STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME



# DIABLO CANYON POWER PLANT SITE ECOLOGICAL STUDY ANNUAL REPORT

July 1, 1973 - June 30, 1974

by

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Laurence L. Laurent
Earl E. Ebert
Fred E. Wendell and
Gary D. Farrens

PACIFIC GAS AND ELECTRIC COMPANY
COOPERATIVE RESEARCH AGREEMENT 6S-1047

MARINE RESOURCES
Administrative Report No. 74-10

December 1974

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ABSTRACT

We completed surveys of 11 permanent subtidal stations, 17 random subtidal stations, 4 permanent intertidal stations, and 29 random intertidal stations during the period. In addition, we conducted studies on the sea otter, *Enhydra lutris*, herd located between Diablo Cove and Point Buchon, continued the annual count of the mature bed of the bull kelp, *Nereocystis luetkeana*, within Diablo Cove, and interviewed commercial abalone and sea urchin divers for catch-per-unit-of-effort data. During the year, sea otters moved south into the cove east of Lion Rock and then into Diablo Cove.

The commercial abalone fishery showed signs of decline, while the commercial sea urchin fishery continued to expand. Several diving surveys were conducted inside Intake Cove to check on dredging progress; the cove appears to have become a haven for juvenile rockfish (*Sebastes*). The red abalone temperature tolerance studies were completed at the Department's marine culture laboratory at Granite Canyon.

This is the first annual report submitted in partial fulfillment of Research Contract No. 6S-1047 between the Department of Fish and Game and the Pacific Gas and Electric Company. Through this contract the Department of Fish and Game is to conduct ecological monitoring studies to determine what changes have occurred since 1970 and 1971 in the base line inventory of the marine biota, with special reference to fish and abalone.

Submitted to:

Barton W. Shackelford, Vice President
Planning and Research Department
Pacific Gas and Electric Company
77 Beale Street
San Francisco, California 94106

Submitted by:

John Radovich - Chief of O.R.B.
California Department of Fish and Game
1416 9th Street
Sacramento, California 95814

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## INTRODUCTION

During 1970 and 1971 Department of Fish and Game biologists conducted studies of intertidal and subtidal plant and animal communities in and around Diablo Cove (Burge and Schultz 1973). These studies placed special emphasis on the abundance of abalone and bony fishes. The data from these preoperational surveys were designed to determine the possible effects on the target species from thermal discharge resulting from the Diablo Canyon Nuclear Power Plant. The first unit of this facility is scheduled to begin operating sometime during 1975.

In 1972 sea otters, *Enhydra lutris*, began foraging just north of the power plant site and by mid-1973 these mammals were making occasional feeding forays into Diablo Cove and the cove just north of Diablo Cove. Two of the major components of the sea otters diet are abalone, *Haliotis* spp., and sea urchins, *Strongylocentrotus* spp.

In addition, commercial sea urchin fishermen began harvesting in the Diablo Canyon area, and commercial abalone fishermen were increasing their efforts in this area due to loss of traditional beds from sea otter foraging north of Morro Bay.

As a consequence of these developments, Pacific Gas and Electric Company contracted with the Department in June 1973 to conduct new ecological studies in Diablo Cove to monitor the effects of sea otters and commercial fisheries on permanent intertidal and subtidal stations.

This report covers results of our studies from July 1, 1973 through June 30, 1974, and includes Quarterly Report data for the period April 1, through June 30, 1974.

## OPERATIONS

During the year we spent 238 man-days at the site, surveying 61 permanent and random intertidal and subtidal stations (Appendix I). Subtidal surveys were occasionally curtailed due to boat breakdowns and poor weather. However, during two breakdown periods, we were able to use the patrol boat RAINBOW. Our efficiency was increased significantly in April when we moved our boat SEBASTES to a permanent mooring in Intake Cove.

Much of our field work involved monitoring or reestablishing and surveying the permanent subtidal and intertidal stations. In addition, we set up a random sampling program in Diablo Cove (intertidal and subtidal) and a Control Area about 1 nautical mile north on the Pecho Ranch (Field's property). Whenever time allowed, we interviewed commercial abalone and urchin divers. Weekly counts were made on the sea otter herd south of Point Buchon.

## SUBTIDAL SURVEYS

### Permanent Stations

#### Methods

Surveys of the permanent stations established in 1970 by Burge and Schultz were conducted in the same way as described by Burge and Schultz (1973) (Figure 1). Two divers swim along the 30 m (99 ft) transect counting or estimating abundance of macroinvertebrates, brown algae and fish, within 1 m (3.3 ft) on either side of the transect line. Counts are made of abalone, abalone competitors and predators, and bull kelp. In addition, we quantified an additional 20 to 25 species of invertebrates, and whenever possible, obtained a ¼ $m^2$ (2.7 $ft^2$) sample of red algae off the transect for species composition and quantification (see intertidal methods for details).

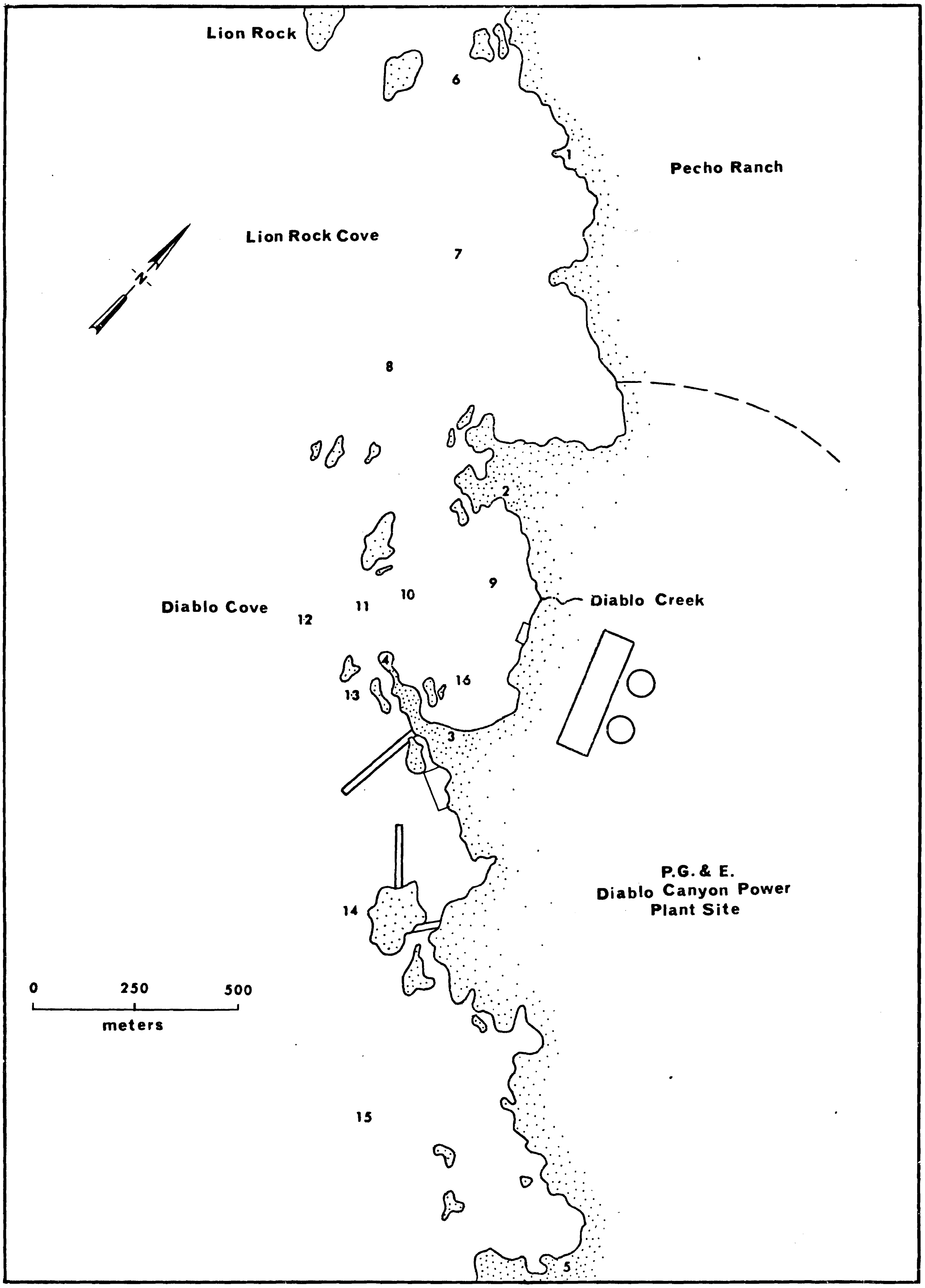


FIGURE 1. Location of permanent subtidal stations - Diablo Canyon power plant site.

Results

In September and October 1973, we located and replaced buoys on stations 7, 8, 9, 10, 11, 12, 15 and 16. We also conducted fall surveys of these stations. Station 6 was located and buoyed, but weather conditions and poor underwater visibility prevented us from conducting a survey. Stations 13 and 14 were not located. Bat stars, *Patiria miniata*, and giant red sea urchins, *Strongylocentrotus franciscanus*, were the most abundant invertebrates quantified during fall surveys (Table 1). Generally, the numbers of red abalone, *Haliotis rufescens*, rock crabs, *Cancer antennarius*, and giant red sea urchins decreased when compared with 1971 mean counts (Table 2, Figure 2). However, counts of sunflower stars, *Pycnopodia helianthoides*, increased. The activities of foraging sea otters and commercial urchin and abalone fishermen probably contributed to the decline in numbers.

Random Stations

Methods

In order to obtain a better understanding of the plant and animal communities of Diablo Cove and a suitable control area, we initiated a stratified random sampling plan similar to the one used at Point Arena (Gotshall et al. 1974). The Pacific Gas and Electric Co. bathymetric map of Diablo Cove was used to divide the cove into blocks 30.5 m (100 ft) on a side. The blocks were numbered and then separated into shallow (2.1-7.6 m) and deep (7.9-18.3 m) strata. Four shallow and two deep stations are selected from random number tables. If these stations are completed before the end of the survey period, six more stations are selected. Stations are located utilizing a fathometer and triangulation with hand-held compass. Subtidal

TABLE 1. Numbers of 25 Species of Invertebrates Observed During Fall and Winter* at Permanent Subtidal Stations - Diablo Canyon Power Plant Site.

| Species | Station number | 7 | | 8 | 9 | 10 | | 11 | | 12 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fall | Winter | Fall | Fall | Fall | Winter | Fall | Winter | Fall | Fall | Fall |
| PORIFERA | | | | | | | | | | | | |
| *Tethya aurantia* | | 11 | 11 | 6 | 3 | 3 | 4 | 20 | 12 | 2 | 2 | 0 |
| COELENTERATA | | | | | | | | | | | | |
| *Anthopleura artemesia* | | NC | 2 | 0 | 0 | 0 | 0 | NC | 0 | 0 | 0 | NC |
| *Anthopleura xanthogrammica* | | 0 | 0 | 2 | 3 | 3 | 4 | 0 | 3 | 0 | 0 | 4 |
| *Tealia crassicornis* | | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Tealia lofotensis* | | 3 | 3 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| ECHINODERMATA | | | | | | | | | | | | |
| *Cucumaria miniata* | | NC | 0 | 0 | 0 | 1 | 0 | 6 | 0 | 7 | 0 | 0 |
| *Eupentacta quinquesemita* | | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| *Henricia leviuscula* | | 2 | 1 | 5 | 4 | 0 | 2 | 4 | 4 | 2 | 3 | 1 |
| *Orthasterias kohleri* | | 4 | 4 | 4 | 2 | 0 | 3 | 5 | 1 | 8 | 0 | 0 |
| *Pateria miniata* | | 195 | 167 | 214 | 218 | 129 | 119 | 110 | 110 | 163 | 34 | 53 |
| *Pisaster brevispinus* | | 10 | 5 | 0 | 0 | 0 | 1 | 5 | 7 | 0 | 0 | 0 |
| *Pisaster giganteus* | | 9 | 9 | 14 | 1 | 4 | 2 | 6 | 9 | 0 | 19 | 0 |
| *Pisaster ochraceus* | | 0 | 0 | 6 | 0 | 0 | 0 | 3 | 1 | 0 | 26 | 0 |
| *Pycnopodia helianthodes* | | 0 | 1 | 1 | 5 | 4 | 0 | 11 | 1 | 4 | 0 | 1 |

TABLE 1. (cont)

| Species | Station number | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fall | Winter | Fall | Fall | Fall | Winter | Fall | Winter | Fall | Fall | Fall |
| ECHINODERMATA (cont) | | | | | | | | | | | |
| *Stichopus californicus* | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 6 | 0 | 0 |
| *Strongylocentrotus franciscanus* | 131 | 137 | 222 | 363 | 86 | 56 | 89 | 81 | 29 | 289 | 73 |
| *Strongylocentrotus purpuratus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Stylasterias forreri* | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 2 | 0 | 0 | 0 |
| ARTHROPODA | | | | | | | | | | | |
| *Cancer antennarius* | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 |
| MOLLUSCA | | | | | | | | | | | |
| *Astraea gibberosa*+ | 4 | 4 | 1 | 39 | 11 | 26 | 32 | 8 | 3 | 0 | 3 |
| *Cryptochiton stelleri* | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Dendrodoris fulva* | 1 | 9 | 1 | 16 | 3 | 3 | 17 | 3 | 3 | 2 | 1 |
| *Haliotis kamtschatkana* | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 |
| *Haliotis rufescens* | 1 | 0 | 7 | 2 | 0 | 0 | 1 | 0 | 0 | 4 | 48 |
| *Hinnites multirugosus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 6 | 0 |
| CHORDATA | | | | | | | | | | | |
| *Styela montereyensis* | 0 | 0 | NC | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |

* Fall surveys = September-October 1973, winter surveys = March 1974
+ Incorrectly listed as *A. undosa* in third quarterly report
NC Present but not counted

TABLE 2. Comparison of Mean Counts* of Selected Invertebrates at Permanent Subtidal Stations - Diablo Canyon Power Plant Site

| Year | Station 7 | 8 | 9 | 10 | 11 | 12 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|
| | | | | *Cancer antennarius* | | | | |
| 1970 | 0 | 2.0 | 0 | 0.3 | 0 | 0 | 3.5 | 1.0 |
| 1971 | 1.3 | 1.7 | 0.3 | 0 | 0 | 0 | 1.3 | 1.5 |
| 1973 | 0 | 1 | 0 | 0 | 0 | 0 | 5 | 1 |
| 1974 | 1 | - | - | 0 | 0 | - | - | - |
| | | | | *Haliotis rufescens* | | | | |
| 1970 | 3.7 | 2.0 | 0.7 | 0 | 0.3 | 0 | 9.0 | 65.0 |
| 1971 | 5.0 | 1.7 | 0.3 | 0 | 0 | 0 | 6.0 | 89.5 |
| 1973 | 1 | 7 | 2 | 0 | 1 | 0 | 4 | 48 |
| 1974 | 0 | - | - | 0 | 0 | - | - | - |
| | | | | *Pycnopodia helianthoides* | | | | |
| 1970 | 2.0 | 1.0 | 1.0 | 2.7 | 0.7 | 0.3 | 0 | 0.5 |
| 1971 | 3.0 | 1.3 | 4.3 | 3.3 | 1.0 | 0.3 | 1.3 | 3.5 |
| 1973 | 0 | 1 | 5 | 4 | 11 | 4 | 0 | 1 |
| 1974 | 1 | - | - | 0 | 1 | - | - | - |
| | | | | *Strongylocentrotus franciscanus* | | | | |
| 1970 | 188 | 149 | 296 | 78 | 92 | 41 | 152 | 53 |
| 1971 | 275 | 258 | 355 | 109 | 84 | 31 | 252 | 118 |
| 1973 | 131 | 222 | 363 | 86 | 89 | 29 | 289 | 73 |
| 1974 | 137 | - | - | 56 | 81 | - | - | - |

* Mean counts for 1970 and 1971 from Burge and Schulz (1973)

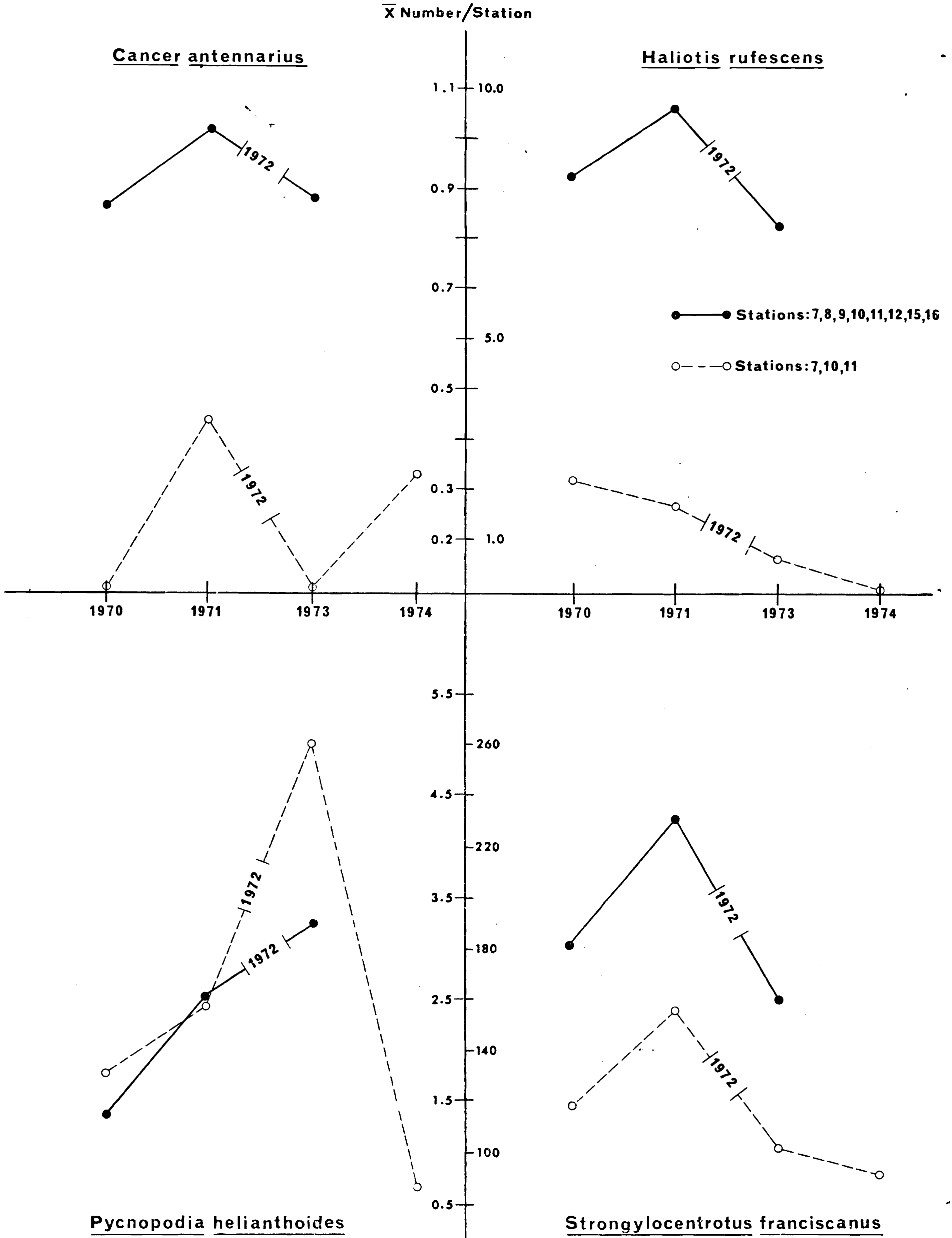


FIGURE 2. Mean counts of selected invertebrates at permanent subtidal stations - Diablo Canyon Power Plant site - 1970-1974 (Stations 7,10,11 presented separately as they are the only stations surveyed in 1974).

random sampling will only be conducted once a year, during the period May through August. At each station counts are made of selected, countable invertebrates within a 30 $m^2$ arc; the boat's anchor serves as the center of the circle. Counts are also made on selected species of brown algae. Numbers of fishes observed in the arc are estimated and recorded. Red algae are quantified by collecting all red algae from a randomly placed ½ $m^2$ within the 30 $m^2$ arc (see intertidal section for methods of processing the red algae). Physical data including depth, substrate, visibility and surface and bottom temperatures are also recorded at each station.

Selection of random stations in a control area about one mile north of Diablo Cove (Figure 3) is accomplished in a different manner because of a lack of a bathymetric map. The six stations are chosen by selecting six numbers from 20 to 60 (compass bearing from a prominent landmark in the center of the area) from random number tables. Then six stations ranging from 2.1 m (7 ft) to 18.3 m (60 ft) are selected from the tables; three numbers from 2.1 m to 7.6 m (25 ft), two from 7.9 m (26 ft) to 15.2 m (50 ft) and one from 15.6 m (51 ft) to 18.3 m (60 ft). Stations are located as before with hand bearing compass and fathometer.

Results

The North Control Area differs from Diablo Cove in being somewhat more exposed. This difference probably accounts for most of the difference in mean counts of invertebrates (Table 3). For example, the sponge, *Tethys aurantia,* and red turbin snail, *Astraea gibberosa,* were more abundant in Diablo Cove. Green aneomones, *Anthopleura xanthogrammica*; red sea stars, *Henricia leviuscula*; sea stars, *Orthasterias kohleri, Pisaster giganteus, Pisaster ochraceus;* sunflower stars; sea cucumbers, *Stichopus californicus;* and tunicates, *Styela montereyensis;* were more abundant in the North Control.

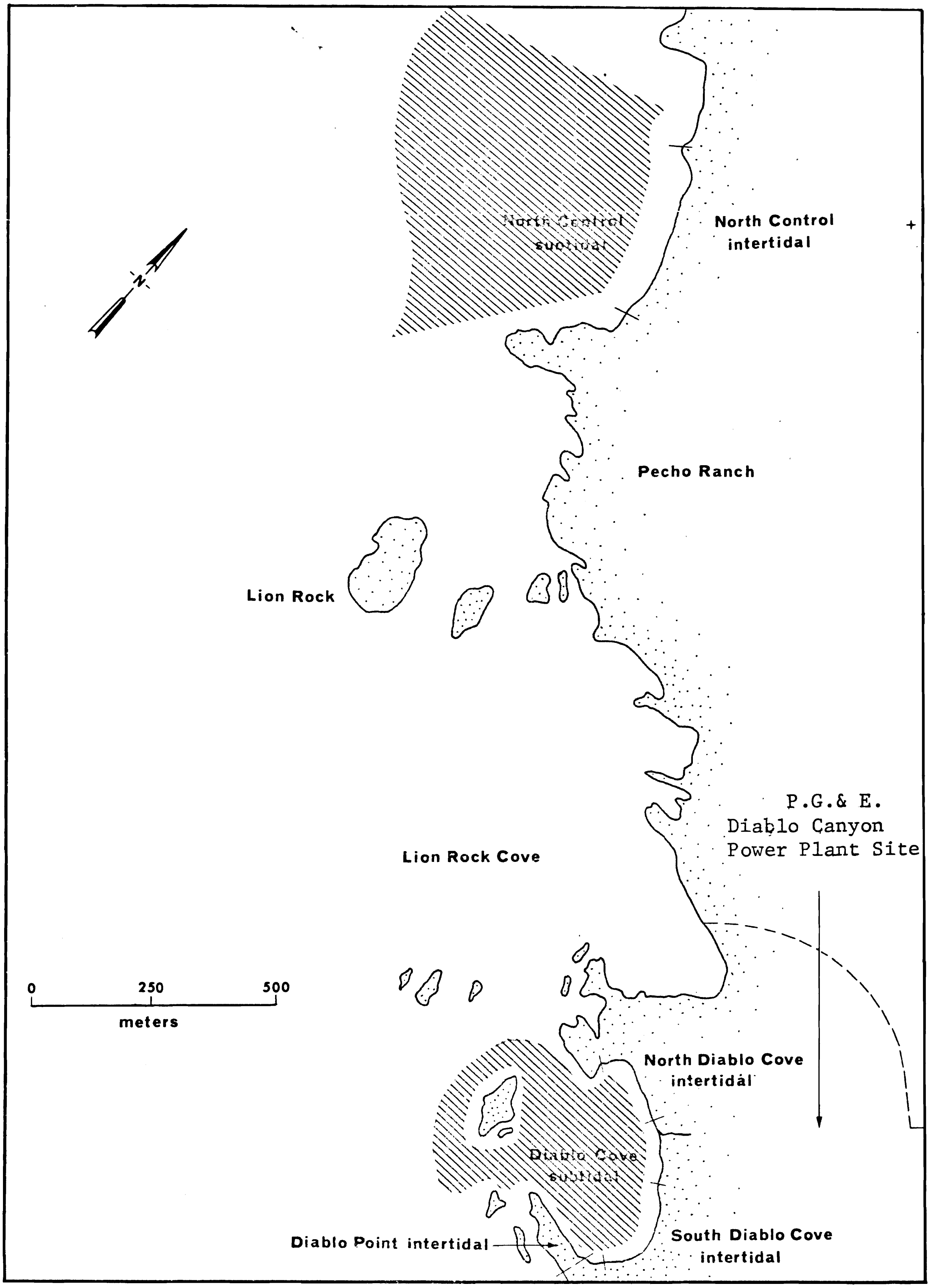


FIGURE 3. Location of random subtidal and intertidal areas - Diablo Canyon power plant site.

TABLE 3. Comparison of Numbers and Percent Frequency of Occurrence of 28 Species of Invertebrates - Random Subtidal Stations - North Control and Diablo Cove - Diablo Canyon Power Plant Site - May and June 1974.

| Species | Diablo Cove | | | North Control | | |
|---|---|---|---|---|---|---|
| | Sum | Percent frequency | Mean/ 30 $m^2$ | Sum | Percent frequency | Mean/ 30 $m^2$ |
| PORIFERA | | | | | | |
| *Tethya aurantia* | 35 | 63.6 | 3.18 | 8 | 33.3 | 1.33 |
| COELENTERATA | | | | | | |
| *Allopora californica* | 0 | 0.0 | 0.00 | 3 | 16.7 | 0.50 |
| *Anthopleura artemesia* | 17 | 9.1 | 1.54 | 6 | 16.7 | 1.00 |
| *Anthopleura xanthogrammica* | 32 | 81.8 | 2.91 | 23 | 66.7 | 3.83 |
| *Tealia crassicornis* | 3 | 18.2 | 0.27 | 2 | 16.7 | 0.33 |
| *Tealia lofotensis* | 9 | 36.4 | 0.84 | 5 | 33.3 | 0.83 |
| ECHINODERMATA | | | | | | |
| *Cucumaria miniata* | 2 | 9.1 | 0.18 | 1 | 16.7 | 0.17 |
| *Henricia leviuscula* | 19 | 72.7 | 1.73 | 14 | 66.7 | 2.33 |
| *Leptasterias aequalis* | 2 | 18.2 | 0.18 | 1 | 16.7 | 0.17 |
| *Orthasterias kohleri* | 10 | 45.4 | 0.91 | 14 | 50.0 | 2.33 |
| *Pateria miniata* | 783 | 100.0 | 71.18 | 392 | 100.0 | 65.33 |
| *Pisaster brevispinus* | 0 | 0.0 | 0.00 | 2 | 16.7 | 0.33 |
| *Pisaster giganteus* | 12 | 45.4 | 1.09 | 31 | 50.0 | 5.17 |
| *Pisaster ochraceus* | 3 | 27.3 | 0.27 | 4 | 50.0 | 0.67 |
| *Pycnopodia helianthodes* | 20 | 90.9 | 1.82 | 13 | 100.0 | 2.17 |
| *Stichopus californicus* | 2 | 9.1 | 0.18 | 9 | 50.0 | 1.50 |
| *Strongylocentrotus franciscanus* | 1264 | 100.0 | 114.91 | 188 | 66.7 | 31.33 |
| *Strongylocentrotus purpuratus* | 1 | 9.1 | 0.09 | 0 | 0.0 | 0.00 |
| *Stylasterias forreri* | 1 | 9.1 | 0.09 | 0 | 0.0 | 0.00 |

TABLE 3. (cont)

| Species | Diablo Cove | | | North Control | | |
|---|---|---|---|---|---|---|
| | Sum | Percent frequency | Mean | Sum | Percent frequency | Mean |
| ARTHROPODA | | | | | | |
| *Cancer antennarius* | 4 | 18.2 | 0.36 | 0 | 0.0 | 0.00 |
| MOLLUSCA | | | | | | |
| *Astraea gibberosa* | 126 | 90.9 | 11.45 | 8 | 50.0 | 1.33 |
| *Cadlina luteomarginata* | 4 | 27.3 | 0.36 | 0 | 0.0 | 0.00 |
| *Cryptochiton stelleri* | 0 | 0.0 | 0.00 | 1 | 16.7 | 0.17 |
| *Dendrodoris fulva* | 26 | 81.8 | 2.36 | 17 | 50.0 | 2.83 |
| *Haliotis kamtschatkana* | 2 | 9.1 | 0.18 | 0 | 0.0 | 0.00 |
| *Haliotis rufescens* | 7 | 18.2 | 0.64 | 2 | 16.7 | 0.33 |
| *Hinnites multirugosus* | 2 | 18.2 | 0.18 | 0 | 0.0 | 0.00 |
| CHORDATA | | | | | | |
| *Styela montereyensis* | 1 | 9.1 | 0.09 | 5 | 16.7 | 0.83 |
| TOTAL STATIONS | 11 | | | 6 | | |

The larger mean counts of giant red sea urchins, red abalone, rock crabs, and probably red turbin snails in Diablo Cove are due to a large extent to the heavy foraging of sea otters in the North Control Area.

Bathymetric distribution in both Diablo Cove and North Control were similar for the following species: *Tethya aurantia, Tealia crassicornis, Leptasterias aequalis, Orthosterias kohleri, Pateria miniata, Pisaster giganteus, P. ochraceus, Pycnopodia helianthoides, Dendrodoris fulva,* and *Styela montereyensis* (Tables 4 and 5).

Some species occurred at our random stations in one area but not in the other, among these were: *Pisaster brevispinus, Strongylocentrotus purpuratus, Stylasterias forreri, Cancer antennarius, Cadlina luteomarginata, Cryptochiton stelleri, Haliotis kamtschatkana,* and *Hinnites multirugosus.*

The most abundant animals in both areas were giant red sea urchins and bat stars.

## Diver Observed Fishes

### Methods

At each permanent and random station the divers identified and estimated the abundance of fishes within the station boundries. We also indicated whether or not the fish were juveniles or adults.

### Results

The divers identified 28 species of fish at 22 stations in Diablo Cove and 6 stations in the North Control Area (Table 6). Blue rockfish, *Sebastes mystinus*, adults and juveniles were not only the most abundant fishes, but were also observed at more stations (78.6%), than any of the other species. Painted greenling, *Oxylebius pictus*, and kelp greenling, *Hexagrammos decagrammus*, were the second and third most frequently observed fishes,

TABLE 4. Numbers and Frequency of Occurrence by Depth of 25 Species of Invertebrates - Random Subtidal Stations - Diablo Cove - Diablo Canyon Power Plant Site - May and June 1974.

| Species | Depth range: 2.4 - 7.6 m Sum | Percent frequency | Mean | 7.9 - 15.2 m Sum | Percent frequency | Mean |
|---|---|---|---|---|---|---|
| PORIFERA | | | | | | |
| *Tethya aurantia* | 21 | 55.6 | 2.33 | 14 | 100.0 | 7.00 |
| COELENTERATA | | | | | | |
| *Anthopleura artemesia* | 0 | 0.0 | 0.00 | 17 | 50.0 | 8.50 |
| *Anthopleura xanthogrammica* | 24 | 88.9 | 2.67 | 8 | 50.0 | 4.00 |
| *Tealia crassicornis* | 1 | 11.1 | 0.11 | 2 | 50.0 | 1.00 |
| *Tealia lofotensis* | 8 | 33.3 | 0.89 | 1 | 50.0 | 0.50 |
| ECHINODERMATA | | | | | | |
| *Cucumaria miniata* | 2 | 11.1 | 0.22 | 0 | 0.0 | 0.00 |
| *Henricia leviuscula* | 18 | 77.8 | 2.00 | 1 | 50.0 | 0.50 |
| *Leptasterias aequalis* | 2 | 22.2 | 0.22 | 0 | 0.0 | 0.00 |
| *Orthasterias kohleri* | 6 | 44.4 | 0.67 | 4 | 50.0 | 2.00 |
| *Patiria miniata* | 594 | 100.0 | 66.00 | 189 | 100.0 | 94.50 |
| *Pisaster giganteus* | 6 | 44.4 | 0.67 | 6 | 50.0 | 3.00 |
| *Pisaster ochraceous* | 2 | 22.2 | 0.22 | 1 | 50.0 | 0.50 |
| *Pycnopodia helianthodes* | 16 | 88.9 | 1.78 | 4 | 100.0 | 2.00 |

TABLE 4. (cont)

| Species | Depth range: 2.4 - 7.6 m Sum | Percent frequency | Mean | 7.9 - 15.2 m Sum | Percent frequency | Mean |
|---|---|---|---|---|---|---|
| ECHINODERMATA (cont) | | | | | | |
| *Stichopus californicus* | 2 | 11.1 | 0.22 | 0 | 0.0 | 0.00 |
| *Strongylocentrotus franciscanus* | 1197 | 100.0 | 133.00 | 67 | 100.0 | 33.50 |
| *Strongylocentrotus purpuratus* | 1 | 11.1 | 0.11 | 0 | 0.0 | 0.00 |
| *Stylasterias forreri* | 1 | 11.1 | 0.11 | 0 | 0.0 | 0.00 |
| ANTHROPODA | | | | | | |
| *Cancer antennarius* | 4 | 22.2 | 0.44 | 0 | 0.0 | 0.00 |
| MOLLUSCA | | | | | | |
| *Astraea gibberosa* | 78 | 88.9 | 8.67 | 48 | 100.0 | 24.00 |
| *Cadlina luteomarginata* | 3 | 22.2 | 0.33 | 1 | 50.0 | 0.50 |
| *Dendrodoris fulva* | 19 | 77.8 | 2.11 | 7 | 100.0 | 3.50 |
| *Haliotis kamtschatkana* | 0 | 0.0 | 0.00 | 2 | 50.0 | 1.00 |
| *Haliotis rufescens* | 7 | 22.2 | 0.78 | 0 | 0.0 | 0.00 |
| *Hinnites multirugosus* | 2 | 22.2 | 0.22 | 0 | 0.0 | 0.00 |
| CHORDATA | | | | | | |
| *Styela montereyensis* | 0 | 0.0 | 0.00 | 1 | 50.0 | 0.50 |
| TOTAL STATIONS | 9 | | | 2 | | |

TABLE 5. Numbers and Percent Frequency of Occurrence by Depth of 22 Species of Invertebrates - Random Subtidal Stations - North Control - Diablo Canyon Power Plant Site - May and June 1974.

| Species | 2.4 - 7.6 m | | | 7.9 - 15.2 m | | | 15.6 - 22.9 m | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sum | Percent frequency | Mean | Sum | Percent frequency | Mean | Sum | Percent frequency | Mean |
| PORIFERA | | | | | | | | | |
| *Tethya aurentia* | 5 | 33.3 | 1.67 | 0 | 0.0 | 0.00 | 3 | 100.00 | 3.00 |
| COELENTERATA | | | | | | | | | |
| *Allopora californica* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 3 | 100.00 | 3.00 |
| *Anthopleura artemesia* | 0 | 0.0 | 0.00 | 6 | 50.0 | 3.00 | 0 | 0.00 | 0.00 |
| *Anthopleura xanthogrammica* | 17 | 100.0 | 5.67 | 6 | 50.0 | 3.00 | 0 | 0.00 | 0.00 |
| *Tealia crassicornis* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 2 | 100.00 | 2.00 |
| *Tealia lofotensis* | 0 | 0.0 | 0.00 | 2 | 50.0 | 1.00 | 3 | 100.00 | 3.00 |
| ECHINODERMATA | | | | | | | | | |
| *Cucumaria miniata* | 0 | 0.0 | 0.00 | 1 | 50.0 | 0.50 | 0 | 0.0 | 0.00 |
| *Henricia leviuscula* | 4 | 33.3 | 1.33 | 4 | 100.0 | 2.00 | 6 | 100.0 | 6.00 |
| *Leptasterias aequalis* | 1 | 33.3 | 0.33 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Orthasterias kohleri* | 0 | 0.0 | 0.00 | 4 | 100.0 | 2.00 | 10 | 100.0 | 10.00 |
| *Pateria miniata* | 37 | 100.0 | 12.33 | 261 | 100.0 | 130.50 | 94 | 100.0 | 94.00 |
| *Pisaster brevispinus* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 | 2 | 100.0 | 2.00 |
| *Pisaster giganteus* | 0 | 0.0 | 0.00 | 18 | 100.0 | 9.00 | 13 | 100.0 | 13.00 |

TABLE 5. (cont)

| Species | 2.4 - 7.6 m | | | 7.8 - 15.2 m | | | 15.6 - 22.9 m | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sum | Percent frequency | Mean | Sum | Percent frequency | Mean | Sum | Percent frequency | Mean |
| ECHINODERMATA (cont) | | | | | | | | | |
| *Pisaster ochraceus* | 1 | 33.3 | 0.33 | 1 | 50.0 | 0.50 | 2 | 100.0 | 2.00 |
| *Pycnopodia helianthoides* | 4 | 100.0 | 1.33 | 7 | 100.0 | 3.50 | 2 | 100.0 | 2.00 |
| *Stichopus californicus* | 2 | 66.7 | 0.67 | 0 | 0.0 | 0.00 | 7 | 100.0 | 7.00 |
| *Strongylocentrotus franciscanus* | 10 | 33.3 | 3.33 | 135 | 100.0 | 67.50 | 43 | 100.0 | 43.00 |
| MOLLUSCA | | | | | | | | | |
| *Astraea gibberosa* | 2 | 33.3 | 0.67 | 6 | 100.0 | 3.00 | 0 | 0.0 | 0.00 |
| *Cryptochiton stelleri* | 0 | 0.0 | 0.00 | 1 | 50.0 | 0.50 | 0 | 0.0 | 0.00 |
| *Dendrodoris fulva* | 2 | 33.3 | 0.67 | 10 | 50.0 | 5.00 | 5 | 100.0 | 5.00 |
| *Haliotis rufescens* | 2 | 33.3 | 0.67 | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| CHORDATA | | | | | | | | | |
| *Styela montereyensis* | 0 | 0.0 | 0.00 | 5 | 50.0 | 2.50 | 0 | 0.0 | 0.00 |
| TOTAL STATIONS | 3 | | | 2 | | | 1 | | |

TABLE 6. Percent Frequency of Occurrence of Diver Observed Fishes at Permanent and Random Subtidal Stations by Depth - Diablo Canyon Power Plant Site - September 1973 through June 1974.

| Species | Depth range | | | |
|---|---|---|---|---|
| | 2.4 - 7.6 m | 7.9 - 15.2 m | 15.6 - 22.9 m | Combined |
| BATHYMASTERIDAE | | | | |
| *Rathbunnela hypoplecta* | 0.0 | 0.0 | 75.0 | 10.7 |
| BOTHIDAE | | | | |
| *Citharichthys* sp. | 6.6 | 0.0 | 0.0 | 3.6 |
| COTTIDAE | | | | |
| *Orthonopias triacus* | 6.6 | 44.4 | 25.0 | 21.4 |
| *Scorpaenichthys marmoratus* | 46.7 | 44.4 | 0.0 | 39.3 |
| EMBIOTOCIDAE | | | | |
| *Brachyistius frenatus* | 6.6 | 0.0 | 0.0 | 3.6 |
| *Cymatogaster aggregata* | 6.6 | 0.0 | 0.0 | 3.6 |
| *Damalichthys vacca* | 13.3 | 11.1 | 25.0 | 14.3 |
| *Embiotoca jacksoni* | 20.0 | 11.1 | 0.0 | 14.3 |
| *Embiotoca lateralis* | 33.3 | 22.2 | 0.0 | 25.0 |
| *Hypsurus caryi* | 6.6 | 0.0 | 0.0 | 3.6 |
| *Phanerodon atripes* | 6.6 | 0.0 | 0.0 | 3.6 |
| GASTEROSTEIDAE | | | | |
| *Aulorhynchus flavidus* | 0.0 | 11.1 | 0.0 | 3.6 |
| GOBIESOCIDAE | | | | |
| *Gobiesox meandricus* | 6.6 | 0.0 | 0.0 | 3.6 |
| GOBIIDAE | | | | |
| *Coryphopterus nicholsii* | 6.6 | 66.7 | 50.0 | 32.1 |

TABLE 6 (cont)

| Species | Depth Range 2.4 - 7.6 m | 7.9 - 15.2 m | 15.6 - 22.9 m | Combined |
|---|---|---|---|---|
| HEXAGRAMMIDAE | | | | |
| *Hexagrammos decagrammus* | 40.0 | 77.8 | 25.0 | 50.0 |
| *Hexagrammos superciliosus* | 6.6 | 0.0 | 0.0 | 3.6 |
| *Ophiodon elongatus* | 6.6 | 33.3 | 25.0 | 17.8 |
| *Oxylebius pictus* | 46.7 | 44.4 | 100.0 | 53.6 |
| LABRIDAE | | | | |
| *Oxyjulis californica* | 13.3 | 0.0 | 0.0 | 7.1 |
| SCORPAENIDAE | | | | |
| *Sebastes carnatus* | 13.3 | 55.6 | 100.0 | 39.3 |
| *Sebastes chrysomelas* | 26.7 | 0.0 | 0.0 | 14.3 |
| *Sebastes melanops* | 6.6 | 11.1 | 25.0 | 10.7 |
| *Sebastes miniatus* | 0.0 | 11.1 | 25.0 | 7.1 |
| *Sebastes mystinus* | 73.3 | 88.9 | 75.0 | 78.6 |
| *Sebastes pinniger* | 6.6 | 11.1 | 25.0 | 10.7 |
| *Sebastes rastreliger* | 20.0 | 0.0 | 0.0 | 10.7 |
| *Sebastes serranoides* | 6.6 | 11.1 | 50.0 | 14.3 |
| CLINIDAE | | | | |
| *Gibbonsia* sp. | 33.3 | 0.0 | 0.0 | 17.8 |
| NUMBER OF STATIONS | 15 | 9 | 4 | 28 |

occurring at 53.6 and 50.0% of the stations respectively. In 1970 Burge and Schultz reported that painted greenling, blue rockfish and kelp greenling respectively were the three most frequently observed species. In 1971 the pattern changed, black and yellow rockfish, *Sebastes chrysomelas*, replaced kelp greenling as the third most commonly encountered fish.

Some trends in bathymetric distribution worth noting include the following: generally the sanddabs, *Citharichthys* spp.; most surfperches (Embiotocidae); clingfish, *Gobiesox maeandricus*; rock greenling, *Hexagrammos superciliosus*; senorita, *Oxyjulis californica*; black and yellow rockfish, *Sebastes chrysomelas*; and kelp fish, *Gibbonsia* sp. occurrences were limited to the shallow stations. Conversely, smooth ronquils, *Rathbunella hypoplecta*; pile surfperch, *Damalichthys vacca*; painted greenling, *Oxylebius pictus*; gopher rockfish, *Sebastes carnatus*; black rockfish, *S. melanops*; vermilion rockfish, *S. miniatus;* canary rockfish, *S. pinniger*; and olive rockfish, *S. serranoides*, were more frequently observed at deeper stations.

The stations in Diablo Cove yielded more species than the stations in the North Control Area, 28 as opposed to 14 (Table 7). This difference may be due, at least in part, to the smaller number of stations surveyed in the North Control Area.

Several species recorded during 1970 and 1971 diving surveys have not yet been encountered by our divers, namely: wolf eel, *Anarrhichthys ocellatus*; California sheephead, *Pimelometopon pulchrum*; kelp rockfish, *Sebastes atrovirens*; monkeyface-eel, *Cebidichthys violaceus*; and copper rockfish, *Sebastes caurinus*.

TABLE 7. Percent Frequency of Occurrence of Diver Observed Fishes at Permanent and Random Subtidal Stations - Diablo Cove and North Control - Diablo Canyon Power Plant Site - September 1973 through June 1974.

| Species | Diablo Cove | North Control |
|---|---|---|
| BATHYMASTERIDAE | | |
| *Rathbunnela hypoplecta* | 13.6 | 0.0 |
| BOTHIDAE | | |
| *Citharichthys* sp. | 4.5 | 0.0 |
| COTTIDAE | | |
| *Orthonopias triacus* | 22.7 | 16.7 |
| *Scorpaenichthys marmoratus* | 40.9 | 33.3 |
| EMBIOTOCIDAE | | |
| *Brachyistius frenatus* | 4.5 | 0.0 |
| *Cymatogaster aggregata* | 4.5 | 0.0 |
| *Damalichthys vacca* | 9.1 | 33.3 |
| *Embiotoca jacksoni* | 18.2 | 0.0 |
| *Embiotoca lateralis* | 13.6 | 66.7 |
| *Hypsurus caryi* | 4.5 | 0.0 |
| *Phanerodon atripes* | 4.5 | 0.0 |
| GASTEROSTEIDAE | | |
| *Aulorhynchus flavidus* | 4.5 | 0.0 |
| GOBIESOCIDAE | | |
| *Gobiesox* | 4.5 | 0.0 |
| GOBIIDAE | | |
| *Coryphopterus nicholsii* | 36.3 | 16.7 |

TABLE 7 (cont)

| Species | Diablo Cove | North Control |
| --- | --- | --- |
| HEXAGRAMMIDAE | | |
| *Hexagrammos decagrammus* | 59.1 | 16.7 |
| *Hexagrammos superciliosus* | 4.5 | 0.0 |
| *Ophiodon elongatus* | 18.2 | 16.7 |
| *Oxylebius pictus* | 59.1 | 33.3 |
| LABRIDAE | | |
| *Oxyjulis californica* | 9.1 | 0.0 |
| SCORPAENIDAE | | |
| *Sebastes carnatus* | 45.5 | 16.7 |
| *Sebastes chrysomelas* | 18.2 | 0.0 |
| *Sebastes melanops* | 13.6 | 0.0 |
| *Sebastes miniatus* | 4.5 | 16.7 |
| *Sebastes mystinus* | 77.3 | 83.3 |
| *Sebastes pinniger* | 13.6 | 0.0 |
| *Sebastes rastreliger* | 9.1 | 16.7 |
| *Sebastes serranoides* | 13.6 | 16.7 |
| CLINIDAE | | |
| *Gibbonsia* sp. | 18.2 | 16.7 |
| NUMBER OF STATIONS | 22 | 6 |

## Subtidal Algae

Through March, 1974, only two ¼ $m^2$ (2.7 $ft^2$) samples of benthic algae were taken at the subtidal stations. One sample, from permanent station 8 on September 25, 1973, was particularly rich, while the second sample from permanent station 7 on March 14, 1974, was poor in comparison. The total dry weights of algae for stations 8 and 7, respectively, were 191.9 gms (6.8 oz) vs. 5.0 gms (0.2 oz), and the sample from station 8 was composed of 14 species, whereas, the station 7 quadrat yielded 5 species. The two more abundant species were *Botryoglossum farlowianum* and *Hymenena flabelligera*.

Although little effort was dedicated to benthic red algae during this period, the large brown algae were enumerated at all of the permanent and random subtidal stations. A special effort was also made during fall of 1973 to derive an absolute population figure for bull kelp, *Nereocystis leutkeana*, within Diablo Cove.

Seven species of large brown algae were observed at four of eight permanent stations surveyed during fall 1973 and winter 1973-74 (Table 8). Of these, *Desmarestia herbacea, D. munda* and *Dictyoneurum californicum* were most frequently observed. None of the enumerated brown algae occurred at the four deepest stations (7, 10, 11, 12).

The numbers of four species of brown algae were counted at the random stations (Table 9). Those alga whose abundances were estimated (especially *Desmarestia* spp. and *Dictyoneurum californicum*) are not included in this table. Very little similarity can be distinguished between Diablo Cove and the North Control subtidal from this data. This is probably due primarily to the low sample size considered here. As sample size is increased as study progresses through the Upwelling Period, these discrepancies are

TABLE 8. Occurrence of Seven Species of Brown Algae Observed During Fall 1973 and Winter 1973-74 - Surveys at Permanent Subtidal Stations - Diablo Canyon Power Plant Site.

| Species / Station number | 7 | | 8 | 9 | 10 | | 11 | | 12 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fall | Winter | Fall | Fall | Fall | Winter | Fall | Winter | Fall | Fall | Fall |
| *Cystoseira osmundacea* | | | | | | | | | | | A |
| *Desmarestia herbacea* | | | A | S | | | | | | C | A |
| *Desmarestia munda* | | | A | S-C | | | | | | C | C |
| *Dictyoneurum californicum* | | | A | C | | | | | | C | A |
| *Laminaria setchellii* | | | C | | | | | | | C-A | |
| *Nereocystis luetkeana* | | | 11 | | | | | | | 2 | 11 |
| *Pterygophora californica* | | | | | | | | | | | C |
| Station depth (m) | 10.7 - 12.2 | | 5.5-10.7 | 6.1-7.6 | 10.7 - 13.7 | | 15.2 - 16.8 | | 22.9 | 2.4-12.2 | 3.0 |

S = sparse

C = common

A = abundant

TABLE 9. Number and Frequency of Occurrence of Four Species of Brown Algae by Depth - Random Subtidal Stations - Diablo Cove and North Control - Diablo Canyon Power Plant Site - May-June 1974.

| Species | Depth range: 2.4 - 7.6 m Sum | Percent frequency | Mean | 7.9 - 15.2 m Sum | Percent frequency | Mean |
|---|---|---|---|---|---|---|
| **Diablo Cove** | | | | | | |
| *Cystoseira osmundacea* | 58 | 22.2 | 6.44 | 0 | 0.0 | 0.00 |
| *Laminaria setchellii* | 13 | 55.6 | 1.44 | 0(1) | 50.0 | 0.00 |
| *Nereocystis leutkeana* | 210(1) | 44.4 | 26.25 | 0 | 0.0 | 0.00 |
| *Pterygophera californica* | 135 | 22.2 | 15.00 | 0 | 0.0 | 0.00 |
| TOTAL STATIONS | 9 | | | 2 | | |
| **North Control** | | | | | | |
| *Cystoseira osmundacea* | 0 | 0.0 | 0.00 | 0 | 0.0 | 0.00 |
| *Laminaria setchellii* | 0 | 0.0 | 0.00 | 22 | 100.0 | 11.00 |
| *Nereocystis leutkeana* | 1 | 33.3 | 0.33 | 118 | 100.0 | 59.00 |
| *Pterygophera californica* | 16 | 33.3 | 5.33 | 44 | 100.0 | 22.00 |
| TOTAL STATIONS | 3 | | | 2 | | |

* ( ) Number of stations observed but not counted.

expected to level out. The *Nereocystis* population within Diablo Cove appeared in 1973 to be on the ascendancy from their numbers in 1970 and 1971 (Figure 4). Since this kelp may be an important cold-water obligate, its numbers in the area of the discharge are being closely watched. Preliminary observations of the 1974 juvenile sporophyte crop seem to indicate a bumper year.

## INTERTIDAL SURVEYS

### Methods

Intertidal surveys at the Diablo Canyon site were performed using two methods: 1) stratified random sampling, and 2) surveying permanent transects established by Burge and Schultz (1973). Most effort went to random sampling, but permanent stations were surveyed once during the first half of 1974.

For the random sampling program, four study areas were established; three in the area of cooling system discharge (Diablo Cove) and one control area about 2.5 km (1.6 miles) north of the plant site (Figure 3). All of the areas are primarily composed of rocky substrate, either as benches or as medium-size boulders 0.6 to 1.5 m ( 2 to 5 ft) in diameter. The rationale for establishing three study areas within Diablo Cove was based on the need to sample smaller areas with hope of reducing statistical variability among populations of plants and animals. The three areas are also different in makeup and in factors, such as currents and wave action, that affect them. North Diablo Cove Intertidal area (NDCI) is composed primarily of boulders with some 'bench' strata, and profile here extends to about +1.2 m (+4.0 ft) above MLLW. Diablo Creek separates North Diablo Cove Intertidal from South Diablo Cove Intertidal (SDCI) which is formed mostly of low

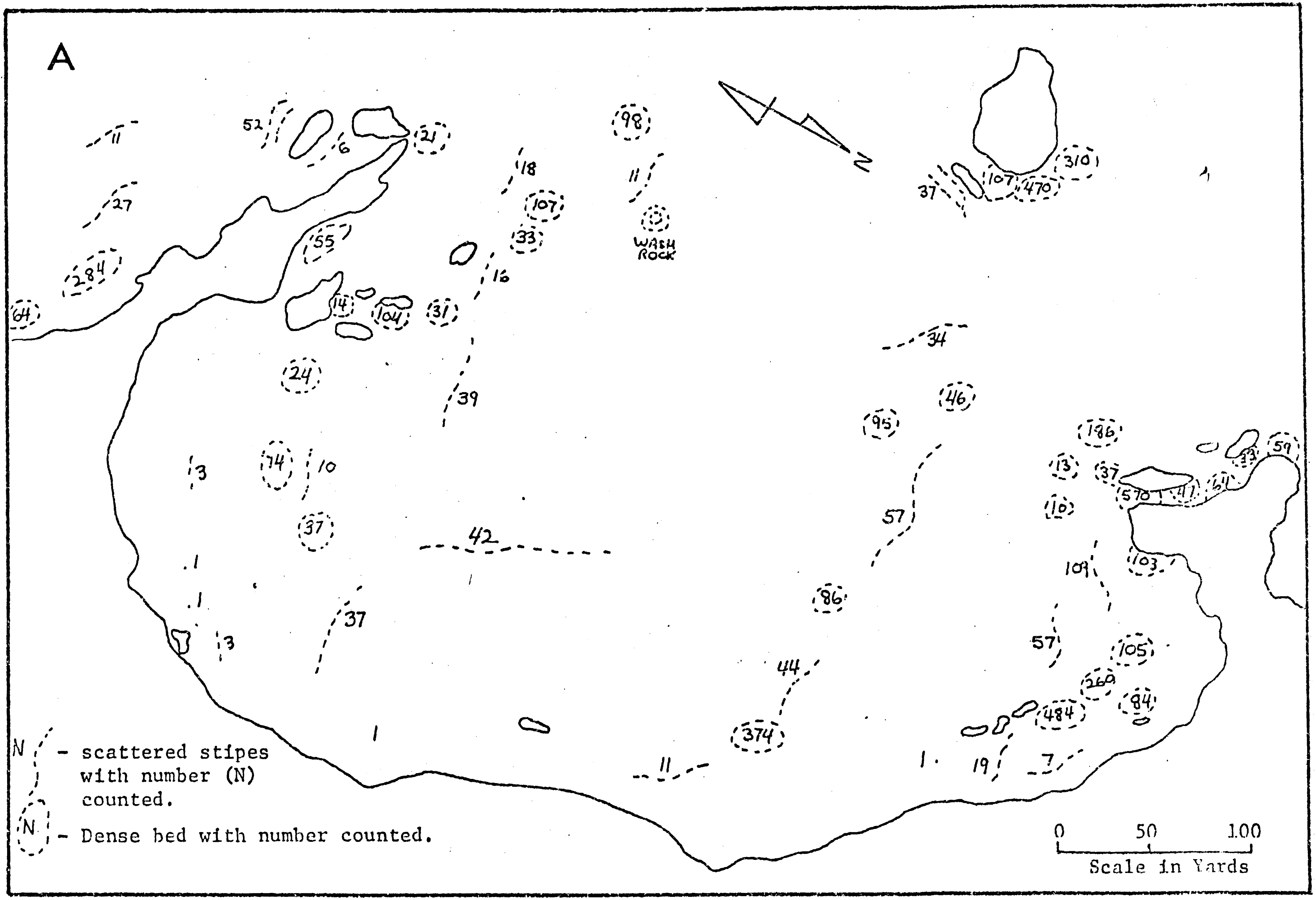


FIGURE 4. A, Distribution and counts of *Nereocystis leutkeana* in Diablo Cove on October 20, 1970 (Burge and Schultz 1973).

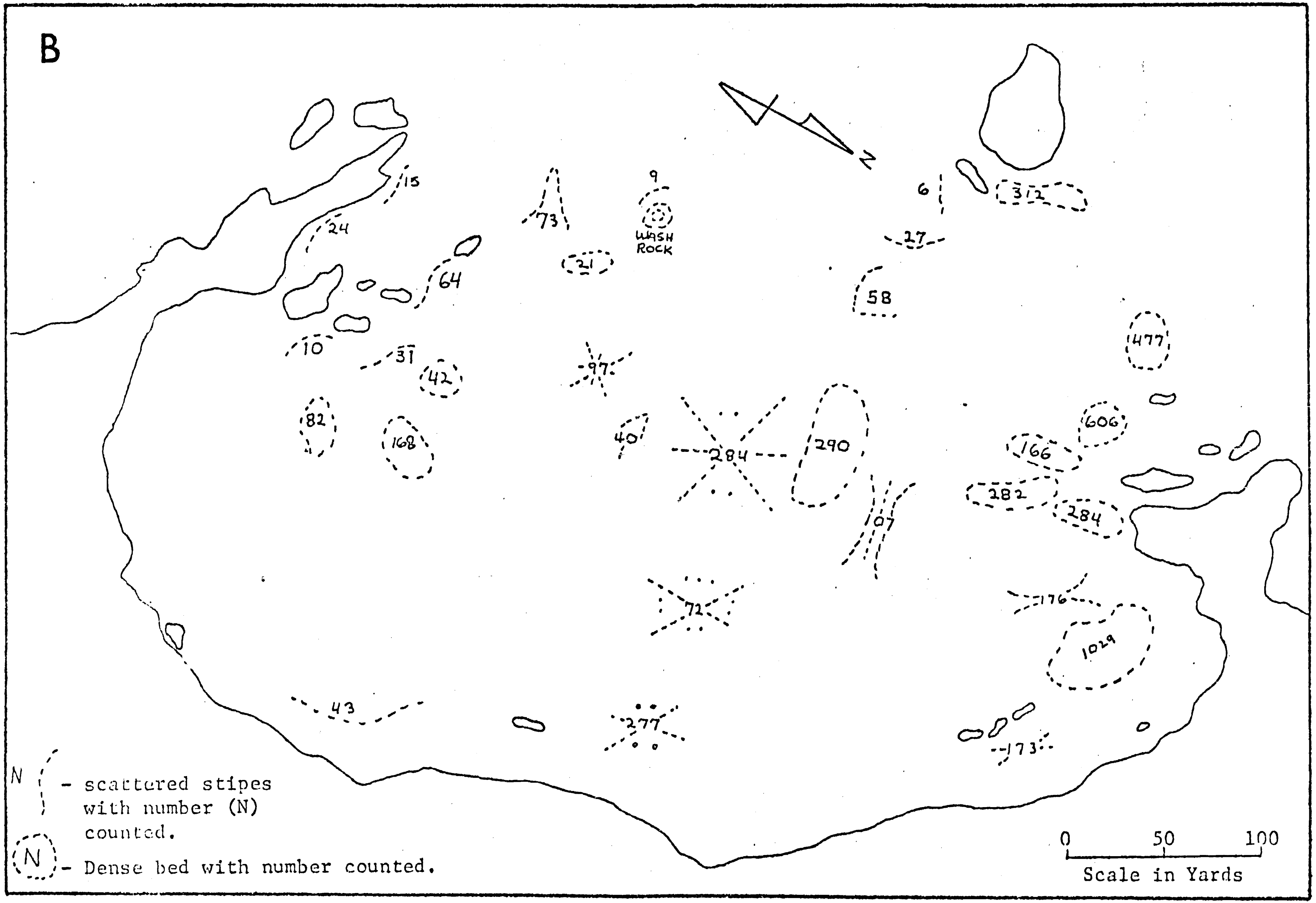


FIGURE 4. (cont) B, October 1, 1971 (Burge and Schultz 1973).

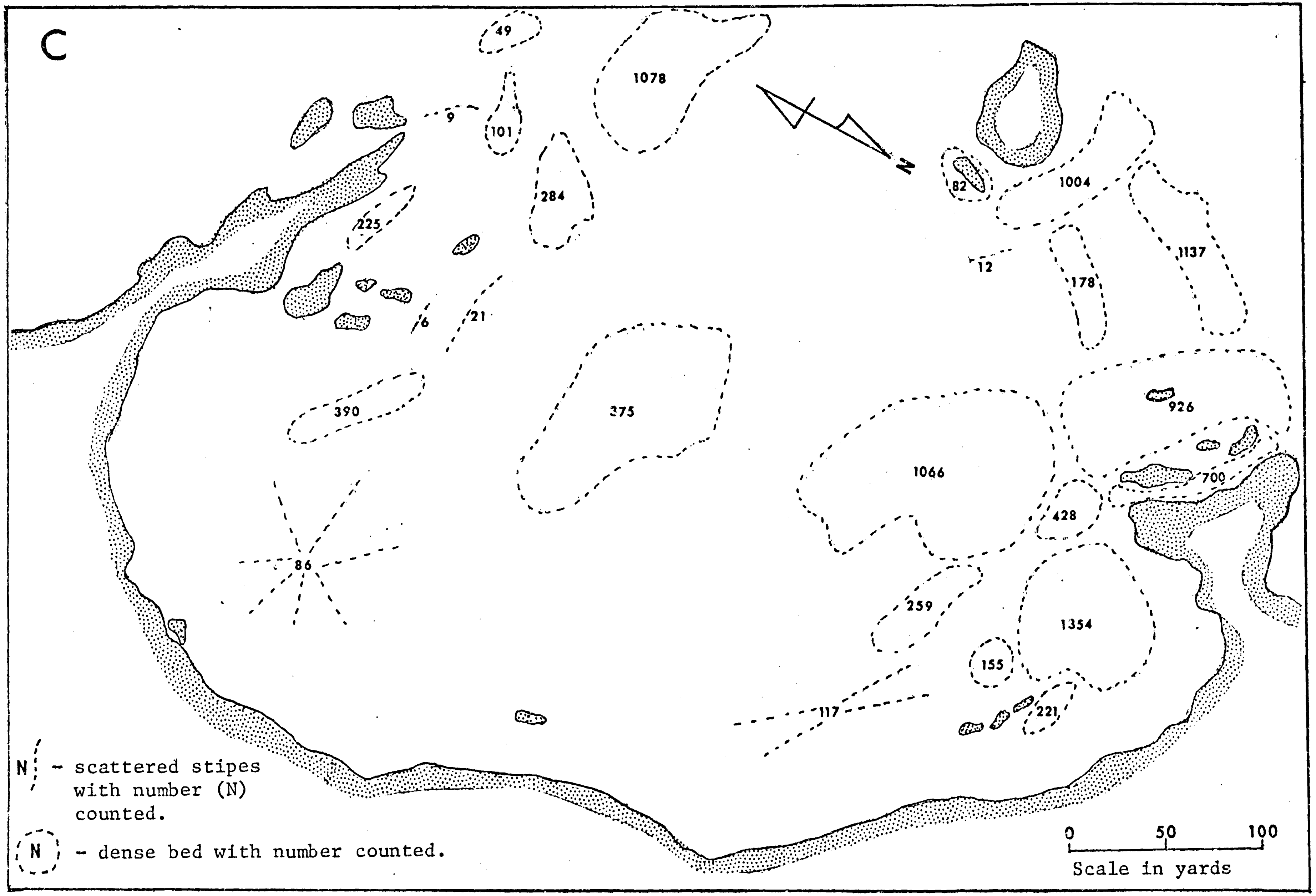


FIGURE 4. (cont) C, September 20, 1973.

relief benches with comparatively few boulders strewn about. Profile is also lower, on the average, than in NDCI, extending to approximately +0.9 m (+3.0 ft) above MLLW. Diablo Point Intertidal (DPI) is an exposed, usually wave-battered point, composed of contiguous strata with a biotic profile extending to the highest reaches of wave splash. North Control Intertidal (NCI), although not as protected as the Diablo Cove area, is closely similar in profile and makeup to stations in both NDCI and SDCI.

Each of the three Diablo Cove study areas consist of nine stations which are each 32 m (100 ft) long (parallel to shore). The North Control is composed of 20 such stations. Because of the larger size of NCI, stations were marked with numbered stakes on the bordering cliff face to facilitate location.

Before each sampling period, which corresponds to an oceanographic season, a series of station numbers are chosen from a standard table of random numbers. Alternate station numbers were selected in the event that a primary station was inaccessible to sampling.

The areas were sampled during periods of minus tides. A 30-m (99 ft) line marked in 1 m (3.3 ft) increments was placed at a subjective starting point and laid as close to water level as sea swell and topography would permit. The level at which the line ran was usually maintained at a constant height. A ¼ $m^2$ (2.7 $ft^2$) metal quadrat was placed on the substrate at four preselected random meter marks along the line. Within each quadrat all noncryptic macroinvertebrates larger than 10 mm (0.4 inches) and the larger brown algae were identified and counted. The soft red, green and smaller brown algae within the quadrat were scraped and collected in appropriately labeled plastic gallon jars or plastic bags. For each quadrat/

station the following information was recorded on a plastic sheet: quadrat number, time at collecting, approximate height relative to tidal level, counts of invertebrates and larger brown algal species, and an estimation of percent cover by articulated coralline algae and *Phyllospadix scouleri*. Counts of abalone along a 2 m (6.6 ft) swath of the 30 m (99 ft) transect line were also made at most of the stations.

The soft algae were collected to determine their specific biomass (dry weight) in the sampled areas. In the laboratory, algae samples were either placed in formalin to be worked up at a later time, or, preferably worked up fresh. "Working up" entailed washing the sample in fresh water to remove associated salts and detritus, draining thoroughly, sorting to species, obtaining a 'wet' weight, and, after a minimum period of 24 hr in a drying oven at 60 to 70°C (140 to 158°F), obtaining a dry weight for each species. Weights were measured on a triple beam balance to the nearest 0.1 g (0.004 oz). This method has been used by other workers performing algae biomass studies (Doty 1969; Hansen 1972).

In order to facilitate later quantification of invertebrates and algae, the intertidal was divided into three semi-arbitrary vertical life zones labeled A, B & C, which roughly correspond to Richetts and Calvin's (1962) Zones 2, 3 & 4. Zone A includes the intertidal from 0.9 m (3 ft) above mean lower low water, to approximately 1.8 m (6 ft); Zone B encompasses the area from 0.0 to +0.9 m (0.0 to 3.0 ft); and Zone C represents the area exposed below 0.0 m.

Four of the five permanent stations established in 1970 were remarked using methods developed by Burge and Schultz (1973). Several stations which could not be found again were reestablished in areas similar to their original location. When the survey of these stations was conducted in June, one crucial station marker and at least two other quadrat markers could not be found and the data yielded by our surveys was only partial. Although it was hoped that resurveys of these permanent stations would provide a source of continuous information, it now appears that the best data we can expect will come from a comparison of abalone counts from the transects.

Results

The data for invertebrates, articulated corallines and surf grass, *Phyllospadix scouleri*, are quantified from samples taken between November 1973 and June 1974. The reason for this is that these populations, while being cyclical to some extent, are largely considered perennial. However, the data for the 'soft' (non-calcareous) algae are presented only from samples collected during the Davidson Period, November through February. Most of the green, red and brown algae are annual in occurrence and some have adult life stages lasting only a few months. To treat their populations as perennial would very likely cause great statistical variation.

The numbers and calculations of abundance and occurrence are tabularly presented by category of animal or plant, by study area and by intertidal position (zone). Confidence intervals were calculated for mean biomass and/or mean percent cover of the different categories of plants studied, but due to smaller numbers and greater variation involved, no confidence intervals were calculated for invertebrates. Confidence intervals may be worth calculating when a full year of data is available.

Random Stations

Invertebrates

Diablo Point Intertidal Area (DPI). The invertebrates enumerated from the ¼ $m^2$ (2.7 $ft^2$) samples from both Zones A and B (Tables 10 and 11) are

TABLE 10. Numbers and Percent Frequencies of Occurrence of Invertebrates Found in Intertidal ¼ $m^2$ Samples (N=6), Zone A, Diablo Point Intertidal Area - Diablo Canyon Power Plant Site - November 1973 to June 1974.

| Species | Sum | Mean/¼$m^2$ | Percent frequency |
|---|---|---|---|
| COELENTERATA | | | |
| *Anthopleura elegantissima* | 2 | 0.33 | 16.7 |
| *Anthopleura xanthogrammica* | 10 | 1.67 | 83.3 |
| ANNELIDA | | | |
| Unidentified nereid | 2 | 0.33 | 16.7 |
| ARTHROPODA | | | |
| *Balanus* sp. | 43(1C)* (1A) | 7.17+ | 100.0 |
| *Pachycheles* sp. | 1 | 0.17 | 16.7 |
| *Pollicipes polymerus* | 60 | 10.00 | 16.7 |
| *Pugettia producta* | 2 | 0.33 | 16.7 |
| *Tetraclita squamosa* | 48 | 8.00 | 50.0 |
| MOLLUSCA | | | |
| Acmaeidae | 34 | 5.67 | 100.0 |
| *Fissurella volcano* | 2 | 0.33 | 33.3 |
| *Haliotis cracherodii* | 5 | 0.83 | 16.7 |
| *Molpalia* spp. | 10 | 1.67 | 66.7 |
| *Mytilus californanus* | 40 | 6.67 | 83.3 |
| *Nuttallina californica* | 5 | 0.83 | 33.3 |
| *Tegula brunnea* | 5 | 0.83 | 33.3 |
| *Tonicella lineata* | 1 | 0.17 | 16.7 |

TABLE 10. (cont)

| Species | Sum | Mean/¼m$^2$ | Percent frequency |
|---|---|---|---|
| ECHINODERMATA | | | |
| *Leptasterias* spp. | 5 | 0.83 | 83.3 |
| *Pisaster ochracerous* | 1 | 0.17 | 16.7 |
| *Stronglocentrotus purpuratus* | 47 | 7.83 | 66.7 |

*C = Common

A = Abundant

TABLE 11. Numbers and Percent Frequencies of Occurrence of Invertebrates Found in Intertidal ¼ $m^2$ Samples (N=18); Zone B, Diablo Point Intertidal Area - Diablo Canyon Power Plant Site - November 1973 to June 1974.

| Species | Sum | Mean/¼$m^2$ | Percent frequency |
|---|---|---|---|
| PORIFERA | | | |
| *Rhabdodermelia nuttingi* | 5 | 0.28 | 5.6 |
| Unidentified encrusting | NC | - | 16.7 |
| COELENTERATA | | | |
| *Aglaophenia* sp. | NC | - | 11.1 |
| *Anthopleura elegantissima* | 91 | 5.06 | 33.3 |
| *Anthopleura xanthogrammica* | 28 | 1.56 | 38.9 |
| *Corynactis californica* | 75+ | 4.17+ | 16.7 |
| *Epiactis prolifera* | 10 | 0.56 | 38.9 |
| ANTHROPODA | | | |
| *Balanus* sp. | 12 (1C)* (2A) | 0.67+ | 38.9 |
| *Cancer antennarius* | 1 | 0.06 | 5.6 |
| *Idothea* sp. | 2 | 0.11 | 11.1 |
| *Pollicipes polymerus* | 178 | 9.89 | 22.2 |
| *Pugettia producta* | 6 | 0.33 | 22.2 |
| *Pugettia richii* | 1 | 0.06 | 5.6 |
| MOLLUSCA | | | |
| Acmaeidae | 6 | 0.33 | 22.2 |
| *Aletes squamigera* | 13 | 0.72 | 33.3 |

TABLE 11. (cont)

| Species | Sum | Mean/¼$m^2$ | Percent frequency |
|---|---|---|---|
| MOLLUSCA (cont) | | | |
| *Aldisa sanguinea* | 1 | 0.06 | 5.6 |
| *Cadlina leuteomarginata* | 1 | 0.06 | 5.6 |
| *Calliostoma ligatum* | 4 | 0.22 | 11.1 |
| *Dendrodoris fulva* | 1 | 0.06 | 5.6 |
| *Fissurella volcano* | 3 | 0.17 | 11.1 |
| *Haliotis cracherodii* | 18 | 1.00 | 27.8 |
| *Katherina tunicata* | 4 | 0.22 | 16.7 |
| *Molpalia* sp. | 1 | 0.06 | 5.6 |
| *Mytilus califorianus* | 6 | 0.33 | 16.7 |
| *Nuttallina californica* | 4 | 0.22 | 11.1 |
| *Pododesmus macroschisma* | 1 | 0.06 | 5.6 |
| *Tegula brunnea* | 53 | 2.94 | 61.1 |
| *Tegula funebralis* | 2 | 0.11 | 11.1 |
| *Thais emarginatus* | 1 | 0.06 | 5.6 |
| *Tonicella lineata* | 6 | 0.33 | 22.2 |
| Unidentified chiton | 1 | 0.06 | 5.6 |
| ECHINODERMATA | | | |
| *Henricia leviuscula* | 8 | 0.44 | 22.2 |
| *Leptasterias* spp. | 9 | 0.50 | 38.9 |
| *Pisaster ochraceous* | 14 | 0.78 | 33.3 |
| *Stronglocentrotus purpuratus* | 52 | 2.89 | 66.7 |
| TUNICATA | | | |
| Unidentified ascidians | NC | | 5.6 |

* 1C = 1 occurrence of common    2A = 2 occurrences of abundant
NC = Not counted

those classically associated with exposed open-coast situations in central and northern California. Some of the more dominant forms in the two zones are: *Strongylocentrotus purpuratus*, *Pollicipes polymerus*, *Mytilus californianus*, the Acmaeids, *Balanus* sp. and *Tetraclita squamosa*. The numbers and frequencies with which these and other invertebrates occur are generally much higher in this study area than in the other, more protected study areas. There were also greater numbers of countable ($\geq$ 10 mm) species found in the combined zones of DPI than in the other areas. If thermal impact is going to have an effect on the DPI area, any changes will be relatively easy to detect due to the consistent nature of many of these populations.

<u>South Diablo Cove Intertidal Area (SDCI).</u> The invertebrate populations in the SDCI and the other study areas are not as well defined as those in the DPI. The average numbers and percent frequencies of occurrence of invertebrate species in both Zones B and C of the SDCI (Tables 12 and 13) are greatly diminished when compared to invertebrates in DPI. There are, however, several species which appear consistently (e.g. with fairly high frequencies): *Epiactis prolifera*, juvenile *Pugettia producta*, the Acmaeids, *Tegula brunnea*, *Henricia leviuscula* and *Leptasterias* spp.

<u>North Diablo Cove Intertidal Area (NDCI).</u> Invertebrate populations also appear to be depressed in this area. Some of the animals which occurred with higher numbers and frequencies in either Zone B or Zone C (Tables 14 and 15) are: *Epiactis prolifera*, juvenile *Pugettia producta*, *Fissurella volcano*, *Tegula brunnea* and *Tegula funebralis*, and *Henricia leviuscula*.

<u>North Control Intertidal Area (NCI).</u> Approximately the same number of species were found in Zones B and C (Tables 16 and 17) in this area as were found in stations in the NDCI and SDCI areas, although average numbers of individuals appear to be slightly higher here. Some of the more dominant

TABLE 12. Numbers and Percent Frequencies of Occurrence of Invertebrates Found in Intertidal ¼ $m^2$ Samples (N=11), Zone B, South Diablo Cove Intertidal Area - Diablo Canyon Power Plant Site - November 1973 to June 1974.

| Species | Sum | Mean/¼$m^2$ | Percent frequency |
|---|---|---|---|
| COELENTERATA | | | |
| *Anthopleura xanthogrammica* | 8 | 0.73 | 27.2 |
| *Epiactis prolifera* | 14 | 1.27 | 45.5 |
| ANNELIDA | | | |
| Unidentified nereid | 1 | 0.09 | 9.1 |
| ARTHOROPODA | | | |
| *Cancer antennarius* | 4 | 0.36 | 18.2 |
| *Pugettia producta* | 8 | 0.73 | 36.4 |
| *Pugettia richii* | 1 | 0.09 | 9.1 |
| MOLLUSCA | | | |
| Acmaeidae | 11 | 1.00 | 54.6 |
| *Aletes squamigera* | 2 | 0.18 | 9.1 |
| *Fissurella volcano* | 2 | 0.18 | 9.1 |
| *Mopalia* spp. | 4 | 0.36 | 27.2 |
| *Tegula brunnea* | 7 | 0.64 | 36.4 |
| *Tonicella lineata* | 2 | 0.18 | 18.2 |
| ECHINODERMATA | | | |
| *Henricia leviuscula* | 9 | 0.82 | 27.2 |
| *Leptasterias* spp. | 5 | 0.45 | 36.4 |
| *Stronglocentrotus purpuratus* | 1 | 0.09 | 9.1 |

TABLE 13. Numbers and Percent Frequencies of Occurrence of Invertebrates Found in Intertidal ¼ $m^2$ Samples (N=29), Zone C, South Diablo Cove Intertidal Area - Diablo Canyon Power Plant Site - November 1973 to June 1974.

| Species | Sum | Mean/¼$m^2$ | Percent frequency |
|---|---|---|---|
| PORIFERA | | | |
| Basket sponge | 1 | 0.03 | 3.4 |
| COELENTERATA | | | |
| *Epiactis prolifera* | 28 | 0.97 | 37.9 |
| ANNELIDA | | | |
| Unidentified tube worms | 40+ | 1.38+ | 13.8 |
| ARTHROPODA | | | |
| *Cancer antennarius* | 1 | 0.03 | 3.4 |
| *Pugettia gracilis* | 1 | 0.03 | 3.4 |
| *Pugettia producta* | 29 | 1.00 | 51.7 |
| *Pugettia richii* | 4 | 0.14 | 10.3 |
| MOLLUSCA | | | |
| Acmaeidae | 5 | 0.17 | 10.3 |
| *Aletes squamigera* | 1 | 0.03 | 3.4 |
| *Astraea gibberosa* | 6 | 0.21 | 13.8 |
| *Conus californica* | 2 | 0.07 | 6.9 |
| *Fissurella volcano* | 1 | 0.03 | 3.4 |
| *Molpalia* spp. | 2 | 0.07 | 6.9 |
| *Mytilus califorianus* | 1 | 0.03 | 3.4 |

TABLE 13. (cont)

| Species | Sum | Mean/¼m$^2$ | Percent frequency |
|---|---|---|---|
| MOLLUSCA (cont) | | | |
| *Phidiana nigra* | 1 | 0.03 | 3.4 |
| *Tegula brunnea* | 28 | 0.97 | 27.6 |
| *Tebula funebralis* | 2 | 0.07 | 6.9 |
| *Tonicella lineata* | 2 | 0.07 | 3.4 |
| Unidentified chiton | 2 | 0.07 | 6.9 |
| ECHINODERMATA | | | |
| *Henricia leviuscula* | 28 | 0.97 | 51.7 |
| *Leptasterias* spp. | 11 | 0.38 | 27.6 |
| *Patiria miniata* | 1 | 0.03 | 3.4 |
| TUNICATA | | | |
| *Amaroucium* sp. | NC | - | 3.4 |
| *Clavelina huntsmani* | 3 | 0.10 | 3.4 |

NC = Not counted

TABLE 14. Numbers and Percent Frequencies of Occurrence of Invertebrates Found in Intertidal ¼ $m^2$ Samples (N=14), Zone B, North Diablo Cove Intertidal Area - Diablo Canyon Power Plant Site - November 1973 to June 1974.

| Species | Sum | Mean/¼$m^2$ | Percent frequency |
|---|---|---|---|
| COELENTERATA | | | |
| *Anthogrammica xanthogrammica* | 1 | 0.07 | 7.1 |
| *Epiactis prolifera* | 1 | 0.07 | 7.1 |
| ANNELIDA | | | |
| Unidentified nemertean | 1 | 0.07 | 7.1 |
| ANTHROPODA | | | |
| *Balanus* sp. | 1A* | - | 7.1 |
| *Cancer antennarius* | 1 | 0.07 | 7.1 |
| *Cancer jordani* | 1 | 0.07 | 7.1 |
| *Pugettia producta* | 13 | 0.93 | 50.0 |
| MOLLUSCA | | | |
| Acmaeidae | 3 | 0.21 | 14.3 |
| *Fissurella volcano* | 14 | 1.00 | 35.7 |
| *Haliotis rufescens* | 1 | 0.07 | 7.1 |
| *Molpalia* sp. | 1 | 0.07 | 7.1 |
| *Mytilus califorianus* | P† | - | 7.1 |
| *Nuttallina californica* | 7 | 0.50 | 21.4 |
| *Tegula brunnea* | 14 | 1.00 | 21.4 |
| *Tegula funebralis* | 11 | 0.79 | 28.6 |
| *Tonicella lineata* | 1 | 0.07 | 7.1 |

TABLE 14. (cont)

| Species | Sum | Mean/¼m$^2$ | Percent frequency |
|---|---|---|---|
| ECHINODERMATA | | | |
| *Henricia leviuscula* | 4 | 0.29 | 28.6 |
| *Leptasterias* spp. | 3 | 0.21 | 21.4 |

A* = One count of abundance.

P† = Present, abundance not estimated.

TABLE 15. Numbers and Percent Frequencies of Occurrence of Invertebrates Found in Intertidal ¼ $m^2$ Samples (N=16), Zone C, North Diablo Cove Intertidal Area - Diablo Canyon Power Plant Site - November 1973 to June 1974.

| Species | Sum | Mean/¼$m^2$ | Percent frequency |
|---|---|---|---|
| COELENTERATA | | | |
| *Epiactis prolifera* | 34 | 2.12 | 62.5 |
| ANNELIDA | | | |
| Unidentified nemertean | 1 | 0.06 | 6.2 |
| ARTHROPODA | | | |
| *Balanus* sp. | 15 | 0.97 | 6.2 |
| *Idothea* sp. | 1 | 0.06 | 6.2 |
| *Pugettia producta* | 12 | 0.75 | 43.8 |
| *Pugettia richii* | 3 | 0.19 | 6.2 |
| MOLLUSCA | | | |
| ACMAEIDAE | 4 | 0.25 | 18.8 |
| *Astraea gibberosa* | 2 | 0.12 | 12.5 |
| *Fissurella volcano* | 3 | 0.19 | 18.8 |
| *Haliotis cracherodii* | 5 | 0.32 | 12.5 |
| *Haliotis rufescens* | 1 | 0.06 | 6.2 |
| *Tegula brunnea* | 34 | 2.12 | 43.8 |
| *Tegula funebralis* | 3 | 0.19 | 6.2 |
| *Thais emarginata* | 1 | 0.06 | 6.2 |
| *Tonicella lineata* | 3 | 0.19 | 18.8 |

TABLE 15. (cont)

| Species | Sum | Mean/¼m$^2$ | Percent frequency |
|---|---|---|---|
| ECHINODERMATA | | | |
| *Henricia leviuscula* | 14 | 0.88 | 31.2 |
| *Leptasterias* spp. | 4 | 0.25 | 25.0 |
| *Pateria miniata* | 1 | 0.06 | 6.2 |
| *Pycnopodia helianthoides* | 1 | 0.06 | 6.2 |
| *Stronglocentrotus purpuratus* | 1 | 0.06 | 6.2 |
| TUNICATA | | | |
| *Clavelina huntsmani* | 31 | 1.94 | 12.5 |
| Unidentified ascidians | | | 18.8 |

TABLE 16. Numbers and Percent Frequencies of Occurrence of Invertebrates Found in ¼ $m^2$ Samples (N=23), Zone B, North Control Intertidal - Diablo Canyon Power Plant Site - November 1973 - June 1974.

| Species | Sum | Mean/¼$m^2$ | Percent frequency |
|---|---|---|---|
| COELENTERATA | | | |
| *Corynactis californica* | 6 | 0.26 | 4.3 |
| *Epiactis prolifera* | 1 | 0.04 | 4.3 |
| ANNELIDA | | | |
| Unid. nereid | 4 | 0.17 | 13.0 |
| Unid. tube worms | 1 | 0.04 | 4.3 |
| ARTHROPODA | | | |
| *Pollicipes polymerus* | 50 | 2.17 | 13.0 |
| *Pugettia producta* | 10 | 0.43 | 26.1 |
| *Tetraclita squamosa* | 18 | 0.78 | 8.7 |
| MOLLUSCA | | | |
| ACMAEIDAE | 116 | 5.04 | 52.2 |
| *Astraea gibberosa* | 1 | 0.04 | 4.3 |
| *Fissurella volcano* | 28 | 1.22 | 39.1 |
| *Haliotis cracherodii* | 32 | 1.39 | 21.7 |
| *Haliotis rufescens* | 1 | 0.04 | 4.3 |
| *Mopalia* spp. | 19 | 0.83 | 34.8 |
| *Mytilus californianus* | 54 | 2.35 | 26.1 |
| *Nuttallina californica* | 21 | 0.91 | 21.7 |
| *Rostanga pulchra* | 2 | 0.09 | 4.3 |
| *Tegula brunnea* | 31 | 1.35 | 30.4 |

TABLE 16. (cont)

| Species | Sum | Mean/¼$m^2$ | Percent frequency |
|---|---|---|---|
| MOLLUSCA (cont) | | | |
| *Tegula funebralis* | 50 | 2.17 | 47.8 |
| *Thais emarginata* | 8 | 0.35 | 21.7 |
| ECHINODERMATA | | | |
| *Henricia leviuscula* | 1 | 0.04 | 4.3 |
| *Leptasterias* spp. | 6 | 0.26 | 26.1 |
| *Strongylocentrotus purpuratus* | 5 | 0.22 | 17.4 |

TABLE 17. Numbers and Percent Frequencies of Occurrence of Invertebrates Found in ¼ $m^2$ Samples (N=23), Zone C, North Control Intertidal - Diablo Canyon Power Plant Site - November 1973 - June 1974.

| Species | Sum | Mean/¼$m^2$ | Percent frequency |
|---|---|---|---|
| COELENTERATA | | | |
| *Epiactis prolifera* | 44 | 1.91 | 39.1 |
| ARTHROPODA | | | |
| *Cancer antennarius* | 1 | 0.04 | 4.3 |
| *Cancer productus* | 1 | 0.04 | 4.3 |
| *Crangon dentipes* | 3 | 0.13 | 13.0 |
| *Pugettia producta* | 4 | 0.17 | 17.4 |
| MOLLUSCA | | | |
| Acmaeidae | 2 | 0.09 | 4.3 |
| *Mytilus californianus* | 1 | 0.04 | 4.3 |
| *Tegula brunnea* | 27 | 1.17 | 47.8 |
| *Tegula funebralis* | 12 | 0.52 | 8.7 |
| *Tonicella lineata* | 2 | 0.09 | 4.3 |
| ECHINODERMATA | | | |
| *Henricia leviuscula* | 2 | 0.09 | 8.7 |
| *Leptasterias* spp. | 11 | 0.48 | 26.1 |
| *Patiria miniata* | 1 | 0.04 | 4.3 |
| *Strongylocentrotus purpuratus* | 1 | 0.04 | 4.3 |

forms are: *Epiactis prolifera*, the Acmaeids, *Tegula brunnea* and *Tegula funebralis*, *Fissurella volcano*, *Haliotis cracherodii* and *Mytilus californianus*.

Abalone

Two species of abalone, *Haliotis rufescens* (red abalone) and *Haliotis cracherodii* (black abalone) were found in every study area along a 2 m (6.6 ft) swath of the 30 m (99 ft) transect line with the exception of the Diablo Point Intertidal where only black abalone occurred (Tables 18 and 19). In two of three areas where the two species co-occurred, *H. cracherodii* was by far most abundant: 2.84 black abalone per $m^2$ (10 $ft^2$) vs. 0.31 red abalone per $m^2$ (10 $ft^2$) were found in the NDCI and 0.69 black abalone per $m^2$ (10 $ft^2$) vs. 0.05 red abalone per $m^2$ (10 $ft^2$) in the NCI. Although both species appear depressed in SDCI, red abalone outnumbered black abalone 0.10 per $m^2$ (10 $ft^2$) to 0.03 per $m^2$ (10 $ft^2$). In DPI, where no red abalone were found, black abalone occurred at the rate of 0.94 per $m^2$ (10 $ft^2$).

Size frequencies of *Haliotis rufescens* measured from transects conducted in NDCI and SDCI (Figure 5) are approximately similar and appear to agree with the size ranges of red abalone removed from the Discharge Cove cofferdam site in 1970 (Burge and Schultz 1973). Size frequencies of the *H. cracherodii*, however, vary by area Figures 6 and 7); whereas, individuals measured from NDCI and NCI appear to have similar size ranges. Abalone from the more exposed DPI seem to be significantly smaller.

The abalone counts made in June 1974 along the permanent station transects established by Burge and Schultz agree very closely with counts made by them at three surveys in 1971 (Table 20). Distribution and numbers of abalone from permanent transects are also supportive of average numbers and distribution of abalone as found in our random studies (Table 18).

TABLE 18. Numbers of Abalones at Intertidal Stations (Area = 30 X 2 m) in Discharge Cove Study Areas - Diablo Canyon Power Plant Site - November 1973 to June 1974.

| NORTH DIABLO COVE INTERTIDAL | | | SOUTH DIABLO COVE INTERTIDAL | | | DIABLO POINT INTERTIDAL | |
|---|---|---|---|---|---|---|---|
| Station number | *Haliotis rufescens* | *Haliotis cracherodii* | Station number | *Haliotis rufescens* | *Haliotis cracherodii* | Station number | *Haliotis cracherodii* |
| 1 | 27 | 2 | 1 | 8 | 5 | 3 | 2 |
| 3 | 45 | 282 | 3 | 13 | 0 | 9 | 128 |
| 3 | 30 | 215 | 4 | 15 | 1 | 8 | 28 |
| 4 | 8 | 180 | 5 | 1 | 0 | 6 | 71 |
| 5 | 10 | 99 | 5 | 0 | 10 | 7 | 52 |
| 7 | 7 | 186 | 5 | 1 | 0 | | |
| 8 | 11 | 386 | 6 | 7 | 0 | | |
| 9 | 11 | 12 | 8 | 3 | 0 | | |
| Total number abalone | 149 | 1362 | | 48 | 16 | | 281 |
| Total area surveyed $m^2$ (10 $ft^2$) | 480 | 480 | | 480 | 480 | | 300 |
| Mean numbers abalone per $m^2$ (10 $ft^2$) | 0.31 | 2.84 | | 0.10 | 0.03 | | 0.94 |

TABLE 19. Numbers of Abalone at Intertidal Stations (Area = 30 X 2 meters) in North Control Study Area - Diablo Canyon Power Plant Site - December 1973 - February 1974.

| Station number | *Haliotis rufescens* | *Haliotis cracherodii* |
|---|---|---|
| 1 | 1 | 128 |
| 5 | 0 | 171 |
| 6 | 4 | 58 |
| 12 | 10 | 7 |
| 12 | 1 | 0 |
| 13 | 11 | 8 |
| 15 | 0 | 2 |
| 20 | 0 | 0 |
| 20 | 0 | 0 |
| Total number abalone | 27 | 374 |
| Total area surveyed | 540 $m^2$ | 540 $m^2$ |
| Mean number abalone per $m^2$ (10 $ft^2$) | 0.05 | 0.69 |

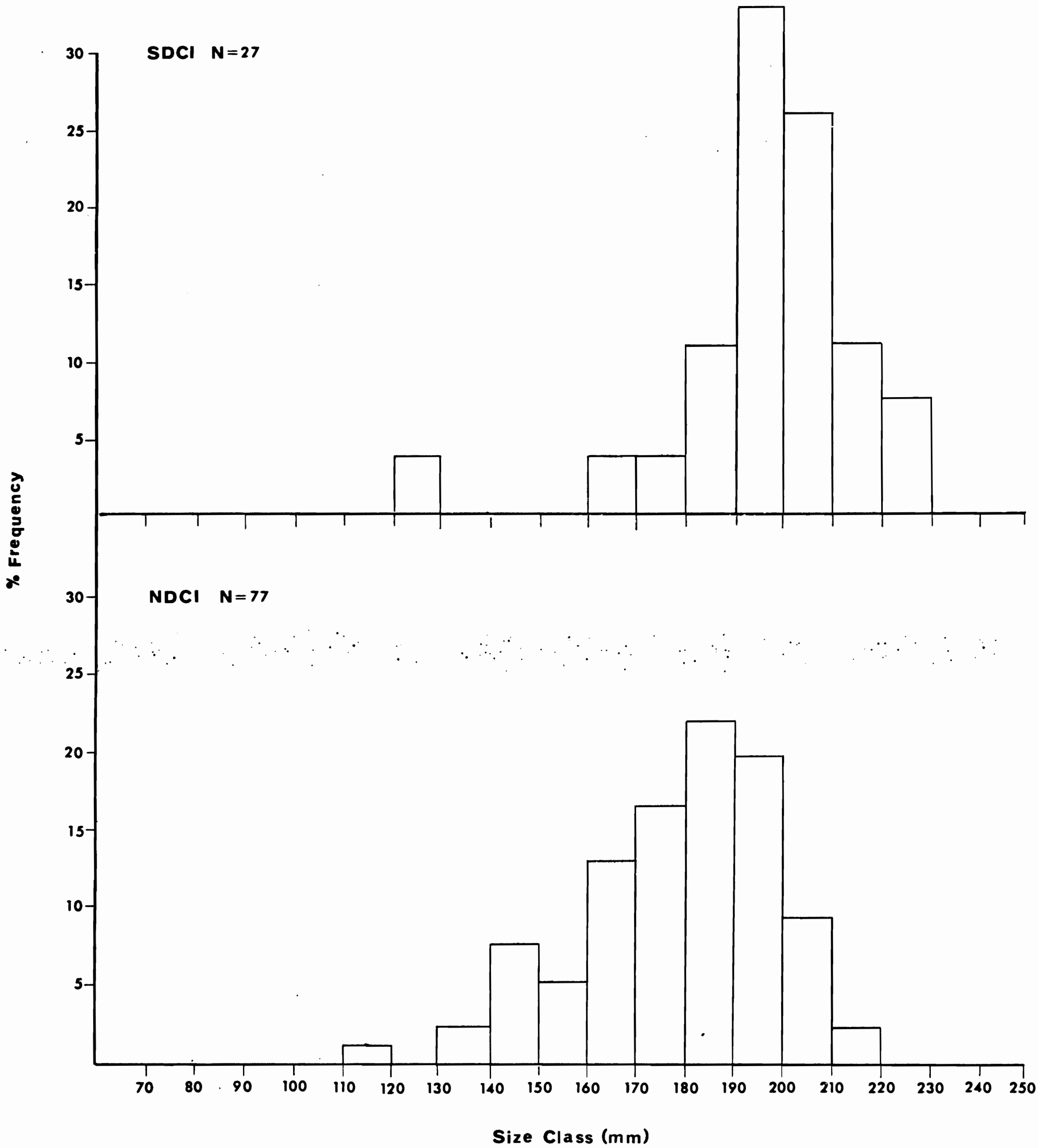


FIGURE 5. Length frequencies of *Haliotis rufescens* from random intertidal transects - South and North Diablo Cove study areas - (N = number measured) - Diablo Canyon power plant site. November 1973-May 1974.

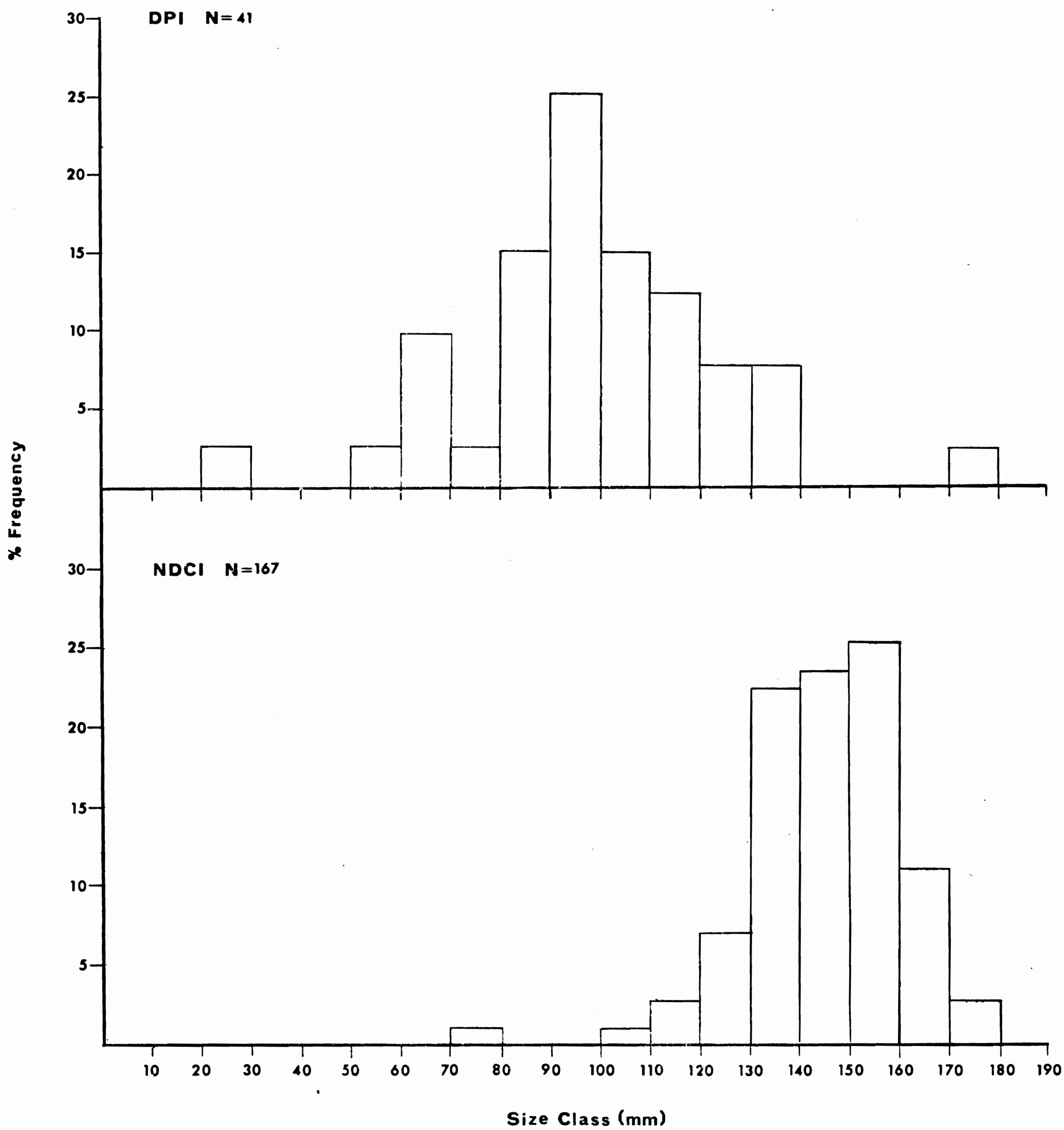


FIGURE 6. Length-frequencies of *Haliotis cracherodii* from the random intertidal transects - Diablo Point and North Diablo Cove study areas - (N = number measured) - Diablo Canyon power plant site. November 1973-May 1974.

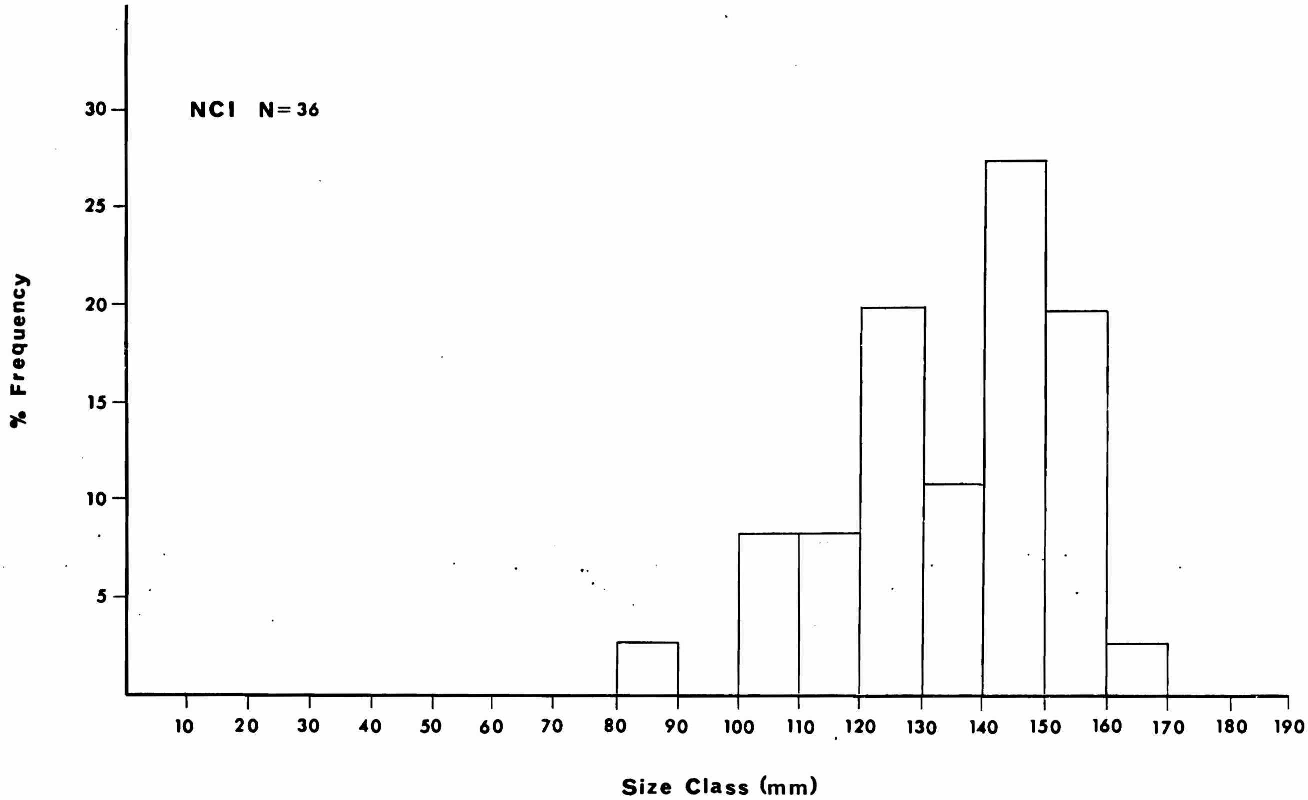


FIGURE 7. Length-frequencies of *Haliotis cracherodii* from random intertidal transects - North Control study area - (N = number measured) - Diablo Canyon power plant site. November 1973-May 1974.

TABLE 20. Comparison of Abalone Counts Made at Intertidal Permanent Transects During 1971 and 1974. Diablo Canyon Power Plant Site.

| Transect | 1971* | | 1974 | |
|---|---|---|---|---|
| | *Haliotis cracherodii* | *Haliotis rufescens* | *Haliotis cracherodii* | *Haliotis rufescens* |
| 2A | 267 | 2.7 | 250 | 1 |
| 2B | 113 | 3.6 | 133 | 3 |
| 3A | 22 | 2.3 | 21 | 0 |
| 4B | 55 | 0 | 32 | 0 |
| 4C | 44 | 0 | 28 | 0 |

*1971 counts are means from 3 surveys.

Permanent transects 2A and 2B are located in our NDCI, transect 3A is in our SDCI, and transects 4B and 4C are in our DPI study area.

Soft Algae, Articulated Corallines and Phyllospadix

For this annual report, only the data for soft red algae, which occurred with frequencies greater than 25% in at least one study area, are presented (Table 21). This frequency appears to be sufficient to enumerate the major floral components since these 'dominant' species form from 70.0 to 98.3% of the total biomass taken in the samples from the various study areas. The most common species was *Iridaea cordata* var. *splendens* which was found in every zone in every area, ranging from 7.7 to 57.3 g/¼ $m^2$ (0.1 to 0.7 oz/$ft^2$). The only other alga which occurred in appreciable quantity in every study area was *Prionitis lanceolata* which ranged from 0.8 to 18.2 g/¼ $m^2$ (0.01 to 0.2 oz/$ft^2$) in the various areas. As a glance at the data shows, the variation by species in mean weights and occurrence is very high from one study area to another. However, when the total biomass of 'soft' algae is treated by zone and by area, as the percent cover by articulated corallines and *Phyllospadix scouleri* has been, the variation between zones and area are greatly lowered (Table 22). In most instances, the 95% confidence intervals of the mean are much less than their means. One exception to this among the 'soft' algae is the mean figure for Zone C in SDCI for which the confidence interval is slightly higher than the mean. The reason for this is that 1 of 14 samples yielded an excessive 647.5 g (1.4 lb) *Iridaea cordata* var. *splendens* which was 552.4 g (1.2 lb) heavier than the next largest sample. When this sample is omitted, the mean and confidence interval becomes $42.9 \pm 15.8$ g/¼ $m^2$ ($0.6 \pm 0.2$ oz/$ft^2$), a number that compares favorably with other figures of algal abundance.

TABLE 21. Dominant* Red Algae from Intertidal Stations - Diablo Canyon Power Plant Site - November 1973-February 1974 (Davidson Period) - (N = Sample Size and gm weights are from dried plants).

| AREA: | Diablo Point Intertidal | | South Diablo Cove Intertidal | | | | North Diablo Cove Intertidal | | | | North Control Intertidal | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Zone: | B (N = 8) | | B (N = 10) | | C(N = 14) | | B (N = 5) | | C (N = 13) | | B (N = 22) | | C (N = 20) | |
| | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. |
| Species | | | | | | | | | | | | | | |
| *Agardhiella tenera* | 0 | - | TR | - | TR | - | 0.9 | 40.0 | 0.1 | 23.1 | 0 | - | 0 | - |
| *Botryoglossum farlowianum* | 0 | - | TR | 20.0 | 3.4 | 64.3 | TR | 20.0 | 3.6 | 69.2 | 2.1 | 36.4 | 1.7 | 55.0 |
| *Cryptopleura lobulifera* | 5.5 | 50.0 | TR | - | TR | - | TR | - | TR | - | TR | - | 0 | - |
| *Cryptopleura* sp. | 0.1 | 37.5 | TR | - | TR | - | 0 | - | 0.3 | 38.5 | 1.3 | 40.9 | TR | 10.0 |
| *Gastroclonium coulteri* | TR | - | 7.9 | 60.0 | 5.7 | 85.7 | 7.3 | 40.0 | 8.5 | 53.8 | 5.2 | 50.0 | 0.1 | 5.0 |
| *Gigartina californica* | 5.5 | 62.5 | TR | - | TR | - | 8.8 | 20.0 | 17.6 | 38.5 | TR | - | TR | - |
| *Gigartina canaliculata* | TR | - | 5.6 | 90.0 | 0.8 | 50.0 | 2.0 | 60.0 | 0.1 | 38.5 | 2.3 | 50.0 | 0.1 | 10.0 |
| *Iridaea cordata* var. *splendens* | 31.7 | 87.5 | 17.9 | 60.0 | 57.3 | 85.7 | 14.1 | 100.0 | 7.7 | 69.2 | 24.9 | 90.0 | 8.8 | 60.0 |
| *Iridaea heterocarpum* | 0 | - | 0.3 | 50.0 | TR | 14.3 | TR | - | TR | - | 0 | - | 0 | - |
| *Laurencia spectabilis* | 0.7 | 50.0 | 0.5 | 40.0 | 2.0 | 100.0 | 0.3 | 20.0 | 0.2 | 46.2 | TR | - | TR | - |
| *Microcladia borealis* | 0.4 | 50.0 | 0 | - | 0 | - | 0 | - | TR | - | TR | - | TR | - |
| *Microcladia coulteri* | 0.1 | 37.5 | 0.4 | 60.0 | 1.0 | 71.4 | 0.5 | 40.0 | 0.6 | 61.5 | TR | - | TR | - |
| *Plocamium violaceum* | 0.3 | 25.0 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| *Prionitis lanceolata* | 2.1 | 62.5 | 5.0 | 80.0 | 14.7 | 85.7 | 11.1 | 80.0 | 18.2 | 92.3 | 0.8 | 36.4 | 1.4 | 55.0 |
| *Rhodomela larix* | 0 | - | 8.6 | 50.0 | TR | 7.1 | - | - | 0 | - | 0 | - | 0 | - |
| Mean gms/zone (oz/zone) | 46.4 (1.6) | | 46.2 (1.6) | | 84.9 (3.0) | | 45.0 (1.6) | | 56.9 (2.0) | | 36.6 (1.3) | | 12.1 (0.4) | |

TABLE 21. (cont)

| AREA: | Diablo Point Intertidal | | South Diablo Cove Intertidal | | | | North Diablo Cove Intertidal | | | | North Control Intertidal | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Zone: | B (N = 8) | | B (N = 10) | | C(N = 14) | | B( N = 5) | | C (N = 13) | | B (N = 22) | | C (N = 20) | |
| | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. | Mean gms/¼m² | Percent freq. |
| Total mean gms/zone of all 'soft' algae (oz/zone) | 49.7 (1.8) | | 48.9 (1.7) | | 87.0 (3.1) | | 61.4 (2.2) | | 57.9 (2.0) | | 52.3 (1.8) | | 14.9 (0.5) | |
| Percent composition by dominant species | 93.4 | | 94.5 | | 97.6 | | 73.3 | | 98.3 | | 70.0 | | 81.2 | |

TR = Trace

* Those alga which occurred with frequencies > 25% in the quadrats in at least one study area.

TABLE 22. Average Biomass (Dry Wts) of 'Soft' Algae and Average Percent Cover by Articulated Corallines and *Phyllospadix scouleri* (with 95% Confidence Intervals) and Their Percent Frequencies of Occurrence. Diablo Canyon and North Control Study Areas. November 1973 - June 1974. ( N = Sample Size).

| Area | Zone | 'Soft' Algae* | | Articulated Corallines** | | *Phyllospadix scouleri*** | |
|---|---|---|---|---|---|---|---|
| | | Mean dry wt. (gms)/¼ $m^2$ | Percent freq. of occurrence | Mean percent cover/¼ $m^2$ | Percent freq. of occurrence | Mean percent cover/¼ $m^2$ | Percent freq. of occurrence |
| Diablo Point Intertidal | A | No samples during Davidson | | 22.5 ± 26.1 (N = 6) | 66.7 | 0 (N = 6) | 0 |
| Diablo Point Intertidal | B | 49.7 ± 16.7 (N = 8) | 100.0 | 48.3 ± 10.7 (N = 18) | 100.0 | 0 (N = 18) | 0 |
| South Diablo Cove Intertidal | B | 48.9 ± 25.1 (N = 10) | 100.0 | 18.7 ± 19.0 (N = 11) | 90.9 | 11.1 ± 16.5 (N = 11) | 36.4 |
| South Diablo Cove Intertidal | C | 87.0 ± 96.3 (N = 14) | 100.0 | 13.0 ± 7.4 (N = 29) | 79.3 | 17.6 ± 7.9 (N = 29) | 72.4 |
| North Diablo Cove Intertidal | B | 61.4 ± 39.1 (N = 5) | 100.0 | 12.9 ± 8.2 (N = 14) | 78.6 | 25.6 ± 17.5 (N = 14) | 57.2 |
| North Diablo Cove Intertidal | C | 57.9 ± 38.4 (N = 13) | 100.0 | 26.6 ± 11.2 (N = 16) | 93.7 | 27.2 ± 11.9 (N = 16) | 87.5 |
| North Control Intertidal | B | 52.3 ± 11.7 (N = 22) | 86.4 | 19.5 ± 10.1 (N = 23) | 78.3 | 5.7 ± 7.8 (N = 23) | 21.7 |
| North Control Intertidal | C | 14.9 ± 8.4 (N = 20) | 100.0 | 5.7 ± 4.8 (N = 23) | 26.1 | 68.0 ± 14.6 (N = 23) | 95.7 |

* Sampled from Davidson Period only (November 1973 - February 1974)

** Sampled from Davidson and Early Upwelling Periods (November 1973 - June 1974)

The articulated corallines form a substantial portion of the flora and appear to be more abundant in the DPI than in other areas. The mean percent cover per ¼ $m^2$ (2.7 $ft^2$) ranged from a low of 5.7% in the NCI to a high of 48.3%. *Phyllospadix scouleri* (surfgrass) did not occur in DPI samples, but represents an important component of intertidal plants in all other study areas. The NCI reflected the lowest and highest means for surfgrass: 5.7%/¼ $m^2$ in Zone B and 68.0%/¼ $m^2$ in Zone C.

## Intertidal Fishes

One intertidal icthyocide station was completed on February 20, 1974 in the North Control Area at Station One (lat 35°14'10" N, long 120°52'30" W) using proven collection methods (Gotshall et al. 1974). The collection was made to yield data on a new North Control Area not considered in the pre-operational study (Burge and Schultz 1973). The pool was about 0.7 m (2.3 ft) above mean lower low water and approximately 7.6 m (25.1 ft) long X 3.1 m (10.2 ft) wide X 0.8 m (2.6 ft) deep. Associated marine plants in and around the tide pool included: *Iridea flaccida, Laurencia spectabilis, Callithamnion* sp., *Botryoglossum farlowianum, Agardhiella tenera, Petrocelis franciscana,* and *Phyllospadix scouleri.*

One hundred sixty-eight fish representing 11 species from 5 families and 2 unidentified juvenile cottids were collected (Table 23). *Xiphister atropurpeus* was the most abundant fish taken (35%), and *X. mucosus* was second in abundance (19%). Other species collected were: *Anoplarchus purpurescens, Xererpes fucorum, Oligocottus snyderi, Artedius lateralis, Clinocottus analis, Oligocottus rimensis, Gibbonsia metzi, G. montereyensis,* and *Gobiesox maeandricus.*

It is difficult because of sampling techniques to compare our intertidal fish collection to four previous shore collections (Burge and Schultz

TABLE 23. Fishes Collected at Intertidal Station, North Control Area - Diablo Canyon Power Plant Site - February 20, 1974

| SPECIES | Number | SL in mm |
|---|---|---|
| *Anoplarchus purpurescens* | 15 | 37.9 - 73.9 |
| *Artedius lateralis* | 4 | 58.3 - 114.7 |
| *Clinocottus analis* | 2 | 73.7 - 84.2 |
| *Gibbonsia metzi* | 8 | 107.5 - 185.3 |
| *Gibbonsia montereyensis* | 5 | 64.1 - 83.1 |
| *Gibbonsia* sp. | 2 | 24.9 - 26.4 |
| *Gobiesox maeandricus* | 6 | 35.4 - 76.5 |
| *Oligocottus rimensis* | 3 | 13.9 - 28.9 |
| *Oligocottus snyderi* | 18 | 13.2 - 62.3 |
| *Xererpes fucorum* | 11 | 62.6 - 101.2 |
| *Xiphister atropurpureus* | 61 | 33.8 - 178.0 |
| *Xiphister mucosus* | 33 | 52.8 - 367.0 |
| COTTIDAE (Unidentified) | 2 | 11.3 - 11.5 |
| TOTAL | 170 | |

1973) made in the Diablo Area from May 1970 to July 1971. Each of their collections was made along a predetermined length of shoreline using from 16 to 23 1 (16.8 to 24.1 qt) of icthyocide dispersed over areas of approximately 280 to 370 $m^2$ (3,052 to 4,033 $ft^2$). This collection was made using 1 L (1.05 qt) of icthyocide over an area of approximately 23.2 $m^2$ (252 $ft^2$).

Their fish collections ranged from a low of 189 fish to a high of 1,599 fish representing 25 to 40 species, respectively. These collections were made to a depth of approximately 3 m (9.9 ft). This would increase the number of species in comparison to our tide pool collection which was made to a depth of 0.8 m (2.6 ft).

The absence of the more pelagic species, juvenile rockfish (*Sebastes* spp.), and surfperch (Embiotocidae) from our collection is probably a result of differing collection techniques. However, even with these differences, 77.8% of the fish collected at the previous shore stations (Table 24) were represented by species collected at NCI - 1 and all species collected at this station were collected in previous shore collections.

## SEA OTTER SURVEYS

### Methods

Once a week, from July through December 1973, we made counts of sea otters between Point Buchon and Pecho Rock. From January through June 1974, these counts were conducted by Suzanne Benech, Pacific Gas and Electric Company employee; her data are included in this report.

Counts were made by walking the coast from Point Buchon to Intake Cove; from Intake Cove to Pecho Rock counts were from the road. A 30-60x spotting scope was used to make counts and to observe feeding behavior.

### Results

The number of otters between Point Buchon and Lion Rock increased from a low of 26 otters (one count) in July 1973 to a high of 124 otters in April

TABLE 24. Comparison of Selected Fish Collected at Intertidal Stations - Diablo Canyon Power Plant Site.

| Species | North Control Intertidal* | | Combined Diablo Canyon** | |
|---|---|---|---|---|
| | Number of fish | Percent of total | Number of fish | Percent of total |
| *Xiphister atropurpureus* | 61 | 35.9 | 554 | 16.7 |
| *Xiphister mucosus* | 33 | 19.4 | 541 | 16.3 |
| *Oligocottus snyderi* | 18 | 10.6 | 36 | 1.1 |
| *Anoplarchus purpurescens* | 15 | 8.8 | 69 | 2.1 |
| *Xerepes fucorum* | 11 | 6.5 | 945 | 28.4 |
| *Gibbonsia metzi* | 8 | 5.7 | 40 | 1.2 |
| *Gobiesox maeandricus* | 6 | 3.5 | 76 | 2.3 |
| *Gibbonsia montereyensis* | 5 | 2.9 | 188 | 5.6 |
| *Artedius lateralis* | 4 | 2.4 | 73 | 2.2 |
| *Oligocottus rimensis* | 3 | 1.7 | 2 | 0.1 |
| *Clinocottus analis* | 2 | 1.2 | 54 | 1.6 |
| Cottidae (unidentified) | 2 | 1.2 | -- | -- |
| *Gibbonsia* sp. | 2 | 1.2 | -- | -- |
| TOTAL | 170 | 100 | 2588 | 77.8 |
| TOTAL IN ALL COLLECTIONS | 170 | 100 | 3328 | 100 |

* February 20, 1974 Collection

** 1970 - 1971 Collections

1974 (mean of four counts) and then decreased to a mean count of 60 in June (Table 25). In May we first observed otters in Diablo Cove and by the end of June the numbers in the cove had increased to between 30 and 40 animals. No otters have been observed south of Diablo Cove.

At subtidal stations surveyed in June, there was much evidence of otter foraging in the form of broken empty giant red sea urchin and red abalone shells. At one station we counted 24 dead sea urchins and 126 live sea urchins. The count of giant red sea urchins at random 30 $m^2$ (324 $ft^2$) stations surveyed since May in the cove ranged from 7 to 186 with a mean of 105.

There has been very little commercial sea urchin fishing effort observed in the cove.

Abalone appear to continue to dominate the diet of sea otters in this area; 59 were observed feeding on abalone, 24 on sea urchins and 2 on crabs, and 78 on unidentifiable material.

## COMMERCIAL SEA URCHIN AND ABALONE FISHERY SURVEYS

### Sea Urchin Fishery

#### Methods

Commercial sea urchin fishermen were interviewed whenever possible. Data recorded included total pounds landed, number of diving hours, location and depth of catch, and when time permitted, a sample of 50 sea urchins was weighed in order to determine average weight. Total landings for the area between Morro Bay and Shell Beach were obtained from the Department's biostatistical section in Long Beach.

#### Results

Commercial divers have been harvesting giant red sea urchins, *Strongylocentrotus franciscanus*, from the Diablo Canyon area since 1972 (Table 26).

TABLE 25. Monthly Mean Counts of Sea Otters and Observed Feeding Habits - Point Buchon to Lion Rock - July 1973 through June 1974.

| Date | Mean count | Number of counts | Number observed feeding | | | | |
|---|---|---|---|---|---|---|---|
| | | | Abalone | Urchin | Crabs | Unid. | Misc. |
| July 1973 | 26 | 1 | | | | | |
| August 1973 | 69 | 4 | 11 | | | 3 | |
| September 1973 | 0 | 0 | | | | | |
| October 1973 | 37 | 4 | 7 | 1 | 1 | 1 | |
| November 1973 | 40 | 4 | 3 | 3 | | | |
| December 1973 | 42 | 4 | 1 | 2 | | | |
| January 1974 | 84 | 3 | 5 | 1 | | 1 | |
| February 1974 | 85 | 4 | 7 | 3 | | 1 | |
| March 1974 | 120 | 4 | 3 | 6 | 1 | 2 | |
| April 1974 | 124 | 4 | 9 | 8 | | 15 | |
| May 1974 | 89 | 5 | 5 | | | 40 | 2 |
| June 1974 | 60 | 4 | 8 | | | 15 | |
| Totals | | | 59 | 24 | 2 | 78 | 2 |

TABLE 26. Annual Commercial Landings of Red Abalone and Giant Red Sea Urchins - Morro Rock to Avila - 1965 through 1973.

| Year | Red abalone lb | Red abalone kg | Red urchins lb | Red urchins kg |
|---|---|---|---|---|
| 1964 | 730,947 | (331,484) | 0 | ( 0 ) |
| 1965 | 606,109 | (274,870) | 0 | ( 0 ) |
| 1966 | 389,919 | (176,828) | 0 | ( 0 ) |
| 1967 | 296,814 | (134,605) | 0 | ( 0 ) |
| 1968 | 365,767 | (165,875) | 0 | ( 0 ) |
| 1969 | 284,417 | (128,983) | 0 | ( 0 ) |
| 1970 | 190,504 | ( 86,394) | 0 | ( 0 ) |
| 1971 | 272,271 | (123,475) | 0 | ( 0 ) |
| 1972 | 84,500 | ( 38,321) | 69,861 | ( 31,682) |
| 1973 | 103,468 | ( 46,923) | 264,968 | (120,163) |

The fishery has not operated throughout the year primarily due to the change in condition of the sea urchin gonads. Evidently, the gonads are not acceptable for processing after spawning. For instance, from September through December 1973, processors refused to buy sea urchins in the Avila area.

During 1972 and 1973 the fishing area included Diablo Cove, but in 1974 most landings have come from a relatively small area around Pecho Rock in depths of 3.0 to 13.7 m (10 to 45 ft).

A total of 36 sea urchin divers were interviewed during the year (Table 27). Catch-per-day ranged from 748 kg to 1490 kg (1650 to 3284 lb) per day. The interviewed divers averaged 234 kg of sea urchins per hour (approximately 377 sea urchins).

## Abalone Fishery

### Methods

The same type of information obtained from the commercial sea urchin divers was obtained from commercial abalone divers.

### Results

Fourteen abalone fishermen were interviewed between October and December 1973 (Table 28). These divers averaged 69 red abalone per day or 11 per hr.

Landings of red abalone from the area, Morro Rock to Avila, have been steadily declining, particularly during 1972 and 1973 (Table 26). Part of this decline is probably due to fluctuations in survival of red abalone populations, but the sharp drop which occurred in 1972 and 1973 probably reflects sea otter foraging between Morro Rock and Diablo Cove. There has been a noticeable decline in observed effort during the first half of 1974 and we predeict another sharp decline in landings during the second half of 1974.

TABLE 27. Summary of Commercial Sea Urchin Fishery Interviews - Point Buchon to Avila - July 1973 through June 1974.

| Date | Number of boats sampled | Hours fished | Landings of sea urchins lb | kg | mean weight (kg) |
|---|---|---|---|---|---|
| July 17, 1973 | 1 | - | 1923 | 872 | 0.60 |
| July 18, 1973 | 1 | - | 1953 | 886 | 0.53 |
| February 6, 1974 | 1 | - | 1650 | 748 | - |
| February 7, 1974 | 1 | - | 3284 | 1489 | - |
| April 8, 1974 | 3 | 13.0 | 5256 | 2384 | 0.74 |
| April 12, 1974 | 3 | 9.0 | 4643 | 2106 | 0.56 |
| April 22, 1974 | 4 | 13.0 | 4484 | 2033 | 0.54 |
| April 23, 1974 | 3 | 16.0 | 8391 | 3805 | 0.72 |
| June 11, 1974 | 1 | 3.0 | 1880 | 852 | - |
| June 12, 1974 | 1 | 3.0 | 1960 | 889 | - |
| June 13, 1974 | 1 | 3.0 | 2100 | 952 | - |
| June 16, 1974 | 1 | 3.0 | 2450 | 1111 | - |
| June 17, 1974 | 1 | 3.5 | 2180 | 989 | - |
| June 18, 1974 | 1 | 6.0 | 2240 | 1016 | - |
| June 19, 1974 | 1 | 3.0 | 2220 | 1007 | - |
| June 20, 1974 | 2 | 8.5 | 3220 | 1460 | - |
| June 21, 1974 | 1 | 6.0 | 2140 | 971 | - |
| June 23, 1974 | 1 | 3.5 | 2250 | 1020 | - |
| June 24, 1974 | 1 | 3.0 | 2220 | 1007 | - |
| June 25, 1974 | 1 | 3.0 | 2160 | 980 | - |
| June 26, 1974 | 1 | 3.0 | 2240 | 1016 | - |
| June 27, 1974 | 1 | 3.0 | 2380 | 1079 | - |
| TOTALS | 36 | 105.5 | 63,224 | 28,672 | |

TABLE 28. Summary of Commercial Abalone Fishery Interviews - Point Buchon to Point San Luis - October through December 1973.

| Date | Numbers of boats sampled | Hours fished | Landings of red abalone | | |
|---|---|---|---|---|---|
| | | | Number | average weight (lb) | Size range (mm) |
| October 1, 1973 | 1 | 3.5 | 28 | 3.5 | |
| October 4, 1973 | 1 | -- | 29 | | |
| October 5, 1973 | 2 | -- | 59 | 3.7 | |
| October 9, 1973 | 1 | 6.5 | 50 | 3.9 | |
| October 10, 1973 | 3 | 24.0 | 273 | 4.0 | 196 - 224 |
| October 16, 1973 | 1 | 8.5 | 48 | 4.4 | 200 - 228 |
| October 17, 1973 | 1 | 9.0 | 124 | 4.4 | 196 - 218 |
| October 18. 1973 | 1 | 9.5 | 67 | 4.1 | 196 - 221 |
| November 5, 1973 | 2 | 11.0 | 95 | 3.8 | 195 - 225 |
| December 4, 1973 | 1 | 5.5 | 193 | | 195 - 227 |
| TOTALS | 14 | | 966 | | |
| MEANS | | 7.8 | 69.0 | 4.0 | |

## INTAKE COVE SILTATION

Construction of a cofferdam in Intake Cove using nonwashed materials resulted in a heavy load of silt and mud being deposited within the coffeream reservoir. Subsequent pumping of reservoir water and suspended silt transported considerable amounts of material into the entire Intake Cove area (Burge and Schultz 1973).

Following removal of the cofferdam, we made an inspection dive on December 10, 1973 to locate an adequate silt disposal site pursuant to an agreement between Regional Water Quality Control Board, California Department of Fish and Game, and Pacific Gas and Electric Company to dredge the cove. A disposal site was finally situated along the 30 m (100 ft) contour in an area with predominantly coarse sand substrate.

After 5 months of dredging an inspection dive was made on May 23, 1974 to assess the extent and success of the suction dredging. From 2.5 to 92.5 cm (1 to 36 inches) of silt remained on the bottom in the area already covered by the dredge. Few benthic forms were observed and those noted were detritus feeders in shallow areas; however, the presence of many juvenile rockfish show the potential for the Intake Cove to act as a nursery area.

There are indications that a viable softbottom community would establish in the cove over a period of time. On five different diving surveys the following living benthic invertebrates were observed: *Pateria miniata*, *Corymorpha palma*, *Haliotis rufescens*, *Parastichopus* sp., *Cucumeria miniata*, *Pisaster giganteus*, *P. brevispinus*, *Tethya aurantia*, and *Clavelina huntsmani*.

As an initial step toward restoring the biological productivity to the Intake Cove, dredging was begun in the area immediately in front of and behind the primary intake screens. This was done to allow pump testing without endangering the biological communities in the discharge cove with silt disposition. Another inspection dive on June 6, 1974 showed that dredging had removed most of the silt down to bare rock on the east half of the intake device. All large deposits of silt were removed from behind and in front of the primary screen by June 28, 1974. Subsequent pump testing on the same date caused little silt movement within Intake Cove. However, what appeared to be a large amount of sediments which had accumulated in the intake system, behind the doors, was discharged into the receiving waters. Observations of juvenile rockfish movement during pump testing indicate the possible loss of weaker swimming individuals by slowly being pulled into the intake system due to exhaustion caused by swimming against the 0.5 m/sec (1.5 ft/sec) current near the primary screens.

## RED ABALONE TEMPERATURE TOLERANCE STUDY

The red abalone, *Haliotis rufescens*, comprises an important shellfish resource to California. They are sought extensively both by sports and commercial fishermen.

In the Diablo Canyon region they once constituted a valuable shellfish resource; however, recent predation by the sea otter has significantly reduced former population levels.

Almost no information is available on the temperature tolerance of adult red abalone, or for that matter, on any of the other six species of California abalones. North et al (1964) reported that a 1-hr exposure of adult red abalone to a temperature of 33°C (91.4°F) proved lethal.

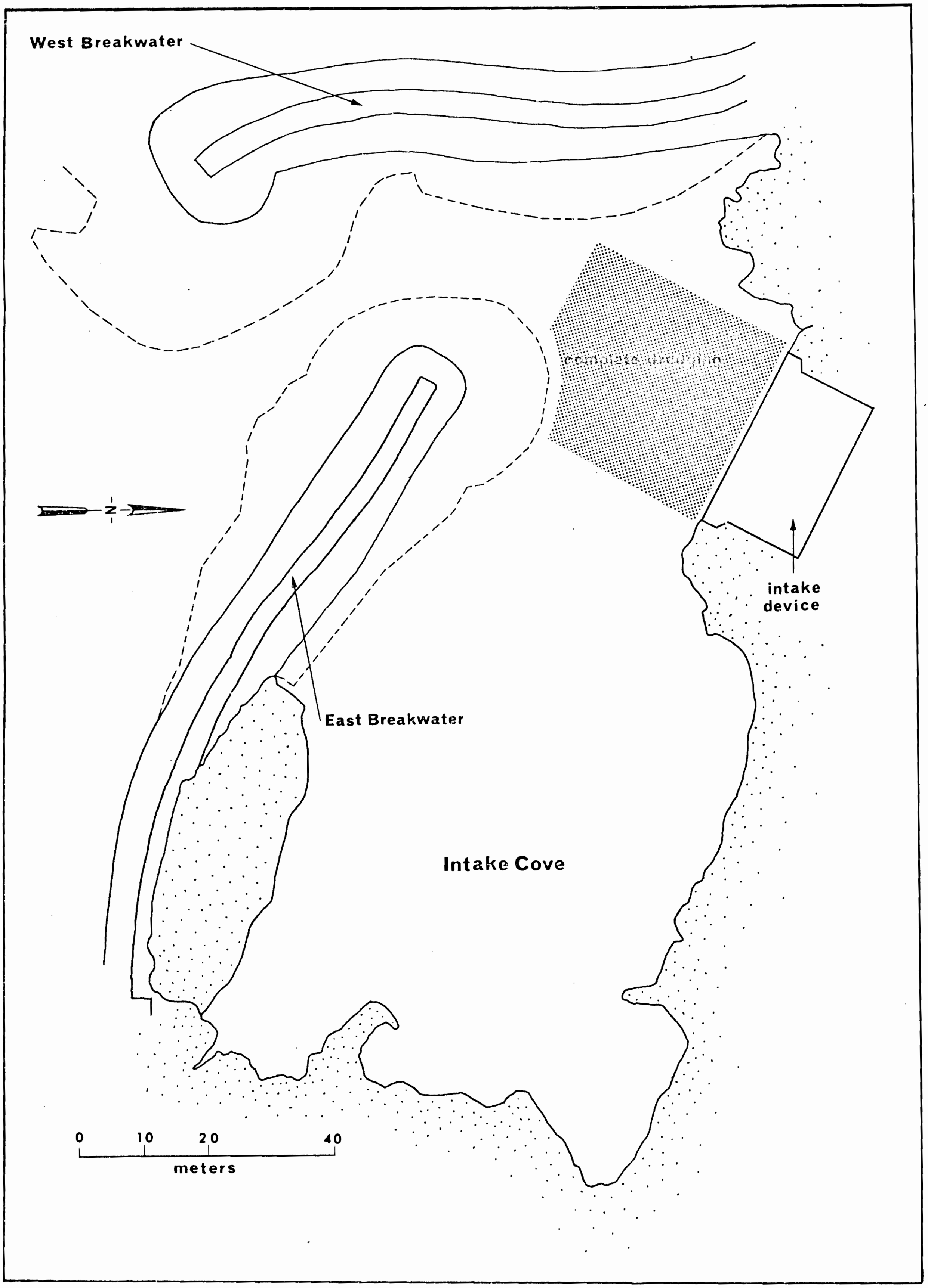


FIGURE 8. Location of intensive dredging area - Intake Cove - Diablo Canyon power plant site.

This study was instituted to investigate the effect of temperature on embryological, larval and post larval stage red abalone.

Methods

Initial effort was centered upon design and construction of a temperature test apparatus. An apparatus was designed and constructed from plastics that delivered six controlled water temperatures, simultaneously, to an equal number of insulated containers that held test animals. Basic components included two cylindrical shaped reservoirs of 20 l (5.3 gal) capacity, 12 water metering valves, and plastic tubing. One reservoir received warmed seawater and the other chilled or ambient temperature seawater, depending upon test temperature mixing requirements. The tubing was connected between each valve of adjacent reservoirs. "Y" shaped connectors were inserted midway in the tubing between adjacent valves. These connectors allowed seawater from both reservoirs to be received at a common junction, mixed, and then shunted into the test animal containers.

Test containers consisted of the commercially available styrofoam plastic type that have good insulatory properties. These containers were rectangular shaped, measuring 33 x 18 x 25 cm (13 x 7 x 10 inches). An overflow was tapped into each container wall such that the containers still had a 12 l (3.2 gal) capacity.

A continuous flow of filtered (15 μ), ultraviolet treated seawater, was supplied to each container. Test temperatures were maintained within 0.5°C (0.9°F) limits.

Description of Embryological and Larval State Temperature Tests. Adult abalones were induced to spawn at a temperature of about 15°C (59.9°F). Developing embryos were collected at the 4 and 8 cell stage and transferred to 18 l (4.8 gal) plastic containers, cuttings were immediately immersed into separate seawater baths and incubated at temperatures of 10, 15, and 20°C (50, 59, and 68°F).

Temperature tests were performed in duplicate series of finger bowls, each having a final volume of 300 ml (0.3 qt) of seawater. Finger bowls were placed in the styrofoam containers partially immersed in running seawater at test temperature. Seawater in the cultures was not aerated or exchanged throughout the test.

Test animal densities were obtained by taking an aliquot sample from a known culture density. Normally 100 to 150 test animals were distributed in each finger bowl.

Test temperatures were selected at various elevations up to 11°C (19.8°F) above each incubation temperature 10, 15, and 20°C (50, 59, and 68°F) so as to encompass the maximum discharge temperature elevation anticipated at the Diablo Canyon power plant.

One series of tests was conducted to simulate the entrainment time of 1 min predicted for the power plant cooling system. These tests consisted of exposing test animals to a selected temperature elevation for 1 min. Immediately following the 1 min, test animals were returned to their incubation temperature water bath.

Embryos were considered dead when cleavage ceased. A larval abalone was considered dead when ciliary movement ceased. These determinations were made by microscopic examination.

Description of Adult Stage Temperature Tests. Preliminary tests consisted of exposing abalones to instantaneous temperature rises from ambient temperature seawater to establish approximate tolerance limits. Acclimation temperatures were then selected at 10, 15, and 20°C (50, 59, and 68°F).

Acclimation was accomplished in daily temperature step increases of 2 to 3°C (3.6 to 5.4°F). Abalone were held at the acclimation temperature for a minimum of 1 week prior to testing.

Twelve abalones, two per insulated container, were used for each test. Two of these served as controls. Abalone sizes ranged from 15 to 20 cm (6 to 8 inches) in length. A constant flow of filtered (15 micron), UV treated seawater was supplied to each container.

An abalone was considered dead when the muscular foot did not respond to a tactile stimulus. Confirmation of the death point was made by replacing test animals into a water bath at acclimation temperature. In addition to the death point, the time at which an abalone could not grip the container wall was also recorded. This latter determination is probably more significant than the death point because, most likely, such an abalone could not survive in its natural environment. Test durations were 120 hr. Observations were made and recorded at various intervals depending upon the temperature elevation.

## Results

Embryological and Larval Stage Temperature Tolerance. Because induced spawning techniques for abalones have not been perfected, difficulties were encountered in obtaining viable gametes for planned test periods. We succeeded to induce, by thermal shock, only one successful spawning during the study.

The abbreviated time period from the fertilized egg to the swimming trochophore stage larvae precludes long term temperature tolerance tests of embryonic stages. At 15°C (59°F) developmental time to the trochophore stage is about 12 hr. Fertilized eggs incubated at 15°C (59°F) were selected for initial tests. These embryos had reached the morula stage (16 to 32 cells: 6 to 7 hr old) when testing began.

No mortality was observed for the simulated entrainment time tests throughout the 48 hr observation period. However, long term (48 hr) elevated temperature exposures did induce some mortality.

Aberrant embryo development was evident after a 6 hr exposure to a temperature of 25°C (77°F). Embryos held at 26°C (79°F) did not achieve the trochophore larval stage, although the bizarre forms that resulted did exhibit ciliary movement and locomotion. At 25°C (77°F), 17% of the test animals achieved a normal trochophore stage after a 10 hr exposure; however, development did not proceed to the veliger stage, and all test animals succumbed after a 42 hr exposure. Test temperatures of 23°C (73°F) and lower did not impair larval development nor effect any mortality (Table 29).

Developing embryos, incubated at 20°C (68°F) had reached the veliger stage, and were approximately 56 hr old when testing began. In this series of tests the larvae were exposed to maximum temperature of 31°C (87.8°F). Unfortunately the tests had to be terminated after 26 hr due to an error made in the aliquot sample size. Culture densities were approximately 3 to 4 times the desired level, inducing excessive mortality, and negating accurate test results.

No mortality was noted for veliger larvae incubated at 20°C (68°F) and subjected to the simulated entrainment test throughout the 26 hr observation period. However, long term (26 hr) elevated temperature exposures did effect mortality at the higher temperature elevations.

After a 2 hr exposure to temperatures of 30 and 31°C test animals were extremely weak and sluggish, exhibited feeble ciliary movement, and

TABLE 29. Percent Survival of Embryonic Stage, Red Abalone, *Haliotis rufescens*, Acclimated at 15°C and Subjected to Instantaneous Elevated Temperature Shock.

| Test temp. °C | Number of test animals | Percent survival | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Exposure time, hours | | | | | | | | |
| | | 2 | 6 | 10 | 18 | 24 | 30 | 36 | 42 | 48 |
| 26 | 100-150 | 100 | *(100) | (86) | (75) | (75) | (50) | 0 | 0 | 0 |
| 25 | 100-150 | 100 | 60(40) | 17(83) | (100) | (100) | (80) | (40) | (5) | 0 |
| 23 | 100-150 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 20 | 100-150 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 18 | 100-150 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 15 | 100-150 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

*Parentheses denote aberrant development remained on the bottom of the culture bowls. Test animals held for a similar period of time at 27°C (80.6°F) exhibited fair ciliary movement, but also remained on the bottom of their culture bowls. At temperatures of 25°C (77°F) and lower the test animals were active and appeared normal.

Mortality ensued after a 10 hr exposure at 31°C (88°F) and total mortality occurred after a 14 hr exposure. A temperature of 30°C (86°F) proved lethal after a 22 hr exposure (Table 30).

Veliger stage larvae incubated at 10°C (50°F) were approximately 125 hr old when temperature elevation tests began. The larvae had not yet obtained the benthonic creeping stage, due to depressed culture temperature.

Test animals were exposed to maximum temperature elevations of 21°C (69.8°F) for 48 hr. However, no mortality was observed throughout the observational period for either short term (1 min entrainment simulation time at maximum temperature elevation), or long term (48 hr) exposure.

Adult Stage Elevated Temperature Tolerances. Test animals acclimated at 10°C (50°F) were subjected to temperatures ranging from 20 to 30°C (68 to 86°F). At 20°C (68°F) all test animals survived and did not exhibit any loss of attachment or other abnormal behavioral responses. Mortality was first recorded after a 24 hr exposure to 23° (73°F), and 50% mortality occurred within 36 hr; however, 20% of the test animals did survive through the 120 hr elevated temperature exposure period. The maximum temperature that test animals were subjected to, 30°C (86°F), effected a total mortality within 6 hr (Table 31).

Loss of attachment ability for test animals acclimated at 10°C (50°F) occurred at varying intervals prior to death; and in all cases, proved to be indicative of impending death. No test animals that lost their attachment ability survived the 120 hr elevated temperature exposure. Loss of

TABLE 30. Percent Survival of Veliger Stage, Red Abalone, *Haliotis refescens*, Acclimated at 20°C and Subjected to Instantaneous Elevated Temperature Shock.

| Test temp. (°C) | Number of test animals | Percent survival | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Exposure time (hr) | | | | | | |
| | | 2 | 6 | 10 | 14 | 18 | 22 | 26 |
| 31 | 700-750 | 100 | 100 | 60 | 45 | 0 | 0 | 0 |
| 30 | 800-850 | 100 | 100 | 100 | 100 | 50 | 0 | 0 |
| 27 | 700-800 | 100 | 100 | 100 | 100 | 100 | 100 | 80 |
| 25 | 650-700 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 23 | 850-900 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 20 | 700-750 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

TABLE 31. Percent Survival of Adult Red Abalone, *Haliotis rufescens*, Subjected to Instantaneous Elevated Temperature Shock.

| Accli-mation temp. (°C) | Test temp. (°C) | Number of test animals | Percent survival | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Exposure time (hr) | | | | | | | | | | | | |
| | | | 1 | 3 | 6 | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 |
| 10 | 20 | 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 10 | 23 | 10 | 100 | 100 | 100 | 100 | 70 | 50 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 10 | 26 | 10 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 28 | 10 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 30 | 10 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 20 | 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 15 | 23 | 10 | 100 | 100 | 100 | 90 | 80 | 70 | 70 | 60 | 60 | 60 | 60 | 60 | 60 |
| 15 | 26 | 10 | 100 | 100 | 100 | 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 30 | 10 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 23 | 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 20 | 27 | 10 | 100 | 100 | 100 | 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 31 | 10 | 100 | 100 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 24 | 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 90 | 90 | 90 | 80 | 80 |
| 22 | 26 | 10 | 100 | 100 | 100 | 100 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 28 | 10 | 100 | 100 | 100 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

attachment ability was first recorded after a one hr exposure to 23°C (73°F). In 12 hr 50% became detached; however, 20% of the test animals remained attached at the termination of the 120 hr test. This may be contrasted with a temperature of 28°C (82°F) where all test animals lost their attachment ability within 1 hr (Table 32).

Abalones acclimated at 15°C (59°F) were subjected to four temperature elevations. At 20°C (68°F) all test animals survived the 120 hr exposure period. Initial mortality occurred after a 12 hr exposure at 23°C (73°F). However, 60% of the test animals survived after a 120 hr exposure to this same temperature. This may be contrasted with a temperature of 26°C (79°F) that effected total mortality within 24 hr or a 30°C (86°F) temperature that caused total mortality within 6 hr (Table 31).

Loss of attachment ability was first observed within 3 hr at 23°C (73°F). At 26°C (79°F), 20% of the test animals lost their attachment ability within 1 hr and all became detached within 3 hr. A temperature of 30°C (86°F) caused all test animals to lose their attachment ability within 1 hr (Table 32).

Abalones acclimated at 20°C (68°F) were subjected to temperatures of 23°C (73°F), 27°C (81°F), and 31°C (88°F). At 23°C (73°F) all test animals survived the 120 hr test. A temperature of 27°C (81°F) effected a 50% mortality in 14 hr, and total mortality within 24 hr. A temperature of 31°C (88°F) proved lethal to all test animals within 12 hr (Table 31).

Abalones acclimated at 20°C (68°F) and exposed to temperature elevations of 23, 27, and 31°C (73, 81, and 88°F) exhibited a marked loss of attachment at the higher temperature elevations. At 23°C (73°F) only 1 abalone became detached during the testing period. This occurred after a

TABLE 32. Percent Remaining Attached of Adult Red Abalone, *Haliotis rufescens*, Subjected to Instantaneous Elevated Temperature Shock.

| Accli-mation temp.(°C) | Test temp. (°C) | Number of test animals | Percent remaining attached | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Exposure time (hr) | | | | | | | | | | | | |
| | | | 1 | 3 | 6 | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 |
| 10 | 20 | 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 10 | 23 | 10 | 90 | 80 | 60 | 50 | 40 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| 10 | 26 | 10 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 28 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 30 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 20 | 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 15 | 23 | 10 | 100 | 80 | 80 | 70 | 70 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| 15 | 26 | 10 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 30 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 23 | 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 90 |
| 20 | 27 | 10 | 100 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 31 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 24 | 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 90 | 90 | 90 | 80 | 80 | 80 |
| 22 | 26 | 10 | 100 | 100 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 28 | 10 | 100 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

108 hr exposure. At 27°C (81°F), 50% of the abalones lost their attachment ability within 3 hr, and none remained attached after 6 hr. At 31°C (88°F) all abalones lost their attachment ability within 1 hr (Table 32).

A temperature of 22°C (72°F) proved to be the maximum at which we could acclimate abalones without any mortality. We completed three temperature elevation tests from this acclimation temperature; however, survival or attachment ability was not enhanced over that found for the 20°C (68°F) acclimation temperature (Tables 30 and 32).

Discussion

Results of the various tests indicate that the upper lethal temperature of the red abalone can be increased by increasing the acclimation temperature at least to 20°C (68°F). For example, adult abalones acclimated at 10°C (50°F) and subjected to a temperature of 23°C (73°F) experienced a 50% mortality within 36 hr. But abalones acclimated at 20° (68°F) exhibited no mortality at this same temperature elevation. The upper temperature limit at which abalones may be acclimated approximates 22°C (72°F).

Incubation temperatures of embryonic and larval stage abalone follow the same pattern noted for acclimation temperatures of adult abalones. That is, developing embryos incubated at 15°C (59°F) and subjected to a temperature of 25°C (77°F) do not develop to the veliger stage, and suffer total mortality within 18 hr. However, those incubated at 20°C (68°F) do not experience any mortality when subjected to the 25°C (77°F) temperature.

## SUMMARY

1. Due to increasing pressures on sea urchin and abalone resources in the Diablo Canyon area, exerted by both commercial fishermen and sea otters, this interim study was begun in June 1973 under the terms of a contract between Pacific Gas and Electric Company and the Department of Fish and Game to monitor the effects of these pressures on the intertidal and subtidal communities adjacent to the company's nuclear power plant site on the San Luis Obispo County coastline.

2. This report covers the results of our studies from July 1, 1973, through June 30, 1974.

3. The specific objectives of the study are: A) To conduct quantitative surveys that would yield relative abundance indices for selected plants and animals including important sport and commercial species present in the area of discharge and a well-removed control area, and to continue monitoring the permanent stations established in 1970. B) To follow the movement and population size of the sea otter herd between Pt. Buchon and Pecho Rock. C) To continue the annual count of the bull kelp plants within Diablo Cove. D) To conduct interviews of commercial abalone and sea urchin fishermen to obtain catch-per-unit-of-effort data.

4. During the year, 238 man days were spent at the site and 61 permanent and random subtidal and intertidal stations were surveyed.

5. Most of the permanent subtidal stations were surveyed in Fall 1973; bat stars, *Patiria miniata*, and giant red sea urchins, *Strongylocentrotus franciscanus*, were the most abundant invertebrates quantified from these stations. Numbers of red abalone, *Haliotis rufescens*, rock crabs, *Cancer*

*antennarias*, and giant red sea urchins appear diminished from earlier (1971) surveys.

6. Subtidal random sampling was begun in Spring 1974. To date, giant red sea urchins and bat stars are also the dominant invertebrates in these surveys, although giant red sea urchins in the North Control area are only about one-quarter as abundant as giant red sea urchins in the Diablo Cove study area -- possibly due to the longer presence of otters in the North Control area. Besides giant red sea urchins and bat stars, 26 other species of invertebrates were enumerated in the two study areas.

7. Of a total of 28 species of fish identified at the subtidal stations, blue rockfish, *Sebastes mystinus*, occurred in highest numbers and greatest frequency. Two Hexagrammids, painted greenling, *Oxylebius pictus*, and kelp greenling, *Hexagrammos decagrammus*, were the second and third most frequently observed fishes.

8. Counts or estimates of abundance were made on seven species of brown algae in the permanent and random subtidal stations, but so far no clear pattern of distribution or abundance has emerged.

9. Counts of individual plants which compose the *Nereocystis leutkeana* canopy within and on the fringes of Diablo Cove were made during September 1973, and 10,263 plants were observed and plotted on a map of Diablo Cove.

10. Three of the five permanent intertidal stations established in 1970 were resurveyed in early summer and because of lost or unlocatable station markers, even these three were incomplete. However, there was good comparability between our abalone counts and counts made in 1971 at similar stations.

11. A total of 37 intertidal stations were sampled randomly in the Diablo Cove and North Control areas. Invertebrates were counted and left in place and algae were collected from the ¼ $m^2$ (2.7 $ft^2$) quadrats at each transect for laboratory quantification.

12. Samples from the intertidal were treated by zones which were semi-arbitrarily chosen and labeled "A", "B", and "C" which represented, respectively, +0.9 to +1.8 m (3.0 to 5.9 ft), 0.0 to +0.9 m (0.0 to 3.0 ft), and 0.0 m and lower, relative to MLLW.

13. Invertebrates in the Diablo Point Intertidal area appear to form more consistent populations than animals in the other study areas as evidenced by their higher average numbers and higher frequencies of occurrence. Also, more countable species, or animals larger than 10 mm (0.4 inches), were found here than in the other, more protected intertidal areas.

14. Invertebrate populations in the other three study areas are not, at this point, as well defined as in the Diablo Point area. The three areas do share, however, several common species which have appeared consistently: the proliferating anemone, *Epiactis prolifera*, juvenile kelp crab, *Pugettia producta*, the limpet family, Acmaeidae, the turban snails, *Tegula brunnea* and *T. funebralis*, and two small predaceous stars, *Henricia leviuscula* and *Leptasterias* spp.

15. Abalone were surveyed at most of the random intertidal stations along a 2 m (6.6 ft) swath of the 30 m (99 ft) transect line. The intertidal in North Diablo Cove appears to provide better habitat for both red and black abalone (*Haliotis rufescens* and *H. cracherodii*) than any of the other study areas. The length frequencies for red abalone within Diablo Cove seem to

be similar to those of abalone removed and measured in 1970 from the discharge cofferdam site.

16. Abalone counts made along the permanent station transects agree very closely with counts made during previous years' surveys.

17. Among the 'soft' algae, 15 species compose from 70.0% to 98.3% of the total biomass found in the various zones in the study areas. *Iridaea cordata* var. *splendens* was the most common form in every area sampled.

18. Means per ¼ $m^2$ (2.7 $ft^2$) and 95% confidence intervals of the means were calculated for dry weights of algae, and percent cover by articulated coralline algae and surf grass, *Phyllospadix scouleri*, found in the various zones of the study area.

19. One intertidal fish collection was performed during this period in the North Control area; 168 fish representing 11 species were taken.

20. Sea otter numbers were counted weekly and their movement followed during most of the year. Mean monthly counts ranged from a low of 26 (July 1973) to a high of 124 (April 1974) along the Point Buchon - Diablo Cove coastal area. Otters moved into Diablo Cove in May 1974. Abalone appear to constitute a major portion of the otter diet.

21. Commercial sea urchin fishermen at Avila were interviewed whenever possible. Activity this last year has been concentrated in the Pedro Rock area and daily take has ranged from 750 kg (1,650 lb) to 1,493 kg (3,284 lb) per boat.

22. Commercial abalone fishermen were interviewed between July and December 1973. Their individual take averaged less than 12 abalone per hr.

23. Dredging of the silt-befouled Intake Cove area was followed closely during much of the year. Spoils were discharged about 515 m (1,700 ft) from shore in 30.5 m (100 ft) of water in a predominantly sandy area. By late June 1974, the area fronting the intake structure was dredged to bare rock so that pump testing could begin and not cause silts to be circulated to Diablo Cove.

24. A study to investigate the effect of elevated temperatures on all stages of red abalone was performed this year at the Department's Granite Creek Shellfish Laboratory. Only one test was conducted on embryos and larval animals due to difficulties in induced spawning, but several tests were run on adults at different temperature levels. Twenty-two degrees centigrade (72°F) appears to be the maximum acclimation temperature without mortality for adults.

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## APPENDIX I

### MAN-DAYS SPENT AT DIABLO CANYON POWER PLANT SITE

April 1 - June 30, 1974

| | |
|---|---|
| Intertidal Surveys: | April 22-26 |
| Participants: | Laurent, Wendell, Farrens |
| | May 20-25 |
| Participants: | Gotshall, Wendell, Farrens |
| | June 19-24 |
| Participants: | Gotshall, Laurent, Wendell |
| Subtidal Surveys: | May 7-10 |
| Participants: | Gotshall, Laurent, Wendell |
| | June 3-7 |
| Participants: | Gotshall, Laurent, Wendell |
| Commercial Sea Urchin Fishery Surveys: | April 8-12 |
| Participants: | Farrens |

### MAN-DAYS SPENT AT DIABLO CANYON POWER PLANT SITE

July 1, 1973 - June 30, 1974

| | July 1, 1973 - March 30, 1974 | April 1 - June 30, 1974 | Totals |
|---|---|---|---|
| Total man-days | 663 | 239 | 902* |
| Total man-days at site | 171 | 67 | 238 |
| Boat days lost to weather | 4 | 4 | 8 |
| Boat days lost to breakdown | 8 | 4 | 12 |
| Total stations surveyed | 37 | 24 | 61 |
| Travel time man-days | 29.5 | 16 | 45.5 |
| Boat time (hr) | 35.5 | | |
| Laboratory time man-days | 462.5 | 156 | 618.5 |

PROJECT PERSONNEL:

| | |
|---|---|
| Daniel W. Gotshall | Senior Marine Biologist, Project Leader |
| Laurence L. Laurent | Associate Marine Biologist |
| Fred E. Wendell | Junior Aquatic Biologist |
| Margaret M. Hughes | Stenographer II |
| Gary D. Farrens | Seasonal Aid |

NON-PROJECT PERSONNEL

| | |
|---|---|
| Earl E. Ebert | Senior Marine Biologist, Operations Research Branch |
| E. E. Martindale | Lieutenant, Fish and Game boat RAINBOW |
| Suzanne V. Benech | Pacific Gas and Electric Company |

*Non-project personnel man-days are not included in totals, and totals do not include time spent on abalone temperature tolerance studies.

# APPENDIX II

Algae Collected and Identified from Subtidal and Intertidal Stations - Diablo Canyon Power Plant Site - November 1973 to June 1974.

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| Chlorophyta | | | |
| *Ulva* sp. | sea lettuce | X | |
| Phaeophyta | | | |
| *Alaria marginata* Postels and Ruprecht | brown alga | X | |
| *Cystoseira osmundaces* (Menzies) C.A. Agardh | brown alga | | X |
| *Desmarestia herbacea* (Turner) Lamouroux | brown alga | | X |
| *Desmarestia munda* Setchell and Gardner | brown alga | | X |
| *Dictyoneurum californicum* Ruprecht | brown alga | X | X |
| *Egregia menziesii* (Turner) Areschoug | feather boa kelp | X | X |
| *Fucus distichus* Linnaeus *edentatus* (De la Paylaie) Powell | brown alga | X | |
| *Heterochordaria abietina* (Ruprecht) Setchell and Gardner | brown alga | X | |
| *Laminaria setchellii* Silva | brown alga | X | X |
| *Nereocystis luetkeana* (Mertens) Postels and Ruprecht | bull kelp | | X |
| *Pelvetia fastigiata* (J.G. Agardh) De Toni | brown alga | X | |
| *Pelvetiopsis limitata* (Setchell) Gardner | brown alga | X | |
| *Postelsia palmaeformis* Ruprecht | palm kelp | X | |
| *Pterygophora californica* Ruprecht | tree kelp | | X |
| Rhodophyta | | | |
| *Agardhiella tenera* (J.G. Agardh) Schmitz | red alga | X | |
| *Botryoglossum farlowianum* (J.G. Agardh) De Toni | red alga | X | X |
| *Callithamnion pikeanum* Harvey | red alga | X | |

APPENDIX II (cont)

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| *Callithamnion rupicolum* Anderson | red alga | X | |
| *Callophyllis violacea* Setchell and Swezy | red alga | X | |
| *Callophyllis* sp. | red alga | X | |
| *Ceramium eatonianum* (Farlow) De Toni | red alga | X | |
| *Cladophora* sp. | red alga | X | |
| *Cryptopleura lobulifera* (J.G. Agardh) Kylin | red alga | X | |
| *Cryptopleura* sp. | red alga | X | |
| *Cryptopleura violacea* (J.G. Agardh) Kylin | red alga | X | |
| *Endocladia muricata* (Postels and Ruprecht) J.G. Agardh | red alga | X | |
| *Erythrophyllum delesserioides* J.G. Agardh | red alga | X | |
| *Farlowia compressa* J.G. Agardh | red alga | X | |
| *Farlowia mollis* (Harvey and Bailey) Farlow and Setchell | red alga | X | |
| *Gastroclonium coulteri* (Harvey) Kylin | red alga | X | |
| *Gelidium coulteri* Harvey | red alga | X | |
| *Gelidium robustum* (Gardner) Hollenberg and Abbott | red alga | X | |
| *Gelidium* sp. | red alga | X | |
| *Gigartina agardhii* Setchell and Gardner | red alga | X | |
| *Gigartina californica* J.G. Agardh | red alga | X | |
| *Gigartina canaliculata* Harvey | red alga | X | |
| *Gigartina cristata* (Setchell) Setchell and Gardner | red alga | X | |
| *Gigartina leptorhynchos* J.G. Agardh | red alga | X | |
| *Gigartina papillata* (C.A. Agardh) J.G. Agardh | red alga | X | |
| *Gigartina* sp. | red alga | X | |

APPENDIX II (cont)

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| Rhodophyta (cont) | | | |
| *Gigartina spinosa* (Kützing) Harvey | red alga | X | |
| *Gloiosiphonia californica* (Farlow) J.G. Agardh | red alga | X | |
| *Gonimophyllum skottsbergii* Setchell | red alga | X | |
| *Grateloupia doryphora* (Montagne) Howe | red alga | X | |
| *Grateloupia setchellii* Kylin | red alga | X | |
| *Gymnogongrus leptophyllus* J.G. Agardh | red alga | X | |
| *Halosaccion glandiforme* (Gmelin) Ruprecht | red alga | X | |
| *Hymenena flabelligera* (J.G. Agarch) Kylin | red alga | X | |
| *Iridea cordata* var *splendens* (Setchell and Gardner) Abbott | red alga | X | |
| *Iridea heterocarpa* (Postels and Ruprecht) Setchell and Gardner | red alga | X | |
| *Iridea lineare* Setchell and Gardner | red alga | X | |
| *Laurencia spectabilis* Postels and Ruprecht | red alga | X | |
| *Microcladia borealis* Ruprecht | red alga | X | |
| *Microcladia coulteri* Harvey | red alga | X | |
| *Pikea californica* (Farlow) Kylin | red alga | X | |
| *Pikea pinnata* Setchell | red alga | X | |
| *Plocamium violaceum* Farlow | red alga | X | |
| *Polyneura latissima* (Harvey) Kylin | red alga | X | |
| *Polysiphonia hendryi* Gardner | red alga | X | |
| *Prionitis andersonii* Eaton | red alga | X | |
| *Prionitis lanceolata* Harvey | red alga | X | |
| *Ptilota densa* C. A. Agardh | red alga | X | |

APPENDIX II (cont)

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| Rhodophyta (cont) | | | |
| *Rhodoglossum parvum* G.M. Smith and Hollenberg | red alga | X | |
| *Rhodomela larix* (Turner) C.A. Agardh | red alga | X | |
| *Rhodomenia pacifica* Kylin | red alga | X | |
| *Schizymenia* sp. | red alga | X | |

## APPENDIX III

Invertebrates Collected and Identified from Subtidal and Intertidal Stations - Diablo Canyon Power Plant Site - November 1973 to June 1974.

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| **Porifera** | | | |
| *Rhabdodermella nuttingi* Urban | urn sponge | X | X |
| *Tethya aurantia* (Pallas) *californiana* de Laub | puffball sponge | | X |
| Unidentified | purple encrusting sponge | | X |
| Unidentified | white encrusting sponge | | X |
| **Coelenterata** | | | |
| *Aglaophenia* sp. | feather hydroid | X | X |
| *Allopora porphyra* (Fisher) | hydrocoral | | X |
| *Anthopleura artemisia* (Pickering in Dana) | anemone | | X |
| *Anthopleura elegantissima* (Brandt) | aggregate anemone | X | |
| *Anthopleura xanthogrammica* (Brandt) | solitary anemone | X | X |
| *Balanophyllia elegans* Verill | orange cup coral | | X |
| *Corynactis californica* Calgren | aggregate anemone | X | X |
| *Epiactis prolifera* Verill | anemone | X | X |
| **Metridium senile* (Linnaeus) | white anemone | | X |
| *Paracyathus stearnsii* Verill | brown cup coral | | X |
| *Tealia crassicornis* (Danielssen) | anemone | | X |
| *Tealia lofotensis* (Danielssen) | anemone | | X |
| **Annelida** | | | |
| *Arebella iricolor* Montagu) | polychaete | X | |

APPENDIX III (cont)

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| Annelida (cont) | | | |
| *Diopatra* sp. | polychaete | | X |
| *Eudistylia polymorpha* (Johnson) | feather-duster worm | | X |
| *Nereis* sp. | polychaete | X | |
| *Syllis* sp. | polychaete | X | |
| Unidentified sabellid polychaetes | plume worms | | X |
| Unidentified terebellid polychaetes | terebellids | | X |
| Mollusca | | | |
| *Acmaea mitra* Eschscholtz | white cap limpet | X | |
| *Acmaea* sp. | limpet | X | |
| *Aldisa sanguinea* (Cooper) | nudibranch | X | |
| *Anisodoris nobilis* (MacFarland) | nudibranch | | X |
| *Archidoris montereyensis* (Cooper) | nudibranch | | X |
| *Astraea gibberosa* (Dillwyn) | red turban | X | X |
| *Bittium* sp. | | X | |
| *Cadlina luteomarginata* MacFarland | nudibranch | | X |
| *Calliostoma ligatum* (Gould) | top shell | X | X |
| *Ceratostoma nuttalli* (Conrad) | Nuttall's hornmouth | | X |
| *Chromodoris* sp. | nudibranch | | X |
| *Collisella scabra* (Gould) | rough limpet | X | |
| *Conus californicus* Hinds | California cone | X | |
| *Crepidula* sp. | slipper shell | X | |
| *Cryptochiton stelleri* (Middendorff) | gumboot chiton | | X |
| *Cyanoplax dentiens* (Gould) | chiton | X | |
| *Dendrodoris fulva* (MacFarland) | nudibranch | | X |

APPENDIX III (cont)

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| Mollusca (cont) | | | |
| *Diaulula sandiegensis* (Cooper) | nudibranch | | X |
| *Fissurella volcano* Reeve | volcano limpet | X | |
| *Haliotis cracherodii* Leach | black abalone | X | |
| *Haliotis kamtschatkana* Jonas | pinto abalone | | X |
| *Haliotis rufescens* Swainson | red abalone | X | X |
| *Haliotis walallensis* Stearns | flat abalone | | X |
| *Hermissenda crassicornis* (Eschscholtz) | nudibranch | | X |
| *Hinnites multirugosus* (Gale) | rock scallop | | X |
| *Hopkinsia rosacea* MacFarland | nudibranch | | X |
| *Ischnochiton regularis* (Carpenter) | chiton | X | |
| *Kathrina tunicata* (Wood) | black chiton | X | |
| *Lacuna* sp. | chink snail | X | |
| *Lottia gigantea* Sowerby | owl limpet | X | |
| *Mitra ida* Melvill | Ida's miter | | X |
| *Mitrella* sp. | dove shell-snail | X | |
| *Mopalia* spp. | chiton | X | |
| *Mytilus califorianus* Conrad | California mussel | X | |
| *Nuttallina californica* (Reeve) | chiton | X | |
| *Phidiana nigra* MacFarland | nudibranch | X | X |
| *Pododesmus cepio* (Grey) | abalone jingle | X | |
| *Rostanga pulchra* MacFarland | nudibranch | | X |
| *Serpulorbis squamigerus* Sassi | scaled worm shell | X | X |
| *Tegula brunnea* (Philippi) | brown turban | X | |

APPENDIX III (cont)

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| Mollusca (cont) | | | |
| *Tegula funebralis* (Adams) | black turban | X | |
| *Tegula montereyi* (Kiener) | turban snail | | X |
| *Tegula pulligo* (Martyn) | turban snail | | X |
| *Thais emarginata* (Deshayes) | emarginate dogwinkle | X | |
| *Tonicella lineata* (Wood) | lined chiton | X | X |
| *Tricolia* sp. | nudibranch | X | |
| *Tritonia festiua* (Stearns) | nudibranch | X | X |
| Arthropoda | | | |
| *Balanus* sp. | barnacle | X | X |
| *Cancer antennarius* Stimpson | rock crab | X | X |
| *Cancer jordani* Rathbun | crab | X | |
| *Cancer productus* Randall | rock crab | X | |
| *Caprella incisa* Mayer | caprellid | X | |
| *Crangon dentipes* (Guérin) | pistol shrimp | X | |
| *Cryptolithoides sitchensis* Brandt | umbrella-backed crab | | X |
| *Dynamenella glabra* (Richardson) | isopod | X | |
| *Hyale frequens* (Stout) | amphipod | X | |
| *Idothea aculeata* (Stafford) | isopod | X | |
| *Lecythorynchus marginatus* Cole | pycnogonid | X | |
| *Loxorhynchus crispatus* Stimpson | masking crab | X | X |
| *Mimulus foliatus* Stimpson | crab | | X |
| *Pachycheles* sp. | crab | X | |
| *Pagurus* sp. | hermit crab | X | X |
| *Petrolisthes cinctipes* (Randall) | porcelain crab | X | |

APPENDIX III (cont)

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| Arthropoda (cont) | | | |
| *Pleustes depressus* Alderman | amphipod | X | |
| *Pollicipes polymerus* (Sowerby) | goose barnacle | X | |
| *Pugettia gracilis* Dana | crab | X | |
| *Pugettia producta* (Randall) | kelp crab | X | X |
| *Pugettia richii* Dana | crab | X | |
| *Tetraclita squamosa* Darwin | barnacle | X | |
| *Xanthias taylori* (Edwards) | crab | X | |
| Ectoprocta | | | |
| *Diaperoecia californica* | bryozoa | | X |
| *Flustrella corniculata* (Smitt) | bryozoa | | X |
| *Phidolopora pacifica* (Robertson) | lace bryozoa | | X |
| Echinodermata | | | |
| *Cucumaria miniata* Brandt | red sea cucumber | | X |
| *Eupentacta quinquesemito* (Selenka) | white sea cucumber | | X |
| *Henricia leviuscula* (Stimpson) | red sea star | X | X |
| *Leptasterias aequalis* (Stimpson) | six-rayed star | X | |
| *Leptasterias pusilla* (Fisher) | six-rayed star | X | |
| *Orthasterias koehleri* (Dehoriol) | long-rayed star | | X |
| *Patiria miniata* (Brandt) | bat star | | X |
| *Pisaster brevispinus* (Stimpson) | pink sea star | | X |
| *Pisaster giganteus* (Stimpson) | sea star | | X |
| *Pisaster ochraceous* (Brandt) | ochre star | X | X |
| *Pycnopodia helianthoides* (Brandt) | sunflower star | X | X |
| *Stichopus californicus* (Stimpson) | sea cucumber | | X |
| *Strongylocentrotus franciscanus* (Agassiz) | red urchin | | X |

APPENDIX III (cont)

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| Echinodermata (cont) | | | |
| *Strongylocentrotus purpuratus* (Stimpson) | purple urchin | X | X |
| *Stylasterias forreri* (de Loriol) | sea star | | X |
| Chordata | | | |
| *Amaroucium* sp. | tunicate | X | |
| *Boltenia villosa* (Stimpson) | spiny-headed tunicate | | X |
| *Clavelina huntsmani* Van Name | tunicate | X | |
| *Cnemidocarpa finmarkiensis* (Kiaer) | tunicate | | X |
| *Styela montereyensis* (Dall) | stalked tunicate | | X |
| *Synoicum* sp. | tunicate | | X |

## APPENDIX IV

Fish Collected and Identified from Subtidal and Intertidal Stations - Diablo Canyon Power Plant Site - November 1973 to June 1974.

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| *Anoplarchus purpurescens* Gill | high cockscomb | X | |
| *Artedius corrallinus* (Hubbs) | coralline sculpin | | X |
| *Artedius lateralis* (Girard) | smoothhead sculpin | X | |
| *Chirolophis nugator* (Jordan and Williams) | mosshead warbonnet | | X |
| *Citharichthys* sp. | sanddab | | X |
| *Clinocottus analis* (Girard) | wooly sculpin | X | |
| *Coryphopterus nicholsii* (Bean) | blackeye goby | | X |
| *Cymatogaster aggregata* Gibbons | shiner surfperch | | X |
| *Damalichthys vacca* (Girard) | pile surfperch | | X |
| *Embiotoca jacksoni* Agassiz | black surfperch | | X |
| *Embiotoca lateralis* Agassiz | striped surfperch | | X |
| *Gibbonsia metzi* Hubbs | striped kelpfish | X | |
| *Gibbonsia montereyensis* Hubbs | crevice kelpfish | X | |
| *Gibbonsia* sp. | kelpfish | X | |
| *Gobiesox maeandricus* (Girard) | northern clingfish | X | X |
| *Hexagrammus decagrammus* (Pallas) | kelp greenling | | X |
| *Hypsurus caryi* (Agassiz) | rainbow surfperch | | X |
| *Oligocottus rimensis* (Greeley) | saddleback sculpin | X | |
| *Oligocottus snyderi* Greeley | fluffy sculpin | X | |
| *Ophiodon elongatus* Girard | lingcod | | X |
| *Oxylebius pictus* Gill | painted greenling | | X |
| *Phanerodon atripes* (Jordan & Gilbert) | sharpnose surfperch | | X |

APPENDIX IV (cont)

| Scientific name | Common name | Intertidal | Subtidal |
|---|---|---|---|
| *Porichthys myriaster* Hubbs and Schultz | specklefin midshipman | X | |
| *Rathbunella hypoplecta* (Gilbert) | smooth ronquil | | X |
| *Scorpaenichthys marmoratus* (Ayres) | cabezon | | X |
| *Sebastes atrovirens* Jordan and Gilbert | kelp rockfish | | X |
| *Sebastes carnatus* (Jordan and Gilbert) | gopher rockfish | | X |
| *Sebastes caurinus* (Richardson) | copper rockfish | | X |
| *Sebastes chrysomelas* (Jordan and Gilbert) | black and yellow rockfish | | X |
| *Sebastes melanops* Girard | black rockfish | | X |
| *Sebastes miniatus* (Jordan and Gilbert) | vermilion rockfish | | X |
| *Sebastes mystinus* (Jordan and Gilbert) | blue rockfish | | X |
| *Sebastes pinniger* (Gill) | canary rockfish (juv) | | X |
| *Sebastes rastrelliger* (Jordan and Gilbert) | grass rockfish | | X |
| *Sebastes serranoides* (Eigenmann and Eigenmann) | olive rockfish | | X |
| *Xererpes fucorum* (Jordan and Gilbert) | rockweed gunnel | X | |
| *Xiphister atropurpureus* (Kittlitz) | black prickleback | X | |
| *Xiphister mucosus* (Girard) | rock prickleback | X | |