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THESIS

THE ECOLOGY OF THE BENTHIC AND ENDOLITHIC COMMUNITIES OF A ROCKY REEF IN THE KELP BEDS OFF DEL MONTE BEACH, MONTEREY, CALIFORNIA

by

Richard Gurney Hoffman, Jr.

June 1981

Thesis Advisor: E. C. Haderlie

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by

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Submitted in partial fulfillment of the
requirements for the degree of

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from the

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June 1981

ABSTRACT

Divers, using SCUBA equipment, conducted an ecological survey along two transects on a large reef-like feature in the exposed shale off Del Monte Beach. A population census and notes concerning the relative location of the various organisms, including the identification of 248 species, is presented. The vertical variations of the populations of bivalve borers and associated benthic and endolithic organisms was investigated. The major environmental factors controlling the populations in this area were seen to be the level of siltation and the hardness of the rock. The large bivalve borers (*Chaceia ovoidea* and *Parapholas californica*) occupy different regions of the ledge. *Chaceia* was found in the vertical regions away from silt deposition and *Parapholas* was found in the horizontal regions, often under several centimeters of sand. Other possible boring organisms were identified. The sipunculid *Themiste pyroides* was found in burrows that are quite different from the typical bivalve burrow. The annelid *Palola paloloides* was found in burrows of apparently its own manufacture. A number of nestling organisms were found. The annelid nestlers found in this region show a large variation across the vertical face that was a result of the different siltation regimes.

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I. INTRODUCTION

A. PREVIOUS STUDIES CONDUCTED

For the last fifteen years, the southern end of Monterey Bay has been the site of a number of investigations by students and faculty of the Naval Postgraduate School. These studies have centered around various aspects of the ecology of certain of the marine fouling and boring organisms. In the latter part of the 1960's, Dr. E. C. Haderlie conducted a number of studies to assess the growth rates and settling characteristics of a number of fouling and wood and rock boring organisms (Haderlie 1967, 1968, 1975). In 1970, a long term investigation into the environment and ecology of the area was begun as a result of the announcement by the City of Monterey of plans to build two new breakwater structures off Del Monte Beach. The resulting investigation, called the Monterey Breakwater Study, included biological sampling using SCUBA divers, bottom dredging, plankton trawls, and chemical and physical sampling, temperature measurements, and wave data. The intent was to accumulate sufficient baseline ecological data so that the affects of the breakwater construction could be assessed at some later time. The ecological analysis concentrated to a great extent on the rock boring bivalves,

primarily of the family Pholadidae. These organisms were selected for study for several reasons. They are very numerous in this region and are represented by a wide variety of species, each of which apparently has a preferred substrate. They are sessile and are not prone to seasonal variations in population due to migration or short term local conditions. Several of the species are quite large and easily identified by a SCUBA diver. The pholads, by penetrating the rock, create new substrates for settlement, increase the submarine erosion of geological structures, and by their numbers, should provide a method of determining changes in the environment. In order to use these organisms as a gauge by which to measure this change, it is important to fully understand the natural history, life cycle and preferred environment of each of the different species.

As part of the Monterey Breakwater Study, three students conducted studies which looked at different aspects of the ecology of the kelp beds. Minter (1971), selected two locations in the central part of the kelp beds, in which he conducted a thorough analysis of the organisms that could be identified in-situ. His two areas, one 4 x 4 m, the other 5 x 5 m, were located so that they would be available for restudy after the breakwater was built. For this reason, he looked only at the surficial organisms and the large rock dwellers (endolithic) which could be identified without

disturbing the substrate. Booth (1972) studied two long horizontal lines (transects) which extended out from the beach to about 15 m depth. Using SCUBA gear he swam along these two lines taking a one-meter wide swath in which he attempted to identify all of the rock boring pholads. His purpose was to determine the horizontal distribution of the pholads along these two transects. One transect was inside, the other outside of the proposed construction. Burnett (1972), from the Moss Landing Marine Laboratory, used the pholads in an attempt to measure the affect of the Monterey sewer outfall on the distribution of rock borers. Clark (1978), extended the study to Santa Cruz in order to observe the distribution of pholads in the intertidal zone. Even after it became evident that the breakwater would not be built, interest in the rock borers continued. Haderlie (1980), gave details of the work that he and others have performed attempting to gain a greater knowledge of the characteristics of these borers in southern Monterey Bay.

B. NATURE OF THE INVESTIGATION

In conjunction with the work that was previously conducted, and as a part of the Monterey Breakwater Study, this investigation centered on certain aspects of rock borer distribution and associated nestling organisms. A detailed analysis of all of the organisms that could be found on a reef-like structure was the main purpose of the study, and

particular attention was to be paid those organisms that were associated with empty burrows in the rock. This analysis was to be similar to the one performed by Minter (1971), but in much more detail and without the intention of revisiting the area at a later date. The vertical variation of the larger pholads was also of particular interest and for this purpose a location was selected which had a sharp vertical scarp.

The study site was a large reef-like feature which was nearly 2 m high. This geological structure was exposed to slightly different effects of wave surge and siltation. These effects were estimated and the variation in the distribution of the rock-borers and nestling organisms across this structure was correlated with the variations in rock hardness and type, and wave surge and siltation effects. Divers, utilizing SCUBA equipment, conducted a number of dives in which they identified and counted as many of the surficial and endolithic organisms as could be found. The surficial organisms were identified and counted to provide a basis for comparing the data with that collected by Minter (1971). Several large rocks were hoisted from the bottom and were analyzed in the laboratory. Particular attention was paid to the organisms that were found as nestlers. Sketches of the reef were made, and some of the more unusual characteristics of the burrows were

photographed. Chemical analyses were made to determine the carbonate content of the rocks and estimates of the calcium carbonate were made.

This study was primarily descriptive due to the near impossibility of accurately counting many of the smaller endolithic organisms. The larger borers and those nestlers that could be identified and counted in-situ, with some reliability, were counted. Many smaller organisms and endolithic individuals could only be identified by removing them from the rock in the laboratory. These individuals were impossible to count so only the relative abundance of these organisms was estimated.

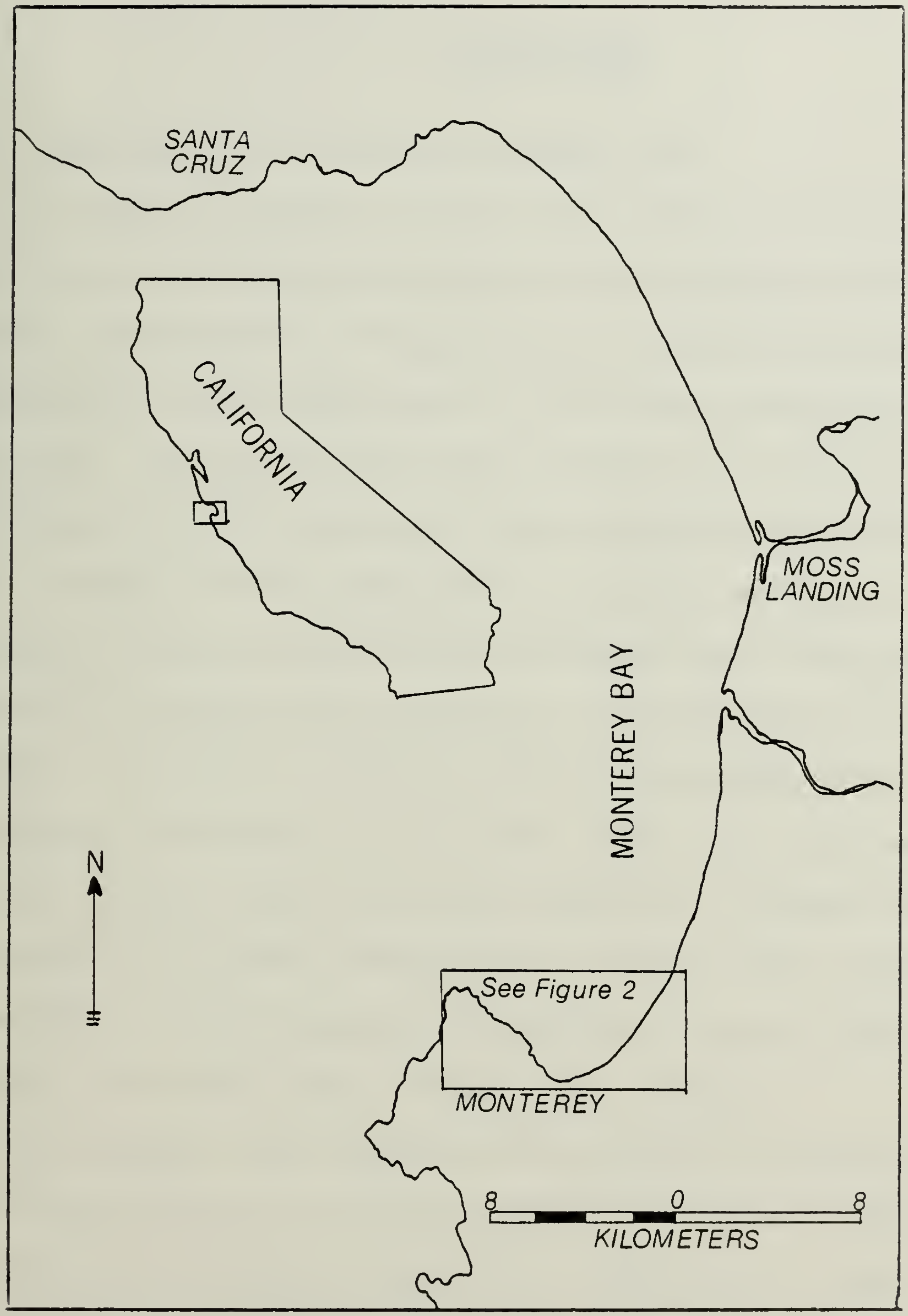

FIGURE 1. Location Map of Monterey Bay.

II. BACKGROUND

A. THE GEOLOGY OF SOUTHERN MONTEREY BAY

In order to properly assess the affect of the geology of this region on the distribution of rock-boring and endolithic organisms it is important to describe the geological features and the composition of the rock formations found in the area. Several recent works describe in some detail the geological characteristics of the southern end of Monterey Bay. Greene (1977), conducted a detailed analysis of the Monterey Peninsula and the surrounding area, detailing the types of rock and the distribution of the faults that are found in the area. Haderlie (1980), discussed the geological characteristics of the entire bay with emphasis on the subtidal and intertidal exposures of shale which are susceptable to borer penetration. Booth (1971) briefly described the rock ledges and outcrops that are found in the center of the kelp beds off Del Monte Beach.

The exposed rocks found on the bottom in the area of the kelp beds consist of shallow outcrops of Miocene shale which belong to the Monterey Formation. This rock is grey-brown siliceous shale which ranges from soft mud-stone to very hard opaline chert (Booth, 1971; Haderlie, 1980). The bedding of the outcrops is essentially planar, and the

individual layers vary in thickness from a few centimeters to 40 cm. The Monterey Formation contacts the main basement rock of the Peninsula, Cretacious Santa Lucia Granodiorite, to the east of Wharf Number 2 (Figure 4). To the east of this contact the shale is fairly flat with a number of exposed faults and cracks. The study area is several hundred meters to the east of this contact area. Much of the shale in the study area is covered with sand, with some of the other areas covered sporadically as a result of sand movement on and off the beach. This movement is a result of wave period and direction and is probably seasonal.

In this region there are a number of faults and fractures which are a part of the Tularcitos Fracture Zone (Greene, 1977). The fracture zone lies perpendicular to the beach (N-NW) and the discontinuous ledges found here lie roughly parallel to it. Seismic reflection profiling indicates a layer of opaline chert which lies about 100 meters below the estimated top of the Miocene strata (Greene, 1977). This profiling indicates that the layer of chert should surface in the kelp beds off Del Monte Beach which Minter (1972) verified. The submarine shale outcrops become more rugged and broken as one moves from west to east. The western portion of this shale is flat, barely exposed rock rarely exceeding 50 cm. in height above the bottom. The exposed outcrops in the study area are very rugged with large hummucks and ledges in evidence.

B. DESCRIPTION OF THE STUDY AREA

The area investigated in this study is typical of the region as it is a wide expanse of flat shale with the holdfasts of the marine algae Macrocystis pyrifera attached to the rock surface. The study area is in the midst of the largest concentration of kelp in the area. The shelves and ledges are quite extensive and some can be seen to extend for several hundred meters. In the area of this study the surface layers of the ledges are almost exclusively chert. This hard resistant rock is not as easily weathered as the overlying rock. Where the faulting has broken the overlying layer of rock, weathering begins on both broken edges. Wave surge and sand scouring dig out the sediments from between the ledges, and the softer rock is eroded away. The harder rocks persist for some time, but eventually they are undercut so severely that they fall under their own weight. In some areas there is a soft layer of rock overlying the chert. This layer is often inhabited by rock borers which can only bore downward as far as the top of the chert layer. The upper surface of the chert ledge is deeply pitted and scarred apparently due to the activities of borers in the soft upper layers which bore as far as the hard chert layer and can go no farther. The pits that are found on the upper surface of the chert, are approximately 1 cm deep. Figure 2 is an artist's rendering of the ledge.

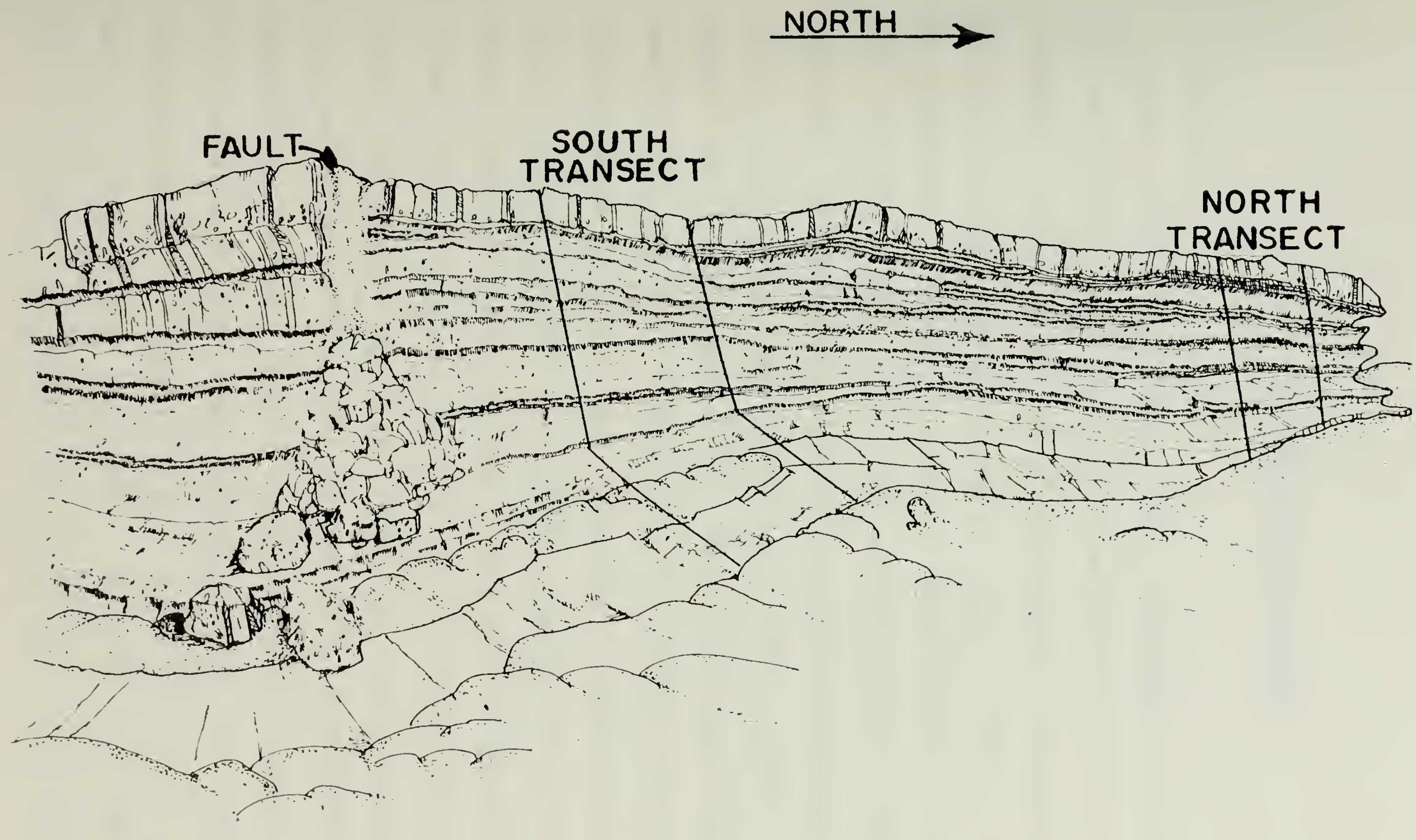

FIGURE 2. Three-Dimensional Artist's View of the Main Ledge.

III. MATERIALS AND METHODS

A. GENERAL

Minter (1971) and Booth (1972) point out the presence of some exceedingly large ledges in water of between 12 and 15 m of depth, in the center and seaward edge of the kelp beds. Using this information as a guide, divers visited this area and conducted a survey in which a large number of ledges were located. After the divers became familiar with the area and variety of geological structures that were available for study, several of the most likely ledges were marked with a small buoy. The ideal area would satisfy several requirements. First, it must not be too close to a large expanse of sand. The ledges were always bordered by sandy areas of varying size. The kelp did not grow in these sandy areas and the wave surge had a more pronounced effect. In addition these areas were easily silted by the divers' fins. The ledge of interest should be nearly parallel to the wave surge. The importance of this requirement was not immediately obvious, however, after the first exploratory dives were conducted it was apparent that the silting and resulting loss of visibility was less severe when the surge was not sweeping over the rocks. Some of the ledges that were found were oblique to the direction of the wave surge

and were prone to silt suspension due to increased turbulence. The diving operations were less hazardous when the surge moved the divers back and forth along the ledge instead of over and into it. Any silt kicked up by the divers' fins were also swept away from the site. The selected ledge should also have a diverse community of organisms. The size of the feature and the amount of area that could be studied was limited, and it was advantageous to choose a site with as much variation in types of organisms as possible in a small area. Additionally, it was necessary to choose an area that had a large population of rock-boring bivalves of various species. A number of the ledges investigated were either devoid of borers or had only one species in the vicinity. The shale off Del Monte Beach is known to be inhabited by two large species of rock-borers, Parapholas californica and Chaceia ovoidea. These two were found in abundance in some areas but not in others. In order to best assess the preferred regime of each species, and of the smaller species as well, it was necessary to find a rock formation that had a community of both. A large rock structure, that had clear geological variations in a fairly small area, would be useful in assessing the characteristics environments preferred by the various bivalves, and their associated fauna.

The study site eventually selected was chosen because it was fairly typical of the ledges in the area, and it offered the advantages discussed above. The base of the ledge was in 14.7 m of water. It was bordered to the east by a small sandy area, which had a dense population of the tube-dwelling annelid *Diopatra ornata*. The tubes of these worms seemed to hold the sediment in place and limited the silting to some extent. The selected ledge was oriented roughly north-south which meant that the wave surge was parallel to it. Any silting from the sand area was swept away, instead of over the area.

The ledge of interest had a number of other desirable characteristics. The area to the west was a fairly flat surface which extended for a distance of nearly 60 m with only minor variations. These variations consist of small steps less than 30 cm in height. Several of these steps were encountered near the area, however no rock-borers were found in these regions so only the nearest one was included in the study. These steps were undercut extensively in some areas often extending back for a distance of over one meter.

Diving operations were conducted in the area of the kelp beds from February, 1980 to April, 1981. A total of 93 dives were made during this period. Ten of these dives were made in the initial survey of the region, and 67 dives were required in the transect study. The remainder of the dives

were spent establishing the transect lines, mapping the study site, moving the buoy clump, and rigging the large rock samples for hoisting. Most of the diving and detailed work at the site was carried out between September, 1980 to March, 1981. The quadrats were established in August, 1980 and required between two and three dives per quadrat for detailed study. Each dive lasted from 45 to 70 minutes. The dives became shorter if they were the second or third dive of the day. Rarely were more than two dives performed on a given day since the divers experienced a degradation of their abilities due to the cold. The water at this depth is quite cold, averaging one to three degrees below the surface temperature. Several of the dives were aborted due to the total lack of visibility in the area or the heavy swell and accompanying surge. Most of the dives were performed in the morning, since the afternoon sea breeze made boat operations and boat diving fairly hazardous.

B. POSITION FIXING

After the ledge was selected, the site was marked with a buoy in order to allow the divers to return to the site easily, and to provide a secure place to tie the boat. The buoy is moored by two 20 Kg concrete clumps which were attached to the buoy by heavy nylon line. The top 7 m of the mooring line was steel cable in order to prevent the line from being cut or the buoys from being easily removed.

The precise location of the ledge was determined using a Motorola Mini-Ranger II system. The Mini-Ranger II is a short-range position fixing system which operates on the principle of a pulse radar. The transmitter, placed on board R/V Acania, was used to interrogate the radar transponder reference stations located at precisely known points. The elapsed time between the transmitted interrogation and the reply received at the boat is used as a basis for determining the range to each transponder. These ranges taken together yield a point fix which is then converted to a Latitude/Longitude position using a simple computer algorithm.

When used to locate the buoy, the transponders were placed at two stations, Mussel Point and Monterey Bay #4 (Figure 3). The location of the study site is seen in Figure 4. The location of these stations and the range to the study site as measured by the Mini-Ranger is given below.

STATION	LATITUDE	LONGITUDE	RANGE TO SITE
Mussel Pt	36-37-18.151N	121-54-11.628W	2880m
Monterey #4	36-37-31.138N	121-50-31.728W	3706m
Site	36-36-25.02N	121-52-36.30W	

TABLE 1. Geographic Location of the Reference Stations, Study Site and Range from Stations to the Site.

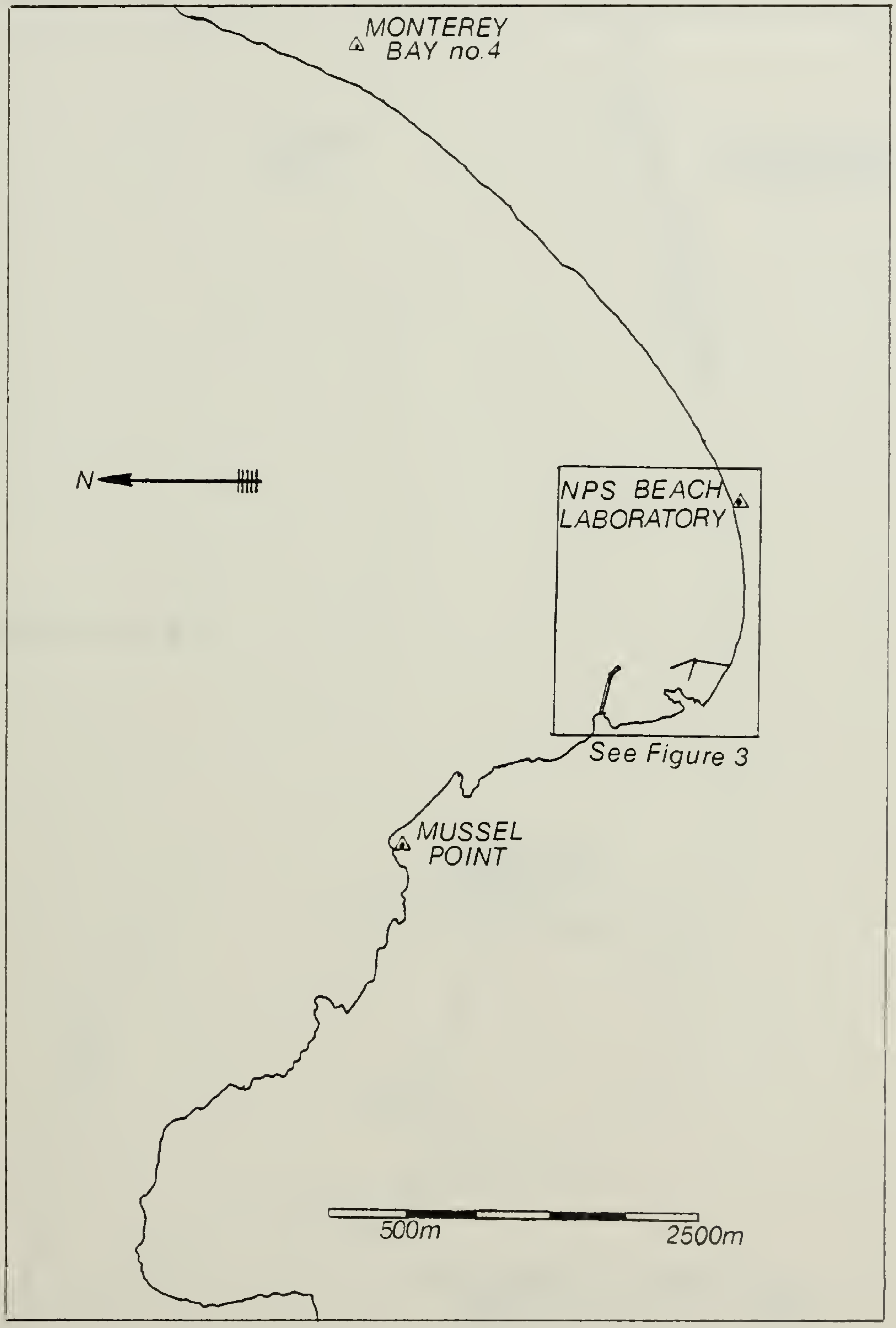

FIGURE 3. Southern End of Monterey Bay Showing Station Positions.

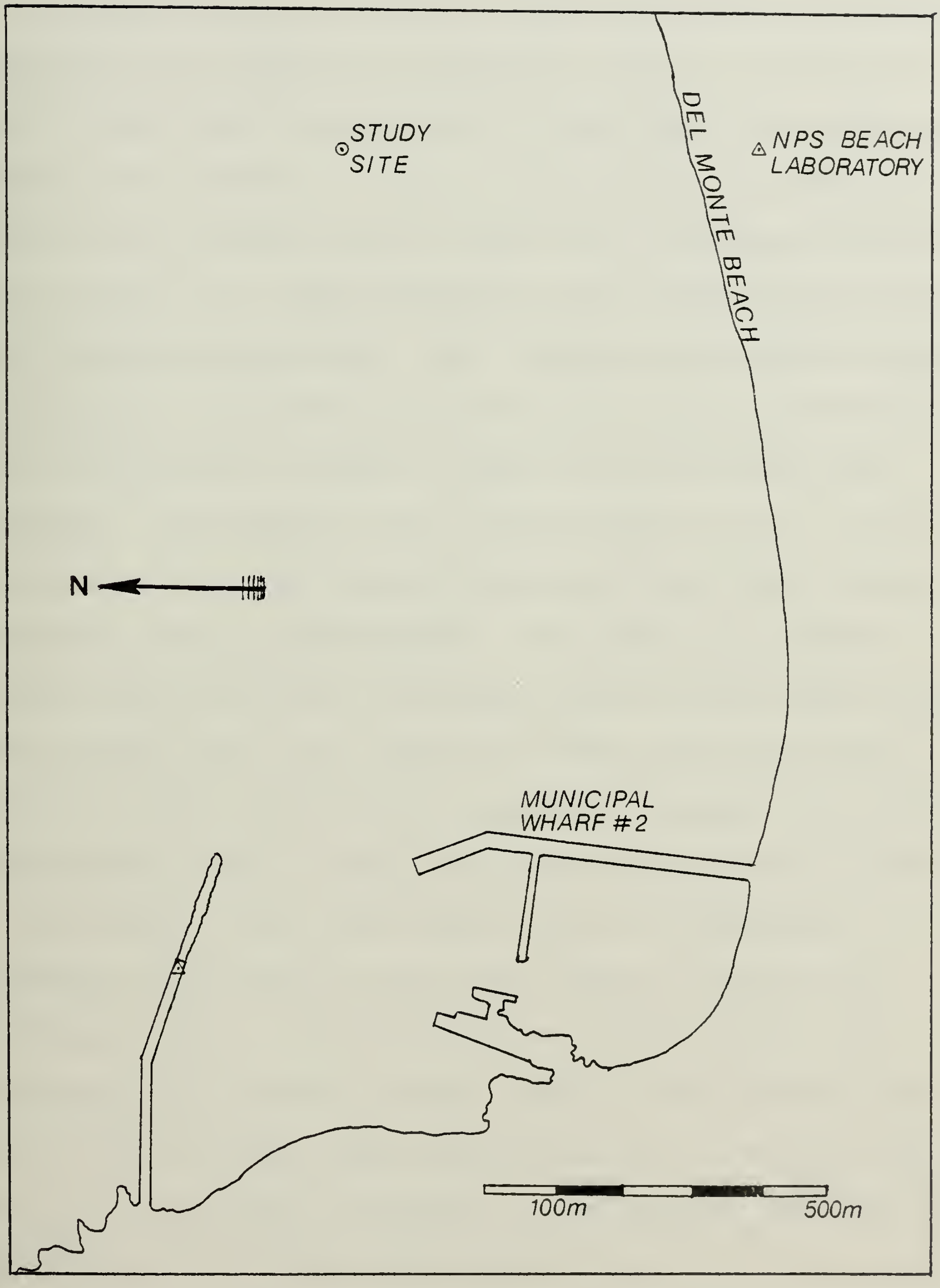

FIGURE 4. Location Map Showing Location of Study Site and Monterey Municipal Wharf Number 2.

C. WATER DEPTH DETERMINATION

The water depth at the site was determined by taking a sounding with a small 10 centimeter long divers "peanut buoy." This buoy was attached to 5 mm nylon line which was marked off in meters. The buoy was released and allowed to float to the surface and the depth was determined directly off of the line. The measurement was taken from the southeast corner of the ledge. The sounding was compared to the tidal gauge data collected at Monterey Municipal Wharf #2 and the depth with respect to Mean Lower Low Water was computed. The depth at this location was 12.9 m. A spike was driven into the rock at this point and it was used as a reference for all measurements. The depth was checked during each dive using a Scubapro helium filled depth gauge. These depths were also adjusted to Mean Lower Low Water using the tidal gauge data. Agreement between the sounding measurements and the depth gauge was always within 20 cm.

The depth of all other features of the ledge was determined by measuring the height above or below the reference point. The difference in depth between the reference point and the larger features was measured using one of the two-meter long aluminum quadrat crossbars marked off in 10 centimeter increments. The smaller features were measured with a plastic meter stick.

D. MAPPING

During the initial dives a sketch of the study area was made in order to provide an idea of the extent of the feature and the significant characteristics that were present. Using the southeast corner of the ledge as a reference, the surface of the ledge and the surrounding area was mapped for 15 m in all directions. Two divers measured the feature using a four meter long polypropelene line marked in ten centimeter increments while a third diver recorded the data on a plastic slate. The heights of the features were determined as discussed before. Quite often during this process the two measuring divers were out of sight of each other due to the low visibility. In this case, the recorder also acted as a messenger to communicate with the divers at each end of the line. While certain errors in measurement probably occurred by using the shorter line, it would have been much more difficult given the diving conditions to use a longer line. The wave surge, low visibility, and lack of convenient communication made this task exceedingly difficult.

E. TRANSECTS

In many ecological studies, transects or swaths are used to analyze a horizontal or vertical area of interest. Booth (1972) established long, one-meter wide transects from the beach in order to evaluate the horizontal distribution of

the rock-borers. Minter (1971) used squares of known area in which he established one-meter wide grids. In ecological work the one meter square area that is used as a reference is called a quadrat. Transects were used in this study to allow a systematic procedure for sampling organisms from every part of the rock reef. The one-meter quadrats along the transects were used to provide a standard area for recording the data and for determining the distribution of species within a reference area.

Two transects were established on separate parts of the ledge. These transects were 2 m wide in order to double the number of quadrats that were studied without having to establish and maintain four or more one-meter wide transects. The transects were established to include as many of the typical characteristics of the ledge as possible and were selected only after numerous dives were conducted to identify the best area for study. They extended across the surface of the ledge and out from the base to the edge of permanent sand deposition. Since there were no borers living in the sandy area at the base of the ledge it was not included in this study. A plan view of the entire ledge showing the location of the two transects can be seen in Figure 5. The two transects were permanently marked by hammering mountaineering pitons into cracks in the rock at the four corners of each area. Where no cracks were found,

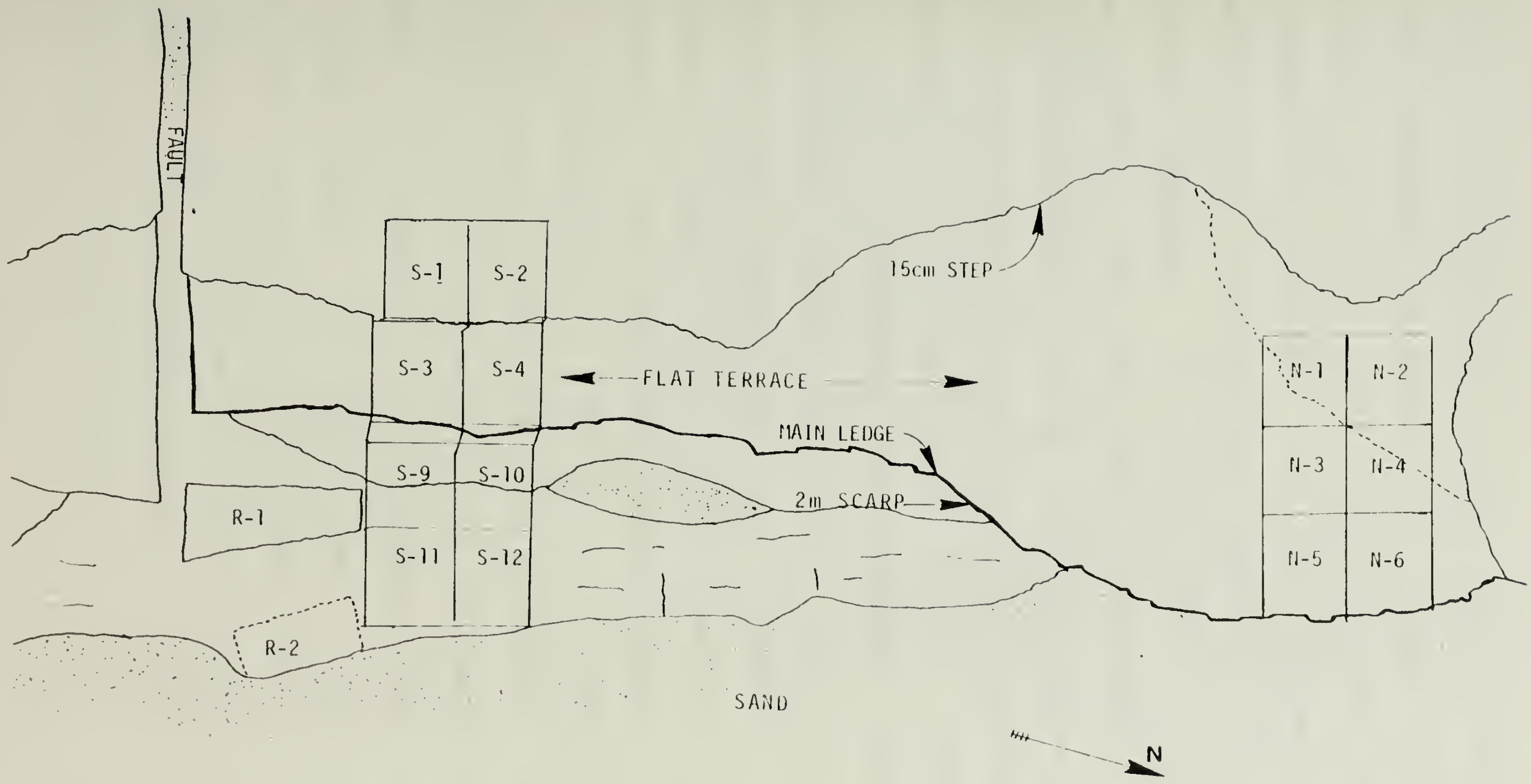

FIGURE 5. Plan View of the Study Area Showing Location of Transects, Horizontal Quadrats and 2 Large Rocks.

holes were made by driving a chisel into the rock and using this for the piton. A length of 10 mm polypropelene line was strung between the pitons to delineate the outline of the two-meter wide transect. The first transect was located two meters north of the southeast corner of the ledge. This was called S-transect. The second transect was 14 m north of the reference point and is called N-transect. Figure 2 is a three-dimensional view of the entire ledge showing the relative positions of the two transects. Three-dimensional cross-sections of the transects are shown in Figures 6 and 7. A three dimensional cross-section of an area between the two transects (Figure 8) shows the variations in the exposed face that occur within short distances.

N-transect was 5 m long and consisted of 10 quadrats. The surface of the ledge was 3 m long and the vertical face under the ledge was 2 m. The base of the ledge was completely sand covered year round so was not included in the study. S-transect was 6 meters long and included 12 quadrats. Two quadrats were on the small step and two were on the main ledge. Four quadrats were located under the ledge, and four were on the horizontal rock at the base of the ledge. Figure 5 shows a plan view of the ledge and the location of the horizontal quadrats. The vertical quadrats are displayed in Figures 6 and 7.

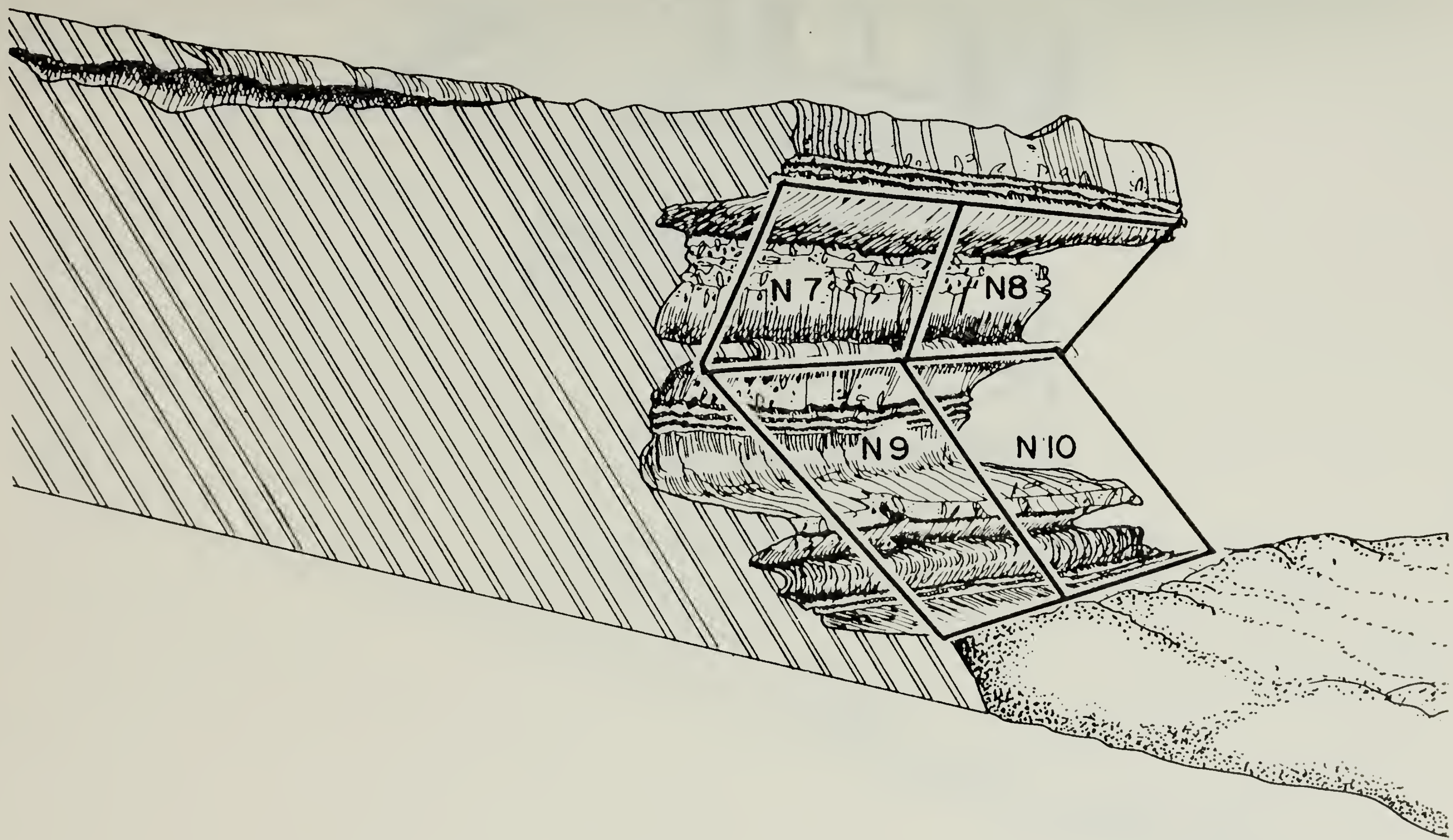

FIGURE 6. Three-Dimensional Cross-Section of the North Transect Showing the Vertical Face and Location of the Vertical Quadrats.

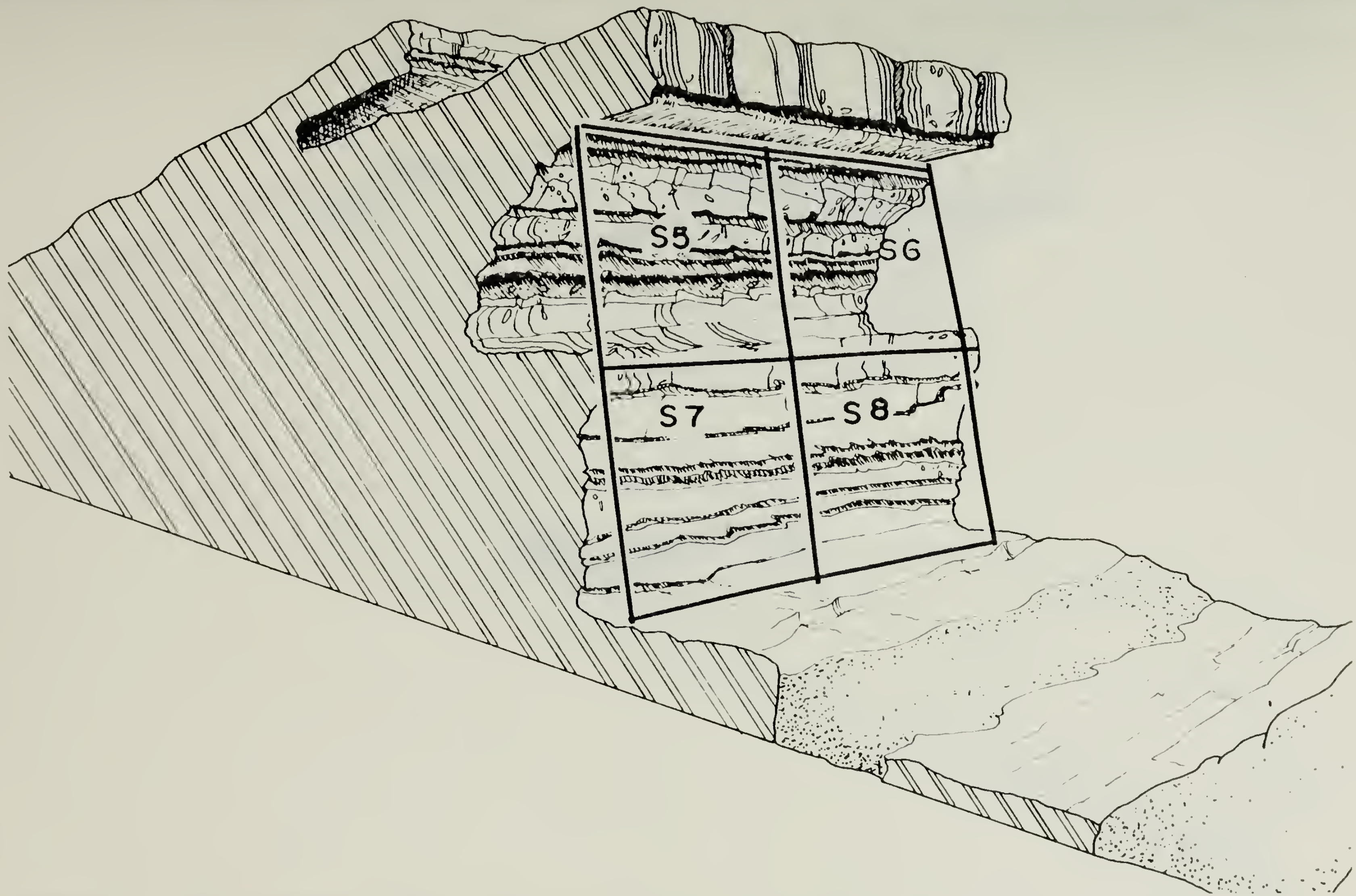

FIGURE 7. Three-Dimensional Cross-Section of the South Transect Showing the Vertical Face and Location of the Vertical Quadrats.

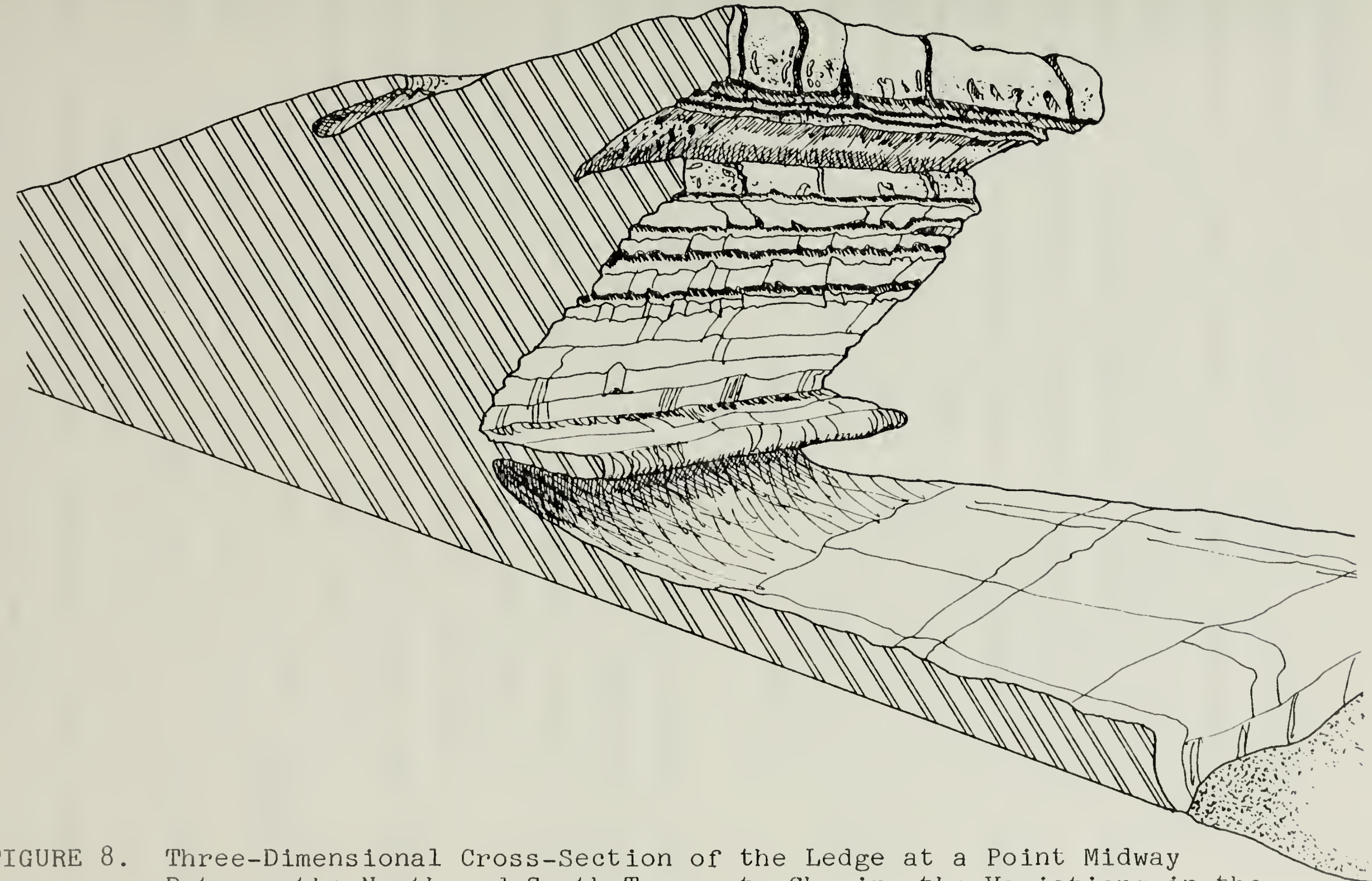

FIGURE 8. Three-Dimensional Cross-Section of the Ledge at a Point Midway Between the North and South Transects Showing the Variations in the Rock.

F. QUADRATS

The analysis of the one-meter square quadrats was carried out in order to gain a thorough knowledge of the various organisms found in the area and at the same time ascertain the preferred substrate. In order to count and identify the endolithic organisms it was necessary to actually break the rock and remove the organisms from the burrows and holes. The two-meter wide transects were subdivided into one-meter square areas by using a pair of aluminum crossbars. These bars were notched in the middle and are marked in 10 cm. increments. The method of operation is illustrated in Figure 9.

The surface organisms were identified and counted first. A master list of the previously identified organisms printed on plastic sheets was used to aid in in-situ identification. The lists were kept on a clipboard and the number of individuals of each species was marked on the sheet in grease pencil. After the surface organisms were tabulated, the boundary of the quadrat was projected in three dimensions down through the rock layer, and this <u>volume</u> was sampled. The same volume of rock could not always be sampled in each quadrat, so a numerical count of the endolithic individuals could not be effectively conducted. The relative abundance of the various species could be determined and these comparative values were recorded. The

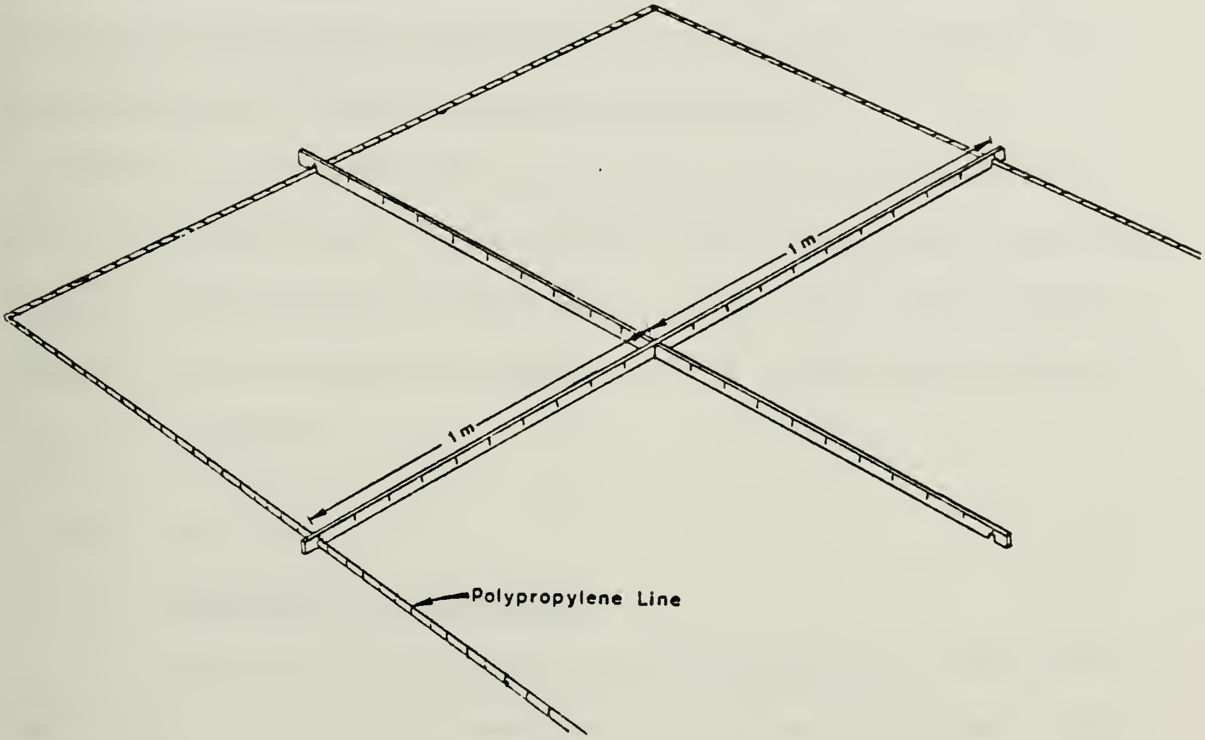

FIGURE 9. Method of Operation of the Quadrat Cross-Bar

horizontal surface quadrats were projected down through the large chert layer, but did not include any of the vertical rock that was under the ledge. The vertical rock was projected back under the ledge and was sampled extensively by breaking off large quantities of rock.

Most of the rock that was broken off was examined in-situ or in the boat. Some of the rock (about 10%) was taken to the laboratory for examination. The data includes two large rocks that were recovered by R/V ACANIA and examined in the laboratory.

G. DATA ANALYSIS

1. Collection of Specimens

During the preliminary dives and during the quadrat sampling, it was often necessary to collect specimens which were new to the observer or not identifiable in-situ. In the early dives, large pieces of rock were broken off using a hammer and chisel or a geologist's hammer. In the area under the ledge it was not possible to swing the hammer due to limited freedom of movement. In this area the rock was broken using a pneumatic air-gun adapted for use with a SCUBA tank.

This broken rock was then lifted to the surface using one of several methods. Two very large pieces of rock were lifted by winch to the deck of R/V ACANIA. Smaller pieces were placed in a nylon mesh collecting bag and

floated to the surface using a mouth inflatable buoyancy compensator. The nylon mesh bag allowed some of the smaller forms to escape and did not provide any protection for the delicate or fragile specimens. Some of the smaller rocks were placed inside plastic bags or wide mouth 3.7 liter jugs in order to prevent the loss of small, mobile organisms.

The collection techniques described by Minter (1971) were valuable in this instance and were followed for most of the small invertebrates. Tunicates, sponges, and coelenterates were carefully lifted from the substrate using a 5 cm wide paint scraper. Small crabs, gastropods, echinoids and large annelids were carefully lifted by hand or with large forceps and placed in the jars. Mobile organisms such as the shrimps and the smaller fishes were trapped by pushing them into a wide mouth glass jar using a 7.5 x 12.5 cm small mesh fish net. Some practice was required to perfect this technique. Larger fishes were identified in-situ.

2. <u>Study of the Rock</u>

The first laboratory work consisted of the breaking and careful analysis of a large piece of rock that was recovered from the base of the ledge. This was block of chert which had broken off the main ledge as a result of severe undercutting. This block was lying at the base of the ledge where it had fallen. The location that the block

of chert occupied before breaking off was readily identifiable under the ledge and is labeled R-1 in Figure 5. The piece was lifted by R/V Acania and was transported to the laboratory in a pick-up truck. Once at the laboratory a sketch and measurements of the block were made. The surface organisms were identified or collected and labeled for later identification. The rock was then broken into smaller pieces using a hammer and chisel and geologist's picks. The endolithic individuals were removed for identification and counting. Several of the larger fragments of rock were maintained in aquaria in the laboratory and examined carefully in order to locate and identify some of the smaller and endolithic organisms which had escaped our attention in the diving phase or in the breaking up of the rock. A second large rock was broken out of the layer at the base of the ledge (R-2 in Figure 5). It was subjected to the same analysis as the first rock.

3. Chemical Analysis of the Rock

In order to better assess the characteristics of the shale, particularly the vertical variations, a number of samples were removed for chemical analysis. In previous work on reefs in Santa Cruz, Clark (1978) determined the level of calcium carbonate in the shale. A similar determination was made by Haderlie (1980) for subtidal shale from Monterey Bay. In order to compare the rocks that were

collected in this study with the rocks collected by Haderlie and Clark, similar determinations were made. Hardness tests were not conducted since there is no universally acceptable method for testing sedimentary rocks, as hardness depends not only on the individual constituents but also on the cementing agent (Clark, 1978). The samples for analysis were taken from each easily definable layer in the vertical face of the ledge. The samples removed were far in excess of the amount required to allow a sample to be later removed from inside the rock. The abundance of spirorbids, barnacles, and bryozoans made it much more difficult to get a sample that was not contaminated with some deposited calcium unless great care was taken. The samples removed from the softer rocks in the vertical region were often completely permeated with small holes and other perforations and had some type of benthic organism on nearly every surface. The samples were rinsed carefully to remove any surface salt water and allowed to dry for several days. After the rock had dried it was broken into smaller pieces which were more suitable for analysis. The samples were taken out of the center of the rocks where possible. Where this was not possible, the surface of the sample was brushed carefully with a wire brush to remove all of the encrusting organisms. The rock was then washed again to remove any residue or powdered calcium. After it was dry, the samples

were ground into powder using a mortar and pestle. The samples were analyzed for calcium at the U.S. Geologic Survey branch office at Menlo Park, California. They were processed using a LECO W12 Carbon determinator. The full details of the process that was used was as described by Clark (1978). Briefly stated, the determinator subjects some of the powdered samples to hydrochloric acid and measures the carbonate gas that is released. Another part of the sample is then tested for organic carbonates to allow the determination of the total calcium carbonate present in the sample.

4. Photography

No attempt was made to include underwater photography in this project. The lack of adequate lighting, the wave surge which is present so much of the year, and the limited visibility in this area makes photography by an unskilled individual frustrating and fruitless. A large body of photographs of most of the organisms that were of interest already exists and is available. Booth (1972) and Haderlie (1975) include a number of photographs showing the siphon characteristics of many of the rock-borers for in-situ identification. These siphons are illustrated in Figure 8. Some photographs were taken in the area in order to provide some impression of the extent and geology of the area. The only significant effort at photographing the

ledge was done in conjunction with the operational testing of an underwater television camera. An attempt was made to get black and white still photographs from the video-tape, but the effort was not successful. The video-tape and the still photographs were used to provide a view of the ledge for the three-dimensional artist's sketches of the transects. These artist's conception of the ledges show more detail than would be possible using photographic techniques (Figures 7-9).

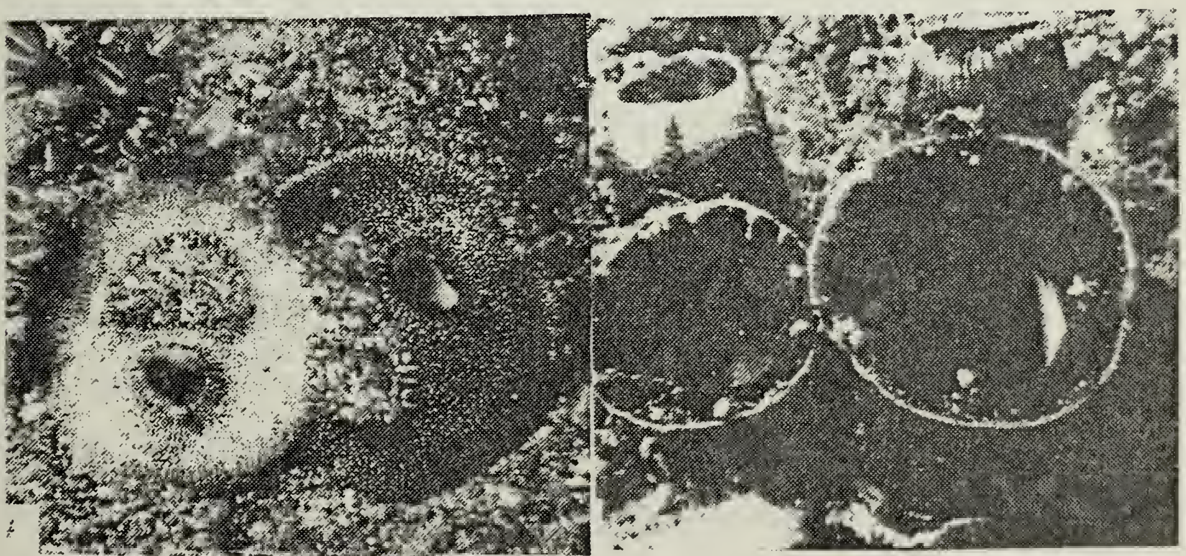

FIGURE 10. Siphons of Parapholas californicas (Left) and Chaceia ovoidea (Right) Showing Distinctive Morphology (from Haderlie, 1975).

IV. DISCUSSION OF OBSERVATIONS AND RESULTS

A. LEDGE CHARACTERISTICS

The ledge studied in this project is oriented 345 degrees true and is roughly perpendicular to the beach. It extends nearly 120 m southward from the reference point on the ledge. Twenty meters to the north, the ledge and another formation to the east run together and are covered with sand and rubble. The primary ledge disappears at this point. The ledge is also not continuous along its length to the south but is interrupted in at least three locations. The main break occurs at the location previously described as the southeast corner of the ledge. At this location there is a fault that breaks the ledge and continues to the east and west for several hundred meters. This fault is filled with sand and annelid worm tubes (*Diapatra ornata*) for its entire length. It is 400 cm wide at the edge of the ledge and narrows to 10-12 cm to the west. the fault line was followed on one dive nearly 200 m to the west without any indication of deviation or diminishment. It could be traced to the east by the *Diapatra* tubes for nearly 100 m.

The study area is located about 50 m from the seaward side of the kelp beds. There is a region of permanent sand deposition to the east which is either occupied by *Diapatra*

or is barren. Rock ledges and similar structures are found again on the other side of the sandy area. There are several other ledges to the east that were examined in the early stages, some of which were quite large and well defined.

To the west the rock is never covered by sand and is fairly flat with occasional step-like features. These features are mostly parallel to the ledge and are rarely more than 15 cm high. Some of these steps are over crevasses and some are flat rock faces. There are only two steps within 20 m to the west. To the south, the sandy area diminishes and is often replaced by exposed rocks. These rocky areas are a combination of solid substrate exposed by sand removal, or the collection of rubble and rock debris from other sources. Forty meters to the south the sandy region is split in two by a tongue of rock about 1 m high. This rock area widens to the south and develops into a series of ledges on both the eastern and western sides. Thirty meters further, the rock disappears and is replaced by an expanse of sand that extends for several hundred meters to the south and east. The extent of the ledges and exposed rock can be determined in this area by observing the area of *Macrocystis* growth. In the areas where no kelp occurs the rocks are covered by sand a large part of the time. Some of these areas of exposed shale are frequently

covered by sand and are scoured by suspended sand most of the year.

The shale under the chert ledge consists of a number of thin layers of softer shale. These layers are from 2 to 15 cm in thickness. The layers that are slightly harder than those above and below resist weathering and can be seen to extend beyond the face by up to 25 cm (Figures 6-9). There is a soft layer in the hard chert rock that covers the ledge. This soft layer is 4-5 cm thick and can be traced the length of the ledge. This layer is the only place in this rock where borers can be found.

B. BIVALVE BORER DISTRIBUTION

As can be seen in the appendices, the larger rock-boring bivalves were found in some number in most of the rock surfaces. Chaceia ovoidea and Parapholas californica, the largest of the bivalve borers in the area, were found together in the horizontal regions that were protected from sand deposition (Quadrats N-1,2,3). This region had a thin layer of unweathered softer rock, about 15 cm thick, overlying the very hard chert of the ledge. Chaceia and Parapholas are absent from the step and from the surface of the chert ledge. The rock that makes up the step is extremely brittle and fractured, and while it is very hard it is easily broken. The surface of the chert ledge was pitted and scarred, evidently as a result of borers

penetrating a softer overlying rock but not being able to penetrate the chert ledge. There was a distinct variation in the areas that each species seemed to prefer. *Chaceia* were found most commonly in the vertical areas of the ledge. *Parapholas* were found in the vertical areas, however they were not as abundant as *Chaceia*, the ratio being about one in four.

The *Parapholas* were found most commonly in the horizontal surfaces at the base of the ledge. This area was susceptable to heavy wave action and sand motion. These borers were very often buried under several centimeters of sand and could only be detected by brushing the sand off of the rock. *Parapholas* is obviously adapted for life in this sand regime having siphons that are surrounded by numerous branched cirri (Booth, 1972). It is this structure that acts as a filter to prevent sand from entering the siphon. *Chaceia*, on the other hand, lacks any protective structure to prevent sand from entering the siphon. The siphons of these species are seen in Figure 10. During periods of heavy surge and high sediment suspension, the siphons of *Chaceia* were most commonly restricted to a very small opening. The siphons were not withdrawn completely at this time, however, it could be seen that the flow of water was severely restricted. The one *Chaceia* that was found on the lower rock was boring in from the base, parallel to the

surface of the rock. This area was swept clear of sand evidently due to the venturi effect of the water flowing past the elevated rock and the sand *Diapatra* mounds.

The smaller pholads, the *Penitella* species, and the mytilids, *Lithophaga plumula*, and *Adula falcata* showed a similar variation. Members of the genus *Penitella*, notably *P. gabbi* and *P. conradi*, were found in greatest abundance in the rock that was least penetrated by the larger species. The main ledge and the step were occupied by a large number of these borers. *Lithophaga* was found quite frequently in the upper rocks, but was not found at all on the lower ones. Mytilids of the genus *Adula* were exceeding common in the rock surface at the base of the ledge. They were quite abundant in this sand covered region and were of significant importance in the primary penetration of the rock.

The empty shells of some of the rock-borers persist for quite some time in the abandoned burrows. Several very large shells were recovered from rocks, the surface of which had weathered to the extent that the shell was easily lifted free from the surrounding rock. Most of the shells of the mature pholads were intact and showed little sign of wear. Many of these shells acted as shelter for the variety of nestlers that later inhabited the burrow. Very few shells of dead *Adula* or *Lithophaga* were found. The rapid disintegration of these shells seems to be due to the sublayers of

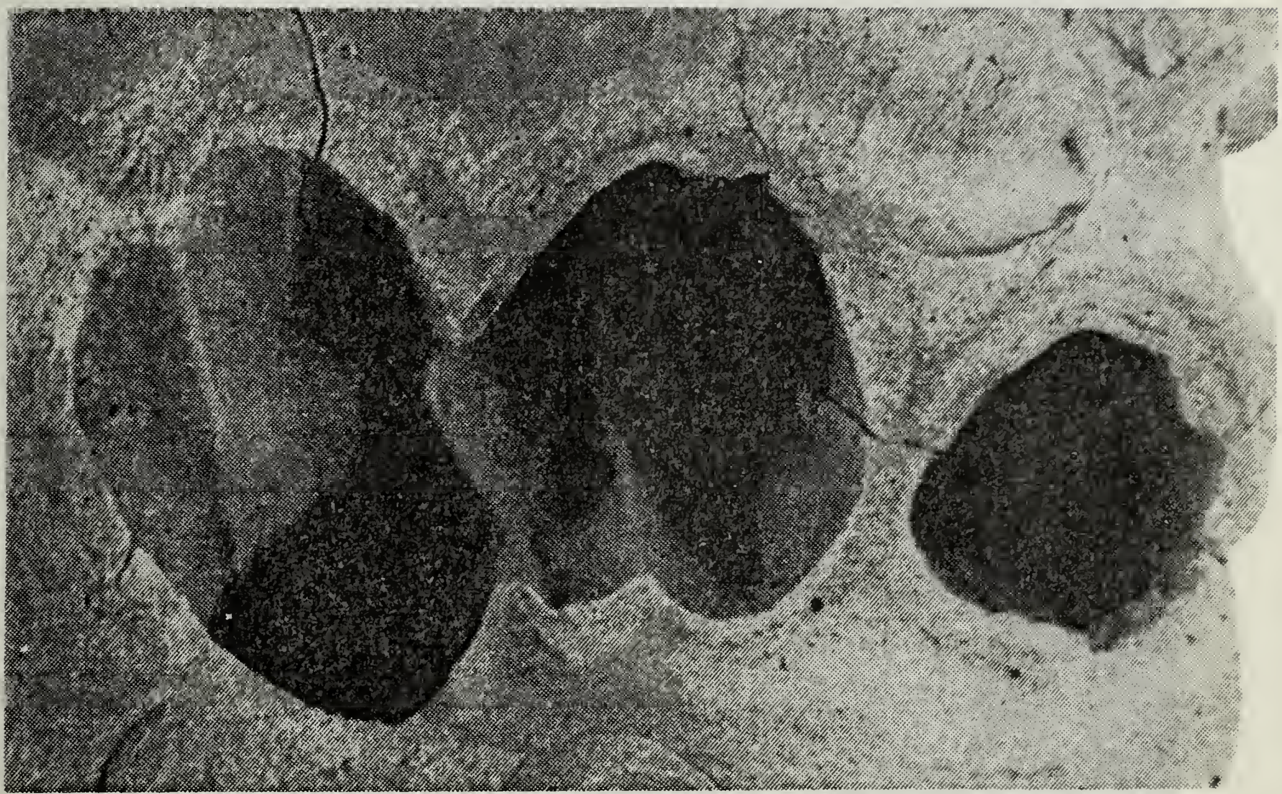

FIGURE 11. Cross-Section of Three Mytilid Burrows (Adula) Showing Distinctive Shape.

the protein conchialin (Haderlie and Abbot, 1980). The empty burrows of these mytilids are quite distinctive and can be readily identified in the rock (Figures 11 and 12).

C. IMPACT OF THE BORERS ON THE ENVIRONMENT

The activities of the rock-boring bivalves have an important impact on the environment in a variety of ways.

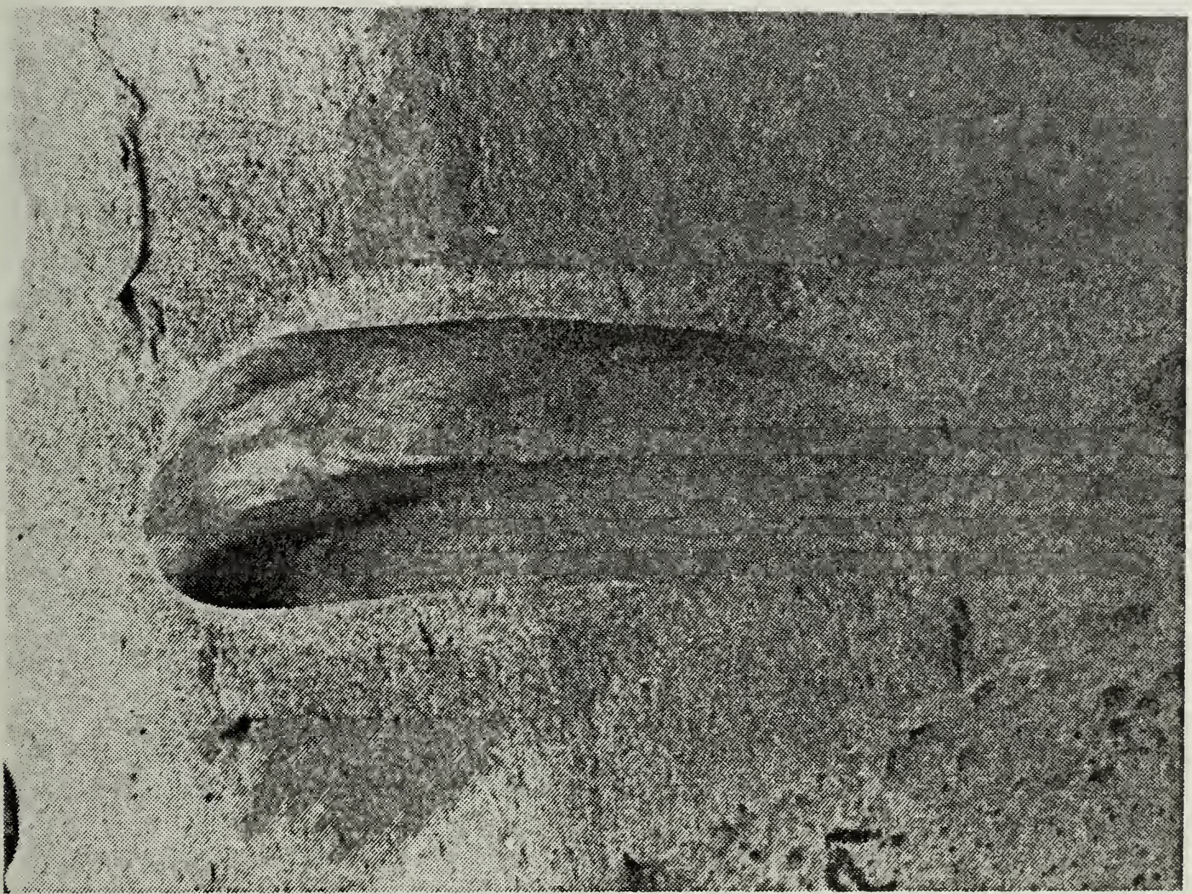

FIGURE 12. Horizontal Cross-Section of a Mytilid Burrow (Adula) Showing Longitudinal Ridge.

First the softer shale is attacked more readily by borers and is removed by wave surge or weakening. When this softer rock is under a harder rock, overhangs and steps are formed. These steps can be from a few centimeters high, to the 2 m high ledge that was the area of study. Typically the small

overhangs provide a shelter for those larger organisms that require protection. A large variety of rock fishes could be found under these ledges. Abalone and sea urchins, favorite prey of the sea otter, were only found in the deepest recesses of these ledges but even here they were not safe as numerous empty shells were found scattered on the bottom. Some of these shells were rubbed almost flat on top by abalone growing in its tight refuge (Figure 13). Large barnacles (*Balanus nubilus* and *B. aquila*) were also found under these narrow ledges where they were protected from sea otters and siltation and were still exposed to fairly strong currents.

Another important affect of the pholads is in the creation of protected burrows for nestlers and soft bodied organisms to inhabit. A number of mollusc nestlers can be found in these burrows, and the soft bodies sipunculids are common members of this community. Examples from nearly every phylum were found seeking refuge in the holes. Some were transients, using the burrows as a place to find food, others were unable to leave. By far, the most diverse members of this community were the polychaete annelids. A wdie variety of errant and sedentariate polychaetes were found not only in the holes left by the pholads, but were in holes of apparently their own making. The holes provided

FIGURE 13. Abalone Shell Showing the Erosion of the Surface.

refuge for some organisms from which they would forage for food. These included small fish (*Neoclinus*), octopus, and many small crustaceans.

Evans (1968) lists a number of the larger or more common of the organisms that are found inside abandoned burrows. He lists 18 members of 6 phyla that are commonly found in the regions of Coos Bay, Oregon. He also notes that these organisms are more abundant and diverse on open coast regions. A number of environmental characteristics affect the size of the population and the variations of the species found in the endolithic community. In the Del Monte kelp beds, two major factors can be identified as significantly affecting the organisms. The most important characteristic is the hardness of the rock and its ease of penetration by borers. The second is the affect of wave surge and resultant sand scouring and deposition. The rock that is not penetrated by borers will have a diminished community of nestlers.

The rock at the base of the ledge was commonly covered by 2 to 4 cm of sand. The empty burrows and abandoned shells were packed with sand and had less variety of inhabitants than the empty shells found in the vertical face. Molluscan nestlers were not seen at all in this area. The sand packed shells at the base of the ledge rarely

contained the number of individuals that were found in the other regions. These burrows usually contained only one or two very large polychaetes or a few large sipunculids (*Themiste pyroides*).

The vertical rock had a large variety of nestlers and much larger populations than that found at the base of the ledge. A great many of the burrows were filled and packed with sediments which appeared to have been accumulated by the inhabitants of the burrow. Many of the terebellid polychaetes formed tubes in the collected sediment. The empty shells and abandoned burrows were often densely packed with a wide variety of organisms, and a number of errantiate organisms were able to take advantage of the holes for protection and foraging. The smaller molluscan nestlers are found less commonly in the very large holes abandoned by *Chaceia* or *Parapholas*. Rather they prefer the smaller burrows abandoned by immature pholads and the smaller species of *Penitella*. Nestlers were found rarely in holes that could by identified as those of the mytilids *Lithophaga* or *Adula*.

In many areas there were cracks or fractures in the rock that were up to one centimeter wide. These fractures existed both in the horizontal rock where the layers were exfoliating, and in the vertical, where the thick rock

layers were breaking along some plane. These vertical fractures were most commonly observed in the thick chert layer and in the thick rock at the base of the ledge. When the rock samples were being removed from either of these surfaces very often a much larger piece would break off in a block parallel to the edge. The fractures found in the rock at the base of the ledge often extended the length of the exposed rock. These fractures were so extensive here that if the rock had not been supported by sand it would have fallen apart. These fractures did not appear to be associated with any molluscan borer penetration, rather they seemed to be a product of weathering. The process of weathering and the eventual destruction of these rocks was probably hastened by the settlement of some of the nestling individuals. Sipunculids and holothuroidians can squeeze into these fissures and exert a considerable pressure. There is no way to assess the amount of impact that nestlers had in this form of weathering, however in nearly every sample where the rock was deeply fractured sipunculids, annelids, small decapod crustaceans and echinoderms had settled in the crack and the rock was gaping apart to some degree.

D. BORING ORGANISMS

1. Boring Mechanisms

While a number of researchers have attempted to explain the method of substrate penetration by various organisms, there has been no significant progress made. The actual mechanical technique employed by the pholads in penetrating the softer substrates, has been documented in a number of sources (Ansell and Nair, 1969, Haderlie and Abbott, 1980). The method of rock penetration by sipunculids and annelids (Rice, 1969, Warme and Marshall, 1969) and the method of penetration of hard chert by bivalves is still a total mystery. While there was no extensive penetration of chert observed in this study, other researchers have found the hardest chert penetrated by both pholads and mytilids (Haderlie, 1980). Figure 14 shows a polychaete burrow in medium hardness shale. Surrounding the burrow can be seen a 1 cm wide area of weathered rock. If this weathered rock is somewhat softer than the surrounding rock, a possible method of penetration by the softer bodied organisms might be that the individual particles of this sedimentary rock can be lifted more easily from the rock matrix.

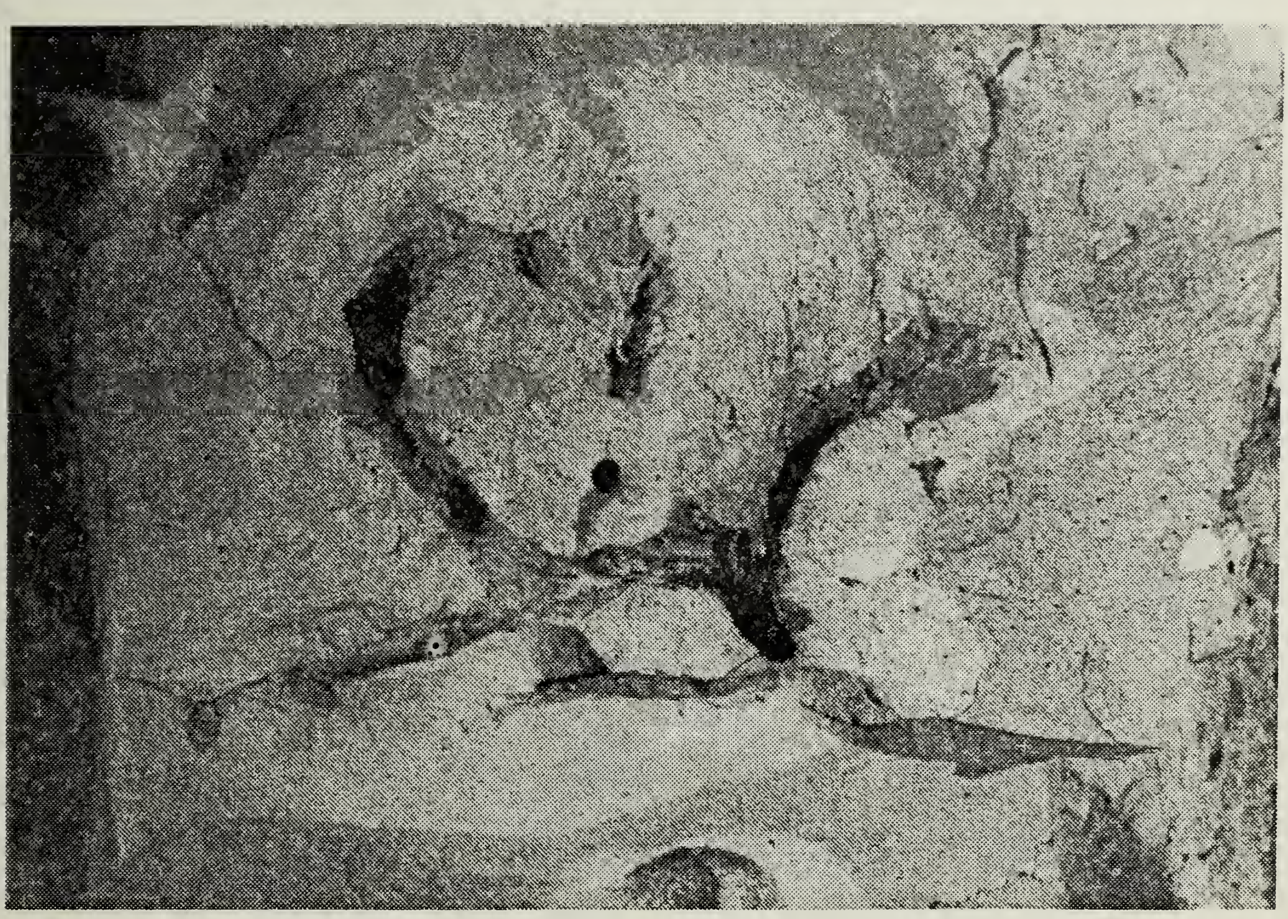

Figure 14. Annelid Burrow Showing the Depth of Penetration of Weathering into the Rock.

2. Sipunculids

The two species of sipunculids found in this area Phascolosoma agassizii and Themiste pyroides favor characteristically different areas in the rock. Phascolosoma is exceedingly abundant in the upper ledges and in the highly perforated vertical face. They are clearly nestlers and are found in every type of burrow, crack, or crevice. In most cases they are found nestling in holes with a wide variety of other nestlers. Commonly they are found tightly wrapped

among the leathery tubes of the annelid *Phylocheatopterus prolifica*. They are rarely seen inhabiting a hole alone and very often there are 10-15 sipunculids wedged tightly into the shell of a small *Penitella* or *Chaceia*. *Themiste pyroides* favors the lower ledges which are often silted and are subject to harsher scouring. It is also not quite so social as *Phascolosoma* and is rarely seen with more than one other individual. The total number of *T. pyroides* that were seen was much less, they were much more abundant here than *P. agassizii*. Only a few individuals were found in the upper ledge and vertical face, while they outnumbered *P. agassizii* about 5/1 in the lower rock. Additionally *T. pyroides* is much larger than *P. agassizii*, with a typical retracted specimen almost double the diameter of the largest *Phascolosoma*.

The ability of sipunculids to bore into $CaCo_3$ substrates has been suggested and investigated, and possible mechanisms for this activity have been postulated (Rice, 1969). While Rice looked specifically at species of the genus *Phascolosoma* in her study, there is no evidence that *Phascolosoma agassizii* can bore into shale. *T. pyroides* were often found in large holes that were not of the same characteristic shape as that of the bivalve borers (Figure 15). *T. pyroides* was often removed from burrows that were rounder at the base and less pear shaped than was

FIGURE 15. Large Burrows to Left and Right are Typical of the Burrows from Which the Sipunculid Themiste pyroides was Removed. The Middle Burrow is a Typical Pholad Burrow.

typical for Penitella sp. or other pholad burrows. They also lacked the imprint of the shell on the sides which can be seen readily in many of the burrows formed by pholads (Figure 16). The burrows in which T. pyroides were most often found were smooth and round at the base and very narrow at the neck with the neck region very often sinuous. The worms also fit into these holes quite tightly when undisturbed. The hole while initially the product of the

FIGURE 16. Imprint of Pholad Shell at the Base of the Burrow.

bivalve, may have been altered to some extent by the activity of the sipunculid. While conclusive evidence is lacking, observations suggest that Themiste pyroides can alter it's burrows to some extent.

3. Boring Polychaetes

Many of the polychaetes are known to bore into calcium carbonate substrates however, worms boring into siliceous shale have not been documented. A number of the various worms that are known to bore into shells or limestone are found in this area. Species of Polydora,

Dodecacarea, and *Boccardia* are all found here in relative abundance, however, none of these were found in holes which could be attributed to their own efforts. *Dodecacarea* were found in secreted tubes in fractures in the rock or in characteristic colonies on the surface of the rock. *Polydora* and *Boccardia* were found in shells but were most commonly seen in mud filled burrows. Only rarely were any pholad shells penetrated by any boring worms. Virtually all of the worms that were found in any abandoned shells were occupying dead *Balanus nubilus* or *B. aquila* shells.

Throughout the rock there are a number of small diameter borings which could not have been made by mussels or sipunculids, because the holes were small or they twisted down as tunnels for several centimeters into the rock (Figures 17 and 18). They were more common on the soft mudstone found on the bottom of the lowest area, however, holes that fit this description were found in some extent in every layer. Rarely were any worms found in any of these borings. Several of the holes that were found did yield worms that could have been the primary excavators. The eunicid *Palolo paloloides* was found in small diameter burrows in five separate rock samples. These worms were commonly found buried several centimeters deep in the rock in tubes that stretched up to 15 cm long. The fact that they were commonly found in burrows that closely fit

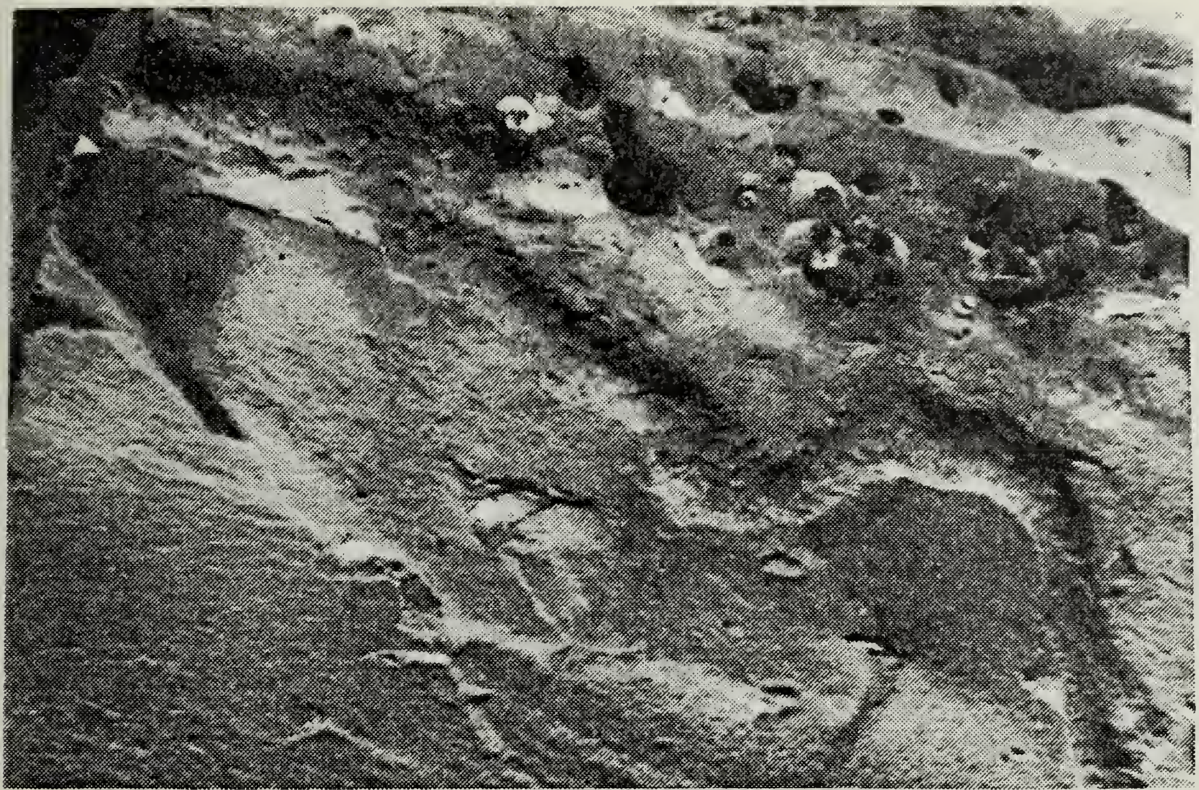

FIGURE 17. Annelid Burrows Showing the Very Rough Tunnel Walls.

their body, and that they are known to bore into coral, leads one to suspect that they can form their own burrows in the Monterey shale. The burrows were usually parallel to the surface of the rock and were from 4 to 10 cm deep. The opening could be either the wall of a pholad hole or from the surface of the rock. The method that might be employed for penetration is not obvious since they have no readily identifiable organ or structure that might be capable of penetrating this hard substance. Several

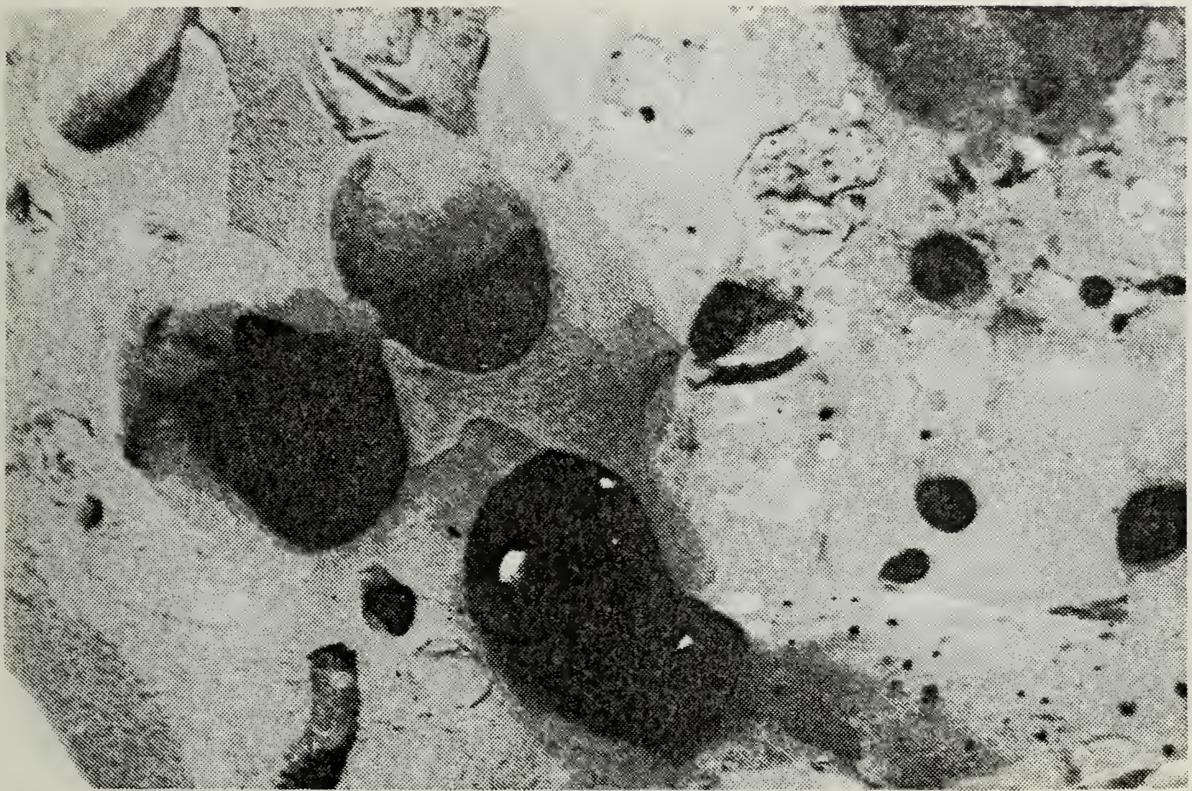

FIGURE 18. Pholad Burrow Showing Penetration at the Base by Annelid Worms.

lumbrinerids were found in tubes of similar construction. These burrows also fitted the worms closely and had characteristics similar to those seen in the case of *P. paloloides*.

Underneath the rock at the base of the ledge at transect S (Quadrats S-11/12) and in many places in the vertical region, the surface of the rock was pitted with a large number of small holes (8-10 per 10 cm square). No living organisms were ever found in these holes, however, nearly 60% of these holes contained small leathery tubes.

FIGURE 19. Rock Sample of Soft Mudstone Showing the Paired "U"-Shaped Annelid Burrows

These holes were actually small "U"-shaped tubes which penetrated several centimeters into the rock. These tubes were not unlike those occupied by <u>Phyllochaetopterus prolifica</u> except that they are much smaller and more fragile. Several small lumbrinerids and syllids were found in some of the empty holes while no living organisms were found in the tubes. The small, empty "U"-shaped burrows are seen in Figures 19 and 20.

FIGURE 20. Close-Up of "U"-Shaped Annelid Burrows.

E. NESTLING ORGANISMS

1. Crustacean Nestlers

Many of the decapod crustaceans identified here utilized the empty borings for protection in some parts of their life cycle. The daytime dives often recovered rocks with the crabs *Pachycheles rudis* and *P. pubescens* wedged tightly into small holes with their large claw acting as a plug (Haig and Abbott, 1980). These species were quite abundant in the upper ledge and on the vertical face. They were not observed on the surface of the rock and when

removed from a burrow they immediately sought refuge in another one. The anamuran hermit crabs were found inhabiting a wide variety of protective coverings. *Pagarus hirsutiusculus* and *P. samuelis* were quite common in this area and were found with old worm tubes, *Macrocystis* holdfast pieces, and gastropod shells. Several small *P. hirsutiusculus* were found inhabiting small bore holes in the side of the rock. The small crabs had no shell to protect them and were not found unprotected anywhere else. The burrows that these individuals occupied were on the lower edge of the main ledge in an area of high water motion. It appeared that the small crabs were not able to find a shell to inhabit, and they lived in the rock instead. The area that they inhabited was on the soft shale layer in the vertical face of the upper chert ledge. Their small holes were rarely more than 1 cm wide at the mouth. These crabs resided alone and apparently were able to survive on the detritus that is present in the water. *P. samuelis* were not seen inhabiting the bore holes. Another type of nestling by the hermit crabs was observed. Commonly the crabs that occupied shells or bits of tubes would pull themselves into burrows or into sand filled depressions. This behavior was most noticable when the wave surge was high, and the crabs appeared to be anchoring themselves to the bottom in order to control their movements. These

individuals were not truly nestling but only seeking temporary refuge from the effects of wave surge. Similar behavior was noted by some of the larger gastropods *Ceratostoma foliatum* and *Pteropurpura sp*.

The shrimp-like macrurans were seen throughout the area. *Alpheus dentipes* and *Beteus harfordi* were found only in deep holes in collected rock samples. *Alpheus dentipes* was fairly common in the rocks but was only rarely collected. These individuals were often seen only in the laboratory when a rock sample in the porcelain dish began clicking. Larger shrimps, *Pandulus danae* and *Heptocarpus pictus* were found throughout the area on the surface of the rock. This species was seen under mounds of rubble rock but never in a boring or a hole.

2. Annelid Nestlers

A great many annelids were found nestling in abandoned pholad holes and these species are identified in Appendix C. A few general comments about these species are in order. The most common varieties of annelid nestlers included individuals of the family Terebellidae. The nestling charactertistics of these organisms is mentioned by Evans (1967). These individuals were most abundant in the vertical face and in the recessed regions of the ledge. Several large *Thelepus setosus* were found inhabiting a thin crack in a rock that had become exfoliated and was resting

in place. The species *Pista elongata* with its characteristic tube was also in evidence on the vertical face of the ledge.

The large capitellids were the most abundant and largest nestlers found in the sand packed *Parapholas* shells in the lower rock. These large worms were found wrapped completely around the inside of the mollusc shell or were packed quite tightly by sand into the burrows. Also found on this lower level below the ledge were worms of the family Cirratulidae which preferred the dead pholad shells which were not so densely packed with sand. Often, individuals of this family were outside of the shell, between the shell and the rock.

Other annelid worms must be included as nestlers here, even if the burrows do not provide primary protection. The most common of these are *Phyllochaetopterus prolifica* and *Diapatra ornata*. These two species are found with their bases packed into the burrows acting as anchors. Sometimes quite densely packed into the holes, these two species preferred different areas of the ledge. *Phyllochaetopterus* prefer the surface of the ledge and the vertical face, where it was often covered by the calcarious sponge *Leucosolenia eleanor*. *Diapatra* is found mainly in regions of heavy sand settlement. These individuals are quite common on the lower rock and in the sand away from the ledge. They were

sometimes found in sand packed shells on the surface of the ledge, and were abundant in the sand filled fault. Diapatra was observed in a number of locations where it was not anchored by the pholad burrows, rather they were buried in deep sand. Phyllochaetopterus was found only anchored in the rock.

F. CARBONATE ANALYSIS

The results of the carbonate analysis are listed in Table 2. These results demonstrate that there are extremely low amounts of calcium carbonate in all of these rocks, which compares quite favorably with the results of Clark (1978). These low carbonate levels would indicate that the borers could not erode the rock by secreting acids. Figure 21 shows the approximate location that the samples were removed from.

G. PRESENTATION OF DATA

The data collected in this study are presented in Appendices A and B. These Appendices give the numerical count by quadrat of the organisms identified in the two transects. In many cases the relative abundance of the organisms is represented vice the actual numerical count. Table 3 gives the key to the symbols used. The organisms are listed in order of phylum and family as listed in Light's Manual (Smith and Carlton, 1975). The genus and

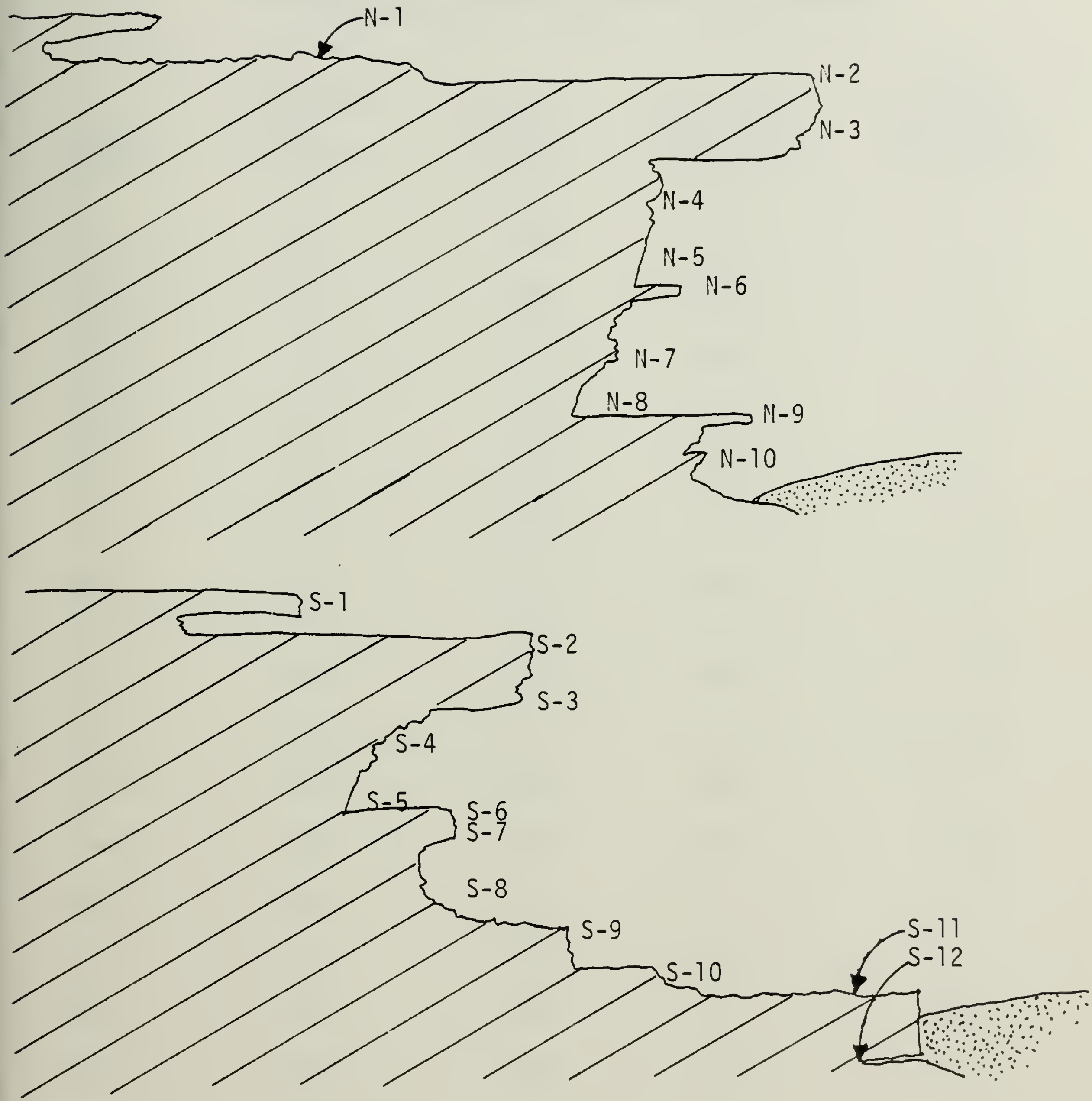

FIGURE 21. Location of Rock Samples Removed for Carbon Analysis

TABLE 2

SUMMARY OF CHEMICAL ANALYSIS RESULTS

Sample	Percent Inorganic Carbon	Total Carbon	Percent Carbonate	Percent Calcium Carbonate
N-1	.031	.034	.155	.257
N-2	.021	.025	.103	.172
N-3	.019	.026	.094	.157
N-4	.017	.021	.085	.141
N-5	.021	.025	.105	.175
N-6	.018	.027	.091	.152
N-7	.021	.022	.105	.176
N-8	.017	.019	.086	.144
S-1	.018	.020	.092	.154
S-2	.024	.026	.119	.199
S-3	.017	.022	.089	.144
S-4	.030	.032	.151	.252
S-5	.021	.024	.104	.172
S-6	.025	.029	.127	.211
S-7	.027	.033	.137	.228
S-8	.026	.029	.130	.217
S-9	.022	.026	.113	.188
S-10	.019	.023	.095	.158
S-11	.025	.029	.123	.205
S-12	.029	.316	.146	.242

species are listed alphabetically under the family with the exception of the shelled gastropods which are separated into limpets and snails.

Appendix C is a list of the species identified in the transects. A number of species were seen away from the study site. However, these individuals are not included in the species list. The List of Species includes some brief, pertinent comments concerning a few of the organisms.
Table 4 is a list of the organisms which were identified primarily as nestlers in empty pholad burrows. The nestlers identified here may very well be found in some other location or even free-living, however, during this study and in this area, they were seen most often within the empty burrows or depressions caused by bivalve boring. Two examples of organisms included by this definition are the starfish Pisaster giganteus and the anemone Anthopleura artemisia. Small P. giganteus were often found tightly wedged into wide mouthed or eroded pholad burrows, often several centimeters from the surface. Larger individuals were often seen out on the ledge but the nestling behavior of the young was so common that they are included as nestlers. For this reason all of the brittle stars are included as nestlers, even though they were found under rocks and in other areas of the ledge. Anthopleura artemesia lives on the horizontal surfaces of the sand

covered ledges, attached to the rock beneath the layer of sand. On sand-free surfaces, they were often found with their bases attached to the side or bottom of burrows which were full of sand.

Nearly every annelid could be included in this list. Rather than merely reproducing the list of annelid species that were identified, the list of nestlers includes only the names of the families in which all of the species listed demonstrated nestling behavior. The families which were most common and abundant as nestlers were the Terrebellidae, Cirratulidae, Capitellidae, and Lumbrineridae. Other families such as the polynoids and phyllodocids were abundant in the burrows but were also seen outside the rocks. They are included in the list because they were far more abundant in the burrows than on the surface.

H. CONCLUSIONS

While this study is primarily descriptive in nature, enough data was collected to make general statements about the findings. From the chemical analysis of the shale, it is clear that the mechanism of boring by either bivalves, sipunculids or annelids is not primarily chemical. Acids would have little effect on the primarily siliceous shales. The area of settlement preferred by the various boring bivalves can be established in this area based on the wave regime encountered, and the level of siltation. *Parapholas*

californicas is found predominantly in the area of heavy siltation. And as a result of it's morphology, is quite successful in this region. *Chaceia ovoidea* is found much more commonly on the vertical regions under the ledge where settling sediments are not a problem. The hardness of the rock does not appear to affect the two species differently, since they are found in some areas inhabiting the same layers. The very hard chert, and the highly fractured step region, are resistant to penetration by large species of pholads.

The sipunculids encountered in this region show a similar variation in population with the large *Themiste pyroides* found almost exclusively at the base of the ledge under sand cover. Additionally, the shape of the burrows in which *Themiste* is found, suggests the possibility that they can penetrate the soft mudstone. Many of the annelids show a similar variation in distribution, with a much larger number of different species and individuals found in the region of the vertical face where the empty burrows are not densely packed with sand. Different types of nestling behavior was observed and a number of nestling organisms were identified.

I. RECOMMENDATIONS FOR FURTHER RESEARCH

This study demonstrates the large variety of species found in this small area. Further research in this region

could concentrate on identifying the various annelids that burrow into the rock. Little is known about the annelids in this region, and further research in this area would yield valuable information about their distribution and ecology. Another study such as the present one, concentrating on a smaller area or performing a detailed analysis of a smaller structure would be useful in determining if even smaller scale variations in populations exist. An analysis of a deeper structure where the wave surge is less severe would also yield supplementary information that would be useful in our understanding of the rock boring bivalves.

TABLE 3

LIST OF NESTLERS

Anthozoa

Anthopleura artemesia
Halcampa crypta

Platyhelmenthes

Alloeocoela sp.
Kuberakia excelsa
Stylochus californicus

Nemertea

Cerebratulus californiensis
Micrura verrilli
Nemertopsis gracilis
Tubulanus sexlineatus

Sipunculid

Phascolosoma agassizii
Themiste pyroides

Annelida

Polynoidae
Phyllococidae
Syllidae
Onuphidae
Eunicidae
Lumbrineridae
Spionidae
Chaetopteridae
Cirratulidae
Capitellidae
Oweniidae
Terebellidae

Arthropoda

Pachycheles rudis
Pachycheles pubescens
Alpheus dentipes
Betaeus harfordi

Mollusca

Octopus spp.
Hiatella arctica
Irus lamellifer
Kellia laperousii
Crepidula perforans
Crepipatella lingulata

Echinoidea

Strongylocentrotus purpuratus
Strongylocentrotus franciscanus
Pisaster giganteus (Young)
Cucumaria piperata
Eupenctacta quinquesemita
Amphipolis squamata
Ophiopholis aculeata
Ophioplucus esmarki
Ophiopteris papillosa

Chordata

Neoclinus uninotatus

TABLE 4

KEY TO SYMBOLS USED

P . . . . . The species is present in the quadrat but not counted.

C . . . . . The species is relatively common in the quadrat.

A . . . . . The species is relatively abundant in the quadrat.

XX% . . . . The estimated percent of the surface of the quadrat covered by an encrusting species.

APPENDIX A

Animals (248) Quadrat	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
PORIFERA												
Acarnus erithacus	2	1										
Aplysilla polyraphis	10%	5%	10%	10%	20%	20%	20%	5%	5%			
?Astylinifer arndti		3	4		2	1						
Axocielita originalis	1		3	4		2	1					
Cliona ? celata californica			15%	15%	20%	20%	10%	10%				
Halichondria panicea	1		1	3		1						
Haliclona sp.B	1	3	4		3	2	1	1	2			
Hymedesmia sp.B		1	4	1	2							
Hymenamphiastra cyanocrypta	20%	10%	5%	5%	5%			5%	5%	5%		
Leptoclathria asodes	1		2	1		1						
Leucandra heathi	9	11	6	4	3	9	6	2	3	1		
Leucilla nuttingi	9	2	1	6	3	1	2					
Leucosolenia eleanor	A	A	P	P	P	P	P	P	P	P		
Lissodendoryx topsenti				6	4	2	4	1				
Mycale richardsoni			1		1	1						
Ophlitaspongia pennata	1	1	2	1		1						
Spongia idia				1	2	1	4	2				
Tethya aurantia var. californiana		1				1						
Zygherpe hyaloderma							1					
CNIDARIA												
Hydrozoa												
Obelia spp.	P	P				P			P			
Aglaophenia spp.	P		P	P	P	P						
Plumularia spp.			P	P	P							
Anthozoa												
Anthopleura artemisia	2	1		1				13	9	8	7	
Balanophyllia elegans	49	22	57	49	19	14	28	24	16	23	27	15
Corynactis californica	33	41	63	54	26	27	13	11	11	8	4	6
Epiactis prolifera			1	2				1		3	4	2
Halcampa crypta											2	1
Pachycerianthus fimbriatus											1	
Tealia crassicornis								1				
Tealia coriacea												
Tealia lofotensis	1											
PLATYHELMENTHES												
Alloeocoela Sp.			1									
Kaburakia excelsa												
Notoplana acticola	2				1		2	8				
Pseudostylochus burchami				1		1						
Stylochus californicus				1			1					
NEMERTEA												
Amphiporus bimaculatus									1	2	1	
Cerebratulus californiensis	2	1		1		2	4	2		5	8	6
Micrura verrilli							1				1	
Nemertopsis gracilis				2	1							
Paranemertes peregrina		3	1	4	2	2						
Tubulanus pellucidus							1		1			
Tubulanus sexlineatus	1					2	2	1				
Zygeupolia rubens					1							

APPENDIX A (contd.)

Animals (248) contd. Quadrat	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
SIPUNCULIDS												
Phascolosoma agassizii	C	C	C	C	C	C	P	P	P	P	P	P
Themiste pyroides				P	P	P			C	C	C	C
ANNELIDA												
Polychaeta												
Polynoidae												
Arctonoe pulchra			P		P							
Arctonoe vittata												P
Halosydna brevisetosa			P	P	C	C	C	C	P	P	P	P
Harmothoe imbricata				P			P	P	P			
Lepidasthenia longicirrata											P	P
Lepidonotus squamatus								P				
Euphrosinidae												
Euphrosine aurantiaca				1								
Phyllodocidae												
Anaitides madierensis						1						
Anaitides medipapillata								1				
Anaitides mucosa				P						P		P
Anaitides williamsi							P	P		P		
Eulalia aviculiseta	P		P									P
Eulalia bilineata			P	P	P			P				
Eumida sanguinea				1								
Genetyllis castanea								1				
Phylodoce sp.												
Hesionidae												
Ophiodromus pugettensis	P	P	P	P	P			P		P		
Syllidae												
Amblosyllis sp.				P								
Eusyllis assimilis						P	P					
Pionosyllis gigantea				P				P				
Syllid sp.	P	P	P	P	P	P	P	P	P	P	P	P
Typosyllis aciculata						P						
Typosyllis fasciata												
Nereidae												
Nereis sp.			P									
Onuphidae												
Diopatra ornata									3		22	29
Eunicidae												
Marphysa stylobranchiata										C	P	
Palola paloloides			P	P								
Dorvilleidae												
Dorvillea monilocaras		P			P	P						

APPENDIX A (contd.)

Animals (248) contd. Quadrat	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Lumbrineridae												
Lumbrineris luti												
Lumbrineris tetraura			P	P	P			P				
Lumbrineris zonata			P	P		P	P					
Lumbrineris sp.			P	P	P	P	P	P	P	P		
Arabellidae												
Arabella iricolor								1				
Spionidae												
Polydora sp.	P	P	P	P								
Polydora elegantissima	P											
Polydoris socialis			P	P	P	P	P					
Polydora websteri			C									
Chaetopteridae												
Phyllochaetopterus prolifica		7	9	16	3	6	12	4	18	13		
Cirratulidae												
Caulleriella spp.					P		P				P	P
Cirratulus cirratus			P	P		P		P	P		P	P
Cirriformia luxuriosa				P	P	P		P	P	P		
Cirriformia spirabranchia				P	P	P	P	P				
Dodecaceria fewkesi	P	P	P	P								
Flabelligeridae												
Pherusa inflata			P	P		P	P		P			
Pherusa papillata												
Capitellidae												
Dasybranchus glabrus									P	P	P	P
Heteromastus filiformis										P	P	C
Mediomastus californiensis								P	P	P	P	
Oweniidae												
Owenia collaris										P	P	P
Maldanidae												
Axiothella rubrocincta												
Sabellariidae												
Phragmatopoma californica			P	P		P	P	P	P			
Sabellaria cementarium	P	P	P	P	P	P	P					
Pectinariidae												
Pectinaria californiensis					P							
Terebellidae												
Amphitrite cirrata					P							P
Neoamphitrite robusta						P			P	P	P	P
Pista brevibranchiata							P		P			
Pista elongata							1		1			
Ramex californiensis										P	P	
Terebella californica			P		P							
Thelepus crispus							P	P	P	P	C	C
Thelepus setosus							P				P	

Animals (248) contd. Quadrat	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10	S 11	S 12
Sabellidae												
Myxicola infundibulum												
Sabella crassicornis		P	P	P		P	P					
Sabella media							P					
Serpulidae												
Salmacina tribranchiata	P	P	P	P				P				
Serpula vermicularis	P	P	P	P	P	P	P	P		P		
Spirorbis sp.	A	A	A	A	P	P						
Vermiliopsis multiannulata	P	P	P	P	P	P						
ARTHROPODA												
Cirripedia												
Balanus aquila	2		1									
Balanus crenatus	19	25	97	86	3	3						
Balanus nubilus	1		1									
Megabalanus californicus	1	2										
Caprellidea												
Caprella sp.												
Tritella pilimana												
Macrura												
Alpheus dentipes					2	1	1					
Betaeus harfordi		1		1								
Heptacarpus pictus			2		1	2			2			
Pandalus danae										1		
Spirontocaris prionota			2	1								
Brachyura												
Cancer antennarius						1		1				
Heterocrypta occidentalis												
Loxorhynchus crispatus			2				1					
Mimulus foliatus	1		3	2					1			
Pelia tumida						1						
Pinnexa franciscanus									1			
Pugettia gracilis							1					
Pugettia richii											1	
Anomura												
Hapalogaster cavicauda								1				
Pachycheles pubescens	P		C	C		C	C	C				
Pachycheles rudis			1	1	3		2					
Paguristes ulreyi					P	P	P					
Pagurus hirsutiusculus			P	P		P	P	P				
Pagurus samuelis		2			7	2		3				
Petrolisthes eriomerus		1										
Phylolithoides papilosus										1		

Animals (248) contd.	Quadrat	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
MOLLUSCA													
Polyplacophora													
Basiliochiton heathii		1											
Cryptochiton stelleri									1				
Ischnochiton radians							2	1		1			
Lepidozona mertensii						1	2	1	1	3			
Mopalia ciliata		2					1						
Mopalia lowei		1											
Mopalia muscosa			2		1								
Placiphorella velata					1								
Stenoplax fallax													
Stenoplax heathiana					1								
Tonicella lineata		3	1	6	2	3		1			1		
Shelled Gastropods													
Acmea mitra		4	1		1								
Crepidula perforans				P	P	P	P	P	P	P	P	P	P
Crepipatella lingulata								1					
Diodora aspera													
Haliotis rufescens		1	2										
Haliotis Sp.										1			
Megathura crenulata				1			1						
Amphissa versicolor													
Bittium Sp.		12	6	4				2	9	1			
Ceratostoma foliatum		3				1	2	4	3	2			
Calliostoma annulatum		1	2		2								
Calliostoma canaliculatum			1										
Calliostoma ligatum					2	1							
Fusinus luteopictus													
Mitrella carinata			6	5	3	9	4	2		1			
Mitra idae							3	6	4	2			
Ocenebra interfossa		3	4	6	2	1		5	2	1			
Pteropurpura trilata			1					1					
Opisthobranchia													
Aegires albopunctatus					1								
Anisodoris nobilis		1	2			1		1					
Archidoris montereyensis						1							
Archidoris odhneri										1			
Cadlina marginata			1										
Coryphella iodinia		2	1		1								
Coryphella trilineata									1				
Discodoris heathi													
Discodoris sandiegensis									1	2			
Phidiana crassicornis													
Onchidoris spp.				1									
Okenia angelensis									1				
Polycera atra									1				
Rostanja pulchra			2	1		1			1				
Cuthona albocrustata					1		1						
Tritonia festiva				1									
Triopha catalinae					1								

APPENDIX A (contd.)

Animals (248) contd. Quadrat	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Bivalvia												
Adula falcata			P	P					P	P	C	C
Chaceia ovoidea			1		6	11	4	7	1	3		
Hiatella arctica	P	P	P		P	P	P	P				
Hinnites giganteus	1				2							
Irus lamellifer	P		P	P			P					
Kellia laperousii	P	P	P			P	P					
Lithophaga plumula kelseyi			P	P	P		P					
Parapholas californica			3				3	1	4	6	29	41
Penitella conradi	P	P	P	P	P	P						
Penitella gabbii			P	P				P				
Penitella penita	P					P	P					
Penitella Sp.	P	P	P	P	P	P		P	P			
Pododesmus cepio												
ENTOPROCTA												
Bowerbankia gracilis	P	P	P	P	P	P	P	P				
Bugula californica	4	1	2	3	6	4	7	3	2	1		
Bugula neritina					1	2		4	3			
Cellepraria brunnea	2	1	3	1	2	7	4	2				
Crisulipora occidentalis					9	7	4	1	1			
Cryptosula pallasiana	4	3	4	6	9	7	4	2		3		
Diaporoecia californica	4	1	2	3	6	4	7	3	2	1		
Hippodiplosia insculpta	1											
Membranipora tuberculata	3	2	4	6	3	2	6	4				
Microporella californica	1	1	2	2	4			3	4			
Phidolopora pacifica			1		3	2	1	2				
Tricellaria occidentalis												
ECTOPROCTA												
Barentsia gracilis	P	P		P	P	P						
ECHINOIDEA												
Echinoidea												
Strongylocentrotus franciscanus	1											
Strongylocentrotus purpuratus	2	3			1			1				
Asteroidea												
Dermasterias imbricata		1								1		
Evasterias troschelii				1			1					
Henricia leviuscula	1				2							
Patiria miniata		1	1						1			
Pisaster brevispinus					1		1					
Pisaster giganteus	1			2	2	1		1				
Pisaster ochraceus									1			
Pycnopodia helianthoides			1									
Ophiuroidea												
Amphipholis squamata					4	3	11	9	12	4	15	12
Ophiopholis aculeata		1	2	1								
Ophioplocus esmarki					1			3	1	4	2	2
Ophiopteris papillosa	2								3	2		
Ophiothrix spiculata				1					4	11	6	8

APPENDIX A (contd.)

Animals (248) contd. Quadrat	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10	S 11	S 12
Holothuroidea												
Cucumaria miniata												
Cucumaria piperata	3	1	1	2	3	3	5	1				
Eupentacta quinquesemita					1	2		1	2			
Psolus chitonoides												
Stichopus californicus									1			
UROCHORDATA												
Enterogona												
Aplidium californicum	1		2	1	4	6	3	1				
Archidistoma diaphanes	1		4	2	7	9	6	2				
Archidistoma molle			3			2	1					
Archidistoma ritteri			2	4	3	1						
Ascidia ceratodes			1		6	5	5	2	3	4		
Clavilina huntsmani	24	31	19	14	6	3	11	9				
Cystodytes lobatus			4	6	9	7	4	3	3	2		
Pycnoclavella stanleyi			2	3								
Trididemnum opacum					2	1	1	4				
Pleurogonia												
Boltenia villosa		2				3	1					
Halocynthia hilgendorfi igaboja						1						
Pyura haustor				1	3	1						
Styela montereyensis		1										
ALGAE												
Phaeophyta												
Macrocystis pyrifera	1											
Rhodophyta												
Lithothamnium californicum	15%	10%	10%	10%							20%	20%
Lithothamnium pacificum	5%	5%	10%	10%								

APPENDIX B

Animals (248) Quadrat	N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	N 10	R 1	R 2
PORIFERA												
Acarnus erithacus	1	3	5		1	3						
Aplysilla polyraphis				P	5%	5%	20%	30%	30%	30%		
?Astylinifer arndti			1	1	2	1						
Axocielita originalis	1	6	3	1	2	1	1					
Cliona ? celata californica				5%	10%	10%	15%	20%	20%	15%		
Halichondria panicea			2		2	1		3	1			
Haliclona sp.B	16	23	19	14	21	17	3	3	1			
Hymedesmia sp.B	2	4	6	1	2	3	2	P				
Hymenamphiastra cyanocrypta			5%	10%	5%		P	P				
Leptoclathria asodes		2	1	1								
Leucandra heathi	28	32	37	21	29	19	16	11	15	7		
Leucilla nuttingi	9	13	7	4	1							
Leucosolenia eleanor	A	A	P	P	P	P	A	A	P	P		
Lissodendoryx topsenti	6	13	4	11	9	7	3	4				
Mycale richardsoni		1						1	2			
Ophlitaspongia pennata				1	2	1						
Spongia idia	1						1	1				
Tethya aurantia var. californiana	2			1								
Zygherpe hyaloderma			2									
CNIDARIA												
Hydrozoa												
Obelia spp.												
Aglaophenia spp.												
Plumularia spp.												
Anthozoa												
Anthopleura artemisia	2		1	1	4	2	3	4	4	6		
Balanophyllia elegans	219	263	161	183	116	98	63	52	39	51	42	18
Corynactis californica	178	157	143	126	139	113	74	46	27	29	61	2
Epiactis prolifera	1	1	4	1		2	342					
Halcampa crypta					1							
Pachycerianthus fimbriatus												
Tealia crassicornis					1							
Tealia coriacea				1								
Tealia lofotensis									1			
PLATYHELMENTHES												
Alloeocoela sp.												1
Kaburakia excelsa												1
Notoplana acticola											4	1
Pseudostylochus burchami											1	1
Stylochus californicus												
NEMERTEA												
Amphiporus bimaculatus								P				1
Cerebratulus californiensis	P	P					P		P	P	2	7
Micrura verrilli											1	
Nemertopsis gracilis											1	
Paranemertes peregrina	P	P				P	P	P			3	
Tubulanus pellucidus		1									1	
Tubulanus sexlineatus	P	P									3	5
Zygeupolia rubens												1

APPENDIX B (contd.)

Animals (248) contd. Quadrat	N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	N 10	R 1	R 2
SIPUNCULIDS												
Phascolosoma agassizii	A	A			C	C	A	A	C	P	118	12
Themiste pyroides					P	P		P	P	P	2	56
ANNELIDA												
Polychaeta												
Polynoidae												
Arctonoe pulchra	P		P								P	
Arctonoe vittata	P					P						
Halosydna brevisetosa	P	P			P		P	P	P	P	C	
Harmothoe imbricata	P	P				P		P				
Lepidasthenia longicirrata										P		
Lepidonotus squamatus	P											
Euphrosinidae												
Euphrosine aurantiaca											1	
Phyllodocidae												
Anaitides madierensis												P
Anaitides medipapillata											P	P
Anaitides mucosa	P				P	P			P		C	
Anaitides williamsi											P	
Eulalia aviculiseta		P				P				P		
Eulalia bilineata	P	P					P	P			C	
Eumida sanguinea											P	
Genetyllis castanea											P	
Phylodoce sp.												
Hesionidae												
Ophiodromus pugettensis	P	P			P	P	P	P	P	P	C	P
Syllidae												
Amblosyllis sp.	P										P	
Eusyllis assimilis											P	
Pionosyllis gigantea											P	
Syllid sp.	P	P	P	P	P	P	P	P	P	P	P	P
Typosyllis aciculata											P	
Typosyllis fasciata											P	
Nereidae												
Nereis sp.				P								
Onuphidae												
Diopatra ornata	11	6	3							2		
Eunicidae												
Marphysa stylobranchiata												C
Palola paloloides						P						
Dorvilleidae												
Dorvillea moniloceras	P											

APPENDIX B (contd.)

Animals (248) contd. Quadrat	N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	N 10	R 1	R 2
Lumbrineridae												
Lumbrineris luti											P	
Lumbrineris tetraura	P	P				P	P				P	
Lumbrineris zonata	C			P			P					
Lumbrineris sp.	P	P				P	P	P	P	P	P	
Arabellidae												
Arabella iricolor												
Spionidae												
Polydora sp.	P	P	P				P	P				P
Polydora elegantissima											P	
Polydoris socialis					P	P						
Polydora websteri							P					
Chaetopteridae												
Phyllochaetopterus prolifica	14	9	3			9	18	6	11	3	23	
Cirratulidae												
Caulleriella spp.												
Cirratulus cirratus		P	P				P	P			P	P
Cirriformia luxuriosa	P					P	P	P			P	
Cirriformia spirabrancha												P
Dodecaceria fewkesi					P	P						
Flabelligeridae												
Pherusa inflata	P	P			P		P	P			P	
Pherusa papillata			P								P	
Capitellidae												
Dasybranchus glabrus												2
Heteromastus filiformis											3	
Mediomastus californiensis							P				1	
Oweniidae												
Owenia collaris	P	P	P					P				8
Maldanidae												
Axiothella rubrocincta											P	
Sabellariidae												
Phragmatopoma californica	C	C			P	P	P	P			P	
Sabellaria cementarium							P	P	P	P	P	
Pectinariidae												
Pectinaria californiensis		P										
Terebellidae												
Amphitrite cirrata							P				P	P
Neoamphitrite robusta	P			P				P				P
Pista brevibranchiata							P			P		
Pista elongata		1					2	1				
Ramex californiensis						P			P		P	
Terebella californica	P										P	
Thelepus crispus												
Thelepus setosus												

Animals (248) contd. Quadrat	N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	N 10	R 1	R 2
Sabellidae												
Myxicola infundibulum												
Sabella crassicornis												
Sabella media												
Serpulidae												
Salmacina tribranchiata							C	C	C	P		
Serpula vermicularis				P	P	P	P	P	P	16		
Spirorbis sp.					P	P	C	C			P	
Vermiliopsis multiannulata	P					P	P	P			P	
ARTHROPODA												
Cirripedia												
Balanus aquila												
Balanus crenatus												
Balanus nubilus												
Megabalanus californicus												
Caprellidea												
Caprella sp.												
Tritella pilimana												
Macrura												
Alpheus dentipes	2			1								
Betaeus harfordi				1								
Heptacarpus pictus		1				2		1				
Pandalus danae								1				
Spirontocaris prionota				1					1			
Brachyura												
Cancer antennarius												
Heterocrypta occidentalis												
Loxorhynchus crispatus	1	2			1							
Mimulus foliatus	2	3	2				1	3				
Pelia tumida			1									
Pinnexa franciscanus		1										
Pugettia gracilis									1			
Pugettia richii		1										
Anomura												
Hapalogaster cavicauda												
Pachycheles pubescens		2						1	3			
Pachycheles rudis				1		1						
Pagurietes ulreyi												
Pagurus hirsutiusculus		P			P	P			P			
Pagurus samuelis			3	5			3	1				
Petrolisthes eriomerus								1				
Phyllolithoides papilosus			1									

Animals (248) contd. Quadrat	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	R1	R2
MOLLUSCA												
Polyplacophora												
Basiliochiton heathii		2		1		1						
Cryptochiton stelleri								1	1			
Ischnochiton radians					1	2	1		1	1		
Lepidozona mertensii			1		1	1	1	2		1		
Mopalia ciliata		2									3	
Mopalia lowei				1								
Mopalia muscosa	1			1							2	
Placiphorella velata												
Stenoplax fallax		1										2
Stenoplax heathiana												1
Tonicella lineata	1	3	1	1	4			1		6	1	
Shelled Gastropods												
Acmaea mitra			1		3	2						
Crepidula perforans	C	C			P	P	P	P	P	P	21	9
Crepipatella lingulata		3		1							3	
Diodora aspera	1			1								
Haliotis rufescens												
Haliotis Sp.												
Megathura crenulata								1				
Amphissa versicolor	5	4	4	6	1	2						
Bittium Sp.	7	5	2				3	4	1	5		
Ceratostoma foliatum	2	1	2	1	1		2	4	3	1		
Calliostoma annulatum	2	3		1	2							
Calliostoma canaliculatum		1	2		1							
Calliostoma ligatum	1			1								
Fusinus luteopictus				1								
Mitrella carinata	11	6	5	3	8	4		3	2	5	1	
Mitra idae			1	2			7	3	1	4		
Ocenebra interfossa	7	11	9	6	8	3	1	3	2	1		
Pteropurpura trilata	3	5	1			2	3	1	1			
Opisthobranchia												
Aegires albopunctatus		1										
Anisodoris nobilis	2		1	1	1							
Archidoris montereyensis		1					1					
Archidoris odhneri										1		
Cadlina marginata											1	
Coryphella iodinia		1			2							
Coryphella trilineata												
Cuthona albocrustata												1
Discodoris heathi												
Discodoris sandiegensis				1		2						
Phidiana crassicornis			1									
Onchidoris spp.											1	
Okenia angelensis			1									
Polycera atra			1									
Rostanga pulchra	1		1	2	1	3					5	2
Tritonia festiva			1									
Triopha catalinae					1							

APPENDIX B (contd.)

Animals (248) contd. Quadrat	N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	N 10	R 1	R 2
Bivalvia												
Adula falcata					P	P				P	8	17
Chaceia ovoidea		2			1	3	9	8	7	4	2	16
Hiatella arctica	P	P				P	P	P			9	1
Hinnites giganteus								2	3			
Irus lamellifer	P	P				P	P	P	P		4	11
Kellia laperousii	P	P			P	P					14	
Lithophaga plumula kelseyi	7	4				3		4			8	2
Parapholas californica	11	14			3	1		6	9	8	2	1
Penitella conradi	P	P			P	P		P			5	
Penitella gabbii	P	P			P	P	P	P			12	
Penitella penita						P	P				6	1
Penitella Sp.	P	P			P	P		P	P	P		
Pododesmus cepio	1										1	
ENTOPROCTA												
Bowerbankia gracilis	P	P	P	P	P	P	P	P	P	P		
Bugula californica	1	3	1	6	3	2	6	9	4			
Bugula neritina			1		1			2	1			
Celleporaria brunnea	3	1	1		1	2		2	3	1		
Crisulipora occidentalis	4	2	1	4	6	19	6	9	6	11		
Cryptosula pallasiana	5	2	1	4	3	7	11	13	11	9		
Diaporoecia californica	3	7	6	2	4	4	11	16	14	9		
Hippodiplosia insculpta							1	2				
Membranipora tuberculata				2	3	1	3	5	2	3		
Microporella californica			1			1	2	1		1		
Phidolopora pacifica	1				2	3	5	7	2	6		
Tricellaria occidentalis												
ECTOPROCTA												
Barentsia gracilis	P	P	P	P				P				
ECHINOIDEA												
Echinoidea												
Strongylocentrotus franciscanus									1			
Strongylocentrotus purpuratus	1					2	1	3				
Asteroidea												
Dermasterias imbricata		1									1	
Evasterias troschelii					1							
Henricia leviuscula		1	1			2	1	1				
Patiria miniata	1		1	2								
Pisaster brevispinus			1									
Pisaster giganteus			1		1	1	2	2	3			
Pisaster ochraceus	1											
Pycnopodia helianthoides					1							
Ophiuroidea												
Amphipholis squamata	4	6	1		3	2		4	4	3		
Ophiopholis aculeata	2	3					2					
Ophioplocus esmarki						4	2	1	1			
Ophiopteris papillosa	1	2	2					3	2			
Ophiothrix spiculata	3	5	2				2	1		2		

Animals (248) contd. Quadrat	N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	N 10	R 1	R 2
Holothuroidea												
Cucumaria miniata						1						
Cucumaria piperata	9	4			3	2		1	4	1		
Eupentacta quinquesemita		1			3	4		P	P			
Psolus chitonoides												
Stichopus californicus								1				
UROCHORDATA												
Enterogona												
Aplidium californicum	5	3	3	4	6	7	4	3	7	8	3	
Archidistoma diaphanes	5	3	3	2	6	3	4	6	3	4	1	
Archidistoma molle	2	1			2	4	1		1	1	2	
Archidistoma ritteri		1				3	2	2	1	3		
Ascidia ceratodes		1			4	7	3	1	3	5	2	
Clavelina huntsmani	33	44	16	27	14	11	17	14			12	
Cystodytes lobatus	4	6	3	4	8	7	9	8	4	6	3	
Pycnoclavella stanleyi			1			1						
Trididemnum opacum					2	4	5	3	4	1		
Pleurogonia												
Boltenia villosa		2			1							
Halocynthia hilgendorfi igaboja				1				1				
Pyura haustor		1			1		3	1				
Styela montereyensis					1							
ALGAE												
Phaeophyta												
Macrocystis pyrifera			1	1								
Rhodophyta												
Lithothamnium californicum	10%	10%	20%	20%	20%	20%						
Lithothamnium pacificum	20%	10%	20%	20%	20%	20%						

APPENDIX C

LIST OF SPECIES

PORIFERA

Acarnus erithacus de Laubenfels, 1927. Very common on the tops of the rock ledges. Some of the colonies were 30 cm. across.

Aplysilla polyraphis de Laubenfels, 1930.

?*Astylinifer arndti* de Laubenfels, 1927. This common sponge was seen in a variety of colors, from cream/beige, to orange.

Axocielita originalis (de Laubenfels, 1930). Common on the face and underside of the main ledge. Not common on the upper surface of the main ledge.

Cliona ? celata californica Grant, 1826. Abundant on the under side of the ledges. Most often seen on the downward facing rocks. Covered up to thirty percent of the underside of the ledge.

Halichondria panicea (Pallas, 1766).

Haliclina sp. Fairly common on the main ledge and on the vertical face.

Hymedesmia sp.

Hymenamphiastra cyanocrypta (de Laubenfels, 1930). Cobalt blue sponge. Found commonly on and at the base of the main ledge.

Leptoclathria asodes (de Laubenfels, 1930).

Leucandra heathi Urban, 1905.

Leucilla nuttingi (Urban, 1902).

Leucosolenia eleanor Urban, 1905. This species was exceedingly abundant, growing on the tubes of the annelid *Phyllochaetopterus prolifica*.

Lissodendoryx topsenti (de Laubenfels, 1930).

Mycale richardsoni Bakus, 1966.

Ophlitaspongia pennata (Lambe, 1895).

Spongia idia de Laubenfels, 1932. Extremely common on the underside of the ledges. Seen frequently on rock that is buried in the sand.

Tethya aurantia var. *californiana* (Pallas, 1766). Common on the surface of the ledge. Seen throughout the area.

Zygherpe hyaloderma de Laubenfels, 1932.

CNIDARIA

Hydrozoa

Obelia spp.

Aglaophenia spp.

Plumularia spp.

Anthozoa

Anthopleura artemesia (Pickering in Dana, 1848). Very common on the horizontal surfaces under the ledge and at it's base. The base of the individual is attached to the rock under a layer of sand or attached to the side of a pholad hole.

Balanophyllia elegans Verrill, 1864. Extremely common on all horizontal surfaces. This species replaces *Corynactis* in the area of surge and sand deposition.

Corynactis californica Carlgren, 1936. Numerous on all surfaces. Found with B. Elegans in nearly equal numbers except where surge and sand scouring and deposition had a greater affect.

Epiactis prolifera Verrill, 1869. Not common. Found on the surfaces of the ledge, especially in N-transect.

Halcampa crypta Siebert and Hand, 1974. This small form was found with it's base secured in sand filled burrows. Not common anywhere. Found only on horizontal surfaces.

Metridium exilis Hand, 1955. Not common. Found in sand filled depressions or holes.

Pachycerianthus fimbriatus McMurrich, 1910. Fairly common in the sandy regions away from the ledge associated with *Diapatra ornata*. One was seen in quadrat S-11.

Tealia crassicornis (Muller, 1776).

Tealia coriacea (Cuvier, 1798).

Tealia lofotensis (Danielssen, 1890).

PLATYHELMENTHES

Alloeocoela sp.

Kaburakia excelsa Bock, 1925. Only one individual, nearly 8 cm. long, was found inside a large empty burrow.

Notoplana acticola (Boone, 1929). Fairly common ranging over the vertical face in both transects. Usually found in burrows under the main ledge.

Pseudostylochus burchami (Heath and McGregor, 1912).

Stylochus californicus Hyman, 1953.

NEMERTEA

Amphiporus bimaculatus (Coe, 1901).

Cerebratulus californiensis Coe, 1905. This species was found commonly in the sand filled burrows at the base of S-transect. Several were found that were 30 cm. long.

Micrura verrilli Coe, 1901. Not common in this area.

Nemertopsis gracilis Coe, 1904.

Paranemertes peregrina Coe, 1901.

Tubulanus pellucidus (Coe, 1894).

Tubulanus sexlineatus (Griffin, 1898). Commonly found in the vertical regions. Several individuals were observed out on the surface of the ledge.

Zygeupolia rubens (Coe, 1895).

SIPUNCULIDS

Phascolosoma agassizii Keferstein, 1867. Very abundant.

Themiste pyroides (Chamberlain, 1919). Nowhere abundant, these individuals were most common in the rock at the base of the ledge.

ANNELIDA (Polychaeta)

Polynoidae

Arctonoe pulchra (Johnson, 1897).

Arctonoe vittata (Grube, 1855).

Halosydna brevisetosa Kinberg, 1855. The single most common annelid seen, it was seen in nearly every sample.

Harmothoe imbricata (Linnaeus, 1767).

Lepidasthenia longicirrata Berkely, 1923.

Lepidonotus squamatus (Linnaeus, 1767).

Euphrosinidae

Euphrosine aurantiaca Johnson, 1897. Three individuals were found in depressions or shallow burrows on the chert ledge.

Phyllodocidae

Anaitides madierensis (Langerhans, 1880).

Anaitides medipapillata Moore, 1909.

Anaitides mucosa (Oersted, 1843).

Anaitides williamsi Hartman, 1934.

Eulalia aviculiseta Hartman, 1936.

Eulalia bilineata (Johnston, 1840). Fairly common.

Eumida sanguinea (Oersted, 1843).

Genetyllis castanea (Marenzeller, 1879).

Phylodoce sp.

Hesionidae

Ophiodromus pugettensis (Johnson, 1901). This species is very common in this area. It is a quick moving, errant species which can be seen in almost every quadrant.

Syllidae

Amblosyllis sp.

Eusyllis assimilis Marenzeller, 1875.

Pionosyllis gigantea Moore, 1908.

Typosyllis aciculata Treadwell, 1945.

Typosyllis fasciata

Nereidae

Nereis sp.

Onuphidae

Diapatra ornata Moore, 1911. Common on sand covered substrates, the tube was anchored in the sand filled burrows over the rock.

Eunicidae

Marphysa stylobranchiata Moore, 1909. Several large individuals were found nestling at the base of the ledge. They were found only in the sand-filled burrows.

Palola paloloides (Moore, 1909). Fairly common inside the rock. Several large individuals (greater than 60 cm. long) were seen boring into the rock in the main ledge and in the rock on the face.

Dorvilleidae

Dorvillea moniloceras (Moore, 1909). The candy striped worm, was not common here.

Lumbrineridae

Lumbrineris sp. The Lumbrinerids were found in all areas, most commonly nestling in burrows or abandoned shells. They were very hard to identify to species, however a few of the larger individuals were keyed out.

Lumbrineris luti Hartman, 1944. One very large individual was identified by Mark Silberstein of the Moss Landing Marine Laboratory.

Lumbrineris tetraura (Schmarda, 1861).

Lumbrineris zonata (Johnson, 1901).

Arabellidae

Arabella iricolor (Montagu, 1804).

Spionidae

Polydora sp.

Polydora elegantissima Blake and Woodwick, 1972.

Polydoris socialis (Schmarda, 1861).

Polydora websteri Hartman, 1943).

Chaetopteridae

Phyllochaetopterus prolifica Potts, 1914. Abundant under the ledge and on the face, they were often wedged tightly into burrows or cracks in the rock.

Cirratulidae

Caulleriella spp.

Cirratulus cirratus (Muller, 1776).

Cirriformia luxuriosa (Moore, 1904).

Cirriformia spirobranchia (Moore, 1904).

Dodocaceria fewkesi Berkeley and Berkeley, 1954. Several small concretions were found on the surface of the main step. This species was commonly found in secreted tubes in the cracks and fissures of the main chert ledge.

Flabelligeridae

Pherusa inflata (Treadwell, 1914). Fairly common under the ledge, on the surface of the rock.

Pherusa papillata (Johnson, 1901).

Capitellidae

Dasybranchus glabrus Moore, 1919. Several individuals were seen living in fragile mucous and silt tubes. One very large (60 mm) commensal *Lepidasthenia longicirrata* was found in the tube. Found most commonly at or near the base of the ledge.

Heteromastus filiformis (Claperede, 1864).

Mediomastus californiensis Hartman, 1944. A common nestler in sand packed burrows or shells.

Oweniidae

Owenia collaris Hartman, 1955. Common. Found associated with *Diapatra* tubes in the rocks. Very often several Owenia tubes were found sticking out of a burrow wedged tightly with five or six Diapatra.

Maldanidae

Axiothella rubrocincta (Johnson, 1901).

Sabellariidae

Phragmatopoma californica (Fewkes, 1889). Commonly found on the vertical face.

Sabellaria cementarium Moore, 1906. Found on nearly every exposed surface that was free of sand deposition. Often found on the sides of partially eroded burrows.

Sabellaria gracilis Hartman, 1944. Several individuals were seen in the area, however, none were found in the transects. Same locale as above.

Pectinariidae

Pectinaria californiensis Hartman, 1941. Only a few individuals seen (N-1/2).

Terebellidae

Neoamphitrite robusta (Johnson, 1901).

Pista brevibranchiata Moore, 1923.

Pista elongata Moore, 1909. The characteristic tube of this species is seen on the vertical face quite commonly. The tube was often anchored in a small burrow or crack.

Ramex californiensis Hartman, 1944.

Terebella californica Moore, 1904.

Thelepus crispus Johnson, 1901. The most common annelid nestler. Large numbers of these terrebelids were observed in the large empty burrows at the base of the ledge, and in the narrow gaps in the foliating layers of the rock. Often associated with *Halosydna brevisetosa* and *Arctonoe vittata*.

Thelepus setosus (Quatrefages, 1865).

Sabellidae

Myxicola infundibulum (Renier, 1804).

Sabella crassicornis Sars, 1851.

Sabella media (Bush, 1904).

Serpulidae

Salmacina tribranchiata (Moore, 1923). Several large masses of these worms were seen under the ledge in N-transect.

Serpula vermicularis Linnaeus, 1767. Most commonly found on the underside of the ledge and step.

Spirorbis sp. Large numbers of these small annelids are seen on the underside of the ledge and step. Not seen on the heavily overgrown vertical face region.

Vermiliopsis multiannulata (Moore, 1923).

ARTHROPODA

Cirripedia

Balanus (*Balanus*) *aquila* Pilsbry, 1907. Several very large individuals were seen under the step. A sea otter was observed eating a very large *B. aquila* or *B. nubilus*.

Balanus (*Balanus*) *crenatus* Bruguiere, 1789. Numerous small individuals were seen under the step and under the ledge. They were covered by the calcium boring sponge *Cliona* and were almost all dead.

Balanus (*Balanus*) *nubilus* Darwin, 1854.

Megabalanus californicus Pilsbry, 1916.

Caridea

Alpheus dentipes Guerin, 1832. Often nestling in the burrows on the vertical face.

Betaeus harfordi (Kingsley, 1878).

Heptocarpus pictus (Stimpson, 1871).

Pandalus danae Stimpson, 1857.

Spirontocaris prionota (Stimpson, 1864).

Brachyura

Cancer antennarius Stimpson, 1856.

Heterocrypta occidentalis (Dana, 1854).

Loxorhynchus crispatus Stimpson, 1857. Several very large individuals were seen throughout the area.

Mimulus foliatus Stimpson, 1860. This species is seen in great numbers in the late summer and early fall. They are quite common on all surfaces of the ledge.

Pelia tumida (Lockington, 1877).

Pinnexa franciscanus Rathbun, 1918.

Pugettia gracilis Dana, 1851.

Pugettia richii Dana, 1851.

Anomura

Hapalogaster cavicauda Stimpson, 1859.

Pachycheles pubescens Holmes, 1900.

Pachycheles rudis Stimpson, 1859.

Paguristes ulreyi Schmitt, 1921.

Pagarus hirsutiusculus (Dana, 1851). Several of these small hermit crabs were found living in very small burrows on the main ledge. They lacked any shell and seemed to be living on suspended detritus.

Pagarus samuelis (Stimpson, 1857).

Petrolisthes eriomerus Stimpson, 1871.

Phylolithoides papilosus Brandt, 1849.

MOLLUSCA

Cephalopoda

Octopus sp. Only small individuals found in this area. Most commonly found under the ledges, large rocks, or inside large pholad holes. One individual was found inside an empty *Balanus aquila* shell. Nowhere common.

Polyplacophera

Basiliochiton heathii (Pilsbry, 1898).

Cryptochiton stelleri (Middendorf, 1846). Found on all surfaces common throughout the area.

Ischnochiton radians (Carpenter in Pilsbry, 1892).

Lepidozona mertensii (Middendorf, 1846).

Mopalia ciliata (Sowerby, 1846).

Mopalia lowei Pilsbry, 1918.

Mopalia mucosa (Gould, 1846).

Placiphorella velata Dall, 1879.

Stenoplax fallax (Pilsbry, 1892) (=*Ischnochiton fallax*). Several large individuals were found under rocks buried in sand. Two were seen on the same rock when it was lifted from place. The two were in a narrow gap in between the rock layers, less than a cm. wide.

Stenoplax heathiana Berry, 1946 (=*Ischnochiton heathiana*). One individual found attached to the underside of the lowest rock surface. Nearly 6 cm. long.

Tonicella lineata (Wood, 1815). Quite common in small depressions on the surface of the ledge. Sometimes buried under slight sediment deposits.

Shelled Gastropods

Acmea mitra Rathke, 1833.

Crepidula perforans (Valenciennes, 1846). This slipper limpet is exceedingly abundant in small bore holes throughout the area. Nearly 10% of the small holes in the upper ledge,. and 15% of the holes in the vertical face were occupied by living individuals. The empty shells were seen in every area of the rock where the surface was penetrated.

Crepipatella lingulata (Gould, 1847). The small shelled limpet was found nestling in the shallow depressions on the surface of the rock. The shells were commonly covered with bryozoans or sponges making them impossible to see in situ. Probably rare in this area.

Diadora aspera (Rathke, 1833). Common under the ledge.

Haliotis rufescens Swainson, 1822. The bottom was littered with the empty shells. There were six individuals, from 9-14 cm. in length under the very small ledge on top of the rock. They were situated well in the back of the overhand where they were protected from attack by Sea Otters which were common here. They were wedged under the ledge so tightly that the top of their shells were highly eroded from rubbing against the rock. All of the shells that were found on the bottom showed the same wear.

Haliotis sp. Several small individuals were seen under the step but could not be removed for identification. Booth (1972) indicates that specimens of *H. currugata*, *H. cracherodii* and *H. Kamischatkana* were seen during his study, however, only *H. Rufescens* was seen on this ledge.

Megathura crenulata (Sowerby, 1852). Seen throughout the area.

Amphissa versicolor Dall, 1871.

Bittium sp. These small gastropods were found commonly buried in sand. The shells were most often occupied by small hermit crabs.

Ceratostoma foliatum (Gmelin, 1791) (=*Purpura foliata*). These organisms were often buried in the sand collected in the mouth of a pholad hole. They were abundant under the ledge, and were commonly found in the sand during periods of heavy swell. It appeared that they were anchoring themselves to avoid being swept away. This behavior was less common during calm periods.

Calliostoma annulatum (Lightfoot, 1786).

Calliostoma canaliculatum (Lightfoot, 1786).

Callistoma ligutum (Gould, 1849) (=*C. costatum* Martyn, 1784).

Fusinus luteopictus (Dall, 1877).

Mitra idae Melville, 1893.

Mitrella carinata (Hinds, 1844).

Ocenebra interfossa Carpenter, 1864.

Pteropurpura trilata (Sowerby, 1841).

Opisthobranchia

Aegires albopunctatus MacFarland, 1905.

Anisodoris nobilis (MarFarland, 1905).

Archidoris montereyensis (Cooper, 1863).

Archidoris odhneri (MacFarland, 1966).

Cadlina marginata MacFarland, 1905.

Coryphella iodinea (Cooper, 1862) (=*Flabellinopsis iodinea*)

Coryphella trilineata O'Donoghue, 1921.

Cuthona albocrustata (MacFarland, 1966).

Dendrodoris albopunctata (Cooper, 1863).

Discordoris heathi (MacFarland, 1966).

Discodoris sandiegensis (Cooper, 1863).

Phidiana crassicornis (Eschscholtz, 1831).

Onchidoris sp.

Okenia angelensis (Lance, 1966).

Polycra atra MacFarland, 1905.

Rostanga pulchra MacFarland, 1905.

Tritonia festiva (Stearns, 1873).

Triopha catalinae (Cooper, 1863).

Bivalvia

Adula californiensis (Philippi, 1847).

Adula falcata (Gould, 1851).

Barnea subtruncata (Sowerby, 1834) (=B. pacifica Stearns, 1871).

Chacaea ovoidea (Gould, 1851) (=Pholadidea ovoidea)

Hiatella arctica (Linnaeus, 1767). The most abundant bivalve nestler.

Hinnites giganteus (Gray, 1825).

Irus lamellifer (Conrad, 1837).

Kellia laperousii (Deshayes, 1839).

Lithophaga plumula kelseyi Hertlein and Strong, 1946.

Parapholas californica (Conrad, 1837).

Penitella conradi Valenciennes, 1846.

Penitella gabbii (Tryon, 1863).

Penitella penita (Conrad, 1837).

Penitella sp.

Pododesmus cepio (Gray, 1850).

ENTOPROCTA

Bowerbankia gracilis O'Donoghue, 1926.

Bugula californica Robertson, 1905.

Bugula neritina Linneaus, 1758.

Celleporaria brunnea (Hincks, 1884).

Crisulipora occidentalis Robertson, 1910.

Cryptosula pallasiana (Moll, 1803).

Diaporecia californica (d'Orbigny, 1852).

Hippodiplosia insculpta (Hincks, 1882). Small under-developed colonies were seen on the vertical face. More common in N-transect than in S-transect.

Membranipora tuberculata (Bosc, 1802).

Microporella californica (Busk, 1856).

Phidolopora pacifica (Robertson, 1908). Several small colonies were seen on the vertical face.

Tricellaria occidentalis (Trask, 1857).

ECTOPROCTA

Barentsia gracilis (M. Sars, 1835).

ECHINOIDEA

Echinoidea

Strongylocentrotus franciscanus (Agassiz, 1863). Rare in this area.

Strongylocentrotus purpuratus (Stimpson, 1857). Common to abundant under the step, and under flat rocks. Seen inside fissures on the main ledge.

Asteroidea

Dermasterias imbricata (Grube, 1857).

Evasterias troschelii (Stimpson, 1862).

Henricia leviuscula (Stimpson, 1857).

Patiria miniata (Brandt, 1835).

Pisaster brevispinus (Stimpson, 1857).

Pisaster giganteus (Stimpson, 1857).

Pisaster ochraceus (Brandt, 1835).

Pycnopodia helianthoides (Brandt, 1835).

Ophiuroidea

Amphipolis squamata (Delle Chiaje, 1829) (=*Axiognathus squamatus*).

Ophiopholis aculeata (Linnaeus, 1767) form *kennerlyi* (Lyman, 1860).

Ophioplucus esmarki Lyman, 1874.

Ophiopteris papillosa (Lyman, 1875).

Ophiothrix spiculata Le Conte, 1851.

Holothuroidea

Cucumaria miniata Brandt, 1835. Only one individual was found.

Cucumaria piperata (Stimpson, 1864). A fairly common nestler.

Eupentacta quinquesemita (Selenka, 1867). A very common nestler in the empty holes, burrows and cracks in the rocks. Never found in burrows that are full of sand.

Psolus chitonoides Clark, 1902. Two small individuals were found. The hard granulate plate was exposed with the soft ventral region placed into a shallow depression in the rock. Rutherford (1975) indicates that it is not commonly found in Monterey Bay.

Stichopus californicus (Stimpson, 1857).

UROCHORDATA

Enterogona

Aplidium californicum (Ritter and Forsyth, 1917).

Archidistoma diaphanes (Ritter and Forsyth, 1917).

Archidistoma molle (Ritter, 1900).

Archidistoma ritteri (Van Name, 1945).

Ascidia ceratodes (Huntsman, 1912).

Clavilina huntsmani Van Name, 1931.

Cystodytes lobates (Ritter, 1900).

Pycnoclavella stanleyi Berrill and Abbott, 1949.

Trididemnum opacum (Ritter, 1907).

Pleurogonia

Boltenia villosa (Stimpson, 1864).

Halocynthia hilgendorfi igaboja Oka, 1906. One individual found in the vertical region in S-transect.

Pyura haustor (Stimpson, 1864).

Styela montereyensis (Dall, 1872). Found only rarely on the surface of the ledge, and on the broad flat area to the west of the study site.

LIST OF FISHES ENCOUNTERED IN THE AREA

With the exception of Neoclinus sp. none of the fishes encountered were included in the tabulation of the species. This was because they were so mobile that they could not really be associated with a particular quadrat or even part of the ledge. During the course of the dives, observations on the fishes were made to gain an impression of the fishes found in the area and the preferred area of habitation. This is a partial list of the fishes seen. Many fish were not identified because they were seen only once or were fish the diver was not sufficiently familiar with to attempt to identify without a specimen.

LIST OF FISHES

Artedius corallinus, Corraline Sculpin. One of the most abundant of the fishes on the ledge. They are found everywhere in the area.

Brachyistius frenatus, Kelp Surfperch. Found rarely in the kelp in the water column.

Citharichthys sordidus, Pacific Sanddab. Sometimes quite abundant in the sandy regions between the two ledges. Individuals are rarely larger than ten cm. long.

Coryphopterus nicholsii, Blackeye Goby. One of the most common fishes in the area. They are seen most often under rocks, in the rubble or in eroded, wide pholad holes.

Gibbonsia montereyensis, Crevice Kelpfish. Seen under the small ledges or in the open.

Girella nigricans, Opaleye. Not common in this area.

Heterostichus rostratus, Giant Kelp Fish. Seen often resting on the rock or under the small ledge.

Hexagrammos decagrammus, Kelp Greenling. Not common.

Hexagrammos superciliosus, Rock Greenling. Common in this area. Seen in nearly every location.

Myliobatis californica, Bat Ray. Rare. Two individuals were seen at the site during this study. One was in the sandy area between the ledges, the other swam over the diver as he was swimming to the surface.

Neoclinus blanchardi, Sarcastic Fringehead. Not common, Observed inhabiting the small pholad holes. Rarely seen in the open.

Neoclinus uninotatus, One-spot Fringehead. Not common. Only seen while inhabiting the pholad holes or living under rock and rubble.

Ophioden elongatus, Lingcod. Not common. Seen on the ledge or swimming through the area.

Oxylebius pictus, Painted Greenling. Not common. As above.

Paralichthys californicus, California Halibut. One small individual was seen in the sand region in August.

Porichthys notatus, Plainfin Midshipman. Rare in this area. Only seen near the base of the ledge or on the vertical face.

Raja binoculata, Big Skate. One individual seen swimming through the area, in August.

Sebastes atrovirens, Kelp Rockfish.

Sebastes auriculatus, Brown Rockfish.

Sebastes melanops, Black Rockfish.

Sebastes miniatus, Vermillion Rockfish. Easily identified by it's distinctive coloration. This species is not common in this region. In September and October, five of these individuals were seen near the south end of the ledge and remained in the area for two months.

Sebastes mystinus, Blue Rockfish. The most common of the Rockfishes. These fish commonly school in the mid-water during most of the year. They appear to nest or spawn in March and April and can be found under the small ledges or in cracks in the rocks. Abundant.

Sebastes nebulosus, China Rockfish.

Sebastes rubrovinctus, Flag Rockfish.

Sebastes serranoides, Olive Rockfish.

Sebastes serricups, Treefish.

Torpedo californica, Pacific Electric Ray. Several individuals were found in the sand area during the summer. Not seen any other time. They were first identified by touching them with a gloved hand. The wet suit glove however was permeated with salt water and the diver received a strong electrical shock.

ALGAE

The algae found in this area varied a great deal seasonally. The algae (with the exception of the encrusting Lithothamnion) were found only on the surface of the step and the main ledge. The populations were not counted due to the extreme seasonal variability. However, most of the species that were observed were identified and are listed here. Species were keyed out using Abbott and Hollenberg (1976).

Algae

Phaeophyta

Macrocystis porifyra (Linnaeus) C. A. Agardh, 1820.

Rhodophyta

Bossiella orbigniana (Decaisne) Silva, 1957.

Bossiella plumosa (Manzo) Silva, 1957.

Botryocladia psuedochitoma (Farlow) Kylin, 1931.

Calliarthron sp.

Callophylis flabellulata Harvey, 1862.

Corallina officinalis var. *chilensis* (Decaisne) Kutzing, 1847.

Lithothamnium sp.

Lithothamnium californicum Foslie, 1900.

Lithothamnium pacificum (Foslie) Foslie, 1906.

Lithothrix aspergillum Gray 1867.

Porphyra occidentalis Setchell and Hus, 1900.

Rhodymonia pacifica Kylin, 1931.

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