Evaluation and Augmentation of the Shallow Subtidal Monitoring Plan for the Channel Islands National Marine Sanctaury Marine Protected Areas

The Donald Bren School of Environmental Science and Management,
University of California, Santa Barbara

Submitted by:
Adina Abeles
Kevin Afflerbaugh
Larry Chiang
Ben Pitterle
Matt Stadler

Clients: California Department of Fish and Game
NOAA Channel Islands National Marine Sanctuary

Advisor: Dr. Hunter Lenihan

Evaluation and Augmentation of the Shallow Subtidal Monitoring Plan for the Channel Islands National Marine Sanctuary Marine Protected Areas

As authors of this Group Project report, we are proud to archive it on the Bren School's web site such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Donald Bren School of Environmental Science & Management.

_____ _____

Adina Abeles Kevin Afflerbaugh

_____ _____

Larry Chiang Benjamin Pitterle

_____

Matthew Stadler

The mission of the Donald Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) Program. It is a four-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

_____

Hunter Lenihan, PhD
May 2004

_____

Dean Dennis Aigner
May 2004

Abstract

On April 9th, 2003 a network of 12 Marine Protected Areas (MPAs) was established in the California State waters of the Channel Islands National Marine Sanctuary (CINMS). These MPAs were implemented in part to protect ecosystem biodiversity and achieve sustainable fisheries. To determine if the MPAs are an effective conservation and management tool, the California Department of Fish and Game (CDFG) was charged with developing a biological monitoring plan to detect the effects of MPAs on marine biological resources. Our group worked with CDFG, CINMS, scientists, and fishers to help develop and evaluate this monitoring plan. Development began by assembling a summary of existing research programs within the Sanctuary and by hosting a Biological Monitoring Workshop to obtain expert advice. Analysis was performed on two benthic invertebrate sampling protocols incorporated by the plan to determine whether the protocols are statistically comparable and powerful, and therefore useful as baseline monitoring data. A monitoring program for California spiny lobster (*Panulirus interruptus*) was created to address sustainable fishery goals of CINMS. Finally, we developed a database to manage data from multiple research programs and a website to provide public outreach and research coordination for future monitoring efforts. These project deliverables will assist in evaluating the effectiveness of the MPAs as a marine resource conservation and management tool.

Acknowledgements

Satie Airame, PhD and Sean Hastings from the Channel Islands National Marine Sanctuary; John Ugoretz from the California Department of Fish and Game; David Kushner and Gary Davis from the National Park Service; Bruce Kendall, PhD and Hunter Lenihan, PhD of the Donald Bren School of Environmental Science and Management at the University of California, Santa Barbara; Burr Heneman of Commonweal Ocean Policy Reform; Jenn Caselle, PhD and Chris Jones of the Partnership for the Interdisciplinary Studies on Coastal Oceans; Kathy Ann Miller, PhD of the Wrigley Institute for Environmental Studies; Jack Engle of the Marine Science Institute, at the University of California, Santa Barbara; California Sea Grant; Nick Caputi, PhD Fisheries Western Australia; Craig Barilotti, Seafoam Enterprises; Bernardo Broitman from the Ecology, Evolution, and Marine Biology at the University of California, Santa Barbara; Merit McCrea, Chris Miller, Bruce Steele, and Ken Bortolazzo.

Executive Summary

The Channel Islands National Marine Sanctuary (CINMS) was established in 1980 with the primary goal of protecting the natural and cultural resources of the Channel Islands and is now one of 13 marine sanctuaries in the United States. The CINMS is located approximately 46 kilometers off the coast of Santa Barbara and Ventura Counties, California and surrounds the five northern Channel Islands of Anacapa, Santa Cruz, Santa Rosa, San Miguel and Santa Barbara. The CINMS encompasses the waters surrounding these islands, which extend from mean high water to 11 kilometers offshore, and encompasses a total area of 3,756 square kilometers.

Anthropogenic perturbations in CINMS and oceans everywhere have increased significantly in recent decades, leading to negative impacts on marine resources. Over-fishing, climate change, habitat destruction, pollution, coastal development, and non-native species invasions are just a few of the perturbations that threaten the world's oceans (Pew Ocean Commission, 2003). These threats have left many marine populations at a fraction of their historical levels (Jackson et al., 2001). Human activities also have changed the structure and function of marine ecosystems, thereby threatening the health and economic well-being of the human populations that rely on them. A number of marine management and conservation techniques are being implemented to abate ecosystem degradation and restore marine resources. One such technique is the establishment of Marine Protected Areas (MPAs).

MPAs are sections of the ocean that are set aside with varying degrees of protection, ranging from limited extraction of some resources to the prohibition of all extractive activities. In general, MPAs are shown to cause increases in the size-frequency, biomass, and abundance of species within their boundaries and can have positive spillover effects outside their boundaries (Halpern, 2003). However, MPAs are a controversial management tool, particularly among fishers, who believe that MPAs result in unnecessary access restrictions and economic hardship. There also is debate about the effectiveness of MPAs due to the inherent complexity of marine ecosystems. Nevertheless, the need for ecosystem protection and concern from California citizens resulted in the establishment of a network of 12 MPAs within CINMS on April 9th, 2003.

The 12 CINMS MPAs are located in State waters, which extend from mean high tide to 4.8 kilometers offshore. The MPAs cover a total area of 350 square kilometers that encompasses approximately ten percent of CINMS waters. Ten of the new MPAs are designated "no-take" areas, which prohibit all extraction of living, geological, or cultural resources. Two of the MPAs allow only limited take of California spiny lobster and pelagic finfish. The MPA network was created to conserve ecosystem structure and function and to help maintain long-term production in local fisheries. The only means of evaluating whether MPAs are an effective marine resource tool is to monitor them through time. Our Donald Bren School Masters of Environmental Science and Management (Bren School) group project focused on the development, design, implementation, and administration of a biological monitoring plan for the CINMS MPA network.

The California Department of Fish and Game (CDFG) is the agency charged with monitoring the MPAs, and the continued existence of MPAs may rely on CDFG's ability to monitor effectively. However, CDFG required assistance to design and enact a comprehensive monitoring program. Our group worked with regulatory agencies, scientists, and fishers to evaluate and improve CDFG's Draft Biological Monitoring Framework for the MPAs through seven project components.

The components of our project included: (1) collecting and summarizing the existing biological and ecological research programs within the Santa Barbara Channel, (2) assisting with a biological MPA monitoring workshop to formulate monitoring recommendations, (3) performing statistical analysis on the power and comparability of the benthic species monitoring protocols chosen by CDFG, (4) development of a spiny lobster MPA monitoring plan to help address fishery concerns, (5) collection of local ecological knowledge to assist with the new MPA site selection process and the development of a spiny lobster monitoring plan, (6) creation of a central database to manage data from various biological MPA monitoring efforts, and (7) construction of a MPA monitoring website to improve public outreach and to facilitate improved MPA monitoring coordination. These seven components are described sequentially below.

Problem formulation and data collection

An initial component of our project was to assist with the compilation of existing biological and ecological research programs within the Santa Barbara Channel. This summary served two purposes: (1) to determine if existing research throughout CINMS could be used to evaluate the MPAs; and (2) to help plan the Channel Islands Marine Protected Areas Monitoring Workshop. Information from 43 research programs was collected regarding the research questions addressed by each program, the study organisms and research techniques, and the locations of each program's research sites within the Santa Barbara Channel. The document summarizing the existing monitoring programs can be found at: http://www.dfg.ca.gov/mrd/channel_islands/existing_research_programs.pdf.

The research summary document was instrumental in planning the Channel Islands Marine Protected Areas Biological Monitoring Workshop, held at the Bren School in the spring of 2003. The workshop brought together more than 60 researchers, regulatory officials, environmental group representatives, and stakeholders to help develop preliminary MPA monitoring efforts in CINMS and to provide monitoring recommendations. Our group recorded recommendations from this workshop and worked with CDFG to produce the Summary of Monitoring Worksheet Results. Our group chose five major monitoring recommendations for further consideration. These recommendations were: to focus on a monitoring design that used paired sites (inside vs. outside MPAS) in the shallow subtidal ecosystem; to address fishery monitoring; to incorporate local ecological knowledge in the monitoring process; to address database management concerns; and to improve public outreach.

Evaluation of Draft Monitoring Framework

Due to limited funding, CDFG is relying primarily on existing and on-going research programs within CINMS for biological monitoring data. One type of biological monitoring consists of measuring the density of benthic organisms that inhabit communities on the shallow subtidal seafloor. CDFG selected the National Park Service (NPS) Kelp Forest Monitoring Programand the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) as the two primary benthic community-monitoring programs from which data will be combined and used to assess the CINMS-MPAs. Our objective was to test whether data from the two programs were statistically similar, thereby providing a robust, flexible, and geographically broad baseline data set. Using ANOVA, we determined that the NPS and PISCO sampling programs are sufficiently comparable for use by CDFG.

We also performed a statistical power analysis to determine whether the NPS and PISCO benthic community sampling data will provide enough power to detect statistical differences in the density of benthic organisms inside and outside the MPAs if they occur. Statistical power is a function of sample size, variation in the data, and the size of effect of the experimental treatment, in this case, the implementation of the reserves. Results from our analysis indicate that sufficient power to detect change in benthic communities could be a challenge for CDFG using these protocols and the proposed number of samples.

In addition to providing statistical analysis on the proposed benthic invertebrate monitoring protocols, we augmented CDFG's plan by addressing the following four components.

Augmentation of CDFG's Draft Monitoring Framework

Fishery concerns

The existing monitoring programs within CINMS are designed to monitor long-term changes in community structure and may be used to evaluate impacts of MPAs on communities of organisms, thereby providing an assessment of whether MPAs are conserving and protecting ecosystem structure and function (CINMS Research Summary, 2003). The impact of MPAs on local and regional fishery-related processes is not well addressed within the ecosystem monitoring effort. To help address these concerns and to integrate MPAs into existing fisheries management, we created a cooperative MPA monitoring plan for an economically and ecologically important harvested species: the California spiny lobster (*Panulirus interruptus*). Lobster monitoring is particularly important, considering the lack of fishery-dependent and independent research about this species in California over the past 25 years and because of the potential for spillover effects to the lobster fishery from MPAs. The monitoring plan uses trapping and tagging techniques to evaluate the effects of the MPAs as a refuge to lobster while providing essential fishery information on the biological and ecological dimensions of the California lobster fishery. The plan also facilitates collaboration and cooperation between the lobster fishery, governmental agencies, and the scientific community.

Local ecological knowledge

A breadth of ecological knowledge exists among fishers and divers that work at CINMS. This knowledge is very important to the monitoring effort. We conducted interviews with local fishers and divers who were willing to assist in the development of CDFG's monitoring plan. Information collected during these interviews was incorporated into the monitoring plan in two ways. First, to aid in the selection of new monitoring sites, information was collected regarding the locations of comparable habitats within the MPA network. This information was then provided in GIS format to researchers. The effort required in locating potential new monitoring sites is expensive and time consuming for researchers. The information our project collected regarding comparable habitat minimized this effort by directing CDFG and researchers directly to potentially comparable sites. Second, discussions with local commercial and recreational fishers improved the design and applicability of the cooperative fishery based monitoring plan for spiny lobster. This dialogue was successful both in gathering information and in forming relationships for potential collaboration and participation in the monitoring program.

Database management

Data acquisition and management is an essential aspect to ecological and policy analyses. CDFG is relying on the various agencies already monitoring and researching the shallow subtidal ecosystem of CINMS because its limited budget prohibits the initiation its own monitoring program. It is important to be able to store data from these multiple, existing monitoring programs so that scientists can examine monitoring data in a broader regional context, allowing for more comprehensive evaluations. The CDFG requires a means to store monitoring data from multiple programs in order to make these evaluations. Our group created an MPA monitoring database for CDFG that allows it to access and analyze monitoring data to evaluate the performance of the MPAs

Public outreach

Public outreach and involvement has been integral throughout the MPA implementation process. To continue to inform and educate the public about the MPAs and monitoring efforts in CINMS, our project created a website that is available on CDFG's server (http://www.dfg.ca.gov/mrd/channel_islands/sse_monitoring/index.html). This website contains information regarding the various components of the monitoring program: experimental protocols, lists and descriptions of focal species, and the locations of MPA monitoring sites throughout the MPA network. The website provides information in a format that is useful, appealing to the public, and readily accessible (Figure 5). In addition to making this information accessible to the public, the website assists in the coordination of future monitoring efforts by potentially minimizing overlap in MPA research

Conclusions

Based on the results of our power analysis, we recommend that CDFG be aware of the possibility of a lack of sufficient power to detect 100% difference in benthic invertebrate density between sites inside and outside of the MPAs. The results were obtained from calculations using data collected by protocols with low sample size of four transects, and therefore low power. With CDFG's intended sample size of 24 transects, increased power may be likely. Therefore, we do not state with certainty that CDFG's monitoring program lacks power, but CDFG should prepare itself for the possibility of the need to increase power by increasing sample size above the intended 24 transects or that change may not be detectable in a short timeframe. We recommend that further examination of the statistical power of the benthic community sampling program be undertaken by an expert biostatistician.

We recommend the lobster monitoring program be implemented to help address the need for MPA fishery monitoring. This plan takes a major step toward determining the value of the MPAs as a fishery management tool while collecting information to potentially improve management of the lobster fishery. The cooperative nature of the plan can be refined and tailored to achieve an effective balance between the needs of industry, science, and the public.

Ultimately, the website should support on-line database queries to allow interested parties to access and analyze data from MPA monitoring. This will encourage greater input from researchers and the public, while further enhancing public involvement and government transparency.

As additional programs become part of CDFG's overall shallow subtidal monitoring, we recommend that they follow the Cooperative Research and Assessment of Nearshore

Ecosystems (CRANE) protocol as a baseline for their survey methods. If they use a different protocol, statistical analysis should be performed to determine data comparability. If the programs are not comparable, then the data should not be analyzed across programs.

The CDFG also should actively work to support and incorporate other monitoring programs. For example, volunteer programs such as Reef Environmental Education Foundation (REEF) or programs that involve commercial "fishing for data" could be extremely useful for expanding and improving the MPA monitoring effort. Presently, the lobster monitoring program is not sufficient to address and evaluate the entire range of MPA fishery effects. Additional fishery monitoring should also be incorporated to take advantage of the unique research opportunities that MPAs provide.

The tasks our group performed throughout our project augmented CDFG's MPA monitoring program. Our project outlined and addressed considerations management agencies should take in the future. At its core, our project was undertaken to further incorporate the needs and interests of the public while improving governmental management of marine resources. The challenges CDFG will face in accomplishing this goal are great and indicative of the broad nature of the public's interest. CDFG is charged with the task of managing resources that are of both economic and ecological value. Although stakeholders may differ in the nature of their concern, all are united in their desire for the public management of the marine resources to be efficient, effective, and accountable.

Table of Contents

Table of Figures

List of Tables

List of Commonly Used Abbreviations and Acronyms

ANOVA	Analysis of Variance
CDFG	California Department of Fish and Game
CFGC	California Fish and Game Commission
CL	Carapace Length
CINMS	Channel Islands National Marine Sanctuary
CRANE	Cooperative Research and Assessment of Nearshore Ecosystems
EFI	Essential Fishery Information
FKNMS	Florida Keys National Marine Sanctuary
FMP	Fishery Management Plan
GIS	Geographic Information System
LEK	Local Ecological Knowledge
MLMA	Marine Life Management Act
MPA	Marine Protected Area
MRWG	Marine Reserves Working Group
NFMP	Nearshore Fishery Management Plan
NOAA	National Oceanic and Atmospheric Association
NPS	National Park Service Kelp Forest Monitoring Program
PISCO	Partnership for the Interdisciplinary Studies on Coastal Oceans
SAC	Sanctuary Advisory Council

1 Introduction

Anthropogenic perturbations of the marine environment have increased significantly in recent decades, leading to negative impacts on marine resources. Over-fishing, climate change, habitat destruction, pollution, coastal development, and non-native species invasions are just a few of the perturbations that threaten the world's oceans (Pew Ocean Commission, 2003). These threats have left many marine populations at a fraction of their historical levels (Jackson et al., 2001). Human activities also have changed the structure and function of marine ecosystems, thereby threatening the health and economic well-being of the human populations that rely on them. A number of marine management and conservation techniques are being implemented to abate ecosystem degradation and restore marine resources. One such technique, recently implemented in California, is the establishment of Marine Protected Areas (MPAs).

MPAs are sections of the ocean in which use of resources and/or access is restricted to some degree. A network of 12 MPAs was implemented in California State waters within the Channel Islands National Marine Sanctuary (CINMS) on April 9th, 2003. Ten of the new MPAs are designated "no-take" areas, which prohibit take of all living, geological, or cultural resources. Two of the MPAs allow only limited take of California spiny lobster and pelagic finfish. The CINMS is located approximately 46 kilometers off the coast of Santa Barbara and Ventura Counties in southern California. The CINMS encompasses the waters surrounding Anacapa, Santa Cruz, Santa Rosa, San Miguel and Santa Barbara islands, extending from mean high water to 11 kilometers offshore. State waters extend from mean high tide to 4.8 kilometers offshore. The 12 CINMS MPAs encompass an area of 350 square kilometers, or approximately ten percent of CINMS waters (Ugoretz, pers. comm.).

The MPA network was created as part of a management strategy to help maintain long-term production in local fisheries and to conserve ecosystem structure and function. The five major goals of the MPAs relate to the protection of ecosystem biodiversity; the maintenance of long-term socio-economic viability while minimizing short-term economic losses; the maintenance of natural and cultural heritage; to help achieve sustainable fisheries; and to provide educational opportunities (MRWG, 2002). The only means of evaluating whether these goals are to be achieved is to assess them through time through a field monitoring program. Our Bren School group project focuses on the development, design, implementation, and administration of a biological monitoring plan for the CINMS MPA network.

1.1 Project importance

Field-based monitoring of changes in resource levels through time and space is the only means of accurately assessing and evaluating the performance of CINMS MPAs. The burden of evaluating the effectiveness of the MPAs is on the California Department of Fish and Game (CDFG), the lead regulatory agency for the state waters within CINMS. Monitoring results are provided to the California Fish and Game Commission (CFGC), the rule making body concerning fish and wildlife resources in California. The CFGC requested that CDFG gather sufficient biological data to evaluate the effectiveness of MPAs. The continued existence of the MPAs may rely on CDFG's ability to meet this objective (MRWG, 2002).

The CINMS MPAs were enacted before a comprehensive MPA monitoring program was established. Although there are a variety of biologic and oceanographic sampling

programs within CINMS, none are specifically designed to measure the effects of MPAs. However, some existing programs collect information that could be useful for monitoring and CDFG is using data from on-going research as the starting point to produce a cost-effective and comprehensive MPA monitoring plan.

An initial evaluation of MPA effectiveness will include a comparison of the spatial and temporal trends in the dynamics of marine populations and communities located inside and outside of reserves. The CDFG has indicated that the monitoring plan should have enough statistical power to determine if there is a response in marine communities five years after the implementation of the MPAs. This evaluation will have implications to marine resource managers at a local and global scale.

Our project assisted CDFG in developing, designing, evaluating and enhancing their biological monitoring program for the CINMS MPAs. This involved summarizing research being conducted in CINMS and recommendations from researchers and stakeholders regarding MPA monitoring. Then these recommendations were applied to CDFG's existing monitoring plan to eliminate several shortcomings.

1.2 Project objectives

Our group worked to improve and supplement CDFG's MPA biological monitoring plan. The objectives of our project include:

1. To summarize both existing biological monitoring efforts within the Santa Barbara Channel and the recommendations of experts in this field;
2. To analyze and evaluate CDFG's proposed biological monitoring plan;
3. To develop and implement an approach to fill several needs identified in the proposed plan.

1.2.1 Objective 1: Summarize current programs and recommendations

Due to budgetary constraints, CDFG will incorporate existing and ongoing research into their monitoring plan. Currently, government agencies, private researchers and academic institutions are conducting research within CINMS. Our project was instrumental in collecting and summarizing information regarding existing research in CINMS, which will be incorporated by CDFG and CINMS into the final monitoring plan.

Our group also participated in a workshop that brought together leading marine researchers and local stakeholders to address monitoring issues and to formulate monitoring recommendations. Our group helped summarize these recommendations and provided them to CDFG.

1.2.2 Objective 2: Analyze Draft Monitoring Framework

The workshop recommendations provided the basis for an analysis of CDFG's monitoring framework. The analysis addressed the following five questions:

- Does the proposed plan adequately monitor the effects of MPAs on benthic communities?
- Does the proposed biological MPA monitoring plan address fishery concerns?
- Can the ecological knowledge of local fishers be incorporated into the monitoring plan?
- Does CDFG have a centralized database and standardized means of storing biological monitoring data?

- Does CDFG have a medium for public outreach and MPA research coordination?

The analysis helped identify gaps existed in CDFG's monitoring plan.

1.2.3 Objective 3: Fill shortcomings determined by analysis

This group took steps to improve the proposed biological monitoring plan by filling several needs. These steps included:

- Development of a MPA monitoring program for California spiny lobster (*Panulirus interruptus)* that addresses fishery goals;
- Collection of additional ecological knowledge from local community members to enhance the monitoring process;
- Creation of a centralized database and standardized means of storing biological monitoring data;
- Design and construction of a website to provide public outreach and to coordinate future monitoring efforts.

2 Background: Marine protected areas in the Channel Islands National Marine Sanctuary

The Southern California Bight, which incorporates the coastal ocean waters from Point Conception to just south of San Diego, is one of the most productive ocean environments in the world (http://seis.natsci.csulb.edu/bperry/scbweb/introduction.htm). The nutrient-rich waters, combined with the dynamic island habitats of the Channel Islands, support incredible biological diversity. Whales migrate and feed in this area while dolphins, seals, and sea birds abound. Rich kelp forest habitats support an incredibly diverse array of fish and invertebrate species. These productive waters also support prolific commercial and recreational fisheries and a significant tourist industry.

In an effort to protect and conserve the marine resources around the islands, CINMS was established in 1980 (see Figure 2-1). The 3,756 square kilometer CINMS is now one of 13 marine sanctuaries in the United States created to protect significant marine resources. The CINMS restricts oil and gas development within its borders, but commercial and recreational fishing is allowed under regulations promulgated by the California Fish and Game Commission (CFGC) and the Pacific Fishery Management Council.

Figure 2-1 Channel Islands National Marine Sanctuary outlined in black (Photo from http://www.cinms.nos.noaa.gov/focus/about.html)

In 1998, recognizing that marine resources were in decline and that the goal of CINMS was not being met by existing regulations, stakeholders sought additional tools to improve marine resource protection among the islands. One of these tools included the establishment of a network of MPAs within CINMS that would protect species and habitats and supplement fishery management by working to complement traditional fishery management tools already in place.

2.1 Fishery management efforts

Traditional fishery management efforts are commonly based on a stock-oriented paradigm. Theoretically, this principle allows the fisheries to maintain stable fish populations through the implementation of tactics that manage harvested species independently of each other. Due to ecological uncertainties, accurate numerical predictions regarding catch are virtually impossible, often leading to unsustainable fisheries (Wilson *et. al.*, 1994). Evidence of this is shown by the fact that less than 60% of the world's fisheries are currently being either overfished or fished at capacity (Botsford et al, 1997, Worm and Myers, 2003). This has caused many stakeholders to consider other approaches to protecting marine resources. One such method is the implementation of MPAs.

2.1.1 Marine protected areas

The use of MPAs as a marine resource tool is a relatively new concept in mainstream fishery management. MPAs are ecosystem-based management tools that protect entire ecosystems through the elimination of extractive activities. The CDFG defines MPAs as areas where "it is unlawful to injure, damage, take, or possess any living, geological, or cultural marine resource, except under a permit or specific authorization from the commission for research, restoration, or monitoring purposes." (CDFG, 2003b). While creating refuges or parks on land is an accepted method of preserving natural resources, no-take MPAs are controversial and rarely used. For example, in North America, the amount of land preserved in state and federal parks outweighs the amount of area in MPAs by 100 to one (Pew Ocean Commission, 2003). There is no official count of the number of no-take MPAs in the world. However, the hundreds of no-take MPAs that are documented encompass less than one percent of the world's oceans and have a median size of 2.4 square kilometers (PISCO, 2003). The vast majority of MPAs in the United States are less than 1.6 square kilometers in area (Halpern, 2002).

Studies show that MPAs lead to increases in species size, diversity, biomass, and abundance within MPA boundaries and can have positive effects on populations outside the boundaries through spillover effects (Halpern, 2003; Edger and Barrett, 1999; Martell, *et al*, 2000). MPAs complement existing traditional fisheries management efforts by offering protection to entire ecosystems rather than single, fisheries targeted species. Responding to mounting evidence of ecosystem decline and the reported positive benefits of MPAs, nations across the world are beginning to implement MPAs in greater numbers (Agardy et al, 2003).

Implementation of MPAs in the United States is supported through federal and state legal mandates. Federal legislation does not explicitly detail the establishment of MPAs but instead offers broad conservation objectives that MPAs can fulfill. This legislation includes the Marine Protection, Research, and Sanctuaries Act, which was passed in 1972 and amended and renamed the National Marine Sanctuaries Act in 1992. It also includes the Magnuson-Stevens Fishery Conservation and Management Act passed in 1976 and amended in 1996. Another method of federal action includes Executive Order 15138 issued in 2000 that calls for the expansion of the MPA program across the United States. California state legislation explicitly outlines a process for the establishment of MPAs through the Marine Life Protection Act (MLPA) in 1999 and the Marine Life Management Act (MLMA) passed in 1999.

2.2 Creation of the CINMS MPAs

In 1998, recognizing that the traditional marine management regime was lacking an ecosystem component and noting personal observations of declining populations, concerned citizens approached CFGC to recommend designating areas within the CINMS as MPAs (J. Ugoretz, pers. comm.). The Channel Islands National Marine Sanctuary Advisory Council (SAC), an advisory council to CINMS, created the Marine Reserves Working Group (MRWG), a body of 17 commercial and recreational fishers, concerned citizens, CDFG, CINMS, NPS, and National Marine Fisheries Service staff, to develop MPAs within CINMS. For nearly three years, MRWG debated about the possible placement, size, and number of MPAs in a process that was often both difficult and contentious. During their time together, MRWG developed the five goals for MPAs described in the introduction as well as outlined importance of an effective monitoring program. MRWG stated that a monitoring program is necessary to determine the effects of the MPAs and to understand if MPAs are an acceptable marine resource management tool. These monitoring efforts are critical in determining whether MPAs are successful in achieving the outlined goals.

MRWG finished its process in 2001 without a final solution, but the group was able to offer valuable information to SAC including two MPA designs that reflected the interests of group members. Using MRWG's information, SAC, CINMS, and CDFG worked together to craft a final version of the MPA network. The proposed project and five alternatives were considered by CFGC and on October 23, 2002, CFGC voted to adopt the proposed project. On April 9, 2003, the MPAs within CINMS state waters became law (see Figure 2-2)

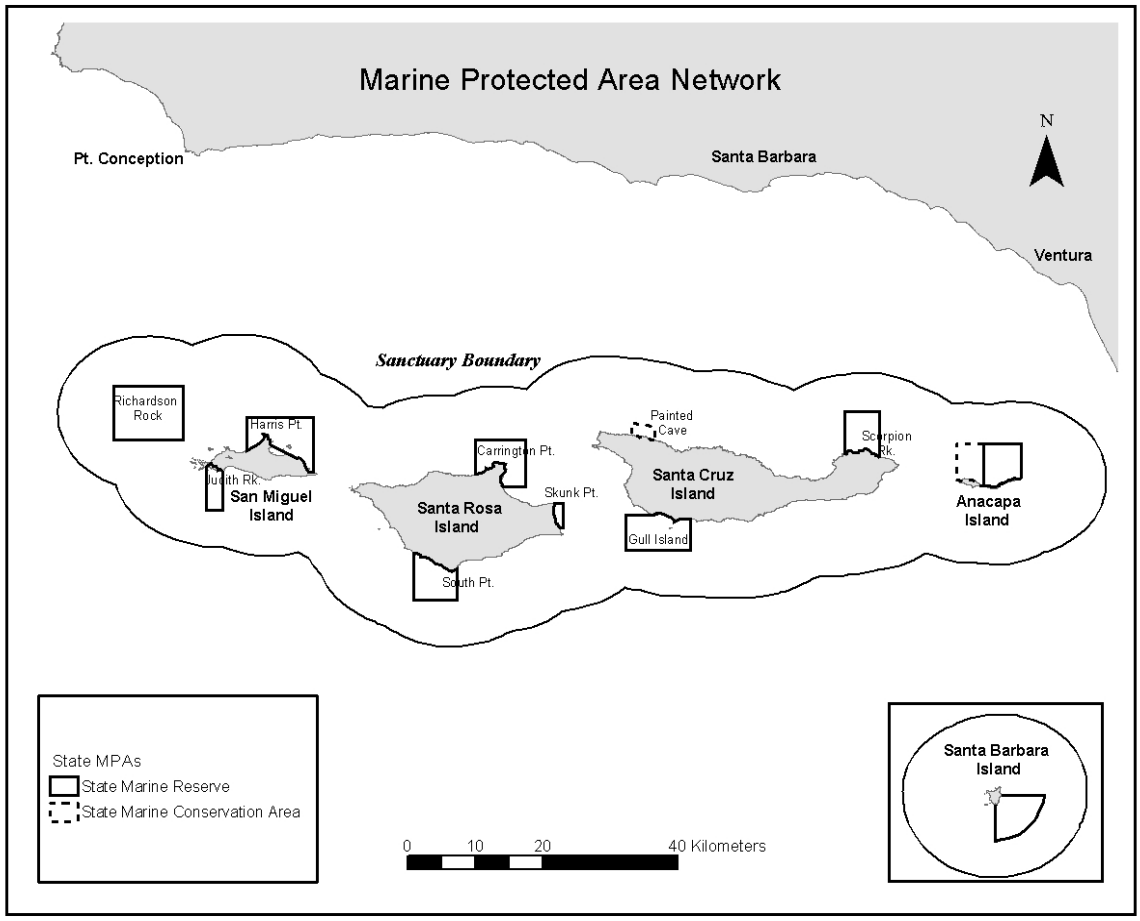


Figure 2-2 Existing MPAs implemented into law on April 9, 2003

Ten of the 12 MPAs are designated no-take State Marine Reserves while two of the MPAs are designated State Marine Conservation Areas, which allow limited recreational lobster diving and recreational fishing for pelagic species such as tuna. Additionally, limited commercial trapping of lobster is permitted within the Conservation Areas.

2.3 Future MPAs: phase II expansion

The regulatory agencies agreed to implement the MPAs two phases. Phase I involved the implementation of MPAs in state waters. Phase II is the expansion of the MPAs into federal waters, those located beyond 5.6 kilometers. The CINMS is the lead agency in this second phase and currently undertaking the steps necessary to establish MPAs in the federal waters within CINMS.

2.4 Conflicts surrounding MPAs

Controversy surrounds the use of MPAs despite their scientifically documented benefits and the public process that led to their establishment. This controversy has created polarization between fishers and the scientific and regulatory communities, as well as the general public in general and arises from four main areas. First, the ocean is a complex and dynamic environment that makes evaluation of whether or not MPAs are effective a difficult task. This is especially true since MPAs are a relatively new management tool with limited long-term studies of their effectiveness. Secondly, fishers believe that closing areas of CINMS from fishing will create significant economic losses. According to the California Sportfishing Coalition, losses could reach $100 million and 2,700 jobs (http://www.savefishing.com/economic/mpa.asp). These figures are significantly higher than the predicted figures of approximately $3.3 million in losses described in the Environmental Impact Report (Ugoretz, 2002), but the Coalition report illustrates the significant concern of the fishing community. Thirdly, many fishers believe MPAs are an unfair method of fishery management because they affect all fishers equally despite differences in the amounts of impact of different sectors of the fishing community. Finally, many stakeholders including scientists, recreationists, and citizens concerned about the environment, consider the goods and services provided by marine ecosystems to be public resources that should be more equitably and sustainably managed in part through the use of MPAs. This numerous and diverse group of stakeholders often cite the effectiveness of terrestrial parks and preserves as conservation tools as motivation for the increased use of reserves in marine systems.

3 Objective 1: Summarize current research and recommendations

To assist CDFG in creating a comprehensive monitoring program, our group compiled information from the current research programs in CINMS and summarized recommendations from an MPA monitoring workshop.

3.1 Compilation of existing research programs

In Winter 2003, our group assisted in compiling a summary of all existing biological and ecological research programs within the Santa Barbara Channel. These scientific research programs have conducted studies within CINMS for decades. The CDFG is interested in these programs because they may be useful in future MPA monitoring and may provide an important source of baseline data. Information was collected from 43 research programs conducted by governmental agencies such as CINMS and CDFG, educational institutions such as the University of California and California State University, fishing community groups, and private research groups. A summarized table of agencies and institutions involved in research within CINMS is presented in Table 3-1.

Table 3-1 Agencies and Institutions Involved in Sanctuary Research

Governmental Agencies	Educational Institutions	Private Institutions
Alaska Fisheries Service Center	California Institute of Environmental Studies	California Abalone Association
California Department of Fish and Game	Humboldt State University	Cascadia Research
Channel Islands National Park	Institution for Computation Earth System Science	Pfleger Institute for Environmental Research
Channel Islands National Marine Sanctuary	Occidental College	Reef Environmental Education Foundation
National Marine Fisheries Service	Oregon State University, Corvallis	Santa Barbara and Ventura County Fishermen
National Marine Mammal Laboratory	Southwest Fisheries Science Center	Vantuna Research Group
San Francisco Bay Estuary Field Station	Stanford University	Partnership for Interdisciplinary Studies of Coastal Oceans
Sea Grant	UC Davis	---
US Fish and Wildlife Service	UC Santa Barbara	---
US Geological Survey	UC Santa Cruz	---
Western Ecological Research Center	UC San Diego -Scripps Institution of Oceanography	---

The information gathered from each program is summarized in Figure 3-1. Our group compiled this information and worked with CINMS to produce an official document which summarized the existing monitoring programs and mapped the location of their monitoring sites using GIS (See Appendix B). Figure 3-2 shows the number of existing research sites as of Winter 2003.

Research Program:
Agency or Institution:
Contact:
Email:
Address:
Phone:
Fax:
Objectives:
Questions:
Data Collected Since:
Frequency of Data Collection:
Data Type:
Availability of Data:
What format is used to store the data?
Are the data available to the public?
Techniques: *Include the technique, the area or distance covered during the survey, and the number of times each technique is applied at each site.*
Number of Species Studied:
Species List:
Number of Sites:
Location of Sites: *Please provide latitude and longitude coordinates and a GIS shapefile of coordinates or hard copy map with locations of the study sites.*
Staff Available for Monitoring: *Number of staff and amount of time staff is available to conduct research.*
Resources Available for Monitoring: *Equipment (including boats, airplanes, submersibles, etc.)*
Annual Funding Level and Source

Figure 3-1 Research Summary Template used to collect information from research programs in and around CINMS.

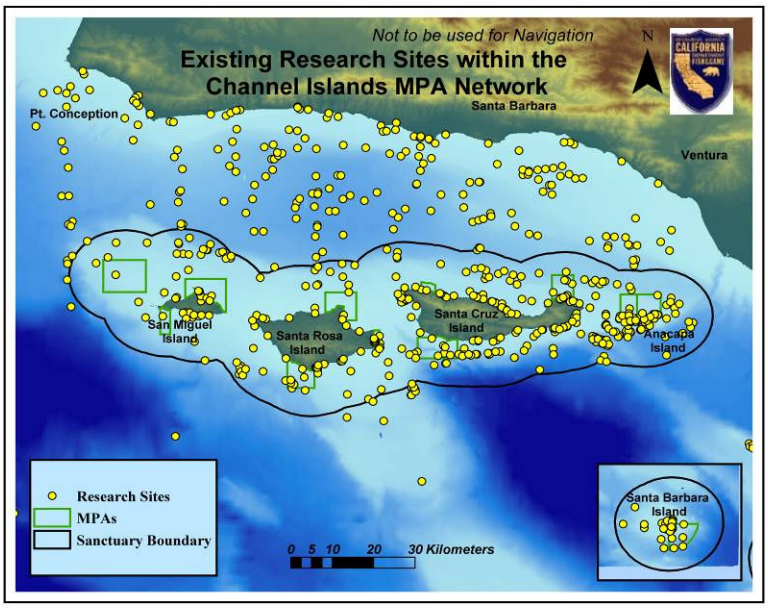


Figure 3-2 Existing monitoring sites within the Channel Islands region (Winter 2003)

A summary of findings shows that research programs within CINMS focus on the biological, environmental and physical aspects of the region. Biological monitoring focuses on a variety of species, ranging from terrestrial and marine mammals and birds to fish, invertebrates and marine plants. Monitored habitats include sandy beaches, rocky intertidal zones, kelp forests, subtidal rocky reefs, and the open ocean (Abeles *et al.*, 2003). The information gathered in this summary document was instrumental in planning a monitoring workshop held in the Spring 2003.

3.2 Summary of monitoring workshop

Our group participated in the Channel Islands Marine Protected Areas Biological Monitoring Workshop, held at the Bren School, March 14-16, 2003. The workshop's goals were to help develop preliminary MPA monitoring efforts in CINMS and to provide monitoring recommendations to CDFG. The workshop brought together over 60 participants, including researchers, statisticians, regulatory officials, fishers, and environmental group representatives.

The workshop consisted of five breakout sessions, each focusing on a separate marine community. These communities included: the intertidal; shallow subtidal benthic; shallow subtidal fish; deep subtidal; and marine mammals and birds. Each working group was asked to make several monitoring recommendations based on varying scenarios of budgetary constraint. Recommendations answered a variety of questions including: what monitoring questions would best address the effectiveness of MPAs; what existing and new programs could be used for monitoring; where and when should monitoring occur; and which species would be best to monitor? Breakout groups provided their answers to these questions to CDFG to facilitate discussion of these issues. Our group recorded comments and recommendations and aided CDFG to produce the "Channel Islands Monitoring Program Worksheet Results" (see Appendix C).

We address five important recommendations made at the workshop in our evaluation and augmentation of CDFG's monitoring framework. These recommendations include: (1) the need to establish and monitor paired sites in the shallow subtidal ecosystem inside and outside the MPA network; (2) the need to monitor fisheries response; (3) the need to incorporate local stakeholders in the monitoring process; (4) the need to address database management concerns; and (5) the need to include public education and outreach. These recommendations provided our group with the information necessary to evaluate CDFG's draft monitoring framework and are discussed in more detail below.

3.2.1 Shallow subtidal monitoring with established paired sites

Shallow subtidal ecosystems (from 0 to ~31meters) were selected as the focus of the monitoring effort for several reasons. First, MPAs were primarily established to protect these ecosystems. Second, shallow subtidal communities contain species that have the potential to respond in a relatively short time period (~5-10 years) with the removal of fishing pressure. These species can show such responses, because they are either fished or they have certain life history characteristics, such as fast growth rates and high fecundity that may allow changes to be detected more rapidly. Third, the shallow subtidal is accessible to SCUBA divers, and has the highest number of existing monitoring sites.

A meaningful assessment of the biological effects of CINMS MPAs requires that responses within MPAs be compared to responses outside of MPAs. There are several methods to accomplish this, but the optimal design for assessing impacts of MPAs is to

sample many points in time before and after the establishment of MPAs. This sampling design is termed Before-After-Control-Impact-Paired-Series (BACIPS). Sampling should occur at sites within the boundaries of each reserve and at sites outside of MPAs (i.e., control sites). Control sites must be chosen so that they have environmental and biological characteristics that are similar to the sites inside the MPAs. However, to assess the effects of the MPAs for fishery related purposes such as spillover, sampling across spatial gradients away from MPAs is likely to be a more effective design.

In some areas, existing research programs have collected data for a substantial period of time before MPA establishment. In these areas, a BACIPS design may be possible. However, in most areas, the lack of data collected from new MPA sites prior to their establishment make the implementation of a BACIPS type sampling design impossible. Therefore, workshop members suggested a sampling design in which sampling sites within each MPA are paired with sampling sites located a short distance outside each MPA.

3.2.2 The need to monitor fisheries

The MPA fishery objective is to help achieve sustainable fisheries by integrating MPAs into existing fisheries management. Workshop participants included members of the local fishing community, and the highest priority for some of these individuals was for the monitoring plan to address issues relevant to the management of local fisheries. Two major issues raised by fishers included whether monitoring data will be collected to address the impact of MPAs on catches, and whether the data that will be collected is valuable to fisheries management. Further recommendations included determining the level of enhancement of size and abundance of fishery species within MPAs and the potential benefits of adult and larval spillover to fishable areas outside the MPAs.

3.2.3 The incorporation of ecological knowledge of the local fishing community

The CINMS MPA biological monitoring is a clear opportunity for local fishers to participate in fisheries research, and CDFG can undertake efforts to incorporate them in the process. Stakeholder participation in MPA management and monitoring is legally justified. Further, stakeholders often show a desire to incorporate their valuable ecological knowledge in marine management planning, which helps to legitimize the process. FGC §7060(a) and (b) state: "Acquiring essential fisheries information can best be accomplished through the ongoing cooperation and collaboration of participants in fisheries," and "The Department to the extent feasible, shall encourage the participation of fishermen in fisheries research within a framework that ensures the objective collection and analysis of data, the collaboration of fishermen in research design, and the cooperation of fishermen in carrying out research."

The fishing community represents a relatively untapped source of relevant, practical ecological knowledge that can be applied to the monitoring process. Olsson and Folke (2000) studied local stakeholder, fishery management associations in Sweden in order to determine what type of ecological knowledge these stakeholders possess and its applicability to resource management. They found that these stakeholders possessed a working ecological knowledge of biotic interactions, disturbance, temporal and physical variability of ecological processes and habitats, and their role on processes such as change in species abundance and community composition. Locally, Haneishi *et al.* (2003) found that fishers of Santa Barbara and Ventura counties who participated in the MPA planning process possess knowledge about marine habitats that would be especially useful for monitoring site selection.

In a pilot study designed to integrate fishermen's knowledge into the MPA planning process for the coast of California, Scholz *et al.* (2004) found that, "85% of interviewed fishermen feel that stock assessments are flawed, that their information has not been well used for management, and more importantly, that they could contribute more accurate and detailed information to improve the situation, but that the agencies have not been very receptive." The CINMS MPA planning process has consistently received criticism from participants in local fisheries. In a review of case studies, Haneishi *et al.* (2003) suggest that fishermen are far more likely to participate in monitoring programs when they are involved in the initial planning process. By including fishermen in the March 2003 Monitoring Workshop, CDFG and CINMS took a visible step towards resolving this issue.

Database management concerns

MRWG promoted several recommendations for the successful implementation and management of MPAs. The recommendations included designing "a data management program that provides mechanisms to ensure data is processed, summarized, and reported to concerned individuals, organizations and agency representatives in an easily understood format on a regular (e.g., bi-annual) basis"(CDFG, 2003f). The primary concern regarding database management is being able to securely store sensitive information in a way that allows accessibility and analysis. This is particularly important because CDFG will be dependant upon other researchers to share their data. However, there is concern among researchers, especially those who are privately funded, about releasing data that has not yet been published. By providing raw data to a government agency such as CDFG, data becomes public information.

Public Outreach

In a public survey prior to the workshop, a majority of citizens who responded stated that they would like monitoring updates on the Internet (CDFG, 2003f). Public outreach is essential to improve knowledge and public awareness about the MPAs and to inform both users and non-users about MPA results. The MPA process has been a public process since its inception, and should continue to be throughout its implementation.

4 Objective 2: Description and analysis of Draft Monitoring Framework

In Spring 2003, CDFG proposed a Draft Monitoring Framework for the CINMS MPAs based on recommendations from the monitoring workshop and marine scientists. The following section describes the major aspects of this framework and provides an evaluation of the strengths and weakness of the plan.

4.1 CDFG's Draft Monitoring Framework

The CDFG chose to follow workshop recommendations and adopt a monitoring design in which sampling sites within each reserve are paired with sampling sites located a short distance outside of each reserve. Newly established sampling sites and future surveys of existing sites will use the Cooperative Research and Assessment of Nearshore Ecosystems (CRANE) protocol. The CRANE protocol is a detailed approach to nearshore stock assessment that records fish and benthic species data over time and space. The CDFG, academic institutions, federal and state marine researchers and fishery managers worked together to produce this protocol. CRANE will be used as a baseline to develop the survey method for newly established sites in the shallow subtidal CINMS MPA ecosystem.

4.1.1 Participating programs

To effectively monitor MPAs, CDFG relies on data from existing programs. Two existing research programs are providing shallow subtidal data to CDFG: the National Park Service's (NPS) Kelp Forest Monitoring and the Partnership for Interdisciplinary Studies on Coastal Oceans (PISCO). Both these programs are included in CDFG's MPA monitoring because they monitor the marine communities of interest to CDFG, and they are willing to share their data with CDFG. Figure 4-1 illustrates where NPS and PISCO performed annual surveys of shallow subtidal benthic and fish communities in Spring 2003.

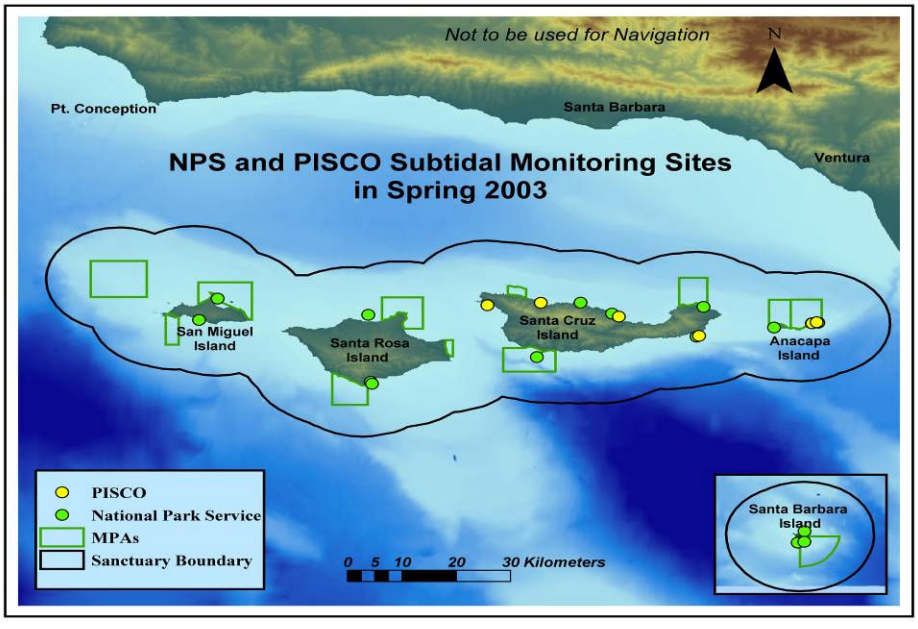


Figure 4-1 Shallow Subtidal Monitoring Sites, Spring 2003

The underlying research objectives of NPS and PISCO differ. A major objective of the NPS shallow subtidal monitoring program is to collect fishery-independent data and collect a long-term baseline for 66 species that will describe population dynamics of the kelp forest ecosystem. In contrast, the major objective of PISCO is to determine the processes underlying the dynamics of the coastal ecosystems. Nevertheless, the shallow subtidal monitoring program used by both programs use similar methods. Both programs collect site-specific, time-series data on the abundance of fish, algae, and invertebrate species that inhabit rocky bottom benthic habitat. These data are collected to quantify population and community at a suite of sampling stations that varying in physical and oceanographic characteristics. A brief description of each protocol follows.

National Park Service Kelp Forest Monitoring

The NPS Kelp Forest Monitoring Program is a part of the National Park Service Vital Signs Monitoring Program. The Channel Islands National Park Vital Signs Monitoring Program was designed with four objectives: (1) to determine present and future ecosystem integrity; (2) to describe empirically normal limits of resource variability; (3) to provide early diagnosis of abnormal conditions; and (4) to identify potential agents of abnormal change (Abeles *et al*., 2003).

The NPS has colleted data annually since 1982 in an effort to maintain a long-term, fishery-independent database on the population dynamics of kelp forest organisms inhabiting the Channel Islands National Park. For a complete species list and experimental protocol, see NPS Kelp Forest Monitoring Protocol (Channel Islands National Park, 1997 – Kelp Forest Monitoring Handbook Volume 1: Sampling Protocol). The Kelp Forest Monitoring Program is an integral part of the MPA monitoring program because its long-term studies have generated significant data. However, NPS does not follow the CRANE protocol adopted by CDFG. For subtidal fish species, NPS distinguishes between the abundance of adults and juveniles, but size data are not recorded. For this reason, additional monitoring is needed at the existing NPS monitoring sites to collect size-frequency data for fish in order to incorporate it into the CDFG monitoring plan.

Partnership for Interdisciplinary Studies on Coastal Oceans (PISCO)

PISCO is a collaborative effort of four U.S. West Coast universities including Oregon State University, Stanford University, the University of California, Santa Barbara (UCSB), and the University of California, Santa Cruz. PISCO was established to meet four objectives: (1) to initiate a novel program in interdisciplinary training and research; (2) to determine the processes underlying the dynamics of the coastal ecosystems along the U.S. West Coast; (3) to establish the scientific basis for the effective design, monitoring, and evaluation of MPAs and other conservation measures; and (4) to integrate this knowledge into the public and policy arenas (http://www.piscoweb.org/).

Within the southern California Bight, PISCO/UCSB scientists integrate long-term monitoring of ecological and oceanographic processes with experimental work in the laboratory and field to explore how individual organisms, populations, and ecological communities vary over space and time. PISCO is an active participant in MPA monitoring and has conducted baseline community surveys at many sites throughout the southern California Bight and also helped develop the CRANE protocol. The consistency between

PISCO and CRANE will allow CDFG to incorporate PISCO's efforts into its monitoring framework.

4.2 Analysis: CDFG's Draft Monitoring Framework

To analyze CDFG's Draft Monitoring Framework, our group addressed the following questions:

- Does the proposed framework adequately monitor the shallow subtidal community with the use of paired sites?
- Does the framework address fishery concerns?
- Is there an opportunity within the guidelines of the framework for greater incorporation of local ecological knowledge?
- Does CDFG have a centralized database and standardized means of storing data?
- Does CDFG have a medium for public outreach?

Our analysis indicated that the Draft Monitoring Framework did not adequately address four of these five questions. The proposed framework did not effectively address fishery concerns, while greater opportunities existed for the incorporation of local ecological knowledge. Further, CDFG had no centralized database in the framework and no specific medium for MPA public outreach. A discussion of these shortcomings and the steps our group took to help eliminate them are provided in Chapter 5. To answer the first question, we performed an in-depth statistical analysis described in detail below.

4.2.1 Does the proposed plan adequately monitor the shallow subtidal community with the use of paired sites?

The main objective of the shallow subtidal monitoring plan is to detect differences in populations and communities of organisms caused by the presence of the MPAs after a 5-year period. Two on-going research programs, PISCO and NPS, will be used to monitor the shallow subtidal environment because the proposed monitoring plan requires too many monitoring sites for any one program to survey in a year. We statistically compared data collected from the two programs from 1999-2002 to determine whether the sampling protocols used in these two programs indicate statistically comparable densities for the monitored organisms. If these programs are found to reach comparable conclusions on organism densities, then CDFG can utilize data from both programs to increase monitoring coverage.

Our project also performed statistical power analysis. Since CDFG's proposed monitoring plan calls for a sampling protocol virtually identical to that used by PISCO (Appendix A.2), our objective for the power analysis was to determine the power of the sample program as it currently exists and to estimate the number of replicate sampling units (i.e., transects per site) that are needed to detect differences inside vs. outside of reserves if they occur. Realtively low sample variability is needed to avoid Type I statistical error, that is a determination that there is a difference between the two treatments (inside vs. outside MPAs) when in fact no difference exists. Statistical power provides a means of avoiding a Type II error, the determination that there is no difference among treatments when in fact there is a difference. The most appropriate way of reducing variability in data collected within each is to increase the number of sample replicates, thereby reducing sampling error.

Statistical power can be increased by increasing sample replication, adjusting the effect size, or adjusting the alpha level of the statistical test. We selected maximum effect size of 100% for the power analysis because 89 evaluations of MPAs around the world surveyed by Halpern (2003) indicate that 100% effect size was the most common for densities of benthic invertebrates. We selected an alpha level of 0.05 because it is not unreasonable to use what is customary. An adequate monitoring plan will have statistical power to detect change in densities of the monitored organisms.

4.2.2 Comparability of protocols

Since the various research programs within CINMS use diverse survey protocols, estimates of organism density or size-frequency at a site in a particular survey season may vary with survey protocol. This variation can hinder CDFG's ability to draw definitive conclusions about the effects and performance of the MPAs. Thus, it is imperative to compare the existing data already gathered to determine the level of agreement between these protocols. Such a comparison will assist in deciding whether data from existing and on-going programs can be used to the advantage of CDFG.

The protocols used by the two research programs are summarized in Appendix A. The data were collected in the years from 1999 to 2002, at Cathedral Cove and Landing Cove off Anacapa Island, and at Pelican Bay and Yellow Banks off Santa Cruz Island. The following sections describe the statistical methods used in comparing the data and the results from the comparison tests.

Statistical analysis: site-wise comparisons

. A site-wise comparison would show whether there is any site-dependent factor (e.g., more suitable habitat) that may affect the level of agreement between the survey protocols. Organism density data on various species (Table 4-1) were gathered by NPS and PISCO at four sites for four years. An ANOVA analysis to compare density data collected using various protocols therefore has three factors: species, site and year. It is possible that at one site the protocols agree more than they do at another site. With site-wise comparisons, data from each site is examined in turn to determine whether organism densities obtained using various protocols statistically agree with each other

Description of site-wise comparisons

In this two-factor ANOVA model, organism density at a given site is the dependent variable, and the independent variables (or factors) are the protocol and the species-year combination. This ANOVA model could be a 3-factor model, with protocol, species and year being the factors. However, we are not interested in the effects of species and year and can combine them into the same factor. Each ANOVA test compares either NPS transect data to PISCO transect data, or NPS quadrat data to PISCO quadrat data, but never transect data to quadrat data.

The equation for the ANOVA model is as follows:

$$\text{density} = \text{protocol} + \text{species-year} + \text{interaction terms} \qquad (1)$$

For site-wise comparisons, we specify the following hypotheses:

H_0: For a given site, the means of densities of all organisms are equal among all protocols.
H_A: For a given site, the means of densities of all organisms are not all equal among protocols.
H_0: For a given site, the means of densities of all organisms are equal among species-year combinations.
H_A: For a given site, the means of densities of all organisms are not all equal among species-year combinations.
H_0: For a given site, there is no interaction of effects from protocols and species-year combinations on the means of densities of all organisms.
H_A: For a given site, there is interaction of effects from protocols and species-year combinations on the means of densities of all organisms.

Table 4-1 Species used for site-wise organism density comparisons. Data from the years 1999 to 2002 were used for comparisons.

For quadrat comparisons		For transect (band-swath) comparisons	
Centrostephanus coronatus	Coronado urchin	*Aplysia californica*	Califnornia brown sea hare
Cypraea spadicea	Chestnut cowrie	*Crassedoma giganteum*	Rock scallop
Eisenia arborea	Southern sea palm	*Haliotis corrugata*	Pink abalone
Lythrypnus dalli	Bluebanded goby	*Haliotis fulgens*	Green abalone
Macrocystis pyrifera	Giant kelp	*Haliotis rufescens*	Red abalone
Strongylocentrotus franciscanus	Red sea urchin	*Kelletia kelletii*	Kellet's whelk
Strongylocentrotus purpuratus	Purple sea urchin	*Lytechinus anamesus*	White sea urchin
Styela montereyensis	Stalked tunicate	*Megathura crenulata*	Giant keyhole limpet
-	-	*Panulirus interruptus*	California spiny - lobster
-	-	*Pycnopodia helianthoides*	Sunflower star
-	-	*Tethya aurantia*	Orange puffball sponge
-	-	*Urticina lofotensis*	White-spotted rose anemone

The site-wise comparison design using the two-factor ANOVA is missing data for the factor of species-year combination because certain protocols contain no data for a few species in specific years. Since it is imperative that all cells in an ANOVA design must have at least one replicate of data, each test must be designed carefully by choosing species-year combinations where data exists.

Table 4-2 is an illustration of how data is selected to meet the conditions of ANOVA test for any particular site. Table 4-2 shows that at Cathedral Cove, for the NPS band

transect protocol, there is a lack of data on *C. giganteum* (abbreviated as "CRAGIG") for all of the four years. Even though the PISCO swath transect protocol has data for *C. giganteum*, the data is not used.

Table 4-2 Selection of data for site-wise ANOVA analysis. The goal of this selection is to ensure that every cell in the ANOVA test has at least one replicate of data. "*" denotes existence of data and "-" denotes lack of data.

site: Cathedral		factor 1: protocols					
		NPS			PISCO		
		band	quad_1m	quad_5m	swath	quad_pisco	
factor 2: species/year combinations	APLCAL1999	*	-	-	*	-	✔
	APLCAL2000	*	-	-	*	-	✔
	APLCAL2001	*	-	-	*	*	✔
	APLCAL2002	*	-	-	*	-	✔
	CRAGIG1999	-	*	-	*	-	
	CRAGIG2000	-	*	-	*	-	
	CRAGIG2001	-	*	-	*	-	
	CRAGIG2002	-	*	-	*	-	
		●		●		●	
		●		●		●	
		●		●		●	
	TETAUR1999	*	-	-	*	-	✔
	TETAUR2000	*	-	-	*	*	✔
	TETAUR2001	*	-	-	*	*	✔
	TETAUR2002	*	-	-	*	*	✔
		✔			✔		

Results of site-wise comparisons

The results from the site-wise comparisons in Table 4-3 show that there are high levels of agreement between protocols at Cathedral Cove and Landing Cove. At Pelican Bay, data from NPS 1-meter quadrat surveys agree with PISCO quadrat surveys only when *S. purpuratus* (purple sea urchin) is removed from the analysis. At Pelican Bay, data from NPS band transects and PISCO swath transects have borderline agreement (if significance level is set at 0.05). At Yellow Banks, data from NPS 1-meter quadrats and PISCO quadrats have agreement only when *L. anamesus* (white sea urchin) and *S. purpuratus* are removed from the analysis, and there is no agreement between NPS band transect and PISCO swath transect.

PISCO transects and quadrats were placed directly on top of NPS's fixed transect lines at Cathedral Cove and Landing Cove, while at Pelican Bay and Yellow Banks the two research teams conducted their surveys some distance apart (Caselle, pers. comm., 2003). According to Caselle (2003), this explains why there was agreement at Cathedral Cove and Landing Cove but not at Pelican Bay and Yellow Banks.

Table 4-3 Results of site-wise comparison of organism density

Sites	protocols compared	p-value for main effect of sampling protocols	p-values for interactions between protocol and species/year factors	If significance level is 0.05, do these protocols agree?
Cathedral Cove	quad-1m, quad-pisco	0.65402	0.93559	yes
	band, swath	0.87380	0.17046	yes
Landing Cove	quad-1m, quad-pisco	0.97682	0.00033	yes
	band, swath	0.14984	0.00020	yes
	band, swath *Crassedoma giganteum* removed	0.97646	0.03329	yes
Pelican Bay	quad-1m, quad-pisco	0.00807	0.00000	no
	quad-1m, quad-pisco *S. purpuratus* removed	0.12555	0.00000	yes
	band, swath	0.05473	0.00000	yes
Yellow Banks	quad-1m, quad-pisco	0.00000	0.00000	no
	quad-1m, quad-pisco *Lytechinus anamesus* *S. purpuratus* removed	0.30455	0.00030	yes
	band, swath	0.00000	0.00000	no
	band, swath *Lytechinus anamesus* removed	0.00028	0.00000	no

Statistical analysis: species-wise comparisons

Description of species-wise comparisons

With species-wise comparisons, data for each species is examined to test whether organism densities obtained using various protocols agree with each other. This informs us as to whether there is any species-dependent factor (e.g., high abundance) that may affect the level of agreement between the survey protocols. In species-wise comparisons, we performed a two-way ANOVA test for each species. As in site-wise comparisons, cells without any data were not included in the analysis.

For species-wise comparisons, we specify the following hypotheses:

H_0: For a given species, the means of its density are equal among protocols.

H_A: For a given species, the means of its density are not all equal among protocols.

H_0: For a given species, the means of its density are equal among all site-year combinations.

H_A: For a given species, the means of its density are not all equal among site-year combinations.

H_0: For a given species, there is no interaction of effects from protocols and site-year combinations on its density.

H_A: For a given species, there is interaction of effects from protocols and site-year combinations on its density.

Results from species-wise comparisons using data from all four sites.

Table 4-4 lists the results of comparisons using data from all four sites. When all protocols are included in a per-species analysis, the level of agreement is not as high as when only similar (transect data with transect data or quadrat data with quadrat data) protocols are compared. For 15 out of 24 species there is agreement between similar protocols.

Table 4-4 Results of species-wise comparison of organism density (cases given "unknown" as conclusion of significance are those with significant interaction effects)

species	protocols compared	p-value for main effect of sampling protocols	p-values for interactions between protocol and species/year factors	If significance level is 0.05, do these protocols agree?
Aplysia californica	band, swath, quad-pisco	0.01187	0.16254	no
	band, swath	0.50159	0.11486	yes
Asterina miniata	quad-1m, swath	0.11469	0.01903	yes
Centrostephanus coronatus	quad-1m, swath, quad-pisco	0.65341	0.60434	yes
	quad-1m, swath	0.36512	0.52734	yes
	quad-1m, quad-pisco	0.97216	0.63654	yes
Crassedoma giganteum	band, swath, quad-pisco	0.00000	0.09338	no
	band, quad-pisco	0.00000	0.15653	no
	band, swath	0.00983	0.00201	unknown
Cypraea spadicea	quad-1m, swath, quad-pisco	0.13748	0.16809	yes
	quad-1m, swath	0.19084	0.01013	yes
	quad-1m, quad-pisco	0.69719	0.23037	yes
Eisenia arborea	quad-1m, swath, quad-pisco	0.00000	0.064702	no
	quad-1m, swath	0.00000	0.41433	no
	quad-1m, quad-pisco	0.00596	0.00117	unknown
Haliotis corrugate	band, swath, quad-pisco	0.49869	0.85856	yes
	band, quad-pisco	0.52136	0.56461	yes
	band, swath	0.037576	0.70200	no
Haliois fulgens	band, swath	0.43650	0.94121	yes
Haliotis rufescens	band, swath	0.43650	0.94121	yes
Kelletia kelletii	band, swath, quad-pisco,	0.00929	0.01188	no
	band, quad-pisco	0.05002	0.00340	yes
	band, swath	0.08423	0.26786	yes
Lithopoma undosum	quad-1m, quad-pisco, swath	0.57238	0.08033	yes
	quad-1m, swath	0.27920	0.54155	yes
	quad-1m, quad-pisco	0.75527	0.05329	yes

Lytechinus anamesus	band, quad-1m, swath, quad-pisco	0.00000	0.00000	unknown
	quad-1m, quad-pisco	0.00000	0.00171	unknown
	band, swath	0.00000	0.00000	unknown
Lythrypnus dalli	quad-1m, quad-pisco	0.00207	0.85098	no
Macrocystis pyrifera	swath, quad-1m, quad-5m, quad-pisco	0.00000	0.00000	no
	quad-5m, quad-pisco	0.52111	0.00000	yes
Megathura crenulata	band, swath, quad-pisco	0.00240	0.18395	no
	band, quad-pisco	0.00150	0.13710	no
	band, swath	0.00897	0.00001	no
Panulirus interruptus	band, swath	0.91496	0.96601	yes
Parastichopus parvimensis	quad-1m, swath, quad-pisco	0.00007	0.45035	no
	quad-1m, swath	0.00001	0.00511	unknown
	quad-1m, quad-pisco	0.00235	0.28920	no
Pisaster giganteum	quad-1m, quad-5m, swath	0.00000	0.00000	no
Pycnopodia helianthoides	band, swath	0.26155	0.08005	yes
Strongylocentrotus franciscanus	quad-1m, quad-pisco	0.12615	0.14934	yes
Strongylocentrotus purpuratus	quad-1m, quad-pisco	0.04963	0.00002	no
Styela montereyensis	quad-1m, quad-pisco	0.44637	0.92407	yes
Tethya aurantia	band, swath, quad-pisco	0.00053	0.27286	no
	band, quad-pisco	0.00020	0.14954	no
	band, swath	0.11773	0.00368	yes
Urticina lofotensis	band, swath	0.00002	0.00822	no

Results from species-wise comparisons using data from only Cathedral Cove and Landing Cove

The results from species-wise comparisons using data from all four sites show agreements between similar protocols for 15 out of 24 species. This level of agreement is not as high as the level of agreement between protocols from site-wise comparisons at Cathedral Cove and Landing Cove. This lack of statistical similarity in organism density can be attributed to a number of factors, including patchy distribution of organisms and sampling error. It is possible that using data from all four sites, rather than from just Cathedral Cove and Landing Cove, resulted in the low statistical similarity. Thus, the species-wise comparisons were run again, but using only data from Cathedral Cove and Landing Cove.

Table 4-5 summarizes the results of the ANOVA comparisons using just Cathedral Cove and Landing Cove data. There are four species where comparisons are invalid since zero density was found, and therefore the total number of valid comparisons was 16 species.

Of 16 comparisons, only ten species were in agreement between protocols. This fraction, ten out 16 or 62.5%, is identical to the result of 15 out of 24 (62.5%) when all four sites are used in the analysis. These results demonstrate that excluding sites where protocols do not agree (Pelican Bay and Yellow Banks) in a site-wise comparison does not improve overall level of agreement in species-wise comparisons.

Table 4-5 Results of species-wise comparisons using only data from Cathedral Cove and Landing Cove

Species	p-values from comparisons of log-transformed data	Do the protocols agree if the significance level is 0.05?
Aplysia californica	0.76592	yes
Centrostephanus coronatus	0.32712	yes
Crassedoma giganteum	0.0029522	no
Cypraea spadicea	0.69103	yes
Eisenia arborea	0.017736	no
Haliotis corrugata	0.15098	yes
Haliotis fulgens	-	not applicable
Haliotis rufescens	-	not applicable
Kelletia kelletii	0.12501	yes
Lithopoma undosum	0.11994	yes
Lytechinus anamesus	0.26914	yes
Lythrypnus dalli	0.0034777	no
Macrocystis pyrifera	0.58438	yes
Megathura crenulata	0.0015043	no
Panulirus interruptus	0.41277	yes
Parastichopus parvimensis	0.011907	no
Pycnopodia helianthoides	-	not applicable
Styela montereyensis	-	not applicable
Tethya aurantia	0.38839	yes
Urticina lofotensis	0.000032579	no

Conclusions from protocol comparison study

The high level of agreement between similar protocols in site-wise comparisons at Cathedral Cove and Landing Cove may be attributable to the sampling units from these protocols being placed at identical locations. At Yellow Banks and Pelican Bay, the survey teams placed their sampling unit quite a distance apart (more than 100 meters), which may have contributed to the disagreement between protocols at these sites (Caselle, pers. comm., 2003). The fact that two different protocols at identical physical locale yielded highly agreeable organism density results indicates that CDFG does have the flexibility to use data obtained from either NPS or PISCO protocols. This flexibility is important in helping CDFG to obtain a complete and credible evaluation of trends in organism density between paired sites inside and outside of MPAs because they are able to have greater geographical

monitoring coverage. However, even with this flexibility, geographic gaps in the monitoring sites still exist.

4.2.3 Power analysis

Since CDFG intends to use PISCO's swath transect protocol to monitor benthic invertebrate and algae density, we performed power analysis to determine whether PISCO swath transect protocol has sufficient power to detect changes. We used existing data from PISCO surveys collected between 1999 through 2002 to examine variances within the data. Power calculations based on these variances can shed light on what sample sizes are necessary to achieve a given power for detecting certain effect sizes.

Our power analysis determines whether the existing protocols have sample sizes large enough to reduce variances in the data and the power to detect differences. The test sites are two paired sites, one inside the MPA, which is considered the treated site with no-take protection, and one outside of the MPA subject to consumptive use pressure and considered the control. The goal is to detect if differences exist in organism densities between these paired sites. We conduct power analysis assuming that one or all of the following tests will be performed in the course of monitoring and evaluating the effect of the MPAs:

(1) two-sample t-test with equal variance
(2) two-sample t-test with unequal variance
(3) ANOVA test using the model: density = site + year + depth + interaction terms

The CDFG intends to use 24 PISCO-type swath transects for surveying benthic invertebrates (J. Ugoretz, pers. comm., 2003). Therefore, this power analysis places special emphasis on power calculations with sample size of 24.

Power analysis for two-sample t-test, equal variances

Data description

The data was collected using the PISCO swath transect from 1999 though 2002, at four sites off Anacapa and Santa Cruz Islands, for 25 species. As described in Section A.2.1, transects are placed in the inner reef (five meters of depth), and the outer reef (15 meters of depth). For the purpose of this power analysis for two-sample t-test with equal variances, power is calculated for each individual species-site-year-depth sample in turn. Each set has a mean organism density and a variance, calculated using densities from all transects of a site at one of the two depths, for a given year and species.

There are several key considerations when analyzing the results:

- There are 25 species, four sites, four years and two depth zones. This amounts to 800 possible species-site-year-depth sets of means and variances.
- Not all sets of data were collected.
- Many species-site-year-depth sets have variance of 0, therefore cannot be used.

Therefore, the results, as expressed as percentage of total number of valid species-site-year-depth samples (where data is collected and have non-zero variance), are larger than if they are divided by 800 (i.e. the total possible number of species-site-year-depth samples).

Statistical analysis methodology

In this power analysis for two-sample t-test with equal variances, we examine each species-site-year-depth sample of mean and variance. We assume the sites are similar in habitat and environmental conditions, and therefore have equal variances. Then, using the mean of organism density, an alternate mean is calculated for a given effect size, where the effect size is a percentage of the original mean. Without having the monitoring sites selected and without a pilot study, this assumption of equal variance cannot be verified.

Certain data is not included in the power calculations. Data from the two depth zones are not included in the same mean and variance calculation because it would increase the variance (thus decreasing power). Samples that have zero variance such as species-site-year-depth samples with either only one transect, or with no individual organisms found cannot be included in the power calculation.

Results: an overview of power in all valid data sets

For detecting a given effect size with certain power, some species-site-year-depth samples have low enough variability to require few transects, but others are too variable and therefore require large number of transects. Table 4-6 summarizes the results of the power for the entire set of PISCO's benthic invertebrate data for the years 1999-2002. Table 4-6 shows that each percentage is a fraction of all valid samples that requires a certain range of transects (e.g., zero to 24) to detect a given effect size (e.g., 50%) with a given power (e.g., 0.8). For a given power, the fraction that requires zero to 24 transects increases as effect size to be detected increases. For example, for power of 0.8, the fractions in the range of 0 to 24 transects to detect 20%, 40%, 60%, 80% and 100% effect sizes are 10%, 24%, 36%, 45% and 59% respectively. For a given effect size, the fraction that requires 0 to 24 transects decreases when the required power increases. For example, for an effect size of 80%, the fractions in the range of zero to 24 transects for power of 0.8, 0.9, 0.95 and 0.99 are 45%, 38%, 36% and 32% respectively.

Table 4-6 Results of power analysis for t-test assuming equal variance. Each percentage is a fraction of all valid samples that requires a certain range of transects (e.g., zero to 24) to detect a given effect size (e.g., 50%) with a given power (e.g., 0.8)

	Effect size:	20%				40%			
	power:	0.8	0.9	0.95	0.99	0.8	0.9	0.95	0.99
number of transects	0 – 24	10%	8%	7%	5%	**24%**	21%	19%	15%
	24 - 100	15%	15%	16%	13%	21%	19%	16%	17%
	100 – 200	10%	11%	10%	7%	30%	18%	13%	11%
	200 – 500	16%	16%	14%	15%	19%	25%	35%	34%
	500 – 1000	31%	19%	20%	13%	6%	16%	17%	17%
	1000 - 2000	11%	12%	15%	17%	0%	0%	0%	5%
	2000 - 3000	6%	12%	10%	9%	0%	0%	0%	0%
	3000+	0%	6%	9%	19%	0%	0%	0%	0%

	effect size	60%				80%			
	power	0.8	0.9	0.95	0.99	0.8	0.9	0.95	0.99
	0 – 24	36%	31%	28%	24%	45%	38%	36%	32%
	24 - 100	41%	28%	28%	21%	47%	45%	42%	29%
	100 – 200	16%	23%	22%	17%	8%	17%	15%	23%

number of transects	200 – 500	8%	17%	21%	30%	0%	0%	8%	17%
	500 – 1000	0%	0%	0%	8%	0%	0%	0%	0%
	1000 - 2000	0%	0%	0%	0%	0%	0%	0%	0%
	2000 - 3000	0%	0%	0%	0%	0%	0%	0%	0%
	3000+	0%	0%	0%	0%	0%	0%	0%	0%

	effect size	100%			
	power	0.8	0.9	0.95	0.99
number of transects	0 – 24	59%	47%	44%	37%
	24 - 100	41%	45%	39%	42%
	100 – 200	0%	8%	17%	16%
	200 – 500	0%	0%	0%	6%
	500 – 1000	0%	0%	0%	0%
	1000 - 2000	0%	0%	0%	0%
	2000 - 3000	0%	0%	0%	0%
	3000+	0%	0%	0%	0%

Results: power for 24 transects

The CDFG will use 24 transects at each site, and we analyzed power for this sample size. Table 4-7 shows the fraction of species-site-year-depth samples that, with 24 transects, can detect a given effect size (e.g., 40%) with a given range of power (e.g., 0.8 to 0.9 with 24 transects). For example, to detect an effect of 40% with a power of at least 0.8, 33% (29% + 4%, see bold-faced numbers) of the data sets have sufficient power.

Table 4-7 Power for 24 transects

	Effect size									
power	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0 - 0.1	65%	24%	6%	0%	0%	0%	0%	0%	0%	0%
0.1 - 0.2	15%	36%	34%	17%	8%	0%	0%	0%	0%	0%
0.2 - 0.3	4%	8%	14%	23%	13%	8%	6%	0%	0%	0%
0.3 - 0.4	4%	4%	8%	11%	3%	13%	2%	6%	0%	0%
0.4 - 0.5	1%	3%	3%	4%	17%	3%	9%	6%	6%	0%
0.5 - 0.6	3%	4%	3%	5%	10%	16%	7%	6%	11%	8%
0.6 - 0.7	2%	1%	3%	4%	3%	4%	15%	6%	0%	9%
0.7 - 0.8	1%	2%	3%	3%	5%	10%	4%	16%	6%	0%
0.8 - 0.9	1%	4%	4%	**4%**	5%	5%	11%	4%	17%	7%
0.9 - 1.0	3%	13%	21%	**29%**	35%	42%	47%	58%	60%	76%

Results: discernible species-dependent patterns in power

The distribution of certain species may exhibit less spatial variability in abundance, and can be important as key species to monitor for community change as a result of the MPAs. After scrutinizing results of this power analysis, no discernible pattern is found that points to any species with such characteristics in its distribution. For this analysis, all species-site-year-depth samples were placed in a table with their associated powers, and the resulting table was sorted by power in ascending order, and then examined for any species with consistently high power. There is a high degree of randomness in the distribution of species in the sorted table, which indicates a lack of any discernible pattern.

Conclusions for power analysis for t-test with equal variance

Using two different calculations, less than one third of the species-site-year-depth samples have at least a power of 0.8 to detect an effect size of 40%, using a maximum of 24 transects. For larger effect sizes such as 100%, with power of at least 0.8, we can expect it to be detected by a sample size of 24 transects 76% of the time. We can conclude that a maximum of 24 transects can adequately detect effect size of 100%, but loses considerable power if effect sizes of 40% or 50% is desired.

Power analysis for two-sample t-test, unequal variances

Power analysis also was performed by assuming that the variances in organism abundance data between paired sites are unequal. Without having the monitoring sites selected and without a pilot study, this assumption cannot be verified. However, the power analysis with assumed equal variances was a good basis to examine the variability of organism density. We do not know how different the variances between the yet-to-be-selected paired sites are, but we can use existing monitoring sites and their variances as a foundation (Schroeter, pers. comm., 2003).

Data description

This power analysis does pair-wise comparisons among sites within given species, year and depth zone and is modeled after an analysis performed by Ecometrics Environmental Service for the Channel Islands National Park in 1994 (Ecometrics, 1994). For this analysis, there are 18 species, seven PISCO sites, two years, two depth zones (inner and outer), and ten effect sizes ranging from 10% to 100%. Each of the sites is compared once with another site. This yields 21 power calculations for one species, one year, one depth zone and one effect size, which amounts to 15,120 power calculations. However, not all of the calculations yield valid results due to the data yielding variances of 0. Again, the results are shown as fractions of comparisons that can detect a certain effect size with a given power. These fractions are computed by dividing the total number of valid data and not by 15,120.

Statistical analysis methodology

The power calculations were performed using the statistical software S-Plus.

Results

Table 4-8 shows the results. For each species, the fractions (expressed as percentage) of total number of pair comparisons (in columns labeled %) and the number of pair comparisons (in columns labeled N) that can detect a given range of effect sizes with a power of at least 0.8 are tabulated in this table. For example, for the species *A. californica*, none of the pair comparisons had power greater than 0.8 to detect any change less than 100%. For the species *Asterina miniata*, 12% of the pair comparisons had power greater or equal to 0.8 to detect 50% or 60% of effect size. We are unable to perform calculations to examine what power exists using the 24 transects prescribed by CDFG.

Table 4-8 Results of power calculations with assumption of unequal variances among sites
N= Number of Comparisons
%=fraction of total number of pair comparisons

	Effect size (as proportion of the larger mean)									
	10% - 20%		30% - 40%		50% - 60%		70% - 80%		90% - 100%	
species	%	N	%	N	%	N	%	N	%	N
Aplysia californica	0%	0	0%	0	0%	0	0%	0	0%	0
Asterina miniata	1%	1	7%	7	12%	12	25%	25	53%	54
Crassedoma giganteum	0%	0	0%	0	0%	0	5%	4	11%	9
Cypraea spadicea	0%	0	0%	0	7%	8	12%	14	16%	19
Eisenia arborea	0%	0	0%	0	0%	0	0%	0	0%	0
Haliotis corrugata	0%	0	0%	0	0%	0	0%	0	0%	0
Kelletia kelletii	0%	0	0%	0	0%	0	0%	0	3%	2
Lithopoma gibberosum	0%	0	0%	0	0%	0	13%	2	13%	2
Lithopoma undosum	0%	0	9%	9	11%	11	25%	25	48%	49
Macrocystis pyrifera	0%	0	0%	0	9%	7	20%	15	22%	17
Megathura crenulata	0%	0	0%	0	0%	0	0%	0	0%	0
Panulirus interruptus	0%	0	0%	0	0%	0	0%	0	0%	0
Parastichopus parvimensis	7%	9	7%	10	15%	20	22%	30	38%	51
Pisaster giganteum	0%	0	0%	0	3%	3	18%	19	51%	53
Pterygophora californica	0%	0	0%	0	0%	0	0%	0	0%	0
Pycnopodia helianthoides	0%	0	0%	0	0%	0	0%	0	25%	2
Tethya aurantia	0%	0	0%	0	0%	0	2%	1	12%	6
Urticina lofotensis	0%	0	0%	0	0%	0	16%	6	37%	14

Conclusions for power analysis for t-test with unequal variance

This analysis concludes that, in general, the power is quite low in the data if one assumes unequal variance. For only one out of 18 species the fraction of pair comparisons exceeded 50% for having at least a power of 0.8 to detect effect size of 90% to 100%.

Power analysis for ANOVA tests, PISCO data

Our project also performed power analysis for ANOVA tests. ANOVA is another way of testing for differences in parameters among treatments. Unlike the t-test, where parameter estimates can be tested for equality or differences between only a pair of treatments, ANOVA can test for equality and differences between more than two

treatments. CDFG is likely to use ANOVA as the tool for detecting differences between sites inside and outside the MPAs (Gaines, pers. comm., 2003).

In this analysis, as in the analysis for t-test with unequal variances, the relative variances among the sites in existing PISCO benthic survey program are assumed to be similar to those that would be found in the yet-to-be-selected paired monitoring sites. This power analysis can reveal the level of power to detect differences if the yet-to-be-selected monitoring sites exhibit patterns in relative variances similar to these PISCO sites. It can assist in determining necessary sample size for the design of a monitoring program.

Data description

The analysis used data from Cathedral Cove, Landing Cove, and Middle Isle from Anacapa Island in addition to Pelican Bay, Yellow Banks, Forney, and Hazard from Santa Cruz Island. Because ANOVA requires that each "cell" of the design have at least one replicate of data (See Section 4.2.2), we can use only the years 2001 and 2002 data as the other years do not have data at some sites.

Statistical analysis methodology

The calculations are made using the software JMP. The power calculations are only for the treatments of the factor "site", for detecting effect size of 50% and 100% between sites. No power calculation is done for the factors of year and depth. The data had been log-transformed to achieve homoskedasticity (homogeneity of variances).

Results

Table 4-9 presents the results of power calculations. To detect effect sizes of 50% and 100%, the table shows the numbers of transects necessary at a power of approximately 0.8 for a variety of species.

Table 4-9 Results of power analysis for ANOVA tests, for PISCO data

species	Effect sizes			
	50%		100%	
	number of transects	power	number of transects	power
Aplysia californica	550	0.79824	200	0.81506
Asterina miniata	350	0.83196	120	0.81129
Crassedoma giganteum	400	0.80869	150	0.82429
Cypraea spadicea	800	0.80033	300	0.83488
Eisenia arborea	400	0.80619	150	0.83193
Haliotis corrugata	100	0.74389	50	0.83378
Kelletia kelletii	550	0.78546	200	0.80267
Lithopoma gibberosum	150	0.73158	70	0.83387
Lithopoma undosum	400	0.81733	140	0.80994
Lytechinus anamesus	NA	NA	80	0.81065
Macrocystis pyrifera	650	0.81770	220	0.80237
Megathura crenulata	400	0.78229	150	0.80924
Panulirus interruptus	350	0.77375	130	0.79310
Parstichopus	350	0.81250	120	0.79100

parvimensis				
Pisaster giganteum	400	0.78764	150	0.81434
Pterygophora californica	150	0.74733	65	0.80608
Pycnopodia helianthoides	200	0.83278	70	0.79303
Tethya aurantia	400	0.80849	140	0.80098
Urticina lofotensis	250	0.82282	90	0.81337

Conclusions

As shown by the results presented in the last section, the number of transects to detect 50% and 100% effect sizes with a power of 0.8 greatly exceeds 24, the number intended to be used by CDFG.

Power analysis for ANOVA tests, NPS data

The fixed transects of the NPS, larger sample size, and the longer term of data gathering (from 1983 through 2002) may have an effect on power, thus causing power in NPS data to be different than that in PISCO data. To test this hypothesis, our group conducted power calculations for ANOVA tests on the NPS organism density time series for a number of species.

Data description

For this analysis, data from the years 1986 through 2002 are used. Since there was a slight protocol change in 1986, the data from years 1983 through 1985 was eliminated. The data analyzed came from the sites outlined in Table 4-10. Species were chosen based on the completeness of data.

Table 4-10 Sites from which data are used for power calculations for ANOVA tests on NPS data.

Island	Site
Anacapa Island	Admiral's Reef
	Cathedral Cove
	Landing Cove
Santa Barbara Island	Arch Point
	Cat Canyon
	SE Sea Lion Rookery
Santa Cruz Island	Fry's Harbor
	Gull Island South
	Pelican Bay
	Scorpion Anchorage
	Yellow Banks
San Miguel Island	Hare Rock
	Wyckoff Ledge
Santa Rosa Island	Johnson's Lee North
	Rodes Reef

Statistical analysis methodology

The calculations are made using the software JMP as in the previous section. The power calculations are only for the treatments of the factor "site", for detecting effect size of 50% and 100% between sites. No power calculation is done for the factors of year and depth. The data had been log-transformed to achieve homoskedasticity (homogeneity of variances).

Results

Again, as in the case of PISCO data, the necessary numbers of transects to detect 50% or 100% effect size at a power of approximately 0.8 are very high for all the species examined.

Table 4-11 Results from power calculations on NPS data. '*' denotes cases where the computational software was unable to reach a definitive result.

species	Effect sizes			
	50%		100%	
	number of transects	power	number of transects	power
Aplysia californica	500	0.78445	290	0.79343
Crassedoma giganteum	650	0.78340	310	0.81903
Haliotis corrugata	320	0.80412	280	0.84135
Haliotis rufscens	300	0.83759	*	*
Kelletia kelletii	580	0.80768	300	0.83950
Lophorgorgia chilensis	360	0.80989	280	0.74652
Megathura crenulata	600	0.80750	300	0.82239
Panulirus interruptus	340	0.81818	280	0.79900
Pycnopodia helianthoides	321	0.83749	280	0.86850
Stylaster californica	280	0.84016	*	*
Tethya aurantia	540	0.79494	300	0.86246
Urticina lofotensis	340	0.79041	280	0.77334

Conclusions

With different protocols, higher sample size and longer-spanning data, power in data is not significantly different than that in PISCO data.

Summary of power analysis

The goal of this power analysis was to assess the power of detecting effects using 24 transects, the sample size intended by CDFG. In the power analysis for two-sample t-tests with equal variances, about 59% of the comparisons were able to detect 100% change with a power of 0.8 using fewer than 24 transects. Computing for the power for exactly 24 transects, 76% of the comparisons can detect 100% change with a power of at least 0.9. In the power analysis for two-sample t-tests with unequal variances, the fractions of comparisons capable of detecting 90% or 100% effect size with a power of 0.8 were not large, for any species. In the power analysis for ANOVA tests, for most species, the number of transects necessary to detect 100% effect size with a power of 0.8 was greater than 100, much larger than 24.

In performing power calculations for our study, we needed to know what would be realistic effect sizes for which power is to be determined. Halpern (2003) reviewed 89 evaluations of MPAs around the world and synthesized their findings on how MPAs affect four biological measures: density, biomass, size and diversity. Our study focuses solely on density, and Halpern's synthesis showed that the overall mean ratio of density (density inside the MPAs divided by density outside) was 1.91 ± 0.28. For invertebrates, the mean ratio was 2.04 ± 6.15. A ratio of 2/1 translates to a difference of 100% ($2/1 = (1 + 1)/1$). For this reason, we calculated power for detecting differences of 100%. Note that in Halpern's synthesis, the mean ratio for invertebrates has quite a large confidence interval: ± 6.15. If

one extrapolates Halpern's synthesis to the CINMS MPAs, this large confidence interval means that these MPAs may have a very large effect, or have no effect at all. Our study did not calculate power to detect a two-fold to six-fold increase.

The results of the analysis using t-test with equal variance indicated adequate power for 24 transects, while those using t-test with unequal variance and ANOVA did not. As it is less likely that paired sites would exhibit equal variance in density data, this analysis points to the conclusion that a sample size of 24 transects does not have power of 0.8 to detect an effect size of 100%. Since these analysis results were obtained from mathematical calculations using data collected through protocols with low sample sizes (four transects), the variances in the data were expectedly high, thus yielding low power. The CDFG's monitoring program uses a much higher sample size of 24 transects, and may collect data with less variance and thus may yield higher power.

We conclude that based on this power analysis, CDFG should be aware of the potential of low power in detecting an effect size of 100%. The CDFG should be aware that an increased sample size might be necessary in order to increase power to an acceptable level. However, at this point, we do not state with certainty that CDFG's intended sample size of 24 transects will yield insufficient power.

5 Objective 2: Fill needs identified in CDFG's Draft Monitoring Framework

The following gaps in the Draft Monitoring Framework include: funding and protocols for fisheries independent monitoring; geographic gaps in existing monitoring; no central database to store information; and no MPA public outreach program. One objective of our group project was to address the major gaps in the monitoring framework. We accomplished this by: 1) creating a fishery monitoring plan for a major fishery species; 2) documenting local knowledge to find paired sites and close geographic gaps; 3) creating a database to synthesize the data collected, and 4) designing a shallow subtidal monitoring website for use by researchers and the interested public. The following sections describe the approaches we took to move towards eliminating these gaps.

5.1 Cooperative fishery monitoring plan for spiny lobster (*Panulirus interruptus*) in the CINMS MPAs

5.1.1 Introduction

There exists a limited understanding of the regional effects MPA networks have on fisheries populations (Palumbi, 2001). MPA monitoring programs for important commercial and recreational fishery species at CINMS are valuable for several reasons (CDFG, 2003c, 2004). First, MPA networks allow replication of rigorous experimental designs and allow strong scientific testing of MPAs as a fishery and conservation management tools (Murray *et al.*, 1999). Second, MPAs can act as dynamic reference sites in experiments for comparison with exploited systems (Davis and Dodrill, 1979). This can enable CDFG to distinguish between natural and anthropogenic changes and aid in assessing the efficacy of management controls (Parrish, 2003).

The California spiny lobster (*Panulirus interruptus* Randall) is a substantial commercial and sport invertebrate fishery in California (Leet *et al.*, 2001). Having generated over $4.6 million in commercial landings for the 2002-03 season, the fishery is one of California's most valuable (J. Ugoretz, pers. comm., 2003). Approximately one-quarter of commercial lobster landings for the 2002-03 season were from the northern Channel Islands (CDFG logbook data, 2003). The lobster fishery generally is perceived as a relatively healthy fishery, however, the lack of recent or ongoing research on the lobster population provides little scientific basis to support this assumption.

Through predation and competition, lobster play important ecological roles in the organization and dynamics of benthic communities (Cobb and Caddy, 1989). Lobster are the largest benthic invertebrate predator in their environment and may regulate sea urchin densities, which in turn influence kelp population dynamics (Tegner and Levin, 1983; Dayton *et al.*, 1998). The ecological and economic importance of this species and the recent establishment of a network of MPAs provide a unique opportunity to establish a lobster monitoring program.

Monitoring spiny lobster at CINMS is a critical step in understanding the ecological and socio-economic effects of the recently established MPA network. A lobster monitoring study inside and outside the MPAs will provide an excellent opportunity to gather Essential Fishery Information (EFI) that will enhance our knowledge of the life history of this species, and subsequently improve lobster fishery management. Lobster monitoring is particularly

important considering the lack of fishery-dependent and independent research on this species in California over the past 25 years, and because of the potential benefits of the MPAs to the lobster fishery via spillover.

The existing monitoring programs within CINMS are designed to evaluate impacts on communities of organisms, thereby providing assessment of whether MPAs are conserving and protecting ecosystem structure and function (Appendix B). The impact of MPAs on local and regional fishery-related processes is not well addressed within the ecosystem monitoring effort. These processes include, but are not limited to spillover, growth rates, mortality estimates and the reproductive conditions of fished species. Moreover, the few monitoring programs that survey lobsters at CINMS, such as NPS and PISCO, collect only presence/absence data on lobster and are not designed to answer fishery specific questions. Herein, we propose a lobster monitoring plan to address fishery related management concerns, including an evaluation of MPAs as a refuge for lobster.

The spiny lobster industry has shown an interest in determining whether or not recently established MPAs achieve fishery goals, providing a basis for a cooperative relationship for research (C. Miller, pers. comm., 2003). In addition, the industry would like to see the MPA goal for sustainable fisheries fulfilled: to achieve sustainable fisheries by integrating MPAs into fishery management (MRWG, 2002). Quantitative monitoring addressing fishery concerns is needed to rigorously assess the effects of MPAs on lobster and to ensure data are relevant to the lobster fishery.

We propose a spiny lobster monitoring plan designed to test whether or not the CINMS MPAs affect population dynamics and regional fishery yields of spiny lobster. We use a collaborative approach involving fishers and scientists. Our major objective is to collect, analyze, and organize population data on the trappable lobster populations from replicate MPAs and their associated control (or fished) sites. The collaborative partnership will primarily involve the commercial lobster fishery, CINMS**,** CDFG, the Bren School, and the University of Southern California. The goals and objectives of the monitoring plan are:

Goals

1) To evaluate the effects of the CINMS MPAs as refuges for lobster;
2) To obtain Essential Fishery Information on the biological and ecological dimensions of the California lobster fishery; and
3) To facilitate collaboration and cooperation between the lobster fishery, governmental agencies and the scientific community on MPA and fishery monitoring.

Objectives

a) To determine the relative abundance and size-frequency of lobster within, near and far from MPAs by comparing the catch per trap pull over time;
b) To determine the growth rates and patterns of movement of lobster from mark and recapture tagging within, near and far from MPAs;
c) To estimate population size, natural and fishing mortality and exploitation rates of lobster from mark and recapture tagging; and
d) To determine the sex ratios and the reproductive conditions of female lobster.

The monitoring plan will build on findings from similar studies around the world, contributing to our knowledge of the effects of MPAs and complementing lobster fishery management in California.

The effects of MPAs on lobster populations: previous studies

There is a paucity of scientific data about the effects of MPAs on lobster populations. This is particularly true for temperate regions of the world (Kelly *et al.*, 2000). Information from prior lobster MPA studies is important for the design of this study and to provide a basis for predictions at the Channel Islands. Table 5-1 summarizes the basic scientific findings about the effects of different MPAs around the world on lobster populations.

Although these studies used various techniques to sample lobster populations, and in many cases addressed different questions, some broad patterns are apparent. In general, these studies show that the protection offered by MPAs can increase the density, biomass, size, and fecundity of lobster populations inside MPA boundaries. Furthermore, movement from MPAs to fished areas has been demonstrated [to varying degrees]. These trends are generally stronger for MPAs that have been established for longer periods of time. Some of these studies have focused on EFI, including stock assessment, age and growth characteristics, reproductive characteristics, and movement patterns.

Table 5-1 A summary of the effects of different MPAs from around the world on average lobster density, biomass, size, fecundity and movement inside and out of MPAs.

Study Location	Number of MPAs Studied and Time Since MPA Establishment	Study Technique	Lobster Species	Average								Movement	Reference
				Density		Biomass		Size		Fecundity			
				Inside	Out	Inside	Out	Inside	Out	Inside	Out		
Florida Keys, National Marine Sanctuary, Western Sambos Reseve	1 MPA: first 5 yrs. of establishment	Trapping	*Panulirus argus*	4.7 lobster per trap	1.2 and 2 lobsters per trap	-	-	85mm CL	76mm CL and 75mm CL	-	-	Spillover not detected within 5 years- low tag return rates	Annual Report, Sentinel Lobster Fisheries Project, (1998)
North-eastern New Zealand	4 MPAs: ranging from 3-21 yrs. after establishment	Diver Surveys	*Jasus edwardsii*	3.9% increase per year of protection (shallow water), 9.5% increase per year (deep)	-	5.4% increase per year of protection (shallow), 10.9% increase per year (deep)	-	Increased 1.14mm CL per year of protection	-	4.8% increase per year (shallow) and 9.1% increase per year (deep)	-	-	Kelly et al., (2000)
Florida Keys, Dry Tortugas National Park lobster sanctuary	1 MPA: 23 yrs. after establishment	Diver Surveys	*Panulirus argus*	-	-	-	-	101mm CL	77mm CL	0.8 million	0.3 million	-	Bertelsen and Matthews, (2001)
North-eastern New Zealand	1 MPA: ~ 20 yrs. after establishment	Trapping and diver surveys	*Jasus edwardsii*	-	-	-	-	-	-	-	-	50% moved beyond MPA boundaries over 6 months	Kelly, (2001)
Newfoundland, Bonavista Bay	2 MPAs: first 3 yrs. of establishment	Trapping	*Homarus americanus*	Much greater and similar	-	-	-	Increased	-	Proportion of ovigerous females increased and remained the same	-	-	Rowe, (2002)
North-eastern New Zealand	1 MPA: ~ 20 yrs. after establishment	Trapping and diver surveys	*Jasus edwardsii*	-	-	-	-	-	-	-	-	20% crossed MPA boundary (either into or out of)	Kelly and MacDiarmid, (2003)
Southern California, Anacapa Island	1 MPA: ~ 25 yrs. after establishment	Diver Surveys	*Panulirus interruptus*	5.5 times more abundant	-	-	-	-	-	-	-	-	Lafferty, (in press)
Southern California, Catalina Island.	1 MPA: 16 yrs. after establishment	Trapping	*Panulirus interruptus*	CPUE varies throughout the year from 4.7 ± 0.6 (SE) winter to 11.0 ± 1.0 (SE) summer	10.3 ± 0.09 (SE) summer	-	-	85.66 ± 12.34 (SD) mm CL	84.2 ± 11.3 (SD) mm CL	peak of 85% ovigerous in late June	-	7% crossed MPA boundary during a 6 month period	Miller et al. (in prep.)
Southern California, Catalina Island	1 invertebrate closure: 24 yrs. after establishment	Trapping	*Panulirus interruptus*	CPUE: 6.4 ± 0.2 (SE) (observed in late summer)	CPUE: recreational: 6.2 ± 0.2 (SE) Commercial: 3.6 ± 0.2 (SE)	-	-	84.10 ± 13.98 (SD) mm CL	Recreational: 81.16 ± 14.60 (SD) mm CL Commercial: 77.89 ± 7.34 (SD) mm CL	-	-	-	Miller et al. (in prep.)

Obtaining essential fishery information through collaborative research

The Marine Life Management Act (MLMA) of 1999 promotes ecosystem research that will enable better management decisions (Fish and Game Code [FGC) §7050(b) (5)]. To improve the management of fisheries the MLMA requires that EFI on biological and ecological dimensions of a fishery are described (FGC §7060). Much of the EFI for the lobster fishery was collected over 25 years ago or has not yet been collected. This information is required to prepare Fishery Management Plans (FMPs), the foundation of the MLMA. In addition, the MLMA encourages the formation of cooperative and collaborative partnerships with fishery participants, public and private entities, and research institutions to acquire EFI and conduct research [FGC §7056(k)]. Cooperative efforts involving members of the industry, scientists and managers are more likely to be successful collecting the appropriate data and developing monitoring strategies that are acceptable to all parties. The proposed cooperative MPA lobster monitoring plan is the first step necessary for developing a FMP for lobster.

The types of EFI that are required under the MLMA are listed in order of importance below. Bold font indicates those EFI categories that may be partially answered by this study. Subsequently described is the specific information expected from our project to address these categories.

1) Spatial and temporal estimates of abundance
2) Total mortality by species and temporal and spatial variation in mortality
3) Age and growth characteristics
4) Recruitment
5) Ecological interactions
6) Reproductive characteristics
7) Distribution of stocks
8) Movement patterns

(http://www.dfg.ca.gov/mrd/nfmp/pdfs/section1_chap4.pdf).

Summary of Expected Project Information

Indices of abundance and size-frequency

Data will be collected on the total catch of lobster per trap pull over time. Spatial and temporal indices will be developed from this information to describe the relative abundance by sex and size of the trappable lobster populations within, near, and far from MPAs. Combined with information on growth rates, these data can be used to answer fishery specific questions such as, what size class of lobster is likely to reach legal size the following season based on the size of molts? Trap sampling in fished and non-fished areas over time will gather data to demonstrate the effects of MPA protection and aid the evaluation of lobster management measures.

Movement patterns

Information on the net movement patterns of lobster can be used to determine the home range and site fidelity of lobster, seasonal migrations, spillover responses, environmental cues, spawning grounds and depth distributions (http://www.dfg.ca.gov/mrd/nfmp/section1_chap4.html#movement). We designed a lobster program to quantify patterns of lobster movement using tag and recapture

techniques. This information is essential for evaluating the effect of MPAs. Movement data are required to predict species responses to protection and to examine the role MPAs have in fisheries management (Kelly and MacDiarmid, 2003). Potential movement patterns may include:

- Unidirectional movement from MPAs to surrounding waters, potentially through a "spillover" response from increased lobster density in MPAs;
- Unidirectional movement into MPAs from surrounding waters;
- Seasonal inshore-offshore or alongshore movements related to molting, breeding or feeding cycles;
- Longer distance migratory patterns, either inshore-offshore or along shore.

Growth rates

Information on growth rates can provide critical parameters necessary for stock assessment models, which can assist in guiding management. Growth rates for tagged lobster can be determined by measuring recaptured lobster that have molted. Tagging a range of sizes of lobster will provide information for developing such models. In addition, if California spiny lobster growth is density-dependent as it is for other species of lobster, new information could be obtained concerning the effect of lobster density on growth rates within MPAs compared to fished areas (McGarvey *et al.*, 1999).

Population size, natural and fishing mortality and exploitation rates

Tagging experiments can also be used to estimate population size, total mortality, and fishing and natural mortality, which are frequently of interest to fisheries biologists and managers (Pine *et al.*, 2003). Capture-recapture models provide direct estimates of population size and the probability of capturing an individual. If spillover from MPAs is low, unexploited areas can provide standards for carrying capacity and mortality estimates that would otherwise be unavailable (Davis and Dodrill, 1979). Natural mortality may be estimated directly from mortality in no-take MPAs, and compared to total mortality estimates made outside MPAs.

Reproductive characteristics

Improving our understanding of the reproductive characteristics of lobster can assist in managing the fishery. Reproductive characteristics can be obtained from trap capture observations. These may lead to information on size at maturity, when female lobsters are setose or have an attached spermatophore and information regarding fecundity at size.

5.1.2 Materials and methods

This monitoring plan proposes to use commercial lobster traps to assess the effectiveness of the CINMS MPAs as a refuge to lobsters and to gather EFI. The plan was designed after an extensive review of the literature on the biology of California spiny lobster (Appendix D). We also evaluated the methodology of using traps to scientifically assess crustacean populations (Appendix E). These steps are essential to accurately interpret and assess the experimental results and to understand limitations of the plan. The following section describes the areas within CINMS where the study will be conducted.

Study areas

CINMS

The study will be conducted at Anacapa Island and Santa Cruz Island. These islands were chosen after numerous discussions with local lobster fishers and scientific researchers in the region. Three of the major considerations in choosing these islands included:

- Oceanographic conditions, such as water temperature, are more similar at these two islands than the more western Channel Islands, reducing the potential to confound results;
- Oceanographic conditions at these islands are generally more representative of the rest of the spiny lobster distribution in California. Therefore, results may be more relevant to the entire fishery;
- These islands are more readily accessible by boat.

MPAs

Study sites will be selected within, near, and far from the MPAs on Anacapa and Santa Cruz Islands. Sites within the MPAs will be chosen on suitable lobster habitat near the center of each MPA. The sites near the MPAs will be chosen as the closest suitable lobster habitat on the outside edges of the MPAs and the sites far from the MPAs will be selected approximately 2km distant from the MPAs. An effort will be made to ensure that trapping sites are symmetrical with regards to the near and far sites that are on either side of the within sites. This will ensure that if the lobsters undertake a net movement (referred to locally as a "crawl") in one direction, it will be detected. Three MPAs were considered to be the minimum number of replicates required for the study due to the inherent spatial and temporal variability of ecological responses. Further, a series of smaller experiments at several sites is generally more informative and is likely to provide a better estimate of the average effect of MPAs than one large experiment done in one place (Underwood, 1997).

MPA sites selected for sampling are listed in Table 5-2 below. Note that many of the control sites are not shown in Table 5-2 because they have not been chosen yet.

Table 5-2 The names, status and site types of the lobster monitoring study regions

Island	MPA	MPA Status	Site Type
Anacapa Island	State Marine Reserve	New MPA to be sampled – no take zone	Treatment Site
	State Marine Conservation Area	New MPA to be sampled – lobster fishing allowed	Control Site
	Natural Area	Pre-existing reserve to be sampled – no take zone	Treatment site (analyzed separately)
	Brown Pelican Closure	Part year fishing closure	Control site
Santa Cruz Island	Scorpion State Marine Reserve	New MPA to be sampled – no take zone	Treatment Site
	Near Scorpion	Not yet selected	Control Site
	Far from Scorpion	Not yet selected	Control Site
	Gull Island State Marine Reserve	New MPA to be sampled – no take zone	Treatment Site
	Near Gull Island	Not yet selected	Control Site
	Far from Gull Island	Not yet selected	Control Site

Study depths

Shallow (4-7m), moderate (10-14m), and deep (20-27m) rocky reefs are recommended for sampling. The shallower depth was chosen because sampling periods coincide with those months when lobsters typically move into shallower waters (Engle, 1979). The moderate depth was chosen based on logbook data showing an average depth of 12m fished in October by the entire California lobster fishery over the past five seasons (CDFG logbook summary data, J. Ramsey). The deep sampling depth was chosen to cover almost the whole depth distribution fished by commercial operators (approximately 90% of commercial lobster trapping occurs at depths shallower than 27m; Barilotti, 2001). A range of depth was chosen to account for variability in bottom relief and to increase the area available for sampling.

Sites and habitat

Monitoring sites will be chosen on rocky reefs within, near and far from the MPAs. The rocky reefs chosen for monitoring will be as comparable as possible with respect to topographic relief, habitat type and oceanographic conditions. Paired reef systems will be chosen using a range of techniques. These include ethnographic knowledge of the region, nautical charts, side-scan sonar and multi-beam images incorporated into a Geographic Information System (GIS; See Section 5.1.2.3.3). For example, Figure 5-1 shows a map of side-scan sonar data of the Anacapa Island MPAs (Cochrane, 2003) with the pre-existing MPA Natural Area at Anacapa Island that was established in 1978, the pre-existing Brown Pelican Closure, the new State Marine Reserve and the new State Marine Conservation Area. The hard bottom habitats in which sites are more likely to be chosen by fishers are shown in red. Figure 5-2 and Figure 5-3 show the nautical charts of Scorpion Rock State Marine Reserve and Gull Island State Marine Reserve, respectively. The approximate depths to be sampled in the study are indicated by the 10m, 20m and 30m contour lines in each figure. Ultimately, the comparability of sites will be ground-truthed using SCUBA, and the size of each site will be standardized (e.g., 200m^2).

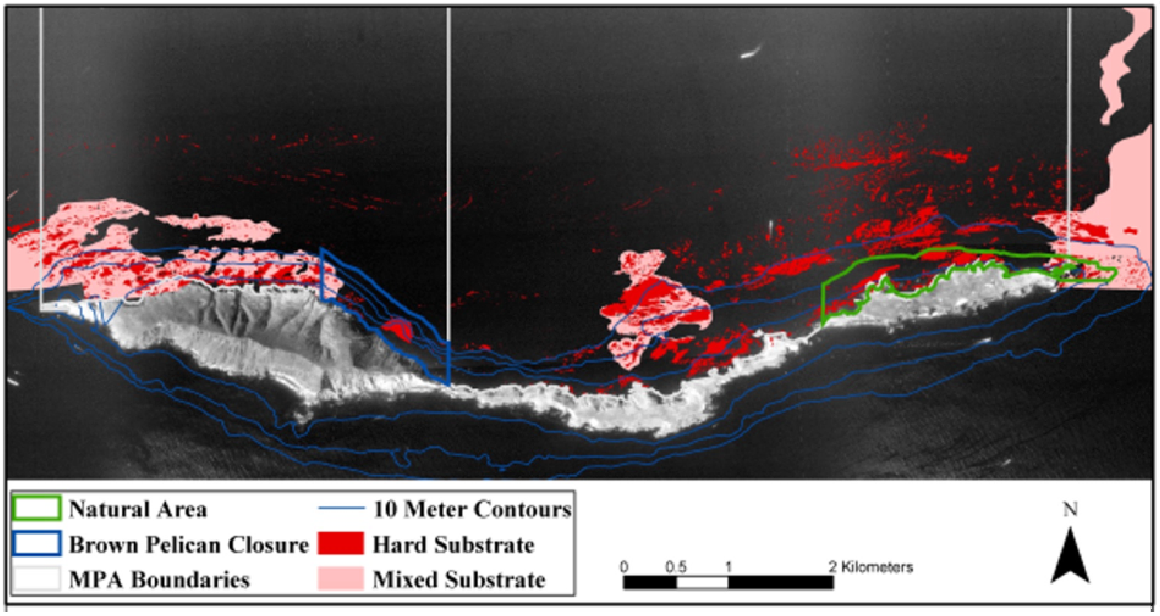


Figure 5-1 Side-scan sonar image of the north side of Anacapa Island incorporated into GIS. Sidescan data from Cochrane (2003)

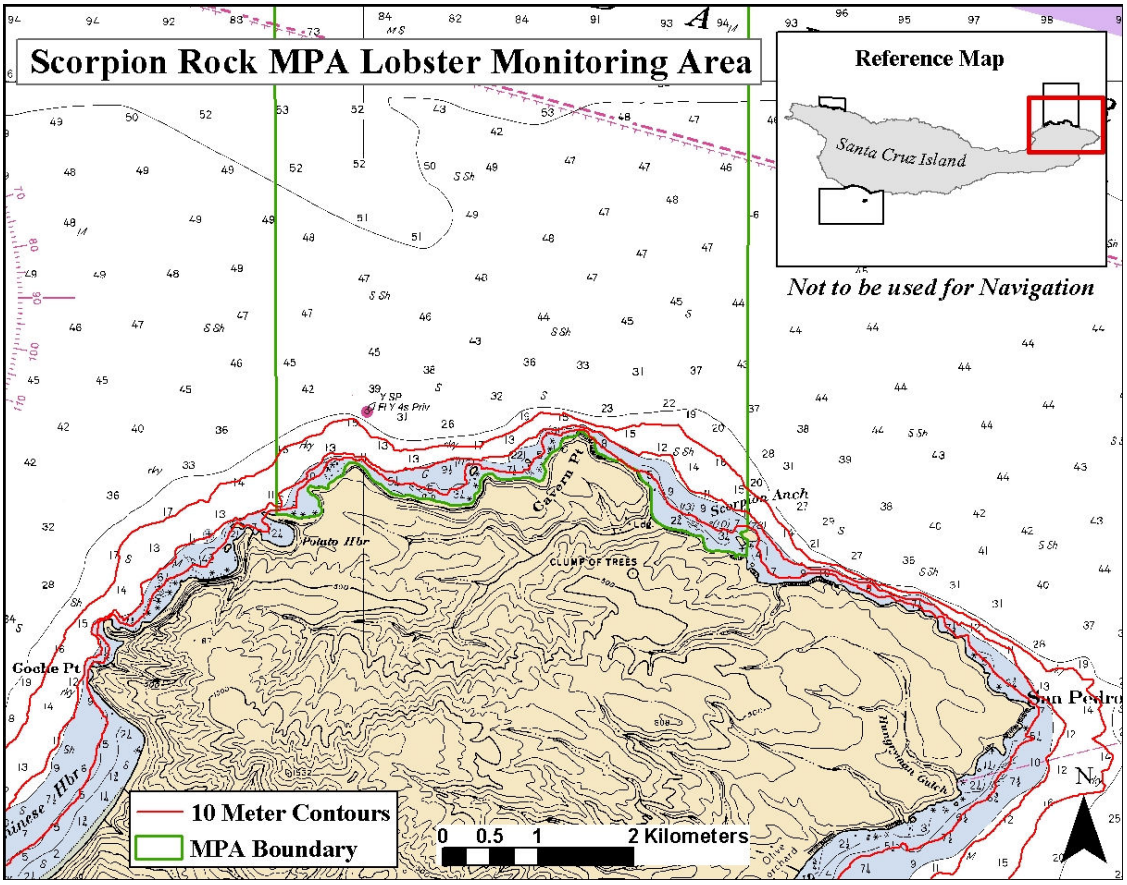


Figure 5-2 Nautical chart of Scorpion Rock State Marine Reserve. Adapted from NOAA http://chartmaker.ncd.noaa.gov

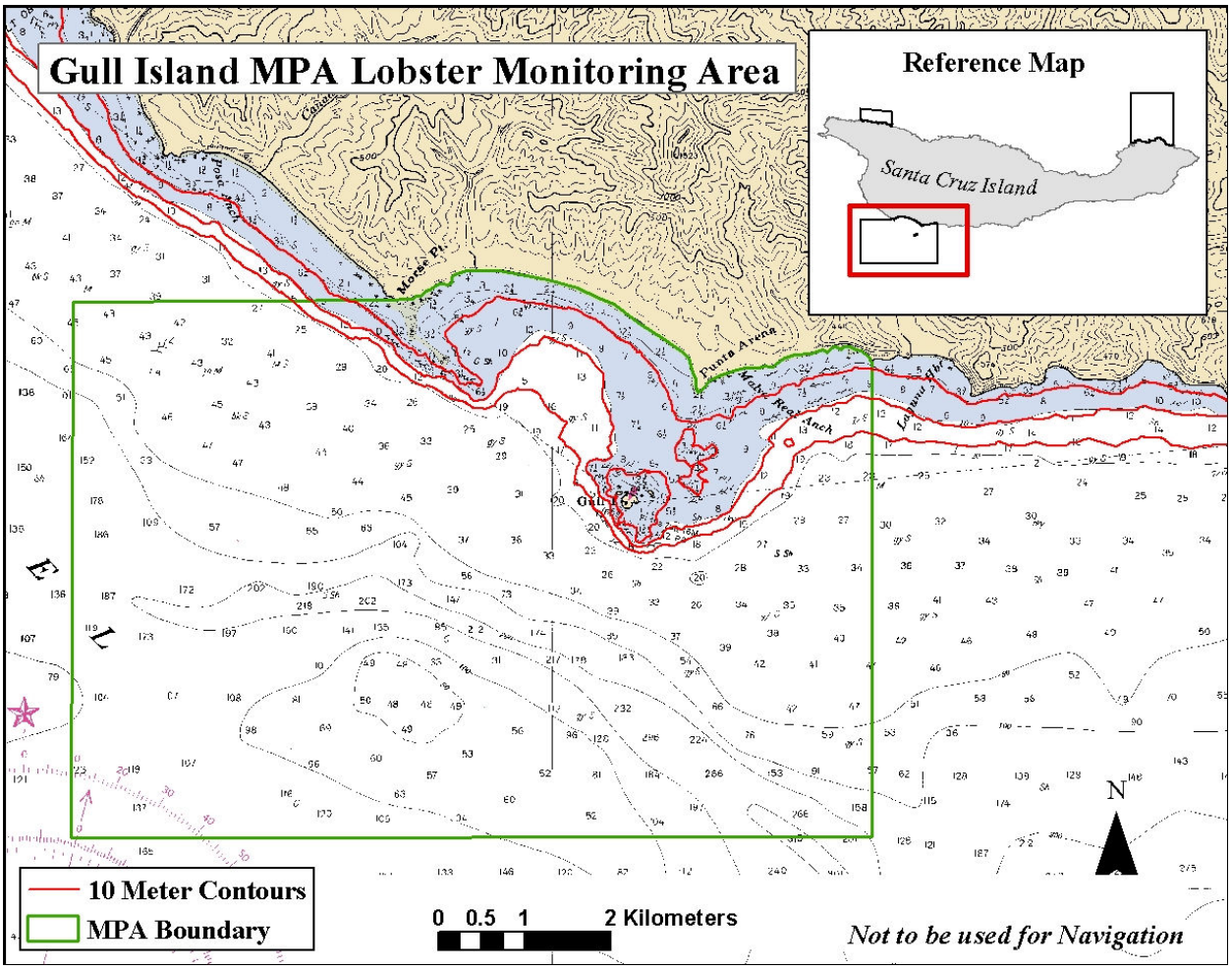


Figure 5-3 Nautical chart of Gull Island State Marine Reserve. Adapted from NOAA http://chartmaker.ncd.noaa.gov

Sampling periods

The monitoring plan will be tested and reviewed in this first year and baseline data on the lobster populations at each of the sites will be gathered. This information can be used to review, modify and refine the survey design over time. We recommend continuation of monitoring for at least five years to detect temporal and spatial changes in lobster populations due to MPA effects and to obtain sufficient information to refine the EFI collected.

Sampling will occur twice a year, in the months of June and September. A two-week sampling period in each of these months around the new moon is suggested (i.e., the dark lunar period). The new moon occurs on the June 17th and September 14th , 2004.

June was chosen to begin sampling because at this time lobster generally have not yet molted but have moved into shallower, warmer waters. Re-sampling in September will increase the chance that tagged lobsters are are recaptured after molting. Sampling before and after the molt is critical to estimating growth rates. Further, pre-season sampling will avoid the possible confounding effects of having commercial traps close to study traps (See Appendix E). Pre-season sampling also may permit development of long-term indices of lobster abundance, which are used by some fishery managers (e.g., in Western Australia) to predict lobster catches for coming seasons (Caputi and Brown, 1986).

Experimental design

Overview

The monitoring plan will include sampling along a gradient at three locations (i.e. within, near, and far) from three MPAs. Sampling will occur at a number of sites nested within each location. Three depths will be sampled at each gradient location. Table 5-3 summarizes the number of traps that need to be set per day (i.e. the number of trap days, where one trap day is a single trap set over a 24 hour period), the total number of days of sampling required, the total number of trap days required, and the total number of traps set in each locational gradient**.** A discussion of how these numbers were calculated follows.

Table 5-3 Experimental design overview, including the number of traps conservatively estimated to detect a 50% effect size with an alpha of 0.05.

Site	Locational Gradient	Depth	Total no. of traps set per day	No. of days sampling required	Total no. of trap days	Total no. of traps in each locational gradient
Anacapa Island						
State Marine Reserve	within	shallow	9	4	36	108
		moderate	9		36	
		deep	9		36	
	near	shallow	9		36	108
		moderate	9		36	
		deep	9		36	
	far	shallow	9		36	108
		moderate	9		36	
		deep	9		36	
		Total	**81**		**324**	**324**
Natural Area	within	shallow	4		16	48
		moderate	4		16	
		deep	4		16	
	near	shallow	Compare to near and far sites as sampled above			
		moderate				
		deep				
	far	shallow				
		moderate				
		deep				
		Subtotal	**12**	**4**	**48**	**48**
Santa Cruz Island						
Scorpion State Marine Reserve	within	shallow	9	4	36	108
		moderate	9		36	
		deep	9		36	
	near	shallow	9		36	108
		moderate	9		36	
		deep	9		36	
	far	shallow	9		36	108
		moderate	9		36	
		deep	9		36	
		Subtotal	**81**	**4**	**324**	**324**
Gull Island State Marine Reserve	within	shallow	9	4	36	108
		moderate	9		36	
		deep	9		36	
	near	shallow	9		36	108
		moderate	9		36	
		deep	9		36	

Site	Locational Gradient	Depth	Total no. of traps set per day	No. of days sampling required	Total no. of trap days	Total no. of traps in each locational gradient
	far	shallow	9		36	108
		moderate	9		36	
		deep	9		36	
		Subtotal	**81**	**4**	**324**	**324**
Grand Total			***255***	***12***	***1020***	***1020***

Replication: trap days

Replication is necessary to be able to demonstrate that significant differences are due to experimental treatments and not just chance variation in measurements (Underwood, 1997). However, there is a tradeoff between (1) cost and time and (2) precision and power (Underwood, 1997). A pilot study is the best means to estimate variation between samples and to thereby calculate the best compromise.

A related study was used as a pilot study by performing power analysis on abundance and size-frequency data from trap catches of lobster inside and out of an MPA at Santa Catalina Island in 2003 (Miller *et al.*, unpublished). This analysis was used to estimate the number of trap days necessary to detect a given effect size at a range of alpha values. An effect size of 50% with a 0.05 probability was selected based on the resources believed to be available for the study. Data provided by Miller *et al.* (unpublished) suggests that approximately 28 trap days are necessary to detect differences in abundance between fished and unfished areas. A total of 100 lobster traps are available for this study. Thus, each depth (i.e. shallow, moderate and deep) and gradient location (i.e. within, near, and far) can have a total of nine traps set per day for a four-day period. The total number of trap days is 36, a conservative estimate to detect the 50% effect size with a 0.05 probability.

The number of trap days necessary to detect differences between MPAs and fished sites depends on the desired effect size and the tolerance of a Type I error. The intrinsic variability in abundance and size-frequency of the lobster populations at Anacapa and Santa Cruz islands are the only components of the experiment that are not under the control of researchers. However, the estimates of trap days here provide approximations essential to determine costs and time to perform the study.

Randomization

The stratified random design for trapping sites within, near, and far from these MPAs will be primarily based on local knowledge of lobster fishermen in the area. Traps will be set in a stratified random design in areas where lobster fishermen have traditionally fished. Stratifying the design in this manner will minimize trap catches of zero or very few lobsters and provide a substantial gain in the precision of the index of abundance. Random stratification within specified sites will also help avoid the potential confounding effects of having different lobster fishers (of varying experience) setting traps between years.

GIS can help identify random locations within strata where traps should be set. Using available side-scan sonar data for the northern side of Anacapa Island, areas of hard substrate/rocky reef can be identified and digitized as a spatial layer within a GIS. Using existing digital bathymetry data, areas to be sampled can be constrained to chosen study depths. The random point generator created with Arc Avenue Scripts programming language is available free on the World Wide Web and can be used to randomly select trapping sites within selected strata. The user has the option of

selecting the number of random points generated, the minimum distance between points, and the minimum distance between each point and the site boundary. The side-scan sonar images are not yet available for Scorpion State Marine Reserve and Gull Island State Marine Reserve but the random point generator can still be used for this purpose.

All sites will be ground-truthed using SCUBA to ensure that control and treatment sites are as similar as possible with regards to habitat, but the spatial scale of this study (i.e. kilometers) may render this difficult. However, it is not essential that the chosen habitats are exactly the same and that lobster abundance is uniform at each of the sites because these changes will be tracked over time.

Balanced sampling

The monitoring plan will strive to maintain balanced samples (i.e. samples that are all of the same size). For each sampling day, sites should be chosen at random from the possible sites, with equal numbers of MPA and control sites on a given day. Samples may become unbalanced due to loss of data, for instance if traps are lost or if buoys are pulled under water by currents and irretrievable on a certain day. However, if there are numerous replicates (*n*) and only an occasional loss, the unbalanced analysis can be performed because the amount of difference is small and the effect on precision is miniscule when *n* is large (Underwood, 1997). The situation where some samples have large and others have small *n* should be avoided.

Trapping procedure

The trapping procedure to be used in this monitoring program has been designed after review of findings from trap use in previous studies (See references from Table 5-1).

Trap types

A total of 100 traps will be needed for use in the study. A standardized commercial lobster trap type will be used for all replicates. The trap type used is the same as those used by Miller *et al.* (unpublished). The traps used are 92cm (length) x 72cm (width) x 42cm (height) with a 19cm hoop diameter (see Figure 5-4**)**. The escape port will be barred off to ensure that undersize lobsters entering the traps are more likely retained. This will enable a more representative population structure to be sampled. Three data loggers will be fitted to moderate (10-14m) depth traps within, near, and far from MPAs to log bottom water temperature information.

Figure 5-4 A picture of the lobster traps to be used in this study (picture courtesy Miller *et al.*)

Trap spacing and layout

Two vessels will work simultaneously to deploy the traps at a minimum distance of 30m apart, in the sites chosen by fishermen. Trap placement will be determined using a stratified random design as described in the Randomization section above.

Immersion time

Prior to sampling all traps need to be soaked in the ocean for a period of approximately four days. This is a standard commercial lobster fishing practice that acclimates the traps to ocean conditions and improves their catch success by eliminating bubbling, unusual smells and other factors. Actual sampling will use a standardized immersion time (soak period) of 24 hours, after which the traps will be pulled and reset.

Bait

Fresh mackerel (*Scomber japonicus*) an oily fish bait consistent with that used by Miller *et al.* (unpublished) will be placed in the traps. Two mackerel (~500 grams) will be placed in a perforated bait container, allowing the bait to last (and smell) all night in each trap. The bait will be replaced each time the trap is pulled. The quantity, type, and presentation of bait will be standardized for all traps throughout the entire monitoring plan.

Trap checking and data collection

Data on oceanographic and environmental conditions will be recorded daily. These data include the swell direction and height, wind direction and speed, and bottom water temperature at 10m. Traps will be pulled every 24 hours for a four-day sampling period. Lobster data to be recorded for each trap pulled will include:

- GPS location of trap pull, depth and date of trap pull
- Total number of lobster in the trap
- Size (CL) measured with vernier calipers to the nearest 0.1 millimeter
- Sex
- Reproductive characteristics of female lobster (i.e. setose, plastered or egg bearing)
- Notes on injuries (e.g., missing limbs or death)
- Whether lobster is to be tagged (see Section below) or if a tag is present
- Tag number
- The presence of all bycatch in traps (e.g., sheephead, *Semicossyphus pulcher*)

All trapping data should be checked for errors on the day of recording and entered into a standardized database.

To minimize potential harm to trapped lobster they should be kept under cool, wet, dark conditions until they are released. Lobster could be kept in a live-well if the vessel is equipped with one. Lobster should be returned to the sea as quickly as possible, preferably within 5 minutes, and as close as possible to the location where they were caught. All lobster should be processed before the next trap is pulled. All dead lobster and lobster parts should be removed from traps before they are redeployed.

Tagging procedure

A proportion of trapped lobster will be tagged to enable recapture data to be collected on movement, growth rates, population size, mortality, and exploitation rate. Tags are inserted laterally into the lobster between the membrane separating the carapace and abdomen, into the abdominal muscle block. The tags are angled toward the tail slightly (Figure 5-5**)**. Tags are inserted laterally to minimize the effects of tail flipping and to avoid rubbing on rock ledges above or on the substrate. Lateral tagging also will ensure consistency between this study and that of Miller *et al.* (unpublished). Damaged lobster (e.g., lobster with missing limbs) should not be tagged as growth rates may be slowed (Brown and Caputi, 1985). However, if limbs are lost after tagging this should be recorded. Tagged lobster should have the one third of the second left pleopod clipped off with scissors to determine if a tagged lobster has molted when recaptured (Booth, 2003). Determining whether a lobster has molted can be an issue when growth increments are very small and even negative. This has been noted for other species of lobster, particularly for very large mature female *Jasus edwardsii* (Booth, 2003).

Figure 5-5 Lateral tag insertion point into the lobster (picture courtesy Miller *et al*).

Tag type and details

Floy tag model #FTLS-97 will be used to tag the lobster (Floy Tag Inc., Seattle, WA). This is the same tag model used by Miller *et al.* (unpublished) who estimate from captive tagged lobster trials and the literature that the tags are generally retained in lobster for two to three molts. The tag has a phone number to be called in case a tagged lobster is captured and a tag identification number that corresponds to data taken on the lobster when it was first captured.

If researchers recapture a tagged lobster it should have the appropriate data recorded and be returned to the sea as soon as possible. This will allow for future recapture information to be obtained. Commercial and recreational fishers should not retain undersized, tagged lobster for any reason, as this is illegal. Tagged legal sized lobster may be retained and tag information should be reported to the researchers.

Numbers of lobsters tagged

Approximately 1,700 lobster will be tagged in each of the two sampling months between all of the sites combined (Table 5-4). This should provide enough tag recaptures for preliminary estimates of growth rates and movement patterns to be made if recapture rates are similar to preliminary results reported by Miller *et al* (unpublished) at Santa Catalina Island of approximately ten percent. To test for tag loss rate, approximately 100 lobster should be double tagged. The number of recaptures is likely to be much lower in the no-take MPAs because research trapping is the only means for recapture. Commercial and sport fishing outside MPAs should result in higher tag recapture rates if reporting rates are high. Thus, a greater number of lobster should be tagged inside MPAs compared to outside (e.g., an inside: outside MPA tagging ratio of 2:1).

Ultimately, recapture rates, time constraints and the precision of required growth estimates will need to be reviewed after the September sampling to determine the number of lobster to be tagged in future sampling.

Size ranges of tagged lobster

Two size ranges (sublegal and legal) of lobster should be tagged within, near, and far from MPAs. The first tag group should include undersize lobsters between the minimum size generally caught in traps (i.e. 65mm CL) and the legal minimum size (i.e. 83.5mm CL). The second tag group includes lobster larger than 83.5mm CL. Equal numbers of each size group should be tagged to increase the range of potential growth rate and movement data from the study.

Table 5-4 A breakdown of the numbers of lobster to be tagged for each variable in the study.

Site	Locational Gradient	Depth	Size Class of Lobster	Number of Lobster to be tagged
Anacapa Island				
State Marine Reserve	within	shallow	sublegal	40
			legal	40
		moderate	sublegal	40
			legal	40
		deep	sublegal	40
			legal	40
	near	shallow	sublegal	20
			legal	20
		moderate	sublegal	20
			legal	20
		deep	sublegal	20
			legal	20
	far	shallow	sublegal	20
			legal	20
		moderate	sublegal	20
			legal	20
		deep	sublegal	20
			legal	20
		Total		**480**
Natural Area	within	shallow	sublegal	40
			legal	40
		moderate	sublegal	40
			legal	40
		deep	sublegal	40
			legal	40
	near	shallow	Compare to near and far sites as sampled above	
		moderate		
		deep		
	far	shallow		
		moderate		
		deep		
		Subtotal		**240**
Santa Cruz Island				
Scorpion State Marine Reserve	within	shallow	sublegal	40
			legal	40
		moderate	sublegal	40
			legal	40
		deep	sublegal	40

Site	Locational Gradient	Depth	Size Class of Lobster	Number of Lobster to be tagged
			legal	40
	near	shallow	sublegal	20
			legal	20
		moderate	sublegal	20
			legal	20
		deep	sublegal	20
			legal	20
	far	shallow	sublegal	20
			legal	20
		moderate	sublegal	20
			legal	20
		deep	sublegal	20
			legal	20
Subtotal				**480**
Gull Island State Marine Reserve	within	shallow	sublegal	40
			legal	40
		moderate	sublegal	40
			legal	40
		deep	sublegal	40
			legal	40
	near	shallow	sublegal	20
			legal	20
		moderate	sublegal	20
			legal	20
		deep	sublegal	20
			legal	20
	far	shallow	sublegal	20
			legal	20
		moderate	sublegal	20
			legal	20
		deep	sublegal	20
			legal	20
Subtotal				**480**
Grand Total				***1680***

Public awareness

Public awareness is imperative to increase the likelihood of information on tagged lobster being recorded and provided to researchers by lobster fishers throughout the fishing season. Most tagging programs concentrate the majority of their resources on tagging large numbers of animals, and tend to neglect the tag recovery end of the project (Hilborn and Walters, 2001). Tag recovery efforts will be more successful if fishers and other interested public are engaged in the process.

Commercial lobster fishers that work at Anacapa or Santa Cruz islands should be personally notified about the lobster monitoring program. The objectives of the project should be clearly explained and a brief flier describing the project should be sent to these fishers. Additional details of the monitoring plan should be provided on the World Wide Web. In addition, small cards could be printed and given to commercial fishers that list details that need to be recorded upon capture of a tagged lobster (i.e. cards with fields for precise GPS location of capture, date and depth of capture and CL measurement). Fishers should be asked to submit the information by phone, by mail or in person. However, it is unlikely that commercial or recreational fishers will have measuring devices of the accuracy needed to record CL measurements. To overcome this problem commercial lobster receivers could assist with measuring.

Licensed commercial lobster receivers in Ventura and Santa Barbara should be notified of the program in case any tagged lobster are found among the catch. While fishers record the GPS location, date and depth of tagged lobster commercial lobster receivers could precisely measure legal-sized tagged lobster that are included in the catch.

Local dive shops also should be notified and receive posters describing the project. If undersized lobster are captured, their capture details should be recorded and the lobster returned as quickly as possible to the sea and as close to the capture site as possible.

If funding can be arranged, a reward system for tag returns should be implemented to increase the tag return rate from fishers. For example, an effective incentive in similar studies for tag returns is the "lottery tag reward system" where a few high value tag rewards (e.g., $100-$500) are offered for certain returned tag numbers (unknown to the capturer) or each returned tag is entered into an annual drawing. Even minimal rewards can be incentive for recreational fishers, especially when accompanied by information on when and where the lobster was originally tagged and how much it had grown.

Data follow-up: public feedback

All tag return information should be publicly accessible and posted on the World Wide Web. This information should include the dates of release and recapture, growth increment over that period, the distance and direction between tagging and recapture sites, and the depth and capture means. Providing this information in a timely manner will provide a sense of inclusiveness in the project to the broader fishing community and will increase awareness and interest in the research.

5.1.3 Experimental analysis

This section outlines the descriptive and statistical tests that will be used to analyze the results from sampling described above. The analysis is described for each of the four study objectives.

Objective 1: To determine the relative abundance and size-frequency of lobster within, near and far from MPAs by comparing the catch per trap pull over time.

Catch per unit trap pull (CPUP) will be calculated as the total number of lobster caught per trap pull. This will be calculated overall and for legal and sublegal lobster catches. The variability of observations of lobster size and relative abundance within, near, and far from MPAs will be graphically plotted as relative frequency distributions. Relative frequency distributions from several populations are directly comparable, regardless of the sizes of the populations (Underwood, 1997). The mean size, standard error and 95% confidence interval of lobster populations sampled within, near and far from MPAs also will be calculated and compared.

A 3-way ANOVA will be used to analyze the data to determine if significant differences are observed in relative abundance and size-frequency of lobster within, near and far from MPAs. The

three factors in the ANOVA are the MPA, gradient location and depth. The measure of interest is the difference (*delta*) of the biological parameter value between the control and the impact site as assessed on each of the sampling dates (Osenburg *et al.* 1996). An analysis of covariance (ANCOVA) of lobster catchability with environmental conditions (e.g., swell height) also should be undertaken.

Objective 2: To determine the growth rates and patterns of movement of lobster from mark and recapture tagging within, near and far from MPAs.

Lobster growth rates will be estimated from the differences in size between tagged and re-captured lobster that have molted. A model based on the von Bertalanffy growth equation could be used to describe the average growth of lobsters at the Channel Islands based on tagging data (See Chubb *et al.*, 2000). The higher the number of lobster that can be tagged the greater the precision of growth estimates that can be made from the model.

The distances moved by tagged lobster will be calculated from the minimum straight line differences between capture and re-capture GPS locations. Movements will be plotted in GIS (ArcGIS 8.3) and visually and quantitatively assessed for any trends in direction and distance traveled. Tag recapture data also will allow calculations of net movement into and out of MPAs to test for spillover. It also will be possible to scientifically compare changes in depth distributions via movement over time. Given significant additional funding, certain lobster could be tagged with acoustic tracking tags and monitored with an existing array of hydrophones at Anacapa Island. This would provide detailed daily movement information that could be related to habitat.

Objective 3: To estimate population size, natural and fishing mortality and exploitation rates of lobster from mark and recapture tagging

Population size, survival and capture probability will be estimated from tagged lobster using capture-recapture models, such as Mark, Capture and Jolly, which are available from the web (see www.cnr.colostate.edu/~gwhite/mark/mark.htm and www.mbr-pwrc.usgs.gov/software). The different estimates from these models can be evaluated in part, by examining how well the assumptions for each model are met by the study design and by how well each model fits the data (Pine *et al.*, 2003). Population size estimates can only be made by recaptures from research traps because we will not know the number of non-tagged lobster caught by commercial and recreational fishers. Similarly, the best estimates of natural mortality will be derived from within MPA sampling. Fishing mortality can be estimated by subtracting natural mortality from total mortality and exploitation rates can be estimated by examining the total recapture rate of tagged lobster over the fishing season.

Objective 4: To determine the sex ratios and the reproductive conditions of female lobster.

A simple ratio of the number of male to female lobster caught can be calculated within and between MPAs, locational gradients, and depth categories. Trends in the reproductive characteristics of the female lobster sampled in June and September will be explored graphically.

Study limitations

Without data at sites inside and out of MPAs prior to their implementation, this study will be unable to conclude with certainty that differences between MPAs and fished areas are solely due to protection from harvesting within MPAs. To determine this would require quantification of pre-existing differences between the selected MPAs and control areas over several years (e.g., by using a Before-After-Control-Impact-Paired-Series study design). These data have not been collected for

lobster at the Channel Islands[1]. Several other factors could be acting on and influencing the sites being sampled, and several different processes may cause the observed changes other than protection from fishing. With the potential for these other influences to confound results, it is not possible to attribute causality to the observed difference from before to after protection from fishing (Underwood, 1997). This monitoring plan attempts to minimize the potential for these factors to affect results (e.g., by sampling paired sites and standardizing methodology throughout). While we do not have pre-existing data, it is critical that monitoring be undertaken to objectively evaluate changes and impacts over time that are most likely attributable to MPA protection.

[1] There is the potential for these baseline data to obtained from previous seasons lobster logbook records at CINMS but the accuracy and validity of such comparisons will require thorough investigation.

5.2 Incorporating local ecological knowledge into the monitoring framework

Our analysis of the Draft Monitoring Framework found that CDFG's plan to combine monitoring protocols from PISCO and NPS was statistically adequate, particularly in terms of benthic community comparability. This indicates that CDFG could use both PISCO and NPS existing sites. The combination of these two programs provides CDFG with monitoring sites throughout CINMS. However, as is evident in Figure 5-6, large geographic gaps still exist in the coverage of established monitoring sites throughout the MPA system. This is especially true throughout the western MPAs off of San Miguel and Santa Rosa islands.

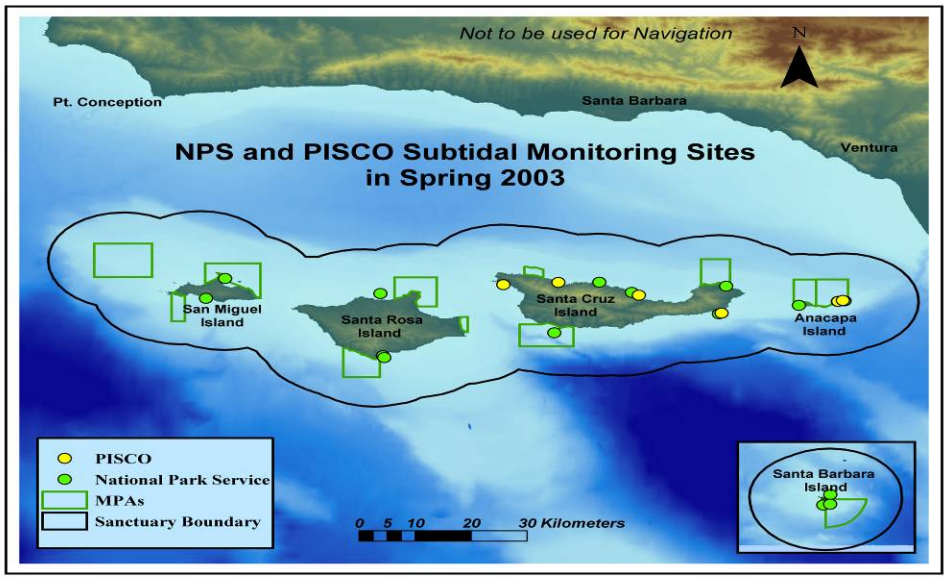


Figure 5-6 NPS and PISCO sites in Spring, 2003

To fill some of these geographical gaps, new monitoring sites must be established. During the summer of 2003, CDFG proposed adding several subtidal sites to its existing study area that would be relevant to MPA monitoring. New sites must be comparable to existing sites in terms of habitat. This requires that researchers first locate rocky reef substrate using echo sounding equipment from their boat. Potential sites must then be ground-truthed by SCUBA divers. This process can be taxing to researchers in terms of both time and effort.

The CDFG believed that the extensive ecological knowledge of local communities could be a great assistance to the selection of new monitoring sites. Information concerning habitat characteristics of the island's subtidal zone could save researchers time and effort during the site selection process. Although ground-truthing would still be necessary, such information could give researchers valuable starting locations. To obtain the local knowledge, CDFG organized a meeting in the early summer of 2003 between local fishers and divers. At the meeting, CDFG was able to gather information describing general habitat characteristics of certain regions. Although this information was useful, our group believed that further input from local fishers and divers would be valuable to CDFG and researchers during the site selection process. To address this issue, our group conducted interviews with local fishers and divers who were willing to assist with the site

selection process using a list of fishing community contacts provided by CDFG and CINMS. The list was comprised of commercial fishers and divers who already had been involved in the MPA planning process. We informed the individuals any information they provided would be shared with CDFG and PISCO to assist with their site selection.

5.2.1 Lobster fishermen interviews

Three lobster fishers from the contact list were contacted and were willing to share their knowledge about the lobster fishery. Interviews were conducted with these people to gain insight into the following topics:

- Distribution of historical lobster fishing effort in current MPAs
- Trapping issues such as proper depth and the minimum distance between traps to avoid traps 'competing'
- Location of comparable sampling habitats within, near and far from MPAs;
- Potential participants in monitoring program;
- Potential cost estimates for the use of fishers services in sampling (e.g., boat, fuel, deck hand, skipper, bait per day, and traps)
- Additional suggestions

These interviews were highly successful both in gathering this information and in forming relationships for potential collaboration and participation in the monitoring program. Follow-up interviews also were conducted, further aiding the monitoring planning process. Ultimately, we hope that a workshop bringing together interested lobster fishers, scientists and governmental agencies can be organized to discuss the monitoring plan.

5.2.2 Site selection interviews

Four fishers from the list were contacted to discuss their participation in the site selection process. Some of those contacted felt it was ultimately not in their best interest to share this knowledge. The near-shore, rocky, reef habitat where researchers will establish monitoring sites is the same habitat where many fishers focus their fishing effort. In a highly competitive fishing industry, the knowledge of these locations is closely guarded. Some fishers were particularly reluctant to share this information with CDFG who was already responsible for the closure of 19% of the state waters surrounding the Channel Islands into MPAs.

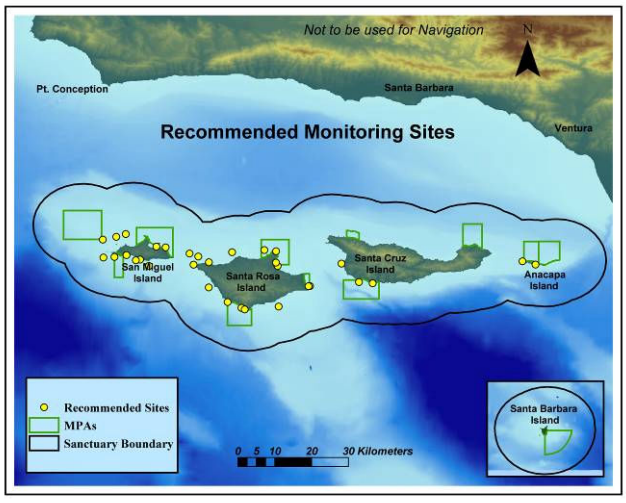


Figure 5-6 Potential Sites Locations (32) located through site selection interviews

Individuals also believed that their input during the planning process was not incorporated into the monitoring design, specifically by not addressing issues relevant to fishery management. For these reasons, some of those contacted declined to participate in this process. Nevertheless, two individuals were willing to share their knowledge about specific habitat characteristics of CINMS. Private meetings were held with these individuals and we provided maps and nautical charts of the Channel Islands to use as aids. The interviewees worked both from

memory and using personal logbooks to identify the locations of rocky reefs in the near-shore, subtidal zone off the islands at a depth of less than 60 feet.

One of the interviewees marked potential site locations directly on maps and nautical charts. The other provided specific LORAN-C coordinates from his personal logbook. In total, 32 potential site locations were identified throughout CINMS (Figure 5-6). Emphasis was placed on the San Miguel and Santa Rosa Islands due to the relative lack of existing sites off of these islands. This information was provided directly to CDFG and PISCO, and PISCO used these sites as starting points for site selection surveys during the summer of 2003. Figure 5-7 illustrates the new monitoring sites established by PISCO during the summer.

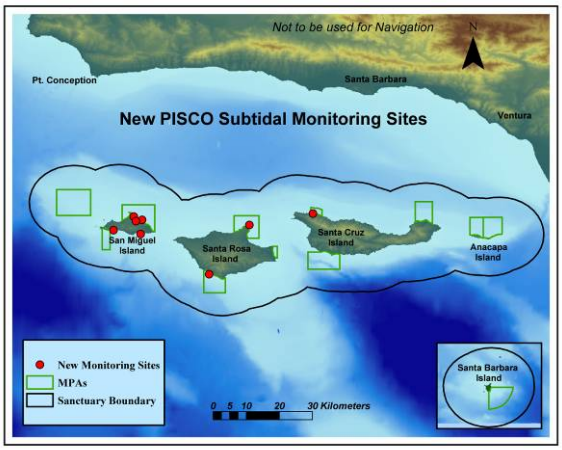


Figure 5-7 Additional PISCO monitoring sites located with assistance from local ecological knowledge

5.3 Centralized database: data acquisition and management

5.3.1 Problem statement

Throughout the ecological and policy realm, data acquisition and management is increasingly recognized as an essential aspect to ecological analyses. "The inability to easily integrate data becomes critical when the data also have major practical implications for policy planning or decision-making" (Reichman *et al.*, 1999). Other data management initiatives have set precedent to store data from various programs in order to allow scientists to look at monitoring data in a broader regional context and to allow more comprehensive evaluations. These programs include the Multi-Agency Rocky Intertidal Network (MARINe) database of southern California and the monitoring database for the Florida Keys marine ecosystem monitoring plan (FKNMS, 2003)

Due to the various agencies monitoring and researching the shallow subtidal ecosystem of CINMS and the limited budget of CDFG to initiate its own monitoring program, CDFG is relying on the data acquired by other programs. The CDFG must have a means to collect the data and store it in a useful way. The data storage must allow analysis that will provide answers to CDFG's questions regarding the performance of MPAs. We designed a database using Microsoft Access for CDFG to use in MPA monitoring analysis. The steps taken to achieve this are outlined below.

5.3.2 Approach

To design an effective database, we had to define the questions that the information stored in the database were intended to address, and then determine what type of data needs to be stored to answer these questions. The questions were based on the rationale behind monitoring, which is to understand the impact of MPAs on the marine communities, habitat, and structure. Six hypotheses to be tested by the database are listed below:

Hypothesis 1: The diversity of fishes will be influenced by MPAs.
Hypothesis 2: The mean fish length will be influenced by MPAs.
Hypothesis 3: Fish species abundance will be influenced by MPAs
Hypothesis 4: Invertebrate and algae species diversity will be influenced by MPAs.
Hypothesis 5: Invertebrate and algae abundance will be influenced by MPAs.
Hypothesis 6: Habitat structure will be influenced by MPAs.[2]

These hypotheses provide the necessary baseline to determine what type of data should be stored by CDFG. The following sections specify what data CDFG is storing and how it is organized.

Monitoring site characteristics

The CDFG needs to store spatially explicit data on community changes among monitoring sites inside and outside MPAs. Therefore, it is imperative to record the geographic coordinates of sites to determine their spatial relationship (inside or outside) to an MPA. It is also important to indicate the monitoring program that conducts research at each site. Additionally, the database requires information on the monitoring program should any questions arise regarding the collected

[2] The terms used in the above questions are defined as:

Species diversity:	Number of different species found at site
Species abundance:	Number of individuals in species/ meter^2
Paired sites:	Comparable sites inside an outside reserve: comparable in depth, substrate, habitat and oceanographic and environmental conditions.

data. This information includes contact information for the researchers as well as the protocol they use (See Appendix F for the specific information stored).

Species list

PISCO and NPS monitor the shallow subtidal communities, which are composed of many species and habitat types. The major community types in CINMS are the benthic, or ground dwelling communities, and fish communities, while the major habitat types include rocky reefs often dominated by kelp forest and soft-sediment bottom. Both monitoring programs record data on the majority of the species in each community. Our group worked with CDFG to create a narrow species list from NPS and PISCO data that highlights species encompassing the range of possible responses from the marine community to MPAs. This list allows CDFG to have more manageable data, while not losing any important information regarding MPA effects. The official species lists (including fish, invertebrates, algae) are found in Appendix F.

Further, 'focal species' were identified at the March 2003 workshop. Species were chosen for their range of expected responses to MPA implementation. Species with high fecundity and high exploitation rates have the ability to show a rapid response to removal of fishing pressure, while moderately exploited species with low fecundity will take longer to show a response. Some species may actually decline inside MPAs as a response to an increase in their previously exploited predators (CDFG, 2004). Table 5-5 lists the nine fish, 12 invertebrates, and one algal focal species as well as their fecundity and exploitation history.

Table 5-5 Focal Species. These species were highlighted by CDFG as focal species for monitoring MPA responses. These species range in expected response due to their life history and exploitation history. (http://www.dfg.ca.gov/mrd/channel_islands/monitoringplan0204.pdf))

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.

Habitat data

Both NPS and PISCO use the Random Point Contact method to determine ground cover at their sites. This method randomly selects numerous points along a transect and records the type of ground cover at that point. In this way, a picture of what percentage of the ground is covered by certain types of rocks, algae or other benthic organisms is recorded. The ground cover CDFG will store information on is shown in table Table 5-6.

Table 5-6 Habitat Records. This table shows the information CDFG will collect on the mean percent ground cover of each monitoring sites. At times, the NPS and PISCO have slightly varied definitions for the ground cover; these are explained in the definition column.

Ground Cover	Common Name/ definition
Cystoceira spp.	Bladder Chain
Desmarestia spp.	Acid Kelps
Eisenia arborea	Southern Sea Palm
Laminaria farlowii	Oar Weed
Macrocystis pyrifera	Giant Kelp
Pterygophora californica	California Sea Palm
Cobble	NPS def = easily moved by diver; PISCO def = diameter is <10cm
Encrusting Algae	Encrusting coralline algae
Rock	NPS def = impossible to move; PISCO def = boulder (10cm-1m) or bedrock (>1m)
Sand	Sand
Relief	The greatest vertical relief that exists within a 1-meter wide
Bare Substrate	No cover, devoid of living organisms

Once the species and ground cover lists were established, the next step was to determine what type of data to store. To minimize issues with private and sensitive data collected by agencies or researchers that are funded by grant money, CDFG only asks the participating programs for data summaries, rather than raw data. By only requiring data summaries, CDFG hopes that more researchers will be willing to contribute information. The data summaries required for ground cover and species at each monitoring site for each year are:

- Mean percent cover (for ground cover)
- Mean length of species (for relevant fish and benthic species)
- Abundance of species (for benthic and fish species)

5.3.3 Database design

When designing a database, it is important to minimize the amount of redundancy in the data. This reduces human error in data entry, and reduces the amount of space the data will occupy. Further, without redundant values, it is easy and efficient to update values. All tables in the database can be related through the use of primary and foreign keys.

Primary and foreign keys are tools in a relational database. The primary key is simply a unique value given to a row in the database, which allows the key to represent all the data in its row.

The foreign key is the use of the primary key in another table, relating it to the foreign key's row in its original table.

In the design phase, the first step is to construct the logical model of the database, followed by the physical model. The logical model consists of the entities, attributes and relationships. These are outlined in the Shallow Subtidal Monitoring Database User Guide (Appendix G). The physical model implements the relationships in the database. The relationships (Figure 5-7) show how the tables are related through the primary keys and foreign keys in each table.

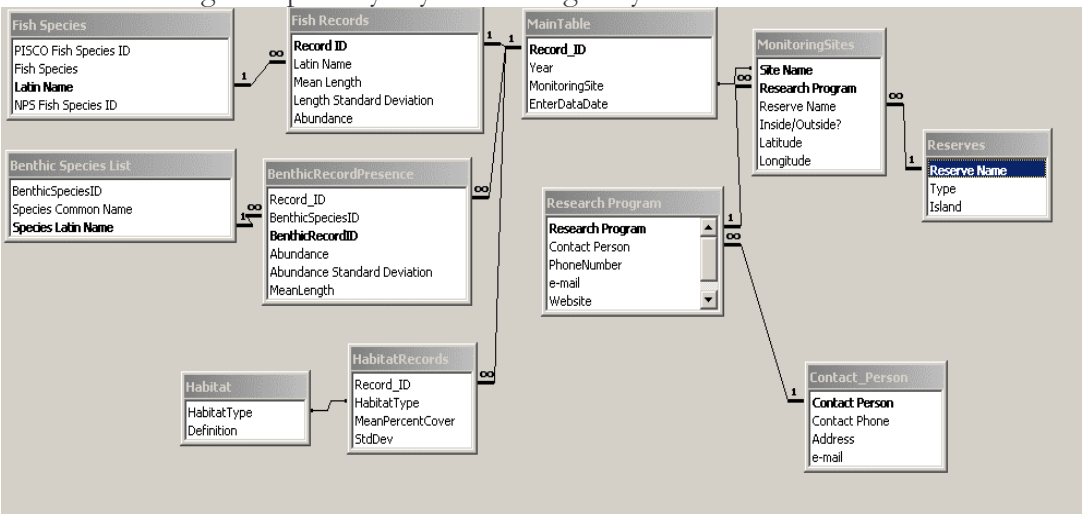


Figure 5-7 Relationships in Shallow Subitidal Monitoring Database. Lines indicate where fields are related. Bold lettering indicates primary keys. The line attaches primary keys to foreign keys in other tables. When these two attributes are equal, the data is linked.

5.3.4 Data interpretation

All data from the different participating research programs is standardized. For instance, all abundance data for species is in numbers of organisms per square meter; random point contact data is considered habitat data and is expressed in percentages and organisms that have mean length or average size data is expressed in millimeters.

When analyzing the data it is important to understand the comparison (or comparative) analysis discussed in section 4.2.2. This analysis considered the comparability of species results between the two protocols. The benthic species analyzed to determine comparability between NPS data and PISCO data are outlined in Table 5-7. Data on certain species can be analyzed from both programs (NPS and PISCO)(*i.e.* inter-program) and other species should be analyzed with data solely from the program that collected it (*i.e.* intra-program). When CDFG analyzes focal species, these constraints must be considered.

Table 5-7 Benthic species analyzed to determine comparability between NPS and PISCO data. The species in bold are focal species.

Benthic Species (Focal species in Bold)	Compare Data inter-program	Compare Data intra-program
Aplysia californica	*	
Asterina miniata	*	

Crassedoma giganteum		*
Cypraea spadicea	*	
Eisenia arborea		*
Haliotis corrugata	*	
Haliotis fulgens	*	
Haliotis rufescens	*	
Kelletia kelletii	*	
Lithopoma undosum	*	
Lytechinus anamesus		*
Macrocystis pyrifera	*	
Megathura crenulata		*
Panulirus interruptus	*	
Parastichopus parvimensis		*
Pisaster giganteus		*
Pisaster ochraceus		*
Pycnopodia helianthoides	*	
Strongylocentrotus franciscanus	*	
Strongylocentrotus purpuratus		*
Styela montereyensis	*	
Tethya aurantia	*	

Microsoft Access is the tool that was selected for the database design because it is easily accessible by CDFG. The program uses queries to analyze the data, import the data, organize the data in various ways, or provide charts and graphs to visualize the data. This database provides macros as well, which allow the user to run through a set of queries in a certain order. The database is set-up to allow the user to create macros that will take the summarized data, and provide a report (to see the database's queries, macros and forms see Appendix G).

To ease the import of NPS data, three macros were created to standardize the import and summarize the data. In the future, these will be created for PISCO data or for any participating program. For example, if data from the proposed spiny lobster monitoring plan is collected, then CDFG can coordinate with the lobster data managers, to collect and summarize the data in a way that will ease import into the centralized database.

The database allows the user to either import data or enter data by hand into the Shallow Subtidal Monitoring Entry Form (Figure 5-8). To understand how and when to use the form see the Shallow Subtidal Monitoring Database User Guide, Appendix G.

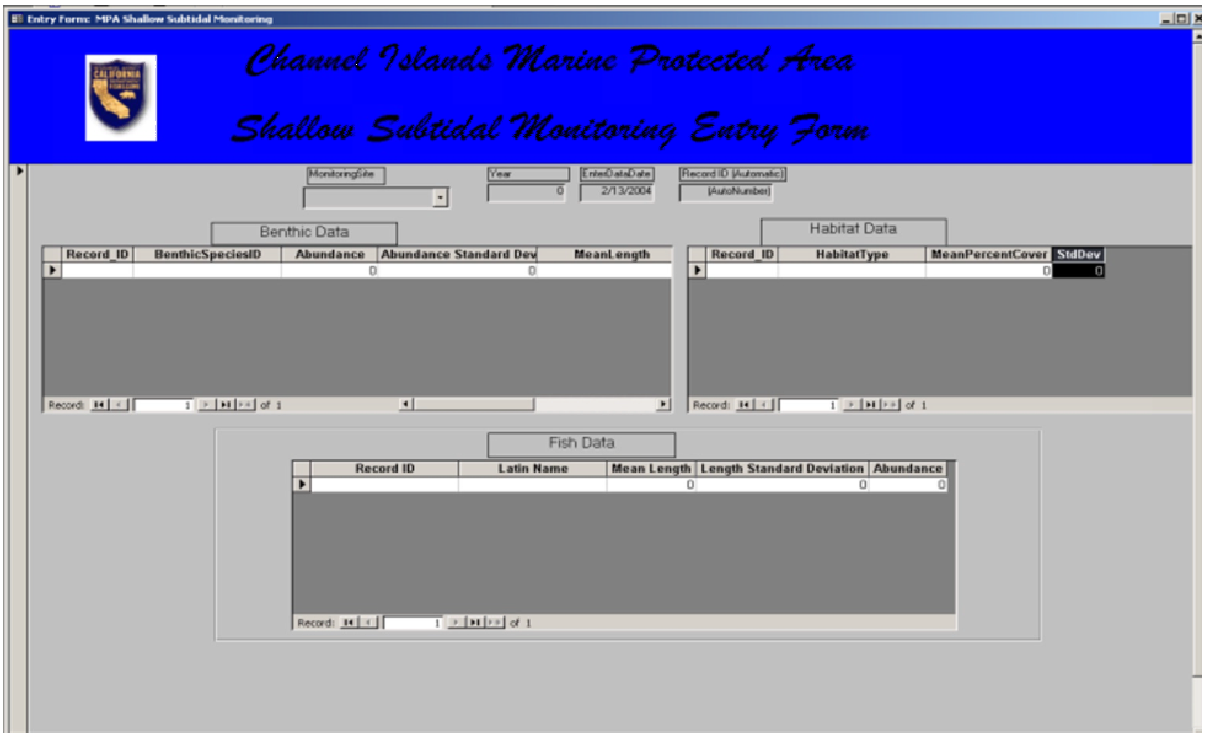


Figure 5-8 Screen shot of entry form from the Channel Islands Shallow Subtidal MPA Monitoring Database.

5.3.5 Database Use

New Program:

When a new program becomes part of the DFG shallow subtidal monitoring, information regarding the program must be entered into the database initially into three tables. By opening the table "Research Program" the database user can enter the name of the research program, the contact person, a URL and a link to the program's subtidal protocol. Further information, such as phone numbers, address and e-mail, can be entered into the table "Contact_Person." Finally, the sampling site information and characteristics must be entered. To do this, the user should first open the "Monitoring Sites" table. This table holds information on the site name, the program that researches the site, the site coordinates, which reserve the site is associated with, and if it is inside or outside the associated reserve.

New Data Entry:

To enter new data summaries into the database, the database user must first make sure that the data corresponds to a record ID. A record ID is simply a unique number given to a specific site during a specific year. By opening the form "Entry Form: MPA Shallow Subtidal Monitoring" and going to a new entry, the user can enter the monitoring site name from a list, and enter the year. The database will automatically provide the unique record ID. This same form allows the user to enter habitat, benthic, and fish data that correspond with the site and year combination.

5.4 Creation of a shallow subtidal ecological monitoring program website

Our group designed and created a website for CDFG to assist in its efforts to make information concerning the current status of the MPA monitoring plan accessible to the public. It was desirable to create a webpage that was informative to the public, as well as a practical source of information

relevant to researchers interested in contributing to MPA monitoring. Participating researchers must have access to information regarding the types of monitoring being conducted, the experimental protocols being used, and the locations of existing monitoring sites throughout CINMS. Our group created a webpage that contains the following information:

- Participating monitoring programs
- Experimental protocols of these programs
- Lists and descriptions of focal species
- Locations of monitoring sites throughout CINMS

Our group worked with CDFG representatives at the local Santa Barbara office to ensure that the web content we provided was both sufficient and appropriate towards CDFG's goals. We also coordinated with CDFG's web server administrator in Sacramento to ensure compatibility to the existing CDFG website format. To ensure compatibility and to make the site easily updateable, html code was written directly without the use of proprietary html editors. The CDFG's existing file structure also was maintained during the website creation. Both PISCO and NPS were consulted during the website development to ensure that each program approved of the website content. Our group also consulted with PISCO's website and GIS technicians for input and advice.

Our effort to summarize existing research programs throughout CINMS generated much of the information required for the website. Throughout our project, our group compiled, maintained, updated, and manipulated an extensive GIS database. We already created spatial GIS layers representing existing monitoring sites and gathered experimental protocols of participating programs were readily available.

Figure 5-9 Shallow Subtidal Monitoring Website main page

The construction of this website took place concurrently with PISCO's efforts to establish new monitoring sites for MPA monitoring. To keep the website current our group coordinated its work closely with PISCO throughout the summer to include the new monitoring sites. As PISCO completed site surveys, we received and incorporated latitude and longitude coordinates into our group's existing GIS database.

Figure 5-9 shows the main page for the shallow subtidal monitoring website. Users can click on links in the side menu to view more detailed information on participants in the program, focal species, and monitoring site locations.

The link to "participating partners" provides a page with descriptions of the NPS and PISCO programs. Along with general descriptions, users can access each program's individual experimental protocols (Figure 5-10). The page also provides a link to the summary of existing research programs.

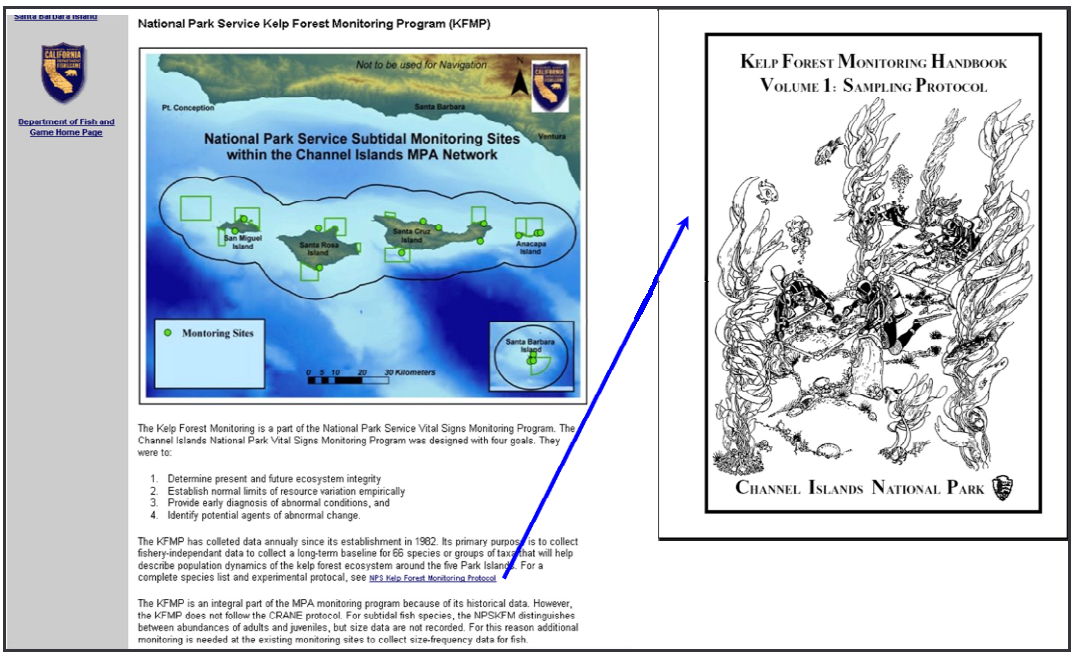


Figure 5-10 Demonstrates the link to participating programs' survey protocols.

The species list page includes a list and description of 34 finfish species, eight species of macroalgae, and 29 invertebrates. Each species' name provides a link, which accesses short descriptions or existing CDFG documents written about the species. Photographs of many of the species also can be accessed (Figure 5-11).

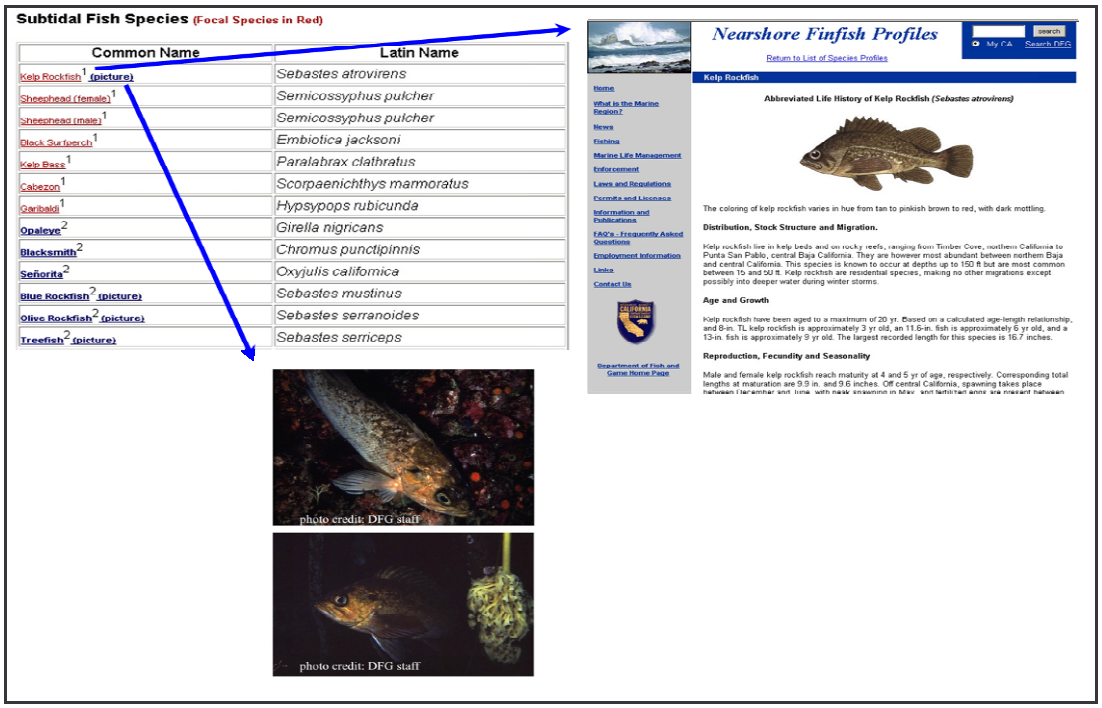


Figure 5-11 Species list, and available information such as pictures and fish profiles.

To view the locations of monitoring sites throughout the islands, a user can simply click on a specific island link in the side menu or on an island itself in the map on the main page. These links allow the user to view nautical chart images of each island along with points to indicate existing monitoring sites. When a user clicks on a monitoring site point, they can view aerial photographs with transect survey boundaries overlaid (Figure 5-12).

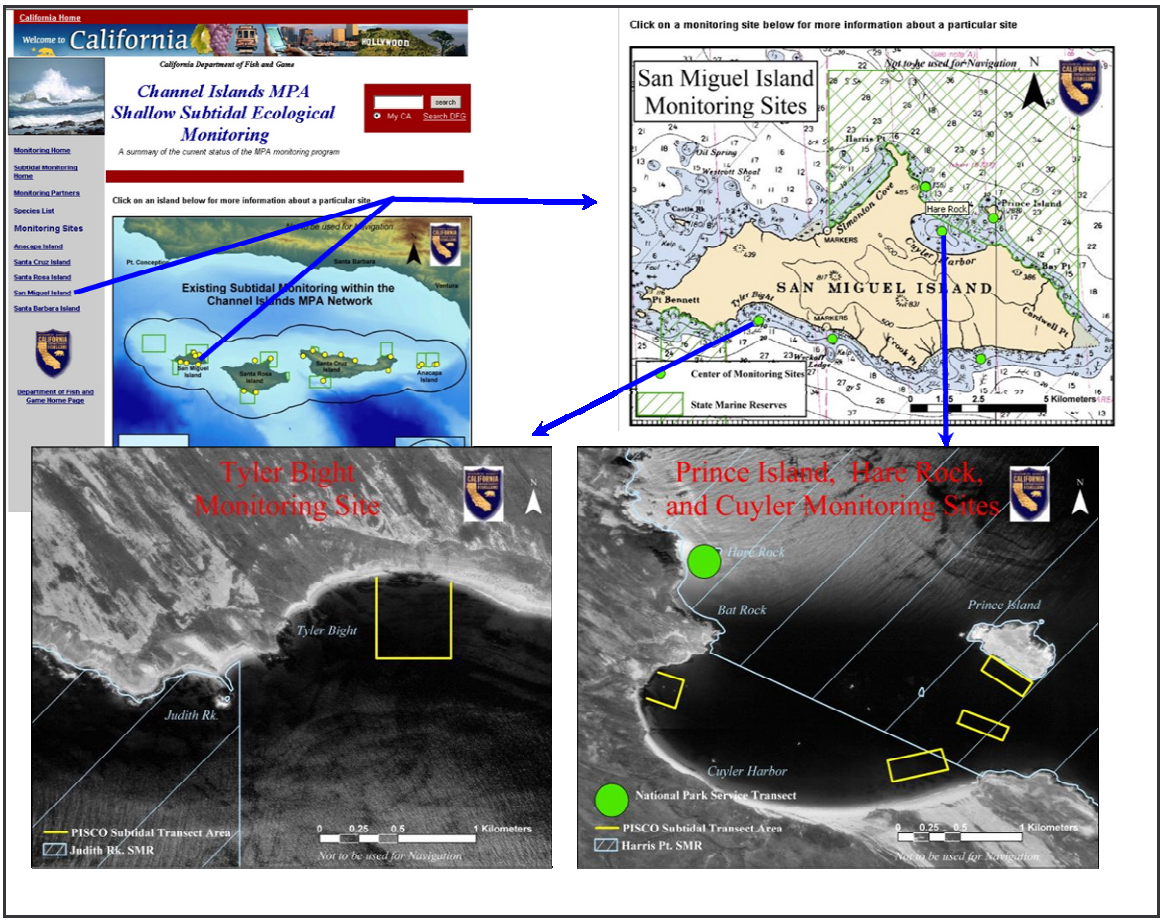


Figure 5-12 Website has the ability to show aerial photographs of monitoring sites with transect survey boundaries overlaid.

The website is designed to help managers, scientists and the public to stay up-to-date on the status of the subtidal monitoring program. A future project could include the development of a page that allows users to access summarized data collected from individual monitoring sites.

6 Recommendations

Based on the results of our power analysis, we recommend that CDFG be aware of the possibility of a lack of sufficient power to detect 100% difference in benthic invertebrate density between sites inside and outside of the marine protected areas. The results were obtained from calculations using data collected by protocols with low sample size of four transects, and therefore show low power. With CDFG's intended sample size of 24 transects, increased power may be likely. Therefore, we do not state with certainty CDFG's monitoring program lacks power, but CDFG should prepare itself for the possibility of the need to increase power by increasing sample size above the intended 24 transects. We also recommend that our methodology and the accuracy of our resulted be checked by an expert biostatistician and that other means of calculating power of the PISCO and NPS data be explored

We recommend the lobster monitoring program be implemented to help address the need for MPA fishery monitoring. This plan takes a major step toward determining the value of MPAs as a fishery management tool while collecting information to potentially improve management of the lobster fishery. The cooperative nature of the plan can be refined and tailored to achieve an effective balance between the needs of industry, science, and the public.

Ultimately, the website should support on-line database queries to allow interested parties to access and analyze data from MPA monitoring. This will encourage greater input from researchers and the public, while further enhancing public involvement and government transparency.

As additional programs become part of CDFG's overall shallow subtidal monitoring, we recommend that they follow the CRANE protocol as a baseline for their survey methods. If they use a different protocol, statistical analysis should be performed to determine data comparability. If the programs are not comparable, then the data should not be analyzed across programs.

The CDFG also should actively work to support and incorporate other monitoring programs. For example, volunteer programs such as REEF (Reef Environmental Education Foundation) or programs that involve commercial fishers fishing for data could be extremely useful for expanding and improving the MPA monitoring effort. Presently, the lobster fishery monitoring program is not sufficient to address and evaluate the entire range of fishery benefits that MPAs may provide. Additional fishery monitoring should also be incorporated to collect essential fishery information.

7 Conclusion

Our project attempted to fill gaps in CDFG's shallow subtidal monitoring plan. Marine regulations and policies are beneficial only if the regulated community accepts them and if they achieve the claimed objectives. Our project was undertaken to assist CDFG in determining whether or not MPAs are the proper management tool for conserving biodiversity and enhancing the region's depleted marine resources, as well as to address stakeholder concerns, and to increase transparency of the regulatory process.

During an initial analysis, we found that the programs currently participating have comparable experimental protocols. This allows CDFG to include all of the NPS and PISCO sites for its benthic community monitoring. This comparability, however, only exists with data on a certain subset of benthic species. The CDFG may include data from both program's monitoring sites when analyzing these species. However, data for other species can only be analyzed using other data from individual programs or protocols.

Even with the flexibility to use various programs, there was still not complete monitoring coverage of the MPAs. In order to expedite the establishment of new sites with similar habitat, we contacted fishers with extensive knowledge of CINMS. Certain fishers were reluctant to provide information due to frustration with or distrust of the government. However, some fishers were interested in participating in the process and provided valuable knowledge about the location of comparable habitat throughout CINMS. These sites provided direction to the scientists and CDFG while adding new monitoring sites in the summer of 2003, or year zero of the monitoring framework.

The initial analysis also indicated that there might not be sufficient power to detect 100% effect size using the sample size of 24 transects intended by CDFG, given the data collected by PISCO. The PISCO data were collected using small sample size and exhibited large variances, which results in low power. Using mathematical formulas, the power that can be achieved by a sample size of 24 transects was projected using the highly variable PISCO data. This projection yielded somewhat low power for 24 transects. However, power may not be as low as projected when CDFG actually carries out the monitoring with 24 transects. The projection performed by our project serves to forewarn CDFG of the potential of low power using CDFG's intended sample size of 24 transects.

To address the MPAs fishery objective, we are proposing a Fishery Monitoring Plan for the California spiny lobster. This plan will allow CDFG and the fishery to determine the effects of the MPAs on the lobster. Additionally, there has been little to no direct monitoring on this fishery in

recent times, and this plan will allow for the gathering of EFI needed for proper fishery management. It is hoped that the cooperative and transparent nature of this program will garner support from the community.

The lack of a central database was a straightforward problem with a complex answer that is still in development. Our group designed a database that can hold all the information necessary for CDFG to answer the questions it asks about the effects of MPAs. The design allows for the ability to query the data to address spatial, temporal, and biological analysis. The database is also equipped with macros to adjust the data format of the NPS protocol before importing it into the database. Macros can be created for every program that participates in monitoring. This will allow CDFG to easily import data from various programs that may have recorded their data in different methods. For example, this database will allow CDFG to easily import data generated from the lobster monitoring program our group designed.

Finally, CDFG has a legal responsibility to make its progress in the monitoring effort available to the public. Although CDFG did not have a plan to directly address this issue, they did have the existing infrastructure to make this information public using their Internet web server. Our project designed and created web pages that provide information on the current status of the monitoring program to place on CDFG's existing web site. This information includes a list and description of participants, protocols, focal species, and monitoring site locations. Those researchers who wish to contribute to the monitoring effort can view the website both to determine where additional sites are needed and what protocols must be followed. This page helps fulfills CDFG's responsibility to make its efforts public and may facilitate further expansion of the monitoring coverage throughout the MPAs.

The tasks our group performed throughout our project augmented CDFG's MPA monitoring program. Our project outlined and addressed considerations management agencies should take in the future. At its core, our project was undertaken to further incorporate the needs and interests of the public while improving governmental management of marine resources. The challenges CDFG will face in accomplishing this goal are great and indicative of the broad nature of the public's interest. CDFG is charged with the task of managing resources that are of both economic and ecological value. Although stakeholders may differ in the nature of their concern, all are united in their desire for the public management of the marine resources to be efficient, effective, and accountable.

8 References

Agardy, T., Bridgewater, P., Crosby, M., Day, J., Dayton, P., Kenchington, R., Laffoley, D., McConney, P., Murray, P., Parks, J., and Peau, L. (2003). Dangerous targets? Unresolved issues and ideological clashes around marine protected areas. *Aquatic Conservation: Marine and Freshwater Ecosystems* **13** (4) pp. 353-367.

Allen, B. M. (1916). Notes on the spiny lobster (*Panulirus interruptus*) of the California Coast. Univ. Calif. Publ. Zool. 16 pp. 139-152.

Alolkoy: News from the Channel Islands National Marine Sanctuary (2002). Channel Islands National Marine Sanctuary. Vol. 15, No. 2.

Annual report. Sentinel lobster fisheries project for the Florida Keys National Marine Sanctuary (1998). Principal Investigator Douglas R. Gregory, Jr. University of Florida/Florida Sea Grant. http://monroe.ifas.ufl.edu/lobster_rpt_final98.htm

Auster, P., Malatesta, R., Langton, R., Watling, L., Valentine, P., Donaldson, D., Langton, E., Shepard, A., and Babb, L. (1996). The impacts of mobile fishing gear on sea floor habitats in the Gulf of Maine (Northwest Atlantic): implications for conservation of fish populations. *Reviews in Fisheries Science* **4**: pp. 185-202.

Barilotti, C. (2001). California's spiny lobster fishery: An overview. California Seafood Council. Prepared by Sea Foam Enterprises, San Diego.

Barrett, N. and Buxton, C. (2002). Examining underwater visual census techniques for the assessment of population structure and biodiversity in temperate coastal marine protected areas. Technical report series. Tasmanian Aquaculture and Fisheries Institute, University of Tasmania. http://www.utas.edu.au/tafi/TAFI_Homepage.html

Bell, R. R. (1974). California commercial lobster fishery: 1973-1974 season, Marine Resources California Department of Fish and Game.

Bertelsen, R. D. and Matthews, T. R. (2001). Fecundity dynamics of female spiny lobster (*Panulirus argus*) in a south Florida fishery and Dry Tortugas National Park lobster sanctuary. *Marine and Freshwater Research* **52**: pp. 1559-65.

Booth, J. D. (2003). Research sampling design for rock lobsters in Te Tapuwaeo Rongokako Marine Reserve. Department of Conservation, Science Internal Series 128. Wellington 25p.

Bortolazzo, K. (2003). Personal communication. Channel Islands commercial lobster fisherman, California.

Botsford L., Castilla, J., Peterson, C. (1997). The management of fisheries and marine ecosystems. *Science* **277**: pp. 509-515.

Brock, R. E. (1982). A critique of the visual census method for assessing coral reef fish populations. *Bulletin of Marine Science* **32**(1): 269-276.

Brosnan, D., Buffam, I. and Brosnan, I. (2002). Scientific monitoring: report and recommendations. The marine reserve of St. Barthelemy, French West Indies. Sustainable Ecosystems Institute, Portland, Oregon. http://www.sei.org

Brown, R. S. and Caputi, N. (1985). Factors affecting the growth of undersize western rock lobster, *Panulirus cygnus* George, returned by fishermen to the sea. *Fishery Bulletin*: Vol. 83, No. 4.

Brown, R. S. and Dibden, C. J. (1987). A re-examination of the methods used for handling undersize western rock lobster. Fisheries Department, Western Australia. Report No. 78

California Sportfishing Coalition.http://www.savefishing.com/economic/mpa.asp. Last Accessed 2/1/04

California Department of Fish and Game (2003a). Nearshore Fishery Management Plan. http://www.dfg.ca.gov/mrd/nfmp/section1_chap4.html#movement

California Department of Fish and Game (2003b). Marine protected areas in NOAA's Channel Islands National Marine Sanctuary. Final environmental document. Chapter 1. http://www.dfg.ca.gov/mrd/ci_ceqa/index.htm

California Department of Fish and Game (2003c). Draft biological monitoring framework. http://www.dfg.ca.gov/mrd/channel_islands/draft_bmf.pdf

California Department of Fish and Game and the Channel Islands National Marine Sanctuary (2003d). Summary of research programs in the Channel Islands National Marine Sanctuary. February 20, 2003.Assembled by: Abeles, A., Chiang, L., Stadler, M., Pitterle, B.: Donald Bren School of Environmental Science and Management, University of California, Santa Barbara. Airamé, S and Fangman, S.: Channel Islands National Marine Sanctuary. Bergen, M. and Ugoretz, J. : California Department of Fish and Game. http://www.cinms.nos.noaa.gov/marineres/PDF/sum_research.pdf

California Department Fish and Game; Fish and Game Commission (2003e). Digest of California commercial fish laws and licensing requirements (Jan 1st).

California Department of Fish and Game (2003f). Channel Islands Monitoring Workshop Participant Worksheet Results. http://www.dfg.ca.gov/mrd/channel_islands/monitoring_worksheet_summary.pdf

California Department of Fish and Game (2004). Final draft monitoring plan. http://www.dfg.ca.gov/mrd/channel_islands/monitoringplan0204.pdf

Caputi, N. and Brown, R. S. (1986). Predictions of recruitment in the western rock lobster (*Panulirus cygnus*) fishery based on indices of juvenile abundance. *Canadian Journal of Fisheries and Aquatic Science*. **43**(11): pp. 2131-39.

Casselle, J. (2003). Personal communication. Biologist, Marine Sciences Institute, University of California Santa Barbara

Channel Islands National Marine Sanctuary. http://www.cinms.nos.noaa.gov/focus/about.html Last Accessed 2/1/04

Channel Islands National Marine Sanctuary (2002). Marine Reserve Working Group. History of the community-based process on marine reserves at the Channel Islands National Marine Sanctuary 1999-2001. http://www.cinms.nos.noaa.gov/marineres/PDF/mpa_history%20of%20process.pdf

Channel Islands National Park. Kelp Forest Monitoring Handbook Vol.1: Sampling Protocol at www.nature.nps.gov/im/units/chis/HTMLpages/KFM-HandbookVol1.pdf Online. 8 August 2001.

Cobb, J. S. and Caddy, J. F. (1989). The population biology of decapods. *In* Marine invertebrate fisheries: their assessment and management (1989). [ed] John F. Caddy, New York, John Wiley and Sons Inc.

Cochrane, Guy R. , 2002, Coverage nanhab -- Habitat polygons for North Anacapa: USGS Open-File Report USGS OFR 03-85, U.S. Geological Survey, Menlo Park, CA.

Cooper, R. A. and Uzmann, J. R. (1977). Ecology of juvenile and adult clawed lobsters, *Homarus americanus*, *Homarus gammarus*, and *Nephrops norvegicus*. C.S.I.R.O., Division of Fisheries and Oceanography Circ. **7**:187-208.

Crear, B. J. and Forteath, G. N. R. (2001). Recovery of the western rock lobster, *Panulirus cygnus*, from emersion and handling stress: the effect of oxygen concentration during re-immersion. *Journal of Shellfish Research* Vol. 20, No. 3 pp. 921-929.

Davis, G. E. and Dodrill, J. W. (1979). Marine parks and sanctuaries for spiny lobster fisheries management. Proceedings of the Gulf and Caribbean Fisheries Institute, 32nd Annual Session.

Davis, G. E. (1981). Effects of injuries on spiny lobster, *Panulirus argus*, and implications for fishery management. *Fishery Bulletin*, U.S. 78: pp. 979-984

Davis, G. E. (2003). Personal communication. Visiting Chief Scientist, Ocean Programs U. S. National Park Service, Washington, DC.

Dayton, P. K., M. J. Tegner, P. B. Edwards & K. L. Riser. (1998). Sliding baselines, ghosts, and reduced expectations in kelp forest communities. *Ecological Applications* **8**: pp. 309-322.

Dow, R. L. and Trott, T. T. (1956). A study of major factors of Maine lobster production fluctuations. Department of Marine Resources, Augusta, Maine.

Edgar, G. and Barrett, N. (1999). Effects of the declaration of marine reserves on Tasmanian reef fishes, invertebrates and plants. *Journal of Experimental Marine Biology and Ecology* **242** (1) pp.107-144

Ecometrics Environmental Services. Evaluation of the sampling design for the Kelp Forest Monitoring Program, Channel Islands National Park (1994). http://www.nature.nps.gov/im/units/chis/HTMLpages/Protocols_Reviews/ProtocolReviews.htm

Engle, J. M. (1979). Ecology and growth of juvenile California spiny lobster, *Panulirus interruptus*. PhD thesis (Biology), University of Southern California.

Ennis, G. P. (1973). Food, feeding and condition of lobsters, *Homarus americanus*, throughout the seasonal cycle in Bonavista Bay, Newfoundland. *Journal of the Fisheries Research Board of Canada.* **30**:1905-1090.

Enriquez, R. P., Vega, A., Avila, S. and Sandoval, J. L. (2001). Population genetics of red spiny lobster (*Panulirus interruptus*) along the Baja California Peninsula, Mexico. *Marine and Freshwater Research* **52**, pp. 1541-49.

Florida Keys National Marine Sanctuary http://www.fknms.nos.noaa.gov/research_monitoring/welcome.html Last Accessed 2/13/04

Ford, R. F. and D. A. Farris (1977). An evaluation of growth, molting frequency and associated tagging methods for the California spiny lobster, *Panulirus interruptus,* based upon mark recapture and impoundment studies. (Abstract) pp. 32-33 *in* Phillips, B. F. and J. S. Cobb, [eds.]. Workshop on lobster and rock lobster ecology and physiology. CSIRO Division of Fisheries and Oceanography. Circ. No. 7.

Gaines, S. (2003). Personal communication. Director, Marine Sciences Institute, University of California Santa Barbara.

Griffin, D. A., Wilkin, J. L., Chubb, C. F., Pearce, A. F. and Caputi, N. (1999). Ocean currents and the larval phase of Australian western rock lobster, *Panulirus cygnus*. *Marine and Freshwater Research* **52**. pp. 1187-99.

Hall, N. and Chubb, C. (2001). The status of the western rock lobster, *Panulirus cygnus*, fishery and the effectiveness of management controls in increasing the egg production of the stock. *Journal of Marine and Freshwater Research* **52** pp. 1657-67.

Halpern, B. S. (2003). The impact of marine reserves: do reserves work and does reserve size matter. *Ecological Applications* **13** (1) pp.117-137.

Hepper, B. T. (1971). An apparent relationship between catch per unit effort and temperature in the English lobster fishery. Shellfish Benthos Comm., ICES C. M. K: 8.

Hilborn, R. and Walters, C. J. (2001). Quantitative fisheries stock assessment: choice dynamics and uncertainty. Kluwer Academic Publishers 570pp.

Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R. Bradbury, R. Cooke, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner, and R.Warner. 2001. Historical overfishing and the collapse of marine ecosystems. **Science** 293: 629-638.

Johnson, M. W. (1956). The larval development of the California spiny lobster, *Panulirus interruptus* (Randall) with notes on *Panulirus gracilis* (Streets). Proceedings of the California Academy of Sciences. Fourth Series. 29: 1-19.

Johnson, M. W. (1960). Production and distribution of larvae of the spiny lobster *Panulirus interruptus* (Randall) with records on *Panulirus gracilis* (Streets). Bulletin of Scripps Institute of Oceanography. University of California. 7: pp. 413-446.

Johnson, M. W. and Brinton, E. (1963). Biological species, water masses and currents pp. 381-414. *In* M. W. Hill [ed.]. The sea, ideas and observations in progress in the studies of the seas. John Wiley and Sons, New York. 554p.

Kelly, S. (2001). Temporal variation in the movement of the spiny lobster, *Jasus edwardsii*. *Marine and Freshwater Research* **52**: pp. 323-331.

Kelly, S., Scott, D., MacDiarmid, A. B. and Babcock, R. C. (2000). Spiny lobster *Jasus edwardsii*, recovery in New Zealand marine reserves. *Biological Conservation* **92**: pp. 359-369.

Kelly, S. and MacDiarmid, A. B. (2003). Movement patterns of mature spiny lobsters, *Jasus edwardsii*, from a marine reserve. *New Zealand Journal of Marine and Freshwater Research* **37**: pp149-158.

Krouse, J. S. (1989). Performance and selectivity of trap fisheries for crustaceans. *In*: Marine invertebrate fisheries: their assessment and management. [Ed.] Caddy, J. F. John Wiley and Sons, Inc.

Lafferty, K. D. (in press). Fishing for lobsters indirectly increases epidemics in sea urchins. *Ecological Applications*.

Leet, W. S., Dewees, C. M., Klingbeil, R. and Larson, E. J. (2001). California's living marine resources: a status report. The Resources Agency and The California Department of Fish and Game. http://www.dfg.ca.gov/mrd/status/

Lindberg, R. G. (1955). Growth, population dynamics and field behavior of spiny lobster, *Panulirus interruptus* (Randall). University of California Publication Zoology. 59 pp. 157-248.

Marine Life Management Act: Essential Fishery Information http://www.dfg.ca.gov/mrd/nfmp/pdfs/section1_chap4.pdf

Marine protected areas: tools for sustaining ocean ecosystems (2001). Commission on Geosciences, Environment and Resources, Ocean Studies Board. National Academy Press, Washington DC. 272 pages.

Marine Reserve Working Group (MRWG), (2002). Channel Islands National Marine Sanctuary. History of the community-based process on marine reserves at the Channel Islands National Marine Sanctuary 1999-2001. http://www.cinms.nos.noaa.gov/marineres/PDF/mpa_history%20of%20process.pdf

Martell, S., Walters, C. and Wallace, S. (2000). The use of marine protected areas for conservation of lingcod (*Ophiodon elongatus*). *Bulletin of Marine Science*, **66** (3): pp. 729-743.

McCrone, A. (2002). National overview of biological monitoring in New Zealand's marine protected areas. Department of Conservation, New Zealand.

McGarvey, R., Ferguson, G. J. and Prescott, J. A. (1999). Spatial variation in the mean growth rates at size of southern rock lobster *Jasus edwardsii*, in south Australian waters. *Marine and Freshwater Research* **50**: pp. 333-342.

Meyer-Rochow, V. B. (1994). Light-induced damage to photoreceptors of spiny lobsters and other crustaceans. *Crustaceana* **67** (1): pp. 97-111.

Miller, C. (2003). Personal communication. Vice President California Lobster and Trap fisherman's Association.

Miller, K. A., Iacchei, M. and Robinson, P. (unpublished data). Wrigley Marine Science Center, University of Southern California. Contact kam@usc.edu

Mitchell, C. T., Turner, C. H. and Strachan, A. R. (1969). Observations on the biology and behaviour of the California spiny lobster, *Panulirus interruptus* (Randall). California Fish and Game 55(2): pp. 121-131.

Murray, S. N., Ambrose, R. F., Bohnsack, J. A., Botsford, L.W., Carr, M. H., Dayton, P. K., Gotshall, D., Gunderson, D. R., Hixon, M. A., Lubchenco, J., Mangall, M., MacCall, A., McArdle, D. A.,

Ogden, J. C., Roughgarden, J., Starr, R. M., Tegner, M. J. and Yoklavich, M. M. (1999). No-take reserve networks: sustaining fishery populations and marine ecosystems. *Fisheries* **24** (11): pp. 11-25

Oceanography of the Southern California Bight http://seis.natsci.csulb.edu/bperry/scbweb/homepage.htm Last accessed: 2/2/04.

Odemar, M. W., Bell, R. R., Haugen, C. W., Hardy, R. A. (1975). Report on California spiny lobster *Panulirus interruptus* (Randall), research with recommendations for management. State of California. The Resources Agency. Department of Fish and Game.

Olsson, P. and Folke, C. (2001). Local ecological knowledge and institutional dynamics for ecosystem management: A study of Lake Racken Watershed, Sweden. *Ecosystems* **4**: pp. 85-104

Owen, R. W. (1980). Eddies of the California Current system: physical and ecological characteristics. pp. 237-263. *In* D. Power [ed.]. The California Islands. Proceedings of a multidisciplinary symposium. Santa Barbara Museum of Natural History, Santa Barbara, California 787pp.

Palumbi, S. R. (2001). The ecology of marine protected areas. *In* Marine community ecology. [Eds.] Bertness, M. D., Gaines, S. D. and Hay, M. E. Sinauer Associates Inc.

Parrish, R. (1999). Marine reserves for fisheries management: why not. CalCOFI Report, Volume 40.

Parrish, R (2003). Marine reserves to supplement management of west coast groundfish resources: phase 2 – draft concepts for California waters. National Marine Fisheries Service, Southwest Fisheries Science Center, Pacific Fisheries Environmental Laboratory.

Partnership of Interdisciplinary Studies of Coastal Oceans (2002). The science of marine reserves. 22 pages. http://www.piscoweb.org/

PEW Oceans Commission (2003). America's living oceans: charting a course for sea change. http://www.pewoceans.org/oceans/oceans_report.asp

Phillips, B. F., Cobb, J. S. and George, R. W. (1980). General biology. *In*: Cobb, J. S. and Phillips, B. F. [Eds.] The biology and management of lobsters, Vol. 1. Academic Press, New York pp.1-82.

Pine, W. E., Pollock, K. H., Hightower, J. E., Kwak, T. J. and Rice, J. A. (2003). A review of tagging methods for estimating fish population size and components of mortality. American Fisheries Society. *Fisheries*, October 2003-Vol. 28 No. 10.

Pringle, J. D. (1986). California spiny lobster (*Panulirus interruptus*) larval retention and recruitment: A review and synthesis. *Canadian Journal of Fisheries and Aquatic Science*. Vol. 43.

Reichman, O.; Schildhauer, M. and Jones, M. (1999). Integrating marine ecology data for scientific analysis and resource management: a community database prototype. National Science Foundation proposal. http://www.nceas.ucsb.edu

Research, B. M. (1995). Southern California lobster survey, Burke marketing Research: 8.

Rowe, S. (2002). Population dynamics of American lobster inside and outside no-take reserves in Bonavista Bay, Newfoundland. *Fisheries Research* **56**: pp. 167-175.

Russ, G. and Alcala, A. (1996). Do marine reserves export adult fish biomass? Evidence from Apo Island, Central Philippines. *Marine Ecology Progress Series* **132**, pp.1-9.

Scholz, A., Bonzon, K., Fujita, R., Benjamin, N., Woodling, N., Black, P., Steinback, C. (2004). Participatory socioeconomic analysis: drawing on fishermen's knowledge for marine protected area planning in California. *Marine Policy*. **28** (4) pp. 335-350

Schroeter, S. (2003). Personal communication. Research Ecologist, Marine Sciences Institute, University of California Santa Barbara.

Serfling, S. A. (1972). Recruitment, habitat preference, abundance and growth of the puerulus and early juvenile stages of the California spiny lobster *Panulirus interruptus* (Randall). M. S. Thesis. San Diego State Univ. 124pp.

Serfling, S. A. and Ford, R. F. (1975). Ecological studies of the puerulus larval stages of the California spiny lobster *Panulirus interruptus*. *Fishery Bulletin* **73**: pp. 360-377.

Stewart-Oaten, A. (1996). Problems in the analysis of environmental monitoring data. pp 109-131. *In* Detecting Ecological Impacts. [eds.] Schmitt, R. J. and Osenberg, C.W. Academic Press, New York.

Sumaila, U., Guenette, S., Alder, J., Chuenpagdee, R., (2000). Addressing ecosystem effects of fishing using marine protected areas. *ICES Journal of Marine Science*, **57**: 752-760.

Tegner, M. J. and Levin L. A. (1983). Spiny lobsters and sea urchins: analysis of a predator-prey interaction. *Journal of Experimental Marine Biology and Ecology*, **73**: pp.125-150.

Thomas, H. J. (1953). The efficiency of fishing methods employed in the capture process of lobsters and crabs. *J. Cons., Cons. Int. Explor. Mer* **18**: pp. 333-350.

Thompson, A. P., Hanley, J. R. and Johnson, M. S. (1996). Genetic structure of the western rock lobster, *Panulirus cygnus*, with the benefit of hindsight. *Marine and Freshwater Research* **47**, pp. 889-96.

Tremblay, J. (2002). Lobster catchability studies. Hook line and thinker. The newsletter of the fishermen and scientists research society. Issue 4:pp.6-8. http://www.fsrs.ns.ca/doc/2002-Fall.pdf.

Ugoretz, J. (2002). Marine protected areas in the National Oceanic and Atmospheric Administration's Channel Islands National Marine Sanctuary. California Department of Fish and Game. Vol. 1. http://www.dfg.ca.gov/mrd/ci_ceqa/pdfs/cover_vol1.pdf

Ugoretz, J. (2003). Personal communication. California Department of Fish and Game, Senior Biologist.

Underwood, A. J. (1997). Experiments in ecology: their logical design and interpretation using analysis of variance. Cambridge University Press. 485pp.

Velazquez, A. V. (2003). Reproductive strategies of the spiny lobster *Panulirus interruptus* related to the marine environmental variability off central Baja California, Mexico: management implications. *Fisheries Research* (in press). Available online at www.sciencedirect.com

Wilson, J., Acheson, J., Metcalfe, M., and Kleban, P., (1994). Chaos, complexity, and community management of fisheries. *Marine Policy* **18** (4) pp. 291-305.

Wilson, R. C. (1948). A review of the southern California spiny lobster fishery. California Fish Game 34: 71-80.

Winget, R. R. (1968). Trophic interactions and metabolic energy budget of the California spiny lobster *Panulirus interruptus* (Randall). M. S. Thesis. San Diego State University 232pp.

Appendix A. Protocols of Existing Surveys

A.1 Kelp Forest Monitoring Program of National Park Service at Channel Islands

The National Park Service Kelp Forest Monitoring Program, administered by the National Park Service (NPS), has 16 permanent survey sites around the northern Channel Islands. At each of these 16 sites, there is a 100-meter transect line fixed to the hard substrate. Each year, the survey teams return to these fixed lines to conduct their survey. All of the protocols they used, with the exception of the roving fish survey, are conducted based on this 100-meter line.

For the purpose of this comparison, data from only three of the NPS protocols are used for comparison with PISCO data, due to their compatibility with PISCO's protocols. These protocols are the band transect, the 1-meter quadrat and the 5-meter quadrat. These are described sequentially hereafter.

A.1.1 Band transect

The band transect survey protocol is based on the 100-meter transect line. Before the survey, a random number between zero and eight is chosen. This number is the number of meters from one end of the 100-m transect line, a point that serves as the first of a series of 12 points along the 100-meter transect line. Subsequent points are eight meters apart.

At each of the 12 points, a band transect is laid out perpendicular to the 100-meter line. From each of the 12 points, a pair of SCUBA divers swim in opposite directions perpendicular to the 100-m transect line, for 10 m (See Figure A-1 below). Each of the divers holds a 1.5-m rod perpendicular to the direction of swim (parallel to the 100-meter transect line). All organisms of the species of interest are counted. The two divers cover a total of 3 m × 20 m × 12 = 720 m^2. (Channel Islands National Park, 1997). Organism density of a given species for each one of the 24 band transects is the total count inside the band transect divided by 30 m^2. Density is expressed in number of individuals per square meter.

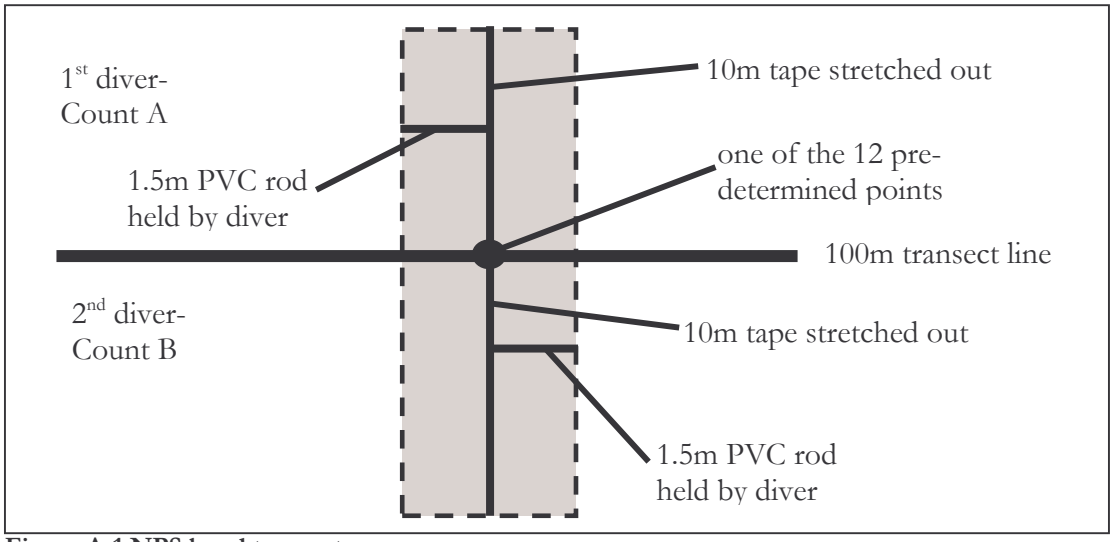


Figure A-1 NPS band transect

A.1.2 1-m quadrat

The 1-meter quadrat protocol involves sampling 24 1 m × 1 m squares along the 100-m transect line. Before entering the water, a random number between zero and eight is chosen. This number is the number of meters from one end of the 100-m transect line, a point that serves as the first of a series of 12 points. The 12 points are 8 m apart. Each SCUBA survey diver places a three-sided 1- m^2 quadrat alongside the 100-m transect line, at each of the 12 chosen points (Figure A-2). The quadrats held by the two divers must be on opposite sides of the 100-m transect line. Inside the quadrats, species of interest is counted.

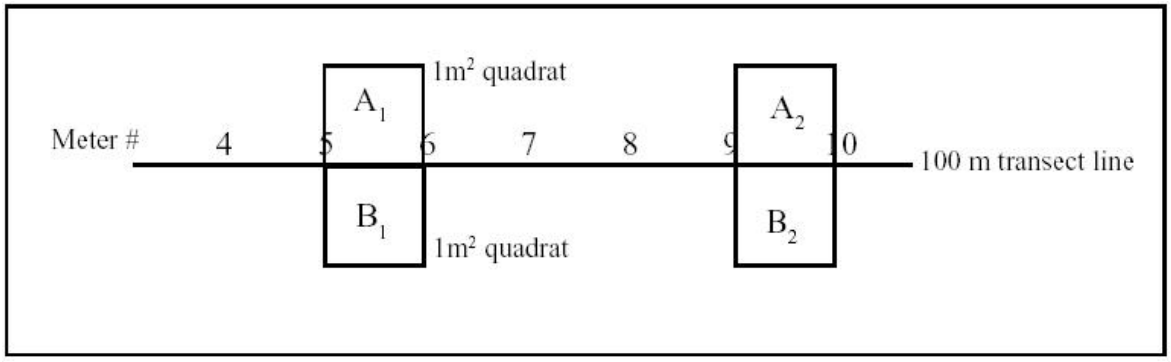


Figure A-2 1-m quadrat

A.1.3 5-m quadrat

The purpose of the 5-m quadrat is to determine the abundance of selected rare, clumped, sedentary, indicator species. The 100-m transect line is divided into 20, 5-m segments. Each of the 5-m segments forms one side of one 5-m × 1-m quadrat on each side of the 100-m transect line (Figure A-3), giving rise to a total 40 5-m × 1-m quadrats. Species of interest is counted and the density in each quadrat is the total count divided by 5 m^2.

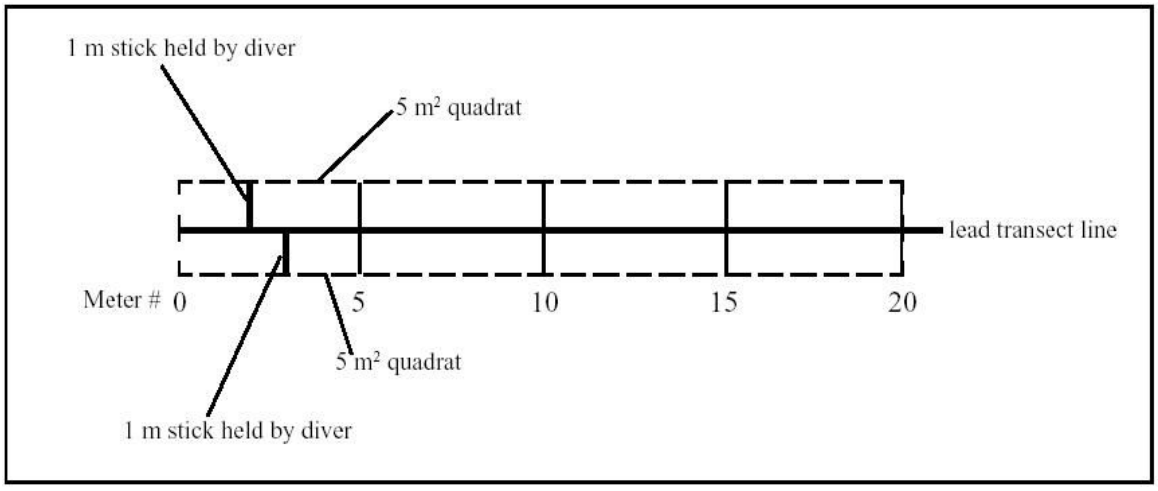


Figure A-3 5-m quadrat

A.2 PISCO (Partnership in Interdisciplinary Study of Coastal Oceans)

PISCO began sampling intertidal and subtidal communities in 1999. In its subtidal surveys, benthic invertebrates, algae and fish are counted. PISCO employs the swath transect and the quadrat survey techniques for determining densities of organisms occurring at varying densities.

PISCO has several sites off the northern Channel Islands and several sites off mainland coast of California. At each site, two or three "areas" are delineated. Within each area, sampling is conducted in at least two or sometimes three "depth zones". The most common depth zones are at five meters ("inner") and 15 meters ("outer") of depth.

Unlike NPS's permanently fixed transect line, PISCO's sampling units are randomly placed. PISCO document did not specify their randomization procedure.

A.2.1 Swath transect

The purpose of the swath sampling is to estimate the density of conspicuous, solitary and mobile invertebrates as well as specific macroalgae. Individual invertebrates and plants are counted along the entire 30-m × 2-m transect. Within each "area" of a site, four 30-m × 2-m replicate swath transects are sampled, two at each of the 5-meter and 15-m depths (PISCO, 2002). See Figure A-4.

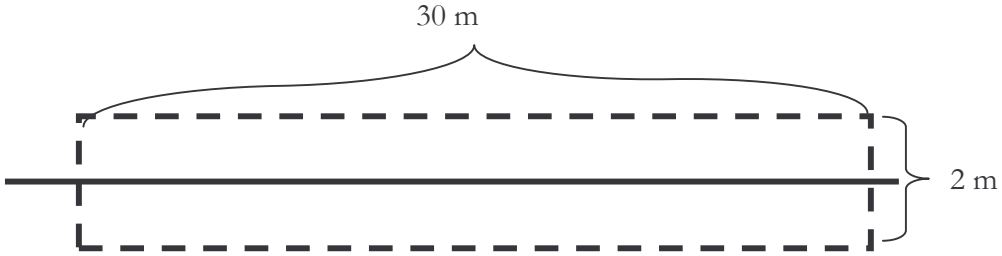


Figure A-4 PISCO swath transect

A.2.2 Quadrat

The purpose of quadrat samplings is to determine the density of (a) small invertebrate species, (b) recruit invertebrate and macroalgal species, (c) cryptic or small benthic fishes, and (d) species that are too abundant to count on the 30-m × 2-m swath transect. Divers carry a three-sided 1- m^2 PVC folding quadrat and place it on the bottom adjacent to the transect line tape at meters 2, 7, 12, 17, 22 and 27. The quadrat is positioned so that the tape completes the fourth side. The diver then records the number of all targeted species in the quadrat. Substrate beneath the understory is searched, however no organisms are removed. The depth of each quadrat is recorded (PISCO, 2002). See Figure A-5 for depiction of the quadrat protocol.

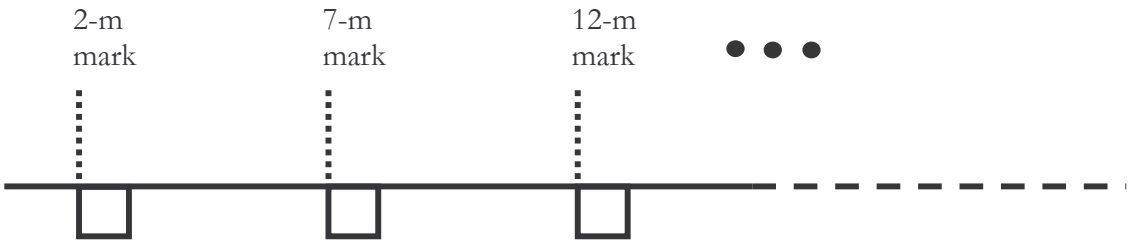


Figure A-5 PISCO quadrat

Appendix B. Summary of Existing Research Programs

http://www.dfg.ca.gov/mrd/channel_islands/existing_research_programs.pdf

Appendix C. Channel Islands Monitoring Program Worksheet Results

http://www.dfg.ca.gov/mrd/channel_islands/monitoring_worksheet_summary.pdf

Appendix D. Lobster Background

D.1 Spiny Lobster Biology

Here we present a brief summary of the life history of *Panulirus interruptus* that is necessary to understand the biological basis of the monitoring plan and the management options presented in Appendix H. One reason that the spiny lobster population requires careful protection is that juveniles take a long time to reach maturity. Spiny lobsters have a biphasic life cycle with a planktonic larval stage, and benthic (i.e. bottom dwelling) juvenile and adult stages. The various life stages and the time periods spent in each stage are shown diagrammatically in **Figure D-1** and described afterwards.

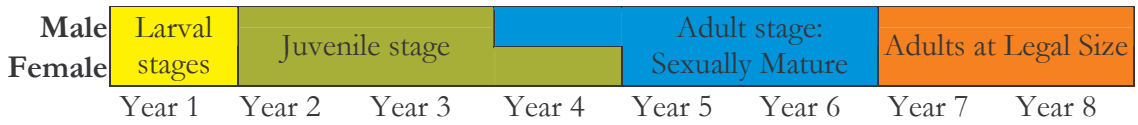


Figure D-1 The estimated time frames of the male and female lobster life stages (adapted from Engle, 1979).

D.1.2 Larval Stages

The larval stage consists of two main phases, the phyllosoma and puerulus, each described separately below.

Phyllosoma (Planktonic)

A fertilized lobster egg hatches into a planktonic larval stage called a phyllosoma, which is transparent, flattened in shape and has long fragile legs. Johnson (1956) collected and analyzed close to 3,500 phyllosomes from 1949-1955 and found that the larvae spend roughly 7-9 months in the open sea. While phyllosoma are truly planktonic and cannot actively swim, they are known to rise to the surface of the water column at night and descend to greater depths during the day (140m; Griffin *et. al.*, 1999; Pringle, 1986). This has implications for larval dispersal as they may be utilizing different oceanic currents. During their time in the open sea the phyllosoma go through 11 rather poorly defined planktonic stages (Pringle, 1986). At each phyllosoma stage the larvae grow and feed before metamorphosis into the next major larval puerulus stage.

Puerulus (Nektonic)

The puerulus is believed to be a transitional pelagic phase lasting 2-3 months, which is specifically adapted to return larvae to near-shore habitats before settlement into benthic juveniles (Serfling and Ford, 1975). Pueruli are nektonic, capable of continuous and directed swimming and may have the ability to test and select for suitable substrates before settling (Serfling and Ford, 1975). In California, puerulus settlement occurs between June and October. Thus, the entire open ocean planktonic stage, both phyllosoma and puerulus, lasts approximately one year. This may vary anywhere from 9-15 months depending on oceanic conditions. Extremely high mortality is believed to occur in the larval stages of lobster. The pueruli that survive to settle to the bottom go through a series of morphological and behavioral changes resulting in the transformation to a benthic juvenile form.

D.1.3 Juvenile stage

The majority of newly settled juvenile *P. interruptus* have been found in shallow depths (0-4m) on exposed or semi-protected rock reefs densely covered with surfgrasses and bushy algae (Serfling, 1972; Engle, 1979). The juvenile stage is characterized by rapid growth and development, as signified by multiple moltings of the exoskeleton each year (Engle, 1979). High juvenile mortality may occur during the molting process itself and its aftermath, when lobster are soft and more vulnerable to predation (Cobb and Caddy, 1989). The inter-molt period and growth increment per molt generally increases with increasing size (Engle, 1979; Cobb and Caddy, 1989). Juveniles grow faster in warmer water, if food is not limiting (Engle, 1979). At Santa Catalina Island, a newly settled juvenile with a 7 mm CL may reach 56 mm CL by age three years (Engle, 1979). The diet of juvenile lobster is similar to that of adult lobster, predominantly mollusks, then crustaceans (mostly crabs) and echinoderms (mostly sea urchins). Juveniles consume proportionately smaller food items and tend not to forage over large distances at night (Lindberg, 1955; Winget, 1968; Engle, 1979).

D.1.4 Adult Stage

Age and Size at Sexual Maturity

Adult *P. interruptus* range from Magdalena Bay, Mexico to Monterey Bay, California but they are rare north of Point Conception (Pringle, 1986). Disagreement has arisen between various studies using diverse methodologies to establish the age and size at which *P. interruptus* reaches sexual maturity and legal size. Lobster age is determined indirectly from size but growth rates may be affected by a number of factors including injury, water temperature, food supply and social interactions (Cobb and Caddy, 1989). The figures presented here are therefore generalizations, which may vary between years and geographic locations.

In three separate studies, 90% of female *P. interruptus* were found to be sexually mature with eggs between 68 and 73mm CL (Wilson, 1948; Lindberg 1955; Odemar *et. al.*, 1975). In a recent 10-year study conducted in central Baja California, Mexico, 50% of the sexually mature females in a sample of 250,000 lobsters were 72.6mm CL (Velazquez, 2003). If it takes 4 years before lobsters are approximately 60-70mm CL then males should be sexually mature by age 4 and females by age 5 years (Engle, 1979). Lindberg (1955) believed male lobsters to be sexually mature by approximately 58mm CL. However, differences may exist between physiological and functional maturity in lobsters. A lobster may be physiologically capable of mating but not yet behaviorally interested in mating (Cobb and Caddy, 1989).

Sexually mature lobster usually molt only once per year and can grow to over 282mm CL, weighing 16kg and perhaps reach ages of over 50 years (Engle, 1979). Lobsters are believed to suffer lower rates of natural predation as they attain larger sizes, termed a 'size refuge', and because they molt less frequently (Engle, 1979).

Age at Legal Size

Best estimates of the age at which lobster attain the legal CL measurement of 82.5mm (the California minimum legal size limit) are between 7-8 years of age (Lindberg 1955; Ford and Farris, 1977; Engle, 1979). This is approximately two years after attainment of sexual maturity (Engle, 1979). Females likely reach legal size later than males due to reallocation of energy for egg production (Engle, 1979).

Reproductive Cycle

Generally, mating takes place in deeper waters between December and March. The female carries the grayish/white or black male sperm packet (the spermatophore) on the abdomen (sternal plates of the cephalothorax) between December and May (Mitchell *et al.*, 1969). A female lobster with a spermatophore attached is commonly referred to as 'plastered' or a 'tar spot' lobster. Shortly after being plastered females move inshore where the eggs are extruded, fertilized, and become attached to the pleopods (termed a berried lobster). Berried females are found most between March and July. Only one brood of eggs is produced annually (Figure D-2; Johnson, 1960; Mitchell *et al.*, 1969; Velazquez, 2003). Egg bearing females remain in shallow waters and the eggs are carried on the pleopods for 9-10 weeks (Allen, 1916; Johnson, 1960; Mitchell *et al.*, 1969; Pringle, 1986). The basic relationship between the size of a female lobster and the number of eggs carried is shown in Figure D-3 (adapted from Lindberg, 1955). After this time the eggs hatch into the larval phyllosoma and complete the life cycle. Warm summer sea temperatures are believed to expedite embryonic development in the eggs. Cooler periods of water temperature (e.g., La Niña) are believed to delay the commencement of mating and egg development while warm conditions (e.g., El- Niño) accelerate breeding and egg hatching (Velazquez, 2003).

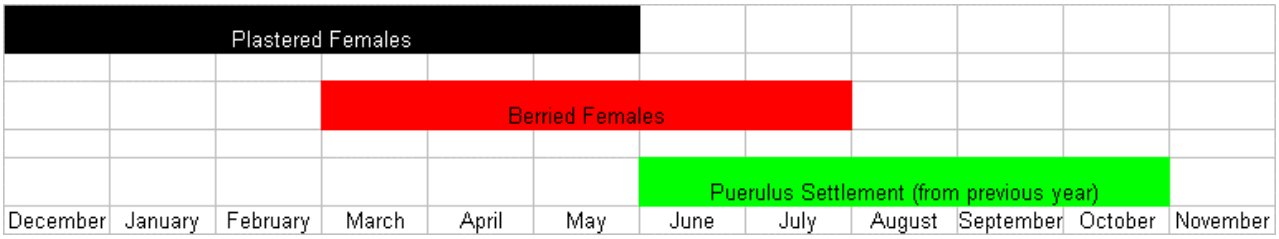


Figure D-2 Female reproductive stages and puerulus settlement time frames (adapted from Engle, 1979).

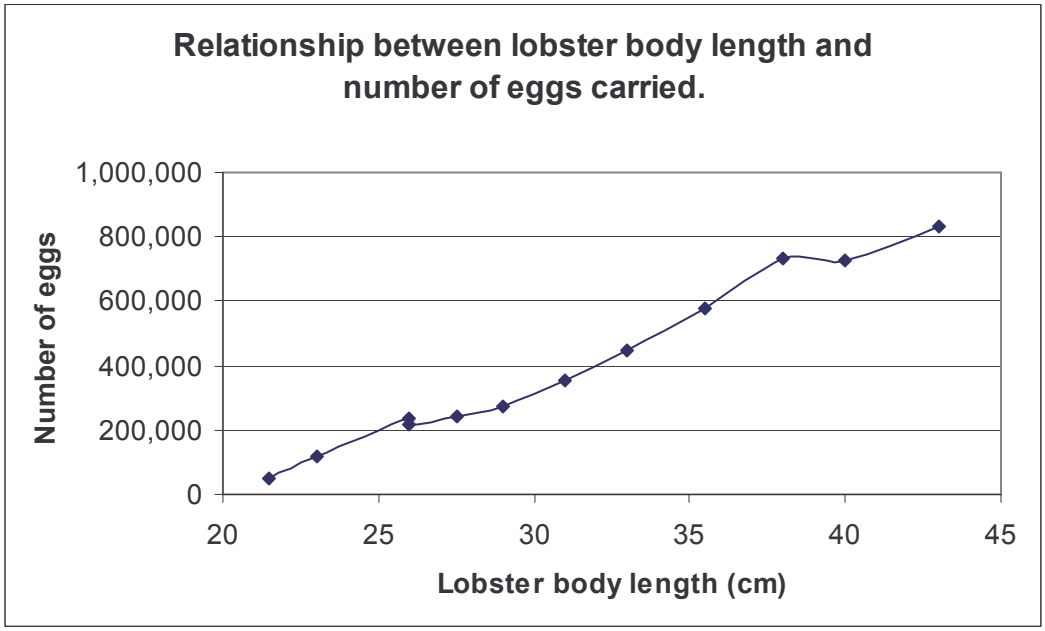


Figure D-3 The relationship between the body length of a female lobster (cm) and the number of eggs carried (n= 392; Lindberg, 1955).

Appendix E. Trapping Methodology

E.1 Review of Trapping Methodology

Failing to provide rational justification for for an experimental approach adds to the confusion in experimental sciences (Underwood, 1997). By exploring the advantages, disadvantages, biases and statistical considerations of the methodologies that can be used to obtain data on lobster it should be easier to correctly interpret the experimental results and to understand limitations. This section details the background information that led to the development of the methodology proposed for this study.

E.1.1 Why traps?

Using traps to sample the lobster population at the Channel Islands provides several advantages over the other major alternative sampling technique- visual surveys. Some of the major advantages of sampling using traps include:

- *High replication.* A commercial fisher can pull and reset up to 100 traps per day, although measurement time taken by researchers may cut this number in half. This enables extensive areas of lobster habitat to be sampled relatively quickly;
- *Large sample size.* Large numbers of lobster can be caught in traps and specimens can be sampled rapidly onboard the vessel. Depending on catch rates, data on many hundreds to thousands of lobster can be taken per day (e.g., lobster size, sex, reproductive state, physical condition and so forth);
- *Applicability.* Studies using practices similar to commercial trapping techniques obtaining CPUE data are more applicable to socio-economic studies;
- *Relevance to Industry.* The results from trapping studies may be more relevant and comprehensible to the fishing community;
- *Cooperative Involvement.* Direct involvement of commercial lobster fishers in data collection is possible and their extensive trapping experience improves the efficiency of the research;
- *Relative Ease of Training.* Limited scientific training is required in the data collection process and specific SCUBA training and dive insurance are not required;
- *Time Constraints.* Traps are not subject to the constraints of SCUBA divers (e.g., depth and time restrictions, cold and fatigue).

E.1.2 The Alternative: SCUBA Surveys

Using SCUBA, lobster can be caught, measured, sexed and tagged underwater. However, the process is very labor intensive and time consuming (Kelly and MacDiarmid, 2003). Kelly and MacDiarmid (2003) estimated that it took them five minutes per lobster to accomplish the above tasks. At depths between 15m and 20m, which will be sampled in this study, the maximum bottom times for a SCUBA diver are 60 and 38 minutes, respectively (DSAT Recreational Dive Planner). This would permit approximately twelve and eight lobsters to be "processed" per diver, per dive at these depths. Such low sample sizes have the potential to severely limit the power of a study to detect changes between reserve and non-reserve areas and to gather enough information to be relevant to the fishery.

In addition, it is essential that studies, which may be repeated and conducted over the long-term, are standardized between years. Consistency may be compromised by inter-observer biases introduced by different divers surveying lobster between years over the studies duration (Brock,

1982). In addition, SCUBA surverys may introduce substantial biases against detecting highly cryptic, nocturnal animals such as lobster, that often reside in crevices and under ledges.

The major advantages of SCUBA are that it allows lobster to be returned to the same den in which they were captured; lobsters are not brought to the surface and therefore do not suffer from emersion stress and the samples are independent. SCUBA is also less biased against very small and very large lobster that may not be retained in traps or not enter them at all. Thus, SCUBA surveys minimize disturbance to lobster disturbance and the assumptions required by statistical tests are not violated. Sampling using SCUBA would provide an excellent complement to trap sampling and could be incorporated in the plan given significant additional funding. For example, SCUBA surveys estimating the absolute abundance of lobster could be calibrated to the index of abundance gained by traps.

E.1.3 Background to Proposed Trapping Methodology

Catch per unit effort (CPUE) data obtained from lobster traps can be used as a relative index of population size. CPUE data can elucidate trends in catches that may be related to population abundance. The CPUE approach assumes that probability of capture (or catchability) is consistent over time and between varying sampling conditions (Pine et al., 2003). However, the assumption about possible trap entry and retention depends on a series of environmental, physiological and behavioral factors along with mechanical characteristics of the trap (Krouse, 1989). An understanding of the capture process and the means to obtain the most consistent and reliable CPUE data is beneficial for accurate interpretation and assessment of these data. This section describes the factors affecting capture by traps and the implications of these factors for a trap study design.

E.1.4 Factors Affecting Capture by Traps

Several factors can affect lobster capture by traps, including the bait, trap spacing, trap characteristics and immersion time. Biological and behavioral characteristics as well as oceanographic conditions also can affect capture by traps. In addition to these factors, there are several considerations for minimizing the impacts from trapping procedures on lobster. Each of these factors is discussed below. This review aided the development of the experimental design and trapping procedure in this monitoring plan and will assist in the interpretation of results from the study.

Bait

Crustaceans have well-developed chemoreceptory senses and are adept at distant detection and location of the source of food odors (Phillips *et al*., 1980). The choice and amount of bait used in a trap can have significant implications on catch rates of lobsters (Thomas; 1953; Dow and Trott, 1956). In addition, the olfactory response of lobster is affected by environmental conditions (*e.g*., temperature) and physiological factors (*e.g*., molt and reproductive condition; Krouse, 1989). These factors have led fishers to exploit certain baits under certain circumstances. However, in general, traps baited with fresh oily fish are more efficient than other baits (Dow and Trott, 1956). In addition, the amount of bait used, the frequency with which bait is changed and the characteristics of the bait-holding container can affect capture success. For these reasons it is necessary to standardize the quantity and type of bait used in a trapping survey. Standardizing bait type, quantity and presentation should eliminate or at least minimize changes in CPUE between replicates due to potential confounding bait effects. For example, the area effectively fished by a trap should be similar for traps set with standardized bait in similar locations during the same time period.

Trap Spacing

The spacing between traps is critical to catch success (Krouse, 1989). If traps are placed too close together, then overlapping bait plumes may effectively cause the traps to 'compete' with each other. This can result in lower catches than if traps were set farther apart. Suitable spacing between traps should be sought to maintain independence between replicate traps and to render research results as similar (and thus, relevant) as possible to typical commercial fishing practices. However, the distance at which traps are effectively competing may vary substantially depending on the density of lobsters at a site and the habitat at that site. Local commercial fishers at the Channel Islands believe that in general, a minimum distance of around 30m between traps prevent traps competition (K. Bortolazzo, pers. comm., 2003). Further, if sampling occurs prior to the opening of the lobster season, the potential for the confounding influence of commercial lobster traps competing with research traps outside of MPAs will be eliminated.

Trap Characteristics

Numerous behavioral and mechanical variables affect the probability that a lobster enters and is retained by a trap. For example, the trap mesh size, the number and size of trap entrances, whether or not escape openings are present and the overall size of a lobster trap all affect the selectivity and catch rates of lobster traps (Krouse, 1989). Therefore, standardized traps must be used for all sampling.

To obtain a more representative sample of the size structure of lobster in a trapping study it is necessary for traps to retain all size classes of lobster that enter the traps. Preliminary research conducted at Catalina Island in 2003 by Miller et al. (unpublished data) showed that the size structure of lobster retained between traps with varying mesh sizes was similar (i.e. traps covered with typical 2x4 inch mesh size and 1x2 inch mesh size caught the same sized lobster). Thus, it appears that it is unnecessary to cover the lobster traps in this study with a finer mesh. However, the traps used in this monitoring program will not have escape gaps, or will have escape gaps barred off to retain juvenile size classes that would normally be able to exit through escape gaps.

Catchability

The catchability of crustaceans with traps is affected by various oceanographic, physiological and behavioral factors (Krouse, 1989). For example, water temperature affects the catchability of the American and European lobsters (*Homarus americanus* and *H. gammarus*, respectively; Hepper, 1971). Peak catches of *H. gammarus* were associated with warmer water temperatures which favor increased molting (greater legal-sized recruitment) and metabolic rates. This may result in increased foraging activity and hence, enhanced vulnerability to traps (Hepper, 1971). By attaching temperature data loggers to traps in this study, we may elucidate patterns in catch rates between sites and between years.

Catchability is strongly affected by the feeding rates of lobster. Feeding may stop during the molt or pre-molt period, whereas after ecdysis crustaceans can display high feeding rates to hasten physiological recovery from the molt (Ennis, 1973). Further, the moon phase also is believed to have a marked effect on the movement and feeding patterns of *P. interruptus* in southern California. While this theory is being investigated in California, commercial fishers consider that foraging movement can be at its highest during the dark periods of the lunar phase (K. Bortolazzo, pers. comm., 2003). Greater movement is believed to occur during those periods after sunset and before the moon comes out during the brighter lunar period. Thus, a trapping program should be designed

to account for temporal variation in the lunar cycle. This may be achieved by sampling consistently only over darker periods or over the duration of an entire lunar cycle.

Catchability and lobster size

The use of CPUE size data is based on the assumption that changes in trap-caught size-frequencies reflect changes in the population size structure. This assumption may not hold true for smaller and larger size classes of lobster. Smaller lobster are believed to be highly cryptic and unlikely to enter traps for fear of predation, while very large lobsters may be prevented from entering traps due to mechanical size-selective properties of trap entrances (Krouse, 1989). For example, attempts by researchers to trap *H. americanus* under 40mm CL have been unsuccessful due to their cryptic behavior (Cooper and Uzmann, 1977) and lobster traps used in southern California do not catch lobsters larger than about 8-12lbs (Barilotti, 2001). Further, differential vulnerability to traps related to size and sex in association with behavioral differences (Krouse, 1989). Catchability coefficients may be specific to an area, season, habitat, trap design and trapping strategy (Tremblay, 2002). In addition, catchability differs by size: The smallest pre-recruit lobsters seen in traps (51-60mm CL) generally had the lowest catchability coefficients. Above certain sizes catchability sometimes decreases, but not consistently (Tremblay, 2002). Tremblay (2002) noted that large lobsters (>130mm CL) are more likely to be seen by SCUBA divers than in research traps. Miller et al., (unpublished data) found the maximum size of trapped lobster at Santa Catalina Island to be approximately 130mm CL, whereas the smallest were generally 65mm CL. Catchability also differs by season, perhaps due to temporal molting differences (e.g., males molt before females and therefore may be interested in feeding earlier than females; Tremblay, 2002).

Biotic Interactions

Intraspecific and interspecific behavioral interactions, such as competition for food and space, predation, cannibalism, agonistic encounters, and attraction and avoidance behaviors can affect whether a lobster enters a trap, is retained, or escapes (Krouse, 1989). Lobsters are less likely to enter a trap containing a predator, (e.g., an octopus or predatory fish) while they may be more likely to enter a trap with living conspecifics. Trap saturation and behavioral interactions may occur if lobsters continue to enter and fill a baited trap. The large size of commercial traps used in the Californian commercial fishery should prevent this from occurring over the soak time for this study (see below). The Western Australian spiny lobster *P. cygnus* avoids entering traps with dead conspecifics or parts of conspecifics (e.g., broken limbs) and fishers are diligent to ensure that any such body parts are removed between trap retrieval and re-setting.

Immersion time

The duration of time between setting a trap and hauling has a marked affect on catch (Krouse, 1989). Loss of bait is one factor that may cause a reduction in CPUE with soak time. For example, softer baits such as fresh sardines can be eaten by isopods and small fish in relatively short periods of time, resulting in a reduced or negligible bait plume over time. Miller *et al.*, (unpublished data) noted that longer soak periods could result in very high densities of lobster at Santa Catalina Island (i.e. 50 or more lobster per trap) if traps were left to soak over many days. Thus, a trapping program should attempt to avoid the potential for trap saturation and the statistical problems of positive correlation within samples (**see section E. 1.6**) by reducing soak time to a minimum and standardizing the soak period for traps.

E.1.5 Methodology Used to Minimize Disturbance to Lobster

Exposure Time of Trapped Lobster

An exposure time of five minutes or more can affect the likelihood of survival of lobster returned to the sea and an exposure period of 15 minutes or more severely affects undersize lobster survival (Brown and Dibden, 1987). To minimize exposure time of lobster in this study, lobster should be processed directly from the trap or immediately after the trap has been emptied and returned to the sea as soon as possible. In either case, all lobster should be processed before the next trap is pulled and the lobster should be kept under the best possible conditions (i.e. cool and wet or in a live-well tank if possible). In addition, a lobster's vision can be damaged by exposure to direct sunlight (Meyer-Rochow, 1994). Thus, lobster should be placed under a dark cover during the recording process and until they are returned to the sea.

Minimize displacement of lobster

To minimize the potential adverse effects of displacement caused by trapping (i.e. raising lobster to the surface and returning them to the sea in a different location) the vessel should attempt to remain as close a possible to the capture site while data recording is in process. Lobster should be returned as close as possible to their capture site. This will improve the likelihood that lobster can return to their den (or a very similar area to that in which they were caught) and it ensures that the specific GPS position in which tagged lobster were returned is known. If lobster were returned to different habitat or water depths than their capture sites (e.g., if the vessel drifted out and off a large drop off), then movement and survival patterns may be affected, thereby biasing tag return data. For these reasons, the vessel should not travel to the next trap or site until all recording is complete.

E.1.6 Statistical Issues with Traps: Independence of Samples

Statistical problems arise due to the use of traps as a sampling tool. These include that one replicate or sample mean may be affected by or related to the values of other replicates or sample means from traps. This can result in statistical non-independence (Underwood, 1997). Statistical analysis based on probability theory depends on data being considered as independent events taken from distributions of independent entities (Underwood, 1997). Lobster may exhibit a behaviorally induced form of non-independence (i.e. whether a lobster enters a trap or not is partially determined by whether other lobsters are already in that trap). This is referred to as "positive correlation within samples" (Underwood, 1997). Determining whether or not it occurs in a particular experiment is not easy. However, in general, the influence of positive correlation among replicates is to cause excessive Type I error in statistical tests on differences among samples (Underwood, 1997). This is because positive correlation can result in a substantial decrease in the variance within samples, thereby making it more likely to detect apparent differences among treatments than what are predicted by chance.

To minimize the potential influence that positive correlation within samples may have on results, trap soak time should be set at a minimum of 24 hours. A short soak time should reduce behavioral gregariousness. For example, local lobster fishers have noted that, to maximize catches, an optimum soak time can be up to four days (C. Miller pers. comm. 2003). Further, reducing the alpha value required to conclude that there is a statistically significant difference in abundance between MPA and control sites may be necessary. For example, a p-value of less than 0.01 could be chosen rather than 0.05 to avoid rejecting the null hypothesis when it is true.

Appendix F. Species List and Other Tables

Table F-1 Fish Species

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

Rubberlip Surfperch[3]	*Rhacochilus toxotes*
Vermillion Rockfish[3]	*Sebastes miniatus*
Yellowtail Rockfish[3]	*Sebastes flavidus*

[1] Fish species recommended by shallow subtidal fish group during MPA monitoring workshop, UCSB, outlined in workshop summaries
[2] Fish species from Kelp Forest Monitoring Handbook, National Park Service
[3] Aditional fish species added by CDFG

Table F-2 recommended by CDFG Benthic Species List

Invertebrates	
Common Name	**Latin Name**
Sponges	
Orange Puffball Sponge[1]	*Tethya aurantia*
Cnidarians	
California hydrocoral[1]	*Stylaster californicus*
Red Gorgonian[2]	*Lophogorgia chilensis*
Brown Gorgonian[2]	*Muricea fruticosa*
CA Golden Gorgonian[2]	*Muricea californica*
Molluscs	
Red Abalone[1]	*Haliotis rufescens*
Black Abalone[1]	*Haliotis cracherodii*
Green Abalone[1]	*Haliotis Haliotis fulgens*
Pink Abalone[1]	*Haliotis corrugata*
California Sea Hare[1]	*Aplysia californica*
Chestnut Cowrie[1]	*Cypraea spadicea*
Giant Keyhole Limpet[1]	*Megathura crenulata*
Kellet's Whelk[1]	*Kelletia kelletii*
Red Top Snail[1]	*Lithopoma gibbersosum*
Rock Scallop[1]	*Crassedoma giganteum*
Wavy Top Snail[1]	*Lithopoma undosum*
Echinoderms	
Bat Star[1]	*Asterina miniata*
Ochre Sea Star[1]	*Pisaster ochraceus*
Short Spined Sea Star[1]	*Pisaster brevispinus*
Giant Spined Sea Star[1]	*Pisaster giganteus*
Sunflower Star[1]	*Pycnopodia helianthoides*

Purple Sea Urchin	*Strongylocentrotus purpuratus*
Red Sea Urchin[1]	*Strongylocentrotus franciscanus*
White Sea Urchin[2]	*Lytechinus anamesus*
Warty Sea Cucumber[1]	*Parastichopus parvimensis*
California Sea Cucumber[1]	*Parastichopus californicus*
Other Invertebrate	
California Spiny Lobster[1]	*Panulirus interruptus*
Sheep Crabs[2]	*Loxorhynchus spp.*
Stalked Tunicate[1]	*Stylea montereyensis*

[1]Species outlined in the Channel Islands Marine Protected Areas Monitoring Plan, February, 2004
[2] Recommended by CDFG

Table F-3 Algal Species List

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

Algae list is outlined in the Channel Islands Marine Protected Areas Monitoring Plan, February 2004

The following tables illustrate the logical model of the database.

Table F-4 Benthic Species List

Attribute	Type	Domain
Species ID	Text	Free text
Common name	Text	Free text
Latin name	Text (primary key)	Free text

Table F-5 Fish Species

Attribute	Type	Domain
PISCO ID	Text	Free text
NPS ID	Text	Free text
Latin name	Text (primary key)	Free text
Common Name	Text	Free text

Table F-6 Reserves

Attribute	Type	Domain
Name of Reserve	Text (primary key)	One of 12 reserve names
Reserve Type	Text	One of two options
Island	Text (Foreign key)	One of 5 islands

Table F-7 Research Program

Attribute	Type	Domain
Research Program	Text	Free text
Contact Person	Text	Free text
Contact Phone	Number (integer)	10-digit phone number
Contact e-mail	Text	Hyperlink
Protocol	Text	Hyperlink
Website	Text	Hyperlink

Table F-8 Monitoring Sites

Attribute	Type	Domain
Site Name	Text (Primary key)	Free text
Research Program	Text (Foreign key)	Participating Program
Inside/Outside reserve?	Text	Inside or outside
Latitude	Number	Double Between 34.06 and 33.46
Longitude	Number	Double: Between –120.39 and –119.03
Reserve Name	Text (Foreign Key)	One of twelve reserves

Table F-9 Benthic Record Presence

Attribute	Type	Domain
RecordID	Number	ForeignKey
BenthicSpecies	Text	ForeignKey
Abundance	Number (Double)	0 or greater
Standard Deviation	Number (Double)	0 or greater
MeanSize	Number (Double)	0 or greater
Benthic Record ID	Number(Primary Key)	Autonumber

Table F-10 Fish Data

Attribute	Type	Domain
RecordID	Number	ForeignKey
FishSpecies	Text	ForeignKey
Fish Length (cm)	Number	Double: 0 or greater
Standard Deviation	Number	Double: 0 or greater
Abundance	Number	Double: 0 or greater

Table F-11 Habitat

Attribute	Type	Domain
Habitat Type	Text	List of habitat types recorded by CDFG
Definition	Text	Free Text

Table F-12 Habitat Records

Attribute	Type	Domain
Record_ID	Number	Foreign key
HabitatType	Text	Foreign key
MeanPercentCover	Number (Double)	0 or greater
Standard Deviation	Number (Double)	0 or greater

Table F-13 Main Record

Attribute	Type	Domain
RecordID	Number (Primary Key)	AutoNumber
CollectionDate	Date	Any date
Monitoring Site	Text	Foreign Key
Date of Entry	Date	Current Date (automatic)

Appendix G. Shallow Subtidal Monitoring Database User Guide

This guide is prepared for the user to be able to 1) understand the tables, queries, macros and forms that are in the Shallow Subtidal Monitoring database and 2) understand how the data is adjusted from different programs to fit the database.

The guide will (1) describe all the contents of the database (2) provide directions on how to import NPS data (3) and finally offer suggestions for importing or entering new data from other programs. The names are all written as they appear in the database, which is case-sensitive.

G.1 Tables

Below, the tables are introduced by the table name. Tables are described in the order in which they appear on Microsoft Access opening view when the Objects clicked on is Tables (see Figure G-1 below). Following each table name will be the table's design view. The design view contains three columns. The first column is the "Field Name" which also can be thought of as column headings. The second column is "Data Type," which describes what type of data can be entered under each field name. Finally there is a "Description" column. This provides space to tell the user more about what each column will contain.

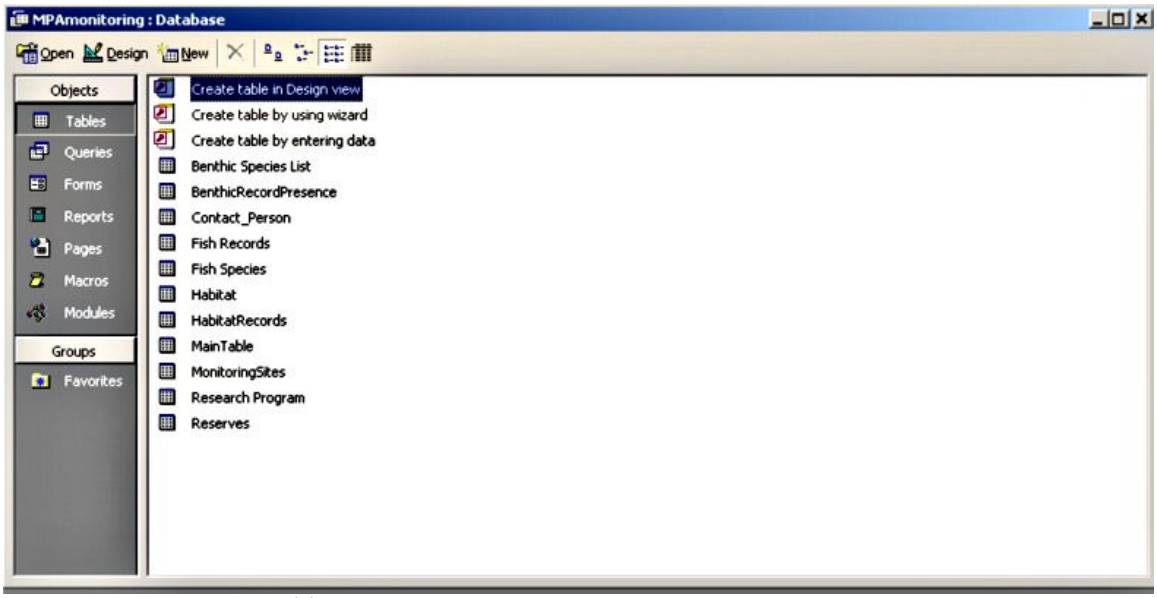


Figure G-1 Screen shot of Tables listed in MPA Monitoring: Database. Notice under Objects section on left hand side, Tables is highlighted.

Database Table 1. *Benthic Species List*

Field Name	Data Type	Description
Benthic Species ID	Text	The six letter code for benthic species used by PISCO – comprised of the first three letters of the genus and the first three letters of the species' Latin name
Species Common Name	Text	The most common name used for the species – and used by CDFG
Species Latin Name	Text	The Primary Key for the Table including the genus and species name for the species in 2004.

This table holds information on 38 different species of benthic animals and algae. There are 39 entries because Macrocysits pyrifera (Giant Brown Kelp) is listed as both an adult and a juvenile.

Database Table 2. *Benthic Record Presence*

Field Name	Data Type	Description
Record_ID	Number (Long Integer)	A foreign key. This number references the primary key of the Main Table. The Record_ID is given to a particular monitoring site on a given year.
Benthic Species ID	Text	A foreign key referencing the primary key in the Benthic Species List table. This allows only one of 39 possible entries to be recorded.
Benthic Record ID	Autonumber (Long Integer)	The primary key. The number itself is not important, but it allows each entry to be unique.
Abundance	Number (Double)	Number of organisms per square meter.
Abundance Standard Deviation	Number (Double)	Standard Deviation calculated for abundance measurements
Mean Length	Number (Double)	Not always available in the data so if there is a null value, it was not calculated for this particular organism. Recorded in millimeters.

Database Table 3. *Contact Person*

Field Name	Data Type	Description
Contact Person	Text	The primary key for the table including the name of the person to contact for information regarding the program.
Contact Phone	Text	Phone number for contact person
Address	Text	Mailing Address
E-mail	Text	E-mail Address

Not all the above information is necessary. Only the person's name and one contact is necessary

Database Table 4. *Fish Records*

Field Name	Data Type	Description
Fish Record ID	Autonumber	The table's primary key. The number itself is not important, but it allows each entry to be unique.
Latin Name	Text	A foreign key referencing the primary key in the Fish Species table. This allows only one of 33 possible entries to be recorded.
Mean Length	Number (Double)	Recorded as the fish length to the nearest centimeter.
Length Standard Deviation	Number (Double)	Standard Deviation calculated when determining the length of the fish.
Abundance	Number (Double)	The number of fish recorded per square meter
Record_ID	Number (Long Integer)	A foreign key. This number references the primary key of the Main Table. The Record_ID is given to a particular monitoring site on a given year

As of 2004 the only program entering data on the fish is PISCO.

Database Table 5. *Fish Species*

Field Name	Data Type	Description
PISCO Fish Species ID	Text	This ID is based on the PISCO protocol. The ID is generally, but not always, the first two letters of the genus and species Latin name of each organism.
Fish Species	Text	The common name used by CDFG in 2004
Latin Name	Text	The Primary Key for the Table, including the Genus and species name for the species in 2004.
NPS Fish Species ID	Text	This ID is based on the NPS protocol. The ID is generally a five-digit code.

This table holds information on 31 species. Since the programs differentiate between male and female Rock Wrasse, and male and female Sheephead, it contains 33 entries.

Database Table 6. *Habitat*

Field Name	Data Type	Description
Habitat Type	Text	Collected by the programs by the random point contact method and describe the ground cover of the site. CDFG chose these flora, fauna, and inorganic materials to be monitored.
Definition	Text	This field explains what each "type" is defined as. For instance it gives sizes for rocks, sand, and boulders.

Although programs may differentiate between juvenile and adult in algal species, this table does not differentiate between these life stages. It simply lists the species. When a species has the word "All" at the end of it, this indicates that NPS or other programs may have differentiated between life stages. The table holds information on 12 different habitat types.

Database Table 7. *Habitat Records*

Field Name	Data Type	Description
Record_ID	Number (Long Integer)	A foreign key. This number references the primary key of the Main Table. The Record_ID is given to a particular monitoring site on a given year
Habitat Type	Text	A foreign key referencing the primary key in the Habitat table. This allows only one of 12 possible entries to be recorded.
Mean Percent Cover	Number (Double)	The recorded percent of ground cover by the habitat type using the random point contact method
StdDev	Number (Double)	The standard deviation calculated when obtaining the mean percent cover
HabitatRecord_ID	Autonumber	The primary key. The number itself is not important, but it allows each entry to be unique.

Database Table 8. *Main Table*

Field Name	Data Type	Description
Record_ID	AutoNumber	The primary key, referenced in both the fish records and benthic records tables. This number represents a sampling event, though the number itself has no value.
Year	Number (Double)	The year the data was collected *** Note that the database only stores information on the year, not the month or date.
Monitoring Site	Text	A foreign key referencing the primary key in the Monitoring Sites table. This allows only one of 33 possible entries to be recorded. As more monitoring sites are added to the CDFG monitoring program, this number will reflect this expansion.
EnterDataDate	Date/Time	Automatically entered when new data is entered into the database. This should give an indication of who is responsible for entering the data.

Prior to importing any data, the monitoring site/year combination must be added to the Main Table. This table will automatically assign this a unique Record_ID which will be added to every piece of data recorded at that site during that year.

Database Table 9. *Monitoring Sites*

Field Name	Data Type	Description
Site Name	Text	Part of a dual or combination primary key for this table. This is where the name of the monitoring site is entered. The PISCO sites all have an "_P" at the end of the site name.
Research Program	Text	Part of the combination primary key for this table. Because some programs may monitor the same site and have similar names, it is necessary to make this a combo primary key so no two-site/research program combination can be the same. This is also a foreign key referencing the primary key in the Research Program table. This allows only one of two possible entries to be recorded as of 2004. As more monitoring programs are added to the CDFG monitoring program, this

		number will reflect this expansion.
Reserve Name	Text	A foreign key referencing the primary key in the Reserves table. The reserve nearest to the monitoring site is listed in order for CDFG to easily determine which monitoring sites are associated with which reserves. The reserve must be in the same oceanographic province as the monitoring site.
Inside/Outside	Text	Location of site relative to the MPA. The data entry here must be either "Inside" or "Outside." This is expressed in the Validation Rule (= "Inside" or "Outside")
Latitude	Text	Approximate location of site in NAD83 decimal degrees
Longitude	Text	Approximate location of site in NAD83 decimal degrees

In Winter, 2004 there were 33 sites recorded.

Database Table 10. Research Program

Field Name	Data Type	Description
Research Program	Text	The primary key for this table. This is the name of a participating monitoring program.
Contact Person	Text	A foreign key referencing the primary key in the Contact_Person table. In 2004 there are two possible entries.
Website	Hyperlink	URL for the monitoring program's website if it has one. By clicking on the URL, the user will be taken to the website.
Shallow Subtidal Protocol	Hyperlink	URL for the monitoring program's shallow subtidal protocol if it is posted on the internet.

Database Table 11. Reserves

Field Name	Data Type	Description
Reserve Name	Text	The primary key for this table, including the name of the marine protected area in the Channel Islands state waters.
Type	Text	There are three types of marine protected areas: State Marine Conservation Area, State Marine Park and State Marine Reserve. The Validation Rule only allows for these three to be entered. If the user wishes to expand the type, the validation rule must be updated.
Island	Text	Island where the MPA is located. This can be one of five islands: Santa Rosa, Anacapa, Santa Cruz, Santa Barbara, or San Miguel. The validation rule ensures these entries. It also ensures that when querying the data, the user can know to enter one of those five names to look for information regarding the separate islands.

G.2 Queries

This section explains the use of each query in the database. New queries are easy to create. Careful review of the tables, their relationships, and the information they contain allows the user to determine what is possible to query. Any attribute mentioned above or field in a table can be queried.

Below each query name is its SQL statement and an explanation. To see the query in design view the user needs to right click on the query and then click on design view. When editing a query, the user must be careful not to double-click on it, because this will run the query rather than open it for edits.

Add5mto1m

```
INSERT INTO Quadrat1mStats
SELECT Improved5m.*
FROM Improved5m;
```

This query adds the "Improve5m" table to the 1mStats table, which adds the *Pisaster giganteus* and *Macrocystis pyrifera* data from 1996 to the 1mStats table. This is done because the 5m quads that did not start until 1996 are better at recording data for these large organisms than the 1m quads.

AddRecord_IdtoHabitat

```
SELECT MainTableNPS.Record_ID, SelectHabitat.SpeciesName, SelectHabitat.Mean, SelectHabitat.StdDev
FROM SelectHabitat INNER JOIN MainTableNPS ON (SelectHabitat.Year = MainTableNPS.Year) AND
(SelectHabitat.SiteName = MainTableNPS.SiteName);
```

This query adds a Record ID from the Main table to the habitat records. This way, each habitat record is associated with a monitoring site and year.

This query is part of the macros: NPS3.

AddSizeto1m

```
SELECT Quadrat1mStats.SiteName, Quadrat1mStats.Year, Quadrat1mStats.SpeciesName, Quadrat1mStats.Mean,
Quadrat1mStats.StdDev, NatHabSizeFrequencyMeans.AvgOfSize
FROM NatHabSizeFrequencyMeans RIGHT JOIN Quadrat1mStats ON (NatHabSizeFrequencyMeans.SiteName =
Quadrat1mStats.SiteName) AND (NatHabSizeFrequencyMeans.Year = Quadrat1mStats.Year) AND
(NatHabSizeFrequencyMeans.[Species Name] = Quadrat1mStats.SpeciesName)
GROUP BY Quadrat1mStats.SiteName, Quadrat1mStats.Year, Quadrat1mStats.SpeciesName,
Quadrat1mStats.Mean, Quadrat1mStats.StdDev, NatHabSizeFrequencyMeans.AvgOfSize;
```

The query adds the Average Size of the benthic species to the table Quadrat1mStats. After this is run, the Quadrat1mStats table will have the Site Name, the Year, the Species Name, the Mean Abundance, the Standard Deviation and the Average Size all together. However, if the SizeFrequency is for a species that does not have abundance data for that particular site and year, it is not added to the data. This will be addressed using other queries so that no size data is omitted.

The query is part of the Macros: NPS2.

Agarum_fimbriatum_adult

This is an update query:

```
UPDATE Quadrat1mStats SET Quadrat1mStats.SpeciesName = "Agarum fimbriatum"
WHERE [Quadrat1mStats].[SpeciesName]="Agarum fimbriatum adult";
```

Because CDFG is not differentiating between adult and juvenile *Agarum fimbriatum*, this is part of the process to eliminate the differentiation in the NPS data.

This is part of Macros: NPS1

Agarum_fimbriatum_juvenile

This is an update query:

```
UPDATE Quadrat1mStats SET Quadrat1mStats.SpeciesName = "Agarum fimbriatum"
WHERE [Quadrat1mStats].[SpeciesName]="Agarum fimbriatum juvenile";
```

Because CDFG is not differentiating between adult and juvenile *Agarum fimbriatum*, this is part of the process to eliminate the differentiation in the NPS data.

This is part of Macros: NPS1

AppendMeanAgarum

This is an append query.

```
INSERT INTO Quadrat1mStats
SELECT MeanAgarum.*
FROM MeanAgarum;
```

This adds the *Agarum fimbriatum* data to the Quadrat1mStats table once the juvenile and adult information have been combined into another table: MeanAgarum, and the old *Agarum fimbriatum I*data has been removed from the Quadrat1mStats table.

This is part of macros: NPS2.

AppendSizeAbundance

```
INSERT INTO SizeAbundance
SELECT SizeLeftOut.*
FROM SizeLeftOut;
```

Because NPS data can have size data even if the species do not have abundance data, there are certain species that are left out of the SizeAbundance table. This query adds on the species' recorded sizes for those with no abundance data.

This is part of macros NPS3.

Benthictime

This is not part of any macros. This is an example of what type of query is possible:

```
SELECT BenthicRecordPresence.BenthicSpeciesID, MainTable.Year, MainTable.MonitoringSite,
BenthicRecordPresence.Abundance, BenthicRecordPresence.Record_ID, MonitoringSites.[Inside/Outside?]
FROM (MonitoringSites INNER JOIN MainTable ON MonitoringSites.[Site Name] = MainTable.MonitoringSite)
INNER JOIN BenthicRecordPresence ON MainTable.Record_ID = BenthicRecordPresence.Record_ID
GROUP BY BenthicRecordPresence.BenthicSpeciesID, MainTable.Year, MainTable.MonitoringSite,
BenthicRecordPresence.Abundance, BenthicRecordPresence.Record_ID, MonitoringSites.[Inside/Outside?]
HAVING (((BenthicRecordPresence.BenthicSpeciesID)="Aplysia californica"));
```

This query allows the user to search for all records of *Aplysia californica* and creates a list of the record ID, the year, the site, the abundance and whether it was inside or outside a reserve. Although the SQL statement looks intimidating, the query's design view is simple.

CompareLeftOutSize

When the query "AddSizeto1m" is run, certain species/size combinations are omitted because it is possible for NPS to have size data without having abundance data. This query is the first step in allowing the user to determine which species/size combinations were omitted.

```
SELECT NatHabSizeFrequencyMeans.SiteName, NatHabSizeFrequencyMeans.Year,
NatHabSizeFrequencyMeans.[Species Name], NatHabSizeFrequencyMeans.AvgOfSize,
NatHabSizeFrequencyMeans.SiteNumber, AddSizeto1m.SpeciesName
FROM AddSizeto1m RIGHT JOIN NatHabSizeFrequencyMeans ON (AddSizeto1m.SpeciesName =
NatHabSizeFrequencyMeans.[Species Name]) AND (AddSizeto1m.Year = NatHabSizeFrequencyMeans.Year)
AND (AddSizeto1m.SiteName = NatHabSizeFrequencyMeans.SiteName);
```

When run, this query lists all the species names, site, year, size, and presence or absence of abundance data for the same site and year. If the species was not present, the [AddSizeto1m].[SpeciesName] is null, or it has no value.

This is part of Macros NPS2.

Condense5m

```
SELECT Quadrat5mStats.SpeciesName, Quadrat5mStats.SiteName, Quadrat5mStats.Year,
Sum(Quadrat5mStats.Mean) AS SumOfMean, Avg(Quadrat5mStats.StdDev) AS AvgOfStdDev
FROM Quadrat5mStats
GROUP BY Quadrat5mStats.SpeciesName, Quadrat5mStats.SiteName, Quadrat5mStats.Year;
```

This query allows the user to take the Quadrat5mStats data and select only what is needed by CDFG. Since CDFG does not differentiate between sub-Adult and Adult *Macrocysits pyrifera*, the abundance and standard deviation for these categories had to be combined into *Macrocystis pyrifera* adult. In order to do this, the abundances were summed and the standard deviation was averaged.

This is part of Macros NPS1.

DeleteExtra1m

This is a delete query.

```
DELETE Row AS Expr1, [Quadrat1mStats].[SpeciesName]
FROM Quadrat1mStats
WHERE ((([Quadrat1mStats].[SpeciesName])="Alloclinus holderi" Or
([Quadrat1mStats].[SpeciesName])="Lythrypnus dalli" Or ([Quadrat1mStats].[SpeciesName])="Centrostephanus
coronatus" Or ([Quadrat1mStats].[SpeciesName])="Coryphopterus nicholsii" Or
([Quadrat1mStats].[SpeciesName])="Eisenia arborea adult" Or ([Quadrat1mStats].[SpeciesName])="Eisenia
arborea juvenile" Or ([Quadrat1mStats].[SpeciesName])="Laminaria farlowii adult" Or
([Quadrat1mStats].[SpeciesName])="Laminaria farlowii juvenile" Or
([Quadrat1mStats].[SpeciesName])="Macrocystis pyrifera All" Or
([Quadrat1mStats].[SpeciesName])="Pterygophora californica adult" Or
([Quadrat1mStats].[SpeciesName])="Pterygophora californica juvenile" Or
([Quadrat1mStats].[SpeciesName])="Aplysia californica" Or ([Quadrat1mStats].[SpeciesName])="Crassedoma
giganteum" Or ([Quadrat1mStats].[SpeciesName])="Haliotis rufescens" Or
```

([Quadrat1mStats].[SpeciesName])="Kelletia kelletii" Or ([Quadrat1mStats].[SpeciesName])="Lytechinus anamesus"));

The rows are deleted from Quadrat1mStats where either CDFG does not have the species on its list, if the species is better represented by data from another protocol such as the NPS band transect, or if the species is differentiated into adult and juvenile when CDFG simply wants the total species (the data also has the category "species All" which allows the user to delete the juvenile and adult categories without losing data).

DeleteExtraAgarum

DELETE row
FROM Quadrat1mStats
WHERE Quadrat1mStats.SpeciesName="Agarum fimbriatum";

This delete query removes the *Agarum fimbriatum* data from the 1mStats table to make room for updated data on this species.

This is part of NPS1.

DeleteExtraBand

DELETE Row AS Expr1, BandTransectStats.SpeciesName
FROM BandTransectStats
WHERE (((BandTransectStats.SpeciesName)="Urticina lofotensis"));

This query deletes rows that contain data from the band transects that are not required by CDFG.

This is part of Macros NPS1.

DeleteExtraSize

DELETE ROW AS Expr1, NatHabSizeFrequencyMeans.[Species Name]
FROM NatHabSizeFrequencyMeans
WHERE (((NatHabSizeFrequencyMeans.[Species Name])="Centrostephanus coronatus"));

This deletes the rows that contain size data on species not required by CDFG.
This is part of Macros NPS1.

DeletePisANDMacro1996_1m

DELETE Row
FROM Quadrat1mStats
WHERE ((([Quadrat1mStats].[SpeciesName])="Pisaster giganteus") And (([Quadrat1mStats].[Year])>1995)) Or ((([Quadrat1mStats].[CommonName])="Giant kelp Adult") And (([Quadrat1mStats].[Year])>1995)));

The 5m stats data is a better representation of *Pisaster giganteus* and *Macrocystis pyrifera.* This protocol started in 1996. Therefore, it is better to use this information after 1996. All the Quadrat1mStats data regarding *Pisaster giganteus* and *Macrocystis pyrifera* is deleted from 1996 on to make room for the Quadrat5mStats on these species.

This is part of Macros NPS1.

Delete_Extra_Habitat_Sites

This will have to be updated if there are any other sites that NPS records, yet that are not in the areas of interest.

```
DELETE Row
FROM SelectHabitat
WHERE (((SelectHabitat.SiteName)="Boy Scout Camp" Or (SelectHabitat.SiteName)="Horse Beach Cove" Or
(SelectHabitat.SiteName)="Miracle Mile" Or (SelectHabitat.SiteName)="Northwest Harbor" Or
(SelectHabitat.SiteName)="Eel Point"));
```

These sites deleted from the SelectHabitat query are on Santa Clara Island and are not in the area of interest.

This is part of Macros NPS3.

Delete_Extra_Sites

This query was run the first time NPS data was imported into the CDFG Shallow Subtidal Monitoring Database. It should not have to be run again. For the record it is copied below.

```
DELETE MainTable.*, [MainTableNPS].[SiteName]
FROM MainTableNPS
WHERE ((([MainTableNPS].[SiteName])="Boy Scout Camp" Or ([MainTableNPS].[SiteName])="Horse Beach
Cove" Or ([MainTableNPS].[SiteName])="Miracle Mile" Or ([MainTableNPS].[SiteName])="Northwest Harbor"
Or ([MainTableNPS].[SiteName])="Eel Point"));
```

This is part of the Macros entitled "FirstEntryOnlyNPS."

Delete_Extra_SizeAbundance_Sites

This will have to be updated if there are any other sites that NPS records, yet that are not in the areas of interest.

```
DELETE Row
FROM SizeAbundance
WHERE (((SizeAbundance.SiteName)="Boy Scout Camp" Or (SizeAbundance.SiteName)="Horse Beach Cove" Or
(SizeAbundance.SiteName)="Miracle Mile" Or (SizeAbundance.SiteName)="Northwest Harbor" Or
(SizeAbundance.SiteName)="Eel Point"));
```

This is part of Macros NPS3.

FocalBenthic

This was created to help the user select the CDFG's specified "focal" benthic species and their attributes.

```
SELECT MainTable.Year, MonitoringSites.[Inside/Outside?], MainTable.MonitoringSite,
BenthicRecordPresence.BenthicSpeciesID, BenthicRecordPresence.Abundance,
BenthicRecordPresence.[Abundance Standard Deviation], BenthicRecordPresence.MeanLength
FROM (MonitoringSites INNER JOIN MainTable ON MonitoringSites.[Site Name] = MainTable.MonitoringSite)
INNER JOIN BenthicRecordPresence ON MainTable.Record_ID = BenthicRecordPresence.Record_ID
WHERE (((BenthicRecordPresence.BenthicSpeciesID)="Panulirus interruptus" Or
(BenthicRecordPresence.BenthicSpeciesID)="Strongylocentrotus franciscanus" Or
```

```
(BenthicRecordPresence.BenthicSpeciesID)="Strongylocentrotus purpuratus" Or
(BenthicRecordPresence.BenthicSpeciesID)="Haliotis corrugata" Or
(BenthicRecordPresence.BenthicSpeciesID)="Haliotis cracherodii" Or
(BenthicRecordPresence.BenthicSpeciesID)="Haliotis fulgens" Or
(BenthicRecordPresence.BenthicSpeciesID)="Haliotis rufescens" Or
(BenthicRecordPresence.BenthicSpeciesID)="Haliotis spp." Or
(BenthicRecordPresence.BenthicSpeciesID)="Parastichopus parvimensis" Or
(BenthicRecordPresence.BenthicSpeciesID)="Asterina miniata" Or
(BenthicRecordPresence.BenthicSpeciesID)="Pisaster giganteus" Or
(BenthicRecordPresence.BenthicSpeciesID)="Pisaster ochraceus" Or
(BenthicRecordPresence.BenthicSpeciesID)="Pycnopodia helianthoides" Or
(BenthicRecordPresence.BenthicSpeciesID)="Macrocystis pyrifera Adult" Or
(BenthicRecordPresence.BenthicSpeciesID)="Macrocystis pyrifera Juvenile"));
```

Once the query is run, the data show the focal species, the year, the monitoring site, whether it is inside or outside the reserve, the abundance, the standard deviation, and the mean length.

FocalFish

This was created to help the user select CDFG's specified "focal" fish species and their attributes.

```
SELECT [Fish Records].[Latin Name], MainTable.Year, MainTable.MonitoringSite,
MonitoringSites.[Inside/Outside?], HabitatRecords.HabitatType, HabitatRecords.MeanPercentCover,
HabitatRecords.StdDev, [Fish Records].[Mean Length], [Fish Records].[Length Standard Deviation], [Fish
Records].Abundance
FROM [Fish Records] INNER JOIN ((MonitoringSites INNER JOIN MainTable ON MonitoringSites.[Site Name]
= MainTable.MonitoringSite) INNER JOIN HabitatRecords ON MainTable.Record_ID =
HabitatRecords.Record_ID) ON [Fish Records].Record_ID = MainTable.Record_ID

WHERE ((([Fish Records].[Latin Name])="Semicossyphus pulcher(f)" Or
([Fish Records].[Latin Name])="Semicossyphus pulcher(m)" Or
([Fish Records].[Latin Name])="Paralabrax clathratus" Or
([Fish Records].[Latin Name])="Scorpaenichthys marmoratus" Or
([Fish Records].[Latin Name])="Ophiodon elongatus" Or
([Fish Records].[Latin Name])="Sebastes atrovirens" Or
([Fish Records].[Latin Name])="Sebastes carnatus" Or
([Fish Records].[Latin Name])="Hypsypops rubicunda" Or
([Fish Records].[Latin Name])="Halicoeres semicinctus(f)" Or
([Fish Records].[Latin Name])="Halicoeres semicinctus(m)" Or
([Fish Records].[Latin Name])="Embiotica jacksoni"));
```

Once the query is run, the data show the focal species, the year, the monitoring site, whether it is inside or outside the reserve, the habitat type and mean percent cover and standard deviation, the mean length and associated standard deviation, and the abundance of each species.

joinBandto1m

This is an append query which will add data to the Quadrat1mStats table.

```
INSERT INTO Quadrat1mStats ( SiteName, SpeciesName, CommonName, [Year], Mean, StdDev )
SELECT BandTransectStats.SiteName, BandTransectStats.SpeciesName, BandTransectStats.CommonName,
BandTransectStats.Year, BandTransectStats.Mean, BandTransectStats.StdDev
FROM BandTransectStats;
```

This query is run to include information on the species that were deleted earlier from the Quadrat1mStats table. These species are better represented by the band transect protocol due to their clumping nature.

This is part of Macros NPS2.

LeftOutSpecies

This is the second step in determining which species' sizes are not recorded.

```
SELECT CompareLeftOutSize.SiteName, CompareLeftOutSize.Year, CompareLeftOutSize.[Species Name],
CompareLeftOutSize.AvgOfSize, CompareLeftOutSize.SpeciesName
FROM CompareLeftOutSize
WHERE (((CompareLeftOutSize.SpeciesName) Is Null));
```

This selects the rows with null values from the table CompareLeftOutSize. This selection is all the information regarding the species that have size data but no abundance data.

This is part of Macros NPS2.

LeftOutSpeciesWithSize

This query creates a list of species name, year, site name and average size of species with no abundance data. This step is necessary to organize the data to make it into a table.

```
SELECT DISTINCT SizeAbundance.SiteName, SizeAbundance.Year, [LeftOutSPecies].[Species Name],
[LeftOutSPecies].AvgOfSize
FROM LeftOutSPecies INNER JOIN SizeAbundance ON ([LeftOutSPecies].Year=SizeAbundance.Year) AND
([LeftOutSPecies].SiteName=SizeAbundance.SiteName);
```

This is part of Macros NPS2.

Make5mTable

This is a make table query. This takes the condense5m query and creates a table for use later.

```
SELECT Condense5m.* INTO Improved5m
FROM Condense5m;
```

This is part of Macros NPS1.

MakeAgarumTable

This is a make table query. This takes the MeanAgarumFimbriatum query and creates a table called MeanAgarum to be used later.

```
SELECT MeanAgarumFimbriatum.* INTO MeanAgarum
FROM MeanAgarumFimbriatum;
```

This is part of Macros NPS1.

MakeBenthicRecordPrensence

This is a make table query. This will create the table TOBEBenthicRecordPresence.

```
SELECT Record_IDtoSizeAbundance.* INTO TOBEBenthicRecordPresence
FROM Record_IDtoSizeAbundance;
```

This is part of Macros NPS3. This table is ready for export to Excel and to be prepared to import into the official database (see Database Directions for Importing NPS Data below).

MakeHabitatDataTableNPS

This is a make table query. This allows the AddRecord_IdtoHabitat query to be saved as the table HabitatDataNPS. This is important for later use.

```
SELECT AddRecord_IDtoHabitat.* INTO HabitatDataNPS
FROM AddRecord_IDtoHabitat;
```

This is part of Macros NPS3. This table is ready for export to Excel and to be prepared to import into the official database (see Database Directions for Importing NPS Data below).

MakeMainTableNPS

This query was run the first time NPS data was imported into the CDFG Shallow Subtidal Monitoring Database. It should not have to be run again. For the record it is copied below.

```
SELECT SiteName_Year.* INTO MainTableNPS
FROM SiteName_Year;
```

This is part of the Macros entitled "FirstEntryOnlyNPS."

MakeSizeAbundance

This is a make table query which creates the table SizeAbundance. This table has site name, year, species name, mean abundance, standard deviation, and size. This table does not include rows for the species with data on size but no data on its abundance. It therefore is missing size data that must be included by other queries.

```
SELECT AddSizeto1m.* INTO SizeAbundance
FROM AddSizeto1m;
```

This is part of Macros NPS2.

MakeSizeLeftOutTable

This is a make table query which creates the table SizeLeftOut from the query LeftOutSpeciesWithSize.

```
SELECT LeftOutSPeciesWithSize.* INTO SizeLeftOut
FROM LeftOutSPeciesWithSize;
```

This is part of Macros NPS2.

MeanAgarumFimbriatum

This query allows the user to take the *Agarum fimbriatum* data for both juvenile and adults and combine them into one category by summing their abundances and averaging the standard deviation.

```
SELECT Quadrat1mStats.SiteName, Quadrat1mStats.Year, Quadrat1mStats.SpeciesName,
Sum(Quadrat1mStats.Mean) AS SumOfMean, Avg(Quadrat1mStats.StdDev) AS AvgOfStdDev
FROM Quadrat1mStats
GROUP BY Quadrat1mStats.SiteName, Quadrat1mStats.Year, Quadrat1mStats.SpeciesName
HAVING (((Quadrat1mStats.SpeciesName)="Agarum fimbriatum"));
```

This is part of Macros NPS1.

Record_IDtoSizeAbundance

This provides a record ID to every entry in the SizeAbundance table.

```
SELECT MainTableNPS.Record_ID, SizeAbundance.SpeciesName, SizeAbundance.Mean,
SizeAbundance.StdDev, SizeAbundance.AvgOfSize
FROM SizeAbundance INNER JOIN MainTableNPS ON (SizeAbundance.Year = MainTableNPS.Year) AND
(SizeAbundance.SiteName = MainTableNPS.SiteName);
```

This is part of Macros NPS3.

Report_Pisaster_Inside

This is an example of a select query to use when the user understands the relationships among tables. This query selects year, abundance, and inside/outside data on *Pisaster giganteus*.

```
SELECT BenthicRecordPresence.BenthicSpeciesID, MainTable.Year, Avg(BenthicRecordPresence.Abundance) AS
AvgOfAbundance, MonitoringSites.[Inside/Outside?]
FROM ((MonitoringSites INNER JOIN MainTable ON MonitoringSites.[Site Name] = MainTable.MonitoringSite)
INNER JOIN BenthicRecordPresence ON MainTable.Record_ID = BenthicRecordPresence.Record_ID) INNER
JOIN HabitatRecords ON MainTable.Record_ID = HabitatRecords.Record_ID
GROUP BY BenthicRecordPresence.BenthicSpeciesID, MainTable.Year, MonitoringSites.[Inside/Outside?]
HAVING (((BenthicRecordPresence.BenthicSpeciesID)="Pisaster giganteus"));
```

SelectHabitat

This query selects only the random point contact data that CDFG is interested in storing.

```
SELECT [RandomPointContactStats].[SiteName], [RandomPointContactStats].[Year],
[RandomPointContactStats].[Mean], [RandomPointContactStats].[StdDev],
[RandomPointContactStats].[SpeciesName]
FROM RandomPointContactStats
WHERE ((([RandomPointContactStats].[SpeciesName])="Bare Substrate" Or
([RandomPointContactStats].[SpeciesName])="Cobble" Or
([RandomPointContactStats].[SpeciesName])="Cystoseira Spp." Or
([RandomPointContactStats].[SpeciesName])="Desmarestia Spp." Or
([RandomPointContactStats].[SpeciesName])="Eisenia arborea All" Or
([RandomPointContactStats].[SpeciesName])="Encrusting Coralline Algae" Or
([RandomPointContactStats].[SpeciesName])="Laminaria farlowii All" Or
([RandomPointContactStats].[SpeciesName])="Macrocystis pyrifera All" Or
([RandomPointContactStats].[SpeciesName])="Pterygophora californica All" Or
([RandomPointContactStats].[SpeciesName])="Rock" Or ([RandomPointContactStats].[SpeciesName])="Sand"));
```

This is part of Macros NPS1.

SiteName_Year

This query was run the first time NPS data was imported into the CDFG Shallow Subtidal Monitoring Database. It should not have to be run again. For the record it is copied below.

```
SELECT DISTINCT Quadrat1mStats.SiteName, Quadrat1mStats.Year
FROM Quadrat1mStats;;
```

This is part of the Macros entitled "FirstEntryOnlyNPS." This results in all the possible site/year combinations so that each combination may be given a unique record ID.

UpdateEiseniaName

This is an update query. This will update the name of "*Eisenia arborea* All" to "*Eisenia arborea*." This will allow the data to fit the database.

```
UPDATE Quadrat1mStats SET Quadrat1mStats.SpeciesName = "Eisenia arborea"
WHERE [Quadrat1mStats].[SpeciesName]="Eisenia arborea All";
```

This is in Macros NPS1.

UpdateLaminariaName

This is an update query. This will update the name of "*Laminaria farlowii* All" to "*Laminaria farlowii"*. This will allow the data to fit the database.

```
UPDATE Quadrat1mStats SET Quadrat1mStats.SpeciesName = "Laminaria farlowii"
WHERE [Quadrat1mStats].[SpeciesName]="Laminaria farlowii All";
```

This is in Macros NPS1.

UpdateMAC5mAdultName

This is an update query. This will update the name of *"Macrocystis pyrifera* Adult (>1m and haptera above the primary dichotomy)" to "*Macrocystis pyrifera* Adult". This will allow the data to fit the database.

```
UPDATE Quadrat5mStats SET Quadrat5mStats.SpeciesName = "Macrocystis pyrifera Adult"
WHERE [Quadrat5mStats].[SpeciesName]="Macrocystis pyrifera Adult (>1m and haptera above the
primary dicotomy";
```

This is in Macros NPS1.

UpdateMAC5mSubAdultName

This is an update query. This will update the name of *"Macrocystis pyrifera* Subadult (>1m and no haptera above the primary dichotomy)" to "*Macrocystis pyrifera* Adult". This will allow the data to fit the database that differentiates between adults and juveniles, but not between adults and subadults.

```
UPDATE Quadrat5mStats SET Quadrat5mStats.SpeciesName = "Macrocystis pyrifera Adult"
```

```
WHERE [Quadrat5mStats].[SpeciesName]="Macrocystis pyrifera Subadult (>1m and no haptera above the primary dichotomy)";
```

This is in Macros NPS1.

UpdateMacAdultName

This is an update query. This will update the name of "*Macrocystis pyrifera* Ad.(>1m)" to "*Macrocystis pyrifera* Adult". This will allow the data to fit the database.

```
UPDATE Quadrat1mStats SET Quadrat1mStats.SpeciesName = "Macrocystis pyrifera Adult"
WHERE [Quadrat1mStats].[SpeciesName]="Macrocystis pyrifera Ad.(>1m)";
```

This is in Macros NPS1.

UpdateMacJuvenileName

This is an update query. This will update the name of "*Macrocystis pyrifera* Ad.(<1m)" to "*Macrocystis pyrifera* Juvenile". This will allow the data to fit the database.

```
UPDATE Quadrat1mStats SET Quadrat1mStats.SpeciesName = "Macrocystis pyrifera Juvenile"
WHERE [Quadrat1mStats].[SpeciesName]="Macrocystis pyrifera Juvenile (<1m)";
```

This is in Macros NPS1.

UpdatePterygophoraName

This is an update query. This will update the name of "*Pterygophora californica* All" to "*Pterygophora californica*". This will allow the data to fit the database.

```
UPDATE Quadrat1mStats SET Quadrat1mStats.SpeciesName = "Pterygophora californica"
WHERE [Quadrat1mStats].[SpeciesName]="Pterygophora californica All";
```

This is in Macros NPS1.

G.3 Macros

Macros allow the user to perform numerous operations quickly and in a certain order. The following macros were designed to ease the import of NPS data in the future by organizing the above queries.

In order for these macros to work, the NPS data must come in the same format as in 2003 (Kushner, 2003). The following shows the proper format and column headings for the NPS data if the following Macros are to be used. There are five pertinent tables:

Table Title: BandTransectStats
Field Names:

SiteNumber	IslandCode	IslandName	SiteCode	SiteName	Species	SpeciesName
CommonName	Year	Mean	StdDev	Count	Cases	

Table Title: NatHabSizeFrequencyMeans
Field Names:

SiteNumber	IslandName	IslandCode	SiteName	SiteCode	Year	Species	Species Name	AvgOfSize

Table Title: Quadrat1mStats
Field Names:

SiteNumber	IslandCode	IslandName	SiteCode	SiteName	Species	SpeciesName
CommonName	Year	Mean	StdDev	Count	Cases	

Table Title: Quadrat5mStats
Field Names:

SiteNumber	IslandCode	IslandName	SiteCode	SiteName	Species	SpeciesName
CommonName	Year	Mean	StdDev	Count	Cases	

Table Title: RandomPointContactStats
Field Names:

KF_SetupSiteNumber_SiteNumber	IslandCode	IslandName	SiteCode	RandomPointContactStats_SiteNumber
SiteName	Species	SpeciesName	Year	Mean
StdDev	Cases	---	---	---

For exact directions on how to import NPS data see section: Database Directions for Importing NPS Data.

Macros 1. FirstEntryOnlyNPS

This Macros was used when entering all historical data for NPS. It is kept as a record of how the data was entered and should not be run again.

Step 1: open query: SiteName_Year. This combines all possible site and year combinations.
Step 2. open query: MakeMainTableNPS. This makes a table of the site/year combinations.
Step 3. open query: Delete_Extra_Sites This removes the sites from the Main table that are not in the area of interest (not in the Sanctuary).

Macros 2. NPS1

This is the first of three Macros that should be run each time NPS data is imported.

Step 1. open query: DeleteExtra1m
Step 2. open query: DeleteExtraBand
Step 3. open query: DeleteExtraSize
Step 4. open query: SelectHabitat
Step 5. open query: DeletePisANDMacro1996_1m
Step 6. open query: UpdateEiseniaName
Step 7. open query: UpdateLaminariaName
Step 8. open query: UpdateMAC5mAdultName
Step 9. open query: UpdateMAC5mSubAdultName
Step 10.open query: UpdateMacAdultName
Step 11.open query: UpdateMacJuvenileName
Step 12.open query: UpdatePterygophoraName

Step 13.open query: Condense5m
Step 14.open query: Make5mTable
Step 15.open query:
Agarum_fimbriatum_adult
Step 16.open query:
Agarum_fimbriatum_juvenile
Step 17.open query: MeanAgarumFimbriatum
Step 18.open query: MakeAgarumTable
Step 19.open query: DeleteExtraAgarum
Step 20.MsgBox (provides message when finished with previous step)
Message: "OPEN THE "Improve5m" TABLE AND SWITCH THE FIELD NAME FROM "SumOfMean" to "Mean" and from "AvgOfStdDev" to "StdDev""

Step 21.MsgBox
Message: "OPEN THE "AgarumTable" AND SWITCH THE FIELD NAME FROM "SumOfMean" to "Mean" and from "AvgOfStdDev" to "StdDev""

Macros 3. NPS2

Step 1. open query: AppendMeanAgarum
Step 2. open query: Add5mto1m
Step 3. open query: joinBandto1m
Step 4. open query: AddSizeto1m
Step 5. open query: CompareLeftOutSize
Step 6. open query: LeftOutSpecies
Step 7. open query: MakeSizeAbundance
Step 8. open query: LeftOutSpeciesWithSize
Step 9. open query: MakeSizeLeftOutTable
Step 10.MsgBox:
Message: "OPEN "SizeLeftOut" TABLE. In the design view, change the field name "Species Name" to "SpeciesName" (remove the space)."

Macros 4. NPS 3

Step 1. open query: AppendSizeAbundance
Step 2. open query: Delete_Extra_SizeAbundance_Sites
Step 3. open query: Delete_Extra_Habitat_Sites
Step 4. open query: AddRecord_IdtoHabitat
Step 5. open query: Record_IDtoSizeAbundance
Step 6. open query: MakeBenthicRecordPrensence
Step 7. open query: MakeHabitatDataTableNPS
Step 8. MsgBox:
Message: "Export Tables "HabitatNPSData" and "TOBEBenthicRecordPresence" to Excel, and prepare column headings for import."
Step 9. MsgBox:
Message: "Change Column headings of "TOBEBenthicRecordPresence" to: 'Record_ID', 'BenthicSPeciesID', 'Abundance', 'Abundance Standard Deviation", 'MeanLength'."
Step 10. MsgBox:
Message: "Change Column headings of "HabitatData" to "Record_ID", HabitatType", "MeanPercentCover", StdDev"."

G.4 Forms

There is one main form and three subforms in this database. Only the main form should be used to enter data.

It is essential that when entering new data, the user is on a blank entry form, otherwise data already entered may be manipulated. This form allows the user to enter the monitoring site andthe year, while the Record ID will be provided automatically. The Record ID is then added to all three subforms. There is one subform for benthic data, one for habitat data and one for fish data.

G.5 Database Directions for Importing NPS Data

Prior to importing any data, the monitoring site/year combination must be added to the Main Table. This table will automatically assign this a unique Record_ID, which will be added to every piece of data recorded at that site during that year.

Once this is accomplished, there are ten steps to successfully importing NPS data. Note: it is important to have the same Table Names and column headings for the ten following steps to work correctly. In number (1)(a-f) below, the spacing and cases are deliberate, as Microsoft Access is case sensitive. The columns that are necessary are in section (ii) of each letter section in step one below. The other columns are not needed (but it is OK if they are there)

1. **Import the tables as they are into the MPA database. The tables the user import should be:**
    a. BandTransectStats
        i. Column headings: IslandCode, IslandName, SiteCode, SiteName, Species, SpeciesName, CommonName, Year, Mean, StdDev, Count, Cases
        ii. Needed: SiteName, SpeciesName, Year, Mean, StdDev
    b. FishTransect1NormalizedDensity/m2
        i. Column headings – not important
    c. NatHabSizeFrequencyMeans
        i. Column Headings: SiteNumber, IslandName, IslandCode, SiteName, Year, Species, Species Name, AvgOfSize
        ii. Needed: SiteName, Year, SpeciesName, AvgOfSize
    d. Quadrat1mStats
        i. Column Headings: SiteNumber, IslandCode, IslandName, SiteCode, SiteName, Species, SpeciesName, CommonName, Year, Mean, StdDev, Count, Cases
        ii. Needed: SiteName, SpeciesName, Year, Mean, StdDev
    e. Quadrat5mStats
        i. Column Headings: SiteNumber, IslandCode, IslandName, SiteCode, SiteName, Species, SpeciesName, CommonName, Year, Mean, StdDev, Count, Cases
        ii. Needed: SiteName, Year, SpeciesName, Mean, StdDev
    f. RandomPointContactStats
        i. Column Headings: KF_SetupSiteNumber_SiteNumber, IslandCode, IslandName, SiteCode, RandomPointContactStats_SiteNumber, SiteName, Species, SpeciesName, Year, Mean, StdDev, Cases
        ii. Needed: SiteName, Year, SpeciesName, Mean, StdDev

Note: The user does not need to import (b) FishTransect1NormalizedDensity/m2. However, the presence of this information is not a problem

In 2004, Dave Kushner created these tables for the purposes of entering the data into the MPAmonitoring database.

2. **Enter the new Monitoring Site and Year combination into the MainTable of the MPAmonitoring Database**
3. **Go to Macros – run NPS1**
4. **Once the Macros is run, there will be two new tables.**
    a. Open the 'Improve5m' table. In the design view, change the field name "SumOfMean" to "Mean" and the field name "AvgOfStdDev" to "StdDev"
    b. Open the 'MeanAgarum' and do same as in part 4(a)
5. **Go to Macros – run NPS2**
6. **Once the Macros is run, there will be one new table to edit.**
    a. Open 'SizeLeftOut' table. In the design view, change the field name "Species Name" to "SpeciesName" (remove the space).
7. **Go to Macros – run NPS3**
8. **Export two tables into Excel Files:**
    a. Export TOBEBenthicRecordPresence
    b. Export HabitatDataNPS
9. **Open these two tables in Excel. Change the column headings so they are exactly the same as the column headings in the MPAmonitoring Database**
    a. HabitatDataNPS column headings should read:
    Record_ID HabitatType MeanPercentCover StdDev
    b. TOBEBenthicRecordPresence column headings should read:
    RecordID BenthicSpeciesID Abundance Abundance Standard Deviation MeanLength
10. **Import Data to MPAmonitoring Database:**
    a. Import HabitatDataNPS into 'HabitatRecords'
    b. Import TOBEBenthicRecordPresence into 'BenthicRecordPresence'

G.6 Suggestions for Other Data Import

1. If a new program is being imported, enter all information on the new program
2. If a new site is being imported, enter all information on the new site(s)
3. Always make sure that the site/ year combination has a Record ID before entering data from that site on that date.
4. Prepare queries to remove unnecessary data and to ensure names are equivalent to names used in the database.
5. Prepare data so that it is in the same format (columns, field names etc.) as the database – this will allow smooth import.

Appendix H. Potential Spiny Lobster Management Options

H.1 Introduction

The California spiny lobster (*Panulirus interruptus*) provides one of California's most valuable fisheries. A commercial fishery for California spiny lobster began in 1872 (Odemar *et al.*, 1975) and commercial landings have been recorded since 1916. Over this period landings have fluctuated between a low of 152, 000 pounds in the 1974/75 season and highs of 1.05 million pounds and 950, 000 pounds in the 1949-50 and 1997/98 seasons, respectively (Leet *et al.*, 2001). Commercial landings of 686,300 pounds were recorded in the 2002/03 season and valued at $4.6 million (J. Ugoretz, pers. comm., 2003). A substantial sport fishery also targets the species, but the value and catch of this sector is not well quantified. Only one very limited investigation, conducted by the National Marine Recreational Fishing Statistics Survey has estimated the sport catch for southern California (Research, 1995). The estimated 1994 sport catch was 140, 000 lobsters but this result was based only on the response of 11 out of 5, 561 households surveyed. The sport fishery catch in 1993/94 equated to about 29% of the total lobster catch (Barilotti, 2001).

The state of California considers it a high priority to successfully manage the fishery for the long-term benefit of commercial and recreational users. Maintaining healthy populations of spiny lobster is also important ecologically. For example, lobster play a role in regulating sea urchin densities, which in turn inflences kelp population dynamics (Tegner and Levin, 1983; Dayton *et al.*, 1998). The state is legally required to sustain the lobster fishery on a long-term basis under The Marine Life Management Act of 1998 [MLMA, Fish and Game Code (FGC) §7050, et seq.]. The Act requires that, "Fisheries should be conducted sustainably so that long-term health is not sacrificed for short-term benefits" [FGC §7056(a)]. While commercial landings have been relatively stable, the true status of California's lobster population is not known (Leet *et al.*, 2001). Baseline data on the status of the fishery (e.g., historical landings and effort data), the life history of the species, and the effectiveness of current management strategies will help resource managers evaluate whether the California lobster fishery is sustainable.

Here we present a summary of existing regulations in the California spiny lobster fishery and four potential management options that should be further investigated by the fishery.

The chapter is divided into two sections including:

1) The existing commercial and recreational lobster fishing regulations in California and a description of the reasoning behind each regulation;
2) An overview and brief critique of certain aspects of California lobster fshery management;
3) Management options drawn from three sources: The scientific literature on *P. interruptus*; discussions with California commercial and recreational lobster fishers and successful lobster fishery management strategies used in other parts of the world.

H.2 Existing California Spiny Lobster Fishery Regulations

The broad goals of most fisheries regulations are to ensure that a fishery is operating in an efficient, effective and responsible manner and to optimize the socio-economic benefits derived from a fishery. Regulations that prevent over-fishing are paramount to management. Fisheries biologists generally divide over-fishing into two conceptual ideas: growth over-fishing and recruitment over-fishing (Parrish, 1999). Growth over-fishing refers to a species being harvested at an average size that is smaller than the size that would produce the maximum yield per recruit, which is generally close to the size or age of sexual maturity (Parrish, 1999). Recruitment over-fishing is defined as fishing that reduces reproductive output to levels that markedly decrease

recruitment (Parrish, 1999). For either growth or recruitment over-fishing, fishing less would produce higher landings (http://www.lobsterconservation.com/growthoverfishing/).

Almost all fishery regulations are variations or combinations of techniques that control two factors: life history attributes of the fished species taken (e.g., the size and breeding condition of fished lobster or the "catch") and the number or rate of annual removals of the species (*i.e.* effort). Typical management measures to avoid growth over-fishing in lobster fisheries include size restrictions, trap mesh size restrictions and the use of escape gaps. Examples of management techniques used to avoid recruitment over-fishing can include setting annual quotas or fleet sizes at levels that will not reduce the adult biomass below some reference level (Parrish, 1999). However, even if these management strategies are implemented they may fail if socio-economic and political concerns are not addressed. For example, regulations should minimize the potential for excessive competition between fishers (e.g., the "race for fish") and be perceived as equitable.

Many of the concepts discussed above are being utilized in the California lobster fishery. It is important to understand what the existing regulations are and their intended purposes to begin to address whether changing or adopting new management regulations may improve the sustainability and socioeconomic performance of the fishery. Lobster fishing regulations for California are found in the California Code of Regulations (CCR). Sections relating specifically to lobster fisheries are Sections 29.9 (sport or recreational) and §121, §121.5, §122, (commercial) of Title 14 (Natural Resources) (See http://ccr.oal.ca.gov/cgi-bin/om_isapi.dll?clientID=349853&infobase=ccr&softpage =Browse_Frame_Pg42). Table H-1 presents a summary of the recreational and commercial lobster fishing regulations for California since 1955 and provides a brief explanation of some of the reasons for adopting those regulations.

Table H-1: Recreational and Commercial Lobster Fishery Regulations. (* Indicates a relatively complicated regulation and further explanation is provided below.)

		Regulations		Reasons	
Categories	Year Implemented	Recreational	Commercial	Recreational	Commercial
Minimum Size Limit	1955	3.25 inches (82.5mm) carapace length. Undersized lobster must be returned immediately.	Same as recreational.	Lobster reaching this size are believed to have bred at least a couple of times.	Same as recreational.
Season	1961	Fishing only allowed from the Saturday preceeding the first Wednesday in October to first Wednesday after the 15th March (approximately 6 months and 1 week).	Fishing only allowed from the first Wednesday in October to first Wednesday after 15th March (approximately 6 months)	To limit effort and reduce the take of female lobster in a breeding state. Season is advanced a week to give recreational sector a catch advantage.	To limit effort and reduce the take of female lobster in a breeding condition.
Permit Requirements	Commercial since 1965	Annual valid sportsfishing licence ($31.25 resident) with Ocean Enhancement Stamp ($3.50).	Annual lobster operator permit ($265) and crew member permits ($125)	To support research, management and enforcement.	Same as recreational.
Catch Restrictions	1971	Only 7 lobster can be taken per person per day (reduced from 10). Lobster must be kept with their body intact.	No catch limit. Lobster must be kept with their body intact.	To limit excessive take by individuals. Lobsters are kept with body intact so that carapace can be measured to determine if lobsters are of legal size.	Significant auditing of catch would be required (e.g., if quotas were used). Costly to enforce. No stock assessment has been performed for lobster. Lobsters are kept with body intact so that carapace can be measured to determine if lobsters are of legal size.
Logbook Requirements	1973	Only commercial passenger dive boats report the number of lobsters taken.	Logbooks have been required since 1973.	To monitor catch from this sector.	To monitor regional and total commercial catch, to estimate fishing effort and spatial extent of fishery.
Capture Method	Trapping largely unchanged since 1975	Hands only, free-diving or SCUBA allowed	Only traps can be used (*See details below). (Note:The number of traps fished per operator is not regulated.)	To reduce the efficacy of lobster take.	Economically efficient, minimal adverse ecological effects and highly selective at catching lobster.
		Baited hoop nets (5 hoop nets per person- maximum 10 per		To account for non-divers.	
Number of Participants	1997	Not regulated.	Approximately 225. Restricted access fishery (the number of participants is regulated).	Public trust resource & not politically feasible.	Concerns regarding over-capitalization and competion from new entrants.
Moratorium on Commecial Entrants	2003	N/A	Moratorium on issuing any new commecial permits. 237 permits issued for 2002/03 season.	N/A	First step towards potentially implementing a transferable permit system.
Restricted Fishing Areas	Major = MPAs at the northern Channel Islands implemented in 2003.	State Marine Reserves (no-take); State Marine Conservation Areas (no-take for certain species); State Marine Parks (commercial fishing prohibited, recreational prohibition for some species).	Same as recreational plus Santa Monica Bay and other minor restrictions (e.g., no traps set within 750ft of publicly ownded piers).	Potential ecological benefits (e.g., more natural population structure); fisheries benefits (e.g., spillover, fraction of stock protected- buffer from management mistakes). Potential fisheries science 'control' sites.	Same as recreational.

One of the regulation types in Table H-1 (i.e. Commercial Capture Method) is rather complicated and requires further explanation to better understand the first two management options presented.

H.3 Commercial Capture Method- Traps:

Lobster traps are an efficient means to catch lobster: they are relatively cheap, highly selective (*i.e.* they predominantly catch only lobster) and their deployment appears to have minimal adverse ecological impacts (http://www.deh.gov.au/coasts/fisheries/assessment /wa/rocklob/report/summary.html). Traps used in California are rectangular in shape and two chambered. The first chamber has one or two side entrance funnels and another funnel leads to the second chamber, which is baited.

Since 1958, California lobster traps have been built of rectangular wire mesh with mesh measurements not less than 47.5mm by 98.5mm with the 98.5mm mesh parallel to the trap floor (CA Commercial Fish Laws Digest, 2003). Very small lobsters (<60mm Carapace Length (CL)) can escape through mesh of this size (Odemar *et. al.*, 1975). In addition, as of 1976, a rigid escape port is to be placed on an outside wall of the inner trap chamber with inside measurements not less than 60.3mm by 292mm and within 50.8mm of the floor. This port permits undersized lobster to fit through the vertical rigid bar space for them to escape. The escape port reduced the number of sublegal or undersized lobsters caught and allowed the escape of rock crabs (*Cancer spp.*) (Odemar *et al.*, 1975; Engle, 1979).

Traps may not be pulled or dropped one hour after sunset to one hour before sunrise to avoid multiple trap deployments over a 24hr period. Allowing multiple trap pulls per day may lead to excessive effort and competition between fishers during the season (particularly early season when most of the catch is taken) and night time operations may create additional problems for enforcement agencies.

Modern traps have many advantages. Although they reduce the proportion of lobsters caught below the minimum legal size, they do not solve the problem of significant mortality and reduced growth rates that can be associated with trapping and handling stress of sublegal spiny lobster (Brown and Dibden, 1987). From a number of tank trials it was estimated 80% of sublegal lobsters could escape through this gap space (Odemar *et al.*, 1975). However, field trials revealed that even this marked decrease in sublegal catch using the existing escape port design still resulted in a catch ratio of sublegal to legal lobsters of approximately 1:1. Over the past five lobster seasons the ratio of sublegal to legal lobsters captured by commercial fishers in the California fishery varied but on average has remained well above the 1:1 ratio described by Odemar *et al.* (1975) (Table H-2). Finally, "destruct clips" (i.e. clips that will corrode or break down) are required on every trap to ensure that if lost the trap will not continue fishing[3].

H.4 Management Overview

Existing fishery regulations for the California spiny lobster have evolved from local knowledge of lobster fishers, scientific research and from awareness of increased fishing pressure on the fishery. We conducted a search of the literature that indicated the vast

[3] More details on the regulations specific to traps used in California can be found in Fish and Game Code Sections: §§8250-8259, §9002- 9010.

majority of research for this fishery was conducted between the 1950s and the 1970s. The CDFG currently has no personnel actively researching lobster. Since the late 1970s little to no lobster fishery research has been conducted in California and resource management has relied almost solely on monitoring the total commercial lobster catch as an indicator of the fisheries health. While the total catch has remained relatively stable over the last 25 years, this type of 'static management' has many potential problems. For instance, the potential to improve productivity and catches in the fishery are not being explored and little is being done to evaluate and strengthen areas of management that are central to ensuring the continued performance of the fishery.

Management of the California lobster fishery through the various regulations listed above appear to have been effective in maintaining a relatively stable total commercial lobster catch over the past 87 years (Figure H-1). In addition, Leet *et. al.* (2001) states that, "The consistent presence of lobsters under legal size is generally a good indicator of a healthy fishery and population". Thus, common sense may suggest that there is no reason for management to change if the current system is working. However, there are several reasons why changes to current management may be in the best interests of this fishery.

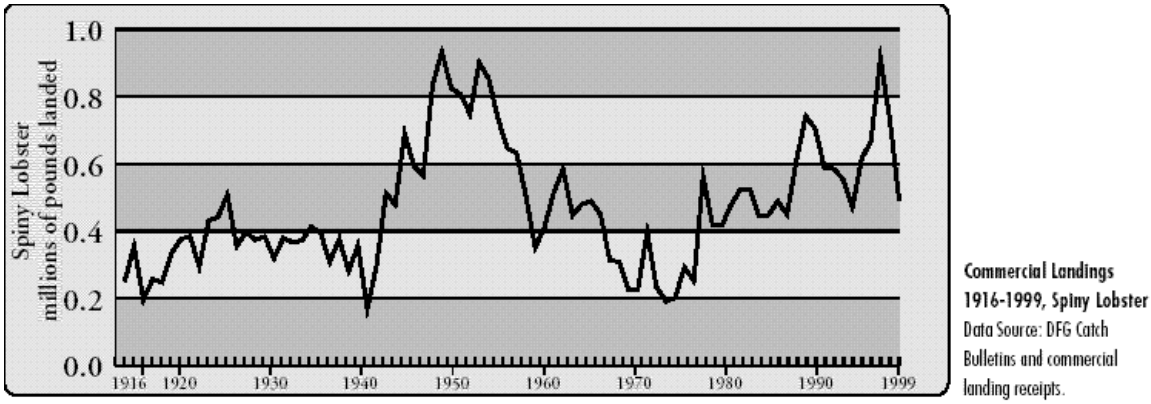


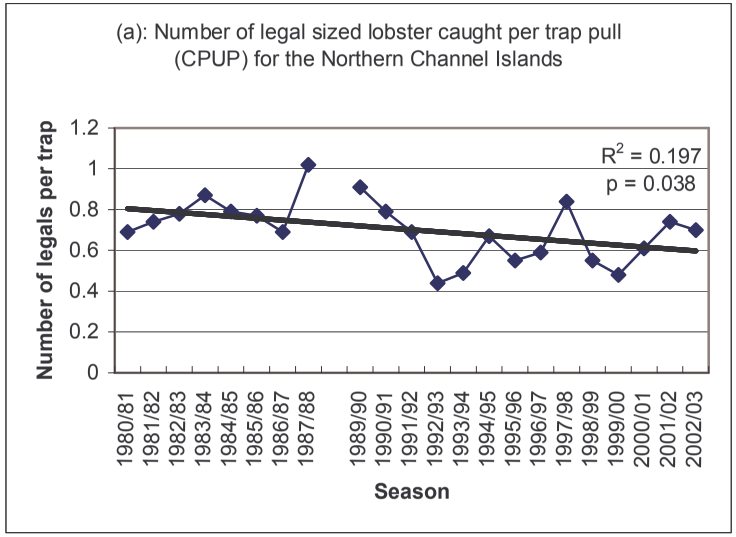
Figure H-1. The total commercial landings reported for spiny lobster in California for the period between 1916 and 1999. (http://www.dfg.ca.gov/mrd/status/ca_spiny_lobster.pdf).

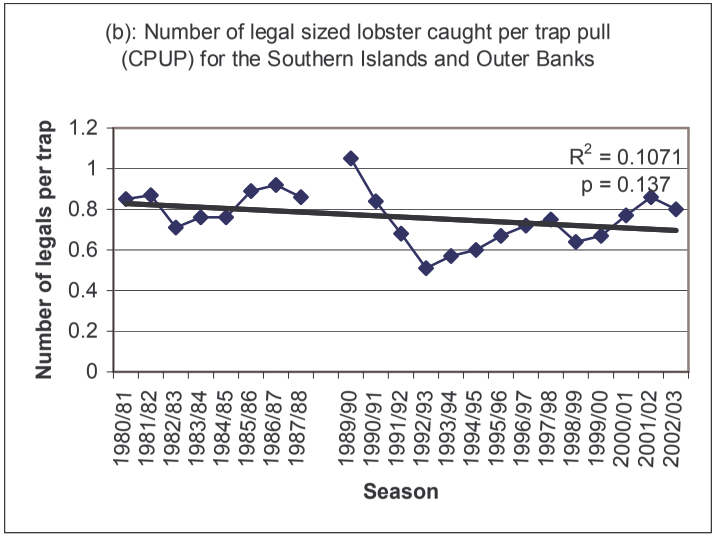
Relying on total catch as an indicator of the status of a fishery can be misleading and may not necessarily reflect the status of a fishery (Hillborn and Walters, 2001). Catch can remain stable even when stocks have declined due to expanded fishing effort or from changes in the ability to catch a species (i.e. catchability). For example, improved technologies such as faster boats, global positioning systems, echo sounders and so forth may allow high catches to be maintained with a declining stock size. This is a common concern across many fisheries (Hilborn and Walters, 2001). To provide any context to total catch data a measure of effort must be included. Therefore, at a minimum, total catch should be complemented with a measure of catch per unit effort and incorporated into the management regime.

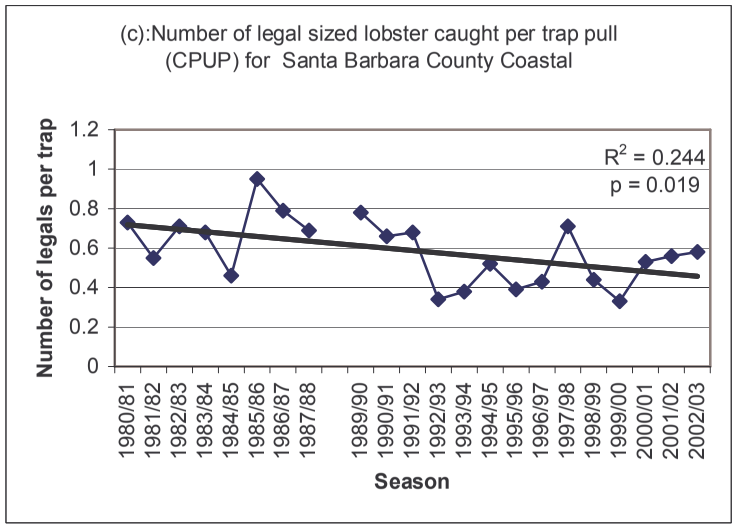
Logbook records of the average number of legal sized lobster caught per trap pull (CPUP) are considered the best estimate of catch per unit effort (CPUE) in the California spiny lobster fishery (Bell, 1974). The CDFG provided commercial lobster logbook data summaries from 1980 to 2002 for this preliminary analysis of CPUP (with the exception of the 1988/89 season for which data was not available). The CPUP for each of the seven California lobster fishery regions was calculated separately (Figure H-2 a-g), and then

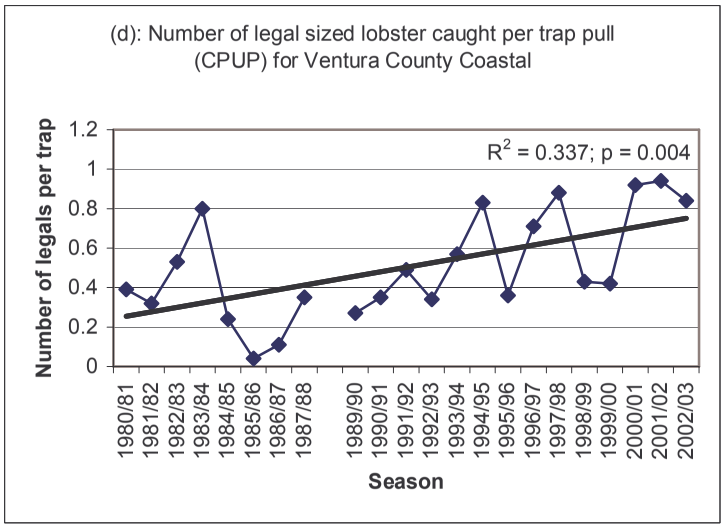
combined to calculate the CPUP for the whole California fishery (Figure H-2 h). Linear regressions and r^2 values were fitted to the data from each region and for the whole fishery (shown in the top right of each figure). These data indicate no statistical change in the CPUP for the Southern Islands and Outer Banks, Los Angeles County Coastal and San Diego County Coastal (p-value> 0.05); a significant decline in the CPUP for the Northern Channel Islands, Santa Barbara County Coastal, and Orange County Coastal (p-value< 0.05) and a significant increase in the CPUP for Ventura County Coastal (p-value< 0.05). In general, Los Angeles County Coastal, San Digo County Coastal and Orange County Coastal all have a lower CPUP compared to other regions. The high variability in the CPUP within and between regions may reflect intra-seasonal changes in lobster abundance.

A number of considerations must be taken into account when considering such logbook data analysis. First, several assumptions must be made regarding the relationship between commercial CPUP and abundance. These include: (1) that CPUP is directly proportional to abundance; (2) accurate reporting in logbooks and (3) the catchability of lobster has remained constant over time and between varying sampling conditions (Hilborn and Walters, 2001). Barilotti (2001) found a significant correlation between landings and CPUP, supporting the idea that CPUP probably provides a good estimate of lobster abundance. Anecdotal evidence also suggests that trapping methods have remained mostly unchanged since the 1975/76 season (Barilotti, 2001). However, to improve our ability to interpret these results the logbook data should be compared to the spatial change in catch for each region over the same time period. Veteren lobster fishers in each region will also have extensive knowledge to help explain and interpret patterns in catch.


(a): Number of legal sized lobster caught per trap pull (CPUP) for the Northern Channel Islands
Number of legals per trap
1.2
1
0.8
0.6
0.4
0.2
0
R2 = 0.197
p = 0.038
1980/81
1981/82
1982/83
1983/84
1984/85
1985/86
1986/87
1987/88
1989/90
1990/91
1991/92
1992/93
1993/94
1994/95
1995/96
1996/97
1997/98
1998/99
1999/00
2000/01
2001/02
2002/03
Season


(b): Number of legal sized lobster caught per trap pull (CPUP) for the Southern Islands and Outer Banks
Number of legals per trap
1.2
1
0.8
0.6
0.4
0.2
0
R2 = 0.1071
p = 0.137
1980/81
1981/82
1982/83
1983/84
1984/85
1985/86
1986/87
1987/88
1989/90
1990/91
1991/92
1992/93
1993/94
1994/95
1995/96
1996/97
1997/98
1998/99
1999/00
2000/01
2001/02
2002/03
Season


(c):Number of legal sized lobster caught per trap pull (CPUP) for Santa Barbara County Coastal
Number of legals per trap
1.2
1
0.8
0.6
0.4
0.2
0
R2 = 0.244
p = 0.019
1980/81
1981/82
1982/83
1983/84
1984/85
1985/86
1986/87
1987/88
1989/90
1990/91
1991/92
1992/93
1993/94
1994/95
1995/96
1996/97
1997/98
1998/99
1999/00
2000/01
2001/02
2002/03
Season


(d): Number of legal sized lobster caught per trap pull (CPUP) for Ventura County Coastal
Number of legals per trap
1.2
1
0.8
0.6
0.4
0.2
0
R2 = 0.337; p = 0.004
1980/81
1981/82
1982/83
1983/84
1984/85
1985/86
1986/87
1987/88
1989/90
1990/91
1991/92
1992/93
1993/94
1994/95
1995/96
1996/97
1997/98
1998/99
1999/00
2000/01
2001/02
2002/03
Season

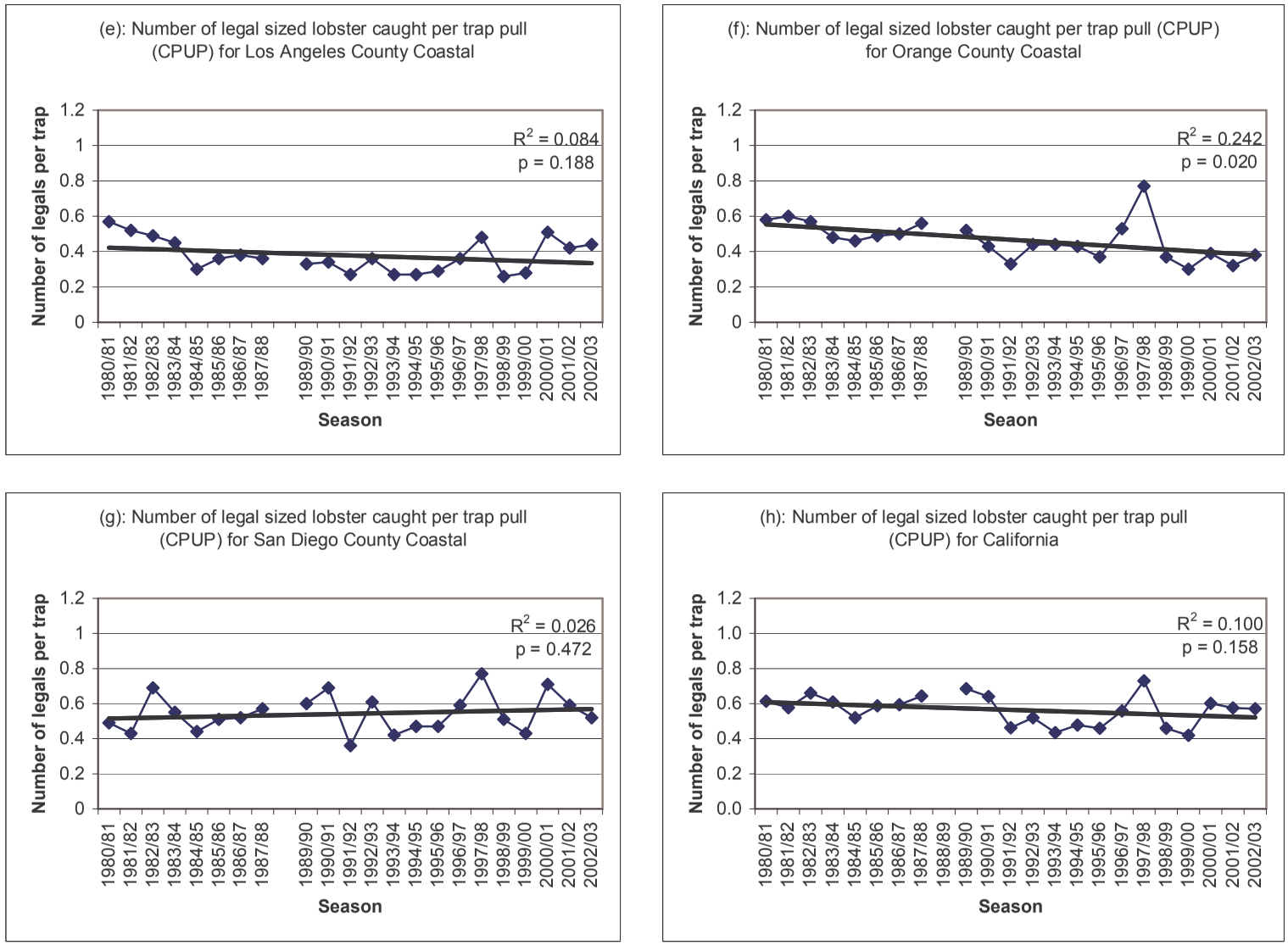


Figure H-2 The Average Number of legal sized lobster caught per trap pull (CPUP) for each of the seven Califonia lobster fishery regions and fishery-wide for California

Trends in lobster CPUP shown in Figure H-2 indicate the possibilty that some regions of the fishery may be experiencing declining productivity. Other regions appear to be relatively stable but generally have lower CPUP. While these data are preliminary, they highlight the need for a more comprehensive investigation on trends and management strategies used in the fishery. Such an evaluation may ensure that CDFG and industry have the data necessary to objectively assess and potentially improve the fishery. For example, an understanding of the causes behind the significant increase in CPUP for Ventura County Coastal could lead to similar improvements in other regions. Further reasons to assess the existing lobster management strategies and regulations include:

- A lack of fishery-dependent and independent research conducted on lobster in the past 25 years;
- The CDFG has no personnel actively researching lobster and under California's current budgetary constraints it is unlikely that the state will obtain funding for lobster research;
- From the early 1980s to 1998 California's population grew from 22 million people to over 32 million people. This growth has resulted in an increased pressure and demand on fish and wildlife resources (http://www.dfg.ca.gov/fg_comm/message.pdf).
- The size distributions and abundance of lobster are clearly different form historical patterns (Dayton *et al.*, 1998). The commercial fishery began in 1872 and in 1887 the average lobster taken was approximately 150mm CL (~4lb) (Rathbun, 1887 cited in Tegner and Levin, 1983). By 1955, the average lobster taken was approximately 119mm CL (~2lb) and the average harvest size in San Diego from 1976 to 1980 varied from 86-90mm CL. In 1888, 260 traps yielded almost the same mass (231 060 lbs) as 19, 000 traps fished in 1975 (233, 179lbs) (Collins, 1889 cited in Odemar *et al.*, 1975).

The management options that follow are based on the scientific literature on *P. interruptus*; discussions with California commercial and recreational lobster fishers and from successful lobster fishery management strategies used in other parts of the world. The options presented are preliminary and intended to heighten awareness and create discussion regarding the fishery and potential management options that should be further investigated. Four of these options are discussed below.

H.5 Management Options

Option 1: Increase the number of escape gaps in commercial traps.
Option 2: Position an escape port opposite the pull rope.

Minimizing the capture of sublegal or undersized lobster (locally referred to as "shorts") has the potential to reduce economic loss in the California lobster fishery. This may be accomplished by simply adding another escape port of similar dimensions to lobster traps and/or placing the existing escape port opposite the pull rope attachment. The benefits of reducing the number of undersize lobster trapped are threefold: (1) reducing the time devoted to handling and throwing back undersize lobster; (2) reducing sublegal lobster mortality associated with handling stresses and (3) preventing adverse affects to sublegal

lobster returned to the sea, such as lower growth rates associated with exposure, handling and displacement.

The overall effects of capturing and handling undersize lobster can be consequential. In the Western Australian *Panulirus cygnus* fishery, between 16-20 million undersize spiny lobsters are brought aboard fishing vessels by normal fishing operations in a season, despite escape gaps in all traps (Brown and Caputi, 1985). All undersized lobster in this fishery must be returned as soon as possible to the sea. However, three tagging trials documented the negative effects of incidental catches. Negative effects included: damage (i.e. when appendages were lost), exposure (i.e. the effects of being removed from the water and of handling stress) and displacement from home range, all of which were observed to significantly reduce the growth rate of lobster returned to the sea (Brown and Caputi, 1985; Crear and Forteath, 2001). Further, handling undersized lobster affects their survival rate by increasing rates of predation because of disorientation when they return to the sea floor (Brown and Caputi, 1985). Davis (1981) found that minor damage results in similar reductions in growth rate to that of a more seriously damaged lobster. Reduced growth rate prolongs the time it takes for a lobster to attain legal size and potentially enter the fishery. The additive effect of these factors can cause a significant decline in lobster catches over a lobster season (estimated at 14.6% reduction in recapture rate in the West Australian fishery for the 1978-79 season). This equated to an economic loss of $9.1 million for the fishery (Brown and Dibden, 1987).

The traps used in the California lobster fishery are fitted with a single rectangular escape port with measurements and position described in section H.4. The single escape port design was implemented due to ease of installation and its relative effectiveness in allowing the escape of sublegal lobsters. However, testing of port designs revealed that four escape ports per trap (arranged in two rows, with two escape ports on the upper level and two on the lower level) was the most effective design in allowing the escape of undersized lobsters (Odemar *et. al.*, 1975). Traps with escape ports had higher catch rates than those traps without ports. The single escape port used in the trials and still used in the fishery produced a ratio of sublegals to legals of 0.94:1, whereas installing four ports of smaller length (8 inches vs. 11.5 inches) resulted in a catch ratio of sublegals to legals of 0.22:1. In addition, trials did not test positioning of the ports in the trap. Placing the existing escape port opposite the pull rope attachment on the trap will 'tip out' more undersize lobster from the trap as it is being pulled to the surface (this positioning is a requirement in the West Australian lobster fishery).

Preliminary analysis of logbook data collected over the past five lobster seasons shows that fishery-wide, the ratio of sublegal to legal sized lobster caught has been consistently above 2:1 (Table H-2). However, this ratio is not consistent across the seven lobster fishery regions with the highest sublegal to legal lobster catch occurring at San Diego County Coastal (4.07:1) and the lowest at the Northern Channel Islands (0.55:1) (See Table H-3). The total number of sublegal lobster landed each year also varies between each of the seven regions (See Figure H-3). Figure H-3 shows that San Diego County Coastal consistently catches (and releases) the highest number of sublegal lobster, followed by Orange County Coastal and the Southern Islands and Outer Banks.

Table H-2 The ratios of sublegal to legal lobster catch for the California lobster fishery over the past five seasons and the logbook data used to calculate this ratio (Source: adapted from CDFG logbook summary data, J. Ramsey, CDFG).

Season	# of traps pulled	# of sublegals released	# of sublegals retained	# of sublegals per trap	# of legals per trap	Ratio of sublegals: legals
1998/99	861,143	822,294	395,366	0.95	0.46	2.06:1
1999/00	813,448	807,308	340,334	0.99	0.42	2.36:1
2000/01	805,360	1,071,353	484,673	1.33	0.6	2.22:1
2001/02	786,269	987,564	452,146	1.26	0.58	2.17:1
2002/03	864,234	1,174,974	493,106	1.36	0.57	2.39:1

Table H-3 The regional ratios of sublegal to legal lobster catch for the California lobster fishery over the past five seasons (Source: adapted from CDFG logbook summary data, J. Ramsey, CDFG).

Fishing Area	Average regional ratio of sublegals to legals
Northern Channel Islands	0.55:1
Southern Islands and Outer Banks	1.69:1
Santa Barbara County Coastal	1.36:1
Ventura County Coastal	0.90:1
Los Angeles County Coastal	1.21:1
Orange County Coastal	2.59:1
San Diego County Coastal	4.07:1
Undetermined	2.58:1

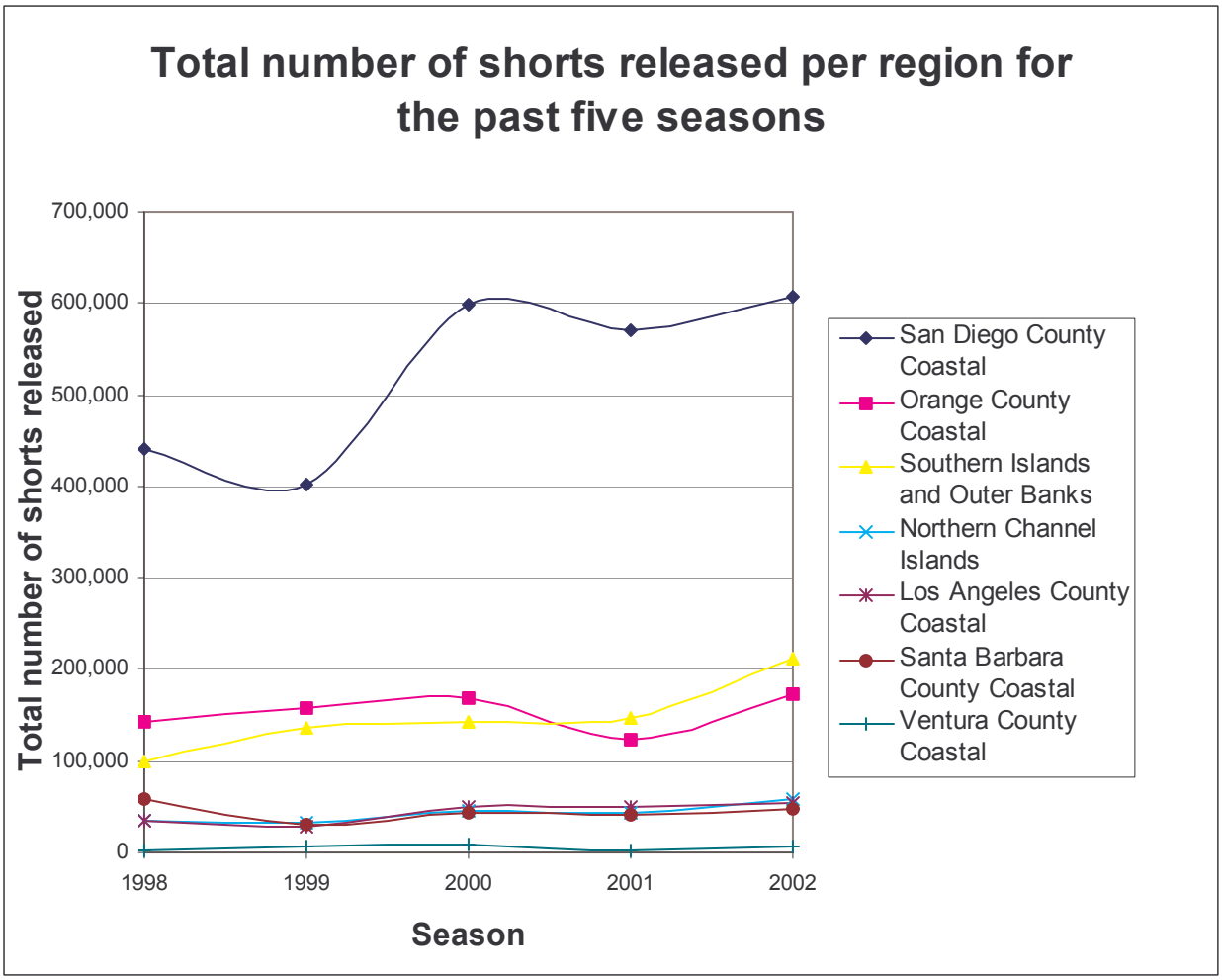


Figure H-3 The total number of sublegal lobster (shorts) released from each of the seven regions in the California lobster fishery over the past five seasons (Source: adapted from CDFG logbook summary data, courtesy J. Ramsey).

Many potential explanations for these varied sublegal to legal ratios exist. For example, the longer soak periods typically fished at the Channel Islands (up to four days) may give juvenile lobster more time to escape via the escape port than in San Diego County Coastal, where soak periods are generally shorter (C. Miller pers. comm. 2003). The suitability of habitats in the different regions for juveniles probably also plays a role in determining sublegal lobster abundance (e.g., San Diego County Coastal may be more of a "nursery area" than the Northern Channel Islands).

The potential benefits of increasing the number and/or repositioning the escape port opposite the pull rope (i.e. a higher future legal sized CPUP) would be greater for those regions with high sublegal to legal ratios. Impacts could include increasing the time taken to construct a trap with an extra escape port, the cost of the port and the time and effort involved in any experimental trials conducted. These costs may be well worth accepting if recapture rates increase in a similar magnitude to that of the Western Australian Fishery (approximately 15%; Brown and Caputi, 1985). Placing the escape port opposite the pull

rope would only involve educating trap fishers to the benefits of doing so. Commercial fishers could conduct trials to compare the effects of adding new escape ports and altering their position by recording their undersize capture rates between altered and unaltered traps.

Option 3: No retention of reproducing female lobster, including egg bearing females(berried), females with an attached spermatophore or setose females (females with ovigerous setae).

The number of larval recruits is considered a main factor limiting the number of future adult lobster in the California fishery and subsequently in limiting the season catch. Lindberg (1955) believed that larvae were the "keystone of the population ...and about the larval stage little is known". Therefore, providing for increases in egg production through further protection of reproducing female lobster may be in the best interests of the California lobster fishery. Egg bearing female lobster were protected in the fishery in the early 1900's (Odemar *et al*., 1975). However, the relationship between egg production and recruitment levels is not known for this fishery, and stock-recruitment relationships are notoriously difficult to demonstrate (Caputi, 1993). Questions still surround the supply and dispersal of larvae, and the local benefits of protecting reproducing females may only be reaped if pueruli are returning to local waters.

One of the main arguments to be addressed in the California lobster fishery is the extent of female lobster protection required, given the perception that California larvae are carried from Mexican waters and that larvae produced in Californian waters are carried south across the border to supply the Mexican fishery. It is believed that because of the long planktonic life (approximately 6-12 months), phyllosoma larvae of *Panulirus* species tend to be transported by marine currents over long distances (Thompson *et al*., 1996). The literature on .*P interruptus* larvae may suggest that larvae are retained more locally than once thought (Enriquez *et. al.* 2001).

Surprisingly little work has been conducted on phyllosome ecology, given its economic and ecological importance (Pringle, 1986). Plankton tow samples conducted by the California Cooperative Oceanic Fisheries Investigations (Cal COFI) from 75 cruises between 1949 and 1955 recovered very low numbers of phyllosomes. This is in contrast to Lindberg's (1955) assertion that because of the large reproductive potential of the species, the larvae must be common. Further, based on the much larger size of the Mexican lobster fishery, Lindberg (1955) reasoned that lobster egg production in the Southern California Bight (SCB) was of little consequence to this area's future fishery recruitment. Despite this perception, management exercised precaution and maintained a minimum size limit above that of sexual maturity.

Oceanographic factors such as water currents and eddies play a significant role in determining the fate and supply of larvae. The complex of the Channel Islands and associated Banks are capable of generating and shedding eddies (Owen, 1980). Johnson (1960) suggested the potential of the Southern California Eddy (SCE) as a larval retainer due to its large size (~200km in diameter) and predictable appearance between July and January. Johnson (1960) concluded that "Recruitment of lobsters on the coast of southern California and Baja, California must depend upon the development of large eddies, swirls, and counter currents, which retard the flushing out of larvae to the south with the California Current". However, Johnson and Brinton (1963) questioned the validity of this hypothesis based on the low probability of oceanographic retention of larvae with such a long planktonic duration (~8 months). Thus, retention of larvae may be enhanced by the SCE but in itself

the SCE may not be enough to retain lobster larvae produced in California north of the Mexico border.

Pringle (1986) reviewed the plankton tow data collected by CalCOFI (above) in light of recent physical oceanographic information and *Panulirus* larval biology. He concluded that, "Most often the lobster larvae are swept out of the SCB to Baja California waters. It is suggested that during these years, if recruitment occurs, it is via pueruli transported north-westward on the Davidson Current" (Pringle, 1986). Studies by Parker, (1972) and Serfling and Ford (1975) indicated that pueruli enter coastal waters off San Diego during May and appear regularly though September and that peak pueruli abundance appears to be correlated with seasonal sea-surface maxima. Thus, while California lobster larvae (phyllosoma stages) may be swept out of Californian waters, they may later return in the Davidson Current as matured pueruli to settle.

The results from Enriquez *et. al.* (2001) suggest that *P interruptus* exhibits three genetic subpopulations along the Baja California Peninsula. These are shown diagrammatically in Figure H-4 (taken from Enriquez *et. al.* 2001).

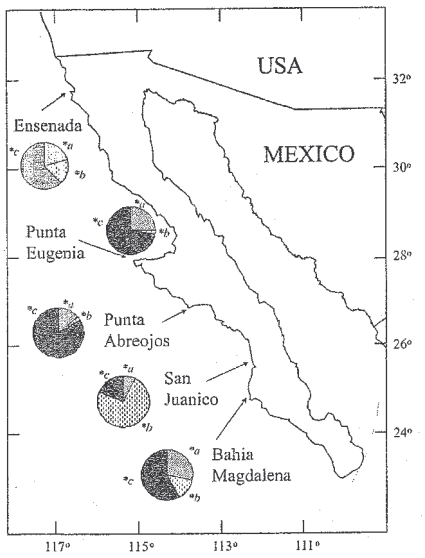


Figure H-4 Genetic variability between lobsters subpopulations indicated by allele frequencies along the Baja peninsula.

The three genetically distinct subpopulations of *Panulirus interrupus* detected are believed to be:

- The northern region surrounding Ensenada
- The central part of the Peninsula (Punta Eugenia and Punta Abreojos)
- The southernmost area of the distribution (Bahia Magdalena and San Juanico)

The study by Enriquez *et. al.* (2001) may indicate that if larvae are being carried southward out of Californian waters (and they are genetically similar to those in Ensenada) then the larvae may well be retained in the northern most Ensenada subpopulation of the Baja Peninsula. The northern subpopulation is comparatively much smaller than the central subpopulation, where lobsters are most abundant (Enriquez *et al.*, 2001). This could imply that depletion of larvae coming from California may have a proportionately greater impact

on limiting total larval production for the smaller northern subpopulation, assuming the larger subpopulation off Central Baja is not contributing as many larvae as previously thought. Thus, California larvae may not be supplemented as much as previously thought by Baja and lobsters spawned in California may play a large role in sustaining their own population over time.

It is important to clarify whether the populations on either side of the US/Mexico border are genetically similar and the extent to which they are isolated. This information will allow predictions to be made about the capacity of areas to recover if they are over-exploited, by way of recruitment arising from distant locations (Enriquez *et. al.*, 2001). There is also the possibility that the more southern sub-populations recruit to California but do not have the physiological adaptations necessary to grow and survive in these waters. Until this information and improved knowledge regarding the environmental and biological factors influencing recruitment are obtained, precautions should be taken and the fishery should attempt to maximize larval production. Therefore, it is recommended that the egg bearing, setose and plastered females not be taken as they are in the process of reproducing and potentially about to contribute to the larval pool of California.

The lobster season currently provides good protection for egg bearing females, as the season closure approximately coincides with the beginning of the egg production period, approximately in March and April. However, before female lobster lay their eggs there are two signs that they are beginning to spawn. The first of these is the growth of long, fine, filament like hairs (or setae) underneath their tails. These setae are attached to inner forked structures called endopodites, which form part of their swimmerets (http://www.fish.wa.gov.au/rec/broc/rocklob/rlsetose.html). The eggs stick to these hairs enabling the eggs to be carried under their tails. A second sign that a female lobster is ready to spawn is the presence of a spermatophore on the underside of the carapace between the hindmost pair of legs. This grayish/white or black putty like spot is a sperm packet attached to the female by a male during mating. Plastered and setose females are offered less protection as the fishing season overlaps approximately four months with this stage of the reproductive cycle.

In the West Australian *Panulirus cygnus* fishery, Hall and Chubb (2001) found that protecting female setose lobster was the most effective management control to increase egg production, followed by trap reduction, and then the introduction of a maximum legal size. While there are obvious differences between these two lobster fisheries, drawing on successful management strategies used elsewhere may be the most efficient means to improve the California fishery considering the limited amount of research conducted in California.

Percentages of the commercial catch that females in this reproductive state represent are not known. However, considering the majority of the catch is taken early in the season it may be minimal. The financial impact on commercial fishers could easily be quantified in several ways. For example, asking a range of fishers to record what proportion of the females they caught were in any of these reproductive states and multiplying that sample across the fishery would give a rough estimate. Alternatively, a more rigorous estimate could be made by sampling the catch from lobster processing plants over the season. The recreational sector catch is less likely to be affected due to these reproductive conditions occurring later in the season and in the colder months when diving is less likely to occur and lobster have moved into deeper waters. It could also be argued on moral grounds that returning reproductive females should be an ingrained ethical practice followed wherever possible.

Option 4: Establish a slot limit (minimum and maximum lobster size range) for both male and female lobsters.

A slot limit allows the take of a species between a minimum and maximum size range. Slot limits are not a new management tool in the Californian lobster fishery. A regulatory change in 1948 dispensed with the slot limit and allowed the retention of large lobsters. A slot limit between the current minimum lobster size of 82.5mm CL and some maximum size (e.g., 115mm CL) could be employed to provide a 'refuge' for larger lobster that survive natural and fishing mortality through this size range. For a slot limit to be effective a lobster will have to escape capture and natural mortality for many years (e.g., 6 or 7 years) to grow through this size range. The present exploitation rate in the fishery will have a huge bearing on the likelihood of lobster survival to incrementally larger sizes and this information could be used to set a suitable maximum slot limit size.

Larger lobsters perform different ecological roles and per capita, contribute significantly more to larval production than smaller lobsters (Lindberg, 1955). Fecundity, growth, feeding behavior and habitat selection all are size-dependent in decapod populations, as is intraspecific competition (Cobb and Caddy, 1989). Lobster are the largest benthic invertebrate predator in their environment. Through their predation and competition they play important roles in the organization and dynamics of the benthic communities (Cobb and Caddy, 1989). Gut content analysis and field studies in California suggest lobster play important trophic ecological roles by feeding on urchin populations, which in turn feed on kelp forests (Tegner and Levin, 1983; Lafferty, in press.). However, feeding studies have shown that only the larger lobster are capable of handling and feeding on larger urchins (Tegner and Levin, 1983).

Slot limits should apply equally to male and female lobster. It was the experience in the Florida *Panulirus* fishery that applying a slot limit only to females was ineffective unless similar sized male lobster were present for mating. The reason for this is biological. During mating a male lobster must be able to "overpower" the female and flip her over, which requires that the male be of comparable size (G. Davis, Pers. Comm., 2003). Thus, applying a female only slot limit may result in a number of large, non-reproductive females in the population, which is undesirable from a management perspective.

The impact of a slot limit on the recreational and commercial lobster fisheries could be quite distinct. Market consumers generally do not prefer lobsters substantially above plate size and the majority of the present commercial lobster catch does not contain these larger lobsters anymore. In addition, the traps used by commercial fishers are generally size selective, preventing very large lobsters from entering the traps. A study that documented the size-frequency of lobster caught by commercial fishers (e.g., documenting processor samples) would help determine the economic impact of various slot limit introductions. A maximum size could be established that did not affect commercial catches substantially but that would be effective in letting some lobster get though the slot range.

For the most part 'trophy hunting' recreational lobster fishers would be socially impacted by a slot limit regulation. The idea of catching a rare, prized, large lobster drives some recreational lobster fishers and removing this chance may cause outrage in the recreational sector. Therefore, the reasons for the slot limit, including to reestablish a more natural size structure; ecological roles and increased egg production, would need to be well defined, in addition to clearly stating that the regulation applied to both commercial and

recreational sectors so that equity is perceived. The regulation could also be mitigated by not ruling out the opportunity to catch larger lobster, as long as lobster were thrown back within a reasonable time frame (e.g., 5 minutes). This would permit the lobster to be measured, photos to be taken and so forth and then thrown back as quickly as possible. While some mortality would be associated with this catch and release practice it is accepted by many fishers as an excellent regulation for other long-lived highly prized species (e.g., billfish) that can be returned without suffering high mortality rates. While research on the mortality rate of lobsters caught and released by commercial fishers indicates that the impact on sublegal sized lobsters is significant for a fishery, this is primarily due to the large quantity of undersize individuals caught. Finally the impact of catch and release of 'jumbo lobster' by recreational fishers will be proportionally lower as trophy catches are not a regular event.