

Kelp forest monitoring program : a preliminary report on biological sampling design, Channel Islands National Park and marine sanctuary / by Gary E. Davis (Channel Islands National Park)

Davis, Gary E

Davis, Calif. : Cooperative National Park Resources Studies Unit, University of California at Davis, Institute of Ecology, [1985]

<http://hdl.handle.net/2027/uc1.31822035181437>

HathiTrust



www.hathitrust.org

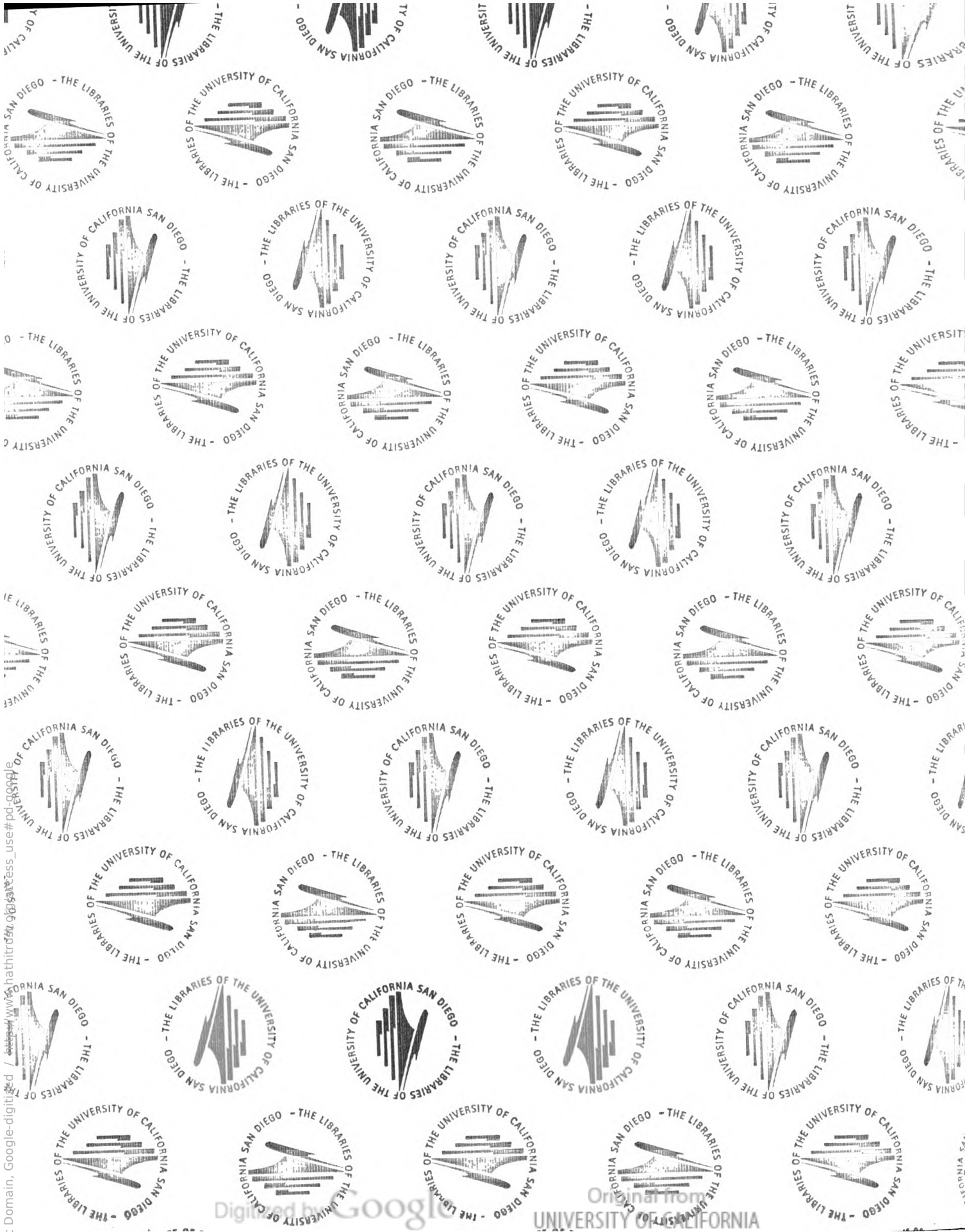
Public Domain, Google-digitized

http://www.hathitrust.org/access_use#pd-google

This work is in the Public Domain, meaning that it is not subject to copyright. Users are free to copy, use, and redistribute the work in part or in whole. It is possible that heirs or the estate of the authors of individual portions of the work, such as illustrations, assert copyrights over these portions. Depending on the nature of subsequent use that is made, additional rights may need to be obtained independently of anything we can address. The digital images and OCR of this work were produced by Google, Inc. (indicated by a watermark on each page in the PageTurner). Google requests that the images and OCR not be re-hosted, redistributed or used commercially. The images are provided for educational, scholarly, non-commercial purposes.

Digitized by Google

Original from
UNIVERSITY OF CALIFORNIA



UCSD Lib.



Cooperative National Park

RESOURCES STUDIES UNIT

**Technical Report No. 19
Kelp Forest Monitoring Program
A Preliminary Report on Biological Sampling Design
Channel Islands National Park and Marine Sanctuary**

BY Gary E. Davis



**University of California
Davis, California 95616**

**Western Region
National Park Service
Department of the Interior
San Francisco, Ca . 94102**

COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT

University of California - National Park Service

The National Park Service and the University of California signed a Master Memorandum of Understanding on May 4, 1979, that provided for the establishment and operation of the Cooperative National Park Resources Studies Unit as an affiliate of the Institute of Ecology on the Davis Campus. Effective October 1, 1981, the Master Memorandum of Understanding was superceded by a Cooperative Agreement between the National Park Service and the University of California. This Unit is dedicated to development and facilitation of ecological, environmental and sociological programs of research and study in the interest of use, conservation, and management of natural areas and other components of the National Park system in California.

The Unit Leader conducts research and assists Park Service personnel in developing and coordinating research to provide information relevant to resource management decision in park areas. Cooperatively, the Unit Leader and the Unit Coordinator consider programs of research and study of mutual interest to the National Park Service and researchers in California and other interested parties, and promote and facilitate cooperative interactions between Park Service and research personnel on problems and programs of mutual interest.

NOTICE: This document contains information of a preliminary nature and was prepared primarily for internal use in the National Park Service. This information is NOT intended for use in open literature prior to publication by the investigators named unless permission is obtained in writing from the investigators named and from the Unit Leader.

SCRIPPS INSTITUTION OF OCEANOGRAPHY LIBRARY

COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT

University of California at Davis

Institute of Ecology

Davis, California 95616

Charles van Riper III -- Unit Director

Christine Schonewald-Cox -- Unit Coordinator/NPS

Peter J. Richerson -- Unit Coordinator/UC

**Technical Report No. 19
Kelp Forest Monitoring Program
A Preliminary Report on Biological Sampling Design
Channel Islands National Park and Marine Sanctuary**

BY Gary E. Davis

Channel Islands National Park
1901 Spinnaker Drive
Ventura, CA 93001

May 1985

Final Report to National Park Service

Contribution Number CPSU/UCD 323/03

Channel Islands National Park and Channel Islands National Marine Sanctuary

Kelp Forest Monitoring Program Preliminary Report, 1984

ABSTRACT

The National Park Service, National Marine Sanctuary Program, and California Department of Fish and Game Initiated a cooperative research project to design a long-term kelp forest monitoring program. The objectives of the project are: (1) to select kelp forest indicator organisms; (2) to develop, field test, and standardize sampling techniques; (3) to select and test appropriate analyses; and (4) to develop standardized reporting systems for monitoring kelp forests in Channel Islands National Park and National Marine Sanctuary. The ultimate goal of the project is to provide resource managers with a monitoring program that produces information needed to distinguish between natural and man-caused variations in kelp forest populations, and to identify and define trends in those variations. This information is not available for any kelp forest and it is essential for the management and perpetuation of California kelp forest ecosystems.

In 1981, 60 indicator organisms were selected, and 17 sampling sites were established which represent the range of environmental conditions and biogeographical variations of kelp forests in the study area. In 1982, a workshop attended by 37 scientists was held at U.C. Santa Barbara to evaluate existing sampling techniques, and seven 5-day cruises were conducted to field test techniques and to begin characterizing kelp forests in the park. In 1983, seven 5-day cruises were conducted to develop new fish sampling techniques and test modified plant and invertebrate sampling techniques, based on analysis of 1982 data.

Virtually all sampling was done by observers using SCUBA. To reduce sample variability among large numbers of observers needed for a long-term monitoring program, sampling techniques that produced long-lasting records and that could be conducted reliably by non-scientifically trained divers were tested for accuracy, precision, and cost. A total of 82 observers made 2,510 SCUBA dives without an accident and spent 907 diver-days on the project during the first three years.

Abundance data for 65 taxa at 17 locations were collected for two years using six different sampling techniques. These data represent approximately 125,000 independent observations of kelp forest indicator organisms. Four techniques for sampling plants and invertebrates were tested: 1) random point contacts; 2) quadrats; 3) band transects; and 4) photographic plots. Two remote sensing techniques were evaluated to determine extent of giant kelp canopy. Three visual techniques of sampling fishes were tested: 1) baited stations; 2) video transects; and 3) video circular plots.

Effects of severe winter storms and el niño events were detected, and distinct geographical patterns in species distributions were apparent. Additional field work is required to develop adequate fish sampling techniques. In situ plant and invertebrate sampling techniques appeared adequate, and photo-plots produced similar results for conspicuous sessile organisms.

TABLE OF CONTENTS

INTRODUCTION	1
METHODS	5
Species Selection	5
Monitoring-Site Selection	5
Sampling Techniques	6
RESULTS AND DISCUSSION	8
Indicator Organisms	8
Monitoring-Site Locations	12
Sampling Techniques	15
Random Point Contacts	18
Quadrats	19
Band Transects	24
Photographic Plots	25
Fishes	28
Baited Stations	30
Video Transects	32
Video Circular Plots	32
ACKNOWLEDGEMENTS	39
LITERATURE CITED	40
TECHNICAL REPORT LIST	43

LIST OF TABLES

Table 1	Organisms selected for long-term population dynamics monitoring in kelp forests, and the sampling techniques selected for field testing	Page 9
Table 2	Descriptions of kelp forest monitoring stations in Channel Islands National Park and Channel Islands National Marine Sanctuary	Page 14
Table 3	Summary of sampling effort for Channel Islands National Park and Channel Islands National Marine Sanctuary kelp forest monitoring project 1982 - 1983	Page 17
Table 4	Seasonal variation in aerial extent of kelp canopy for identical areas having photographic coverage in November 1981 and May 1982	Page 29
Table 5	List of fishes collected with electrofishing apparatus in Channel Islands National Park, California, 1983 . .	Page 37

LIST OF FIGURES

- Figure 1 Locations of Kelp Forest Monitoring stations in
Channel Islands National Park and Channel Islands
National Marine Sanctuary Page 13
- Figure 2 Example of a detailed site description of a kelp
forest monitoring station Page 16
- Figure 3 Mean bottom sea temperatures (C), underwater visibility
(m), and densities of four species of macroalgae at 17
monitoring stations, arrayed from San Miguel Island (NW)
to Santa Barbara Island (SE); solid bars represent 1982;
open bars represent 1983 Page 20
- Figure 4 Distributions of 21 selected kelp forest invertebrates
determined by random band transects and quadrat counts
at 17 monitoring stations arrayed geographically from
San Miguel Island (NW) to Santa Barbara Island (SE);
solid bars represent 1982 and open bars represent
1983 Page 21-23
- Figure 5 Diagram of photo-plot showing the array of 0.25 m²
quadrats photographed in sequence from 1 to 80 . . . Page 26
- Figure 6 Distribution of nine selected kelp forest fishes
determined by baited counts at 17 monitoring stations
arrayed geographically from San Miguel Island (NW) to
Santa Barbara Island (SE); solid bars represent 1982
and open bars represent 1983 Page 31

INTRODUCTION

Southern California giant kelp forests are very productive ecosystems. Historically, they provided valuable fishery harvests for sport and commercial fishermen (Tegner, 1980). Direct harvest of the giant kelp (Macrocystis pyrifera), and other chemical-bearing algae support a significant industry in the region (Frey, 1971). Man's activities have severely damaged many of these kelp forest ecosystems and otherwise significantly reduced their productivity (Dayton and Tegner, 1984a). Harvest pressures on slow growing, long-lived organisms such as abalone (Haliotis spp.), and spiny lobster (Panulirus interruptus), reduced their populations. The disruptive potential of pesticides on these coastal ecosystems is exemplified by the brown pelican population collapse of the 1960s (Risebrough, et al., 1971). General declines in several fish populations such as giant sea bass (Stereolepis gigas), white seabass (Atractoscion nobilis), sheephead (Semicossiphys pulcher), and kelp bass (Paralabrax clathratus), have been observed as well (Frey, 1971). Numerous efforts are being made to re-establish kelp forests in southern California. While these efforts show considerable promise, alone they are not yet capable of restoring the region's kelp forests to their former productivity (Wilson et al., 1978).

One third of the kelp forests in southern California are located in Channel Islands National Park and Channel Islands National Marine Sanctuary (Davies, 1968). Because of their relative isolation, man's impact on island kelp forests has been minimal compared to that on kelp forests along the mainland coast, but the potential for disruption is still great. Pressure for exploitation continues to focus on island kelp forests as the last enclaves of clean water, undisturbed habitat, and large populations of

Digitized by Google

Original from
UNIVERSITY OF CALIFORNIA

harvestable organisms. Park waters are also considered prime locations for construction of sea-bed aquaculture facilities, sources of mariculture stock for transplantation, as well as ideal sites for introductions of laboratory-raised juvenile organisms for growing commercial crops. If these developments continue unabated, the last southern California kelp forests will be altered by modern man without knowing their true potential or how they function; there will be no way to determine normal variations in populations that should be expected, or any way to evaluate management actions on these unique natural resources. A need exists for control areas in the kelp forest and ways to establish standards to which rehabilitation efforts can aspire. Kelp forest areas are also needed where new resource management techniques can be developed and tested to improve and sustain kelp forest productivity. Studies of southern California kelp forests have shown generation times and cycles on the order of 10 to 20 years (Dayton and Tegner, 1984a). Natural phenomena that are significant determinants of kelp forest dynamics, such as major storms and el niño events, also occur at 20 to 30 year intervals (Dayton and Tegner 1984b). Long-term studies that span several generations and cycles are therefore needed to understand these kelp forest ecosystems and to manage them wisely.

The National Park Service, the National Marine Sanctuary Program, and the California Department of Fish and Game are designing a cooperative long-term kelp forest monitoring program to determine the population dynamics of kelp forest organisms. The park consists of five of the eight California Channel Islands (San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara Islands) and the submerged lands and waters within one nautical mile of each of the islands. Channel Islands National Marine Sanctuary encompasses the sub-tidal portions of the park and the sanctuary boundary extends six miles from the park islands. Nearly all kelp forests

In the sanctuary are also within the park boundary. This program will monitor kelp forests in both the park and sanctuary. Jurisdiction of marine resources in these kelp forests is held by the State of California and managed through its Department of Fish and Game. The Federal Law which established Channel Islands National Park (PL 96-199) required that the Secretary of the Interior (National Park Service) monitor the natural resources in the park. This law specifically requires that inventories of species, including population dynamics, be conducted and that present conditions and probable future trends of these populations be reported biennially for a decade. It also required that these biennial reports contain "recommendations as to what actions should be considered for adoption to better protect the natural resources of the park."

An ad hoc committee of marine scientists from the National Park Service and the California Department of Fish and Game was created to oversee a cooperative research program. The specific objectives of the research program are:

1. to select kelp forest indicator organisms;
2. to develop, field test, and standardize sampling techniques for the selected organisms;
3. to select and test appropriate analyses to describe population dynamics;
4. to develop standardized reporting systems for monitoring kelp forests; and
5. to provide a basis for making management recommendations as required by PL 96-199.

The monitoring program that this research project designs will ultimately provide information needed to distinguish between natural and

man-caused variations in kelp forest populations and to identify and define trends in those variations. This interim report presents the first results of the project. It describes selection of species to be monitored, selection and establishment of permanent monitoring stations, preliminary selection of sampling techniques, and partial results of two years of sampling.

METHODS

Species Selection

Organisms were selected for long-term monitoring from a list of nearly 1,000 species known to occur in the study area. The list was developed by Dr. J.M. Engle from extensive surveys of the Channel Islands supported by the Tatman Foundation. Since it was neither possible or desirable to monitor population dynamics of all 1,000 species, it was necessary to select indicator species. Seven criteria were used to prioritize species on the list. Species selected were: (1) endemic to the California Channel Islands; (2) species with special legal status, i.e. rare and endangered or protected from harvest or harassment; (3) major elements of endangered species habitat; (4) legally harvested; (5) exotics; (6) dominate or characteristics of kelp forests in the study area; and/or (7) highly visible and extremely numerous species.

Monitoring-Site Selection

The Study area lies on the boundary of two major biogeographical provinces (Hedgepeth, 1957; Seapy and Littler, 1980; and Murray et al., 1980). To the northwest, San Miguel and Santa Rosa Islands generally represent the southern extent of the boreal (Oregonian) province, and to the southeast Santa Barbara and Anacapa Islands represent the northern extent of the temperate (Californian) province. There is a transition zone between these two provinces along Santa Cruz Island. North of the Islands lies the shallow Santa Barbara Channel, and to the south and west lie deep oceanic basins. Strong prevailing winds and powerful winter storms buffet northwestern shores, whereas the relatively protected southern shores are

treated to rich nutrients upwelling from the depths of adjacent basins. Stations that represent this array of biogeographical and physical conditions were selected for long-term monitoring of kelp forest dynamics.

Sampling Techniques

The diverse array of organisms and physical settings associated with kelp forests in the study area required equally diverse sampling approaches to monitor their population dynamics. A workshop to review potential sampling techniques was held at the Marine Science Institute, University of California at Santa Barbara. A total of 37 scientists participated in the two-day workshop in late January, 1982. Sampling techniques for kelp forest organisms were evaluated for long-term monitoring using the following criteria: (1) ability to sample target species accurately and precisely; (2) impacts on target and other species; (3) efficiency (cost effectiveness); (4) ability to create "permanent" records of samples for confirmation and future analysis; and (5) requirements for highly trained observers or extremely complex procedures or equipment. Accuracy (the closeness of a measured value to its true value) is the paramount attribute of a sampling technique, but precision (the closeness of repeated measurements of the same quantity) and ability to sample several target species at once must also be great to make a technique efficient enough to use underwater in a kelp forest. Accuracy and precision of sampling techniques used in long-term monitoring programs must also be transmitted through several generations of observers without degradation. Finally, sampling techniques for this monitoring program must provide values relatively free of variation among observers and must not significantly reduce populations of organisms being monitored or alter their environment.

Remote sampling of kelp forest organisms from the sea surface is neither accurate nor precise enough to monitor population dynamics. Development of diving equipment during the past 30 years has spawned an array of in situ sampling techniques that have potential for providing accurate and precise measures of abundance, distribution, age (size) structures, reproduction, recruitment, growth rates, mortality rates, sex compositions and phenologies of kelp forest populations. This project tested a variety of techniques which use photographic systems that yield "permanent" records of the samples, require minimal sampling time on site, and may be operated by non-scientifically trained observers.

Physical environmental factors greatly influence kelp forest dynamics. Accurate interpretation of ecological dynamics requires knowledge of these physical parameters. A separate, but coordinated, research project will establish a program to continuously monitor sea temperature and water movement at selected kelp forest monitoring sites. This project was funded by the National Park Service in fiscal 1984, and data collection will begin in 1985.

RESULTS AND DISCUSSION

Indicator Organisms

The ad hoc committee developed a preliminary list of species to monitor using the seven selection criteria described above. The list included 15 plant taxa, 33 invertebrates, and 12 fishes. It is presented in Table 1 with sampling techniques chosen for field testing indicated to the right of each taxon. These species are characteristic of kelp forests in the study area. There are representatives of both boreal and temperate biogeographical provinces and some species whose centers of abundance fall within the transition zone. Some species, such as giant kelp and red urchins are ubiquitous in the study area and others, such as California hydrocoral, are found only at a few isolated sites. Some are extremely abundant, such as the purple urchin, while others, such as the giant-spined sea star, which are just as widespread and common in their distribution, occur in low densities. Many of the selected organisms are long-lived, with life spans of 10 to greater than 50 years, and thus their abundance provides a stable measure of conditions in kelp forests that is relatively insulated from year-to-year fluctuations. At the same time, reproductive efforts of these populations and annual recruitment to them provide measures of annual variations in conditions which augment observations of short-lived species, such as the bluebanded goby, whose very existence depends on local environmental conditions from year to year. This combination of organisms provides mechanisms for detecting both short and long term variations in kelp forests. These species also represent a wide array of trophic levels, from primary producers and obligate herbivores to high level predators and detritivores; feeding techniques ranging from sessile filter feeders and sedentary grazers to highly mobile planktivorous

Table 1. Organisms selected for long-term population dynamics monitoring in kelp forests, and the sampling techniques selected for field testing.

ORGANISM	1X2m RPCs	1X1m QUAD	BAND TRANS	BAITED FISH CTS	VIDEO TRANS	PHOTO QUADS
PLANTS						
Brown Algae						
Bladder chain kelp, <u>Cystoseira osmundacea</u>	X					X
<u>Desmarestia ligulata</u>	X					X
Southern sea palm, <u>Eisenia arborea</u>		X				X
Oar weed, <u>Laminaria farlowii</u>		X				X
Giant kelp, <u>Macrocystis pyrifera</u>	X	X				X
<u>Pterygophora californica</u>		X				X
Sargassum weed, <u>Sargassum muticum</u>	X					X
Misc. filamentous	X					X
Misc. non-filamentous	X					X
Red Algae						
Articulated coralline	X					X
Crustose coralline	X					X
Sea tongue, <u>Gigartina spinosa</u>	X					X
Agarweed, <u>Gelidium robustum</u>	X					X
Misc. filamentous	X					X
Misc. non-filamentous	X					X
ANIMALS						
Sponges						
Orange puffball sponge, <u>Tethya aurantia</u>			X			X
Aggregated vase sponge, <u>Polymastia pachymastia</u>	X					X
White calcareous sponge <u>Leucetta losangelensis</u>	X					X
Corals and Anemones						
California hydrocoral, <u>Allopora californica</u>			X			
La Jolla cup coral, <u>Astrangia lajollensis</u>	X					X
Orange cup coral, <u>Balanophyllia elegans</u>	X					X
Red gorgonian, <u>Lophogorgia chilensis</u>			X			
Brown gorgonian, <u>Muricea fruticosa</u>			X			

Table 1. (cont'd)

ORGANISM	1X2m RPCs	1X1m QUAD	BAND TRANS	BAITED FISH CTS	VIDEO TRANS	PHOTO QUADS
Strawberry anemone, <u>Corynactis californica</u>	X					X
White-spotted rose anemone, <u>Tellia lofotensis</u>			X			
Polychaete Worms						
Ornate tube worm, <u>Diapatra ornata</u>	X					X
Colonial sand-tube worm, <u>Phragmatopoma californica</u>	X					X
Crustaceans						
California spiny lobster <u>Panulirus interruptus</u>			X			
Mollusks						
Giant keyhole limpet, <u>Megathura crenulata</u>			X			
Red abalone, <u>Haliotis rufescens</u>			X			
Pink abalone, <u>Haliotis corrugata</u>			X			
Green abalone, <u>Haliotis fulgens</u>			X			
Wavy turban snail, <u>Astrea undosa</u>		X				X
Chestnut cowrie, <u>Cypraea spadicea</u>		X				X
Kellets whelk, <u>Kelletia kelletii</u>			X			
Scaled worm shell, <u>Serpulorbis squamigerus</u>		X				X
Rock scallop, <u>Hinnites giganteus</u>			X			
California brown sea hare, <u>Aplysia californica</u>			X			
Bryzoans						
Southern staghorn bryozoan, <u>Diaperoecia californica</u>	X					X
Sea Urchins and Sea Stars						
Giant red sea urchin, <u>Stronglyocentrotus franciscanus</u>		X				X
Purple sea urchin, <u>Stronglyocentrotus purpuratus</u>		X				X
White sea urchin, <u>Lytechinus anamesus</u>			X			
Sunflower star, <u>Pycnopodia helianthoides</u>			X			
Sea bat, <u>Patiria miniata</u>		X				X
Giant-spined sea star, <u>Pisaster giganteus</u>		X				X

Table 1. (cont'd)

ORGANISM	1X2m RPCs	1X1m QUAD	BAND TRANS	BAITED FISH CTS	VIDEO TRANS	PHOTO QUADS
Warty sea cucumber, <u>Parastichopus parvimensis</u>		X				X
Sea cucumber, <u>Pachythyone rubra</u>	X					X
Tunicates						
Stalked Tunicate <u>Styela montereyensis</u>		X				X
Fishes						
Blue rockfish, <u>Sebastes mystinus</u>				X	X	
Kelp rockfish <u>Sebastes atrovirens</u>				X	X	
Black perch, <u>Embiotoca jacksoni</u>				X	X	
Striped seaperch, <u>Embiotoca lateralis</u>				X	X	
Opaleye, <u>Girella nigricans</u>				X	X	
California sheephead, <u>Semicossyphus pulcher</u>				X	X	
Señorita, <u>Oxyjulis californica</u>					X	
Blackeye goby, <u>Coryphopterus nicholsi</u>		X		X		
Bluebanded goby, <u>Lythrypnus dalli</u>		X		X		
Garibaldi, <u>Hypsypops rubicundus</u>				X	X	
Blacksmith, <u>Chromis punctipinnis</u>					X	
Kelp bass, <u>Paralabrax clathratus</u>				X	X	

fishes and wide ranging benthic foragers. Reproductive strategies of these species run the gamut from live births of surf perches and protected demersal eggs of garibaldi to precarious releases of gametes into the sea by abalone and urchins and long-lived pelagic larvae of spiny lobsters. The selected array of species provides many opportunities to monitor conditions of kelp forests and potential impacts of man's activities, ranging from pollution to habitat disturbance and direct removal.

Monitoring-Site Locations

A total of 17 monitoring stations was established and sampled for two years. Locations of the stations are indicated on Figure 1. Their locations are defined by latitude and longitude, Loran-c positions, and depths (Table 2). Stations are distributed along the north and south sides of the northern channel islands from San Miguel to Anacapa and at Santa Barbara Island so that they represent the entire range of biogeographical and physical conditions of kelp forests in the park and sanctuary. They ranged in depth from 4.5 m to a maximum of 18 m. The 18 m depth limit was arbitrarily selected to allow sufficient bottom time for sampling within the constraints imposed on observers by the no-decompression diving policy of the National Park Service. Most giant kelp forests in the study area are above the 18 m depth contour; nevertheless, significant portions of giant kelp forests are found below this depth and both natural and man-caused fluctuations in population dynamics in these greater depths may be independent of events in shallower regions.

The specific site of each monitoring station was initially determined after reconnaissance of the rocky-bottom, giant kelp-dominated habitat in locations known to be representative of kelp forests in each area by members of the ad hoc committee and Dr. J.M. Engle. Information from the

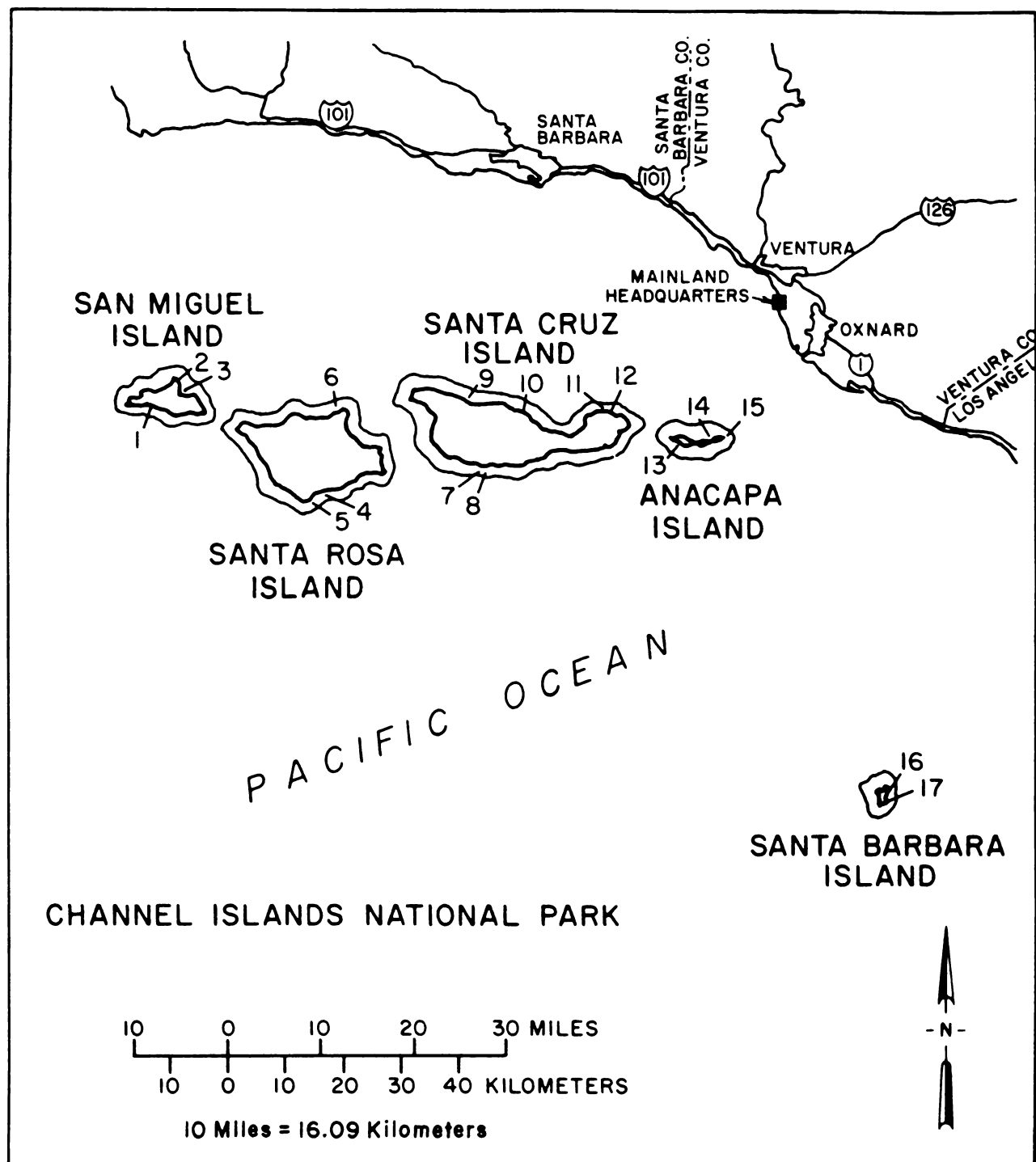


Figure 1. Locations of Kelp Forest Monitoring stations in Channel Islands National Park and Channel Islands National Marine Sanctuary.

Table 2. Descriptions of kelp forest monitoring stations in Channel Islands National Park and Channel Islands National Marine Sanctuary.

Station Number	Location	Latitude	Longitude	Depth (m)
San Miguel Island				
1	Wycoff Ledge	34°00.91' N	120°23.31' W	13.6
2	Nifty Rock	34°03.79' N	120°21.92' W	9.1
3	Hare Rock	34°02.84' N	120°21.45' W	9.1
Santa Rosa Island				
4	Johnsons' Lee North	33°53.74' N	120°06.16' W	10.6
5	Johnson's Lee South	33°53.50' N	120°06.00' W	16.6
6	Rodes Reef			
Santa Cruz Island				
7	Gull Island North	33°56.68' N	119°49.82' W	13.6
8	Gull Island South	33°56.66' N	119°49.57' W	16.6
9	Fry's Harbor	34°03.09' N	119°45.14' W	12.1
10	Pelican Bay	34°01.86' N	119°42.00' W	7.6
11	Scorpion Anchorage	34°02.77' N	119°32.81' W	4.5
12	Scorpion Rock	34°02.76' N	119°32.58' W	13.6
Anacapa Island				
13	Admiral's Reef	34°00.33' N	119°25.86' W	15.1
14	Cathedral Cove	34°00.71' N	119°22.29' W	9.1
15	Landing Cove	34°01.00' N	119°21.63' W	12.1
Santa Barbara Island				
16	SE Sea Lion Rookery	33°27.45' N	119°01.52° W	15.1
17	Arch Point	33°28.77' N	119°01.51' W	9.1

Tatman Foundation's Channel Islands Research Project (Engle, pers. comm.) and the extensive experience of California Department of Fish and Game scientists were invaluable in this selection process. Use of this unpublished catalog of personal knowledge of kelp forest distributions saved years of field work.

Each monitoring station was marked with a 100 m-long transect permanently affixed to the bottom. Each transect consists of 11 stainless steel eyebolts (9.5 mm dia.) embedded with epoxy in 2.5 cm diameter holes drilled 20-25 cm into bed rock. Eyebolts were placed approximately 10 m apart and connected by 10 lengths of lead-core nylon line (12.5 mm dia.). This design has several advantages. Eleven eyebolts provide precise locations for orientation of biological sampling techniques and reduce probability of losing an entire transect to storms or boat anchors dragged across the line. It also made relocation and replacement easier and quicker with several eyebolts for which to search. After two years in place, less than 10 percent of the lead line and eyebolts needed to be replaced. A notebook containing detailed descriptions and photographs of each station was prepared and was used to relocate the sites each year. An example of the detailed description is shown in Figure 2.

Sampling Techniques

From the array of sampling techniques discussed at the January 1982 workshop, six were selected and modified by the ad hoc committee for field evaluation: random point contact (RPC), $1 \times 1 \text{ m}^2$ quadrat counts, $2 \times 20 \text{ m}$ band transects, photographic plots, baited fish stations, and video transects. Table 3 summarizes the sampling effort for each technique in 1982 and 1983. The author also developed and tested two new marine fish sampling techniques; electrofishing and circular video plots. Results of

CHANNEL ISLANDS NATIONAL PARK KELP FOREST MONITORING PROJECT
SITE DESCRIPTION

Location: Fry's Harbor	Island: Santa Cruz
Code Name: SCIFH	Date Established: August 1981
Latitude: 34°03.09' W	Longitude: 119°45.14' N
LORAN C TD1: 27972.94	TD2: 41496.55

Range and Bearing to Prominent Points: NONE

Transect Orientation in Degrees: 180° - 360° mag

Stake No.	Depth (ft.)	Bearing to Next Stake	Distance To Stake	Bottom Type
0	40	210°	15 m	rock
1	40	210°	10 m	rock
2	40	170°	15 m	rock
3	40	190°	10 m	rock
4	40	180°	10 m	rock
5	42	190°	11 m	rock
6	44	200°	10 m	rock
7	44	205°	13 m	rock
8	39	206°	5 m	rock
9	40	180°	9 m	rock
10	40			

Photo-plot location relative to permanent transect:
(i.e. compass bearing and distance from stake number)

One meter west. 45-48 m from the south end of the transect

Description of surface location (i.e. North edge of kelp bed):

The transect is east of the rock cliff on the west side of Fry's Harbor. The north end is just inside the point, the line parallels the cliff at a depth of 40 feet, and the south end is just north of a large cave on the surface.

Description of bottom topography: Talus slope of boulders dropping sharply to the east.

Figure 2. Example of a detailed site description of a kelp forest monitoring station.

Table 3. Summary of Sampling effort for Channel Islands National Park and Channel Islands National Marine Sanctuary kelp forest monitoring project 1982 - 1983.

LOCATION	NUMBER OF SAMPLES									
	RPC'S		QUADRATS		BAND TRANS.	BAITED FISH CTS.		VIDEO TRANS.	PHOTO QUADS	
	82	83	82	83		82	83		82	83
	—	—	—	—		—	—		—	—
ANACAPA ISLAND										
Admiral's Reef	23	45	30	40	10	6	8	9	80	0
Cathedral Cove	25	40	30	40	10	8	8	9	80	77
Landing Cove	25	40	30	40	10	6	8	9	80	80
SANTA BARBARA ISLAND										
Arch Point	25	40	30	40	10	8	8	6	80	80
SE Sea Lion Rkry	25	39	30	40	10	8	8	5	80	80
SANTA CRUZ ISLAND										
Fry's Harbor	25	39	30	40	10	10	8	9	80	80
Gull Island No	25	40	30	40	10	8	0	0	80	80
Gull Island So	24	40	30	40	10	8	8	9	80	80
Pelican Bay	25	34	30	40	10	8	8	9	80	80
Scorpion Anchorage	25	40	30	40	10	6	8	9	80	80
Scorpion Rock	25	36	30	40	10	6	8	9	80	80
SANTA ROSA ISLAND										
Johnson's Lee No	95	40	188	40	10	22	8	9	80	44
Johnson's Lee So	25	40	30	40	10	8	8	9	80	36
Rodes Reef	50	40	60	40	10	16	7	9	160	44
SAN MIGUEL ISLAND										
Hare Rock	25	36	30	40	10	8	8	9	80	71
Nifty Rock	25	36	29	40	10	8	8	9	80	77
Wyckoff Ledge	25	29	30	40	10	5	8	9	0	0
TOTAL	517	654	667	680	170	149	127	137	1360	1084

RPC's: 1,171 1X2 m quadrats = 16,880 random points
 QUADRATS: 1,347 1X1 m quadrats
 BAND TRANSECTS: 170 2X20 m areas = 6,800 m²
 BAITED FISH CTS: 267 10-minute counts = 46 hours of fish counting
 VIDEO TRANSECTS: 137 100-m long, 5 minute samples = 8.5 transect miles and 11.4 hours of video tape
 PHOTO QUADS: 2,444 color slides of 0.25 m² quadrats within 17 permanently marked sites

field trials for each technique are presented below.

Random Point Contacts

Random point contact (RPC) quadrats were used to determine percent cover of small extremely numerous species that carpeted the bottom and those not forming discrete, easily countable units (Table 1). The technique employed was a modification of the point quadrat method described by terrestrial plant ecologists Goodall (1952) and Greig-Smith (1964) and employed underwater by Foster (1975). Two random numbers between 0 and 100 were selected for each quadrat. The first number determined where along the permanent transect line the RPC sample was to be taken, and the second determined where within the RPC quadrat the points were located. A 1 X 2 m quadrat was defined for each sample with a one meter-long rod, marked in 10 cm increments, which had a one meter-long length of lead-core nylon line attached so that it could slide the entire length of the rod. On the lead-core line five small nylon cable ties were arbitrarily affixed to define the points to be sampled. For each sample the rod was laid parallel and adjacent to the permanent transect line at the appropriate randomly selected site. The lead-line was then stretched perpendicular to the rod, and the presence or absence of each species to be sampled which occurred under, or within one meter above, each of the five cable ties was noted on a data form. The lead-line was then stretched to the opposite side of the rod and five more observations were recorded. In 1982, 25 RPC quadrat samples were taken at each monitoring stations, with 20 randomly selected points recorded in each quadrat. Variation among quadrats indicated that precision of the samples could be significantly improved by increasing the number of quadrats at each monitoring station, and that a reduction in the number of points within each quadrat would have no effect on their

precision. Consequently, in 1983, 40 RPC quadrats were sampled with 10 points in each quadrat. The total number of points at each station was thus reduced 20 percent (from 500 to 400 points), but the number of quadrats was increased 60 percent to reduce the variability due to patchy distributions of organisms. These data have not been completely analyzed yet, but the modification appeared successful. RPC sampling required four to six observer-hours of bottom time at each station.

Quadrats

One meter square quadrats which could be disassembled to easily include tall plants in the sample, were placed at randomly selected sites along permanent transect lines. Selected organisms within the quadrats were counted and recorded in situ by observers using SCUBA (Table 1). If the random number for the sample was even, the quadrat was placed southeast of the transect, if it was odd it was placed northwest of the transect. In 1982, 30 quadrats were sampled; in 1983 the sample was increased to 40 to reduce sample variances and improve precision. Quadrat counts required two observer-hours of bottom time to complete.

Results of quadrat counts are summarized in Figures 3 and 4 which depict total numbers of organisms observed in 30 quadrats at each station (1983 observations were proportionally reduced to 30 using the mean of the 40 quadrats actually sampled). Total numbers of organisms, rather than means and variances, were presented to evaluate sampling adequacy in terms of biological significance as distinguished from statistical significance of sampling precision. In the figures, stations are arrayed from northwest to southeast to make geographical distributions of the organisms apparent. For example, stalked tunicates (Styela montereyensis), and the sea stars

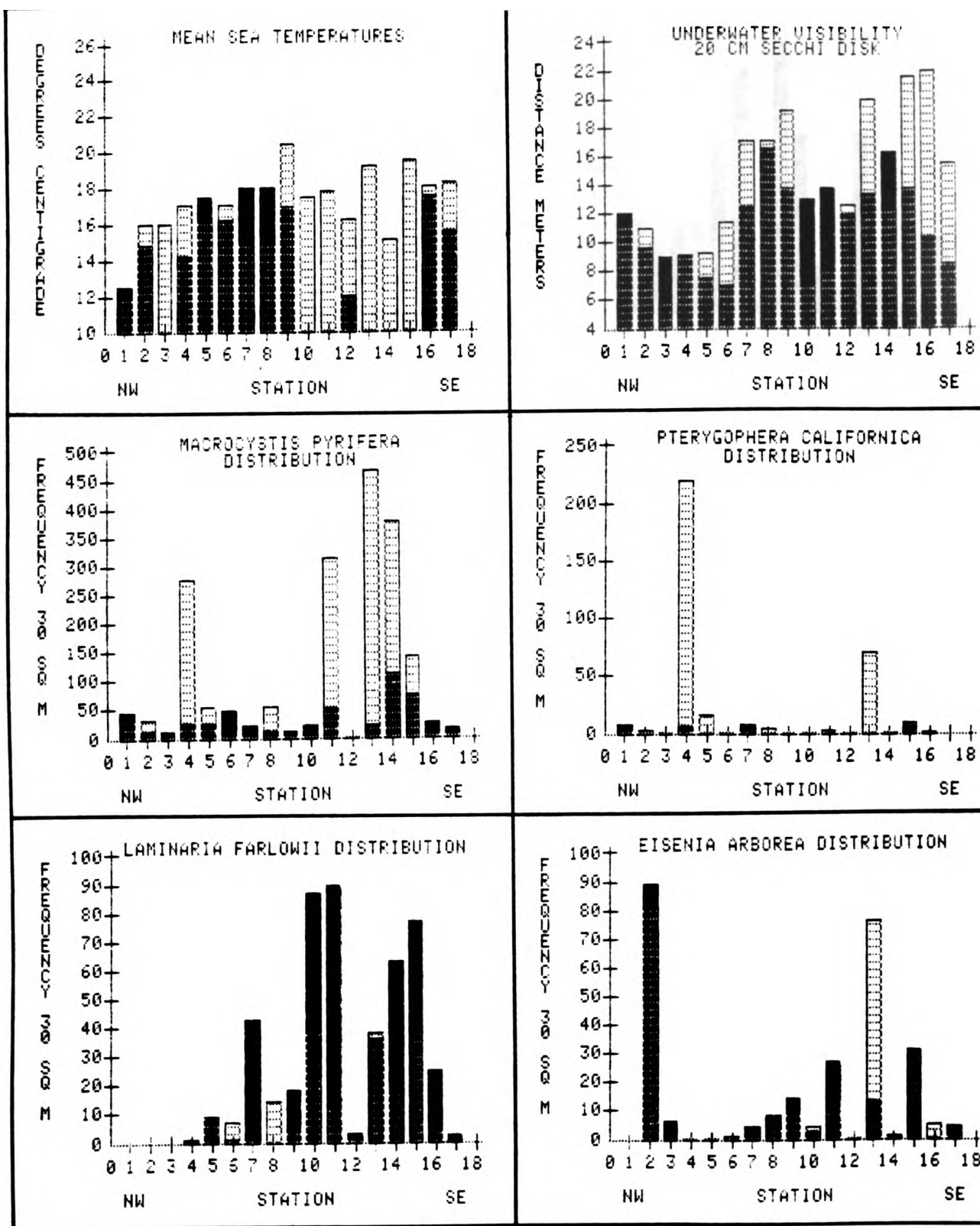


Figure 3. Mean bottom sea temperatures ($^{\circ}\text{C}$), underwater visibility (m), and densities of four species of macroalgae at 17 monitoring stations, arrayed from San Miguel Island (NW) to Santa Barbara Island (SE); solid bars represent 1982; open bars represent 1983.

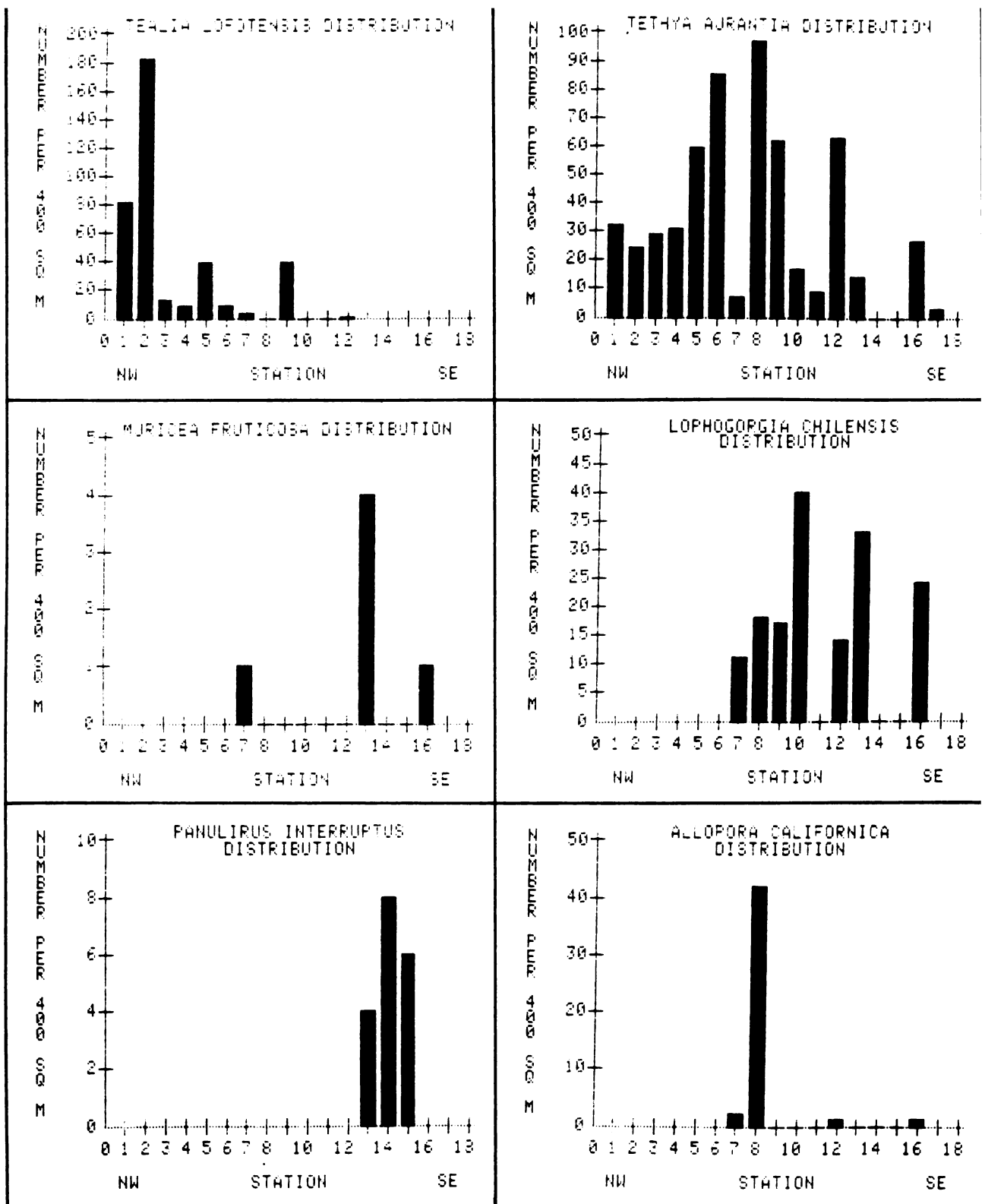


Figure 4. Distributions of 21 selected kelp forest invertebrates determined by random band transects and quadrat counts at 17 monitoring stations arrayed geographically from San Miguel Island (NW) to Santa Barbara Island (SE); solid bars represent 1982 and open bars represent 1983.

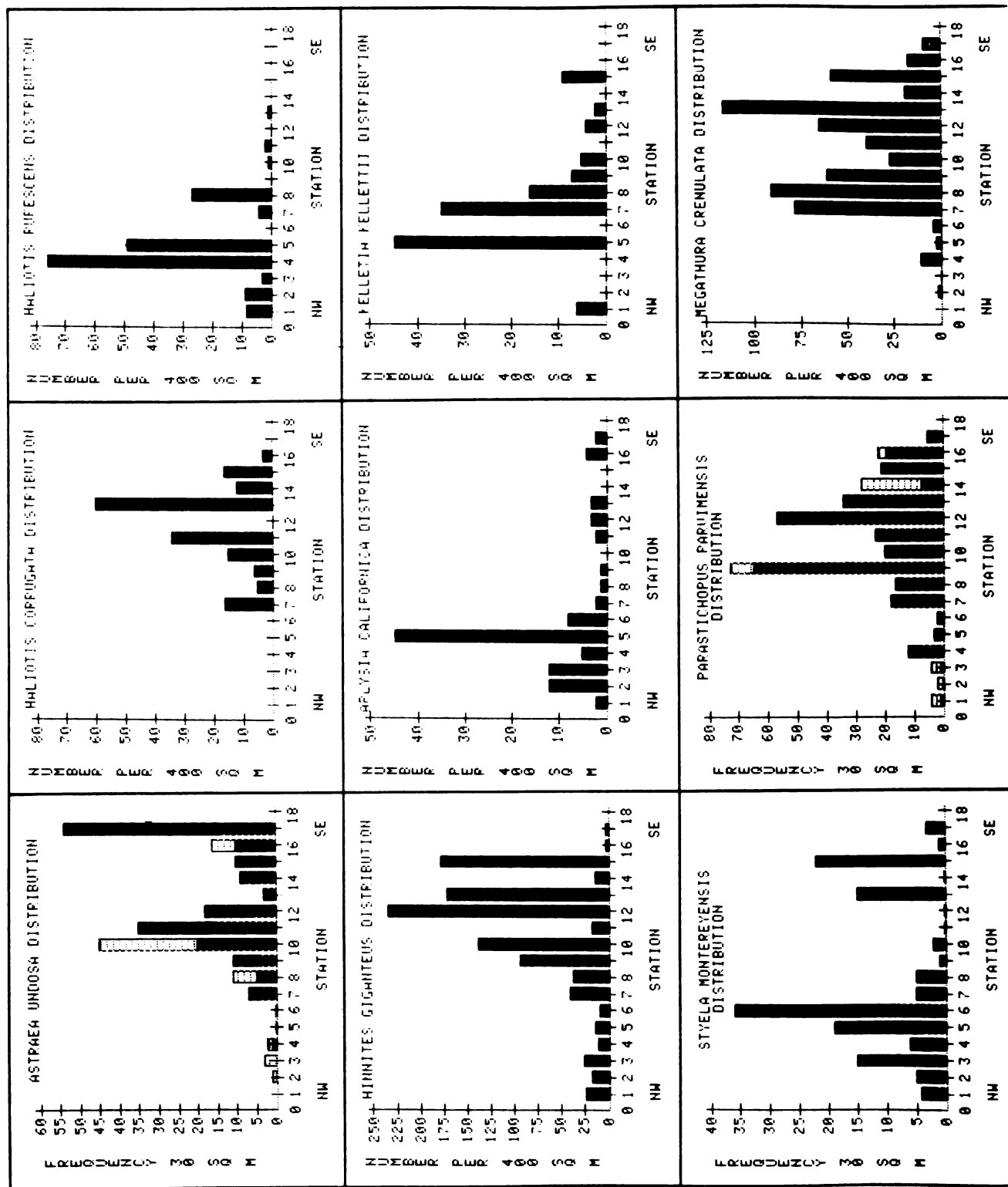


Figure 4 (Continued)

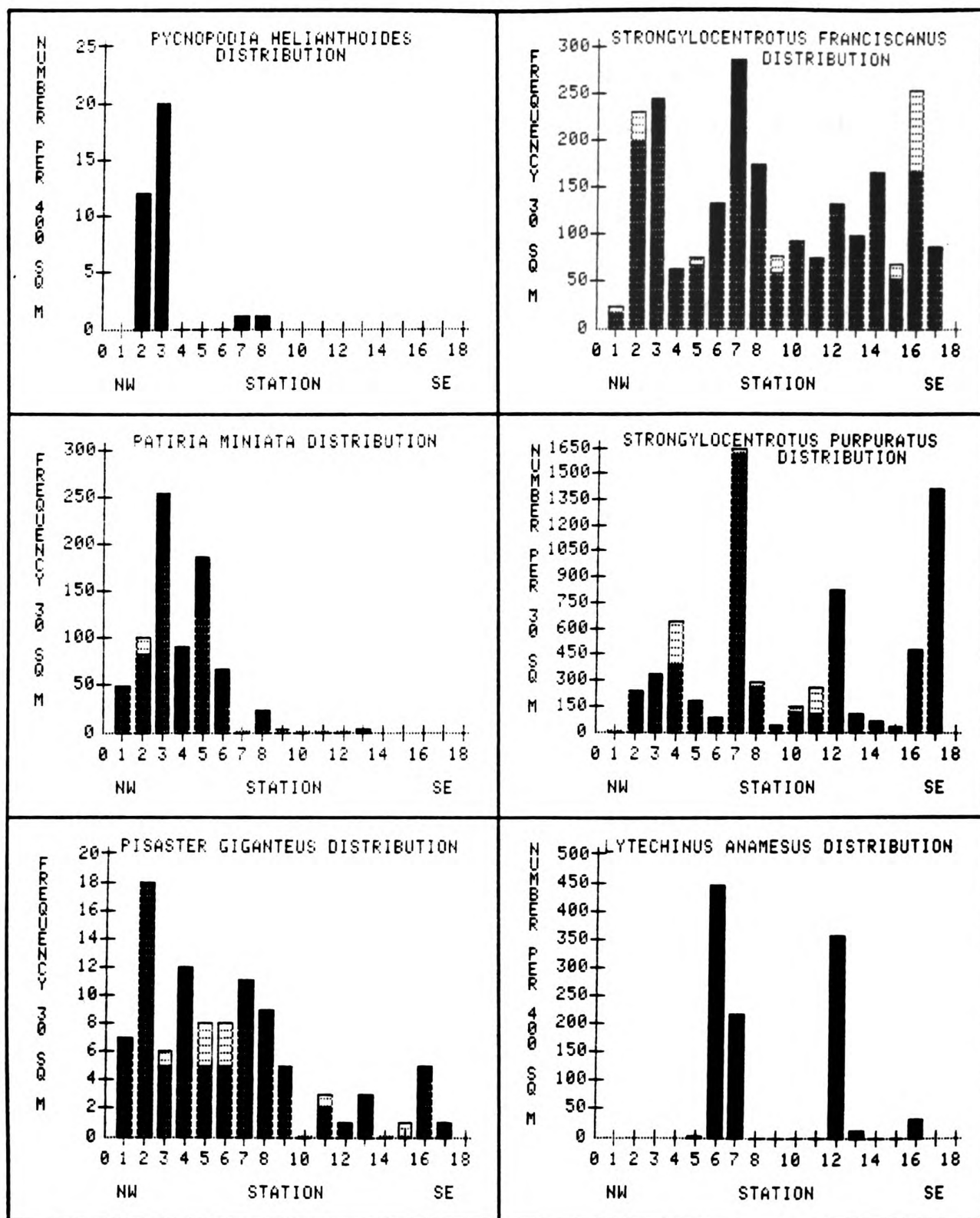


Figure 4 (Continued)

(Patiria miniata and Pisaster giganteus) were found primarily at northwestern stations (San Miguel and Santa Rosa Islands); whereas abundance of warty sea cucumbers (Parastichopus parvimensis), peaked in the transition zone along Santa Cruz Island. In contrast, wavy topshell (Astrea undosa), oar weed (Laminaria farlowii), and giant kelp distributions peaked at the southeastern stations off Anacapa and Santa Barbara Island. Some species, such as the urchins (Strongylocentrotus franciscanus and S. purpuratus), were found at virtually all stations in high numbers. Differences between 1982 and 1983 are also apparent in Figures 3 and 4 for some species, such as dramatic increases of giant kelp at the southeastern stations where it occurred in 1982. The apparent increase in giant kelp resulted from heavy recruitment of juvenile plants (< 1 m high). Canopies of adult giant kelp plants were greatly reduced in this year of extreme el niño events (Dayton and Tegner, 1984b).

Band Transects

Many species to be monitored occurred rarely or were strongly clumped in their local distributions. One meter square quadrats inadequately sampled these organisms because probability of selecting a quadrat containing an individual of the target species was too low. In 1983, 10 band transects, each 2 x 20 m with their long axis perpendicular to the permanent transect line, were searched by SCUBA equipped observers at randomly selected sites. Increasing the sampled area from 30 m² to 400 m² and consolidating the sampled areas into larger contiguous plots, greatly increased the probability of regularly encountering target species.

Results of band transect sampling are shown in Figure 4. Similar to the quadrat data, total numbers of organisms are reported and geographical distributions are readily apparent. Sunflower stars (Pycnopodia

hellanthoides), white-spotted rose anemones (Telia lofotensis), and red abalone (Haliotis rufescens), occurred primarily at northwestern stations; whereas pink abalone (H. corrugata), California spiny lobsters, rock scallops (Hinnites giganteus), giant keyhole limpets (Megathura crenulata), and the gorgonians (Lophogorgia chilensis and Muricea fruticosa) were characteristic of the southeastern stations.

Photographic Plots

A permanent photographic plot was established at each monitoring station. Each photo-plot consisted of four brass survey stakes epoxied into the bedrock at the corners of a square, two meters on a side. A portable frame, also 2 m on a side, which divided the frame into four 1 x 1 m sections was placed over at least two adjacent stakes which held it rigidly in position. In this manner five quadrats each, 2 x 2 m, were defined for a total area of 20 m² at each photo-plot (Fig. 5). An underwater camera with a wide angle lens (Nikonos IV-A, 15 mm lens) was mounted on a quadrapod above a 0.5 x 0.5 m quadrat with two underwater strobe lights (Oceanic 2001). By aligning two adjacent sides of the camera quadrat with two adjacent sides of the portable frame (which was held in place by stakes in bedrock), a sequence of 80 photographs, each of 0.25 m², was taken in such a way that the sequence could be repeated each year to accurately resample the entire 20 m² photo-plot. Color slide film, Ektachrome ASA 64, and black and white print film, Plus-X ASA 125, were tested at one station. Color was essential for rapid positive identification of organisms and was subsequently used exclusively for the remaining plots. Each photo-plot required two observer-hours of bottom time to sample.

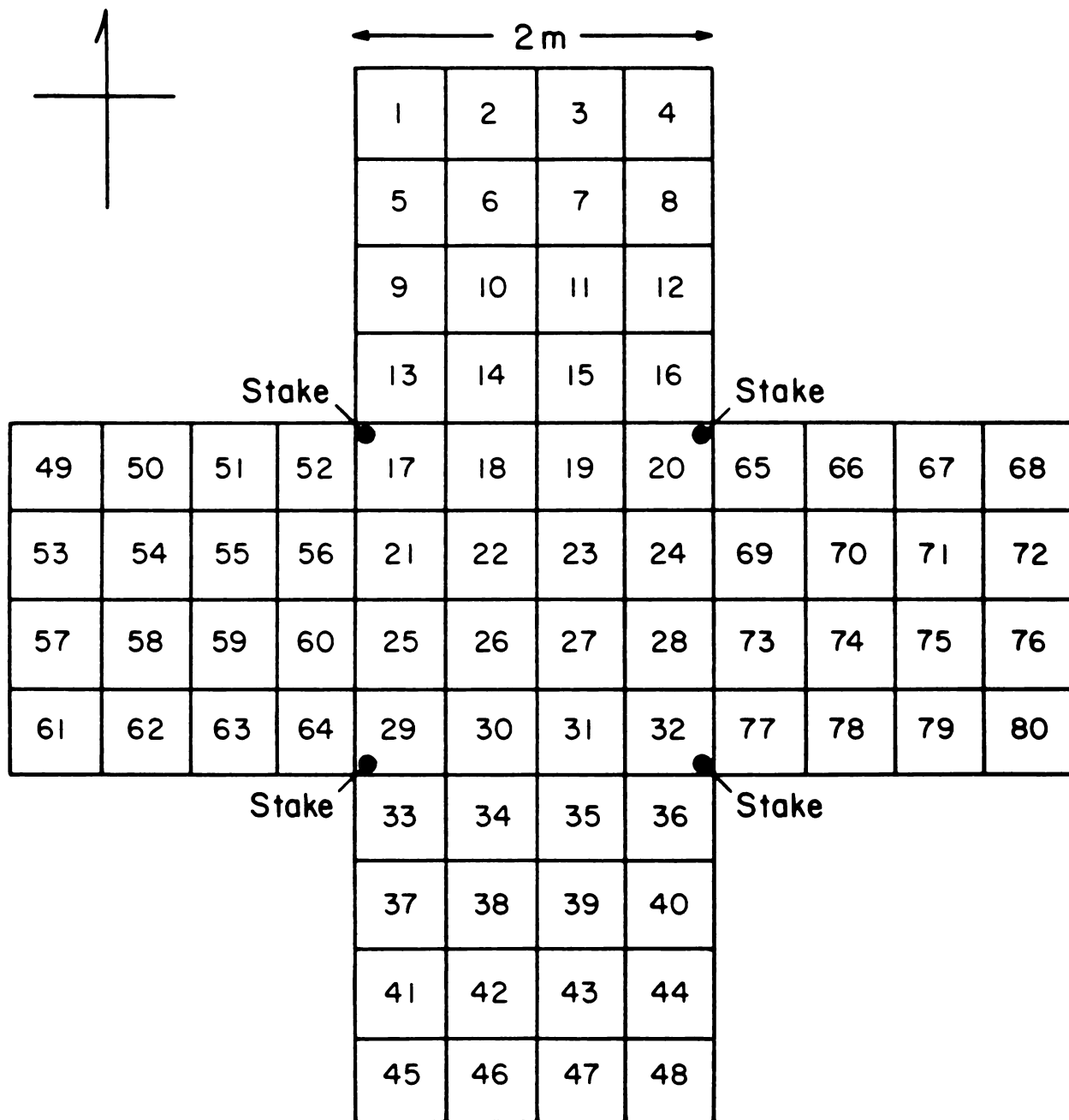


Figure 5. Diagram of photo-plot showing the array of 0.25 m² quadrats photographed in sequence from 1 to 80.

Preliminary analysis of photo-plot data at two stations, Nifty Rock and Gull Island South, showed promising results. Using this technique, samples taken by non-scientifically trained divers provided permanent records that may be analyzed and re-analyzed by experts. They also provided size frequency distributions of target species. Slides were cataloged by station and location in sequence (Fig. 5). They were viewed with a dissecting microscope at 10x. An ocular micrometer was used to measure diameters of selected organisms. Observed abundance in photo-plots showed the same high variance to mean ratios encountered in RPC, quadrats, and band transects. Therefore data were transformed to $\log(N+1)$ values before comparing photo-plot data with RPC and quadrat count data for the same stations and species. Those analyses are not complete, but there appeared to be generally good agreement among in situ observations and photo-plot data, in spite of the fact that portions of populations may be hidden from view by cracks, crevices, and plants in photo-plots. The photo-plots appeared promising for monitoring conspicuous sessile organisms.

Aerial extent of giant kelp canopy at the sea surface is an accurate indicator of kelp forest condition in the study area. It is also amenable to monitoring by remote sensing with false-color infrared aerial photography or multispectral scanner. As part of this project, the U.S. Environmental Protection Agency and the National Park Service remote sensing section in Denver, Colorado, conducted a feasibility study to compare these techniques (Page and Shelton, 1982). They concluded that airborne multispectral scanning can accurately survey, map, and compile aerial extent statistics on nearshore kelp resources in the study area. Unfortunately, the cost of \$12-15,000 per sample and the seasonal nature of variability in kelp canopy which requires multiple samples each year,

renders this approach to monitoring unacceptably expensive at the present time. The seasonal variation in kelp canopy detected during the study is shown in Table 4.

Fishes

Most traditional fishery sampling approaches use nets, hooks, traps, poisons, or explosives and cannot be used for long-term monitoring of kelp forest fishes without having deleterious impacts on the monitored populations. Scientists have been observing and photographing fishes underwater for 70 years (Longley and Hildebrand, 1941). For 30 years, attempts have been made to quantify these visual observations with varying degrees of success (Brock, 1954; Jones and Thompson, 1978; Stephens and Zerba, 1981). Precision and field effort required for each technique is of paramount interest in comparing efficacies of these techniques. As monitoring tools to produce indices of abundance, accuracy of most of these techniques does not seem to be a serious problem, as long as inherent biases are consistent from year to year. Nevertheless, patchiness and variability of highly mobile and schooling fishes necessitated many replicates to achieve accuracy. Visual samples were compared to mark/recapture population estimates of two species at one location. This activity will be expanded during the 1984 field season.

Three visual sampling techniques were evaluated: (1) baited stations (Gotshall et al. 1974); (2) video transects (after Ebling et al. 1980); and (3) video circular plots (this study). Data from two locations near Santa Cruz Island (Fry's Harbor and Gull Island) and five fishes were used to compare three sampling techniques. The fishes were black perch (Embiotoca jacksonia), señorita (Oxyjulis californica), sheephead, blacksmith (Chromis

Table 4. Seasonal variation in aerial extent of kelp canopy for identical areas having photographic coverage in November 1981 and May 1982.

Area Sampled	Hectares of Kelp Canopy	
	November	May
San Miguel Island, Southwestern Shore	254.97	72.09
San Miguel Island, Southeastern Shore	525.54	264.62
Santa Rosa Island, Southwestern Shore	1053.55	356.47
Santa Rosa Island, Southern Shore	265.23	134.09
Santa Rosa Island, Southeastern Shore	214.44	75.17
Total	2312.73	902.44

punctipinnis), and kelp bass. Mark recapture estimates of sheephead and kelp bass populations at Fry's Harbor, were made using an electrofishing device and spaghetti tags.

Baited Stations

For baited stations, eight sampling sites were selected randomly along the permanent transect line. At each site, a perforated PVC canister, 10 cm in diameter, containing approximately 225 g of squid was attached at the center of four 1 m lengths of chain which were deployed in a cross to define a 2 m diameter circle. A small net-float on a 1 m cord was also attached to the center of the chains and defined the upper limit of the sampling area. Two diver-observers were stationed on opposite sides of the bait canister, 6-8 m apart, depending on underwater visibility and surge conditions. Upon a signal from the lead diver, both divers simultaneously started digital elapsed timers. The maximum number of each fish species which came within 1 m of the bait canister was recorded each minute for 10 consecutive minutes. At the conclusion of the sample, the bait canister was re-enclosed in a plastic bag to prevent contamination of subsequent samples in the vicinity. Observations of the two divers were reconciled soon after the dive, and the maximum number of individuals observed for each species during each one minute period was recorded. The results of baited counts for nine fishes at 17 stations in 1982 and 1983 show interesting distributions and changes between years. Maximum numbers of each species observed in one minute periods during ten minute samples were totaled for eight samples at each station and displayed in Figure 6.

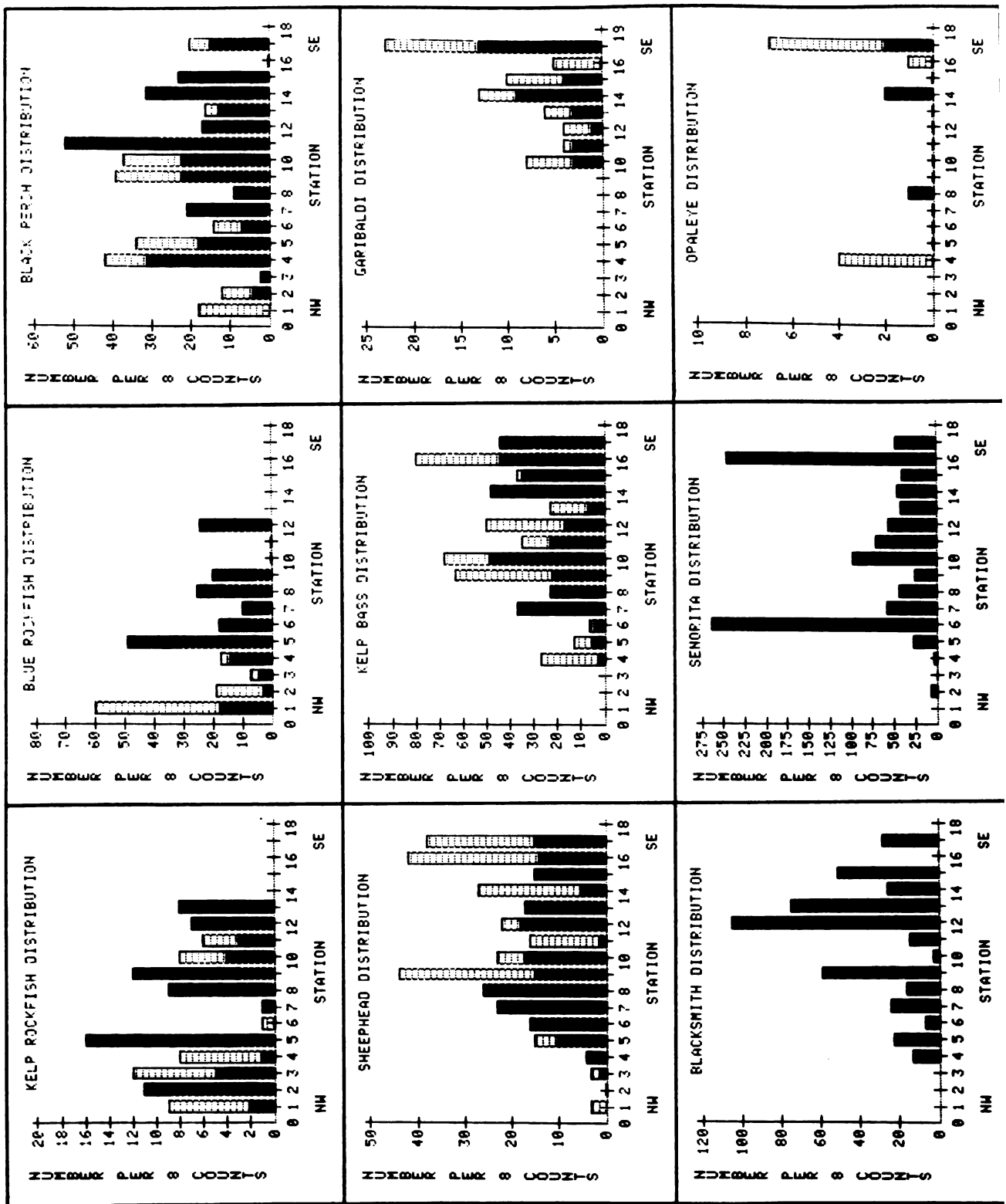


Figure 6. Distribution of nine selected kelp forest fishes determined by baited counts at 17 monitoring stations arrayed geographically from San Miguel Island (NW) to Santa Barbara Island (SE): solid bars represent 1982 and open bars represent 1983.

Video Transects

The video transect technique was patterned after the visual transect approach of Quast (1968), and the cine-transect methods of Ebling et al. (1980). In this study, both the length of time and the distance covered in each sample were controlled. Three parallel 100 meter-long transects were established at each location. fish along each transect were recorded on high resolution color video tape using only ambient light. Each transect line was sampled three times with a diver-operated camera 1 m above the bottom. Length of time of each sample was standardized at five minutes. Elapsed time was recorded on the upper left of the video screen, and was visible to the diver during the sampling period so that swimming speed along the transect could be regulated. The entire sample at each location consisted of nine 100 meter-long transects, each five minutes in duration. Numbers of each species observed on the video tape were recorded independently by two observers for each transect at each location.

Video Circular Plots

The third method evaluated in this study also used a video camera, but instead of recording fish along a transect line, fish were sampled at discrete points. At eleven points, 10 m apart along a permanent transect line, the diver swung the camera in a 360 degree arc over a period of 60 to 90 seconds. The number of fishes observed on the video tapes was determined independently by two observers, just as it was done with the video transects.

In general, the data produced by all three of these sampling techniques had very large and similar variance to mean ratios, so they were transformed to $\log(N+1)$ values before coefficients of variation were

computed. Since each technique sampled a different area or proportion of the population it was impossible to compare directly the absolute sample values, but it is useful to compare total numbers of each species sampled and precisions of the techniques. Number of fish of a given species sampled by the baited stations ranged from 0 to 80, and coefficients of variation ranged for 11% to 92%. Number of fish of each species on the video transects ranged from 0 to 439, and coefficients of variation ranged from 9% to 58%. In circular plots, number of fish by species ranged from 0 to 194, and coefficients of variation ranged from 10% to 139%. While coefficients of variation less than 30% probably indicate acceptable precision and those approaching 100% (> 50%) are unacceptable, it is not yet clear what level of precision will be required to detect population trends.

Baited stations generally produced more precise results than the other two techniques for less numerous species such as sheephead, black perch, and kelp bass. For schooling species, blacksmith and señorita, which occurred in much larger numbers, video transects and circular plots produced similar results which were superior to baited stations. Fish behavior introduces significant sources of variability that are independent of abundance at baited stations. For example, attractiveness of bait may be dependent on hunger, availability of natural food, and sea temperatures. When large predators appeared at bait canisters, other fish were apparently intimidated and stayed outside the sampling zone. Replicate sampling reduces effects of these biases somewhat, but numbers of smaller more timid species sampled by this technique are dependent as much on population levels of large predators as it is on their own abundance. This bias may be true of any visual sampling technique, but it is made more apparent by

concentrating fishes at a food source. Overall, the three techniques produced quite similar results in terms of sampling precision. Yet none of the techniques sampled more than five percent of the estimated populations of kelp bass or sheephead at Fry's Harbor.

Major differences among sampling techniques were associated primarily with the amount of effort required for sampling. Baited stations required about six diver-hours of bottom time and an additional two man-hours of reconciling. Video transects required two diver-hours of bottom time and two man-hours of data recording. Circular plots required only one diver-hour of bottom time and less than one man-hour of data recording. For roughly the same levels of precision, circular plots took 1/4 of the total time, and only 1/6 of the costly diver bottom time as baited stations. In addition, the video tapes provide a permanent record of the samples which can be re-evaluated and analyzed in the future. Furthermore, the video samples can be taken by non-scientifically trained divers. These are important considerations in the design of long-term monitoring programs which will be conducted by a variety of observers over the course of many years. Nevertheless, a great deal more data analysis will be required before decisions regarding the final sampling techniques for this program will be made.

Phillips and Scolaro (1980) developed and described an electrofishing device for collecting juvenile rock lobsters in Western Australia. An electrofishing apparatus was built to the same specifications by Coffelt Electronics in Englewood, Colorado, and tested to determine its efficacy in collecting kelp forest fishes. The electrofishing apparatus, as tested, produced a 60 cycle AC stunning field of 36 volts at 125 amperes, and was powered by a 15 kilowatt generator on board the National Park Service vessel, Pacific Ranger. Two electrode arrays were tested: (1) a 4.0 m

diameter cathode ring with a 0.5 m diameter anode in the center, both electrodes were composed of 0.3 m high lengths of 2 cm diameter stainless steel tubing; (2) two identical square grids of 2 cm diameter stainless steel tubing, approximately 0.6 m on a side were deployed upright 2-3 m apart. The electrodes were connected to the electrofisher with 45 m lengths of heavy-duty welding cable. Quick-disconnects between the electrodes and the power cables permitted easier deployment of the electrodes.

Divers collected fish with an electrofishing device to estimate the populations of kelp bass and sheephead at Fry's Harbor. Stunned fish were tagged with spaghetti tags and released in the area of capture when they recovered. The next day fishes were counted visually and by video camera. The tagged status (tagged or untagged) of kelp bass and sheephead was determined during 30 minute systematic searches in the 20 x 100 m area in which they had been released.

Eight test sites were selected to represent the range of kelp forest habitats and fish assemblages found in the study area. Sites were selected at all five islands:

Santa Barbara Island
Arch Point
Anacapa Island
Cathedral Cove
Santa Rosa Island
Johnson's Lee

Santa Cruz Island
Gull Island
Fry's Harbor
Pelican Bay
Scorpion Anchorage
San Miguel Island
Wyckoff Ledge

Divers deployed electrode arrays on the bottom at depths of 10 to 18 m. Fish were usually baited into the stunning field with frozen squid or fresh sea urchin roe. With circular electrodes, divers left the water before shocking took place, and returned to collect stunned fish after the electrofisher was turned off. After cautious experimentation, we found

divers could remain in the water during shocking, and approach to within one meter of the upright grid electrodes and the stunning field without harm to the divers. In this way, a diver-observer could signal the electrofisher operator on the Pacific Ranger when desired fishes were in the stunning field, which made fish collection both selective and efficient. Fishes stunned by the electrofisher were collected by SCUBA divers, transported to the surface in nylon mesh bags, measured to the nearest millimeter (total length), and marked with spaghetti tags. After tagging, fish were retained in floating baskets until they recovered, at which time they were released. Fish that did not recover completely within 30 minutes were recorded as mortalities and released.

A total of 391 fishes, including 24 species representing 11 families, was collected with the electrofisher. They ranged in size from 6° to 500 mm total length (Table 5). Shocking times from five seconds to five minutes were tested. The number of fish stunned with each shock ranged from 0 to 13, with a mean of 4.3. Total recorded mortality was seven percent. Of the 20 dead fish, 16 were señoritas. If señoritas were removed from the sample, remaining mortality was only five percent. The optimum shocking interval was 25-30 seconds. Shorter times did not stun the fish long enough to be collected by on-site divers, and longer time, > 60 seconds, increased mortality and made collection of partially stunned fish which drifted out of the stunning field difficult (dangerous) for the divers to collect while shocking was still ongoing. Mortality appeared to be more related to decompression effects on swim bladders (i.e. rapid gas expansion) than effects of stunning. Measuring and tagging fish underwater near the site of collection may reduce this source of mortality and would not be prohibitively inefficient. A team of three people, two divers and an equipment operator, appeared to be the optimum number of people to

Table 5. List of fishes collected with electrofishing apparatus in Channel Islands National Park, California, 1983.

SPECIES		SIZE TL (mm)	NUMBER COLLECTED
<u>Paralabrax clathratus</u>	kelp bass	122-369	61
<u>Caulolatilus princeps</u>	ocean whitefish	305	1
<u>Girella nigricans</u>	opaleye	246-301	2
<u>Medialuna californiensis</u>	halfmoon	305-370	4
<u>Embiotoca jacksoni</u>	black perch	150-309	35
<u>E. lateralis</u>	striped seaperch	170-329	27
<u>Hypsurus caryl</u>	rainbow seaperch	173-190	2
<u>Chromis punctipinnis</u>	blacksmith	60-251	46
<u>Hypsypops rubicundus</u>	garibaldi	216-270	27
<u>Halichoeres semicinctus</u>	rock wrasse	190-290	3
<u>Oxyjulus californica</u>	señorita	101-230	119
<u>Semicossyphus pulcher</u>	California sheephead	151-500	41
<u>Rathbonella hypoelecta</u>	smooth ronquill	101	1
<u>Alloclinus holderi</u>	Island kelpfish	80	1
<u>Gibbonsia elegans</u>	spotted kelpfish	110-121	2
<u>Heterostichus rostratus</u>	giant kelpfish	190	1
<u>Sebastes atrovirens</u>	kelp rockfish	170-220	4
<u>S. caurinus</u>	gopher rockfish	348-352	2
<u>S. chrysomelas</u>	black-and-yellow rockfish	199-249	2
<u>S. miniatus</u>	vermillion rockfish	396	1
<u>S. mystinus</u>	blue rockfish	225-319	4
<u>S. serriceps</u>	treefish	301-303	2
<u>Oxylebius pictus</u>	paintned greenling	159	1
<u>Scorpaenichthys marmoratus</u>	cabezon	256-389	2
TOTAL		60-500	391

conduct this operation. Surface supplied air and a hardwire communication system to the boat would greatly increase the safety and efficiency of the operation. Upright grid electrodes were by far superior to the circular array for collecting kelp forest fishes. They were much easier to deploy and more effective in stunning fishes.

ACKNOWLEDGMENTS

The need for this project was perceived by Superintendent W.H. Ehorn and other members of the California Advisory Board on Underwater Parks and Reserves. Guidance was provided by an ad hoc committee of marine scientists from the California Department of Fish and Game. In addition to the author, principle members of the committee have been H. Frey, D. Gotshall, J. Grant, K. Wilson, D. Parker, and P. Haaker. I appreciate the assistance of D. Coon and the other 36 participants of a two-day workshop held in January, 1982 at the Marine Science Institute of the University of California, Santa Barbara to discuss state-of-the-art biological sampling techniques for kelp forest organisms. M.D. Conlin, T. Herrlinger, D.V. Richards, and J. Lewis of the National Park Service conducted much of the field work and contributed greatly to the success of the project. M. Kolipinski improved the quality of both the project and this report with his reviews of the proposal and manuscript. I am also indebted to over 80 National Park Service divers, graduate students, and scientists from several universities, private firms, and governmental agencies who contributed their time and energies to the collection of field data, and Silvia C. Hillyer for typing this manuscript. Finally, J.M. Engle provided encouragement to undertake the project, expertise in monitoring site selection, able assistance in the field, and knowledgeable reviews of research plans and manuscripts. This work is the result of research sponsored by the National Park Service, the National Marine Sanctuary Program, and the California Department of Fish and Game.

LITERATURE CITED

- Brock, V. 1954. A preliminary report on a method of estimating reef fish populations. J. Wildl. Mgmt. 18:297-308.
- Davies, D.H. 1968. Statistical analysis of the relation between kelp harvesting and sportfishing in the California kelp beds. In W.J. North and C.L. Hubbs (eds.) Utilization of Kelp-bed Resources in Southern California, pp. 151-212. State of California Fish Bulletin 139.
- Dayton, P.K., and M.J. Tegner. 1984a. The importance of scale in community ecology: a kelp forest example with terrestrial analogs. In P.W. Price and W.S. Gaud, (eds.), A New Ecology, pp. 457-481. John Wiley & Sons, Inc. New York.
- , 1984b. Catastrophic storms, El Niño, and patch stability in a southern California kelp community. Science 224:284-285.
- Ebling, A.W., R.J. Larsen, W.S. Alevizon, and R.N. Bray. 1979. Annual variation of reef-fish assemblages in kelp forests off Santa Barbara, California. Fishery Bulletin 78(2):361-377.
- Foster, M.S. 1975. Algal succession in a macrocystis pyrifera forest. Marine Biology 32:313-329.
- Frey, H. 1971. California's living marine resources and their utilization. State of California, The Resources Agency, Department of Fish and Game. 148 pp.
- Goodall, D.W. 1952. Some considerations in the use of point quadrats for the analysis of vegetation. Austral. J. of Sci. Res., Series B, 5, 1-41.
- Gotshall, D.W., L.L. Laurent, E.E. Ebert, F.E. Wendell, and G.D. Farrens. 1974. Diablo Canyon power plant site ecological study annual report

- July 1, 1973 - June 30, 1974. W.J. North (ed.) Environmental Investigations at Diablo Canyon, 1974. p. 199-305. Calif. Dept. Fish and Game Mar. Resour. Admin. Rep. 74-100.
- Grelg-Smith, P. 1964. Quantitative plant ecology, 2nd ed. Butterworth's, London. 256 pp.
- Hedgepeth, J.W. (ed.) 1957. Marine biogeography. In Treatise on marine ecology and paleoecology. Vol. 1, Ecology. Geol. Soc. Amerl., Mem. 67:1-1296.
- Jones, R.S. and M.J. Thompson. 1978. Comparison of Florida reef fish assemblages using a rapid visual technique. Bull. Mar. Sci. 28(1):159-172.
- Longley, W.H. and S.F. Hildebrand. 1941. Systematic catalogue of the fishes of Tortugas, Florida with observations on color, habits, and local distribution. Papers from Tortugas Laboratory, Vol. XXXIV. Carnegie Institution of Washington Publication 535, Washington, D.C. 331 pp.
- Murray, S.N., M.M. Littler, and I.A. Abbott. 1980. Biogeography of the California marine algae with emphasis on the southern California islands. In D.M. Power (ed.) The California Islands: proceedings of a multidisciplinary symposium, pp. 325-339. Santa Barbara Museum of Natural History, California.
- Page, S.H. and G.A. Shelton. 1982. Remote sensing of kelp beds demonstration report, Channel Islands National Park, California. Environmental Monitoring Systems Laboratory, USEPA TS-AMD-82003, Contract NO. 68-03-3049. 18 pp.
- Phillips, B.F. and A.B. Scolaro. 1980. An electrofishing apparatus from sampling sublittoral benthic marine habitats. J.Exp. Mar. Biol. Ecol.

47:69-75.

- Quast, J.C. 1968. Estimates of the populations and the standing crop of fishes. In W.J. North and C.L. Hubbs (eds.) Utilization of kelp-bed resources in Southern California, p. 81-108. Calif. Dept. Fish and Game Fish Bull. 139.
- Risebrough, R.W., F.C. Sibley, and M.N. Kirven. 1971. Reproductive failure of the Brown Pelican of Anacapa Island in 1969. Am. Birds 25:8-9.
- Seapy, R.R. and M.M. Littler. 1980. Biogeography of rocky intertidal macroinvertebrates of the southern California islands. In D.M. Power (ed.), The California Islands: proceedings of a multidisciplinary symposium, pp. 307-323. Santa Barbara Museum of Natural History, California.
- Stephens, J.S. Jr. and K.E. Zerba. 1981. Factors affecting fish diversity on a temperate reef. Env. Biol. Fish. 6(1):111-121.
- Tegner, M.J. 1980. Multispecies considerations of resource management in southern California kelp beds. Can. Tech. Rep. Fish Aquat. Sci. 945:125-143.
- Wilson, K.C., P.L. Haaker, and D.A. Hanan. 1978. Kelp restoration in southern California. In R. Krauss (ed.), The Marine Plant Biomass of the Pacific Northwest Coast, pp. 183-202. Oregon State University Press, Corvallis.

LIST OF PUBLICATIONS OF CPSU/UCD TECHNICAL REPORTS

- Technical Report No. 1 - - - June 1981
- Ecology of the Black Bear in Sequoia National Park
Goldsmith, A., M. E. Walraven, D. Graber, and M. White
- Technical Report No. 2 - - - September 1981 **NOT AVAILABLE**
- Black Bear Behavior and Human-Bear Relationships in Yosemite National Park
Hastings, B. C., B. K. Gilbert, and D. L. Turner
- Technical Report No. 3 - - - October 1981 **NOT AVAILABLE**
- Historical Evaluation and Management Recommendations for Beavers at Lassen Volcanic National Park
Fellers, G. M.
- Technical Report No. 4 - - - November 1981
- Management Recommendations for the Removal of Introduced Perennials Along Franklin Creek, John Muir National Historic Site, Martinez, California
Davis, W. E.
- Technical Report No. 5 - - - January 1982 **NOT AVAILABLE**
- Ecology and Management of Black Bears in Yosemite National Park
Graber, D. M.
- Technical Report No. 6 - - - January 1982
- Winter Utilization and Food Habits of Pine Martens in Yosemite National Park
Hargis, C. D.
- Technical Report No. 7 - - - April 1982 **NOT AVAILABLE**
- Early Life History and Protection of the Tidewater Goby Eucyclogobius newberryi: (Girard) in the Rodeo Lagoon of the Golden Gate National Recreation Area
Wang, J. C. S.

Technical Report No. 8 - - - July 1982

Sensitive Plant Species of Sequoia and Kings Canyon National Parks
Norris, L. L. and D. A. Brennan

Technical Report No. 9 - - - November 1982

A Survey of Endangered Raptorial Birds in Lassen Volcanic National
Park, California
Baldridge, F., P. Deltrich, and C. van Riper III

Technical Report No. 10 - - - March 1983

A Study to Assess Competition and Carrying Capacity Among the
Ungulates of Point Reyes National Seashore
Elliott, H. W.

Technical Report No. 11 - - - May 1983

Investigation of Animal Hosts for Giardia spp. in California's Sierra
Nevada Mountains
Suk, T. J.

Technical Report No. 12 - - - June 1983

Sierra Nevada Bighorn Sheep: History and Population Ecology
Wehausen, J. D.

Technical Report No. 13 - - - August 1983

Levels of Selected Micronutrients in Soils and Vegetation and Dietary
Implications for Tule Elk at Point Reyes National Seashore
Akeson, M., L. D. Whittig, R. G. Bureau, V. V. Rendig,
and R. D. Meyer

Technical Report No. 14 - - - November 1983

The Ecology and Management of the Mineral King Deer Herd
Cornett, D. C., W. M. Longhurst, R. E. Hafenfeld, T. P. Hemker,
and W. A. Williams

Technical Report No. 15 - - - February 1984 **NOT AVAILABLE**

On the Ecological Status of the Tidewater Goby, Eucyclogobius
newberryi (Girard), in a Lagoon and Lake of the Golden Gate National
Recreation Area, California
Wang, J. C. S.

Technical Report No. 16 - - - March 1984 **NOT AVAILABLE**

Management of an Endangered Species In a National Park: The Peregrine
Falcon In Yosemite
Asay, C. E. and W. E. Davis

Technical Report No. 17 - - - March 1984

Update to Technical Report No. 8, Sensitive Plant Species of Sequoia
and Kings Canyon National Parks
Norris, L. L.

Technical Report No. 18 - - - May 1985

Plant Communities of the Tule Elk Range, Point Reyes National Seashore
Lathrop, K. T. and P. J. P. Gogan

Technical Report No. 19 - - - May 1985

Kelp Forest Monitoring Program: A Preliminary Report on Biological
Sampling Design
Davis, G. E.

Technical Report No. 20 - - - March 1985

Hydric Montane Meadows of Sequoia National Park, California: A
Literature Review and Classification
Halpern, C. B.

BIANNUAL REPORTS

Biannual Report No. 1	November 1979	NOT AVAILABLE
Biannual Report No. 2	March 1980	
Biannual Report No. 3	September 1980	NOT AVAILABLE
Biannual Report No. 4	June 1981	
Biannual Report No. 5	December 1981	
Biannual Report No. 6	June 1982	
Biannual Report No. 7	December 1982	
Annual Report No. 8	December 1983	NOT AVAILABLE

Proceedings of the First Biennial Conference of Research in California's
National Parks: University of California, Davis, California,
September 9-10, 1982.

3 9874

