MONTEREY BAY NATIONAL MARINE SANCTUARY

SIMoN

Sanctuary Integrated Monitoring Network

OCTOBER 2000

M B A R I

MONTEREY BAY AQUARIUM®

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Developed in collaboration
with and support by the

Monterey Bay Aquarium Research Institute
Monterey Bay Aquarium
&
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Executive Summary

This document is the blueprint for a comprehensive, integrated monitoring network to detect natural and human induced changes to the Monterey Bay National Marine Sanctuary and its resources.

Program Goals - Comprehensive, long-term monitoring is a fundamental element of resource management and conservation. The Sanctuary Integrated Monitoring Network (SIMoN) has been design in partnership with the regional science and management community to identify natural and human induced changes to the National Oceanic and Atmospheric Administration's (NOAA) Monterey Bay National Marine Sanctuary (MBNMS). The integration of high quality scientific research and long-term monitoring data sets through this program will furnish the information needed for effective management and provide a greater basic understanding of the Sanctuary, its resources and its processes. The principal goals of SIMoN are to:

- Integrate existing monitoring conducted in the MBNMS,
- Initiate basic surveys or characterizations of all habitats and regions of the MBNMS,
- Initiate specific, question driven monitoring efforts with fixed durations,
- Establish a series of essential long-term monitoring efforts that will continue into the future, and
- Provide timely and pertinent information to managers and decision makers, the research community, and the general public.

Process and Products - The program presented here was built in a systematic manner over two years. The MBNMS has established ties with existing programs and has documented and prioritized important areas of monitoring need. The SIMoN program will utilize existing data sets, support and augment current research/monitoring efforts, and initiate new efforts to address important gaps in our knowledge of the Sanctuary and its resources. The strength of this program is that the MBNMS will serve as the hub for regional ecosystem monitoring. Local scientists will continue to collect the large majority of monitoring data, but the Sanctuary will help generate much of the funds required to maintain or expand some existing efforts and to initiate new programs. The funds secured by the MBNMS will be granted to researchers and institutions for specific monitoring efforts through annual requests for proposals (RFP's). RFP topics will be decided on by a committee of scientists and managers working from a list of priority areas of need, whereas experts from around the nation will rigorously review proposals.

Through SIMoN, the MBNMS will also integrate and interpret results of individual efforts in a large ecosystem-wide context and continuously update and disseminate data summaries to facilitate the communication between researchers, managers, educators, and the public. Timely and pertinent information will be provided to all parties through a SIMoN web site, annual symposium, and a series of technical and public reports (i.e., annual "State of the Sanctuary" reports).

While SIMoN has been designed to serve as a comprehensive monitoring network long into the future, it will have a phased approach with periodic external reviews. The first phase of the SIMoN effort will include an initial year for instituting the various program components (proposed for 2001), a second year for the initiation of preliminary monitoring efforts, and four following years for installing full scale monitoring programs throughout the Sanctuary.

Priority Areas of Need and Recommendations - A two-day workshop with over 80 regional academic scientists and resource managers produced a series of priority questions that must be addressed for effective monitoring of the MBNMS and its resources. These results were then

evaluated for common themes, compared with information on historic data sets and existing monitoring efforts to identify gaps, and synthesized into Sanctuary-wide "areas of need" by a scientific advisory committee and MBNMS staff. Based on this assessment, the following areas of need were identified:

1. Overarching Programs
   a. Basic surveys and long-term monitoring
   b. Historic data
2. Specific Focus Programs
   a. Anthropogenic inputs
   b. Fishing and other consumptive activities
   c. Effectiveness of protected areas
   d. Coastal erosion
   e. Estuary and wetland modification
   f. Non-consumptive, physical human disturbances
3. Rapid Response Programs
   a. Unforeseen extraordinary changes

It is the intent of the SIMoN program that existing efforts will be continued or enhanced and new programs initiated in the context of the areas of need.

Conclusions - SIMoN will be a comprehensive, long-term program that takes an ecosystem approach to identify and understand changes to a large marine protected area. It will provide resource managers with the information needed for effective decision making and make possible an unparalleled basic understanding of a complex and important marine environment. SIMoN will also facilitate the critical but often overlooked communication between researchers, resource managers, educators and the public. Finally, NOAA's National Marine Sanctuary Program is interested in using SIMoN as a model monitoring program for other marine sanctuaries nationwide.

I. Background and General Goals

A. Ecosystem Monitoring

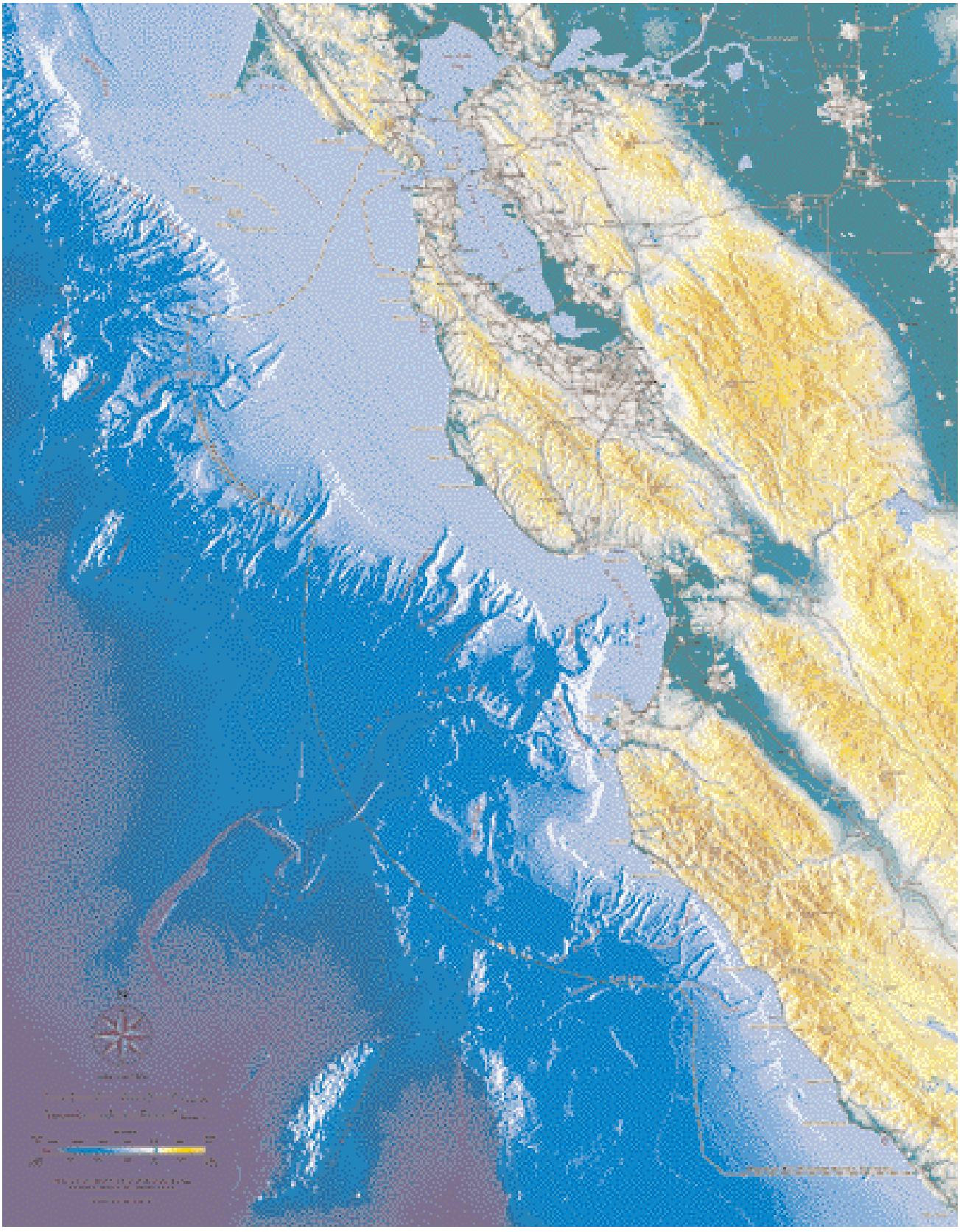
Comprehensive, long-term monitoring is a fundamental element of resource management and conservation. It has been recognized in numerous reviews and studies that coordinated, standardized approaches to monitoring are essential to effectively determine temporal and spatial trends [1]. However, despite the substantial efforts by private and government organizations, monitoring programs are typically incomplete, inconsistent, fragmented and inaccessible. This is commonly a result of insufficient infrastructure and funding to achieve a comprehensive, long-term perspective. To assure the effective and continuous evaluation of a region and its resources, particularly large areas on the scale of the Monterey Bay National Marine Sanctuary (MBNMS), a commitment towards a stable network of flexible ecosystem and issue-based monitoring programs is needed.

B. Monterey Bay National Marine Sanctuary

The MBNMS is a federally protected marine area offshore of California's central coast (Fig. 1). Stretching from Rocky Point (Marin County) to Cambria (just north of Morro Bay), it encompasses nearly 300 miles of shoreline, 5,322 square miles of ocean, and extends from mean high tide to a seaward boundary an average of 35 miles offshore. At its deepest point, the MBNMS reaches depths of 3,250

"We do not currently have adequate monitoring programs to assess regional ecological conditions. The EPA's EMAP, USGS's NAWQA, and NOAA's Coast Watch are aimed in the right direction. However, the overall lack of consistent support for long-term monitoring will continue to hinder progressive ecosystem management."
1996 Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management [2].

Figure 1. Monterey Bay National Marine Sanctuary (© Monterey Bay National Sanctuary Foundation)



meters (nearly two miles). It is the nation's largest marine sanctuary, and by volume, the world's largest as well (Australia's Great Barrier Reef is the largest by area).

The MBNMS was officially established in 1992 by authority of the Secretary of Commerce (under the 1972 Marine Protection, Research, and Sanctuaries Act) because:

- The area is of special national significance due to its resource or human-use values
- existing state and federal authorities are inadequate to ensure coordinated and comprehensive conservation and management of the area, including resource protection, scientific research, and public education
- designation of the area will ensure comprehensive conservation and management, including resource protection, scientific research, and public education
- the area is of a size and nature that will permit comprehensive and coordinated conservation and management.

The aesthetic, ecological and economical value of the MBNMS is unmatched. It spans marine environments of striking contrasts and beauty, encompassing windswept coastal bluffs of the north sanctuary, broad sand beaches and dunes of Monterey Bay, spectacular cliffs and countless creeks of the Big Sur coast, and the dramatic depths of Monterey Canyon and numerous lesser submarine canyons. The Sanctuary's waters bathe a great variety of habitats, including lush kelp forests, productive coastal lagoons, and unique deep-sea cold seep communities, that are home to rare and in some cases threatened and endangered species such as sea otters and snowy plovers. The MBNMS also supports a wide variety of commercial ventures important to both the local and national economy. For example, fishing provides over $50 million per year and 2,000 jobs to local economies of the MBNMS [3], and tourism in Monterey County alone (most of it centered around the ocean) is responsible for nearly $2 billion per year and is approaching 20,000 travel and tourism related jobs [4].

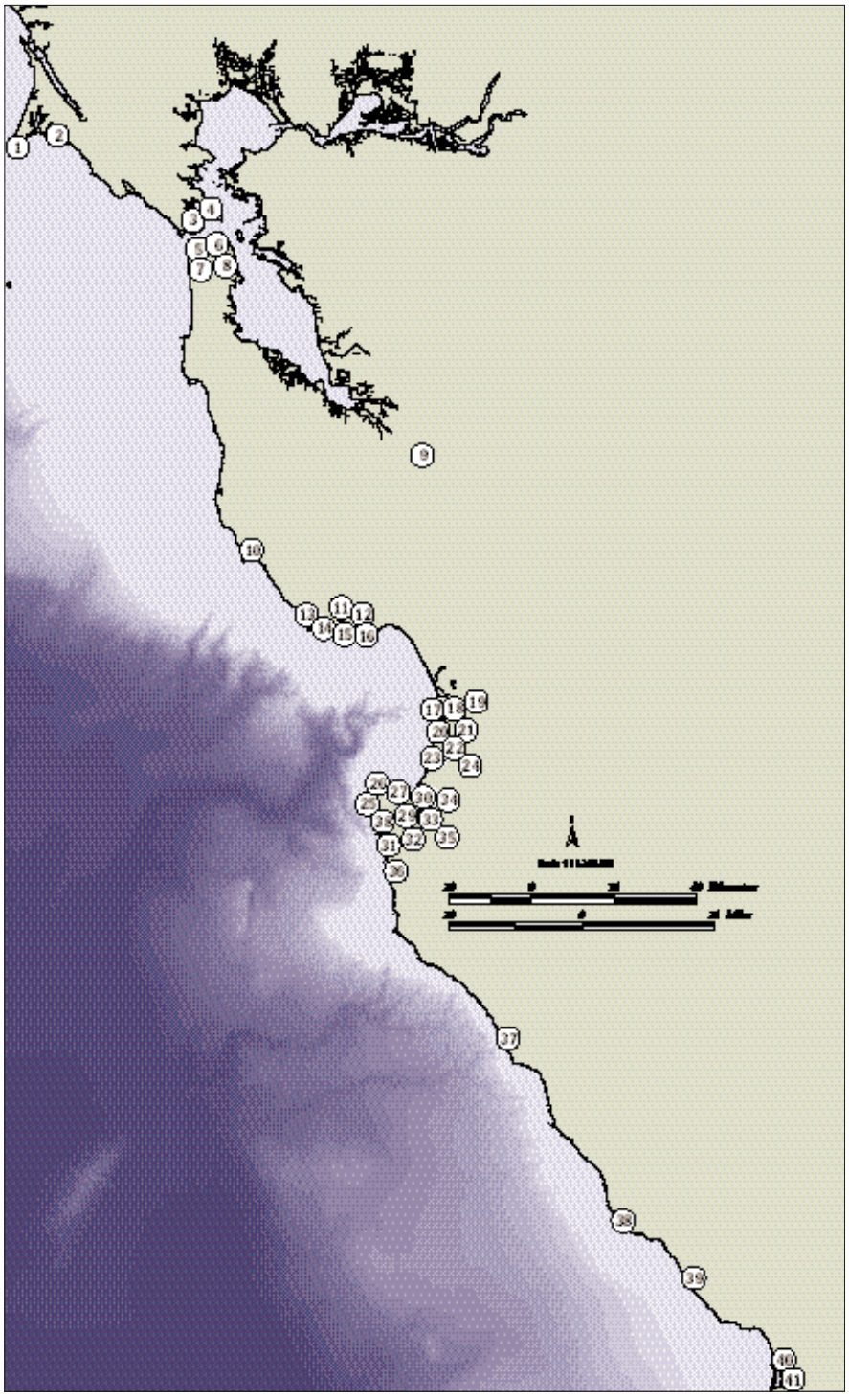
C. Rationale, Objectives and Methods

The management plans for all national marine sanctuaries mandate implementation of a monitoring program [5]. The purpose of such programs is to detect natural and human induced changes to sanctuary resources and advise resource managers on necessary steps to protect those resources. Additional, directed monitoring efforts can then be employed to determine the success of management strategies. Given the size and complexity of the MBNMS and number of potential human impacts, this is not a trivial task. However, the MBNMS is uniquely suited for the challenge of comprehensive, long-term monitoring.

With over 40 institutions and organizations along the central California coast examining various aspects of the Sanctuary (Fig. 2), the greater Monterey Bay area is an internationally recognized leader in marine research, resource management, and policy. Much of the infrastructure needed for extensive monitoring of this region is therefore in place. The entire MBNMS can be managed more effectively by summarizing and integrating information from existing monitoring efforts at these regional institutions and by identifying and filling critical gaps in our current knowledge. Through a series of steps (summarized below), the MBNMS has established ties with existing programs and has documented and prioritized important issues to be addressed in a new long-term, integrated ecosystem monitoring network that utilizes existing data sets, supports and augments current research/monitoring efforts, and addresses important information gap. This Sanctuary Integrated Monitoring Network (SIMoN) is the blueprint for effective, comprehensive monitoring of the Monterey Bay National Marine Sanctuary and can serve as a model for other national marine sanctuaries and perhaps marine protected areas worldwide. NOAA's National Marine Sanctuary Program will pay critical attention to how SIMoN is developed and how well it works in coordinating data collection and analysis so it can be replicated or modified depending on the monitoring needs of individual sanctuaries and the resources available from partner institutions.

The SIMoN program presented here was built in a sys-

Figure 2. Research Institutions and Organization adjacent to the Monterey Bay National Marine Sanctuary



1 Point Reyes National Seashore

2 Point Reyes Bird Observatory

3 Romberg Tiburon Center for Environmental Studies (San Francisco State University)

4 Marine Mammal Center

5 Gulf of the Farallones National Marine Sanctuary - NOAA

6 Cordell Bank National Marine Sanctuary - NOAA

7 California State University of San Francisco

8 Environmental Protection Agency (Region 9)

9 San Jose State University

10 Año Nuevo State Reserve

11 University of California, Santa Cruz

12 U.S. Geological Survey

13 Long Marine Laboratory - UCSC

14 Marine Pollution Studies Laboratory - CDFG

15 National Marine Fisheries Service Tiburon Lab Relocation - NOAA

16 Marine Wildlife Veterinary Care and Research Center - CDFG

17 Monterey Bay Aquarium Research Institute

18 National Undersea Research Program

19 Elkhorn Slough National Estuarine Research Reserve

20 Moss Landing Marine Laboratories, California State University

21 University of California Sea Grant Extension Program

22 Pacific Cetacean Group

23 California State University of Monterey Bay

24 University of California - Monterey Bay Education Science, and Technology Center

25 Hopkins Marine Station, Stanford University

26 Monterey Bay Aquarium

27 Monterey Institute of International Studies

28 Pacific Fisheries Environmental Group - NOAA

29 Monterey Bay National Marine Sanctuary - NOAA

30 Naval Post Graduate School

31 Naval Research Laboratory

32 Fleet Numerical Meteorology and Oceanography Center

33 National Weather Service - NOAA

34 Monterey Peninsula College

35 California Department of Fish and Game

36 Granite Canyon Marine Laboratory - CDGF

37 Big Creek Ecological Reserve - University of California

38 Piedras Blancas Field Station, Western Ecological Research Center - USGS

39 Cambria - Monterey Bay National Marine Sanctuary Satellite Office - NOAA

40 California Polytechnic State University, San Luis Obispo

41 Central Coast Regional Water Quality Control Board

tematic manner. Beginning in July 1999, surveys of scientists and resource managers throughout the MBNMS, and searches of reference material (peer-reviewed, "gray" and electronic) were conducted to identify programs and data sets that are pertinent to monitoring MBNMS resources. Biological, geological, physical, chemical, and human impact data were then assembled in a summary table of monitoring efforts (App. 1). A review of existing national and international monitoring efforts was also conducted and while the great majority were specific, problem-driven programs (e.g., water quality or rare species), several successful approaches were identified and will be incorporated into new SIMoN efforts. A workshop was then held in April 2000 with regional scientists and resource managers to identify and develop basic approaches for answering the key questions to be addressed in a new Sanctuary-wide monitoring network (App. 2). Finally, using the workshop results and the summary table of historic data sets and ongoing programs, MBNMS staff worked with an advisory committee of local experts (listed in App. 2) to (1) identify the critical gaps and "areas of need", (2) develop basic strategies for addressing monitoring needs while integrating existing programs and data sets, and (3) develop strategies for disseminating information. The results of these exercises are presented in the next section.

The strength of SIMoN is that the MBNMS will serve as the hub for regional marine ecosystem monitoring. Local scientists will continue to collect the large majority of monitoring data, but the Sanctuary will help generate much of the funds required to maintain or extend some existing efforts and to initiate new programs in the identified areas of need. The MBNMS will also integrate and interpret results of individual programs in a large ecosystem-wide context and continuously update and disseminate data summaries to facilitate the sharing of information between researchers, managers, educators, and the public. Finally, researchers can also use the areas of need listed in this document, and the SIMoN program itself, as added justification of their work when submitting proposals for funding independent of the MBNMS. As with existing programs, newly funded independent efforts will be welcomed into SIMoN where the Sanctuary gains additional information about its resources and researchers are able to place their work into a larger conservation and resource management context.

II. Sanctuary Integrated Monitoring Network (SIMoN)

A. PRIMARY GOALS

The five initial goals for SIMoN are to:

(1) Integrate existing monitoring conducted in the MBNMS - The first goal is to coordinate and synthesize historic data sets with information from the various research and monitoring efforts currently underway within the MBNMS. A large portion of this process has already been completed as part of SIMoN's development but integration efforts will continue throughout the life if this program.

(2) Initiate basic surveys or characterizations of all habitats and regions of the MBNMS - This second major goal is based on the undisputed conclusions of the advisory committee and workshop participants that a better understanding of the Sanctuary, its natural processes and the distributions of its resources is needed before most monitoring efforts can be truly effective. These groups concluded that in most cases not enough information is available about the Sanctuary and the resources it protects to identify and monitor important changes.

Table 1. The priority questions generated at the MBNMS Ecosystem Monitoring Workshop (see App. 2) are listed below with reference to which areas of need they address, and to what extent they are currently being accounted for by existing programs. The areas of monitoring need have been identified as: A) Community and habitat surveys / characterizations, B) Historic data, C) Anthropogenic inputs, D) Fishing and other consumptive activities, E) Effectiveness of protected areas, F) Coastal erosion, G) Estuary and wetland modification, and H) Non-consumptive physical human disturbances.

Priority Questions from the April 2000 Monitoring Workshop	Corresponding area of need	Covered completely by existing programs	Covered partially by existing programs	Not currently being addressed
Dunes and Bluffs				
What is the abundance and distribution of invasive dune and bluff species?	A, C, E		X	
What is the abundance and distributions of sensitive dune and bluff species?	A, C, E		X	
What are the rates and causes of dune and bluff erosion over time?	F		X	
How has the distribution and structure of buff and dune systems change on long-term time scales?	A, B, F			X
What are the impacts of human activities?	C, E, F, H		X	
Bays, Estuaries and Riparian				
What is the extent of habitat modification, pollution, invasive species and biodiversity and ecosystem degradation?	A, D, E, G, H		X	
Which resources are affected by habitat modification, pollution, invasive species and biodiversity and ecosystem degradation?	A, D, E, G, H		X	
What are historic conditions and carrying capacities?	A, B, G			X
What is seasonal, annual, long-term and spatial variability?	A, G		X	
Rocky Intertidal and Nearshore				
Where are species located geographically within the rocky habitat?	A		X	
What are the temporal, spatial and geographic patterns of target taxa in rocky subtidal habitats?	A, B		X	
How do spatial and temporal patterns of subtidal target taxa differ within and outside of marine protected areas?	A, E		X	
What are the temporal, spatial and geographic patterns of target taxa in rocky intertidal habitats?	A, B		X	
How do spatial and temporal patterns of intertidal target taxa differ within and outside of marine protected areas?	A, E		X	
What are the select pathogen, pollutant and parasite (ppp) loads in sea otters and harbor seals (live and dead), shellfish and birds?	A, C		X	
What are the impacts of direct exploitation (e.g., fishing)?	A, D, E		X	
What are the impacts of non-consumptive disturbances (e.g., trampling) on intertidal and subtidal habitats?	A, H		X	
What are the impacts of changes in activity, abundance and distribution of apex predators (e.g., sea otters and harbor seals)?	A			X
What are the spatial and temporal changes in temperature, storm activity, nutrients, upwelling, light transmission, current patterns, sea levels, river input, and cloud cover / fog?	A, B		X	
Sandy Beaches and Nearshore Soft Bottoms				
What are the physical and biological effects of trawl exclusion zones?	A, D			X
What are the impacts of trawling in deep water habitats (> 1000m)?	A, D			X
What is the frequency and distribution of trawling activity?	D		X	
What are the sedimentary, biological, chemical inputs to the nearshore system from individual watersheds?	A, C, F, G			X
What are the ecological effects of sedimentary, biological, chemical inputs to the nearshore system from individual watersheds?	A, C, F, G			X
What are the effects of long-term primary productivity changes on near-bottom and benthic communities?	A, B			X
What are the patterns of extreme storms cycles, waves, currents, runoff, and sediment transport?	A, B, F, G			X
What is the impact of long-term fluctuations on ecological systems?	A, B			X

Priority Questions from the April 2000 Monitoring Workshop	Corresponding area of need	Covered completely by existing programs	Covered partially by existing programs	Not currently being addressed
Deep Benthic				
What are the impacts of bottom trawling and other fishing gear on benthic habitats and communities?	A, D			X
What are the impacts of bottom seafloor cables on benthic habitats and communities?	A, C			X
What are the impacts of chemical pollutants / contaminants on benthic habitats and communities?	A, C			X
What are the seasonal, interannual, and longer time scales of environmental variability in the distribution and abundance of habitats and organisms?	A, B		X	
What is the role of natural / designated harvest refugia?	A, E			X
What is the paleo-oceanographic context of present day variability?	A			X
What are the sources and sinks of carbon and other material in the Sanctuary?	A		X	
How do canyon dynamic processes and material transport affect the carbon and material budget?	A			X
Open Ocean				
Long line surveys: How do (climate-related) variations in the strength of the undercurrent and the depth of the thermocline influence ecosystem production and community structure?	A		X	
Mesoscale surveys: How do the variations in the strength of winds and upwelling influence ecosystem production and community structure?	A		X	
What are the residence times and dispersal patterns of non-point source pollutants?	A, C			X
What are the impacts, both positive and negative, of flux of material from the coastal margins?	A		X	
Where are areas of high vs. low risk to health of Sanctuary from military exercises and operations?	A, C, H			X
What are the impacts of acoustic monitoring on the health of the system being studied?	A, H			X
Pelagic Megafauna				
What are the past, present and future distribution and abundance patterns of pelagic megafauna in the MBNMS for sensitive species, caught species (i.e. species affected by human actions) and indicator species, and what are the major natural influences on the patterns with respect to biological interactions (e.g., predators, prey, and competition)?	A, B		X	
What are the past, present and future distribution and abundance patterns of pelagic megafauna in the MBNMS for sensitive species, caught species (i.e. species affected by human actions) and indicator species, and what are the major natural influences on the patterns with respect to physical and chemical processes, and climate and environmental variability?	A, B, D		X	
What are the major influences of fisheries on distribution and abundance patterns of pelagic megafauna in the MBNMS?	A, D		X	
What are the critical habitats for pelagic megafauna in the MBNMS and how do they change over time?	A, B		X	
What are the major land-based and ocean-based anthropogenic influences on the distribution and abundance patterns of pelagic megafauna in the MBNMS?	A, C		X	

(3) Initiate specific, question driven monitoring efforts with fixed durations - This third goal is in response to the need for identifying and quantifying the impact of particular natural processes or human activities on specific resources. Efforts in these areas will be hypothesis driven and can be terminated once the specific questions are answered. For example, the advisory committee and workshop participants concluded that a better understanding of impacts from fishing activities (particularly bottom trawling) on non-target species and the environment is critical.

(4) Establish a series of essential long-term monitoring efforts that will continue into the future - This fourth goal is based on the findings of the workshop and numerous reviews that long-term approaches to monitoring are required for temporal and spatial trends to be resolved. For example, simple seawater temperature data taken daily from a fixed location off of the Hopkins Marine Station (Pacific Grove, California) for nearly a century have been correlated with local changes in intertidal species distributions [6].

(5) Provide timely and pertinent information to appropriate parties - Monitoring data are only truly of value if they are readily available and provide timely and pertinent information to managers and decision makers, the research community and/or the general public. SIMoN will therefore not only be a center for initiating and integrating data collecting efforts but also for disseminating information.

B. PRIORITY AREAS OF NEED

Two separate steps were taken to identify specific areas of need for the initial phase of the SIMoN program. First, a two-day workshop with over 80 regional academic scientists and resource managers produced a series of priority questions to be addressed for seven different components of the Sanctuary (dunes and bluffs; bays, estuaries and riparian habitats; rocky intertidal and nearshore habitats; sandy beaches and nearshore soft bottom habitats; deep seafloor; open ocean; pelagic megafauna). The workshop priority questions are summarized in Table 1 with full details available in Appendix 2. Sanctuary staff and the advisory committee then evaluated the priority questions for common themes and compared them with the summary table of ongoing monitoring and historic data sets to identify gaps. This analysis ultimately led to the following list of Sanctuary-wide areas of need that synthesize all questions generated at the workshop into cross cutting themes.

Monterey Bay National Marine Sanctuary Areas of Monitoring Need

1. Overarching Programs
   a. Basic surveys and long-term monitoring
   b. Historic data
2. Specific Focus Programs
   a. Anthropogenic inputs
   b. Fishing and other consumptive activities
   c. Effectiveness of protected areas
   d. Coastal erosion
   e. Estuary and wetland modification
   f. Non-consumptive, physical human disturbances
3. Rapid Response Programs
   a. Unforeseen extraordinary changes

It is the ultimate goal of the SIMoN program to directly address the priority questions developed at the monitoring workshop by continuing or enhancing existing efforts and initiating new programs in the context of the areas of need.

1. Overarching Programs - Two areas of need correspond to all regions of, or important issues for, the MBNMS.

a. Basic surveys and long-term monitoring - The advisory committee and each workshop breakout group agreed overwhelmingly that there is a need for more comprehensive physical, geological, chemical and biological mapping or characterization of the MBNMS. It is therefore recommended that surveys of communities, habitats and processes should be conducted for all regions of the Sanctuary. These initial surveys should be broad characterizations, cover the entire MBNMS, and start with those habitats or

regions with the least amount of existing information (e.g., deep-sea, midwater and soft bottom habitats).

In addition to characterizing communities and habitats as they exist today, it is recommended that paleo-ecological and archeological studies be employed to determine historic conditions. Data collected from core samples and fossil records can provide valuable insight to environmental changes over hundreds to thousands of years, as well as long-term human impacts.

From these broad surveys and existing data, selected/target species or resources, key processes, and physical parameters will then be identified as emphases for core long-term monitoring program that will continue into the future. The following criteria will be used to select long-term monitoring emphases:

- Critical role in a particular community or habitat
- Indicator of environmental change
- Threatened or vulnerable resource
- Commercially exploited resource
- Exotic or introduced species

After monitoring emphases are selected, it is recommended that new long-term programs address one or more of the following questions:

1) What are the past and present patterns of distribution and abundance for selected species or resources?

2) Can distribution and abundance patterns of selected species or resources be predicted into the future?

3) What are the major natural influences on the patterns with respect to biological/trophic interactions (e.g., predation and competition)?

4) What are the major natural influences on the patterns with respect to physical and chemical processes, and climate and environmental variability?

Several past and current programs have surveyed or monitored parts the MBNMS marine ecosystem. For example, the U.S. Geologic Survey and the Monterey Bay Aquarium Research Institute have been collecting high resolution side-scan bathymetric data for precise seafloor mapping, most of which falls within the Sanctuary's boundaries [7]. In the past, the California Cooperative Oceanic Fisheries Investigations (CalCOFI) have also collected important physical and biological oceanographic data with a series of station/grid shipboard surveys within the MBNMS [8]. However, during the past 20 years CalCOFI has focused solely on waters off of Southern California. Recently the Partnership for the Interdisciplinary Study of Coastal Oceans (PISCO) program has begun a new geographically broad effort (Oregon to Southern California) to examine rocky shore communities and how nearshore coastal processes affect them [9]. Finally, sea otter populations have been tracked along the central California coast since 1983 in a cooperative effort between the U.S. Geological Survey, California Department of Fish and Game, and Monterey Bay Aquarium [10].

Although these and many other programs have collected valuable data for describing and understanding the Sanctuary (and will be incorporated into SIMoN), additional work is clearly needed. New efforts that expand the frequency, number of parameters and locations monitored by existing programs, and that initiate new surveys addressing insufficiently studied regions (such as the soft bottom habitats), must be started. However, it is important that any new monitoring efforts consider existing and historic programs so, when possible, they can be designed to produce comparable data. All programs will also be encouraged to present results in similar formats so trends across systems and over time can be identified. Finally, new technologies must be explored to increase the amount and ease of information collected for community, habitat or process surveys. In particular, remote sensing techniques such as autonomous underwater vehicles, satellite imagery and aerial hyperspectral surveys are showing promise for being very effective and efficient monitoring tools.

b. Historic data - Detecting important ecosystem trends or changes is dependent on a long-term perspective. It is therefore critical to identify, locate, analyze, archive and,

when possible, build upon historic data sets. The great majority of past and ongoing monitoring programs in the Sanctuary have published their results in technical reports or peer review journals, almost all of which have been listed in the summary table (App. 1). However, data in technical reports often have limited distributions and are forgotten over time. For example, Kinnetic Laboratories Inc. has been collecting regional city and county outfall and wastewater discharge impact data for over ten years [11]. Extremely valuable time series information on physical, chemical and biological characteristics of habitats and organisms around outfalls and at control sites are presented in annual reports to specific governing bodies; however, they are not widely circulated and are not part of any library or archival system. It is therefore recommend that the SIMoN program work with regional libraries to obtain and house copies of all relevant monitoring publications at one central location and assure that new publications (in particular technical reports) are continuously added to the archive to reduce the potential for losing valuable information.

It is further recommended that historic data sets that have not been published are recovered and analyzed before being forgotten or lost. Several agencies and organizations have traditionally collected data on various issues but for a variety of reasons (typically the lack of funds) have not analyzed or published this information. For example, the California Department of Fish and Game requires all commercial fisherman to submit logbooks and landing receipts from their fishing activities (date, location, equipment used, target species, weight of catch, etc.). However, only when specific information is required (and funding is available) are subsets of the logbooks and receipts analyzed. Thus, very little of this valuable information is ever examined. Another recent example is the entire original punch card set of the key EASTROPAC (Eastern Tropical Pacific Research Program, 1967-1968) oceanographic data [12] was discarded because no one from the original program remained active in research. Although much of the EASTROPAC results have been published, it is now impossible to re-examine or re-analyze the original data sets. SIMoN will therefore fund programs to locate copies of all pertinent data sets before they are lost, and when appropriate, to analyze them for a greater historic understanding of the MBNMS and its resources.

2. Specific Focus Programs - Beyond the basic surveys and new long-term monitoring efforts, six specific areas were singled out by the workshop participants and advisory committee as requiring particular attention, with anthropogenic inputs and fishing being the two most important.

a. Anthropogenic inputs - Because of their potential to harm marine resources, manmade inputs to the environment have traditionally received the most attention in monitoring programs. Of these efforts, water quality monitoring and determining ecological and human health impacts of pollutants, contaminants and pathogens have been emphasized. In the MBNMS region there are several very effective national, state, private and public water quality programs and both the MBNMS (through its Water Quality Protection Program [13]) and the California State Regional Water Quality Control Board (through its Central Coast Ambient Monitoring Program [14]) have developed specific monitoring and management strategies. As an example of a promising new regional water quality effort, the Monterey Bay Area Dischargers (MBAD) monitoring program plans to establish extensive water, sediment and tissue sampling efforts at effluent sources, streams, rivers and in nearshore marine habitats from Santa Cruz through Carmel, California [15]. While the many ongoing water quality programs in the MBNMS will be incorporated into the SIMoN program, clearly these efforts would also benefit greatly by expanding spatially (in particular offshore and outside of the Monterey Bay), temporally in terms of sampling frequency, and in the number of parameters examined.

Other anthropogenic inputs to the Sanctuary, such as dredge disposal, road slides into the sea, seawalls, jetties, harbors, seafloor cables and coastal development, have traditionally received much less attention. For example, ABA Consulting has conducted preliminary surveys of benthic fauna that might be affected by the installation of a seafloor cable [16], Minerals Management Service surveys rocky shore communities so damage can be quantified if an oil spill ever occurs [17], and various investigators have

examined the impacts of coastal armoring on sediment transport [18]. However, no program is currently tracking the long-term impacts of these types of manmade inputs in the MBNMS.

Given the ongoing work in the area of water quality, it is proposed that new programs initiated under SIMoN focus on identifying other detrimental forms of manmade inputs and to determine their impacts over time on the MBNMS and its resources. Specifically, it is recommended that new efforts address components of the following questions:

1) What are the types, sources, distributions, variability, and magnitude of human inputs?

2) What are the ecological and human health impacts of these inputs?

b. Fishing and other consumptive activities - Fishing is part of the rich cultural history of central California but regional and worldwide fishery collapses have led to concern over the health of target species in the Sanctuary [3]. While the MBNMS does not regulate fishing and harvesting activities, the Sanctuary has the responsibility and mandate to monitor biological resources, particularly those at risk (including non-target resources incidentally harmed by fishing or harvesting activities).

There are several programs designed to evaluate the status of targeted species in the region. For example, the National Marine Fisheries Service conducts triennial groundfish surveys and stock assessments [19], and the California Department of Fish and Game and the MBNMS have a joint study of kelp canopy dynamics and impacts of kelp harvesting [20]. However, like other programs, these efforts that were established to determine sustainability or impacts of a fishery would profit by expanding spatially, temporally (sampling frequency) and taxonomically (with additional species examined).

It has also long been known that the impacts of fishing, collecting, and harvesting can go far beyond the target resource. By-catch (mortality of non-target species) and physical habitat damage through various collecting methods (e.g., bottom trawling) must be determined and followed over time so significant impacts can be brought to the attention of managers before catastrophic or irreversible changes occur. There have been some successful efforts to monitor these impacts, such as the National Marine Fisheries Service observer programs to document by-catch [21] and individual studies of bottom trawling effects on benthic communities [22], but much more information is needed for effective resource management.

It is therefore recommended that new efforts should be established that address components of the following questions, with emphasis on question 2:

1) What are the impacts of select fishing practices (both commercial and recreational) on target species?

2) What are the impacts of select fishing practices on by-catch species (all caught) and habitats?

c. Effectiveness of protected areas - While the entire Monterey Bay National Marine Sanctuary is a “protected area", this term is also used for smaller focused regions that have been specially designated to protect some aspect of their flora or fauna. Often rare/endangered species or sensitive habitats are sheltered with this type of designation by legislation and management plans. It has also been proposed that organisms in focused marine protected areas can serve as important sources of propagules and larvae to supplement communities in non-protected areas of the region, thus a safeguard against local extinctions [23].

Within the MBNMS there are several types of marine zones with over 20 sites that have some form of restrictions on various human activities (see App. 3):

- Golden Gate National Recreation Area
- James V. Fitzgerald Marine Reserve
- Año Nuevo State Reserve
- Elkhorn Slough National Estuarine Research Reserve

- Moss Landing Wildlife Area
- Hopkins Marine Life Refuge
- Pacific Grove Marine Refuge
- Pacific Grove Marine Gardens Fish Reserve
- Carmel Bay Ecological Reserve
- Point Lobos Ecological Reserve / State Reserve
- California Sea Otter Game Refuge
- Big Creek Marine Ecological Reserve
- Julia Pfeiffer Burns State / Underwater Park
- and all State Beaches

While these areas have been established to preserve particular habitats and/or species, in very few cases have monitoring efforts been established to determine their effectiveness. In one protected area where a monitoring program was designed to examine the effects of human exclusion from specific regions of the James V. Fitzgerald Marine Reserve, it appears that limiting access to visitors can enhance the abundance and biodiversity of intertidal organisms [24]. The PISCO program has also recently initiated similar efforts to compare the abundance and biodiversity of nearshore subtidal organisms within and outside of protected areas in the MBNMS (Hopkins Marine Life Refuge and Point Lobos Ecological Reserve) [9].

However, like most management strategies, the great majority of protected areas are not evaluated for their success in preserving habitats or species, or for their impacts on non-protected areas. It is therefore recommended that new programs be established to answers the following questions:

1) In what ways are marine protected areas effective in protecting or enhancing target resources or habitats?

2) What are the impacts of marine protected areas within and beyond their boundaries?

d. Coastal erosion - Land sea interfaces are dynamic environments because of both natural processes and human activities. In particular, beaches and dunes can be considered "rivers of sand" because sands naturally drift and move along the coast. Yet human activities such as damming streams and rivers, armoring coastlines and mining are altering the natural supply and transport of sand to ecologically and commercially important beaches and dunes of the MBNMS [25]. Similarly, seacliffs and bluffs are important wildlife habitats (and sources of sand) which are being altered by growing pressures of coastal development and armoring. It is therefore critical to understand the natural process regulating shoreline erosion and retreat and to determine and monitor the impacts of human activities. Areas of particular concern within the Sanctuary are Año Nuevo Island, the bluffs of Capitola, the beaches and dunes of Monterey Bay, and Hwy 1 along the Big Sur coast.

Several programs have examined coastal geology, sediment budgets and erosion within the Sanctuary. For example, the U.S. Geological Survey has recently begun to use scanning airborne laser altimetry to study California coastline dynamics [26], and the MBNMS is working closely with the California Department of Transportation (Caltrans) to better understand the active Big Sur slides and their impacts on marine systems. However, much more work is needed.

It is recommended that programs be established that address the following questions:

1) How has the distribution and structure of beaches, dunes, cliffs and bluffs changed on long-term time scales?

2) What are the rates and causes of shoreline change over time?

3) What are the impacts of human activities on the structure of shorelines?

4) What regions are most susceptible to erosion, retreat, landslides and slumping?

e. Estuary and wetland modification - Estuaries and coastal wetlands are unique and productive areas that function as wildlife habitats, fish nurseries, flood and erosion controls, natural pollution filters, and education and tourist centers. However, of all the coastal systems, estu-

aries and wetlands are perhaps the most affected by human activities. Nearly half of all coastal wetlands in the U.S. have been destroyed since pre-Columbian times [27]. Threats include draining and filling for agriculture, road construction and urban development, degradation through non-point source pollution and, in the future, reduction in size through global sea level rise.

Although legislation exists to prevent further losses through development, an inadequate number of programs exist to monitor changes or degradations to these important environments, and they typically focus only on selected sites. For example, the Elkhorn Slough National Estuarine Research Reserve (in collaboration with the Elkhorn Slough Foundation) has promoted scientific research on topics such as erosion, marine mammals and introduced invertebrate species, and has the longest running water quality monitoring program of any National Estuarine Research Reserve (NERR) site [28]. However, much more work is required to assure the health and stability of the Elkhorn Slough, while new efforts are greatly needed to characterize and monitor other estuaries and wetlands in the Sanctuary.

It is therefore recommended that new programs be established to answers the following questions:

1) What are the past and present physical characteristics of estuaries and wetlands in or adjacent to the MBNMS?

2) What are the past and present distributions of species and communities in estuaries and wetlands of the MBNMS, with particular emphasis on rare, threatened and introduced species?

3) What are the major human influences on estuaries and wetlands?

4) What are the major natural influences on estuaries and wetlands with respect to physical and chemical processes, and climate and environmental variability?

The MBNMS will work closely with the Elkhorn Slough NERR to integrate their existing efforts into SIMoN and to establish new core estuary and wetland monitoring efforts both in the Slough and throughout the Sanctuary.

f. Non-consumptive physical human disturbances - Of all the potential anthropogenic impacts to marine environments, perhaps the most overlooked are non-consumptive physical disturbances such as noise, ecotourism, trampling, and other by-products of human presence. Simply passing through or visiting the MBNMS can have impacts on various marine organisms. Ship noise may hinder the communication of whales and dolphins [29], aircraft overflights can flush nesting seabird off the shoreline [30], while visitor approaches on foot or in watercrafts can dramatically alter the behaviors of seals and sea otters [31]. Yet very little direct work has been done on these types of issues. Some of the best examples of work on non-consumptive physical disturbances are the separate studies of visitor impacts on intertidal organisms at Natural Bridges State Park [32] and James V. Fitzgerald Marine Reserve [24]. Although results varied, it can be concluded that simply walking on and picking up intertidal organisms can cause significant mortality and in some cases alter community structure. It is therefore critical to determine the effects of these and other similar activities on the MBNMS and its resources so guidelines can be established to assure human access while minimizing impacts. It is recommended that programs be established that address components of the following questions:

1) What are the various non-consumptive human disturbances in the Sanctuary?

2) What are the impacts of these disturbances on Sanctuary resources and how can the significant disturbances be reduced or eliminated?

3. Rapid responses - In addition to establishing efforts described above, it was concluded by the workshop participants and advisory committee that the SIMoN program must have the ability to respond rapidly to unforeseen events.

a. Unforeseen extraordinary changes - Occasionally unforeseen events or phenomena occur that can dramatically alter habitats, communities, populations or human health. For example, oil spills, mass marine mammal strandings, and harmful algal blooms take place sporadi-

cally and are almost always unexpected. While their influence on the MBNMS can be quite large, it is often difficult to differentiate their impacts against background variability. The ephemeral nature of these events also makes extraordinary changes difficult to study and the few programs that do examine these organisms or processes directly are often unable to respond to major unforeseen events because funding is not available for comprehensive investigations on short notice.

It is therefore recommended that an avenue be established to quickly determine causes and quantify impacts of unusual or dramatic changes to resources of the Sanctuary. As part of the SIMoN program, sufficient funds will be set aside by the MBNMS to allow the rapid establishment of investigations by researchers or any of the network monitoring programs that identify extraordinary events or trends to their systems.

C. DATA MANAGEMENT AND INFORMATION DISSEMINATION

Monitoring data is useful only if it is readily available and provides timely and pertinent information to managers and decision makers, the research community and the general public. SIMoN will therefore not only be a center for initiating and integrating data collecting efforts but also for disseminating information. Although various issues or geographically related subsets of monitoring efforts have been consolidated, very few comprehensive and readily accessible multi-disciplinary directories of monitoring data currently exist, and none on the scale of the MBNMS or with the scope of the proposed SIMoN program.

SIMoN information dissemination efforts will rely on individual investigators to analyze and summarize their own data. On a regular basis (quarterly to yearly), SIMoN will ask investigators to provide summary data in a standard format that provides critical management information by address the following questions:

- What are the general trends found?
- What are the causes of these trends?
- Are there any unexpected results?
- Are there any causes for concern?
- What needs to be done next and why?

Moreover, SIMoN staff will meet periodically with individual research groups to enhance each program's ability to inform resource managers.

Once this information is received, SIMoN will rely on six basic approaches to disseminate information to researchers, managers, educators and the public:

- Map based web page with links to all relevant programs, researcher's contact information, data summaries and, when possible, full data sets.
- Annual "State of the Sanctuary" reports with a grading system for how resources of the MBNMS are changing over time.
- Annual monitoring symposia and workshops for all the researchers and managers to share information and needs.
- Electronic list server bulletins for timely information to be shared with researchers and managers.
- Periodic technical reports presenting results of individual programs or significant multidisciplinary findings.
- Annual graduate level seminar course on Ecosystem Monitoring and Resource Management.

The web page describing SIMoN and containing a GIS (Geographic Information System) map of the Sanctuary with links to monitoring locations and topics will be the foundation for day-to-day information dissemination. The MBNMS has begun a pilot study with the NOAA Special Projects Office, Marine Sanctuaries Division headquarters and Environmental Systems Research Institute (ESRI) to develop this monitoring information hub using ArcIMS (Internet Mapping System) and the Sanctuary's beach cast monitoring program (Beach COMBERS). The ArcIMS architecture has been specifically engineered to serve GIS data and services on the Internet. Distributing geographi-

cally referenced monitoring information through a web site allows for real-time integration of spatial and temporal data from various programs and provides a common platform for the query, display, exchange and analysis of information at the local site and throughout the Internet.

Precisely how the web page and other approaches are designed and run will be determined during the first year of SIMoN with the help of public relations and Internet/GIS personnel, and through a series of separate workshops that ask researchers, managers and educators what information they require and what format would be most useful. Feedback from all parties on information needs and format will also be sought throughout the life of the project.

D. ADMINISTRATION AND PROGRAM MANAGEMENT

Personnel - SIMoN will be a major component of the research program at the Monterey Bay National Marine Sanctuary. It will be directed by an oversight board and Sanctuary management, and will include technical assistance from a science committee (Fig. 3). The oversight board will be established to periodically review the network and to assure that the principal goals are being achieved. The day-to-day operations of SIMoN will require supervision by a program manager with support from new staff with expertise in resource and program management, geographic information systems (GIS), data management, and information dissemination. MBNMS is pursuing additional funding or staff to provide these important personnel resources. All advisors and regional scientist have expressed the perspective that these core staff are a critical component to the success of SIMoN and an obvious obligation of NOAA, as administering agency for the Sanctuary.

A science committee of regional academic researchers and resource managers (the core of which will come from the current monitoring advisory committee; see App. 2) will be created to guide the specific monitoring focuses and to evaluate the scientific and management merit of proposed and ongoing programs. Finally, because of its close relationship with the MBNMS and experience in managing the finances of large programs, the Monterey Bay Sanctuary Foundation (a nonprofit corporation whose goal is to promote protection and public understanding of the MBNMS) will administer budget and accounting matters for the network.

The Process - The first year of this effort will be spent organizing the network administration, further integrating existing monitoring programs, refining specific strategies for disseminating information, and developing priorities and criteria of proposal requests and evaluation. Beginning in year two, the focus will be on establishing new monitoring efforts. New SIMoN sponsored programs will be initiated through a four-step process (Fig. 4). Each year, the science committee will decide on requests for proposals (RFP's) topics that address one or more of the Sanctuary's areas of need. Specific RFP topics will be selected based on a set of criteria to be established by the science committee but will include factors such as urgency and significant threat to ecosystem or human health. There will also be constant feedback from project scientists, resource managers and SIMoN staff to aid the science committee in selecting RFP topics. Although proposals related to any area of need will be accepted for review, preference will be given to work that directly addresses topics selected for that particular funding cycle. Emphasis will also be given to programs that can demonstrate a commitment to continuous, long-term monitoring of the MBNMS.

Proposals submitted to the SIMoN program will then be sent out for thorough and objective review by selected national experts in the appropriate fields and graded on scientific merit and feasibility. Proposals (with reviewer comments) will then be evaluated by the science committee and SIMoN staff for their ability to provide the information needed by the Sanctuary and other management agencies, with final approval granted by the program manager and MBNMS superintendent. Scientifically sound programs that do not properly address specific monitoring needs will be encouraged to resubmit proposals after management or conservation concerns are addressed.

Figure 3. Flow diagram describing the administration and management of the Monterey Bay National Marine Sanctuary's SIMoN program.

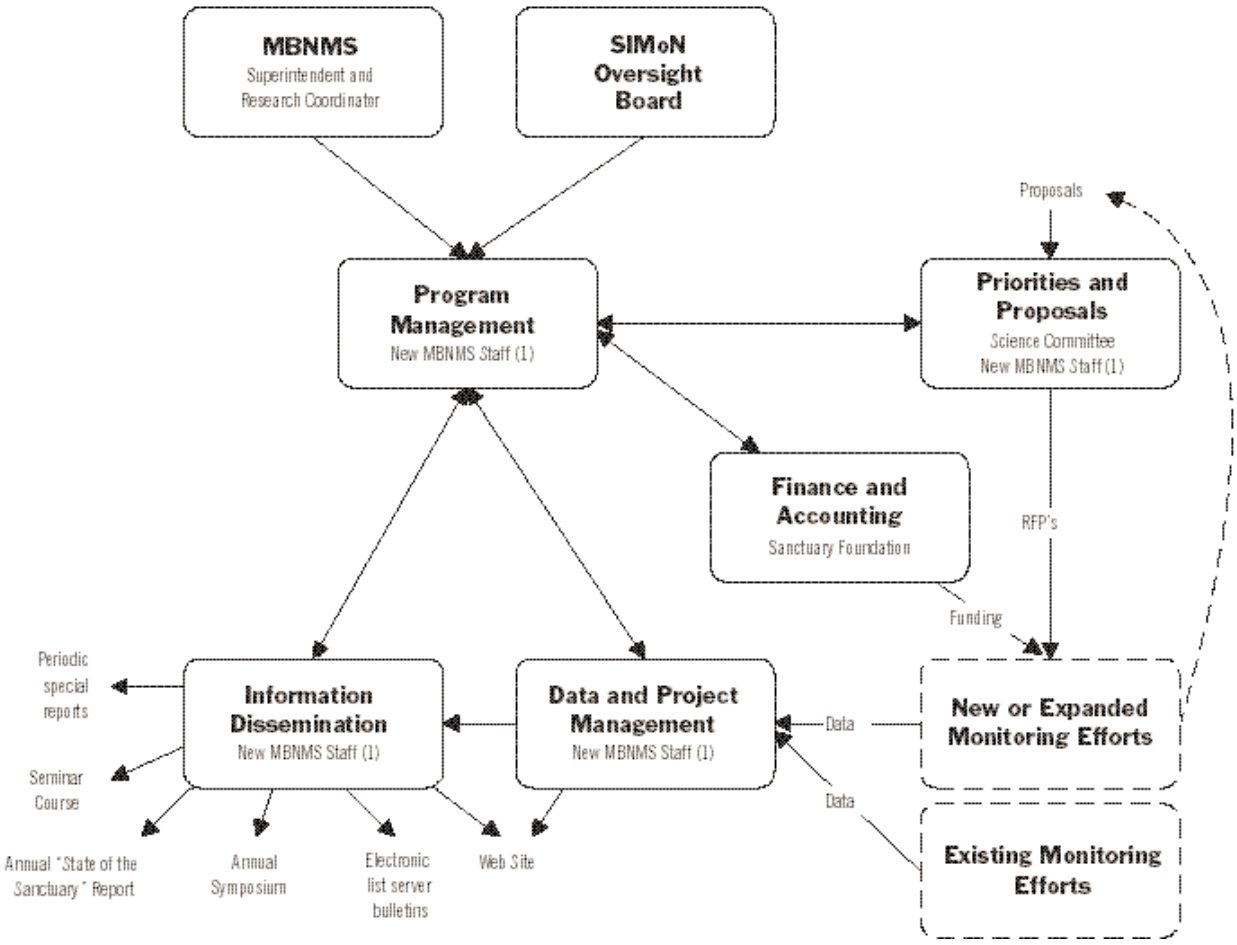
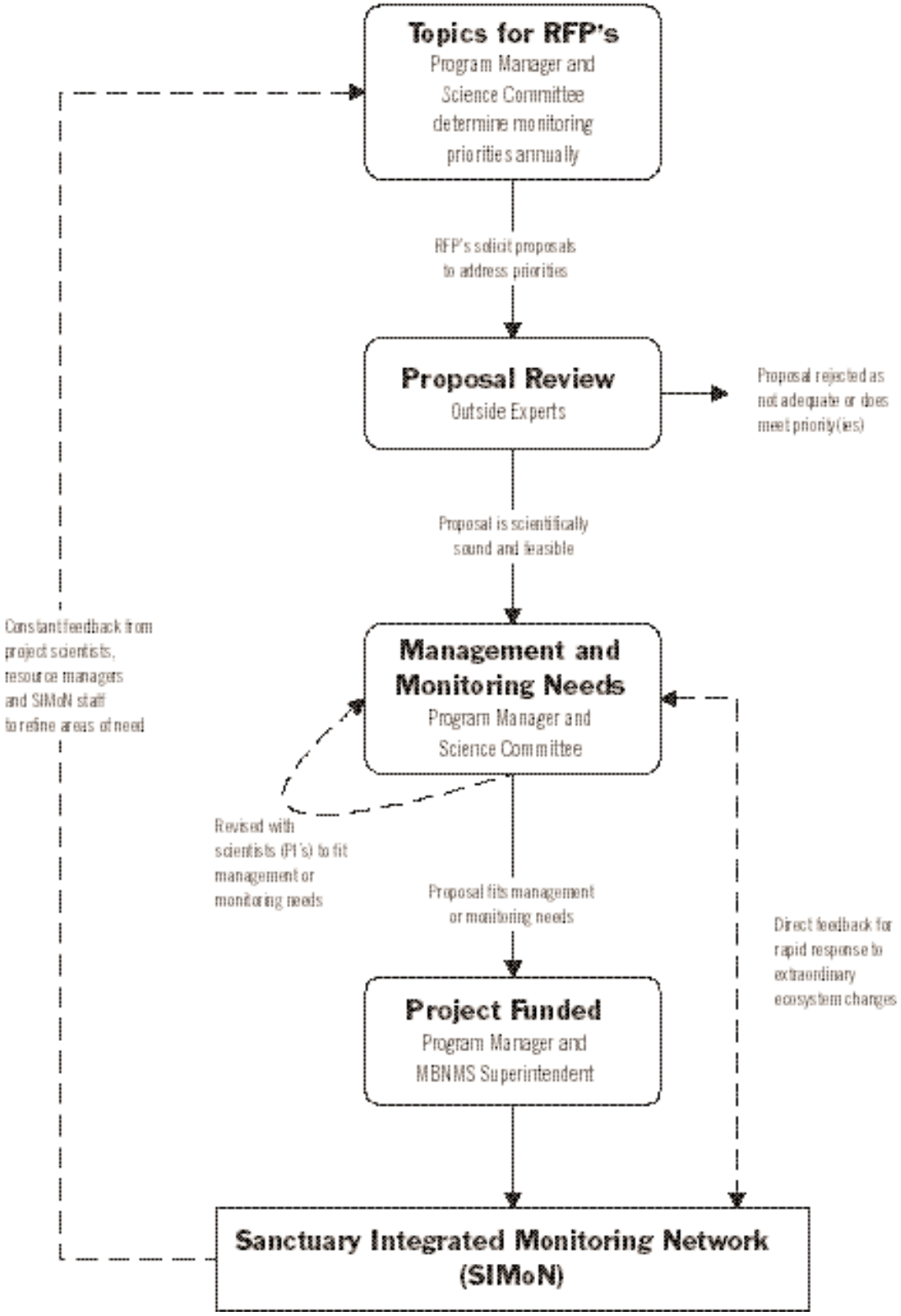


Figure 4. Flow diagram of the process to select topics for proposal requests (RFP's) and proposals to be funded through the SIMoN program.



Question driven monitoring programs will be funded for one or more years, depending on the nature of the effort. Long-term programs will be supported in five-year blocks, with reviews for continued funding by the science committee and SIMoN staff after each cycle. When appropriate, funding through SIMoN will also be used as matching money for efforts with partial support and to expand the scope of currently funded programs temporally, spatially or in the number of parameters examined.

Schedule and Review - While SIMoN has been designed to serve as a comprehensive monitoring network long into the future, it will have a phased approach. Phase 1 of the SIMoN program will include a preliminary year of setup and organization (proposed for 2001), a second year for the initiation of urgent programs, and four following years to install full scale monitoring efforts throughout the Sanctuary. After this initial six-year phase, SIMoN and its individual programs will be reevaluated for their effectiveness and to determine future direction. A visiting committee of nationally respected scientist and program managers will be invited to work with the SIMoN oversight board, science committee, and staff to conduct a general review of the overall program direction and to update specific areas of need. Similar reviews of the SIMoN program will then be conducted on a five-year basis

E. FUNDING STRATEGY

There are four basic components that will be brought together to support SIMoN. First, NOAA will need to provide salary support for the new MBNMS staff needed to manage all aspects of the SIMoN program. Second, the many ongoing private and government funded efforts, monitoring various aspects of the MBNMS, will be included into the network. These programs will make up a large portion of SIMoN and range from small individual investigator studies to large multi-institutional programs (see App. 1). Ongoing monitoring efforts in the Sanctuary have a presently combined annual budget of approximately $9 million. However, these existing programs address only a portion of the Sanctuary's monitoring needs and the great majority have funding for fixed durations (i.e., not guaranteed into the future). Therefore, as the third strategy, the numerous researcher in the region will be encouraged to purse grant and institutional funding to extend existing programs and to initiate new monitoring efforts that address priority questions in Table 1. Finally, the MBNMS will secure external support to ensure that critical monitoring efforts continue, to initiate new efforts is the areas of need, to disseminate monitoring information, and to sustain the day-to-day operations of SIMoN.

For this fourth component, the MBNMS proposes an annual science budget for SIMoN of $4 - $5 million, which will be granted to researchers and institutions to conduct specific monitoring projects. This budget figure was determined through an analysis of costs for various research efforts and budgets of similar programs. For example, comprehensive surveys of only a specific element of the Sanctuary such as seabirds and marine mammals would cost approximately $400,000 per year (monthly shipboard meso-scale surveys in Monterey Bay, plus quarterly aerial surveys and yearly shipboard surveys of the entire MBNMS), while PISCO has an annual budget of approximately $1 million for investigations of kelp and rocky shore community dynamics within the Sanctuary.

In the scope of effort, SIMoN can be compared to the Long Term Ecological Research (LTER) Network established in 1980 by the National Science Foundation. This national network is made up of 24 focused aquatic and terrestrial sites, such as the Santa Barbara Coastal LTER which is working towards an understanding of coastal runoff patterns and their impacts on the long-term population dynamics and survival of kelp forest communities. The LTER network provides each of the 24 sites an annual budget of $700,000, totaling nearly $17 million. Clearly the geographic scale of the MBNMS (at least 5x the size of Santa Barbara's coastal area) and the diverse range of important monitoring issues (see Table 1) requires a significant financial commitment to assure the effective and continuous evaluation of the Sanctuary and its resources.

F. CONCLUSIONS

SIMoN will be a comprehensive, long-term program that takes an ecosystem approach at identifying and under-

standing changes to a large marine protected area. Through the integration of high quality scientific research and long-term monitoring data sets, SIMoN will empower decision-makers with the information needed for effective management and provide an unparalleled basic understanding of a complex and ecologically, economically, and aesthetically important marine environment.

Specifically, SIMoN will provide a much more complete characterization of the MBNMS while determining and quantifying impacts of natural processes or human activities on Sanctuary resources. SIMoN will also facilitate the critical but often overlooked communication between researchers, resource managers, educators and the public through data synthesis and several targeted information dissemination programs.

Finally, the development of SIMoN has been conducted in collaborations with both the regional science and management communities, and NOAA. The National Marine Sanctuary Program is using SIMoN as a model for monitoring efforts at all national marine sanctuaries and plans to develop similar programs at other sites over the next five years. MBNMS has also been in communication with National Estuarine Research Reserve System sites (Elkhorn Slough and North Inlet-Winyah Bay) and the Australia Great Barrier Reef Park Authority on building similar monitoring networks. While other locations may not have access to the extensive marine science and management resources available along the central California coast, the basic integrative approach to building and running a comprehensive, ecosystem-based monitoring network can be utilized worldwide.

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