Channel Islands Marine Protected Areas

Monitoring Plan

California Department of Fish & Game
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I. INTRODUCTION

In April 2003 the California Department of Fish and Game (Department) implemented a new network of Marine Protected Areas (MPAs) in the State Waters within the National Oceanic and Atmospheric Administration's (NOAA) Channel Islands National Marine Sanctuary (Sanctuary). The MPAs were adopted by the California Fish and Game Commission (Commission) in November 2002, after more than four years of public meetings, working group discussions, and scientific analysis.

The network consists of ten State Marine Reserves (SMRs) where no take of living, geological, or cultural resources is allowed except for permitted scientific collection and two State Marine Conservation Areas (SMCAs) where limited commercial and/or recreational take is allowed. The no-take areas represent approximately 132 square nautical miles, or approximately 19% of the State waters within the Sanctuary. The limited take areas represent an additional 10 square nautical miles of area.

These MPAs were established to meet a variety of goals including: to help protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems; to help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted; to improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance; and to manage these uses in a manner consistent with protecting biodiversity. MPAs help achieve these goals by creating areas where species occur at more natural abundances, size ranges, and diversities. MPAs also help protect critical interactions between species and habitats, and allow research in areas not impacted by fishing.

An important part of the long term management of MPAs is establishing programs to monitor biological, social, and economic changes in areas that are within, nearby, and distant from the MPAs. Together, these monitoring programs will help managers determine the impacts and effectiveness of the MPA network. MPAs may also offer valuable information to aid in stock assessments. They can act as reference sites, providing useful data on natural populations in the absence of fishing pressure. Much needed data on natural mortality rates, growth rates, population structure, effects of various environmental changes, and other parameters can be obtained.

II. PURPOSE

A workshop was held in March 2003 where representatives from recreational and commercial fisheries, the scientific community, conservation groups, government agencies, and the general public developed preliminary biological and socioeconomic monitoring recommendations (NOAA 2003). Further discussions with interested parties and preliminary data collection efforts led to the creation of this document. The purpose of this document is to provide an overview of activities that will be included in annual monitoring programs. While the document is divided into biological and social and economic sections, it must be recognized that significant overlap between the two types of monitoring exist.

This document identifies specific monitoring activities, types of data collected, and how these data will be used to determine the effects of MPAs on species, ecosystems, and fisheries in the northern Channel Islands area. The document describes several monitoring categories and activities to monitor the new MPAs effectively. It also details lower priority activities that could potentially enhance the monitoring programs, should additional funding and personnel become available. These additional activities along with descriptions of the status of current activities funding provide a guideline for individuals or institutions interested in supporting additional monitoring efforts (Section V and Appendix A).

Monitoring details have been included for activities where existing protocols meet the monitoring needs. For some activities, the details have not been included, but will be added as monitoring protocols are developed. In particular, a conference and workshop being held by the National Fisheries Conservation Center (NFCC) and NOAA starting in 2004 to address the integration of MPAs and fishery science may contribute significantly. Certain activities are already ongoing or will begin immediately in order to ensure that appropriate year “zero” (April 2003-March 2004) and “one” (April 2004-March 2005) data are collected. Work will be conducted in a cooperative effort among established university and agency field research programs as well as new volunteer and contracted data collection efforts.

Most importantly, this document should be viewed as a part of the adaptive management process. It provides a starting point of monitoring that will likely change over time. This document will be updated as monitoring activities are added or modified.

Monitoring Program Overview

The following tables provide an overview of the monitoring activities. Tables 1 and 2 summarize the biological, and social and economic monitoring activities, respectively.

Table 1. Summary of biological monitoring programs.

Monitoring Activities	**Measurements**	**Question(s) Addressed**
SCUBA Surveys Visual surveys of focal species inside and outside target areas	Focal species abundance, sizes, and composition; Habitat characteristics	Do focal species change in composition, size, abundance, or reproductive potential?
Trap/Fixed Gear Surveys Tag and recovery studies and CPUE estimates inside and outside focal areas	Catch per unit effort, size, date and location of tag and recapture	Do focal species change in composition, size, or abundance? What is the level of adult spillover/movement?
Newly Settled Fish Surveys Collection of newly settled fishes using standardized modules inside and outside target areas	Indices of fish recruitment	Are recruitment levels changing over time? Does recruitment affect abundance inside and outside MPAs?
Aerial Monitoring of Kelp Canopy Aerial surveys using multi-spectral camera	Percentage cover of kelp canopy	Is giant kelp forest coverage more or less stable in MPAs than outside?
ROV Surveys Visual surveys of focal species	Focal species abundance, sizes, and composition; Habitat characteristics	Do focal species change in composition, size, abundance, or reproductive potential?
Submersible Surveys Visual surveys of focal species	Focal species abundance, sizes, and composition; Habitat characteristics	Do focal species change in composition, size, abundance, or reproductive potential?
Intertidal Monitoring MARINe program surveys of focal species	Focal species abundance, sizes, and composition; Habitat characteristics	Do focal species change in composition, size, abundance, or reproductive potential?

Table 2. Summary of social and economic monitoring programs.

Monitoring Activities	**Measurements**	**Question(s) Addressed**
Social Science Coordinator Seek funding for a full time position, possibly contracted by Channel Islands National Marine Sanctuary	Overall coordinator to collect and manage data and summarize results	Coordination of following programs
Commercial Fish Landing Receipts Annual review of commercial fish landing receipts	Quantity and value of catch and relative changes in fisheries	Is commercial catch or income changing at the Channel Islands?
Commercial Fish Log Books Monthly review of commercial squid, sea urchin, lobster, and sea cucumber logbooks	Location, catch per unit effort, and presence and/or amount of displaced effort	Are commercial catch, CPUE, or fishing locations changing at the Channel Islands?
California Recreational Fishery Survey (CRFS) Onboard and dockside sampling of recreational catch, location, and effort	Location, level of effort, species, size, and amount of catch from recreational fisheries	Are recreational catch, CPUE, or fishing locations changing at the Channel Islands?
Sanctuary Aerial Monitoring and Spatial Analysis Program (SAMSAP) Bi-monthly aerial surveys of all five islands	Level and location of fishing and boating, presence and/or amount of displaced effort	Are locations of fishing and boating activities changing at the Channel islands?
Survey of Non-Consumptive Charter Industry Travel cost study of charter boat users, with additional information on knowledge of MPAs and regulations	2003 pilot study collected baseline information from a small subset of charter boat users	What is the value of MPAs to non-consumptive users and are these users accessing the islands because the MPAs are there?
Knowledge, Perceptions and Attitudes Surveys Survey of local user groups and public	Public and user group knowledge, attitudes, and perceptions of MPAs	How are knowledge, attitudes, and perceptions regarding the MPAs changing over time?
Educator Use Tracking Tracking of educational use	Estimates of numbers of educators accessing the islands in general and MPAs in particular	Are educators accessing the islands and MPAs?
Scientific Use Tracking Tracking of scientific use	Annual numbers of researchers using the islands and MPAs	Are researchers accessing the islands and MPAs?
Public Outreach Providing MPA background information, updates, and data summaries to the public	N/A	Providing information to the public to help increase awareness and knowledge

III. BIOLOGICAL MONITORING

One of the major goals for establishing a network of MPAs in the Channel Islands is to determine the effects of MPAs on species, ecosystems, and habitats. Another major goal is to help improve or sustain local fisheries. From a biological standpoint, it is believed that MPAs may enhance fisheries primarily through two different mechanisms: the spillover of juveniles and adults from MPAs into unprotected areas and the export of eggs and larvae from MPAs to unprotected areas. To achieve these goals, several objectives have been set. These objectives need to be evaluated relative to MPA size and placement within the Channel Islands and against specific estimates of expected change. The objectives are to determine:

- Changes in abundance, size, biomass, and spawning biomass of species;
- Species composition as it relates to ecosystem function;
- Habitat changes as they relate to physical alteration (e.g., trawling) and secondary impacts of biological community changes (e.g., habitat forming algae);
- Amount of spillover; and
- Changes in CPUE and total catch

Various monitoring techniques will be used to achieve these objectives. Visual SCUBA surveys, trap/fixed gear surveys, remotely operated vehicle and submersible surveys, and analysis of logbooks and other CPUE databases will be the primary methods to directly determine changes in MPAs relative to nearby and distant unprotected areas. Direct evidence for a net export of eggs and larvae, resulting in increased recruitment and fishery yields will not be gathered. Instead, the level of reproductive output and potential benefit to fisheries will be inferred from other data.

Spillover occurs when the emigration rate for post-settlement and larger individuals from the MPA exceeds the immigration rate into the reserve. Spillover is due to higher species densities inside MPAs relative to surrounding unprotected areas. A significant spillover effect results in density changes outside the MPA with more individuals being available to the fishery. The spillover rate (number of individuals per unit time) and fishing intensity (risk of fishing mortality per unit time) and duration (length of time exposed to fishing mortality) are all important aspects of spillover (Ward et al. 2001). These components of spillover are expected to vary among species due to differences in mobility, natural tendencies to relocate, and existing fishing pressure. Also important to spillover rates will be the suitability of habitat outside MPAs. Mark/recapture and Catch Per Unit Effort (CPUE) studies are the two primary methods used for detecting the occurrence of spillover.

It is assumed that a net export of eggs and larvae from MPAs to unprotected areas will increase larval pool supply, enhance settlement and increase recruitment to fisheries, resulting in greater fishery yields; however, providing direct evidence of this is difficult. Instead, most studies focus on determining whether MPAs increase abundance and sizes of individuals, and then infer the benefit to fisheries by calculating the expected increase in reproductive output. The area affected by this increased reproductive output will vary among species depending on the average dispersal of planktonic larvae. The greater reproductive output may eventually result in increased recruitment to the fishery, CPUE, and fishery yields.

This monitoring plan will focus on directly determining if increases in species density, size, biomass, and spawning biomass occur in MPAs relative to nearby and distant unprotected areas. If so, then it will be assumed that a net export of eggs and larvae can occur. While direct monitoring of recruitment will occur, benefit to fisheries will be measured by determining CPUE and total catch for certain fisheries. These parameters will be primarily determined through visual scuba surveys, trap/fixed gear surveys, and analysis of logbooks and other CPUE databases.

Biological monitoring activities have been separated into four general habitat/ecosystem categories: shallow subtidal; deep subtidal; intertidal; and seabirds and marine mammals. The monitoring categories have been prioritized based on the expected level of impact MPAs will have on the species or habitats, the need for new monitoring activities, the feasibility of determining changes, and the relative level of previous consumptive use. For each category, recommended monitoring activities are given. Additional activities which could supplement this plan given additional funding and resources are listed in Appendix A.

Effectiveness and Timelines of MPAs

Once data on the effects of MPAs have been obtained, they can then be evaluated with respect to data collected in other California and worldwide MPAs to determine if the intended goals have been achieved. The evaluation of these data along with a statement of confidence determines the effectiveness of MPAs.

It is also necessary to establish timelines that specify when one would expect to see results. This includes both lower and upper time frames, within which reference levels should be achieved. Since most biological responses often lag behind a particular action, lower time limits need to be established. To meet the ongoing needs of an adaptive management process it is also necessary to establish upper time limits.

Specific reference levels and timelines for determining effectiveness of the Channel Island MPAs were based on discussions with several scientists, past MPA studies, species life history characteristics and exploitation histories, and the power or ability to detect changes. Halpern's (2003) review of studies around the world estimates that on average: abundances doubled, biomass increased nearly three times, animals were a third larger, and diversity increased by one third within MPAs. While a few studies on colder water regions in this review showed similar results to warmer areas, the majority of studies were on tropical ecosystems. In addition, responses of individual species are highly variable and the above review looks at aggregates of many species. Against the background of average increases seen in Halpern (2003), some species declined, as would be expected as food webs return to an unexploited state (Micheli et al. *in press*). Because of this potential variation, examinations of data collected from existing California MPAs were made. Specific data on the species found in the Channel Islands region were used to estimate potential levels of change. This allows a more realistic comparison of potential changes, based on species and habitats that most closely approximate those at the Channel Islands.

Sources of Uncertainty

A variety of sources of uncertainty in biological processes and measurements of parameters exist that confound efforts to determine MPA effects. Inherent variability in species abundances is one of the primary factors. The numbers of an individual species can vary dramatically from year to year due to natural environmental fluctuations, success in reproduction or recruitment, and other events such as storms that may significantly alter particular habitats or species behavior. These fluctuations will decrease the ability of any monitoring program to identify changes due to reserve establishment.

When considering individual species, estimates of potential for change within MPAs can only be approximate. In certain cases, unforeseen ecosystem impacts and intra-specific interactions can lead to unexpected results. Predator-prey interactions and trophic cascades have been documented in existing MPAs as causes for the initial decline of certain species while others increase (Micheli et al. *in press*). Thus it becomes difficult to set a single performance standard that will work for all focal species.

Any monitoring program will also have some amount of measurement error and variation. The variation will differ among species, making it more difficult to compare statistically the change in some species relative to others. Final monitoring results are thus expressed with confidence intervals, describing how likely the change could be due to random chance.

Measuring Performance

Performance of the Channel Islands MPA network will be measured based on comparisons of changes within MPAs to changes outside the MPAs. If the MPAs function as expected, there will be a differential change within MPAs, such as significantly higher abundance, mean size, and reproductive potentials of a variety of species. As mentioned above, it is extremely difficult to set specific target levels of expected change. Instead, performance of the Channel Islands MPAs will be based on analysis of trends in these biological parameters. The Channel Islands MPA network will be considered as performing satisfactorily if the biological trends within MPAs approach given estimates of potential change more rapidly than areas outside.

The estimated levels of potential change listed in this document should not be considered hard targets or performance criteria. Many of these estimates are based on areas that differ in location, climate, and other factors from the northern Channel Islands. When comparing results at the Channel Islands MPAs with these estimates, one must take into consideration the length of time existing areas have been established, local environmental conditions, and the design of the individual areas. The estimates should be viewed as guideposts, which will help determine how MPAs are functioning. Individual MPAs may surpass or show rapid progression towards these estimated levels, or show slow progression towards them over a period of many years.

Not all estimates for all species in all MPA versus unprotected area comparisons will necessarily be met. If an estimated level of potential change is not met within a single species or area it does not suggest that the Channel Island MPAs are not meeting their intended goals. Significant effects for some parameters may be seen for individual MPAs or species, but not when averaged across all MPAs. This is an important distinction since the size and placement of MPAs may be an important component affecting results in the Channel Islands. As noted above, overall trends within MPAs compared to areas outside are the best measure of performance.

Sufficient time must be provided for these changes to occur and for the monitoring program to collect enough data to detect changes and have statistical significance. Though some changes may be very rapid, most will take many years to accrue, especially given the biology of fish and invertebrate species in the region. In order to allow the process of adaptive management to continue, however, review cannot be put off indefinitely. Thus, it is recommended that a major review of this monitoring program's results occur approximately 5 years after reserve implementation, in the spring of 2008.

A. Shallow Subtidal Monitoring

Shallow subtidal monitoring (from 0 to ~100 feet/31 m) will be the highest priority activity. The shallow subtidal region includes the primary areas for consumptive uses at the islands, has the highest number of existing monitoring programs available, and provides information not only on MPAs but the entire nearshore ecosystem.

1. General Sampling Design

Monitoring will consist of a variety of data collection activities. As noted above, the general approach will be to compare change within MPAs to areas nearby and distant from their boundaries. Initial levels, or baselines, are important to compare the starting points of individual sites. Since MPAs at the Channel Islands were implemented in April 2003, before this monitoring plan was developed, it will be necessary to rely on as much relevant historical data as possible. Fortunately, a robust set of data is available from existing monitoring programs. These include the National Park Service's Kelp Forest Monitoring program (KFM) with more than 20 years of data and the Partnership for Interdisciplinary Studies of Coastal Oceans' (PISCO) programs with 4 years of data at sites within, near, and distant from the MPAs. In addition, the sampling done during year "zero" (April 2003-March 2004) of MPA implementation can be used to compare the starting points of areas both within and outside MPAs. Thus, over time relative amount of change can be measured as well as total change inside and outside MPAs. The goal is to sample within and outside as many Channel Islands MPAs as possible during year zero and year one to provide additional standardized data. More intensive sampling may take place at specific sites during succeeding years to address specific questions (see below). At a minimum, areas within and outside one MPA in each of the three biogeographic provinces (Californian, transitional, and Oregonian) will be sampled annually.

2. Site Selection

Central to any monitoring plan is the location of sampling effort, or sites. For shallow subtidal monitoring at the Channel Islands, a site is defined as an approximately 500m stretch of primarily rocky reef habitat. Obviously, it is important to select similar habitats inside and outside MPAs for comparison. Continued sampling at existing sites is crucial, since analysis of monitoring results will make comparisons to historical or baseline data.

Considerable input was received from fishermen regarding the specific location of monitoring sites within and outside the MPAs. This input provided information on areas with comparable habitat and similar levels and types of catch that could be used for comparison. Suggested areas were used as a starting point for site selection surveys in 2003. Final site selection was based on visual observations of habitat to ensure areas contained enough similar habitat to complete the necessary number of transects.

For the first two years (2003-2004), shallow subtidal sampling will occur, at a minimum, at single sites within and outside each SMR, with the exception of Richardson Rock SMR (San Miguel Island) and Skunk Point SMR (Santa Rosa Island) (Figure 1). These two sites do not have significant areas of shallow subtidal habitat. Additional sites at the edges and far away from MPAs may be sampled during the first two years, depending upon funding and resources. For the following four years (2005-2008), sampling will occur annually as above for a core group of sites, while other sites will be sampled on a rotating basis every two years.

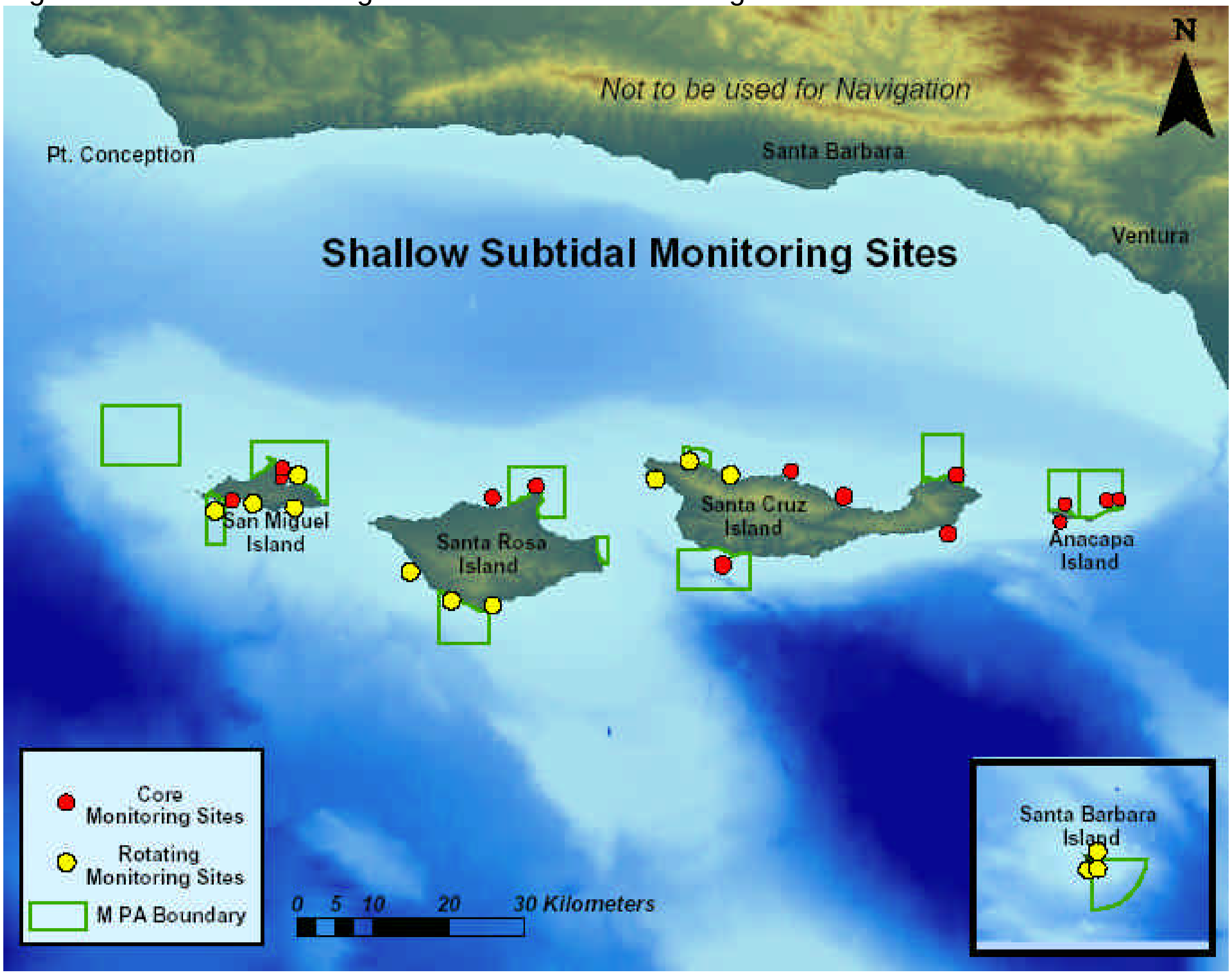
The core group of sites consists of at least one site within and outside one SMR at each of the four northern Channel Islands. The core sites were chosen primarily because they have historical data and are currently being sampled by existing programs (KFM and PISCO). They are also primarily on the northern sides of the islands which allows connectivity between sites where prevailing currents are likely to transport larvae, and are thus more likely to show measurable effects of MPA placement. They do, however, include sites on the south side of Santa Cruz Island for comparison. Establishment of a core group of sites will enable a more detailed analysis of the effects of the MPAs on an annual basis and will prevent misinterpretation of the results due to anomalous events that may happen in unsampled years. Note that each site may have more than one sampling area (See Appendix B). The core group of sites listed below is shown in Figure 1:

San Miguel Island: Hare Rock, Cuyler Harbor, and Tyler Bight
Santa Rosa Island: Carrington Point and Rodes Reef
Santa Cruz Island: Gull Island, Yellowbanks, Scorpion, Pelicans, and Fry's
Anacapa Island: Landing Cove, Cathedral Cove, West Anacapa, and Admiral's Reef

The rotating sites were chosen to increase overall replication of sampling efforts and provide sampling over a broader range of conditions, habitats, distances from reserves and reserve sizes. Several of these sites also have historical data and are currently being sampled by existing programs (KFM and PISCO). By rotating these sites, more intensive, frequent sampling necessary to address spillover and larval export issues will be possible. Also, since changes for many species will take several years, annual comparisons at all sites are not necessary. The rotating sites are shown in Figure 1:

San Miguel Island: Prince Island, Crook Point, Judith Rock, and Wyckoff ledge
Santa Rosa Island: South Point, Johnson's Lee, and Bee Rock
Santa Cruz Island: Painted Cave, Hazards, and Forney
Santa Barbara Island: Arch Point, Sea Lion Rookery, and Cat Canyon

Figure 1. Core and rotating shallow subtidal monitoring sites.



3. Species Selection

Although attempts will be made to identify and enumerate all organisms sampled, reporting will focus on a subset of species in order to facilitate review. These focal species will be used as indicators and examples of change in the area. It is desirable that these species have different life history characteristics, varying exploitation histories, and play different roles in the ecosystem in order to evaluate fully the performance of MPAs.

By choosing species over a wide spectrum of attributes, certain species are expected to show large changes for some parameters fairly quickly while others might show little or no change, even over a longer time period. For example, species with high productivity (i.e., fast growth and high fecundity) and high exploitation rates may show rapid increases following the establishment of MPAs, whereas species with low productivity and moderate exploitation may take longer to realize effects. In addition, species with little or no exploitation are not expected to show any differences between MPA and non-MPA sites, and may actually decline in response to increases in their predators. It is important to select some species that are not expected to change due to the establishment of MPAs to control for environmental or other perturbations, unrelated to fishing activities. Through input received at the March 2003 monitoring workshop and other meetings, 9 fishes, 12 invertebrates, and 1 alga were chosen as focal species for shallow subtidal monitoring. The focal species include California sheephead (*Semicossyphus pulcher*), kelp bass (*Paralabrax clathratus*), cabezon (*Scorpaenichthys marmoratus*), lingcod (*Ophiodon elongatus*), kelp rockfish (*Sebastes atrovirens*), gopher rockfish (*S. carnatus*), garibaldi (*Hypsypops rubicundus*), rock wrasse (*Halichoeres semicinctus*), black surfperch (*Embiotica jacksoni*), California spiny lobster (*Panulirus interruptus*), red sea urchin (*Strongylocentrotus franciscanus*), purple sea urchin (*S. purpuratus*), red abalone *(Haliotis rufescens*), black abalone (*H. cracherodii*), pink abalone (*H. corrugata*), green abalone (*H. fulgens*), warty sea cucumber (*Parastichopus parvimensis*), bat star (*Asterina miniata*), giant-spined star (*Pisaster giganteus*), Ochre star (*P. ochraceus*), sunflower star (*Pycnopodia helianthoides*), and giant kelp (*Macrocystis pyrifera*). These species exhibit many different life history characteristics and exploitation histories (Table 3). At least one species has been the subject of a recent federal stock assessment (cabezon) and another one (California sheephead) is currently being assessed.

Table 3. Focal shallow subtidal fish, invertebrate, and algal species to be monitored within and outside MPAs at the Channel Islands, and selected relative attributes of those species. Growth rate and fecundity categories were not determined for invertebrates and the alga

Species	Growth Rate[1]	Fecundity[1]	Life span[1, 2]	Exploitation History[3]	Relative Ability to Detect Change[4]
California sheephead	---	High	Very long	Moderate	High
Kelp bass	Low	High	Very long	Moderate	High
Cabezon	Moderate	High	Long	Moderate	Low
Lingcod	Low	High	Long	Heavy	Low
Kelp rockfish	Moderate	High	Long	Low	Moderate
Gopher rockfish	Moderate	High	Long	Moderate	Moderate
Garibaldi	---	High	Long	None	Moderate
Rock wrasse	---	---	Long	None	Moderate
Black surfperch	High	Low	Medium	Low	High
California spiny lobster			Long	Heavy	Low
Red sea urchin			Long	Heavy	High
Purple sea urchin			Long	Low	High
Abalones			Long	Heavy	Low
Warty sea cucumber			Long	Moderate	Moderate
Bat star			---	None	Moderate
Giant-spined sea star			---	None	Moderate
Ochre sea star			---	None	---
Sunflower star			---	None	---
Giant kelp			Short	Moderate	---

[1] Relative growth rate, fecundity, and longevity categories for fishes were modified from Musick et al. (2000).
[2] Invertebrate relative life span was determined as short (≤5 years), medium (6-20 years), and long (>20 years).
[3] Relative exploitation history was based on the amount and trends of recreation and/or commercial landings over the past 20 years.
[4] Relative ability to detect change was determined from analysis of data previously collected in existing MPAs at Anacapa Island and surrounding areas. Average coefficient of variation (CV) in population density for each species was compared for fish and invertebrates separately. For fish the relative measure was defined as low detectability (CV>2.99), moderate (2.00-2.99), and high (CV<2.00) and for invertebrates low (CV>1.99), moderate (1.00-1.99) and high (CV<1.00).
--- Information not available for this species.

4. Monitoring Activities and Data Collected

SCUBA Diving – A major part of the shallow subtidal monitoring will involve SCUBA diving surveys using existing and new protocols. These surveys will be conducted between 5m (15 ft.) and 20m (60 ft.). The Cooperative Research and Assessment of Nearshore Ecosystems (CRANE) protocol was used as a baseline to develop a comparable survey method for the Channel Islands MPAs (Appendix B). Adjustments were made to maximize the number of sites that could be sampled. Many existing programs will continue to collect additional information that will enhance overall knowledge. The Department will ensure that these programs collect information using the Channel Islands MPA protocol as a minimum standard.

SCUBA surveys will obtain information on fishes, invertebrates, algae, and habitat. Specifically, information on abundance and sizes of all non-cryptic fishes and select macroinvertebrate and algal species will be collected (Appendix C). These data will be used to determine densities, average sizes, biomass, and spawning biomass of select focal species within and outside MPAs. Information on the habitat will include the type of substrate, relief height, and substrate percent cover.

Fish surveys at each site will be made up of 24 random benthic and 24 midwater transects (Appendix B). There will be 12 random benthic transects for the macroinvertebrate and algal surveys at each site. Additional surveys will occur throughout the year depending on funding, staff availability and most importantly ocean conditions.

Additional focused SCUBA surveys will be used to record location and movement of tagged fishes between MPAs and unprotected areas to assess spillover effects. Tags will be marked to facilitate underwater identification of fish tagged within and outside MPAs.

SCUBA surveys will occur during the summer-fall season (June-December) when conditions are best for diving. Some year-round SCUBA surveys may also be done to answer specific questions. In particular, sea urchin density and habitat information may be obtained by volunteer divers from the commercial sea urchin fishery. If implemented, this program's protocols will follow those proposed by Prince and Hilborn (Appendix D), with suggestions and modifications from the Department and the Sea Urchin Harvesters Advisory Committee (SUHAC).

Estimates of Expected Change

Studies of other California MPAs were reviewed to provide an estimate of the expected difference in various parameters inside and outside MPAs. These studies were primarily conducted in long-established MPAs (with the exception of Big Creek) and provide estimates of what might occur in the Channel Islands over the long-term. Again, because no two areas are expected to be exactly the same, these data only provide guidelines for what may occur and the areas in this program may not have equal results.

Paddack and Estes (2000) found mean densities for a variety of rockfish and other species 12-35% greater (all species combined) within three central California reserves (Hopkins Marine Life Refuge, Pt. Lobos Ecological Reserve, and Big Creek Marine Resources

Protection Act Ecological Reserve) than adjacent fished areas, though due to lack of statistical power their results were not significant. In their study average densities for kelp rockfish, gopher rockfish, cabezon, and lingcod were 31%, 83%, 22% and 100% greater inside the MPAs than outside, respectively. California sheephead were much greater within one reserve in this study, but very infrequent or not seen at all in other areas. Sheephead is at the northern edge of its range in central California and results are likely not comparable to southern California.

Paddack and Estes (2000) also reported mean sizes for all rockfish species combined in their study. In two of the three reserves mean size was greater and in the third reserve (which had been established the least amount of time) mean size was nearly equal. On average over all three reserves mean size of rockfishes was about 14% greater within the reserves than outside.

Limited data were reviewed from surveys inside and outside the Catalina Marine Science Center MPA. Sheephead and kelp bass densities were 48% and 29% greater inside the MPA compared to outside, respectively (Caselle unpublished data). Unfished species were less abundant inside, with both garibaldi and rock wrasse being 42% less dense inside the MPA compared to outside.

The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) data from the 2000 through 2001 field seasons were examined to compare sites inside the Anacapa Island Ecological Reserve Natural Area (Anacapa Island) with a single site outside the MPA at Middle Anacapa Island (Caselle unpublished data). For estimates of difference in density, the inside MPA site with more similar habitat to the outside site was used, while for estimates of average size both inside MPA sites were used. Sheephead, kelp bass, rock wrasse, garibaldi and black surfperch densities were 137%, 103%, 173%, 79%, and 398% greater inside the MPA compared to outside, respectively. Sheephead, kelp bass, and rock wrasse average sizes were 13%, 9%, and 3% greater inside the MPA compared to outside, respectively. Garibaldi and black surfperch average sizes, however, were 4% and 24% smaller inside the MPA compared to outside, respectively.

National Park Service data (Kushner unpublished data) were examined to compare relative densities and sizes of invertebrate species inside the Anacapa Ecological Reserve Natural Area (Anacapa Island) compared with areas nearby. In all cases, sites were only included in the comparison if the focal species were present in more than 2 out of the most recent 10 years of data. In this analysis, average spiny lobster and warty sea cucumber densities were 592% and 141% greater inside the MPA, respectively. In contrast, average red urchin, purple urchin, bat star, and giant-spined star densities were 13%, 91%, 66%, and 77% less inside the MPA, respectively. Red urchins, the one commercially fished invertebrate species that is less dense inside the MPA, are significantly larger inside the MPA. Red urchins are approximately 60% larger inside the MPA compared to areas outside. In addition, while nearly 60% of red urchins were larger than the minimum legal commercial size inside the MPA on average, only about 11% were outside. Purple urchins were also larger on average (26%) inside the MPA. These results may indicate the types of ecosystem changes that can occur in MPAs as certain species become less abundant when fished species become more abundant or grow to larger sizes.

Based on these existing studies, approximate levels of expected change can be developed for certain parameters. As noted above, these estimates are not targets and may differ significantly from area to area. They do, however, provide some guidance regarding the expected amount of change for individual species within Channel Islands MPAs compared to reference areas. Certain unfished or very lightly exploited species are not expected to show changes within MPAs. Table 4 shows examples of potential differences in density and size within MPAs compared to areas outside for a variety of species for which data were available.

Table 4. Ranges of estimated potential differences in focal species density and size within reserves compared to areas outside based on data from other California MPAs.

Species	Estimated Density Difference (%)	Estimated Size Difference (%)
California sheephead	50 to150	15
Cabezon	20	No Data
Kelp bass	30 to 100	10
Lingcod	100	No Data
Kelp rockfish	30	15
Gopher rockfish	80	15
Garibaldi	-40 to 80	-5
Rock wrasse	-40 to 175	5
Black Surfperch	400	-25
Red sea urchin	-15	60
Sea cucumbers	140	No Data
Lobster	600	No Data
Sea stars	-60 to -80	No Data
Purple urchin	-90	No Data

Trap/Fixed Gear – Deeper surveys will use primarily fixed gear or Remotely Operated Vehicles (ROV). Traps and other fixed gear such as fixed vertical longline (stick gear) will be used to collect fishery independent data. This sampling will enlist specially trained commercial fishermen working cooperatively with researchers to trap within and outside MPAs at several sites. Most of these efforts will occur at Anacapa and Santa Cruz, but will expand to other islands if funding becomes available. All fish and invertebrates caught will be identified, measured, sexed if possible, and released. Fixed gear surveys will be employed as follows:

1) Traps will be used to complement SCUBA surveys at the end of year zero and beginning of year one. It is well known that some fishes are difficult to observe or are affected behaviorally by SCUBA divers. Traps will obtain CPUE information that will be compared with estimates of fish density derived from SCUBA surveys. This information will be used to calibrate the two techniques as survey methods for monitoring MPAs.

2) Annual trap surveys are proposed to collect fish and lobster CPUE information, but not funded at this time. Typical nearshore fish and lobster traps will be used with standardized bait and soak times.

3) Traps are proposed to be used to capture focal fish species and lobsters for marking/recapturing on an annual basis to examine spillover effects. This is also not funded at this time. Tags will be color coded to facilitate identification of fish tagged within

and outside MPAs. Information on movements within and outside MPAs will be obtained during trapping efforts and by visually re-sighting tagged individuals through quarterly SCUBA surveys. More frequent visual surveys for tagged fish and lobster can be made by volunteer divers.

4) In addition to traps, hook and line gear is currently being used in a cooperative fish tagging program between an independent consultant, the Department, Pacific States Marine Fisheries Commission (PSMFC), and the Sportfishing Association of California (SAC). This program has already marked thousands of individuals (including focal fish species) within and outside MPAs throughout southern California and the Channel Islands during 2002-2003. With additional funding, these efforts may be expanded in 2004-2005 and tailored to fit MPA monitoring needs. Movement information on these tagged fish can be obtained by hook and line fishermen or through diving observations.

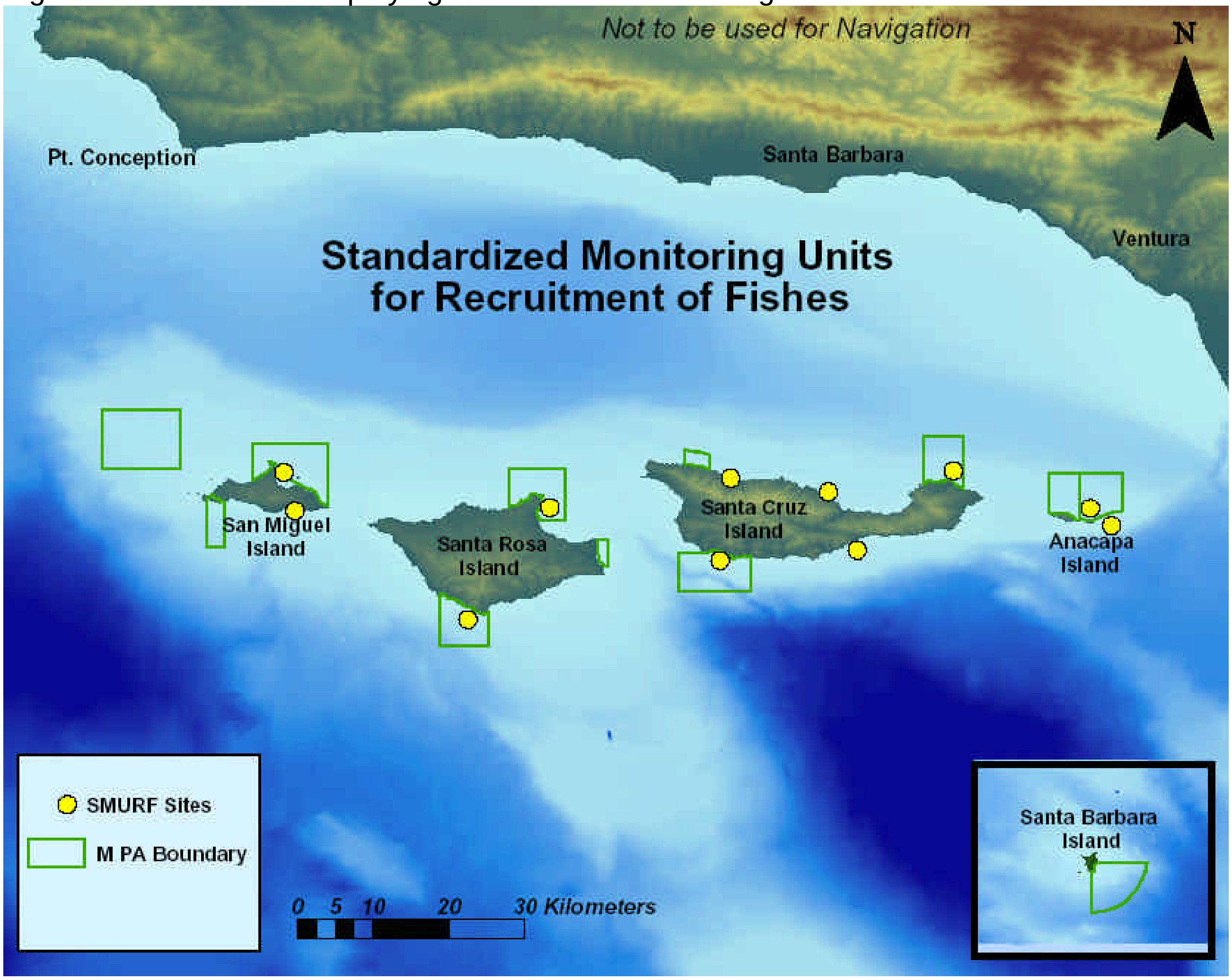
Estimates of Expected Change

CPUE is expected to generally increase in MPAs and nearby areas relative to distant areas for California sheephead, cabezon, kelp bass, lingcod, kelp rockfish and lobster. Other fishes that are less heavily exploited (e.g., black surfperch), or not fished at all (e.g., garibaldi and rock wrasse) are not expected to show significant changes in CPUE.

Based on existing mark-recapture studies, it is expected that a significant proportion of several species of fish tagged within MPAs will remain in the MPAs. These include California sheephead, kelp bass, cabezon and black surfperch. Some fish are expected to move outside the MPAs. Fish tagged within MPAs and subsequently seen outside MPAs are expected to be re-sighted nearby.

Newly Settled Fish Surveys - Standard Monitoring Units for Recruitment of Fishes (SMURFs) will be used to sample newly settling juvenile fishes. These recruitment modules are 1.3 m long by 0.3 m diameter tubes made out of plastic fencing material with an outer mesh size of 2.5 cm. These modules are placed 1.5 m below the surface during spring through fall, and are checked at least monthly. SMURFs have been deployed by PISCO since 1999 at several sites (Figure 2). Given continued funding, sampling will continue within and outside MPAs at all four of the northern Channel Islands. These modules provide useful information on recruitment and the effects of environmental conditions, especially for those fishes that recruit into the kelp canopy.

Figure 2. PISCO sites deploying standardized monitoring units for recruitment of fishes.



Data from SMURFs are mainly used to relate recruitment events with oceanographic processes, and secondarily to better understand spatial recruitment patterns. They can also help explain or groundtruth changes in density and biomass within and outside MPAs. Based on past data, SMURFs are likely to continue to provide good recruitment indices for kelp bass, cabezon, and a variety of rockfishes, and may provide information on relative recruitment rates from sites inside and outside of reserves. Because dispersal of larvae is expected to be extensive relative to the size of the Channel Islands MPAs, there is no *a priori* expectation of the patterns of recruitment relative to the proximity of reserves. Equally, since recruitment rates are highly variable from year to year, it may require a long time series before the effects of reserve establishment on recruitment can be detected.

Annual Kelp Aerial Surveys – It is well recognized that kelp forests provide a unique ecosystem, playing a major role in the life histories of some of the most important sport and commercial species. The Department has conducted only a few coastwide kelp aerial surveys (1967, 1989, 1999, 2002, and 2003), while others have completed more frequent surveys but over a limited geographic area. Fortunately, the 2003 Department survey provides a good baseline for future comparisons.

Existing surveys using Department aircraft and photographic equipment will continue. These surveys fly the entire California coast, including the Channel Islands, using a multi-spectral digital camera to photograph kelp beds. These surveys will not only provide kelp canopy cover information but some sub-surface algal cover data as well. These surveys typically take place in late August or September and provide information on annual changes in this important habitat. Annual surveys will be compared to those for the rest of southern California to examine variability within and outside MPAs.

Estimates of Expected Change

It is not expected that kelp would increase in the MPAs due to the prohibition on kelp harvesting and fishing; however, ecosystem changes including the flourishing of kelp beds could occur as the result of many other ecological interactions. For example, giant kelp within the already existing MPA at Anacapa Island has persisted, probably due to the increase of large predators (e.g., California sheephead and lobsters) that feed on animals that consume kelp (e.g., sea urchins: Lafferty and Kushner, 2000).

Annual ROV Surveys – Deeper surveys will use primarily fixed gear or Remotely Operated Vehicles (ROV). Annual ROV surveys will be used to sample depths from 20-100 m. For shallow subtidal monitoring, ROV surveys will fill in the depth range from 20-33 m where SCUBA diver observation times are severely limited. ROV surveys will provide geo-referenced video documentation of habitat and associated species within and outside MPAs. A preliminary survey using these methods was conducted in 2003. These surveys obtain information on type of habitat, abundance and sizes of all non-cryptic fishes, and abundance of focal invertebrate species within and outside MPAs. ROV collected data will be potentially used to determine densities, average sizes, biomass, and spawning biomass of select focal species; however, the accuracy and precision of these data have not been determined. Additional funding is necessary to insure these surveys continue annually. Specific ROV survey methods are listed in Appendix E.

B. Deep Subtidal Monitoring

Deep subtidal monitoring is the second highest priority, and occurs at depths greater than 33 m. While many species occupy depths both shallower and deeper than 33 m, the methods used to monitor species in the deeper ranges are generally different. It is acknowledged that other recent management activities have produced several confounding factors that will complicate interpretation of data from deeper surveys. Examples of these management activities include large seasonal and year-round area closures, reductions in allowable take, and Federal vessel buyback programs.

1. General Sampling Design

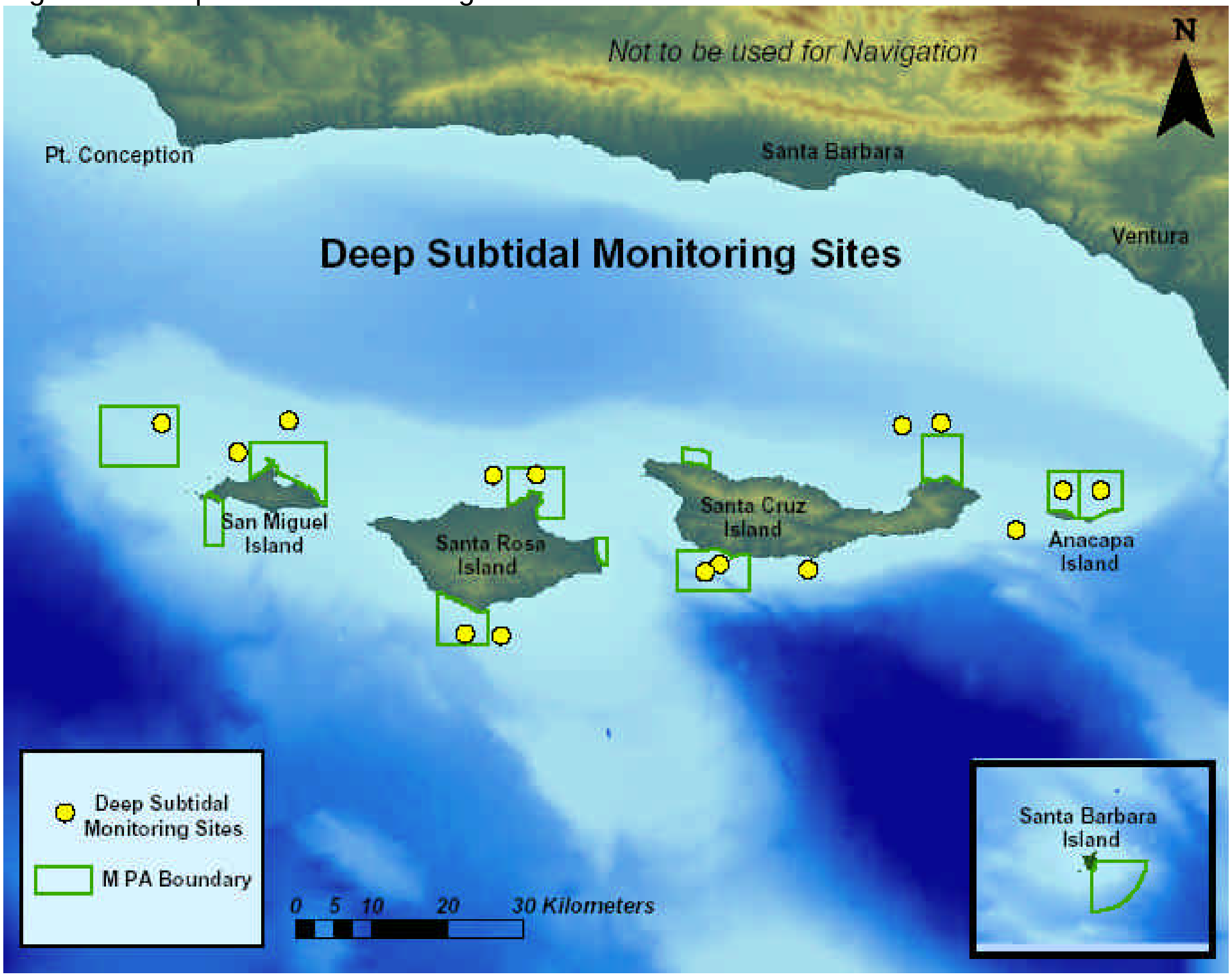
Considerably less sampling has occurred in deeper subtidal areas than in shallow subtidal habitats. In addition, the level of pre-implementation monitoring and fishing effort differs between deep and shallow subtidal areas in the region. Comparisons between MPAs and unprotected areas will be made using as many historical baseline data as possible. In particular, existing submersible survey data will be compared with subsequent surveys of the same areas.

2. Site Selection

Deep subtidal monitoring focuses on sampling a subset of MPAs in order to maximize data collection and eliminate areas that are covered by other programs. While the overall focus will be on rocky reef areas, some soft bottom monitoring will be done as well. Some areas outside three miles will be included in order to help determine impacts of trawling (which is prohibited closer to shore) and to provide a baseline if Federal MPAs are implemented. Deep subtidal monitoring using visual surveys (ROV or submersible) will occur at the following sites, within and outside MPAs (Figure 3):

San Miguel Island: Harris Point, Richardson Rock, and Wilson Rock
Santa Rosa Island: Carrington Point, South Point, and Rodes Reef
Santa Cruz Island: Gull Island, Santa Cruz Canyon and Scorpion
Anacapa Island: West Anacapa, East Anacapa, and the Footprint area

Figure 3. Deep subtidal monitoring sites.



3. Species Selection

There is considerable interest in obtaining data for species whose depth distributions extend out from the shallow subtidal. In addition, it will be important to obtain information for overfished and endangered species that occur in deeper water. Similar to shallow subtidal monitoring, species were selected that display a wide range of attributes.   The focal species list consists of 14 fishes and 6 invertebrates; angel shark (*Squatina californica*), blue rockfish (*Sebastes mystinus*), bocaccio (*S. paucispinis*), copper rockfish (*S. caurinus*), cowcod (*S. levis*), olive rockfish (*S. serranoides*), pygmy rockfish (*S. wilsoni*), squarespot rockfish (*S. hopkinsi*), swordspine rockfish (*S. ensifer*), vermillion rockfish (*S. miniatus*), California halibut (*Paralichthys californicus*), cabezon (*Scorpaenichthys marmoratus*), lingcod (*Ophiodon elongatus*), California sheephead (*Semicossyphus pulcher*), abalone (*Haliotis spp.*) - especially white abalone (*H. sorenseni*), California spiny lobster (*Panulirus interruptus*), red sea urchin (*Strongylocentrotus franciscanus*), purple sea urchin (*S. purpuratus*), market squid (*Loligo opalescens*) and rock crabs (*Cancer spp.*). A variety of pelagic finfish were also recommended for monitoring given additional funding, resources, or a specific protocol (Appendix A).

4. Monitoring Activities and Data Collected

Submersible/ROV – The primary methods for monitoring deep water habitats include visual surveys using both submersibles and Remotely Operated Vehicles (ROVs). Submersible and ROV surveys will collect information on fishes, invertebrates, and habitat. Specifically, these surveys will obtain abundance/density information for the above focal species, and determine species diversity within MPAs and unprotected areas. All of the above sites will be sampled annually, with the exception of Scorpion SMR which has limited rocky habitat. Sampling protocols for submersibles developed by University of California, Santa Barbara (UCSB) and the National Marine Fisheries Service (NMFS), and established ROV protocols (Appendix E) will be used. Several submersible surveys have occurred in these areas in the past and a preliminary survey was conducted in 2003. Submersible surveys may be complemented by more extensive and frequent ROV surveys, given additional funds. Existing NMFS and Department ROVs need to be supplemented with a locally owned/operated ROV.

Bight Surveys – Recognizing the need for integrated assessment of the southern California coastal ocean, 12 government organizations, including the 4 largest municipal wastewater dischargers and the 5 agencies regulating discharges in southern California, collaborated to conduct a comprehensive regional monitoring survey in 1994. Called the Southern California Bight Pilot Project (SCBPP), the survey's primary objective was to assess the spatial extent and magnitude of ecological disturbances on the mainland continental shelf of the Southern California Bight (SCB) and to describe relative conditions among different regions therein.

The SCBPP sampled 261 sites in the SCB during July and August, 1994. Sampling sites were limited to the mainland continental shelf (10 to 200 m water depth) in the U.S. portion of the SCB and were selected randomly to ensure that they were representative of conditions in the study area. At each site, a series of indicators was selected to address three major concerns to scientists, managers, and the public: 1) the extent of pollutant exposure, or the condition of the physical and chemical environment in which biota live; 2) the status of biological resources, or the existence of healthy, diverse, and sustainable biological communities; and 3) the presence of marine debris, which addresses concerns about aesthetic conditions.

The SCBPP assessed communities of bottom-dwelling species, including external anomalies and parasites of fishes at 114 sites. In addition, measurements were made for 14 organic contaminants on livers of 3 fish species from approximately 50% of the sites. Benthic trawls and sediment sampling provided the basis for data collection efforts.

In 1998 a total of 415 sites were sampled for sediment chemistry, sediment toxicity, benthic macrofauna and fish, though not all sites were sampled for all parameters. The survey was completed again in 2003 with new locations selected within and outside the Channel Islands MPAs. These surveys should be repeated at 4 to 5 year intervals.

C. Intertidal Monitoring

Intertidal consumptive use at the Channel Islands is relatively low, and fishing restrictions from the new MPAs are not expected to directly affect these areas. In the intertidal zone at the islands, regulations on fishing probably have a smaller direct impact than existing limitations on access or entry. In many cases, access is either prohibited by National Park or other regulations or by the nature of the environment. Changes to the intertidal zone are primarily expected through secondary ecosystem effects, such as increased production in the shallow subtidal zone leading to increased recruitment in the intertidal. These secondary effects may take many years to be recognizable. Therefore, intertidal monitoring is a lower priority than shallow and deep subtidal monitoring.

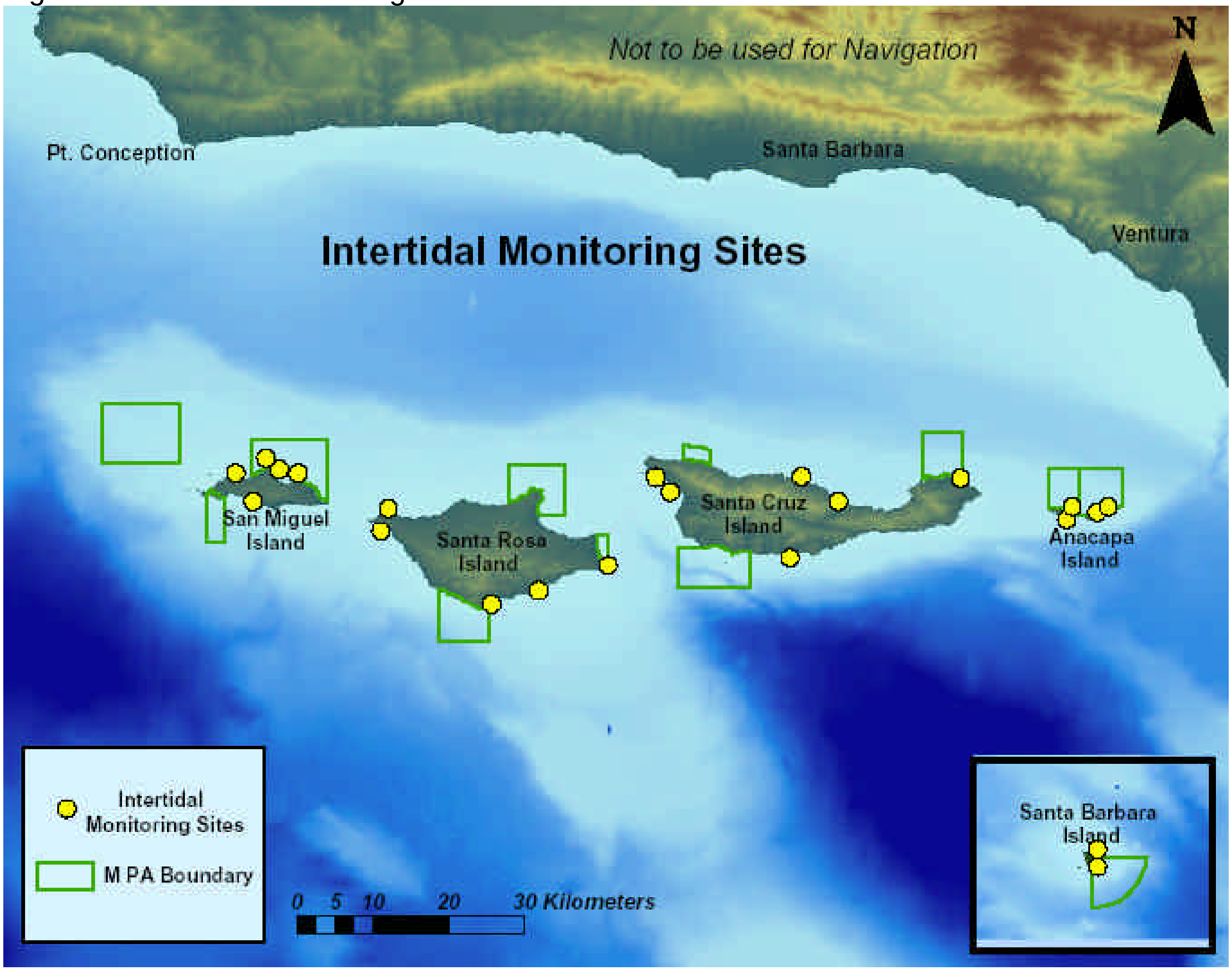
1. General Sampling Design

Intertidal monitoring will be completed through the ongoing National Park Service (NPS) and Multi-Agency Rocky Intertidal Network (MARINe) programs. Monitoring will occur within and outside a subset of MPAs. Monitoring will place emphasis on sites that have been sampled prior to implementation of the Channel Island MPAs in order to provide useful comparisons to baseline data.

2. Site Selection

The NPS and MARINe programs monitor 29 mainland sites and 29 island sites in 6 different counties in southern California in the spring and fall. Of the 29 island sites, 22 are located within or outside the Channel Islands MPAs (Figure 4). These sights are not ideally situated for monitoring the Channel Islands MPAs. With additional funding, monitoring sites could be added at Santa Cruz and Santa Rosa Islands within and outside one of the MPAs at each island. Additional sites, if selected, will be placed in areas where one-time or historical surveys were completed whenever possible and in areas of comparable rocky intertidal habitat.

Figure 4. Intertidal monitoring sites.



3. Species Selection

There are 13 target species monitored by MARINe: black abalone (*Haliotis cracherodii*), ochre sea star (*Pisaster ochraceus*), owl limpet (*Lottia gigantea*), aggregating anemone (*Anthopleura elegantissima/A.sola*), thatched barnacle (*Tetraclita rubescens*), small acorn barnacle (*Chthamalus dalli/C. fissus*), large acorn barnacle (*Balanus glandula*), gooseneck barnacle (*Pollicipes polymerus*), California mussel (*Mytilus californianus*), surfgrass (*Phyllospadix scouleri/P. torreyi*), feather boa kelp (*Egregia menziesii*), rockweed (*Hesperophycus californicus* and *Silvetia compressa*), and turfweed (*Endocladia muricata*). These species represent the focal list of intertidal species. Other "core" species that are found in association with these target species and are important in understanding abundance trends, and "optional" species that may occur at a few sites in high concentrations are also monitored.

4. Monitoring Activities and Data Collected

Intertidal survey protocols are those currently employed by MARINe and PISCO researchers. The particular method depends upon the species being targeted. Estimates of expected change are not set for these activities within and outside MPAs:

Band Transect/Irregular Plots – The number and size of sea stars (primarily ochre sea stars) and black abalone are monitored along band transects or within irregularly-shaped plots, depending on site topography. Sea star transects are typically 2 x 5 m and abalone transects are typically 1 x 10 m. This activity provides abundance/density and size information for these two species.

Timed Searches – Site-wide timed searches have been employed at locations where abalone and sea stars exist in too few numbers to monitor within a limited area. One person spends 30 minutes (or 2 people spend 15 min. each) haphazardly searching crevices and pools along the low intertidal zone throughout the site for occurrences of ochre sea stars or black abalone. Numbers encountered and size measurements (at some sites) are recorded. This activity provides abundance/density and size information for these two species.

Permanent Plots – The number and sizes of owl limpets are recorded within permanent circular plots (1 m radius, 3.14 m^2 area) at most intertidal sites. These plots were originally located in areas of high limpet density. This activity provides abundance/density and size information for this species.

Photoplots – The cover of target species as well as other core and optional species/taxa/substrates is sampled by photographing permanent 50 x 75 cm plots per target species, then scoring point contact occurrences on the photo image. Individual taxa beneath the points are identified and recorded. Plots were established in areas of high target species density wherever possible. This activity provides abundance/density and species diversity information.

Transects – The cover of surfgrass is sampled by point-intercepts along 10 m long permanent transects. Transects were established in areas of high surfgrass density wherever possible. Most sites have three replicate transects. Each transect is divided into 100 points distributed at 10 cm intervals. The top-layer target, core, or optional species/taxon/substrate is scored under each point. In addition, surfgrass is separately scored if it occurs beneath another species. This activity provides abundance/density information for surfgrass and many other species.

IV. SOCIAL AND ECONOMIC MONITORING

Another monitoring goal is to determine the effects of MPAs on the social and economic environment of the region. The monitoring program is guided by the goals and objectives developed by the Marine Reserves Working Group (MRWG), a constituent based group which discussed Channel Islands MPAs for more than two years. The MRWG came to consensus on a broad socioeconomic goal of maintaining long-term economic viability while minimizing short-term losses. This goal was followed by more specific objectives including:

- To provide long-term benefits for all users and dependent parties;
- To minimize and equitably share short-term loss in activity for all users and dependent parties;
- To maintain the social and economic diversity of marine resources harvest by equitably sharing the loss of access to harvest grounds among all parties to the extent practical when designing reserves; and
- To address unavoidable socioeconomic losses created by reserve placement through social programs and management policy.

The MRWG followed these objectives with several implementation recommendations including the following for monitoring, evaluation, and oversight:

- To understand ecosystem functions in order to distinguish natural processes from human impacts (overlaps with biological monitoring);
- To monitor and evaluate the short- and long-term effectiveness of reserves for managing living marine resources including harvested populations; and
- To widely publicize the results of findings of monitoring and evaluation efforts.

The following describes a suite of proposed activities to assess the social and economic effects of the Channel Islands MPA network. These activities focus primarily on the short-term question of whether MPAs have a negative effect on economics and whether vessels have been displaced or effort concentrated due to the MPAs. As with biological monitoring, existing activities will provide the bulk of ongoing social and economic monitoring. In the case of social and economic monitoring, however, significantly fewer existing programs are in place.

Many additional activities were detailed in a report developed from the March 2003 Monitoring Workshop (NOAA 2003). This report provides recommendations on how to expand programs or meet needs for more detailed monitoring. The NOAA (2003) recommendations should be considered as potential activities that could supplement this plan given increased funding or support. The monitoring activities described here meet only the minimum recommendations in the NOAA (2003) document. Additional monitoring recommendations not included in this monitoring plan are summarized in Appendix A.

Estimates of Expected Change

Interpretation of social and economic monitoring measurements is challenging. Determining the causes and effects of social and economic changes from MPAs versus other factors is a difficult and sometimes impossible task. International, national and regional economic conditions, natural environmental conditions, and other management strategies and regulations will affect many social and economic measurements. A comprehensive monitoring program needs to incorporate information on these other factors to support evaluation.

Another key issue in evaluating a monitoring measurement is the issue of measurement thresholds. Throughout the MRWG process, socioeconomic advisors were asked to define when social and economic impacts become significant. The socioeconomic advisors maintained that social and economic scientists are limited in their ability to make judgments about the significance of impacts based on existing legal descriptions. These legal "significance" findings only serve to determine whether more studies are necessary and did not directly answer concerns about individual impacts, such as changes in an individual's income. While significance of impacts as judged by "Normative" guidelines of equity or fairness is political in nature, "significance" of changes can be held to the same statistical guidelines as biological monitoring. A statistically significant change in income, ex-vessel value, or other parameter can be measured and then examined to determine whether MPAs were a causative factor.

In order to evaluate socioeconomic impacts on individuals or specific user groups, statistically significant changes should be examined with regards to a community acceptable threshold. Establishing thresholds is necessary and may be an appropriate activity for a community oversight panel, as recommended below (see Section V). Because of the political nature of establishing social and economic measurement thresholds, this plan does not make suggestions as to their value. Where possible, the link between social and economic impact and biological changes (such as changes in CPUE) is made and an estimate of potential change given.

A. Social Science Coordination

Social Science Coordinator – A single social science coordinator is recommended to facilitate coordination of social and economic data collection and review of information. Ideally, this person would be contracted (pending funding) through a neutral funding source to minimize any perceived bias. The duties of this full-time position include timely review and reporting on social and economic data. This position is currently not funded, though several potential funding sources are being examined.

B. Use, Catch and Value

Commercial and Recreational Fishing Effort Analysis (Logbooks, Landing Receipts, and Surveys) – Logbooks were developed to access the professional knowledge and observations of fishermen to improve fishery management. Logbooks require that fishermen record information such as catch, location fished, and time spent fishing each time their fishing gear is deployed. Logbooks are not mandatory for all fisheries; only sea urchins, sea cucumbers, lobsters, market squid and commercial passenger fishing vessels require logbooks. In addition, a monthly kelp harvesters report is required. Logbooks for red sea urchin, sea cucumbers, lobsters, and squid will be used to calculate CPUE for specific areas within the Channel Islands. Logbook data will also be analyzed for information on total catch and value as well as fishing locations to determine changes in the fisheries. A voluntary logbook system may also be used, especially for the nearshore live finfish fishery (see Appendix A).

Commercial buyers are required to complete landing receipts or "fish tickets" when catches are off-loaded. These receipts provide information on species or species groups, general location fished (10 minute Lat. x 10 minute Lon. blocks), weight of catch, and price paid for the catch. This information will be used in the socioeconomic analyses when logbooks are not available. Because landing receipt fishing location information is very coarse, it will be combined with aerial monitoring (see below) to determine level and location of effort.

Information on recreational catch and effort for fishes is obtained through commercial passenger fishing vessel (CPFV) and California Recreational Fisheries Survey (CRFS) programs. CPFV operators are required to keep logbooks on the location of fishing, number of passengers aboard, species and amount of catch. Similar to commercial landing receipts, the location information is very coarse. In January 2004, the CRFS program was implemented with the goal of producing more timely fishery-dependent data. The program will replace the existing Marine Recreational Fisheries Statistics Survey (MRFSS) in California. The CRFS program will improve data usefulness by reporting catch and effort at monthly intervals, using a finer geographical resolution, increasing dockside sampling, and estimating effort using an angler database.

Estimates of Expected Change

CPUE and abundance may not be directly related due to many factors including the behavior of fishers and changing catchability over time (Hilborn and Walters 1992). Nonetheless, CPUE is expected to increase over time for California sheephead, cabezon, kelp bass, lingcod, kelp rockfish, lobster, red sea urchin, and sea cucumbers in areas near MPAs relative to distant areas. Using data from MRFSS and CRFS programs, an increase in average size and more, larger individuals are expected in areas near MPAs relative to areas far away. Average length of California sheephead, kelp bass, cabezon, lingcod, and kelp rockfish caught within 5 km of SMRs should be greater than areas more distant.

C. Displacement and Edge Effects

The Sanctuary instituted an aerial survey program in June of 1997. The Sanctuary Aerial Monitoring and Spatial Analysis Program (SAMSAP) uses a Lake Seawolf seaplane to fly transects of the entire Sanctuary on a bi-weekly basis. Equipped with an on-board Global Positioning System (GPS) and a laptop computer containing a custom designed software package, the aircraft allows frequent and efficient monitoring and spatiotemporally recording of physical and anthropogenic phenomena within and adjacent to Sanctuary boundaries. Biological data collected during surveys include pinniped sightings, cetacean sightings, and giant kelp (*Macrocystis pyrifera*) canopy locations. Cultural data collected include vessel types and locations and marine debris sightings.

Aerial surveys typically take place with the pilot and a data recorder on board. The normal survey flight is 100 kn at 1,000 ft, flown in "figure eight" transects between the northern islands (Anacapa, Santa Cruz, Santa Rosa, and San Miguel), and a double outward radiating spiral at Santa Barbara Island. The laptop computer receives one-minute interval updates on horizontal and vertical position from the GPS, which are fed into the computer's aerial survey software. The laptop can manually receive position data at up to one-second intervals if required.

Once a transect is complete, a data file containing numerically encoded sighting records is ready for import into a Geographic Information System. The data are imported into an ArcView 3.0a basemap as point attributes. The data may be viewed in combination with historical data to analyze trends such as vessel distributions and density of use. Attributes are also viewed and analyzed across data types to find spatiotemporal relationships, such as urchin vessel locations relative to kelp beds.

Estimates of Expected Change

Historical levels of use have been continually low at the islands. SAMSAP data were analyzed prior to MPA establishment. This analysis showed very few vessels inside proposed MPA boundaries, even on the days with the highest numbers of vessels seen. Therefore little displacement of vessels would be expected. Some focus on edge fishing, however, is likely. Fishing effort of certain users should increase over time at the edges of the MPAs to take advantage of expected edge effects and spillover. This would include lobster trapping, recreational angling, and possibly commercial fish trapping.

D. Knowledge, Attitudes and Perceptions

Public attitudes with regards to MPAs are generally positive when viewed on the average across all Californians. The Public Policy Institute of California (PPIC) conducted a survey of Californians with regards to a variety of marine and coastal issues (Baldassare 2003). The PPIC report indicates that three in four Californians (75%) favor creating more marine reserves off the California coast, even if it means that some ocean areas will be off-limits to commercial and recreational fishing (Baldassare 2003). Three-quarters of Californians (77%) also favor protecting wetlands and habitats near the bays and beaches, even if it means less commercial activity near the coast (Baldassare 2003).

These results, however, do not provide information on specific attitudes or perceptions of the people most affected by the Channel Islands MPAs or details on the level of knowledge in both the local and statewide communities. A pilot study conducted by students from the University of California Santa Barbara's Donald Bren School of Environmental Science and Management in 2003 has collected some information. This study focused only on non-consumptive recreation through limited surveys of charter vessel passengers.

It is recognized that additional surveys of public knowledge, attitudes, and perceptions must occur for the Channel Islands. At present, funding and the specific nature of these surveys are unknown. The Department and its partners will seek additional funding and specific survey proposals in the coming year.

A comprehensive survey of knowledge, attitudes, and perceptions should be conducted as soon as possible. Subsequent surveys need not occur immediately, as these factors should change slowly over time. At a minimum, follow-up surveys should be completed at year 4, or prior to the first major review of the MPA network.

E. Education, Research, and Outreach

Educator Use Tracking - Sanctuary and National Park Service databases and information will be used to provide annual estimates of numbers of educators accessing the islands in general, and MPAs in particular. Potential questionnaires could provide information on whether educators were focusing on the MPAs or other aspects of the islands. Data will be collected and processed by existing staff and the new Social Science Coordinator.

Scientific Use Tracking - Sanctuary research permittee and Department scientific collecting permit databases will be used to track annual numbers of researchers at the islands. The projects will be evaluated to determine numbers of researchers studying the MPAs or their effects. Data will be collected and processed by existing staff and the new Social Science Coordinator.

Public Outreach - The Department, Sanctuary, and National Park have ongoing outreach programs. These programs will be coordinated to the extent possible to maximize the number of people reached and amount of information provided. The agencies have already developed new pamphlets and flyers to provide information on the MPAs and their regulations. The Sanctuary has developed a volunteer “Adopt-A-Business” program to ensure that local marine-related businesses receive printed information and updates in a timely fashion.

V. ADMINISTRATIVE STRUCTURE, STAFFING, AND FUNDING

Staffing and Collaboration

Monitoring programs will be coordinated by existing Department senior staff. As noted in the social and economic monitoring section above, additional support in the form of a social science coordinator is being sought. The Department has dedicated a senior supervisor and three field staff with expertise in nearshore finfish, invertebrates, and kelp monitoring to help implement monitoring at the Channel Islands. These individuals will be supplemented with additional Department field staff for specific data collection efforts.

As noted in the Section II above, much of the monitoring will be conducted cooperatively with agencies, universities, and other institutions outside the Department. These cooperative efforts will help cover some of the costs estimated below. Outside partnerships along with the development of volunteer programs and user group sampling will be critical to the success of the monitoring plan. It should be noted that while outside programs and funding are currently covering much of the needed budget for the monitoring program, many are funded by grants that may change or end in the future. In addition, funding for existing programs may need to increase over time to cover the costs of long-term monitoring. It is critical that annual reviews of this plan take into account available funding and the potential for changes. Tables 5 and 6 provide estimates of the staff needed, costs, and level of funding currently available for monitoring. The portion of each activity currently funded by the Department is listed; remaining staff, equipment, and funds are currently provided by cooperative agreements. Activities requiring additional funds to continue on an ongoing basis are noted.

Table 5. Summary of biological monitoring programs, staffing, costs, and percentage funded by Department resources.

Monitoring Activities	Necessary Staffing (total annual time)	Estimated Annual Cost	Department Funding[1]
SCUBA Surveys	Three supervisory biologists and 10 seasonal field technicians (5 months)	$200,000 - $300,000	10%
Trap/Fixed Gear Surveys[2]	One supervisory biologist, 4 seasonal field technicians, and 2 contracted fishermen (2 months)	$60,000	5%
Newly Settled Fish Surveys	One supervisory biologist and 4 seasonal field technicians (5 months)	$100,000	0%
Aerial Monitoring of Kelp Canopy	Two geographic information system biologists (6 months)	$100,000	100%
ROV Surveys[2]	Two supervisory biologists, 2 biologists, and 2 technicians (2 months)	$50,000	50%
Submersible Surveys[2]	Two supervisory biologists, 2 biologists, and 2 technicians (2 months)	$150,000	5%
Intertidal Monitoring	One supervisory biologist and 4 seasonal field technicians (4 months)	$10,000	5%

[1] Percent funding includes direct funds and in-kind support.
[2] Preliminary surveys during years zero and one are funded; future surveys will require additional funds.

Table 6. Summary of social and economic monitoring programs, staffing, costs, and percentage funded by Department resources.

Monitoring Activities	Necessary Staffing (total annual time)	Estimated Annual Cost	Department Funding[1]
Social Science Coordinator[2]	1 supervisory scientist (12 months)	$50-75,000	0%
Commercial Fish Landing Receipts	1 supervisory scientist and 1 data technician (2 months)	$75,000 - $100,000[3]	75%
Commercial Fish Log Books	1 supervisory scientist and 1 data technician (3 months)	See Note[3]	See Note[3]
California Recreational Fishery Survey - Channel Islands portion	1 supervisory biologist (1 month) and 2 field technicians (3 months)	$50,000	50%
Sanctuary Aerial Monitoring and Spatial Analysis Program	1 scientist/observer and 1 pilot (bi-monthly, 12 months)	$60,000	0%
Survey of Non-Consumptive Charter Industry[4]	4 graduate student researchers (6 months)	$10,000	0%
Knowledge, Perceptions and Attitudes Surveys[2]	4 graduate student researchers (6 months)	$20,000	0%
Educator Use Tracking	1 supervisory scientist and 1 data technician (2 months)	See Note[3]	See Note[3]
Scientific Use Tracking	1 supervisory scientist and 1 data technician (2 months)	See Note[3]	See Note[3]
Public Outreach	1 supervisory educator and 2 data technicians (4 months)	See Note[3]	See Note[3]

[1] Percent funding includes direct funds and in-kind support through staffing, equipment, and vessel time.
[2] Not funded at this time.
[3] Estimated cost of staff time for participation in all noted programs. This assumes various employees working for specified time frames throughout the year.
[4] Preliminary survey completed in 2003; additional funds needed for ongoing surveys.

Assistance with data management and database development will be provided initially by students at the University of California Santa Barbara's Donald Bren School of Environmental Science and Management. Collected data will be housed at the Department to ensure its long-term management and availability.

Public Advisory Panel/Steering Committee

A Channel Islands Monitoring Advisory Panel/Steering Committee will be formed to provide guidance for the implementation of this document and oversee other research interests in the Channel Islands area. The Committee will consist of representatives from the recreational and commercial fishing industries, scientific community, environmental groups, and government agencies. The committee will evaluate monitoring data reports to help determine if the monitoring plan is meeting its objectives and goals. The committee will meet twice a year, most likely in June (before the majority of annual biological sampling takes place), and in January (after the majority of annual biological sampling takes place). The committee will provide a formal written review of the monitoring plan and its effectiveness every five years.

During the formation of this Committee existing Department and other advisory bodies will be used for interim input. These include a variety of groups such as the Channel Islands Cooperative Marine Research steering panel, SUHAC, and others.

Appendix A.
Recommended Additional Activities
for Monitoring Channel Islands MPAs

BIOLOGICAL

Shallow Subtidal

Plankton/Larval Surveys – A regular ichthyoplankton and zooplankton monitoring schedule needs to be established within and outside the MPAs. These surveys will be carried out using existing Department, UCSB, and Sanctuary Vessels, with NMFS assistance for species identification. Surveys would be modifications of the CalCOFI plankton surveys and follow protocols developed during the MERRP (Marine Ecological Reserves Research Program-Sea Grant). A continuous underway fish egg sampler (CUFES) and vertical BONGO and MANTA net tows would be carried out along the 20, 40, 60 and 100m depth contours within the MPA and in adjacent fished areas outside the MPAs. These surveys would also sample eggs and larvae produced from the deep subtidal habitats. GPS drifters would be deployed during sampling to estimate the trajectory of the drift plume from the MPA.

Otolith Microchemistry – A growing amount of research has been focusing on the sources and destinations of larvae, along with their dispersal distances. As larvae grow, certain structures in fish (otoliths) and invertebrates (statoliths) grow, incorporating trace elements from their surroundings. Specific techniques have been developed to analyze these elemental signatures which are compared to environmental conditions to determine where larvae have been. This research needs to continue so patterns of signatures from otoliths and statoliths from many species along with surrounding environmental conditions can be catalogued.

Genetic Studies – Genetic studies provide another method for determining source populations of settling larvae. One can determine larval dispersal distances by looking at subtle genetic differences in individuals from site to site. Genetic techniques are also being developed to aid in species identification of mixed larval samples.

Nearshore Fishery Logbook – A voluntary nearshore fishery logbook would have great value. Currently, there is little specific information on catch and effort for this fishery. Interested commercial fishermen could volunteer to record important fishery information, including gear type used, catch (to species level), effort, and specific location fished.

Deep Subtidal

Tagging - Archival and sonic tags may be used to determine the range of fish movements for a variety of deeper species. It is difficult to perform tagging without high incidental death rates and high expense making this a lower priority to be completed with outside funding only. In particular, the use of sonic tags and hydro-acoustic tracking can provide tremendous detail on both daily and long-term movements, though these techniques are often prohibitively expensive. Continuing work by the Pfleger Institute for Environmental Research (PIER) around Anacapa Island may be expanded to other islands and depths. Also, tagging of deeper fish species such as bocaccio and greenspotted rockfish has been successful in Monterey (Star et al. 2002). This tagging used divers to tag the fish at a depth of 30 ft. to limit barotraumas.

Tagging and CPUE studies for pelagic finfish have also been recommended. These studies would potentially determine impacts on both pelagic fishes and the fishermen who target them. Given the relatively small size of the Channel Island MPAs relative to the home ranges of these fishes, MPAs are not expected to have increased densities, sizes or numbers or pelagic finfish. They may, however, provide some protection to pelagic species during spawning, feeding or other aggregating events.

Intertidal

Landscape Monitoring – This would involve aerial photographs of the intertidal zone to determine long-term changes in the overall habitat stratification. This type of monitoring is not currently in place and would require helicopter surveys. The MPAs are not expected to have direct effects on landscape.

Sandy Beach Monitoring – The National Park Service conducts some sandy beach monitoring at sites within and outside reserves, but these surveys are not completed every year. Additional funding is necessary for a comprehensive program.

Seabirds and Marine Mammals

Seabirds and marine mammals are not expected to be directly impacted by the establishment of MPAs as they were already protected prior to implementation. Fishing impacts on seabirds are indirect, caused by bycatch or disturbance. It is recommended that existing monitoring of breeding and nesting colonies continue. This monitoring could be expanded to monitor MPA effects more directly. MPAs are likely to indirectly affect some of these species in a variety of ways, such as through increases in forage base or by reduced vessel traffic near breeding colonies. The primary effects that can be monitored are likely to be related to the foraging activities of these species within and nearby the new MPAs. Monitoring activities could show how MPAs affect seabirds and marine mammals and how these species impact the trophic structure within MPAs through foraging.

Species Selection

Focal species would be chosen that are likely to have impacts on prey species or may indicate changes in prey availability through dietary changes. Threatened or endangered species are also of concern. Key seabird species are Brandt's and Pelagic Cormorants (*Phalacrocorax penicillatus, P. pelagicus*), Pigeon Guillemot (*Cepphus columba*), and California Brown Pelican (*Pelecanus occidentalis californicus*). Key marine mammal species include California sea lion (*Zalophus californianus*) and Pacific harbor seal (*Phoca vitulina richardsi*). Other marine mammals such as southern sea otters (*Enhydra lutris nereis*) will be monitored if encountered.

Monitoring Activity and Data Collected

Foraging Activity Surveys – Foraging activities of marine mammals and birds will be monitored within and outside MPAs through visual observations. These surveys will examine diet and location of foraging to determine potential impacts both on the animals (e.g., diet changes corresponding to increases or decreases in prey availability) and to the MPAs from the animals (e.g., increased feeding leading to decreases in prey populations). Seabird surveys could occur from shore-based locations while marine mammal surveys are likely to occur from kayaks or small vessels. An ongoing study at San Miguel Island may provide additional information for marine mammals. Existing programs monitoring seabird and marine mammal populations are recommended to continue.

Light and Sound Level Surveys – Comparative surveys of light and sound levels will be conducted within and outside MPAs at seabird breeding locations. These surveys would determine whether reduced fishing activities have a correlating reduction in noise and sound disturbance to nesting seabirds. Surveys would be conducted during breeding seasons and times when squid and other fishery activities are high and low at unprotected sites.

Shorebird Surveys – Shorebirds could be added to seabird monitoring given adequate funding. They have a much lower priority, however, because MPAs are not expected to have direct impacts on these species. It is recommended that outside groups undertake shorebird monitoring if possible.

SOCIAL AND ECONOMIC

The NOAA (2003) summary of socioeconomic monitoring recommendations provides significant details on how existing programs could be expanded. These expanded programs would in many cases provide more detailed monitoring of specific activities and user groups. They are incorporated here by reference. Two recommendations in the summary have no existing component and are listed below:

Option/Nonuse Values of Consumptive Users of Reserves – A new survey of the for-hire industry passengers will be required. The scope could be expanded to include those that access the Sanctuary from private household boats. This could also be done through add-on surveys to NMFS-CRFS or a new survey from State of California and Coast Guard boat registration files. Due to complexity in survey design, baseline costs are relatively high.

Value of Reserves to Nonusers – Surveys of nonusers could be combined with surveys of non-consumptive recreational users. Several options are available including: limiting the scope geographically to those boaters living in Santa Barbara, Ventura and Los Angeles counties; expanding the geographic scope to the population of boaters living in California beyond Santa Barbara, Ventura and Los Angeles counties; or expanding scope to the general population of the U.S. Each requires new survey designs and programs.

Appendix B.
Channel Islands SCUBA Diving Survey Protocols

Site stratification: The sites are rocky reefs between 5 and 20 m (15-60 ft). Each site is divided into halves with preferably 3 depth zones in each half. Twenty-four 30-meter transects per fish survey site distributed evenly among the zones are performed (Figure B1). A diver pair should be able to complete this number of transects in two days. Twelve 30-meter invertebrate transects are similarly completed. Stratified random location of transects will be generated using existing bottom habitat maps where feasible. In other areas, locations are haphazardly chosen within appropriate habitat. Zonation and transect location may have to be modified in the field. Selected monitoring sites are listed below (Table B1).

Survey protocol: Dives are conducted between 0800h and 1600h to ensure adequate light and visibility. The survey zone is a 2m X 2m swath along a 30 m transect. Distance between transects is a minimum of 30 meters. Transect depth should be maintained within ± 2.5 m. If there is an intervening obstacle, the transect continues over it so long as the depth change is less than 2.5 m. If the obstacle is greater than 2.5 m in height, the transect circumvents it. Though sites will be in primarily rocky habitat, transects should be completed even if sand is encountered. When there is sand for more than 5 m and it appears that the habitat continues primarily as sand, the direction of the transect is changed the minimum amount necessary to remain on rocky habitat.

Training: All divers collecting fish data must have prior experience in conducting subtidal surveys. Since it is important that protocols are consistently applied, divers will participate in annual training exercises, including at least one day of class time, three days of diving and a proficiency examination. The proficiency exam includes a quality control check for size estimation, using target fish models of known size. All divers must pass the examination prior to conducting actual surveys.

Weather contingencies: Surveys are only conducted in conditions that are safe for diving. In addition, surveys are not attempted if visibility is less than 2.5 m measured with the transect line or if surge prevents the diver from staying on the transect line. If conditions do not meet minimum requirements over the majority of a site, sampling for the day is cancelled.

<u>Conditions and Habitat Data</u>

Data are collected on both fish and invertebrate surveys for time of day, water temperature, surge (on a relative scale 0 = no surge, 1 = light surge, 2 = moderate surge, and 3 = heavy surge), and visibility (measured using the transect tape). Habitat data are collected using relative ranges during invertebrate surveys. These data include percent rock, percent algal cover, percent kelp canopy, (0 = 0%, 1 = 1-24%, 2 = 25-49%, 3 = 50-74%, and 4 = 75-100%) and bottom relief (0 = flat rock, 1 = low relief, 2 = moderate relief, 3 = high relief).

Fish Surveys

One diver counts and estimates the total length (TL) of all conspicuous non-cryptic fish between the bottom and 2 m above the bottom (benthic transect). Fish less than 15 cm TL are estimated to the nearest cm; larger fish are estimated to the nearest 5 cm. If a school of fish (>10 fish) is encountered, the number of fish is estimated within each size group. The diver maintains a steady pace such that a transect is completed in 5-10 minutes. The second diver surveys fish in the area from 4-6 m above the bottom (midwater transect) using the same protocols.

Invertebrate Surveys

Focal Invertebrates are sampled using a variable area methodology. Individuals of each focal species are counted to a maximum of 30 in any 10m increment. If 30 are counted, the distance along the transect line is noted and counting begins again at the next 10m increment for that species. The first diver counts invertebrates and measures abalone. The second diver collects urchins as per the protocol below, counts *Macrocystis* plants, and counts *Macrocystis* stipes at 1 meter above the bottom. Time permitting, additional information on other invertebrate species may be collected.

Urchin protocol: Red and purple urchins are either measured *in situ* or collected for later measurement until 100 of each species are measured for the site. Emergent animals as well as urchins found under spine canopies are measured. In areas with low urchin density fewer urchins may be measured. Collected urchins are returned on the subsequent dive.

Figure B1. Schematic representation of a monitoring site. Twenty-four 30-meter fish transects are shown, divided by depth strata and site halves. For Invertebrate surveys, each depth strata would have 2 transects.

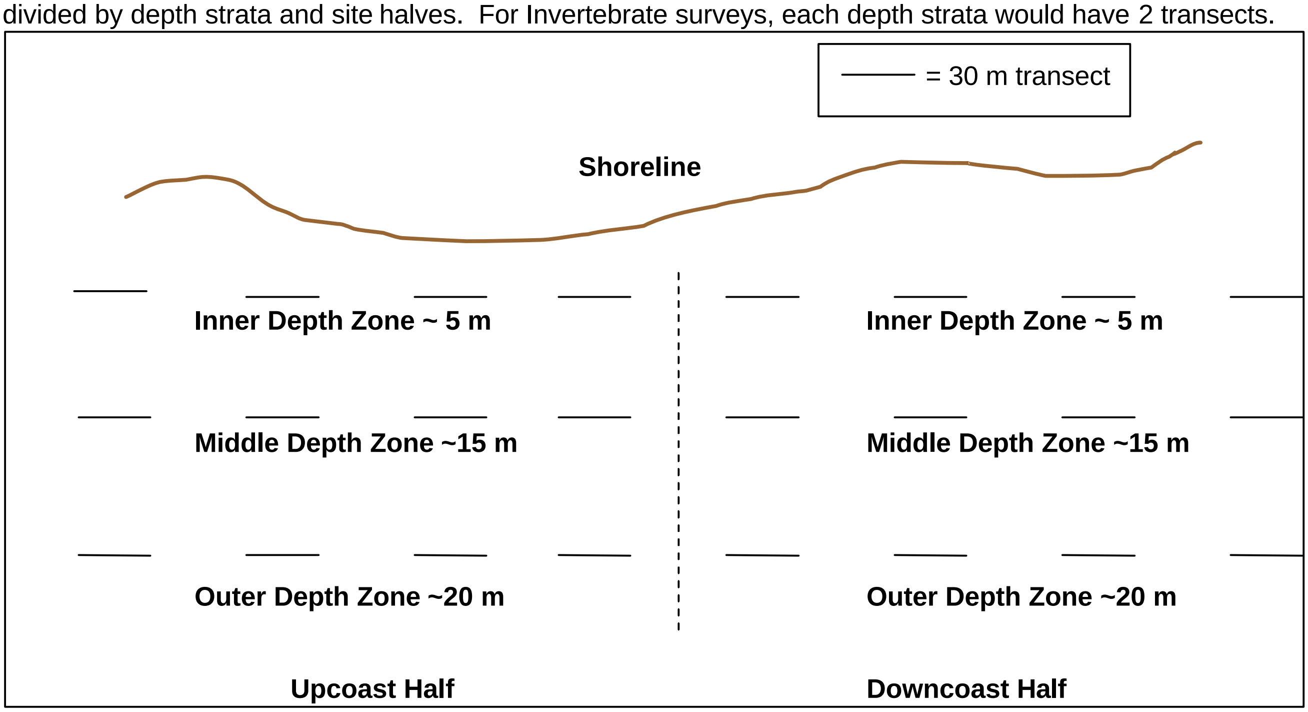


Table B1. Shallow subtidal monitoring sites. Latitude and longitude (decimal degree) are provided for reference to the general site location only. Some sites have one or more sub-sites (e.g., East/West). MPA position refers to whether the site is inside or outside the nearest MPA.

Name	Latitude N.	Longitude W.	Nearest MPA	MPA Position
Santa Barbara Island				
Arch Point	33.49	119.03	Santa Barbara SMR	Out
Sea Lion Rookery	33.47	119.03	Santa Barbara SMR	In
Cat Canyon	33.46	119.04	Santa Barbara SMR	Out
Anacapa Island				
Landing Cove (East/West)	34.02	119.36	Anacapa SMR	In
Cathedral Cove (East/West)	34.02	119.37	Anacapa SMR	In
Middle Isle (East/West)	34.01	119.39	Anacapa SMR	In
West Isle	34.02	119.43	Anacapa SMCA	In
Admiral's	34.01	119.43	Anacapa SMCA	Out
Scorpion (East/West)	34.05	119.555	Scorpion Rock SMR	In
Yellowbanks (East/West)	33.99	119.56	Scorpion Rock SMR	Out
Pelican (East/West)	34.03	119.69	Scorpion Rock SMR	Out
Fry's Harbor	34.06	119.76	Painted Cave SMP	Out
Hazards	34.05	119.82	Painted Cave SMR	Out
Painted Cave (East, Central, West)	34.07	119.86	Painted Cave SMR	
Forney	34.05	119.91	Painted Cave SMR	Out
Gull Island	33.95	119.83	Gull Island SMR	In
Santa Rosa Island				
Carrington (East, Central, West)	34.04	120.04	Carrington Point SMR	In
Rodes Reef	34.03	120.11	Carrington Point SMR	Out
Johnson's (North/South)	33.90	120.10	South Point SMR	Out
South Point (East/West)	33.90	120.13	South Point SMR	In
Bee Rock	33.95	120.20	South Point SMR	Out
San Miguel Island				
Prince Island (North/South)	34.06	120.33	Harris Point SMR	In
Cuyler (East/West)	34.05	120.34	Harris Point SMR	Out
Hare Rock (North/South)	34.06	120.36	Harris Point SMR	In
Crook Point (East/West)	34.02	120.34	Judith Rock SMR	Out
Wyckoff Ledge	34.02	120.39	Judith Rock SMR	Out
Tyler Bight	34.03	120.41	Judith Rock SMR	Out

Appendix C.
List of Monitored Shallow Subtidal Species

Fish Species

Common Name	***Species***
Black & Yellow Rockfish[3]	*Sebastes chrysomelas*[3]
Black Surfperch[1]	*Embiotica jacksoni*
Blackeyed Goby[2]	*Coryphopterus nicholsii*
Blacksmith[2]	*Chromis punctipinnis*
Blue Rockfish[2]	*Sebastes mystinus*
Bluebanded Goby[2]	*Lythrypnus dalli*
Cabezon[1]	*Scorpaenichthys marmoratus*
California Scorpionfish[3]	*Scorpaena guttata*
Copper Rockfish[3]	*Sebastes caurinus*
Garibaldi[1]	*Hypsypops rubicundus*
Gopher Rockfish[3]	*Sebastes carnatus*
Island Kelpfish[2]	*Alloclinus holderi*
Halfmoon[3]	*Medialuna californiensis*
Kelp Bass[1]	*Paralabrax clathratus*
Kelp Greenling[3]	*Hexagrammos decagrammus*
Kelp Rockfish[1]	*Sebastes atrovirens*
Kelp Surfperch[3]	*Brachyistius frenatus*
Lingcod[3]	*Ophiodon elongatus*
Ocean Whitefish[3]	*Caulolatilus princeps*
Olive Rockfish[2]	*Sebastes serranoides*
Opaleye[2]	*Girella nigricans*
Painted Greenling	*Oxylebius pictus*
Pile Perch[2]	*Damalichthys vacca*
Rainbow Surfperch[3]	*Hypsurus caryi*
Rock Wrasse (male/female)[2]	*Halichoeres semicinctus*
Rubberlip Surfperch[3]	*Rhacochilus toxotes*
Señorita[2]	*Oxyjulis californica*
Sheephead (male/female)[1]	*Semicossyphus pulcher*
Striped Surfperch[2]	*Embiotica lateralis*
Treefish[2]	*Sebastes serriceps*
Vermillion Rockfish[3]	*Sebastes miniatus*
Yellowtail Rockfish[3]	*Sebastes flavidus*

[1] species recommended during MPA monitoring workshop, March 2003 or listed in the Channel Islands Marine Protected Areas Monitoring Framework DRAFT document May 29, 2003
[2] species from Kelp Forest Monitoring Handbook, National Park Service
[3] other recommended species

Invertebrate Species

Common Name	*Species*
Red Abalone[1]	*Haliotis rufescens*
Black Abalone[1]	*Haliotis cracherodii*
Green Abalone[1]	*Haliotis fulgens*
Pink Abalone[1]	*Haliotis corrugata*
Bat Star[1]	*Asterina miniata*
Brown Gorgonian[3]	*Muricea fruticosa*
CA Golden Gorgonian[3]	*Muricea californica*
California Hydrocoral[1]	*Stylaster californicus*
California Sea Cucumber[1]	*Parastichopus californicus*
California Sea Hare[1]	*Aplysia californica*
California Spiny Lobster[1]	*Panulirus interruptus*
Chestnut Cowrie[1]	*Cypraea spadicea*
Giant Keyhole Limpet[1]	*Megathura crenulata*
Giant Spined Sea Star[1]	*Pisaster giganteus*
Kellet's Whelk[1]	*Kelletia kelletii*
Ochre Sea Star[1]	*Pisaster ochraceus*
Orange Puffball Sponge[1]	*Tethya aurantia*
Purple Sea Urchin	*Strongylocentrotus purpuratus*
Red Gorgonian[3]	*Lophogorgia chilensis*
Red Sea Urchin[1]	*Strongylocentrotus franciscanus*
Red Top Snail[1]	*Lithopoma gibberosum*
Rock Scallop[1]	*Crassedoma giganteum*
Sheep Crabs[3]	*Loxorhynchus spp.*
Short Spined Sea Star[1]	*Pisaster brevispinus*
Stalked Tunicate[1]	*Styela montereyensis*
Sunflower Star[1]	*Pycnopodia helianthoides*
Warty Sea Cucumber[1]	*Parastichopus parvimensis*
Wavy Top Snail[1]	*Megastraea undosa*
White Sea Urchin[3]	*Lytechinus anamesus*

[1] species recommended during MPA monitoring workshop, March 2003 or listed in the Channel Islands Marine Protected Areas Monitoring Framework DRAFT document May 29, 2003
[2] species from Kelp Forest Monitoring Handbook, National Park Service
[3] other recommended species

Algal Species

Common Name	*Species*
Acid Kelps[1]	*Desmarestia spp.*
Bladder Chain[1]	*Cystoseria spp.*
California Sea Palm[1]	*Pterygophora californica*
Feather Boa[1]	*Egregia menziesii*
Giant Kelp[1]	*Macrocystis pyrifera*
Oar Weed[1]	*Laminaria farlowii*
Sieve Kelp[1]	*Agarum fimbriatum*
Southern Sea Palm[1]	*Eisenia arborea*

[1] species recommended during MPA monitoring workshop, March 2003 or listed in the Channel Islands Marine Protected Areas Monitoring Framework DRAFT document May 29, 2003
[2] species from Kelp Forest Monitoring Handbook, National Park Service
[3] other recommended species

Appendix D.
Proposed Survey Methodology for Collecting
Additional Sea Urchin Information[1]

The following proposal is taken from a contracted recommendation made to the Sea Urchin Harvesters Advisory Committee by Drs. Jeremy Prince and Ray Hilborn. Their recommendation is for data collection throughout California. It is included here for its potential to increase data collection at the Channel Islands.

Introduction - The Concept of Scientific Fishing

The context for developing the fishing industry's capacity for involvement in stock monitoring, research and stock assessment is this; the modern fishing industry has a tendency to develop excess fishing capacity while the associated government agencies see their own resources progressively limited by budget cuts and expanding mandates and work loads.

The idea behind Scientific Fishing is to expand the concept of commercial fishing to include 'fishing for data' alongside the aim of 'fishing for profit'. In most fisheries careful observation will reveal opportunities by which slight modification to normal fishing practices can create opportunities for collecting enhanced levels of fishery-dependent data and even fishery-independent data, with minimal (or at least acceptable) impact on normal commercial profitability. By taking advantage of these opportunities the excess capacity of the fishing fleet can hopefully bolster the development of sustainable fisheries.

The idea of using the fishery to collect fishery independent data may seem a contradiction in terms. But the concept of fishery independent involves independence from the processes that change fishing patterns over time, influencing catch and effort trends and undermining their value as indices of stock abundance. Fishery independent data can be collected with the fishing fleet if means can be found to insulate the data collection from the impact of changing fishing patterns. In the current situation the aim is to collect fishery independent data with sea urchin divers by designing a system that will remain independent from the fishing practices that may evolve over time in the fishery.

Another concern that commonly arises about using fishing fleets to collect data is the lower level of precision that may result from involving trained fishers rather than trained scientists. Inevitably designing a data collection system which can be inserted into commercial fishing practices will involve compromising on the techniques that might be deployed by a team of scientists. However the aim in this respect is to minimize the uncertainty around estimated population abundance trends and so increase the power for detecting significant changes over time. Uncertainty in the estimate of average values is determined by both the number of samples and the level of precision in each measurement. Both increasing the number of samples, and the precision of each measurement will reduce the level of uncertainty

[1] Adapted from: Prince, J. and R. Hilborn, 2003. The Development of Industry Based Sustainability Surveys for the Californian Sea Urchin Fishery Advisory Committee, report to the Sea Urchin Harvest Advisory Committee, 54 p.

around an estimated trend. There is always a compromise that can be reached between collecting small (numerically limited) sets of highly precise data and collecting large sets of much less precise data.

Within the context of scientific fishing the aim is to bolster the sample size to such an extent that despite the loss of sampling precision the estimated level of uncertainty is reduced. Some provisional estimation of the extent of sea urchin beds and the likely data density required to estimate spatial trends across the fishery can provide the context for the approach being suggested here.

Interviews with commercial divers indicated that considerable areas of unfished sea urchin ground exist for a range or reasons; poor roe quality, excessive depth, and low or patchy sea urchin abundance etc. It was estimated that at the Farallon Islands as little as 30% of the sea urchin grounds may be commercially harvested, this is probably an extreme case, but perhaps along the Californian coast as much as 50% of the red sea urchins may not be fished.

For the sake of these ‘ball-park' estimates the published (CDFG 2001b) maximum estimate for the area of giant kelp canopy along the entire Californian coast (70 square miles in 1967) will be used as a proxy for the total area of sea urchin beds, and arbitrarily assume that the lower 1989 estimate of the area of giant kelp canopy (40 square miles) provides an estimate of the smaller area of commercially utilized sea urchin grounds. Further the survey protocol proposed below will be assumed to take one hour of bottom time for a commercial diver to sample the sea urchin abundance over an area of approximately 150' x 150'.

Using these estimates some 1200 surveys per year could achieve a sampling density of 30 surveys per square mile of commercially utilized sea urchin ground. Assuming one third of an industry of 300 divers could be encouraged to undertake surveys this would require 12 surveys per year by each participating diver. Further assuming that each diver could complete 3 surveys per day this would require the 100 volunteers undertaking 4 days of surveying each year. Alternatively a smaller team of 20 divers could complete the 1200 surveys if they were prepared to undertake surveys on 20 days each year.

It has to be admitted that this level of coverage would only provide coverage of a little over 2% of the commercial grounds which here are estimated as being 40 square miles in area. However the context for this level of coverage is given by the scope of the CDFG sea urchin and abalone transects which during the summer of 2003 reportedly entailed 85 30m x 2m transects (CDFG Newsletter October 2003). Using the same estimates of reef area this is equivalent to just 0.00004% of the area of the fishery. When considering the trade-off between precision and sample size in determining the reliability of estimated trends, this comparison suggests the strictly scientific technique will need to be something like 5 orders of magnitude (100,000 times) more precise than the industry technique to provide data of equivalent reliability. This would seem to provide the industry surveys with a considerable level of flexibility to trade off lower precision for a level practicality which will encourage commercial divers to voluntarily participate, while still improving the quality of the data available for stock assessment.

These estimates are just the tip of the iceberg in comparison to what might be achieved if the approach recommended here can be made practical enough to eventually be taken up as a routine part of normal commercial operations in this fishery. During 2002 the CDFG logbooks suggest some 54,191 hours were spent harvesting sea urchins. On the basis of previous estimates this represents the potential for annually surveying some 110% of the fishery.

Clearly these numbers are extremely rough but they indicate both the general feasibility of the approach being recommended and the great potential that could be unlocked if practical means can found to harness the existing dive power of the fishery for collecting survey data.

Overview

There would eventually be three types of surveys collected in the proposed design for the fishery:

- First would be electronic logbook entries for divers collected as a routine part of normal commercial operations. These fisheries dependent data will utilize survey protocols developed for commercial divers to gather enhanced relative indices of abundance (CPUE) for commercial fishing areas and develop detailed maps of the commercial beds. The aim of this survey system would be to develop trend based estimates of biomass and sustainable yield for the sea urchin beds supporting the commercial fishery.

- Second would be a fixed point survey design conducted by volunteer divers on designated survey days using the same survey protocols developed for normal commercial diving. The fixed survey points would be distributed across all known sea urchin beds on the basis of maps developed during the fishery dependent surveys (see above). The fishery independent survey system would gather relative indices of abundance for both commercial and non-commercial sea urchin beds with the aim of developing trend based estimates of biomass and sustainable yields for the entire Californian sea urchin resource.

- Thirdly would be the research surveys currently being conducted by the government agencies working with the sea urchin industry. These surveys are based on fewer survey sites, but use more precise survey techniques, than is proposed for use by commercial divers. Besides providing the agencies a means of verifying industry surveys, an additional research project could aim to calibrate the relative densities measured by the industry surveys. If this were achieved it may be possible to convert industry surveys into more immediately useful estimates of absolute biomass.

These three forms of surveys are complimentary and the exact ratio of effort allocated to the three methods will undoubtedly evolve over time. The emphasis in this report is on the design of surveys to be conducted by commercial sea urchin divers rather than the surveys which will be conducted by the researchers of CDFG.

Survey Protocols

The scientific protocols will probably stay under development for some period as techniques are trialed in the field and, where they are found to be impractical, modified to suit conditions. Once a body of data has been gathered it will also be necessary to analyze their statistical power, in turn this analysis may suggest further modifications to the survey protocols. In this report a suggested approach is provided for developing these protocols and developing systems and processes for handling and analyzing the data that will be collected.

In this context the developmental work that has already been conducted in this respect by Steve Schroeter since January, 2002 when discussions first began about involving the industry more fully in data collection and stock assessment must be acknowledged.

Fishery Dependent and Fishery Independent Data Sets

The long term aim is to equip sea urchin industry to gather two overlapping but slightly different data set using the same basic protocols and data handling systems.

The first data set will be a Fishery Dependent data set collected as a part of normal commercial diving on urchin beds selected by participating diver for their own commercial reasons. As already demonstrated by the data collected by just one diver working in collaboration with Schroeter, and presented to the Los Alamitos workshop (Appendix 1) these data will be useful for mapping out the commercial sea urchin beds and tracking the abundance and size profile of sea urchins in those beds. These data will track trends within the commercial fishing grounds and changes that might occur in the extent and location of commercial fishing grounds. Over time the comparison of stock trends and commercial catch should make it possible to estimate the biomass and sustainable yield of urchins on the commercial beds. However this data set will always be liable to influence by factors which influence commercial fishing patterns and their spatial distribution can be expected to change if the area of commercial beds change.

The second data set will be the Fishery Independent data set. It will incorporate and extend the first data set. Its aim will be to systematically gather representative data from all existing sea urchin beds and not just the beds being used commercially. The aim of this will be to derive estimates of the total biomass that are not influenced by changing fishing practices. Besides enabling sea urchin populations in both commercial and non-commercial areas to be monitored, this data set could also be designed to monitor abundance trends inside MPAs.

Fishery Dependent - Survey Protocol

The aim here is to develop a protocol that can be potentially repeated every day of commercial diving and preferably every dive if divers move more than 200-300 yards between dives i.e. every new dive spot. The rationale of this is to derive the greatest possible coverage of the fishery. Beyond some minimum amount of data required to provide adequate coverage it will not be critical if data is not collected every dive. However if too few data are collected, or there is insufficient coverage over large areas of the fishery, the data set will have limited statistical value. To maximize there usefulness these data would ideally be dispersed relatively evenly across the entire area of commercial sea urchin beds.

At each dive site the following data should be recorded:

- Commercial catch in lbs (and numbers if possible)
- Total dive time (all divers)
- Number of divers
- A size profile
- An index of total area searched
- Associated observations of dive conditions which could be incorporated into a covariate analysis (i.e. Kelp & Current conditions, Visibility, Bottom Roughness)

The first two of these elements are self evident and are already being collected for existing logbooks for every dive. The last three elements may require some further developmental discussion and/or research by SUFAC, although Schroeter already has in place operational protocols. The principal here is that some level of standardization is required, but there will also need to be a trade-off between techniques that are relatively crude, quick and easy, and those that are more precise but so much trouble to complete no-one will volunteer to do them regularly. In this trade-off SUFAC will be advised to adopt the crude, quick and easy option with the aim of collecting a larger body of data (the more the better). It may also be that by collecting some associated observations of dive conditions crude measures can be improved through the application of covariate analyses.

Size Profile Data

The size profile of a population and the way it changes over time provides a lot of stock assessment information.

The first principle here is that the size profile of both sub-legal and legal size urchins is required. This provides information on the abundance of size classes that will grow into the fishery, and the fishing pressure on legal-sizes urchins. For this purpose the protocol developed by Schroeter of collecting 30 sea urchins for measurement, regardless of their size is recommended. These should be bagged separately and measured at the end of the dive.

The rationale for this sample size is that while 30 is an inadequate number for a single length-frequency histogram, current regulations allow a sea urchin diver to have up to 30 sub-legal urchins aboard their vessel without being in breach of the law. This provides a pragmatic basis for collecting size distributions of both legal and sub-legal sized animals during normal diving operations. By itself a sample of 30 sea urchins will be an inadequate size sample, however aggregated over three dives per day, a total of 90 measurements begins to approach a reasonable sample size on a daily basis, and aggregated over approximately 10-30 dives per square mile of productive sea urchin ground it produces a sample size of around 300-900 individuals which provides a reasonable basis for following fine scale spatial variability in size profiles across the fishing grounds.

It may also be worth establishing a lower size limit below which SUFAC is consciously not searching for sub-legal size sea urchins. This is for the purpose of practicality. In some areas an extended search could probably locate urchins down to a test diameter of 1-2 inches. But data on these animals will be patchy and time consuming to collect. A lower size limit should be established for the purpose of the survey protocol, probably around 2.0-2.5 inches.

The second principle in collecting size profile data is that the sample being measured should be collected in a way that avoids the natural human tendency to unconsciously select the biggest individuals, or bias the sample in any other way. The sample should accurately portray what is on the bottom. This can be done in a number of ways. The important thing here is not necessarily for the technique to be exactly the same in every instance. The important point is to discipline the selection of the sample to be measured, and so avoid the common source of bias which results from unconsciously selecting bigger individuals in preference to smaller individuals. It may be that the protocols which achieve this aim vary between ports to reflect differing conditions in each port.

Possible techniques for avoiding this sort of bias could include:

- Where anchors are dropped into the middle of a commercial urchin bed select the 30 urchins found closest to the anchor.
- Where the boat is anchored off-shore and divers swim into the commercial bed a shot-line could be thrown inshore to the commercial bed and the urchins sampled around the anchor of the shot-line.
- Alternatively the diver could swim their net-bag onto the urchin aggregation and having selected the point at which they will begin collecting urchins commercially (say a density of at least three urchins per square meter), stop and collect the 30 urchins closest to their net-bag for their sample.
- Scientists tend to use methods which define a fixed area, say with a square metal quadrat, or by tethering themselves in some way, and then collecting all the animals in the defined area. This is obviously the most rigorous means of disciplining sampling but commercial divers may find the use of quadrats and tethers too impractical to combine with commercial diving.

All these techniques are valid. The important thing is to discipline the natural tendency to skim over little animals that may be easily hidden in kelp or crevices, and selectively take just the bigger more obvious individuals.

<u>An Index of Swept Area (Area Searched)</u>

Typically in a dive fishery catch rates remain extremely stable over a wide range of stock densities because divers search visually and swim further as densities decline. For this reason recording some measure of the area searched by a diver to make their catch will greatly improve estimates of stock abundance.

SUFAC should develop an agreed protocol for estimating and recording a measure of searching area.

The important principle in this is not that the area searched should be measured precisely. A precise measurement will probably be too difficult, few people will volunteer to do it on a daily basis as it will be too time consuming and significantly reduce commercial catch rates. Instead a simple but efficient method that records gross changes over time will suffice if it is simple and easy enough to be done repeatedly.

At least two methods will be necessary; one for hookah divers working at anchor, and another for nitrox and hookah divers who work without anchoring. Techniques that could be used include:

- Rigorously scientific techniques normally place a strong emphasis on accurately defining survey areas and deploy a leash attached to a central point (i.e. Ugoretz, et al. 1997), a square (quadrat) or circular (hoop) of fixed size, or a straight line transect which is searched out to a given width on either side (CDFG survey protocol). All these methods will be highly precise but potentially too laborious to be consistent with commercial diving practices and so unlikely to be practical in the long-run.
- An alternative for divers using hookah equipment from an anchored boat would be to record the length of hose dragged off the vessel during each dive. This could be facilitated by marking hoses with paint or tape at fixed intervals. This suggestion has been criticized because strong currents in some areas or at some times will also drag hose off a vessel. This might be partially controlled by tying off a length of hose, which to some extent would make it similar to the leash method mentioned above. Variation in kelp coverage will also cause some variation in the length of hose used. Across the data base that will be developed both these factors might be accounted for by recording some basic data on dive conditions (current strength, kelp coverage and visibility). Over time these data could be used as part of a covariate analysis which might derive statistical correction factors.
- Nitrox divers do not have the option of measuring hose length; however they apparently make greater use of GPS and plotters. These devices could be used to estimate the length and breadth of the area covered by the divers.
- Hookah divers working live, or without anchoring could similarly use GPS and plotters to calculate a similar index.
- In a similar way hookah divers working at anchor could use their own knowledge of the reef they are working, together with the length of their hoses, or other measures of distance (GPS or visual estimation) to roughly estimate an equivalent width and breadth of the area being worked.
- Alternatively, along the lines developed by Schroeter, maps of the kelp beds could be overlaid with a fine scale grid system and divers record the cells they dive through during each dive.

In choosing which of these methods to adopt SUFAC members will be forced to decide between precise measures which are laborious to use and which consequently deter their members from using them and an apparent lack of precision. Importantly the technique that is adopted should interfere minimally with normal commercial catch rates.

It should be borne in mind that in most cases a large amount of relatively imprecise data will still measure gross changes (trends) over time more accurately than a few highly precise measurements. The pertinent advice here is “Do NOT get hung up on detailed measurements when it is the bigger longer term trends which are important.” Any of these measures of swept area will add significantly to the simple catch and effort data currently being collected, even though they will at times and in places produce poor quality data points.

SUFAC should trial these techniques and determine which methods are most applicable for their circumstances before scaling up the system to encompass the entire fishery.

Data Analysis

In the short term (1-3 years) these fishery dependent data will be used to map the commercial sea urchin beds and monitor the size profile of the sea urchins they contain. In the longer term (5-10 years) these data could be used to estimate catch rate trends on the basis of both dive time and swept area. These data will provide a solid preliminary basis for quantitatively assessing the stock in the commercial beds.

As discussed below, if an additional program of research is conducted to calibrate the measure of swept area adopted by SUFAC with actual urchin densities (i.e. urchins per unit area) these data could also be used in the shorter term (2-3 years) to estimate the absolute biomass of urchins within the commercial urchin beds. Potentially this estimate of absolute biomass, together with existing estimates of natural mortality, could be used much more quickly to derive a relatively accurate estimate of the sustainable yield of urchins in the commercial beds.

Fishery Independent - Survey Protocol

The survey protocol outlined above will only derive data for the portion of the urchin resource fished commercially. The extent and location of commercially utilized grounds is likely to change over time as kelp conditions cycle, roe prices vary, and urchin abundance and roe condition varies. This variation will tend to confound biomass estimates produced using fishery dependent data.

A fishery independent approach will be necessary if the industry has an interest in deriving estimates for the total sea urchin resource of California. This could be done using industry’s knowledge of non-commercial sea urchin beds to map the full extent of sea urchin beds. Survey points would then be selected spread as evenly as possible throughout the full extent of the non-commercial sea urchin beds and the survey protocol outlined above would be conducted at each of these points. When combined with the fishery dependent data set this additional data would make it possible to estimate the total biomass of sea urchins and the potential sustainable yield if all urchin beds were to be utilized.

As noted above, this extension of the survey protocol could also be used to monitor trends within MPAs and so compare trends in sea urchins population outside and inside MPAs.

Design Phase

The initial phase of implementing fishery independent surveys would be a mapping and design phase. The aim of the design phase would be to ensure that through a combination of the two survey systems data is gathered from across the entire urchin resource.

The first step in the design phase would be to convene a meeting in each port with all interested divers and to map the complete extent of sea urchin beds for that area. The starting point for this mapping exercise should be the spatial data already collected through the fishery dependent survey program. Diver knowledge would then be used to map in urchin beds that have not been covered sufficiently by that survey system. The mapped urchin beds would be extended through this process to include; historically fished areas that are no longer fished either because of market or abundance, and areas that have rarely if ever been fished because of poor roe quality and other factors.

On the basis of these maps survey sites (GPS points) would be selected with the aim of gathering data in the areas where insufficient data already exist. These additional survey points should be selected through some relatively random process which has the aim of distributing survey points relatively evenly throughout the urchin beds that have not been covered sufficiently by the fishery dependent survey.

Assuming the total area of urchin grounds is similar to the published maximum estimate (1967) for the area of giant kelp canopy beds (i.e. around 70 square miles) and a density of 20 sampling points per square mile can provide a reasonable index of the resource, something like 1,400 survey dives could be necessary. However, a considerable proportion of this area will probably already be covered through the fishery dependent surveys. If 40% of the total resource is assumed to already have a reasonable coverage of data only a further 840 survey points would be necessary to upgrade the fishery dependent survey into a more complete and rigorous fishery independent survey. Undertaking 3 survey dives per day this would take a team of 30 volunteer divers approximately 9-10 days of diving to complete.

Survey Protocol

The survey protocol at each selected sampling site would be the same as described above for the fishery dependent surveys. The only difference being that because the additional survey points will be mainly distributed through non-commercial fishing grounds the survey divers will probably wish to minimize the dive time involved. In this situation a 30-60 minute dive at each survey point would probably be sufficient to obtain both a size sample and record a characteristic catch, dive time and area searched.

Data Analysis

Assuming the additional program of research has been conducted to calibrate the measure of swept area adopted by SUFAC with actual urchin densities (urchins per unit area), it will be possible to use the data collected from the combination of fishery dependent and independent survey system to directly estimate the total biomass of the entire Californian urchin resource. With this estimate and published estimates of natural mortality sustainable yields could be derived.

In the absence of a calibration factor a 5-10 year time series of these combined surveys could be used to estimate trends in relative abundance which in comparison to commercial catches could be used to derive estimates of biomass trends and sustainable yields.

Appendix E.
Methods for ROV Site Surveys

Methods were developed for ROV surveys that would parallel the CRANE/PISCO shallow subtidal SCUBA site design while accommodating the broad depth range and various slopes expected for nearshore ROV sampling. The method is designed to utilize advantages of the ROV in allowing long, linear dive transects (Barry and Baxter 1993). In addition the design was intended to gradually move up slope, minimizing down-slope segments that are difficult to capture on forward video. The design also provides flexibility to accommodate the 20-100 m depth range designated as optimal for ROV sampling. As for shallow subtidal SCUBA surveys, sites within and outside reserves will be monitored.

Figure E1 illustrates a hybridized approach between running the ROV parallel and perpendicular to the depth contour across a depth change from 2 km to 0.5 km within the 20-100 m target depth range. Due to the limitations inherent to ROV and advantages of a long transect line, a systematic random approach was developed (Barry and Baxter 1993). The design is to zigzag from deep to shallow at all (A-C) but the most extreme depth slopes. The exception (D) is for parallel lines spaced 63 m apart when this depth range occurs over 500 m or less. Both the zigzag and parallel approach produce useable legs 510 m long. When these legs are divided systematically into non contiguous strip-transects spaced 10 m apart, they provide 13, 8, and 7 transects of 30, 60, or 90 m length, respectively (Table E1). Both designs provide a buffer where a pivot or vessel turn is needed. Pivot or turn points can also provide stops for sonar capture and needed navigational corrections of both the mother ship and the ROV. The buffer allows sufficient "run-way" for re-establishing the needed paired heading and velocity of both vessels. For example, (A) to (C) provide pivot spacing ranging from 613 to 574 m apart, respectively (Figure E1). Each of the examples illustrated encompasses a site 500 m wide except the parallel spaced site (D) which spans 510 m with added 30 m buffers on each side for turns. Site D could also span 500 m but would thus only allow for 24, not 26 - 30 m transects spaced by 20 m depth strata.

This design effectively provides 26 systematically random placed 30 m transects at each range of depth strata (21-40, 41-60, 61-80, and 81-100 m). Average depth of transects is expected at 30, 50, 70, and 90 m in each of the designs A-C and D, respectively. If a greater number of transects is desired, especially for rare events or linger transects, sites A-C can be replicated from deep to shallow starting from the opposite corner in a cross hatched pattern. The parallel method (D) can be replicated with an offset of 31 m.

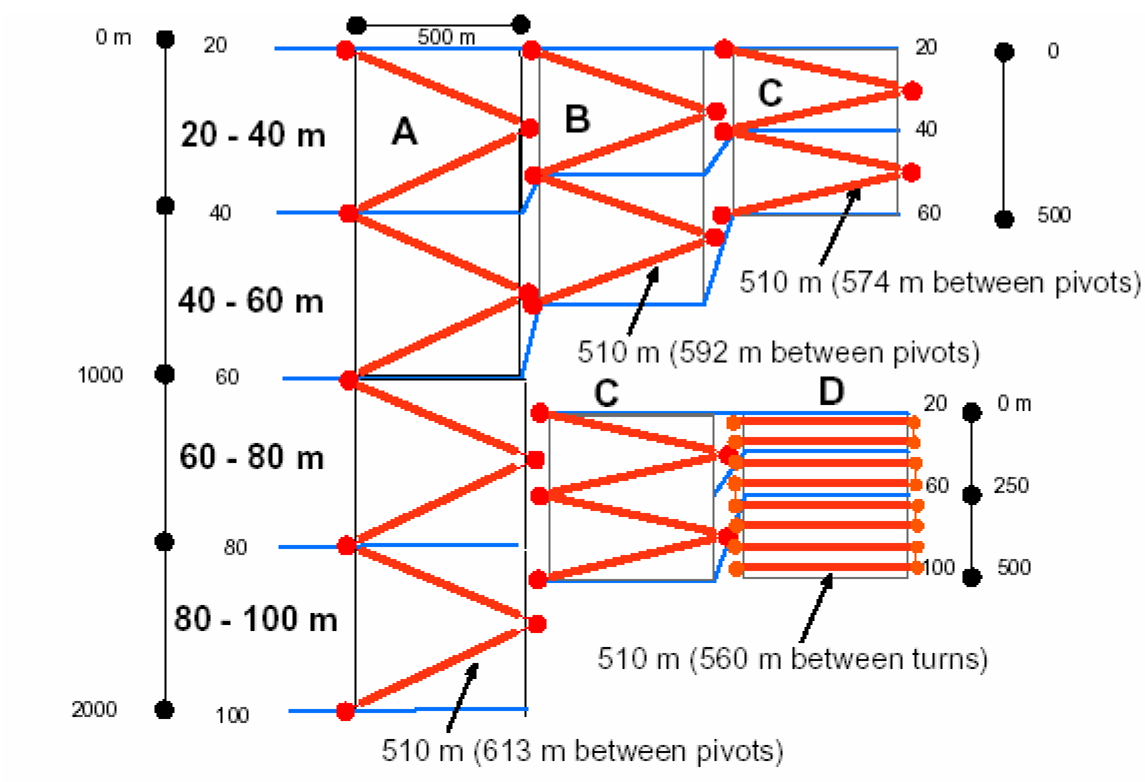
In addition to this spatial orientation, transects will be kept linear and the ROV flown at a constant velocity to provide complements to navigational precision needed to augment tracking imprecision inherent in the Track 2 technology. A planned buffer of ± 10 m will surround each 510 m planned leg to provide piloting reference to both the pilot of the ROV and the ship's captain.

Table E1. Site leg distances and transect numbers using zigzag method across 500 m of shoreline at various depth contours.

Figure 1 reference code	Depth change of 20 m Distance (m)	Site Width Distance (m)	Point to Point Pivot distance(m)	Tracked Distance Leg length (m)
A	125	560	560	510
B	250	560	574	510
C	386	560	592	510
D	500	560	613	510

	Number of transects per leg spaced 10 m apart per 10 m of depth change.		
Figure 1 reference code	30 m transect	60 m transect	90 m transect
A	13	8	7
B	13	8	7
C	13	8	7
D	13	8	7

Figure E1. Hybridized approach between running the ROV parallel and perpendicular to depth contours.



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