be gathered on the level of secular variations in the structure and composition of the benthic communities. In the present case, we know that the number of Listriolobus pelodes in the dense part of the bed off Santa Barbara did not vary appreciably during one year (AHF:USC, 1965:203), but we know nothing about long-term variations in the beds, due to variations in the influx of terrestrial sand and silt on the shelf, etc.

In the present study such an approach was impossible; partially because of the time limitations, partially because prior information about normal, long-term variations in the benthos was incomplete. It should here be noted that the shelf off Southern California probably is as well-known as any area in the world in terms of the benthic environment; the fact remains that these areas are too poorly understood to permit a rapid, simple study of the effects of one pollutant on the environment. The material collected during the State Survey and the Pollution Study could form the nucleus for a long-term study program since both surveys were made with quantitative gear and would permit complete identification of macro-organisms if the taxonomists and technical help could be found to set up such a continuous program. At present this is impossible to do; the few taxonomists that exist are unable to cope even with the material coming in from totally unknown areas of the world.

There are several distinct sources of the problems concerning the benthos off Santa Barbara.

1. Natural sources. It is known that the rainfall and the associated influx of terrestrially derived sediments fluctuate widely from year to year (Emery, 1960:25). In the year 1969 there was abnormally high rainfall and partially disastrous flooding in the area (for documentation, see Volume 2); thus the influx of sediments to the area were heavier than normal. Hartman (1960:66-67) reported the extinction of a large proportion of the fauna in the immediate vicinity of Ventura following the heavy spring rains of April, 1958. Such a die-off of the fauna would be temporary and the fauna would probably recuperate within a year or two, depending on the timing of the rainfall and the life-cycles of the animals involved. There is no clear-cut evidence, however, that this extinction reported by Hartman extended as far out on the shelf as to Platform A; thus there is no clear precedent for the loss of standing crop in the Listriolobus beds off Carpinteria. In fact, the close-spaced repeat-sampling grid in the Listriolobus bed (AHF:USC, 1965, Appendix, p. 269) shows no appreciable drop in standing crop in the area in September, 1958, i.e., only five months after the heavy influx of sediments near Ventura. It should here be noted that the rivers emptying near Ventura are the nearest large rivers discharging onto the Santa Barbara shelf areas. Thus, while the abnormally

high rainfall during the winter of 1969 cannot be excluded as responsible for the loss of standing crop in Listriolobus, there is evidence to suggest that such heavy rainfalls do not influence the beds of these animals.

The long-term fluctuations in the populations of major organisms are unknown. As mentioned above, there are no indications according to the State Survey that such fluctuations take place in the number of Listriolobus, but this does not mean that fluctuations spanning several years may not be present. Long-term variants in the physical parameters include such factors as temperature (AHF:USC, 1965:31-37) and the related oxygen concentrations; the temperature relations of Listriolobus and its associated fauna remain unknown.

2. Effects of the oil spill. No effects directly attributable to the oil spill could be seen in this part of the study. As mentioned above, with the technique used it was not possible to separate the effects of the oil spill from the general background "noise" of other factors influencing the benthos. This does not in any way or manner imply that the oil spill was without effects. The change in consistency in the sediments alone would be enough to influence those organisms that are heavily dependent on sediment-structure for their survival. The effects are not visible because the technique and the time allotted is not conducive to showing such effects.

In general, it should be remembered that natural oil seepages are common in the area. Hartman (1960:67) commented on the reduced fauna of the oil seepage areas off Goleta; a similar effect might be expected of the much more concentrated release of oil in the oil spill.

3. Effects of drilling. The most striking drop in standing crop has taken place in an area where several wells have been drilled in recent years. Barnard and Hartman (1959:14) indicated that the presence of the Listriolobus beds probably were due to the composition of the sediments and only secondarily to the food supply in the area. It is thus feasible that even a minor disturbance of the sediments may adversely affect the density of the beds. Similarly, changes in the water circulation patterns will have the same effect.

4. Sewage. The general rise in human populations in the surrounding areas, especially in Santa Barbara and the Summerland-Carpinteria areas during the last ten years, has increased the flow of sewage onto the shelf areas off Santa Barbara. It should be remarked that however well-treated, this sewage represents an increased load of suspended material and thus represents a change in the environment of the area. If the balance between inflow and outflow of material in the *Listriolobus* beds was fairly delicate, it would not take a very large change in the load of suspended material to upset it. Susceptible organisms could be drastically reduced in number by the new sedimentary regime.

SUMMARY

The standing crop of benthic macro-organisms has decreased dramatically over the ten-year period separating the State Survey and the Pollution Study. The change is especially noticeable in the eastern portion of the *Listriolobus* beds east of Santa Barbara, but may also be seen as a general lowering of the peak standing crop in the whole bed. The drop in standing crop appears to be due to a reduction in numbers of *Listriolobus pelodes*; the standing crop of other organisms seems less affected. Some species of polychaetous annelids formerly common in the area have disappeared and may have been replaced by other species of the same genus.

A series of possible causes of these changes are discussed. The heavy rainfall in the winter of 1969 may have caused some damage, but it is unlikely that this caused the reduction in *Listriolobus* numbers. Drilling in *Listriolobus* beds may be directly responsible for the damage, but the January, 1969, oil spill from Platform A may also have influenced the numbers of *Listriolobus* in the bed. A lack of data from dates between the State Survey and the start of the oil spill makes it impossible to pinpoint the exact cause of the reduction in standing crop It is possible that the increased flow of sewage over the shelf may have an effect on the beds, but this cannot be determined, since the relationships between the fauna and the pollutants are unknown.

It is strongly recommended that a large-scale program be instituted to follow and monitor the benthos in considerable detail so an understanding of it can be gained. Presently it is impossible to predict any changes in the benthos due to proposed human activity, except for the general statement that any changes made will be deleterious, no matter how carefully done. It is further recommended that a minimal program of exploitation be instituted on the Santa Barbara shelf. The *Listriolobus* beds are a completely unique biological environment, not known from any other area in the world; it is thus of great importance that they be preserved. The study of these beds would furnish material of considerable interest for an understanding of the establishment and maintenance of biological communities in the sea. Such a study would be of immense value to biologists and generally to all interested parties the world over

REFERENCES

Allan Hancock Foundation, University of Southern California
1965 An oceanographic and biological survey of Southern California mainland shelf. California State Water Quality Control Board, Publ. 27: 1-232. Appendix Data: 1-445.

Barnard, J. L., and Olga Hartman
1959 The sea bottom off Santa Barbara, California: Biomass and community structure. Pacific Naturalist, 1(6): 1-16.

Barnard, J. L., and F. C. Ziesenhenne
1961 Ophiuroid communities of Southern Californian coastal bottoms. Pacific Naturalist, 2: 131-152.

Durham, F. E.
1955 Improved techniques for ocean bottom sampling. *In* Hartman, Olga. Quantitative survey of the benthos of San Pedro Basin, Southern California. Part 1. Preliminary results. Allan Hancock Found. Pac. Expeds., 19: 152-153.

Emery, K. O.
1960 The sea off Southern California. Wiley and Sons, New York. 366p.

Hartman, Olga
1955 Quantitative survey of the benthos of San Pedro Basin, Southern California. Part 1. Preliminary results. Allan Hancock Found. Pac. Expeds., 19: 1-185.

1960 The benthonic fauna of Southern California in shallow depth and possible effects of wastes on the marine biota. In Pearson, E. A., ed. Proc. of the First Internatl. Conf. on Waste Disposal in the Marine Environment. Pergamon Press, New York. pp. 57-81.

Jones, G. F.
1969 The benthic macrofauna of the mainland shelf of Southern California. Allan Hancock Monogr. Mar. Biol., 4: 1-219.

McGinitie, G. E., and N. McGinitie
1949 Natural history of marine animals. McGraw-Hill, New York. 473p.

Reish, D. J.
1965 The effect of oil refinery wastes on benthic marine animals in Los Angeles harbor, California. In Comn. Internatl. Explor. Sci. Mer Méditerr., Symp. Pollut. Mar. par Microorgan. Prod. Pétrol., Monaco. pp. 355-361.

Thorson, Gunnar
1957 Bottom communities (sublittoral on shallow shelf). In Treatise on marine ecology and paleoecology, 1, Ecology. Geol. Soc. Amer., Memoir, 67: 461-534.

Table 1

Pollution Study Station List

Station	Date	Location	Depth	Sediment	Standing Crop	Percentage of S.C. Treated	Comments
12741	March 5, 1969	34 24 20 119 54 10	27				Box core
12742	March 5, 1969	34 23 48 119 54 12	45				Box core
12745	March 6, 1969	34 22 45 119 54 00	108	Clayey silt	89.3	45	Heart-urchin
12746	March 6, 1969	34 23 32 119 34 58	18	Clayey silt	208.0	87	
12747	March 6, 1969	34 20 51 119 36 04	41	Silty clay	8.2	89	
12748	March 6, 1969	34 18 55 119 36 50	90	Silty clay	112.0	66	Holothurian
12751	March 6, 1969	34 23 45 119 35 10					Beam trawl
12752	March 6, 1969	34 20 50 119 36 00					Beam trawl
12792	March 20, 1969	34 05 30 119 10 25	36	Sand	24.7	85	
12793	March 20, 1969	34 08 00 119 18 30	27	Fine sand	29.44	96	

Table 1--Continued

Station	Date	Location	Depth	Sediment	Standing Crop	Percentage of S.C. Treated	Comments
12794	March 20, 1969	34 09 50 119 18 15	18	Sand	20.8	93	Poor sample
12795	March 20, 1969	34 14 30 119 29 45	85	Silty clay	153.4	84	
12796	March 20, 1969	34 16 50 119 26 15	45	Silty clay	30.2	34	Stylatula
12797	March 20, 1969	34 23 30 119 35 00	26	Sandy silt	147.12	64	Nemerteans, Stylatula
12798	March 20, 1969	34 21 56 119 35 08	43	Silty clay	58.5	55	Stylatula
12800	March 20, 1969	34 18 45 119 36 28	76		105.2	28	Holothurian
12801	March 21, 1969	34 17 40 119 36 30	58	Silty clay	76.0	95	
12802	March 21, 1969	34 16 00 119 37 15	99	Silt	84.7	94	
12803	March 21, 1969	34 17 15 119 28 30	90	Silty clay	76.8	83	
12804	March 21, 1969	34 23 27 119 40 58	31	Fine sand	52.0	79	
12805	March 21, 1969	34 21 58 119 40 56	54	Sandy silt	95.7	78	Holothurian

Table 1--<u>Continued</u>

Station	Date	Location	Depth	Sediment	Standing Crop	Percentage of S.C. Treated	Comments
12806	March 21, 1969	34 19 45 119 41 00	76	Sandy silt	101.66	63	
12799	March 1969	34 20 56 119 36 12					
12807	March 21, 1969	34 18 27 119 37 52	89	Silty clay	68.7	79	
12808	March 21, 1969	34 19 00 119 37 13	76	Sandy silt	65.8	73	<u>Stylatula</u>
12809	March 22, 1969	34 21 00 119 36 58	49	Sand	59.0	51	Solitary corals
12812	March 22, 1969	34 22 15 119 34 20	36	Silty clay	347.4	88	
12814	March 22, 1969	34 16 55 119 34 28	90	Silty clay	89.2	87	
12815	March 22, 1969	34 18 30 119 32 10	67	Clay	66.5	68	
12816	March 22, 1969	34 21 45 119 28 40	18	Sand	124.2	75	Oil
12817	March 23, 1969	34 19 15 119 29 50	85	Silty clay	145.2	46	Holothurian
12818	March 23, 1969	34 16 20 119 31 30	85	Silt	88.2	82	

Table 1--Continued

Station	Date	Location	Depth	Sediment	Standing Crop	Percentage of S.C. Treated	Comments
12819	March 23, 1969	34 17 20 119 28 55	58	Silt	115.5	21	Ceriantthid, Holothurian
12820	March 23, 1969	34 18 00 119 26 30	36	Silty clay	42.6	76	Acorn worm
12821	March 23, 1969	34 18 45 119 23 55	18		181.4	88	Oil
12852	April 2, 1969	34 04 30 119 10 50	45	Fine sand	18.6	74	
12853	April 3, 1969	34 23 18 119 38 17	36	Silty clay	700.4	96	
12854	April 3, 1969	34 23 18 119 38 07	54	Silty clay	761.7	97	
12855	April 3, 1969	34 23 18 119 37 53	38	Silty clay	522.2	96	
12856	April 3, 1969	34 23 12 119 38 18	44	Silty clay	489.8	48	Holothurian, oil
12857	April 3, 1969	34 23 08 119 38 06	41	Clay, silty clay	855.7	71	Holothurian
12858	April 3, 1969	34 23 08 119 37 53	41	Silty clay	463.2	80	Holothurian
12859	April 3, 1969	34 22 58 119 37 53	41	Silty clay	346.0	52	Holothurian

Table 1--Continued

Station	Date	Location	Depth	Sediment	Standing Crop	Percentage of S.C. Treated	Comments
12860	April 3, 1969	34 22 58 119 38 05	41	Silty clay	632.5	49	Holothurian
12861	April 3, 1969	34 22 58 119 38 17	36	Clay, silty clay	178.3	23	Holothurian, oil
12862	April 3, 1969	34 23 30 119 37 20	36	Silty clay	499.9	85	Sea anemone, oil
12863	April 4, 1969	34 22 20 119 37 36	45	Silty clay	276.3	78	Holothurian, oil
12864	April 4, 1969	34 21 15 119 38 00	45	Coarse sand			Sample incomplete
12865	April 4, 1969	34 19 40 119 38 30	63	Sandy silt	115.7	61	
12866	April 4, 1969	34 18 45 119 39 05	63	Sandy silt	172.4	77	
13030	May 7, 1969	34 21 24 119 39 45	54		10.0	44	
13031	May 7, 1969	34 22 22 119 31 39	27		61.32	60	
13032	May 7, 1969	34 20 00 119 27 22	32				Oil, analysis
13255	July 24, 1969	34 19 31 119 38 59	67	Silty sand	52.24	79	

Table 1--Continued

Station	Date	Location	Depth	Sediment	Standing Crop	Percentage of S.C. Treated	Comments
13256	July 23, 1969	34 19 10 119 41 30	99		50.0	42	Polychaetes
13258	July 24, 1969	34 21 30 119 29 20	22	Sandy silt	223.9	88	
13418	Oct. 14, 1969	34 23 00 119 38 15	40	Slightly silty clay	426.4	78	Polychaetes
13419	Oct. 14, 1969	34 23 00 119 38 15	40	Slightly silty clay	451.8	79	Polychaetes
13420	Oct. 14, 1969	34 23 00 119 38 15	40	Slightly silty clay	445.1	56	Holothurian, polychaetes
13421	Oct. 14, 1969	34 21 00 119 39 30	43	Hard clay	7.40	7.3	Polychaetes, _Glottidia_
13422	Oct. 14, 1969	34 21 00 119 39 30	43	Hard clay	25.9	10.3	Polychaetes, starfish
13423	Oct. 15, 1969	34 21 00 119 39 30	43	Hard clay	37.7	28.2	Polychaetes
13424	Oct. 15, 1969	34 19 15 119 41 00	46	Silty sand	73.0	56.6	Polychaetes
13425	Oct. 15, 1969	34 22 20 119 35 30	40	Silty clay	67.48	28.3	Polychaetes
13426	Oct. 15, 1969	34 22 20 119 35 30	40	Silty clay	156.8	31.0	Polychaetes, holothurian

Table 1--Continued

Station	Date	Location	Depth	Sediment	Standing Crop	Percentage of S.C. Treated	Comments
13427	Oct. 15, 1969	34 22 20 119 35 30	40	Silty clay	250.7	45.8	Polychaetes
13428	Oct. 15, 1969	34 20 30 119 38 00	45	Silty clay	10.9	25.5	Polychaetes
13429	Oct. 15, 1969	34 20 30 119 38 00	45	Silty clay	27.1	25.0	Polychaetes
13430	Oct. 15, 1969	34 20 30 119 38 00	45	Silty sand	99.9	8.9	Echinoderms, polychaetes
13431	Oct. 15, 1969	34 18 20 119 39 20	90	Silty clay	77.6	86.6	
13432	Oct. 15, 1969	34 21 20 119 34 40	36	Silty clay	26.0	32.5	Polychaetes, starfish
13433	Oct. 15, 1969	34 21 20 119 34 40	36	Silty clay	25.5	43.4	Polychaetes
13434	Oct. 15, 1969	34 21 20 119 34 40	36	Silty clay	35.9	72.5	Polychaetes
13435	Oct. 15, 1969	34 20 00 119 35 55	54	Black silt	27.4	91.6	Oil
13436	Oct. 15, 1969	34 20 00 119 35 55	54	Black silt	29.9	13.4	Oil, starfish
13437	Oct. 15, 1969	34 20 00 119 35 55	54	Black silt	39.4	44.5	Oil, holothurian

Table 1--Continued

Station	Date	Location	Depth	Sediment	Standing Crop	Percentage of S.C. Treated	Comments
13438	Oct. 15, 1969	34 17 30 119 37 00	90	Silty clay	54.6	69.0	Polychaetes
13439	Oct. 15, 1969	34 21 00 119 33 00	43	Silty clay	69.5	50.4	Oil, polychaetes
13440	Oct. 15, 1969	34 21 00 119 33 00	43	Silty clay	341.8	64.8	Polychaetes, holothurian
13441	Oct. 15, 1969	34 21 00 119 33 00	43	Silty clay	144.3	78.8	Polychaetes
13442	Oct. 15, 1969	34 19 00 119 34 15	59	Stiff, slightly silty clay	167.8	38.4	Polychaetes
13444	Oct. 15, 1969	34 19 00 119 34 15	59	Silty clay	110.4	56.5	Polychaetes

Table 2

State Survey Station List

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
4783	Dec. 18, 1956	34 17 20 119 37 45	102	126.4	Absent
4808	Jan. 16, 1957	34 20 10 119 50 25	294	324.0	Absent
4809	Jan. 15, 1957	34 22 10 119 50 25	71	101.6	Absent
4810	Jan. 15, 1957	34 24 00 119 50 45	14	94.4	Absent
4825	Jan. 17, 1957	34 24 28 119 38 20	13	91.6	Absent
4826	Jan. 17, 1957	34 22 30 119 38 20	43	176.0	Present
4827	Jan. 17, 1957	34 20 28 119 38 20	53	79.2	Present
4828	Jan. 17, 1957	34 18 20 119 38 20	81	180.0	Absent
4951	April 10, 1957	34 19 40 119 43 10	89	280.0	Present
4952	April 10, 1957	34 21 40 119 43 05	77	83.2	Absent
4953	April 10, 1957	34 23 12 119 43 05	20	104.0	Absent
4954	April 10, 1957	34 22 10 119 39 10	60	983.6	Present

Table 2--Continued

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
4955	April 10, 1957	34 23 15 119 39 10	37	2368.0	Present
4956	April 10, 1957	34 24 28 119 39 10	19	170.8	Absent
4980	April 11, 1957	34 15 50 119 34 28	94	110.8	Present
4981	April 11, 1957	34 18 00 119 34 30	83	320.0	Present
4982	April 11, 1957	34 20 00 119 34 35	55	311.6	Present
4983	April 11, 1957	34 22 12 119 34 35	21	1188.0	Present
4984	April 11, 1957	34 24 15 119 34 35	18	442.0	Present
5001	April 18, 1957	34 14 00 119 41 15	147	-	Absent
5160	July 2, 1957	34 23 00 119 54 00	77	174.4	Absent
5161	July 2, 1957	34 24 35 119 54 00	20	663.6	Present
5165	July 3, 1957	34 24 30 119 40 30	12	638.8	Present
5166	July 3, 1957	34 23 05 119 40 40	38	430.0	Present
5167	July 3, 1957	34 21 40 119 40 40	53	111.2	Absent
5168	July 3, 1957	34 20 20 119 40 40	67	172.0	Absent
5169	July 3, 1957	34 18 58 119 40 45	95	128.0	Absent

Table 2--Continued

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
5170	July 3, 1957	34 20 35 119 45 30	82	277.6	Absent
5171	July 3, 1957	34 22 25 119 45 15	62	748.8	Present
5172	July 3, 1957	34 24 00 119 45 25	15	101.6	Absent
5173	July 3, 1957	34 14 50 119 32 25	94	297.2	Absent
5174	July 3, 1957	34 17 00 119 32 25	83	258.0	Absent
5175	July 3, 1957	34 19 00 119 32 25	70	100.8	Present
5176	July 3, 1957	34 21 15 119 32 35	41	1184.4	Present
5177	July 3, 1957	34 23 15 119 32 35	16	139.2	Absent
5258	Sept. 18, 1957	34 12 17 119 29 15	96	300.8	Absent
5259	Sept. 18, 1957	34 12 30 119 28 10	68	148.4	Absent
5260	Sept. 18, 1957	34 14 50 119 26 55	57	370.0	Present
5261	Sept. 18, 1957	34 16 00 119 25 55	44	146.8	Present
5262	Sept. 18, 1957	34 17 15 119 24 40	36	200.8	Present
5263	Sept. 18, 1957	34 18 30 119 23 30	18	184.0	Present
5269	Sept. 19, 1957	34 22 30 119 36 45	47	79.2	Absent

Table 2--Continued

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
5270	Sept. 19, 1957	34 20 45 119 36 45	47	101.2	Absent
5271	Sept. 19, 1957	34 19 00 119 36 45	76	91.6	Absent
5325	Oct. 17, 1957	34 15 48 119 34 25	97	166.8	Absent
5330	Oct. 17, 1957	34 15 28 119 25 12	43	156.4	Present
5331	Oct. 17, 1957	34 16 17 119 24 20	37	216.0	Absent
5339	Oct. 17, 1957	34 13 02 119 24 35	44	175.2	Absent
5392	Nov. 21, 1957	34 23 04 119 39 47	38	29.2	Present
5394	Nov. 21, 1957	34 23 18 119 39 02	39	1364.0	Present
5395	Nov. 21, 1957	34 23 18 119 39 02	38	523.6	Present
5396	Nov. 21, 1957	34 23 18 119 39 02	37	918.0	Present
5398	Nov. 21, 1957	34 23 21 119 38 17	38	858.4	Present
5399	Nov. 21, 1957	34 23 21 119 38 17	38	1360.4	Present
5401	Nov. 21, 1957	34 23 22 119 36 45	36	1026.4	Present
5402	Nov. 21, 1957	34 24 15 119 36 45	26	435.6	Present
5403	Nov. 21, 1957	34 24 10 119 35 10	22	340.4	Present

Table 2--Continued

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
5404	Nov. 21, 1957	34 23 30 119 35 10	34	1331.2	Present
5405	Nov. 21, 1957	34 22 40 119 35 10	39	1528.8	Present
5406	Nov. 21, 1957	34 21 50 119 35 10	41	47.6	Absent
5407	Nov. 21, 1957	34 21 10 119 35 10	44	151.2	Present
5408	Nov. 22, 1957	34 23 15 119 34 20	36	525.2	Present
5409	Nov. 22, 1957	34 22 50 119 33 20	37	1050.0	Present
5410	Nov. 22, 1957	34 22 15 119 32 28	35	765.6	Present
5411	Nov. 22, 1957	34 21 40 119 33 28	36	3.6	Absent
5412	Nov. 22, 1957	34 21 00 119 34 20	46	437.6	Present
5413	Nov. 22, 1957	34 20 25 119 33 28	50	666.8	Present
5414	Nov. 22, 1957	34 20 00 119 32 20	53	608.8	Present
5415	Nov. 22, 1957	34 19 45 119 31 15	53	324.0	Present
5416	Nov. 22, 1957	34 20 55 119 31 20	40	1087.6	Present
5417	Nov. 22, 1957	34 22 00 119 31 25	32	1107.6	Present
5418	Nov. 22, 1957	34 22 00 119 30 20	31	310.0	Present

Table 2--Continued

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
5419	Nov. 22, 1957	34 20 45 119 30 17	39	1803.6	Present
5420	Nov. 22, 1957	34 19 16 119 30 15	50	684.4	Present
5421	Nov. 22, 1957	34 17 58 119 30 15	67	274.8	Present
5565	Jan. 28, 1958	34 23 00 119 53 45	78	132.4	Absent
5566	Jan. 28, 1958	34 24 35 119 53 40	21	110.8	Present
5567	Jan. 29, 1958	34 20 43 119 45 15	86	112.4	Absent
5568	Jan. 29, 1958	34 22 30 119 45 15	67	180.8	Present
5569	Jan. 29, 1958	34 24 00 119 45 15	19	6.8	Absent
5570	Jan. 29, 1958	34 23 20 119 43 00	19	213.6	Absent
5571	Jan. 29, 1958	34 21 42 119 43 00	73	102.4	Absent
5572	Jan. 29, 1958	34 19 42 119 43 00	93	104.0	Absent
5573	Jan. 29, 1958	34 18 45 119 40 35	101	80.8	Absent
5574	Jan. 29, 1958	34 20 05 119 40 35	70	719.6	Absent
5575	Jan. 29, 1958	34 21 35 119 40 35	60	80.4	Absent
5576	Jan. 29, 1958	34 22 57 119 40 35	41	112.1	Present

Table 2--Continued

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
5577	Jan. 29, 1958	34 24 15 119 40 35	17	176.0	Absent
5578	Jan. 29, 1958	34 24 36 119 39 10	115	400.0	Present
5579	Jan. 29, 1958	34 23 20 119 39 10	39	1323.2	Present
5580	Jan. 29, 1958	34 22 15 119 39 10	51	549.6	Present
5581	Jan. 29, 1958	34 24 14 119 34 30	17	318.0	Present
5582	Jan. 29, 1958	34 22 20 119 34 30	40	797.2	Present
5583	Jan. 30, 1958	34 23 15 119 32 25	15	84.0	Absent
5584	Jan. 30, 1958	34 21 03 119 32 25	41	1047.6	Present
5585	Jan. 30, 1958	34 20 15 119 34 25	49	524.4	Present
5586	Jan. 30, 1958	34 18 55 119 32 10	69	423.6	Present
5587	Jan. 30, 1958	34 18 00 119 34 25	87	99.6	Absent
5588	Jan. 30, 1958	34 16 50 119 32 10	85	153.6	Absent
5589	Jan. 30, 1958	34 15 58 119 34 25	98	50.4	Absent
5590	Jan. 30, 1958	34 14 45 119 32 10	97	204.4	Absent
5591	Jan. 30, 1958	34 12 28 119 28 50	93	94.0	Absent

Table 2--Continued

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
5592	Jan. 30, 1958	34 13 40 119 27 48	73	221.6	Absent
5593	Jan. 30, 1958	34 15 00 119 26 45	55	86.8	Absent
5594	Jan. 30, 1958	34 16 15 119 25 40	43	178.8	Present
5595	Jan. 30, 1958	34 17 30 119 24 25	41	388.4	Present
5829	Aug. 21, 1958	34 10 35 119 25 24	88	87.6	Absent
5830	Aug. 21, 1958	34 12 28 119 25 00	47	32.4	Absent
5831	Aug. 21, 1958	34 14 58 119 22 31	27	109.6	Absent
5832	Aug. 21, 1958	34 16 10 119 21 35	24	252.0	Present
5833	Aug. 21, 1958	34 17 43 119 21 17	12	17.2	Absent
5835	Aug. 21, 1958	34 14 44 119 20 25	23	14.4	Absent
5836	Aug. 21, 1958	34 13 48 119 21 00	23	138.0	Absent
5845	Sept. 16, 1958	34 10 40 119 20 17	26	24.8	Present
5846	Sept. 16, 1958	34 16 20 119 29 20	70	266.0	Absent
5856	Sept. 17, 1958	34 19 40 119 38 35	71	75.2	Absent
5858	Sept. 17, 1958	34 13 10 119 38 45	134	610.4	Absent

Table 2--Continued

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
5868	Sept. 18, 1958	34 17 10 119 40 45	139	242.0	Present
5869	Sept. 18, 1958	34 13 48 119 41 40	152	209.6	Absent
5870	Sept. 18, 1958	34 12 45 119 36 05	180	154.8	Absent
5872	Sept. 18, 1958	34 14 30 119 36 45	134	296.4	Absent
5873	Sept. 19, 1958	34 14 47 119 28 43	71	305.6	Present
5874	Sept. 19, 1958	34 11 45 119 25 43	68	185.6+	Present
6015	Dec. 17, 1958	34 22 45 119 50 40	70	46.8	Present
6133	March 10, 1959	34 11 00 119 29 55	154	12.0	Absent
6134	March 10, 1959	34 11 35 119 32 35	153	41.6	Absent
6135	March 10, 1959	34 16 08 119 28 45	148	20.8	Absent
6154	March 11, 1959	34 13 28 119 30 00	86	112.0	Absent
6155	March 11, 1959	34 14 00 119 23 25	29	141.2	Present
6156	March 11, 1959	34 12 33 119 21 45	28	146.8	Absent
6157	March 11, 1959	34 11 29 119 22 28	35	56.8	Absent
6297	June 25, 1959	34 24 48 119 40 54	3.3	-	Absent

Table 2--Continued

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
6298	June 25, 1959	34 24 47 119 40 54	4.2	-	Absent
6299	June 25, 1959	34 24 45 119 40 54	5.2	-	Absent
6300	June 25, 1959	34 24 44 119 40 54	5.2	-	Absent
6301	June 25, 1959	34 24 42 119 46 54	5.5	-	Absent
6302	June 25, 1959	34 24 37 119 40 54	6.1	-	Absent
6303	June 25, 1959	34 24 33 119 40 53	7.3	-	Absent
6304	June 25, 1959	34 24 29 119 40 53	8.8	-	Absent
6307	June 25, 1959	34 21 40 119 27 46	14	17.6	Absent
6308	June 25, 1959	34 20 00 119 27 46	32	514.0	Present
6309	June 25, 1959	34 20 16 119 25 46	14	10.8	Absent
6310	June 25, 1959	34 19 20 119 26 30	31	816.8	Present
6311	June 25, 1959	34 18 30 119 27 46	42	136.0	Present
6684	Dec. 3, 1959	34 25 00 119 53 40	6.4	-	Absent
6685	Dec. 3, 1959	34 24 47 119 53 33	9.1	-	Absent
6686	Dec. 3, 1959	34 24 12 119 50 45	4.9	-	Absent

Table 2--Continued

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
6687	Dec. 3, 1959	34 24 05 119 50 45	6.1	-	Absent
6688	Dec. 3, 1959	34 24 00 119 50 45	9.1	-	Absent
6690	Dec. 3, 1959	34 24 50 119 48 15	6.1	-	Absent
6691	Dec. 3, 1959	34 25 00 119 48 15	3.3	-	Absent
6694	Dec. 3, 1959	34 24 15 119 45 40	9.1	-	Absent
6695	Dec. 3, 1959	34 24 28 119 45 44	6.1	-	Absent
6696	Dec. 3, 1959	34 24 30 119 45 40	3.0	-	Absent
6698	Dec. 3, 1959	34 24 59 119 38 10	5.2	-	Absent
6702	Dec. 3, 1959	34 24 58 119 35 40	5.9	-	Absent
6721	Dec. 4, 1959	34 23 02 119 30 40	9.1	-	Absent
6722	Dec. 4, 1959	34 23 05 119 30 40	6.7	-	Absent
6723	Dec. 4, 1959	34 23 10 119 30 40	7.6	-	Absent
6724	Dec. 4, 1959	34 23 15 119 30 40	5.8	-	Absent
6728	Dec. 6, 1959	34 18 12 119 20 48	4.2	-	Absent

Table 2--Continued

Station	Date	Location	Depth	Standing Crop	*Listriolobus*
6729	Dec. 6, 1959	34 18 05 119 20 55	6.1	-	Absent
6730	Dec. 6, 1959	34 18 00 119 21 00	7	-	Absent
6731	Dec. 6, 1959	34 17 53 119 21 05	7	-	Absent
6732	Dec. 6, 1959	34 17 46 119 21 10	9.1	-	Absent
6735	Dec. 6, 1959	34 19 00 119 23 02	6.1	-	Absent
6736	Dec. 6, 1959	34 18 55 119 23 05	6.7	-	Absent
6737	Dec. 6, 1959	34 18 52 119 23 10	9.4	-	Absent

Table 3

Species of Selected Families of Polychaetous Annelids Collected off Santa Barbara during the State Survey and the Pollution Study

Name	State Survey	Pollution Study
Aglaophamus dicirris	x	x
Arabella geniculata	-	x
Arabella iricolor	x	x
Arabella pectinata	-	x
Arabella semimaculata	x	-
Ceratocephale crosslandi americana	x	x
Chloeia entypa	-	x
Chloeia pinnata	x	-
Diopatra neotridens	-	x
Diopatra ornata	x	x
Diopatra tridentata	x	x
Dorvillea articulata	x	-
Drilonereis falcata	x	x
Drilonereis filum	-	x
Drilonereis longa	x	x
Drilonereis nuda	x	-
Eunice americana	x	x
Glycera americana	x	x
Glycera branchiopoda	-	x
Glycera capitata	x	x
Glycera convoluta	x	-
Glycera dibranchiata	x	-
Glycera robusta	x	x
Glycera tenuis	x	-
Glycera tesselata	x	-
Hyalinoecia juvenalis	x	x
Labidognathus forcipes	-	x

Table 3--Continued

Name	State Survey	Pollution Study
Lumbrineris bassi	x	-
Lumbrineris bicirrata	x	x
Lumbrineris californiensis	x	x
Lumbrineris cruzensis	x	x
Lumbrineris index	-	x
Lumbrineris lagunae	x	x
Lumbrineris limicola	x	x
Lumbrineris minima	x	x
Lumbrineris pallida	-	x
Lumbrineris cfr. sarsi	x	-
Lumbrineris tetraura	x	-
Lumbrineris cfr. zonata	x	x
Marphysa conferta	-	x
Marphysa disjuncta	x	x
Marphysa stylobranchiata	-	x
Nephtys assignis	x	x
Nephtys caecoides	x	x
Nephtys californiensis	x	-
Nephtys ferruginea	x	x
Nephtys glabra	x	x
Neanthes sp. 1	-	x
Neanthes sp. 2	-	x
Nereis latescens	x	-
Nereis procera	x	-
Nereis sp. 1	-	x
Ninoe gemmea	x	x
Nothria elegans	x	-
Nothria iridescens	x	x
Nothria pallida	x	-
Nothria stigmatis	x	-
Notocirrus californiensis	x	-
Onuphis eremita	x	x
Onuphis litoralis	-	x
Onuphis microcephala	-	x
Onuphis nebulosa	x	x
Onuphis parva	x	x
Onuphis vexillaria	x	-

Table 3--Continued

	State Survey	Pollution Study
Panthalis pacifica	x	x
Pectinaria californiensis	x	x
Platynereis bicanaliculata	x	-
Poecilochaetus johnsoni	x	x
Polyodontes panamensis	x	x
Rhamphobrachium longisetosum	x	-
Sternaspis fossor	x	x

Table 4

Species of Mollusks Reported from the State Survey and the Pollution Study

Name	State Survey	Pollution Study	Comments
Acila castriensis	x	-	
Acteocina culcitella	x	x	
Acteocina exima	-	x	
Acteocina intermedia	x	x	
Acteocina cf. inculta	-	x	
Acteon punctocoelata	x	x	
Admete rhyssa	x	-	as Cancellaria
Adontorhina cyclia	x	-	
Aglaja purpurea	x	-	
Alvania rosana	x	-	
Amphissa undata	x	-	
Amygdalum pallidulum	x	x	
Antiplanes abarbarea	-	x	
Antiplanes santarosana	-	x	
Asthenothaerus villosior	x	-	
Axinopsida serricatus	x	-	as Axinopsis
Axinopsida viridis	-	x	
Balcis rutila	x	-	
Bittium catalinense	-	x	
Bittium eschrichtii icelum	-	x	
Bittium larum	x	x	
Bittium oldroydi	-	x	
Bittium subplanatum	x	-	
Calliostoma turbinum	-	x	
Cardiomya californica	x	-	
Carinoturris adristia	x	-	
Chione undatella	x	-	
Chlamys latiaurata	x	-	
Chlamys latiaurata monotimeris		x	

Table 4--Continued

Name	State Survey	Pollution Study	Comments
Clinocardium nuttallii	x	-	
Coleophysis harpa	x	-	
Compsomyax subdiaphana	x	x	
Cooperella subdiaphana	x	x	
Corbula nasuta		x	
Corbula cf. porcella		x	
Crenella columbiana	x	x	
Crenella decussata	x	x	
Crenella divaricata	x	x	
Crepidula norrisiarum	x	-	
Crepipatella lingulata	x	-	
Cryptomya californica	x	-	
Cuspidaria apodema	x	x	
Cuspidaria pectinata	-	x	
Cyclopecten randolphi tillamookensis		x	
Cylichna attonsa	x	x	
Cylichna diegensis	x	x	
Ensis californicus	-	x	
Ensis myrae	x	-	
Epitonium bellastriatum	x	-	
Epitonium catalinae	x	-	
Epitonium crebricostatum	x	-	
Epitonium sawinae	-	x	
Eulima californica	x	-	
Fusinus barbarensis	-	x	
Fusitriton oregonensis	-	x	
Gari californica	x	-	
Gasteropteron pacificum	-	x	
Hiatella arctica	x	x	as Saxicava
Homalopoma paucicostatum	-	x	
Kellettia kellettii	-	x	

Table 4--Continued

Name	State Survey	Pollution Study	Comments
Kellia suborbicularis	-	x	
Lima hemphilli	x	-	as L. dehiscens
Lima subauriculata	x	-	
Lyonsia californica	x	x	
Lyonsia gouldii	-	x	
Macoma balthica	-	x	
Macoma carlottensis	-	x	
Macoma leptonoidea	-	x	
Macoma nasuta	x	-	
Macoma yoldiformis	x	x	
Mangelia arteaga	x	x	
Mangelia arteaga roperi	x	x	
Mangelia barbarensis	x	-	
Mangelia beta	x	x	
Megasurcula carpenterianus	x	x	
Mitra semiusta	x	-	
Mitrella carinata	x	-	as Nitidella
Mitrella gouldi	x	-	as Nitidella
Mitrella tuberosa	x	x	as Nitidella
Mitromorpha aspera	-	x	
Modiolus capax	x	-	
Modiolus neglectus	x	-	
Monilopsis fancherae	-	x	
Monilopsis halcyonis	-	x	
Mysella aleutica	x	-	as Rochefortia
Mysella ferruginosa	x	-	as Rochefortia
Mysella tumida	x	x	as Rochefortia
Mysella sp. 1	-	x	
Nassarius californianus	-	x	
Nassarius cerritensis	-	x	
Nassarius cooperi	-	x	
Nassarius insculptus	x	x	
Nassarius perpinguis	x	x	
Nemocardia centifilosa	x	x	

Table 4--Continued

Name	State Survey	Pollution Study	Comments
Nucula castrensis	-	x	
Nucula linki	-	x	
Nucula tenuis	x	x	
Nuculana hamata	x	x	
Nuculana penderi redondoensis	-	x	
Nuculana oxia	x	-	
Nuculana taphria	x	x	
Odostomia berilda	x	-	
Odostomia tenuisculpta	x	-	
Ocenebra interfossa	-	x	
Olivella baetica	x	x	
Olivella biplicata	x	-	
Olivella pedroana	x	-	
Ophiodermella incisa	x	-	
Pandora bilirata	x	-	
Pandora punctata	x	-	
Panopea generosa	-	x	
Periploma discus	x	x	
Periploma planiuscula	-	x	
Periploma sulcata	-	x	
Phacoides aequizonatus	-	x	
Phacoides annulatus	x	-	as Lucinoma
Phacoides approximatus	-	x	
Phacoides nuttallii	x	-	as Lucinisca
Phacoides richthofeni	x	-	as Linga
Phacoides tenuisculpta	x	x	as Parvilucina
Polinices draconis	x	-	
Polinices lewisii	x	-	
Polinices recluzianus	x	x	
Poromya tenuiconcha	x	-	
Protothaca tenerrima	x	-	
Psephidia cymata	-	x	
Psephidia lordi	x	-	
Pseudopythina chacei	x	-	
Saxicavella pacifica	x	x	
Siliqua lucida	x	-	

Table 4--Continued

Name	State Survey	Pollution Study	Comments
Sinum scopulosum	x	-	
Solamen columbianum	x	x	
Solariella peramabilis	x	-	
Solen rosaceus	x	-	
Solen sicarius	x	x	
Tellina buttoni	x	x	
Tellina carpenteri	x	x	
Tellina idae	x	-	
Tellina leptonoidea	-	x	
Tellina meropsis	x	-	
Tellina modesta	-	x	
Tellina santarosae	-	x	
Terebra pedroana	x	-	
Thracia curta	x	x	
Thracia trapezoides	x	x	
Thyasira barbarensis	x	x	
Thyasira gouldi	x	-	
Trachycardium quadragenarium	x	-	
Trophon (Austrotrophon) catalinensis		x	
Turbonilla aragoni	-	x	
Turbonilla barkleyensis	-	x	
Turbonilla enna	-	x	
Turbonilla newcombi	x	-	
Turbonilla nuttingi	x	-	
Turbonilla painei	x	-	
Turbonilla santarosana	x	x (cf.)	
Turbonilla shuyakensis	-	x	
Turbonilla wickhami	x	-	
Turritella cooperi	x	x	
Venericardia barbarensis	-	x	
Venericardia monilicosta	-	x	
Venericardia nodulosa	-	x	
Venericardia cf. subquadratum	-	x	
Venericardia ventricosa	x	x	

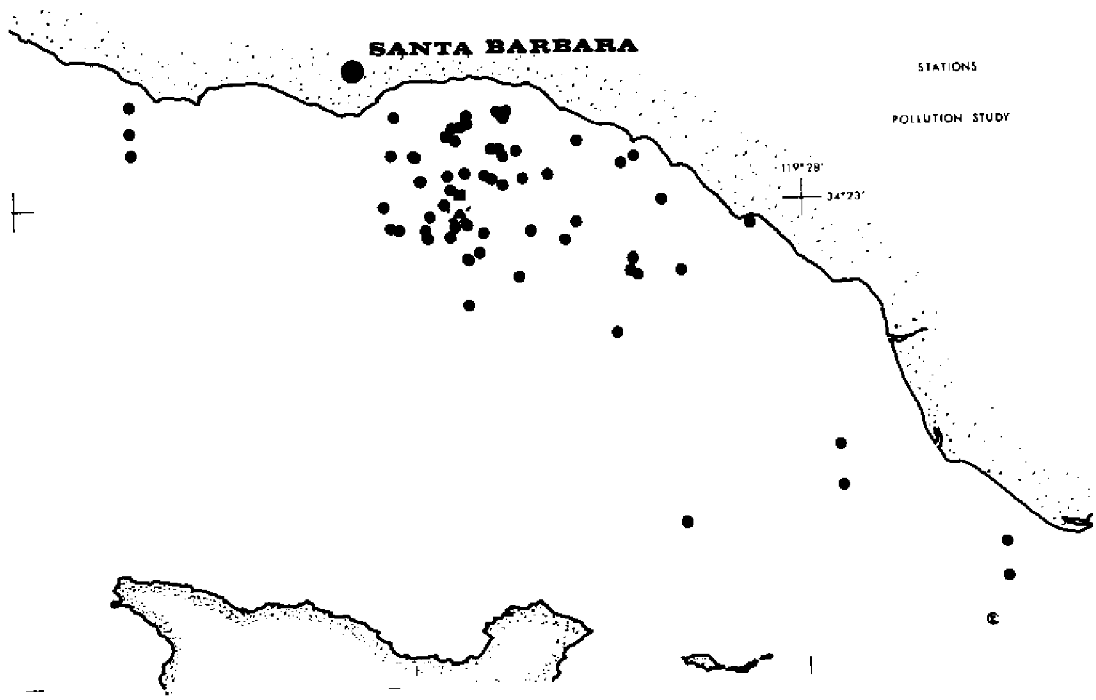
Table 4--Continued

Name	State Survey	Pollution Study	Comments
Vitrinella eshmani	-	x	
Vitrinella oldroydi	x	-	
Vitrinella smithi	-	x	
Volvulella californica	-	x	
Volvulella cylindrica	x	-	
Volvulella tenuissima	x	-	
Yoldia ensifera	x	-	

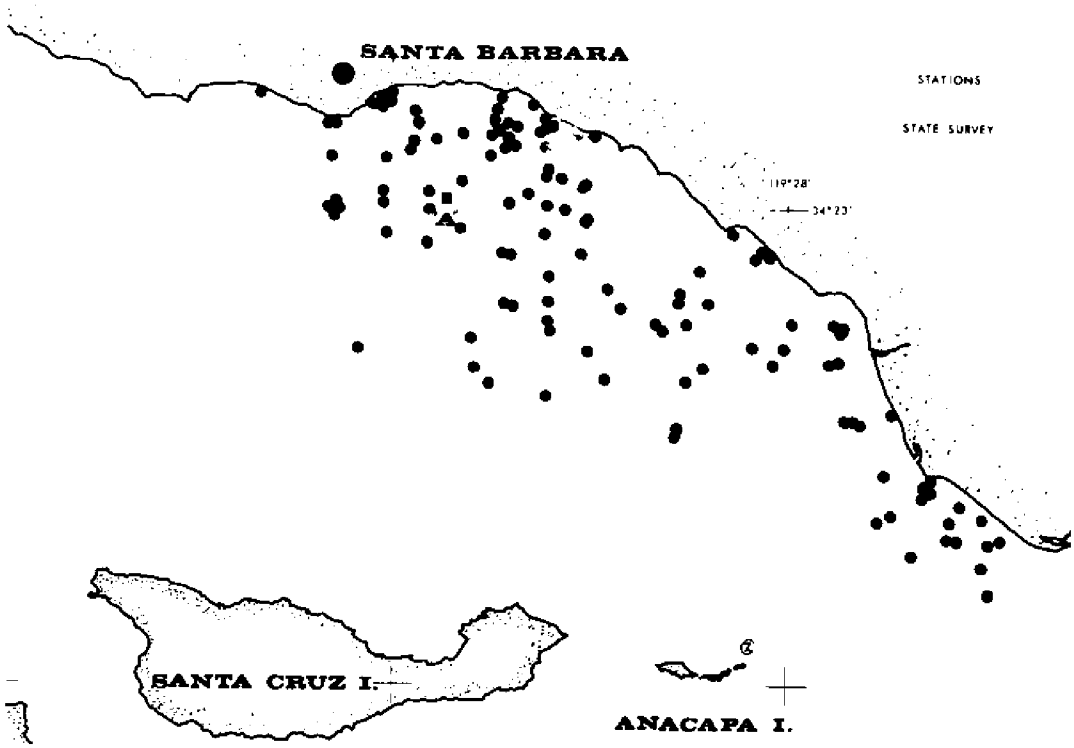
Table 5

Species of Ophiuroidea Reported from the State Survey and the Pollution Study

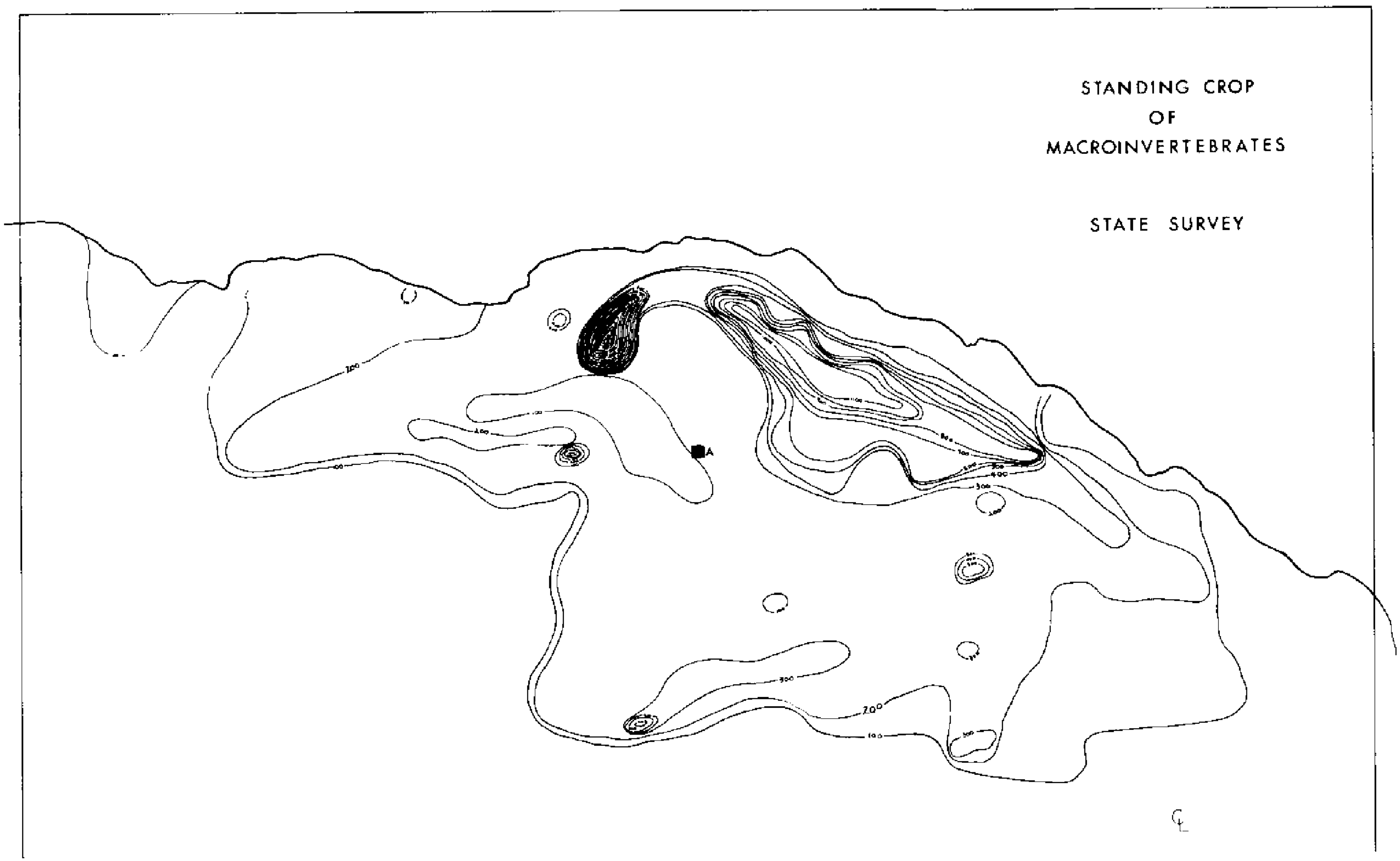
Name	State Survey	Pollution Study
Amphiacantha amphacantha	x	x
Amphiodia occidentalis	x	x
Amphiodia urtica	x	x
Amphipholis squamata	x	x
Amphioplus hexacanthus	x	x
Amphioplus strongyloplax	x	x
Amphiura arcystata	x	x
Amphiura diastata	x	x
Ophiura lutkeni	x	x
Ophiothrix spiculata	x	x



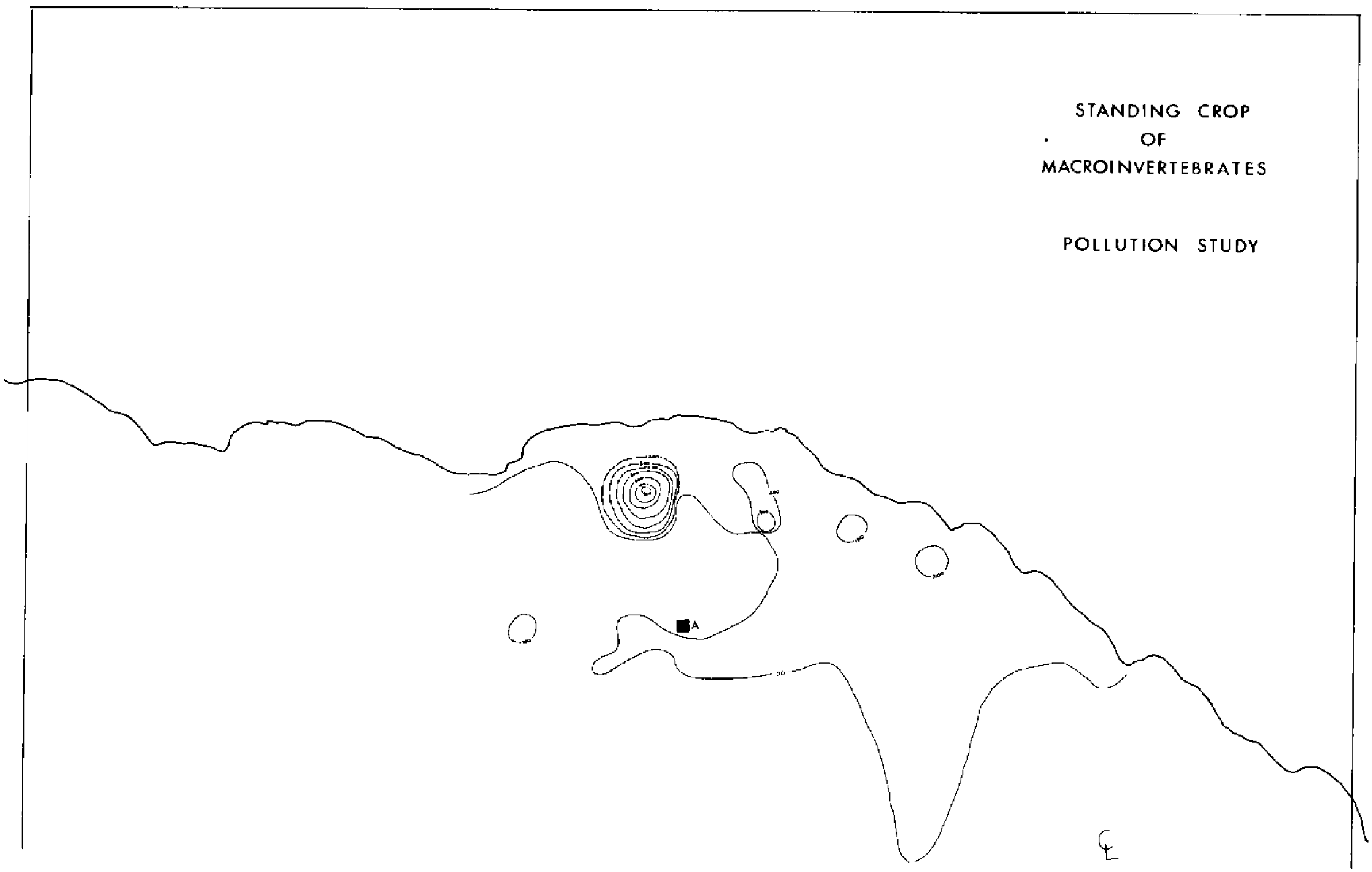
1. Benthic stations off Santa Barbara taken during the Pollution Study.



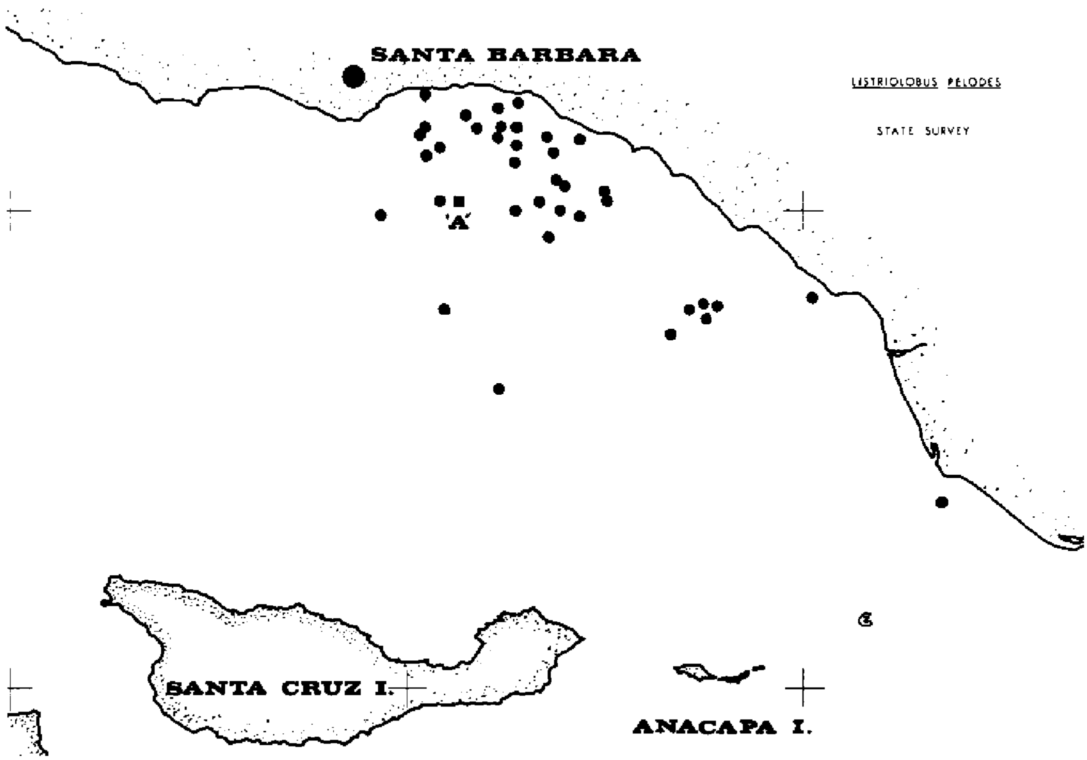
2. Benthic stations off Santa Barbara taken during the State Survey.



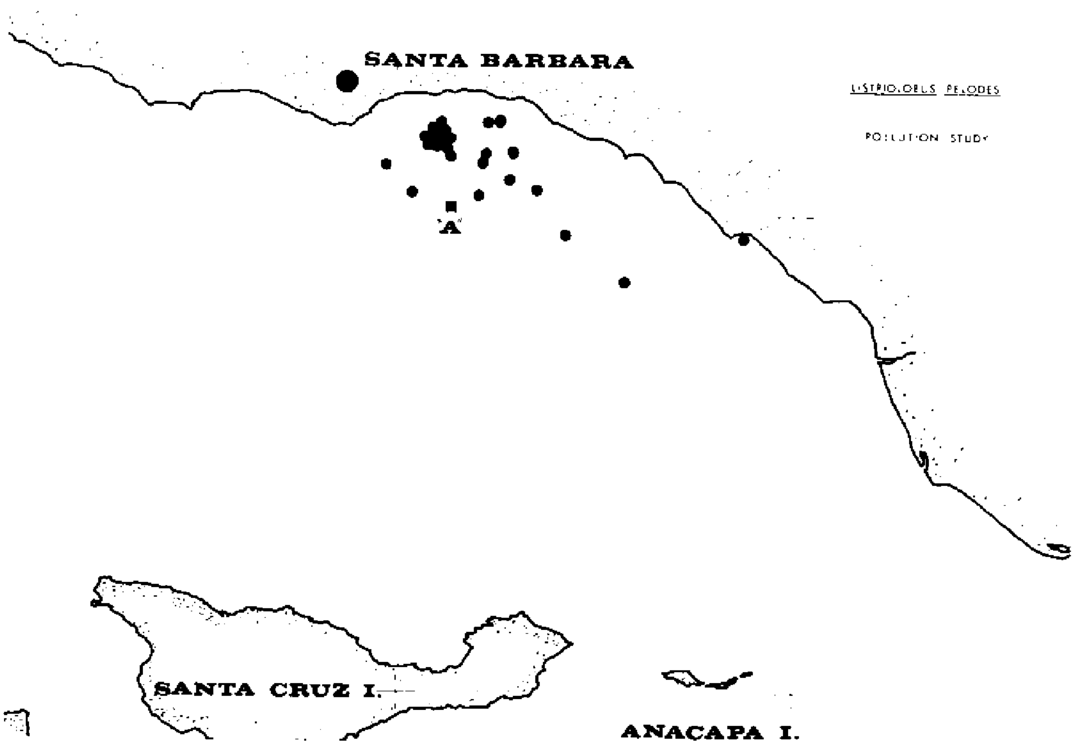
3. Distribution of the standing crop of macro-invertebrates off Santa Barbara during the State Survey. The isopleths are in 100 grams per square meter intervals.



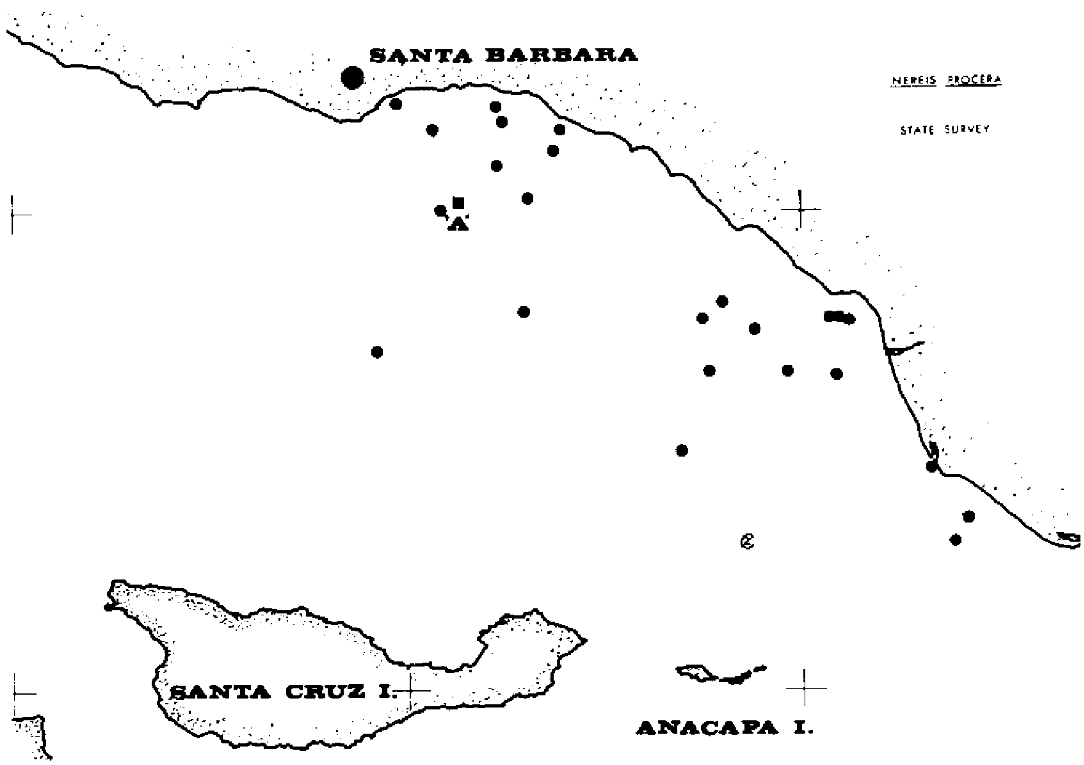
4. Distribution of the standing crop of macroinvertebrates off Santa Barbara during the Pollution Study. The isopleths are in 100 grams per square meter intervals.



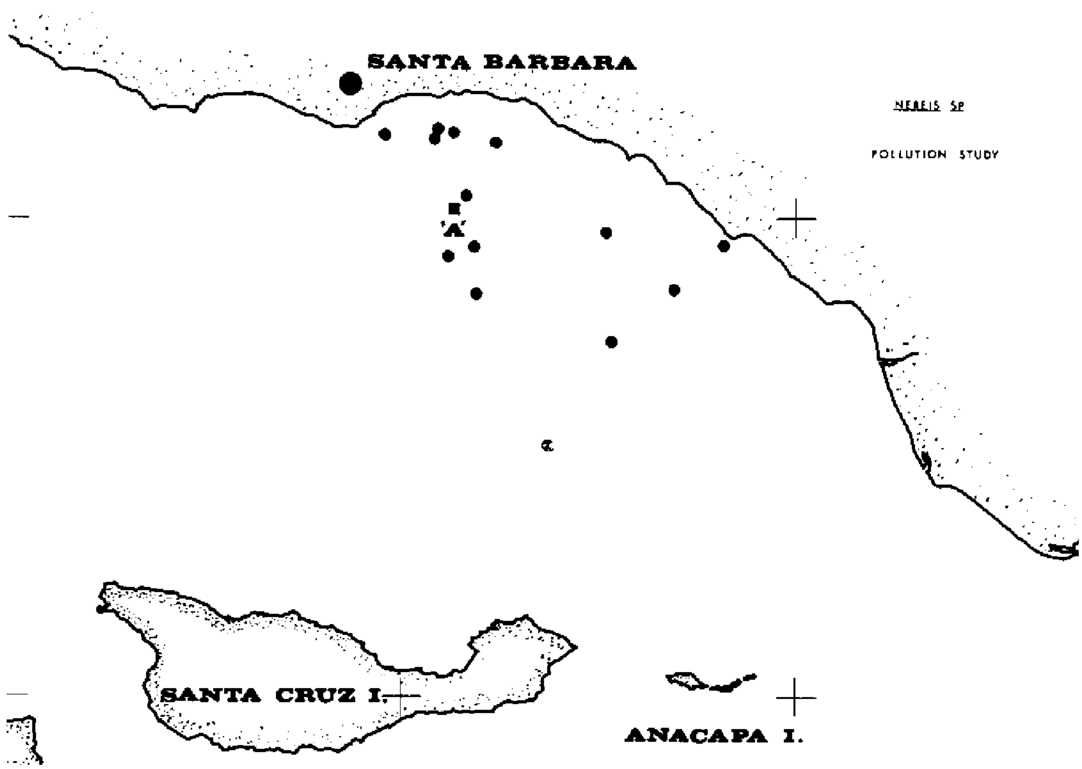
5. Distribution of <u>Listriolobus</u> <u>pelodes</u> off Santa Barbara during the State Survey.



6. Distribution of <u>Listriolobus</u> <u>pelodes</u> off Santa Barbara during the Pollution Study.



7. Distribution of <u>Nereis procera</u> off Santa Barbara during the State Survey.



8. Distribution of <u>Nereis</u> sp. 1 off Santa Barbara during the Pollution Study.

CHAPTER 6

SOME POLYCHAETOUS ANNELIDS FROM THE SANTA BARBARA SHELF AREA

by Raymond Emerson

INTRODUCTION

The polychaetes from fifty stations (see Chapter 5, Table 1) were sorted to family. Thirty-two families were represented (Table 1), including fifteen errantiate and seventeen sedentariate families. Twelve of the thirty-two families were then analyzed to species. The twelve families selected comprise 70% of the total polychaete sampling effort and constitute a major part of the polychaete standing crop. Glyceridae with four species represent about 40% of the polychaete biomass (Table 1). Other individual families treated to species represent from 2 to 8% of the biomass (Table 2).

A preliminary analysis of sediments indicates some pattern of sediment distribution. Coarse sediments grading from sand to sandy silts were found predominantly in shallow waters of less than 50 m, whereas grades of silt and clay were more common in deeper waters below 50 m. There may be exceptions to this general rule, since a series of stations at depths of less than 50 m were classified as silty clay (Table 3).

Five general types of sediments grading from coarse to fine particle size were considered as follows: sand, sandy silt, silt, silty clay, and clay (for definitions, see Chapter 5). Silty clay was the most common sediment grade, represented in 52% of the fifty stations analyzed for polychaetes. Sand and sandy silt each represented 18% with silt and clay representing 10 and 2% respectively (Table 3).

The numbers of polychaetes present in each substrate grade was inversely proportional to the particle size of the sample. The average number of individuals supported per station ranged from 67 in sand to 160 in clay. The number of different species per station remained relatively constant. An average of eight species occurred in silt and an average of ten species in silty clay. Sandy sediments had a similar number of species per station as occurred in the finer grades of silt and clay (Table 3).

An attempt was made to analyze the depth distribution of representative species. The sampling effort ranged from depths of 11 to 110 m, but 32% occurred at 40-50 m and only 2% at 100-110 m (Fig. 1). Therefore a correction for the sampling effort should be included. A depth specificity index (DSI) is herein established to minimize the effect from the unequal sampling frequencies at given depth intervals. The following formula was applied to those species occurring in at least 10% of the samples:

$$\text{Depth Specificity Index (DSI)} = \frac{\text{\% of species occurrence at depth interval}}{\text{\% of stations sampled at depth interval}}$$

A higher index value for a given species indicates a greater degree of selection for a given depth interval relative to its depth range and the sampling effort. As an example, *Ceratocephale crosslandi americana* Hartman yielded high depth specificity indices at intervals between 30 and 50 m, with values of 16.9-19.5; whereas the depth range of this species was from 11 to 110 m with DSI values of less than 5.0 (Table 4).

The distribution of depth specificity indices for *Glycera capitata* Oersted indicated a wider range of preferred depths from 31 to 90 m, with an overall depth range from 11 to 100 m. Other species, such as *Lumbrineris index* Moore and *Marphysa disjuncta* Hartman, showed a more restricted depth preference within a more limited range of occurrence. Species occurring at depths greater than 60 m generally had a broader depth range and indicated less depth specificity. Many of the species occurring at depths less than 60 m had a more restricted depth range and indicated a greater degree of depth specificity (Table 4).

SYSTEMATIC ANALYSIS

Diagnostic characters, distribution and habitat data are given for forty-six species. Pollution survey records are given as follows: 12792(2) = Velero Station 12792, 2 specimens.

Aglaophamus dicirris Hartman, 1950

Aglaophamus dicirris Hartman, 1968:567, 1 fig.

Records: 12792(2); 12795(2); 12800(1); 12802(2); 12803(1); 12806(2); 12807(3); 12809(1); 12810(1); 12812(1); 12817(1); 12821(1); 12855(1); 12857(1); 12865(1); 12866(1); 13255(1); 13256(3).

Remarks: Prostomium with eyespots, interramal cirri recurved and first present from segment 5-8. One specimen from station 12821 has recurved interramal cirri present from segment 3.

Distribution and Habitat: Previously reported from tropical America north to Southern California, in shallow sandy bottoms, intertidal to 72 fms.

Santa Barbara Channel specimens occurred in sand and silty clay from intertidal depths to 110 m, depth specificity indicated below 50 m.

Arabella geniculata (Claparède, 1868)

Arabella geniculata Hartman, 1968:787, 2 figs.

Records: 12809(2).

Remarks: Parapodial lobes not prolonged, maxilla I dentate along its entire margin.

Distribution and Habitat: Previously reported from Southern California, occurring intertidally in kelp.

Santa Barbara Channel specimens occurred in sandy substrate at 50-60 m.

Arabella iricolor (Montagu, 1804)

Arabella iricolor Hartman, 1968:789, 5 figs.
Arabella iricolor Fauchald, 1970:125-128, 4 figs.

Records: 12821(6); 13258(6).

Remarks: Parapodial lobes not prolonged, dorsal cirri short and prostomium with four eyes in a transverse row.

Distribution and Habitat: Previously reported from western Canada to western Mexico, in mixed sediments from intertidal to shelf depths.

Santa Barbara Channel specimens were collected from depths of 11-30 m.

Arabella pectinata Fauchald, 1970

Arabella pectinata Fauchald, 1970:130-132, 6 figs.

Records: 13258(1).

Remarks: Posterior postsetal lobes not prolonged, hooded simple setae absent, maxilla III with 7-11 teeth and maxilla IV with 6-7 teeth.

Distribution and Habitat: Previously reported from Pacific side of Baja California from intertidal depths.

Santa Barbara Channel marks new distribution record for Southern California in silt at 40-50 m.

Ceratocephale crosslandi americana Hartman, 1952

Ceratocephale crosslandi americana Hartman, 1968:499, 3 figs.

Records: 12794(1); 12795(3); 12796(61); 12797(5); 12798(1); 12800(8); 12801(1); 12802(1); 12805(26); 12806(3); 12807(7); 12808(13); 12809(2); 12810(82); 12812(97); 12813(43); 12814(9); 12815(57); 12817(145); 12818(20); 12819(36); 12820(64); 12853(86); 12854(48); 12855(76); 12856(114); 12857(62); 12858(56); 12859(40); 12860(56); 12861(74); 12862(37); 12863(65); 13256(2).

Remarks: Some anterior segments with bifid ventral cirri, hornlike papillae on proboscis, prostomium with four large eyes.

Distribution and Habitat: Previously reported from Southern California in 50 fms and canyons in depths to 478 m.

Santa Barbara Channel specimens occurred in mixed sediments at 10-110 m; depth specificity indicated for 30-60 m.

Chloeia cfr *entypa* Chamberlin, 1919

Chloeia entypa Hartman, 1968:191, 5 figs.

Records: 12800(1); 12802(1); 12803(15); 12806(48); 12807(12); 12808(10); 12852(9); 13255(10); 13256(30).

Remarks: Body short, oval, some posterior notosetae with serrations directed basally and on opposite edge from spine. Number of body segments 18-20.

Specimens resemble *Chloeia pinnata* in general morphology but are specific to *Chloeia entypa* in setal structure. On re-examination, *C. pinnata* specimens from the State Survey, Station 5859, appear more typically *C. entypa*.

Distribution and Habitat: Previously reported from western Mexico to Southern California in 7-66 fms, also Ecuador, north to Panama.

Records from Santa Barbara Channel may substantiate distribution of "8 mm" C. entypa specimens previously reported near Anacapa Island (Hartman, 1968:191). Santa Barbara Channel specimens occurred in sand and silt at 40-110 m; depth specificity indicated below 70 m.

Diopatra cfr neotridens Hartman, 1944

Diopatra neotridens Hartman, 1944:63-66, 12 figs.
Diopatra neotridens Fauchald, 1968:9, 1 fig.

Records: 12811(1).

Remarks: Long filamentous occipital tentacles with bands of pigment. Anterior hooded hooks distally trifid but species differs from D. tridentata in having a more reduced third tooth.

Distribution and Habitat: Previously reported from Baja California, Mexico, south to western Panama, from depths of 5-56 fms.

Santa Barbara Channel specimens were taken from depths of 20-30 m.

Diopatra ornata Moore, 1911

Diopatra ornata Hartman, 1968:659, 5 figs.
Diopatra ornata Fauchald, 1968:10-11, 1 fig.

Records: 12809(2); 12854(1); 12859(1).

Remarks: Branchiae spiraled on some anterior segments, pigmentation occurring at base of parapodial lobes of first segments, and pectinate setae with many small teeth.

Distribution and Habitat: Previously reported from central California south to western Mexico, in littoral depths, in mixed sediments.

Santa Barbara Channel specimens occurred in mixed sediments at 30-60 m.

Diopatra tridentata Hartman, 1944

Diopatra tridentata Hartman, 1968:663, 4 figs.
Diopatra tridentata Fauchald, 1968:13-14, 1 fig.

Records: 12797(1); 12812(1); 12817(1); 12820(3); 12821(1); 13258(2); 13031(1).

Remarks: Prostomium with pair of black eyespots at base of occipital tentacles. Ventral cirri cirriform through four segments, then padlike or blunted. Anterior hooded hooks distally trifid.

Distribution and Habitat: Previously reported from Southern California, south through western Mexico, and the West Indies, in 5-57 fms.

Santa Barbara Channel specimens occurred in mixed sediments at 20-50 m.

Drilonereis falcata Moore, 1911

Drilonereis falcata Hartman, 1968:797, 5 figs.
Drilonereis falcata Fauchald, 1970:135-136, 1 fig.

Records: 12856(1); 12863(1); 13258(1); 13031(1); 13256(2).

Remarks: Maxilla I distally falcate and basally dentate, posterior parapodia with acicular spines but may have reduced postsetal lobes. Anterior parapodia poorly developed.

Distribution and Habitat: Previously reported from central California to western Mexico, in mixed sediments from intertidal to slope depths.

Santa Barbara Channel specimens occurred in mixed sediments at 30-80 m; depth specificity indicated for 20-30 m.

Drilonereis filum (Claparède, 1868)

Drilonereis filum Hartman, 1968:799, 2 figs.
Drilonereis filum Fauchald, 1970:136-137, 1 fig.

Records: 12793(1); 12816(1); 12821(3); 12852(1); 12856(1); 12860(1); 13258(2).

Remarks: Similar to Drilonereis falcata Moore except that maxilla, although distally falcate, lacks basal dentition. Irregular pigmentation pattern on some specimens.

Distribution and Habitat: Previously reported from Southern California, in sandy mud from shelf depths. Also known from western Mexico and Mediterranean Sea.

Santa Barbara Channel specimens occurred in sand and silt at 10-50 m but more commonly in depths of 10-20 m.

Drilonereis longa Webster, 1879

Drilonereis longa Hartman, 1968:801, 1 fig.

Records: 12816(1).

Remarks: Maxilla I distally falcate and basally dentate. Posterior parapodia with prolonged pre- and postsetal lobes.

Distribution and Habitat: Previously reported from San Pedro Channel, from intertidal to shelf depths; Virginia, intertidal in silt.

Santa Barbara Channel specimens occurred in sand at 10-20 m.

Eunice americana Hartman, 1944

Eunice americana Hartman, 1968:709, 5 figs.
Eunice americana Fauchald, 1970:19, 2 figs.

Records: 12799(2); 12809(1); 12811(1); 12853(1); 12854(1); 12864(1).

Remarks: Acicula yellow, subacicular falcigers yellow with long, pointed hood, occipital tentacles smooth.

Distribution and Habitat: Previously reported from Southern California to western Mexico in 15-174 fms.

Santa Barbara Channel specimens occurred in sand and mixed sediments at 20-60 m.

Glycera americana Leidy, 1855

Glycera americana Hartman, 1968:613, 1 fig.

Records: 12793(1); 12794(1); 12795(1); 12797(24); 12804(3); 12809(7); 12810(1); 12811(12); 12816(7); 12817(1); 12821(10); 12853(1); 12856(1); 12858(2); 12862(2); 12863(1); 12865(2); 13256(4); 13258(3); 13031(1).

Remarks: Branchiae dendritically branched, emerging from posterior face of parapodia with two postsetal lobes and two presetal lobes all about equally developed, tips of posterior parapodial lobes usually pigmented.

Distribution and Habitat: Previously reported from western Canada to Peru; New Zealand and Australia, in mixed sediments from littoral to slope depths.

Santa Barbara Channel specimens occurred in sand and mixed sediments at 10-80 m; depth specificity indicated between 10-30 m.

Glycera branchiopoda Moore, 1911

Glycera branchiopoda Hartman, 1968:615, 7 figs.

Records: 12804(9); 12805(5); 12810(7); 12812(14).

Remarks: Posterior parapodia with single postsetal lobe, proboscidial organs without ridges. Distinguished from Glycera capitata Oersted by presence of knoblike dorsal cirrus in anterior setigers. Presetal lobe always shorter than postsetal lobe.

Distribution and Habitat: Previously reported from Southern California in mud from slope and basin depths.

Santa Barbara Channel specimens occurred in sand and mixed sediments at 30-60 m.

Glycera capitata Oersted, 1843

Glycera capitata Hartman, 1968:617, 4 figs.

Records: 12792(5); 12794(5); 12799(6); 12800(6); 12801(13); 12803(5); 12808(7); 12815(10); 12817(16); 12819(4); 12852(1); 12853(10); 12854(18); 12858(10); 12860(5); 12861(5); 12863(1); 12864(2); 12865(3); 12866(5); 13255(7); 13258(6); 13030(3); 13031(8).

Remarks: Posterior parapodia with single postsetal lobe, proboscidial organs without ridges. Distinguished from Glycera branchiopoda Moore by absence of knoblike dorsal cirrus on anterior setigers; however, the length of the postsetal lobe exceeds that of the presetal lobe.

Distribution and Habitat: Previously reported from Southern California in mud at slope and basin depths.

Santa Barbara Channel specimens occurred in sand, silt and mixed sediments at 60-90 m.

Glycera robusta Ehlers, 1868

Glycera robusta Hartman, 1968:627, 4 figs.

Records: 12796(3); 12798(3); 12812(6); 12815(2); 12817(2); 12818(3); 12820(6); 12853(9); 12855(13); 12856(18); 12857(3); 12860(3); 12861(3); 12862(17); 12863(3); 13031(1).

Remarks: Parapodia with blisterlike branchial processes, preacicular lobes equally bifid. Distinctive triangular dorsal cirrus in both large and small specimens. Ventral parapodial lobe previously undescribed in larger specimens.

Distribution and Habitat: Previously reported from Washington to Southern California and Japan; in gravelly sand from intertidal to shelf depths.

Santa Barbara Channel specimens occurred in silty clay at 10-70 m; depth specificity indicated between 20 and 40 m.

Hyalinoecia juvenalis Moore, 1911

Hyalinoecia juvenalis Hartman, 1968:667, 6 figs.
Hyalinoecia juvenalis Fauchald, 1968:14-16, 5 figs.

Records: 12798(1); 12806(1); 12809(2); 12821(1); 12866(1); 13030(2).

Remarks: Lacks peristomial cirri, branchiae present from about segment 18.

Distribution and Habitat: Previously reported from Southern California south to Panama; West Indies; Colombia; and Venezuela, in 8-67 fms.

Santa Barbara Channel specimens occurred in sand and mixed sediments at 40-80 m.

Lumbrineris bicirrata Treadwell, 1929

Lumbrineris bicirrata Hartman, 1968:745, 5 figs.
Lumbrineris bicirrata Fauchald, 1970:77-78, 3 figs.

Records: 12801(1); 12803(4).

Remarks: Composite falcigers absent, acicula black, posterior pre- and postsetal lobes prolonged, simple setae not prolonged.

Distribution and Habitat: Previously reported from Washington south to western Mexico, in mixed and muddy sediments from shelf and slope depths.

Santa Barbara Channel specimens occurred in sand and silt at 81-100 m.

Lumbrineris californiensis Hartman, 1944

Lumbrineris californiensis Hartman, 1968:749, 6 figs.
Lumbrineris californiensis Fauchald, 1970:78-80, 4 figs.

Records: 12792(3); 12804(1); 12811(4); 12821(3); 12852(1); 13256(1).

Remarks: Composite falcigers present in some anterior parapodia, acicula yellow or translucent, posterior parapodia with prolonged pre- and postsetal lobes, anterior parapodia with dorsally directed presetal lobe.

Distribution and Habitat: Previously reported from Southern and central California, in mud and sand from shelf and slope depths.

Santa Barbara Channel specimens occurred in sand at 10-50 m, depth specificity indicated from intertidal to 40 m.

Lumbrineris cruzensis Hartman, 1944

Lumbrineris cruzensis Hartman, 1968:751, 6 figs.
Lumbrineris cruzensis Fauchald, 1970:83-84, 4 figs.

Records: 12792(4); 12799(5); 12804(1); 12806(11); 12807(5); 12808(2); 12810(1); 12813(2); 12815(3); 12818(1); 12852(1); 12861(4); 12866(2); 13255(1); 13030(1).

Remarks: Composite falcigers present in some anterior parapodia, acicula yellow or translucent, posterior parapodia with prolonged pre- and postsetal lobes.

Distribution and Habitat: Previously reported from Southern California in silt from shelf and slope depths.

Santa Barbara Channel specimens occurred in sand and mixed sediments at 30-100 m; depth specificity indicated for 70-80 m.

Lumbrineris index Moore, 1911

Lumbrineris index Hartman, 1968:755, 5 figs.

Records: 12797(5); 12804(1); 12811(4); 12855(1); 13258(2); 13031(3).

Remarks: Composite falcigers present in some anterior parapodia, acicula black, posterior parapodia with prolonged postsetal lobe.

Distribution and Habitat: Previously reported from Southern California in mud and silt from shelf and slope depths.

Santa Barbara Channel specimens occurred in sand and silt at 20-50 m.

Lumbrineris lagunae Fauchald, 1970

Lumbrineris bifilaris Hartman, 1968:747, 6 figs. (in part).
Lumbrineris lagunae Fauchald, 1970:92-94, 5 figs.

Records: 12809(1); 12810(3); 12811(2); 12816(1); 12853(1); 12854(6); 12855(5); 12859(4); 12860(6); 12861(4); 12862(4); 12863(5); 12858(2).

Remarks: Composite falcigers absent, acicula yellow or clear; posterior postsetal lobe usually exceeds presetal lobe, but some specimens with lobes equally developed.

Distribution and Habitat: Previously reported from Southern California, western Mexico and western Canada from subtidal to 27 fms.

Santa Barbara Channel specimens occurred in sand and silty clay at 10-60 m; depth specificity indicated for 30-50 m.

Lumbrineris limicola Hartman, 1944

Lumbrineris limicola Hartman, 1968:765, 6 figs.
Lumbrineris limicola Fauchald, 1970:97-98, 4 figs.

Records: 12792(1).

Remarks: Composite falcigers present in some anterior parapodia, acicula yellow or translucent, posterior parapodia with prolonged postsetal lobe, maxillae III and IV with single tooth.

Distribution and Habitat: Previously reported from Southern California in mud and silt from littoral depths.

Santa Barbara Channel specimens occurred in sand at 30-40 m.

Lumbrineris minima Hartman, 1944

Lumbrineris minima Hartman, 1968:769, 6 figs.

Records: 13255(4); 12817(1).

Remarks: Composite falcigers absent, acicula yellow or translucent, posterior parapodia with slightly prolonged pre- and postsetal lobes, body small and slender.

Distribution and Habitat: Previously reported from Southern California in sandy mud flats from shallow intertidal depths.

Santa Barbara Channel specimens occurred in silty clay at 40-80 m.

Lumbrineris pallida Hartman, 1944

Lumbrineris pallida Hartman, 1968:773, 6 figs.
Lumbrineris pallida Fauchald, 1970:102-103.

Records: 12821(4).

Remarks: Composite falcigers present in some anterior parapodia, acicula yellow or translucent, posterior parapodia with inconspicuous lobe, maxillary carriers taper basally.

Distribution and Habitat: Previously reported from Southern California and western Mexico in mixed sediments from 24-57 fms.

Santa Barbara Channel specimens were collected from depths of 10-20 m.

Lumbrineris zonata (Johnson, 1901)

Lumbrineris zonata Hartman, 1968:777, 4 figs.
Lumbrineris zonata Fauchald, 1970:112-113, 5 figs.

New Records: 12794(2); 12797(1); 12798(1); 12800(1); 12804(3); 12806(13); 12807(1); 12808(4); 12812(7); 12814(3); 12815(1); 12818(2); 12819(1); 12820(1); 12853(4); 12855(3); 12856(8); 12857(14); 12858(6); 12860(5); 12861(3); 12862(8); 12863(8); 12864(4); 12866(1); 13255(4); 13256(18); 13258(2); 13031(11).

Remarks: Composite falcigers absent, acicula yellow or translucent, posterior parapodia without prolonged lobes; in anterior parapodia, presetal lobes exceed the postsetal lobes in length.

Distribution and Habitat: Previously reported from Alaska to western Mexico in sand and mixed sediments from intertidal depths to 46 fms.

Santa Barbara Channel specimens occurred in sand and mixed sediments at 10-100 m.

Marphysa conferta Moore, 1911

Marphysa conferta Hartman, 1968:727, 4 figs.
Marphysa conferta Fauchald, 1970:59-60.

New Records: 12861(2).

Remarks: Peristomial cirri absent, branchiae pinnately branched and beginning on setiger 4, composite setae falcigerous.

Distribution and Habitat: Previously reported from Southern California in rocky and mixed sediments from depths of 76-200 m.

Santa Barbara Channel specimens occurred in silty clay at 40-50 m.

Marphysa disjuncta Hartman, 1961

Marphysa disjuncta Hartman, 1968:729, 3 figs.
Marphysa disjuncta Fauchald, 1970:60-61.

Records: 12797(16); 12798(13); 12799(1); 12804(2); 12811(14); 12812(1); 12816(1); 12853(3); 12854(4); 12855(23); 12857(1); 12859(1); 12862(4); 12864(1); 13256(1); 13258(6); 13031(19).

Remarks: Peristomial cirri absent, branchiae pinnately branched, composite setae spinigerous. Several smaller specimens with branchiae beginning on setiger 12 instead of 13 or 14.

Distribution and Habitat: Previously reported from Southern California in mud at 50-100 m.

Santa Barbara Channel specimens occurred in sand and mixed sediments at 10-50 m; depth specificity indicated for 20-30 m.

Marphysa stylobranchiata Moore, 1909

Marphysa stylobranchiata Hartman, 1968:735, 3 figs.

Records: 12809(2).

Remarks: Peristomial cirri absent, filamentous branchiae present on many segments.

Distribution and Habitat: Previously reported from central California in rocky habitats from intertidal to slope depths.

Santa Barbara Channel specimens occurred in sand at 50-60 m.

Neanthes spp.

Records: 12858(2).

Remarks: Two different specimens, each of which is nonrepresentative of any previously described species from this area.

Distribution and Habitat: Santa Barbara Channel specimens occurred in silty clay at 40-50 m.

Nephtys assignis Hartman, 1950

Nephtys assignis Hartman, 1968:573, 5 figs.

Records: 12802(1); 12803(2); 12853(1); 12866(1).

Remarks: Recurved interramal cirri first present from setiger 6-7, posterior parapodia with foliaceous lobes.

Distribution and Habitat: Previously reported from central and Southern California to western Mexico in sand and mixed sediments at 40-110 m.

Santa Barbara Channel specimens occurred in mixed sediments at 40-110 m.

Nephtys caecoides Hartman, 1938

Nephtys caecoides Hartman, 1968:577, 3 figs.

Records: 12806(2); 12810(1); 12811(1); 12812(1); 12813(2); 12814(2); 12819(1); 12821(3); 12813(2); 12814(2); 12819(1); 12821(3); 12852(2); 12862(1); 12865(1); 13255(1); 13256(1); 13258(4); 13030(1); 13031(5).

Remarks: Recurved interramal cirri first present from fourth setiger, prostomium and anterior segments with restricted pigment pattern.

Distribution and Habitat: Previously reported from central and Southern California to western Mexico in sand and mixed sediments from littoral depths.

Santa Barbara Channel specimens occurred in sand and mixed sediments at 10-100 m; depth specificity indicated for 10-30 m.

Nephtys ferruginea Hartman, 1940

Nephtys ferruginea Hartman, 1940:241, 6 figs.
Nephtys ferruginea Hartman, 1968:583, 4 figs.

Records: 12795(1); 12797(1); 12802(1); 12808(2); 12811(1); 12813(2); 12815(3); 12816(2); 12811(1); 12813(2); 12815(3); 12816(2); 12819(1); 12821(3); 12852(2); 12853(2); 12854(4); 12855(2); 12856(2); 12857(1); 12858(1); 12862(3); 12863(1); 13255(1); 13256(3); 13031(1).

Remarks: Recurved interramal cirri first present from third setiger, eyespots absent, body with extensive pigmentation.

Distribution and Habitat: Previously reported from western Canada to Peru in clay from 10-230 fms.

Santa Barbara Channel specimens occurred in sand, clay, and mixed sediments at 10-80 m.

Nereis sp.

Records: 12795(1); 12796(1); 12800(1); 12801(1); 12804(5); 12807(1); 12809(3); 12817(1); 12821(10); 12853(1); 12854(3); 12856(8).

Remarks: Some of these specimens may be represented in the State Survey as *Nereis procera* Ehlers.

Distribution and Habitat: Santa Barbara Channel specimens occurred in sand, silt, and mixed sediments at 11-90 m; depth specificity indicated for 11 and 30 m.

Ninoe gemmea Moore, 1911

Ninoe gemmea Hartman, 1968:783, 7 figs.

Records: 12792(1); 12794(1); 12797(3); 12806(3); 12808(1); 12812(1); 12813(1); 12853(2); 12854(4); 12855(1); 12856(3); 12858(1); 12860(1); 12862(1); 13031(3).

Remarks: Branchiae present on anterior parapodia, branchiae palmately branched.

Distribution and Habitat: Previously reported from central and Southern California in mud at 79-1272 m.

Santa Barbara Channel specimens occurred in silty clay at 10-80 m. Depth specificity indicated for 20-40 m.

Nothria iridescens (Johnson, 1901)

Nothria iridescens Hartman, 1968:681, 3 figs.
Nothria iridescens Fauchald, 1968:24-25, 1 fig.

Records: 12794(1); 12797(1); 12804(1); 12808(1); 12809(2); 12811(1); 12816(6); 12821(3); 12864(3); 13258(2); 13030(3); 13031(1).

Remarks: Peristomial cirri present, simple branchiae present from first setiger, tentacular ceratophores prolonged, body may be pigmented.

Distribution and Habitat: Previously reported from western Canada to western Mexico; southern South America from littoral depths to 290 fms.

Santa Barbara Channel specimens occurred in sand and sandy silt at 10-80 m.

Onuphis eremita parva Berkeley and Berkeley, 1941

Onuphis eremita parva Hartman, 1968:693.

Records: 12808(1); 13255(1); 12805(1).

Remarks: Similar to Onuphis parva except body smaller, length less than 20 mm. Identification based on body length; however, depth records indicate may possibly be young forms of Onuphis parva.

Distribution and Habitat: Previously reported from Corona del Mar from depths of 12-17 fms.

Santa Barbara Channel specimens occurred in sandy silt at 50-80 m.

Onuphis litoralis Monro, 1933

Onuphis litoralis Hartman, 1968:695, 3 figs.

Records: 12865(1).

Remarks: Peristomial cirri present, branchiae branched on some segments, anterior hooded hooks distally trifid, composite spinigers present in some anterior segments.

Distribution and Habitat: Previously reported from Galapagos Islands and San Nicholas Island in 63-83 fms.

Santa Barbara Channel specimens occurred in sandy silt at 60-70 m.

Onuphis nebulosa Moore, 1911

Onuphis nebulosa Hartman, 1968:699, 6 figs.
Onuphis nebulosa Fauchald, 1968:36-37.

Records: 12792(1); 12794(1); 12809(1); 13030(1).

Remarks: Peristomial cirri present, branchiae not spiraled but branched on some segments, acicular hooks present, anterior hooded hooks trifid and composite spinigers present in some anterior segments.

Distribution and Habitat: Previously reported from central California to Pacific Panama in mixed sediments at 65-172 fms.

Santa Barbara Channel specimens occurred in sand at 11-60 m.

Onuphis parva Moore, 1911

Onuphis parva Hartman, 1968:701, 5 figs.
Onuphis parva Fauchald, 1968:37, 5 figs.

Records: 12800(1); 12801(1); 12803(1); 12807(2); 12814(1).

Remarks: Peristomial cirri present, branchiae branched on some segments, acicular hooks absent, anterior hooded hooks distally bifid.

Distribution and Habitat: Previously reported from central California to western Mexico in mud at 26-184 fms.

Santa Barbara Channel specimens occurred in silt and silty clay at 70-100 m.

Panthalis pacifica Treadwell, 1914

Panthalis pacifica Hartman, 1968:145, 4 figs.

Records: 12795(2); 12800(3); 12801(1); 12803(1); 12805(3); 12807(2); 12808(1); 12814(2); 12815(4); 12818(1); 12819(2); 12855(1); 12857(1); 12858(1); 12859(1); 12860(2); 12861(1); 12863(1); 12865(1); 13256(1).

Remarks: Prostomium with stalked eyes, superior neurosetae with tuft of long bristles.

Distribution and Habitat: Previously reported from Southern California in mud from subintertidal depths to 100 fms.

Santa Barbara Channel specimens occurred in sandy silt and silty clay at 40-100 m.

Pectinaria californiensis Hartman, 1941

Pectinaria californiensis Hartman, 1941:333-335, 7 figs.
Pectinaria californiensis Hartman, 1969:515, 6 figs.

Records: 12792(3); 12793(1); 12794(1); 12797(4); 12801(4); 12802(2); 12803(6); 12804(4); 12805(7); 12806(3); 12807(33); 12809(6); 12810(1); 12811(2); 12812(5); 12813(16); 12814(5); 12815(7); 12816(2); 12817(2); 12819(5); 12852(1); 12853(3); 12854(1); 12855(4); 12856(4); 12857(2); 12859(1); 12860(3); 12862(5); 12865(5); 12866(7); 13255(7); 13256(10); 13030(4).

Remarks: Thirteen or fourteen cephalic spines with slender tips, 13 pairs of slightly hooked scaphal spines, notosetae present but reduced in setigers 1-3.

Distribution and Habitat: Previously reported from central and Southern California in sand at shelf depths.

Santa Barbara Channel specimens occurred in sand and mixed sediments at 10-110 m.

Poecilochaetus johnsoni Hartman, 1939

Poecilochaetus johnsoni Hartman, 1969:203, 5 figs.

Records: 12796(25); 12797(23); 12800(2); 12804(8); 12805(3); 12807(1); 12810(64); 12811(22); 12812(40); 12813(5); 12815(27); 12816(78); 12817(35); 12819(25); 12820(28); 12821(70); 12853(18); 12854(6); 12855(22); 12856(21); 12857(5); 12858(12); 12859(17); 12860(25); 12861(12); 12862(12); 12863(11); 13258(16); 13031(20).

Remarks: Median facial lobe projects forward, nuchal ridge extends back to setiger 6, second and third parapodia with acicular neurosetae, setigers 7-13 flask-shaped.

Distribution and Habitat: Previously reported from Southern California and southeastern United States from littoral depths to 280 m.

Santa Barbara Channel specimens occurred in sand and mixed sediments at 20-80 m.

Polyodontes panamensis (Chamberlin, 1919)

Polyodontes panamensis Hartman, 1968:149, 4 figs.

Records: 12797(1); 12804(1); 12853(1).

Remarks: Prostomium with stalked eyes, superior neurosetae with hirsute tips.

Distribution and Habitat: Previously reported from Panama and Southern California in mud at shelf depths.

Santa Barbara Channel specimens occurred in sand and mixed sediments at 20-40 m.

Sternaspis fossor Stimpson, 1854

Sternaspis fossor Hartman, 1969:351, 1 fig.

Records: 12792(2); 12793(1); 12794(4); 12795(2); 12796(1); 12797(2); 12799(4); 12800(13); 12801(10); 12802(2); 12803(10); 12804(2); 12805(1); 12806(3); 12807(6); 12808(10); 12811(3); 12813(2); 12814(13); 12815(12); 12816(4); 12817(9); 12818(2); 12819(4); 12820(1); 12821(21); 12852(1); 12854(2); 12855(4); 12856(6); 12857(2); 12858(2); 12859(3); 12860(2); 12861(5); 12862(5); 12863(1); 12865(1); 12866(1); 13255(6); 13256(7); 13258(3); 13030(4); 13031(5).

Remarks: Posterior end modified into ventral scute, seventh segment with pair of long nephridial papillae, measures 8-15 mm, bears five pairs of anterior scutal costae and setal bundles.

Distribution and Habitat: Previously reported from Alaska south to Southern California and eastern Canada, in mixed sediments at shelf and slope depths.

Santa Barbara Channel specimens occurred in sand, silt, and mixed sediments at 11-110 m.

SUMMARY

Forty-six species were identified from the Santa Barbara Channel, including several new species. A new distribution record for Southern California was obtained for one species, Arabella pectinata Fauchald.

Fauchald (Chapter 5) made a comparative analysis of the present survey with the California State Water Quality Control Board survey taken ten years ago. Fifty-five species of polychaetes from selected families were recovered in the earlier survey, of which thirty-four species were recovered in the present study.

The family Pilargidae represented less than 1% of the polychaete biomass and was not completely identified to species; however, a new species will be described from the Santa Barbara Channel (Emerson and Fauchald, in press). Several redescriptions and revisions will be forthcoming at a later date as a result of this study.

REFERENCES

Emerson, Raymond, and K. Fauchald
1971 A revision of the genus Loandalia Monro with description of a new genus and species of pilargiid Polychaetes. So. Calif. Acad. Sci., Bull. (in press).

Fauchald, Kristian
1968 Onuphidae (Polychaeta) from western Mexico. Allan Hancock Monogr. Mar. Biol., 3: 1-82, 12 pls.

1970 Polychaetous annelids of the families Eunicidae, Lumbrineridae, Iphitimidae, Arabellidae, Lysaretidae and Dorvilleidae from western Mexico. Allan Hancock Monogr. Mar. Biol., 5: 1-335, 27 pls.

Hartman, Olga
1940 Polychaetous annelids. Part II. Chrysopetalidae to Goniadidae. Allan Hancock Pacific Expeds., 7: 173-287, pls. 31-44.

1941 Polychaetous annelids. Part IV. Pectinariidae, with a review of all species from the western hemisphere. Allan Hancock Pacific Expeds., 7: 325-345, pls. 49-52.

1944 Polychaetous annelids. Part V. Eunicea. Allan Hancock Pacific Expeds., 10: 1-237, pls. 1-18.

1968 Atlas of the errantiate polychaetous annelids from California. Allan Hancock Foundation, Univ. of So. Calif., Los Angeles. 828p.

1969 Atlas of the sedentariate polychaetous annelids from California. Allan Hancock Foundation, Univ. of So. Calif., Los Angeles. 812p.

Table 1

Polychaete Families Represented in Pollution Study

Family	Number of Species	Percentage of Biomass Classified to Species
Errantiate		
Polynoidae		
Polyodontidae*	2	6
Sigalionidae		
Amphinomidae*	1	2
Phyllodocidae		
Pilargidae		
Syllidae		
Nereidae*	4	6
Nephtyidae*	4	5
Glyceridae*	4	40
Goniadidae		
Onuphidae*	10	8
Eunicidae*	4	6
Lumbrineridae*	10	6
Arabellidae*	6	3

*Classified to species

Table 1--Continued

Family	Number of Species	Percentage of Biomass Classified to Species
Sedentariate		
Paraonidae		
Spionidae		
Magelonidae		
Poecilochaetidae*	1	6
Cirratulidae		
Cossuridae		
Flabelligeridae		
Opheliidae		
Sternaspidae*	1	6
Capitellidae		
Maldanidae		
Oweniidae		
Sabellariidae		
Pectinariidae*	1	6
Ampharetidae		
Terebellidae		
Orbiniidae		
	48	100%

*Classified to species

Table 2

Species	Station Frequency	Occurrence	Total Number	Number per Square Meter
Aglaophamus dicirris	18	36	26	1.04
Arabella geniculata	1	2	2	.08
Arabella iricolor	2	4	12	.48
Arabella pectinata	1	2	1	.04
Ceratocephale c. americana	34	68	1,401	56.04
Diopatra neotridens	1	2	1	.04
Diopatra ornata	3	6	4	.16
Diopatra tridentata	7	14	10	.40
Drilonereis falcata	5	10	6	.20
Drilonereis filum	7	14	10	.40
Drilonereis longa	1	2	1	.04
Eunice americana	6	12	7	.28
Glycera americana	20	48	85	3.40
Glycera branchiopoda	4	10	35	1.64
Glycera capitata	24	48	161	6.56
Glycera robusta	16	32	95	3.80
Hyalinoecia juvenalis	6	12	8	.32
Lumbrineris bicirrata	2	4	5	.20
Lumbrineris californiensis	6	12	13	.52
Lumbrineris cruzensis	15	30	44	1.76
Lumbrineris index	6	12	16	.64
Lumbrineris lagunae	13	26	44	1.76
Lumbrineris limicola	1	2	1	.04

Table 2--Continued

Species	Station Frequency	Occurrence	Total Number	Number per Square Meter
Lumbrineris minima	2	2	5	.04
Lumbrineris pallida	1	2	4	.16
Lumbrineris zonata	29	58	140	5.60
Marphysa conferta	1	2	2	.08
Marphysa disjuncta	17	34	111	4.44
Marphysa stylobranchiata	1	2	2	.08
Nephtys assignis	4	8	5	.20
Nephtys caecoides	20	32	37	1.08
Nephtys ferruginea	26	44	48	1.56
Neanthes sp. 1	1	2	2	.08
Neanthes sp. 2	1	2	1	.04
Ninoe gemmea	15	30	27	1.08
Nothria iridescens	12	24	25	1.00
Onuphis eremita parva	3	6	3	.12
Onuphis litoralis	1	2	1	.04
Onuphis nebulosa	4	8	4	.16
Onuphis parva	5	10	6	.24
Panthalis pacifica	20	40	32	1.28
Pectinaria californiensis	35	70	176	7.04
Poecilochaetus johnsoni	29	58	653	23.12
Polyodontes panamensis	3	6	3	.12
Sternaspis fossor	44	88	204	8.92
Nereis sp.	12	26	36	1.96
Chloeia cfr. entypa	9	20	136	5.52

Table 3

Sediment and Species Distribution

Sediment Type	No. of Stations*	Depth Range (Meters)	Percentage of Total Sample	No. of Specimens	Avg. No. of Specimens per Sta.	Avg. No. of Species per Sta.	Range of No. of Species per Sta.
Sand	7	11-60	18	470	67.1	9.7	4-13
Sandy silt	7	20-90	18	603	86.1	9.7	8-14
Silt	4	60-110	10	286	71.5	8.0	6-11
Silty clay	20	30-110	52	2772	138.6	10.1	5-16
Clay	1	70-80	2	160	160	10.0	

*Sediment type for 11 stations was not available.

Table 4

Depth Specificity Index

Species	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110
Aglaophamus dicirris	6.3		8.2	6.3	12.8	19.0	19.1		33.6	26.0
Ceratocephale c. americana	0.1	0.3	16.9	19.5	3.4	4.3	4.8	3.7	1.5	0.1
Chloeia cfr. entypa				2.1		2.3	41.5		51.5	3.5
Diopatra tridentata	20.8	25.0	35.7	3.9						
Drilonereis falcata		40.0		12.5			16.7			
Drilonereis filum	66.8	30.0		9.4						
Eunice americana		14.3	11.2	17.8	23.8					
Glycera americana	37.0	50.5	5.3	2.3	14.3	4.0	1.0			
Glycera branchiopoda			40.0	5.3	20.4					
Glycera capitata	5.0	4.9	14.3	10.0	30.5	13.0	11.6	19.5	3.7	
Glycera robusta	1.6	40.0	38.7		3.5	5.3				
Hyalinoecia juvenalis				3.9	83.2	20.8	10.4			
Lumbrineris californiensis	38.4	30.8	22.0	4.7						
Lumbrineris cruzensis			8.0	9.2	3.8	7.7	32.2	5.7	14.0	
Lumbrineris index		75.0	44.3	5.9						
Lumbrineris lagunae	3.8	4.6	17.8	20.6	3.8					
Lumbrineris zonata	2.3	8.6	11.7	11.4		23.0	12.8	3.5	19.6	
Marphysa disjuncta	1.5	49.2	8.9	11.1						
Nephtys caecoides	17.2	34.5	4.9	5.4	5.7	11.5	2.8		4.2	
Nephtys ferruginea	21.3	7.7	16.5	8.8		17.6	12.8			13.0
Nereis sp.	34.0	26.6	13.1	6.4	10.0		3.3		5.2	
Ninoe gemmea	6.2	22.2	23.7	8.3			3.3			
Nothria iridescens	66.8	20.0	2.9	3.7	33.3		3.3			
Onuphis parva							14.0	41.7	83.8	
Panthalis pacifica				8.7	15.6	10.8	26.0	16.2	19.5	
Pectinaria californiensis	2.8	3.9	8.5	9.1	16.2	16.2	4.7	5.7	31.2	5.5
Poecilochaetus johnsoni	37.2	9.8	9.0	12.7	0.7	6.3	3.6			
Sternaspis fossor	21.7	6.3	3.9	6.9	3.7	1.5	18.5	13.5	16.2	47.0

CHAPTER 7

NOTES ON SOME OPHIUROIDS FROM THE SHELF OFF SANTA BARBARA

by Jack Wintz and Kristian Fauchald

INTRODUCTION

The benthic fauna of the Southern California shelf areas was studied extensively by scientists from the Allan Hancock Foundation from 1956-1960. In a publication stemming from this study, Barnard and Ziesenhenne (1961) described a series of ophiuroid communities along the coast. *Amphiodia urtica* (Lyman) was found to dominate the whole coast both in terms of numbers of specimens per square meter and in that it is either a dominant or a subdominant in all communities.

The shelf off Santa Barbara was described as an *Amphiodia*-*Cardita* community, with *Venericardia* (=*Cardita*) *ventricosa* (Gould) as subdominant. This community covers areas from approximately 50-100 meter depths in silty clay along the coast off Santa Barbara. Inshore of this community is found the *Listriolobus*-beds where *Amphiodia urtica* is a subdominant, and in shallow water other unnamed communities were found.

Ophiuroids were identified in seventy-three of the eighty-five samples taken during the Pollution Study. For a survey of the stations and a review of the sampling techniques see Chapter 5.

The identifications of the ophiuroids in the present collections were made largely after the key by Boolootian and Leighton (1966), but original descriptions were also consulted.

SPECIES OF OPHIUROIDS FOUND IN THE POLLUTION STUDY

The following species of ophiuroids were found in seventy-three samples collected during the pollution study: Amphiacantha amphacantha (McClendon), Amphiodia urtica (Lyman), A. occidentalis (Lyman), Amphipholis squamata (Delle Chiaje), Amphioplus hexacanthus H. L. Clark, A. strongyloplax (H. L. Clark), Amphiura arcystata H. L. Clark, A. diastata McClendon, Ophiura lutkeni (Lyman) and Ophiothrix spiculata LeConte.

The relative frequency, numbers of specimens reported, and the number of specimens per square meter in the analyzed samples are given in Tables 1 and 2.

A SYSTEMATIC NOTE ON AMPHIODIA DIGITATA NIELSEN

Amphiodia digitata was described by Nielsen (1932:277-279) from La Jolla, California, and placed with A. urtica (Lyman) in a new subgenus, Amphispina. A. digitata has spines on the upper row of scales in the ventral scale covering, while in A. urtica scales with spines may be found anywhere on the ventral scale covering but most frequently and most distinctly at the base of the arms and along the genital slits (Nielsen, 1932:276-277; see also Nielsen's key to species of Amphiodia, p. 267). A. digitata should possess few and large scales aborally; A. urtica should have numerous and small ones in similar positions.

In the present material it is possible to select specimens to show a complete range between Nielsen's diagnostic characters. The two species are not separable on these characters alone and are here considered synonymous. Although it is possible that the two might be separable on another set of characters, this was not tested in the present investigation.

Generally, specimens of A. urtica from deeper water appear to have more scales than ones from shallower water and frequently the specimens with numerous spines were recovered in groups, rather than scattered evenly in the whole material of A. urtica.

SOME NOTES ON *AMPHIODIA URTICA*

Amphiodia urtica was present in sixty-eight of the seventy-three samples examined for ophiuroids and some 3500 specimens were recovered. Only one other species, *Amphioplus strongyloplax* (H. L. Clark), was present in more than 10% of the samples.

Amphiodia urtica appears to prefer deeper water, as indicated in Table 3. Barnard and Ziesenhenne (1961:144, Table 3) indicated that *A. urtica* had its highest frequency at 50-60 m depth, with decreasing frequencies in both deeper and shallower water. While more samples were taken in medium deep waters, it appears that the maximum numbers of *A. urtica* off Santa Barbara may be found near the 90 m depth or deeper. The frequency of *A. urtica* appears at any rate to be less at all depths north of Port Hueneme than elsewhere along the Southern California coast; Barnard and Ziesenhenne (1961:137) reported a four-fold increase in the frequency of this species south of that point.

The juveniles of *A. urtica* can be separated from the adults by the following character: The primary plates on the aboral disc consist of a center plate and two concentric rings, each ring containing five plates. The inner ring is radial, the outer is interradial. Secondary scalation obscures these plates in the adults, while in the smaller specimens they are quite distinct. In very small specimens, the secondary scalation has not yet started and the two concentric rings are adjacent and touching. Specimens characterized as juveniles in this paper lacked all secondary scalation but no individual larger than 1.0 mm in disc-diameter was considered juvenile even if secondary scalation was poorly developed or absent.

The percentage of juveniles out of the total number of specimens was calculated for separate depth intervals (Table 3). The percentage obtained for the 61-70 m depth class is considered abnormal; all three stations in this depth-interval were from sand and Barnard and Ziesenhenne (1961:150) indicated that the frequency of *A. urtica* decreased with increased sand content in the substrate. It should be noted that no station taken in sand, irrespective of depth, had more than 11% juveniles.

In general, it appears that the relative number of juveniles decreases with increasing depth, but the numbers are not statistically significant.

SUMMARY

Amphiodia urtica (Lyman) is now the dominant ophiuriod in the whole area sampled, as it was during the State Survey. The frequencies of other ophiuriods are similar or slightly lower than ten years ago.

The numbers per square meter of A. urtica are similar to those reported from the area by Barnard and Ziesenhenne (1961).

The species Amphiodia digitata Nielsen (1932) is here considered synonymous with A. urtica (Lyman), based on the diagnostic characters given by Nielsen (1932).

The depth distribution of A. urtica indicates that the species may be more frequent in deep water than in intermediate depths; this contrasts with the results given by Barnard and Ziesenhenne for the whole coast of Southern California.

Juveniles appear to be more frequent in shallow than in deep water, but the differences in numbers are not statistically significant.

REFERENCES

Barnard, J. L., and F. C. Ziesenhenne
1961 Ophiuroid communities of Southern Californian coastal bottoms. Pacific Naturalist, 2: 131-152.

Boolootian, R. A., and D. Leighton
1966 A key to the species of Ophiuroidea (brittle stars) of the Santa Monica Bay and adjacent areas. Los Angeles County Museum, Contrib. Sci., 93: 1-20.

Clark, H. L.
1911 North Pacific ophiurans in the collection of the United States National Museum. U.S. Natl. Mus., Bull., 75: 1-302.

McClendon, J. F.
1909 The ophiurans of the San Diego region. Univ. Calif. Publ. Zool., 6: 33-64.

Nielsen, Eigil.
1932 Papers from Dr. T. Mortensen's Pacific expedition, 1914-16. LIX. Ophiurans from the Gulf of Panama, California, and the Strait of Georgia. Dansk Naturh. Foren., Vidensk. Medd., 91: 241-346.

Ulrey, A. B.
1918 The starfishes of Southern California. So. Cal. Acad. Sci., Bull., 17: 39-52.

Table 1

Ophiuroid Station Records and Habitat

<u>Amphiacantha</u> <u>amphacantha</u> (McClendon, 1909)

<u>Records</u>: 12802(2); 12803(2); 12866(1); 13423(3); 13424(1).

<u>Habitat</u>: In silt and mixed sediments from depths of 50-110 meters.

<u>Amphiodia</u> <u>occidentalis</u> (Lyman, 1860)

<u>Records</u>: 12804(2); 12816(1); 12864(1).

<u>Habitat</u>: In sand from depths of 11-50 meters.

<u>Amphiodia</u> <u>urtica</u> (Lyman, 1860)

<u>Records</u>: 12792(98); 12795(96); 12796(4); 12797(103); 12799(47); 12800(64); 12801(115); 12802(92); 12803(98); 12804(78); 12805(149); 12806(97); 12807(74); 12808(56); 12809(7); 12810(9); 12811(108); 12812(27); 12813(102); 12814(79); 12815(20); 12816(45); 12817(31); 12818(37); 12819(5); 12821(44); 12852(61); 12853(32); 12854(20); 12855(40); 12856(83); 12857(25); 12858(37); 12859(24); 12860(36); 12861(23); 12862(41); 12863(26); 12864(5); 12865(64); 12866(64); 13030(22); 13031(11); 13032(17); 13255(123); 13256(92); 13418(72); 13419(80); 13402(74); 13421(3); 13422(9); 13423(20); 13424(133); 13425(58); 13426(29); 13427(78); 13428(26); 13430(41); 13431(86); 13432(21); 13433(34); 13434(19); 13435(17); 13436(32); 13437(18); 13438(82); 13439(62); 13440(23).

<u>Habitat</u>: In sand, clay and mixed sediments from depths of 11-110 meters.

Table 1--Continued

<u>Amphipholis</u> <u>squamata</u> (Delle Chiaje, 1828)

<u>Records</u>: 12858(1); 12865(1); 13256(1); 13423(2); 13424(2); 13439(1).

<u>Habitat</u>: In silty clay from depths of 37-100 meters.

<u>Amphioplus</u> <u>strongyloplax</u> (Clark, 1911)

<u>Records</u>: 12793(1); 12795(1); 12800(1); 12802(3); 12806(1); 12809(4); 12814(1); 12815(1); 13424(2); 13431(1).

<u>Habitat</u>: In sand, silt and mixed sediments from depths of 21-110 meters.

<u>Amphiura</u> <u>arcystata</u> Clark, 1911

<u>Records</u>: 12800(1); 12808(1); 12809(2); 12817(1); 12866(1); 13431(3); 13435(1).

<u>Habitat</u>: In sand and silt from depths of 50-80 meters.

<u>Amphiura</u> <u>diastata</u> McClendon, 1909

<u>Records</u>: 12865(1); 13424(6); 13436(1).

<u>Habitat</u>: In sandy silt from depths of 46-55 meters.

<u>Ophiura</u> <u>lutkeni</u> (Lyman, 1860)

<u>Records</u>: 12805(1); 12865(1); 13256(1).

<u>Habitat</u>: In sandy silt from depths of 60-100 meters.

<u>Ophiothrix</u> <u>spiculata</u> LeConte, 1851

<u>Records</u>: 12865(23).

<u>Habitat</u>: In sandy silt from depths of 70 meters.

Table 2

	Occurrence in Percentage of Samples	Total Number Occurring	No./m^2
Amphiodia urtica	96.8	3548	99.99
Amphiodia occidentalis	5.6	5	0.14
Amphioplus hexacanthus	2.8	2	0.06
Amphioplus strongyloplax	14.1	16	0.45
Amphiacantha amphacantha	7.0	9	0.25
Amphiura arcystata	9.9	10	0.28
Amphiura diastata	4.2	8	0.23
Amphipholis squamata	8.4	7	0.20
Ophiura lutkeni	4.2	3	0.08
Ophiothrix spiculata	1.4	23	0.65

Table 3

<u>Amphiodia</u> <u>urtica</u>: Number per Square Meter by Depth and Percentage of Juveniles

	Depth in Meters									
	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110
Number per square meter	89.0 (2)	95.6 (5)	74.0 (10)	80.2 (28)	81.7 (6)	88.7 (3)	152.0 (6)	190.0 (3)	170.3 (6)	184.0 (1)
Percentage of juveniles	19.0 (2)	31.0 (1)	24.4 (9)	21.2 (26)	17.8 (6)	0.67 (3)	13.5 (4)	16.5 (2)	13.2 (5)	

Note:

Numbers in parentheses indicate number of stations.

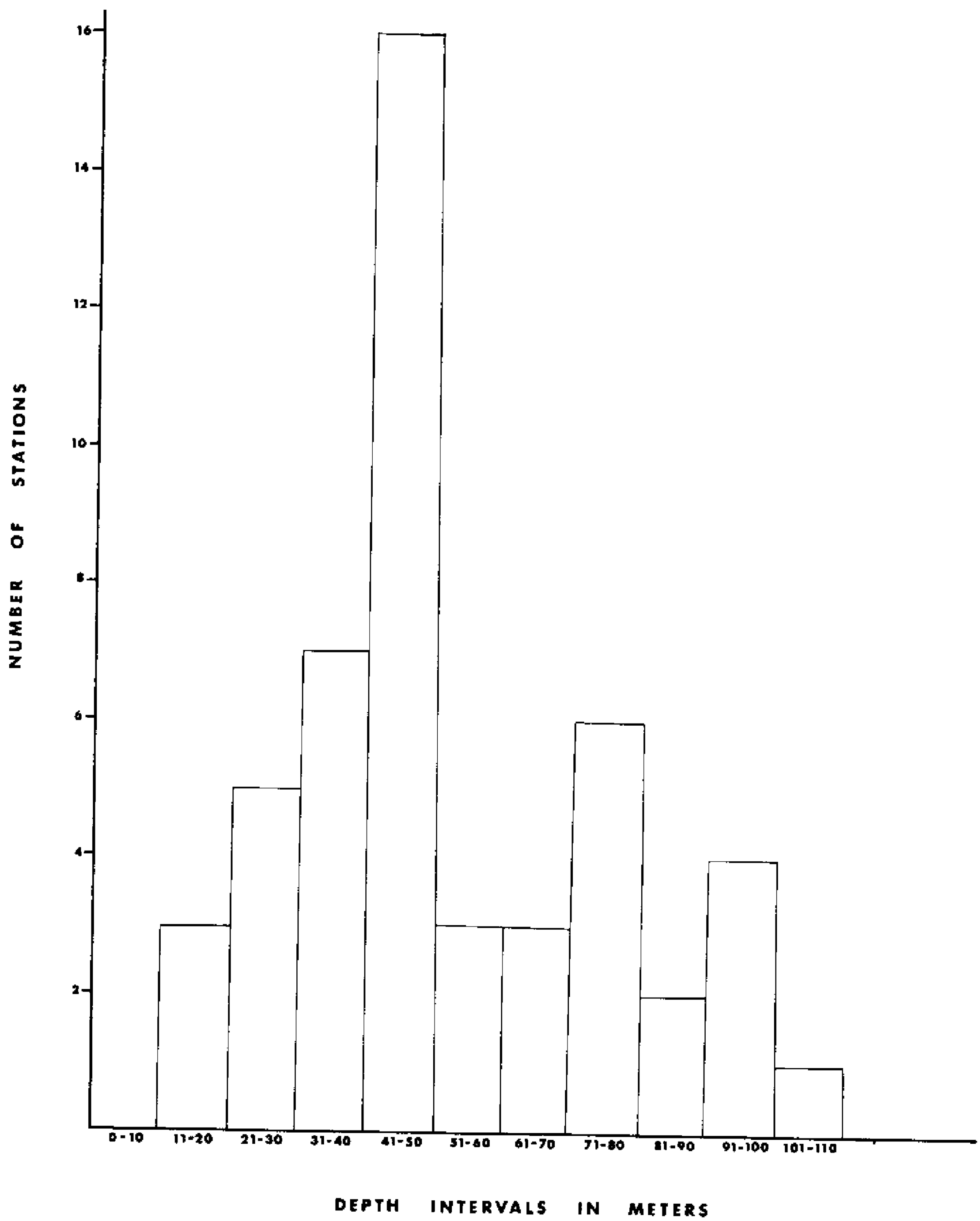


Figure 1. Number of stations sampled at depth intervals of 10 meters.

CHAPTER 8

A STUDY OF THREE SANDY BEACHES IN THE SANTA BARBARA, CALIFORNIA, AREA

by Thomas Trask

INTRODUCTION

A sandy beach sampling program was initiated in the Santa Barbara, California, area in July, 1969, to determine the numbers of species and, very roughly, the species density of the invertebrate infauna of that area. An attempt was made to determine seasonal variation in the number and abundance of species. It is difficult to draw conclusions about the effects of oil from the Platform A blowout on the sandy beach infauna because, as far as can be determined, no investigation of this type had been attempted in the general area previous to the blowout. Thus, the immediate goal of this program was to collect information that could be utilized for comparative purposes during future sandy beach studies in the Santa Barbara area.

Three sandy beaches were designated for the sampling program: Carpinteria State Beach, Coal Oil Point Beach, and Ellwood Beach (see Vol. 2). Carpinteria State Beach received a heavy layer of oil from the Platform A blowout, and oil from offshore natural seeps comes ashore there continuously. Coal Oil Point Beach received less oil from the blowout, but does receive larger amounts of oil from natural seeps than does Carpinteria. Ellwood Beach is probably polluted by oil wells on the beach immediately northwest of the transect line, and probably receives oil from offshore natural seeps as well.

No attempt was made to establish a transect on a "control" beach, as it was obvious that every beach in the area was being polluted by oil from either natural seeps or oil wells, or both, in a more or less continuous manner.

MATERIALS AND METHODS

Ten samples were collected along an established transect line on each of the three beaches during low tides in July and October, 1969, and January and April, 1970. The transect line at Carpinteria State Beach was based on a concrete block structure located above the upper beach level, and ran in a straight line into the surf zone an equal distance between two large rocks on the beach. The base point for the transect line at Coal Oil Point Beach consisted of the base of a large tree growing on the cliff edge just south of a set of concrete steps leading down to the beach, and the line ran into the surf zone a set distance to the left of a rock located in the surf zone. Two steel pipes embedded in concrete above the upper berm were used to triangulate a straight line into the surf zone at Ellwood Beach, with a point equidistant between the two pipes forming the base point for the transect line.

The ten samples were spaced out equally along the transect line according to the width of the beach, which was measured with a 100-foot tape measure from the edge of the upper berm to the edge of the water. The measurements were taken during a low tide in July, 1969, at the time the first series of samples were collected. Thus, on Carpinteria State Beach, the samples were taken seven paces apart (approximately 20 feet), while at Ellwood Beach and Coal Oil Point Beach the samples were taken eight paces apart (approximately 25 feet).

One sample consisted of a shovelful of sand collected by pushing a standard-sized shovel into the substrate at right angles up to the edge of the foot rest on the blade of the shovel. The volume of an average sized shovelful of sand equals approximately 1/100th of a cubic meter. Each sample was placed in a plastic bucket and covered with either 10% formalin or fresh water to control the movements of beach hoppers (Orchestoidea spp.). The substrate from each sample was then washed with fresh water through a

1.5 mm mesh screen; specimens recovered from the washing were placed in a labelled bottle containing a 10% formalin solution. The specimens were later washed with fresh water and transferred to 70% isopropyl alcohol.

RESULTS AND DISCUSSION

Tables 1-12 list the number of specimens of each species recovered from samples taken on each beach from July, 1969, through April, 1970. The tables appear in chronological order according to the date the samples were collected. All species collected during the study appear in the left-hand column of each table. The order of the sample numbers listed from left to right in each table indicates the relative position of each sample on the beach; samples numbered 1, 11, 21, etc. were collected in the surf zone while samples numbered 10, 20, 30, etc. were collected at the high tide mark.

The number of species collected from the beaches during each sampling period is presented in Table 13. The number was lowest in January, 1970, because much of the sand forming each beach was gone and samples could not be collected. The lower intertidal region of Ellwood Beach was composed of rocks from two to five inches in diameter, and other rocky areas were present all along the transect line in January. Coal Oil Point Beach also had exposed rock piles along the transect where there was sand in October; solid rock was all that remained of the upper sandy beach. At Carpinteria State Beach the removal of sand by winter conditions exposed a hard substrate of rocks and asphalt that could not be penetrated by a shovel. No organisms were observed living on the rocky substrates of any of the beaches.

As with the number of species recovered from each beach, the number of specimens collected was lowest in January, 1970, as indicated in Table 14. The removal of the sand habitat of the invertebrate infauna was responsible for the low numbers of specimens recovered inasmuch as fewer samples could be taken. It rained during the sampling period in January at Ellwood Beach and Carpinteria State Beach. It is possible that freshwater run-off encouraged invertebrates to move deeper into the substrate than the sampling depth on these two beaches. Such movement may explain, in part, why lower numbers of species and of specimens were obtained there than at Coal Oil Point Beach.

The number of species and the total numbers of specimens collected from each of the three beaches increased by April, 1970. The sandy portion of each beach was more substantial in April than in January, although not as extensive as in July, 1969.

A comparison of the data presented in Table 15 with that of Tables 13 and 14 would tend to indicate a correlation between the amount of oil observed on the beaches from July, 1969, through April, 1970, and the numbers of species and numbers of specimens recovered from each beach during the same periods. Such a correlation is false, however, as both the amount of oil present on the beaches in January and the numbers of species and specimens recovered in January are related to the amount of sand on the beaches at that time. It appears that the same physical forces that removed sand from the beaches by January, 1970, also removed oil deposits from the beaches. Observations of both Ellwood Beach and Coal Oil Point Beach indicated an increase of oil pollution by April corresponding to the addition of more sand to the beaches. Whether the oil observed during the study originated from offshore natural seeps, offshore oil wells, or from ships' bilges is unknown.

It is difficult to determine the effects of oil deposition on the invertebrates living in sandy beaches in the Santa Barbara area. Oil has been observed coming ashore in the area from offshore natural seeps for the past 200 years (Chapter 2). It is unknown whether any of the invertebrates subjected to this type of selection pressure have adapted to the changed environment. Certainly some invertebrates are killed by toxic fractions of the oil, and undoubtedly others are physically smothered by oil as it is deposited on the beach. It would not be too difficult to determine whether the invertebrate infauna of sandy beaches subjected to oil deposition reproduce successfully or not. It is possible that recruitment from other areas maintains the numbers of species and numbers of specimens found on the three beaches studied.

ACKNOWLEDGMENTS

I would like to thank Ray Emerson for identifying the polychaetes collected during the study, and Mady Trask for assisting with the collections.

Table 1

Species Collected from Ellwood Beach, July 28, 1969

Species	Sample Number									
	1	2	3	4*	5	6	7	8	9	10*
Crustacea:										
Ancinus seticomvus										
Archeomysis maculata		1								
Cirolana chiltoni										
Emerita analoga	9		1		1		5			
Haustoriidae						1				
Lepidopa myops	1									
Orchestoidea spp.										
Phoxocephalidae										
Talitridae										
Unidentified Amphipoda					6			1		
Polychaeta:										
Dispio uncinata										
Eteone sp.										
Euzonus mucronata								2	98	
Hemipodus californiensis										
Lumbrineris zonata										
Magelona pitelkai										
Mediomastus acutus										
Nephtys californiensis			1							
Nerinides acuta								1	2	
Scoloplos armiger										
Mollusca:										
Olivella biplicata										
Miscellaneous:										
Insect larvae										
Unidentified Nemertea										

*No organisms recovered from sample

Table 2

Species Collected from Coal Oil Point Beach, July 29, 1969

Species	Sample Number									
	11	12	13	14	15	16	17	18	19	20
Crustacea:										
Ancinus seticomvus		2	8							
Archeomysis maculata										
Cirolana chiltoni									7	
Emerita analoga					2	2	1			
Haustoriidae		13	2							
Lepidopa myops				2						
Orchestoidea spp.									2	11
Phoxocephalidae	1	3								
Talitridae		1				2		1		
Unidentified Amphipoda										
Polychaeta:										
Dispio uncinata	7	3	3							
Eteone sp.									1	
Euzonus mucronata								302		
Hemipodus californiensis										
Lumbrineris zonata					4	3				
Magelona pitelkai	1									
Mediomastus acutus										
Nephtys californiensis	3	4	3			1				
Nerinides acuta										
Scoloplos armiger		3								
Mollusca:										
Olivella biplicata		3	3							
Miscellaneous:										
Insect larvae										
Unidentified Nemertea	1		1		1					

Table 3

Species Collected from Carpinteria State Beach, July 30, 1969

Species	Sample Number									
	21	22	23	24	25	26	27	28	29*	30*
Crustacea:										
Ancinus seticomvus										
Archeomysis maculata										
Cirolana chiltoni										
Emerita analoga		4	14	7	1	15	10	57		
Haustoriidae										
Lepidopa myops		1	1							
Orchestoidea spp.										
Phoxocephalidae										
Talitridae										
Unidentified Amphipoda										
Polychaeta:										
Dispio uncinata	1									
Eteone sp.										
Euzonus mucronata										
Hemipodus californiensis										
Lumbrineris zonata										
Magelona pitelkai										
Mediomastus acutus										
Nephtys californiensis										
Nerinides acuta		1								
Scoloplos armiger										
Mollusca:										
Olivella biplicata										
Miscellaneous:										
Insect larvae								38		
Unidentified Nemertea								1		

*No organisms recovered from sample

Table 4

Species Collected from Ellwood Beach, October 24, 1969

Species	Sample Number									
	31	32	33	34	35	36	37	38	39	40
Crustacea:										
Ancinus seticomvus										
Archeomysis maculata					1					
Cirolana chiltoni									1	
Emerita analoga	1		4	1					13	
Haustoriidae							2			
Lepidopa myops										
Orchestoidea spp.										1
Phoxocephalidae										
Talitridae										
Unidentified Amphipoda										
Polychaeta:										
Dispio uncinata										
Eteone sp.										
Euzonus mucronata									234	
Hemipodus californiensis									1	
Lumbrineris zonata		1								
Magelona pitelkai										
Mediomastus acutus						2				
Nephtys californiensis		1				1		1		
Nerinides acuta							1			
Scoloplos armiger										
Mollusca:										
Olivella biplicata										
Miscellaneous:										
Insect larvae										
Unidentified Nemertea										

Table 5

Species Collected from Coal Oil Point Beach, October 25, 1969

Species	Sample Number									
	41	42	43	44	45	46	47*	48	49	50
Crustacea:										
Ancinus seticomvus	3									
Archeomysis maculata										
Cirolana chiltoni									2	
Emerita analoga					1			2	36	
Haustoriidae	2	1	1							
Lepidopa myops										
Orchestoidea spp.										5
Phoxocephalidae	2	6								
Talitridae										
Unidentified Amphipoda										
Polychaeta:										
Dispio uncinata	1	1	1							
Eteone sp.										
Euzonus mucronata										
Hemipodus californiensis										
Lumbrineris zonata		1	1		2	3				
Magelona pitelkai	1	1								
Mediomastus acutus										
Nephtys californiensis	2	1		1				1		
Nerinides acuta		1								
Scoloplos armiger	2	6	1							
Mollusca:										
Olivella biplicata	4	1	1							
Miscellaneous:										
Insect larvae										
Unidentified Nemertea		2	2							

*No organisms recovered from sample

Table 6

Species Collected from Carpinteria State Beach, October 26, 1969

Species	Sample Number									
	51	52	53*	54*	55*	56*	57	58	59	60
Crustacea:										
Ancinus seticomvus		1								
Archeomysis maculata										
Cirolana chiltoni										
Emerita analoga							5			
Haustoriidae										
Lepidopa myops										
Orchestoidea spp.	1									57
Phoxocephalidae										
Talitridae								5	13	
Unidentified Amphipoda	1									
Polychaeta:										
Dispio uncinata	1									
Eteone sp.										
Euzonus mucronata										
Hemipodus californiensis										
Lumbrineris zonata										
Magelona pitelkai										
Mediomastus acutus										
Nephtys californiensis										
Nerinides acuta										
Scoloplos armiger										
Mollusca:										
Olivella biplicata										
Miscellaneous:										
Insect larvae										
Unidentified Nemertea		2								

*No organisms recovered from sample

Table 7

Species Collected from Ellwood Beach, January 9, 1970

Species	Sample Number									
	61*	62*	63	64*	65	66*	67	68*	69	70
Crustacea:										
<u>Ancinus</u> <u>seticomvus</u>										
<u>Archeomysis</u> <u>maculata</u>										
<u>Cirolana</u> <u>chiltoni</u>					1					1
<u>Emerita</u> <u>analoga</u>									3	
Haustoriidae										
<u>Lepidopa</u> <u>myops</u>										
<u>Orchestoidea</u> spp.										
Phoxocephalidae										
Talitridae										
Unidentified Amphipoda										
Polychaeta:										
<u>Dispio</u> <u>uncinata</u>										
<u>Eteone</u> sp.										
<u>Euzonus</u> <u>mucronata</u>										
<u>Hemipodus</u> <u>californiensis</u>										
<u>Lumbrineris</u> <u>zonata</u>										
<u>Magelona</u> <u>pitelkai</u>										
<u>Mediomastus</u> <u>acutus</u>										
<u>Nephtys</u> <u>californiensis</u>			1		1		1			
<u>Nerinides</u> <u>acuta</u>										
<u>Scoloplos</u> <u>armiger</u>										
Mollusca:										
<u>Olivella</u> <u>biplicata</u>										
Miscellaneous:										
Insect larvae										
Unidentified Nemertea										

*No organisms recovered from sample

Table 8

Species Collected from Coal Oil Point Beach, January 10, 1970

Species	Sample Number 71	72	73	74	75*	76	77	78*	79*	80*
Crustacea:										
Ancinus seticomvus										
Archeomysis maculata										
Cirolana chiltoni										
Emerita analoga		2					2			
Haustoriidae										
Lepidopa myops										
Orchestoidea spp.										
Phoxocephalidae										
Talitridae										
Unidentified Amphipoda										
Polychaeta:										
Dispio uncinata										
Eteone sp.										
Euzonus mucronata										
Hemipodus californiensis										
Lumbrineris zonata	1	4		1		1	1			
Magelona pitelkai										
Mediomastus acutus										
Nephtys californiensis		2		1						
Nerinides acuta										
Scoloplos armiger	2	3								
Mollusca:										
Olivella biplicata		3								
Miscellaneous:										
Insect larvae										
Unidentified Nemertea	2	1	1							

*No organisms recovered from sample

Table 9

Species Recovered from Carpinteria State Beach, January 11, 1970

Species	Sample Number									
	81*	82*	83*	84*	85*	86*	87*	88*	89*	90
Crustacea:										
Ancinus seticomvus										
Archeomysis maculata										
Cirolana chiltoni										
Emerita analoga										
Haustoriidae										
Lepidopa myops										
Orchestoidea spp.										1
Phoxocephalidae										
Talitridae										
Unidentified Amphipoda										
Polychaeta:										
Dispio uncinata										
Eteone sp.										
Euzonus mucronata										
Hemipodus californiensis										
Lumbrineris zonata										
Magelona pitelkai										
Mediomastus acutus										
Nephtys californiensis										
Nerinides acuta										
Scoloplos armiger										
Mollusca:										
Olivella biplicata										
Miscellaneous:										
Insect larvae										
Unidentified Nemertea										

*No organisms recovered from sample

Table 10

Species Recovered from Carpinteria State Beach, April 24, 1970

Species	Sample Number									
	91	92	93	94	95	96*	97*	98*	99	100
Crustacea:										
Ancinus seticomvus										
Archeomysis maculata										
Cirolana chiltoni										
Emerita analoga	5	8	12	7	10					
Haustoriidae										
Lepidopa myops										
Orchestoidea spp.									12	15
Phoxocephalidae										
Talitridae										
Unidentified Amphipoda										
Polychaeta:										
Dispio uncinata										
Eteone sp.										
Euzonus mucronata										
Hemipodus californiensis										
Lumbrineris zonata										
Magelona pitelkai										
Mediomastus acutus										
Nephtys californiensis										
Nerinides acuta										
Scoloplos armiger										
Mollusca:										
Olivella biplicata										
Miscellaneous:										
Insect larvae										
Unidentified Nemertea										

*No organisms recovered from sample

Table 11

Species Collected from Coal Oil Point Beach, April 25, 1970

Species	Sample Number									
	101	102	103	104	105	106	107	108	109	110*
Crustacea:										
Ancinus seticomvus										
Archeomysis maculata										
Cirolana chiltoni									3	
Emerita analoga	4		1	3	7	9	18	2		
Haustoriidae										
Lepidopa myops										
Orchestoidea spp.										
Phoxocephalidae			1							
Talitridae										
Unidentified Amphipoda										
Polychaeta:										
Dispio uncinata	2	1	1				1			
Eteone sp.										
Euzonus mucronata							27	204	130	
Hemipodus californiensis										
Lumbrineris zonata	1	1	4							
Magelona pitelkai										
Mediomastus acutus										
Nephtys californiensis	1									
Nerinides acuta									1	
Scoloplos armiger	1									
Mollusca:										
Olivella biplicata	2									
Miscellaneous:										
Insect larvae										
Unidentified Nemertea				2						

*No organisms recovered from sample

Table 12

Species Collected from Ellwood Beach, April 26, 1970

Species	Sample Number									
	111	112	113	114	115	116	117	118	119	120
Crustacea:										
Ancinus seticomvus										
Archeomysis maculata										
Cirolana chiltoni									1	
Emerita analoga	1									
Haustoriidae										
Lepidopa myops		1				1	1			
Orchestoidea spp.										5
Phoxocephalidae										
Talitridae										
Unidentified Amphipoda										
Polychaeta:										
Dispio uncinata										
Eteone sp.										
Euzonus mucronata	4		22	20	4		7	23	10	
Hemipodus californiensis										
Lumbrineris zonata										
Magelona pitelkai										
Mediomastus acutus										
Nephtys californiensis										
Nerinides acuta								1	4	
Scoloplos armiger										
Mollusca:										
Olivella biplicata										
Miscellaneous:										
Insect larvae										2
Unidentified Nemertea	1									

Table 13

Numbers of Species Collected from Ellwood Beach, Coal Oil Point Beach, and Carpinteria State Beach between July, 1969, and April, 1970

Beach	Month Samples Collected			
	7/69	10/69	1/70	4/70
Ellwood Beach	8	11	3	8
Coal Oil Point Beach	17	14	6	11
Carpinteria State Beach	6	7	1	2
Total	31	32	10	21

Table 14

Total Number of Specimens Recovered from Ellwood Beach, Coal Oil Point Beach, and Carpinteria State Beach between July, 1969, and April, 1970

Beach	Month Samples Collected			
	7/69	10/69	1/70	4/70
Ellwood Beach	130	266	8	108
Coal Oil Point Beach	407	98	27	427
Carpinteria State Beach	151	86	1	69
Total	688	450	36	604

Table 15

Amounts of Oil Observed on Ellwood Beach, Coal Oil Point Beach, and Carpinteria State Beach during Collecting Trips between July, 1969, and April, 1970

Beach	Month of Observation			
	7/69	10/69	1/70	4/70
Ellwood Beach	Heavy	Medium	--*	Medium
Coal Oil Point Beach	Heavy	Medium	Light	Medium
Carpinteria State Beach	Medium	Light	--*	--*

Notes:

*No oil observed.

Light.--Oily particles left in strand by receding tide.

Medium.--Fresh oil globules 2"-3" across left in strand, slight oil slick in surf.

Heavy.--5-10 2"-3" globules of fresh oil/square meter, similar sized globules in surf.

CHAPTER 9

A STUDY OF THE BACTERIAL POPULATION OF BOTTOM SEDIMENTS IN THE SANTA BARBARA CHANNEL AFTER THE OIL SPILL

by Sister Damien Marie Juge

INTRODUCTION

During the period from 1966 through 1969, research on bacterial reduction in waste fields from ocean outfalls was carried out under the auspices of the Federal Water Pollution Control Administration by J. E. Foxworthy and H. R. Kneeling,[1] with the cooperation of the Allan Hancock Foundation. On February 20, 1969, an anomalous situation was encountered off the coast of Santa Barbara.

Studies prior to February all followed basically the same trend. The bacterial population was always greater at the terminus of the outfall, decreasing as sampling proceeded down the centerline of the tagged plume. At no time were these organisms (*Escherichia coli*) ever found to exist outside of the dyed waste field. On February 20, however, the trend was reversed. While the bacterial population at the terminus remained high, it did not decrease as sampling proceeded down the centerline, but instead, showed a tendency to increase. In addition, *E. coli* was found in samples from background water, that is, water not polluted by the sewage.

The causes of these anomalies were not immediately discernible. However, the major ecological difference was the presence of a large oil slick, originating from the oil blowout which occurred on January 28, 1969, at Platform A in the Santa Barbara Channel. On the basis of these observations it was decided that an investigation of the effects of

---

[1] J. E. Foxworthy and H. R. Kneeling, Eddy diffusion and bacterial reduction in waste fields in the ocean; a final report, Research Grant WP00931, Federal Water Pollution Control Administration

the oil blowout on the bacterial population in this area would enhance the study by scientists of the Allan Hancock Foundation which was already in progress.

As initially planned, the bacteriological study was to include two phases of investigation. One phase was to study the effect of the increased concentration of oil on bacteria introduced into the marine environment at the sewage outfall. The second phase of the investigation was to observe the effect of increased levels of oil and its degradation products on the benthic and sedimentary bacterial populations.

Phase one of the study did not develop beyond the preliminary stage for the following reasons: first, the oil slick did not remain in the area around the sewage outfall; and second, attempts to drop a slug of dyed sewage into the oil slick in the vicinity of Platform A were not successful because an equilibrium between the dyed sewage and the surrounding sea water could not be accomplished. The dyed slug always sank below the surface to a point of equilibrium too deep to sample.

As originally proposed in the second phase, box core samples were to be taken at monthly intervals from nine stations along a transect which extended from an area 1.1 miles off Rincon Point, Station 1, to Station 9 situated in the central area of the Santa Barbara Basin (Fig. 1). The location of Station 9 was chosen because bacteriological studies had been made of sediment samples taken at this site between 1965 and 1968,[2] even though this study included only subsurface samples. Bacteriological data, from surface and subsurface samples of a 48-inch core, taken from this area by Emery and Rittenberg, have also been published (Emery and Rittenberg, 1952). These are the only studies which may be used for comparison as there has been no published information concerning the benthic bacterial population of sediment samples taken from the continental shelf in the area under study.

Bacteriological analysis of sediment samples included the quantitation of population which is primarily marine and should reflect environmental change (presence of oil, etc.) and a population which is specifically terrigenous in

---

[2]Sister Damien Marie Juge, Marine geomicrobiology of the Southern California continental borderland (unpubl. diss., in progress).

origin and should reflect change in contribution or transport of sediment. Sediment samples were also analyzed by gas-liquid chromatography to determine both the qualitative and quantitative hydrocarbon contents.

The anticipated correlation between marine bacterial population and oil concentration was supported by the following: (1) the ability of bacteria to utilize petroleum products as a nutrient source has been demonstrated by the presence of large numbers in oil coming from depths of several thousand feet years after the well was drilled; (2) bacteria have been recovered from petroliferous sediments, some of which are physiologically active at 0° C while others are active at 85° C; and (3) it has been shown that neither salinity nor hydrostatic pressure can be expected to prevent bacterial activity in a petroliferous environment. In vitro studies have shown that petroleum hydrocarbons ranging from simple gases to complex solids are utilized for growth by bacteria under the proper conditions. Methane, petroleum ether, gasoline, kerosene, lubricating oil, paraffin wax, tars, benzene, xylene, anthracene, naphthalene, mineral oil, and cyclohexane are among the common hydrocarbons which are attacked by bacteria. Many of the microorganisms which have been shown to utilize one or more hydrocarbons have also been shown to be widely distributed in the marine environment.

MATERIALS AND METHODS

Cores

Fifty-five sediment cores were obtained, during a series of cruises from May, 1969, through June, 1970, aboard the Allan Hancock Foundation research vessel, the R/V *Velero IV*, with a modified Reineck box-corer (Bouma, 1969). Cores obtained in this manner provide undisturbed sediment samples of the mud-water interface and therefore should be a valid source of material from which the benthic population can be determined. The surface area of all cores was 8 by 14 inches, but their depth varied according to the nature of the bottom and the conditions under which a core was taken.

Sampling and culture methods

As soon as the coring device was recovered, a sample, approximately 100 g, was aseptically obtained from the surface. After this a side panel was removed from the corers and the depth of the core was measured. Then, using a section of thin wire, a longitudinal slice was removed from the exposed side of the core sample. In this way, the nature of the sediment column could be observed and appropriate locations for the two other samples could be determined. As the first core taken in the vicinity of Platform A contained a discrete layer (0.75 cm) of partially degraded oil immediately below the oxidized sediment layer, it was decided that the second sample would be taken from this level (0.75-1.75 cm below the surface). In subsequent core samples this level varied slightly, depending on the thickness of the oxidized material. The location of the third sample from each core varied according to the nature of the sediment and the total depth of the core. With cores taken from the deepest station (305 fms) an effort was made to duplicate the level from which samples had been taken during a previous study (Juge, unpubl. diss.). Before a sample was taken from the freshly cut surface of a core, a thin layer was removed (in one motion) with a sterile spatula and discarded. The sample was then aseptically removed with another sterile spatula and placed in a sterile petri plate. During the course of this study it was found that the second and third samples could be obtained more efficiently by using a sterile plastic 10 ml syringe from which the end had been aseptically cut off. In this way cores measuring 1 cm in diameter could be consistently removed from the desired level.

As soon as each sample was removed from a core, 10 g were aseptically weighed and transferred to a wide mouth bottle containing about 50 glass beads and 90 ml of sterile sea water. The sediment of this 1:10 dilution was adequately suspended by vigorous shaking. Serial dilutions were made into subsequent 9 ml sterile distilled water blanks to a 10^{-5} dilution. Repeated sampling at each station established that 10^{-1} to 10^{-3} dilutions were adequate at all areas sampled.

The medium used for the cultivation of organisms had the following composition: B.B.L.--Trypticase, 5.0 g; B.B.L.--Thiotone, 5.0 g; B.B.L.--Yeast Extract, 1.0 g; Ferric phosphate (N.F. pearls), distilled water, 1 liter (Bouma, 1969). The pH of the medium was adjusted to 7.6 and autoclaved at 121° C for 20 minutes. After cooling to 45-50° C, the medium was poured into plates. Because of the high incubation temperature and to avoid early substrate depletion, 28 ml of medium were poured into each plate. Plates were prepared several days before use to allow time for the surface to dry.

The quantitative distribution of aerobic organisms was determined by counting the colonies isolated on duplicate spread plates made with 0.1 ml portions from each of the series of dilutions made from each sample studied. For each sample analyzed, two sets of plates on each type of medium were made. One set of each medium was incubated at 18° C and the other at 60° C. Incubation periods varied from 2 to 14 days. The termination of the incubation period was indicated by stability in the number of colonies on a plate. After incubation, the colonies were counted on the duplicate plates of the appropriate dilution, and the average was recorded as the number of organisms per gram wet weight of sediment.

Gas chromatography

Immediately after removing the 10 g of sediment from each sample for bacteriological examination, the balance of the sediment was frozen for future chromatographic analysis for the presence of oil.

On the first cruise of this study, samples taken at levels a, b, and c from the site near Platform A and those taken from Station 9 were submitted to Dr. R. Pomeroy of Pomeroy, Johnson and Bailey, Civil and Chemical Engineers, for analysis to determine the feasibility of using gas-liquid chromatography for the detection and identification of hydrocarbons in marine bottom sediment. Frozen samples taken during the previous study (Juge, unpubl. diss.) of sediment at Station 9 and a sample of crude oil from Union Oil Tower A were also analyzed for purposes of comparison.

All other samples taken throughout the investigation were frozen as soon as they were taken and submitted to Dr. Kolpack of the Department of Geology, University of Southern California, for analysis by hydrogen flame ionization gas-liquid chromatography.

RESULTS AND DISCUSSION

Cores

Although the total study includes a geological report, a brief description of the general condition, position and relative quantity of oil present will be given for cores taken from areas in which changes were observed throughout the period of bacteriological sampling.

The area of greatest change was that of Station 2. The first core sample taken on May 30, 1969, had an oxidized layer about 1 cm thick on the surface. Immediately under this was a 0.75 cm layer of oil. The remainder of the core contained the clayey silty sand expected in this area. There was no indication of burrowing organisms throughout the 21 cm depth of this core. The next core was obtained from this station on June 27, 1969, and showed essentially the same composition. In the core taken approximately one month later on July 24, the oil layer was wider and less discrete as the oil began diffusing into the sediment below. Presumably this process continued because in the core taken on October 16, the next ship time available, the oil layer was no longer discrete but had diffused out into the sediment underneath. There was also evidence of a limited amount of burrowing. Evidently there was a new release of oil into this area between October 16 and November 11 because the core that was taken on the latter date had a fresh layer of oil obliterating the surface oxidized layer, which had been clearly defined in all cores taken up to this time. The amount of oil released was sufficient to produce a foamy saturated layer of sediment 3-5 cm deep. Again there was no indication of the presence of burrowing organisms. The core taken less than a month later on December 8 had acquired a thin layer of oxidized material but the oil had diffused to about 5 cm and the sediment oil mixture still had a loose fluffy appearance. The core was still lacking the invertebrate population. The next available cruise was undertaken two months later on February 7, 1970. There was no appreciable change from the appearance of the core taken in December except for an increase in the layer of oxidized material on the surface. Cores taken on March 31, May 1, and June 13, did not change in their oil content although the oil layer seemed to become more compact. The buildup of oxidized surface material above the oil layer acquired in November, and the increased amount of oxidized material on the surface of core taken at stations from the tower out to the basin, suggest that surface sediment was being transported from some other area. The population of burrowing organisms did not appear again during the period of sampling.

Cores taken at Station 1 varied very little throughout the period of study except for the surface, which gradually lost the discrete layer of oxidized material. The core taken in July, 1969, had patches of oxidized material over a 1.5 cm layer of less oxidized material. Stations beyond the tower along the sampling transect changed in the reverse order in that the amount of oxidized material on the surface increased during the period of the study. In all of the cores taken except for the ones by Platform A. there were visible patches of oxidized material throughout the core (maximum depth 35 cm), due to the activity of burrowing organisms. Oil patches began to appear throughout the cores taken at Station 1 and along the transect beyond Platform A after the release of oil noted in November. This condition had decreased but was still present in the cores taken at the end of the study.

Sampling and culture methods

As originally conceived, samples were to be taken near the oil tower. And for purposes of comparison an equal number of samples were to be taken from areas presumed to contain decreasing amounts of oil from the blowout. However, with the amount of ship time available, it was not possible to obtain samples at all stations along the transect during each cruise. Therefore, the number of core samples obtained from each station varied. Ten cores were taken at Stations 1, nearest to shore, and 2, closest to Platform A. The number of samples then decrease with bottom depth along the transect out to the basin. At Stations 4 and 5, eight samples were taken. Six samples were taken at Station 6 and three samples at Station 7. Only one sample was taken at Station 8 and four were taken at Station 9.

Data obtained from plate counts have been tabulated in Tables 1-8. Although the counts from plates incubated at both temperatures tend to fluctuate, those obtained from plates of both media incubated at 18° C are generally higher by an order of magnitude. The results, particularly those obtained from Stations 1 and 2, differ from those obtained during the previous study (Juge, unpubl. diss.) in that the higher counts obtained at 60° C were present on distilled water medium, and at 18° C significantly higher counts were obtained on sea water medium. This reversal is not present in counts from samples taken at Station 3. However, the plates of sea water medium incubated at 60° C produced the highest counts. Plate counts, on both media incubated at both temperatures, from samples taken at Stations 4, 5, 6, 7, and 9, are in the same range and vary very little.

Graphs (Figs. 2-33) were plotted of the results obtained from each of the stations throughout the study, the only exception being those from Station 8 as data from this station were inadequate. Four graphs were made for each station from the counts of plates made of both media incubated at 18° C and 60° C. Plate counts per gram wet weight of sediment were plotted along the _y_ axis and periods of sampling along the _x_ axis.

The graphs of the results obtained at Stations 1 through 3 suggest that there may be some kind of seasonal effect, but it is not possible to interpret this trend with the incomplete data available at this time. This effect does not seem to be present in the graphs of results obtained from the other five stations of the study.

Gas chromatography

Results obtained by gas-liquid chromatography analysis of the preliminary sediment and crude oil samples submitted by Dr. Pomeroy were encouraging. The tabulated report (Table 9), although only roughly quantitative since no correction was made for moisture content, not only supports the suitability of this method for the determination of small quantities of hydrocarbons in marine bottom sediments, but also suggests that patterns may be observed in the presence or absence of certain peaks in the chromatogram from a particular crude oil even after a period of burial in the sediment. Unfortunately this report cannot be confirmed because data from the oil analysis of subsequent samples taken throughout the study have not been received.

Correlation of data

Interpretation of the data contained in this report would necessarily have to take into account two factors capable of significantly affecting the environment during the course of this investigation, the more obvious being the large volume of oil released during the oil spill in January, 1969. The other was the extraordinarily high level of sediment contribution caused by the storms which occurred during the winter months following the oil spill. This was apparent in the thickness of the layer of oxidized material present on the surface of sediment samples obtained with a box corer. This phenomenon may also have influenced the data from Stations 4 through 9, as there were indications of sediment transport to these areas during the latter part of the study. A more detailed description of this process, discussed in the geological report, will be considered in the analysis of bacteriological data. Further discussion of the information acquired in this area of the study is impossible without knowing the oil content of individual sediment samples. Unfortunately these data are not available at the present time. Therefore, this paper will have to be submitted as a preliminary report. It will be followed by a completed report after the necessary data have been obtained.

REFERENCES

Bouma, A. H.
1969 Methods for the study of sedimentary structures. Wiley, New York. 458p.

Emery, K. O., and S. C. Rittenberg
1952 Early diagenesis of California Basin sediments in relation to origin of oil. Amer. Assoc. Petrol. Geol., Bull., 36: 735-806.

Table 1

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)*	Aerobic Bacteria per Gram Wet Weight: 18°C Counts ($x10^3$) Distilled Water	18°C Counts ($x10^3$) Sea Water	60°C Counts ($x10^3$) Distilled Water	60°C Counts ($x10^3$) Sea Water
1	5/30/69	34°21'40" N. 119°29'20" W.	12	0-1	78.50	84.00	13.00	7.50
				1-1.5	140.00	100.00	70.00	11.50
				19-20	215.00	200.00	70.00	19.00
1	6/27/69	34°22'00" N. 119°29'10" W.	12	0-.75	310.00	940.00	70.00	11.50
				.75-1.75	320.00	310.00	31.00	11.50
				19-20	208.00	295.00	40.00	42.00
1	7/24/69	34°21'30" N. 119°29'20" W.	12	0-1	103.00	420.00	2.70	5.30
				2-3	95.50	91.00	7.80	5.60
				24-25	91.50	98.00	3.20	2.90
1	10/16/69	34°21'30" N. 119°29'20" W.	12	0-1	98.00	205.00	7.00	11.00
				2-3	118.00	111.00	6.00	5.00
				23-24	137.00	141.00	6.00	6.40
1	11/11/69	34°21'40" N. 119°29'20" W.	12.5	0-1	124.50	730.00	10.00	5.30
				3-4	255.00	135.00	13.00	10.00
				25-26	170.00	180.00	12.00	4.80
1	12/8/69	34°21'30" N. 119°29'15" W.	12	0-.5	175.00	370.00	6.20	5.50
				1.5-2.5	475.00	415.00	20.00	32.00
				16.5-17.5	270.00	155.00	5.00	7.00

Table 1--Continued

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)*	Aerobic Bacteria per Gram Wet Weight: 18°C Counts (x10^3) Distilled Water	18°C Counts (x10^3) Sea Water	60°C Counts (x10^3) Distilled Water	60°C Counts (x10^3) Sea Water
1	2/7/70	34°21'40" N. 119°29'15" W.	14	0-.5	57.50	181.00	2.10	3.20
				2-3	110.50	155.00	47.00	27.00
				13-14	101.50	118.00	2.80	2.40
1	4/1/70	34°21'40" N. 119°29'20" W.	12	0-.5	99.50	180.00	6.10	7.30
				1-2	177.00	191.00	9.80	12.10
				14-15	188.50	150.00	6.90	5 65
1	4/30/70	34°21'40" N. 119°29'20" W.	12	0-1	221.00	330.50	4.95	4.35
				2-3	168.00	152.50	7.90	9.25
				18-18	82.00	118.00	8.15	5.45
1	6/13/70	34°21'30" N. 119°29'15" W.	12	0-.5	91.00	2100.00	22.00	8.00
				1-2	310.00	510.00	25.00	18.00
				15-16	133.00	176.50	22.00	14.00

*Sample depths refer to levels a, b, and c on all graphs.

Table 2

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)	Aerobic Bacteria per Gram Wet Weight			
					18°C Counts ($x10^3$)		60°C Counts ($x10^3$)	
					Distilled Water	Sea Water	Distilled Water	Sea Water
2	5/27/69	34°14'52" N. 119°36'30" W.	30	0-1 1.5-2.5 15-16	860.00 149.00 64.00	1071.00 156.00 53.00	175.00 20.00 13.00	165.00 12.50 10.50
2	6/27/69	34°20'30" N. 119°36'30" W.	28	0-.75 .75-1.75 16-17	1135.00 770.00 76.00	1100.00 1215.00 65.00	60.00 70.00 15.50	120.00 45.00 9.50
2	7/24/69	34°20'15" N. 119°36'30" W.	30	0-.75 .75-1.75 11-12	815.00 385.00 86.00	148.50 195.00 70.00	85.00 155.00 75.00	63.00 280.00 21.00
2	10/16/69	34°15'52" N. 119°36'30" W.	30	0-1 1-2 11-12	131.50 55.50 26.00	261.50 90.50 71.00	25.00 2.00 2.65	34.50 4.10 1.15
2	11/11/69	34°19'52" N. 119°36'30" W.	27.5	0-1 3.5-4.5 21-22	365.00 170.00 81.50	670.00 108.00 65.50	10.70 7.00 6.00	20.00 3.50 3.00
2	12/8/69	34°20'30" N. 119°36'30" W.	28	0-.25 1-2 14-15	340.00 105.00 54.00	460.00 76.00 38.00	22.00 2.30 2.00	5.50 1.50 1.60

Table 2--Continued

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)	Aerobic Bacteria per Gram Wet Weight: 18°C Counts ($x10^3$) Distilled Water	18°C Counts ($x10^3$) Sea Water	60°C Counts ($x10^3$) Distilled Water	60°C Counts ($x10^3$) Sea Water
2	2/7/70	34°20'15" N. 119°36'40" W.	27	0-.5 1-1.5 13-14	480.00 96.50 62.00	820.00 85.00 48.00	74.00 4.40 4.10	23.00 2.70 2.00
2	3/31/70	34°20'02" N. 119°36'30" W.	30	0-.5 2-3 10-11	216.00 113.00 103.50	273.00 81.00 86.50	12.30 3.10 3.70	11.30 2.35 2.30
2	5/1/70	34°19'52" N. 119°26'30" W.	28	0-.25 2-3 15-16	181.00 108.50 78.50	299.00 92.50 81.50	12.30 4.40 5.25	8.95 3.25 3.15
2	6/13/70	34°19'52" N. 119°36'30" W.	28	0-.5 1-2 15-16	390.00 87.00 38.50	1535.00 82.00 395.00	23.00 4.00 1.20	23.00 2.40 1.30

Table 3

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)	Aerobic Bacteria per Gram Wet Weight: $18^{\circ}C$ Counts ($x10^3$) Distilled Water	$18^{\circ}C$ Counts ($x10^3$) Sea Water	$60^{\circ}C$ Counts ($x10^3$) Distilled Water	$60^{\circ}C$ Counts ($x10^3$) Sea Water
3	7/24/69	34°19'31" N. 119°38'59" W.	37	0-.75 1.5-2.5 19-20	177.50 145.00 49.00	124.50 130.50 27.50	220.00 21.00 12.00	180.00 13 00 4.00
3	10/16/69	34°19'31" N. 119°38'56" W.	38	0-1 1.5-2.5 14-15	62.00 62.50 14.00	109.00 93.50 31.65	7.95 5.55 2.50	10.00 5.25 2.15
3	11/11/69	34°19'31" N. 119°38'59" W.	38	0-.5 2-3 21-22	175.00 125.00 24.50	245.00 82.50 12.50	5.20 7.50 2.00	16.00 4.50 0.75
3	12/8/69	34°19'31" N. 119°38'59" W.	38	0-.5 1-2 14-15	210.00 150.00 44.00	245.00 120.50 31.50	3.50 7.00 2.40	9.00 2.80 1.50
3	2/8/70	34°19'30" N. 119°38'59" W.	36	0-1 1-2 20-21	119.00 120.50 44.50	201.50 88.00 47.50	13.50 7.50 1.00	13.00 8.00 1.80
3	4/1/70	34°20'00" N. 119°39'00" W.	38	0-.5 1-2 10-11	156.00 107.00 82.00	179.50 102.00 64.00	8.20 4.70 2.50	9.80 5.10 3.10

Table 3--Continued

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)	Aerobic Bacteria per Gram Wet Weight: 18°C Counts ($x10^3$) Distilled Water	18°C Counts ($x10^3$) Sea Water	60°C Counts ($x10^3$) Distilled Water	60°C Counts ($x10^3$) Sea Water
3	5/1/70	34°19'30" N. 119°38'58" W.	38	0-.5	168.50	204.00	7.30	10.20
				2-3	157.00	149.00	4.30	5.45
				17-18	54.00	44.50	4.75	2.45
3	6/13/70	34°19'31" N. 119°38'59" W.	38	0-.5	485.00	465.00	2.50	14.00
				1-2	122.00	152.00	13.00	7.00
				15-16	69.50	64.50	6.60	0.75

Table 4

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)	Aerobic Bacteria per Gram Wet Weight: 18°C Counts ($x10^3$) Distilled Water	18°C Counts ($x10^3$) Sea Water	60°C Counts ($x10^3$) Distilled Water	60°C Counts ($x10^3$) Sea Water
4	7/26/69	34°20'00" N. 119°41'30" W.	40	0-.5	186.50	58.50	20.00	15.00
				4-5	95.50	67.50	2.50	2.30
				11-12	80.50	64.00	6.90	3.70
4	10/16/69	34°20'00" N. 119°41'30" W.	40	0-.5	30.50	90.00	2.45	15.00
				2-3	48.00	71.00	1.15	3.50
				15-16	48.00	48.00	9.00	2.60
4	11/11/69	34°20'00" N. 119°41'30" W.	38	0-1	78.00	250.00	8.50	4.00
				1.5-2.5	250.00	215.00	14.00	15.50
				11-12	26.50	50.00	2.50	2.40
4	12/8/69	34°20'00" N. 119°41'30" W.	38	0-.5	102.00	105.50	-	-
				1-2	125.00	121.00	6.00	13.00
				10-11	56.00	47.50	2.50	1.30
4	2/8/70	34°20'00" N. 119°41'30" W.	40	0-1	166.50	163.50	10.00	9.00
				2-3	95.50	90.50	10.00	7.50
				14-15	41.50	29.00	2.00	1.70
4	4/1/70	38°20'00" N. 119°41'30" W.	40	0-.5	82.00	99.50	8.50	5.90
				1-2	125.00	119.00	8.50	5.90
				10-11	109.50	79.00	3.00	3.85

Table 4--Continued

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)	Aerobic Bacteria per Gram Wet Weight			
					18^oC Counts $(x10^3)$		60^oC Counts $(x10^3)$	
					Distilled Water	Sea Water	Distilled Water	Sea Water
4	5/1/70	34°20'00" N. 119°41'29" W.	39	0-.5	77.00	192.00	6.60	7.15
				2-3	127.00	101.00	7.70	5.70
				17-18	118.00	73.50	4.75	3.80
4	6/13/70	34°20'00" N. 119°41'30" W.	40	0-.5	93.00	115.00	11.50	14.00
				1-2	88.00	114.00	3.05	5.25
				15-16	37.00	29.50	2.60	1.25

Table 5

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)	Aerobic Bacteria per Gram Wet Weight: 18°C Counts ($x10^3$) Distilled Water	18°C Counts ($x10^3$) Sea Water	60°C Counts ($x10^3$) Distilled Water	60°C Counts ($x10^3$) Sea Water
5	11/11/69	34°19'00" N. 119°42'07" W.	47	0-.15 2-3 16-17	205.00 115.00 22.00	210.00 150.00 20.50	13.00 6.00 1.50	12.00 4.25 0.80
5	12/8/69	34°19'00" N. 119°42'00" W.	50	0-.5 1-2 13-14	245.00 129.00 20.00	240.00 110.50 12.00	10.00 13.00 2.10	12.00 9.00 1.30
5	2/8/70	34°19'00" N. 119°42'07" W.	47	0-.75 1-2 19-20	185.50 136.00 28.00	214.50 91.00 27.50	13.00 7.00 7.00	15.00 7.50 1.00
5	4/1/70	34°19'00" N. 119°42'07" W.	47	0-.75 1-2 10-11	177.50 127.00 38.50	209.50 138.50 41.00	15.00 12.50 2.50	7.05 6.70 1.55
5	5/1/70	34°19'00" N. 119°42'00" W.	54	0-.75 2-3 20-21	175.50 146.50 102.00	218.50 109.00 85.00	9.50 7.80 1.40	9.00 6.10 0.40
5	6/13/70	34°19'05" N. 119°42'00" W.	50	0-.5 1-2 16-17	129.50 136.50 31.50	141.00 157.50 32.50	12.50 12.00 3.70	13.00 12.50 0.60

Table 6

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)	Aerobic Bacteria per Gram Wet Weight: 18°C Counts ($x10^3$) Distilled Water	18°C Counts ($x10^3$) Sea Water	60°C Counts ($x10^3$) Distilled Water	60°C Counts ($x10^3$) Sea Water
6	11/12/69	34°18'25" N. 119°44'30" W.	110	0-.75	340.00	385.00	14.50	22.00
				1.5-2.5	345.00	280.00	22.00	8.00
				22-23	55.5	97.00	12.00	2.50
6	2/8/70	34°18'25" N. 119°44'30" W.	110	0-.75	169.50	215.00	21.00	9.00
				2-3	143.50	156.50	3.60	3.50
				29-30	88.50	56.50	10.00	2.70
6	4/1/70	34°18'25" N. 119°44'30" W.	105	0-.75	171.50	206.00	13.50	10.50
				1-2	141.00	153.50	12.00	8.90
				10-11	132.00	115.00	9.00	3.25
6	5/1/70	34°18'25" N. 119°44'30" W.	102	0-.75	197.50	232.00	9.50	6.05
				2-3	199.00	173.00	7.85	7.45
				19-20	91.00	71.00	5.30	3.55
6	6/13/70	34°18'30" N. 119°44'30" W.	90	0-.5	154.50	258.50	19.00	14.50
				1.5-2.5	132.50	162.50	13.40	11.50
				16-17	144.00	163.00	6.55	6.35

Table 7

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)	Aerobic Bacteria per Gram Wet Weight: 18°C Counts ($x10^3$) Distilled Water	18°C Counts ($x10^3$) Sea Water	60°C Counts ($x10^3$) Distilled Water	60°C Counts ($x10^3$) Sea Water
7	11/12/69	34°16'50" N. 119°51'00" W.	220	0-.5	240.00	225.00	13.00	20.00
				2-3	190.00	150.00	6.00	13.00
				32-33	56.00	73.50	5.00	3.20
7	2/8/70	34°17'15" N. 119°51'20" W.	210	0-.5	183.00	192.00	14.00	20.00
				1-2	120.50	131.00	11.00	10.00
				14-15	109.00	106.00	9.50	7.50
7	6/13/70	34°17'10" N. 119°51'25" W.	200	0-1	290.00	440.00	14.50	15.50
				1.5-2.5	129.00	154.00	11.00	5.10
				15-16	133.00	130.50	12.50	3.00
8	11/12/69	34°15'45" N. 119°56'10" W.	287	0-1	250.00	250.00	13.50	7.80
				-	-	-	-	-
				-	-	-	-	-

Table 8

Sta.	Date	Latitude and Longitude	Water Depth (fms)	Sample Depth (cm)	Aerobic Bacteria per Gram Wet Weight: 18°C Counts ($x10^3$) Distilled Water	18°C Counts ($x10^3$) Sea Water	60°C Counts ($x10^3$) Distilled Water	60°C Counts ($x10^3$) Sea Water
9	5/28/69	34°15'00" N. 120°07'23" W.	300	0-1	130.00	175.00	16.50	13.50
				9-10	170.00	225.00	80.00	17.50
				29-30	190.00	225.00	15.00	1.85
9	11/12/69	34°15'00" N. 120°02'25" W.	312	0-1	50.00	50.00	20.00	27.00
				-	-	-	-	-
				-	-	-	-	-
9	2/7/70	34°15'25" N. 119°59 20" W.	310	0-.5	320.00	840.00	32.00	13.50
				4-5	171.00	142.00	17.00	15.00
				-	-	-	-	-
9	3/31/70	34°16'00" N. 119°57'15" W.	295	0-.5	209.00	292.50	10.75	13.20
				3-4	165.00	164.00	4.85	5.55
				-	-	-	-	-

Table 9

Trace Amounts of Hydrocarbons in Marine Bottom Sediments, mg/kg

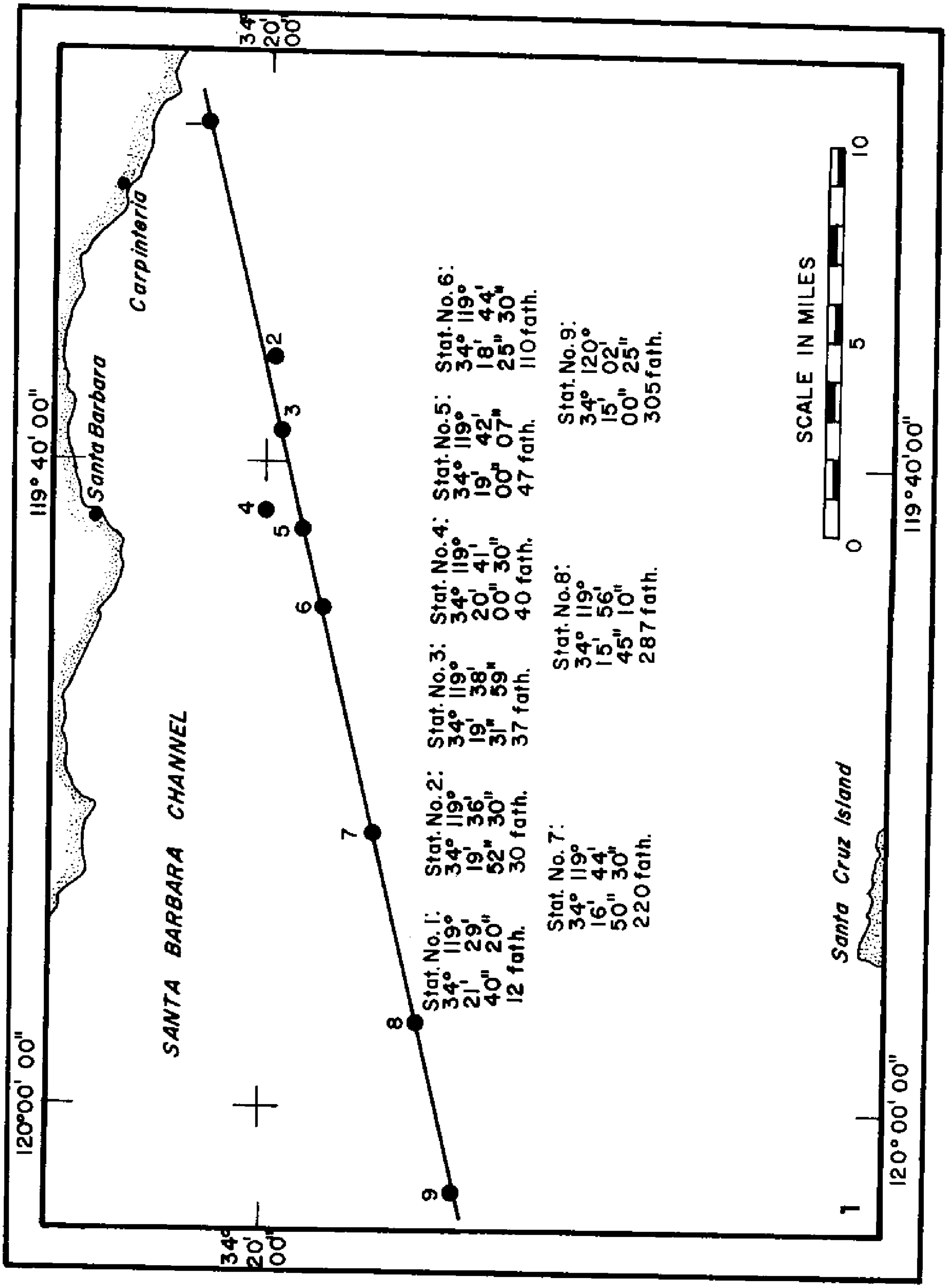
RRT[1]	Compounds Hypothesized as Hydrocarbons	I-1-A	I-1-B	I-1-C	I-2-A	I-2-B	I-2-C	II-1-A[2]	II-1-B	II-1-C	Crude Oil[3]
0.45	iso Pentane	1.3	-	0.9	-	-	-	-	2.3	-	3,300
0.47	n Pentane	-	-	0.7	-	-	-	-	3.5	-	6,700
0.53	2 Methylpentane	-	7.4	1.4	-	-	-	-	-	-	-
0.55	2,2 Dimethylbutane	-	-	-	-	-	-	-	-	-	3,400
0.57	Solvent (CS_2)										
0.61	n Hexane	10	-	-	-	-	4.2	-	-	4.6	14,400
0.69	2,4 Dimethylpentane	-	-	-	-	-	-	1.9	0.5	-	-
0.80	2,2,4 Trimethylpentane	-	8.5	-	-	6.3	-	-	0.3	-	-
0.86	Cyclohexane	28.6	37.4	-	-	-	-	-	0.3	-	440
0.90	n Heptane	-	-	-	-	-	-	-	-	-	7,600
1.00	Benzene	10.4	12.2	0.9	0.3	-	-	1.5	1.8	-	5,000
1.08	Unidentified	-	50.8	-	-	-	-	-	-	-	7,500
1.14	Unidentified	-	52.5	-	-	-	-	-	-	-	200
1.18	2,3,4 Trimethylpentane	4.3	-	0.5	-	-	-	0.3	1.1	-	-
1.23	2,2,5 Trimethylhexane	7.4	-	-	-	-	-	-	-	-	-
1.26	3 Methylheptane	-	-	-	-	-	-	-	-	-	-
1.43	n Octane	4.8	34.8	-	-	-	-	-	-	-	2,640
1.65	Toluene	7.8	15.5	0.7	-	-	-	0.4	1.9	-	14,600
1.90	Unidentified	-	47.5	-	-	-	-	-	-	-	5,300
2.37	n Nonane	-	14.1	-	-	-	-	-	-	-	660
2.55	Unidentified	-	20.8	-	-	-	-	-	-	-	900
2.80	Ethylbenzene	0.5	-	0.3	-	-	-	0.2	0.5	-	-
2.92	Unidentified	-	8.2	-	-	-	-	-	-	-	1,100
2.98	Unidentified	-	8.2	-	-	-	-	-	-	-	-
3.36	p Xylene	-	25.2	-	-	-	-	-	0.2	-	1,120
3.86	Cumene	-	12.6	-	-	-	-	-	-	-	-
3.94	Unidentified	-	-	-	-	-	-	-	-	-	6,000
4.32	n Decane	-	12.9	-	-	-	-	-	-	-	550
4.74	Unidentified	-	2.2	-	-	-	-	-	-	-	-
5.04	Mesitylene	-	0.8	-	-	-	-	-	-	-	-
6.49	Unidentified	-	1.3	-	-	-	-	-	-	-	-
6.82	p Cymene	-	-	-	-	-	-	-	-	-	-
7.82	Unidentified	-	4.4	-	-	-	-	-	-	-	-
N/A	Pristane ($C_{19}H_{40}$) (determined on extract)	-	-	-	-	-	-	-	-	-	9,200

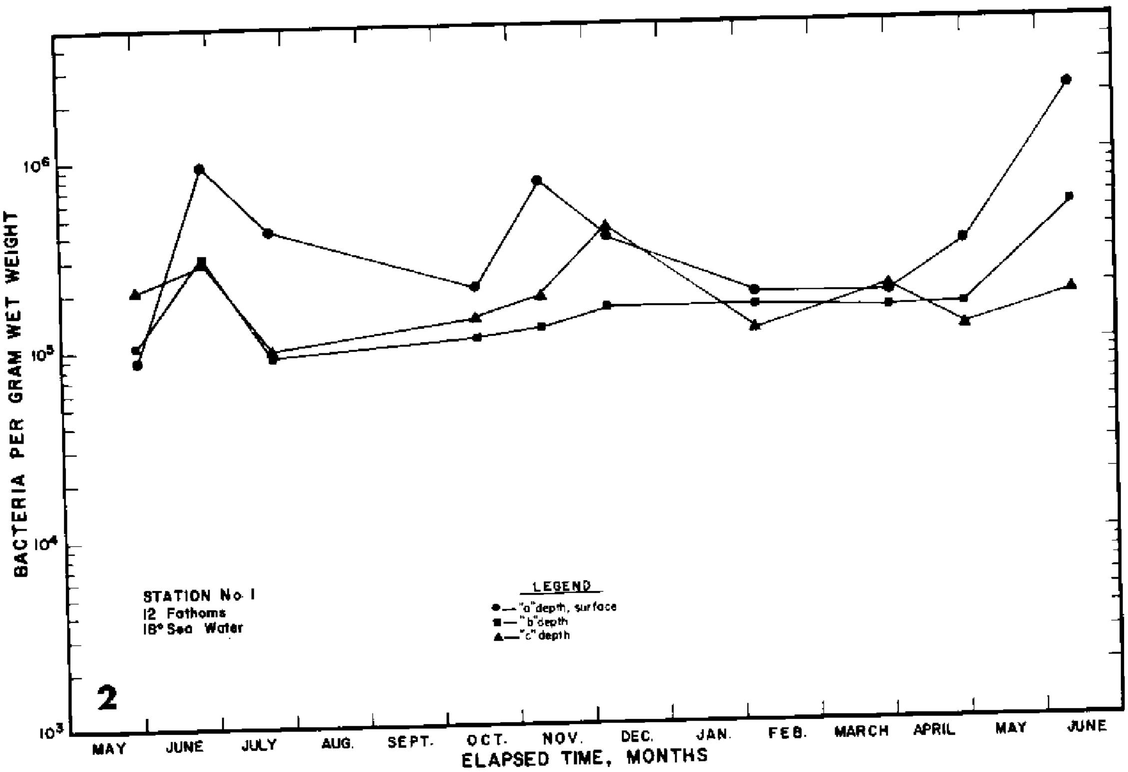
[1] Relative retention time.

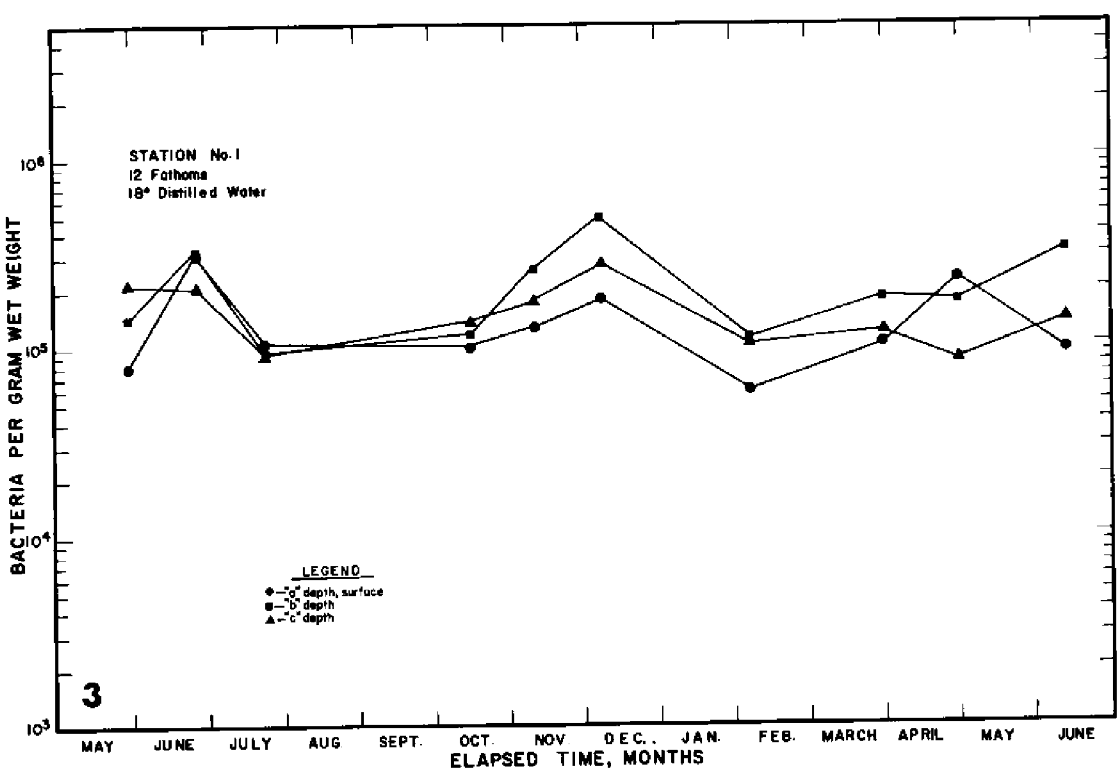
[2] Identified as "II-1-A Sister's Cruise." Samples from study carried out between 1965 and 1968.

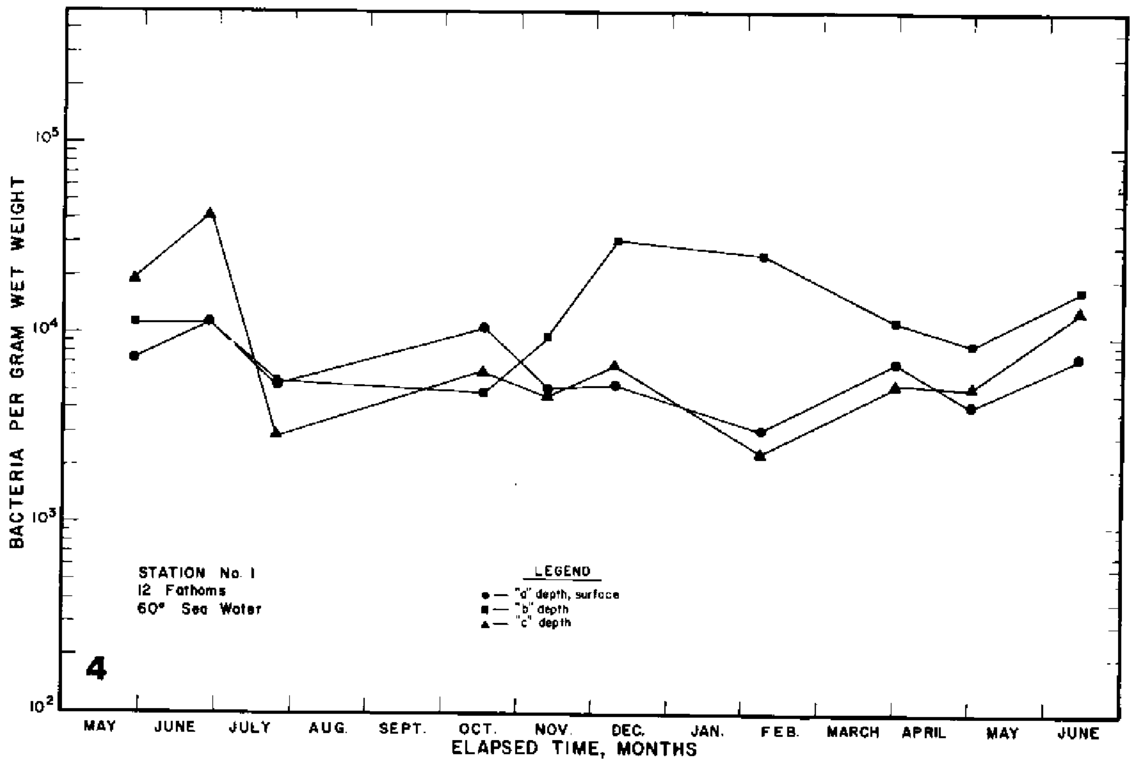
[3] Crude oil from Union Oil Tower A; results in mg/l.

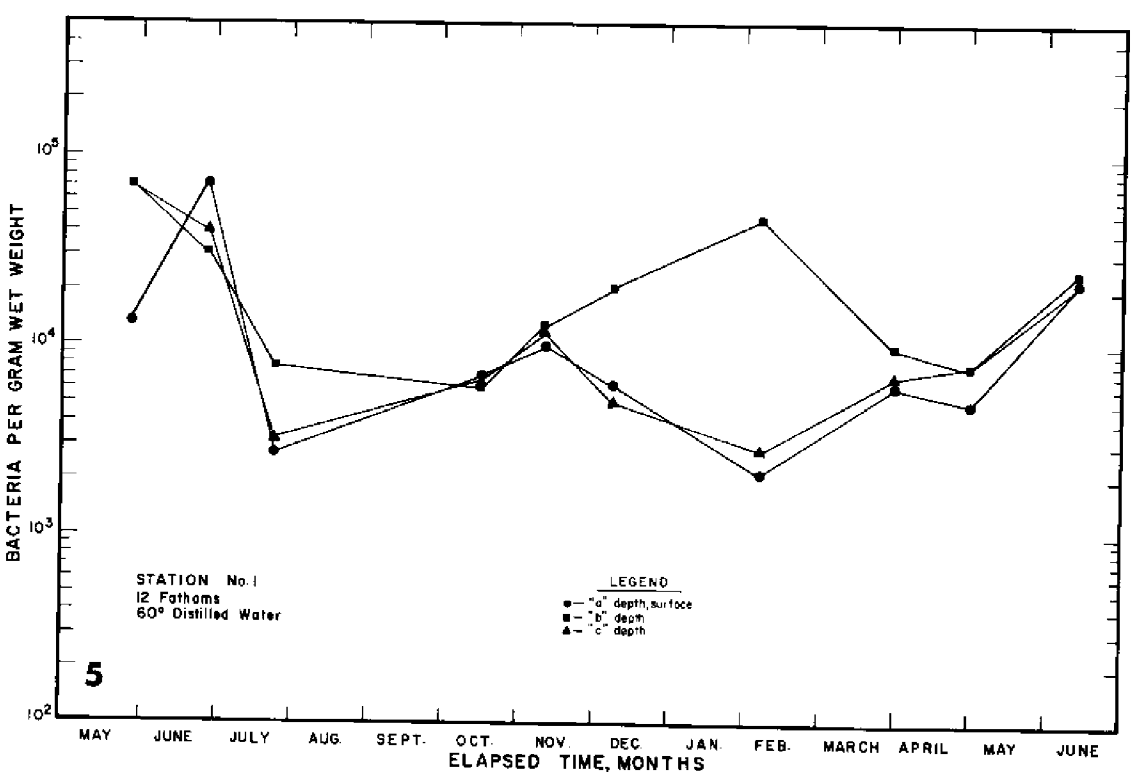
ILLUSTRATIONS

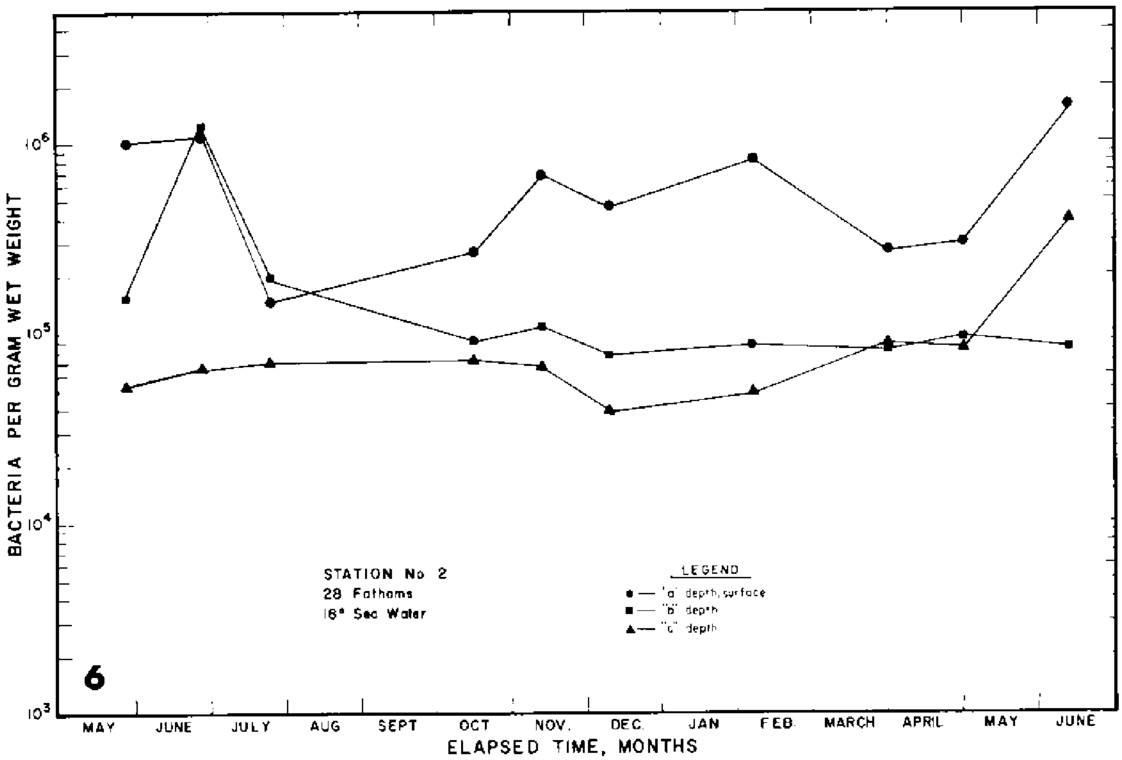

SANTA BARBARA CHANNEL
Santa Barbara
Carpinteria
Santa Cruz Island
119° 40' 00"
120°00' 00"
34° 20' 00"
SCALE IN MILES
0
5
10
1
2
3
4
5
6
7
8
9
Stat. No. 1: 34° 119° 21' 29' 40" 20" 12 fath.
Stat. No. 2: 34° 119° 19' 36' 52" 30" 30 fath.
Stat. No. 3: 34° 119° 19' 38' 31" 59" 37 fath.
Stat. No. 4: 34° 119° 20' 41' 00" 30" 40 fath.
Stat. No. 5: 34° 119° 19' 42' 00" 07" 47 fath.
Stat. No. 6: 34° 119° 18' 44' 25" 30" 110 fath.
Stat. No. 7: 34° 119° 16' 44' 50" 30" 220 fath.
Stat. No. 8: 34° 119° 15' 56' 45" 10" 287 fath.
Stat. No. 9: 34° 120° 15' 02' 00" 25" 305 fath.

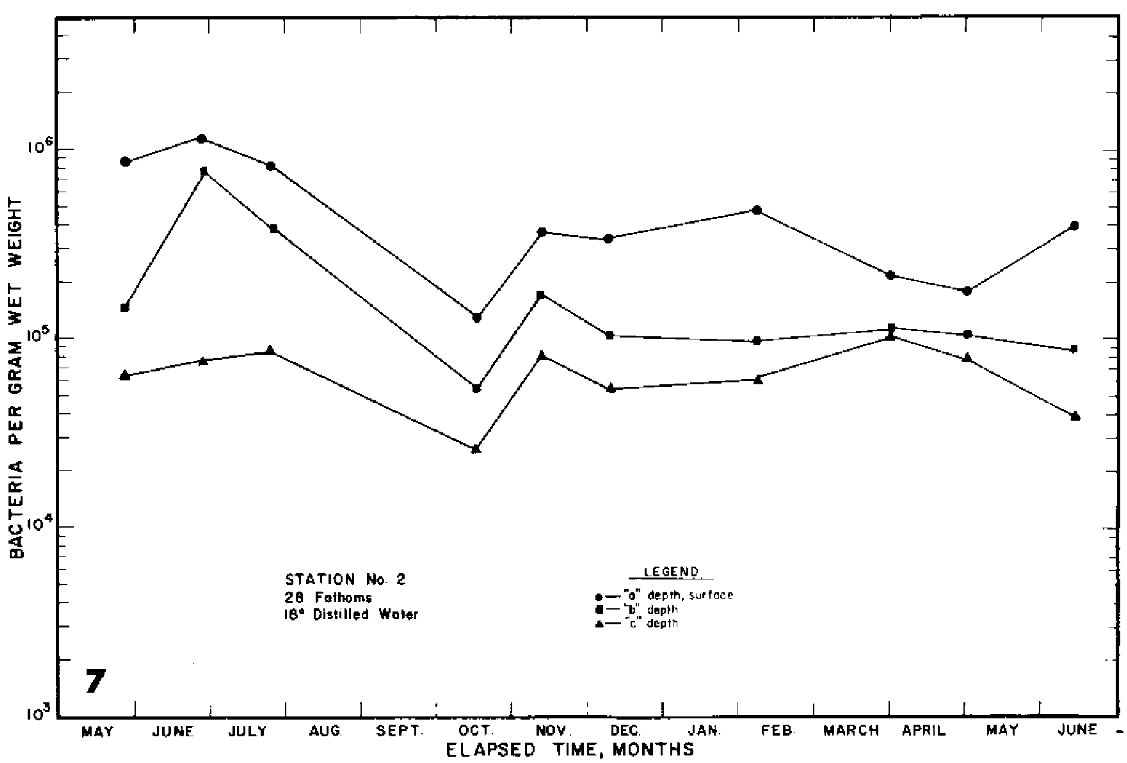

BACTERIA PER GRAM WET WEIGHT
10^6
10^5
10^4
10^3
STATION No. I
12 Fathoms
18° Sea Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
2
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

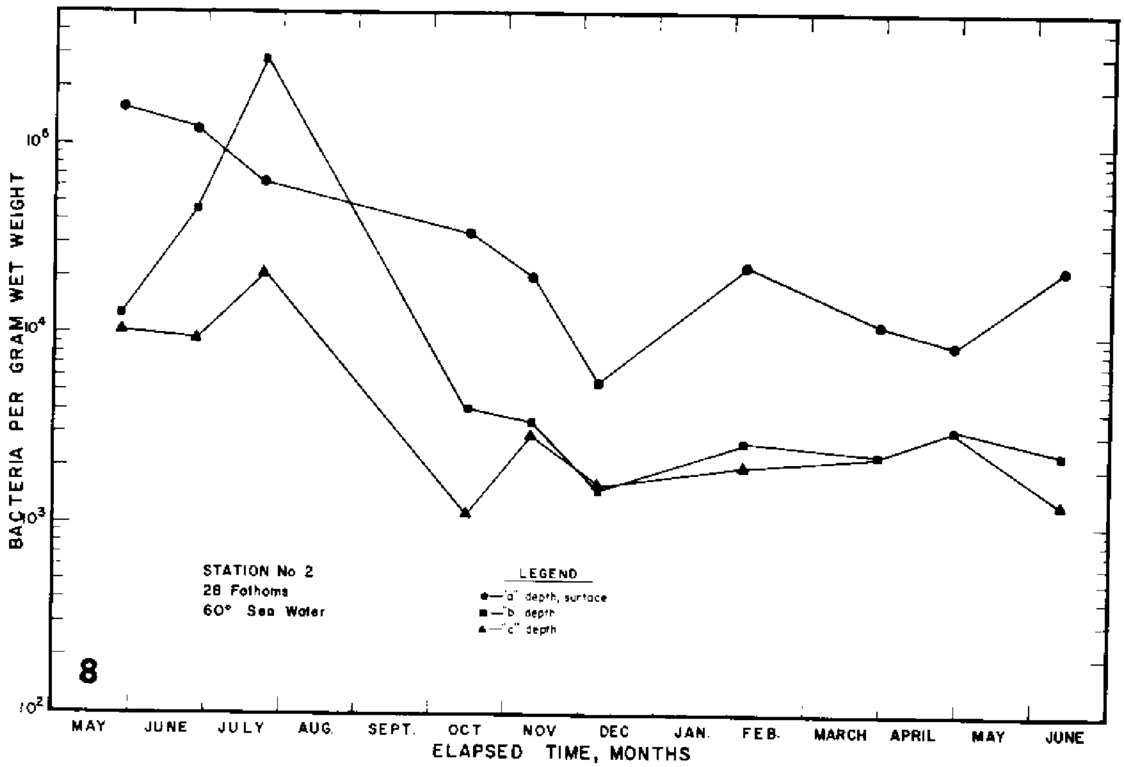

BACTERIA PER GRAM WET WEIGHT
10^6
10^5
10^4
10^3
STATION No. I
12 Fathoms
18° Distilled Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
3
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

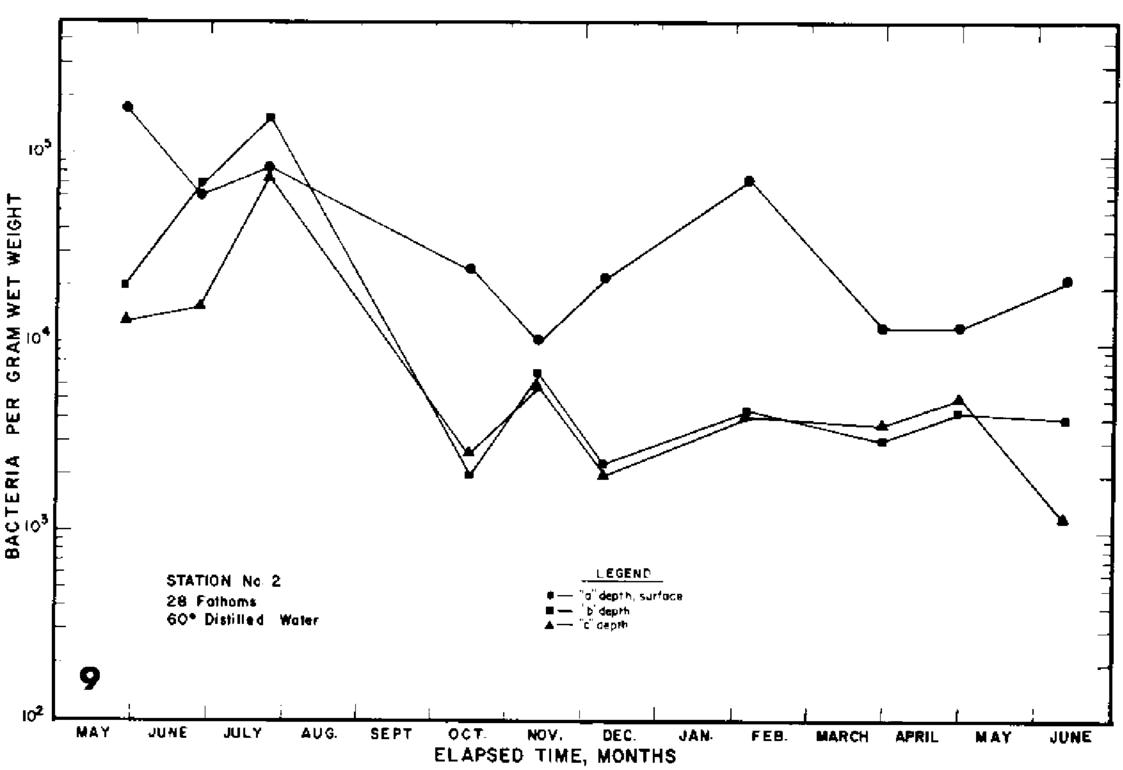

BACTERIA PER GRAM WET WEIGHT
10⁵
10⁴
10³
10²
STATION No. 1
12 Fathoms
60° Sea Water
LEGEND
● — "a" depth, surface
■ — "b" depth
▲ — "c" depth
4
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

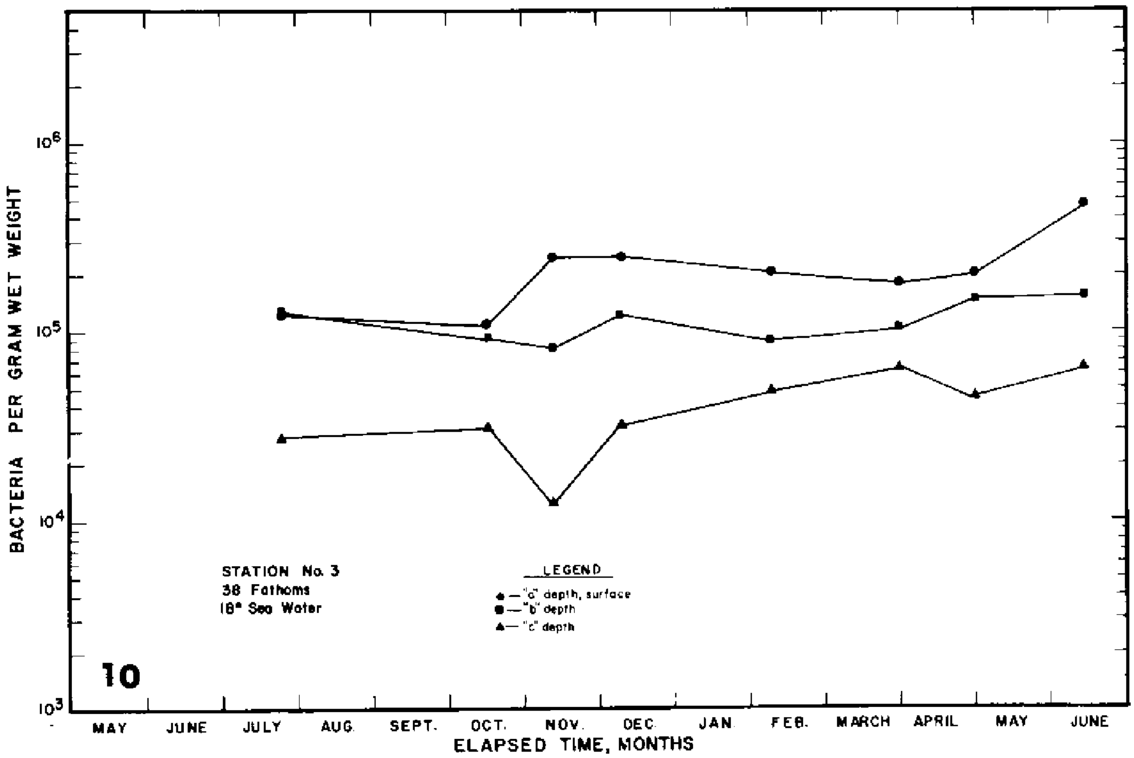

BACTERIA PER GRAM WET WEIGHT
10⁵
10⁴
10³
10²
STATION No. 1
12 Fathoms
60° Distilled Water
LEGEND
● — "a" depth, surface
■ — "b" depth
▲ — "c" depth
5
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

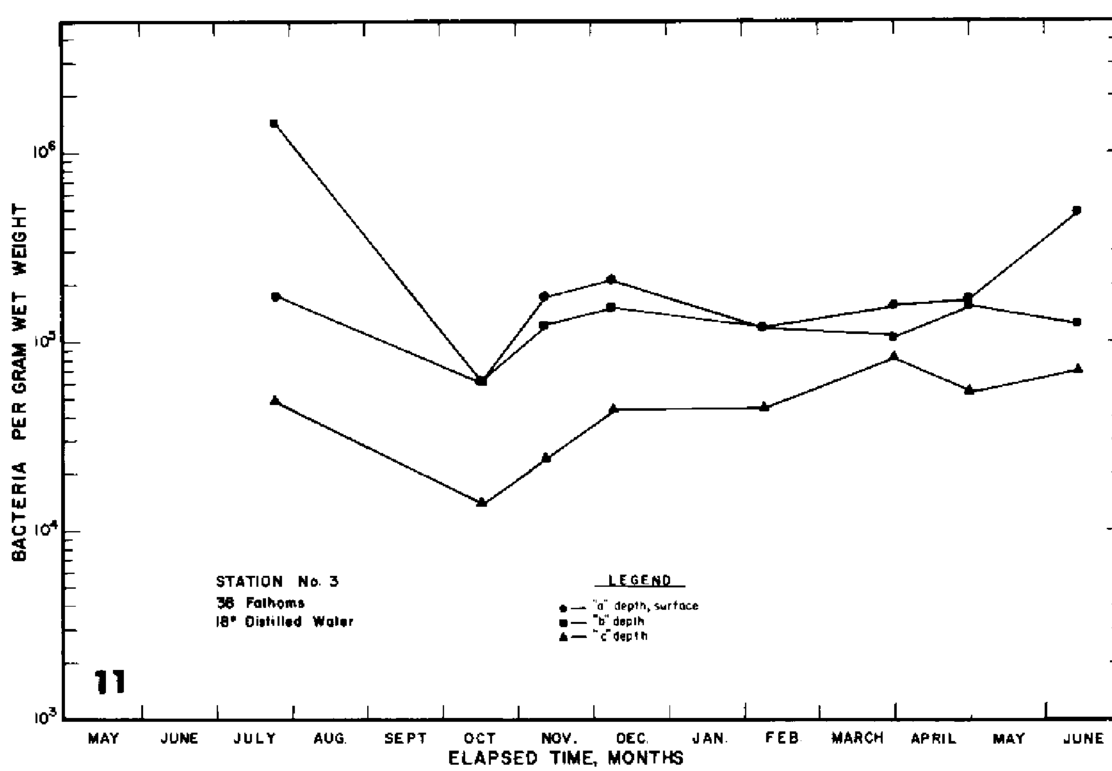

10^6
10^5
10^4
10^3
BACTERIA PER GRAM WET WEIGHT
STATION No 2
28 Fathoms
16° Sea Water
LEGEND
● — "a" depth, surface
■ — "b" depth
▲ — "c" depth
6
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV.
DEC.
JAN
FEB
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

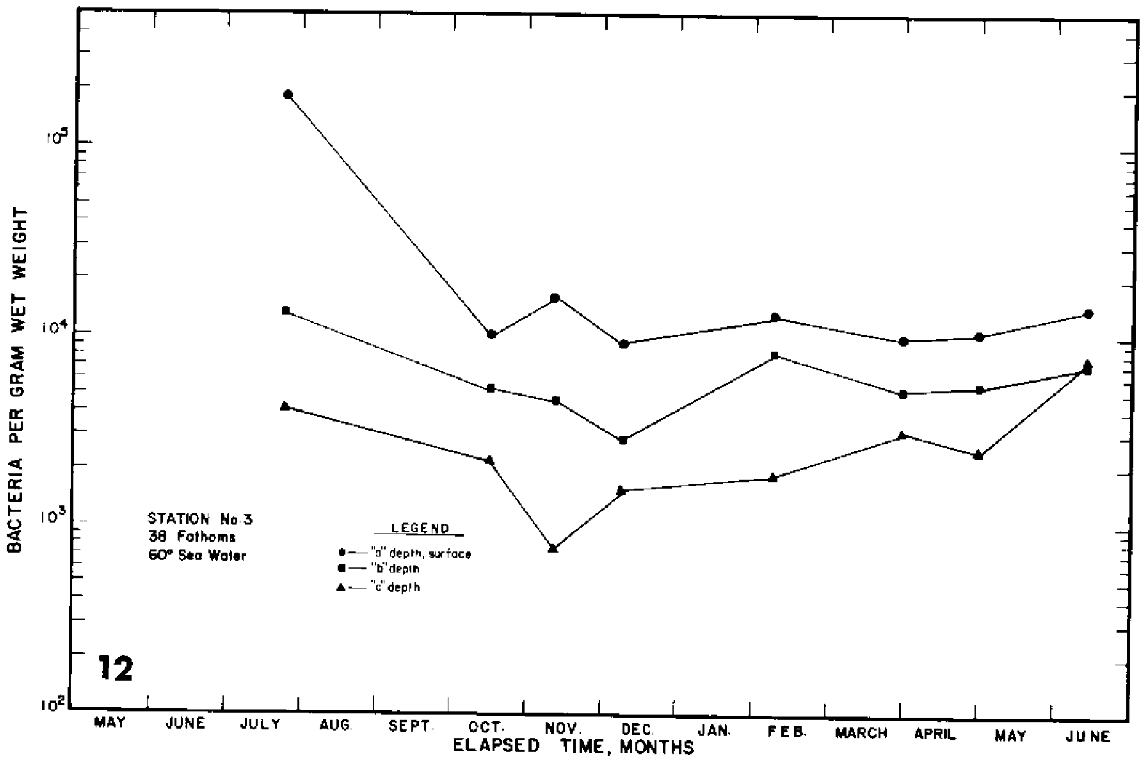

10^6
10^5
10^4
10^3
BACTERIA PER GRAM WET WEIGHT
STATION No. 2
28 Fathoms
16° Distilled Water
LEGEND
● — "a" depth, surface
■ — "b" depth
▲ — "c" depth
7
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

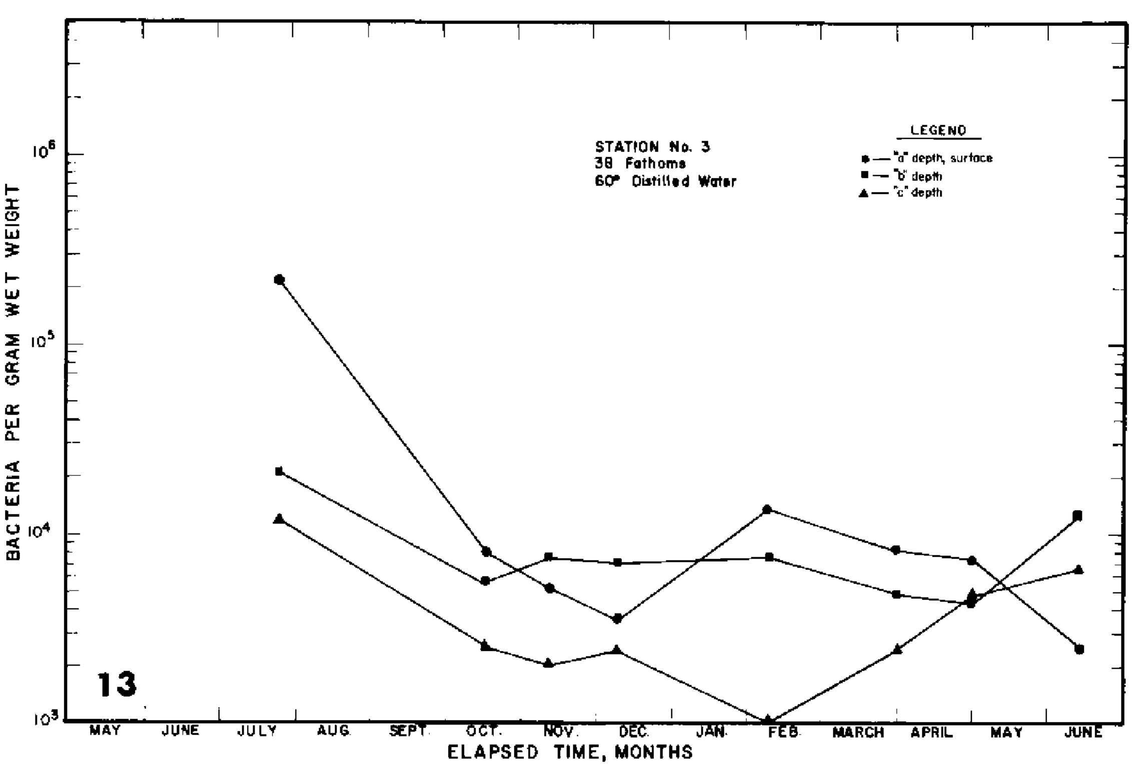

BACTERIA PER GRAM WET WEIGHT
10⁵
10⁴
10³
10²
STATION No 2
28 Fathoms
60° Sea Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
8
MAY
JUNE
JULY
AUG.
SEPT.
OCT
NOV
DEC
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

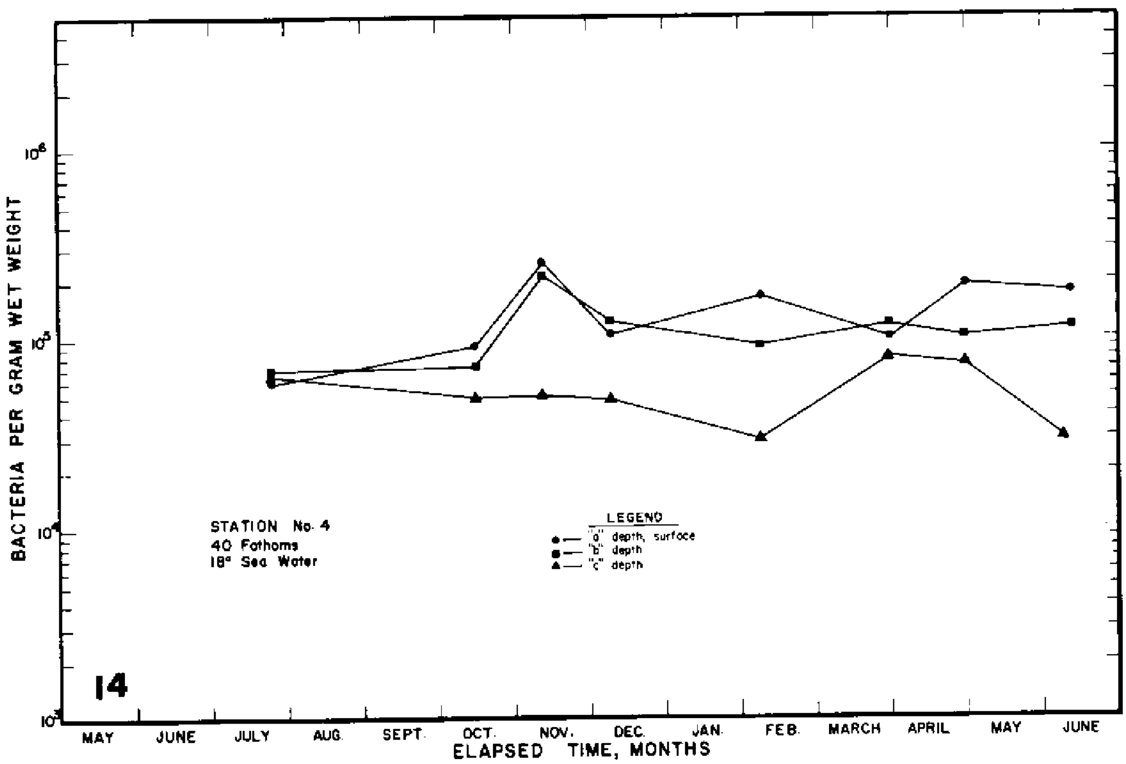

BACTERIA PER GRAM WET WEIGHT
10⁵
10⁴
10³
10²
STATION No 2
28 Fathoms
60° Distilled Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
9
MAY
JUNE
JULY
AUG.
SEPT
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

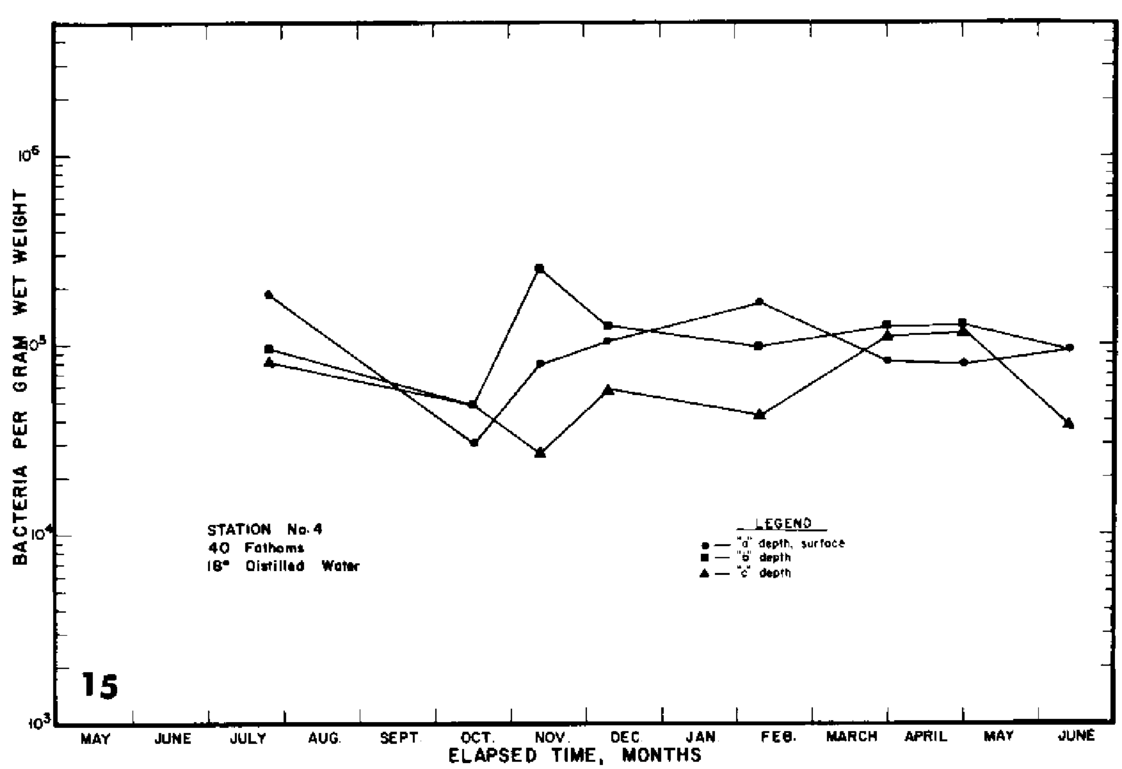

10
10^6
10^5
10^4
10^3
BACTERIA PER GRAM WET WEIGHT
STATION No. 3
38 Fathoms
18° Sea Water
LEGEND
"c" depth, surface
"b" depth
"c" depth
MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MARCH APRIL MAY JUNE
ELAPSED TIME, MONTHS

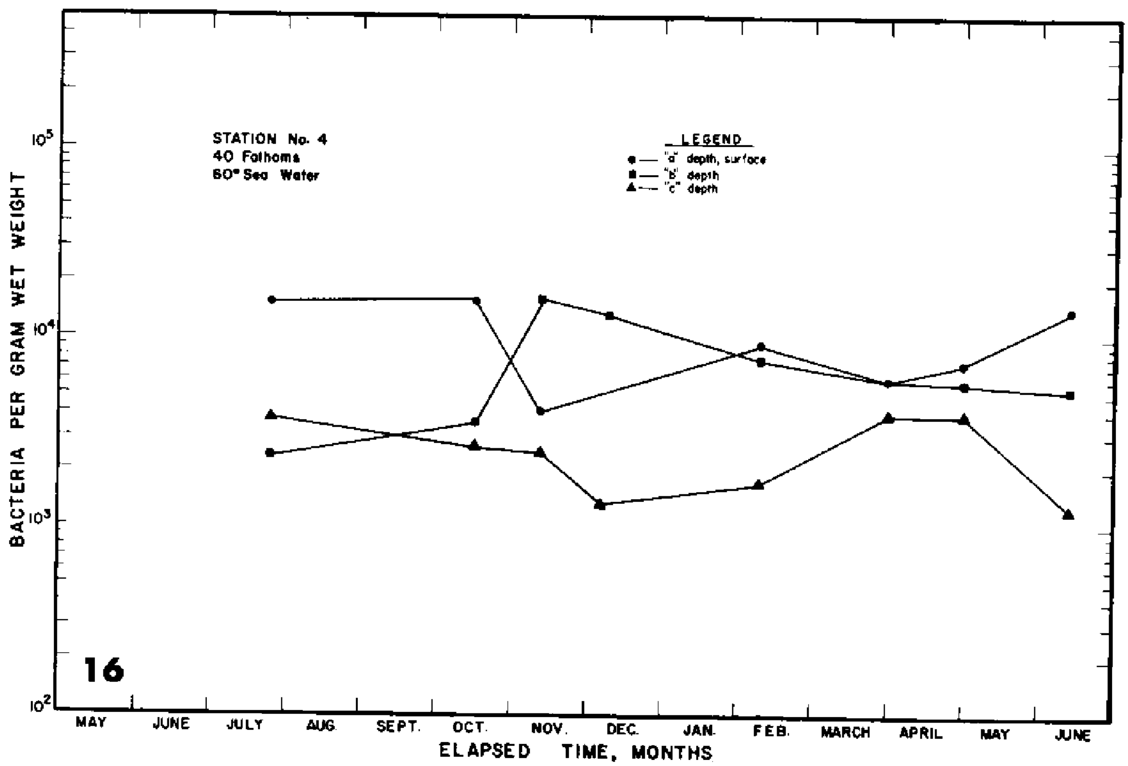

11
10^6
10^5
10^4
10^3
BACTERIA PER GRAM WET WEIGHT
STATION No. 3
38 Fathoms
18° Distilled Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MARCH APRIL MAY JUNE
ELAPSED TIME, MONTHS

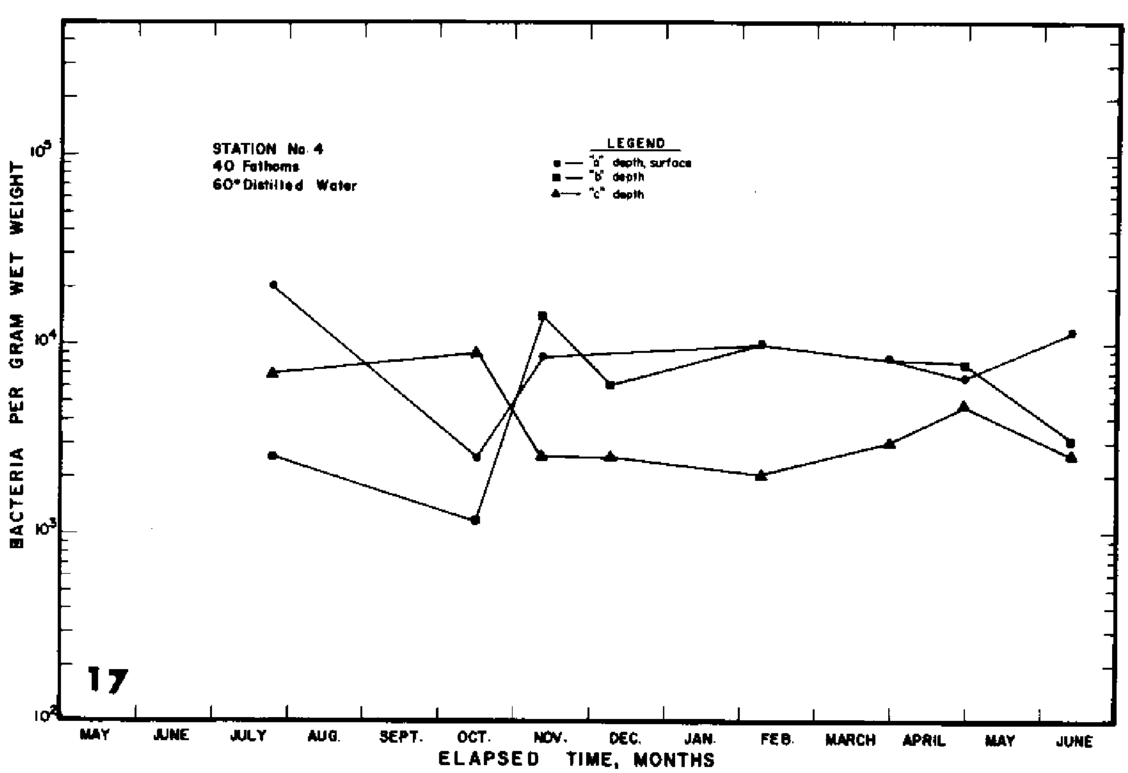

BACTERIA PER GRAM WET WEIGHT
STATION No. 3
38 Fathoms
60° Sea Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
12
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

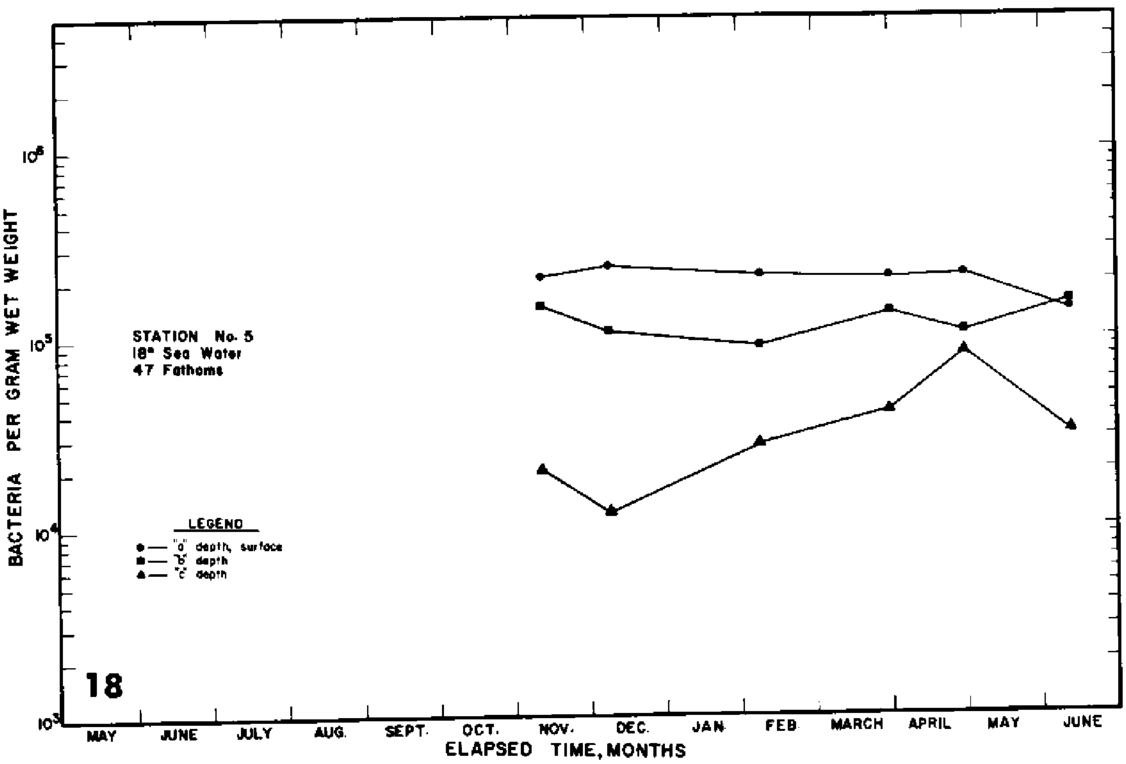

BACTERIA PER GRAM WET WEIGHT
STATION No. 3
38 Fathoms
60° Distilled Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
13
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS


14
STATION No. 4
40 Fathoms
18° Sea Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
BACTERIA PER GRAM WET WEIGHT
10³
10⁴
10⁵
10⁶
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

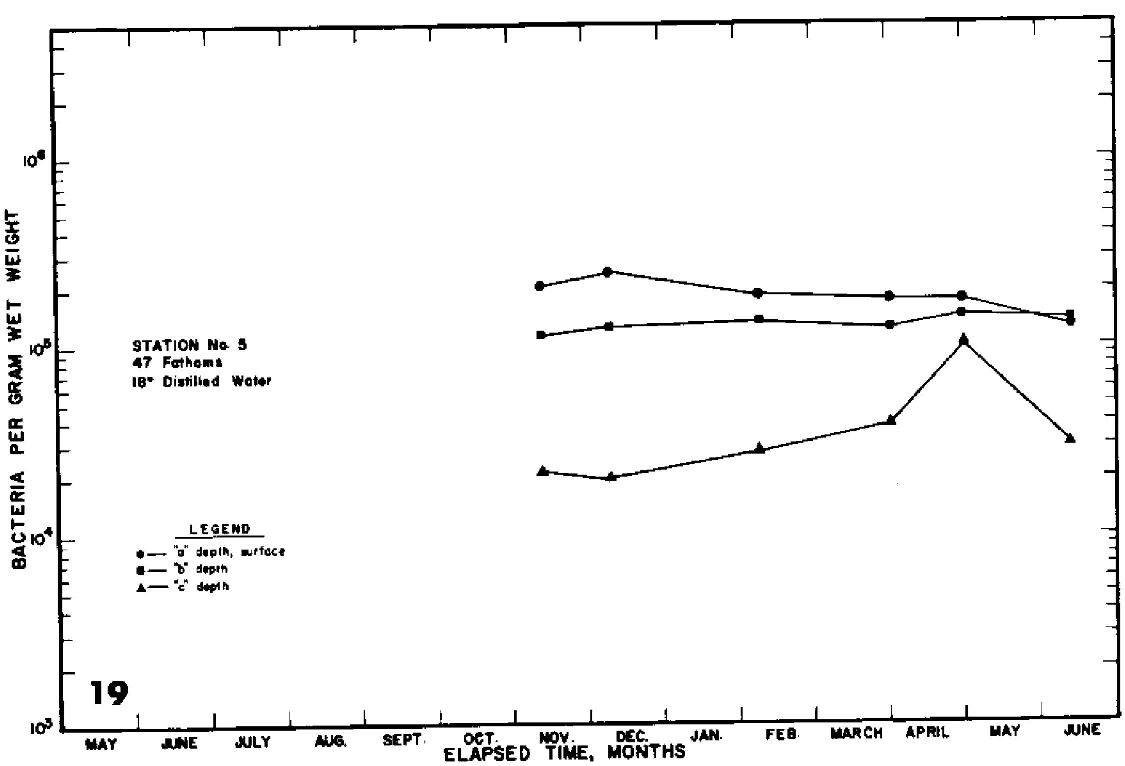

15
STATION No. 4
40 Fathoms
18° Distilled Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
BACTERIA PER GRAM WET WEIGHT
10³
10⁴
10⁵
10⁶
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS


STATION No. 4
40 Fathoms
60° Sea Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
BACTERIA PER GRAM WET WEIGHT
10^5
10^4
10^3
10^2
16
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

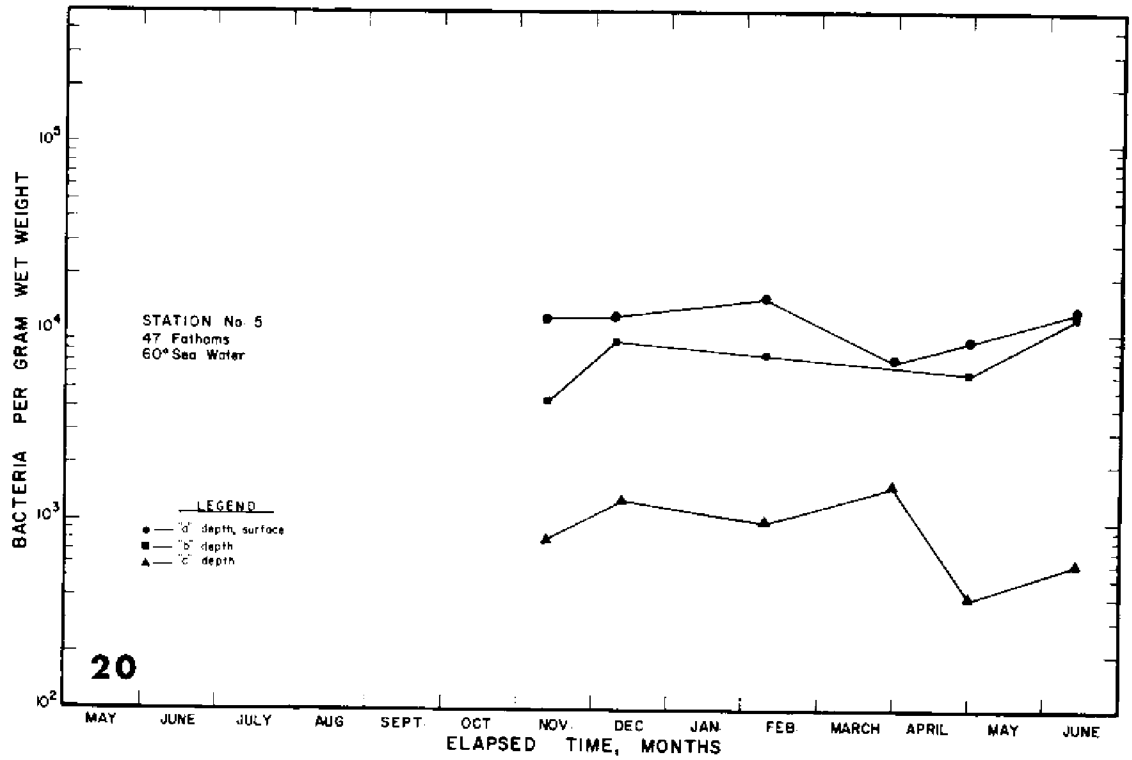

STATION No. 4
40 Fathoms
60° Distilled Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
BACTERIA PER GRAM WET WEIGHT
10^5
10^4
10^3
10^2
17
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

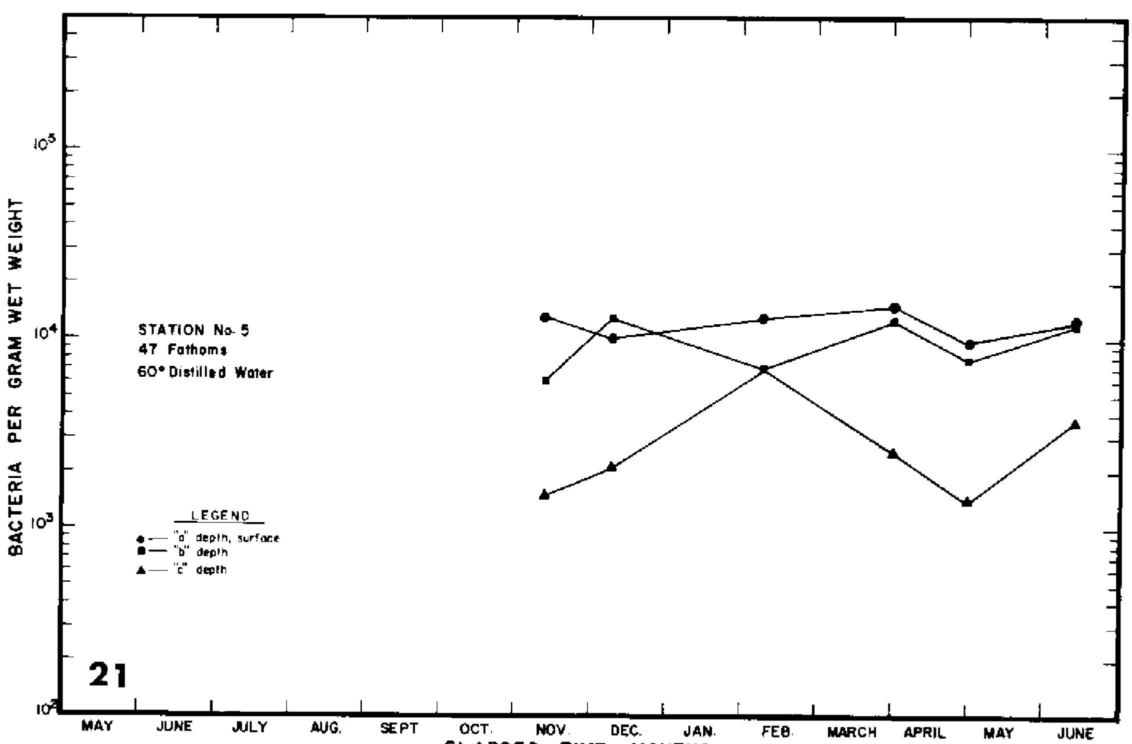


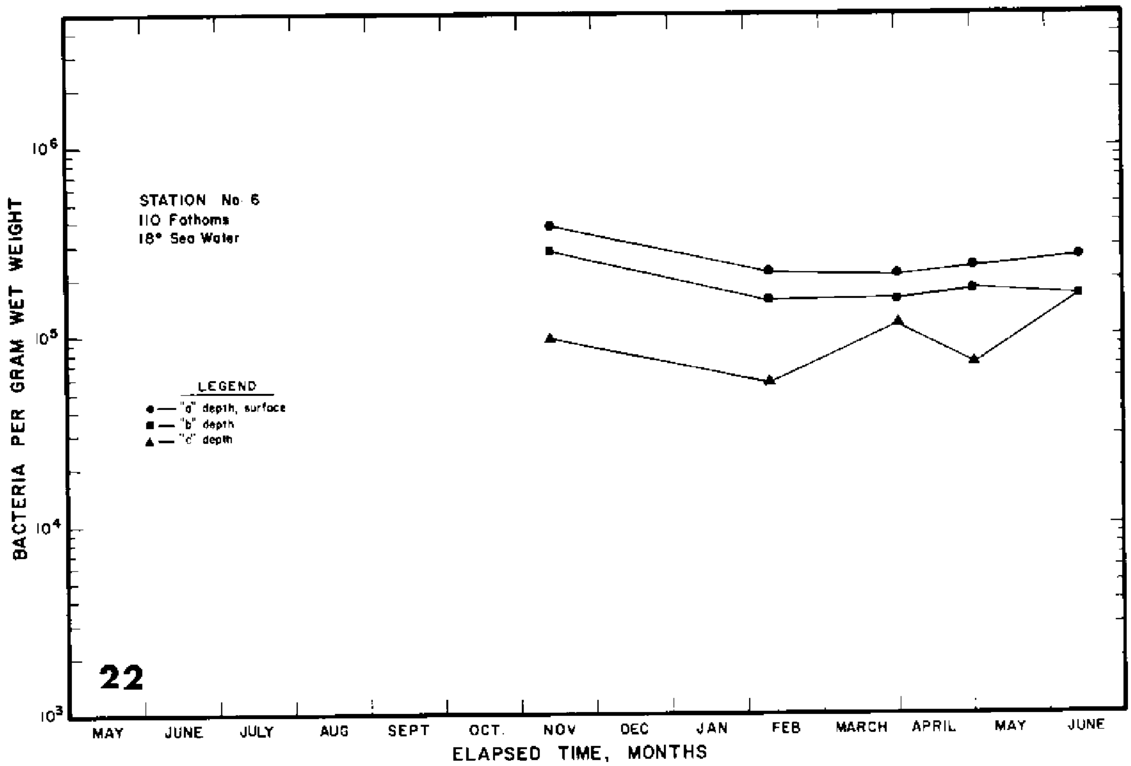
BACTERIA PER GRAM WET WEIGHT
10⁶
10⁵
10⁴
10³
STATION No. 5
18° Sea Water
47 Fathoms
LEGEND
●— "a" depth, surface
■— "b" depth
▲— "c" depth
18
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

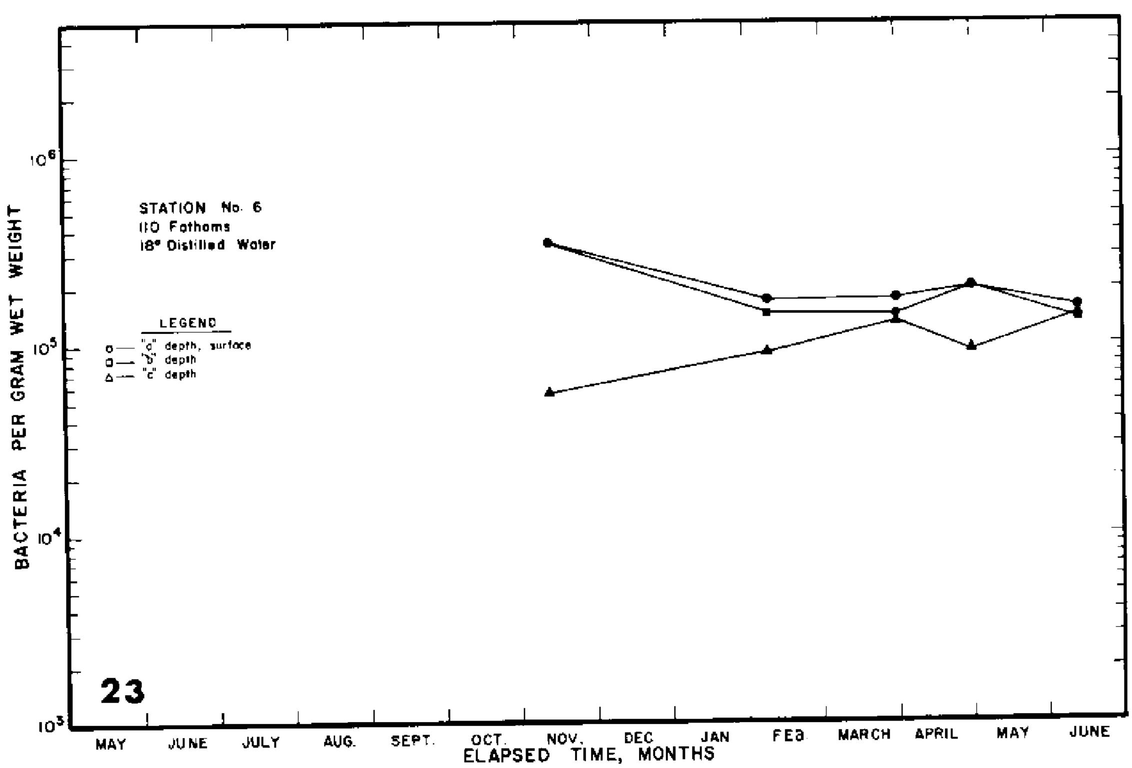


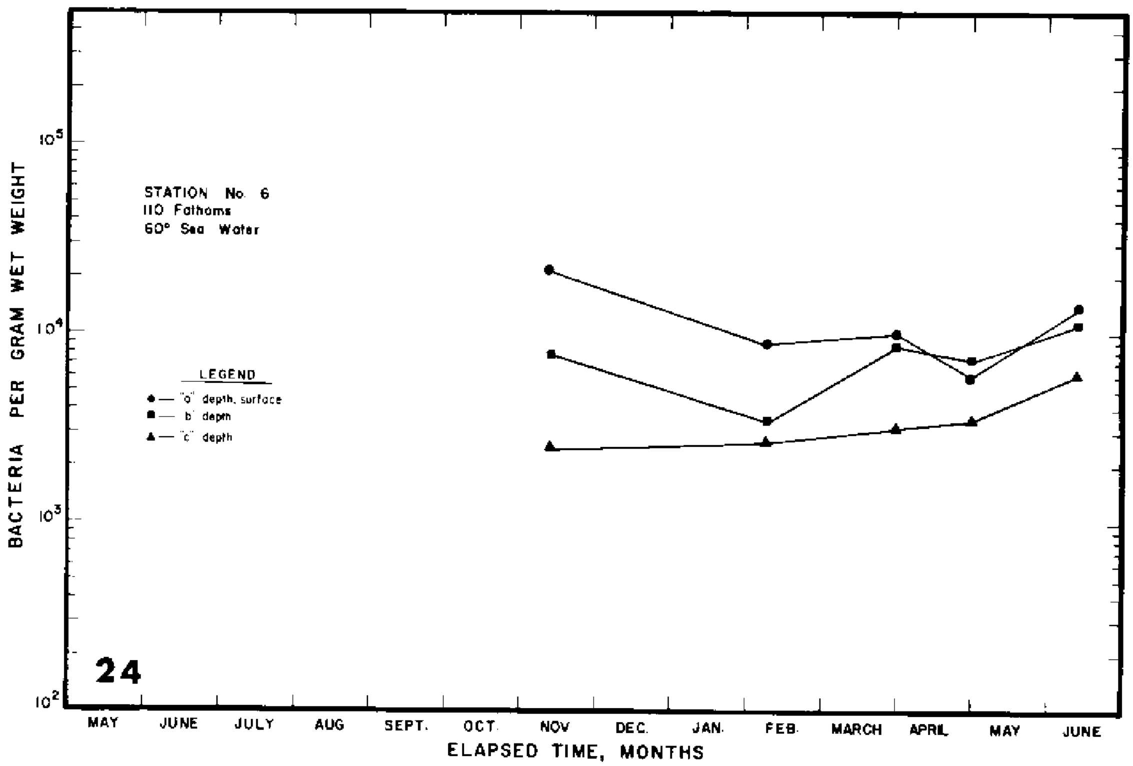
BACTERIA PER GRAM WET WEIGHT
10⁶
10⁵
10⁴
10³
STATION No. 5
47 Fathoms
18° Distilled Water
LEGEND
●— "a" depth, surface
■— "b" depth
▲— "c" depth
19
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

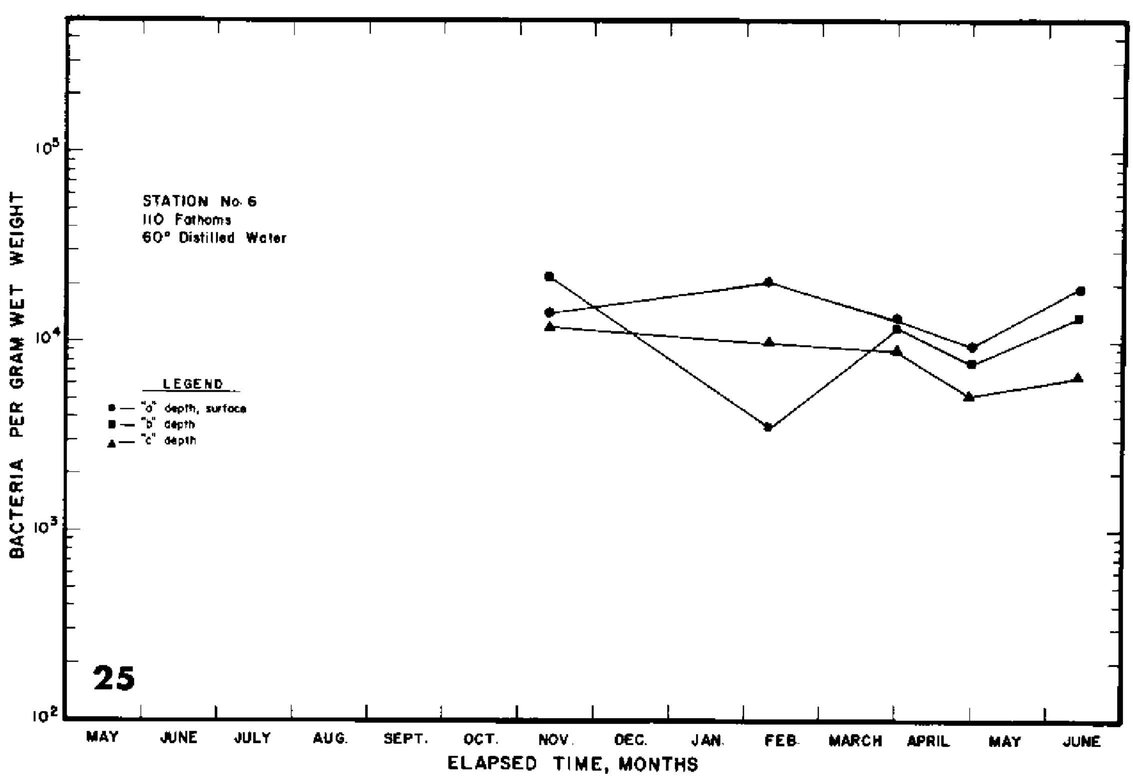

BACTERIA PER GRAM WET WEIGHT
ELAPSED TIME, MONTHS
MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MARCH APRIL MAY JUNE
STATION No. 5
47 Fathoms
60° Sea Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
20

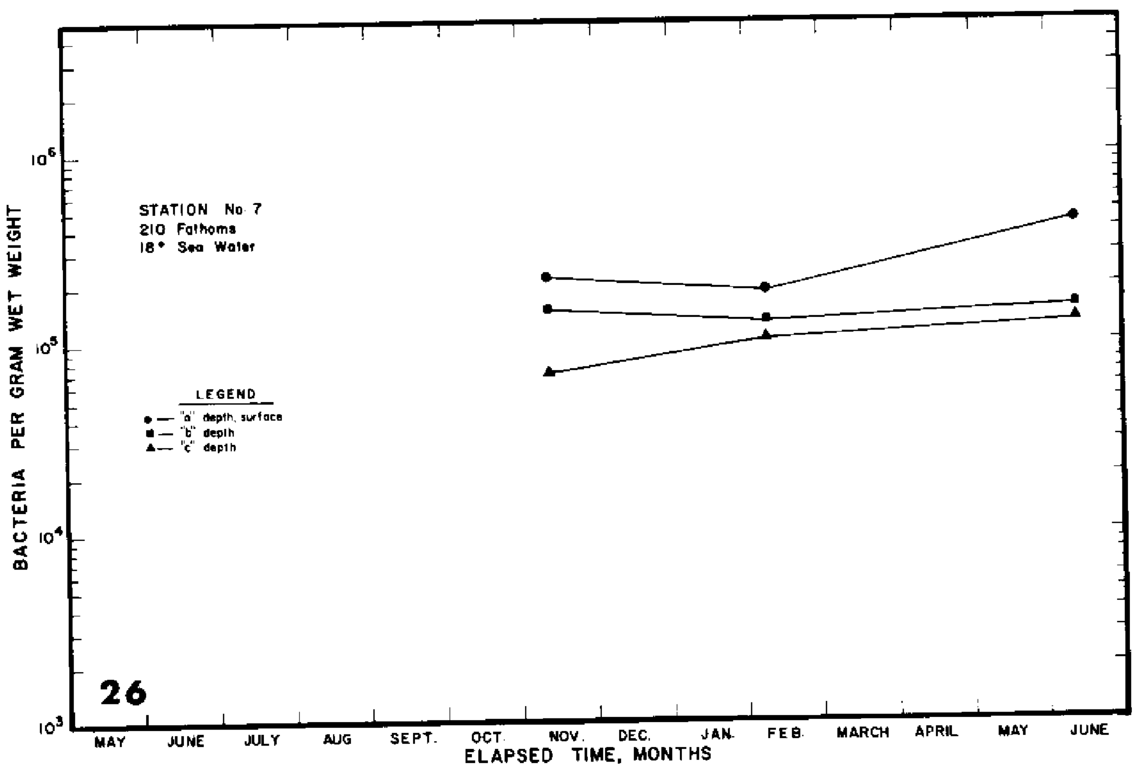

BACTERIA PER GRAM WET WEIGHT
ELAPSED TIME, MONTHS
MAY JUNE JULY AUG. SEPT OCT. NOV. DEC. JAN. FEB. MARCH APRIL MAY JUNE
STATION No. 5
47 Fathoms
60° Distilled Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
21

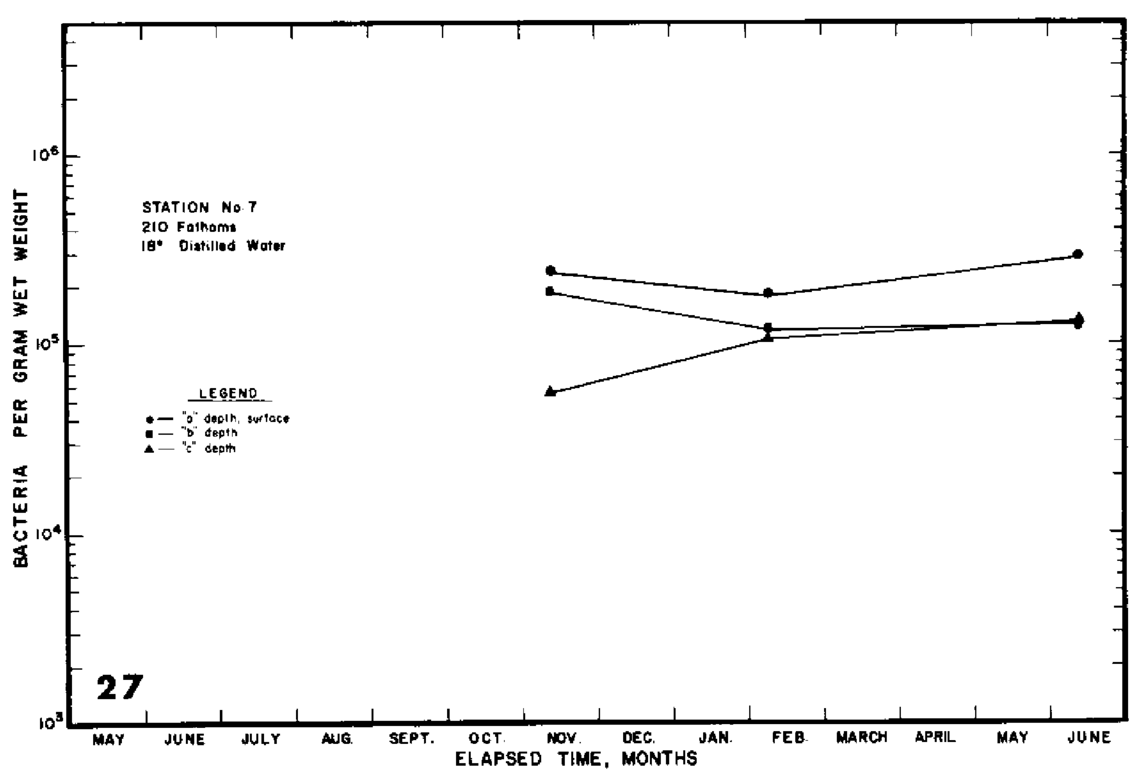

STATION No. 6
110 Fathoms
18° Sea Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
22
BACTERIA PER GRAM WET WEIGHT
10^6
10^5
10^4
10^3
MAY
JUNE
JULY
AUG
SEPT
OCT.
NOV
DEC
JAN
FEB
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

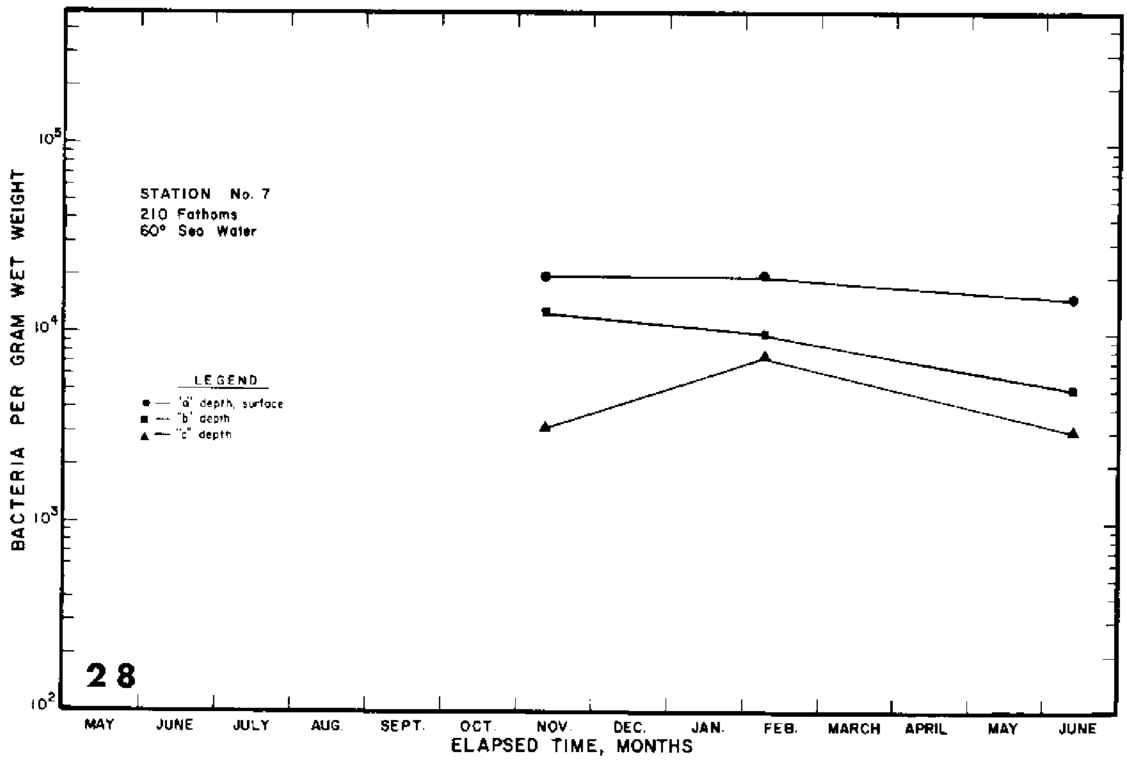

STATION No. 6
110 Fathoms
18° Distilled Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
23
BACTERIA PER GRAM WET WEIGHT
10^6
10^5
10^4
10^3
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC
JAN
FEB
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

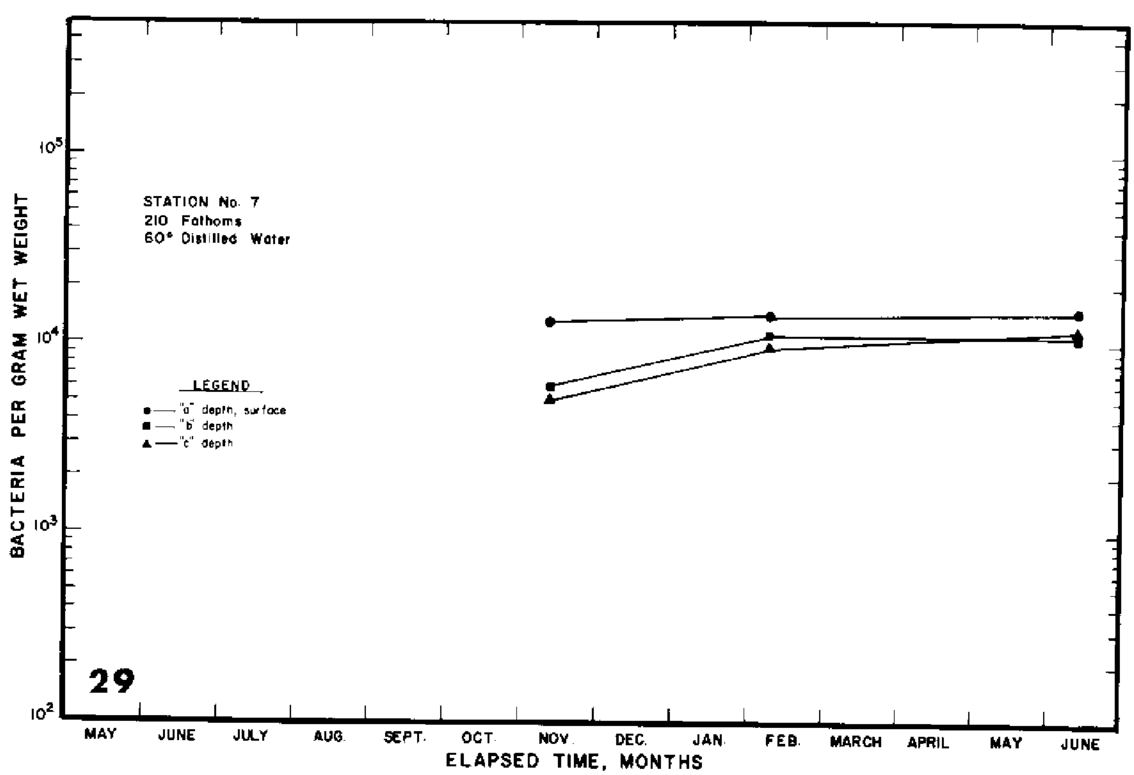

STATION No. 6
110 Fathoms
60° Sea Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
BACTERIA PER GRAM WET WEIGHT
10^5
10^4
10^3
10^2
24
MAY JUNE JULY AUG SEPT. OCT. NOV DEC. JAN. FEB. MARCH APRIL MAY JUNE
ELAPSED TIME, MONTHS

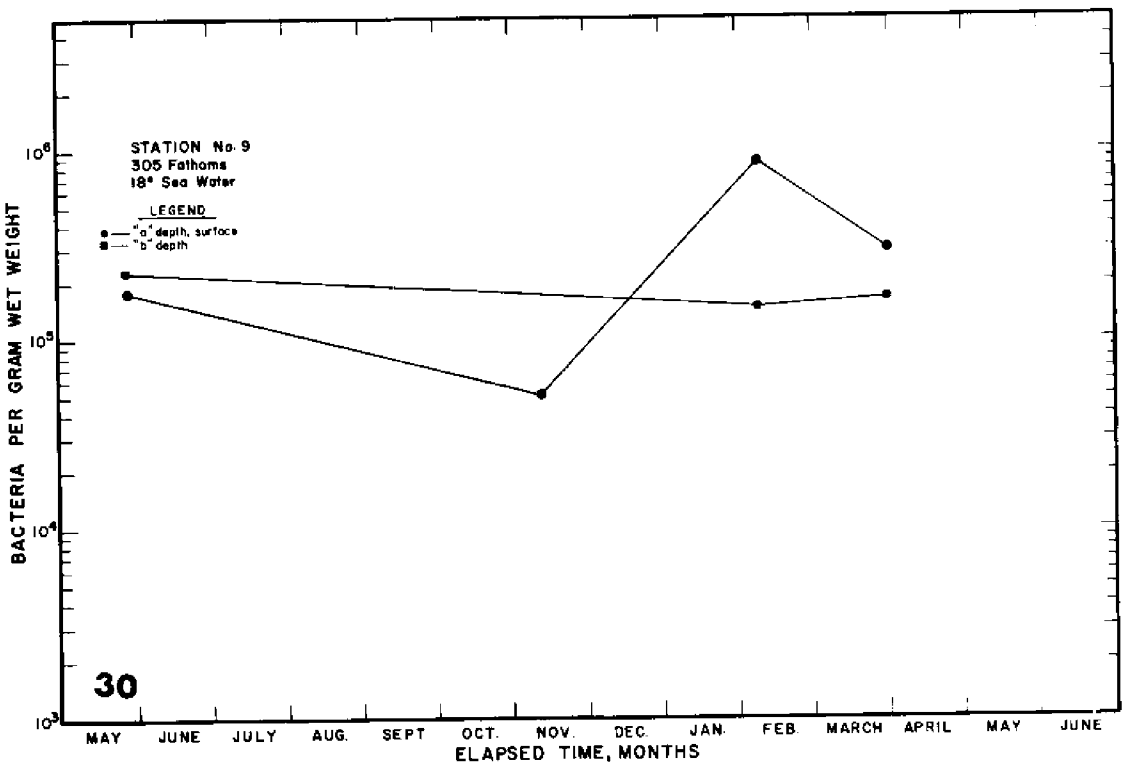

STATION No. 6
110 Fathoms
60° Distilled Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
BACTERIA PER GRAM WET WEIGHT
10^5
10^4
10^3
10^2
25
MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MARCH APRIL MAY JUNE
ELAPSED TIME, MONTHS

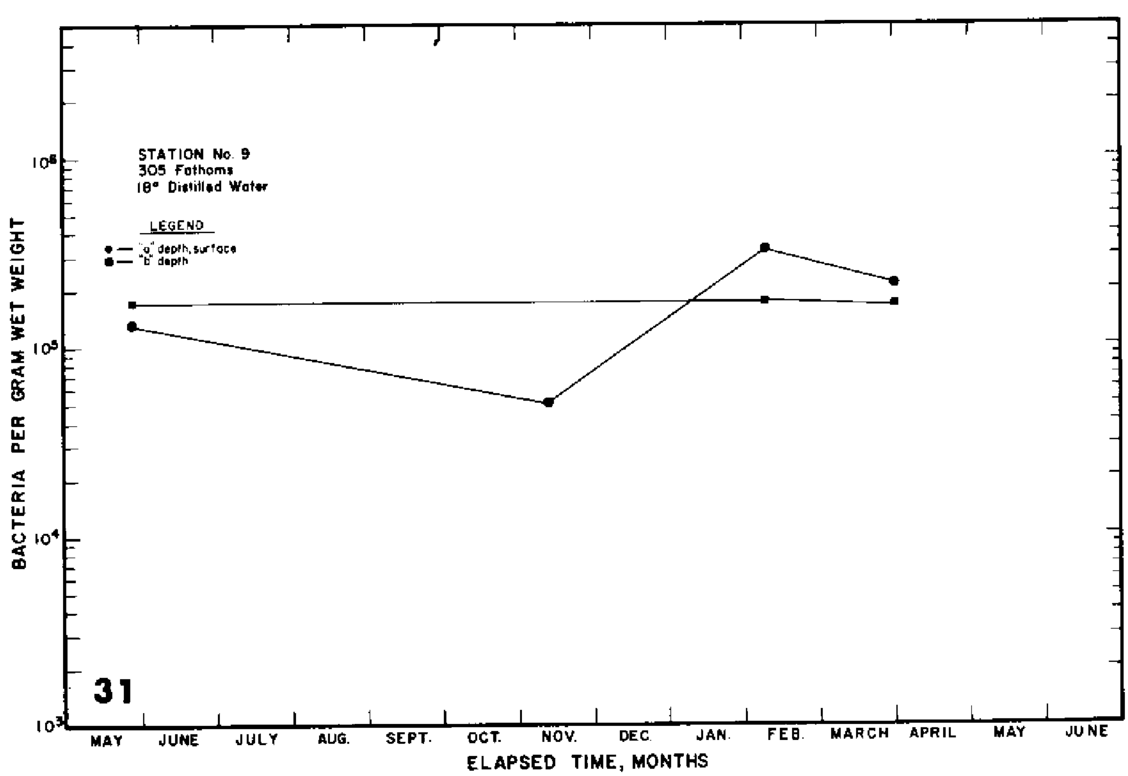

STATION No. 7
210 Fathoms
18° Sea Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
BACTERIA PER GRAM WET WEIGHT
10^6
10^5
10^4
10^3
26
MAY JUNE JULY AUG SEPT. OCT. NOV. DEC. JAN. FEB. MARCH APRIL MAY JUNE
ELAPSED TIME, MONTHS

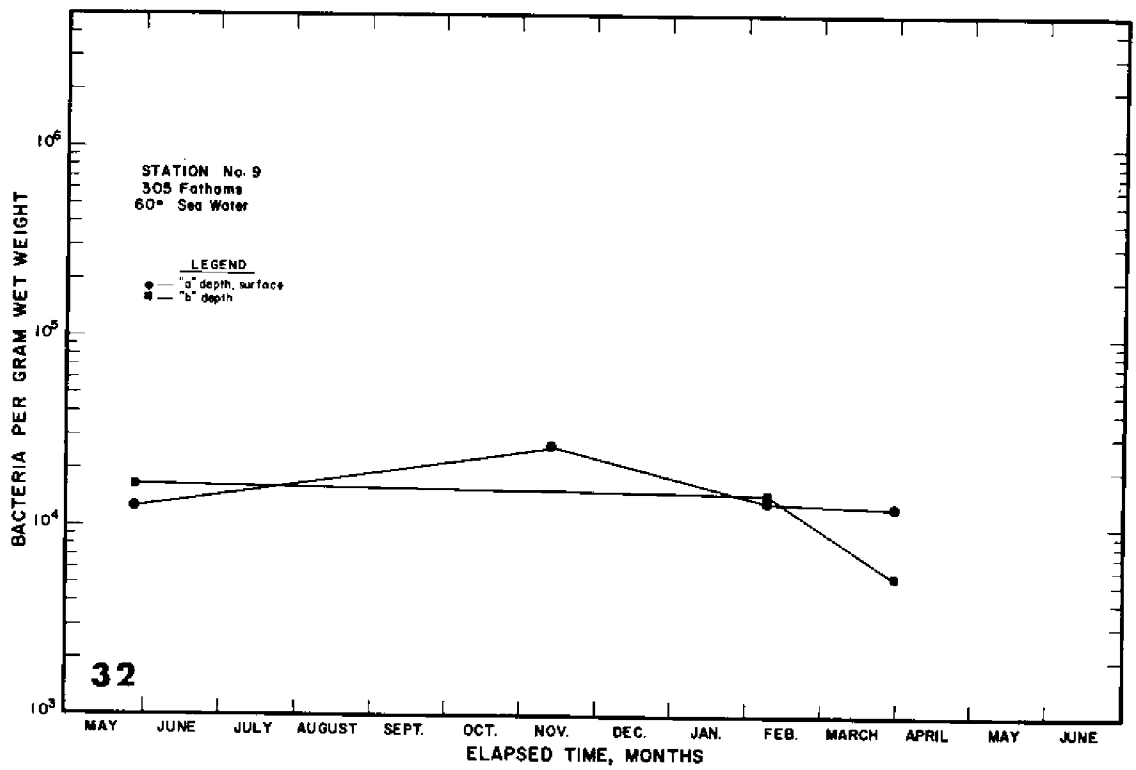

STATION No. 7
210 Fathoms
18° Distilled Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
BACTERIA PER GRAM WET WEIGHT
10^6
10^5
10^4
10^3
27
MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MARCH APRIL MAY JUNE
ELAPSED TIME, MONTHS

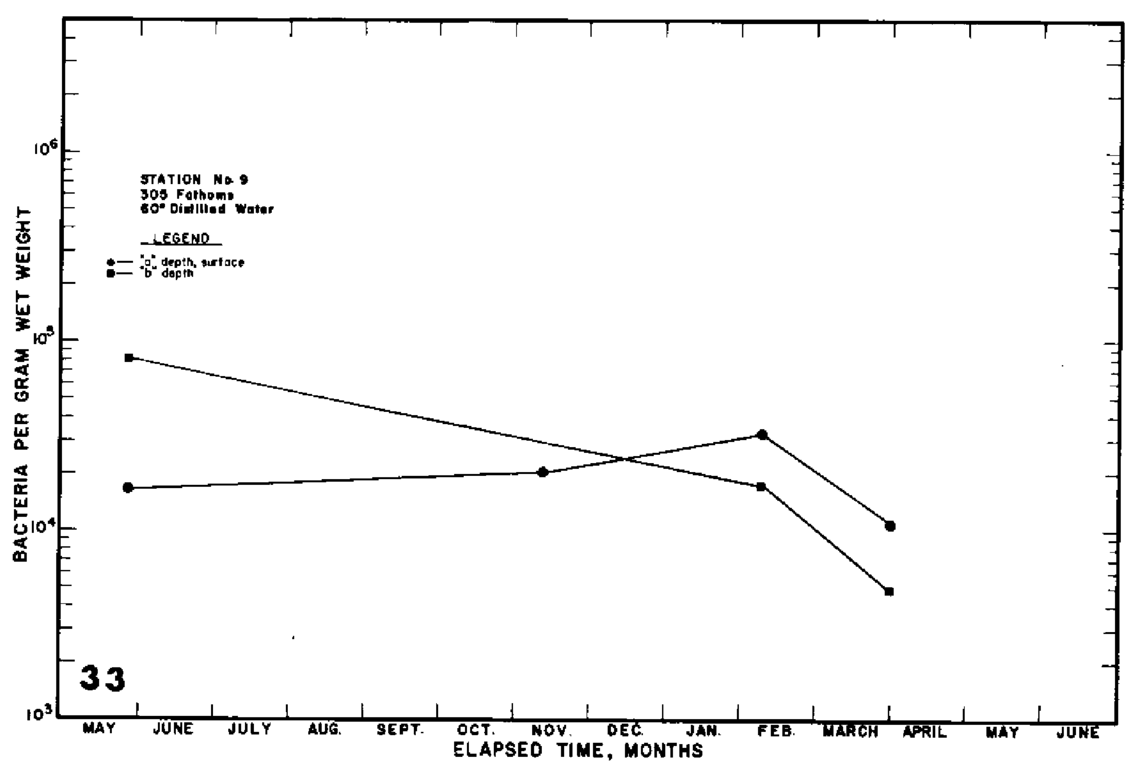

28
STATION No. 7
210 Fathoms
60° Sea Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
BACTERIA PER GRAM WET WEIGHT
10^5
10^4
10^3
10^2
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS


29
STATION No. 7
210 Fathoms
60° Distilled Water
LEGEND
"a" depth, surface
"b" depth
"c" depth
BACTERIA PER GRAM WET WEIGHT
10^5
10^4
10^3
10^2
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS


STATION No. 9
305 Fathoms
18° Sea Water
LEGEND
"a" depth, surface
"b" depth
BACTERIA PER GRAM WET WEIGHT
ELAPSED TIME, MONTHS
MAY JUNE JULY AUG. SEPT OCT. NOV. DEC. JAN. FEB. MARCH APRIL MAY JUNE
30

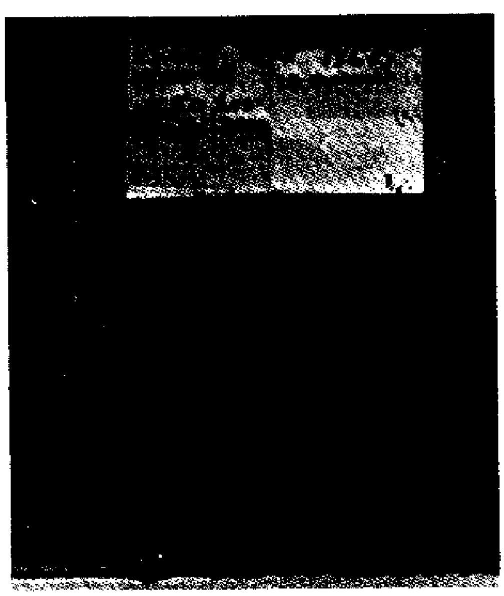

STATION No. 9
305 Fathoms
18° Distilled Water
LEGEND
"a" depth, surface
"b" depth
BACTERIA PER GRAM WET WEIGHT
ELAPSED TIME, MONTHS
MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MARCH APRIL MAY JUNE
31


STATION No. 9
305 Fathoms
60° Sea Water
LEGEND
"a" depth, surface
"b" depth
BACTERIA PER GRAM WET WEIGHT
10^6
10^5
10^4
10^3
32
MAY
JUNE
JULY
AUGUST
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

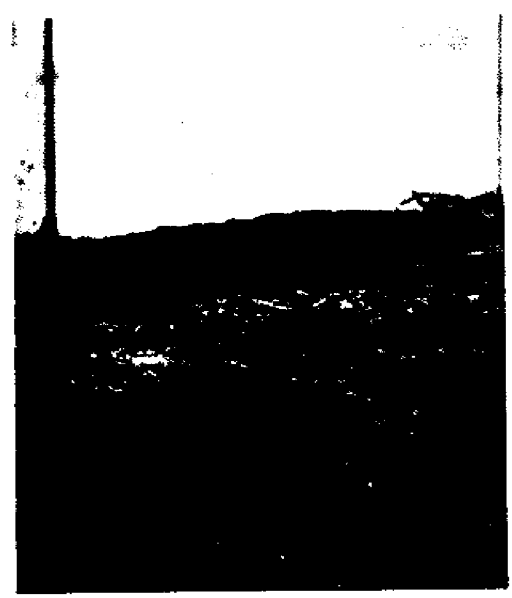

STATION No. 9
305 Fathoms
60° Distilled Water
LEGEND
"a" depth, surface
"b" depth
BACTERIA PER GRAM WET WEIGHT
10^6
10^5
10^4
10^3
33
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
ELAPSED TIME, MONTHS

Modified Reineck
Box-Corer

STATION NO. 1
12 Fathoms



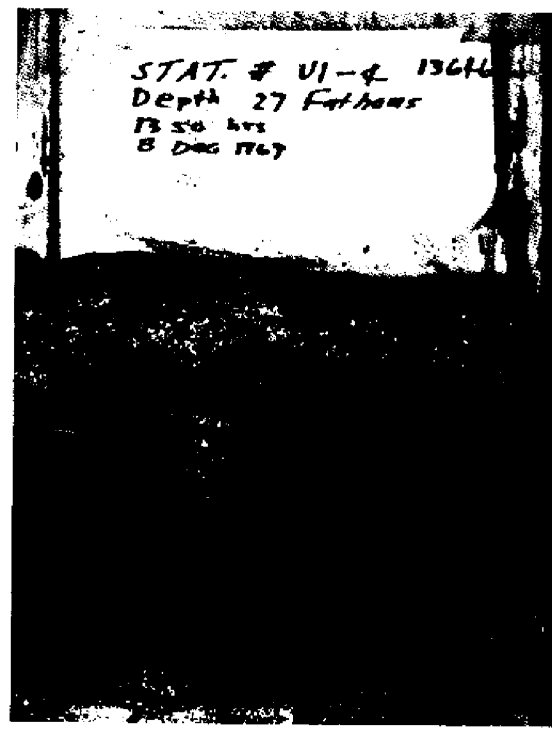
December 8, 1969



February 8, 1970

STATION NO. 2
27 Fathoms

July 24, 1969



December 8, 1969

February 8, 1970

STATION NO. 2
27 Fathoms

March 31-April 1, 1970

Before cutting
and cleaning

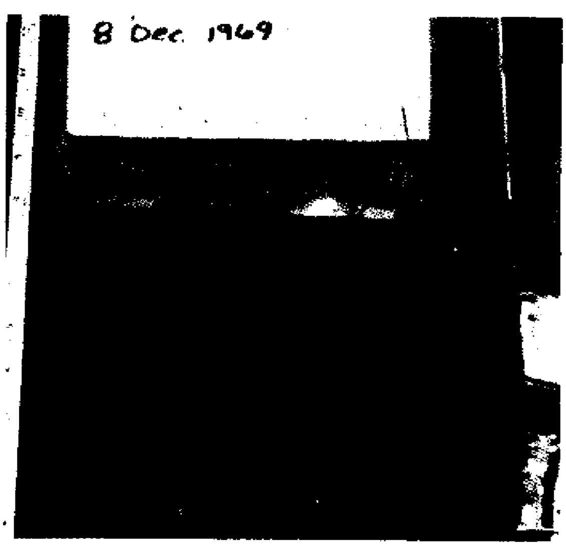
Core cleaned and
ready for sampling

STATION NO. 3
38 Fathoms

December 8, 1969

March 31-April 1, 1970

STATION NO. 4
40 Fathoms



December 8, 1970

March 31-April 1, 1970

CHAPTER 10

BREEDING AND LARVAL SETTLEMENT OF CERTAIN INTERTIDAL INVERTEBRATES IN THE SANTA BARBARA CHANNEL FOLLOWING POLLUTION BY OIL

by Dale Straughan

Although mortality was high among intertidal animals which were covered by oil by the January, 1969, oil spill, some animals survived under a layer of oil. Animals not covered by a layer of oil appeared to survive unharmed. However, sublethal doses of many pollutants have adverse effects that are not immediately obvious. These include reduction or prevention of reproduction and larval settlement. No prior field study has been attempted on such effects. Animals in certain areas of the Santa Barbara Channel that are exposed to sublethal doses of oil from natural seeps, together with those surviving exposure to oil following the January, 1969, spill, are ideal for such a study. The aims are twofold: (1) to determine effects of sublethal doses of oil from natural seepage on breeding and larval settlement; (2) to determine effects of exposure to sublethal doses of oil from a "single" spill on breeding and larval settlement.

Sedentary species from different levels in the intertidal region were studied because these species could not move to escape the pollution. Three species of barnacles were chosen--*Chthamalus fissus* Darwin from high intertidal rocky shores, *Balanus glandula* L. from mid-intertidal rocky shores, and *Pollicipes polymerus* Sowerby from low intertidal rocky shores. Observations were also made on two mussel species, *Mytilus californianus* Conrad from exposed low intertidal rocky areas and *M. edulis* L. from sheltered low intertidal rocky areas. Isolated observations were made on two species of limpet from rocky shores, Acmaea digitalis Eschsholtz and A. paradigitalis Fritchman, and two sandy beach species--a sand crab, Emerita analoga (Stimpson), and the blood worm Euzonus (Thoracophelia) mucronata (Treadwell).

BACKGROUND INFORMATION

Although Southern California is an area where marine scientists have been active for a long period, few background data are available on the distribution and biology of the common species studied. Balanus glandula and Pollicipes polymerus are northern species recorded as far south as 30°15' N latitude and 30° N latitude respectively, while Chthamalus fissus is a southern species extending as far north as 37°30' N latitude (W. Newman, personal communication) (Fig. 1). Mytilus californianus and M. edulis are both northern species that extend into Mexico (Ricketts and Calvin, 1968) (Fig. 1). Hence, all these species in the Santa Barbara Channel are only a few degrees latitude from either the northern or southern limit of distribution. Species near the limit of their distribution range are often under stress and may survive but not breed. M. edulis is the only species in which previous literature records suggest that some populations are not breeding--Ricketts and Calvin (1968) state that M. edulis occurs only in isolated populations south of Puget Sound and that these populations may not all be breeding populations. However, Moore and Reish (1969), working with M. edulis in Alamitos Bay in the Los Angeles area, reported a winter peak in breeding.

The data available on breeding in Mytilus californianus presents a confused picture. Stohler (1930) recorded breeding peaks in July and December. Whedon (1936) reported three peaks in spawning in October-November, January-February, and May-June in the San Francisco area, with the greatest peak in the winter months. Young (1942) recorded that the major spawning season occurred between October and March at La Jolla, but the species may spawn at any time of the year.

No data are available on breeding in Chthamalus fissus.

Connell (1970:54) discussed the breeding season of Balanus glandula in some detail: "In California the settlement seasons are also earlier (than on Vancouver Island) where the sea temperatures are higher. At Pacific Grove, lat. 36°5' N, the sea temperature rarely rises above 16° C and the settlements begin in March (Hewatt, 1935) and extend through October (Glynn, 1965). At Santa Barbara, lat. 34.5° N, I found B. glandula settling only between January and June, at La Jolla, lat. 32.5° N, the settlement extends from January to May (Barnes and Barnes, 1956)." Connell also concluded that B. glandula breeds at least twice each year.

Hilgard (1960) found that Pollicipes polymerus bred eight months of the year in Monterey Bay, California (36°40' N). In 1957 developing embryos were present in the population from April to December, the warmer months of the year, when the shore temperatures (average every 12 days) ranged from 12.3° C to 17° C. Eggs enlarged during March but the first fertilized eggs of the breeding season were not found until April. During the breeding season an average of 50% to 60% of the population of large animals carried ovigerous lamellae at any one time, with a maximum of 69%. An average large animal probably produced three to four broods each breeding season and each brood may contain 104,000 to 240,000 larvae.

METHODS

Regular samples of at least ten animals of each species of barnacle and Mytilus californianus were collected from Goleta Point, a moderately oiled locality (see Chapter 1 for definition), from March, 1969, to August, 1970. As little pre-spill data were available on breeding in the selected species, collections were initially at weekly intervals to detect any monthly breeding periodicity. When no breeding periodicity was detected in the first four months of the survey, samples were collected at monthly intervals. No samples were collected in November and December, 1969. Samples were also collected at seep and non-seep areas within the Santa Barbara Channel and from outside the Santa Barbara Channel (see Fig. 1 for collecting localities). Samples of M. edulis were collected from

Goleta Point in April and May, 1969, and January, February, May, 1970. Unless otherwise stated, data refer to samples collected from Goleta Point.

The animals were either frozen or preserved in alcohol. Samples were then examined to determine:

1. Amount of oil on animal

2. New settlement

3. The fraction of adults breeding

The criterion selected for breeding in barnacles was presence of developing egg masses in the body cavity. The stage of development of eggs and larvae was determined. The presence or absence of eggs and sperm, as well as size of gonad, was recorded for *Mytilus* and *Acmaea*.

RESULTS AND OBSERVATIONS

Chthamalus fissus contained developing eggs in the body cavity in all months from March, 1969, to August, 1970. No difference was detected between the percentage of adults containing developing eggs in the period March to June, 1969, and the period March to June, 1970. Peaks in numbers of larvae settling occurred in May and September, 1969, and June, 1970, at Fisherman's Cove, Santa Catalina Island (author's unpublished data). No existing records indicate whether there are normally two peaks in larval settlement per year or when these occur. Larvae were first recorded settling on oil from the January spill on *Mytilus californianus* in November, 1969, at East Cabrillo Beach. *C. fissus* first settled on shaded oiled surfaces in Fisherman's Cove, Santa Catalina Island, in June, 1970. This oil came ashore in January, 1970.

Balanus glandula contained developing eggs from March 18 (first sample) to June 24, in 1969. On the latter date, 0.1 animals contained only developing eggs while the remaining animals had started to accumulate food reserves. No eggs were recorded from July through October, 1969. On January 22, 1970, 0.1 adults already contained naupli in the body cavity. Developing eggs were found in subsequent samples up to and including those collected May 24, 1970. No eggs were found and all animals were accumulating food reserves in samples examined on June 23, July 7, July 23 and August 4, 1970. Naupli were recorded in March and May in 1969, and January-February and April-May in 1970. This supports Connell's (1970) idea that B. glandula breeds twice each year. Connell (1970) also suggests that the onset of breeding may be a temperature dependent factor. Surface water temperatures at Santa Barbara were lower (max. 13.9° C; min. 11.2° C; mean 12.6° C) in February, 1969, than in February, 1967 (max. 14.7° C; min. 13.0° C; mean 13.84° C), February, 1968 (max. 17.2° C; min. 12.9° C; mean 14.48° C) and February, 1970 (max. 15.0° C; min. 13.0° C; mean 13.4° C; see Table 2) (data supplied by Scripps Institution of Oceanography). The lower water temperatures in February, 1969, may have slowed larval development, resulting in a slightly later breeding season in 1969 than in 1970.

Reproduction in Balanus glandula specimens covered with a layer of oil was compared with reproduction in specimens not covered by oil. On March 18, 1969, of specimens collected from rocks on Leadbeaters Beach (a heavily oiled beach in Santa Barbara), 0.5 of the oiled animals contained no eggs, 0.4 contained eggs at different stages of development, and 0.1 contained naupli; 0.6 of the unoiled animals contained no eggs, 0.3 contained eggs at different stages of development, and 0.1 contained naupli. Hence, a thick layer of oil apparently had no effect on reproduction in B. glandula.

Larval settlement commenced prior to March 18 in 1969 and between January 22 and February 22 in 1970. Some of the former larvae settled on a layer of dry oil between adults present from before the January spill. However, young B. glandula were not found on large exposed rocks covered by dry oil at that time.

Pollicipes polymerus. Two observers independently assigned abundance ratings to P. polymerus on rocky shores studied by Cimberg and Nicholson (Chapter 17), and at Pismo Beach. The abundance at each locality and the relationship to substrate and presence of oil is given in Table 1. This species is rarely found on unstable rocks. On stable rocks it is less abundant at localities south of the Santa Barbara

Channel than at non-seep localities along and to the north of the Channel. It was also less abundant on stable oil seep areas than on stable non-seep areas within and to the north of Santa Barbara Channel.

During the initial stages of the study, no data were available on the breeding habits of P. polymerus. Hence, a rapid survey was made of a few specimens in each sample from Goleta Point and stations south of the Santa Barbara Channel to determine the reproductive cycles. Using these methods, P. polymerus was scored as breeding only in June, July, 1969, from Goleta Point. Under these conditions the species appeared to be a summer breeding species. However, eggs were then recorded in the body cavity of P. polymerus in January and February, 1970. As it was unlikely that this species bred in mid-summer and mid-winter near the southern end of its range, a more detailed examination was made of reproduction of this species.

The results in the rapid survey probably came from examining samples of too few and/or too small individuals. Hence, several series of samples of increasing numbers were examined to determine a suitable sample size. At Gaviota and Carpinteria, an examination of samples of 10, 20 and 30 clean specimens showed that fractions of 0.2, 0.25, 0.36 and 0.2, 0.1, 0.25 respectively were brooding eggs in the body cavity. At East Cabrillo, samples of 10 and 20 animals each yielded 0.7 brooding eggs, while at Coal Oil Point samples of 10 and 15 yielded fractions of 0.6 and 0.5 respectively brooding eggs. At each station, there was only a small variation in the fraction brooding eggs in samples of different sizes. Hence, it was concluded that a sample of 10 individuals gave a reasonable measure of the fraction of the population breeding. If the sample was too small, one would expect to find irregular variations between the fraction breeding monthly. However, there is a gradual change from month to month in the fraction brooding eggs (Table 2).

The distance from the base to top of the calcareous plates (the maximum height of capitulum) was used as a measure of size of animals. Dimensions of the stalk were unsuitable because these varied with population density. Fertilized eggs were never found in animals measuring less than 12 mm. Samples of animals measuring 12 to 15 mm had from 0.1 to 0.5 of the individuals brooding eggs. The fraction of animals larger than 15 mm brooding eggs was constant at each station. Therefore, while some individuals breed when they measure 12 to 15 mm, others do not commence to breed until they measure more than 15 mm. At Dana Point and Corona del Mar (Fig. 1), the two southern locations, it was difficult to find animals measuring more than 15 mm. This suggests that the species is stunted at these stations and breeding is inhibited, or that animals do not reach maturity.

Data shown in Table 2 indicate that P. polymerus breeds throughout the year. There is a peak in breeding during the winter months with a maximum recorded in February. P. polymerus had settled on barnacle stalks in all unoiled samples.

Possible effects of oil in the field were studied in four ways: (1) comparing the fraction breeding in 1969 with that breeding in 1970; (2) comparing the fraction of adults brooding, covered by different amounts of oil; (3) comparing the fraction of adults brooding from different localities exposed to different amounts of oil; (4) larval settlement on P. polymerus stalks bearing different amounts of oil.

Animals were examined from March, 1969, to August, 1970, from Goleta Point to determine differences in breeding immediately after the January, 1969, oil spill (Table 2). No similar pre-spill data are available. Clean animals were collected on only two occasions in 1969--April and October. The fraction of animals brooding in April, 1969, is only slightly lower than in April, 1970. Lightly oiled animals collected in May and June, 1969, have a similar fraction of adults brooding as in the corresponding months in 1970. More adults were brooding eggs in the unoiled sample, August, 1970, than in the lightly oiled sample, August, 1969. However, the lightly oiled sample collected in March, 1969, had 0.1 animals brooding compared with 0.8 in March, 1970. This indicates a reduction in breeding in March, 1969. In April, 1969, there was a range in the fraction of P. polymerus brooding eggs (0.1-0.9). This may be due to a delay in breeding in areas where the oil came ashore at the height of the breeding season. Data from March and April, 1969, suggest that the rate of breeding was reduced early in 1969.

It was impossible to determine how much oil each animal was exposed to. The animals were therefore ranked on a four-point scale as clean, light oil (a thin film not visible in the photograph), medium oil and heavy oil (Plate 1a). In all cases when samples covered by different amounts of oil were examined, there was an inverse relationship between the fraction of adults brooding and the amount of oil on the adults (Table 3). Using the Spearman Rank Correlation Coefficient (Siegel, 1956), $r_s = -0.642$, this negative correlation is significant between .01 and .05 levels for a one-tailed test.

Comparison of the fraction of clean adults brooding in natural seep areas and in areas not exposed to natural seeps in April, 1969, and June, 1970, shows that the fraction of adults brooding eggs in non-seep areas north and within the Santa Barbara Channel was almost twice that of adults brooding eggs in seep areas (Table 4). Non-seep areas south of the Santa Barbara Channel generally had a lower or equal fraction of adults brooding than seep areas (April, 1969, October, 1969, June, 1970), while the non-seep area north of the Santa Barbara Channel had a higher fraction of adults brooding than seep areas (July, 1970). In April, 1969, both beaches in the Santa Barbara Channel still had some soft oil from the January spill. In June, 1970, Coal Oil Point (0.4 adults brooding) was the only beach with fresh oil but all seep beaches had some tar on the rocks, while the non-seep beaches in the Santa Barbara Channel still bore a few traces of the January, 1969, spill.

P. polymerus settlement was recorded from all unoiled samples but was never recorded from moderately or heavily oiled areas of stalks. Young P. polymerus were found on lower clean sections of stalks but not on the upper oiled section of stalks (Plate 1b). Normally, settlement occurs on any portion of the stalk (see Barnes and Reese, 1960, pl. 4). Settlement was recorded on lightly oiled stalks in samples collected May through August, 1969. However, it is impossible to determine if the oil film covered the stalks before or after larval settlement.

Mytilus californianus in every sample except one in the period between March, 1969, and August, 1970, contained at least a few eggs. Gonads were empty in the sample collected in September, 1969. The only sample of M. californianus with gonads very swollen with eggs or sperm was collected from Ellwood Beach, two miles north of Goleta Point, on August 6, 1969. In samples from Goleta Point,

M. californianus gonads were slightly swollen in March, April, June, and August, 1970. Sperm were recorded in M. californianus from Goleta Point in August, 1969, and May, June, July and August, 1970. These data suggest that M. californianus bred in August, 1969, in the Santa Barbara area. The increase in gametes in the summer of 1970 indicates they may breed in August. However, M. californianus from Goleta Point did not produce as many gametes in 1969 as in 1970, based on gonad size, nor as many as at Ellwood Beach. Ellwood Beach is not regarded as an oil seep beach, in contrast to areas such as Carpinteria where there are large asphalt deposits in the upper intertidal and usually some fresh oil on rocks and in pools.

All samples of M. edulis contained a few eggs. None, however, appeared in breeding condition.

In April, 1969, 113 Acmaea digitalis and 35 A. paradigitalis were examined; 80% of these animals had gonads swollen with eggs or sperm, while in the other 20% of the animals the gonads appeared "spent." Forty-eight A. digitalis and 26 A. paradigitalis were from oiled areas and were eating oil. Fifty-seven/65 clean A. digitalis and 40/48 oiled A. digitalis contained eggs or sperm. Nine/9 clean A. paradigitalis and 7/7 oiled A. paradigitalis contained eggs or sperm early in April. The other 19 A. paradigitalis were examined April 27. At this time 11 animals contained eggs or sperm and the remainder appeared "spent" individuals. The data suggest that A. digitalis and A. paradigitalis are able to ingest Santa Barbara crude oil residues without any decrease in their ability to produce eggs and sperm.

Emerita analoga were breeding on East Cabrillo Beach June 3, 1969. A gravid female was kept in an aquarium and larvae hatched two weeks later. Newly settled E. analoga were found on East Cabrillo and Carpinteria beaches on June 3, 4, 1969 respectively.

Euzonus mucronata were examined in June and July, 1969. On both occasions eggs were fertilized and visible under laboratory conditions.

DISCUSSION

Data collected between March, 1969, and July, 1970, on reproduction in C. fissus do not indicate any effect of oil on reproduction in adults surviving the January, 1969, oil spill. While settlement on oiled surfaces occurred within 6 months at Catalina Island, it was not recorded until 8 months after the shore was oiled in the Santa Barbara Channel. There was a peak in larval settlement 3 to 4 months after Santa Barbara's shores were oiled but no settlement was recorded on oiled surfaces. This suggests that the minimum "lag" phase before resettlement by C. fissus on oiled substrates is between 4 and 6 months.

The breeding season in B. glandula was delayed in 1969. As there was no difference between the fraction of oiled and non-oiled adult B. glandula breeding, this delay was probably due to the lower water temperatures that were recorded in the area in early 1969. Connell (1970) suggests that the onset of the breeding season is dependent on water temperatures.

Settlement of B. glandula occurred on sheltered oiled surfaces within two months of oil coming ashore. Settlement was not recorded on exposed oiled surfaces on beach transects prior to May, 1970 (Cimberg, personal communication). This indicates a lag phase of 16 months on exposed surfaces and two months on sheltered surfaces. Likewise there was a different lag phase prior to larval settlement of C. fissus on exposed and sheltered surfaces. The sheltered surfaces were shaded from the sun. This suggests that settlement may be further delayed on exposed surfaces due to a heat effect. This could work in one or a combination of several ways. The black oil may absorb more heat and by raising the substrate temperature either prevent the larvae from settling or kill the larvae after settlement; the higher temperature may merely melt the oil and make the substrate unsuitable for settlement; or it may release substances that inhibit settlement. These possibilities are at present under investigation.

In sheltered areas, B. glandula settled on oil several months prior to C. fissus. B. glandula may be able to settle on oil sooner than C. fissus because the former secretes a protective basal plate which is lacking in the latter.

P. polymerus from localities south of the Santa Barbara Channel are less abundant, generally smaller and have a lower fraction of adults brooding eggs than at localities within and north of the Santa Barbara Channel. This may be because the species is under stress near the southern end of its range or because of pollution or public usage. Dana Point is a private beach while Corona del Mar is a public beach. The latter (0.0) had a lower fraction of adults brooding eggs than the former (0.2). Pollution from the heavily populated areas to the west and north may influence breeding. Possible effects of public usage and pollution from other sources than oil are discussed by Nicholson and Cimberg, in Chapter 17. These beaches were not subjected to massive oil pollution, but whatever the cause, *P. polymerus* there have a low rate of reproduction. Specimens from these areas did not give adequate control data for monitoring effects of oil pollution on this species in the Santa Barbara Channel.

Data on breeding in *P. polymerus* show a reduction in the fraction of adults breeding both in oil seep areas and in areas polluted by the January, 1969, oil spill. *P. polymerus* forms clumps in the lower intertidal area. Oil that contaminates these animals does not dry out between the animals. Hence, *P. polymerus* is exposed to liquid oil for longer periods than *C. fissus* and *B. glandula*, which occur in upper intertidal areas where the oil dries between the animals. This would indicate a longer exposure to chemical effects of oil and a greater chance of ingestion of oil by *P. polymerus* than by *C. fissus* and *B. glandula*. Oil pollution was not observed to affect breeding in these latter two species.

P. polymerus appears to be gregarious during larval settlement, as settlement rarely occurs anywhere other than on stalks of adults. Gregariousness during larval settlement has been demonstrated in several groups of sedentary invertebrates, including sessile barnacles (Knight-Jones, 1953, 1955). Settlement was recorded on clean *P. polymerus* stalks in all months of the year but was not recorded on moderately or heavily oiled stalks. Lightly oiled *P. polymerus* stalks bore new settlements in mid-1969.

However, it was impossible to determine if the stalks were covered with the film of oil before or after larval settlement. Oiling of P. polymerus stalks reduces the preferred area of settlement.

Heat is unlikely to be responsible for lack of settlement in this case because the stalks are sheltered in clumps and the dark surfaces are not exposed to the sun. P. polymerus cyprids may be attracted to the adult stalks chemically and/or by the surface texture of the stalks. The presence of liquid oil could mask any chemical attractant, be chemically inhibiting, or make the surface texture unattractive.

Obviously this species has survived in the presence of natural seeps in the Santa Barbara Channel. However, recolonization may be continually occurring from non-seep areas. It is important to consider just where the reduction in breeding and in space for larval settlement reaches the level where the population cannot be maintained.

In marine invertebrate populations, many times the number of larvae that could possibly survive to maturity are produced. Connell (1970) calculates that in a population of B. glandula producing 1,000,000 larvae, 62 survive to begin breeding and only 2 survive for 8 years. In the Santa Barbara Channel, each P. polymerus produces 100 ±20 naupli in each batch. This differs from the figures recorded in Monterey Bay by Hilgard by a factor of 100. In the absence of further data it is impossible to say if the lower numbers of naupli produced per brood in the Santa Barbara Channel reflect a gradual reduction in brood size towards the south of the range or the effect of exposure to small quantities of oil over a long period; or if brood sizes fluctuate between different localities.

Mortality rate during the planktonic stage of P. polymerus is unknown and may be increased in the presence of oil. If this is so, there is less intraspecific competition for the reduced settling space and if fewer larvae settle, there is reduced intraspecific competition during juvenile stages. Barnes and Reese (1970) found that P. polymerus never contain egg lamellae when the capitellum measures less than 10-11 mm in height. This was confirmed in the present study. Barnes and Reese (1970) assumed that maturity is not attained before the fifth year and that a fully grown animal may be 20 years old or more. Therefore, to successfully complete the life cycle a nauplius must survive in the plankton, find an unoiled P. polymerus stalk, settle and survive at least five years, before it breeds.

Up to 69 newly settled P. polymerus were counted on the stalk of one adult P. polymerus. Hence, there is also a high mortality after settlement. This is not uncommon in intertidal invertebrates. Straughan (1969) showed that the intertidal zone formed by a serpulid, Pomatoleios kraussii, in Hawaii, was composed of only a small fraction of the larvae settling intertidally. Most larvae did not survive seasonal competition with ascidians.

Large fluctuations are common in intertidal invertebrate populations both through physical and biological causes. Frank (1968) notes that long-lived species are characteristic of stable marine invertebrate populations. However, following loss of a population from an area, several years may lapse before the breeding community can be re-established. In marine invertebrate species with a free swimming larval stage, assuming that the substrate remains suitable for larval settlement, recruitment can occur from areas outside the immediate vicinity. Recruitment of species in a denuded area depends on the location of other breeding populations, water currents, and length of planktonic life. The rate at which the breeding community is re-established in an area is dependent on the length and stage of the breeding season, the "lag" phase before the substrate is suitable for resettlement, and time taken for animals to reach sexual maturity.

At this stage one can say that the presence of oil both from natural seepage and the January, 1969, spill apparently causes a reduction in reproduction in P. polymerus. The level of reproduction necessary to maintain the population is unknown. However, while oil affects only isolated areas, repopulation can continue on unoiled surfaces by larvae produced in unpolluted areas. This species ranges over several thousand miles of coastline. If the species were confined to a smaller section of the coastline so that a much larger percentage of the population was exposed to oil, it would be a different matter. Similarly, the data indicated that breeding in M. californianus of Goleta Point was probably reduced after oil pollution. Here effects of both the January, 1969, spill and natural seepage may be involved. As with P. polymerus, M. californianus occurs over several thousand miles of coastline and while a small fraction of the population is exposed to oil, the species, as a whole, is not endangered from oil pollution and recolonization should occur in non-oiled areas.

The hypothesis has been advanced that organisms living in the Santa Barbara Channel are more resistant than normal to oil pollution, due to intermittent exposure to low doses from natural seeps. Data for P. polymerus and M. californianus indicate that even if they are better able to survive, their rate of reproduction is still lower in the presence of oil.

Production of eggs and sperm in the two limpets A. digitalis and A. paradigitalis was apparently unimpaired when the limpets grazed oil off rocks. Other authors, including George (1961), Nelson-Smith (1968), and Spooner (1968), reported that limpets grazed oil off rocks in the Gulf of Mexico, Cornwall, and West Indies respectively without any apparent ill effects.

SUMMARY

In the sedentary species, no reduction in breeding due to oil pollution was found in two sessile barnacles, Chthamalus fissus and Balanus glandula, but, contrary to preliminary reports, breeding rate was reduced in the stalked barnacle, Pollicipes polymerus, and the mussel, Mytilus californianus. The latter two species occur in lower intertidal areas than the former, and were exposed to liquid petroleum for longer periods than upper intertidal species. Hence, these species were probably more exposed to the chemical effects of oil pollution than upper intertidal species, while the upper intertidal species were exposed mainly to the physical effects. However, as long as only a small fraction of the entire population of these species is exposed to oil pollution, the species as a whole are not endangered by it.

Larval settlement in all three species of barnacle was at least temporarily inhibited by oiling of substrates. While Balanus glandula started to recolonize oiled surfaces prior to March 18, 1969, Chthamalus fissus did not settle on oiled surfaces until November, 1969. I have no confirmed records of Pollicipes polymerus settlement on oil from the January, 1969, oil spill.

The limpet Acmaea digitalis appeared able to ingest oil without inhibition of reproduction. Emerita analoga and Thoracophelia mucronata were breeding in sandy beaches in June, 1969.

Low breeding rates were recorded in Pollicipes polymerus from localities south of the Santa Barbara Channel. Animals in two populations examined were also smaller than those collected from more northern localities. This may be due to higher human population and pollution pressures but it is also possible that as one is approaching the southern extremity of the range of P. polymerus, the species is stunted and does not breed.

ACKNOWLEDGMENTS

I wish to thank Dr. J. Connell of the University of California, Santa Barbara, for his enthusiastic assistance in the field and enlightened advice. I also wish to thank John Cubit, University of California, Santa Barbara, Bob Cimberg and Tom Trask, University of Southern California, for assistance. Margaret K. Robinson, Scripps Institution of Oceanography, and Dr. A. Ebbling, University of California, Santa Barbara, provided water temperature data.

REFERENCES

Barnes, H., and E. S. Reese
1960 The behaviour of the stalked intertidal barnacle Pollicipes polymerus J. B. Sowerby, with special reference to its ecology and distribution. J. Anim. Ecol., 29: 169-185.

Connell, J. H.
1970 A predator-prey system in the marine intertidal region 1. Balanus glandula and several predatory species of Thais. Ecol. Monogr., 40: 49-78.

Frank, P. W.
1968 Life histories and community stability. Ecology, 49: 355-357.

George, M.
1961 Oil pollution of marine organisms. Nature, 192: 1209.

Hilgard, G. H.
1960 A study of reproduction in the intertidal barnacle, Mitella polymerus, in Monterey Bay, California. Biol. Bull., 119(2): 169-188.

Knight-Jones, E. W.
1953 Laboratory experiments on gregariousness during settling in Balanus balanoides and other barnacles. J. Exp. Biol., 30: 584-598.

1955 The gregarious settling reaction of barnacles as a measure of systematic affinity. Nature, 175: 266.

Moore, D. R., and D. J. Reish
1969 Studies on the Mytilus edulis community in Alamitos Bay, California. IV. Seasonal variation in gametes from different regions in the Bay. Veliger, 11: 250-255.

Nelson-Smith, A.
1968 The effects of oil pollution and emulsifier cleansing on shore life in south-west Britain. J. Applied Ecology, 5: 97-107.

Ricketts, E. F., and J. Calvin
1968 Between Pacific tides. Rev. by Joel W. Hedgpeth. 4th ed. Stanford University Press, Stanford, California. 614p.

Stohler, R.
1930 Beitrag zur Kenntnis des Geschlechtszyklus von _Mytilus californianus_. Zool. Anz., 90: 263-268.

Straughan, Dale
1969 Intertidal zone-formation in _Pomatoleios kraussii_ (Annelida: Polychaeta). Biol. Bull., 136: 469-482.

Whedon, W. F.
1936 Spawning habits of the mussel _Mytilus californianus_ Conrad, with notes on the possible relation to mussel poison. Univ. Calif. Publ. Zool., 41: 35-44.

Young, R. T.
1942 Spawning season of the Californian mussel _Mytilus californianus_. Ecology, 23: 490-492.

Table 1

Abundance of P. polymerus in Relation to Locality and Substrate

Locality	Position			Substrate		Oil Seep Area		Abundance
	N	I	S	Stable	Unstable	Yes	No	
Pismo Beach	+			+			+	A
East Cabrillo		+		+			+	A
Gaviota		+		+		+		C
Goleta Point		+		+		+		C
Carpinteria		+		+		+		C
Coal Oil Point		+		+		+		P
El Capitan		+			+		+	R
Hobsons Beach		+			+		+	
Arroyo Sequit			+		+		+	
Corona del Mar			+	+			+	C
Dana Point			+	+			+	C

Note:

N--North of Santa Barbara Channel; I--Within Santa Barbara Channel; S--South of Santa Barbara Channel; A--Abundant; C--Common; P--Present; R--Rare.

Table 2

Fraction of Adult *P. polymerus* Brooding Eggs at Goleta Point Compared with Surface Water Temperature Data at Santa Barbara (34°24'3" N, 119°41'5" W)

	Clean	Lightly Oiled	Water Temperatures[c]		
			Mean	Max.	Min.
1969					
March		0.1	13.4	15.4	12.0
April	0.4	0.55[a]	14.6	16.2	13.0
May		0.4	15.0	17.5	13.3
June		0.3	17.0	19.2	15.5
July		[b]	17.2	18.7	15.6
August		0.2	17.8	19.6	17.0
September		[b]	17.2	18.5	16.0
October	0.4		17.4	19.4	15.3
November			15.5	16.7	14.6
December			15.7	18.5	12.8
1970					
January	0.7		13.9	15.0	13.3
February	0.9		13.4	15.0	13.0
March	0.8		13.9	14.7	13.2
April	0.6		13.1	16.1	11.1[d]
May	0.5		14.8	16.5	11.7
June	0.3		16.1	18.2	15.1
July	0.3		16.9	17.9	15.2[d]
August	0.6				

[a] April, 1969, ranged from 0.1 to 0.9.

[b] No clean or lightly oiled samples examined. In July, 1969, moderately and heavily oiled samples averaged 0.3 adults brooding eggs and in September, 1969, moderately oiled samples had 0.2 adults brooding eggs.

[c] Daily water temperature data supplied by Scripps Institution of Oceanography.

[d] Data not available for every day of month.

Table 3

Fraction of Adult *P. polymerus* Brooding Eggs When Exposed to Different Levels of Oil Pollution

Locality	Date	Clean	Oiled		
			Light	Moderate	Heavy
Arroyo Burro	4/27/69	0.9			0.0
Goleta Point	4/18/69	0.5			0.0
Goleta Point	5/12/69		0.4	0.0	
Goleta Point	5/20/69		0.4	0.2	
Goleta Point	7/14/69			0.5	0.2
Goleta Point	7/23/69			0.5	0.0

Table 4

Fraction of Unoiled Adult *P. polymerus* Brooding Eggs in Seep and Non-Seep Areas

Date	Seep	Non-Seep		
		N	I	S
April 1969	0.5		0.9	0.0
October 1969	0.4			0.2
June 1970	0.3 (0.2-0.4)		0.7	0.2
July 1970	0.3	0.6		

Note:

N--North of Santa Barbara Channel; I--Within Santa Barbara Channel; S--South of Santa Barbara Channel.

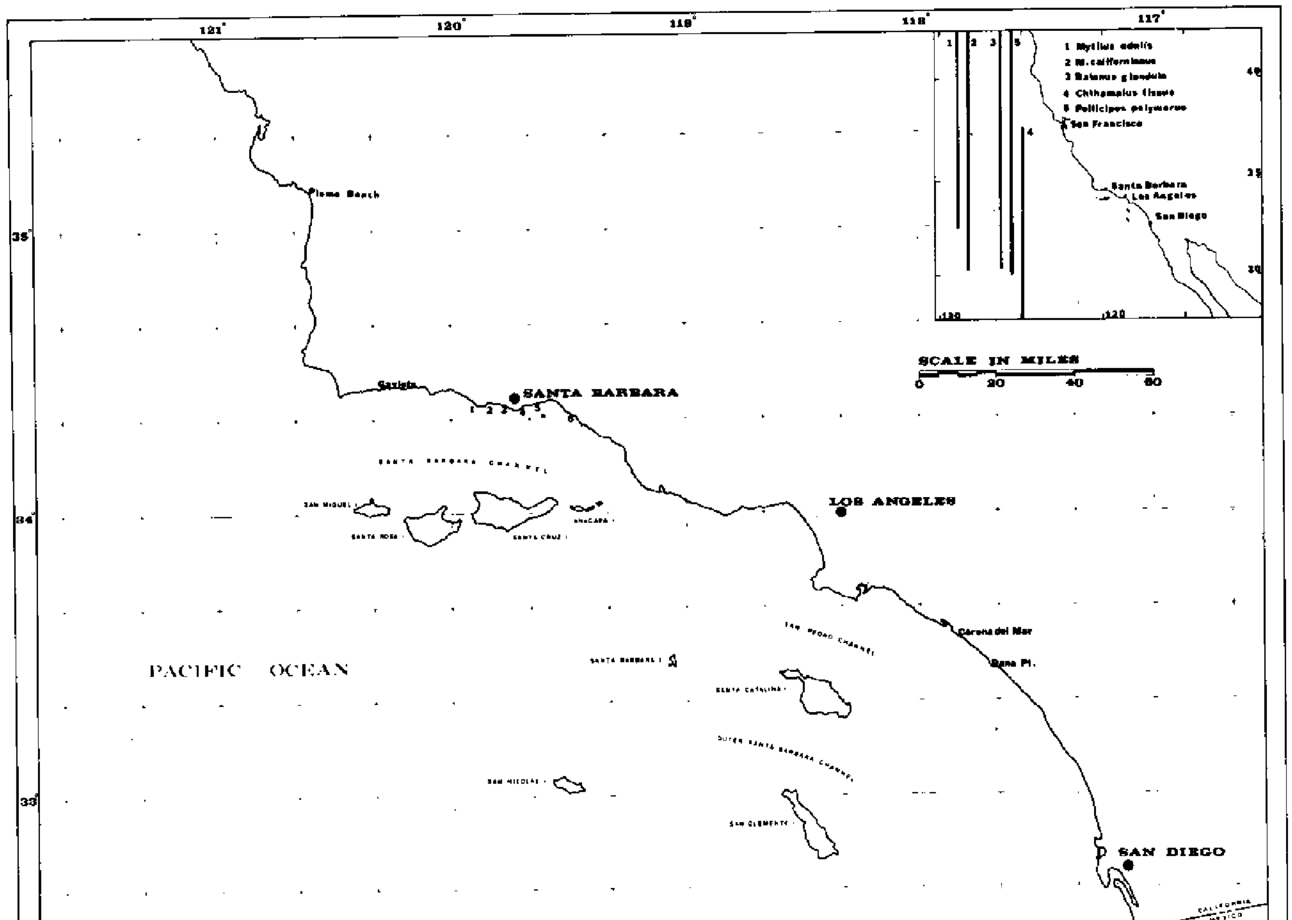
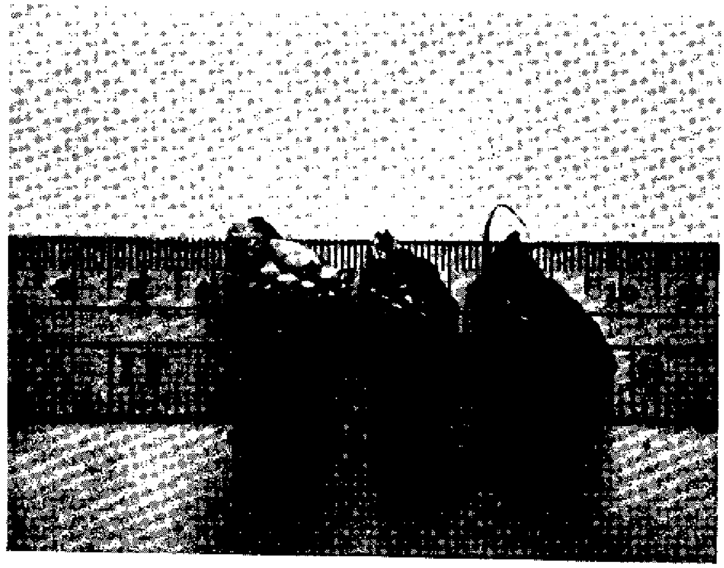


Figure 1

Map of Southern California showing localities mentioned in text. ■ - position of Platform A. Numbered stations near Santa Barbara are:- 1 - Coal Oil Point; 2 - Goleta Point; 3 - Arroyo Burro; 4 - Leadbeaters Beach; 5 - East Cabrillo; 6 - Carpinteria. Inset map shows the distribution limits of M.edulis, M.californianus, B.glandula, C.fissus, P.polymerus on the west coast of the United States and Mexico.



a. Specimens of _P.polymerus_ that are lightly oiled, moderately oiled, and heavily oiled. Lightly oiled specimens appear clean in photographs.
b. Specimens of _P.polymerus_ with young _P.polymerus_ on unoiled lower section of adult stalk. There are no young _P.polymerus_ on the darker upper oiled sections of the stalk.

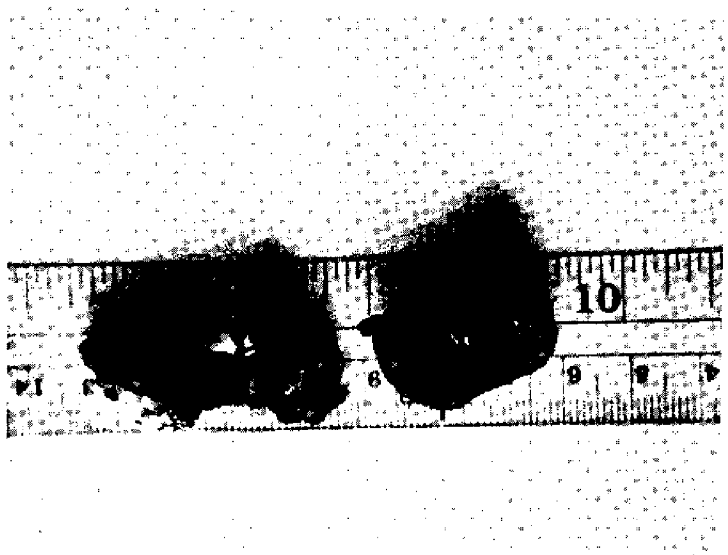


Plate 1

CHAPTER 11

OIL POLLUTION AND FISHERIES IN THE SANTA BARBARA CHANNEL

by Dale Straughan

Soon after oil started to spill into the Santa Barbara Channel in January, 1969, lower catches of fish were reported, the implication being that there were fewer fish in the area. Many observers neglected to mention that very few fishermen would want to use their boats and fishing gear in the oily waters because of damage to the gear, extra time needed for cleaning boats and gear, and the possibility fish might be contaminated by oil from the gear. Fears were also expressed that any fish living in the Santa Barbara Channel would be tainted with oil. To my knowledge, neither the Federal nor State Government authorities received any reports of fish tainted by oil.

The California Department of Fish and Game (1969) surveyed the Santa Barbara Channel to assess the effect of oil contamination on pelagic school fishes. These surveys were identical to the routine sea surveys conducted by the Department since 1965, designed to determine the abundance and distribution of the important pelagic species. They report (1969:36): "All fish appeared healthy, well-fed, and failed to show indications of starvation which might imply an impairment of the food chain. The species composition and numbers of fish taken varied from station to station and varied at the same station from cruise to cruise. Nevertheless, a comparison of surveys revealed few changes and that species diversity has been maintained."

The Department's pelagic fish surveys (1969:30) "indicate no adverse effects on the anchovy, Engraulis mordox, population as a result of the oil leak. The anchovy population of this area appears to be thriving and in no way harmed by the oil, either at the height of contamination or at present. The U.S. Bureau of Commercial Fisheries found no gross evidence of dead or deformed larvae or fish eggs, and no gross departure from the expected specific composition of the ichthyoplankton in the Santa Barbara Channel when they surveyed the area on February 11, 1969."

> "Since 1965, the area had been surveyed twelve times prior to the oil leak in the same manner as the three special surveys since February, 1969. The northern anchovy always has been the predominant species with far fewer quantities of jack mackerel, Trachurus symmetrius, Pacific mackerel, Scomber japonicus, and Pacific bonito, Sarda chiliensis. When we compare the results of the three surveys with the twelve conducted prior to the oil leak, we find only one pre-leak survey detected more schools than those made since February, 1969. School sizes and concentration indicate a greater biomass than ever before. The largest concentration of anchovies in southern California was located during the August cruise only 20 miles from the oil platform." (California Department of Fish and Game Report, 1969:31-32)

Commercial landings of fishery products for the February-July period were compared for the years from 1965 to 1969 inclusive at Santa Barbara, Ventura, Oxnard and Port Hueneme by California Department of Fish and Game. Landings at Ventura were very low (total 336 pounds) during 1969 as a result of the damage done to the harbor by the January, 1969, floods. While landings were lower in each month at Santa Barbara, the greatest decline in landings occurred in February when the harbor was closed at times because of the oil spill. Landings at Oxnard were unusually high during February (52,780 pounds compared to 410-4,954 pounds in previous years), which might account for some of the fishery products which normally would have landed at Santa Barbara. Landings at Port Hueneme were above the five-year average for the six months, but this was the result of large anchovy catches. Unfortunately no fishing effort data are available so that it is not known if the decline in landings at Santa Barbara was a result of lower catches or a decrease in fishing effort.

The number of fish taken from partyboats operating out of Santa Barbara declined during the period February-July, 1969, when the reported landings were only 10% the size of those in the same months for the previous four years (California Department of Fish and Game, 1969, Table 5).

"The major portion of this decline can unhesitatingly be attributed to lack of fishing effort (Table 6). Because of the adverse publicity of the oil spill, sportsmen fished elsewhere. The total number of boat days during the six-month period was only 13% of the average fishing effort for a comparable period during the previous four years. Only 723 sportsfishermen used partyboat facilities at Santa Barbara during this period in 1969, while 5,693 used them in 1968. A comparison of sport catch to fishing effort during the six-month period, reveals that the catch per fisherman day was 6.7 in 1969 compared to 8.9 in 1968. In 1967, 12.0 fish were caught per angler day, in 1966, success was 7.7 fish per angler day, and 12.1 fish were taken per angler day in 1965. These data indicate the catch per angler day fluctuates widely in this area, but it was slightly lower than average on the Santa Barbara partyboats in 1969. During the February-July period, 201,159 fish were taken by 17,161 anglers fishing from partyboats operating in the Santa Barbara-Port Hueneme area. This means there were about 11.7 fish per angler day. In 1968 during the same period, 332,615 fish were taken by 31,350 anglers which means their success was 10.6 fish per angler day. The lower catch per fisherman day off the Santa Barbara based partyboat may be attributed to a little longer running time and less fishing time, since they mainly fished the islands." (California Department of Fish and Game, 1969:34)

The total commercial fish catch for the Santa Barbara Channel and Channel Islands was calculated using data from the California Department of Fish and Game for origin blocks 651-658, 664-672, 683-691, 706-714 (Fig. 1 shows area enclosed in these blocks). The data for origin of catch are provided on a voluntary basis by fishermen. Hence they do not represent the total poundage taken in an area. These data are presented based on the assumption that a similar percentage of catch is reported each year. In February and March, the catch was lower in 1969 than during the previous four years (Table 1). However, the catch rose from April onwards so that the catch for the period February-July, 1969, was higher than that recorded for the same months in 1968 (4,143,953 pounds compared to 3,377,833 pounds). During these months the catch for the area that would possibly be most affected by the oil leak was slightly higher than that reported for the same area in 1968 (2,337,931 pounds in 1969 compared to 2,124,820 pounds in 1968) (Fig. 1).

Fish spotting data were obtained from the Bureau of Commercial Fisheries at Tiburon. These data are obtained by small aircraft flying over the area and are considered 95% accurate. Unfortunately no standard numbers of flights or standard flights are flown each month. The data are voluntarily supplied to the Bureau by fish spotters employed by the fishing industry.

Table 2 gives the average number of pounds of fish reported per flight for each month from January, 1967, to June, 1970, inclusive. Figs. 2-4 show the average number of pounds of northern anchovies, Pacific bonito, and mackerel reported per flight over the same period.

Due to lack of standardization of flights, these data should be interpreted with care. However, the data do show that fish continued to live in the Santa Barbara Channel after the oil spill. They also indicate that a large catch of one pelagic species can mask effects on other species when the total fish present are considered. For example, all the fish sighted in February, 1969, were mackerel. The large amount of fish recorded in March, 1969, (Table 2) can be attributed to the presence of large numbers of northern anchovies (Fig. 2) and mackerel (Fig. 4). Pacific bonito was absent for several months following the oil spill in January, 1969. However, the species is usually absent or scarce for three or four months from March or April onwards (Fig. 3).

In summary, fish were still present in the Santa Barbara Channel following the January, 1969, oil spill. The California Department of Fish and Game did not note any adverse effects in the reports of their surveys. All available data indicate that after February, 1969, the reduction in fish catches in the Santa Barbara area was probably due to the problems of fishing in oily water rather than to the lack of fish.

REFERENCES

California. Department of Fish and Game.
1969 Santa Barbara oil leak. California Department of Fish and Game, Interim Report, December 15, 1969. (Mimeographed.) 50p.

Table 1

Total Commercial Fish Catch for the Santa Barbara Channel, February-July, 1965-1969[a]

'ear	February	March	April	May	June	July	Total
.965	517,046	857,051	378,925	882,508	968,992	880,550	4,485,072
.966	756,937	1,442,512	3,377,910	2,652,603	315,822	495,053	9,040,837
.967	5,013,312	4,043,390	436,344	631,067	534,245	644,891	11,303,239
.968	893,847	536,039	343,941	419,959	480,201	703,846	3,377,833
.969	126,298	344,618	865,178	917,148	477,663	1,413,048	4,143,953

[a]Data supplied by California Department of Fish and Game

Table 2

Fish Spotting Data, January, 1967-June, 1970 (Weight Estimate in Pounds/Flight)

	J	F	M	A	M	J	J	A	S	O	N	D
1967	6,066	1,636	415	264	1,016	10,401	442	423	181	132	158	143
1968	217	206	45	0[a]	83	148	273	73	75	0[b]	5[a]	0[a]
1969	758	38	16,736	316	954	2,366	8,702	120	3,387	758	123	1,216
1970	283	68	179	194	508	905						

[a]One flight

[b]No data

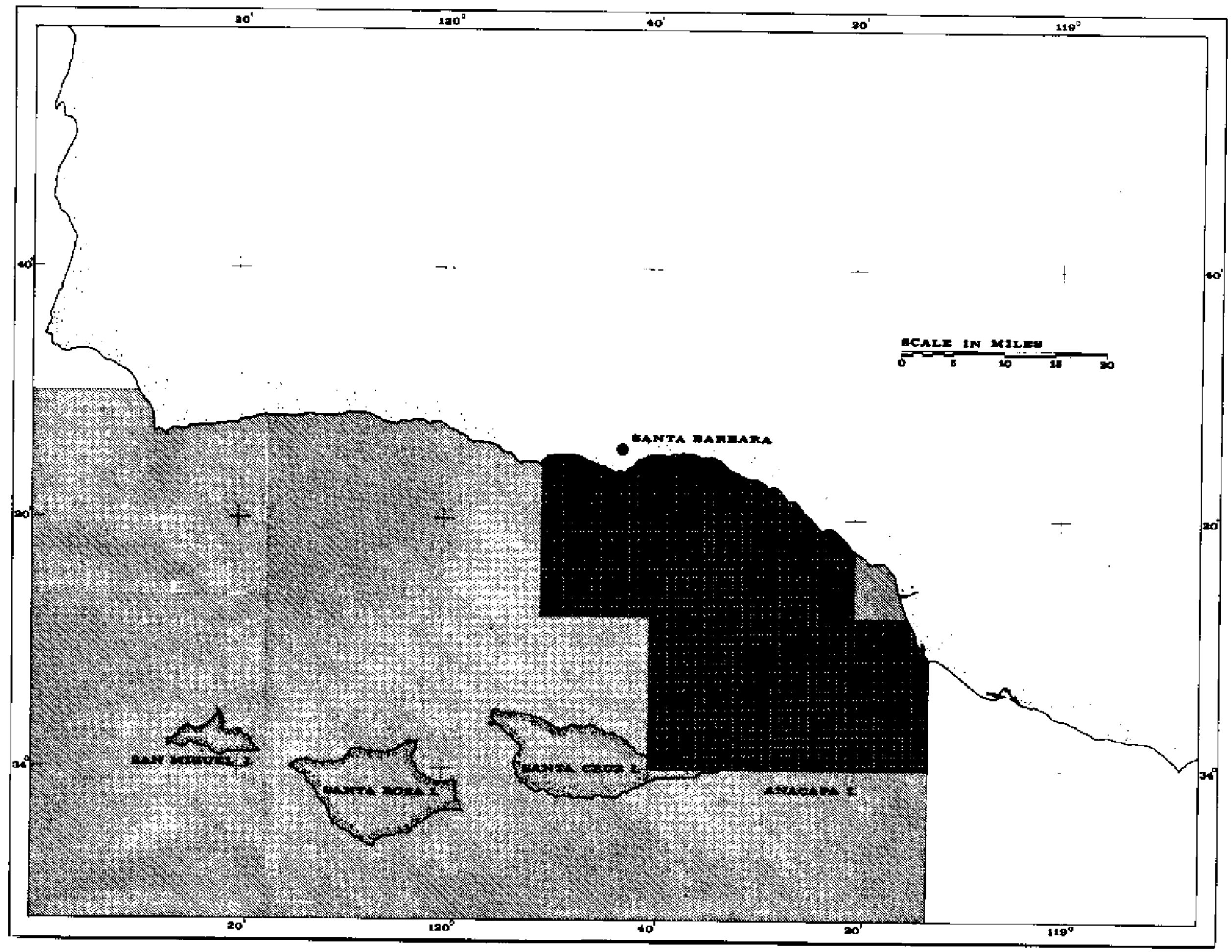


Figure 1. Map of Santa Barbara Channel showing areas considered for fish catch from the Channel (light) and fish catch from area most affected by the oil spill (dark).

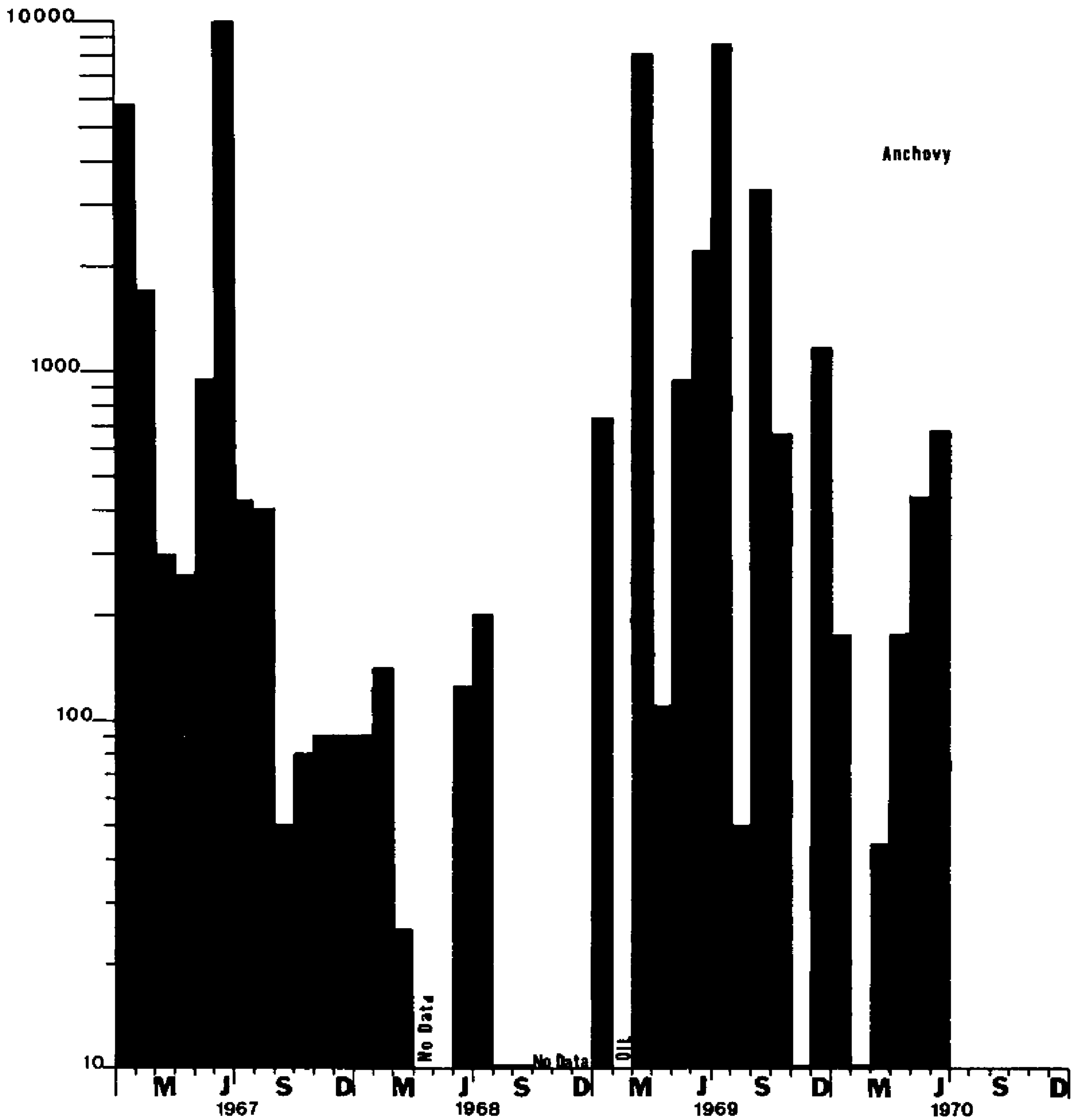


Figure 2. Semi-log histogram of estimated weight in pounds per flight of anchovies seen in the Santa Barbara Channel January, 1967, to June, 1970, inclusive.

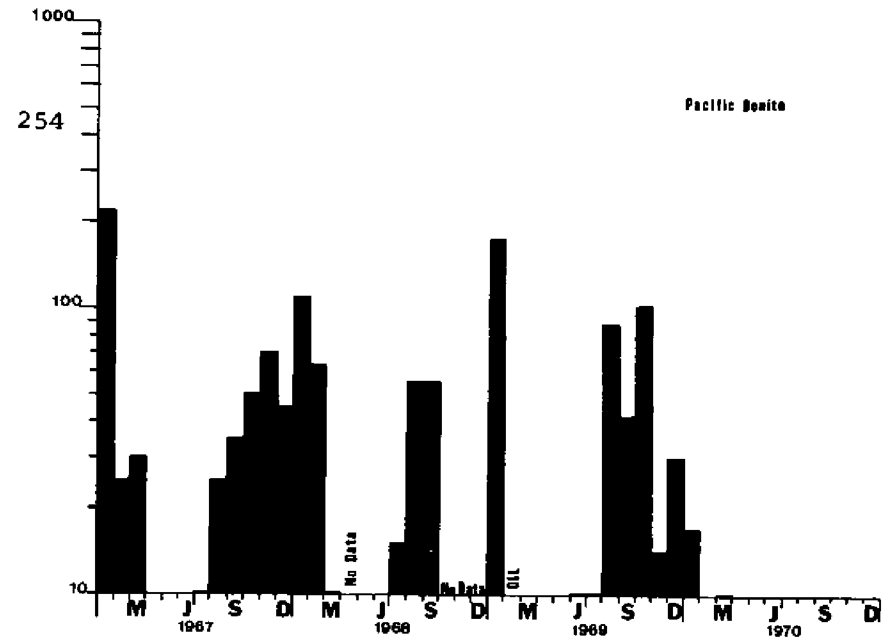


Figure 3. Semi-log histogram of estimated weight in pounds per flight of Pacific bonito seen in the Santa Barbara Channel January, 1967, to June, 1970, inclusive.

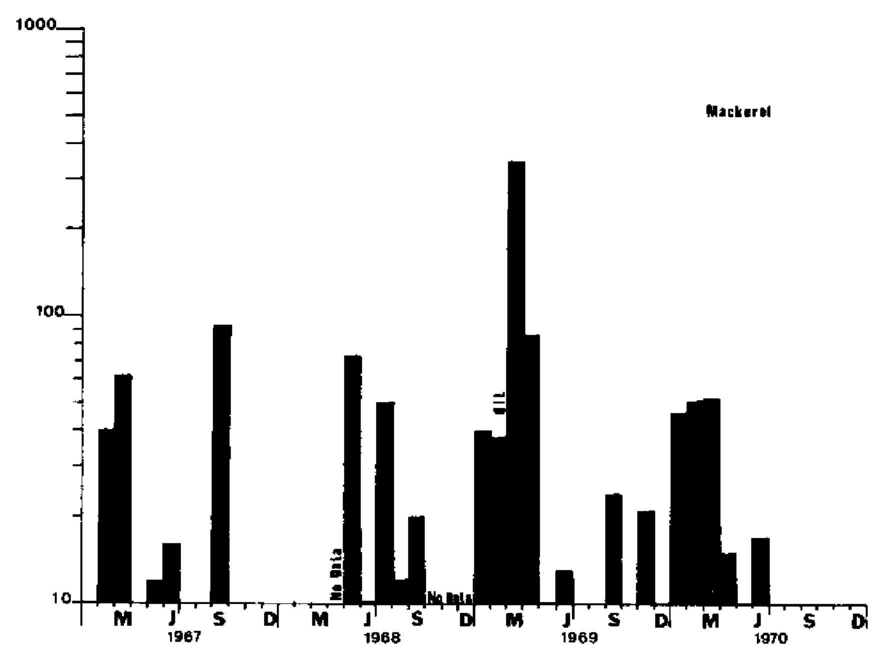


Figure 4. Semi-log histogram of estimated weight in pounds per flight of mackerel seen in the Santa Barbara Channel January, 1967, to June, 1970, inclusive.

CHAPTER 12

WHALES, DOLPHINS AND OIL POLLUTION

by Robert L. Brownell, Jr.[1]

On January 28, 1969, Union Oil's offshore well A-21 in the Santa Barbara Channel blew out and spilled a large quantity of oil into these waters for eleven days, until February 8 when the leak was sealed. This blowout is unusual in that on February 25, oil and gas "found their way outside the well wall and discharged from the seabed at several points along a line running eastward about 800 feet from the drilling platform" (Carter, 1969:530), and at this writing, one year later, some seepage still continues. The pollution was heaviest during the initial blowout and the early months of the seepage. Each year, gray whales (Eschrichtius glaucus) migrate south and then north through and to the west of this area, but the majority of the California herd had already passed south before the initial blowout and was unaffected. The entire north migration, however, passed through (or westward around) the area while it was contaminated.

By February 3 the State of California Department of Fish and Game had personnel in the Santa Barbara area and had set up a wildlife monitoring program to determine the oil pollution effects on wildlife. Seven ocean aerial and four beach transects were established, and wildlife populations and losses were monitored from February 3 to March 28.

---

[1]Department of Pathobiology, Johns Hopkins University, Baltimore, Maryland.

A progress report by the California Department of Fish and Game (see references) stated that "within the study area 3 sea lions and 4 porpoises were found dead. Autopsies were performed on 2 porpoises; their death could not be positively attributed to oil" (see discussion of individual strandings).

NEWS MEDIA AND JOURNAL REPORTS

One of the first major nationwide reports after the Santa Barbara oil pollution started was in Time magazine (February 21, 1969:21) in an article entitled "Santa Barbara Oil Disaster." This article stated that "six seals floated onto Santa Barbara beaches. Autopsies performed on one of the dead dolphins showed that its blowhole had been clogged with oil causing massive lung hemorrhages." Note the discrepancy in reference from seals to dolphins in the above statement.

A number of newspapers reported in mid-March that six whale (five of them gray whale) carcasses had come ashore as of March 18, 1969. Newspaper reports speculated that the above whales had died as a result of the Santa Barbara oil leak. Details of these strandings are given in Table 1. Of the five gray whales reported, one stranded almost one year previous to the Santa Barbara oil leak, and one whale at Half Moon Bay was a sperm whale. The sixth whale that stranded was a pilot whale (really a large dolphin).

At least four journal reports have discussed oil pollution and whale and dolphin deaths. These papers by Orr, McCaull, McHugh and McMillan were all published in 1969, and are discussed below.

McCaull (1969:7) reported the following about marine mammal deaths after the oil pollution in Santa Barbara Channel:

> "Possible damage to mammals that abound in the waters off California is a matter of conjecture that has not been resolved. For example, four dead porpoises, several seals, and six whales washed ashore after the oil leak began. The animals were coated with crude oil contamination. Results of examination of tissue from some of the whale carcasses by federal investigators had not been made available by mid-June."

With reference to the Santa Barbara oil spill, McHugh (1969:1076) reported:

> "Early in 1969, five dead whales came ashore in the area south of San Francisco. Conservationists in California were concerned that these deaths might have been caused by man-made changes in the environment. One had been harpooned by the whalers engaged in scientific sampling (see Table 2) and it was recovered. The cause of death of the others is unknown. The deaths could have been caused by careless whaling or by other sources of mortality. The Bureau of Commercial Fisheries responded by calling a halt to the scientific sampling program, not in reaction to emotional public pressures, but because if whales were being killed by other human activities, the safety factor built into the sampling program might have been exceeded. It is known now that the number of stranded whales was about what would be expected from past experience. Thus, the halt was not necessary, but it was the prudent thing to do under the circumstances."

The only reference to cetaceans and oil pollution by McMillan (1969) is the caption under the photograph of a crisscross dolphin that stranded on the beach in front of the University of California Santa Barbara campus, Goleta, Santa Barbara County, on February 6, 1969. He stated that beached bottle-nose dolphins had oil in the blowhole. No supporting evidence is given for this statement.

Orr's (1969) article entitled "The Gray Whale 'Crisis' of 1969" centered around his studies and surveys of the Santa Barbara oil pollution and stranded cetaceans. The biology of the gray whale is also discussed, along with Orr's own investigations of several stranded whale carcasses. Orr concluded as follows regarding cetacean deaths (1969:7):

> "In summary, three gray whales and one sperm whale were found dead along the central California coast and one pilot whale and at least one common dolphin along the southern California coast in February and March, 1969. All died subsequent to the blowout at Platform A off the coast of Santa Barbara County on January 28, 1969. . . . One could conclude this account by saying

that no positive evidence was obtained to show that any gray whales died on their northward migration from the effects of crude oil pollution. However, the fear that oil might have been responsible for the death of three individuals aroused such nationwide interest that it may well turn out to be a most effective factor in the cause of gray whale conservation."

DISCUSSION OF INDIVIDUAL STRANDINGS REPORTED AFTER THE SANTA BARBARA OIL SPILL

In various sources (mainly newspapers) seven whales and four dolphins were reported dead on California beaches after the start of the Santa Barbara oil spill. These strandings are listed in Table 1 and details of the individual strandings are listed below. Other strandings between February and early May, 1969, that were not published are listed in Table 2.

Two gray whales stranded within two days of each other and received the most publicity. On March 11, 1969, the first whale was reported on the beach at the foot of Golden Gate Park (Ocean Beach), San Francisco County. This whale was a male 10.67 m (35 feet) in length and was badly decomposed and shark bitten. Allen A. Wolman reported (personal communication, April, 1969) that he found an extremely light oil and dirt film on the baleen plates. No oil was found in the gastro-intestinal and respiratory tracts. The amount of oil on this whale can be considered normal for a dead animal that floated at sea for some time before stranding. The other gray whale, also a male, 10.90 m (35-1/2 feet), stranded on March 12, 1969, approximately one mile south of Mussel Rock, Pacific Manor, San Mateo County. This carcass was transported by truck to a nearby whaling station. Tissue samples were taken to check for possible oil pollution and sent to the Federal Water Pollution Control Administration laboratory in Alameda, California (see section on analysis of whale tissue). A two-page color photograph of this whale appeared in _Life_ magazine in April 18, 1969. These two strandings of gray whales only one day apart and the oil reported in the mouth of one whale, gave the news media (television, radio, and newspapers) the idea that possibly whales were dying as the result of swimming through the oil polluted waters off Santa Barbara. News stories to this effect were carried nationwide for several days.

McHugh (1960) reported that one of the dead whales that stranded in the San Francisco area had been harpooned by whalers engaged in scientific sampling. This specimen was examined at Pt. Reyes, Marin County, on March 19, 1969. It was a male 11.89 m (39 feet) in total length (Allen A. Wolman, in litt., February 18, 1969).

A gray whale carcass on the beach two miles north of Bolinas, Marin County, was reported to have stranded after the start of the Santa Barbara oil spill. Lawrence G. Barnes (personal communication, April, 1969) stated that he first examined this carcass on February 14, 1969. The whale was 12.70 m (41 feet, 8 inches) long but approximately 1.2 m (4 feet) of the tail was missing.

Another carcass was first seen on March 8, also about two miles north of Bolinas. This gray whale was a badly decomposed male 12.35 m (40 feet, 6 inches) in length (Allen A. Wolman, personal communication, April 25, 1969).

A sperm whale (Physeter catodon) stranded on February 27, 1969, at Miramar about two miles north of Half Moon Bay, San Mateo County. This whale was approximately 9 m (30 feet) in length. A photograph of the carcass was published by Orr (1969).

A small pilot whale (Globicephala scammonii) that stranded on March 13, 1969, on Laguna Beach was first reported as a "gray whale calf." This animal was the last whale stranding reported by the news media. A pregnant dead crisscross dolphin (Delphinus delphis) stranded on February 6, 1969, on the beach in front of the University of California at Santa Barbara. News of this dead dolphin found only a few days after the start of the Santa Barbara oil spill received nationwide attention. A photograph of its carcass first appeared in the Santa Barbara News-Press on March 7, 1969. The photograph was also published in the Sierra Club Bulletin, March, 1969. This dolphin received such unusual publicity because Newsweek (February 10, 1969) reported that the blowhole of the animal was clogged with oil and the lungs had hemorrhaged. Dr. Oscar Brunetti of the California State Department of Fish and Game autopsied the animal and reported to me (personal communication, January 9, 1970) that no oil was found in this specimen.

A 1969 unpublished California State Department of Fish and Game report stated that the above dolphin, plus three others, stranded in the Santa Barbara area between January 28 and March 31, 1969, but gave no additional details. However it was noted that two dolphins were autopsied and that "their death could not be positively attributed to oil." On February 1, 1969, a dead Pacific striped dolphin (*Lagenorhynchus obliquidens*) was found 2-1/2 miles south of Goleta Post Office. A dead dolphin was found along the north shore of Santa Cruz Island on February 4, 1969. I have not been able to obtain any additional information on the fourth dolphin.

Senator Alan Cranston of California was instrumental in having a moratorium ordered against the killing of gray whales off San Francisco by Crowther after the deaths of six whales were in the news. I view this moratorium as an unfortunate event. Had the whaling operations continued, even for a short period of time, a sample of whales would have been available for tests of possible oil contamination. Cranston stated (*in litt.*, April 2, 1969) that "However, under the circumstances I am delighted that the Bureau of Commercial Fisheries acted with such dispatch in declaring the moratorium. While there is a question as to the cause of death of the species, at a time when there is a possible change in their ecosystem, prudence dictates that hunting be halted."

ANALYSIS OF WHALE TISSUE

The Alameda Laboratory of the Federal Water Pollution Control Administration made an analysis of whale tissue collected from one of the stranded whales (March 12, Pacifica) and two gray whales taken during commercial whaling operations off San Francisco. The results of the above tissue analyses were sent by letter from Paul de Falco, Jr., Director for the Pacific Southwest Region of the Federal Water Pollution Control Administration, on April 18, 1969, to Ford Wilke, Director of the Marine Mammal Biological Laboratory, Bureau of Commercial Fisheries, Seattle, Washington. This letter is quoted below in its entirety.

"Subject: Results of Whale Tissue Analyses

"Reference is made to your March 21, 1969 letter. Tissue specimens from three gray whales delivered by your representative have been analyzed by our laboratory in Alameda, California. Within the limits of methods and instrumentation used we were unable to detect the presence of crude oil in these tissue samples. Methods used are as follows:

Method of Analysis of Whale Tissue

"The tissue was blended with chloroform to remove any crude oil that might be present. The sample was filtered, dried and the chloroform evaporated off. The residue was then saponified using methanol and potassium hydroxide. The sample was then partitioned between water and chloroform. The chloroform layer was eluted through silica gel using iso-octane and then benzene. The solvent was removed by evaporation and the residue taken up in chloroform. A portion was injected into a gas chromatograph using a specific sulfur and flame ionization detector.

"Samples of 'normal' tissue from whales killed at sea were subjected to the above procedure. Lung tissue from two different whales were fortified with an over-spike of 1% and 100 PPM of Santa Barbara crude oil. These fortified samples were carried throughout the clean-up process and oil identification was positive. Samples of baleen, esophagus, trachea and material from the thoracic cavity from the whale which was washed ashore at Pacifica, California were then subjected to the clean-up procedure. No lung material was furnished from suspect whale. Oil identification was negative on all tissues from the suspect whale. This method is sensitive in the 50-100 PPM level.

"Sensitivity to lower concentrations are not reliable due to the extensive natural tissue oils that must be removed prior to analysis.

"If we can be of further assistance please do not hesitate to contact us again."

Population size and censuses

Gilmore (1969) reported that current population size of the gray whale was estimated at 8,000 to 9,000. These census estimates of the total California herd population were made by the U.S. Fish and Wildlife Service from Yankee Point near Carmel, California in 1967-1968.

Whaling operations along the coast of California and Baja California, between 1850 and 1890, reduced the California gray whale population of 25,000 to 50,000 to a few thousand. From 1890 to 1924, the population increased. From 1924 to 1937, whaling was again carried on, but since 1937, the species has had complete legal protection (see Gilmore, 1960).

Food and feeding habits

Gilmore (1961) reported that gray whales were rarely seen feeding. There is little or no food in winter in the lagoons. Also, a migrating whale has little time to hunt and stop for food, if it is to make its appointments 6,000-7,000 miles apart in 2-1/2 months.

Finally, hundreds of stomachs from gray whales captured by the industry, on migration and on winter grounds, over the past 100 years in Korea, California and Canada have been empty. Rare exceptions had "sea-moss," kelp, pebbles, and "sardines."

The conclusion is strong that the gray whale starves for much of the nine months of swimming south, remaining on the winter grounds, and swimming back north, although there is also no doubt that, when food is available, the gray whale takes a meal. On the rare occasion when gray whales were feeding, they were crisscrossing through a dense school of small fish, like anchovies, off San Diego.

> "The best data available on the feeding habits of migratory whales resulted from a study of the stomach contents from 200 gray whales captured (with special

permission from the U.S. Fish and Wildlife Service over a several year period) by a whaling company at Richmond, near San Francisco. They took grays for study during both northward and southward legs of the annual migration.

"Postmortem examination showed that there was nothing in the stomachs of 198 whales, some sand and gravel in one, and a small amount of some reddish substance thought to be the remains of crab larvae in the other. A parallel study found the stomachs of ten gray whales taken off northern Vancouver Island on northward migration in 1952 to be empty." (Gilmore, 1969:15)

Migration and distribution

Gilmore (1961) states that the main herd arrives in mid-November to early December in northern California, after passing Oregon, and may be seen from the headlands at Sea Lion Caves near Florence, Oregon, Port Orford, Crescent City, Patrick Point and Trinidad Head.

At San Francisco, the date of arrival is early to mid-December, and for six weeks people can see whales from Bodega Head, Point Reyes, Montara Point, Pigeon Point, and near Santa Cruz. Below Monterey, Carmel and Point Lobos are favorite spots, and further south, later, there are Big Sur, Piedras Blancas, Point Conception, Santa Barbara, Point Dume, Palos Verdes Peninsula, the cliffs of Laguna, and finally La Jolla and Point Loma at San Diego.

The line splits at Point Conception, just west of Santa Barbara, where a few individuals take the island-route as the coast turns abruptly eastward. These island-hoppers continue to the last islands, Santa Catalina and San Clemente, and then turn eastward to the coast as if accurate memory, or the instinct to go eastward and hug the coast on the left when migrating south, determined the direction.

Two months are spent on the breeding grounds in Baja California.

Gilmore (1961) states that the northward migration at San Diego becomes heavy in late February or early March, and continues heavy until late April, tapering off rapidly through early May. A few early northward migrators in middle and late February lap the late southward migrators both moving in opposite directions at the same time, sometimes close to each other like cars on a highway without recognition.

Some gray whales hop northward across the great bight of Southern California from Point Loma at San Diego, and the Coronado Islands 20 miles south and 5 miles offshore, to Catalina Island, and the Palos Verdes Peninsula. From Catalina Island, these island-hoppers go to tiny Santa Barbara Island, over the horizon to the west 21-1/2 miles, operating by memory, and thence to Anacapa and Santa Cruz Islands. They make a landfall on the coast near Point Conception and meet those that went up the Santa Barbara Channel, or skirted the shore from the Palos Verdes Peninsula.

DISCUSSION

A total of 30 dead whales have been reported in California during the past ten years (see Tables 1-3). The deaths of five or six of these whales are known to be unnatural as they were shot or became tangled in fishing nets. At least three gray whales died in each of the following years: 1961, 1963, 1964, 1968, and 1969.

The number of gray whale strandings in 1969 does not differ significantly from that of previous years. A pilot whale (Globicephala scammoni) was reported stranded on Laguna Beach. The genus Globicephala, usually referred to as blackfish, is subject to strandings throughout the world (Moore, 1953, and Gilmore, 1959). Norris and Prescott (1961:347) reported that "Usually one or more individual pilot whales strand on Pacific coast beaches yearly." The only other non-gray whale stranding, reported from Half Moon Bay, was a sperm whale. Several accounts of sperm whale strandings in the eastern north Pacific have been published (see Gilmore, 1957 and 1959, and Roest, 1964). Six dolphins, of which only one was reported by the news media, stranded between February and May, 1969 (see Tables 1-2). The one dolphin reported was said to have died from a massive lung hemorrhage caused by its blowhole being clogged with oil, but there is no evidence to support this statement. Of the remaining five dolphins, three were examined by me, and the other two by two of my colleagues. None of these animals showed any external oil contamination. Carcasses of Delphinus and other species of dolphins commonly strand along Southern California beaches each year.

From the data in Tables 1-3, and the fact that the population of the gray whales is increasing, we can expect to continue seeing these carcasses wash ashore on California beaches each year during the migration season. Infant mortality on the Mexican calving grounds is reported as a common occurrence (Eberhardt and Norris, 1964). Along the California coast at least five newborn calves have stranded and perished. The smallest one, a 374 cm female that stranded at Shelter Cove, Humboldt County, on February 18, 1968, may represent a stillbirth. Eberhardt and Norris (1964) reported the stranding of six newborn animals ranging from 395.5 cm to 540.5 cm, with a mean of 468.3 cm. They suggested that their smallest animal, which is larger than the Shelter Cove specimen, may have represented a stillbirth. Seven other gray whales ranging in size from the middle twenties to thirty feet in length and considered yearlings stranded or became entangled in fishing nets and died. Thus, it appears that mortality of newborn calves and yearling animals along the California coast is higher than in other age classes.

Three additional stranded yearling gray whales from outside California waters should be noted. These support my statement that mortality in yearlings is higher than other age classes except for newborns. Gilmore (1960) reported a dead whale found between Sea Lion Caves and Heceta Head, Oregon, in April, 1958, that was undoubtedly a yearling. On August 16, 1966, a young male 824 cm in length (27 feet) was found on the beach at Wreck Bay, near Uclurlet, Vancouver Island (Pike and MacAskie, 1969). The cause of death was unknown. The third whale was reported to me by Lloyd T. Findley. This carcass was found on March 21, 1969, approximately ten miles southeast of El Golfo de Santa Clara, Sonora, Mexico, in the Gulf of California. The specimen measured 762 cm in length (25 feet).

Mortality of gray whales on their feeding grounds in Alaska has been discussed by Wilke and Fiscus (1961). These authors reported the following observations (1961:109): "A gray whale, 43 feet in length, had drifted ashore at Cape Thompson in early August. Two others were reported on the beach in the vicinity. On 29 August, a dead gray whale was found drifting about 50 miles west of Kivalina village. It was not greatly bloated. The cause of death of these whales is unknown."

In summary, it can be predicted that three or four gray whales and various numbers and species of dolphins will annually strand on California shores. If the population of gray whales continues to increase, the number of whales stranded will also increase. Reported strandings on California beaches have increased over the past ten years in part because of both public and scientific interests. The major factors in the number of dead whales and dolphins found after the Santa Barbara oil spill were the coastal and island surveys conducted by the California State Department of Fish and Game and public interest in possible wildlife destruction.

ACKNOWLEDGMENTS

A number of people have been helpful in many different ways during my studies of stranded cetaceans along the California coast: Lawrence G. Barnes, Robert C. Boice, Lloyd T. Findley, Paul T Gilbert, Jr., Raymond M. Gilmore, Earl S. Herald, Warren J. Houck, Carl L. Hubbs, Robert E. Jones, Edward Mitchell, Robert T. Orr, John M. Olguin, William F. Perrin, John H. Prescott, Dale W. Rice, Aryan I. Roest, Dale Straughan, William A. Walker, Ford Wilke, and Allen A. Wolman.

APPENDIX

1970 WHALE STRANDINGS

I know of four whales that came ashore on California beaches by July 1, 1970: three gray whales and one Little Piked Whale (Balaenoptera acutorostrata).

A male gray whale (15 m) was examined by Warren J. Houck and Robert E. Jones (Jones, in litt., March 3, 1970) on February 28 at Punta Gorda (a half mile south of the abandoned Coast Guard station), Mattole River, Humboldt County. A local hermit reported to Houck and Jones that the whale stranded dead three weeks previous to their visit.

The second gray whale stranded at Davenport, Santa Cruz County. This animal was reported to Lawrence G. Barnes (Barnes, in litt., June 25, 1970) on March 7. On March 14 the carcass, which had been burned, was examined by Barnes and Jones. The approximate total length was 8 m. Barnes collected the tympanic bullae (LGB 313).

Barnes (in litt., June 25, 1970) reported also that "A gray whale was beached by the Coast Guard at Port Costa, Contra Costa County, on May 3. It was probably brought there from somewhere in Carquinez Straits." The animal was a female and the approximate total length was 7.70 m. The whale was buried at Port Costa by county employees. A photograph of this whale was published by the Contra Costa Times on May 7, 1970, p. 1.

A male Little Piked Whale was reported (photograph) by the Independent Press-Telegram on May 15, 1970 (p. A-4) to have "beached near the Golden Avenue launch ramp where it was dragged by Long Beach lifeguards who found the mammal dead and drifting offshore Thursday May 14." The whale was said to be 25 feet in length.

Two of the three gray whales were yearlings and support the statement already made that mortality is high in this age class. The 15 m gray whale would have been an adult approaching the maximum length for the species. The Little Piked Whale was probably a subadult or adult. Two newborn strandings of this species were reported from Southern California by Norris and Prescott (1961).

REFERENCES

California. Department of Fish and Game.
1969 Progress report on wildlife affected by the Santa Barbara Channel oil spill (January 28-March 31, 1969).

Carter, L. J.
1969 Offshore oil: Channel blowout points up information gap. Science, 164: 530-532.

Eberhardt, R. L., and K. S. Norris
1964 Observations of newborn Pacific gray whales on Mexican calving grounds. J. Mammal., 45: 88-95.

Gilmore, R. M.
1957 Whales aground in Cortés' Sea. Pacific Discovery, 10(1): 22-27.

1959 On the mass strandings of sperm whales. Pacific Naturalist, 1(10): 9-16.

1960a A census of the California gray whale. U.S. Fish and Wild. Serv., Spec. Sci. Rep., Fish., 342: 1-30.

1960b Whale in the grass. Sea Frontiers, 6: 18-23.

1961 The story of the gray whale. 2d ed. Yale Printing Co., San Diego. 17p.

1969 The gray whale. Oceans Magazine, 1(1): 9-20.

McCaull, Julian
1969 The black tide. Environment, 11(9): 2-16.

McHugh, J. L.
1969 The United States and world whale resources. Bioscience, 19: 1075-1078.

McMillan, I. I.
1969 Disaster at Santa Barbara. Defenders of Wildlife News, 44(1): 24-28.

Moore, J. C.
1953 Distribution of marine mammals to Florida waters. Amer. Midl. Nat., 49: 117-158.

Norris, K. S., and J. H. Prescott
1961 Observations on Pacific cetaceans of Californian and Mexican waters. Univ. Calif. Publ. Zool., 63: 291-402.

Orr, R. T.
1969 The gray whale "crisis" of 1969. Pacific Discovery, 22(6): 1-7.

Pike, G. C., and I. B. MacAskie
1969 Marine mammals of British Columbia. Canada, Fish. Res. Board, Bull., 171: 1-54.

Rice, D. W.
1965 Offshore southward migration of gray whales off Southern California. J. Mammal., 46: 504-505.

Roest, A. I.
1964 _Physeter_ and _Mesoplodon_ strandings on the central California coast. J. Mammal., 45: 129-136.

1970 _Kogia simus_ and other cetaceans from San Luis Obispo County, California. J. Mammal., 51: 410-417.

Wilke, Ford, and C. H. Fiscus
1961 Gray whale observations. J. Mammal., 42: 108-109.

Table 1

Whale and Dolphin Strandings Reported along California Beaches from January 28 through March 31, 1969

Date	Locale		Size and Sex
2/1/69	2 1/2 miles S. of Goleta Post Office, Santa Barbara Co.	Pacific Striped Dolphin (<u>Lagenorhynchus obliquidens</u>)	M
2/4/69	North shoreline of Santa Cruz Island, Ventura Co.	Unidentified	
2/6/69	Beach in front of UCSB Campus, Goleta, Santa Barbara Co.	Crisscross Dolphin (<u>Delphinus</u> <u>delphis</u>)	F pg.
Note: A fourth dolphin was reported but no additional information was available.			
2/14/69	2 miles N. of Bolinas, Marin Co.	Gray Whale*	41'8" without flukes
2/26/69	2 miles N. of Half Moon Bay, San Mateo Co.	Sperm Whale* (<u>Physeter</u> <u>catadon</u>)	<u>ca</u>. 30'
3/8/69	2 miles N. of Bolinas, Marin Co.	Gray Whale*	ca. 40'
3/11/69	1/3 mile S. of Cliffhouse (Pacifica), Ocean Beach, San Francisco	Gray Whale*	35' M

Table 1--Continued

Date	Locale		Size and Sex
3/12/69	1 mile S. of Mussel Rock, Pacific Manor, San Mateo Co.	Gray Whale*	34' M
3/13/69	Laguna Beach, Orange Co.	Pilot Whale	ca. 10-12'
3/19/69	Pt. Reyes, Marin Co.	Gray Whale	37' M

*Animals reported as Gray Whales by press prior to March 31, 1969

Table 2

Whale and Dolphin Strandings Not Reported
(January through May, 1969)

Date	Locale		Size and Sex
2/69	Fort Bragg, Mendocino Co.	Gray Whale	ca. 30' M
3/5/69	15100 Pacific Coast Highway, Pacific Palisades, L.A. Co.	Crisscross Dolphin (*Delphinus*)	201 cm M
3/27/69	Huntington Beach, Orange Co.	Crisscross Dolphin (*Delphinus*)	180 cm F
4/7/69	Cabrillo Beach, L.A. Co.	Crisscross Dolphin (*Delphinus*)	226 cm M
5/3/69	ca. 3/4 mile S. of Beach Blvd., Huntington Beach State Park, Orange Co.	Crisscross Dolphin (*Delphinus*)	188 cm F

Table 3

Gray Whale Deaths in California Waters, 1960-1968

Date	Locale and Comments	Size and Sex	Authority
12/16/60	Pacifica Beach, San Mateo Co.	ca. 16' M	R. T. Orr
1/10/61	San Francisco Bay (wedged between piles [wharf]; animal was shot)	28'	Gilmore, 1961
2/6/61	S.W. of Newport Bay pier, Orange Co.	468 cm F	E. D. Mitchell
3/27/61	Crescent City, Del Norte Co.	35'	W. J. Houck
3/?/61	N. of Silver Strand State Park, San Diego Co. (tangled in some nets and exhibited wounds)	30'	C. L. Hubbs
1/20/62	Beach at Rose Ave., Venice, L.A. Co.	ca. 15'	E. D. Mitchell and Star News 1/22/62, Culver City, Calif.
7/13/62	Fishing boat "Jimmey Boy" (whale in gill net [shot])	ca. 22-23'	J. H. Prescott
11/28/62	ca. 1 1/4 miles W. of Long Point, Catalina Island (floating)	ca. 19-20'	J. H. Prescott
1/28/63	Imperial Beach, San Diego Co. (deep gash reported on back)	28'	L.A. Times 1/28/63, pt. 1, p. 19
5/?/63	Off Cabrillo Beach, San Pedro Harbor, L.A. Co.		J. M. Olguin

Table 3--Continued

Date	Locale and Comments	Size and Sex	Authority
6/15/63	La Jolla, San Diego Co. (caught in fishing net and shot)	27'3" M	
8/6/63	1 1/2 miles S. of Crescent City, Del Norte Co.	33'8"	Creisler, 1965
8/?/63	Portuguese Bend, Los Angeles Co. (stranded after caught in net)		J. H. Prescott
2/25/64	Sunset Beach, Orange Co.	762 cm	R. L. Brownell, Jr., and R. C. Boice
3/9/64	Pinole Point, Contra Costa Co.	875 cm F	R. L. Brownell, Jr., and R. C. Boice
3/12/64	Dana Point, Orange Co.	15'	P. T. Gilbert, Jr.
9/14/65	2 miles S. of Nuclear Power Plant, San Onofre, Orange Co.		LACM 27059
3/19/66	1 mile S. of Freshwater Lagoon, Humboldt Co.	33' F	W. J. Houck
11/15/66	Morro Bay Sand Spit, San Luis Obispo Co.	25'	Roest, 1970
1/23/67	N. of Scripps, UC, La Jolla, San Diego Co. (numerous cuts on back)	13.9 m F	C. L. Hubbs and R. L. Brownell, Jr.; Gilmore, 1969
4/17/67	Portuguese Bend, Los Angeles Co. (beach in front of tennis court)	_ca_. 27'	_L.A. Times_ 4/18/67 and J. M. Olguin
2/14/68	2 miles N. of Bolinas, Marin Co.	41'8" without flukes	L. G. Barnes

Table 3--Continued

Date	Locale and Comments	Size and Sex	Authority
2/18/68	Shelter Cove, Humboldt Co.	374 cm F	W. J. Houck (HSC 68-3)
3/?/68	Mouth of San Simeon Creek, N. of Cambria, San Luis Obispo Co.	40'	Roest, 1970; L.A. Times 3/20/68, pt. 1, p. 25

CHAPTER 13

OIL CONTAMINATION AND ELEPHANT SEAL MORTALITY: A "NEGATIVE" FINDING

by Burney J. Le Boeuf[1]

When crude oil from the Santa Barbara Channel oil spill washed up on an elephant seal rookery at San Miguel Island shortly before March 17, 1969, over 100 pups were coated with oil, sand and detritus (Peterson and Le Boeuf, 1969, unpublished report of an expedition to San Miguel Island, March 25-28, 1969). The news media acted quickly in expressing concern for the lives of these animals (e.g., San Francisco Chronicle, April 3, 1969, and Los Angeles Times, April 6, 1969). The National Park Service requested an investigation (Simpson and Gilmartin, 1970), the results of which suggest that the oil caused neither illness nor mortality. This paper presents additional data which help to evaluate the initial investigation and support the conclusion that oil-fouling had no deleterious effect on the health of elephant seal pups.

Simpson and Gilmartin spent four days on San Miguel Island between April 7 and 16, 1969, examining animals for clinical signs of sickness and collecting specimens for petroleum residue analysis in the laboratory. They found few sick animals, and no petroleum in the tissue of two dead seals examined (one of which was not coated with external oil) or in blood samples taken from live animals.

Their data are difficult to interpret in light of the methods employed and the incompleteness of the report. They

---

[1]Crown College, University of California, Santa Cruz, California.

do not specify the age, number, or degree of oil-fouling in live animals from which blood and rectal temperatures were obtained. The logic in looking for petroleum in the body of animals as an indication of illness or mortality is questionable. One would not expect significant petroleum residues in blood or tissue unless the animals were ingesting it. This was unlikely since the rookery was contaminated after 90% of the pups had been weaned and were no longer suckling. Furthermore, weaned pups do not feed until they go to sea in late April. Thermoregulatory difficulties might be expected in animals with near-total encapsulation in crude oil. But rectal temperature readings which might reflect this difficulty are highly variable in elephant seals (Bartholomew, 1954) and Simpson and Gilmartin obtained too few recordings to answer this question. Lastly, the nature and timing of their investigation could have demonstrated only short-term effects of oil contamination--effects that might have appeared less than a month after exposure.

The question of whether oil contamination affected the mortality rate of elephant seal pups can be approached simply and directly by marking soiled and non-soiled individuals soon after the former are exposed. As part of our regular tagging program, R. S. Peterson and I attached yellow "Dalton Roto-Tags" to the hindflippers of 714 weaned pups at San Miguel Island on March 25-26, 1969, shortly after the Northwest Cove rookery was fouled (Fig. 1). The outer surface of the plastic tags were numbered from 200-1000. The inner surface of each tag bore the inscription: "NOTIFY U CALIF, SANTA CRUZ USA." The 2 x 4-1/2 cm tags are easily noticed and the numbers can be read from a distance of several meters.

Fifty-eight weaned pups and five yearlings from Northwest Cove, tagged on March 25, had bodies at least 75% covered with a mixture of oil, mud and sand (Fig. 2). An equal number of clean pups tagged on the same day in the adjacent West Cove area were selected randomly to provide a control group for comparison (Fig. 3).[2] Three criteria can be used in evaluating the results: (1) One would expect a higher

---

[2] Experimental animals were marked with numbers in the series 501-567; control animals were marked in the series 601-671.

mortality rate in pups exposed to oil if this exposure is detrimental to their health. (2) If the oil covering affects the animals once they have gone to sea and corpses sink or are destroyed, one would expect fewer tag sightings of live animals in the experimental group. (3) Sightings of previously contaminated animals in healthy condition and bearing no trace of oil would indicate that the substance had no serious effect on the health of these animals.

During the period between April, 1969, and June, 1970, 222 of the 714 animals tagged in March, 1969, were sighted at least once in various locations along the California Coast. This is an overall tag return rate of 31%. Only two pups were reported sick and one was reported dead; these animals were not oily when tagged. The dead animal (yellow tag 868) was coated with oil when found on April 7, 1969, at San Miguel Island.

During the 1-15 month period since tagging, 40% of the pups in the oil group were sighted as compared to 25% of the pups in the control group (Tables 1 and 2). The percentage return for the experimental group exceeds both the control group figure and the overall figure. Except for one animal in the experimental group (tag 558), whose condition was questionable, all animals in both groups were reported to be in apparent good health. The two sick pups did not belong to the randomly selected control group.

At the time the tags were read, the pelage of all experimental animals, except number 508, showed no trace of oil. Control group animals were also clean when sighted.

A seal must be healthy to swim long distances. Eight animals in the experimental group[3] and eight animals in the control group were seen 408 kilometers or more north of the tagging location after November, 1969. One animal from each group was sighted at San Nicolas Island, approximately 120 kilometers south of San Miguel Island.

---

[3]Not included in this count nor in Table 1 was tag 528 which was found on a beach near Santa Cruz unattached to an animal. Since the tags do not float, the tag was undoubtedly lost by its wearer on Santa Cruz.

These data support the conclusion that the crude oil which coated many weaned elephant seals at San Miguel in March and April, 1969, had no significant immediate nor long-term (1-15 months later) deleterious effect on their health. Had the rookery been contaminated earlier in the season when females were nursing, pups might have ingested the crude oil and more serious consequences might have ensued.

On a subsequent tagging expedition to San Miguel Island on March 24-25, 1970, only a few of this new generation of pups were observed bearing small spots of oil and tar. Inspection of the beaches on the western portion of the island revealed that no significant oil deposit had washed ashore during the previous year. The only indication of a previous oil spill at Northwest Cove was dried tar on rocks and driftwood high up on the beach.

ACKNOWLEDGMENTS

I thank Donald E. Robinson, Superintendent of the Channel Islands National Monument, and Jay B. Stoddard for transportation to San Miguel Island, and Frank McCrary, Jr., for assistance in the field. Robert L. DeLong, Daniel K. Odell, Edward D. Asper, Fred C. Sibley, Jim Lewis, and several others were especially helpful in taking the time to collect and report to me information on tagged animals sighted. Observations in Año Nuevo State Reserve were authorized by the California Department of Parks and Recreation, W. P. Mott, Jr., Director. Permission to tag seals was granted by the California Department of Fish and Game, W. T. Shannon, Director. Supported in part by NSF Grant GB-16321.

REFERENCES

Bartholomew, G. A., Jr.
1954 Body temperature and respiratory and heart rates in the northern elephant seal. J. Mammal., 35: 211-218.

Simpson, J. G., and W. G. Gilmartin
1970 An investigation of elephant seal and sea lion mortality on San Miguel Island. Bioscience, 20: 289.

Table 1

Experimental Animals Sighted 1-15 Months after Being Tagged at Northwest Cove, San Miguel Island, on 25 March 1969

Tag Number	Initial Sighting		Latest Sighting	
	Date	Location	Date	Location
558[a]	4/25/69	Palos Verdes, Calif.		
548	5/17/69	San Miguel I.	4/26/70	San Miguel I.
540	8/19/69	San Miguel I.		
557	8/24/69	San Miguel I.		
527	8/24/69	San Miguel I.		
529	9/25/69	San Miguel I.	4/17/70	San Nicolas I.
544	9/25/69	San Miguel I.		
520[b]	11/2/69	near Año Nuevo I.		
521	11/3/69	Año Nuevo I.		
514	11/12/69	Año Nuevo I.	4/18/70	Año Nuevo I.
537	11/12/69	Año Nuevo I.	5/22/70	Año Nuevo I.
563	11/13/69	Año Nuevo I.		
549	12/14/69	Año Nuevo I.	5/14/70	Año Nuevo I.
555	3/12/70	Año Nuevo I.	4/3/70	Año Nuevo I.
510	3/24/70	San Miguel I.	4/22/70	San Miguel I.
567	3/25/70	Año Nuevo I.		
508[c]	4/20/70	San Miguel I.		
536	4/20/70	San Miguel I.		
518	4/21/70	San Miguel I.		
516	4/26/70	San Miguel I.		
539	4/26/70	San Miguel I.		
562	4/26/70	San Miguel I.		
547	4/26/70	San Miguel I.		
512	4/26/70	San Miguel I.		
550	4/26/70	San Miguel I.		

[a]Health condition not specified.

[b]Killed in a fisherman's net.

[c]Coated with an unspecified amount of oil when sighted.

Table 2

Control Animals Sighted 1-15 Months after Being Tagged at West Cove, San Miguel Island, on 25 March 1969

Tag Number	Initial Sighting		Latest Sighting	
	Date	Location	Date	Location
615	11/3/69	Año Nuevo I.		
613	11/13/69	Año Nuevo I.		
621	11/16/69	Año Nuevo I.	5/14/70	Año Nuevo I.
620	11/19/69	San Miguel I.	4/25/70	San Miguel I.
624	11/19/69	San Miguel I.	4/12/70	San Nicolas I.
661	11/19/69	San Miguel I.		
636	11/22/69	Año Nuevo I.		
650	11/22/69	Año Nuevo I.	5/23/70	Año Nuevo I.
657	3/6/70	Año Nuevo I.	5/20/70	Año Nuevo I.
671	4/8/70	Southeast Farallon I.		
643	4/11/70	Año Nuevo I.		
627	4/17/70	San Nicolas I.		
658	4/20/70	San Miguel I.		
628	4/26/70	San Miguel I.		
652	4/26/70	San Miguel I.		
644	4/26/70	San Miguel I.		

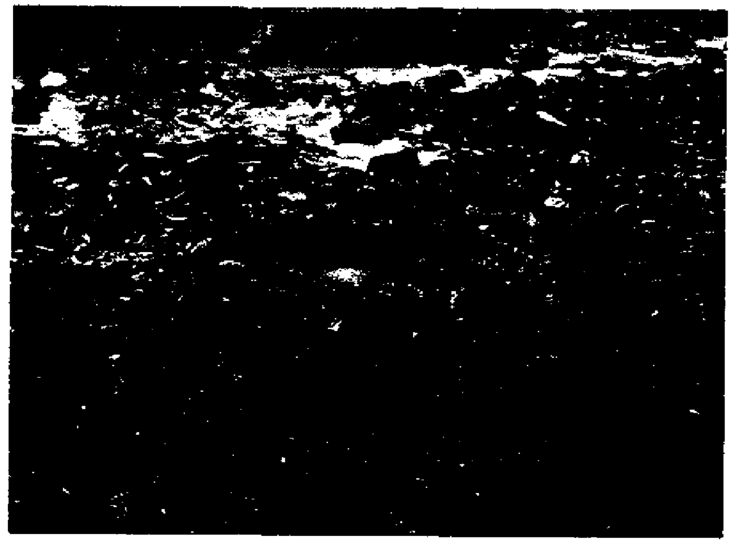


Figure 1. A portion of Northwest Cove, San Miguel Island, at low tide, showing crude oil deposits along the high tide mark. Elephant seal pups can be seen in the foreground and center of the picture. March 25, 1969.

Figure 2. R. S. Peterson tags a newly weaned elephant seal almost covered with crude oil. At Northwest Cove, March 25, 1969.

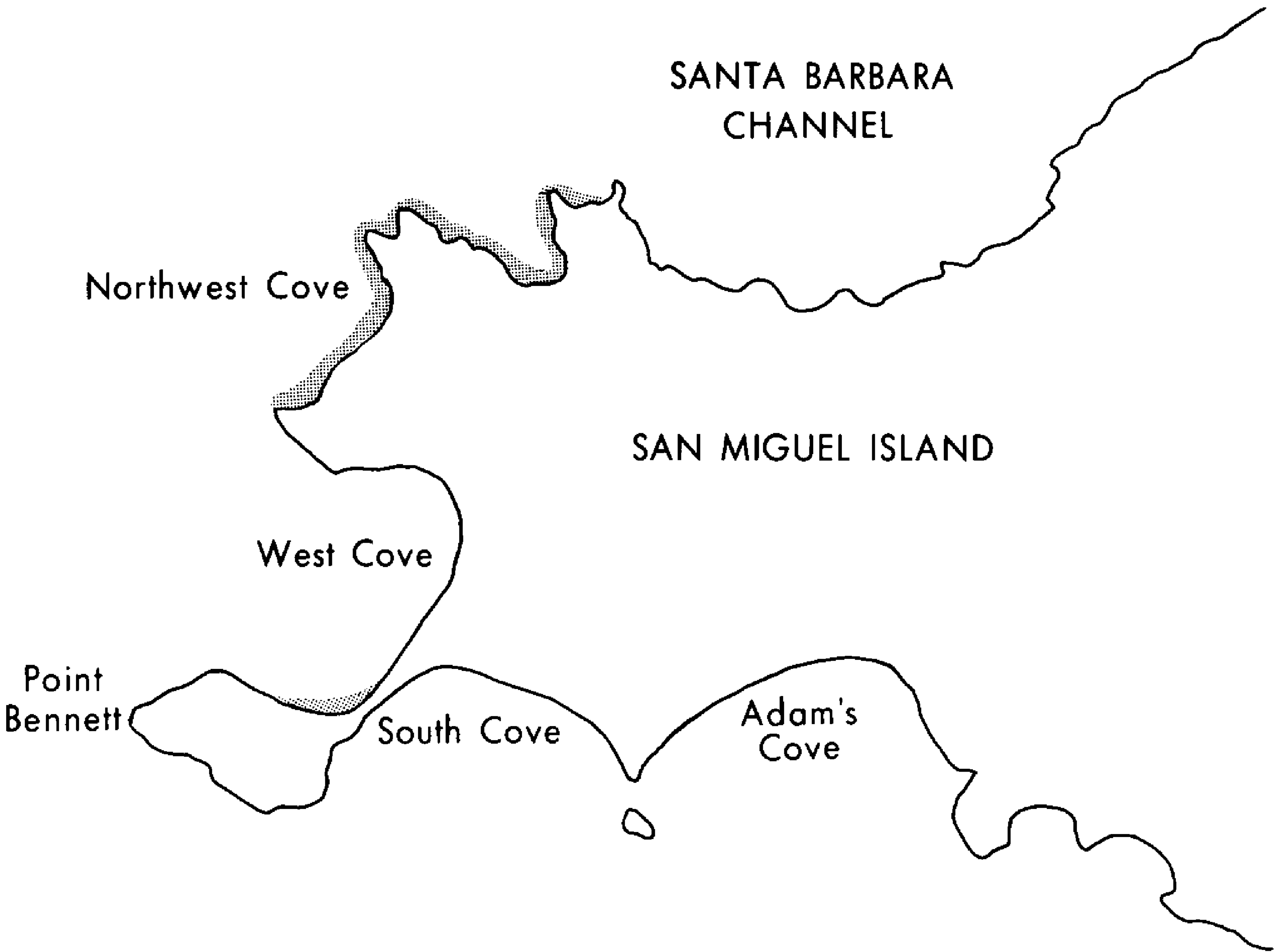

SANTA BARBARA
CHANNEL
Northwest Cove
SAN MIGUEL ISLAND
West Cove
Point
Bennett
South Cove
Adam's
Cove

Figure 3

CHAPTER 14

CALIFORNIA SEA LION MORTALITY: NATURAL OR ARTIFACT?

by Robert L. Brownell, Jr.[1] and
Burney J. Le Boeuf[2]

The California sea lion, Zalophus californianus, well known to the public as the "circus seal," is the most numerous pinniped found in the waters of the western United States and Mexico. Yet, compared to other species in the same area, it is the least understood in terms of biology, ecology and behavior. Systematic data on mortality at various stages in development are notably lacking. Mortality statistics and population data are most complete for species that have been exploited commercially, such as the northern fur seal, Callorhinus ursinus (Bartholomew, 1970).

When environmental disturbances occur, whether in the form of unexpected oil blowouts, increasing levels of pesticides in marine waters, or reported infectious epidemics, questions arise concerning the effect on the sea lion population. Are they being affected adversely? Are they dying in greater numbers? Is the increase in the number of carcasses washing up on the beaches significant? We will attempt to provide a context and background for answering some of these questions.

---

[1]Department of Pathobiology, Johns Hopkins University, Baltimore, Maryland.

[2]Crown College, University of California, Santa Cruz, California.

This paper reviews briefly what little we know about natural mortality in Zalophus; it calls attention to premature births that have been noted in recent years, and reports data bearing on the possible association of pesticides and oil pollution on sickness and mortality in these animals; it speculates on these possible links and stresses the need for normative data.

NATURAL MORTALITY

Mortality figures are usually obtained from pup deaths during the pupping season or from carcasses of animals of all ages found on the rookeries or washed up on mainland beaches at various times of the year.

The pupping season for California sea lions is from about the last week in May until the end of June; females deliver a single pup. Peterson and Bartholomew (1967) reported that the mortality rate of pups on land in their study area on San Nicolas Island in 1965 was much less than that of Callorhinus on the Pribilof Islands, which ranges between 5% and 16% during the breeding season (North Pacific Fur Seal Commission, 1962:5). They counted only ten dead pups out of 250 born in their study area. However, they point out that since Zalophus stays close to the water, pup carcasses may easily wash out to sea and not be counted, thus minimizing the mortality estimate. Estimates in Callorhinus are more reliable because females give birth further inland, thus decreasing the possibility of pups being washed out to sea alive or dead. Dan Odell, who has studied Zalophus on San Nicolas Island during the 1969 and 1970 breeding seasons, reports a mortality figure of 15% or more in his study area; most carcasses washed out to sea quickly (personal communication).

Bonnot, Clark and Hatton (1938) estimated that 25% of Zalophus pups die on the rookeries during the pupping season from multiple causes. They also stated that less than 50% of the pups produced in a year reach the age of one year. This is similar to the figure reported for Callorhinus in the 1961 year class, in which 14% died on the rookery and an additional 50% died at sea (Roppel, Johnson and Chapman, 1965).

In the 1968 breeding season, one of us (R.L.B.) and Ralph W. Schreiber counted living and dead pups on two locations at San Nicolas Island on May 29. Schreiber continued to census one of these areas periodically until August 22. These data are shown in Table 1. There is great variation in the percentage of dead to living pups in these repeated censuses of the same area. The overall average from May 29 to August 22 is 21%, dead to living. These figures must be interpreted with caution for the following reasons: (1) some of the carcasses may have been counted more than once; (2) carcasses may be washed out to sea or buried and so not counted; (3) carcasses washed out in other areas may have washed up here and been included in the count; (4) live pups present difficulties in counting since some may be in the water, particularly late in the season, and some may be hidden behind rocks. In both the latter cases, the denominator in the mortality figure would be reduced and an overestimate of the true mortality would result. On May 29, in a different location (Area 4A), Schreiber and Brownell found that 82 out of 102 pups were dead. This extremely high number of dead pups may have been due to any of several of the reasons already cited, or to the fact that many of these carcasses represented premature births dating back to as early as February, which, because of the terrain, did not wash out to sea. Premature pupping will be treated separately in a subsequent section.

On July 4 and 14, 1970, 697 newborn pups at the far western tip of San Miguel Island were marked with yellow plastic and monel tags as part of a long-term study of the movements of _Zalophus_. Within two months, 15% of the marked pups were found dead on or near the areas where they had been tagged. We are aware that the tagging operation, itself, may have influenced the mortality figure, for the procedure creates a temporary separation of mother and young. However, previous tagging operations of _Zalophus_ on several different rookeries over a three-year period lead us to believe that the detrimental influence is low and accounts for less than 3% of the dead.

The causes of pup mortality on the rookery are probably similar to those reported for the northern fur seal by Keyes (1965): malnutrition, trauma, parasitism, miscellaneous infection and gastrointestinal infection. In addition, _Zalophus_ pups are often washed out to sea.

The cause of death in young Zalophus after they go to sea and begin feeding seems to be parasite related. This is particularly true of young sea lions who display massive infections of the lungworm, Parafilaroides decorus (Dailey, 1970). As many as 18 endoparasites have been found in this species (Dailey and Brownell, in press). The lungworm and the liver fluke, Zalophotrema hepaticum, are the most numerous parasites found. For example, 11 out of 17 young Zalophus examined by William A. Walker (in litt., October, 1970) at Marineland of the Pacific, were parasitized by lungworms. Heavy parasite infestations weaken the hosts and make them more susceptible to other diseases, particularly of a respiratory nature, which ultimately are the principal cause of death.

From time to time, there have been reports of epidemics in several pinnipeds, including Zalophus, which are usually attributed to infectious diseases (Scheffer, 1958). Scheffer (1958:28) writes of an anonymous report which claimed that numerous dead sea lions were seen on the beaches of California in the autumn of 1947 and "health authorities . . . diagnosed the cause of death to be streptococcal pneumonia." Scheffer tried but was unable to obtain more factual information about this presumed epidemic. The most recent epidemic report claims that a "mysterious malady" is responsible for the deaths of numerous California sea lions on the coast of northern California (San Francisco Chronicle, October 14, 1970). The basis for the claim is that 30 Zalophus have been found sick or dead during a one-month period in September and October on beaches near San Francisco (New York Times, October 15, 1970). While this may turn out to be a real epidemic, there is no basis for making such a claim on such meager evidence. There is no basis for claiming that such a figure is "unusually high" when no systematic data on what is usual exist. The mass movements of thousands of Zalophus up and down the coast of California and Mexico have a great effect on the number of sick and dead found at a particular place at a particular time. For example, the number of Zalophus increases tenfold to a total of approximately 10,000 at Año Nuevo Island, about 70 miles south of San Francisco, during the months of September and October (Peterson and Le Boeuf, 1969). One would certainly expect to find more carcasses and sick animals in the vicinity at this time of year simply because there are more animals in the general area.

Killer whales, sharks, and man prey on sea lions. Killer whales, Orcinus orca, are common around Zalophus hauling areas like Año Nuevo Island and some of the larger rookeries, such as San Miguel Island and Islas San Benito in Baja California, Mexico. Remains of California sea lions were found in three of nine killer whales taken in Californian waters (Rice, 1968). Heller (1904:244), who studied Zalophus at the Galapagos Islands, reported that "sharks, chiefly the genera Carcarhinus and Galeocerdo, are the worst enemies the seals have to contend with. Their depredations are confined largely to the pups, though the latter genus is a serious menace even to the adults." Man destroys numerous sea lions each year. Animals are shot by fishermen to keep them away from fishing operations, and weekend sailors on pleasure boats shoot them for sport or for no apparent reason. The few adult carcasses found by Peterson and Bartholomew (1967) on San Nicolas Island during the 1965 breeding season showed signs of buckshot wounds or evidence of clubbing or stoning.

ABORTIONS AND PREMATURE BIRTHS

Although the majority of California sea lion pups are born during the period between May 25 and June 25 (Peterson and Bartholomew, 1967), some females give birth as early as late January and early February. These offspring are best called abortions for they are hairless, not fully developed, and are apparently born dead. Figure 1 shows one of these abortions that washed ashore at Año Nuevo Island on February 1, 1969. The abortion in Figure 2 was photographed at San Miguel Island on March 25, 1969. Dan Odell (personal communication) reports observing Zalophus abortions as early as late January on San Nicolas Island. The phenomenon has also been noted in Steller sea lions, Eumetopias jubata, at Año Nuevo by Orr and Poulter (1967) and Le Boeuf (unpublished observations).

During the first week in March, 1968, Peterson, Gentry and Le Boeuf (unpublished report of investigations of pinnipeds on San Miguel and San Nicolas Islands, February-March, 1968) observed several freshly dead pups on San Miguel Island and six pups on San Nicolas Island. The external appearance of these pups made it obvious that they had been born prematurely. On San Nicolas Island, one female protected her dead pup for several minutes, grasping it in her mouth as she moved in and out of the surf. On March 25-28 of the following year, Peterson and Le Boeuf (unpublished report of an expedition to San Miguel Island) counted 26 dead pups in the Point Bennett area of San Miguel Island. All of them were incompletely developed and had been delivered recently. Schulz, Radovsky and Budwiser (1970) saw six newly dead Zalophus pups and a few live pups on April 7-8, 1968, at Isla San Martín, and Simpson and Gilmartin (1970) reported "a number of aborted California sea lions" on San Miguel Island on April 11, 1970. In late April of 1968, Brownell, DeLong and Schrieber (unpublished report on pinniped populations at Islas de Guadalupe, San Benito, Cedros, and Natividad, Baja California, in 1968) noted numerous dead pups on Cedros Island, Natividad and Islas San Benito. Fifty dead pups were counted on Isla San Benito del Centro. Nose to tail measurements on seven males ranged from 56 to 72.5 cm, and 61 to 67 cm for five females measured. A few viable pups seen at this time appeared weak and lethargic. Females were seen moving into the water carrying dead or feeble pups in their mouths. These females seemed reluctant to desert the pups even though they were dead or dying.

On San Nicolas Island between January and the end of the third week in May, Dan Odell counted 135 premature dead pups in 1969 and 442 in 1970. These figures represent more than a 300% increase from one year to the next.

As the normal pupping season approaches, premature pups resemble full-term pups more and more, particularly in their size, weight, and external appearance, e.g., those born in February are hairless while those born later are increasingly hirsute. The first viable pups are weak and uncoordinated and probably die after a few days. Those born closer to May show coordinated movements resembling those of full-term pups born in June and are more likely to survive.

This phenomenon of premature pupping could represent normal variation in the population. Those females who pup well before the normal pupping season do not produce viable offspring and their genes, if the aberrancy is inherited, are selected out of the population. Even if their pups survive and the post partum estrus is normal (we do not know if it is), there may be no males around to reimpregnate these "early" females. In other words, what we may be seeing is the normalizing aspect of natural selection in progress. If this is the case, we would expect the frequency of premature pupping to be lowest early in the year at the extreme end of the continuum and to increase to a high near the normal pupping period in late May and June, the set-point. Getting baseline data on premature pupping and relating it to adult population estimates in order to determine whether the phenomenon represents normal incidence is made difficult by problems encountered in censusing pups, as well as the large population of adults (Peterson and Le Boeuf, 1969).

On the other hand, the problem may be man-made, an indirect result of man's technology and attempted control of the environment. We shall explore this possibility in the sections which follow.

OIL

The blowout of Union Oil Platform A in the Santa Barbara Channel on January 28, 1969, caused crude oil to wash up on San Miguel Island and San Nicolas Island, two islands where California sea lions breed. Although public attention and scientific concern centered on the northern elephant seals, *Mirounga angustirostris*, who were breeding at the time (Chapter 13), the State of California Department of Fish and Game (1969) reported three dead sea lions in their wildlife survey of the area from February 3 to March 28, 1969. No autopsies were performed and no attempt was made to link these deaths with the crude oil spill.

When crude oil from Platform A washed up on San Miguel Island in mid-March, 1969, the National Park Service asked the Naval Undersea Research and Development Center at Point Mugu, California, to investigate pinniped mortality at Northwest Cove, the location of the oil slick (see Fig. 3 in Chapter 13). The report by Simpson and Gilmartin (1970) which resulted covered examination of both *Mirounga* and *Zalophus*. The blood of two aborted *Zalophus* pups obtained on April 11 was examined for petroleum residue analysis and found to be negative. The report concluded that the cause of death of animals found on San Miguel Island was unknown.[1]

Public concern for sea lions became nationwide in early June when Life magazine (June 13, 1969) published an article linking oil pollution on San Miguel Island to the deaths of over 100 sea lions and elephant seals. Although no more oil had washed ashore at Northwest Cove, the slick remained and approximately 1,000 *Zalophus* females were using the cove as a nursery and a place to give birth. Representatives of Life magazine visited San Miguel Island on May 25, shortly after pupping had begun. The article was emotional and impressionistic and included statements which implied conclusions not based on fact. Consider the following three quotes:

> "Some of the seal lions--a particularly skittish species of seal--could scarcely be distinguished from their lethargic cousins, the elephant seals."

> "Until we became weary and sick of the tally, we counted over a hundred dead sea lions and elephant seals in the immediate area. Some of these were adult animals but most were newborn pups."

---

[1]These investigators also implied that the number of deaths was not unusual because high pup mortality has been reported in other species (i.e., over 50% in Steller sea lion pups on the Año Nuevo rookery). They based this assertion on an observation by Evermann (1921) on Año Nuevo Island, reporting 100 live pups and 106 dead or dying at the time a count was made. They failed to mention the unusual circumstances that preceded this census. Evermann (1921:19) explained that this high mortality "was caused by a severe storm which occurred about the middle of June when the sea washed over the entire rookery, washing practically all the pups off the rocks and into the water. At that time the pups had not yet learned to swim and many were drowned outright. Others were probably so seriously injured they could not get back upon the rocks, and still others were washed ashore. The mothers do not appear to make any search for them and they crawl about and finally starve."

"As to the cause-and-effect relationships of it all, no one can say with any certainty which pups had died of toxicity from nursing a mother whose teats had been dragged through the sludge or which from pneumonia in oil-suffused lungs or of starvation caused by maternal abandonment."

The first quote implies that oil caused sickness, the second implies that oil caused death and the last concludes that oil caused numerous sea lion deaths but the mechanism by which it did this remains unknown.

That the animals these people observed were coated with crude oil is undeniable; further substantiation of this fact follows. However, their interpretation, based on the correlation between the presence of oil and deaths, was derived without consideration or knowledge of other important facts. For example, most of the dead pups they counted had been born prematurely. We have already pointed out that this phenomenon occurs at other rookeries where Zalophus breeds and has been observed at several locations on San Miguel Island in previous years, before the oil slick washed ashore. Furthermore, they did not know or acknowledge that a pup mortality rate of at least 15% during the pupping season is normal, as we have indicated in a previous section.

In an attempt to assess the effect of oil on Zalophus pup mortality, Le Boeuf and R. L. DeLong censused the pup population at Northwest Cove on June 16, 1969, by walking the length of the cove counting all live pups and pups that had died within the last two weeks (inferred from carcass decomposition). Both living and dead pups were divided into two categories: oily and non-oily. Oily pups were defined as pups with 25% or more of their bodies covered with crude oil. Pups with 25% or less of their bodies covered with crude oil were defined as clean. The results are shown below:

Total pups	=	881
Total dead	=	112 or 12.7% of total pups
Oily dead	=	76 or 67.8% of total dead
Total living	=	769 or 87.3% of total pups
Oily living	=	352 or 45.8% of total living

In spite of the fact that 46% of the living pups and 68% of the dead pups were oily, the mortality rate was less than 13%. This figure is well within the normal limits alluded to earlier in this paper. The higher number of oily animals in the dead category may have been due to the fact that they had moved around the rookery and become more soiled than younger, living animals before they succumbed. On the basis of the above data, one still cannot exclude the possibility that oil contamination had a deleterious effect on pup health and in some way increased the probability of death. If this occurred, the effect was unquestionably very small.

ORGANOCHLORINE PESTICIDES

Accumulations of DDT and its metabolites are persistent components of the marine ecosystem (Risebrough, et al., 1967). DDT residues in phytoplankton in Monterey Bay, California, have increased threefold between 1955 and 1969 (Cox, 1970). Concentrations of these pesticides in organisms increase from lower to higher trophic levels and it has been demonstrated that environmental contamination by organochlorine pesticides causes reproductive failure in several species of birds which feed at the top trophic levels. These pesticides affect enzymes associated with egg shell thickness in several avian species (Ames, 1966; Peakall, 1967; Ratcliffe, 1967; Hickey and Anderson, 1968). The thin egg shells break during incubation, resulting in death of the developing young. Gress (1970) reported that eggs from brown pelicans, Pelecanus occidentalis, collected from Anacapa Island, off Southern California, contained pesticide residues up to 2,600 ppm of DDE, the principle metabolite of DDT, and that reproductive success of pelicans in California has been near zero during the last few years.

Like many large marine birds, most pinnipeds feed near the top trophic level in the marine environment and, therefore, might be expected to accumulate high concentrations of pesticides. However, concentrations of organochlorine pesticides reported from most pinnipeds thus far are low compared to the maximum concentrations found in pelicans. Sladen, Menzie, and Reichel (1966) found DDT residues of 39 ppb in the blubber and 13 ppb in the liver of the crabeater seal, Lobodon carcinophagus, which inhabits Antarctic waters. Concentrations up to 5.1 ppm were found in the liver of 30 northern fur seals from the Pribilof Islands (Anas and Wilson, 1970). Holden and Marsden (1967) reported DDT concentrations up to 14.8 ppm in the blubber of gray seals, Halichoerus grypus, collected in Scotland. Cook and Baker (1969) found a total residue concentration of 1.16 ppm in the milk of one harp seal, Pagophilus groenlandicus, in the Canadian western Atlantic. They point out that the Canadian Food and Drug Directorate has set a tolerance of pesticide residues in milk for human use at 1.0 ppm.

Simpson and Gilmartin (1970) examined kidney, liver and spleen of 11 newly aborted Zalophus pups found on San Miguel Island on May 1-2, which were analyzed and found negative for hydrocarbons, DDT and DDE. Similar tests on tissue samples of the uterus, ovaries and blood of an adult female that had just aborted were also negative. However, Michael Bonnell and Le Boeuf (unpublished observations) found total DDT residues in the blubber of four adult California sea lions collected at San Miguel Island in September, 1970, ranging from 41 ppm to 1929 ppm. Maximum residues in brain tissue, muscle and liver were 10.0 ppm, 2.5 ppm and 18.0 ppm, respectively.

It is obvious from these few observations that organochlorine pesticide residues vary greatly among different species of pinnipeds. One would expect this to be so since some of the species studied are not closely related, different species usually feed on different organisms and inhabit and exploit different aspects of the marine environment, and pesticide concentrations are higher in some areas than others. Toxic levels in pinnipeds have not been established.

The configuration of DDT is similar to synthetic estrogen, diethylstilbestrol. DDT has two main isomers: 80% is in the form p,p'-DDT and 15-20% of DDT is in the form of the isomer, o,p'-DDT. The reproductive tissues of rats and birds treated with o,p'-DDT responded as if treated with estrogen while rats receiving p,p'-DDT showed little if any response (Bitman, et al., 1968). It has also been shown in women that the o,p' isomer is more actively metabolized during pregnancy and 10.2 times more highly concentrated in the blood than the p,p' isomer (Polishuk, et al., 1970). It is unfortunate, as Moats and Moats (1970:461) point out, that "most published residue analysis for DDT, DDD, and DDE are based on the p,p' isomers so there is no way of assessing the practical importance of residues of the o,p' isomers in biological systems."

Since DDT can mimic estrogen, it might have something to do with premature pupping in sea lions. We will speculate on how this might come about. The California sea lion is believed to show delayed implantation, as do most other pinnipeds that have been investigated (Bartholomew, 1970), for example, the northern fur seal (Craig, 1964). The period of delay, from the time of fertilization to implantation of the fertilized egg to the uterine wall is 3-1/2 to 4 months in Callorhinus (Craig, 1964) and Zalophus is expected to show a similar delay. The changes that cause the blastocyst to become implanted to the uterine wall are unknown in pinnipeds. In rats, Shelesnyak and co-workers (Shelesnyak, Kraicer and Zeilmaker, 1963; Shelesnyak and Kraicer, 1963) have shown that, in addition to a required progestational uterus, implantation of the rat blastocyst depends on an estrogen surge which occurs a few days after mating has taken place. If an increase in estrogen titers is implicated in implantation in sea lions, then the estrogen-mimicking action of o,p'-DDT may be affecting the time at which implantation occurs by causing no delay or by causing the delay to be shortened, and thus causing some pups to be delivered prior to the normal pupping period. If this explanation alone was correct, the premature pups, at delivery, should resemble full-term pups. The data do not substantiate this reasoning, for abortions occurring February and March are clearly unfinished. This may be the case for pups born in April and early May, but the descriptions of these pups lack sufficient detail. It is possible that failure of implantation to be delayed is coupled with early deliveries; however, this degree of complexity is unlikely. More frequency data and descriptions of premature pups are needed.

Another possibility is that delayed implementation is unaffected and the fetus develops normally for at least four months. After this time, o,p'-DDT, by mimicking estrogen, might terminate pregnancy (see Craig, 1964). It is known that estrogen blocks progesterone, and in doing so could interfere with pregnancy (Csapo, 1956). The reason why abortions do not occur sooner (if they occur, they have not been reported) may be due to the diet sea lions are eating at this time of the year. Some prey undoubtedly concentrate DDT more than others. In this regard, it is notable that Korschgen and Murphy (1967) observed reduced reproductive rates in mature female white-tailed deer when their diet was supplemented with 25 ppm of Dieldrin, an organochlorine pesticide. Dieldrin is stored at concentrations 50% less in pregnant than nonpregnant women (Polishuk, et al., 1970), thus indicating faster metabolism in the former.

DISCUSSION

Sea lions die from a number of causes. Whether oil pollution, pesticides, or other artifacts in the marine environment have any effect on sea lion mortality is unclear at this time. Contamination with crude oil did not have a marked effect on pup deaths on the rookery at San Miguel Island during the 1969 breeding season. The effect of organochlorine pesticides on sea lion mortality is unknown. California sea lions show the highest DDT residues of any pinniped examined thus far and investigations of the possibility that pesticides induce premature pupping in this species are just beginning. Unequivocal answers to questions concerning the causes of mortality will be made possible and facilitated by the collection of normative data. We cannot say what is unusual without reference to what is usual. Frequency data of the following kind will be most helpful in evaluating future calamities: estimates of premature pupping, pup deaths on the rookeries, and strandings and carcass wash-ups on hauling grounds and mainland beaches.

Frequency data on premature pupping could suggest whether the phenomenon is due to "technological fallout" or simply reflects natural variation in a large population. The former would be indicated if abortions were concentrated at a certain time of the year, say early February, and did not grade into the normal pupping period in early summer. We do not have sufficient data at present to determine whether this is the distribution that obtains. An unnatural causation would also be suspected if premature pupping on a single rookery increased dramatically from one year to the next, without a concomitant increase in the adult population. Odell's (1970) observations on San Nicolas Island, which indicate a tripling of premature pups from 1969 to

1970, suggest an artifactual interpretation. Natural causation is most likely to be reflected by relatively stable frequencies from year to year; and within a single year, by a gradual increase in premature pupping from a low early in the year to a high which blends in with the normal pupping period in May and June.

ACKNOWLEDGMENTS

We thank the following for direct and indirect assistance: D. Odell, R. DeLong, D. Straughan, R. Schreiber, W. Walker, P. Wright, S. Oden'hal, R. Kneip, M. Bonnell, J. Carr, S. Leatherwood, F. McCrary, Jr., J. and F. Stoddard, D. Robinson, R. Whiting, R. Gantt, and others. Supported by NSF Grant GB-16321 to B.J.L.

REFERENCES

Ames, P. L.
1966 DDT residues in the eggs of the osprey in the northeastern United States and their relation to nesting success. J. Applied Ecol., 3(Suppl.): 87-97.

Anas, R. E., and A. J. Wilson
1970 Organochlorine pesticides in fur seals. Pesticides Monitoring J., 3: 198-200.

Bartholomew, G. A.
1970 A model for the evolution of pinniped polygyny. Evolution, 24: 546-559.

Bitman, Joel, H. C. Cecil, S. J. Harris, and G. F. Fries
1968 Estrogenic activity of o,p'-DDT in the mammalian uterus and avian oviduct. Science, 162: 371-372.

Bonnot, Paul, G. H. Clark, and S. R. Hatton
1938 California sea lion census for 1938. Calif. Fish and Game, 24: 415-419.

California. Department of Fish and Game.
1969 Progress report on wildlife affected by the Santa Barbara Channel oil spill (January 28-March 31, 1969).

Cook, H. W., and B. E. Baker
1969 Seal milk. I. Harp seal (*Pagophilus groenlandicus*) milk: composition and pesticide residue content. Canad. J. Zool., 47: 1129-1132.

Cox, J. L.
1970 DDT residues in marine phytoplankton: increase from 1955 to 1969. Science, 170: 71-73.

Craig, A. M.
1964 Histology of reproduction and the estrus cycle in the female fur seal, *Callorhinus ursinus*. Canada, Fish. Res. Board, Bull., 21: 773-811.

Csapo, Arpad
1956 The mechanism of effect of the ovarian steroids. Recent Progr. Hormone Res., 12: 405-431.

Dailey, M. D.
1970 The transmission of *Parafilaroides decorus* (Nematoda: Metastrongyloidea) in the California sea lion (*Zalophus californianus*). Helmin. Soc., Wash., Proc., 37: 215-222.

Dailey, M. D., and R. L. Brownell, Jr.
A checklist of marine mammal parasites. *In* Marine mammals; biology, medicine and husbandry. Ed. by S. H. Ridgway. Charles C. Thomas, Springfield, Ill., [in press].

Evermann, B. W.
1921 The Año Nuevo Steller sea lion rookery. J. Mammal., 2: 16-19.

Gress, Franklin
1970 Sea bird contamination. Smithsonian Institution, Center for Short-Lived Phenomena (Event 90-70, October 5, 1970).

Heller, Edmund
1904 Mammals of the Galapagos Archipelago, exclusive of the Cetacea. Calif. Acad. Sci., Proc., (3)3: 233-250.

Hickey, J. J., and D. W. Anderson
1968 Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. Science, 162: 271-273.

Holden, A. V., and K. Marsden
1967 Organochlorine pesticides in seals and porpoises. Nature, 216: 1274-1276.

Keyes, M. C.
1965 Pathology of the northern fur seal. Amer. Veter. Med. Assoc., J., 147: 1090-1095.

Korschgen, L. J., and D. A. Murphy
1967 Pesticide-wildlife relationships: reproduction, growth, and physiology of deer fed dieldrin contaminated diets. Missouri Fed. Aid Project No. 13-R-21 (1967). Work Plan No. 8, Job No. 1, Progress Rpt. 24p.

Moats, S. A., and W. A. Moats
1970 Toward safer use of pesticides. Bioscience, 20: 459-464.

Odell, D. K.
1970 Premature pupping in the California sea lion. In Conf. on Biol. Sonar and Diving Mammals, Menlo Park, Calif., 23-24 October 1970.

Orr, R. T., and T. C. Poulter
1967 Some observations on reproduction, growth, and social behavior in the Steller sea lion. Calif. Acad. Sci., Proc., (4)35: 193-226.

Peakall, D. B.
1967 Pesticide-induced enzyme breakdown of steroids in birds. Nature, 216: 505-506.

Peterson, R. S., and G. A. Bartholomew
1967 The natural history and behavior of the California sea lion. Amer. Soc. Mammal., Spec. Publ., 1: 1-79.

Peterson, R. S., and B. J. Le Boeuf
1969 Population studies of seals and sea lions. North Amer. Wildlife and Nat. Res. Conf., 34th, Trans., 1969: 74-79

Polishuk, Z. W., M. Wassermann, D. Wassermann, Y. Groner, S. Lazarovici, and L. Tomatis
1970 Effects of pregnancy on storage of organochlorine insecticides. Arch. Environ. Health, 20: 215-217.

Ratcliffe, D. A.
1967 Decrease in eggshell weight in certain birds of prey. Nature, 215: 208-210.

Rice, D. W.
1968 Stomach contents and feeding behavior of killer whales in the eastern North Pacific. Norsk Hvalfangst-Tidende, 57: 35-38.

Risebrough, R. W., D. B. Menzel, D. J. Martin, Jr., and H. S. Olcott
1967 DDT residues in Pacific sea birds: a persistent insecticide in marine food chains. Nature, 216: 589-591.

Roppel, A. Y., A. M. Johnson, and D. G. Chapman
1965 Fur seal investigations, Pribilof Islands, Alaska, 1963. U.S. Fish and Wild. Serv., Spec. Sci. Rpt., Fish., 497: 1-60.

Scheffer, V. B.
1958 Seals, sea lions, and walruses: a review of the Pinnipedia. Stanford Univ. Press, Stanford, Calif. 179p.

Schreiber, R. W.
1970 Breeding biology of western gulls (Larus occidentalis) on San Nicolas Island, California, 1968. Condor, 72: 133-140.

Schulz, T. A., F J. Radovsky, and P. D Budwiser
1970 First insular record of Notiosorex crawfordi, with notes on other mammals of San Martin Island, Baja California, Mexico. J. Mammal., 51: 148-150.

Shelesnyak, M. C., and P. F. Kraicer
1963 The role of estrogen in nidation. In Delayed implantation. Ed. by Allen C. Enders. Univ. of Chicago Press. pp. 265-279.

Shelesnyak, M. C., P. F. Kraicer, and G. H. Zeilmaker
1963 Studies on the mechanism of decidualization. I. The oestrogen surge of pseudopregnancy and progravidity and its role in the process of decidualization. Acta Endocrinol., 42: 225-232.

Simpson, J. G., and W. G. Gilmartin
1970 An investigation of elephant seal and sea lion mortality on San Miguel Island. Bioscience, 20: 289.

Sladen, W. J. L., C. M. Menzie, and W. L. Reichel
1966 DDT residues in Adelie penguins and a crabeater seal from Antarctica. Nature, 210: 670-673.

Table 1

Mortality Rate of Pups on Area 1B* at
San Nicolas Island, California, during the
1968 Breeding Season (Modified from Schreiber, 1970)

Date	Total Pups	Live Pups	Dead Pups	Per-centage Dead
29 May	77	55	22	28
17 June	229	197	32	13
2 July	230	222	8	3
22 August	80	50	30	37

*The area we refer to as "1B" is the upper portion of 1B referred to by Peterson and Bartholomew (1967).

Figure 1. A California sea lion abortion found on Año Nuevo Island on February 1, 1969. The specimen is hairless and smaller than a full-term pup. A large segment of umbilical cord is still attached. Photographed by Le Boeuf.

Figure 2. A California sea lion abortion photographed by Le Boeuf on San Miguel Island on March 25, 1969.

CHAPTER 15

OIL POLLUTION AND SEA BIRDS

by Dale Straughan

The first signs of mortality following the oil spill on January 28, 1969, were oiled dead and dying sea birds. These were a pathetic sight. In the next chapter, details of the success of attempts to save and rehabilitate these birds are given. The present article is a summary of available data on bird mortality in the Santa Barbara Channel.

The California Department of Fish and Game carried out aerial and beach surveys of the bird population in the Santa Barbara Channel commencing February 5, 1969 (for details of methods and results see their First and Second Progress Reports on Wildlife Affected by the Santa Barbara Channel Oil Spill, 1969). Aerial surveys between February 5 and March 31, 1969, indicated that bird numbers in the affected area remained relatively stable. Avian population for the 1,075 square miles sampled by the aerial transects was estimated to be 12,000 birds. Species groupings in order of their abundance were gulls, shorebirds, waterfowl, loons and grebes, cormorants and pelicans, and other waterbirds. Most birds appeared to avoid oil-contaminated areas. They were found either in flight, on the shoreline, or resting in open spaces of water which appeared to be free of oil.

Significant bird population movements were recorded on aerial surveys between April 1 and May 31, 1969. A number of species wintering in the Channel area migrated by the end of May to their breeding grounds further north. A large influx of pelagic birds, notably sooty and pink-footed shearwater, was noted offshore. Birds counted on aerial surveys averaged 5,242 per day as compared to 3,490 for the first report period. Estimated bird population in the Channel area sampled was 85,000 for this period.

Beach transects were established to derive an estimate of bird loss, because oil-affected birds either in distress or dead could not be readily determined from the air. A daily average of 439 birds were observed along the 5.7 miles of beach transects in February and March, 1969; 290 of these birds were on the 4.8 miles of oil-contaminated beach transects. These were mostly shorebirds and gulls apparently little affected by oil. Seventy dead birds were recorded. This was exclusive of birds picked up by others and either taken to the bird treatment stations or disposed of during the beach cleaning operations. Nine of these dead birds showed no evidence of oil contamination. On the basis of the transect data, bird losses for the 75.5 miles of beach from Point Conception, Santa Barbara County, to the Ventura River mouth at Ventura, California, were estimated to be 1,603 birds. Added to this loss are the 1,388 birds which died after treatment and 175 turned in to the treatment stations dead and another 439 dead birds reported by other sources and from areas not included in the study areas. An estimated loss of 3,600 birds can be attributed to the oil spill up until March 31, 1969. This loss does not include birds which perished on the open water and failed to drift ashore.

In April and May an average of 391 birds utilized the 4.8 miles of oil-contaminated beach transects. Nine oil-contaminated birds were turned into the bird treatment station during this period. Birds treated to May 31, 1969, number 1,575. Of these, 1,406 or 89.3% died and 169 or 10.7% survived and are still being held or were released. The total loss of birds attributed to the Santa Barbara Channel spill in January, 1969, was 3,686 on May 31, 1969.

Table 1 is a summary of birds recorded on beach transects by the California Department of Fish and Game in February and March, 1969. More birds were found on the control beach than the oiled beaches. I suggest this is partly because of all the human activity on the oiled beaches. Sick or dead birds were more likely to be collected by others from the oiled beaches than from the unoiled beaches. Most of the dead birds were loons and grebes. Cormorants and pelicans were the second most common corpses. These were not the most abundant species seen on the beaches (Table 1), but both were recorded in large numbers on the aerial transects (Table 2).

Although bird numbers are higher in oiled than unoiled areas on the aerial survey (Table 2), it is unlikely that this is due to attraction to oil. The control transects were much shorter than the oiled transects and this difference in sampling area is probably part of the reason for smaller numbers on the control transects.

I have obtained species mortality figures on a total of 432 birds (B. Drinkwater, personal communication, and Table 1). This included a total of 253 loons and grebes (176 of these were western grebes). The remaining dead birds were 76 waterfowl, 69 cormorants and pelicans, 21 pelagic birds, 9 gulls and terns, 2 water-associated birds and 2 shore birds.

Bourne (1968:115) discusses the probability of pollution by oil in relation to the behavior of different groups of bird species. "Aerial species are unlikely to plunge into oil deliberately, and indeed comparatively seldom get oiled at sea, and coastal species may paddle over it or squat in it on the shore, with minimal damage. But swimming species are compelled to bathe in it. It has been suggested that they deliberately settle in polluted areas, in search of food or because the water is calm, but there appears to be little evidence for this. My own observations (Bourne, 1968) suggest that they simply do not notice it until they swim into it, when aerial species such as gulls promptly fly away (except when taken by surprise in the dark, as with the Medway disaster), but aquatic species such as the auks try to escape it like any other hazard by diving." Following the "Torrey Canyon" spill, Bourne (1968) reported that 7,815 birds were affected by oil, 7,746 of them being auks. Bourne (1968) states that the oil causes the fine elements of plumage to adhere together, breaking down the capacity of the feathers to insulate the birds from cold water. Few auks (included under pelagic species) were recorded from the Santa Barbara Channel at the time of the oil spill (Tables 1-2) and only one auklet was brought into the A. Child's Estate for cleaning (see next chapter).

Swimming species had the highest mortality in the Santa Barbara Channel. Loons are open water species, seldom seen on land except when breeding. Ruddy ducks are unable to walk on land. Loons and grebes are expert divers. Both frequently swim submerged in water and thrash on the surface of the water on take off. Cormorants swim low in the water like loons but they frequently perch on rocks and stumps. In contrast, few gulls, terns or shore species died even though abundant groups were seen in the area.

Hence, a study of the habits of different species would indicate their vulnerability to oil pollution at sea. The most abundant bird species in an area will not necessarily provide the most dead birds following a spill.

REFERENCES

Bourne, W. R. P.
1968 Oil pollution and bird populations. In The biological effects of oil pollution on littoral communities. Field Studies, (Suppl.)2: 99-122.

California. Department of Fish and Game.
1969 Progress report on wildlife affected by the Santa Barbara Channel oil spill. January 28-March 31, 1969.

1969 Second progress report on wildlife affected by the Santa Barbara oil spill. April 1-May 31, 1969.

Table 1

Number of Birds Recorded on Beach Surveys of the Santa Barbara Area in February and March, 1969*

Locality and Transect Length	Condition	Loons and Grebes	Pelagic Species	Cormorants and Pelicans	Waterfowl	Water-Associated	Shore Species	Terns and Gulls	Unclassified	Total	No. of Birds/Mi.
Dead Birds											
Arroyo Burro 1.1 miles	Oiled	15	0	5	2	1	0	2	0	25	23
Carpinteria 1.1 miles	Oiled	1	0	0	0	0	0	0	0	1	1
Rincon Beach 2.6 miles	Oiled	10	1	1	0	0	0	1	0	13	5
El Capitan 0.9 miles	Control	19	2	6	3	0	1	0	0	31	34
Total		45	3	12	5	1	1	3	0	70	
Living Birds											
Arroyo Burro 1.1 miles	Oiled	23	0	8	2	1	1494	538	0	2066	1878
Carpinteria 1.1 miles	Oiled	3	0	2	0	0	228	554	0	787	715
Rincon Beach 2.6 miles	Oiled	73	1	21	1	0	840	205	8	1149	442
El Capitan 0.9 miles	Control	381	5	260	97	5	1603	488	1	2840	3155
Total		480	6	291	100	6	4165	1785	9	6842	

*Data from California Fish and Game First Interim Report.

Table 2

Number of Living Birds Recorded on Aerial Surveys of the Santa Barbara Area in February and March, 1969*

Locality and Transect Length	Condition	Loons and Grebes	Pelagic Species	Cormorants and Pelicans	Waterfowl	Water-Associated	Shore Species	Terns and Gulls	Unclassified	Total	No. of Birds/Mi.
Mainland 38.7 miles	Oiled	2851	4	446	323	19	5067	15035	5	23750	614
Channel 81 miles	Oiled	146	83	22	188	0	42	1999	38	2518	31
Island 31.6 miles	Oiled	961	124	1642	141	10	43	18104	116	24141	764
Channel 14.6 miles	Control	37	17	1	4	0	0	215	4	278	19
Mainland 12.2 miles	Control	1749	0	1490	273	8	695	2108	0	6323	518
Total		5744	228	3601	3929	37	5847	37461	163	57010	

*Data from California Fish and Game First Interim Report

CHAPTER 16

SANTA BARBARA'S OILED BIRDS

by Barbara Drinkwater,[1] Maurine Leonard,[1]
and Susan Black[2]

On January 28, 1969, an off-shore oil well began spewing forth thousands of barrels of crude oil into the channel waters off Santa Barbara, California. At the time this article is written three months later, oil continues to flow from the ocean floor, and there appears to be very little hope that the leak will be stopped in the near future. During the height of the disaster, the slick extended some 60 miles along the California coast and encompassed more than 800 square miles of the coastal waters.

The first oil-drenched birds began arriving at emergency cleaning centers on February 1, brought in by Santa Barbara citizens who combed the beaches daily in search of wildlife in distress. Many of those who brought birds stayed to assist in the cleaning process that followed. This report is an account of the efforts toward treatment and rehabilitation in one of the centers, A. Child's Estate, Santa Barbara's Zoological Park under the direction of Mr. Ted McToldridge. It is important to keep in mind that none of those involved in the project were ornithologists and that efforts to obtain information on the treatment of oil-soaked birds usually met with failure. As a result,

---

[1]University of California, Santa Barbara.

[2]A. Child's Estate, Santa Barbara. The authors of this paper were not supported on the W.O.G.A. Grant to the Allan Hancock Foundation.

much of the treatment was of the trial and error variety with ingenuity becoming the key to problem solving. The mistakes as well as the successes are reported so that others who become involved in similar oil spills may learn from our experience.

SURVIVAL STATISTICS

During a 33-day period, 652 birds representing 26 species were cleaned and treated at A. Child's Estate. Fig. 1 shows the survival record of those species of which ten or more birds were treated. For the purpose of the statistical comparison, any bird living at the time data collection was terminated was given a survival period equal to the number of days since its arrival. Many of these birds are still living three months later and the survival period of their species would, of course, be greater if the figures were recomputed. Therefore, these data should be used only for comparison between species and not for absolute values of survival time in days. The proportion of survival for each species has remained relatively unchanged. Very few of the birds numbered as survivors on March 5 have died since then.

It is obvious that certain species have a much better chance for survival than others, although we feel that the rates for some species could be improved in any future oil disaster if the knowledge we have gained were applied. It should also be mentioned that the overall survival rate of 12% might well have been higher except for an unfortunate incident. Permission was granted to a research veterinarian in northern California to take 100 of the Santa Barbara birds north to his laboratory for a research program. The birds he obtained were all past the most critical phase of the program, the first 24 hours after washing, and were already in the rehabilitation phase. Twenty-two of the birds died en route, another 28 died within two weeks, and 26 others were never accounted for. None of these birds are included in our data since they were removed from the controlled situation.

For the species with sample size of less than ten the survival figures were as follows (total received/total surviving): pelagic cormorant (3/0), horned grebe (3/0), canvas back duck (1/1), lesser scaup (4/3), white-winged scoter (8/3), common scoter (1/1), pelican (1/0), cinnamon teal (1/0), pigeon (2/2), sanderling (2/1), godwit (1/1), rhinoceros auklet (1/0), pie-billed grebe (3/0), red-neck grebe (1/0), and green heron (1/0).

The data were also analyzed for each successive group of 100 birds to determine if survival figures varied across time. As can be seen in Fig. 2, the mean survival period in days decreased with each successive group except the last. However, the proportion of treated birds surviving remained about the same. The most likely explanation is that the birds which came in later had been exposed to the oil for a longer period, had had more opportunity to ingest it, and had reached a point of semi-starvation because in their oiled condition they were unable to obtain food. If they were strong enough to survive the initial cleaning period, their chance of survival was equal to that of any other group. The upswing in survival for the last group of birds may reflect improvement in rehabilitation procedures. The obvious explanation, that it is inflated because the birds had not yet had time to expire when the data were analyzed, is negated by the fact that only one or two of these birds have died since the data were collected.

The amount of oil on each bird was noted on arrival as light, moderate, or heavy. Light oil was defined as patches of oil which did not interfere with the bird's movements, heavy oil as a coating completely covering the bird and prohibiting free movement, and moderate oil as any amount in between. No survival pattern related to amount of oil was apparent. The heavily oiled bird had as good or better a chance to survive as those less heavily coated. In fact, during the last week or so of February and through March, many birds arrived at the Estate with little or no oil on their bodies. Almost without exception they were emaciated and weak and died within a few hours of their arrival.

TREATMENT

Large galvanized tubs filled with warm water were set on trestles in a secluded work area in the Park. As the birds arrived, they were held temporarily in large cardboard cartons to await their turn in the tubs. Volunteer workers soon learned that a team approach to washing a bird was most practical; one worker held the head and supported the body while another did most of the actual washing. In the case of some species--cormorants, loons, and grebes--controlling the bird's head was a matter of self-preservation for the washers!

With the exception of the first seven birds, all cleaning was done with Polycomplex A-11, a non-toxic dispersant made by the Guardian Chemical Company, Long Island City, New York. The most successful procedure appeared to be to cover the oiled area with the detergent, add a little water, work the mixture gently into the feathers, and then place the bird in the tub for a rinse. For any but the most lightly oiled birds, several applications were necessary. Although the detergent is reported to be harmless to the bird, every effort was made to keep the bird's head out of the water and to keep the detergent from the eyes. For those birds which were lightly oiled in small patches, the rinse was done with a gentle spray from a hose in an effort to maintain the waterproof integrity of non-affected areas. In either case, it was necessary to rinse several times to remove all trace of the detergent.

Recommendations

1. Train all volunteers before allowing them to work on the birds, emphasizing proper handling, gentle manipulation of the feathers in a sideward and downward motion, and a standard washing procedure.

2. Work as quickly as possible. This is a stressful situation for the bird; we have a nagging suspicion that some of our birds succumbed to oversolicitousness. A prolonged wash period in which one attempts to remove every trace of oil stain may be disastrous.

3. Do not hold birds on their backs for extended periods of time. There may be no scientific basis for this recommendation, but we did observe that birds held in this position seemed to lose some of their strength and vitality.

4. Keep the bird's head out of the wash water and the washing compound out of its eyes. Some birds, especially western grebes, developed a growth on their eye membranes. The incidence of such growths dropped when care was taken to keep eyes free of detergent and eye medication was added to the list of treatments.

As soon as the bird was thoroughly rinsed, it was wrapped in a cloth--partly to absorb excess water and partly to prevent chilling--and taken directly to the infirmary. Here the interior of the beak was cleaned with a cotton swab occasionally moistened with cod liver oil to remove oil which had congealed into a hard, tarry substance. The eyes were treated with Trico Mycortain ophthalmic ointment placed directly on the eyeball. Internal treatment took a variety of forms. When survivors are examined to determine what treatment or combination of treatments was most effective, there is no clear-cut answer. Some birds survived each treatment tried, but no specific treatment was responsible for a large proportion of the survivors, and some birds survived without any internal medication. In a similar situation we would probably use a standard treatment of margerine, Avitron, and vitamin B-1, along with a force feeding for those birds which appear emaciated and weak.

After each bird was treated, it was banded with an adhesive tag on one leg to indicate its admission number. A metal tag bearing a permanent identification number was placed on the other leg. The birds were then placed in "wards," enclosures with shavings on the floor and infrared lamps for heating, and kept there until they were thoroughly dry.

REHABILITATION

A good deal of the time covered by this report passed during one of the rainiest seasons California had experienced in years. As a result, efforts at rehabilitation were complicated by the need to provide pens which could be kept warm and dry. Temporary pens for grebes, loons, murres, and cormorants were constructed with chain link fencing waterproofed with a sturdy opaque plastic covering on all sides and overhead. All other birds were kept inside a 30-foot trailer which had been converted into a dispensary. These facilities made satisfactory holding pens until more permanent quarters were constructed.

Housing the birds proved to be one of the most difficult problems we faced. The final structure, redwood frames covered with chicken wire and roofed with plastic panels, provided five separate areas 8 by 20 by 6 feet. During the cold wet weather, three sides of the structure were protected by plastic sheeting. The floor surface was covered with 4-5 inches of pea gravel. Each of the five areas was set aside for one or more compatible species. In an attempt to make the enclosures habitable, we provided the cormorants, for example, with several large logs and branches. A galvanized tub was sunk into the floor and was continuously filled with circulating water. The cormorants adjusted rapidly, eating well and bathing daily. Had the oil flow stopped and the ocean been clear of slicks, these birds could have been released as soon as they regained their strength. They did not seem to suffer from the loss of waterproofing resulting from their detergent bath as much as did other species. However, since the ocean was still far from hospitable, the cormorants were sent to the San Diego Zoo to be studied by experts and, hopefully, to be induced to breed in captivity.

Other species did not fare as well in the pens. While the gravel facilitated cleaning, it wreaked havoc on the feet and breasts of birds not equipped for locomotion on land. The grebes and loons were soon in pitiful shape with dry, calloused feet and open wounds on the breast. To get the birds off the gravel, we constructed within the pens raised platforms with wire mesh floors. The wire proved to be as hard on the birds as did the gravel; even the scoters began to deteriorate. Our solution was both novel and expensive. From the local swimming pool supply houses we purchased artificial plastic turf and placed it as flooring on the platforms. The resilient plastic grass, extending an inch from the base, cushioned the weight of the birds' bodies, and most of the open wounds on their breasts began to heal. But the feet proved to be a more stubborn problem. Lacking the moisture from their usual immersion in pond or ocean, the feet and legs dried and began to crack. The obvious answer was to rub a lubricating ointment onto the legs of the affected birds. Since individual applications of ointment to the legs of over 100 squawking, struggling birds offered major logistical problems, we were quick to try any method that promised to minimize the number of applications. Thus it was that one afternoon two grebes were outfitted with red flannel booties. When it appeared that the booties did, in fact, retain the moisture and protect the feet, all the remaining grebes were treated with A & D ointment and shod in Bull Durham tobacco bags. These bags, because of their drawstring tops, proved more satisfactory than the taped flannel which was difficult to keep on the feet. In three days the legs and feet had once more become supple, and open wounds had begun to heal. When after five days some feet began showing signs of excessive dampness, it became apparent that the bags were doing their job too well, and we removed them.

The final habitat, and the one in which the birds will be kept until they can be released, involves an attempt to naturalize the surroundings as much as possible. We dug out an area in each pen for a pond, kept it filled by a continuous stream of running water, and surrounded it with clumps of tall grass. The floor of the pen we covered with several inches of beach sand and placed clumps of grass and sandstone rocks around the interior to give the birds a feeling of security. The habitat seems to be having the desired effect. The birds enter the pond which cleans them, gives them some exercise, and helps keep their legs and feet in good condition. When they emerge from the water they are quite busy preening their feathers and moving about their area, activities that seldom occurred when they were on the platform. As soon as individual birds are found to be once again waterproof, strong, and active, we release them in the Santa Barbara Bird Refuge to regain flying strength before taking their place in the wild.

<u>Recommendations</u>

1. As soon as an oil spill is reported, begin preparing a habitat for affected birds.

2. Keep the birds in a warm, dry treatment center until they have recovered from the initial shock of the washing and handling.

3. If the weather is cool or damp, enclose the pen area with plastic sheeting and place heat lamps inside to maintain a temperature around 76 degrees.

4. Allow cormorants and murres immediate access to water. These birds seem to regulate their bathing with a good deal of common sense, and as long as they are kept warm they seem to profit from their swimming.

5. Pens for ducks, such as scoters and mergansers, should have many clumps of tall grass. These birds seem to find comfort in being able to hide themselves in the weeds.

6. The grebe pens should have NO places into which a bird might stick his head and then have difficulty withdrawing it. At least 20 of our grebes drowned when they got their heads caught in the grate over their water dish. The grate was necessary because a grebe never goes around any obstacle; he plows right through it. Until the final habitat was built, a grebe who wandered through his water dish was likely to be dead in the morning, probably a victim of pneumonia. Several others stuck their heads through the cage wire, panicked when they became caught and died.

7. The floors can be kept relatively clean by pouring fresh sand over them every day or so.

8. If the weather becomes warm, the plastic side covers can be removed during the day and replaced at night until finally removed altogether.

9. Above all, KEEP THE BIRDS WARM while they are recuperating. A visiting naturalist came by while we were struggling with problems of housing and told us he had had good luck rehabilitating birds by spraying them with water daily to encourage preening. We followed his advice and, as a result, spent a very unhappy weekend removing dead birds. Either his birds were different species or

they were in better condition, for ours at this stage could not survive the dampness. Finally, when the birds are ready for a swim, be sure the pen area is warm so they will not become chilled when drying.

FEEDING

The majority of the birds began to feed well only after they were put in one of the outdoor pens. Leaving a couple of active birds who eat readily in each indoor treatment area might stimulate the newcomers to follow their example. Almost certainly some of the birds that died were lost to starvation. The ruddy ducks were a particular problem; they simply refused to eat. Finally, we force fed them with a mixture of Pablum, ABDEC vitamins, powdered milk, wheat germ, and Gevral Protein. This apparently stimulated their desire to eat, for they began to feed quite readily on Purina trout chow.

A bird's normal temperature is about 106 degrees, maintained by the protection of feathers and a constant intake of food. When the dispersant bath removed natural oil and the stress of capture depressed appetite, the bird was in trouble. During this critical period, the birds must have access to an unlimited supply of food and must be kept warm. A bird which refuses to eat will burn up its own body reserves and die of starvation. And if, in addition to being undernourished, the bird is cold, it will die in a matter of hours.

The dietary staple for all birds was fish. Originally they were fed a combination of anchovies and smelt, but the anchovies had to be accompanied by a dose of vitamin B-1 to offset the ingestion of thiaminase. Since smelt apparently do not form this substance in their bodies after death, they have become the main course of each feeding with supplements of mackerel for the cormorants. Occasionally shrimp has been added to the scoters' menu, but the fish remains their favorite. Meal worms tossed into the pens for sanderlings, godwits, and yellow legs were apparently enjoyed by the eared grebes as well. One thing we learned by sad experience is that horned and eared grebes cannot swallow a whole smelt. A number of these little creatures must have starved to death before someone noticed that they were having a difficult time trying to get a whole fish in their bills. Once we took the hint and cut their smelt into bite-size pieces, their survival rate improved.

Two other species with some special problem were the pelagic and Brandt cormorants. None of these birds that were put into a pen with the double crested cormorants survived. At least two of the Brandts refused whole fish but would eat pieces tossed to them. It seems illogical to suppose that they could not handle a fish the size of the smelt, but they definitely preferred the smaller pieces. Since they were smaller than the double crested, we finally decided to put the pelagics and Brandts in a separate area to see if that increased their survival rate. But only one such bird, a small pelagic, came in after that decision. Placed in with the murres, it thrived, and was eventually released.

To conclude, we would like to point out the importance of research on treatment and maintenance of seabirds before a pollution incident. Once pollution has occurred, it is necessary to act quickly to save oiled birds. A knowledge of the best methods of handling these unfortunate birds would result in a higher survival in many species, plus a better use of manpower, finance, and equipment.

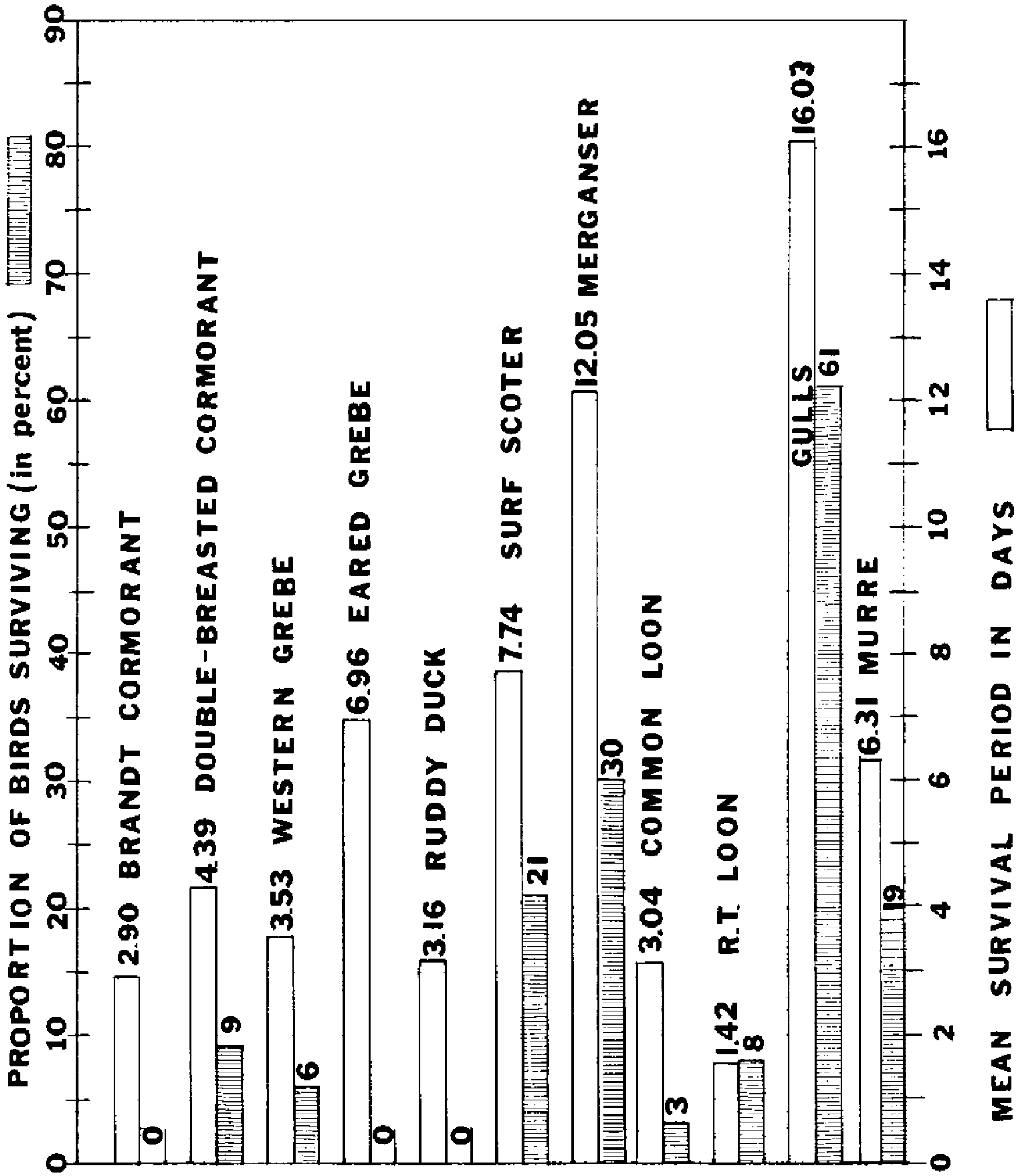


Figure 1. Survival record of species of which ten or more birds were treated at A. Child's Estate.

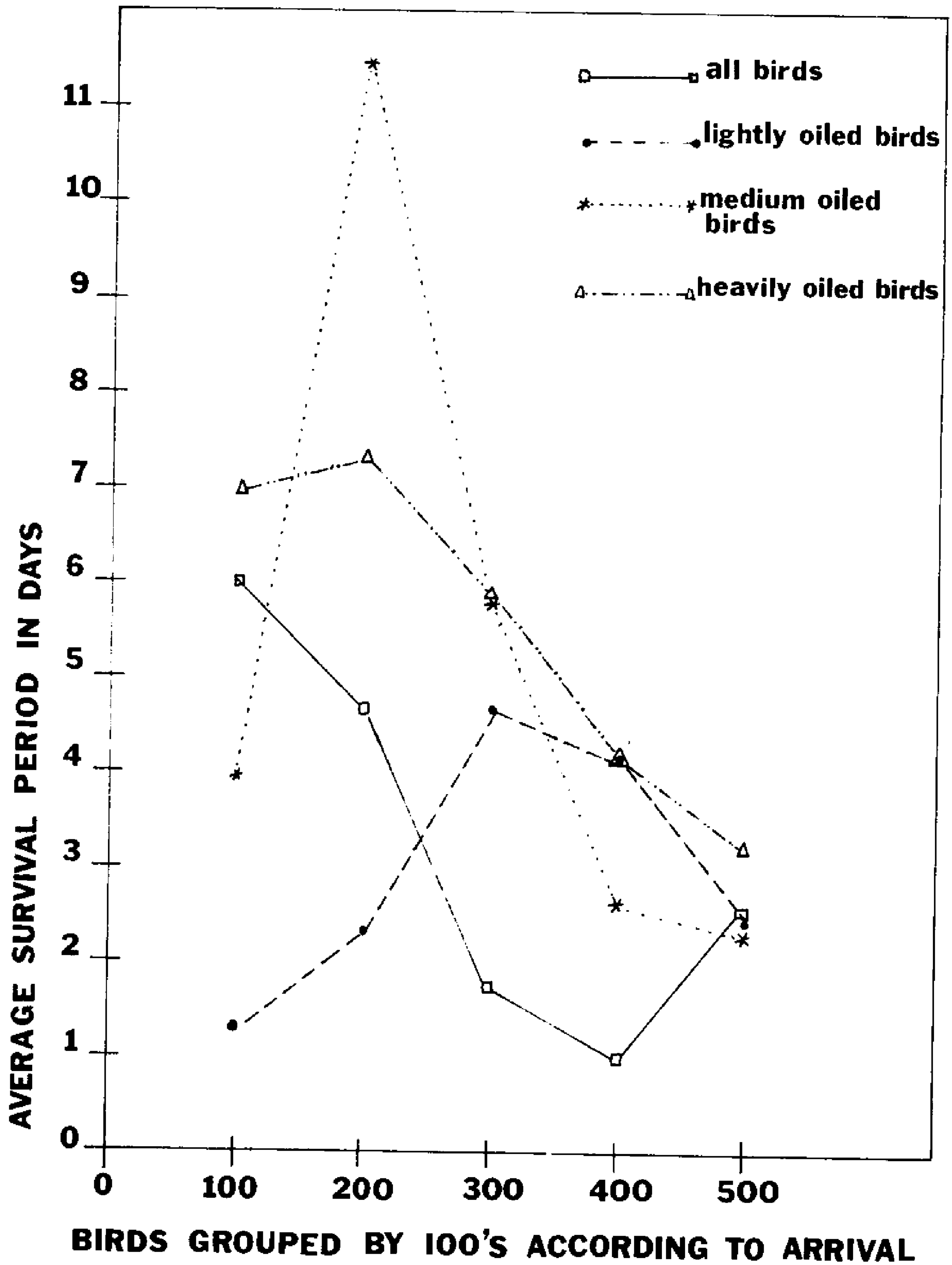


Figure 2. The mean survival of each successive group of 100 birds treated at A. Child's Estate.

CHAPTER 17

THE SANTA BARBARA OIL SPILLS OF 1969: A POST-SPILL SURVEY OF THE ROCKY INTERTIDAL

by Nancy L. Nicholson and Robert L. Cimberg

INTRODUCTION

The 1969 Santa Barbara oil spills

Spillage of crude oil in the Santa Barbara Channel raised debate about the consequences of presence of oil for marine organisms. Intertidal areas in the Channel Islands and on the mainland were intermittently covered with films and lumps of oil for several months in 1969, with most of the oil deposited on rocky areas selectively adhering in the upper intertidal (Table 4, column titled "All Oil").

In the first spill, 11,290-112,900 metric tons of crude oil were estimated to have been released from the ocean floor adjacent to Union Oil Company's Platform A (Allen, 1969a) during the first 100 days. Oil first reached the California mainland at Hobson County Park, and by the end of March 100 miles of coastline were affected from Point Arguello to Port Hueneme (Allen, 1969a). Distribution of oil along the coast by the end of March is shown in Plate 1. The Channel Islands where oil came ashore were Anacapa, Santa Cruz, Santa Rosa and San Miguel (Allen, 1969a).

The second inundation of Channel beaches occurred from a break in an underwater line serving Platform A, releasing an estimated 400 barrels of crude oil (Chapter 1).[1] On

[1]One metric ton = 6.9 barrels, 1 barrel = 42 gallons (60^{o} F, sp. gr. of 0.917 for California crude oil).

December 21, 1969, oil was observed coming ashore at Hobson County Park and Carpinteria State Beach during a low tide in the late afternoon and it was temporarily limited to tide-pools and a few patches of sand (Plates 5a and 6b). With the incoming tide, oil was washed further up the beach. It is worth pointing out here that the slicks were composed of frothy, chocolate-colored oil that readily coated wet as well as dry surfaces. This oil behaved differently from the crude oil in the January spill in that it stayed moist and sticky (the authors' samples from this spill are still fluid at the writing of this paper ten months after the December spill). Gobs of crude oil observed as they came on beaches always formed a "skin" on the surface exposed to the air for a few hours; in a few days' time these lumps of crude oil were quite hard.

Comparison of the Santa Barbara and other spills

There are some major differences between the Santa Barbara spills of 1969 and the _Tampico Maru_ accident in Baja California during early spring of 1957 (North, Neushul and Clendenning, 1965; North, 1967). The _Tampico Maru_ ran aground at the mouth of a small cove, releasing highly toxic dark diesel (8,000 metric tons) into a confined area, producing an immediate and spectacular kill of marine life. In contrast, the Santa Barbara incident resulted in release of crude oil about seven miles offshore, producing slicks that remained at sea for several days before moving onto the beaches. This delay at sea allowed a natural product (crude oil) to lose many of its toxic volatile components through evaporation prior to its arrival on shore. An investigation made soon after the Santa Barbara spill by Anderson, Jones, Mitchell and North[2] for the Western Oil and Gas Association reported few immediate deleterious effects on marine organisms of the mainland and Channel Islands.

---

[2] Anderson, E. K., L. G. Jones, C. T. Mitchell, and W. J. North, Preliminary report on the ecological effects of the Santa Barbara oil spill: Part of a report submitted to Western Oil and Gas Association.

The difference in consequences of spills according to the degree of refinement of the petroleum product involved is further illustrated by the release of 38,647 metric tons of #2 diesel fuel oil when the barge Florida ran ashore off West Falmouth in Buzzard's Bay, Massachusetts (Hampson and Sanders, 1969). Following this incident (September 16, 1969), a drastic kill of fish, worms, crustaceans and molluscs occurred rapidly, even before the application of detergents. Clendenning (1964) had pointed out earlier that diesel fuel is relatively toxic as compared to crude oil.

In comparing the Santa Barbara spills with another spill of crude oil, it is necessary to point out that clean-up methods may drastically affect the health of marine organisms. When the Torrey Canyon ran aground on the Seven Stones Reef, 15 miles from Cornwall, England, in March, 1967, 119,000 metric tons of Kuwait crude oil were released. This is roughly half again the volume released from the Santa Barbara spill and the accident occurred twice as far from shore. Slicks produced from the Torrey Canyon thus had some time to lose toxic volatile fractions, but cleanup operations involved extensive use of detergents and dispersants on and near shore, causing much of the mortality (Smith, 1968). As a result of the observation that detergents, dispersants (some are kerosene-based), and their chemical kin were more toxic to marine organisms than crude oil, the spills from Platform A were handled in a different fashion than those from the English disaster. No dispersants (Chapter 1) were applied inside the one-mile limit except when oil penetrated the Santa Barbara Harbor (Gaines, [in press]). Beaches were cleaned by broadcasting chopped straw over oiled areas (Plate 4a), then scooping the resultant mass into trucks that hauled it away to be burned. During and immediately after the January, 1969, spill, a study was made by marine biologists at the University of California at Santa Barbara (Foster, Neushul and Zingmark, 1969) that did not report massive kills of intertidal organisms.

Records of marine populations on the continental shelf prior to 1969

The scope of this paper was widened beyond the Santa Barbara Channel because it was necessary to select study sites outside the area affected by the spills. Marine biological investigations in Southern California (Point Conception to San Diego) have been principally involved with deep waters beyond the intertidal region (Hartman and Barnard, 1958, 1960; Hartman, 1963, 1966; Jones, 1969), although some of the work extended into relatively shallow water.

Information about intertidal populations at specific sites comes mainly from Yale Dawson's contribution to an oceanographic survey completed for the State Water Quality (Pollution) Control Board (Dawson, 1959, 1965). Dawson established 45 stations at rocky beaches and recorded their populations of seaweeds and marine grasses from 1956 to 1959. There are no comparable data available for populations of intertidal animals.

Dawson concluded (1959, 1965) that reductions in the variety of algae composing the marine flora had already occurred by 1959. He based his conclusions on a reconstruction of the Southern California marine flora from collections made by W. A. Setchell and N. L. Gardner between the years 1898 and 1920. Our marine flora from these early years is best known at White's Point, Point Fermin (both near San Pedro), and the beach at Sunset Boulevard in Santa Monica (Dawson, 1959). Critical early information is even more incomplete in the Santa Barbara region, since Setchell and Gardner made these collections without exact reference to location, and the specimens were not retained or listed in floristic units.

Data from recent studies of Dawson's northern stations (Neushul, personal communication, 1967; see Table 5) and Dawson's southern stations (Widdowson, personal communication, 1970) document a pattern of general decline in variety of the marine intertidal flora. Observations of the subtidal rocky bottom areas near the White's Point sewer outfall indicate that recent ecological changes have occurred (Grigg and Kiwala, 1970).

The present investigation

The purpose of the present study was to document the condition of populations of the Southern California rocky intertidal areas (both on the mainland and in the Southern California Channel Islands) and to evaluate possible effects of crude oil in this environment. In order to evaluate effects of oil present for discrete periods (acute event), it is necessary to isolate changes wrought by oil from changes due to other factors that operate simultaneously. Ideally, the standard for comparison of population patterns in a year wherein an accident occurred with population patterns of "normal" years, should be data from a continuous monitoring program. Unfortunately, we have no data describing natural fluctuations in marine populations and their underlying causes on an annual basis. Our discussions are therefore limited to descriptions of areas where organisms were covered by oil long enough to be affected. Comparisons of sites where oil is chronically (continually) present with areas where it is not present are limited, as the mere presence of an organism in an area chronically exposed to oil yields no information on physiological or genetic mechanisms that permit existence in such a place.

Since our information about marine plant populations forms the bulk of data gathered from the intertidal and since marine plants are more easily sampled than animals (which may live under rocks or hide when disturbed), the flora will be discussed more extensively than the fauna.

MATERIALS AND METHODS

Field procedures for mainland intertidal stations

Ten rocky intertidal stations were surveyed monthly from May, 1969, to June, 1970. Ranging from Gaviota State Beach, approximately 30 miles north of Santa Barbara, to Dana Point, 60 miles south of Los Angeles (Plate 1), these stations were:

Gaviota State Beach (Dawson Station 13)
El Capitan State Beach (Dawson Station 40)
Coal Oil Point or Devereaux Point
  (Neushul, New Series 1; or D.P.)
East Cabrillo Beach (Nicholson-Cimberg Station 1,
  or E.C.B.)
Carpinteria State Beach (Dawson Station 15)
Hobson County Park or Rincon Beach Park No. 4
  (Dawson Station 35)
Palm Street, Ventura (Dawson Station 12)
Arroyo Sequit or Leo Carrillo State Beach
  (Dawson Station 4)
Corona del Mar (Dawson Station 9)
1 mile north of Dana Point or Salt Creek Road Beach
  (Dawson Station 22)

Stations were selected on the basis of degree of exposure to the 1969 oil spill, natural oil seeps, industrial and agricultural operations and exposure to public use. Detailed descriptions of the stations and the station lines (transects) were made by David Drake and Larry Doyle of the University of Southern California Department of Geology (Table 1). Descriptions of eight of Dawson's stations (Dawson, 1965) were followed where feasible in locating shore base points. However, some of the landmarks to which he referred no longer exist and in such cases new base points were established as close to Dawson's as possible. Standard surveying techniques were employed; transit and stadia rods were used where appropriate. Beaches with particularly precipitous cliffs or with remote United States benchmarks required use of an aneroid altimeter. Locations, station lines, and shore base points for the ten beaches are presented in Table 1.

Line intercepts were chosen as the sampling method for this investigation. There are several reasons for the selection of a linear sample. Data from previous investigations were gathered along tapes or cords stretched across the intertidal. The method allowed a rapid cross-section of an entire beach briefly exposed at low tide, and distance relationships of organisms dwelling along the line were preserved. Disadvantages of the method are that the station line may miss some species, and its repeatability is more limited than that of a fixed quadrat. A line intercept does not guarantee a sample of the complete range of tidal levels at which a particular organism is found on a particular beach. In addition, accurate figures for biomass cannot be calculated from line intercept data, but it is possible to use these data to calculate crude cover and frequency values.

Starting at the water's edge and moving ahead of the incoming tide, data were obtained each month by laying a fiberglass tape measure along the established station line and recording at three-inch intervals substratum (sand, rock, pool with sand or rock bottom), presence of oil (if any), reproductive condition (where observable under field conditions), presence of juvenile plants or animals, and types of adult organisms. Since the height of the tides is variable, the length of the recorded station lines varied, but the shore base point was always the end of the line. Surveys conducted at night low tides required the use of miners' headlamps. Portable tape recorders were used to record field data, and these observations were later transcribed onto prepared data sheets.

Since as many as 13 surveys were made at a beach, the practice of collecting monthly voucher specimens could have significantly damaged a station area. Collections (designated Master Transects) of voucher specimens were limited to four, taken at three-month intervals, from each station. These specimens are in the Allan Hancock Foundation Herbarium biological survey files, supplemented with color photographs of station areas (1956-1959, 1969-1970) and raw data sheets.

<u>Bases for selection of stations</u>

Six stations were selected to provide adequate geographical coverage of Southern California:

Gaviota State Beach (Dawson Station 13)
El Capitan State Beach (Dawson Station 40)
Carpinteria State Beach (Dawson Station 15)
Hobson County Park (Dawson Station 35)
Leo Carrillo/Arroyo Sequit (Dawson Station 4)
Corona del Mar (Dawson Station 9)

In addition, Coal Oil Point/Devereaux Point (Neushul, New Series 1, 1967) was chosen as a control for chronic presence of crude oil which comes from a large tar seep area located within 45 feet of water 150 yards offshore (Allen, 1969b).

East Cabrillo Beach was chosen as a field control for dosage of oil derived from the January, 1969, spill (Nicholson-Cimberg Station 1, established 1969). This beach received a graduated coverage of oil (light coat in the lower intertidal to a half inch of adhering oil in the upper intertidal) on the metal groin that constitutes the station area.

Palm Street, Ventura (Dawson Station 12) was selected because it is close to industrial plants and because local agricultural operations are drained by the Ventura River. This beach and Leo Carrillo State Beach (Arroyo Sequit) were subject to heavy influxes of fresh water and sediment during the winter storms of 1969. Palm Street is near the mouth of the Ventura River and Arroyo Sequit is near the mouth of a large creek.

Two beaches were needed to serve as monitors for effects of public use. It was desirable that one of the beaches have strictly regulated public access (private beach north of Dana Point near Salt Creek Road) and that the other be available to large numbers of people (Corona del Mar). Both stations were far enough south to be unaffected by crude oil from the Santa Barbara area (Allen, 1969a).

<u>Treatment of data</u>

In order to compare observations from various investigations, raw data from each study were treated so that the observations were comparable. An investigation conducted by Neushul and student observers in 1967 employed line intercepts and their data are comparable to those from our 1969-1970 stations.

E. Yale Dawson's extensive survey of the Southern California intertidal has provided a substantial reference standard for subsequent comparative studies. His collections of 7,500 specimens from 45 stations were primarily made during winter months and his collection records (made at intervals of 20 to 50 feet along the station line) provide some information regarding frequency of species. By combining most of his voucher specimens with his published field notes (which record some common species such as Ulva, Enteromorpha and Porphyra that were not collected), a complete list of marine plants Dawson found at each station for each month was compiled (Tables 12, 17). This list was used as a baseline representation of the 1956-1959 intertidal flora of the Southern California mainland for purposes of comparison with the present study. Only collections from intertidal station lines were charted (Table 12), since Dawson's voucher specimens included collections away from the station line (labeled to indicate whether they were from nearby sites or subtidal).

To compare data from our investigation (Tables 14, 18) with Dawson's data (Tables 12, 17) on an equal taxonomic basis, the species of the genera listed in Table 9 were grouped as a single entity. For instance, *Bryopsis corticulans* and *B. hypnoides* were counted as one entry, but *Bryopsis* and *Enteromorpha* were counted as two entries. Identifications of some algae were made only at the generic level to avoid erroneous designation of species in the field.

A number of faunal groups had to be combined due to possible inaccuracies in field identifications. Species in the genera *Collisella* (formerly *Acmaea*; MacLean, 1969), *Acanthina*, *Littorina*, and *Tegula* were considered as one group within their respective genera. Species were often grouped into larger taxa when field identifications could not be made to genus, e.g., sponges, chitons, hydroids, nemerteans, and tunicates.

Field procedures for Southern California Channel Island stations

Descriptions of island stations may be found in Table 2. Stations were chosen both in areas affected by the January, 1969, oil spill (Plate 1) and in areas not so exposed.

Owing to the spectacular cliffs of the Channel Islands, accessibility of intertidal stations from the shore is difficult. For this reason all insular stations were investigated by diving or bottom-sampling methods (orange-peel grab or biological chain dredge), using as bases of operation two of the University of Southern California's vessels, the Velero IV and the Golden West.

At each station, divers collected small samples of marine organisms from depths of 0'-10', 10'-20', and 20'-30' in the station area. No effort was made to follow a station line. Permanent anchor points for a station line would be valuable to increase the accuracy of future diving investigations. Dredging was used in waters of 80'-120' depth to conserve divers' energies for shallower waters.

All specimens collected were deposited in the Allan Hancock Foundation Herbarium; in the case of most of the Channel Islands marine algae, duplicate specimens have been deposited in the Gilbert Morgan Smith Herbarium at the Hopkins Marine Station of Stanford University.

Field data obtained from this investigation are presented in Tables 13, 14 and 15 and summarized in Tables 17 and 18.

OBSERVATIONS

Mainland stations

Oil that came onshore in rocky areas adhered selectively in the upper intertidal. There were a variety of reasons for this, the main one being that oil sticks more readily to warm, dry surfaces (upper intertidal is exposed longer, drying and warming more than lower areas) than to cool, wet surfaces. In areas where there were offshore kelp beds, slicks were dammed behind *Macrocystis* fronds floating at the surface, then lifted as the water level rose on the incoming tide. These dammed slicks came onshore after most of the lower intertidal was already flooded, but before the upper reaches were covered, allowing the surf to spatter warm, dry rocks with oil.

During receding and advancing tides that carried slicks, the surf line thoroughly worked and reworked a mixture of water and oil over plants and animals. A number of observations of oiled algae (*in situ* and cast ashore) were made, and it was determined by testing fresh and dead fronds in oil that oil sticks readily to a dead plant but can be easily rinsed off a fresh frond. Fresh, healthy algae often have smooth outer surfaces and their highly hydrated cell walls present a surface with which oily chemicals have little or no affinity. Dead specimens quickly lose their slick surfaces and microbial action or abrasion produce a pitted surface to which oil can adhere. Thus, observations of oil on a dead area of tissue is not proof that oil killed the affected area. If oil sticks to a living surface (as dispersant-treated oil will), and these surfaces are then damaged, oil can be singled out as the causal agent. The frothy, chocolate-colored slicks that struck Santa Catalina Island at the end of December, 1969 (source undetermined) had been chemically treated and stuck readily to the brown alga *Hesperophycus* (dried out at low tide) and killed these plants back to the holdfasts. Most of these plants had regrown new stipes by May, 1969.

In addition to areas where oil from the spills was present, certain beaches were located inshore from natural oil or tar seeps of varying activity (Chapter 1, Fig. 1). The oil slicks from both spills, coming as they did in the winter months, affected a smaller variety of organisms in fully grown and/or reproductive condition. Tables 13 and 14 show the seasonal pattern of species variety for both intertidal animals and plants.

Heavy rains during the winter of 1969 produced an abnormally high influx of fresh water, particularly where beaches were near a creek or river; this water may have carried a burden of insecticides and herbicides, in addition to sediment, if it washed off an agricultural area. Some beaches are near industrial operations or are affected by longshore drift and current systems (Plate 2) that could carry various types of effluents for long distances close to shore. Sand movements have a high potential for damaging marine populations through abrasion and smothering; Arroyo Sequit showed the most marked effects of shifting sand (Plates 8a, 8b, 9a). Use of the study sites by the public varied from activities that leave a beach relatively undisturbed (swimming, picnicking) to activities that produced obvious disruption and damage (clamming, walking over populated rocks, collecting). A summary of various factors operating at mainland stations is presented in Table 11. No overt indication of epidemic outbreaks of disease were noted and are thus not included in Table 11, but the possibility that disease may have affected large intertidal areas between 1959 and 1969 cannot be ignored.

All beaches this survey had in common with Dawson's survey showed a reduction in the variety of their floras (Table 5). The reduction varied in magnitude from a low of 28% (Carpinteria State Beach) to a high of 78% (Palm Street, Ventura, and Arroyo Sequit), with an overall average of 63%. In all cases, different constellations of species were reported as missing (not observed) at the different beaches (Table 6). Fifteen algae, recorded in 1956-1959, were not found on any of the eight Dawson stations reoccupied for this study (Table 7).

In order to facilitate discussion of factors affecting the stations of this survey, beaches were grouped in clusters or treated singly. These groupings do not imply that factors (Table 11) observed operated equally at all beaches in a group.

Gaviota State Beach (Dawson 13)
El Capitan State Beach (Dawson 40)
Coal Oil Point (Neushul, New Series 1)
Carpinteria State Beach (Dawson 15)

These four beaches are near submarine oil seeps of varying distances from shore and of variable activity. Amounts of oil observed on the beaches are presented in Tables 3 and 4. Oil observed during months when spills were not affecting the beach (Table 11) probably came mainly from seeps or shipping operations.

Aside from a heavy cover of crude oil at the time of the January, 1969, oil spill (Allen, 1969a), Coal Oil Point has been reported to have scattered lumps of tarry material amounting to an average of 21.5 lbs per 500 square feet of beach (Merz, 1959). Thus it is likely that a significant proportion of the organisms on this beach may represent oil-tolerant forms (Table 8). There may, however, be some plants or animals with structures that do not permit oil to come into contact with vital parts; these should be classed as oil-evading forms.

At both Carpinteria and Coal Oil Point, surf grasses (Phyllospadix spp.) were observed enmeshed with gobs of oil (Plate 6a). If the oil stayed in contact with the grass long enough, yellowish patches appeared where the oil rested, then these areas later turned brown. Damage to surf grass was also noted by Foster, Neushul and Zingmark (1969).

Carpinteria State Beach showed frequent patches of bleached algae (Plate 5b), as did other beaches (Table 10). The cause(s) of this bleaching is unknown. It may or may not have contributed to the 28% drop in algal variety at Carpinteria (Table 5).

Pollicipes polymerus, the goose-neck barnacle which is found mainly in the middle intertidal zone, had oil reported in its stalk and capitellum on both East Cabrillo and Carpinteria in June, 1969. In March, 1969, these barnacles could easily be pulled off rocks at Carpinteria. In May, 1969, few were left in areas where they were easily detached in previous months.

Gaviota State Beach and El Capitan State Beach suffered reductions in their algal floras (54% for Gaviota and 72% for El Capitan) according to measurements made ten years apart (Table 5). Without data to compare yearly fluctuations in populations with variable activity of the submarine seeps, all that can be done is to record factors that contribute oil to these sites. Petroleum products are handled at several places between these two beaches; tankers frequently dock at the Getty Oil Company facility (Gaviota Marine Terminal). Gaviota Beach is 1.7 miles north of the Gaviota Marine Terminal and receives more oil (Table 3; source undetermined) than does El Capitan Beach, 11.5 miles south of the terminal.

Hobson County Park (Dawson 35)
Corona del Mar (Dawson 9)
1 mile north of Dana Point (Dawson 22)

These beaches are grouped together for the purpose of comparing observations on the activities of people on these sites. The most dramatic disturbance of the beach substratum occurred at Hobson County Park where clammers (Plate 7a) routinely dig large holes and overturn heavy boulders to get at clams (Protothaca staminea). This park suffered a 73% reduction in its marine flora (measured at the opposite ends of a decade) (Table 5). Hobson (Plate 6b) was one of the two stations affected by the December, 1969, spill of treated oil; Carpinteria was the other (Plate 5a). Oil from the second spill was gone after several days.

Corona del Mar, a marine preserve, showed a 68% (Table 5) decline in its flora. The station area is subject to incursions of large numbers of people who tramp over the rocks (reducing the algal inhabitants to a short turf), and collect animals such as starfish or crabs, or perhaps turn over occasional rocks, although collecting activity is expressly forbidden by signs in the area. This beach was also the oiliest of the beaches studied in the Los Angeles area, but the oil was from an undetermined source (Plate 9b, Table 3), possibly from small craft activity near Newport Harbor and barge traffic along the coast.

The station area one mile north of Dana Point is part of a patrolled private beach and showed a smaller than average reduction, 55%, in its marine flora (Table 5). This beach has restricted availability to large numbers of people but is south of regions where industrial wastes are discharged (domestic wastes are discharged from the nearby sewer outfalls of South Laguna and Dana Point). Longshore drift could move contaminated sediments south from the South Laguna area.

Parts of the intertidal at the beaches north of Dana Point and Corona del Mar were periodically covered with sand. Turban snails (Tegula funebralis, T. gallina, T. aureotincta) were observed migrating to the tops of rocks to avoid the sand, but many snails were found partially or totally buried.

A number of species of both plants and animals at various beaches were often found in the sand buried to various degrees and did not appear to be adversely affected. Some of these were:

Anthopleura elegantissima	Sea anemone
Ceramium sp.	Filamentous red alga
Centroceras clavulatum	Filamentous red alga
Spermothamnion snyderae	Filamentous red alga
Polysiphonia sp.	Filamentous red alga
Phyllospadix sp.	Surf grass
Gracilariopsis	Red alga

East Cabrillo Beach
(Nicholson-Cimberg 1, or E.C.B.)

This beach was chosen for a study of the effects of graduated doses of oil on animals inhabiting the upper intertidal, since the dominant organisms at this station are barnacles (Balanus, Chthamalus, Pollicipes) and mussels (Mytilus). There are relatively few algae on the metal groin.

The population at this station area was subject to a graduated dose of oil beginning February 4, 1969. By the end of March it had received a heavy dosage of oil (Allen, 1969a), and on May 5, 1969, the upper 124 feet of the station line were still covered with at least a one-fourth inch coating of oil and straw. Only 50 feet of the oil and straw coating was actually deposited in an area occupied by marine organisms, but on May 5, 1969, and on June 29, 1969, the upper intertidal of this station was reported to consist solely of oil and straw covering dead Chthamalus. Littorina were reported on the oil on June 29, and on September 29 some limpets (Collisella spp.) were also reported. Chthamalus settled and were first reported on the oil-and-straw-crusted substratum in November, 1969. With the exception of additional Chthamalus settlement, no changes were detected at this beach until the study was terminated in June, 1970. At this time the upper intertidal consisted of a layer of straw and oil which covered dead Chthamalus but with live Chthamalus, Collisella (Acmaea), and Littorina on top of weathered oil. In addition, Neushul (personal communication) observed barnacles that settled on oiled surfaces were smaller than a population that had established itself for a comparable period on unoiled surfaces.

Damage to barnacles from smothering layers of oil depends on the height of the barnacles and the thickness of the oil coating on the substratum (Plate 3b illustrates this principle at Coal Oil Point). *Balanus*, up to 1 cm tall, was able to project above most of the oily layer while *Chthamalus*, which is usually less than 0.5 cm high, was smothered.

The presence of periwinkles (*Littorina*) and limpets (*Collisella* or *Acmaea*) at East Cabrillo Beach indicates that these organisms can exist on oil but does not necessarily mean that they settled on it as larvae. Limpets (*Patella*) in England were reported grazing on oil and even producing oil-containing feces following the *Torrey Canyon* spill (Smith, 1968), but there is no report of the limpets being able to settle and develop on oily substrates. Sedentary organisms such as limpets with planktonic larvae could have settled low in the intertidal and then as juveniles migrated upward onto a higher oil-covered area.

Storms, which generated heavy seas in the middle of December, 1969, shifted intertidal substrata and organisms. Storm surf ripped out a seven-foot section of the metal groin at East Cabrillo Beach (Plate 4b). By late December, 1969, on parts of the East Cabrillo and Carpinteria transects, large areas of *Mytilus* beds were pulled off, leaving behind only byssal threads. These denuded areas supported a green algal growth in February, 1970, and in May, 1970, mussels (*Mytilus* spp.) of less than 5 mm were reported.

In addition to the station line at East Cabrillo Beach, a nearby barnacle-covered (*Chthamalus*, a few *Balanus*) rock was observed and photographed at regular intervals. This rock was thickly oiled (one inch) at the January, 1969, spill and was not subject to steam-cleaning. Its position in the upper intertidal, plus the fact that sand was mixed with the oil on its surface, resulted in a tough pavement that smothered all the animals on its surface. The rock was not repopulated as late as June, 1970.

Palm Street, Ventura (Dawson 12)

A 78% decline in variety of the marine flora was observed at this station. The station line was sanded over all year; observations were made by surveying the nearby cobble area 50 yards to the west.

There are a variety of agricultural and industrial operations in the Ventura region which may produce effluents (or runoff) with pesticides, herbicides, heavy metals, hot brine, and the like. Public use of this beach (swimming, surfing, building sand castles) begins approximately one-fourth mile east of the station area, and not much oil was recorded here after the January, 1969, oil leak (Allen, 1969a).

Arroyo Sequit (Leo Carrillo
State Beach, Dawson 4)

This beach was virtually undisturbed by the oil from the 1969 spills (Allen, 1969a; Tables 3,4). It was heavily smothered by sand in January and February, 1970, during the winter storms, but the covered areas of the beach were repopulated as soon as the rocky area was re-exposed (March, 1970).

Sand movement affected all ten beaches surveyed (Table 11) with its greatest consequences on the Arroyo Sequit transect. On December 19, 1969, eight animals and fifteen plant species were recorded on this beach. On January 24, 1970, the entire 110-foot rocky intertidal, composed of approximately foot-high rocks, was completely covered by sand, with the exception of a single two-foot high rock. Two large algae, _Macrocystis pyrifera_ and _Egregia laevigata_, were observed partially covered with sand in the lowest 21 feet of the transect (Plate 8a). Six other species were reported from the lone rock not covered by sand. Sand still covered the intertidal on February 23, 1970, but both the _Macrocystis_ and the _Egregia_ had died, with only some stipes sticking out of the sand (Plate 8b). The lower 61 feet of the rocky intertidal was exposed, and fifteen plants and one animal species were recorded on March 21, 1970 (Plate 9a). Later in the season more sand was cut away from the beach, and on May 8, 1970, 80 feet of rocks were exposed and observed to be inhabited by twenty algal and three animal species. On June 25, 1970, the rocky intertidal was approximately 80 feet wide with sixteen algal and five animal species (Plate 9b) compared to observations made nearly one year before (July, 1969) when 116 feet of rocky intertidal had twenty-two species of plants and six species of animals recorded. A similar sandfill with partial coverage of Egregia and Macrocystis was reported by Dawson in February, 1958 (Dawson, 1965).

Examination of current patterns shown in Plate 2 reveal a southerly loop in the region between Ventura and Leo Carrillo Beach. The possibility exists that wastes discharged in and around Ventura, Port Hueneme and Point Mugu could make their way south to Arroyo Sequit, either by way of the current system or by means of longshore drift. This double potential for delivering contaminated water and sediment is discussed later as a possible factor in the decline of 78% (ten-year period) observed in the algal flora of Arroyo Sequit (Table 5).

Channel Island stations

This study established a minimal baseline (Table 15) for comparison with future investigations. At the time the insular stations were examined in November and December, 1969, and in April, 1970, damage due to oil was not conspicuous. A similar conclusion was reached in an earlier study.

Some species present in the southern Channel Islands are absent or rare in the northern (see Table 15). An investigation conducted by the Geology Department of the University of Southern California for this survey revealed water movements and temperature patterns (Plate 2) pertinent to understanding the distribution of Channel Islands marine algae. Drift card and hydrographic sampling data revealed a counterclockwise gyre of colder water in the northern half of the Channel. Cold water from the area north of Point Conception also moves down the outer edge of San Miguel, Santa Rosa and Santa Cruz Islands. The southern Channel Islands are surrounded by warmer waters.

DISCUSSION

A record of a single year does not suffice to reveal more than seasonal patterns of variation within populations: several years of observations are needed to yield data on long-range fluctuations in numbers of a species. Our lack of annual data for the years between 1959 and 1969 makes it difficult to assess the significance of the data shown in Table 5. What is indicated, however, is a reduction in the variety of species in the Southern California intertidal flora. This may not represent an accompanying decline in biomass, especially if replacement of species has occurred. Comparison of the pattern of species distribution from Tables 12 and 14 shows that certain green algal species characteristic of environments rich in organic chemicals (such as the Los Angeles Harbor) are more abundant in 1969-70 than in 1956-59. If the Southern California waters are being enriched organically (as well as in particulate matter and inorganic chemicals), then the likely candidates for the source are the numerous outfalls along this coast which produce one billion gallons of effluent a day in the Los Angeles area alone. The highly structured nature of the ocean (temperature-salinity barriers, current systems) may prevent effective dilution of this effluent, which is mainly discharged close to shore (within ten miles).

Data from the present investigation document a continuing decline (Tables 5-7) in variety of algal species. Similar conclusions have been reached by other investigators working in Southern California (Grigg and Kiwala, 1970; Neushul and Widdowson, personal communications). Interpretation of the effects of the Santa Barbara oil spills (January and December, 1969) should be weighed against a background of shifting floral (and probably faunal) composition (Tables 5 and 6).

Observations showing declining algal populations (Tables 5 and 6) in Southern California prior to 1969 indicate that factors (Table 11) causing damage to the marine flora were already operative at the time of the January oil spill. Without prior data for intertidal animals, a similar decline can only be postulated. The factors listed in Table 11 represent a number of variables that can act singly or in concert to alter an ecosystem. Some of these deleterious factors are clearly natural and some are direct results of human activity. It is assumed that healthy marine populations (stable over decades) are able to recover from damages of storm surf, fresh water runoff and shifting masses of sand. Unfortunately we have no detailed records to indicate stable patterns. Populations weakened by exposure to agricultural wastes (pesticides, herbicides, etc.), industrial wastes (including petroleum products), sewage, atmospheric pollutants and human predation (specimen collecting, clamming, trampling) may be unable to survive natural disasters. Epidemics of disease are also more likely in weakened populations than in healthy ones.

The possibility that a widespread epidemic might have eliminated a species from a significant portion of its Southern California range should be considered. There are at least two possibilities that could yield such a pattern of disappearance: (1) the epidemic was severe in effect but spotty in distribution; or (2) it occurred early enough in the ten-year period to allow time for recovery (this last consideration includes the possibility of attack of disease(s) in successive years).

If an epidemic affecting algal species had occurred, there should be species in common missing at all or most stations (Table 7). However, it is unlikely that a single disease affected red, brown, and green algal phyla (divisions). It is possible that several different epidemics may have occurred in a ten-year span, especially if marine organisms were weakened by steadily increasing amounts of chemical and particulate wastes in their environment, discharged as a result of steadily increasing population in Southern California. It has been shown (Clendenning, 1964) that particulate matter alters the light-transmitting properties of water and significantly reduces photosynthetic rates in Macrocystis (giant bladder kelp). As a result of this and other factors, this vitally important species is now gone from much of its original habitat in the Los Angeles region. The contribution an epidemic may have made to this decline is unknown.

Factors (summarized in Table 11) discussed above do not equally affect marine populations. The upper intertidal bears the brunt of onslaughts from a variety of natural and man-made events. It is exposed to undiluted fresh water run-off, to high temperatures and desiccation from sun and wind (Santa Ana winds at low tide were particularly damaging). Sun and wind damage may account for part of the algal bleaching observed (Table 10). Contaminated air may contain water-soluble components that are toxic to algae (Okamura, Ueda and Miyake, 1926). Oil adheres more readily to dried and warmed areas of the upper intertidal than to cooler, wet sites in lower zones. As the area most accessible to people, it is tramped on, dug up and picked over. It may be that if we had accurate and continuous records of subtidal populations, they would show smaller, or at least different, patterns of change.

The various groups of algae not observed after a period of ten years (Table 6) were different for each beach, which means that different factors (known and unknown) operated to remove them. Further conclusions about the cause of these disappearances (the missing plants might be back the next year) must be based on laboratory investigations of controlled sets of factors. Synergistic effects of substances in agricultural wastes, industrial wastes and sewage were not investigated during this study, but water samples were taken and are available for analysis.

<u>Chronic presence of crude oil</u>

Coal Oil Point, with a near-shore oil seep, served as a control station to observe chronic presence of crude oil.

The composition of oil from a submarine seep in the Santa Barbara Channel and crude oil spilled from Platform A could be similar (Kolpack, personal communication), and the effects of oil from these two sources could also be similar if they spent an equal amount of time at sea prior to reaching shore.

Aside from a heavy dosage of crude oil from the January, 1969, oil spill (Allen, 1969a), fresh oil was reported on this beach during ten of the twelve monthly surveys, more than at any other station studied. Although the activity of seeps is irregular, on a given day at Coal Oil Point the average weight of tarry material was reported to be 21.5 pounds per 500 square feet and the maximum is 95 pounds per 500 square feet (Merz, 1959). In the same investigation, Gaviota was reported to have the next highest amount of tar deposition, with an average of 0.4 pounds per 500 square feet and a maximum of 1.4 pounds per 500 square feet.

Rocks at Coal Oil Point sustain a dense cover of organisms of at least 38 species (plants and animals, June, 1970). In fact, one of the striking features of this station is the nearly continuous cover of organisms (compare Plate 3a with Plates 7a and 9a). Using the same statistic to compare this beach with Carpinteria (48 organisms, June, 1970) and with the station one mile north of Dana Point (47 organisms, June, 1970), it is evident that Coal Oil Point is characterized by a smaller variety of organisms: those that can tolerate or evade effects of the chronic presence of crude oil (Table 8). Without yearly records of population composition, it is impossible to determine whether or not the present variety of organisms is representative of past variety; natural or man-made factors acting in concert with oil could have changed the floral and faunal composition of Coal Oil Point.

Acute effects of oil spills

Acute effects result from oil present for a discrete length of time and depend on the type of petroleum product spilled, concentration of toxic components (affected by length of time of weathering), and dosage delivered to a beach.

During the spills, intertidal organisms were washed with, but were not killed outright by, films of oil during ebb and incoming tides. Rather than causing the death of single organisms, oil films may interfere with the release of reproductive cells, hamper settlement of reproductive stages on oily surfaces and/or hinder physiological processes such as photosynthesis and respiration. It is likely that only organisms with the ability to evade effects of oil or with physiologically resistant means of reproduction and/or mature stages can survive to populate an area such as Coal Oil Point.

Smaller amounts of oil were present at Gaviota and El Capitan beaches. Whether or not the percentage in loss of species at Gaviota is due to its proximity to a site where oil is abundant could be determined in at least two ways: by the comparison of results from petroleum product tolerance analysis of specimens of present and missing species, and by the occupation of the Refugio Beach Station (Dawson Station 41, 8.7 miles south of the Gaviota Marine Terminal) to determine if a similar and/or intermediate reduction of species has occurred there.

Observations of East Cabrillo Beach were intended to document events during resettlement of an area damaged by oil. Comparison of data from overlapping months in 1969-70 (Tables 14, 18) shows an increase in the number of species present. Barnacles (mainly _Chthamalus_), were smothered and killed by the oil but _Chthamalus_ settled on the weathered oil (toxic components largely gone) at the top of the station line in the fall of 1969.

Perhaps the freshly oiled surface did not present the proper physical substratum to the settling cyprids (barnacles), which are known to favor certain surfaces (Crisp and Meadows, 1963). It is more likely that petroleum fractions, toxic to settling cyprids, prevented their attachment until November, 1969, when such fractions disappeared.

Effects of oil from the Santa Barbara spills

It should not be surprising that spectacular effects are not apparent in the Santa Barbara Channel intertidal one year after the spill; observations at Coal Oil Point (the organisms at Coal Oil Point are present on other beaches) show that crude oil is not lethal to all marine organisms, and widely spaced acute spills may allow some recovery to occur. Furthermore, crude oil is a natural component of the Channel environment.

Effects of both spills might have been more evident if they had occurred during a period of active growth and reproduction (spring or early fall) rather than in the winter, which is a relatively dormant period for the intertidal. The pattern for seasonal variety of plant and animal species can be observed on a monthly basis by examining Tables 13 and 14.

The effects of the January and December, 1969, oil spills can be classified as acute, since oil was present for relatively short periods. The observable effects from these two incidents include smothering of barnacles in the upper intertidal (East Cabrillo Beach) and damage to goose-neck barnacles at Carpinteria in March and June, 1969. It is assumed that the events on these two beaches were representative of events on the many miles of rocky coast that could not be surveyed.

It has not been possible to ascertain the effects of an oil film on the water that washes across organisms in the ebb and return tides. The probable effects of films would be the same as those of films from areas chronically affected: interference with reproductive and settling stages. In the case of acute effects, interference would be restricted to a short period of time. However, a sufficient number of acute incidents would have cumulative effects approaching those of the chronic presence of oil.

Furthermore, a spill may have delayed repercussions; oil was found to seep into sand and was re-exposed as sand was cut from the beach (Kolpack, personal communication). Unaltered fuel oil was reported in sediments at Falmouth Bay two months after a spill; its continued presence might substantially delay the repopulation of affected areas (Blumer, Souza and Sass, 1970).

Post-spill survey of the Southern California Channel Islands

Without a previous baseline study, no conclusions about long-range changes in the Channel Islands marine flora and fauna were possible. Comparison of data from this investigation with those of future studies will need to take into account the various temperatures and patterns of water movement in the Channel.

Distribution of species characteristic of the cool waters north of Point Conception coincide with cold-water masses in the northern Channel Islands; for example, the genera Egregia and Cystoseira show morphological characteristics typical of their northern populations (E. menziezii, E. laevigata ssp. borealis, C. osmundacea) in the northern Channel Islands of Santa Rosa and Santa Cruz. In the southern Channel Islands of San Clemente and Santa Catalina, populations of these two genera are characteristically southern (E. laevigata, C. osmundacea ssp. expansa, and C. setchellii). Transitional forms are particularly evident in the zone of temperature changes at the southern end of Santa Cruz Island, the Anacapa Islands and Santa Barbara Island.

It is necessary to explain distribution of algae in terms of ecological factors before one can conclude that their presence or absence is due to materials added to sea water from various effluents.

Discussion of conditions at Arroyo Sequit

Explanation of the relatively high reduction in species variety (measured at a ten-year interval!!) recorded at Arroyo Sequit poses a problem. If this figure (78%; see Table 5) is reasonably accurate, the question becomes: Why this high reduction in variety of marine algae at a beach distant from industrial, agricultural and domestic outfalls? If influx of fresh water as a result of the heavy rains during the winter of 1969 were the direct cause, then comparison of the spring months (richest in variety) of 1969 with spring months of 1970 (Table 16) should show a slight increase because of the smaller amount of rainfall in the winter following the spill. Examination of the table shows that the reverse was observed; there has been a slight decrease in species of plants and animals between June of 1969 and June of 1970. Whether or not this decline is part of a pattern that will later show an upswing can be determined only by continued monitoring of this beach. Finally, it should be noted that this beach has been cited before (Dawson, 1959) as being a beach where sand movements (associated with heavy influx of sediment-laden water) are conspicuously large.

If natural factors do not adequately account for the reduction in variety of algal species recorded at Arroyo Sequit, there exist other possibilities. In addition to southward movement of water from Ventura-Hueneme-Mugu to the area near this beach (this current passes outfalls at these three locations), longshore drift is capable of moving large amounts of potentially contaminated sediments in the same direction. Energy expended by waves in producing longshore drift is impressive; between Point Conception and Los Angeles roughly five million foot-pounds per foot of beach per day drives a conveyor belt of sand south (Bascom, 1964). Measurements at the sandspit of the Santa Barbara Harbor (Bascom, 1964) showed that the spit grew at a rate of 600 cubic yards per day in normal weather as a result of longshore drift.

SUMMARY

A post-oil spill survey of ten rocky intertidal stations in Southern California (Point Conception to Dana Point) was undertaken monthly for a thirteen-month period. Interpretation of the findings of this investigation was complicated by the fact that populations normally show fluctuating composition and density patterns as a response to a variety of factors:

1. Natural disasters, such as epidemics, abnormal amounts of fresh water (the 1969 winter was the rainiest in 20 years), and sand movements can damage intertidal populations; natural factors can produce significant variations in population size and distribution from which variations due to accidents can be distinguished only after detailed records, correlating specific factors with specific responses, are available.

2. Human activities, such as collecting marine organisms, walking on rocks (crushing plants and animals), and clamming, can disturb intertidal populations.

3. Acute doses of oil from the January, 1969, spill resulted in the smothering of discontinuous patches of organisms, particularly in the upper intertidal. Large floral and faunal differences between spring (May and June) stations of 1969 and 1970 were not detected. A number of closely-spaced acute events constitute chronic conditions, depending on recovery time (different for different types of accident).

4. The biological impact of the oil spills was probably mitigated by their occurrence in the winter when the intertidal was relatively dormant.

5. Comparison of the species composition of the Coal Oil Point (active submarine seep) area with such areas as Dana Point and Carpinteria suggests that:

    a. The flora and fauna of Coal Oil Point where oil is chronically present is composed of forms that may be oil tolerant (some of these could be there because they evade the effects of oil) and is composed of relatively few species, but:

    b. The species that can survive the conditions of stress (tolerance or evasion) are there in large numbers.

6. The decline ranges from 28% (Carpinteria State Beach) to 78% (Palm Street, Ventura, and Arroyo Sequit) measured at opposite ends of the decade. It is not known whether this decline is part of a fluctuating pattern that may show a future upswing. The average reduction in variety for the area from Gaviota to Dana Point is 63%. The contribution that the 1969 oil spills made to the decline is unknown.

7. Baseline surveys for distribution of marine invertebrates and algae were established for the Southern California Channel Islands. The mainland surveys provided a detailed seasonal reference for future investigations.

8. While we were unable to compare our observations concerning intertidal invertebrates with the situation ten years earlier, it was possible to establish a seasonal record of populations for future intertidal surveys.

9. It was found that marine algae attached to a rocky substratum were more easily sampled than animals, since there are many creatures that hide when disturbed or live under rocks (sampling these disturbs their habitat).

ACKNOWLEDGMENTS

We are deeply indebted to the Allan Hancock Foundation for its excellent systematic collections and other resources which provided vital reference materials for comparison with the results of this investigation.

We are especially grateful to Dr. Isabella A. Abbott, Hopkins Marine Station of Stanford University, and to Dr. George J. Hollenberg, Professor Emeritus of Redlands University, for their identifications and for their encouragement during the course of the investigation. Dr. Robert Given of the Santa Catalina Marine Biological Laboratory was generous with his help in collecting and identifying organisms in the Channel Islands, and Dr. James H. McLean of the Los Angeles County Museum of Natural History contributed a great deal to the identification of molluscs.

Our gratitude is expressed, too, to Dr. Olga Hartman, Professor Emeritus of the University of Southern California, and to Dr. Michael Neushul of the University of California at Santa Barbara, for their advice and encouragement in preparing this manuscript.

Special thanks are due to Captain Richard Bergeron of the Golden West and to Captain Fred Ziesenhenne of the Velero IV and to their crews. Without their help the Channel Islands survey for this investigation would not have been possible.

The Channel Islands survey would not have been realized without the cooperation of Herbert W. Hunt, Chief, I.& R.M., National Park Service, who granted permission to collect specimens in the Channel Islands National Monument.

Many others deserve special recognition: Joseph de Vita, Robert Kanter, Jack Wintz and Josephine Yudkin, graduate students at the University of Southern California, who assisted in the station surveys on the mainland and in the Channel Islands; Deborah Orwig and Bruce Harger, graduate students at the University of California at Santa Barbara, who worked on the mainland station surveys; and Mary Patterson, graduate student at the University of Southern California, who, with Robert Setzer, Allan Hancock Foundation Herbarium Assistant Curator, helped in the preparation of charts and tables. David Drake and Larry Doyle of the USC Department of Geology prepared the survey data for the station areas investigated in this study.

REFERENCES

Allan Hancock Foundation, University of Southern California

1959 Oceanographic survey of the continental shelf area of Southern California. California State Water Quality Control Board, Publ., 20: 1-560.

1965 An oceanographic and biological survey of the Southern California mainland shelf. California State Water Quality Control Board, Publ., 27: 1-232. Appendix Data: 1-445.

Allen, A. A.

1969a Santa Barbara oil spill. Statement presented to the U.S. Senate Interior Committee, Subcommittee on Minerals, Materials and Fuels, May 20, 1969.

1969b Estimates of surface pollution resulting from submarine oil seeps at Platform A and Coal Oil Point. General Research Corporation, Santa Barbara, Techn. Mem., 1230: 1-43.

Bascom, W. N.
1964 Waves and beaches, the dynamics of the ocean surface. Doubleday, Garden City, N.Y. 267p.

Blumer, Max, G. Souza, and J. Sass
1970 Hydrocarbon pollution of edible shellfish by an oil spill. Marine Biology, 5: 195-202.

Clendenning, K. A.
1964 _In_ An investigation of the effects of discharged wastes on kelp. California State Water Quality Control Board, Publ., 26: 1-124.

Crisp, D. J., and P. S. Meadows
1963 Adsorbed layers: the stimulus to settlement in barnacles. Royal Society of London, Proc., Ser. B, 158: 364-387.

Dawson, E. Y.
1959 Benthic marine vegetation. _In_ Oceanographic survey of the continental shelf area of Southern California. California State Water Quality Control Board, Publ., 20: 219-264.

1965 Intertidal algae. _In_ An oceanographic and biological survey of the Southern California mainland shelf. California State Water Quality Control Board, Publ., 27: 220-227. Appendix Data: 351-438.

Foster, M., M. Neushul, Jr., and R. Zingmark
1969 Final report dealing with the early stages of the Santa Barbara oil spill. Federal Water Pollution Control Administration, Dept. of the Interior. pp. 25-44.

Gaines, T. H.
Pollution control at a major spill. J. Petrol. Techn., [in press].

Grigg, R. W., and R. S. Kiwala
1970 Some ecological effects of discharged wastes on marine life. California Fish and Game, 56: 145-155.

Hampson, G. R., and H. L. Sanders
1969 Local oil spill. Oceanus, 15(2): 8-10.

Hartman, Olga
1963 Submarine canyons of Southern California. Part II. Biology. Allan Hancock Found. Pac. Expeds., 27: 1-407.

1966 Quantitative survey of the benthos of San Pedro Basin, Southern California. Part II. Final results and conclusions. Allan Hancock Found. Pac. Expeds., 19: 186-456.

Hartman, Olga, and J. L. Barnard
1958 The benthic fauna of the deep basins off Southern California. I. Introduction and preliminary report. Allan Hancock Found. Pac. Expeds., 22: 1-67.

1960 The benthic fauna of the deep basins off Southern California. II. Systematics, summaries, and results. Allan Hancock Found. Pac. Expeds., 22: 69-284.

Jones, G. F.
1969 The benthic macrofauna of the mainland shelf of Southern California. Allan Hancock Monogr. Mar. Biol., 4: 1-219.

McLean, J. H.
1969 Marine shells of Southern California. Los Angeles Co. Mus. Nat. Hist., Sci. Ser. 24, Zool. No. 11: 1-104.

Merz, R.
1959 Determination of the quantity of oily substances on beaches and in nearshore waters. California State Water Quality Control Board, Publ., 21: 1-45.

North, W. J.
1967 "Tampico," an experiment in destruction. Sea Frontiers, 13: 212-217.

North, W. J., M. Neushul, Jr., and K. A. Clendenning
1965 Successive biological changes observed in a marine cove exposed to a large spillage of mineral oil. In Comn. Internatl. Explor. Sci. Mer Méditerr., Symp. Pollut. Mar. par Microorgan. Prod. Pétrol., Monaco. pp. 335-354.

Okamura, K., S. Ueda, and Y. Miyake
1926 On the harmful action of deep fog on Porphyra tenera Kjellm. Tokyo, Imp. Fish. Inst., J., 21(6): 67-68 (English abstract).

Smith, J. E.
1968 "Torrey Canyon" pollution and marine life. Ed. by J. E. Smith. Cambridge Univ. Press, Cambridge, Eng. 196p.

Table 1

Location of the Ten Rocky Intertidal Mainland Stations

Station	Station Area	Station Line	Shore Base Point (SBP)	Elevation SBP	Comments
Gaviota State Beach, Santa Barbara County	125 yds W of pier at Gaviota State Park	Over three large rocks that run parallel to pier	Small rocky ledge 3 ft above the sand and about 3-4 ft inshore of the first large rock	5.8 ft	Station line is usually 90 ft long
El Capitan State Beach, Santa Barbara County	Southeastern end of El Capitan State Park	Bears 256^{o} magnetic to the farthest visible headline to the west (Government Point) and bears 76^{o} magnetic to the northwest end of the yellow bluff to the east	3-4 ft boulder 25 ft NNW of the west bank of the creek	9.0 ft	Station line is usually 150 ft long
Coal Oil Pt., Santa Barbara County	1/2 mi W of beach on Del Playa Rd. and Camino Majorca, Isla Vista	Bears 165^{o} magnetic from shore base point seaward in line with the top of a 4 ft rock, 50 ft from cliff	Junction of the cliff with the beach, below the large cement cross	Not known	Station line is usually 340 ft long
East Cabrillo Beach, Santa Barbara County	200 yds E of beach opposite Clark Bird Sanctuary, Santa Barbara	Runs along the top of the second groin (barrier) on this beach	Junction of the barrier and the cliff	Not known	Station line is usually 220 ft long
Carpinteria State Beach, Santa Barbara County	Rocky shelf on east part of Carpinteria State Park	Bears 14^{o} magnetic on the center of the three eucalyptus trees shoreward of railroad tracks	Junction of asphalt and sand, 40 ft E of lifeguard stand	7.0 ft	Station line is usually 500 ft long
Hobson Park Beach, Ventura County	Hobson (Rincon Park No. 4) about 3 mi S of Carpinteria	Seaward extension of a steel fence on western end of property line	Base of green sign which prohibits driving on the beach	8.5 ft	Station line is usually 440 ft long

Table 2

Location of the Subtidal Island Stations

Station Number	Island	Station Area	Date	Collection Method
-	Santa Catalina	Isthmus Cove Catalina Harbor	1969-70	Dive
1	Santa Catalina	White's Landing	11/69	Grab
2	San Clemente	NW Harbor	11/69	Grab
3	San Clemente	Wilson's Cove	11/69	Dive
4	San Nicolas	NE End	11/69	Dive
5	Santa Barbara	Near Old Coast Guard Landing	11/69	Dive
6	Santa Barbara	Largest Rock, NE End	11/69	Dive
7	Anacapa	West End of East Island (southern exposure)	12/69	Dive
8	Santa Cruz	Prisoners Harbor	12/69	Dive
9	Santa Rosa	Corral Point	12/69	Dive
10	Santa Rosa	Between Ford Pt. and East Pt.	12/69	Dive
11	Santa Cruz	Smuggler's Cove	12/69	Dive and Dredge
12	Santa Cruz	Smuggler's Cove	4/70	Dive and Dredge
13	Santa Cruz	Blue Banks Anchorage	4/70	Dive and Dredge

Note: Dive includes both free and SCUBA; Grab indicates orange peel grab; and Dredge indicates biological chain dredge.

Table 3

Occurrence of Oil on the Ten Rocky Intertidal Mainland Stations

Date	Stations									
	Gaviota	El Capitan	Coal Oil Point	East Cabrillo	Carpinteria	Hobson's	Palm St., Ventura	Arroyo Sequit	Corona del Mar	Dana Point
5/69	-	-	-	413	-	34	-	-	-	-
6/69	42	0	24	380	1	8	-	-	-	-
7/69	40	16	49	479	75	30	0	0	8	0
8/69	0	0	88	230	0	0	-	0	22	0
9/69	1	0	35	384	0	0	-	0	11	0
10/69	20	30	96	177	5	0	0	0	21	0
11/69	38	12	41	-	-	0	-	0	-	0
12/69	23	-	195	308	106	670	-	0	-	-
1/70	-	0	8	251	1	291	-	0	2	0
2/70	13	36	59	254	48	6	-	0	6	0
3/70	7	18	44	208	114	1	-	0	4	0
4/70	-	-	-	-	-	-	-	-	-	-
5/70	27	9	43	92	1	0	-	0	11	0
6/70	63	4	28	156	0	0	-	0	24	0
Total	274	125	710	3332	351	1040	0	0	109	0
Average	25	11	59	277	32	80	0	0	12	0

Note:

Table indicates number of times oil was observed at three-inch intervals along transect; dashes (-) indicate no oil data available.

Table 4

Percentage of Oil Observations (at every three inches) Below and Above the Highest Sessile Organism at the Ten Rocky Intertidal Mainland Stations

	% Fresh Oil on Water		% All Fresh Oil		% All Oil	
	Above	Below	Above	Below	Above	Below
Gaviota	0	0	9	91	26	74
El Capitan	0	0	51	49	76	24
Coal Oil Point	0	100	52	48	52	48
East Cabrillo	0	0	0	0	68	32
Carpinteria	0	100	2	98	15	85
Hobson Beach	0	100	17	83	18	82
Palm St., Ventura	No Oil Recorded on Beach					
Arroyo Sequit	No Oil Recorded on Beach					
Corona del Mar	0	0	0	100	20	80
North Dana Pt.	No Oil Recorded on Beach					
All ten beaches	0	100	18	82	52	48

Table 5

Number of Marine Plants Recorded on the Rocky Intertidal Mainland Stations During This Study Compared to Previous Investigations in Comparable Months

Study, Year	Gaviota	El Capitan	Carpinteria	Hobson	Palm St., Ventura	Arroyo Sequit	Corona del Mar	North Dana Pt.
	Stations							
Dawson, 1956[1]	42(Dec.)				20(Dec.)	41(Nov.)	30(Dec.)	
Dawson, 1957[1]	22(Aug.)		36(Jan.)	24(Dec.)	14(July)		26(Nov.)	25(Feb.)
	22(Oct.)		36(Sept.)					
Dawson, 1958[1]		19(Jan.)				23(Feb.)		37(Nov.)
		30(Dec.)						
Dawson, 1959[1]	25(Jan.)			28(Jan.)	21(Feb.)			
Average 1956-59[2]	28	25	36	26	18	32	28	31
Neushul, 1967[3]	13(Nov.)	20(Dec.)	29(Nov.)	13(Dec.)	17(Dec.)	14(Dec.)		
AHF, 1969[4]	6(Aug.)	8(Dec.)	25(Sept.)	7(Dec.)	4(July)	11(Nov.)	13(Nov.)	14(Nov.)
	18(Oct.)				4(Oct.)			
AHF, 1970[4]	16(Dec.)							
	11(Jan.)	6(Jan.)	27(Jan.)	7(Mar.)	5(July)	2(Feb.)	5(Jan.)	14(Feb.)
Average 1969-70[2]	13	7	26	7	4	7	9	14
% decrease[5] 1969-70 vs 1956-59	54	72	28	73	78	78	68	55

[1] Modified data from Table 17
[2] Total number divided by number of surveys
[3] Personal communication
[4] Modified data from Table 18
[5] $= \frac{\text{average ('69-'70)} - \text{average ('56-'59)}}{\text{average '56-'59}} 100$

Table 6

Marine Plants not Recorded during this Study (All Surveys) but Recorded by E. Y. Dawson, 1956-1959 (All Surveys) at the Following Rocky Intertidal Mainland Stations: 13, Gaviota; 40, El Capitan; 15, Carpinteria; 35, Hobson; 12, Palm St., Ventura; 4, Arroyo Sequit; 9, Corona del Mar; and 22, North Dana Pt..*

	13	40	15	35	12	4	9	22
ANGIOSPERMAE								
Phyllospadix sp.					X	X	X	
CHLOROPHYTA								
Bryopsis sp.					X			
Chaetomorpha sp.					X			
Cladophora sp.	X	X			X	X		
Codium fragile								X
PHAEOPHYTA								
Cystoseira sp.						X	X	X
Dictyopteris zonarioides							X	
Dictyota flabellata				X			X	
Ectocarpus sp.	X				X			
Egregia laevigata					X			
Halidrys dioica		X		X				
Hapterophycus canaliculatus							X	
Hesperophycus harveyanus							X	
Leathesia nana			X					
Macrocystis pyrifera				X			X	
Pachydictyon coriaceum						X		
Pelvetia fastigiata						X	X	
Petrospongium rugosum			X				X	
Phaeostrophion australe							X	
Sargassum agardhianum							X	
Scytosiphon lomentaria							X	
Zonaria farlowii						X	X	
	13	40	15	35	12	4	9	22
RHODOPHYTA								
Acrosorium uncinatum	X	X			X		X	
Agardhiella tenera					X	X		
Anisocladella pacifica			X					
Bossiella sp.	X					X	X	
Botryoglossum farlowianum					X			
Callophyllis sp.		X						
Centroceras clavulatum	X				X			
Ceramium sp.					X			
Chondria sp.	X	X		X	X			
Corallina sp.					X			
Cryptonemia obovata	X							
Cryptopleura sp.					X	X		
Erythrocystis saccata			X					
Gastroclonium coulteri	X							
Gelidium coulteri					X			

* Dawson did not survey Coal Oil Pt and East Cabrillo Beach.

Table 6 (cont.)

	13	40	15	35	12	4	9	22
Gelidium crinale	X	X						
Gelidium pulchrum and G. purpurascens		X				X	X	
Gelidium robustum				X		X	X	
Gigartina harveyana	X							
Gigartina leptorhynchos					X			
Gigartina volans	X		X		X			
Gracilaria sp.					X	X		
Gracilariophila oryzoides		X	X		X			
Gracilariopsis sp.		X						
Gymnogongrus leptophyllus		X			X	X		
Iridaea sp.	X							
Laurencia sp.				X		X		
Lithothrix sp.				X		X		
Lophosiphonia sp.	X					X		X
Melobesia sp.							X	
Myriogramme sp.					X			
Nienburgia sp.	X	X		X				
Phycodrys setchelli	X		X					
Pleonosporium dasyoides	X	X						
Plocamium sp.		X			X		X	
Pogonophorella californica			X					
Polyneura latissima			X					
Polysiphonia sp.					X			
Prionitis sp.		X				X		X
Pseudogloiophloea confusa	X					X		
Pterocladia pyramidale						X		
Pterosiphonia baileyi						X		
Pterosiphonia dendroidea					X			
Rhodoglossum affine	X							
Rhodoglossum roseum	X							
Rhodymenia sp.		X					X	
Rhodosiphonia californica				X				
Schizymenia sp.			X			X		
Smithora naiadum							X	
Spermothamnion synderae				X				
Stenogramme interrupta					X			
Total number of marine plants not recorded during the 1969-70 study (all surveys) but recorded by Dawson, 1956-59	19	15	10	10	25	21	21	4
Total number of marine plants recorded by Dawson, 1956-59 (all surveys)	50	34	48	34	31	44	38	45
Percentage of marine plants not recorded during the 1969-70 study (all surveys) but recorded by Dawson, 1956-59 (all surveys)	38	44	21	29	81	48	55	9

Table 7

Marine Plants not Recorded during this Survey at any of the Eight Re-occupied Dawson Stations but Recorded on at Least One Station by Dawson, 1956-1959.

CHLOROPHYTA
- Cladophora sp.
- Codium fragile

PHAEOPHYTA
- Hapterophycus harveyanus
- Leathesia nana
- Phaeostriphon australe

RHODOPHYTA
- Callophyllis sp.
- Cryptonemia obovata
- Myriogramme sp.
- Phycodrys setchelli
- Pleonosporium dasyoides
- Pogonophorella californica
- Polyneura latissima
- Rhodoglossum roseum
- Rhodosiphonia californica
- Schizymenia sp.

Table 8

Marine Plants Recorded at Coal Oil Point, 1969-1970.

ANGIOSPERMAE
- Phyllospadix spp.

CHLOROPHYTA
- Bryopsis hypnoides
- Chaetomorpha aerea
- Enteromorpha spp.
- Ulva spp.

PHAEOPHYTA
- Ectocarpus spp.
- Egregia laevigata
- Endarachne binghamiae
- Pelvetia fastigiata
- Ralfsia spp.
- Scytosiphon lomentaria

RHODOPHYTA
- Agardhiella tenera
- Anisocladella pacifica
- Bangia fuscopurpurea
- Bossiella spp.
- Botryoglossum farlowianum
- Centroceras clavulatum
- Ceramium spp.
- Chondria nidifica
- Chondria pacifica
- Corallina vancouveriensis
- Cryptopleura spp.
- Gastroclonium coulteri
- Gelidium coulteri
- Gelidium crinale
- Gelidium purpurascens
- Gigartina canaliculata
- Gigartina leptophynchos

(cont.)
- Gigartina spinosa-armata complex
- Gracilariopsis spp.
- Gymnogongrus spp.
- Iridaea spp.
- Laurencia pacifica
- Laurencia spectabilis
- Lithothamnion spp.
- Lithothrix spp.
- Melobesia spp.
- Microcladia coulteri
- Plocamium coccineum var pacificum
- Polysiphonia spp.
- Porphyra perforata
- Pterocladia pyramidale
- Pterosiphonia baileyi
- Pterosiphonia dendroidea
- Rhodoglossum affine
- Rhodoglossum americanum
- Rhodymenia spp.
- Smithora naiadum
- Spermothamnion snyderae
- Stenogramme interrupta

CHRYSOPHYTA
- Diatoms

Table 9

Plant Taxa in which the Species were Counted as a Single Entity for the Purpose of Comparison to previous Studies. These Groups Contain Species that are Difficult to Differentiate in the Field.

ANGIOSPERMAE
- Phyllospadix

CHLOROPHYTA
- Bryopsis
- Cladophora
- Enteromorpha
- Ulva

PHAEOPHYTA
- Ectocarpus, Giffordia and Feldmannia
- Laminaria

RHODOPHYTA
- Bossiella
- Calliarthron
- Callophyllis
- Ceramium
- Chondria
- Corallina
- Cryptopleura
- Gelidium pulchrum and G. purpurascens
- Gigartina eatoniana and G. spinosa-armata (complex)
- Gigartina serrata and G. canaliculata
- Gracilaria
- Gracilariopsis
- Grateloupia
- Herposiphonia
- Iridaea
- Lithothamnion and Lithophyllum
- Lophosiphonia

(cont.)
- Melobesia
- Plocamium
- Polysiphonia
- Porphyra
- Prionitis
- Rhodymenia

OTHERS

Cyanophyta (blue-greens) not counted or used for comparison.
Grazed or turf alga not counted or used for comparison.

Table 10

Presence of Discolored or Bleached Marine Plants Recorded by Month and Station, 1969-1970

Species	Station: Gaviota	El Capitan	Coal Oil Point	East Cabrillo	Carpinteria	Hobson	Palm St.	Arroyo Sequit	Corona del Mar	North Dana Pt.
Ceramium spp.					2/70					
Corallina vancouveriensis			11/69, 1/70 2/70, 5/70		1/70, 2/70, 3/70				11/69, 1/70, 2/70, 3/70	10/69, 11/69, 1/70, 2/70, 3/70
Enteromorpha spp.	5/70				2/70			8/69		
Egregia laevigata			2/70							
Gigartina canaliculata		11/69	8/69, 2/70		7/69, 9/69 10/69, 2/70			11/69, 12/69		2/70
Gigartina leptorhynchos				2/70	2/70			10/69, 11/69, 12/69		
Gracilariopsis spp.			9/69, 11/69,		3/70					
Laurencia pacifica			2/70							11/69, 1/70 2/70
Phyllospadix spp.		6/69	2/70, 3/70 5/70		7/69, 11/69, 1/70, 3/70	8/69				
Pterocladia pyramidale										1/70, 2/70
Porphyra perforata					5/70					1/70, 2/70
Ulva spp.			11/69, 2/70		7/69, 2/70 6/70	7/69, 11/69		11/69		8/69

Table 11

Summary of Factors Affecting Mainland Stations

	Station									
Factor	Gaviota	El Capitan	Coal Oil Pt.	East Cabrillo	Carpinteria	Hobson	Palm St. Ventura	Arroyo Sequit	Corona del Mar	North Dana Pt.
Jan. 1969 oil spill (Allen, 1969a)	Moderate amounts	Moderate amounts	Moderate amounts	Heavy amounts	Heavy amounts	Heavy amounts	Moderate amounts	None	None	None
Dec. 1969 oil spill	-------	-------	-------	-------	Moderate amounts	Moderate amounts	-------	----	----	-----
natural oil seeps	Nearly	Nearby	Nearby; active	-------	Nearby; active	--------	-------	-----	----	-----
substratum	Large rocks	Large rocks	shelf and sand	metal groin	shelf and sand	rocks	rocks	rocks	shelf	rocks
sand movement	Little	Little	Moderate	Little	Moderate	Moderate	Heavy, station covered 69-70	Heavy, station covered 2 months	Moderate	Moderate
Usage	Public camping	Public camping	Public collecting, surfing	Public swimming	Public collecting, camping	Public clamming, camping	Public surfing	Public camping, surfing	Public collecting, swimming	Private surfing, swimming
Industrial effluents	-------	-------	----------	--------	----------	--------	possible large amounts	possible large amounts	possibly affected by Newport Harbor water	--------
Agricultural effluents	-------	-------	----------	--------	possible moderate amounts	--------	possible large amounts	-------	----------	--------
Nearest sewage outfall	-------	-------	----------	Santa Barbara	--------	Mussel Shoals ?	Ventura	Point Mugu	Laguna	South Laguna, Dana Pt.
Fresh water	Small creek	Small creek	----------	-------	Nearby creeks, town flooded winter, 1969	-------	Heavy, Ventura River	Heavy, large creek	------	--------

Table 12

Marine plants recorded by E.Y. Dawson on mainland stations, 1956-1959.

● voucher specimens, Allan Hancock Herbarium.
▲ published field notes only, State Water Quality Control Board, Publ. 27, 1965a.
□ dive station.

Station #	Location	Date
29	Gov't. Pt.	5/57
	Gov't. Pt.	11/57
13	Gaviota	12/58
	Gaviota	8/57
	Gaviota	10/57
	Gaviota	1/59
20	Arroyo Hondo	2/57
	Arroyo Hondo	6/58
	Arroyo Hondo	9/58
	Arroyo Hondo	12/58
41	Rufugio	1/58
	Rufugio	11/58
40	El Capitan	1/58
	El Capitan	12/58
28	Goleta Pt.	4/57
	Goleta Pt.□	10/57
	Goleta Pt.	2/58
27	S. Barbara Pt.	4/57
	S. Barbara Pt.	10/57
	S. Barbara Pt.	1/58
30	Montecito	12/57
	Montecito	8/58
	Montecito	2/58
36	Loon Pt.	12/57
	Loon Pt.	2/59
15	Carpinteria	1/57
	Carpinteria	9/57
9	Rincon del Mar	12/57
	Rincon del Mar	1/59
5	Mussel Shoals	11/56
	Mussel Shoals	10/57
	Mussel Shoals	1/59
35	Hobsons	12/57
	Hobsons	1/59
32	Pitas Pt.	11/57
	Pitas Pt.	2/58
6	2 mi. W. Vent.	11/56
	2 mi. W. Vent.	1/59
12	Palm St.	12/56
	Palm St.	7/57
	Palm St.	2/59
14	Port Hueneme	12/56
	Port Hueneme	8/57
31	Pt. Mugu	10/57
	Pt. Mugu	1/58
37	Bass Rock	12/57
	Bass Rock	2/59
3	Yerba Buena	11/56
	Yerba Buena	5/58
	Yerba Buena	2/59
4	Arroyo Sequit	11/56
	Arroyo Sequit	2/58
26	Lechuza Pt.	3/57
	Lechuza Pt.	7/57
	Lechuza Pt.	11/58
11	Pt. Dume Bay	12/56
	Pt. Dume Bay	5/57
	Pt. Dume Bay	2/59
19	Latigo Rd.	2/57
	Latigo Rd.	7/57
	Latigo Rd.	5/58
34	Malibu Rd.	12/57
	Malibu Rd.	3/58
18	Malibu Beach	1/57
	Malibu Beach	11/57
	Malibu Beach	5/58
10	B. Rock Beach	12/56
	B. Rock Beach	5/57
2	Topanga Rd.	11/56
	Topanga Rd.	4/57
	Topanga Rd.	1/58
1	Sunset Beach	11/56
	Sunset Beach	5/57
	Sunset Beach	2/58
7	Flat Rock Pt.	11/56
	Flat Rock Pt.□	6/57
25	Lunada Bay	3/57
	Lunada Bay	6/57
	Lunada Bay	10/57
39	Portuguese Pt.	11/57
17	Whites Pt.	1/57
	Whites Pt.	6/57
16	Pt. Fermin	1/57
	Pt. Fermin	10/57
9	Corona	12/56
	Corona	11/57
42	Crystal Cove	1/58
21	Laguna Beach	2/57
	Laguna Beach	11/57
22	N. Dana Pt.	2/57
	N. Dana Pt.	11/58
24	C. Pendleton	2/57
30	Scripps Reef	6/57
8	Neptune Pl.	12/56
	Neptune Pl.□	6/57
	Neptune Pl.	2/58
23	Bird Rock	2/57
	Bird Rock	11/57
10	Scripps Reef	2/58
	Scripps Reef	11/58

MARINE PLANTS

ANGIOSPERMAE
- Phyllospadix scouleri
- P. torreyi

CHLOROPHYTA
- Bryopsis corticulans
- B. hypnoides
- Chaetomorpha aerea
- C. torta
- Cladophora spp.
- C. graminea
- C. hemisphaerica
- C. microcladioides
- C. trichotoma
- Cladophoropsis fasciculatus
- Codium fragile
- C. setchellii
- Enteromorpha spp.
- E. compressa
- E. crinita
- E. intestinalis
- E. minima (Blidingia minima)
- Ulva spp.
- U. angusta + U. taeniata
- U. californica
- U. crinita
- U. lactuca
- U. linza (Enteromorpha linza)
- U. lobata
- U. rigida

PHAEOPHYTA
- Colpodesme rigida
- Colpomenia sinuosa
- Cystoseira osmundacea
- C. setchellii
- Desmarestia herbacea
- D. latifrons
- Dictyopteris zonarioides
- Dictyota flabellata
- Ectocarpus spp.
- E. mucronatus
- Eisenia arborea
- Egregia laevigata
- Endarachne binghamiae
- Feldmannia spp.
- Fucus distichus spp. edentatus
- Giffordia spp.
- G. granulosa
- G. mitchellae
- Halidrys dioica
- Haplogloia andersonii
- Hapterophycus canaliculatus
- Hesperophycus harveyanus
- Laminaria farlowii
- L. sinclairii
- Leathesia difformis
- L. nana
- Macrocystis pyrifera
- Pachydictyon coriaceum
- Pelvetia fastigiata
- Petalonia debilis
- Petrospongium rugosum
- Phaeostrophion australe
- Ralfsia spp.
- Sargassum agardhianum
- Scytosiphon lomentaria
- Soranthera ulvoidea
- Taonia lennebackerae
- Zonaria farlowii

RHODOPHYTA
- Achrochaetium spp.
- A. daviesii
- Acrosorium uncinatum
- Agardhiella tenera
- Ahnfeltia gigartinoides
- A. plicata

Amphiroa zonata
Amplisiphonia pacifica
Anisocladella pacifica
Antithamnion pygmaeum
Bangia fuscopurpurea
Bossiella spp.
B. cooperi
B. dichotoma v. gardneri
B. insularis
B. lingulata
B. orbigniana
B. plumosa
B. sagittata
Botryoglossum farlowianum
Calliarthron spp.
Callithamnion pikeanum
Callophyllis obtusifolia
C. violacea
Centroceras clavulatum
Ceramium spp.
C. eatonianum
C. californicum
C. pacificum
Chondria californica
C. cornuta
C. decipiens
C. nidifica
C. pacifica
Coeloseira compressa
C. parva
Corallina spp.
C. gracilis
C. officinalis v. chilensis
C. pinnatifolia
C. polysticha
C. vancouveriensis
Cruoriella dubyi
Cryptonemia obovata
Cryptopleura spp.
C. corallinara
C. crispa
C. lobulifera
C. violacea
Cryptosiphonia woodii
Cumagloia andersonii
Dermatolithon ascripticium
D. dispar
Endocladia muricata
Erythrocystis saccata
Farlowia crassa (F. mollis)
Gastroclonium coulteri
Gelidium spp.
G. coulteri
G. crinale
G. densum
G. pulchrum
G. purpurascens
G. pusillum
G. ramuliferum
G. robustum
Gigartina spp.
G. asperifolia
G. canaliculata
G. corymbifera
G. eatoniana
G. harveyana
G. leptorhynchos
G. papillata
G. serrata
G. spinosa-armata complex
G. volans
Gloiosiphonia californica
G. verticillata
Gracilaria spp.
G. cunninghamii
G. verrucosa
Gracilariophila oryzoides
Gracilariopsis spp.
G. andersonii
G. sjoestedtii
Grateloupia spp.
G. abbreviata
G. doryphora (schizophylla)
G. howei
G. prolongata
G. setchellii
Gymnogongrus spp.
G. leptophyllus
G. linearis
G. platyphyllus
Herposiphonia secunda
H. subdisticha
H. verticillata
Hildenbrandia sp.
Hymenena spp.

Species
[illegible] spp.
Iridaea spp.
I. agardhianum
I. flaccidum
I. heterocarpum
I. lineare
I. reediae
I. splendens
Jania spp.
J. natalensis
J. tenella
Jaczewskia gardneri
Laurencia spp.
L. diegoensis
L. lajolla
L. pacifica
L. spectabilis
L. splendens
L. subopposita
Leptocladia binghamiae
Lithophyllum decipiens
Lithothamnion spp.
L. californicum
Lithothrix aspergillum
Lophosiphonia obscura
L. reptabunda
L. scopulorum
L. villum
Melobesia marginata
M. mediocris
Microcladia coulteri
Myriogramme spectabilis
Nienburgia andersoniana
Nemalion helminthoides
Ozophora clevelandii
Petrocelis franciscana
Petroglossum parvum
Phycodrys setchellii
Pleonosporium dasyoides
Plocamium coccineum v. pacificum
Plocamium violaceum
Pogonophorella californica
Polycoryne gardneri
Polyneura latissima
Polyopes bushiae
Polysiphonia spp.
P. collinsii
P. hendryi
P. inconspicua
P. pacifica
P. paniculata
P. simplex
P. snyderae
Porphyra lanceolata
P. perforata + P. thuretii
Prionitis spp.
P. andersoniana
P. cornea
P. lanceolata
P. linearis
Pseudogloiophloea confusa
Pterochondria woodii
Pterocladia complanata
P. parva
P. pyramidale
Pterosiphonia baileyi
P. dendroidea
Ptilota filicina
Rhodoglossum affine
R. americanum
R. coriaceum
R. linguiforme
R. lingulata
R. roseum
Rhodomela larix
Rhodosiphonia californica
Rhodymenia spp.
R. californica
R. lobulifera
R. pacifica
R. palmettiformis
R. rhizoides
Schizymenia spp.
S. navicula
S. pacifica
Smithora naiadum
Spermothamnion snyderae
Stenogramme interrupta
Stromatocarpus gardneri
OTHERS
Diatoms
Grazed or Turf Algae
Gigartina californica
Rhodoglossum sp.
CYANOPHYTA (blue-greens)
Griffithsia sp. ?

Table 13

Marine animals reported at mainland stations, 1969-1970.

▲ Station line was covered by sand, all data is from first rocky area west, 50 yards.

STATION #	Location	DATE	Total
13	Gaviota	6/69	13
13	Gaviota	7/69	10
13	Gaviota	8/69	11
13	Gaviota	9/69	13
13	Gaviota	10/69	8
13	Gaviota	11/69	7
13	Gaviota	12/69	8
13	Gaviota	1/70	8
13	Gaviota	2/70	7
13	Gaviota	3/70	8
13	Gaviota	5/70	8
13	Gaviota	6/70	11
40	El Capitan	6/69	11
40	El Capitan	7/69	11
40	El Capitan	8/69	11
40	El Capitan	9/69	10
40	El Capitan	10/69	9
40	El Capitan	11/69	7
40	El Capitan	12/69	7
40	El Capitan	1/70	5
40	El Capitan	2/70	6
40	El Capitan	3/70	11
40	El Capitan	5/70	8
40	El Capitan	6/70	13
NSI	Coal Oil Pt.	6/69	14
NSI	Coal Oil Pt.	7/69	13
NSI	Coal Oil Pt.	8/69	7
NSI	Coal Oil Pt.	9/69	16
NSI	Coal Oil Pt.	10/69	9
NSI	Coal Oil Pt.	11/69	10
NSI	Coal Oil Pt.	12/69	14
NSI	Coal Oil Pt.	1/70	14
NSI	Coal Oil Pt.	2/70	8
NSI	Coal Oil Pt.	3/70	12
NSI	Coal Oil Pt.	5/70	10
NSI	Coal Oil Pt.	6/70	12
NCI	East Cabrillo	5/69	10
NCI	East Cabrillo	5/69	12
NCI	East Cabrillo	6/69	11
NCI	East Cabrillo	7/69	10
NCI	East Cabrillo	8/69	10
NCI	East Cabrillo	9/69	12
NCI	East Cabrillo	10/69	9
NCI	East Cabrillo	11/69	11
NCI	East Cabrillo	12/69	11
NCI	East Cabrillo	1/70	12
NCI	East Cabrillo	2/70	12
NCI	East Cabrillo	3/70	8
NCI	East Cabrillo	5/70	13
NCI	East Cabrillo	6/70	12
15	Carpinteria	7/69	10
15	Carpinteria	7/69	16
15	Carpinteria	8/69	17
15	Carpinteria	9/69	25
15	Carpinteria	10/69	22
15	Carpinteria	12/69	15
15	Carpinteria	1/70	15
15	Carpinteria	2/70	17
15	Carpinteria	3/70	18
15	Carpinteria	5/70	16
15	Carpinteria	6/70	16
35	Hobson	5/69	13
35	Hobson	7/69	20
35	Hobson	7/69	24
35	Hobson	8/69	18
35	Hobson	9/69	15
35	Hobson	10/69	11
35	Hobson	11/69	11
35	Hobson	12/69	10
35	Hobson	1/70	6
35	Hobson	2/70	6
35	Hobson	3/70	9
35	Hobson	5/70	14
35	Hobson	6/70	10
12	▲ Palm St., Vent.	7/69	3
12	▲ Palm St., Vent.	7/69	2
12	▲ Palm St., Vent.	10/69	2
12	▲ Palm St., Vent.	7/70	2
4	Arroyo Sequit	7/69	6
4	Arroyo Sequit	8/69	13
4	Arroyo Sequit	9/69	11
4	Arroyo Sequit	10/69	10
4	Arroyo Sequit	11/69	10
4	Arroyo Sequit	12/69	8
4	Arroyo Sequit	1/70	1
4	Arroyo Sequit	2/70	0
4	Arroyo Sequit	3/70	1
4	Arroyo Sequit	5/70	3
4	Arroyo Sequit	6/70	5
9	Corona del Mar	7/69	15
9	Corona del Mar	7/69	14
9	Corona del Mar	8/69	14
9	Corona del Mar	9/69	18
9	Corona del Mar	10/69	12
9	Corona del Mar	11/69	15
9	Corona del Mar	1/70	10
9	Corona del Mar	2/70	14
9	Corona del Mar	3/70	14
9	Corona del Mar	5/70	17
9	Corona del Mar	6/70	20
22	N. Dana Pt.	7/69	20
22	N. Dana Pt.	8/69	18
22	N. Dana Pt.	8/69	11
22	N. Dana Pt.	9/69	18
22	N. Dana Pt.	10/69	13
22	N. Dana Pt.	11/69	13
22	N. Dana Pt.	1/70	13
22	N. Dana Pt.	2/70	12
22	N. Dana Pt.	3/70	15
22	N. Dana Pt.	5/70	22
22	N. Dana Pt.	6/70	16

MARINE ANIMALS

PORIFERA
- sponge

CNIDARIA
- Anthopleura spp.
- hydroid

NEMERTINA
- nemerteans

BRYOZOA
- bryozoans

MOLLUSCA
- Acanthina spp.
- Anisodoris nobilis
- Aplysia californica
- chiton
- Collisella (Acmaea) spp.
- Crepidula norrisiarum
- Fissurella volcano
- Flabellina iodinea
- Hermissenda crassicornis
- Lacuna unifasciata
- Lassea subviridis
- Littorina sp.
- Lottia gigantea
- Mitrella spp.
- Mytilus californianus
- Norrisia norrisi
- Notoacmea fenestrata
- Notoacmea insessa
- Notoacmea paleacea
- Ocenebra spp.
- Octopus bimaculatus
- Olivella biplicata
- Penitella penita
- Protothaca staminea
- Pseudochama exogyra
- Serpulorbis squamigerus
- Septifer bifurcatus
- Tegula spp.
- Thais emarginata

POLYCHAETA
- Ophiodromus (Podarke) pugettensis
- Phragmatopoma californica
- Nereis vexillosa
- serpulid

ARTHROPODA
- Balanus glandula
- Balanus tintinnabulum
- Cancer spp.
- Chthamalus fissus
- Emerita analoga
- Hemigrapsus nudus
- Ligia occidentalis
- Orchestoidea spp.
- Pachygrapsus crassipes
- Pagurus spp.
- Petrolisthes cinctipes
- Pollicipes polymerus
- Pugettia producta
- Tetraclita squamosa

ECHINODERMATA
- Astrometis sertulifera
- Patiria miniata
- Pisaster ochraceus
- Strongylocentrotus franciscanus
- S. purpuratus

CHORDATA
- Colonial tunicate
- Nestling tunicate
- Styela montereyensis

Table 14

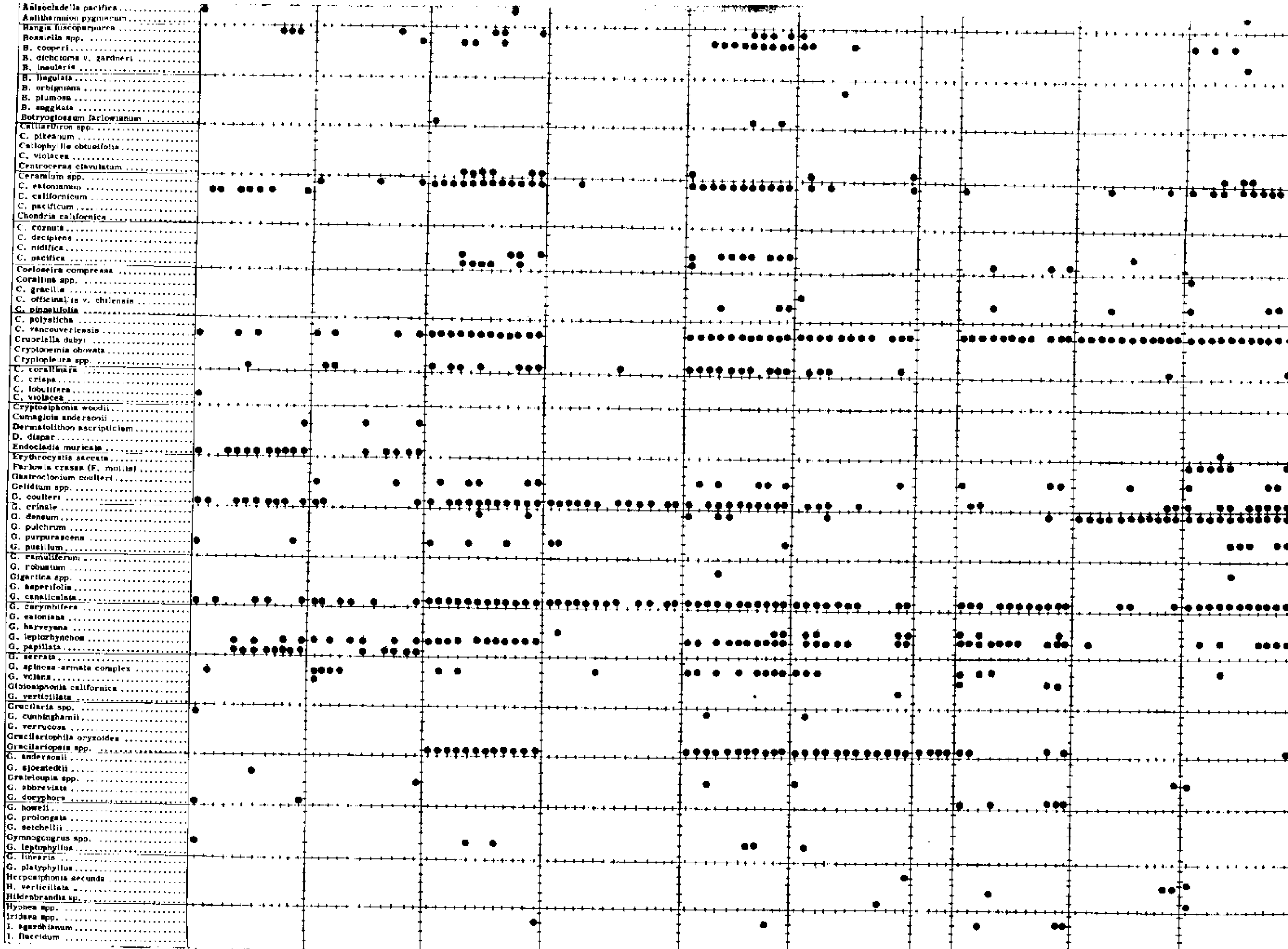
Marine plants reported at mainland stations, 1969-1970.

▲ Station line was covered by sand, all data is from first rocky area west, 50 yards.

Survey dates by station (station # in parentheses):
Gaviota (13): 6/69, 7/69, 8/69, 9/69, 10/69, 11/69, 12/69, 1/70, 2/70, 3/70, 5/70, 6/70
El Capitan (40): 6/69, 7/69, 8/69, 9/69, 11/69, 12/69, 1/70, 2/70, 3/70, 5/70, 6/70
Coal Oil Pt. (NS1): 6/69, 7/69, 8/69, 9/69, 10/69, 11/69, 12/69, 1/70, 2/70, 3/70, 5/70, 6/70
East Cabrillo (NC1): 5/69, 6/69, 6/69, 7/69, 8/69, 9/69, 10/69, 11/69, 12/69, 1/70, 2/70, 3/70, 5/70, 6/70
Carpinteria (15): 7/69, 7/69, 8/69, 9/69, 10/69, 12/69, 1/70, 2/70, 3/70, 5/70, 6/70
Hobson (35): 5/69, 7/69, 8/69, 9/69, 10/69, 11/69, 12/69, 1/70, 2/70, 3/70, 5/70, 6/70
▲Palm St., Vent. (12): 7/69, 7/69, 10/69, 7/70
Arroyo Sequit (4): 7/69, 8/69, 8/69, 9/69, 10/69, 11/69, 12/69, 1/70, 2/70, 3/70, 5/70, 6/70
Corona del Mar (0): 7/69, 7/69, 8/69, 9/69, 10/69, 11/69, 1/70, 2/70, 3/70, 5/70, 6/70
N. Dana Pt. (32): 7/69, 8/69, 8/69, 9/69, 10/69, 11/69, 1/70, 2/70, 3/70, 5/70, 6/70

Dates at which each plant was recorded (● on the chart); "(1st)"/"(2nd)" distinguishes repeated date columns:

MARINE PLANTS	Gaviota (13)	El Capitan (40)	Coal Oil Pt. (NS1)	East Cabrillo (NC1)	Carpinteria (15)	Hobson (35)	▲Palm St., Vent. (12)	Arroyo Sequit (4)	Corona del Mar (0)	N. Dana Pt. (32)
ANGIOSPERMAE										
Phyllospadix spp.	6/69, 7/69	6/69, 9/69, 6/70	all dates		all dates	7/69				7/69, 8/69 (2nd), 9/69, 1/70, 3/70, 5/70, 6/70
CHLOROPHYTA										
Bryopsis corticulans										
B. hypnoides	10/69, 1/70		9/69							
Chaetomorpha aerea	10/69, 6/70	11/69, 3/70	2/70	11/69		11/69		8/69 (1st), 9/69, 11/69		
C. torta										
Cladophora spp.										
C. graminea										
C. hemisphaerica										
C. microcladioides										
C. trichotoma										
Cladophoropsis fasciculatus										
Codium fragile										
C. setchellii										
Enteromorpha spp.	8/69, 9/69, 10/69, 11/69, 12/69, 1/70, 2/70, 3/70, 5/70, 6/70	6/69, 7/69, 8/69, 9/69, 11/69, 3/70, 5/70	6/69, 8/69, 9/69, 10/69, 11/69, 12/69, 1/70, 2/70, 3/70, 5/70, 6/70	all dates	all dates	5/69, 7/69, 8/69, 9/69, 10/69, 11/69, 1/70, 2/70, 3/70, 5/70, 6/70	all dates	7/69, 8/69, 8/69, 9/69, 10/69, 11/69, 12/69, 3/70, 5/70, 6/70	11/69	8/69, 8/69, 6/70
E. compressa										
E. crinita										
E. intestinalis										
E. minima (Blidingia minima)										
Ulva spp.	all dates	all dates	all dates	all dates	all dates	5/69, 7/69, 8/69, 9/69, 11/69, 1/70, 2/70, 3/70, 5/70, 6/70	all dates	7/69, 8/69, 8/69, 9/69, 10/69, 11/69, 12/69, 3/70, 5/70, 6/70	5/70, 6/70	7/69, 8/69, 8/69, 9/69, 10/69, 1/70, 2/70, 3/70, 5/70, 6/70
U. angusta + U. taeniata						9/69, 10/69				
U. californica										
U. crinita										
U. lactuca										
U. linza (Enteromorpha linza)										
U. lobata										
U. rigida										
PHAEOPHYTA										
Coilodesme rigida										7/69
Colpomenia sinuosa				7/69, 12/69					5/70, 6/70	7/69, 10/69, 5/70, 6/70
Cystoseira osmundacea					3/70					
C. setchellii										
Desmarestia herbacea										
D. latifrons										
Dictyopteris zonarioides										3/70
Dictyota flabellata										7/69, 3/70, 6/70
Ectocarpus spp.			7/69, 8/69, 12/69	6/70				7/69, 8/69, 8/69, 9/69, 10/69, 11/69, 12/69, 5/70, 6/70		7/69, 10/69, 11/69
E. mucronatus										
Eisenia arborea									9/69, 5/70, 6/70	6/70
Egregia laevigata	6/69, 7/69, 10/69, 6/70	6/69, 6/70	7/69, 8/69, 9/69, 10/69, 11/69, 2/70, 3/70, 5/70, 6/70	7/69, 6/70	all dates	5/69, 7/69, 8/69, 9/69, 10/69, 11/69, 12/69, 1/70, 5/70, 6/70		7/69, 8/69 (2nd), 12/69, 1/70, 2/70, 3/70, 5/70, 6/70	5/70, 6/70	all dates
Endarachne binghamiae	10/69, 11/69, 12/69, 1/70, 2/70, 5/70	11/69, 6/70	11/69, 12/69, 1/70, 2/70, 3/70	2/70	1/70, 2/70, 3/70	8/69		11/69, 12/69		7/69, 8/69 (2nd), 9/69, 10/69, 5/70, 6/70
Feldmannia spp.				12/69					11/69	
Fucus distichus ssp. edentatus										
Giffordia spp.										
G. granulosa										
G. mitchelliae										
Halidrys dioica										
Haplogloia andersonii										
Hapterophycus canaliculatus										
Hesperophycus harveyanus										8/69 (2nd)
Laminaria farlowii										
L. sinclairii	6/69, 7/69	7/69, 9/69, 11/69			7/69 (2nd)	8/69		8/69 (1st)		
Leathesia difformis										
L. nana										
Macrocystis pyrifera		9/69		5/70	5/70			8/69 (2nd), 1/70, 5/70		7/69, 8/69 (2nd), 6/70
Pachydictyon coriaceum					3/70				11/69	7/69, 10/69, 1/70, 2/70, 3/70, 5/70, 6/70
Pelvetia fastigiata			10/69, 5/70							all dates
Petalonia debilis	9/69									
Petrospongium rugosum	10/69, 12/69	11/69				10/69, 1/70				7/69, 8/69 (2nd)
Phaeostrophion australe										
Ralfsia spp.	7/69, 9/69, 5/70	5/70	11/69, 12/69, 1/70, 2/70, 3/70, 5/70, 6/70		7/69 (2nd), 8/69, 9/69, 10/69, 12/69, 1/70, 2/70, 3/70, 5/70, 6/70	8/69, 9/69, 10/69, 11/69, 12/69, 1/70, 2/70, 5/70, 6/70		8/69 (2nd), 10/69, 11/69, 12/69, 1/70	all dates	7/69, 8/69 (2nd), 9/69, 10/69, 11/69, 1/70, 2/70, 3/70, 5/70, 6/70
Sargassum agardhianum										10/69, 6/70
Scytosiphon lomentaria	10/69, 11/69, 12/69, 1/70, 2/70, 3/70		7/69, 12/69, 1/70, 2/70, 3/70		8/69	5/69, 7/69, 1/70, 5/70, 6/70		11/69, 12/69		5/70
Soranthera ulvoidea										
Taonia lennebackerae	6/70							7/69		
Zonaria farlowii										7/69, 10/69, 1/70, 3/70, 5/70, 6/70
RHODOPHYTA										
Achrochaetium spp.										
A. daviesii										
Acrosorium uncinatum										9/69
Agardhiella tenera	6/69, 7/69	6/69	6/69, 7/69, 5/70, 6/70		2/70, 3/70, 5/70, 6/70					
Ahnfeltia gigartinoides										
A. plicata	12/69					9/69		7/69		
Amphiroa zonata										
Amplisiphonia pacifica										11/69



Anisocladella pacifica
Antithamnion pygmaeum
Bangia fuscopurpurea
Bossiella spp.
B. cooperi
B. dichotoma v. gardneri
B. insularis
B. lingulata
B. orbigniana
B. plumosa
B. sagittata
Botryoglossum farlowianum
Callithamnion spp.
C. pikeanum
Callophyllis obtusifolia
C. violacea
Centroceras clavulatum
Ceramium spp.
C. eatonianum
C. californicum
C. pacificum
Chondria californica
C. cornuta
C. decipiens
C. nidifica
C. pacifica
Coeloseira compressa
Corallina spp.
C. gracilis
C. officinalis v. chilensis
C. pinnatifolia
C. polysticha
C. vancouveriensis
Cruoriella dubyi
Cryptonemia obovata
Cryptopleura spp.
C. corallinara
C. crispa
C. lobulifera
C. violacea
Cryptosiphonia woodii
Cumagloia andersonii
Dermatolithon ascripticium
D. dispar
Endocladia muricata
Erythrocystis saccata
Farlowia crassa (F. mollis)
Gastroclonium coulteri
Gelidium spp.
G. coulteri
G. crinale
G. densum
G. pulchrum
G. purpurascens
G. pusillum
G. ramuliferum
G. robustum
Gigartina spp.
G. asperifolia
G. canaliculata
G. corymbifera
G. eatoniana
G. harveyana
G. leptorhynchos
G. papillata
G. serrata
G. spinosa-armata complex
G. volans
Gloiosiphonia californica
G. verticillata
Gracilaria spp.
G. cunninghamii
G. verrucosa
Gracilariophila oryzoides
Gracilariopsis spp.
G. andersonii
G. sjoestedtii
Grateloupia spp.
G. abbreviata
G. doryphora
G. howeii
G. prolongata
G. setchellii
Gymnogongrus spp.
G. leptophyllus
G. linearis
G. platyphyllus
Herposiphonia secunda
H. verticillata
Hildenbrandia sp.
Hypnea spp.
Iridaea spp.
I. agardhianum
I. flaccidum

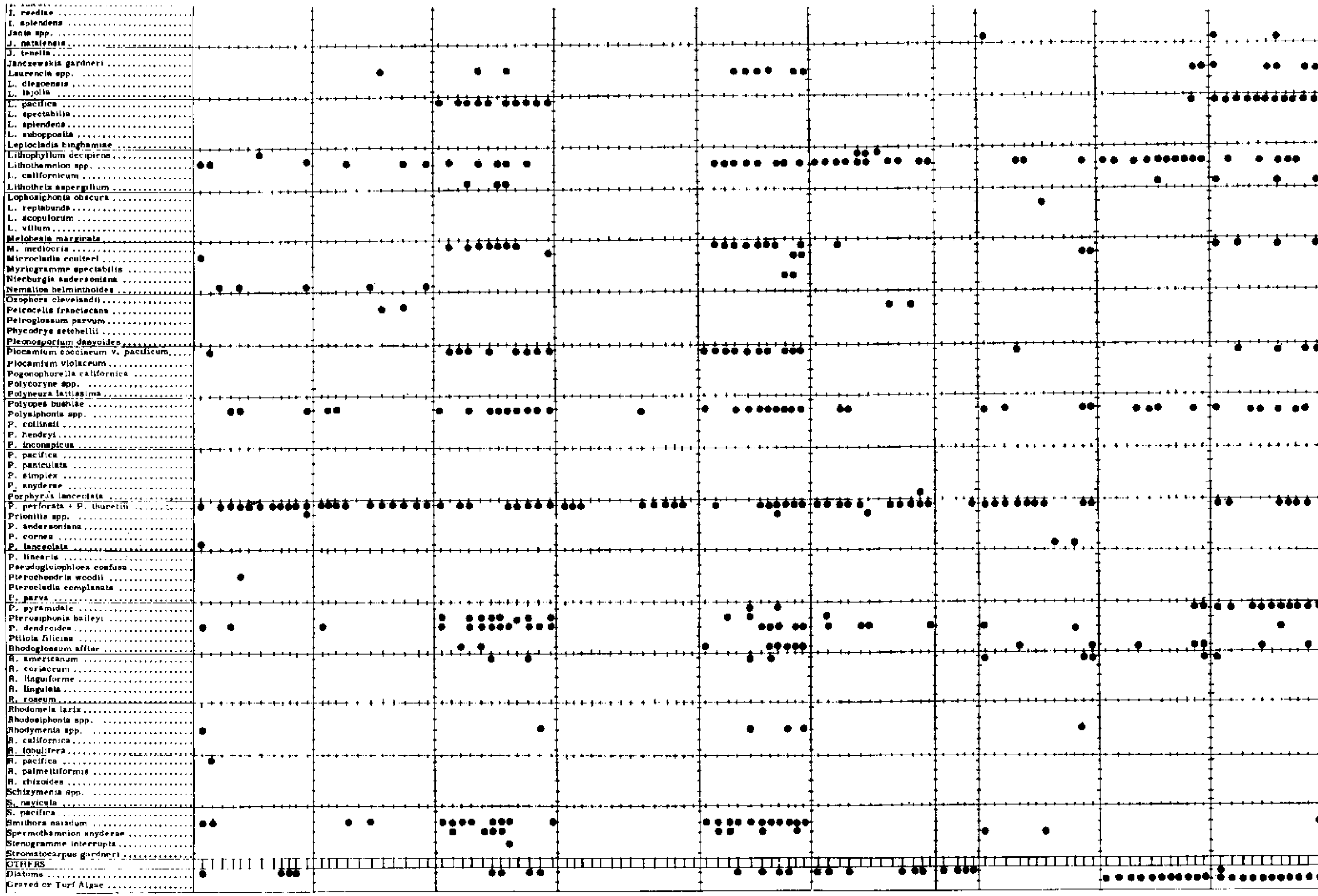

I. ...
I. reediae
I. splendens
Jania spp.
J. natalensis
J. tenella
Janczewskia gardneri
Laurencia spp.
L. diegoensis
L. lajolla
L. pacifica
L. spectabilis
L. splendens
L. subopposita
Leptocladia binghamiae
Lithophyllum decipiens
Lithothamnion spp.
L. californicum
Lithothrix aspergillum
Lophosiphonia obscura
L. reptabunda
L. scopulorum
L. villum
Melobesia marginata
M. mediocris
Microcladia coulteri
Myriogramme spectabilis
Nienburgia andersoniana
Nemalion helminthoides
Ozophora clevelandii
Petrocelis franciscana
Petroglossum parvum
Phycodrys setchellii
Pleonosporium dasyoides
Plocamium coccineum v. pacificum
Plocamium violaceum
Pogonophorella californica
Polycoryne spp.
Polyneura latissima
Polyopes bushiae
Polysiphonia spp.
P. collinsii
P. hendryi
P. inconspicua
P. pacifica
P. paniculata
P. simplex
P. snyderae
Porphyra lanceolata
P. perforata + P. thuretii
Prionitis spp.
P. andersoniana
P. cornea
P. lanceolata
P. linearis
Pseudogloiophloea confusa
Pterochondria woodii
Pterocladia complanata
P. parva
P. pyramidale
Pterosiphonia baileyi
P. dendroidea
Ptilota filicina
Rhodoglossum affine
R. americanum
R. coriaceum
R. lingiforme
R. lingulata
R. roseum
Rhodomela larix
Rhodosiphonia spp.
Rhodymenia spp.
R. californica
R. lobulifera
R. pacifica
R. palmettiformis
R. rhizoides
Schizymenia spp.
S. navicula
S. pacifica
Smithora naiadum
Spermothamnion snyderae
Stenogramme interrupta
Stromatocarpus gardneri
OTHERS
Diatoms
Grazed or Turf Algae

Table 15.

Marine plants reported at island stations, 1969-1970.

* Location / Station	Santa Rosa Is.	Corral Pt.	Bet. Ford Pt. & Last Pt.	Santa Cruz Is.	Prisoner's Harbor	Smuggler's Cove	Smuggler's Cove	Blue Banks Anchorage	Anacapa Is.	West End of East Is. (So. Exposure)	Santa Barbara Is.	Near Old Coast Guard Landing	Largest Rock, NE end	San Nicolas Is.	NE end	Santa Catalina Is.	White's Landing (Dredge only)	Isthmus Cove, Catalina Harbor	San Clemente Is.	NW Harbor	Wilson's Cove
Date		12/69	12/69		12/69	12/69	4/70	4/70		12/69		11/69	11/69		11/69		11/69	69-70		11/69	11/69
Station		9	10		8	11	12	13		7		5	6		4		1			2	3
MARINE PLANTS																					
ANGIOSPERMAE																					
Phyllospadix torreyi										●					●			●		●	
Zostera marina					●		●	●													
CHLOROPHYTA																					
Bryopsis sp.																		●			
Chaetomorpha sp.										●											
C. catalinae																		●			
C. torta																		●			
Cladophora sp.								●										●			
C. hutchinsiae							●	●													
C. trichotoma																		●			
Codium sp.																					
C. cuneatum															●			●			
C. fragile			●			●						●						●			
C. johnstonii								●													
C. setchellii																		●			
Derbesia sp.																		●			
D. marina																		●			
D. prolifera																		●			
Enteromorpha sp.																					
Ulva sp.			●		●																
U. dactylifera																		●			
U. lobata		●																			
PHAEOPHYTA																					
Acinetospora sp.								●													
Agarum fimbriatum								●										●			
Collodesme sp.																					
C. californica										●		●						●			
C. rigida															●			●			
Colpomenia peregrina												●			●						
Cystoseira sp.			●			●		●		●								●			
C. osmundacea ssp. expansa																		●		●	
C. setchelli																					
Desmarestia herbacea			●		●	●		●													
Dictyopteris sp.																					
D. zonarioides					●							●			●			●			
Dictyota sp.			●																		
D. binghamiae								●										●			
D. flabellata																		●			
Ectocarpus sp.																		●			
E. codiophila																					
E. confervoides var. pygmaeus															●						
E. corticulans																					
E. corticulatus																		●			
E. pygmaeus						●				●											
Eisenia arborea							●			●		●	●		●			●			
Egregia sp.																					
Egregia menziesii ssp. laevigata																		●			
E. menziesii ssp. filiformis															●						
E. menziesii ssp. borealis						●	●			●											
Endarachne binghamiae																		●			
Feldmannia cylindricus var. codiophilus						●															
F. globifer																					
Giffordia granulosa															●			●			
G. hincksiae															●			●			
G. mitchelliae															●			●			
G. sanderiana																					
Halidrys dioica						●	●	●							●			●			
Hapterophycus canaliculatus																		●			
Hesperophycus harveyanus																		●			
Kuckuckia sp.																		●			
Laminaria farlowii					●			●													
Macrocystis pyrifera			●		●	●		●		●					●			●		●	
Pachydictyon coriaceum					●	●	●	●		●					●			●			
Pelagophycus porra						●												●			
Pelvetia fastigiata var. gracilis																		●			
Pterygophora californica																					
Sargassum agardhianum																		●			
S. palmeri								●										●		●	
Scytosiphon lomentaria															●			●			
Sphacelaria subfusca																		●			
Sporochnus sp.																		●			
Stictyosiphon																					
Streblonema sp.																					
Taonia lennebackerae								●													
Tinocladia crassa																					
Zonaria farlowii												●						●		●	
RHODOPHYTA																					
Acrochaetium sp.		●				●				●											
Acrosorium uncinatum		●	●		●	●	●	●							●		●				●
Agardiella tenera		●			●																
Ahnfeltia sp.							●														
Amphiroa zonata																					
Antithamnion sp.																					
A. dendroideum		●															●				
A. occidentale							●														
A. pygmaeum							●														
Binghamia forkii															●						
Bonnemaisonia hamifera																					
Bossiella sp.																		●			
B. dichotoma															●						
B. insularis													●								
B. orbigniana			●				●	●													

B. ruprechtiana													
Branchioglossum sp.											●		
Calliarthron tuberculosum								●	●	●			
Callithamnion sp.													
C. biseriatum													
C. ramosissima													
C. rupicolum													
Callophyllis sp.													
C. firma							●						
C. flabellulata					●	●		●					
C. heanophylla						●					●		
C. violacea	●	●	●										
Centroceras clavulatum										●			
Ceramium sp.	●	●		●		●	●	●					
C. californicum ?	●												
C. codicola				●						●			
C. eatonianum								●					
C. gardneri			●	●									
C. pacificum	●		●										
C. personatum				●									
C. procumbens				●			●						
C. serpens													
C. sinicola				●									
Champia parvula													
Chondria sp.													
C. californica						●						●	
C. decipiens													
C. nidifica	●	●								●			
Chrysymenia sp.										●			
Coeloseira compressa		●											
Corallina sp.													
C. officinalis var. chilensis													
C. polysticha										●			
C. vancouveriensis													
Cryptonemia angustata						●							
C. borealis					●								
C. obovata					●	●							
Cruoriella sp.													
Cryptopleura sp.													
C. corallinara			●	●			●	●		●			
C. crispa			●		●	●		●	●				
C. violacea	●	●											
Dasya sp.												●	
D. abyssicola												●	
D. spinigera													
Dermatolithon sp.			●	●			●	●					
D. coralliniae													
D. marginata													
Endocladia muricata										●			
Erythrocladia sp.													
E. irregularis										●			
Erythrocystis saccata										●		●	
Erythrotrichia sp.	●						●	●					
E. welwitschii												●	
Falkenbergia sp.												●	
Fauchea sp.						●							
Gastroclonium sp.													
G. coulteri		●											
Gelidiocolax mammilata						●							
G. microsphaerica													
Gelidium sp.				●			●					●	
G. nudifrons												●	
G. pulchrum								●					
G. robustum			●	●	●	●	●	●					
Gigartina sp.	●				●	●	●	●					
G. armata - spinosa complex	●		●			●							
G. armata var. echinata												●	
G. californica		●											
G. canaliculata								●				●	
G. corymbifera													
G. harveyana	●	●	●	●		●	●						
G. serrata													
Goniotrichum sp.			●				●						
G. cornu-cervi										●		●	
G. elegans	●						●			●			
Gracilaria sp.					●	●							
G. robusta					●	●							
G. sjoestedtii(Gracilariopsis?)					●	●							
Grateloupia sp.													
G. doryphora													
G. howeii ?												●	
Griffithsia sp.	●												●
Gymnogongrus sp.		●			●								
G. leptophyllus		●											
G. platyphyllus					●								
Haliptylon gracilis								●				●	
Halymenia sp.													
H. californica					●	●							
Herposiphonia sp.			●	●									
H. littoralis												●	
H. plumosa				●									
H. plumula var. parva								●		●			
Heterosiphonia sp.										●		●	
H. assymmetria													●
H. densiuscula						●							
H. erecta						●							
Iridaea lineare									●				
Janczewskia gardneri						●							
Jania natalensis								●					
J. tenella													
Jantinella sp.	●												
Kallymenia pacifica					●	●							
Laurencia sp.													
L. masoni													
L. pacifica												●	
L. snyderae var. snyderae												●	
L. spectabilis var. diegoensis							●	●					
L. splendens						●				●			
L. subdisticha										●			
L. subopposita													
Leptocladia sp.													
L. binghamiae			●				●						
Liagora californica												●	

Lithothrix aspergillum				●		●	●	●				●		
Melobesia mediocris														
Membranoptera sp.								●						
Microcladia sp.														
M. californica	●							●						
M. coulteri	●													
Murrayellopsis sp.					●	●								
Myriogramme sp.														
M. hollenbergii						●								
Nienburgia andersoniana	●		●	●			●							
Nitophyllum sp.	●						●							
Ozophora sp.														
Petroglossum parvum														
Petrospongium sp.														
Peyssonelia sp.														
P. meridionalis						●								
Phycodrys sp.	●					●								
P. profunda											●			
P. simplex					●	●					●			
Phyllophora ? sp.					●	●								
Platysiphonia sp.														
P. clevelandii						●								
Platythamnion sp.					●	●					●			
P. pectinatum					●									
Pleonosporium sp.	●													
P. dasyoides														
P. polycarpum														
P. pygmaeum														
Plocamium coccineum var. pacificum	●		●		●		●		●	●		●	●	
Polyneura latissima		●			●	●								
Polyopes bushiae (Carpopeltis)			●				●							
Polysiphonia sp.	●	●		●			●	●				●		
P. bifurcata														
P. collinsii														
P. flaccidissima														
P. hendryi var. gardneri														
P. pacifica					●	●								
P. paniculata			●											
P. scopulorum							●							
Prionitis australis				●	●			●						
P. lanceolata	●						●							
Pseudogloiophloea confusa		●												
Pterochondria woodii ssp. pygmaeus	●	●		●	●	●	●			●				
Pterocladia sp.				●								●		
P. calloglossoides					●									
P. capillacea														
P. pyramidale				●			●	●						
Pterosiphonia sp.														
P. baileyi		●	●	●	●	●	●	●		●		●		
P. dendroidea	●							●		●				
P. pinnata														
Pugetia fragilissima						●				●				
Rhodoglossum affine												●		
R. americanum					●									
Rhodophysema sp.								●						
Rhodoptilum sp.														
R. densum						●								
Rhodymenia sp.					●		●							
R. californica		●	●		●									
R. pacifica			●		●	●		●						
R. palmata														
R. rhizoidea					●	●								
Sarcodiotheca sp.	●				●									
S. tenuis ?						●								
Sciadophycus sp.										●				
Scinaia johnstoniae														
Smithora naiadum					●	●								
Sorella delicatula var. californica														
S. divaricata								●						
Spermothamnion sp. (Tiffaniella)	●					●								
S. phycophilum														
S. snyderae														
Stenogramme interrupta					●	●								
Veleroa subulata														
Wurdemannia sp.														
Total	31	24	28	33	45	61	36	33	6	41	7	68	7	2

Table 16

Comparison of Number of Plants and Animals Reported on Spring Stations, 1969-1970

Stations (North to South)	1969 May	1969 June	1970 May	1970 June	Change between June, 1969, and June, 1970
Gaviota (Dawson 13)					
Plants	---	23	10	18	-5
Animals	---	13	8	11	-2
El Capitan (Dawson 40)					
Plants	---	15	6	17	+2
Animals	---	11	8	13	+2
Coal Oil Point (Neushul 1)					
Plants	---	19	24	26	+7
Animals	---	14	10	12	-2
East Cabrillo (Nicholson-Cimberg 1)					
Plants	6	5	6	6	+1
Animals	10	11	13	12	+1
Carpinteria (Dawson 15)					
Plants	---	19	30	32	+13
Animals	---	10	16	16	+6

Table 16 (cont.)

Stations (North to South)	1969 May	1969 June	1970 May	1970 June	Change between June, 1969, and June, 1970
Hobson County Park (Dawson 35)					
Plants	15	23	16	16	-7
Animals	13	20	14	10	-10
Palm Street Ventura (Dawson 12)					
Plants	---	4	---	5	+1
Animals	---	3	---	2	-1
Leo Carrillo (Dawson 4)					
Plants	---	22	19	16	-6
Animals	---	6	3	5	-1
Corona del Mar (Dawson 9)					
Plants	---	5	18	17	+12
Animals	---	15	17	20	+5
1 mile north of Dana Point (Dawson 22)					
Plants	---	35	24	31	-4
Animals	---	20	22	16	-4

Table 17

Total Number of Marine Plants Recorded by E. Y. Dawson, from Voucher Specimens in the AHF Herbarium and Published Field Notes (State Water Quality Control Board Publ. 27 [1965]).

	Station							
Year	Gaviota	El Capitan	Carpinteria	Hobson	Palm St.	Arroyo Sequit	Corona del Mar	North Dana Pt.
1956	Dec. 42 (48)				Dec. 20 (24)	Nov. 41 (52)	Dec. 30 (34)	
1957	Aug. 22 (23) Oct. 22 (23)		Jan. 36 (43) Sept. 36 (42)	Dec. 24 (26)	July 14 (15)		Nov. 26 (27)	Feb. 25 (28)
1958		Jan. 19 (19) Dec. 30 (31)				Feb. 23 (23)		Nov. 37 (44)
1959	Jan. 26 (27)			Jan. 28 (29)	Feb. 21 (22)			
Total no. of different marine plants (All months 1956-1959)	50 (63)	34 (37)	48 (63)	34 (38)	31 (38)	44 (59)	38 (45)	43 (54)

Note: Numbers in Parentheses Indicate Raw Data; Other Numbers Represent Modified Data (see "Treatment of Data"). This Table Summarizes Table 12.

Table 18

Total Number of Marine Plants Recorded during this Survey at Mainland Stations

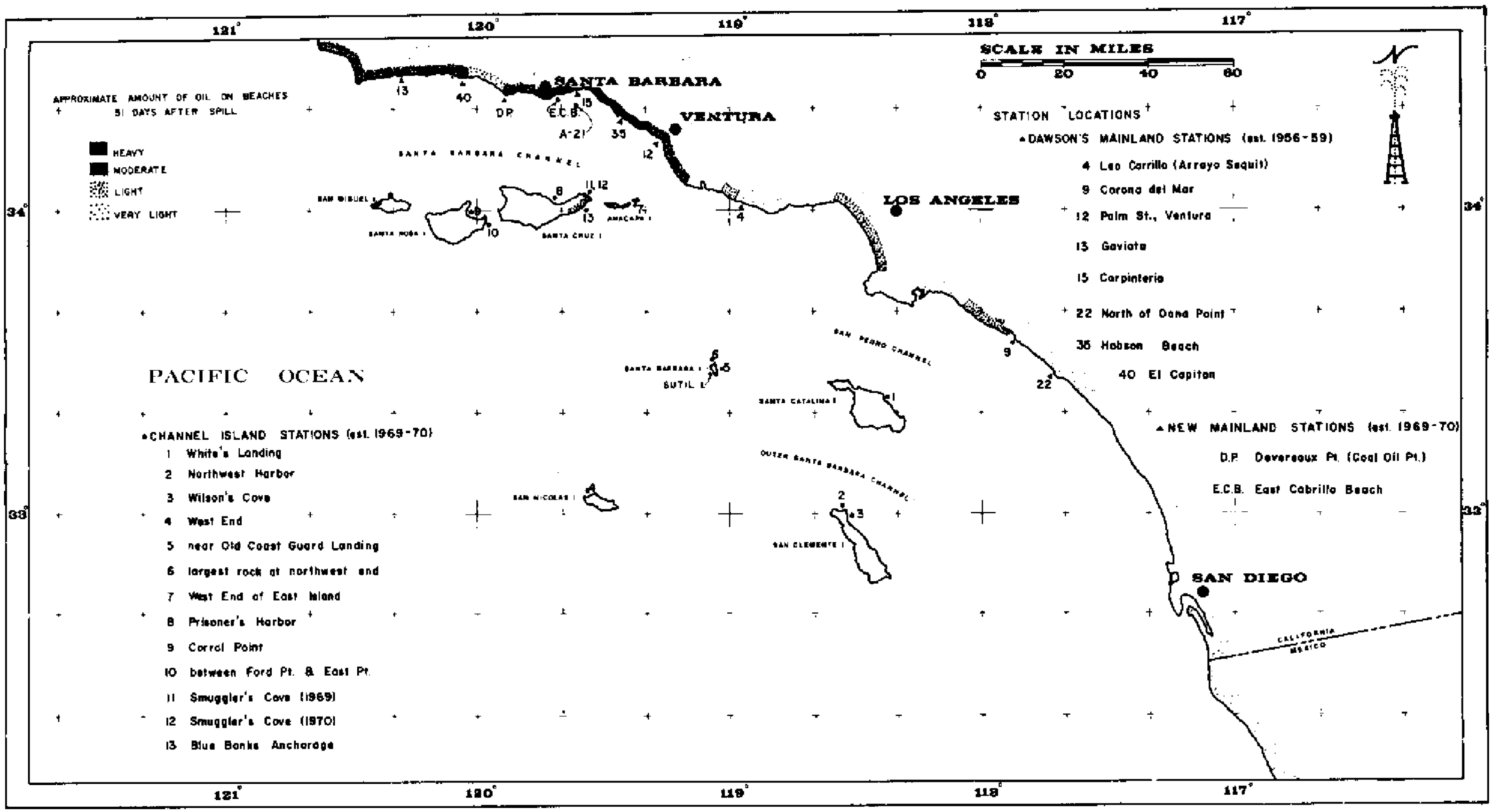
Stations

Month Year	Gaviota	El Capitan	Coal Oil Pt.	East Cabrillo	Carpinteria	Hobson	Palm St.	Arroyo Sequit	Corona del Mar	North Dana Pt.
May '69	- -	- -	- -	6 (6)	- -	15 (15)	- -	- -	- -	- -
June '69	23 (23)	15 (15)	19 (19)	7 (7) 5 (5)	- -	- -	- -	- -	- -	- -
July '69	13 (13)	9 (9)	18 (18)	7 (7)	19 (20) 20 (20)	23 (23)	4 (4) 4 (4)	22 (22)	5 (5) 6 (6)	35 (38)
August '69	6 (6)	8 (8)	17 (17)	4 (4)	21 (21)	18 (18)	- -	11 (11) 15 (15)	4 (4)	13 (14) 18 (20)
Sept. '69	8 (8)	10 (10)	25 (26)	5 (5)	25 (26)	18 (18)	- -	14 (15)	9 (10)	19 (21)
Oct. '69	18 (18)	- -	23 (24)	3 (3)	25 (25)	13 (14)	4 (4)	9 (9)	7 (7)	22 (24)
Nov. '69	10 (10)	8 (8)	27 (27)	6 (6)	- -	13 (14)	- -	11 (11)	13 (13)	14 (16)
Dec. '69	16 (11)	8 (8)	25 (25)	7 (7)	25 (25)	7 (7)	- -	13 (13)	- -	- -
Jan. '70	11 (11)	6 (6)	24 (25)	5 (5)	27 (27)	11 (11)	- -	6 (6)	5 (5)	24 (26)
Feb. '70	10 (10)	4 (4)	22 (22)	6 (6)	28 (28)	8 (8)	- -	2 (2)	5 (5)	14 (16)
March '70	10 (10)	12 (12)	25 (26)	3 (3)	31 (31)	7 (7)	- -	14 (14)	5 (5)	21 (23)
April '70	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
May '70	10 (10)	6 (6)	24 (24)	6 (6)	30 (30)	16 (17)	- -	19 (19)	18 (18)	24 (27)
June '70	18 (18)	17 (17)	26 (26)	6 (6)	32 (32)	16 (16)	- -	16 (16)	17 (17)	31 (33)
July '70	- -	- -	- -	- -	- -	- -	5 (5)	- -	- -	- -
Total no. of different marine plants (All months 1969-1970)	44 (48)	34 (34)	47 (50)	17 (18)	51 (54)	39 (45)	5 (5)	41 (41)	27 (29)	56 (60)

Note: Numbers in Parentheses Indicate Raw Data; Other Numbers Represent Modified Data (see Treatment of Data). This Table Summarizes Table 14.

Plate 1

Location of mainland and offshore island stations surveyed during the 1969 Santa Barbara oil spill study.



SCALE IN MILES
0 20 40 60
APPROXIMATE AMOUNT OF OIL ON BEACHES 51 DAYS AFTER SPILL
HEAVY
MODERATE
LIGHT
VERY LIGHT
SANTA BARBARA
VENTURA
LOS ANGELES
SAN DIEGO
PACIFIC OCEAN
SANTA BARBARA CHANNEL
SAN PEDRO CHANNEL
OUTER SANTA BARBARA CHANNEL
SAN MIGUEL I.
SANTA ROSA I.
SANTA CRUZ I.
ANACAPA I.
SANTA BARBARA I.
SUTIL I.
SANTA CATALINA I.
SAN NICOLAS I.
SAN CLEMENTE I.
CALIFORNIA
MEXICO
STATION LOCATIONS
▲DAWSON'S MAINLAND STATIONS (est. 1956-59)
4 Leo Carrillo (Arroyo Sequit)
9 Corona del Mar
12 Palm St., Ventura
13 Gaviota
15 Carpinteria
22 North of Dana Point
35 Hobson Beach
40 El Capitan
▲NEW MAINLAND STATIONS (est. 1969-70)
D.P. Devereaux Pt. (Coal Oil Pt.)
E.C.B. East Cabrillo Beach
▲CHANNEL ISLAND STATIONS (est. 1969-70)
1 White's Landing
2 Northwest Harbor
3 Wilson's Cove
4 West End
5 near Old Coast Guard Landing
6 largest rock at northwest end
7 West End of East Island
8 Prisoner's Harbor
9 Corral Point
10 between Ford Pt. & East Pt.
11 Smuggler's Cove (1969)
12 Smuggler's Cove (1970)
13 Blue Banks Anchorage
A-21
121° 120° 119° 118° 117°
34° 33° 32°

Plate 2

Generalized system of currents in the Santa Barbara Channel.

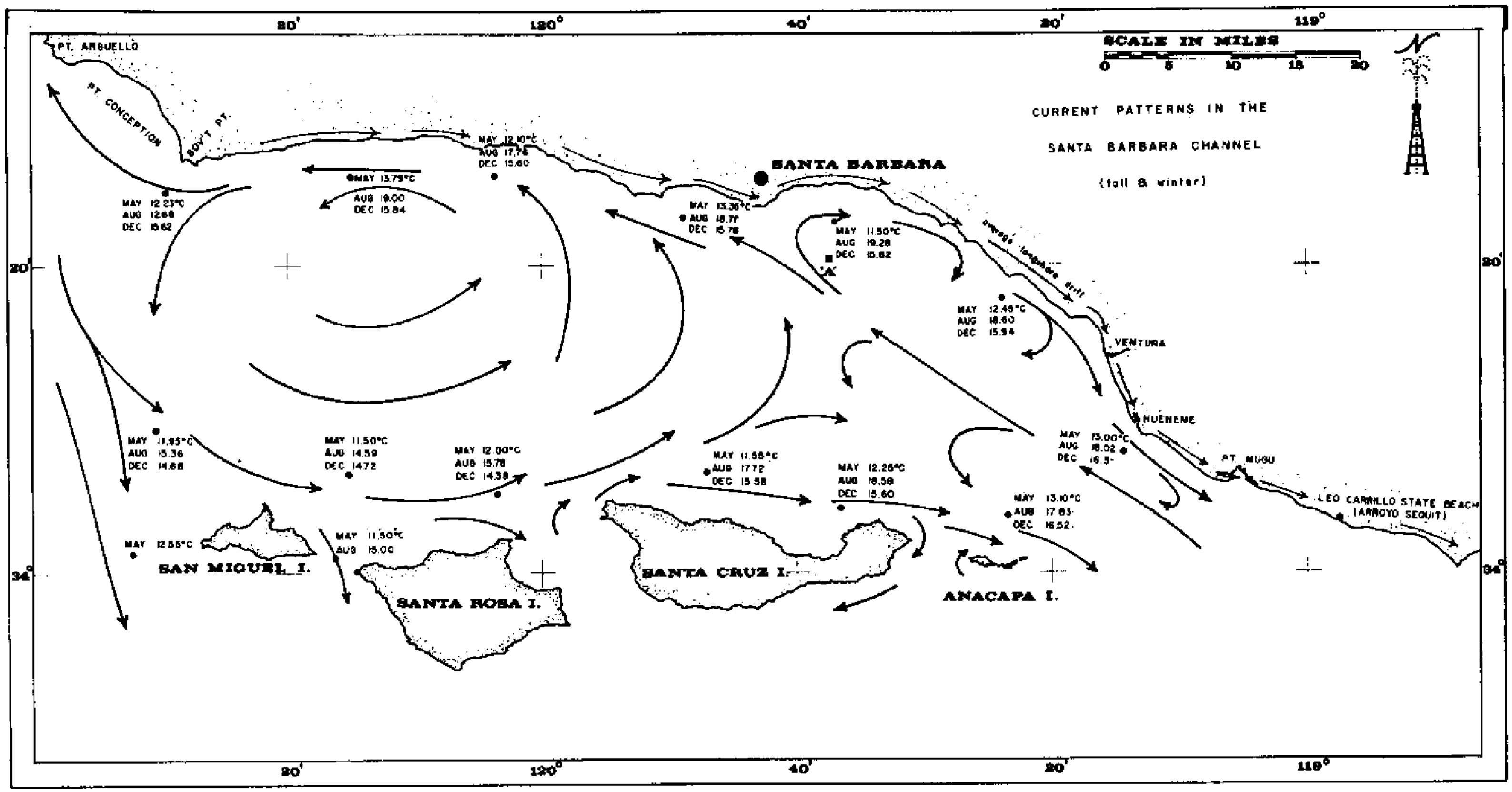
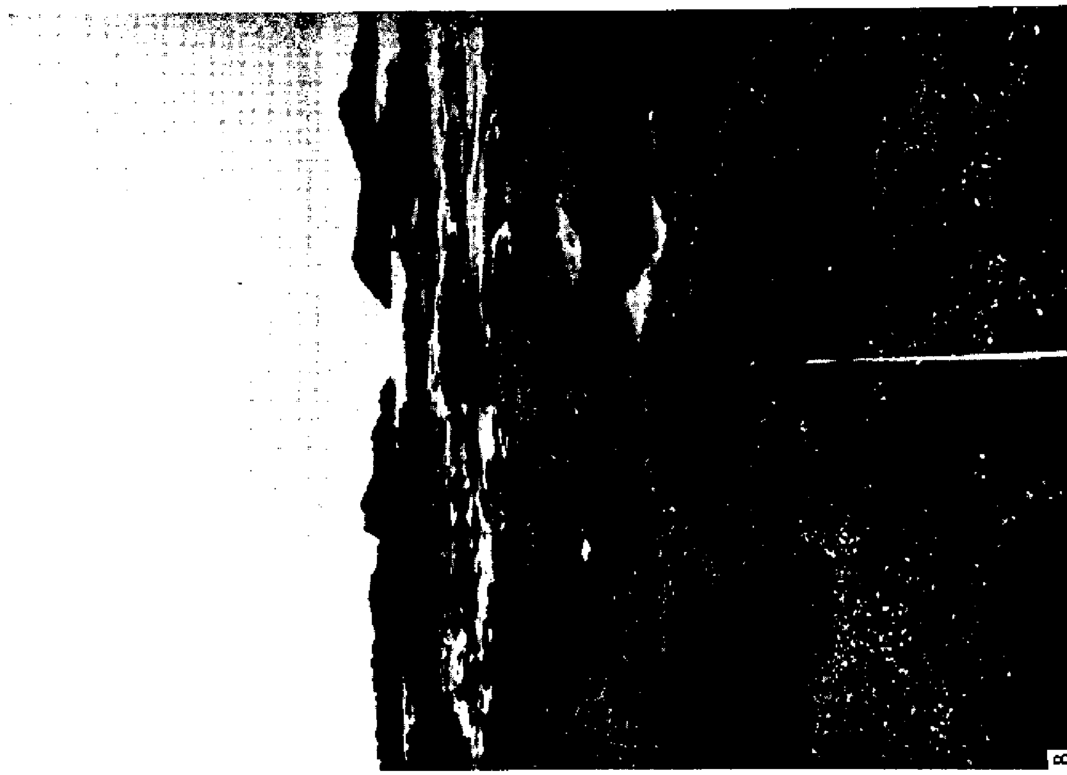

CURRENT PATTERNS IN THE
SANTA BARBARA CHANNEL
(fall & winter)
SCALE IN MILES
0 5 10 15 20
PT. ARGUELLO
PT. CONCEPTION
GOV'T PT.
SANTA BARBARA
average longshore drift
VENTURA
HUENEME
PT. MUGU
LEO CARRILLO STATE BEACH
(ARROYO SEQUIT)
SAN MIGUEL I.
SANTA ROSA I.
SANTA CRUZ I.
ANACAPA I.
120°
119°
34°

Plate 3

A. Coal Oil Point -- rocks in lower intertidal covered by the sea anemone, *Anthopleura*, and the marine plants, *Phyllospadix*, *Ulva*, *Gigartina*.

B. Coal Oil Point -- oil-covered barnacles (predominantly *Chthamalus*) in the upper intertidal.



B

A

Plate 4

A. East Cabrillo Beach -- clean-up operations (chopped straw on oil) following the January, 1969, Santa Barbara oil spill.

B. East Cabrillo Beach -- 7-foot section of metal groin knocked by the December, 1969, storms.

A

B

Plate 5

A. Carpinteria State Beach -- December, 1969, spill showing emulsified oil on sand.

B. Carpinteria State Beach -- algal bleaching during winter of 1969.

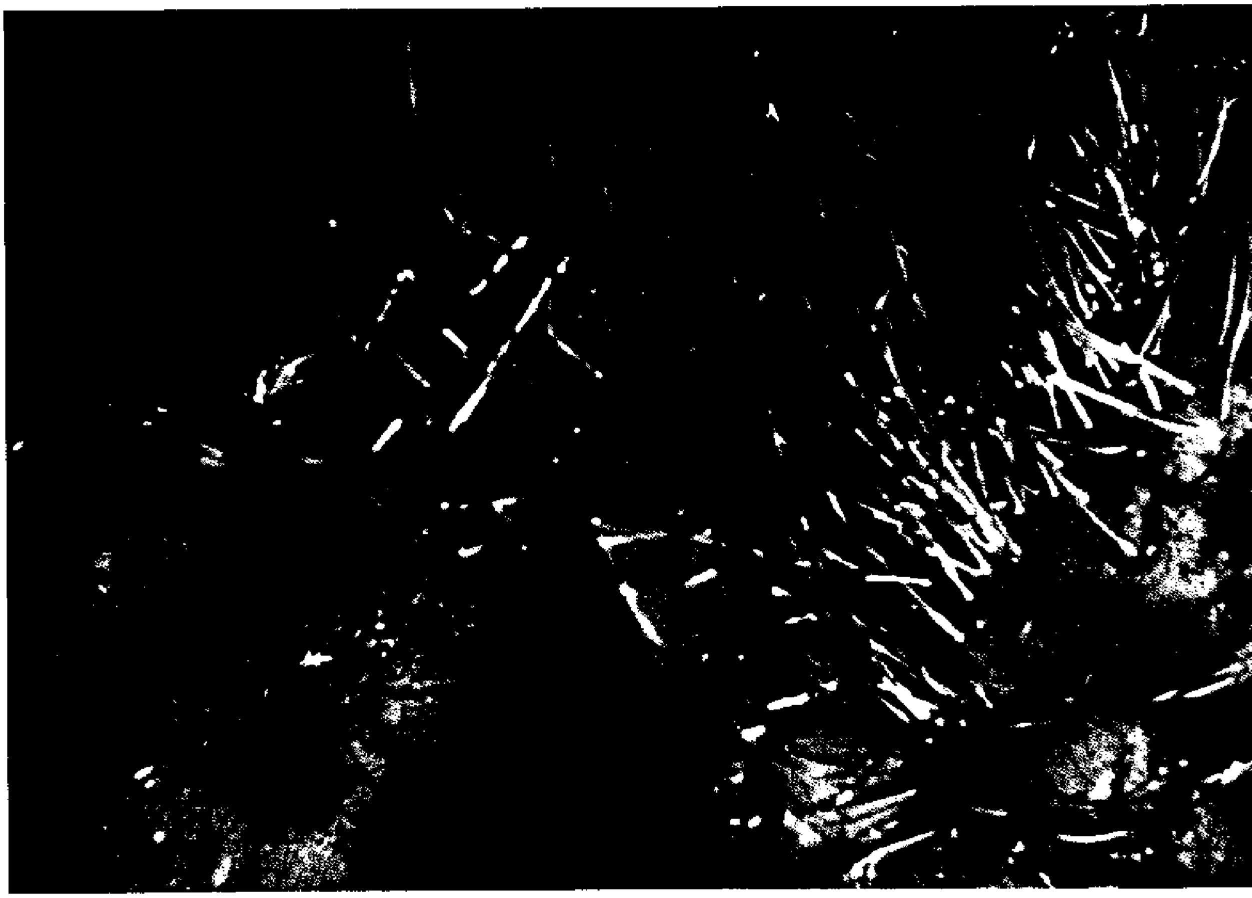
A

B

Plate 6

A. Carpinteria State Beach -- oil enmeshed in *Phyllospadix*.

B. Hobson County Park -- December, 1969, spill showing emulsified oil on beach.



A

B

Table 7

A. Hobson County Park -- clamming activity disturbing the rocky substratum.

B. Palm Street, Ventura -- green algal and diatom growth west of sand-covered station line.

A

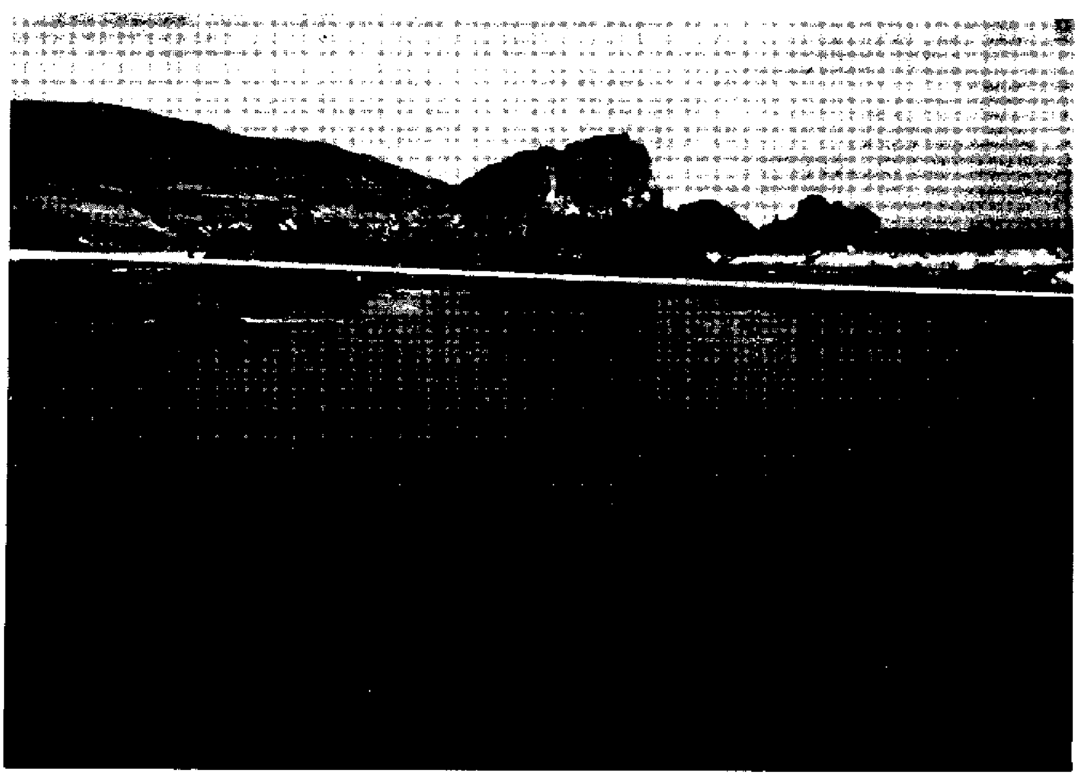
B

Plate 8

A. Leo Carrillo State Beach (Arroyo Sequit) -- sand covering most of the station line; the kelps *Egregia* and *Macrocystis* appearing through the sand.

B. Leo Carrillo State Beach (Arroyo Sequit) -- sand remaining on most of the station line with only stipes of *Egregia* and *Macrocystis* remaining.

A



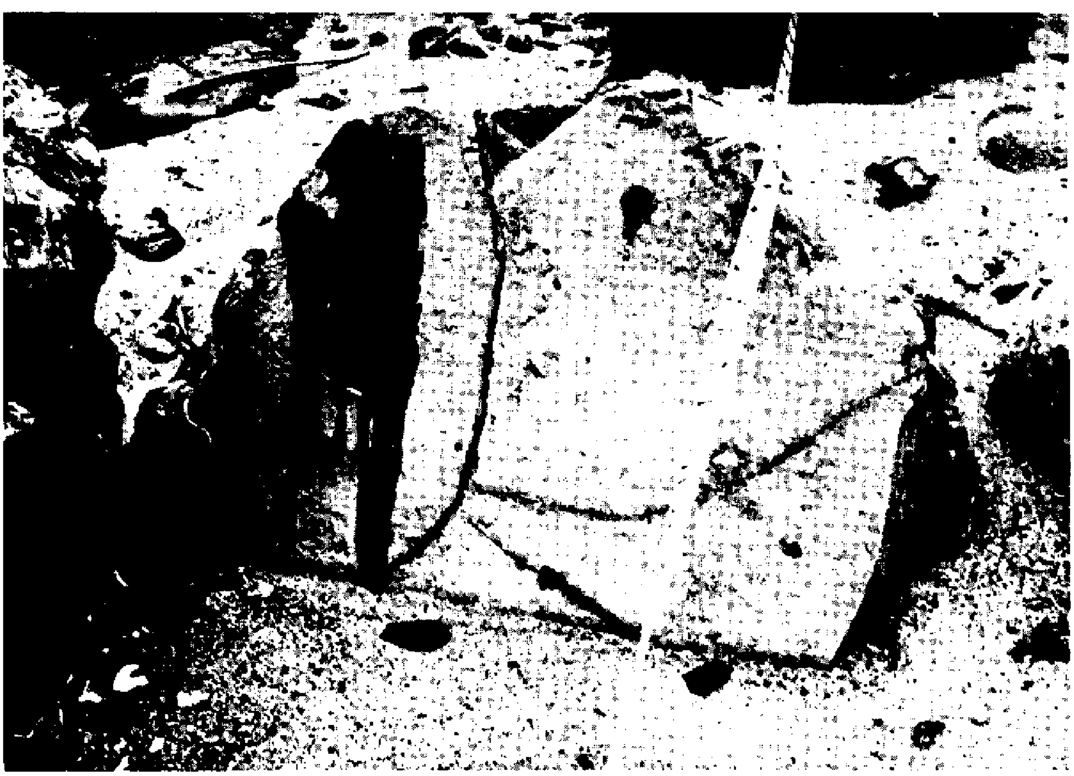
B

Plate 9

A. Leo Carrillo State Beach (Arroyo Sequit) -- sand cut from beach revealing rocky substratum.

B. Corona del Mar -- oil from undetermined source on rocks in the upper intertidal.

A



B

CHAPTER 18

WHAT HAS BEEN THE EFFECT OF THE SPILL ON THE ECOLOGY IN THE SANTA BARBARA CHANNEL?

by Dale Straughan

This is the question posed by the Western Oil and Gas Association. First, we do not know all of the answers--we will probably never know all of the answers. This is due partly to the complex interaction of forces operating in the area at the time of the spill and partly to general lack of knowledge of the ecology of the area. True, some background data were available, but not enough to answer the question in full.

Several factors that complicated the problem of determining the effects of the oil spill were operative in the Santa Barbara Channel at the time of the spill. There were active natural oil seeps in the area. Was the oil on the beaches all from the spill or was part of it from natural seepage? How did the natural seepage influence the ecology of the Santa Barbara Channel? The spill occurred during a period of unusually heavy rains, with peak flooding on January 25 and February 25. In some areas, the biota was under stress at the time of the spill from lowered salinities, increased sedimentation, and possibly an increase in pesticides. Here the task was to differentiate between effects caused by these environmental factors, the oil spill and possible synergistic effects.

There is no evidence of gross effects of oil pollution on plankton in the Santa Barbara Channel (Oguri, Chapter 3, and McGinnis, Chapter 4). This must be considered in the light of the fact that the plankton is poorly known from this area--particularly in the inshore surface waters.

The United States Bureau of Commercial Fisheries (1969), on a cruise through the area on February 11, 1969, reported no effects on fish eggs and larvae; and while the phytoplankton count was lower than at a nearby station in the previous month, there is no way of knowing if this variation is a function of patchiness in phytoplankton distribution, a normal seasonal variation, or a direct or indirect effect of the oil spill.

However, I do not find the lack of gross effects on the plankton in the Santa Barbara Channel unexpected. The oil floated and was relatively insoluble in water. Oil movement was partially dependent on wind so that the oil was not static relative to the surface water. In addition, the United States Bureau of Commercial Fisheries (1969) did not detect any oxygen depletion under the oil slick, but there was a reduction in penetration of ultra-violet light. In relatively open waters such as the Santa Barbara Channel, surface waters would be exposed to the oil slick for relatively short periods only. Hence one would not expect the type of lethal and malforming effects that have been demonstrated in laboratory experiments of several days duration. These may occur when oil is trapped in an enclosed area such as a harbor or sheltered bay for an extended period. In a situation such as the Santa Barbara Channel, the neuston, microscopic organisms living in the surface water film, would still be in close contact with oil. Unfortunately this is a poorly known group of organisms, known only to very few, and no study was made of them. However, it is difficult to envision how these organisms could not be affected by oil.

Changes were recorded in the benthic fauna over the decade from 1959 to 1969. There was an overall decrease in standing crop throughout the area studied. This would be due not to the oil spill, but either to a normal general change in the community or to pollutants that are widespread through the area, such as those resulting from sewage outfalls or agricultural pesticides. In addition, Fauchald (Chapter 5, Figs. 5 and 6) reports a dramatic change in standing crop in the triangle between Santa Barbara Harbor, Platform A, and Carpinteria. This is entirely due to a reduction in Listriolobus pelodes population. In particular the part of the bed extending towards Carpinteria was severely reduced. While Fauchald suggests that drilling activity, by disturbing the sediments, may be directly responsible for the damage, he does not discount possible pollution effects from the increased human population in the area. However, there was no change in the area occupied by L. pelodes and there are no indications that the species was reduced markedly in the vicinity of Platform A.

Unfortunately oil analyses from samples used in the study of benthic bacteria are incomplete. As there were several variables operative during this period, interpretation of results is impossible. Increases in the bacteriological counts occurred in the summers of 1969 and 1970 and following an increase in natural seepage in the October-November period. These changes could be attributed to oil, movement of flood sediments and/or seasonal effects.

A study of benthic foraminifera (Morin, Volume 2) detected no mortality attributable to oil. Evidence suggests that there was higher productivity in inshore waters. This is possibly due to increased nutrients entering the area by coastal flooding.

Studies of the sandy beach fauna did not reveal any direct effects of oil pollution. However, they showed a seasonal change in abundance of organisms which is probably associated with the amount of sand on the beaches. Animals were more abundant in summer when there was more sand on the beaches than in winter when some beaches were exposed rocks. Trask also comments that fewer animals were collected when collections were made in the rain. This may, at least partially, explain the reports "that nothing moved on the beaches" after the oil came ashore. Perhaps there was nothing on the beaches before the oil came ashore, due to seasonal and fresh water influences.

Immediately after the Santa Barbara oil spill, Dr. Michael Neushul[1] initiated a study in intertidal and kelp bed areas. The dosage of oil on selected beaches was

---

[1]Santa Barbara Oil Pollution, 1969; Final Report Dealing with the Early Stages of the Santa Barbara Oil Spill, written for the Federal Water Pollution Control Administration, U.S. Department of the Interior, Contract No. 14-12-516, principal investigator: Michael Neushul.

determined for February 8-13, 1969. The estimated amount of oil ashore from El Capitan to Port Hueneme on February 8 was 4,508 metric tons.

Beaches were surveyed in February and March, 1969, to determine immediate effects of oil pollution on rocky intertidal shores. Data collected by Dr. Neushul's students in 1966-67 and that published by Dawson for the period 1956-59 were used as baseline information. Nicholson and Cimberg (Chapter 17) found Dawson's published data were incomplete. Table 12, Chapter 17 is a complete report on Dawson's data for the stations examined by Nicholson and Cimberg. The study by Nicholson and Cimberg was partially designed to follow the surveys made by Neushul. Neushul's work was to determine immediate effects of the oil spill while the work by Nicholson and Cimberg was aimed at determining the longer term effects.

Discussion by both Neushul and Nicholson and Cimberg is based on comparison of the variety of species present. The variety was calculated on single line transects in both cases--which may or may not be a true indication of variety of species on that beach. This method also gives no indication of relative abundance of species nor does it give any indication of possible changes in actual species composition. Species diversity and importance values for each species would be better measures for showing changes on the beaches. However, none of these methods may reveal any effects of oil pollution in an area. The California Department of Fish and Game (1969:60) in their summary state that "species diversity has remained high and there are no indications of any major modifications in numbers." However, data presented in Tables 1 and 2 of the report consist solely of presence/absence data at various localities and give no indication of species diversity or population size. One can only conclude that the statement on species diversity is based on unpublished data.

Of more value are the data supplied by Neushul (see Tables 1 and 2) and Nicholson and Cimberg (Chapter 17, Table 10) recording oiled and/or dead species. Simple records of changes in species composition, species diversity, or species abundance may give no indication of actual causes of such changes--particularly in a situation where many possible factors may be responsible for them. A prime factor analysis of species composition and abundance relative to possible causes is more valuable.

A study team from the California Institute of Technology reported minimal damage by oil from surveys made in mid-February, 1969 (reported in full, Straughan, Chapter 1).

Neither Neushul nor Nicholson and Cimberg were able to demonstrate widespread effects of oil pollution from the January, 1969, oil spill on intertidal species. Both these studies, along with a study by the California Department of Fish and Game, reported smothering of Chthamalus fissus and mortality in Phyllospadix torreyi. The California Department of Fish and Game (1969) reported that the latter species was growing again in damaged areas on the Channel Islands in August, 1969. At Punta Arena, Santa Cruz Island, Hesperophycus harveyanus was damaged by the oil, but "by August 6, near normal quantities of alga were observed" (California Department of Fish and Game, 1969:8). Nicholson and Cimberg reported that Pollicipes polymerus was loose and later lacking from the substrate at Carpinteria and East Cabrillo beaches. They attribute this to oil pollution. While P. polymerus is present in low numbers at oil seep areas such as Coal Oil Point (Straughan, Chapter 10), in these areas it is found growing with bases surrounded by oil. Hence this effect on P. polymerus may have been caused by other factors, particularly as it is unclear from the text if these particular animals were covered by oil.

The California Department of Fish and Game, after surveys at Anacapa and Santa Cruz Islands (1969:9), reported that "While the shells of such invertebrates as black abalone, Haliotis cracherodii, and goose-neck barnacles, Pollicipes polymerus, were covered with oil, the animals themselves appeared to be healthy and viable." They did not record any loss of Pollicipes polymerus.

Neushul and Nicholson and Cimberg surveyed five common beaches, El Capitan State Park, Coal Oil Point, Carpinteria Beach, Hobson Beach, and Leo Carrillo State Park (Arroyo Sequit). Oil was not recorded in either study on Arroyo Sequit (Table 3), which is just south of the Santa Barbara Channel (see Nicholson and Cimberg, Chapter 17, Fig. 1). Oil was recorded on the other four beaches. However, no attempt was made to differentiate between natural seep oil and oil from the area of Platform A. Table 3 shows whether there was oil in the water and whether the oil on shore was fresh or old.

Oil was recorded at Coal Oil Point and Carpinteria each month these beaches were surveyed. Coal Oil Point has long been known as an area of active oil seepage. Carpinteria has old tar mounds with no records of recent seep activity prior to 1969. Wintz and Ventura (Chapter 2) reported seep activity in March and April, 1969, while Weaver (1969:3) shows a photograph of seep activity in June, 1969. Nicholson and Cimberg regard Coal Oil Point as an area of natural oil seepage but not Carpinteria. However, there is no doubt that Carpinteria was an area of natural oil seepage during 1969.

Oil originating from the area of Platform A came ashore in quantity in two periods--the heaviest pollution commencing in February, 1969, from the initial oil spill, and then less pollution for a short period commencing December 21, 1969, from a second disturbance. There was also an increase in natural seep activity during the latter part of October and November, 1969 (H. Morrison, personal communication). During this period, fresh oil, presumably from the seep activity, was recorded on El Capitan, Coal Oil Point, Carpinteria beaches as well as in box corers off Carpinteria (Juge, Chapter 9). Fresh oil reported at Hobson Beach on December 21 originated in the area of Platform A. Oil was never observed in the water at El Capitan and recorded in the water at Hobson Beach only following increased flow from the Platform A area.

It is difficult in retrospect to determine just how much oil was removed from these beaches through the activities of Union Oil and how much by natural factors. Union Oil had cleaning teams operating at El Capitan, Carpinteria and Hobson Beach. Coal Oil Point, as a known area of active oil seeps, was relatively untouched by the cleaning teams. Problems on Carpinteria Beach largely centered on the presence of flood debris which became covered by oil. All beaches were cleaned for public use by June 15, 1969, and there were few instances of recontamination after this date. Hence from July, 1969, onwards, the absence of oil on the substrate at El Capitan and Hobson Beach (Table 3) was a result of natural factors such as wave action, sand action, and bacterial action on the oil. After the December, 1969, spill, the natural factors may have been aided by Union Oil at Hobson Beach.

The rate of loss of oil from the intertidal substrate under natural conditions is variable. Areas such as Coal Oil Point always have dry oil in the intertidal. The length of time this oil has been ashore is unknown. Kolpack (personal communication) reported that oil from the January spill was lost from exposed rocks within three weeks of its arrival on shore. Nicholson and Cimberg reported that a large amount of oil and straw was still present in the upper intertidal transect on East Cabrillo in June, 1970. There was less oil present in June, 1970, than in June, 1969. In November, 1970, only very small isolated patches of oil and straw remained in very sheltered positions on the metal groin that formed this transect. This oil-straw mixture tends to have a crumbly texture and is easily removed from the substrate. This is unlike deposits from natural seeps which eventually become hard solid surfaces.

Larger amounts of oil and straw were present in sheltered positions on rocks in the retaining wall at Santa Claus on November 12, 1970. This was very high in the intertidal region and no larval settlement was observed on the oil-straw residue or the rocks. The straw appears to prevent the oil from forming a hard substrate and thus the mixture is more easily removed by wave action than are pure tar residues. Even so, in sheltered areas in the high intertidal zones the process of removal can still take many months, in this case 22+ months. Oil and straw were also found on rocks in the Mussel Shoals area on November 12, 1970.

Fig. 4 shows the number of algal species recorded by Neushul in the winter, 1966-67, and in February-March, 1969, and those recorded by Nicholson and Cimberg (1969-70) for the five stations common to both surveys. Comments are confined to algal species because many of the animal species are incompletely identified to general categories, e.g., sponges. There are also no similar data for comparison available on the animal species prior to May, 1969. The algal species numbers used are all species and not the data modified for comparison with Dawson's data. Two of the beaches, Carpinteria and Coal Oil Point, are oil seep areas with stable substrates, while El Capitan, Hobson Beach and Arroyo Sequit are non-oil seep areas and have an unstable substrate (Straughan, Chapter 10, Table 1). Neushul found there was a strong correlation between species variety and substrate stability, more species of algae being recorded on a stable substrate than on an unstable one. This is reflected in Fig. 1 with some overlap in species numbers in June, July, August, 1969.

Similar species numbers were recorded in winter, 1966-67, and February-March, 1969, at El Capitan, Carpinteria and Hobson Beach. The difference at Arroyo Sequit was probably due to the presence of large amounts of sand over the rocks. Neushul records that this transect had the most sand of any examined in February-March, 1969. Insufficient data are available even to speculate on the reason for the differences in species numbers at Coal Oil Point on these two occasions.

There was a decrease in the number of algal species found at both Coal Oil Point and Carpinteria between February-March (winter), 1969, and June-July (summer), 1969. The lowest number of algal species was recorded at Carpinteria (18) in July, 1969, and at Coal Oil Point (15) in August, 1969. Subsequent to this, there was an overall increase in the number of species recorded at both stations during the next twelve months. The pattern and extent of reduction and increase in species numbers was similar at both Coal Oil Point and Carpinteria, even though the former received a negligible amount of clean-up by Union Oil and the latter was subjected to large scale clean-up operations.

At Hobson Beach and Arroyo Sequit, there was an increase in species numbers between February-March, 1969, and July, 1969. There was a decrease in species numbers during the winter months to February-March, 1970, at these two beaches and at El Capitan, followed by a gradual increase in species numbers to June, 1970. This indicates a seasonal pattern of fewer species present in winter than summer. The winter reduction of species numbers at Arroyo Sequit is inversely related to the presence of sand on the beach. Hobson Beach was covered in fresh oil at the time of the December survey. It is possible that all species were not recorded on the transect line simply because they were not visible through the oil.

At El Capitan, species numbers decreased between February-March, 1969, and June, 1970. This is similar to the trend recorded at Coal Oil Point and Carpinteria. However, over the following twelve months, changes in species numbers were similar to those recorded at Hobson Beach and Arroyo Sequit. El Capitan was the area of lowest total number of species (34) compared to Coal Oil Point (50), Carpinteria (54), Hobson Beach (45) and Arroyo Sequit (41). As it is the most northerly beach and close to the northern limit of the southern species, it is possible that southern species which occur at the other four beaches do not extend that far north. The species decline following the oil spill occurred at the three most northerly beaches. It is possible that these were northern colder water species which do not extend as far south as Hobson Beach and Arroyo Sequit. Research at present in progress indicates that oil raises temperatures in the intertidal area at low tide. These species may have succumbed to the temperature changes caused by the oil. The fact that they normally survive at the oil seep areas of Carpinteria and Coal Oil Point would not be surprising, as these areas are not subjected to layers of oil over the whole area, such as were recorded during the spill. Unfortunately data are not available to test this hypothesis.

The total number of algal species recorded at both beaches in areas of natural seepage is greater than that recorded at other beaches within the Santa Barbara Channel. Nicholson and Cimberg, who ignore the seep activity at Carpinteria, compared numbers of plants and animals recorded in June, 1970, at Coal Oil Point, Carpinteria Beach and Dana Point. They state (Chapter 17) "it is evident that Coal Oil Point is characterized by a smaller variety of organisms: those that can tolerate or evade effects of the chronic presence of crude oil." Dana Point is a non-oil seep, private beach situated south of the Santa Barbara Channel. Hence there are two differences operating here--the difference in use by the public, and the difference in exposure to oil. The substrate formation at these three beaches is similar. A total of 60 algal species were recorded at Dana

Point. While the statement made by Nicholson and Cimberg (quoted above) may indeed be correct, the available data do not prove it.

Recovery of the intertidal areas depends on the sub-lethal effects on breeding populations and/or inhibition of larval settlement. Straughan (Chapter 10) examined several intertidal species for such effects. The most detailed studies were made on three barnacle species. No effects on breeding were found on surviving oiled individuals of two species of barnacles, *Balanus glandula* and *Chthamalus fissus*, in upper intertidal areas, while breeding was reduced in oil seep areas and in oiled individuals of *Pollicipes polymerus* in lower intertidal areas. As this species ranges from Alaska to Mexico, a reduction in breeding in a small section of its range will not endanger the species as a whole.

Balanus glandula settled on oil less than seven weeks after the spill, *Chthamalus fissus* not until ten months after the spill. There are no records of *Pollicipes polymerus* settling on oiled surfaces. Newly settled *P. polymerus* were collected when both they and the substrate were covered by an oil film, but it was impossible to determine whether the barnacles settled before or after the surface was exposed to the oil film. Larval settlement in two of the three barnacle species was delayed by the presence of oil on the substrate. *Chthamalus fissus* was present on the oil-straw residue at East Cabrillo and was removed when the oil-straw residue was removed from the substrate. Therefore even though *Chthamalus* can settle on the oil-straw residue, this would appear to be of little value in recolonizing the area if the oil-straw residue and animals will be removed from the substrate by natural forces. Hence an oil-straw mixture will cause an even longer delay in recovery of the biota than the presence of oil alone.

Data presented on fish catch in the area, and surveys by the California Department of Fish and Game (Straughan, Chapter 11) suggest that the oil did not deplete the fish population and that the fishing industry suffered economic losses more through indirect causes such as the closing of harbors and fouling of boats and equipment. This is not surprising because the oil is relatively insoluble in water and fish were unlikely to be directly exposed to the oil.

Data on the marine mammal populations do not prove large scale mortality as a result of the oil spill. This does not mean there was no mortality due to the oil. Whales and elephant seals appear unharmed by the spill but there was mortality among the California sea lions in an area exposed to the spill. Although Le Boeuf and Brownell (Chapter 14) indicate that DDT may be a major cause of this mortality, the possibility exists that some of the mortality in California sea lion pups may have been a result of the spill. While data on the populations are inadequate, it appears that the oil did not cause a major disaster in the colonies.

A high mortality was recorded in pelagic bird populations. Only a very low percentage (10.7%) of all birds taken to cleaning centers survived. Pelagic species fared poorly, mainly because of the difficulties of keeping these species in recovery areas. Their feet could not tolerate the hard substrates. Data on bird populations in the Santa Barbara Channel for 1970 have not been made available by the California Department of Fish and Game. At this point, it is still not known if the pelagic species in the area have recovered.

In summary, this study has shown significant mortality in bird populations, in populations of the intertidal barnacle *Chthamalus fissus*, in the marine grass *Phyllospadix torreyi* and the marine alga *Hesperophycus harveyanus*. Mortality in other areas can be attributed to other sources or possibly to a combination of oil and other sources. Recolonization commenced in the intertidal areas within seven weeks of the spill. As of November, 1970, most intertidal areas now have a "normal" population of intertidal invertebrates. Sublethal effects include a reduction in breeding in *Pollicipes polymerus* in localized areas.

Why, in the light of statements expressing fears for the ecology of the area and reports of large scale damage following other spills, was so little damage reported in the Santa Barbara Channel? One hypothesis is that the biota of the area had a high tolerance to oil built up by almost continuous exposure to small amounts of similar oil from natural seeps over long periods. This hypothesis is at present being investigated at the Allan Hancock Foundation.

The presence of oil in the area may have resulted in a normally high population of oil degrading bacteria. Asphaltic deposits are always present on some Santa Barbara beaches and Santa Barbara crude oil has a high asphaltene component (Table 4). Traxler (1970) reports the isolation from seawater of bacteria that will degrade asphaltenes. Hence while the degradation of these asphaltic deposits is not immediately visible, one assumes that it proceeds slowly and that in these areas of asphaltic deposits the deposition rate is higher than the degradation.

Another hypothesis is that the large amounts of sediment and debris washed into the Santa Barbara Channel during the period prior to and following the spill acted as a sinking agent for the oil. Results presented in Volume 2 will throw light on this theory.

Other reasons relate to the composition and behavior of Santa Barbara crude oil (Table 4). This oil is relatively insoluble in water. Kolpack (personal communication) found negligible amounts of petroleum dissolved in water in active natural oil seep areas. The oil floats on the surface of the water where the volatile components are rapidly lost. As the volatiles are lost, the specific gravity increases. If the oil does not wash ashore, it will gradually sink with increasing specific gravity.

This slow solubility and the tendency of oil to remain at the surface, thus allowing the loss of volatile components, reduce the potential toxicity of the oil. In general, this oil has to be in actual contact with an organism to affect it. The aromatic fraction which is generally regarded as the most acutely toxic fraction, is low (Kolpack, personal communication). Most damage in intertidal areas was due to smothering. Such appeared to be the case with _Chthamalus fissus_. Here, then, in spite of fears and predictions to the contrary, we find the Santa Barbara crude oil apparently caused only a small amount of short term damage in the environment. Many of these dire predictions were based on experience in other oil spills (Table 5). Evidence available after the Chevron spill (Gulf of Mexico crude oil) and the _Torrey Canyon_ spill (Kuwait crude oil) also indicates that if the crude oil remains at sea for a period, damage in intertidal areas will be limited to smothering of some species. Most of the intertidal and subtidal damage following the Torrey Canyon disaster was caused by the addition of large amounts of detergents, mainly BP 1002, which had an aromatic base. These were more toxic than the oil itself.

Mr. W. H. Williams, Government Fisheries Office at Plymouth, reports that along the Cornish coast the catch at the time of the Torrey Canyon disaster did not suffer by more than a negligible amount. This was in spite of the use of relatively toxic detergents in the area. Immediately after the wreck most fishermen were drafted for spraying. When they resumed their normal tasks, the lobster catches on only three boats were affected. One catch of mackerel was also contaminated. In all cases, the contamination was by detergents and not oil. While results of effects on commercial fishing following the spill in the Gulf of Mexico are still tied up in litigation, preliminary reports indicate negligible damage to the industry.

At the other end of the oil pollution scale is the spill of No. 2 fuel oil that occurred from the Florida in Falmouth, Massachusetts, in September, 1969 (Blumer, 1969). This was a light oil that contained 41% aromatics and rapidly dispersed through the water column. Crude oils from Santa Barbara and the Gulf of Mexico contain a lower percentage of aromatics and the oil floats, allowing evaporation of volatile fractions. Seven to ten days after the Florida spill, mortalities of 95-100% were recorded in intertidal and subtidal areas to down to ten feet in the area of the spill. As of June, 1970, oil remained in intertidal sediments and there was no obvious evidence of recolonization. In fact, through a redistribution of oiled sediments following winter runoff in the area, an even larger area was contaminated.

The Tampico Maru spill was probably the best known oil spill in Southern California prior to the Santa Barbara one. Here a small area was exposed to a high dose of oil for a prolonged period. North *et al*. (1964) report that the cargo was diesel oil. The situation is not directly comparable to the Santa Barbara oil spill because different oils are involved, the dose rate from the Tampico Maru was higher than at Santa Barbara, and the oil from the Tampico Maru was trapped in the cove for several months, while the oil at Santa Barbara remained in one area for a much shorter period.

Evidence is accumulating emphasizing the fact that because all oil is not the same, its effects when spilled will vary. The composition and behavior of oil is important. A crude oil such as that found in Santa Barbara is far less toxic than a light refined oil. However, the crude oil that remains floating at sea poses a greater direct threat to pelagic birds than an oil that disperses through the water column. Here we have a dilemma because oil collection devices are still ineffectual under many conditions at sea. Does one disperse floating oil at sea, save the birds, and increase the exposure of species living in the water column, or does one leave the oil to come ashore, endanger birds, and not risk species in the water column? Incidentally the first alternative will also reduce pollution of beaches. With present decreasing toxicity and increasing efficiency of new dispersants, the case for dispersing floating oil at sea is gaining strength.

The Dillingham Corporation has recently completed a study of the characteristics of major oil spills (Smith et al., 1970). About 75% of spills originate from vessels and about 5% from offshore drilling. While this is poor consolation if one is directly affected by a spill from offshore drilling, it does indicate that such spills are only a small percentage of the problem. About 80% of the oil spilled is crude oil and just under 20% is light oil. Hence while the crude oils discussed here are less damaging to the environment than the light oils, they are spilled in much greater quantities. Evidence indicates that recovery is also more rapid after one of these crude oil spills than after a refined oil spill.

Following an oil spill, how, when, and where can one expect to find effects on the biota? In an incident such as a spill from the barge Florida, where 95-100% mortality was recorded in a few days, the acute effects are obvious. In the Santa Barbara spill these effects are less obvious, as, for example, the smothering of one species of barnacle and not another. It would take close examination to record when the smaller species died. A casual observer might not even know they were under the oil and, seeing the larger species alive, assume that all was well.

When are these effects going to occur? Neushul's surveys were made within days of contamination by oil. Nicholson and Cimberg (Chapter 17) did not commence surveys until summer, 1969. What happened in the intervening period? There were decreases in species numbers at three stations. When did these decreases occur and were they directly related to oil?

In general, one can see the oil if it is present in Santa Barbara. In areas contaminated by the Florida spill, the oil is not initially visible. However, working the mud to produce a pool of water will also reveal an oil film. Hence one cannot always assume that because oil is not visible, it is not present.

Supposing one finds dead animals after an oil spill. Their death may not be the result of the spill. Following the Santa Barbara oil spill, some observers attributed the death of barnacles, killed by fresh water flooding immediately prior to the spill, to the effects of oil (J. Cubit, personal communication). Autopsies and tissue analysis were performed on several dead marine mammals but the biology of these animals is so poorly known that it is unlikely that either the presence or absence of oil could be used to "prove" or "disprove" the effects of oil.

The survey technique is not the answer to the problem. It may work when the pollutant is evenly distributed over an area (e.g., DDT pollution) or becomes evenly diluted away from a point source (e.g., sewage pollution). Crude oil, however, does not behave in this way. Doses are unevenly distributed throughout the areas. Direct observation on specimens in contact with oil is important. A species list merely gives information on which species may have disappeared from the area and which may not.

Ideally, detailed knowledge on communities in the area is required, as well as information on species which show whether the community is viable in the area. Such species could then be used as indicator species. This concept is already used widely in pollution work. The presence of *Capitella capitata* only in an area indicates a high degree of pollution. Escherichia coli is used as an indicator of sewage pollution. It would be impossible to sample for all kinds of bacteria. The presence of E. coli indicates that pathogenic bacteria could be present and appropriate action is taken.

Sanders and Grassle (personal communication), following the Florida spill, are using living/dead ratios of amphipods as an indication of oil pollution with considerable success. The species used are very sensitive to the presence of this oil. The use of an indicator organism that is sensitive to oil and not sensitive to other environmental changes operating in the area (such as pesticide or sewage pollution) would aid in the determination of which changes are due to oil and which are due to other environmental factors.

The trend in pollution studies to date has been automatically to regard the loss of a species as a detrimental effect without consideration of the effects on the energy and nutrient budget of the system. Replacement by another species either from without or within the system could more than compensate for the loss of a species. However, continuous replacement of species from within the system leads to a decrease in species diversity and a decrease in stability of the community.

Another method to determine oil pollution effects is being used at the Oil Pollution Research Unit Orielton Field Centre in Wales. Experimental plots are oiled at different seasons of the year and at different frequencies. This allows determination of seasonal effects of oil pollution, recovery rates from oil pollution, and the effects of repeated exposure to oil pollution (Baker, 1969). Laboratory experiments also form an important part of this work. However, care must be taken in extrapolation from laboratory experiments to field conditions.

Sublethal effects of pollution are more difficult to detect. Such effects of pollution by halogenated hydrocarbons went undetected until in many cases it was too late to reverse the negative trends. A species may survive in a polluted area but may not breed or may not recolonize the area when the present population dies. Reduction in the breeding rate in Pollicipes polymerus and interference with larval settlement in Chthamalus fissus and Pollicipes polymerus were demonstrated in the Santa Barbara Channel. However, this occurred only over a small percentage of the entire range of these species. C. fissus will recolonize oiled surfaces while it is doubtful if P. polymerus will. Sublethal effects such as these warrant further study. If recolonization will be delayed significantly by the presence of oil and/or oil and straw, it may be wiser to clean intertidal areas with detergents if it will allow more rapid recovery of an area.

Blumer (1969, 1970) warns about the incorporation of hydrocarbons into the food chain. He demonstrated that scallops (Aequipecten irradians) and oysters (Crassostrea virginica) incorporated hydrocarbons from the No. 2 fuel oil spill into their tissues. These oyster beds are at present condemned. What are the effects of these hydrocarbons in the food chain? At the moment we do not know. Surely here is an area that requires urgent research, particularly in the light of statements such as "While the direct causation of cancer by crude oil and crude oil residues has not yet been demonstrated conclusively, it should be pointed out that oil and residues contain hydrocarbons similar to those in tobacco tar" (Blumer, 1969:5).

Organisms living in the Santa Barbara Channel have been exposed to oil over a long period. If these organisms are incorporating oil hydrocarbons into their tissues to their detriment and the detriment of species further along the food chain, these effects should be discernible. To my knowledge, there has been no research on this topic in this area. Extrapolation of results to other areas must take into account the composition of oils involved.

In conclusion, I would like to reiterate that damage to the biota was not widespread, but was limited to several species, and that the area is recovering. In retrospect, it is not surprising that the studies after the Santa Barbara oil spill revealed such a small amount of damage. However, recurrent spills of this type at frequent intervals would probably result in large ecological changes. Likewise, spills of refined oils present an entirely different problem and one that warrants far more concern.

REFERENCES

Baker, J. M.
1969 The effects of oil pollution on salt marsh communities. Field Studies Council Oil Pollution Research Unit, Ann. Rpt. for 1968, Sect. B: 1-10.

Blumer, M.
1969 Oil pollution of the ocean. Oceanus, 15(2): 2-7.

Blumer, M., G. Souza, and J. Sass
1970 Hydrocarbon pollution of edible shellfish by an oil spill. Woods Hole Oceanographic Inst., Ref. 70-1.

California. Department of Fish and Game.
1969 Santa Barbara oil leak. California Dept. of Fish and Game Interim Rpt., December 15, 1969.

Hampson, G. R., and H. L. Sanders
1969 Local oil spill. Oceanus, 15(2): 8-11.

North, W. J., M. Neushul, Jr., and K. A. Clendenning
1964 Successive biological changes observed in a marine cove exposed to a large spillage of mineral oil. In Comn. Internatl. Explor. Sci. Mer Méditerr., Symp. Pollut. Mar. par Microorgan. Prod. Pétrol., Monaco. pp. 335-354.

Smith, D. D., G. A. Gilmore, A. H. Rice, E. H. Shenton, and W. H. Moser
1970 A review of the problem. Characteristics of major oil spills. Industry-Government Seminar on Oil Spill Treating Agents, April 8-9, 1970, Washington, D.C., Proc. pp. 9-56.

Smith, J. E.
1968 "Torrey Canyon," pollution and marine life. Cambridge Univ. Press, Cambridge, Eng. 196p.

Traxler, R. W.
1970 Microbiological aspects of oil pollution. Paper presented at the 1970 Evangeline Section Regional Meeting of the Society of Petroleum Engineers of AIME on "Oilfield Pollution," Lafayette, La., November 9-10, 1970.

U.S. Bureau of Commercial Fisheries
1969 Monthly report for February, 1969, of the Fishery Oceanography Center, La Jolla, California.

Weaver, D. W.
1969 Geology of the northern Channel Islands. Pacific Sections of the Amer. Assoc. Petrol. Geol. and Soc. Econ. Paleont. Mineral., Special Publ.

Table 1

Plants Observed Oil Covered and/or Dead Along Station Transects

Plant	Dates and Stations Plants Observed Covered	Amount of Oil on Transect Population[1]	Dates and Stations Plants Observed Dead	Population Mortality Along Transect[2]	Remarks
Phyllospadix torreyi	2/11,2/13,3/1 (D)	***	3/1,6/4 (D)	50-60%	Percent of exposed blades damaged.
	3/13,3/16 (E)	***			
	2/13,3/4,3/16 (F)	***	5/5 (F)	90-100%	
	2/12,3/15 (G)	***	3/15,5/4 (G)	30-50%	
	3/17 (I)	***			
Enteromorpha compressa	2/8 (B)	*	4/26 (A)	1-5%	Thalli white.
	2/12,3/15 (C)	**	3/15 (C)	10-20%	
	2/10 (D)	**			
	2/11 (G)	**	2/11 (G)	20%	
	2/12 (H)	**			
Chaetomorpha aerea	3/1 (E)	*			
Ulva californica	2/12 (H)	*	4/26 (A)	1-5%	Thalli white.
Ralfsia sp.	2/10,2/11,2/13 (D)	**			
Egregia laevigata	2/10,2/13,6/4 (D)	***			Oiled stipes with some blades green and some blades gone.
	5/5 (F)	**			
	3/15,5/4 (G)	**			
Porphyra sp.	3/1,3/13 (A)	*	4/26 (A)	1-5%	Thalli white.
	2/8,3/14 (B)	**	3/14 (B)	1-5%	
			5/4 (G)	20%	
Endocladia muricata	3/1 (A)	*			
Hildenbrandia sp.	2/13 (D)	*			
Rhodoglossum affine	2/13 (D)	*			
Gigartina leptorynchos	3/4,5/5 (F)	**			
	2/12 (G)	*			
Gigartina canaliculata	3/4,5/5 (F)	*	4/26 (A)	1-2%	
Chondria nidifica	3/15 (G)	**			

1. Amount of oil on transect population represents average over dates given in second column.

2. Percents represent mortality along transect as estimated by the field investigator.

Legend: * = light oil coverage
** = moderate oil coverage
*** = heavy oil coverage

This is Table 3, pp. 31, 32 from Neushul's report.

Table 2

Animals Observed as Oil Covered and/or Dead

Animal	Dates and Stations Animals Observed Covered	Amount of Oil on Transect Population[1]	Dates and Stations Animals Observed Dead	Population Mortality Along Transect[2]	Remarks
Anthopleura elegantissima	2/12,3/15 (G)	***			Oil on body debris.
	2/12 (H)	**			
Chthamalus fissus			4/26 (A)	1%	
	3/14 (B)	*			
	2/12,3/15 (C)	*	2/12,3/15,4/28 (C)	20%	
	2/11 (D)	***	4/26 (D)	80-90%	
	3/1 (E)	***			
	2/13 (F)	***	5/5 (F)	10%	
	3/17 (I)	*			
Balanus glandula	3/15 (C)	**			
Pollicipes polymerus	2/12,3/15 (C)	**	4/28 (C)	1-5%	
	3/1,5/4 (G)	**	3/1,5/4 (G)	1-5%	
Pachygrapsus crassipes			2/11 (D)	1 individual	
Pagurus samuelis	3/4 (F)	**			Oil on hermit crab shells.
Orchestoidea sp.			2/8 (D)	1 individual	
Mytilus spp.			4/26 (A)	1%	
	3/15 (C)	***	3/15,4/28 (C)	1%	
	2/12,5/4 (G)	*			
	2/12 (H)	*			
Acmea spp.	4/26 (A)	*			Oil on shells and feet.
	4/28 (C)	***			
	2/11,4/26 (D)	***			
	3/1 (H)	*			
Pisaster ochraceous			2/10 (D)	1 individual	
Stronglylocentrotus purpuratus			2/10 (D)	1 individual	

1. Amount of oil on transect population represents average over dates station was visited, as does percent mortality.

2. Percents represent mortality along transect as estimated by field investigator.

Legend: * = light oil coverage
** = moderate oil coverage
*** = heavy oil coverage.

This is Table 4, pp. 36, 37 from Neushul's report.

Table 3

Records of Oil at Beaches between January, 1969, and June, 1970, compiled from Neushul's Report, and Nicholson and Cimberg (Chapter 17)

	1969												1970					
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
El Capitan	?	–	?	?	?		–			–	+			+	–	?	–	–
Coal Oil Point	?	⊕	?	?	?	⊕	–	–	⊕	⊕	⊕	⊕	–	+	⊕	?	⊕	⊕
Carpinteria Beach	?	⊕	?	?	?	–	⊕	–	–	⊕	?	⊕	⊕	+	⊕	?	⊕	–
Hobson Beach	?	⊕	?	?	+	–	+					⊕	–	–	+	?		
Arroyo Sequit	?			?	?											?		

Legend: –, old oil on shore; +, fresh oil on shore; o, oil in water; ?, no data.

(Records do not indicate if the oil was fresh or old at Hobson Beach in January and February, 1970).

TABLE 4

General Characteristics of Crude Oil from Different Areas

	Santa Barbara	Gulf Coast	Middle East
Asphaltenes	High	High	Medium
Wax	Low	Low-Medium	Medium
Aromatics	Medium	Low-Medium	Medium-High
Naphthenes	High	High	Medium
Parafins	Low	Low-Medium	Low-Medium
Sulpher	Medium-High	Medium	High
Nitrogen	Medium	Low	?
Pour Point	Low	Low-Medium	Medium-High

Table 5

Comparison of circumstance and documented damage of oil spills.

Spill	Locality	Date	Oil	Detergent	Damage
Tampico Maru	Baja California, Mexico	March 29, 1957	Diesel, total 9380 m^3 (1/3 lost on stranding)	0	Very high mortality recorded one month after spill. Six years later recovery almost complete. Rocky cove 1/2 mile entrance. 3/4 cove blocked. (North et al, 1964).
Torrey Canyon	Isles of Scilly off Cornwall, England	March 18, 1967	96,000 m^3 Kuwait crude	2 1/2 million gallons	Damage greatly increased where detergent was used. Subtidal damage blamed on detergent. Detergent on approx. 140 miles English beaches. (Smith, 1968).
Florida	Falmouth, Mass., USA	September 16, 1969	650-700 m^3 No. 2 fuel oil	0	95-100% mortality in intertidal and subtidal areas to 10 meters. June 1970, intertidal marsh grass still dead and no sign of recovery in intertidal areas. (Hampson and Sanders, 1969).
Oil Rig	Santa Barbara Channel, USA	January 28, 1969	Santa Barbara Crude Oil	43,010 gallons over 13 months at sea	Mortality patchy in intertidal and confined to areas covered with thick oil. Recovery of algae and seagrasses and resettlement of barnacles commenced in 1969. Oil smothering rather than toxic. (Unpublished data from Allan Hancock Foundation).
Oil Rig	Chevron, Gulf of Mexico, USA	March 1970	Gulf Crude	minimal use at sea only	Unofficially reported as aesthetic damage only. Unable to show damage to oyster beds. Fishing not affected. (Results tied up in litigation).

Figure 1

Total number of plant species recorded at El Capitan (▲), Coal Oil Point (✪), Carpinteria Beach (●), Hobson Beach (★), and Arroyo Sequit (•), on surveys made in winter of 1966-67, and in February, March, 1969, by Dr. M. Neushul and his students, and surveys made from May, 1969, to July, 1970, by Nicholson and Cimberg.