Introduction

Kelp forests constitute one of the largest, most complex, and most threatened ecosystems in the Channel Islands National Park (CINP). Located at the boundary of two major biogeographical provinces and near unusually persistent upwelling features, the park is endowed with marine ecosystems of exceptional diversity. The five park islands are surrounded by extensive kelp forest habitat with high productivity, which supports large and diverse seabird and pinniped populations. As a result of these conditions and the relative isolation from the mainland, kelp forests in the park are among the best examples of this important ecosystem in southern California.

The park boundary extends one nautical mile around each of the five islands, including the waters and submerged lands therein. The living marine resources in the park are managed by the State of California. The National Park Service (NPS), in cooperation with the State of California and the U. S. Department of Commerce, are charged with the responsibility of monitoring the health of park ecosystems and recommending actions to better protect those systems (16 USC 41Off Sec. 203).

The waters in CINP constitute less than 3% of California's coastal zone, yet it is responsible for about 15% of the State's coastal fishery harvests (source?). In spite of closed seasons, individual size and bag limits, and restricted uses in some areas, there are virtually no limits on total harvest of fish, lobster, algae, and other marine organisms from park waters. With the impact of harvesting and the threat of chronic and acute pollution from mainland waste disposal and adjacent offshore petroleum development, the potential for major anthropogenic disturbances of these ecosystems is of great concern. Natural disturbances also play an important role in the park, yet very little information on the long-term dynamics of the system is available. Providing the information required to manage these resources effectively is a challenge, but without the knowledge, there is a risk of losing these resources. Managing and conserving kelp forests requires innovative approaches and a better understanding of the ecosystem than currently exists.

Channel Islands National Park Kelp Forest Monitoring (KFM) Program began in 1981 with the establishment of 13 permanent long-term monitoring sites located at the five northernmost Channel Islands. Additional sites were installed in 1983, 1986, 2001 and 2004, and 2005 (Table 1). In 2005, 16 additional sites were added to assist the State of California in assessing the effectiveness of the newly established Marine Reserves around the Channel Islands. These 16 sites were installed to collect baseline data from areas both inside and adjacent to the Marine Reserves for later evaluation. Since their establishment, each KFM site has been visited at least once every year to collect data on specifically selected species of algae, invertebrates and fish. The KFM Program now monitors up to 33 sites annually, providing the longest set of fishery independent data along the west coast.

From 2005 to 2007, fish abundance and size monitoring was conducted by University of California Santa Barbara's Partnership for Interdisciplinary Studies of Coastal Oceans (UCSB/PISCO) under a cooperative agreement at 24 of the monitoring sites as part of a fine scale Marine Reserve evaluation that was designed by the park. PISCO has published several scientific papers using data collected during this time period.

In the 1990's, the state of California began using data collected by this program to assist its abalone resource management strategies. Much of the data collected by this program aided in the State's decision to close the pink, green, and white abalone fisheries in 1996, and the red abalone fishery in southern California in 1997. Fisheries were closed to prevent brood stock extinction caused by overharvesting.

This handbook describes design considerations for a long-term population dynamics approach to monitoring kelp forest ecosystems and documents the protocol for monitoring kelp forests in the Park. This is the third edition of the Kelp Forest Monitoring Handbook. Changes have been made following 30 years of monitoring and a formal review of the program in 1995 (Davis et. al., 1996). We discuss a selection of index species and monitoring sites and present detailed instructions for data collection. Historical data collection techniques and changes in protocol are also described. Data management and data entry procedures are now described in this handbook, while prior they were in Volume II of the previous version.

Monitoring Design Considerations

Species Selection

Specific kelp forest plants and animals were selected for monitoring from a list of nearly 1,000 species compiled by Dr. John M. Engle of the Tatman Foundation. The list was derived from scientific literature and data collected during a series of Tatman Foundation supported cruises in the Channel Islands while Dr. Engle was working for the University of Southern California Catalina Marine Science Center. The primary objective in selecting taxa for monitoring was to provide a representative cross section of the ecological roles present in the park kelp forests. These taxa serve as ecological "vital signs" of system health. To fulfill this objective, selected species needed to include representatives of all trophic levels, a variety of reproductive strategies, both sessile and mobile organisms, and variety of feeding strategies.

Six criteria were used to select species from the list. Species were selected that were:

- specifically mentioned in the park's enabling legislation or protected by law (e.g. endangered)
- legally harvested
- exceptionally common or characteristic of entire communities
- alien to the park/invasive species
- endemic to the park, or extremely limited in distribution
- well known or "charismatic"

Using these criteria, 15 algae, 38 invertebrate and 15 fish taxa were originally selected for long-term monitoring. Since its conception, the list of taxa has been modified through the process of statistical and peer review (Davis et. al, 1996). Some taxa have been removed from the list while others have been added. Changes to the original list of taxa have been minor to maintain consistency of year to year data comparisons. There are currently 16 algae or groups of algae, 41 invertebrates, and all identifiable fish (113 species as of 2011) taxa monitored (Appendix A). The changes to the original list of taxa are discussed in the data history section of this handbook.

The monitored species are characteristic of kelp forests throughout the park. They represent both boreal and temperate biogeographical provinces and species whose centers of abundance fall within the transition zone. Some species, such as giant kelp, *Macrocystis pyrifera,* and red sea urchins, *Strongylocentrotus franciscanus,* are ubiquitous in the park. Other species, such as the California hydrocoral, *Stylaster (Allopora) californicus,* are found only at a few isolated sites. Some species are extremely abundant like the purple sea urchin, *Strongylocentrotus purpuratus,* whereas others like the giant-spined sea star, *Pisaster giganteus,* are wide spread in distribution but generally occur in low densities. Many of the selected species are long-lived, with life spans of 10 to more than 50 years, thus their abundance provides a stable measure of conditions in kelp forests that is relatively insulated from annual fluctuations. At the same time, annual recruitment and reproductive efforts of some populations provide measurements of year-to-year fluctuations that augment observations of short-lived species. For example, the abundance of the blue-banded goby, *Lythrypnus dalli,* depends heavily on local environmental conditions.

The combination of organisms provides mechanisms for detecting both short and long-term variations in kelp forests. The monitored species also represent a wide array of trophic levels,

from primary producers and obligate herbivores to high level predators and detritivores. In addition, the organisms demonstrate feeding techniques ranging from sessile filter feeders and sedentary grazers to highly mobile planktivorous fishes and wide ranging benthic foragers. Reproductive strategies of these species run the gamut from live births seen in surf perches to the precarious release of gametes into the sea by abalone and urchins, to the long-lived pelagic larvae of spiny lobsters, *Panulirus interruptus.* The selected array of species provides many opportunities to monitor the health of kelp forests and potentially to detect the facets of human impact, extending from pollution to habitat disturbance and direct removal.

Site Selection

The waters of CINP give refuge to an ecologically diverse collection of species assemblages. The park is located at the boundary of two major biogeographical provinces: the Oregonian province to the north and the Californian to the south. The western park islands, San Miguel and Santa Rosa, are bathed by northern waters carried south by the California current and therefore reflect the biological assemblages of the Oregonian province. Waters around the eastern park islands of Anacapa and Santa Barbara come from the south along the mainland coast and support the warm temperate biota characteristic of the Californian province. Around Santa Cruz Island, at the boundary of these two provinces, there is a broad transition zone where plants and animals from both provinces mingle and create a special assemblage of species that are capable of adapting to the unique and variable conditions of the transition zone.

Prevailing winds and the bathymetry of adjacent basins also greatly influence marine communities in the park. Strong north winds buffet the north sides of the islands, while the biota of the southern coasts reflects their more sheltered location. Upwelling nutrients from 2,000 meter-deep basins to the south and west of the park produce exceptionally productive food webs and temperature regimes that differ significantly from the shallow northern sides of the islands.

When the sites were selected, detailed benthic habitat maps in areas of persistent kelp were not available for the Channel Islands. Had detailed maps such as these been available, site selection would have been random with the site selection criteria listed below. As a result, sites were chosen by deploying divers on rocky bottom (using an echo sounder) at a selected depth and reeling out a 100 meter tape along the depth contour when possible but also maintaining a consistent heading, usually parallel to shore. If at least 80 meters was over rocky bottom and the reef was at least 100 meters long (rocky on both ends), it was chosen as a site.

Since the KFM Program began collecting data in 1982, there have been two main periods during which sites were established in CINP: 1981/82 and 2005. In addition to these two main periods, one additional site was established in CINP at San Miguel Island in 2001 as well as four sites at the US Navy owned, San Clemente Island in 2003. All site selection events are described below.

The original 16 sites were selected to represent the north and south sides of each of the islands as well as the east-west transition from Californian to Oregonian provinces for long term population monitoring. The sites reflect the broad range of conditions and biological assemblages in the park. Other than the location at the Islands to represent this broad range of conditions, the sites were selected for the presence or known recent presence of kelp forests. The original site selection plan was to select locations meeting the above criteria and then place one deep and one shallow transect at each location. It was soon realized that logistically the KFM Program could

not monitor this many sites and one transect per location was installed. The exception to this is Johnson's Lee (North and South), Santa Rosa Island, where a shallow and deep transect were retained. As a result of this original plan of deep and shallow sites, the 16 site depths have a moderately wide range from 4-18 meters.

In August and September 1981, a total of 45 SCUBA divers conducted 643 dives to locate and establish the 13 original 100 m permanent transects. The divers used the NPS vessel Pacific Ranger as a platform of operation. Six week-long cruises were conducted, with eight to ten divers on each cruise. Five biologists from the California Department of Fish and Game assisted the NPS in selecting and establishing the transects. During the remaining cruises, 33 divers from the NPS Western Region dive team and seven scientists from local universities and the National Marine Fisheries Service established the permanent transect lines on the sea floor. Establishment of each transect line consisted of a sequence of operations involving specialized equipment and skills developed specifically for this project (Appendix B). One additional transect was added in 1983 and two in 1986. These 16 sites established between 1981-1986 are considered the original KFM sites (Table 1).

In 2001, the Miracle Mile site at San Miguel Island was installed. This site was established by Jim Marshall, a commercial abalone and sea urchin fisherman, in conjunction with the County of Santa Barbara and with the assistance of CINP, specifically to monitor the abalone population at this site. Originally, three sites were proposed to better monitor the abalone population at San Miguel Island but only this site was funded. Jim Marshall selected this site based on its exceptionally high density of *H. rufescens*. We initially observed a decrease in density of *H. rufescens* following establishment of this site, but density has recently stabilized, maintaining a relatively high density of this species. Following the establishment of a site that was selected for its high abundance of a targeted species, it is not uncommon for a decrease in density such as this to occur. The KFM Program continues to monitor this site as we think more than the original two sites are needed to adequately monitor the kelp forests and abalone at this island.

In 2003, four KFM sites were established on San Clemente Island in conjunction with the Navy. The Navy funded the monitoring of these site from 2003-2004. Funding was not available after 2004 and subsequent monitoring has not occurred by NPS. However, the Navy contracted Tierra Data Systems to conduct monitoring at these sites in 2008-2009. To date, we do not believe monitoring has occurred since. The data collected from 2008-2009 resides with the Navy. Site selection at San Clemente Island was similar to the regularly monitoring KFM sites. These sites were selected to represent all four sides of San Clemente Island, and were chosen at similar depths (9-14 meters) with the criteria of the presence of at least 100 meters of rocky reef with kelp forests.

In 2005, the park was awarded three years of funding from the NPS Natural Resources Preservation Program (NRPP) to establish baseline ecological conditions of newly established Marine Reserves at the Channel Islands. This project began with the establishment of 16 new permanent sites. These sites were placed inside or adjacent to the following four newly established Marine reserves: Santa Barbara Island, Anacapa Island, Scorpion Anchorage at Santa Cruz Island, and South Point at Santa Rosa Island. Four of the 11 newly established Marine Reserves were selected because of limited funding and logistics of conducting this type of monitoring. These four Marine Reserves were chosen for all or some of the following reasons:

accessibility/logistically feasible to monitor, to make the best use of the KFM Program's existing base line data from original KFM sites, and fishing impact. New sites were established to complement existing sites so that at least three sites were inside and three adjacent to each of the four chosen Marine Reserves. Site selection was based on choosing locations of similar depths ranging from 8-17 meters, and even distribution of sites inside and directly adjacent to the selected Marine reserves.

Description of all 37 kelp forest monitoring sites with their specific locations and other pertinent information are found in Table 1.

Sampling Technique Selection

The great diversity of organisms and the physical habitats associated with kelp forests require carefully selected sampling approaches to effectively monitor species population dynamics. Accuracy (the closeness of a measure value to its true value) and precision (the closeness of repeated measurements of the same quantity) are two important attributes to good field sampling used in long-term monitoring programs. The ability to sample several target species at once is also an essential skill for sampling in a dynamic kelp forest environment.

Finally, sampling techniques for this monitoring program must provide values relatively free of variation among observers and must not significantly affect populations of organisms being monitored or alter their environment.

At this time, the technology for remote sensing or sampling of kelp forest organisms from the sea surface is neither accurate nor precise enough to monitor population dynamics of key species. Development of diving equipment has spawned an array of in situ sampling techniques that have potential for providing accurate and precise measures of population abundance, distribution, age structure, reproduction, recruitment, growth rate, mortality rate, sex composition, phenology of kelp forest organisms, and oceanographic and videographic equipment that yields permanent records.

In January 1982, a workshop to review potential sampling techniques was held at the Marine Science Institute, UCSB. Thirty-seven scientists participated in the two-day workshop. Sampling techniques for kelp forest organisms were evaluated using the following criteria:

- ability to sample target species accurately and precisely
- impacts on target and other species
- efficiency (cost effectiveness)
- ability to create permanent records of samples for confirmation and future analysis
- requirements for highly trained observers or extremely complex procedures or equipment

Permanent transects were used to reduce within-site variability and provide precise measurements of population dynamics where the major variable is time. Each transect of 12-mm diameter lead-filled woven nylon line was permanently affixed to the bedrock with stainless steel eyebolts positioned about every 10 meters along the transect (a detailed description on transect installation is found in Appendix B). The permanent transects are relocated each time with GPS coordinates. The transects provide a reference for divers and for sample plot orientation which facilitates data collection during the limited bottom time available to divers.

Revisions of the original sampling techniques have been implemented prior to and following a review workshop held in 1995 (Davis et.al., 1996). The most current sampling techniques used are described in this Handbook. Changes in protocols are documented in the Data Management and Data History section of this Handbook.

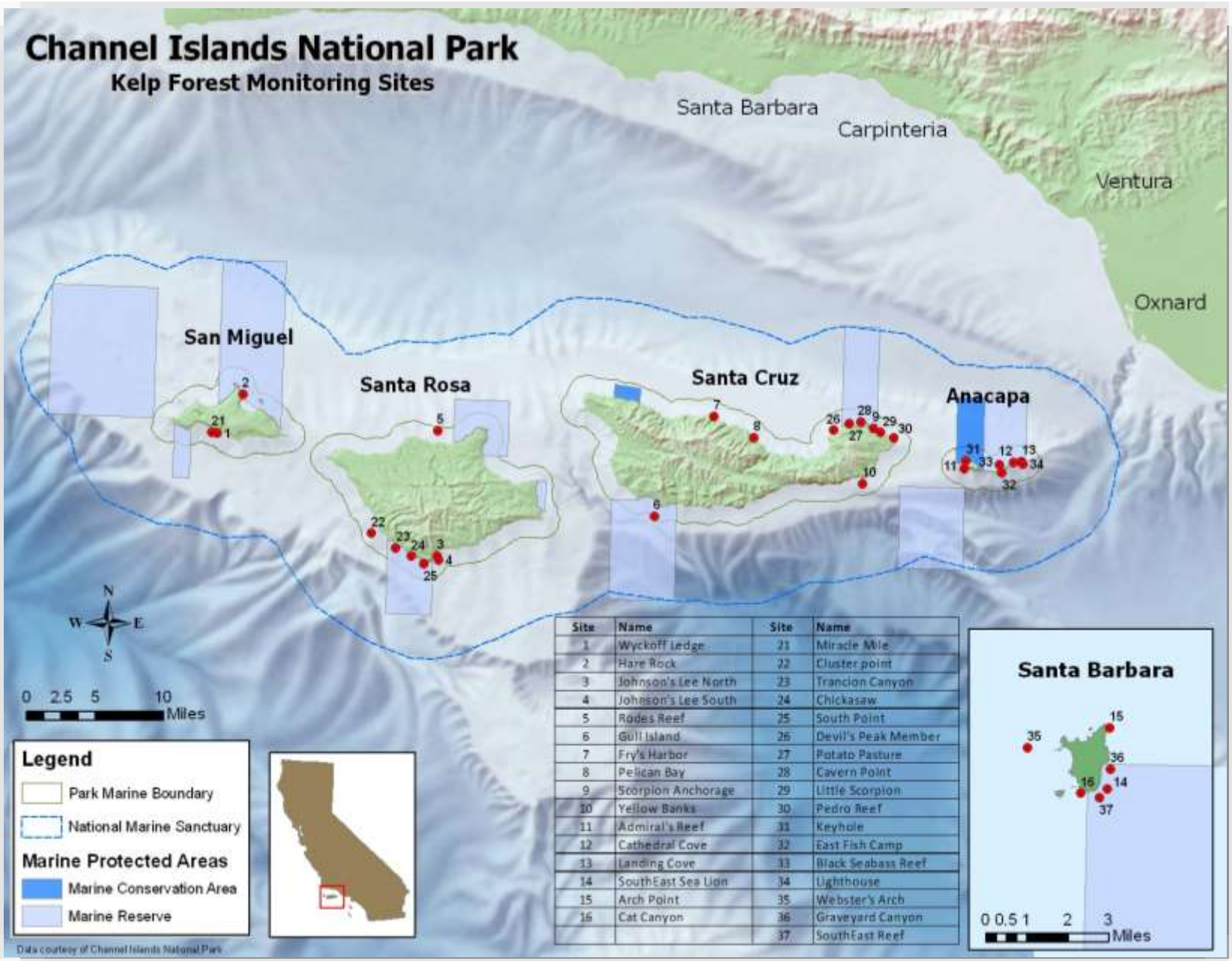

Figure 1. Map of Kelp Forest Monitoring site locations.

Table 1. Description of KFM sites.

Island	Location	Site Code	Site #	Date Established	Latitude/ Longitude	Depth Range (m)
San Miguel	Wyckoff Ledge	SMWL	1	1982	34° 00.342´N, 120° 23.248´W	14-16
San Miguel	Hare Rock	SMHR	2	1982	34° 02.863´N, 120° 21.396´W	6-10
Santa Rosa	Johnson's Lee North	SRJLNO	3	1982	33° 54.088´N, 120° 06.178´W	8-12
Santa Rosa	Johnson's Lee South	SRJLSO	4	1982	33° 53.852´N, 120° 06.045´W	15-18
Santa Rosa	Rodes Reef	SRRR	5	1983	34° 01.957´N, 120° 06.420´W	15-18
Santa Cruz	Gull Island	SCGI	6	1982	33° 56.980´N, 119° 49.655´W	15-18
Santa Cruz	Fry's Harbor	SCFH	7	1982	34° 03.381´N, 119° 45.309´W	13-14
Santa Cruz	Pelican Bay	SCPB	8	1982	34° 02.070´N, 119° 42.200´W	6-9
Santa Cruz	Scorpion Anchorage	SCSA	9	1982	34° 02.879´N, 119° 33.084´W	4-8
Santa Cruz	Yellow Banks	SCYB	10	1986	33° 59.390´N, 119° 33.784´W	15-16
Anacapa	Admiral's Reef	ANAR	11	1982	34° 00.465´N, 119° 26.063´W	14-16
Anacapa	Cathedral Cove	ANCC	12	1982	34° 00.952´N, 119° 22.304´W	6-11
Anacapa	Landing Cove	ANLC	13	1982	34° 01.000´N, 119° 21.700´W	5-13
Santa Barbara	SE Sea Lion Rookery	SBSESL	14	1982	33° 27.967´N, 119° 01.667´W	13-15
Santa Barbara	Arch Point	SBAP	15	1982	33° 29.252´N, 119° 01.655´W	7-9
Santa Barbara	Cat Canyon	SBCAT	16	1986	33° 27.865´N, 119° 02.350´W	7-9
San Clemente	Northwest Harbor	CLNWH	17	2003	33° 02.281´N, 118° 35.724´W	10-13
San Clemente	Boy Scout Camp	CLBSC	18	2002	33° 00.148´N, 118° 32.935´W	10-13
San Clemente	Eel Point	CLEP	19	2003	32° 54.923´N, 118° 32.699´W	10-14

Table 1. Continued.

Island	Location	Site Code	Site Number	Date Established	Latitude/ Longitude	Depth Range (m)
San Clemente	Horse Beach Cove	CLHBC	20	2003	32° 48.522´N, 118° 24.485´W	9-14
San Miguel	Miracle Mile*	SMMM*	21	2001	34° 01.422´N, 120° 23.707´W	7-10
Santa Rosa	Cluster Point	SRCP	22	2005	33° 55.382´N, 120° 11.242´W	12-16
Santa Rosa	Trancion Canyon	SRTC	23	2005	33° 54.513´N, 120° 09.330´W	9-14
Santa Rosa	Chickasaw	SRCSAW	24	2005	33° 54.022´N, 120° 08.138´W	9-13
Santa Rosa	South Point	SRSP	25	2005	33° 53.540´N, 120° 07.170´W	12-13
Santa Cruz	Devil's Peak Member	SCDPM	26	2005	34° 02.696´N, 119° 36.084´W	10-13
Santa Cruz	Potato Pasture	SCPP	27	2005	34° 03.134´N, 119° 34.952´W	10-13
Santa Cruz	Cavern Point	SCCP	28	2005	34° 03.257´N, 119° 34.011´W	12-13
Santa Cruz	Little Scorpion	SCLS	29	2005	34° 02.649´N, 119° 32.547´W	9-14
Santa Cruz	Pedro Reef	SCPRF	30	2005	34° 02.302´N, 119° 31.518´W	7-10
Anacapa	Keyhole	ANKH	31	2005	34° 00.985´N, 119° 25.921´W	7-9
Anacapa	East Fish Camp	ANEFC	32	2005	34° 00.270´N, 119° 23.147´W	9-14
Anacapa	Black Sea Bass Reef	ANBSBR	33	2005	34° 00.756´N, 119° 23.351´W	16-17
Anacapa	Lighthouse	ANLH	34	2005	34° 00.846´N, 119° 21.541´W	8-9
Santa Barbara	Webster's Arch	SBWA	35	2005	33° 28.802´N, 119° 03.727´W	13-16
Santa Barbara	Graveyard Canyon	SBGC	36	2005	33° 28.384´N, 119° 01.611´W	11-12
Santa Barbara	Southeast Reef	SBSER	37	2005	33° 27.776´N, 119° 01.876´W	9-15

* Abalone KFM site.

Table 2. ARM and temperature logger information for KFM sites.

Site Code	Transect Bearing	Number of Artificial Recruitment Modules	Remote Temperature Logger Location and Depth
SMWL	090°-270°	None	0 meter mark at east end; depth 14 meters
SMHR	090°-270°	None	7.8 m at 345º from meter 20; depth 11 meters
SRJLNO	030°-210°	9	0 meter mark at northeast end; depth 11 meters
SRJLSO	020°-200°	7	Meter 3, 20 cm from transect line; depth xx meters
SRRR	090°-270°	None	Near 100 meter mark at west end; depth 13 meters
SCGI	000°-180°	14	4 meters west of meter 20; depth 16 meters
SCFH	020°-200°	5	0 meter mark at north end, ~1 m from line; depth 13 meters
SCPB	020°-200°	6	~5 meters west of meter 5; depth 8 meters
SCSA	090°-270°	7	0 meter mark at east end; depth 7 meters
SCYB	090°-270°	20	0 meter mark at east end; depth 15 meters
ANAR	150°-330°	7	0 meter mark at southeast end; depth 14 meters
ANCC	120°-300°	7	100 meter mark at southeast end; depth 6 meters
ANLC	040°-220°	7	7 meters NE of 0 meter mark; depth 5 meters
SBSESL	000°-180°	None	Near 0 meter mark at north end; depth 12 meters
SBAP	010°-190°	None	4 meters east of meter 85; depth 7 meters
SBCAT	090°-270°	None	0 meter mark at east end; depth 7 meters
SMMM	090°-270°	8	logger not installed

Table 2. Continued.

Site Code	Transect Bearing	Number of Artificial Recruitment Modules	Hydrothermograph Location and Depth
SRCP	090°-270°	None	0 meter mark at east end; depth 12 meters
SRTC	090°-270°	None	0 meter mark at east end; depth 9 meters
SRCSAW	090°-270°	None	0 meter mark at east end; depth 10 meters
SRSP	090°-270°	None	0 meter mark at east end; depth 13 meters
SCDPM	050°-230°	None	0 meter mark at northeast end; depth 13 meters
SCPP	090°-270°	None	0 meter mark at east end; depth 11 meters
SCCVP	045°-225°	None	0 meter mark at northeast end; depth 12.5 meters
SCLS	080°-260°	None	0 meter mark at east end; depth 11 meters
SCPRF	120°-300°	None	0 meter mark at southeast end; depth 9 meters
ANKH	090°-270°	None	0 meter mark at east end; depth 11 meters
ANEFC	000°-180°	None	0 meter mark at north end; depth 11 meters
ANBSBR	090°-270°	None	2 meters N of 0 meter mark at east end; depth 17 meters
ANLH	090°-270°	None	0 meter mark at east end; depth 8 meters
SBWA	090°-270°	None	0 meter mark at east end; depth 14 meters
SBGC	145°-325°	None	0 meter mark at southeast end; depth 13 meters
SBSER	090°-270°	None	0 meter mark at east end; depth 11 meters