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The Application Of Observing System Data In California Current Ecosystem Assessments

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The Application Of Observing System Data In California Current Ecosystem Assessments

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COVER

Divers prepare to descend on a mooring to replace data loggers. This mooring is part of the NMSP West Coast Observatory project and collects data on ocean temperature and currents. For more information see: http://www.mbnms-simon.org/sections/obs/nmsp_wco.php. Credit Josh Pederson, NOAA/MBNMS/SIMoN

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ABSTRACT

Ecosystem-based management requires comprehensive assessments of the ecosystem to establish a feedback loop on the conditions in the systems under management. These assessments require observing data that reflect the pressures and ecosystem indicators of concern to managers. This report examines ongoing ecosystem assessment and modeling efforts in the California Current Ecosystem (hereafter referred to as 'ecosystem assessments') in the context of NOAA's model for Integrated Ecosystem Assessment (IEA) development. The goals of this effort are to 1) examine the ecosystem assessments in the context of a DPSIR (Driver, Pressure, State, Impact, Response) approach; and 2) identify ocean observing datasets in use by current assessments to identify gaps in the data and services available to support future assessments.

The purpose, scale, and drivers for 10 selected assessments were compared with the ocean observing data sources used in their development. These 10 assessments vary in the spatial scope of the assessment from the California Current Ecosystem scale to the local scale. A more detailed comparison of the California Current IEA, Module 1 and Northern California Current Ecosystem, Atlantis model was then undertaken to highlight their use of drivers, pressures, and indicators.

Five Sanctuary condition reports, assessments for individual sanctuaries, were examined in depth to understand the relationship between drivers, pressures and responses in the context of management requirements. The sources of data used to evaluate indicators of those responses were then identified. This provided a link between a pressure-state-response model of IEA development and ocean observing data sets. The final step was to examine observing datasets being used by one or more assessment efforts in the California Current Ecosystem. This work provides an assessment of how existing ocean observing efforts are informing assessments efforts in the California Current Ecosystem and where gaps exist.

We identified four datasets available through the Pacific Coast Ocean Observing System that are being used by both large and small-scale assessment efforts. However, the overwhelming majority of the datasets identified in this analysis were used by either small or large-spatial scale assessment efforts but not both. A very large gap exists for data describing the level of human activities that impact the marine environment. In addition, the authors identify a need for more data collected at the sub-regional and local level. Currently, in no single sub-region are data available for all the physical, chemical, and especially biological indicators required for comprehensive analyses.

This review recognized four key barriers to fully exploiting ocean-observing data for ecosystem-based management: data discovery, data access, integrating disparate data, and closing the gap between data needs and data collection. One of the key challenges to IEA application in ecosystem-based management is the lack of available data. Even if there

were no barriers to discovering, accessing, and integrating existing data, effectively developing management alternatives and monitoring effectiveness requires investments in data collection and analysis. In many cases, the necessary data are not available, significantly hampering our ability for taking ecosystem-relevant management actions and increasing uncertainty in outcomes. Resource managers must make the best decisions possible with available information. This requirement to move forward, even with data gaps highlights the importance of maximizing the use of what we do have through data management, improved accessibility, improved integration and compatibility, and more comprehensive analysis.

KEY WORDS

Pacific Coast Ocean Observing System, PaCOOS, Integrated Ocean Observing System, IOOS, Integrated Ecosystem Assessment, IEA, Ecosystem Based Management, EBM, National Marine Sanctuaries, Channel Islands, Monterey Bay, Gulf of The Farallones, Cordell Bank, Olympic Coast, DPSIR, California Current, Atlantis Model, Condition Report

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INTRODUCTION

Incorporating ecosystem principles into resource management is a strategic goal of NOAA (NOAA 2009). This goal requires an ecosystem-based management (EBM) approach that moves beyond individual species or single-issue management to consider a range of relevant ecological, environmental, and human factors (Murawski and Matlock 2006). Integrated Ecosystem Assessments (IEAs) are an EBM approach that helps to overcome barriers to implementation. NOAA defines an IEA as "a synthesis and quantitative analysis of information on relevant physical, chemical, ecological and human processes in relation to specified ecosystem management objectives (Levin et al. 2009). IEAs can help improve our understanding of interactions among climate, water, habitat, living resources and human activities. Collaborative ecosystem-based management requires mobilizing contemporary and historical data from NOAA and other organizations to create a comprehensive picture of the ocean ecosystems and how they are changing. Creating this picture requires alliances among researchers and the professionals entrusted with managing marine resources and a deep understanding of the linkages between management needs and ecosystem observations.

Achieving NOAA's goal of moving to ecosystem-based management entails access to high quality data to develop IEAs that support resource manager's requirements for adaptive management. Levin et al. (2009) have outlined a framework for the development of IEAs that consists of five key steps (Figure 1). This framework begins with a scoping process to identify key threats, management objectives and constraints, and appropriate indicators[1] of ecosystem change. Risk assessments of individual indicators are combined into a determination of overall ecosystem status. The potential of different management strategies to alter ecosystem status is evaluated, and then management actions are implemented and their effectiveness monitored. The cycle is repeated in an adaptive manner. An assessment of stressors on the ecosystem identifies the "drivers" and "pressures". Key relevant datasets are selected to assess the "state" of key indicators of ecosystem baseline conditions. An evaluation of the ecological and economic "impacts" of alternative management options help to identify the management "response" (Levin et al. 2008). The approaches Levin et al. describe provide a framework for understanding how to develop links that extend from observing data through adaptive management.

For IEAs to be useful they must relevant to the management priorities of organizations with ocean stewardship responsibilities (deReynier et al. 2009). Because management actions can only be implemented by those agencies with management authority, agency management processes must be synchronized with the IEA process. National marine sanctuaries bring together the scientific community, stakeholders, and the public to clearly define goals, protocols, and decision points for applying marine ecosystem-based management principles in order to manage ocean resources. Each sanctuary in the National Marine Sanctuary System has a management plan. In general, management

[1] Following the definition in EPA (2000), "An ecological indicator is defined here as a measure, an index of measures, or a model that characterizes an ecosystem or one of its critical components. An indicator may reflect biological, chemical or physical attributes of ecological condition."

plans are used to inform decision making and project planning, while articulating goals, objectives, and priorities. Management plans are organized into action plans that link to management issues. Actions plans have common themes among sanctuaries based on the general goals of the Office of National Marine Sanctuaries (ONMS). One of these goals is to better characterize sanctuary resources, such as water quality, habitat, and living marine resources. Characterizing the condition of natural resources and ecosystem processes is the principal means by which the ONMS improves its understanding of the marine environment. A second major goal of the ONMS is to identify management actions needed to protect and conserve sanctuary resources. Examples of management actions include detecting the impacts of human activities or implementing new marine zones to protect vulnerable resources.

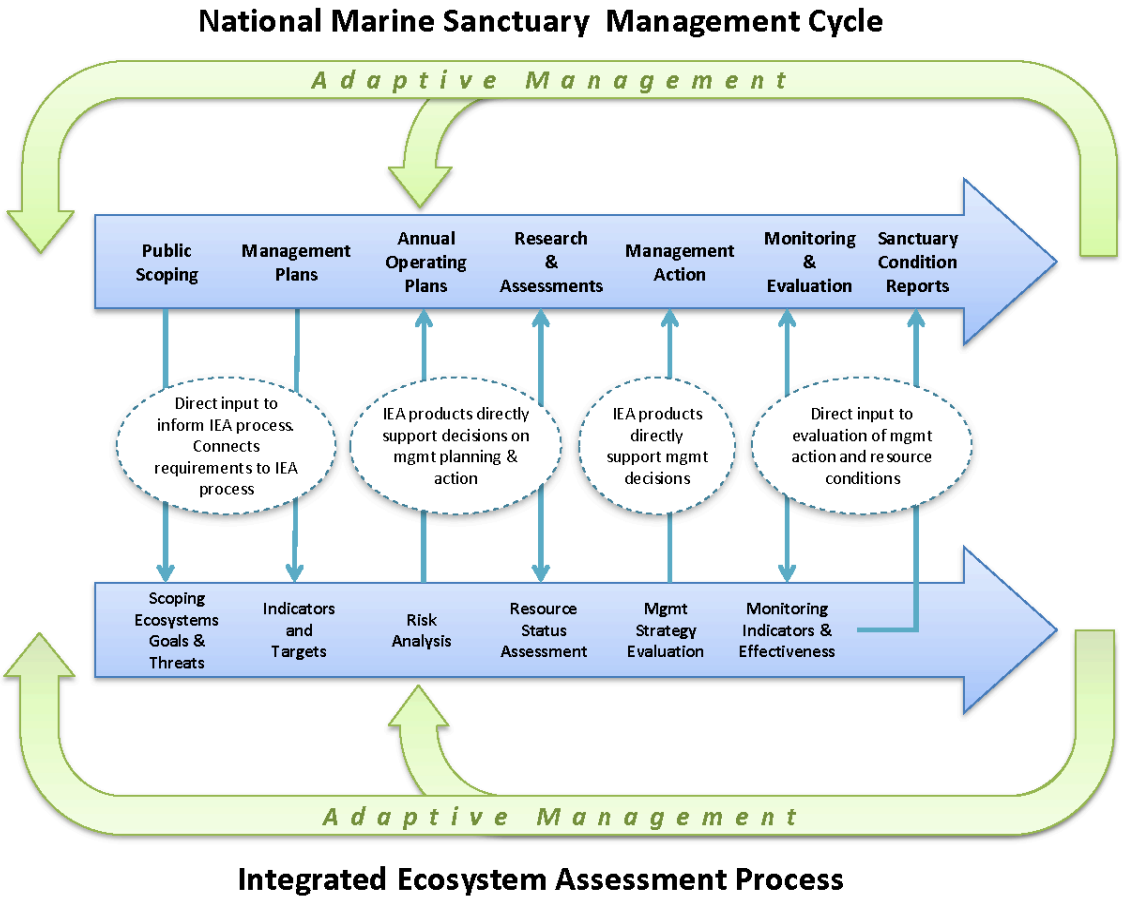

Figure 1 – Interaction between sanctuary management cycle and integrated ecosystem assessment process. The lower blue arrow shows the process of integrated ecosystem assessment (adapted from Levin et al. 2009). The ovals illustrate how a management unit's actions, in this case a sanctuary, both contribute to and depend on results from IEAs.

The connection between National Marine Sanctuary management and the IEA process is one that illustrates the interdependency of sound science and resource management. It is based in connecting science capabilities with management requirements and must consider science, analysis, policy, socioeconomics, and programmatic processes to allow

effective implementation, beginning with public scoping sessions to inform managers on the range of issues that management should consider (Figure 1). A Sanctuary management plan provides the overarching connection between threats to managed resources, social and economic trends, and planned programmatic ecosystem-based management actions (see: http://sanctuaries.noaa.gov/jointplan/welcome.html). Sanctuary management plans, including their associated public scoping process can inform IEA scoping, threat identification, and indicator development. Based on these inputs, managers develop annual operating plans to allocate resources and address the identified threats. IEA risk analysis supports this program planning and investment by identifying high risk and high priority resources, processes, and issues. Each of the elements on the blue arrows in Figure 1 is an integral component of the adaptive management cycle central to EBM.

Monitoring allows managers to assess the effectiveness of specific strategies and overall effectiveness. Sanctuary condition reports provide the assessment and analysis of conditions and trends of sanctuary resources in the context of management plan goals (see: http://sanctuaries.noaa.gov/science/condition). Research and assessment activities provide the information necessary to develop targeted, effective management options. In the sanctuary system, such options can include regulations, permits, non-regulatory actions, and other tools for implementing strategies to address the identified pressures and threats on sanctuary resources. IEA tools (like simulation models) support these options by helping managers evaluate alternative management actions.

Creating a more comprehensive understanding of ecosystem status or health is a goal of many research, modeling, and assessment efforts recently undertaken in the California Current Ecosystem[2]. In this report we compare a number of these efforts in the context of NOAA's DPSIR (Driver, Pressure, State, Impact, Response) and IEA approaches. DPSIR is closely intertwined with IEAs (Koshel and Mcallister 2008; Levin et al. 2008; van Woerden et al. 2007) so it provides a useful comparison tool. The application of an IEA framework for EBM is a relatively new approach with few comprehensive examples. This report reviews assessments that while not meeting all requirements of a complete IEA, go beyond the individual species or single-issue assessment upon which mangers have often relied in the past. These assessments meet one or several of the key IEA components shown in Figure 1 and can provide insight into the kinds of ocean observing data that fully developed IEAs will require. This report refers to these efforts as ecosystem assessments to indicate that they do not necessarily meet all the characteristics of an IEA but do provide managers with insights into the conditions of ecological resources and functions beyond those possible with single sector assessments.

Tallis identifies data acquisition, quality, and utility as a key factor in manager's ability to apply IEA approaches in EBM (Tallis et al. 2009). The goal of this report is to: 1) examine ecosystem assessments in the context of a DPSIR approach; and 2) identify ocean observing datasets in use by current assessments in order to understand the data

[2] The CCE extend from approximately La Paz Mexico to the U.S.-Canadian border (www.lme.noaa.gov/ (accessed 12/12/2009).

and services available to support future assessments. This report compares the purpose, scale, and drivers for 10 selected ecosystem assessments with the data sources used in their development. The CCE includes a wide range of spatial scales that are relevant to ecosystem-based management. Different geographies within the CCE can be described by physical processes (Hickey and Banas 2008), biogeography (Pacific Fisheries Management Council 2008), or by governance (Ekstrom 2009). The 10 assessments in this report represent different scales of investigation including the entire CCE, regions within the CCE, specific management units such as National Marine Sanctuaries, and local areas such as Monterey Bay.

A more detailed comparison of two ecosystem assessments efforts - the California Current IEA, Module I and Northern California Current Ecosystem Atlantis model - was undertaken to highlight their use of drivers, pressures, and indicators. Five Sanctuary condition reports, a component of IEAs for individual sanctuaries, were examined in depth to understand the relationship between drivers, pressures and indicators in the context of management requirements. The sources of data used to evaluate the state of sanctuary resources were then identified. This approach provided the link between the DPSIR model, the IEA framework, and data sources, some of which are IOOS data sets. The final step was to examine which of the observing datasets hosted by PaCOOS were being used by one or more ecosystem assessment efforts in the CCE. This work provides an assessment of how existing IOOS efforts are informing IEA efforts and where gaps exist in data availability.

This report identifies how the resource characterization (Table 1) and management action (Table 2) needs of the five west coast sanctuaries could be addressed, at least in part, by ocean observing data. The management plans for three sites in central California – Monterey Bay NMS, Cordell Bank NMS, and Gulf of the Farallones NMS, were reviewed and updated in 2008 in a process called the Joint Management Plan Review (NOAA 2008a, 2008b, 2008c). Similarly, the management plan for the Channel Islands NMS was recently completed in 2009 (NOAA 2009). The management plan review process at the Olympic Coast NMS began in 2008 and information from issue identification workshops was used to identify site management needs.

The strategies and activities highlighted in action plans help define the specific research topics or questions that need to be answered at each site and the sites' need for monitoring data. Many resource characterizations and management action needs are shared by most or all sanctuaries on the west coast (Tables 1, 2). For example, all five sites have a need for better subtidal benthic habitat characterization and a need to detect natural and human-induced changes to rocky intertidal habitat. However, some needs are more sanctuary specific. For example, the Monterey Bay NMS highlighted the need to monitor impacts to living resources from kelp harvest and desalination plants.

Using an existing inventory of monitoring programs in west coast sanctuaries (see Appendix I), we identified the programs that are collecting observing data applicable to each resource characterization or management action need. For resource characterization needs, we identified datasets that are: 1) being served by PaCOOS; 2) not being served by

PaCOOS (Table 1). For example, the annual surveys of kelp canopy in California and Washington are two observing datasets hosted by PaCOOS that help characterize the status and trend in abundance of this subtidal biogenic habitat in the sanctuaries. In contrast, PaCOOS is not currently serving observing datasets that would help characterize the status and trends of intertidal habitats and the associated living resources.

We also found that many management actions highlighted in management plans would benefit from better characterization of sanctuary resources. For example, assessing the effectiveness of areas within sanctuaries designed for additional levels of protection requires characterizing both habitat and living marine resources. Multiple monitoring programs are collecting these types of data in the intertidal and shallow subtidal habitats in Monterey Bay and Channel Islands NMSs. However, these data are not served by PaCOOS. Thus, for each management action, we identified which resources needed characterization and which monitoring programs were directly addressing the management issue (Table 2).

CCE-specific ecosystem assessments incorporating the IEA development framework in use by NOAA should also examine requirements in the context of ecological scales. Reviewing ecosystem assessments at different scales for the CCE allows us to evaluate how existing data and analysis capabilities inform their development and where gaps exist. This report also examines the link between available datasets and management priorities of the five national marine sanctuaries in the California Current Ecosystem. Our goal is to identify the IOOS datasets, as well as other datasets, that could be used in developing IEAs that are relevant in managing resources in the CCE.

Ecosystem Assessments in the California Current

Survey of Ecosystem Assessments at Multiple Spatial Scales

Organizations conduct assessments at scales representing different ecosystem components. These range from ecosystem (CCE scale) to ecosystem region (i e., Northern CCE), management-unit specific (e.g., a Sanctuary), and sub-management unit (e.g., Monterey Bay). A sanctuary condition report is an example of a management unit-specific ecosystem assessment. Undertaking ecosystem-based management requires knowledge and understanding of the larger ecosystem components of a managed area. There are many ecosystem assessment efforts underway in the CCE, from the local scale to the scale of the entire CCE that make use of observing data (Figure 2). These efforts are interlinked in a hierarchy of scales (Table 3) that allow comparison of drivers, pressures, indicators, and management needs.

Examining ecosystem assessments at multiple scales enables us to frame the context for how observing data are being put to use across the CCE. It is necessary to look at specific examples to understand how existing data are being put to use in ecosystem assessments, where gaps exist, and why those gaps exist.

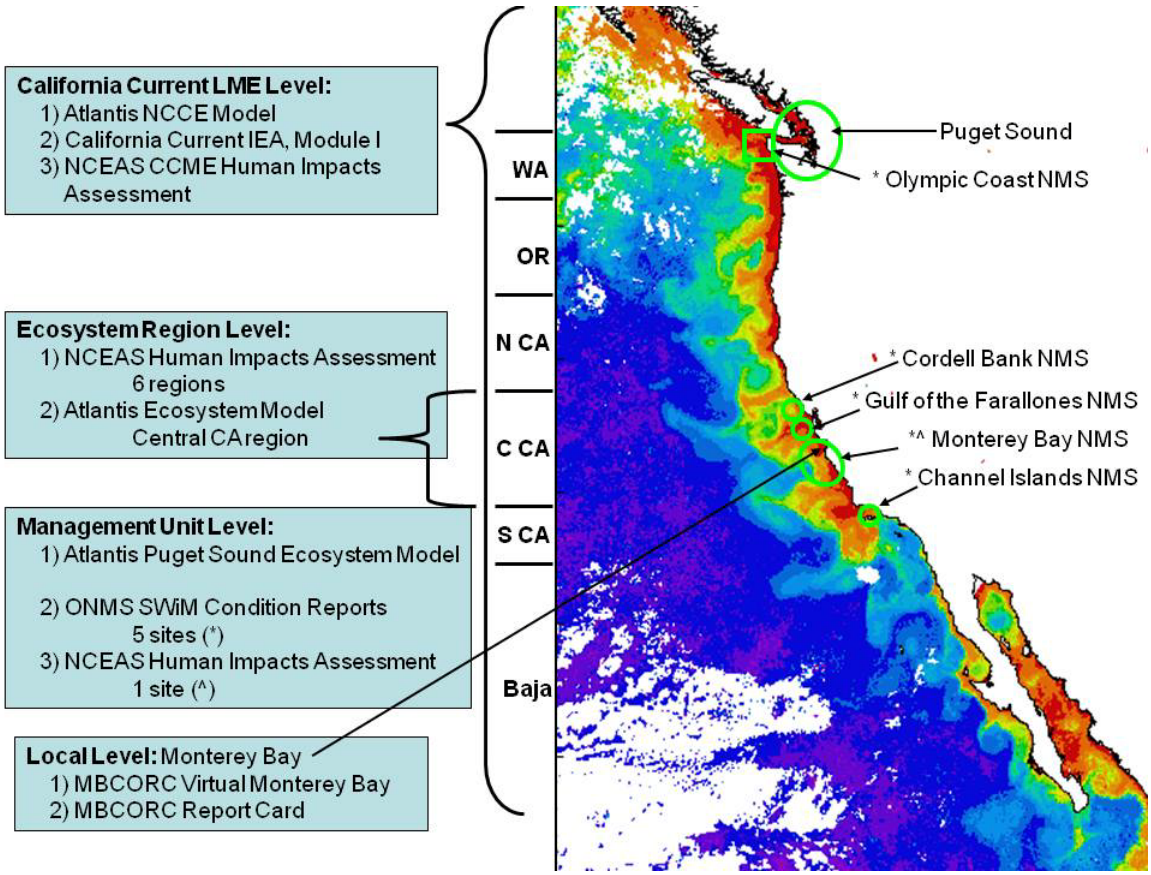

Figure 2 – Selected Ecosystem Assessments in the California Current Ecosystem. See Appendix 2 for background information on each of the ecosystem assessment efforts.

Three ecosystem assessments - the Atlantis model (Brand et al. 2007), Module I (Sydeman and Elliot 2008), and the NCEAS Human Impacts Assessment (Halpern et al 2009) examine the entire California Current Ecosystem. Two of these efforts – the Atlantis model and the NCEAS Human Impact Assessment – also create ecosystem assessments at the ecosystem region and management unit level. Each site in the National Marine Sanctuary system is completing a condition report on the status and trends of managed resources at the site level. Finally, the Monterey Bay Crescent Ocean Research Consortium (MBCORC) has begun efforts to assess the status of the ecosystem at the sub-management unit level through both a report card approach and a ecosystem modeling approach. See Appendix B for a more detailed background of these efforts.

Because these ecosystem assessment efforts differ in both their purpose and geographic scale, there are differences in which drivers are examined, and which indicators are being used to determine ecosystem state (Table 3). We found that each ecosystem assessment effort is using IOOS-related datasets to determine the state of some indicators. However, each of the ecosystem assessments also include datasets that are not integrated into IOOS, which indicates that currently, IOOS datasets are not sufficient to fully meet the data needs of ecosystem assessment efforts in the California Current.

Comparing Two Large-scale Ecosystem Assessment
A more detailed comparison of two ecosystem scale assessments – California Current IEA, Module I (Sydeman and Elliott 2008) and the Northern California Current Ecosystem (NCCE), Atlantis Model (Brand et al. 2007) - illustrates how two ecosystem assessments with different approaches, result in substantial differences in their form and function. (Table 4). Although both the Atlantis model and Module I are focused on an assessment at the California Current Ecosystem scale, they have chosen to employ different approaches and, thus, indicators of ecosystem state.

The goal of California Current IEA Module I is to find a few good, robust indicator datasets that can be used to provide periodic reports on the status of the ecosystem. An additional goal is to identify important changes in ecosystem status and link those to changes in climate and human use drivers. This assessment includes oceanographic indexes and major components of the offshore, pelagic ecosystem such as forage species and top predators. They intend to use these datasets to understand the statistical relationships between the selected indicators and certain pressures to inform management. Based on the indicators that have been selected and the large geographic scale covered by those datasets, this assessment is best suited to drivers and pressures that operate at large spatial scales and those that impact foodweb dynamics, especially top-level vertebrate predators.

In contrast, the NCCE Atlantis is a simulation modeling approach that is spatially explicit and attempts to include as many ecosystem components as possible. Datasets include hydrographic processes, biogeochemical processes, foodweb relationships between multiple functional groups, and human-use patterns, such as harvest. Based on the structure of this model, the Atlantis NCCE can provide more spatial resolution than Module I, though the resolution is limited by how model compartments are established when the model is initialized. Depending on the model structure and datasets used, Atlantis works best for understanding the influence of pressures that impact high biomass, resident, and/or exploited species, such as those found in the middle of the foodweb.

Both Module I and Atlantis have the potential to inform resource management needs, such as those of the Office National Marine Sanctuaries or National Marine Fisheries service. Both assessment approaches can help address characterization and management action needs at large scales. However, the spatial scale of these two models will not be fine enough to address many management needs, such as those of a specific sanctuary site.

Some of the efforts in the CCE have both LME and ecosystem region components. For example, an Atlantis model for the central California ecosystem region is under development. The Atlantis model, which incorporates finer scale data when available, can be useful in addressing more management unit specific or broader regional management needs.

Comparison of the spatial scale of the ecosystem assessments underdevelopment in the CCE helps to illustrate the need to match assessment scale, type, and scope to management need. There needs to be a proper match between the spatial scale of the drivers and pressures that an assessment sets out to address, the data that are used, and the approach for reporting the assessment. Though data may be collected in the CCE on the status and trends of indicators of interest, it may not be collected at a spatial resolution that matches the scale at which the management decision must be made. Identifying the primary indicators for different drivers and pressures and the spatial scale of those management needs is a key step in identifying the observing datasets that are most valuable to the IEA process.

Identifying Applicable Observing Data for Drivers and Pressures in the CCE

To identify the observing datasets that are most useful for IEAs in the CCE, it is important to understand the Drivers and Pressures operating in the ecosystem. A recent study lead by researchers at the National Center for Ecological Analysis and Synthesis (NCEAS) identified and mapped human threats to marine ecosystems in the California Current (Halpern et al. 2009). This study identified the human activities that are potential drivers and pressures on coastal and marine habitats in the CCE and determined the availability of data sets to model the impacts of those drivers. Of the 57 land-based or ocean-based human activities identified in Table 5,CCE-scale observing data were not available for 19 of them. For an additional eight pressures, the authors decided against using the available data because either a comprehensive dataset was not available and the impacts were likely small, or the direction of impacts was not clear (i.e., some positive impacts and some negative impacts) and would be difficult to model.

This study provides a good assessment of the human pressures in the CCE for which data is available for incorporation into an IEA. The available observing data are being combined with information on associated impacts to develop a spatially explicit model of the distribution and magnitude of human threats to marine resources in the CCE. The next step in the DPSIR approach would be to combine this information on the human pressures with observing data on the state of key indicators that will be influence by the pressures threatening the resource. This would allow managers to explore the impact of the pressures and the potential responses of those indicators to management actions that modify human activities. However, because this study is attempting to model pressures for the entire CCE some datasets that only cover a smaller spatial scale were not included. Current and future studies at the sub-regional level (Figure 2) should allow incorporation of those smaller scale datasets and allow further assessment of the variability in the intensity of human pressures at the sub-regional scale.

The drivers and pressures that are important at even smaller spatial scales, such as the ecoregion and local levels, can be examined by looking at ecosystem assessment efforts occurring at these smaller spatial scales (Figure 2). For example, each National Marine Sanctuary is developing, reviewing, and issuing their condition reports. The reports are

part of the ONMS System-Wide Monitoring framework (ONMS 2004). They were developed based on a Pressure-State-Response framework (PSR) that correlates to the (D)PSIR approach. Each report provides a summary of natural and anthropogenic pressures on resources in the focal sanctuary, the current conditions and trends in resources, and management responses to the anthropogenic pressures affecting resources. The PSR framework allows managers to both prioritize management actions and evaluate their effectiveness in meeting conservation or restoration goals.

To identify the current and emerging drivers and pressures at the sanctuary (management unit) scale, we reviewed the pressures section of condition reports from the five sanctuaries in the CCE – Olympic Coast (ONMS 2008), Cordell Bank (ONMS 2009b), Gulf of the Farallones (ONMS draft), Monterey Bay (ONMS 2009c), and Channel Islands (ONMS 2009a) (Table 6). Of the 26 current or emerging pressures identified by one or more sites, nine pressures were common to all sites. These pressures included such activities as harvesting, vessel traffic, oil spills, introduced species, and marine debris. Seven of the pressures were identified by only one or two sites. For example Monterey Bay and Gulf of the Farallones were the only sites to identify dredging/dredge disposal, road construction/landslide disposal, and coastal armoring as human activities that put pressure on sanctuary resources. One or more sites identified six human activities as an emerging pressure. These pressures included aquaculture (both coastal and open ocean based), global climate change, ocean-based energy generation, and bioprospecting.

Although three of the sanctuary sites – Cordell Bank, Gulf of the Farallones, and Monterey Bay – occur in the central California region, there is substantial variability in the pressures identified as important in the site's condition reports (Table 6). There are a number of potential reasons for this variability. One of the sites, Cordell Bank, is an offshore site so land-based and nearshore human activities will not exert as strong of an influence on the resources in this sanctuary. Also, some inconsistencies may be due to each report being separately authored. For example, the sites differed in the extent to which emerging pressures were discussed in the reports.

Understanding the existing and emerging pressures allows us to frame the need for data to support the analysis of conditions and trends. Condition reports also identify the indicators and observing datasets used by each site to assess the current state of sanctuary resources (Table 7-11). Each site determined the status and trends of resources by responding to a standardized set of questions that covered the resource areas of water quality (4 questions), habitat (4 questions), and living resources (6 questions). Each site used readily available information, including observing datasets, to assess the state of multiple indicators and ultimately identify a status rating (e.g., Good, Fair, Poor) and trend (improving, declining, unchanging) for each question. The summaries provided in Tables 7-11 show a comparison of both the indicators identified by each site to address the fourteen standardized question as well as the information used to determine the state of those indicators.

Some of the datasets used in one or more condition reports are currently part of IOOS. Seafloor mapping data, collected by a variety of programs (e.g., CSUMB, OCNMS,

MBARI, USGS) and available on the PaCOOS West Coast Habitat Portal, were used by each site in the assessment of the abundance of benthic physical habitat. In addition, Monterey Bay and Olympic Coast used kelp canopy monitoring data available through the habitat portal to assess the status of this biogenic habitat. Datasets available on the PaCOOS Data Integration Demonstration website were used by one or more sites to assess the status of various living resource indicators. For example, Monterey Bay used data collected by CIMT on phytoplankton and harmful algal blooms. The Olympic Coast used data collected by COASST on beachcast seabirds. Multiple sites used data from NMFS monitoring programs, such as NWFSC groundfish surveys, NOAA Fisheries cold-water corals, and SWFSC marine mammal surveys. In some cases the PaCOOS Data Integration Demonstration website provides access to subsets of these data.

However, many of the datasets available through IOOS, such as those focused on physical oceanography, were not used in the condition reports. One reason that some IOOS datasets were not used is that most of the standardized questions in the condition reports are focused on subjects for which few data are available through IOOS. Of the four questions focused on water quality, at least two cannot be addressed by oceanographic data alone. For example, indicators of human health risks and indicators of human activity levels were needed to answer questions 3 and 4, respectively. The remaining 10 questions were focused on the conditions of habitats and living resources, subjects for which limited data is currently available through IOOS.

There are a variety of other potential reasons that some IOOS datasets, which were applicable to the standardized questions, were not used in the sanctuary condition reports. Sanctuary sites may not have been aware of the availability of some of the IOOS datasets. The PaCOOS data portals were being developed during the same time the condition reports were being drafted so the authors may not have been aware of the types of data available. Also, even if a site was familiar with the datasets available, that site may not have the time or expertise to access, analyze, or interpret the data. Alternatively, a site may have chosen to use other datasets. For example, a site may have used data collected at the site or local level instead of at the regional level.

Comparison of the indicators and datasets used in the five condition reports reveals that, although the questions were standardized, there was considerable variability in the indicators selected by each site to assess each question. Some of this variability was due to the lack of available observing data at larger spatial scales. For example, site-specific monitoring programs, such as the OCNMS intertidal monitoring program, Center for Integrated Marine Technology (CIMT), and Channel Islands National Park (CINP), collected much of the observing data used to assess the state of living resources.

Additional variability was due to the fact that on-going monitoring programs do not target some of the indicators of interest. For example, there are very few programs monitoring the abundance of contaminants in habitats and little monitoring data available to determine the health of the key species identified in the reports. Due to the lack of monitoring data, sites had to rely on one-time studies, which are often limited in spatial and/or temporal coverage, as a basis for their status assessment. For example, Olympic

Coast and Cordell Bank used one-time studies to assess the abundance of persistent organic contaminants in subtidal habitats. Lastly, when monitoring data and published studies were not available to the sites to evaluate the condition of indicators of interest, the sites had to rely on the professional opinion of local science experts.

Obstacles to Management Application of Observing Data

Developing CCE IEA frameworks requires identifying gaps in existing observing capabilities so as to inform IOOS data and product development. While IOOS product development can initially focus on the five core variables, it will need to include other relevant data sets not yet incorporated into the IOOS system. Table 12 lists the datasets that were used by one or more of the CCE IEA frameworks and identifies the datasets that are currently available through PaCOOS data portals. Figure 3 illustrates which datasets were used by small-scale or large-scale ecosystem assessment efforts and highlights the datasets that were used at both scales. In addition, Figure 3 highlights the datasets available through IOOS, and identifies those that are not currently being used by any ecosystem assessment efforts in the CCE.

We identified six datasets available through PaCOOS that are being used by both large and small-scale ecosystem assessment efforts. The Essential Fish Habitat, NWFSC groundfish survey, SWFSC Upwelling Index, and the California Fish Landing database were used by IEAs at multiple spatial scales. Surprisingly, the CIMT and Monterey Bay Time Series datasets, though limited in spatial scale to the Monterey Bay, was used in ecosystem, management unit and, local ecosystem assessments. An additional eight datasets were used in assessments at both spatial scales, but were not available through IOOS. However, the overwhelming majority of the datasets identified in this analysis were used by either small or large-spatial scale ecosystem assessment efforts.

The limited overlap in the use of datasets at both the large and small-scale is likely due to multiple factors. Probably the most influential factor is the spatial scale over which the data are collected. Many of the datasets used in the LME and ecosystem region levels are collected over a fairly large geographic scale. These datasets provide the wide spatial coverage needed by large-scale IEAs, but may be very limited in the amount of data available for an IEA at the local or management unit level. Therefore, the small-scale IEAs must target datasets with higher density of data points at the small scale, but those studies may have limited utility for large-scale IEAs unless similar data are collected at other sites in the region.

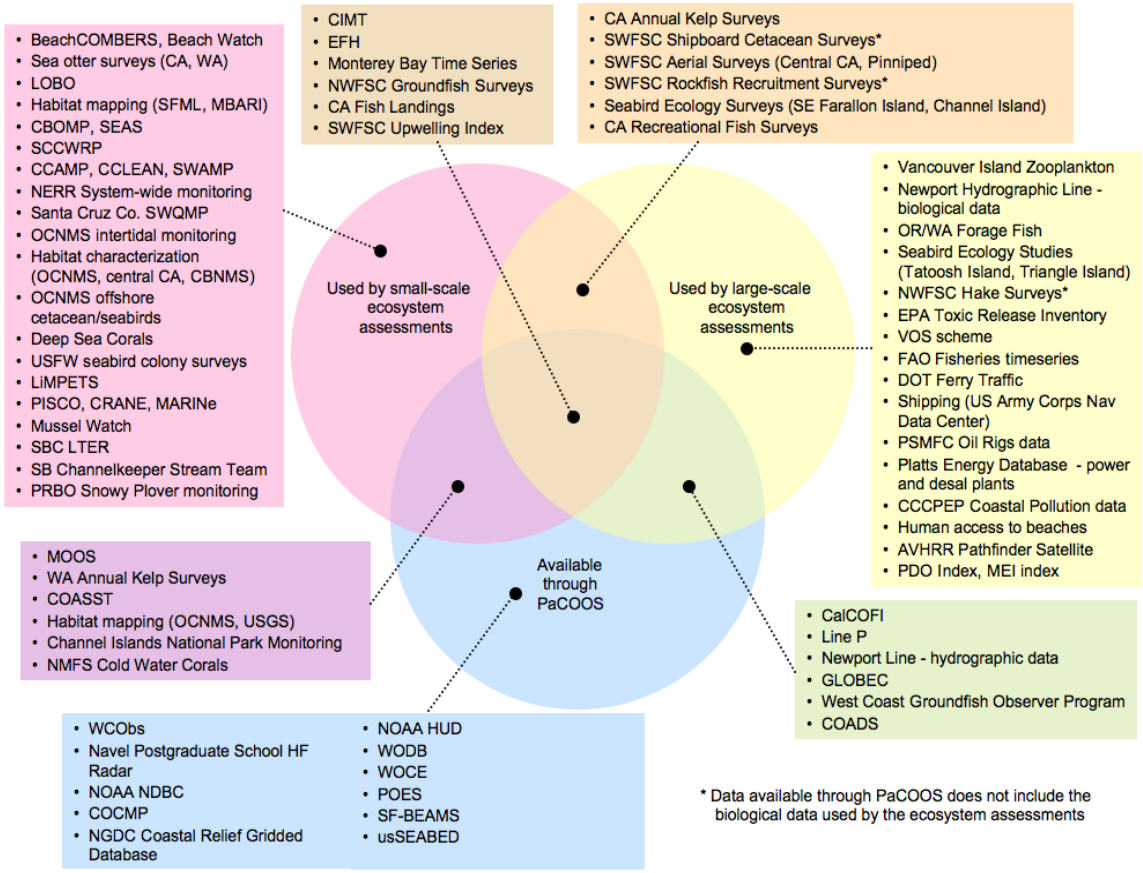

Figure 3. IOOS data as used by small-scale or large-scale ecosystem assessments considering availability through the PaCOOS data portal. At the time of the review, PaCOOS was only hosting oceanographic data and the ecosystem assessments were only using biological data so there was no overlap in the data hosted vs. data used.

There are some examples of datasets being used at both spatial scales (intersection of the pink and yellow circles in Figure 3). Most of these datasets can be used at both large and small scales because they are surveys with wide regional coverage, but fairly high data density at the local level. In addition, these surveys provide the basis for assessments of the status of either fished stocks (e.g., SWFSC rockfish recruitment surveys, CA Recreational Fish Surveys) or sensitive populations (e.g., SWFSC shipboard and aerial surveys) and thus can be a main source of data in any IEA incorporating those assessed species.

In some cases, similar data are collected by two or more studies at the ecosystem region, management unit or, local scale and have the potential to be combined to expand spatial coverage and utility for large-scale IEAs. The Module I large-scale IEA uses data from separate small scale studies occurring over the larger region of interest. For example, it uses hydrographic data collected by Line P in British Columbia, the Newport Hydrographic Line in Oregon, and the CalCOFI surveys in California. Seabird data collected by five different survey efforts are also incorporated into the Module I IEA. Many other datasets currently in use by small scale IEAs appear to have similar potential

for incorporation into larger-scale IEAs. These include annual kelp surveys, sea otter census data, beachcast seabird data (e.g., BeachCOMBERS, Beach Watch, COASST), and rocky intertidal surveys (OCNMS, PISCO, MARINe). Each monitoring effort is likely to have different data collection methods; therefore combining the datasets across larger areas will require a thorough understanding of how the data were collected and what types of intercomparisons are valid.

In some cases data are being collected on indicators of interest at multiple sites, but those datasets have not been integrated into a larger scale monitoring dataset because the monitoring programs at each site are using different methods. For example, beachcast seabirds are monitored in Olympic Coast, Gulf of the Farallones, and Monterey Bay sanctuaries by three separate monitoring efforts, COASST, Beach Watch, and BeachCOMBERS, respectively. Similarly the abundance of sea otters and of kelp canopy is being monitored in both the Monterey Bay and the Olympic Coast sanctuaries, but by separate programs with different methods.

Many of the datasets that are being used by ecosystem assessment efforts are not being hosted by IOOS. Data from many of the NMFS monitoring programs, such as the Newport Hydrographic Line time series, SWFSC Aerial and Shipboard Surveys, and Rockfish Recruitment Surveys, were used by multiple assessment efforts (see Figure 3). However, very few of the data collected by these efforts are currently available through PaCOOS data portals. In two cases (Newport Hydrographic Line and rockfish recruitment surveys) PaCOOS is hosting some oceanographic data, but the biological data, which are the primary data being used by the assessment efforts, are not hosted by PaCOOS data portals.

One very large gap in the data available from IOOS is the level of human activities that impact the marine environment. Although some data on fishing effort (e.g., California Fish Landing database) and impacts on sensitive species (e.g., West Coast Groundfish Observer Program) are available through PaCOOS, not enough data are available to create comprehensive catch reconstructions. This information is crucial for any type of model incorporating fishing activity (I. Kaplan, NMFS-NWFSC, pers. comm.). In addition, no data on the levels of other human activities are hosted. However, data on human activities that are pressures on marine resources in the CCE are available and could be targeted by IOOS. For example, the NCEAS regional ecosystem assessment identified 30 human activity datasets (Table 5). Additional data on the levels of human activities impacting water quality, habitat and living resources is a need identified in all the condition reports from the west coast region. Sydeman and Elliot (2008) also highlighted the need for socio-economic data and other long-term data on human activities in the CCE.

Conversely, many of the datasets available through IOOS were not used by any of the ecosystem assessments identified here (see blue shaded region of Figure 3). For example, much of the data hosted by IOOS could not help answer many of the standardized questions in the ONMS condition reports. Data on contaminants levels in habitats and organisms, such as the data collected by the mussel watch program and by harmful algal

bloom monitoring programs (e.g., ORHAB) are not currently hosted by PaCOOS. Very few data on the state of intertidal and nearshore living resources are available through PaCOOS, although this is a key data need for many management questions and there are a number of monitoring programs collecting the data at the local level and ecosystem region (e.g., PISCO, CRANE, MARINe, CINP, OCNMS intertidal monitoring). In general, biological data for a wide variety of indicator species were needed for the condition reports and very few biological data sets are available through IOOS.

Sydeman and Elliot (2008) discuss a number of gaps in the long-term datasets available for use in regional IEAs. For example the structure of the phytoplankton community (especially the ratio of diatoms to dinoflagellates) appears to be an important index for foodweb development. These data are available in the Monterey Bay region and data collection is commencing in Oregon, but having this type of information available for other locations in the CCE would be extremely valuable. In addition, the authors identify a need for more data collected at the sub-regional and local level. Currently, no single sub-region has the data available for all the physical, chemical, and especially biological indicators required for comprehensive analyses. For a full analysis the ecosystem data has to be combined between regions. However, because there are regional differences within the CCE in climate forcing and ecosystem response, it may prove most useful to evaluate each sub-region separately.

Data on the distribution and abundance of subtidal invertebrates and biogenic habitat was identified as a data gap by the Atlantis NCCE model team (I. Kaplan, NMFS-NWFSC, pers. comm.). Though some data are available through PaCOOS on biogenic habitat (e.g., corals, sponges), the existing data quality is poor relative to the high priority this indicator has for both ONMS and NMFS management needs. The existing Essential Fish Habitat (EFH) data primarily provide kelp and seagrass coverage and sediment type. The best sources of information on the distribution and abundance of structure-forming invertebrates (and the abundance of invertebrates in general) at depths deeper than about 25 meters, are a few scattered studies with limited sample sizes. The Atlantis ecosystem model is focused on groundfish, and one can expect these stocks to be influenced by abundance of invertebrate prey species. Data on the distribution and abundance of benthic invertebrates is a need highlighted in the ONMS condition reports (Table 7-11) and the resources characterization needs outlined in sanctuary management plans (Table 1).

Many other data gaps were identified based on west coast NMS management plans. Though some monitoring data are being collected related to most of the resource characterization (Table 1) and management action needs (Table 2) summarized in the management plans of the five west coast sanctuaries, a very limited amount of that data is currently available through IOOS. Notable gaps include water quality data (e.g., sediment, pathogens, chemical contaminants) and information on most living resources.

Conclusions

Ecosystem-based management requires closely coupled Integrated Ecosystem Assessments to establish a feedback loop on the conditions in the systems under management. These IEAs require observing data that reflect the pressures and ecosystem indicators of concern to managers. The National Marine Protected Area Federal Advisory Committee (2008) identified this need to build strong links between IOOS capabilities and MPAs to provide the data necessary to support adaptive management. Marine protected areas such as national marine sanctuaries reinforce IOOS ocean observation efforts by serving as reference sites to monitor impacts from human activities. The information reported here provides comprehensive assessment of the relationship between IOOS and ocean management requirements. This report brings together information on multiple ecosystem assessment efforts allowing us to identify how existing IOOS capabilities inform IEAs in CCE, where key gaps exist in data necessary to support IEAs, and priorities for closing the gaps. This review recognized four key barriers to fully exploiting ocean-observing data for ecosystem-based management.

Data Discovery

Data have been collected from decades of research and monitoring but managers or scientists cannot easily access them. The most common problems are inconsistency in nomenclature over the history of a data set, incomplete data documentation and quality control, and fragmented data access over the life of the data collection. It is also often difficult to identify data collections relevant to a specific management issue, such as ocean acidification or harmful algal blooms, across data holders. These issues are ones where the IOOS program and others such as NOAA's National Coastal Data Development Center (NCDDC) are making rapid progress by creating standards for data documentation, formatting, and exchange.

Data Access

Bringing existing data into the IOOS system is the primary barrier to access. While in some cases the barrier is primarily one of available resources, there are other factors. There is often a significant lag between data collection and when a principle investigator is willing to make those data available either because of the potential for inappropriate data use or to allow time for their own analysis and publication. The cost and effort of data quality control and assurance is another common barrier. However, cost is not always the problem, access to expertise and computer tools often stymie potential data providers. The data gap is largest in the areas of biological data and data on human activities, the data often most critical to IEAs. There also needs to be a focus on including local data sets that can be highly relevant to specific management actions. For example, it would be useful for data on regional-scale pressures to be collected using the same methods at all locations. Because national programs often prioritize large data sets, multiple data sets at local scales are often overlooked. These are a few of the many cross-organizational issues that are hurdles to incorporating more datasets into IOOS. Solving

data access problems will take a large commitment of funds at the national, regional, and local levels.

Integrating Disparate Data

Ecosystem analysis is fundamentally impeded by disparities among data sets. Those disparities range from incompatible methods, differences in spatial and temporal scale, and inconsistencies in documentation. Tools that help to match management needs with available data, for example bridging the spatial scale of data and the spatial scale of an ecosystem assessment, can help overcome these disparities. The Southwest Fisheries Science Center Environmental Research Division is developing tools that can have a large impact on how managers access and use data. Joint efforts between model developers and managers, such as the Northwest Fisheries Science Center working with Monterey Bay National Marine Sanctuary to implement the Atlantis model, are also key to useful application of observing data. The Atlantis model being implemented in Central California will allow managers to evaluate alternatives by using predictive scenarios to understand the consequences of actions on ecosystem components and humans. This fills a gap in the IEA process for Sanctuaries identified in Figure 1.

Closing the Gap Between Data Needs and Data Collection

One of the key challenges to IEA application to ecosystem-based management is the increase in uncertainty the lack of available data creates for managers. Even if there were no barriers to discovering, accessing, and integrating existing data, effectively developing management alternatives and monitoring outcomes requires investments in data collection. In determining the types of data needed to meet the resource characterization and management actions, we found that while some data are hosted by PaCOOS or regional associations, in most cases, the necessary data are not available for all areas. This makes management unit and ecosystem scale analysis difficult.

Analysis of the indicators and datasets used by sanctuaries in the western region provides an opportunity to identify priority datasets for management at the management unit or larger spatial scale. A priority dataset should meet one or more of the following criteria:

a. Provide the status and trend for one or more indicators related to the questions in the condition report
b. Help accomplish one or more strategies in management plan action plans
c. Observing data collected in more than one west coast sanctuary

While it is important to connect ecosystem assessment and observing data to management requirements, not all management challenges are known in advance. Management areas, like sanctuaries, can serve as sentential sites for detecting, tracking and responding to human-caused and natural changes affecting ocean health. Sentinel sites are places that attract and support collaboration by researchers seeking to understand processes that control ecosystems. This understanding improves our ability to manage the human activities known to affect natural systems, respond to emerging threats, and adapt to changes that are beyond our control. For example, ocean acidification measurements

across all 5 west coast sanctuaries could provide a key indication of changes in ocean chemistry due to atmospheric CO_2 inputs.

IEAs and tools for evaluating management strategies depend upon useful, responsive indictors to address management issues and assess management effectiveness. Those indicators require data with temporal and spatial relevance that allows analyses rich enough to support adaptive management and monitoring of the impacts of management actions and progress towards ecosystem goals. While managers' ability to discover, access, and integrate California Current Ecosystem data is rapidly advancing, significant challenges remain in closing the gap between information needs and data availability and analysis capabilities. Resource managers must make the best decisions possible with available information. This requirement to move forward, even with insufficient data highlights the importance of maximizing the use of what we do have through data management, improved accessibility, improved integration and compatibility, and more comprehensive analysis.

Table 1: Resource characterization needs of the five west coast national marine sanctuaries as described in each site's management plan or in the case of Olympic Coast, management plan review documents. (NOAA 2008a, 2008b, 2008c, 2009).

ID #	Sanctuary	Resource Characterization Need	Specific Topics/Questions	Data Needs	Ocean Observing Data Available though PaCOOS (Appendix I ID #)	Ocean Observing Data Not Available through PaCOOS (Appendix I ID #)	Geographic Scale
		Physical Habitat					
1	OC, CB, GF, CI	Oceanographic Habitat and Processes	Improved characterization of oceanographic and atmospheric conditions including spatial and temporal patterns	wind speed and direction, current direction and speed, air and water temperature, density, salinity, upwelling, nutrients, dissolved oxygen, PAR	WCObs (1); CIMT (3); MOOS (6); NPS HF Radar (8); SEAMAP (55); SWFSC Shipboard Cetacean Surveys (60); CoastWatch (64); CalCOFI (65); MBTS Program (66); NOAA NDBC (68); COCMP (79);	R/V Fulmar and R/V Shearwater data logger (4); MBARI cruise data (11); CDIP/ Wave Rider buoys (14); NEOCO (16); CBOMP (19); TOPP (22); SCCWRP (26); SEAS (28); PnB Project (38); ASOS (52); BML-COS (58); Humboldt Line (69); PRBO At-Sea Surveys (81); Pt. Lobos time series (84)	Large Marine Ecosystem, Ecosystem Region, Management Unit, Local
2	OC, GF, MB	Coastal Habitat and Processes	Improved understanding of nearshore circulation patterns. Monitor coastal and estuarine erosion and sediment transport	nearshore current meters, satellite images; current meters in coastal streams and estuaries; erosion rates; turbidity; currents; sediment transport; salinity	WCObs (1); CIMT (3); NPS HF Radar (8); COCMP (79)	USGS Stream Gauge Network (5); LOBO (12); CDIP/ Wave Rider buoys (14); NEOCO (16); CCLEAN (31); NERR system monitoring (32); SC Co SWQMP (33); CCoWS (34); PORTS (36); PnB Project (38); coastal LiDAR collection (45); MISO (57); PISCO (59); CI-CORE (75)	Management Unit, Local
3	MB	Wetlands	Wetlands: inventory and assessment	map of existing coastal wetlands		coastal LiDAR collection (45)	Ecosystem Region, Management Unit, Local
4	OC, CB, GF, MB, CI	Subtidal Benthic Habitat	Improved characterization of benthic habitat. Improved understanding of spatial distribution of habitats.	high resolution maps of benthos delineating depth, substrate type, relief, rugosity, etc.	OCNMS Habitat Mapping (18); EFH (21); USGS Habitat Mapping (47)	CSUMB-SFML (17); MBARI Monterey Bay Multibeam Survey (20); El Nino coastal erosion study (27); Central CA Habitat Characterization (37); Cordell Bank Habitat Characterization (77)	Ecosystem Region, Management Unit, Local
		Water Quality					

Table 1

ID #	Sanctuary	Resource Characterization Need	Specific Topics/Questions	Data Needs	Ocean Observing Data Available though PaCOOS (Appendix I ID #)	Ocean Observing Data Not Available through PaCOOS (Appendix I ID #)	Geographic Scale
5	GF, MB, CI	Sediment and Nutrients Loads	Develop integrated water quality monitoring for estuarine and nearshore waters. Assess levels of land-based discharges and impacts on Sanctuary resources.	total suspended sediment/ turbidity, nutrients, chlorophyll/ phytoplankton; fresh water flow rates and inputs		USGS Stream Gauge Network (5); LOBO (12); NEOCO (16); SCCWRP (26); CCAMP (30); CCLEAN (31); NERR system monitoring (32); SC Co SWQMP (33); CCoWS(34); PnB Project (38); SWAMP (41); USGS WQ monitoring (49); First Flush (56); USGS SFBay/Delta (63); SFEI RMP (86); Santa Barbara Channelkeeper Stream Team (93); Snapshot Day(100)	Ecosystem Region, Management Unit, Local
6	OC, GF, MB, CI	Pathogens/ Biological Contaminants	Monitoring of pathogens and biological contaminant loads.	bacteria, viruses, HABs		San Diego Ocean Monitoring (24); SCCWRP (26); CCAMP (30); CCLEAN (31); SC Co SWQMP (33); SWAMP (41); SFEI RMP (86); Mussel Watch (88); Santa Barbara Channelkeeper Stream Team (93); Snapshot Day (100)	Ecosystem Region, Management Unit, Local
7	OC, GF, MB, CI	Chemical Contaminants	Monitoring of chemical contaminant loads.	heavy metals, organic pollutants		SCCWRP (26); CCAMP (30); CCLEAN (31); EPA CA coastal Project (39); SWAMP (41); SFEI RMP (86); Mussel Watch (88)	Ecosystem Region, Management Unit, Local
8	OC, CB, GF	Harmful Algal Blooms (HABs)	Track phytoplankton populations to detect HABs. Detect presence of biotoxins in Sanctuary waters or organisms.	bioaccumulation monitoring (mussels, sand crabs, sardine/anchovy); phytoplankton abundance/species composition; bird and mammals stranding	CIMT (3); COASST (15)	BeachCOMBERS (2); LOBO (12); NEOCO (16); CBOMP (19); SEAS (28); CCLEAN (31); PnB Project (38); BeachWatch (54); Mussel Watch (88); MBARI ESP (89); ORHAB (97)	Ecosystem Region, Management Unit, Local
		Living Marine Resources					
9	CB, GF, MB, CI	Biogenic Habitat	Improved characterization, distribution, and abundance of biogenic habitat including deep-sea corals, kelp beds, seagrass beds	Non-destructive sampling methods: video surveys of submerged habitats (reef and soft bottom); aerial surveys of kelp/seagrass to monitor bed location and size	WA Annual Kelp Surveys (9); NWFSC Groundfish Surveys (67)	CA Annual Kelp Surveys (10); CenCA habitat characterization (37); deep-sea corals (43); SBC LTER (51); PISCO (59); CRANE (76); Habitat Characterization/ Biological Monitoring Cordell Bank (77); Love Lab Surveys (78); MARINe (91)	Management Unit, Local
10	OC, GF, MB, CI	Intertidal Habitat (hard bottom); Tidepools	Improved characterization of distribution and abundance of intertial algae, fish, invertebrates; improved understanding of temporal and spatial patterns	repeated surveys of intertidal sites; monitoring of recruitment		OCNMS intertidal monitoring (35); LiMPETS (48); PISCO (59); MARINe (91); PRNS Intertidal Monitoring (95)	Ecosystem Region, Management Unit, Local

Table 1

ID #	Sanctuary	Resource Characterization Need	Specific Topics/Questions	Data Needs	Ocean Observing Data Available though PaCOOS (Appendix I ID #)	Ocean Observing Data Not Available through PaCOOS (Appendix I ID #)	Geographic Scale
11	MB, CI	Intertidal Habitat (soft bottom); Beaches and estuaries	Improved characterization of distribution and abundance of dune plants, invertebrates, shorebirds; improved understanding of temporal and spatial patterns	repeated surveys of dunes and surf zone; shorebird surveys; surveys of mudflats and marshes		LiMPETS (48); BeachWatch (54); ESNERR bird monitoring (90); ESNERR elasmobranch monitoring (92); PRBO Snowy Plover monitoring (96); ESNERR invertebrate monitoring (99)	Ecosystem Region, Management Unit, Local
12	OC, GF, CB, MB, CI	Subtidal Habitat (hard bottom); Kelp Forests and deep reef	Improved characterization of distribution and abundance of demersal, subtidal fish and invertebrates (hard substrate); improved understanding of temporal and spatial patterns	repeated surveys of subtidal reefs; monitoring of recruitment; movement patterns	WA annual kelp surveys (9)	sea otter surveys (7,25); CA annual kelp surveys (10); CDFG/CINP White abalone surveys (40); Deep Sea Corals (43); SBC LTER (51); PISCO (59); REEF Volunteer Surveys (72); CRANE (76); Habitat Characterization/ Biological Monitoring Cordell Bank (77); Love Lab subtidal surveys (78)	Ecosystem Region, Management Unit, Local
13	OC, GF, CB, MB, CI	Subtidal Habitat (soft bottom)	Improved characterization of distribution and abundance of demersal, subtidal fish and invertebrates (soft substrate); improved understanding of temporal and spatial patterns	repeated surveys of subtidal soft bottom habitats including epifauna and infauna; monitoring of recruitment	NWFSC Groundfish Surveys (67)	San Diego Ocean Monitoring (24); SCCWRP (26); CenCA habitat characterization (37); MB Cable Survey (62); CCSF Beach and Ocean Monitoring (74); MLML class trawls (98)	Ecosystem Region, Management Unit, Local
14	OC, GF, CB, MB, CI	Pelagic Habitat (Invertebrates and Fish)	Improved characterization of distribution and abundance of pelagic fishes and invertebrates; improved understanding of temporal and spatial patterns	focus on fisheries independent data: net surveys of phytoplankton, larval fish and inverts, nekton (fish and invertebrates); acoustic backscatter surveys of zooplankton and nekton; satellite tagging	CIMT (3); CalCOFI (65); MBTS Program (66)	CBOMP (19); TOPP (22); SCCWRP (26); SEAS (28); PISCO (59); Humboldt Line (69); PWCC Surveys (80); PRBO At-Sea Surveys (81); MLML class trawls (98)	Ecosystem Region, Management Unit, Local

Table 1

ID #	Sanctuary	Resource Characterization Need	Specific Topics/Questions	Data Needs	Ocean Observing Data Available though PaCOOS (Appendix I ID #)	Ocean Observing Data Not Available through PaCOOS (Appendix I ID #)	Geographic Scale
15	OC, GF, CB, MB, CI	Pelagic Habitat (Seabirds, Turtles, Mammals)	Improved characterization of distribution and abundance of seabirds, turtles, mammals; improved understanding of temporal and spatial patterns	seabird, mammal, marine turtle surveys (aerial, shipboard, land-based, acoustic); satellite tracking; rookery/haulout census	CIMT (3); COASST (15); SEAMAP (55)	BeachCOMBERS (2); sea otter surveys (7,25); SPLASH (13); CBOMP (19); TOPP (22); Tracking Black-footed Albatross (23); SEAS (28); OCNMS offshore surveys (42); SAMSAP (44); USFW seabird colony surveys (46); BeachWatch (54); SWFSC Shipboard Cetacean Surveys (60); SWFSC Central CA Aerial surveys (71); PRBO At-Sea Surveys (81); PRNS pinniped monitoring (94); SBC Aerial Surveys (101)	Ecosystem Region, Management Unit, Local

Table 2: Management drivers of the five west coast national marine sanctuaries as described in each site's management plan or in the case of Olympic Coast, a management plan under review. (NOAA 2008a, 2008b, 2008c, 2009).

Sanctuary	Management Topic	Specific Topics/Questions	Data Needs	General Resource Characterization Needs (Table 1 ID#)	Monitoring Programs Directly Addressing Management Topic (Appendix I ID#)	Geographic Scale
	Marine Protected Areas					
CB, MB, CI	Impacts to Physical Habitat	Detecting impacts of spatial protection to health of the physical habitat inside and outside of MPAs	habitat mapping, monitoring biogenic habitat (corals, kelp, etc.), structure of sediments; compare changes overtime inside and outside MPAs	Subtidal benthic habitat mapping (4); Biogenic habitat surveys (9)		Management Unit, Local
OC, CB, GF, MB, CI	Impacts to Biological Resources	Detecting impacts of spatial protection to health of the biological community inside and outside of MPAs. Evaluate spillover effect for harvested populations. Distinguish between natural and anthropogenic changes.	species composition, richness, diversity of intertidal and subtidal communities; size/age structure, abundance, distribution of populations (including harvested species)	Intertidal habitats (10,11); subtidal benthic habitats (12,13); pelagic habitats (14,15)	CRANE (76); CINMS marine reserve monitoring program [PISCO (59), REEF Volunteer Survey Project (72), Love Lab surveys (78), PIER Acoustic Telemetry Monitoring (82), CINP]	Management Unit, Local
	Detecting Human Impacts					
OC, CB, GF, MB	Fishing	Identifying impacts of fishing on Sanctuary resources. Differentiate between fishing impacts and other human-induced or environmental changes.	size/age structure, biodiversity, density of benthic and pelagic communities (including biogenic habitat); decreased reproductive output (larval abundance or juvenile recruitment); changes in physical structure of habitat; physical oceanography	Intertidal habitats (10,11); subtidal benthic habitats (12,13); pelagic habitats (14,15); biogenic habitat (9); seafloor mapping (4); oceanographic processes (1)	Olympic Coast cable recovery study	Large Marine Ecosystem, Ecosystem Region, Management Unit
MB	Kelp Harvest	Monitor impacts to living resources from kelp harvest	abundance of kelp canopy and associated fish, invertebrates, sea otters; compare areas with harvesting and without harvesting	kelp canopy surveys (9); kelp forest habitat (12); sea otters (15)		Management Unit, Local
OC, GF, MB, CI	Tidepools	Detecting natural and human-induced changes to rocky intertidal habitat. Evaluating impacts of human activities (e.g., trampling, collecting) to tidepool communities	Distribution and abundance of sessile and mobile species at accessible vs. non-accessible sites	rocky intertidal habitat (10)	Tenera Environmental study (Pt. Pinos)	Management Unit, Local

Table 2

Sanctuary	Management Topic	Specific Topics/Questions	Data Needs	General Resource Characterization Needs (Table 1 ID#)	Monitoring Programs Directly Addressing Management Topic (Appendix I ID#)	Geographic Scale
OC, MB	Submerged Cables; Benthic Disturbance	Identifying impacts of submerged cables and other seafloor disturbance to benthic habitats. Identify location of sensitive habitats and species.	Distribution of seafloor habitats, distribution and abundance of sensitive benthic fish and invertebrate species	seafloor mapping (4); subtidal benthic habitat (12,13)	Monterey Bay Cable Survey (62); Olympic Coast cable recovery study	Management Unit, Local
MB	Desalination	Monitor long-term impacts of discharge of desalination facilities.	species composition around discharge; water circulation patterns; salinity	subtidal soft-bottom community (13); coastal processes (2)		Management Unit, Local
MB	Coastal Armoring	Monitor long-term impacts of coastal armoring structures.	monitor size and slope of beaches; develop sand budgets; nearshore currents, sediment transport, wave refraction patterns; map of existing coastal armoring sites; monitor biological community structure	coastal habitat and processes (2); intertidal habitat - beaches (11)	El Nino coastal erosion study (27)	Management Unit, Local
OC, GF, MB, CI	Introduced Species	Detection of new introductions, monitoring populations of existing introduced species.	distribution and abundances of aquatic plants, algae, benthic fish and invertebrates; surveys to detect and monitor introduced species; maps of current distribution of introduces species; plankton surveys to detect larvae of introduced species	intertidal habitats, especially estuaries (10,11); subtidal habitats (12,13); pelagic habitats (14)	MBNMS *Undaria* monitoring, ESNERR "least wanted" monitoring program;	Management Unit, Local

Table 2

Sanctuary	Management Topic	Specific Topics/Questions	Data Needs	General Resource Characterization Needs (Table 1 ID#)	Monitoring Programs Directly Addressing Management Topic (Appendix I ID#)	Geographic Scale
OC, GF, MB	Special Status Species	Improved understanding of population size and trends for special status species (species listed under the federal or state ESA or those designated as overharvested by NMFS) or other sensitive species identified by Sanctuary program. Identification of critical habitats for these species. Identification of causes of mortality.	distribution, abundance and population trends of special status and sensitive species; monitoring of sick, stranded, and dead organisms animals	intertidal habitats (10,11); subtidal habitats (12,13); pelagic habitats (14,15)	Black Abalone monitoring; BeachCOMBERS (2), BeachWatch (54), COASST(15); most studies listed under "Pelagic habitat characterization - seabirds, turtles, mammals; PRNS pinniped monitoring (94); Xantus's Murrelet, Brown Pelican & Ashy Storm-Petrel nest monitoring (CINMS); Cascadia cetacean monitoring; USFWS Marbled Murrelet surveys; USFWS Common Murre restoration; PRBO Snowy Plover monitoring (96); sea otter necropsies	Large Marine Ecosystem, Ecosystem Region, Management Unit
OC, GF, MB, CI	Wildlife Disturbance	Disturbance to wildlife from human activities (e.g., marine vessels, low flying aircraft, acoustics): detecting disturbance and identifying sensitive areas, seasons, and migration routes	bird, mammal, and turtle distributions, movement patterns over time, location and magnitude of disturbance; GIS database of mammal sightings	pelagic habitats - seabirds, turtles, mammals (15)	SEALS program; CIMT passive acoustic monitoring (3); TeamOCEAN; BeachCOMBERS (2), BeachWatch (54), COASST (15)	Ecosystem Region, Management Unit, Local
CB, GF, MB	Entanglement/ Marine Debris	Identify impacts to wildlife from entanglement in active and abandoned fishing gear, aquaculture pens. Identify impacts of other marine debris (e.g., plastic debris). Monitor and inventory marine debris in the Sanctuary.	location and abundance of beach cast birds, mammals; observer data of entanglement in active fishing gear; GIS database to track type, location, and amounts of debris; bird and mammals surveys	pelagic habitats - seabirds, turtles, mammals (15)	BeachCOMBERS (2), BeachWatch (54), COASST (15); Fishery bycatch and mortality (SWFSC); CBOMP (19)	Large Marine Ecosystem, Ecosystem Region, Management Unit, Local
OC, GF, CI	Oil or Chemical Spill	Improve spill and drift models.	surface currents, fine-scale bathymetry, biological productivity	Oceanographic Habitat and Processes(1); Coastal habitat and Processes(2);		Large Marine Ecosystem, Ecosystem Region, Management Unit

Table 2

Sanctuary	Management Topic	Specific Topics/Questions	Data Needs	General Resource Characterization Needs (Table 1 ID#)	Monitoring Programs Directly Addressing Management Topic (Appendix I ID#)	Geographic Scale
OC, GF, MB	Oil or Chemical Spill; Landslide	Predicting impacts to and tracking recovery of Sanctuary resources.	intertidal community structure; subtidal community structure; biogenic habitat (e.g., kelp, seagrass); seabird colony size; mammals rookery/haul-out size; seabird, turtle, mammal foraging hotspots	Biogenic habitat (9); intertidal habitat (10,11); subtidal habitat (12,13); pelagic habitats - seabirds, turtles, mammals (15)	BeachCOMBERS (2), BeachWatch (54), COASST(15)	Ecosystem Region, Management Unit, Local
	Ecosystem Monitoring and Assessment					
OC, CB, GF, MB	Integrated analysis and synthesis to determine the health of the ecosystem and track changes over time (e.g., SWiM condition reports)	How are the physical and biological resources changing in the ecosystem? How do changes in physical processes affect the distribution and abundance of organisms? How are changing oceanographic conditions affecting productivity and trophic dynamics?	extensive characterization of the physical process and biological resources	All characterization data sources (1-15)	CIMT (3); CBOMP (19)	Large Marine Ecosystem, Ecosystem Region, Management Unit, Local
MB	Integrated Monitoring of Big Sur Coast	Integrated GIS database for Big Sur coastal and marine resource management	maps of physical and biological resources along Big Sur coast (updated through "live" portals)	All characterization data sources (but only data collected along Big Sur Coast)	WCObs (1); PISCO (59); CRANE (76)	Management Unit, Local

Table 3: Description of Ecosystem Assessments in the California Current Ecosystem

Name	**Purpose**	**Geographic Scale**	**Output Type**	**Drivers/ Pressures**	**Datasets used that are available through PaCOOS**
Atlantis Ecosystem Model	Spatially explicit ecosystem modeling and management strategy evaluation	California Current Ecosystem; Central California ecosystem region	Dynamic	Natural and anthropogenic, with emphasis on fisheries-related drivers.	GLOBEC, EFH, CalCOFI, NWFSC Groundfish Surveys, West coast groundfish observer program, California Fish Landings
California Current IEA, Module I	Identifying biological indicators of ecosystem state and ocean climate	California Current Ecosystem; (3 ecosystem regions proposed)	Static	Natural and anthropogenic, with emphasis on drivers impacting top vertebrate predators	CIMT, CalCOFI, NWFSC Groundfish Surveys, MBTS?
NCEAS California Current Marine Ecosystem Human Impacts Assessment	Mapping how human activities are affecting marine ecosystems	California Current Ecosystem; and 6 ecosystem regions	Static	Anthropogenic	Annual Kelp Surveys, EFH, AVHRR Pathfinder Satellite data, California Fish Landings
ONMS SWiM Condition Reports	Assessing the status and trends of water, habitat, and living resources and the human activities that affect them	5 management units	Static	Natural and anthropogenic	CIMT, NWFSC Groundfish Surveys, COASST, MBTS, Annual kelp surveys, CSUMB-SFML, USGS Pacific Coast Habitat Mapping Program, MBARI multibeam survey, OCNMS Habitat Mapping
MBCORC Report Card	Assessing ecosystem health using a series of indicators	1 local site (Monterey Bay)	Static	Natural and anthropogenic, with emphasis on anthropogenic	CIMT, NWFSC Groundfish Surveys, MBTS, California Fish Landings
MBCORC Virtual Monterey Bay	Coastal oceanographic observing and modeling system	1 local site (Monterey Bay)	Dynamic	Primarily natural	Not yet available

Table 4: Comparing two Ecosystem Assessments for the California Current Ecosystem.

California Current IEA, Module I (Sydeman and Elliott 2008)	**Northern California Current Ecosystem, Atlantis model** (Brand et al. 2007)

Geographic Range:
• Entire California Current Ecosystem (Vancouver Island, British Columbia, Canada to Punta Eugenia, Baja California Mexico)
• Considering creating separate IEAs for the three sub-ecosystems
  o Northern: southern B.C. to Cape Blanco, southern Oregon
  o Central: Cape Blanco to Pt. Conception
  o Southern: Pt. Conception to Punta Eugenia, Baja Mexico
	Geographic Range:
	• Atlantis model has been created for the Northern California Current Ecosystem (Cape Flattery, Washington to Point Conception, California).
	• In the process of creating separate models for Puget Sound and central California

Drivers/Pressures: The Module I IEA will probably work better for drivers that operate at large spatial scales and/or impact foodweb dynamics, especially top vertebrate predators:
• Environmental change
  o Climate change / climate warming
  o ENSO events
  o PDO phases
  o Ocean acidification (maybe)
• Wildlife disturbance
  o Bycatch/ entanglement/ marine debris
  o Oil spill
  o Harmful Algal Blooms
	Drivers/Pressures: The Atlantis model will work for drivers that operate at the scale of the boxes in the model and impact large biomass population in the middle of the foodweb. May be able to detect changes in abundance of habitat type (at a large scale) and/or living resources with strong habitat associations:
	• Environmental change
	• Fishing-related removal of biomass
	  o Gear-types
	  o Spatial patterns
	  o Temporal patterns
	• Gear-related impacts to benthic habitat
	• Bycatch/entanglement (of species with medium to high biomass)
	• Species introductions (e.g., jumbo squid)

Indicators: This model is currently based on the following indicators:
• Environmental indices
  o Basin-scale PDO index
  o Basin-scale ENSO index
  o Sub-ecoregion Wind, Upwelling, SST
• Zooplankton
  o Copepod species richness and biomass indices (Newport Hydrographic Line)
  o Small plankton volume index (CalCOFI data)
  o Krill abundance (*Thysanoessa spinifera*) in diet of fish (Vancouver Island Zooplankton study)
  o Krill abundance in diet of Cassin's Auklet (Southeast Farallon Island Seabird Ecology Surveys)
	Indicators: this model is based on the following indicators:
	• Benthic Habitat (from EFH data set)
	  o Sediment type (hard or soft)
	  o Kelp and seagrass
	• Hydrographic submodel
	  o Nutrients
	  o Salinity
	  o Dissolved oxygen
	• Ecology submodel contains 54 biomass pools (species or functional groups)
	  o Abundance and distribution information
	  o Growth and consumption rates
	  o Reproduction rates
	  o Migration rates
	  o Predator-prey dynamics

Table 4

California Current IEA, Module I (Sydeman and Elliott 2008)	**Northern California Current Ecosystem, Atlantis model** (Brand et al. 2007)

• Squid abundance from fishery landings and diet of CA sea lions
• Forage fish
  o Anchovy egg abundance (CalCOFI data)
  o Sardine egg abundance (CalCOFI data)
  o Juvenile rockfish abundance in surveys (Rockfish Recruitment Surveys) and diet of Common Murre (Southeast Farallon Island Seabird Ecology Surveys)
• Vertebrate predators
  o Coho salmon survival and juvenile coho growth
  o Pacific hake biomass (NWFSC Groundfish Surveys)
  o Seabird breeding success (Southeast Farallon Island Seabird Ecology Surveys)
  o CA sealion pup abundance (Pinniped Aerial Surveys Project)
	This model works best for indicators that have:
	• Medium to high biomass
	  o especially good for species with good information / high volume in fisheries (as bycatch or target species)
	  o not good for species with small biomass levels
	• Good information on feeding habits
	  o model works well for main predators in the study system
	• Good information on spatial distribution;
	  o model works well for species with widespread distribution in the study area
	  o model works well for species that spend most of their time in the study area
	  o Not good for highly migratory species and/or seasonal visitors

ONMS or NMFS management needs
• Characterization of primarily pelagic habitat, species, and foodweb
• Special status species management
• Wildlife disturbance issues
• Offshore Spatial Management (identification of hotspots / pelagic MPAs / areas to avoid for offshore energy production or aquaculture)
	ONMS or NMFS management needs
	• Characterization
	  o pelagic habitat and foodweb especially middle levels of foodweb
	  o benthic habitat and demersal fishes
	• Fisheries management
	  o Gear changes
	  o Size limits
	  o Take restrictions
	• Spatial management
	  o Time-area closures
	  o Marine protected areas (fewer larger MPAs will be easier to model than many smaller MPAs)
	• Special Status Species (those with medium biomass and/or fairly resident in area)

Table 5

Table 5. Human activities that are potential drivers and pressures in the California Current Ecosystem as identified by the National Center for Ecological Analysis and Synthesis (NCEAS) working group (Carrie Kappel, NCEAS, pers. comm.). The availability of ecosystem-wide observing data used to assess the impact of the pressures on ecosystem resources are identified. Authors decided against inclusion of data for some human activities for various reasons, such as too difficult to model with available data and comprehensive dataset not available.

Human Activities	**Data Source**	**Data Not Available**	**Decided Against**
Land-based			
Agriculture	National Atlas of Canada		
Industrial farms	EPA Toxics Release Inventory		
Small farms		X	
Urbanization	National Atmospheric Deposition Program		
Land infill		X	
Forestry		X	
Road building		X	
Shoreline hardening	NOAA's Environmental Sensitivity Index (ESI)		
Estuarine mouth alterations		X	
Salt ponds/mines		X	
Human access to beaches, intertidal	California Coastal Access Guide; Oregon Geospatial Enterprise Office; Washington State Department of Ecology BEACH Program		
Atmospheric deposition	National Atmospheric Deposition Program		
Dams	National Inventory of Dams (Army Corps of Engineers)		
Sewage outfall/ Septic	EPA Toxics Release Inventory		
Factories	EPA Toxics Release Inventory		
Paper/ Pulp mills	EPA Toxics Release Inventory		
Mines	EPA Toxics Release Inventory		
Ocean-based			
Aquaculture			
Marine plant		X	
Shellfish		X	
Finfish (herbivores)		X	
Finfish (predators)	visually located using Google Earth		
Fishing			
Demersal destructive	California Fish Landings; FAO & Sea Around Us Project		
Demersal non-destructive low bycatch	California Fish Landings; FAO & Sea Around Us Project		
Demersal non-destructive high bycatch	California Fish Landings; FAO & Sea Around Us Project		
Pelagic low bycatch	California Fish Landings; FAO & Sea Around Us Project		
Pelagic high bycatch	California Fish Landings; FAO & Sea Around Us Project		
Aquarium fishing		X	
Recreational fishing	California Recreational Fisheries Survey		
Artisanal fishing	FAO & Sea Around Us Project		
Forestry operations			
Log booms, dumps, sorts		X	
Scientific research			
Collecting			X
Experiments			X
Surveys			X
Ocean mining		X	

Table 5

Human Activities	Data Source	Data Not Available	Decided Against
Dredging		X	
Shipping			
Commercial shipping traffic	World Meteorological Organization Voluntary Observing Ships Scheme		
Cruise ship traffic		X	
Ferry traffic	Department of Transportation (California and Washington)		
Invasive species (Ports)	US Army Corps of Engineers Navigation Data Center		
Oil rigs	Pacific States Marine Fisheries Commission		
Ocean dumping			
Marine debris on beaches	California Coastal Commission Public Education Program		
Toxic materials		X	
Lost fishing gear		X	
Ship wrecks			X
Tourism			
SCUBA diving			X
Recreational boating			X
Kayaking			X
Power or Desalination plants	Platts database (part of McGraw-Hill Companies)		
Military Activity			X
Harmful Algal Blooms		X	
Hypoxic zones		X	
Ocean pollution (oil, chemicals)	California Coastal Commission Public Education Program		
Climate change			
Sea surface temperature	AVHRR Pathfinder Version 5.0 SST data		
UV radiance	GSFC TOMS EP/TOMS satellite program at NASA		
Ocean acidification	aragonite saturation state (Guinotte et al. 2003)		
Sea level rise		X	

Table 6. Drivers and pressures identified in the condition reports for Olympic Coast (OC; ONMS 2008), Cordell Bank (CB; ONMS 2009b), Gulf of the Farallones (GF; ONMS DRAFT), Monterey Bay (MB; ONMS 2009c), and Channel Islands (CI; ONMS 2009a) National Marine Sanctuaries. Grey shading is used to identify the three sanctuaries that occur in the central California sub-region. X = current pressure; E = emerging pressure

Drivers	Pressures	OC	CB	GF	MB	CI	Potential impacts
Seafood consumption; Commerce; Recreational activities	Harvesting - targeted species	X	X	X	X	X	Population, community, and ecosystem-level impacts from biomass reduction and removal of forage species or predators
Seafood consumption; Commerce; Recreational activities	Harvesting - bycatch		X		X	X	Entanglement in active fishing gear by mammals, birds, turtles; Harvest of non-target fishes and invertebrates
Seafood consumption; Commerce; Recreational activities	Harvesting - habitat impacts	X	X	X	X	X	Disturbance to seafloor habitat and biogenic habitat from bottom-contact gear; Disturbance of seabirds and mammals from lights
Seafood consumption	Land-based/Nearshore Aquaculture	E		X	X	E	introduction of pathogens, chemicals, non-native species; eutrophication and/or harmful algae blooms near enclosures or discharges; disturbance of kelp-associated species from kelp harvest to feed cultured abalone; disturbance to seabed
Seafood consumption; Recreational activities; Land-based commerce and development; Maritime trade	Marine debris (lost fishing gear, plastics, etc.)	X	X	X	X	X	Entanglement of habitat, organisms, humans, and vessels; Diminished aesthetic qualities of sanctuary; Ingestion; Transfer of disease, harmful chemicals, non-indigenous species
Maritime trade (vessel traffic, cruise ships, marinas, sunken vessels); Petroleum exploration, production, and refining	Oil and hazardous material spill	X	X	X	X	X	wildlife injury and mortality (seabirds, marine mammals, intertidal communities); habitat degradation (physical and biogenic); fishing closures; water quality; reductions in tourism and local economy
Maritime trade; National security (military operations)	Vessel traffic	X	X	X	X	X	noise pollution (see below); oil or hazardous material spill; lost containers and other large debris; Disturbance to wildlife (e.g., mammals, sharks); Collisions with mammals, turtles
Commerce and development	Global climate change	E	X	E	E	X	sea level rise, temperature increase, acidification, etc.; changes in species distribution, primary productivity, community composition, etc.
Oceanographic conditions	Natural shifts in climate: seasonal, annual, and longer-term (ENSO/PDO)	X	X	X		X	shifts in prey availability and distribution; altered body condition, survivorship and reproductive success; shifts in migratory patterns and timing
Maritime trade; Seafood consumption (aquaculture. harvesting); Aquarium trade; Research; Restoration	Non-indigenous species	X	X	X	X	E	competing with or preying on native and harvested species; altering species composition; altering ecosystem function; habitat degradation; disrupting commercial and recreational activities; introduction and spread of infectious disease

Table 6

Drivers	Pressures	OC	CB	GF	MB	CI	Potential impacts
Maritime trade (marinas); Seafood consumption, Recreational activities	Dredging and dredge material disposal			X	X		physical disturbance to seafloor and benthic organisms; burial of benthic organisms; chemical contamination; turbidity; alteration of water flow and sedimentation and erosion rates
Commerce and development	Coastal armoring			X	X		habitat conversion or loss; alteration of erosion and sediment transport and deposition patterns;
Commerce and development	Road construction and landslide disposal			X	X		burial of intertidal and subtidal habitat and organisms; increased sand scour
Livestock and agriculture; Forestry; Maritime commerce (marinas and cruise ships); Coastal development	Sediment and nutrient pollution	X		X	X	X	elevated nutrient levels, sedimentation, turbidity; harmful algal blooms;
Livestock and agriculture; Maritime commerce (marinas and cruise ships); Coastal development	Chemical pollution (pesticides, oil and grease, heavy metals, detergents, industrial chemicals, radioactive waste)		X	X	X	X	contamination of water, habitat and food chain; health impacts to animals and humans
Livestock and agriculture; Maritime commerce (marinas and cruise ships); Coastal development	Biological contamination (biotoxins/harmful algal blooms, bacteria, protozoa, viruses)	X	X	X	X	X	contamination of water, habitat and food chain; health impacts to animals and humans; beach closures
Ecotourism; Research; Seafood consumption; Recreational Activities	Wildlife disturbance - shore-based (tidepoolers, hikers)	X		X	X	X	trampling; collecting; flushing breeding, foraging, and resting seabirds and mammals;
Ecotourism; Research; Seafood consumption; Recreational Activities	Wildlife disturbance - water-based (whale, bird and shark watching, kayaking, surfing, SCUBA)	X		X	X	X	flushing breeding, foraging, and resting seabirds and mammals;
Ecotourism; Research; Coastal commerce; National security (military operations)	Wildlife disturbance - aircraft	X		X	X		flushing breeding, foraging, and resting seabirds and mammals; collisions with whales, sea otters
National security (military operations); Petroleum exploration; Maritime trade; Research	Wildlife disturbance: noise pollution/sonar	X	X	X	X	X	altered behavior, injury, or death in marine mammals and fish;
Commerce and development; National security (military operations); Research	Submerged cables	X			X		seafloor habitat disturbance; entanglement of anchors, fishing gear and organisms
Commerce and development	Ocean-based energy generation	E			E		damage to seafloor habitat, disturbance of marine mammals and seabirds
Commerce and development	Open-Ocean Aquaculture	E			E	E	pathogen and nutrient loading, seafloor disturbance, entanglement or other disturbance to wildlife
Commerce and development	Desalination				X		brine waste effluent, disturbance to the seafloor; entrainment and impingement of fish and invertebrates
Maritime trade; National Security (military operations); Fishing; Recreational Activities	Sunken vessels	X		X	X		release of hazardous materials (e.g., fuel), entanglement of fishing gear, anchors, etc.

Table 6

Drivers	Pressures	OC	CB	GF	MB	CI	Potential impacts
Commerce; Research	Bioprospecting					E	excessive removal of marine life or plants; habitat disturbance; alteration to structure or function of the community or local ecosystem

Table 7. Datasets used to assess the current condition of water, habitat, and living resources as identified in the condition report for the Olympic Coast National Marine Sanctuary (ONMS 2008). References listed in this table can be found in the "Cited Resources" section of the OCNMS condition report. Blue Text = lack of information noted in report. Green Text = Project ID # from Appendix 1.

Questions	Indicators	Source
Water		
1) Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality?		
	dissolved oxygen	oceanography monitoring stations (OCNMS monitoring data); long-term dataset in sanctuary waters lacking
	dead crabs, fish kills	reported observations (Quinault Natural Resources Department)
	seawater acidity (pH), water temperature, current direction and velocity, fluorometry, conductivity	Wootton unpublished data, Grantham et al. 2004, Barth et al. 2007, Chan et al. 2008; oceanography monitoring stations (OCNMS monitoring data)
	HABs/domoic acid levels in razor clams	monitoring since early 1990s (Washington Department of Fish and Wildlife); long-term dataset not available
	chemicals in water, sediment and biota at 30 stations in OCNMS	30 stations sampled as part of EMAP in 2003 (Partridge 2007); long-term monitoring of some chemicals (NOAA's Status and Trends, Mussel Watch Program (ID 88))
2) What is the eutrophic condition of sanctuary waters and how is it changing?		
	nutrient concentrations in coastal waters	EMAP 2003/Partridge 2007; long-term datasets and sufficient instrumentation are lacking - trend unknown
	water circulation/nutrients/primary production/HABs	satellite imagery (temperature, color), buoy data in and near OCNMS; Foreman et al. 2007, MacFadyen et al. 2008
3) Do sanctuary waters pose risks to human health?		
	biotoxins (PSP and ASP) in shellfish	routine monitoring since 1991 (coastal tribes and Washington Department of Health)
	Harmful Algal Blooms	monitoring began in the 1990s (Juan de Fuca Eddy Steering Committee 2004; Trainer 2005; Trainer & Suddeson 2005)
	bacteria (e.g, fecal coliform, *E. coli, Enterococcus*) in marine waters	Washington Department of Health 2008; Surfrider's Blue water task force 2003-05; limited monitoring
4) What are the levels of human activities that may influence water quality and how are they changing?		
	frequency and tracks of vessel traffic	Canadian vessel traffic system at mouth of Strait of Juan de Fuca; Marine Exchange of Seattle vessel tracking throughout sanctuary
	timber harvest levels	general public information; data not researched
	annual number of cruise ship passengers through the Port of Seattle (2000-2007)	WDOE 2008
	coastal population size and rate of coastal development	Chamber of Commerce and US Census
Habitats		
5) What is the abundance and distribution of major habitat types and how is it changing?		
	relative abundance of species and number of trampled organisms in rocky intertidal	infrequent monitoring of high and low traffic sites (Erickson and Wullschleger 1998; Erickson 2005)
	high resolution imaging of seafloor	Intelmann 2006; Bowlby et al. 2008, unpublished OCNMS data (ID 18)
	low resolution mapping surveys	Intelmann 2006; Bowlby et al. 2008, unpublished OCNMS data (ID 18)

Table 7

Questions	Indicators	Source
	seafloor habitat (impacts of submarine cable installation and bottom contact fishing gear); ROV and video used	periodic monitoring on submarine cable route and benthic surveys (OCNMS data)
	location and intensity of bottom trawling effort	Shoji 1999, National Marine Fisheries Service and Washington Department of Fish and Wildlife data
	groundfish landings	Shoji 1999; National Marine Fisheries Service data
	number of vessels in the trawl fishery	Shoji 1999
6) What is the condition of biologically-structured habitats and how is it changing?		
	abundance and distribution of rocky intertidal macroalgae and invertebrates	monitored since 1989 (Olympic National Park and OCNMS data (ID 35)
	spatial extent of kelp canopy	monitored since 1989 (Washington Department of Natural Resources, in collaboration with OCNMS since 1995) (ID 9)
	distribution and abundance of subtidal structure-forming invertebrates	NWFSC Groundfish Surveys (ID 67) data since 1980 (Whitmore and Clarke 2007); occasional observations (Etnoyer and Morgan 2003); OCNMS video surveys in limited areas (Brancato et al. 2007 (ID 43)); aerial extent of monitoring data is very limited
	Location of hard substrate with potential to host biologically-structured habitat	Essential Fish Habitat (ID 21)
7) What are the contaminant concentrations in sanctuary habitats and how are they changing?		
		limited data available to determine trends
	PCBs, DDT, and other chlorinated pesticides	30 stations sampled as part of EMAP in 2003 (Partridge 2007)
	PAHs and metals in the sediment	Washington State Department of Ecology 1995
	Silver and chromium in sediments	Long et al. 1995, O'Connor 2004
	Chemical concentrations of contaminants in tissues in a variety of invertebrates and sea otters	NOAA's Status and Trends, Mussel Watch Program (ID 88); EMAP 2003 study; Brancato et al. 2006
	tar balls on beaches and oil sheens	noted during monthly beach surveys for dead seabirds (COASST monitoring data (ID 15))
	deposition of atmospheric contaminants	some air contaminant monitoring conducted in adjacent freshwater systems
8) What are the levels of human activities that may influence habitat quality and how are they changing?		
	bottom trawl effort	WDFW and NMFS data
	area subject to commercial trawling	Shoji 1999; National Marine Fisheries Service data
	visitation rates and locations in Olympic National Park	on-going monitoring (Olympic National Park data)
	other intertidal recreational harvesting activities	haphazard and infrequently monitored
	trampling and intertidal exploration	Erickson 2005; not currently monitored
	razor clam digs (harvesting activity)	on-going monitoring (Erickson and Wullschleger 1998)
	amount and location of marine debris on beaches	annual beach cleanup event since 2000 (OCNMS data)
	location and type of subtidal derelict fishing gear	one-time subtidal survey around Cape Flattery (OCNMS data); limited area of survey
	rates of coastal development, road building, timber harvest	anecdotal information
	location and frequency of military operations	broad area information only; no details on types of operations
	location and frequency of underwater noise generation	monitoring data not available

Table 7

Questions	Indicators	Source
	location and intensity of vessel traffic	vessel traffic monitoring (Canadian vessel traffic system; Marine Exchange of Seattle)
Living Resources		
9) What is the status of biodiversity and how is it changing?		
		No monitoring of biodiversity except in the intertidal portion of the OCNMS
	biodiversity in the rocky intertidal	monitored at sites in ONP since 1989 (Olympic National Park data and OCNMS data (ID 35)); Dethier 1995
	abundance of harbor seals	On-going monitoring by WDFW (Jeffries et al. 2003)
	abundance of sea otters	on-going collaborative monitoring program (WDFW, USFWS, and OCNMS data (ID 25)); Lance et al. 2004
	seabird abundance (especially Common Murre, Tufted Puffin, Marbled Murrelet, Cassin's Auklet, Brandt's Cormorant)	monitored during periodic flights and cruises (US Fish and Wildlife Service (ID 46) and OCNMS data (ID 42))
	abundance of assessed fished stocks	NMFS /PFMC stock assessments
	fish species of concern	no monitoring studies focused on population changes in sanctuary waters
	abundance and distribution of listed marine bird and mammal species	some species monitored during periodic flights and cruises (US Fish and Wildlife Service (ID 46) and OCNMS data (ID 42))
	biodiversity of deep water fish assemblages	Rogers and Pikitch 1992, Jagielo et al. 2003; very limited monitoring
	biodiversity in deep water invertebrate communities	Etnoyer and Morgan 2003, Morgan et al. 2006, Lumsden et al. 2007, Brancato et al. 2007 (ID 43); very limited monitoring
10) What is the status of environmentally sustainable fishing and how is it changing?		
	abundance of 22 groundfish species managed at the species level	NMFS/PFMC stock assessments (PFMC 2008a)
	other groundfish grouping or stock complexes	assessed and managed in groupings or stock assessments not available or insufficient data available
	abundance of groundfish species in OCNMS and/or off Washington state	data collected and available (NWFSC Groundfish Surveys (ID 67)), but not analyzed at this spatial scale
	Dungeness crab landings and number of license holders	Washington Department of Fish and Wildlife data
	pink shrimp landings and number of vessels in fishery	Washington Department of Fish and Wildlife data
	Pacific halibut spawning biomass off WA, OR, CA combined	NMFS 2004
	landings from ocean troll fishery for salmon off WA	PFMC 2008b
11) What is the status of non-indigenous species and how is it changing?		
	abundance of *Sargassum muticum*	ONP and OCNMS observations
	range expansion of green crab	collaborative monitoring program (OCNMS and other partners including Canada)
	intertidal surveys	OCNMS Rapid Assessment 2001-2002
	monitoring for invasives	one-time snapshot in 2005 using settlement plates (deRivera et al. 2005); OCNMS monitoring
12) What is the status of key species and how is it changing?		
	abundance of 5 seabird species of concern	monitoring along Washington coast (WDFW data; Wahl and Tweit 2000, Manuwal et al. 2001, Warheit and Thompson 2003, Wahl et al. 2005, Raphael 2006; Lance et al. 2008)

Table 7

Questions	Indicators	Source
	abundance of sea otters	annual census since 1989 (ID 25) (Jameson and Jeffries 2008)
	abundance of deep sea coral and sponge communities	OCNMS data primary source (ID 43); aerial extent of monitoring is limited
	regional abundance of groundfish stocks	few stock assessments are completed at the regional level
13) What is the condition or health of key species and how is it changing?		
	pathogens and chemical contaminants in sea otters	Brancato et al. 2006
	contaminant loads in killer whales	Ross et al. 2000, Ross 2006
	genetic variability in sea otters	Larson et al. 2002
	age structure in rockfish	PFMC 2008a; data not available for all species
	mortality and reproductive rates of Common Murres	Parrish et al. 2001, Warheit and Thompson 2003
	beach-cast seabirds	COASST monitoring data since 1999 (ID 15), Hass and Parrish 2000
	nesting success in Marbled Murrelets	Raphael and Bloxton 2008
14) What are the levels of human activities that may influence living resource quality and how are they changing?		
	shipping traffic frequency and location/risk of oil spill	vessel traffic monitoring (Canadian vessel traffic system; Marine Exchange of Seattle); Washington Dept. of Ecology data
	location and intensity of fishing activity	National Marine Fisheries Service and Washington Department of Fish and Wildlife data

Table 8. Datasets used to assess the current condition of water, habitat, and living resources as identified in the condition report for the Cordell Bank National Marine Sanctuary (ONMS 2009b). References listed in this table can be found in the "Cited Resources" section of the CBNMS condition report. Blue Text = lack of information noted in report. Green Text = Project ID # from Appendix 1

Questions	Indicators	Source
Water		
1) Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality?		
	salinity, water temperature, fluorescence chlorophyll-a levels, stratification	Cordell Bank Ocean Monitoring Program (CBOMP) monthly cruises (ID 19) unpubl. data
	satellite-based-SST (AVHRR), chlorophyll-a levels (SeaWiFS) and turbidity (SeaWiFS) assessed for 1997-2004	Stumpf et al. 2005
	upwelling index, regional buoy data (not specific to CBNMS)	Peterson et al. 2006
	terrestrial-based floating debris and trash	CBOMP monthly cruises (ID 19) unpubl. data
	compounds in treated wastewater (e.g., pharmaceuticals, personal care products, household chemicals)	concern, but no data available
2) What is the eutrophic condition of sanctuary waters and how is it changing?		
	monthly chlorophyll-a levels 1997-2008	1997-2004 in Stumpf et al. 2005; 2004-present CBOMP monthly cruises (ID 19) unpubl. data
	chlorophyll-a and presence of HABs	CBOMP monthly cruises (ID 19) collects samples; samples analyzed by and data available from California Department of Health Services
3) Do sanctuary waters pose risks to human health?		
	HABs [dinoflagellate *Alexandrium catenella*, diatom *Pseudonitzschia* spp]	CBOMP monthly cruises (ID 19) collects samples; samples analyzed by and data available from California Department of Health Services
	discharges from cruise ships	concern, but no data available
4) What are the levels of human activities that may influence water quality and how are they changing?		
	Large vessel traffic (1999-2005)	USCG Automatic Identification System unpubl. data
	discharges from large vessels and cruise ships	no data available
Habitats		
5) What is the abundance and distribution of major habitat types and how is it changing?		
	High resolution backscatter and bathymetry data	California State University Monterey Bay - Seafloor Mapping Lab (CSUMB-SFML) (ID 17); not enough data to determine trend
	benthic communities, habitats, derelict fishing gear	Habitat Characterization and Biological Monitoring of Cordell Bank submersible surveys 2001-2005 (ID 77); CBNMS continental shelf soft bottom community characterization camera sled surveys 2004, 2007 (ID 37)
6) What is the condition of biologically-structured habitats and how is it changing?		
	benthic communities, habitats; derelict fishing gear	Habitat Characterization and Biological Monitoring of Cordell Bank submersible surveys 2001-2005 (ID 77); CBNMS continental shelf soft bottom community characterization camera sled surveys 2004, 2007 (ID 37); not enough data to determine a trend
7) What are the contaminant concentrations in sanctuary habitats and how are they changing?		
	contaminants (e.g., DDT, PCB, PAH) in sediments (limited samples from shelf and	I. Hartwell, unpublished data

Table 8

Questions	Indicators	Source
	slope in CBNMS and Bodega Canyon)	
	contaminants in benthic habitats	Very limited data; further work is needed to understand contaminant levels, transport pathways, and changes in contaminant concentrations over time
8) What are the levels of human activities that may influence habitat quality and how are they changing?		
	Fishing with bottom-tending fishing gear	no monitoring data available
Living Resources		
9) What is the status of biodiversity and how is it changing?		
	seabird population size, migratory species population size, local breeding colony size, mortality rates and reproductive success rates	shipboard monitoring of seabirds during NMFS rockfish recruitment cruises (data published in Ainley and Hyrenbach 2007), Sydeman et al. 2006
	marine mammals stock assessments	Carretta et al. 2007
	distribution of marine mammal in CBNMS	CBOMP monthly cruises (ID 19) unpubl. data, PRBO Conservation Science at-sea monitoring unpubl. data (ID 81); Peterson et al. 2006
	krill abundance	Peterson et al. 2006; PRBO Conservation Science at-sea monitoring (ID 81), Sydeman et al. 2006, Jahncke et al. 2008
	Abundance of groundfish stocks	NMFS/PFMC stock assessments (PFMC 2006)
	Abundance of pelagic juvenile rockfish	Peterson et al. 2006; S. Ralston, unpubl. data, SWFSC Rockfish Recruitment Surveys
	Rockfish fish assemblage	Baskett et al. 2006; Habitat Characterization and Biological Monitoring of Cordell Bank submersible surveys 2001 - 2005 (ID 77); Anderson et al. 2009
	reef-top invertebrates shallower than 60 m	photos from 1970s (Schmieder 1991) and 2005 (ID 77; CBNMS unpubl. data)
	soft bottom invertebrates	limited data on continental shelf (CBNMS camera sled surveys 2004, 2007 (ID 37)), no data for continental slope invertebrates
	pelagic invertebrates (including Humboldt squid)	Zeidberg and Robison 2007
10) What is the status of environmentally sustainable fishing and how is it changing?		
	impacts of long lines, gillnets and bottom trawls on seafloor habitats and benthic organisms	based on 20 submersible dives in 2002, CBNMS unpub data (ID 77)
11) What is the status of non-indigenous species and how is it changing?		
	Abundance of non-indigenous species	Currently no monitoring data
	Comprehensive inventory of species within the sanctuary	Data needed
12) What is the status of key species and how is it changing?		
	Cassin's Auklet	Sydeman et al. 2006, Peterson et al. 2006, Goericke et al. 2007, Ainley and Hyrenbach 2007
	Black-footed Albatross, Sooty Shearwater	world-wide trend (Naughton et al. 2007, U.S. Fish and Wildlife Service 2006); local distribution and abundance (Ainley and Hyrenbach 2007, PRBO Conservation Science unpubl. data (ID 81), CBOMP monthly cruises (ID 19) unpubl. data)
	humpback whales, blue whale	stock-wide trends (Carretta et al. 2007); region-wide distribution changes (Peterson et al. 2006, PRBO Conservation Science unpubl. data (ID 81), CBOMP monthly cruises (ID 19) unpubl. data)

Table 8

Questions	Indicators	Source
	Abundance and distribution of California sea lion	stock-wide trends (Carretta et al. 2007); local patterns (SWFSC Central California Aerial Surveys (ID 71), Lowry and Forney 2005, CBOMP monthly cruises (ID 19) unpubl. data)
	rockfish - abundance trends	NMFS/PFMC stock assessments
	species composition patterns	Anderson et al. 2007
	krill abundance	PRBO Conservation Science at-sea monitoring (ID 81), Sydeman et al. 2006, Jahncke et al. 2008
	reef-top invertebrates shallower than 60 m	photos from 1970s (Schmieder 1991) and 2005 (ID 77; CBNMS unpubl. data)
	leatherback turtle stock population trend and local distribution and abundance	worldwide trends (Spotila et al. 2000); local distribution and abundance (SWFSC Aerial Surveys along the Central California coast (ID 71), Benson et al. 2007)
	Monthly monitoring of marine mammals and seabirds	CBOMP monthly cruises (ID 19) unpubl. data
13) What is the condition or health of key species and how is it changing?		
	lesions on rockfish	Okihiro et al. 1992
	beach cast marine mammals and seabirds linked to HABs	Scholin et al. 2000, Work et al. 1993
	poor condition of seabirds, marine mammals and fishes (related to reduced ocean productivity resulting from anomalous conditions)	Sydeman et al. 2006
14) What are the levels of human activities that may influence living resource quality and how are they changing?		
	landings as indicator of fishing activity	Scholtz et al. 2005
	commercial vessels/month	USCG AIS data
	marine debris (such as plastics)	CBOMP monthly cruises (ID 19) unpubl. data; not enough data to determine a trend

Table 9. Datasets used to assess the current condition of water, habitat, and living resources as identified in the draft condition report for the Gulf of the Farallones National Marine Sanctuary (ONMS draft). References listed in this table can be found in the "Cited Resources" section of the GFNMS condition report. Blue Text = lack of information noted in report. Green Text = Project ID # from Appendix 1

Questions	Indicators	Source
Water		
1) Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality?		
	sedimentation rates, period estero mouths are open vs. closed, salinity (Esteros Americano and de San Antonio)	Gold Ridge Resource Conservation District 2007
	salinity, sedimentation rates, tidal prism (Bolinas Lagoon)	State Water Resources Control Board 2006
	impaired water bodies	State water board 303(d) listing
	coliform and bacterial counts at beaches and estuaries	California Dept. Public Health, State Water Resources Control Board 2006
	sedimentation rates and mercury concentration	
	area of eelgrass beds	
	chronic oil pollution - oily tarballs and oiled birds on shoreline	BeachWatch monitoring data (ID 54)
	discharges of dredge spoil from transport barges	GFNMS enforcement records
	chemicals (DDT, PAHs, PCBs) in sediments	Hartwell 2004, 2007, 2008; limited data - not enough data to determine a trend in estuaries
2) What is the eutrophic condition of sanctuary waters and how is it changing?		
	nutrient concentration, dissolved oxygen, eutrophication, shellfish contamination in Tomales and Bodega bays	Airamé 2003
		not enough data to determine a trend in eutrophic condition for bays and estuaries
	precursors of biotoxin-producing phytoplankton in water samples and domoic acid toxicity in shellfish	15 years of monitoring data, G. Langlois unpub. data. California Department of Public Health
3) Do sanctuary waters pose risks to human health?		
	presence of pathogens in commercial shellfish growing areas	monitoring since the mid-1980s (California Dept Public Health)
	presence of pathogens in swimming areas	monitoring for the last 7 years (CA Dept Public Health?)
	number of shellfish harvesting closures	California Department of Public Health data
		not enough data to determine a trend in estuaries
	bacteria counts at beaches, impaired water bodies	303(d) list, State Water Resources Control Board 2006
	DDT, PAHs and PCBs in sediments	Hartwell 2007, 2008
	pollutant accumulation in upper trophic level organisms	a concern, but no data available
4) What are the levels of human activities that may influence water quality and how are they changing?		
	nutrient and sediment loads in runoff from agriculture	

Table 9

Questions	Indicators	Source
	amount of mudflat and diked marshes in Bolinas Lagoon and Tomales Bay	
	amount of freshwater diversion	
	urbanization/development in watershed	
	number of vessel transiting sanctuary	Harbor Safety Committee of the SF Bay Region 2007
	discharges of oil - based on number of oiled wildlife and tarballs on outer coast beaches	Beach Watch monitoring since 1993 (ID 54)
Habitats		
5) What is the abundance and distribution of major habitat types and how is it changing?		
	sedimentation rates in estuaries	
	change in area of estuarine habitat types, including wetlands, eelgrass beds, marsh	
	volume of tidal prism in Bolinas Lagoon	
	volume of freshwater input into estuaries	
	number of harbor seals at haul-outs	SEALS monitoring program, Tezak et al. 2004
	abundance of habitat-forming algae and surfgrass in rocky intertidal	Tenera 2003, 2004; S. Kimura, pers. comm.
	shoreline erosion rates (both short-term and long-term)	Hapke et al. 2006
	beach width	Marin County Open Space District 2006
	beach profile	BeachWatch photo-documentation monitoring (ID 54)
	number trawl tracks, sediment topography and structure, infaunal and epifaunal community composition in areas previously trawled	Engel and Kvitek 1998; Lindholm, pers. comm.; deMarignac et al. 2009
	spills of dredge spoil from barges into GFNMS	GFNMS data
	location of radioactive waste	sidescan and submersible surveys
	radioactivity levels in sediments and fish	Suchanek 1988, Lindsay 1992, Jones et al. 2001, Karl 2001; more monitoring is needed
6) What is the condition of biologically-structured habitats and how is it changing?		
	area of eelgrass beds	California Department of Fish and Game 2001; Gold Ridge Resource Conservation District 2007
	abundance native oyster	Kimbro and Grosholz 2006
	distribution and abundance of beach wrack	Beach Watch (ID 54); trend information not available
	distribution and abundance drift algae	Sanctuary Ecosystem Assessment Surveys - Pelagic Habitat (SEAS) (ID 28); not enough data to determine a trend
	impact of trawling on biogenic habitat	limited data, not enough data to determine a trend for coastal/offshore areas
7) What are the contaminant concentrations in sanctuary habitats and how are they changing?		
		limited data available to determine status and trend in estuaries
	levels of mercury in clams	Gassell et al. 2004
	contaminants in marinas and boat-works in Tomales Bay and Bolinas Lagoon	data needed
	non-point source discharges of chemicals, metals, and sediments from SF Bay and Russian River	SFPUC 2006

Table 9

Questions	Indicators	Source
	concentration of DDT, PAHs, PCBs in sediments	Hartwell 2007, Hartwell pers. comm.
	organic pollutants (butyltin, chlordane, DDT, dieldrin, PAHs, and PCB) and metals (As, Cd, Cu, Hg, Ni, Pb , Sn, Zn) in mussels	Mussel Watch Program (ID 88) stations in Tomales and Bodega Bays, Kimbrough et al. 2008
		limited data makes it difficult to determine a status for coastal and offshore habitats
8) What are the levels of human activities that may influence habitat quality and how are they changing?		
	road construction and maintenance activity levels	
	boating activity and number of moorings in Tomales Bay	
	location and intensity of fishing and mariculture activity	
	visitation rates at beaches	
	number of vessel transiting sanctuary	Harbor Safety Committee of the SF Bay Region 2007
	management and enforcement activities to reduce chronic oil pollution from sunken vessels and discharges of oily bilge water	
	amount of trawling/area open to trawling	
	intensity and frequency of road maintenance and coastal armoring	
Living Resources		
9) What is the status of biodiversity and how is it changing?		
	eelgrass abundance/area	T. Moore, CDFG, pers. comm.
	abundance of forage species such as pacific sardine, northern anchovy, pelagic juvenile rockfish	SWFSC Rockfish Recruitment surveys (S. Ralston, NMFS-SWFSC, unpubl. data)
	breeding success of Cassin's Auklets	Abraham 2007
	seabird diet composition (krill abundance)	Edgar 1997
	abundance of sea otters, sea urchin, kelp; sea urchin fishery	Paul Peilly, CDFG, pers. comm.
	abundance of Steller sea lions, northern fur seals	
10) What is the status of environmentally sustainable fishing and how is it changing?		
	aquaculture of oysters; harvest of clams, herring, rock crab, perch, halibut	little information available on status of these populations in estuaries
	local abundance of Common Murre	Manuwal et al. 2001
	bycatch of Common Murre, harbor porpoise, sea otters in gillnets	Manuwal et al. 2001, Forney 1999, Carretta et al. 2005
	recreational fish landings and effort	California Recreational Fisheries Survey
	recreational landings of Humboldt squid	no data available
	abundance of pelagic juvenile rockfish	SWFSC Rockfish Recruitment Surveys (S. Ralston, NMFS-SWFSC, unpubl. data,)
	abundance of overfished rockfish species	NMFS/PFMC stock assessments
	number of vessel in the trawl fishery/trawling effort	California Fisheries Information Systems 2007
	abundance of 5 abalone species	Abalone Recovery and Management Plan
11) What is the status of non-indigenous species and how is it changing?		
	number of non-indigenous species in the estuaries	Byrnes 2007
	extent and geographic coverage of non-indigenous species	very little is known, no data to determine a trend in estuaries
	abundance of native gobies	USFWS 2005
	abundance and distribution of *Spartina alterniflora*	

Table 9

Questions	Indicators	Source
	Abundance of green crab and mud snails	
	non-indigenous planktonic species	little data available
	abundance of striped bass	Bennett, pers. comm.
	monitoring in rocky intertidal	limited data
12) What is the status of key species and how is it changing?		
	abundance of eelgrass	limited data
	abundance of tidewater goby	USFWS 2005
	abundance of Brandt	
	abundance of other key estuarine species including herring, leopard shark, bat ray, harbor seal, Brandt's Cormorant, Snowy Plover	
	10 species of mammal, 9 species of birds, 1 species of reptile, 13 species of fish, 11 species of invertebrates, 5 species of plant	
13) What is the condition or health of key species and how is it changing?		
	Mercury levels in fish	
	disturbance of harbor seals in Tomales Bay	Tezak et al. 2005, SEALS monitoring
		very little data on condition of key estuarine species
	frequency of domoic acid events	
	toxin accumulation in pinniped and seabirds (organochlorines and domoic acid) as an indicator	
	gray whale weight	S. Swartz, pers. comm.
	seabird condition	
	pinniped population size	
14) What are the levels of human activities that may influence living resource quality and how are they changing?		
	disturbance of harbor seals (clam digging, kayaking, boating)	Tezak 2005
	levels of poaching, boating, anchoring, visitation, trampling, oil spills, illegal discharges, runoff from agricultural and developed lands, upland hydromodification	
	disturbance at seabird colonies (low flying aircraft, boats, human on foot)	
	flushing of waste and ballast water from vessels	
	vessel traffic levels	
	vessel noise	no recent data
	vessel strikes of whales	
	impact of lights on crab fishing vessels	no data
	frequency of illegal discharges (dredge material, oily bilge water)	
	trawling effort	
	incidence of oiled of birds and mammals	

Table 10. Datasets used to assess the current condition of water, habitat, and living resources as identified in the condition report for the Monterey Bay National Marine Sanctuary (ONMS 2009c). References listed in this table can be found in the "Cited Resources" section of the MBNMS condition report. Blue Text = lack of information noted in report. Green Text = Project ID # from Appendix 1.

Questions	Indicators	Source
Water		
1) Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality?		
	rates of sediment erosion and deposition	Phillip Williams & Associates 1992; Monismith et al. 2005
	dissolved oxygen levels	Beck and Bruland 2000; LOBO (ID 12), Chapin et al. 2004
	levels of organic matter accumulation	ESTWPT 2007
	species distribution related to water quality	Ritter et al. 2008
	waterbodies impaired by levels of pathogens, pesticides, sediments, dissolved oxygen, nutrients, heavy metals	list of impaired waterbodies (SWRCB 2006)
	levels of nutrients and legacy agricultural pesticides (e.g., DDT)	ESNERR et al. 2009; Phillips et al. 2002
	levels of organophosphate pesticides and pyrethroid pesticides in coastal watersheds	Hunt et al. 2003, Anderson et al. 2006; Phillips et al. 2006
	EPA Water Quality Index based on levels of dissolved oxygen, dissolved inorganic nitrogen, ortho-phosphate, chlorophyll, and water clarity in water, sediment and tissue samples	CCAMP monitoring program (ID 30); Sigala et al. 2007
	pollutant concentrations at coastal confluences of watersheds	Conley et al. 2008
	concentration of POPs (e.g., PCBs, PAHs, dieldrin, DDT) in rivers that drain to the sanctuary	CCLEAN monitoring program (ID 31); CCLEAN 2006, 2007
	concentration of emerging pollutants (e.g., pyrethroid pesticides, fire retardants (PBDEs), pharmaceuticals, and personal hygiene products)	a concern, but little information regarding presence or effects in the environment and no water quality standards have been developed
	concentration of nutrients (e.g., nitrate, orthophosphate, urea) and POPs (e.g., PAHs, PCBs, dieldrin) in water samples	CCLEAN monitoring program (ID 31); CCLEAN 2007
	concentration of POPs (e.g., DDT, PCBs, PAHs) in sediments	Hartwell 2008; CCLEAN monitoring program (ID 31); CCLEAN 2007, 2009
	cumulative concentration of POPs and abundance of benthic fauna	CCLEAN monitoring program (ID 31); CCLEAN 2007
	concentration of POPs in sea otters	Miller et al. 2007
	temperature at surface and 60 m, nitrate concentration at 60 m, and chlorophyll concentration at surface, water column stratification 0-20 m	MOOS (ID 6), MBTS Program (ID 66); MBARI 2006, Tanner 2006
	biomass and taxonomic structure of phytoplankton	Jester 2008; MBTS Program (ID 66); CIMT HAB monitoring data (ID 3)
2) What is the eutrophic condition of sanctuary waters and how is it changing?		
	levels of dissolved oxygen, nutrients	list of impaired waterbodies (SWRCB 2006)
	dissolved oxygen, chlorophyll-a, and nitrate concentrations	Bricker et al. 1999, 2007
	nitrate levels and turbidity (from phytoplankton biomass, suspended sediments)	CCAMP (ID 30), Conley et al. 2008; Elkhorn Slough NERR (ID 32), M. Los Huertos, pers. comm.
	nitrate concentration	Elkhorn Slough NERR (ID 32); Caffrey 2002; LOBO (ID 12), K. Johnson in prep

Table 10

Questions	Indicators	Source
	ecological impacts of eutrophication at Elkhorn Slough	limited data
	waterbodies impaired by elevated nutrient levels	list of impaired waterbodies (SWRCB 2006)
	nutrient (nitrate, urea, orthophosphate, ammonia) concentration in river discharges and wastewater	CCLEAN monitoring program (ID 31); CCLEAN 2006, 2007
	HABs and freshwater runoff events and nutrient loading	Kudela and Chavez 2004, Kudela et al. 2008a, 2008b
	toxins in higher trophic level species	Fritz et al. 1992, Scholin et al. 2000, Kreuder et al. 2005, Jester 2008
	concentration of urea	Cochlan et al. 2008, Anderson et al. 2008
	HABs caused by nutrient runoffs	Scholin et al. 2000, Ryan et al. 2008
	Fluorescence Line Height (FLH) = abundance and health of phytoplankton/red tide indicator	Moderate Resolution Imaging Spectrometer (MODIS) aboard the Aqua satellite; J. Ryan, unpublished monitoring data; Ryan et al. 2008
	frequency, spatial extent, and duration of algal blooms in Monterey Bay	CIMT monitoring 2002-2006 (ID 3), CIMT 2006, Howarth 2008
	number of stranded seabirds due to algal bloom	Beach COMBERS (ID 2); Jessup et al. 2009
3) Do sanctuary waters pose risks to human health?		
	levels of pesticides, pathogens	list of impaired waterbodies (SWRCB 2006)
	DDT and other pesticides in bivalve tissue	Phillips et al. 2002
	levels of heavy metals and POPs in mussels	NOAA's National Status and Trends' Mussel Watch program (ID 88) (Kimbrough 2008)
	levels of organophosphate in water and toxicity to small crustaceans	ESNERR et al. 2009, Hunt et al. 2003, Anderson et al. 2004
	number of beach warnings and closures	Rickers and Peters 2006; NOAA 2008a
	Levels of bacterial contamination at local beaches and in coastal lagoons	Santa Cruz County Surface Water Quality Monitoring Program (ID 33); Rickers and Peters 2006
	incidence of illness likely caused by water contact (e.g., earaches, gastrointestinal distress) in beachgoers	Santa Cruz County Department of Health (Rickers and Peters 2006)
	estimated loading of *E. coli* and *Enterococcus* bacteria to nearshore waters	CCLEAN monitoring program (ID 31); CCLEAN 2007
	concentration of chemical contaminants (e.g., dieldrin, DDT, PAHs, PCBs) in mussel tissue	CCLEAN monitoring program (ID 31); CCLEAN 2007
	Mercury concentration in tissue of fish and shellfish collected from coastal areas	SWAMP (ID 41); SWAMP 2005
	concentrations of particulate domoic acid and *Pseudonitzchia* at the Monterey Wharf	J. Smith, MLML, unpubl. monitoring data
	number of shellfish samples with PSP toxin levels above regulatory limits; PSP toxins detected in planktivorous fish	Jester 2008
	contaminants (DDT, PCBs) in killer whales	monitoring in Monterey Bay (Black et al. 2003)
	contaminants (DDT, PCBs) in Black-Footed Albatross	Finkelstein et al. 2006
	contaminants (DDT, PCBs) in Califonria sea lion	Kannan et al. 2004
	mercury concentration in water and large pelagic fishes	little monitoring data available
	biotoxins in planktivorous fishes	Fritz et al. 1992, Scholin et al. 2000, Jester 2008
	domoic acid in beached birds and mammals	Fritz et al. 1992, Scholin et al. 2000; Beach COMBERs data (ID 2)
4) What are the levels of human activities that may influence water quality and how are they changing?		

Table 10

Questions	Indicators	Source
	levels of non-point source pollution from agriculture, urbanization and other human activities	limited data
	levels of nutrients and legacy organochlorines pesticides in watershed wetlands	ESNERR et al. 2009; Phillips et al. 2002
	levels of organophosphate pesticides in watershed	Hunt et al. 2003
	levels of pyrethroid pesticides in watershed sediments	Anderson et al. 2006; Phillips et al. 2006
	alteration of sediment and freshwater flows (e.g., construction of levees, diversion of freshwater)	Van Dyke and Wasson 2005
	changes in water quality in response to management practices to reduce pollution sources	limited data
	nutrient loads from heavily cultivated watersheds	CCLEAN monitoring program (ID 31); CCLEAN 2007; Los Huertos et al. 2003
	levels of regulation of non-point source contaminants	
	level of implementation of better management practices	
	sources of bacterial pollution (e.g., condition of sewer systems, stormwater drainage)	County of Santa Cruz 2006
	application of nutrient management practices	Monterey County 2002
	application of nutrient, pesticide, erosion, and irrigation management practices	RWQCB 2007
	frequency and persistence of algal blooms in Monterey Bay	CIMT (ID 3)
	nutrient loading from human activities	Glibert et al. 1995, CIMT 2006
	number of deep draft vessels entering San Francisco Bay	Harbor Safety Committee of the San Francisco Bay Region 2007
	deposition of oiled seabirds on beaches in MBNMS	monitored by BeachCOMBERS program (ID 2) since 1997 (Nevins et al. in prep), PRBO monitoring program 1971-1985 (Nevins et al. 2003)
	oil slicks on water surface in MBNMS	recorded since 2001 during SWFSC Central California aerial surveys (ID 71) (K. Forney, NMFS-SWFSC, unpubl. data)
Habitats		
5) What is the abundance and distribution of major habitat types and how is it changing?		
	relative abundance of estuarine habitat types	Van Dyke and Wasson 2005, ESNERR unpubl. data
	volume of exported sediment	Sampey 2006
	tidal prism volume	Broenkow and Breaker 2005, Sampey 2006
	bank erosion rates	ESNERR Tidal Erosion Monitoring Program, Van Dyke and Wasosn 2005
	mean cross sectional area of main channel	Dean 2003, Malzone 1999
	sediment composition of main channel	Kvitek et al. 1996
	abundance and distribution of fishes and invertebrates	Yoklavich et al. 2002, Lindquist 2008
	shoreline habitat type	NOAA-Office of Response and Restoration-Environmental Sensitivity Index (Research Planning Inc. 2006)
	rate of change of sandy shoreline habitat	Hapke et al. 2006
	percentage of shoreline that is armored	California Coastal Commission 2005
	location and impacts of burial of rocky intertidal and subtidal habitats	MBNMS Rocky Shores Monitoring Project

Table 10

Questions	Indicators	Source
	Erosion at the head of the Monterey Submarine Canyon	Wong 2006
	benthic habitat type - low resolution multibeam	NOS
	benthic habitat type - med and high resolution multibeam data	MBARI Monterey Bay Multibeam Survey (ID 20), CSUMB Seafloor Mapping Lab (ID 17), Fugro Pelagos International
	benthic habitat type - sidescan sonar	USGS U.S. Pacific Coast habitat mapping program (ID 47)
	impacts to benthic habitat and associated species by submerged cable	Kogan et al. 2006
	abundance of microtopographic structures	Central California Habitat Characterization (ID 37); deMarignac et al. 2009; Engel and Kvitek 1998
	trawling gear footprint	PacFIN trawl logbook data 1997-2007 (from California Department of Fish and Game)
6) What is the condition of biologically-structured habitats and how is it changing?		
	abundance and distribution of eelgrass	MacGinitie 1935; Zimmerman and Caffrey 2002; ESNERR unpubl. data
	abundance and distribution of native oysters	MacGinitie 1935; Heiman 2006; Heiman et al. 2008
	recruitment rates of juvenile oysters	K. Heiman, unpubl. data
	abundance and distribution of non-native tubeworm	Heiman 2006, Heiman et al. 2008
	abundance and distribution of subtidal structure-forming species	PISCO (ID 59), CRANE (ID 76), MBNMS rocky shores monitoring programs
	aerial extent of kelp canopy	CA Annual Kelp Surveys (ID 10)
	abundance and distribution of rocky intertidal structure-forming species	PISCO (ID 59) and MARINe (ID 91) monitoring programs, Pete Raimondi, pers. comm.
	levels of human visitation and abundance and diversity of intertidal structure-forming species	Tenera Environmental 2003
	abundance and distribution of biologically-structured habitats	limited data available
	distribution of structure-forming species on the continental shelf, slope and submarine canyons	MBARI ROV survey data (Jim Barry, unpublished data); NWFSC Groundfish Surveys (ID 67); NMFS 2004; Central California Habitat Characterization (ID 37)
	occurrence of deep-sea corals	Etnoyer and Morgan 2003, Morgan et al. 2005
	distribution of cold seep communities	MBARI ROV surveys of cold seeps (Barry 1996, Paull 2005)
	species composition on whale falls	Monitoring of whale falls in Monterey Bay (Goffredi et al. 2004)
	extent of trawling footprint	PacFIN trawl logbook data (from California Department of Fish and Game)
	impacts of trawling and other human activities	little data available
7) What are the contaminant concentrations in sanctuary habitats and how are they changing?		
	distribution and concentration of contaminants in Elkhorn Slough and Monterey Bay area	literature review (Hardin et al. 2007)
	concentrations of dieldrin, DDT and PCB in mussels from Elkhorn Slough and Moss Landing	Hardin et al. 2007
	concentration of DDT and contaminants in Caspian Tern eggs and embryos	Parkin 1998
	toxicity of sediments in Moss Landing Harbor to crustaceans	Anderson et al. 2004
	concentration of POPS (e.g., PCB, DDT, chlordane) and metals (e.g., arsenic, mercury, lead) in sediment and tissue samples from harbors	CCAMP monitoring program (ID 30); Sigala et al. 2007

Table 10

Questions	Indicators	Source
	concentration of contaminants (e.g., oxychlordane, DDT, PCBs) in sand crabs	Dugan et al. 2005
	concentration of DDT in mussels	CCLEAN monitoring program (ID 31); CCLEAN 2006
	concentration of POPs in stranded sea otters	California Department of Fish and Game study from 2000-2005 (Miller et al. 2007)
	concentration of POPs (e.g., DDT, dieldrin, PAH, PCB) in sediment samples from shelf, slope and canyon habitats	CCLEAN monitoring program (ID 31); CCLEAN 2009, Hartwell 2008, Paull et al. 2002
	impacts of contaminants in sediments on living resources	limited data available
	abundance of infaunal species and cumulative concentration of POPs	CCLEAN monitoring program (ID 31); CCLEAN 2006
	POPs in demersal fish and invertebrate samples	Froescheis et al. 2000, Looser et al. 2000
8) What are the levels of human activities that may influence habitat quality and how are they changing?		
	changes in land use practices to decrease inputs from agricultural fields	ESNERR et al. 2009
	land acquisition for conservation or restoration	ESNERR et al. 2009
	acres under cultivation	ESNERR et al. 2009
	levels of human visitation at rocky intertidal sites	Tenera Environmental 2003
	levels of human harvesting of mussels	PISCO (ID 59) and MARINe (ID 91) monitoring program, Pete Raimondi, pers. comm.
	intensity and frequency of coastal armoring activity	
	location and volume of sand mining	PWA 2008
	volume of kelp harvested from beds in MBNMS	CDFG Kelp Harvesters Monthly Reports
	location and intensity of fishing with trawl gear	PacFIN trawl logbook data 1997-2007 (from California Fish Landings)
	installation of submerged cables	MBNMS submerged cable permitting information
	impacts of ATOC/Pioneer Seamount cable	Kogan et al. 2006
	distribution, abundance and composition of benthic marine debris in Monterey Bay	surveyed in 1993-1994 (Watters et al. 2008)
	distribution and abundance of pelagic marine debris	no data available
Living Resources		
9) What is the status of biodiversity and how is it changing?		
	overall native species richness (including plants, algae, fish, birds, invertebrates) and biodiversity	Caffrey et al. 2002
	loss of once common invertebrate species	comparison of historical accounts to recent surveys (summarized in Wasson et al. 2002)
	biodiversity in benthic invertebrate fauna (including sediment cores)	Wasson et al. 2002
	relative abundance of prey organisms in the stomachs of benthic foraging fish	Lindquist 1998
	relative abundance of clam species	Oliver et al. unpublished data
	relative abundance of large fish and mammalian predators	Yoklavich et al. 2002, Harvey 2002
	relative abundance and biodiversity of fish	Yoklavich et al. 1991, Oxman 1995
	fish assemblages in different habitat types	Yoklavich et al. 2002
	biodiversity in the rocky intertidal	Wasson et al. 2005; PISCO (ID 59) and MARINe (ID 91) monitoring data, P. Raimondi pers. comm.
	composition of intertidal community in relation to black abalone abundance	PISCO (ID 59) and MARINe (ID 91) monitoring data (Miner et al. 2006)

Table 10

Questions	Indicators	Source
	relative abundance of fish species	Starr et al. 2004, PISCO (ID 59) subtidal monitoring data, M. Carr pers. comm.
	biodiversity in the rocky subtidal and kelp forest	PISCO (ID 59) monitoring data
	relative abundance of shallow subtidal fishes inside and outside marine reserves	PISCO (ID 59) monitoring data
	rockfish recruitment levels	SWFSC rockfish recruitment surveys; PISCO (ID 59) monitoring data
	species distribution along the coast	Lonhart and Tupen 2001
	biodiversity in subtidal soft bottom	MLML 2006; very limited data
	abundance of sand crabs	LiMPETS program data (ID 48), George 2008
	abundance of marine mammal stocks	NMFS stock monitoring and assessments (Angliss and Allen 2009, Carretta et al. 2008)
	abundance of locally breeding seabirds	Goericke et al. 2007; PRBO Conservation Science breeding colony monitoring (including surveys on SE Farallon)
	abundance of Sooty Shearwater	Ainley and Hyrenbach, unpubl. seabird data from SWFSC rockfish recruitment surveys
	abundance of Marbled Murrelets in central California	Peery et al. 2008
	relative abundance of groundfishes (e.g., flatfishes, cartilaginous fishes, rockfishes)	Levin et al. 2006 based on NWFSC Groundfish Surveys (ID 67)
	abundance of jumbo squid	Field et al. 2007 based on SWFSC rockfish recruitment survey
	relative abundance of jumbo squid and Pacific hake	Zeidberg and Robison 2007 based on MBARI ROV mid-water monitoring data
	composition and distribution of midwater assemblage	MBARI Midwater Ecology ROV surveys
	composition and distribution of deep benthic assemblage	MBARI Benthic Ecology ROV surveys
10) What is the status of environmentally sustainable fishing and how is it changing?		
	levels of take of shellfish and mudflat invertebrates	Wasson et al. 2002; regulated by CDFG
	abundance and distribution of elasmobranchs based on catch records from elasmobranch derbies	Carlisle et al. 2007
	level of recreational hook -and-line fishing	Yoklavich et al. 2002; limited data available
	impacts of extraction	no data available
	local abundance of large, mobile species in areas open or closed to public access	PISCO (ID 59) and MARINe (ID 91) monitoring data
	size frequency of large, mobile species in areas open or closed to public access	PISCO (ID 59) and MARINe (ID 91) monitoring data, Sagarin et al. 2007
	levels of poaching of black abalone	PISCO (ID 59) intertidal monitoring data, Pete Raimondi, pers. comm.
	abundance of targeted nearshore fish stocks	stock assessments when available; stock assessments not available for many targeted nearshore fish stocks
	local abundance of targeted species in open and closed areas	PISCO (ID 59) monitoring data; Mason 1998, Paddack and Estes 2000, Dorn 2002, Starr et al. 2004
	size frequency of targeted species in open and closed areas	Mason 1998, Paddack and Estes 2000, Dorn 2002, Starr et al. 2004
	impacts of reduced abundance on community and ecosystem function	Berkeley et al. 2004, Palumbi 2004, PISCO 2007; very little information available
	market squid landings	Porzio and Brady 2008
	direct and indirect impacts of squid harvesting on the ecosystem	very little information available

Table 10

Questions	Indicators	Source
	population size of assessed groundfish stocks	groundfish stock assessments (various authors) based in part on NWFSC Groundfish Surveys (ID 67) and SWFSC rockfish recruitment surveys
	average body size of targeted rockfish species	Steve Ralston, SWFSC, unpublished data based on data available in the California Fish Landings
	abundance of Pacific hake	stock assessment (Helser and Martell 2007)
	population size of sardine and mackerel stocks	NMFS stock assessments
	population size of market squid and anchovy stocks	CDFG/PFMC stock assessments
	sustainability of Dungeness crab fishery	Hankin et al. 2004 (no formal population assessment)
	sustainability of spot prawn fishery	Larson and Reilly 2008 (no formal population assessment)
	abundance of benthic invertebrate fauna	MBARI ROV survey data (Jim Barry, unpublished data)
	Composition of the fish assemblage on the continental shelf and slope	Levin et al. 2006 based on NWFSC Groundfish Surveys (ID 67)
	Fish assemblage composition and relative density of large and small bodied rockfish	Yoklavich et al. 2000
	Mean body size of harvested rockfish	Mason 1998
11) What is the status of non-indigenous species and how is it changing?		
	number of non-indigenous, cryptogenic, and native invertebrate species in Elkhorn Slough	Wasson et al. 2005
	number of non-native fish species in Elkhorn Slough	Yoklavich et al. 2002
	relative abundance of native horn snail and Japanese mud snail	Byers 1999, 2000
	distribution and abundance of non-native tube worm and associated invertebrate assemblage	Heiman et al. 2008
	abundance and distribution of the European green crab	ESNERR monitoring data
	presence of non-indigenous species in the rocky intertidal	one-time surveys (Wasson et al. 2005)
	presence of non-indigenous species in the sandy and rocky intertidal, and sandy and rocky subtidal	one-time surveys (Maloney et al. 2006)
	amount of *Undaria pinnatifida* removed from Monterey Harbor	S. Lonhart, MBNMS monitoring data
	abundance and distribution of Japanese bryozoan *Watersipora subtorquata*, Asian kelp Sargassum muticum, and red algae *Caulacanthus ustalatus*	S. Lonhart, MBNMS monitoring program
	presence of non-indigenous species in infaunal samples	one-time surveys (Maloney et al. 2006)
12) What is the status of key species and how is it changing?		
	status of native oysters	MacGinitie 1935; Heiman et al. 2008, Heiman 2006; K. Wasson and K. Heiman, pers. comm.
	status of eelgrass	MacGinitie 1935; Zimmerman and Caffrey 2002; analysis of aerial photographs (ESNERR unpublished data)
	status of pickleweed salt marsh	analysis of aerial photographs (ESNERR unpublished data), Zimmerman and Caffrey 2002
	abundance of non-native species on native biodiversity	Wasson et al. 2002
	abundance of black abalone, mussels and structure-forming algae	PISCO (ID 59) and MARINe (ID 91) monitoring data

Table 10

Questions	Indicators	Source
	trampling of algae and invertebrates	Tenera 2003
	status of subtidal kelp and sea urchins	PISCO (ID 59) and CRANE (ID 76), and MBNMS monitoring data
	abundance of rockfishes, cabezon, lingcod	stock assessments when available
	abundance of California sea otter	California Sea Otter Surveys (ID 7)
	abundance of Pismo clams	Kim et al. 2006
	status of sand dollars	no available data
	status of ornate tubeworm *Diopatra ornate*	no available data
	abundance of Sooty Shearwaters	in Monterey Bay (Adams and Harvey 2006); in central California (Ainley and Hyrenbach, unpubl. seabird data from SWFSC rockfish recruitment surveys)
	abundance of marine mammal stocks	Carretta et al. 2008, Angliss and Allen 2009; based on SWFSC Shipboard Cetacean Surveys (ID 60)
	Steller sea lion population size	NMFS stock assessments (Angliss and Allen 2009)
	Steller sea lion pup counts at Año Nuevo	SWFSC Pinniped Aerial Surveys, M. Lowry, per. comm.
	Chinook salmon abundance	
	abundance of market squid	Porzio and Brady 2008
	relative abundance of phytoplankton groups	MOOS (ID 6), MBTS Program (ID 66); Pennington et al. 2007
13) What is the condition or health of key species and how is it changing?		
	turbidity	Elkhorn Slough NERR water quality monitoring program (ID 32); M. Los Huertos, pers. comm.
	levels of contaminants	Hardin et al. 2007
	health of key estuarine species	not being monitored, very little data available
	trend in abundance of black abalone and incidence of withering syndrome at monitoring sites in central California	PISCO (ID 59) and MARINe (ID 91) intertidal monitoring data; Raimondi et al. 2002
	trend in abundance of sea otters	California Sea Otter Surveys (ID 7)
	cause of death in beach cast southern sea otters	Kreuder et al. 2003, Tinker et al. 2006
	POPs in tissues of beach cast sea otters	Miller et al. 2007
	incidence of food limitation in southern sea otter population	Tinker et al. 2006
	domoic acid poisoning in sea lions	Scholin et al. 2000
	deposition of seabirds and mammals on area beaches	BeachCOMBERS (ID 2) data
	monitoring of pinnipeds entangled in synthetic materials	PRBO Conservation Science Monitoring data (Hanni and Pyle 2000)
	number of stranded pinnipeds injured by entanglement in synthetic materials	Marine Mammal Center data (Goldstein et al. 1999)
	proportion of seabird carcasses with plastic in stomach	Beach COMBERS (ID 2) data, Nevins et al. 2005, Zabka et al. 2006, Phillips et al. 2007
	contaminants in marine mammals, seabirds, and seabird eggs	Jarman et al. 1996, Calambokidis and Barlow 1991, Black et al. 2003, Krahn et al. 2007, Finkelstein et al. 2006, Pyle 1999; lack of consistent monitoring and long-term data
14) What are the levels of human activities that may influence living resource quality and how are they changing?		
	land use, agriculture and development, in surrounding watershed	

Table 10

Questions	Indicators	Source
	run-off of nutrients and contaminants from agricultural activities	Caffrey et al. 2002
	levels of aquaculture in Elkhorn Slough area	
	boating activity in Moss Landing Harbor	
	harvest of living resources	little data available
	entrainment of fish and invertebrates larvae in power plant intake pipes	Wasson, pers. comm.
	human visitation to rocky intertidal	Tenera 2003, PISCO (ID 59) and MARINe (ID 91) monitoring data, P. Raimondi pers. comm.
	extraction of rocky intertidal organisms	PISCO (ID 59) and MARINe (ID 91) monitoring data, P. Raimondi pers. comm.
	distribution and intensity of fishing effort	
	impacts of landslide-caused burial of intertidal and subtidal organisms	CRANE (ID 76) monitoring data (Carr et al. 2006)
	activities that impact sandy beach and subtidal: coastal armoring, sand mining, beach grooming, dredge disposal, discharge from outfalls, recreational use	
	location and intensity of fishing with trawl gear	PacFIN trawl logbook data 1997-2007 (from California Fish Landings)
	level of fishing with bottom contact fishing gear	
	level of bycatch of sensitive or protected species	Forney et al. 2001
	Number of commercial fishermen and fishing vessels	MLPA 2005, CDFG 2007
	Total Landings and total value	MLPA 2005, CDFG 2007
	volume and composition of trash in storm drains	California Department of Transportation pilot study (CIWMB 2004)
	volume and composition of trash on beaches	U.S. Coastal Cleanup Day
	length of submerged cables in MBNMS	MBNMS submerged cable permitting information
	impacts of ATOC/Pioneer Seamount cable	Kogan et al. 2006
	impacts of increasing pH on living resources	limited data
	impacts of acoustic pollution on living resources	NRC 2005; limited data

Table 11. Datasets used to assess the current condition of water, habitat, and living resources as identified in the condition report for the Channel Islands National Marine Sanctuary (ONMS 2009a). References listed in this table can be found in the "Cited Resources" section of the CINMS condition report. Blue Text = lack of information noted in report. Green Text = Project ID # from Appendix

Questions	Indicators	Source
Water		
1) Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality?		
	satellite images of sediment plumes from mainland rivers	Otero and Siegel 2004
	sediment toxicity	on-going monitoring by SCCWRP Southern California Bight Regional Surveys (ID 26), Bay et al. 2005
	DDT in sediment	on-going monitoring by SCCWRP Southern California Bight Regional Surveys (ID 26), Schiff et al. 2006
	DDT in birds	Sydeman et al. 2001, on-going monitoring by Channel Islands National Park
	DDT in fish and other organisms	Jarvis et al. 2007
	intensity and length of *Pseudo-nitzschia* blooms	Anderson et al. in press, Busse et al. 2006, Schnetzer et al. 2007
	domoic acid mortality events	Gulland 2000, Scholin et al. 2000
	effects of global warming (e.g., sea level rise, changes in ocean chemistry, sea water temperature increases)	Not well understood
	withering syndrome pathogen in red abalone	CDFG 2007
2) What is the eutrophic condition of sanctuary waters and how is it changing?		
	nutrient input (from mainland streams/rivers)	On-going monitoring Santa Barbara Coastal Long Term Ecological Research Program (ID 51), McPhee-Shaw et al. 2007
	amount of nutrient enrichment (from island streams)	
	frequency and intensity of harmful diatom blooms	Anderson et al. in press
	nutrient inputs and HABs	Schnetzer et al. 2007
3) Do sanctuary waters pose risks to human health?		
	number of human illnesses reported due to shellfish consumption	
	concentration of biotoxins in harvested shellfish	Novelli et al. 1991
	human fecal pollution in sanctuary waters	
	concentration of harmful bacteria (from vessel discharges)	Santa Barbara ChannelKeeper (ID 93), Altstatt 2007
4) What are the levels of human activities that may influence water quality and how are they changing?		
	number of cargo ship transits	
	effects of vessel discharges	little information available
	concentration of airborne contaminants from shipping traffic	little information available
	contaminants (e.g., DDT) in sediment	on-going monitoring by SCCWRP Southern California Bight Regional Surveys (ID 26), Schiff et al. 2006

Table 11

Questions	Indicators	Source
	abundance of brown pelicans and bald eagles	Sydeman et al. 2001, Engle 2006, H. Carter personal communication 2007, on-going monitoring by Channel Islands National Park
	satellite images of mainland runoff from agriculture and development	Otero and Siegel 2004
Habitats		
5) What is the abundance and distribution of major habitat types and how is it changing?		
	health of deep water habitats	J. Engle (UCSB) personal communication 2007; not well studied
	area closed to fishing with bottom-tending gear	
	impacts of fish traps	
	impacts of marine debris	
6) What is the condition of biologically-structured habitats and how is it changing?		
	abundance of giant kelp and understory habitat-forming algae	Channel Islands National Park Kelp Forest Monitoring Program, Behrens and Lafferty 2004, Lafferty 2004
	abundance/health of deeper hard-bottom coral communities	J. Engle (UCSB) personal communication 2007; not well studied
	area closed to trawling and trapping	
	eelgrass abundance	on-going monitoring, Engle and Miller 2005
	frequency of recreational anchoring	
	mussel bed thickness, biomass, and community diversity	Smith et al. 2006a, Smith et al. 2006b
7) What are the contaminant concentrations in sanctuary habitats and how are they changing?		
	DDT concentrations in sediments	on-going monitoring by SCCWRP Southern California Bight Regional Surveys (ID 26), Schiff et al. 2006
	DDT influence on nesting birds	Channel Islands National Park on-going monitoring, Sydeman et al. 2001, Engle 2006, H. Carter personal communication 2007
	area/geographic extent of plumes of suspended sediments	Otero and Siegel 2004
	illegal discharge from vessels	no data available
	frequency of vessel groundings	
8) What are the levels of human activities that may influence habitat quality and how are they changing?		
	area closed to trawling and trapping activity in the CINMS	
	commercial and sport harvesting of community dominant species (historic and current)	
	marine debris	Richards 1993, National Park Service marine debris surveys
	illegal vessel discharges	
	anchoring	
	commercial and recreational fishing activities	on-going monitoring, Senyk et al. 2008
	visitation by non-consumptive users	on-going monitoring, Senyk et al. 2008
	enforcement of marine reserves	
	public awareness of marine reserve regulations	

Table 11

Questions	Indicators	Source
	number of boats/boating disturbance of wildlife	
	oil production and transport	
Living Resources		
9) What is the status of biodiversity and how is it changing?		
	abundance and size structure of key species (e.g., sheephead, kelp bass, rockfishes, shark, swordfish, lobster, abalone)	Channel Islands National Park Kelp Forest Monitoring Program, D. Richards personal communication 2007
	biodiversity in kelp forest	Channel Islands National Park Kelp Forest Monitoring Program, D. Kushner personal communication 2007
	fishing pressure	Channel Islands National Park monitoring, D. Kushner personal communication 2007
	abundance of kelp and eelgrass	Channel Islands National Park Kelp Forest Monitoring Program, J. Altstatt personal communication 2007, Engle personal communication 2007
	abundance of urchins and brittle stars	Channel Islands National Park Kelp Forest Monitoring Program, J. Altstatt 2005, J. Altstatt personal communication 2007, J. Engle personal communication 2007
	biodiversity (in areas dominated by brittle stars)	J. Altstatt personal communication 2007
	abundance and diversity of mussel bed communities	Smith et al. 2006a, Smith et al. 2006b
10) What is the status of environmentally sustainable fishing and how is it changing?		
	location and intensity of gill netting	
	ghost fishing by lobster and fish traps	
	abundance of sea otter, sharks, giant sea bass, swordfish, rockfishes, abalone	on-going monitoring by CDFG, Leet et al. 2001, Rogers-Bennet et al. 2004
	size structure of red sea urchin, sheephead	Channel Islands National Park Kelp Forest Monitoring Program, D. Richards personal communication 2007
	relative abundance of lobster, urchin, kelp	Channel Islands National Park Kelp Forest Monitoring Program, Behrens and Lafferty 2004
	abundance and distribution of anchovy and sardine (as prey for Brown Pelican)	
	bycatch rates of cormorants and alcids in gill nets	
	bycatch rates of pelicans in recreations fishing gear	
	rates of avian predation, nest abandonments, and collisions with lighted structures and vessels due to light pollution	
		significant gaps in our knowledge of fishery effects and basic life history that impede management
11) What is the status of non-indigenous species and how is it changing?		
	abundance and distribution of several algal species (including *Undaria pinnatifida, Sargassum filicinum, and Caulacanthus ustulatus*)	on-going monitoring, Miller et al. 2006
12) What is the status of key species and how is it changing?		
	relative abundance of echinoderms, kelp, lobster, and fishes (e.g., sheephead and rockfishes)	Channel Islands National Park Kelp Forest Monitoring Program, Lafferty and Kushner 2000, Lafferty 2004, D. Kushner personal communication 2007

Table 11

Questions	Indicators	Source
	giant seabass abundance	Leet et al. 2001
	distribution and abundance of giant kelp	Channel Islands National Park Kelp Forest Monitoring Program, Lafferty and Behrens 2004
	abundance of red abalone	
	abundance of sea otters	
	abundance of Brown Pelicans	
	abundance of Peregrine Falcons	
	abundance of Bald Eagles	
	abundance of Brandt's Cormorant	on-going monitoring, Capitolo et al. 2004 unpublished data, as reported in CINMS Biogeographic Report
	abundance of cormorant	
	abundance of Cassin's Auklet	on-going monitoring, Carter et al. 2007
	abundance of Xantus's Murrelets	on-going monitoring, Whitworth et al. 2006
	abundance of Ashy Storm-Petrels	on-going monitoring, Wolf 2007
	abundance of Tufted Puffins	
	abundance of fin whale, humpback whale, gray whale	on-going monitoring, J. Calambokidis personal communication 2007
	abundance of blue whales	on-going monitoring including Shipboard Cetacean Survey (ID 60), Barlow and Forney 2007
13) What is the condition or health of key species and how is it changing?		
	withering syndrome disease in red abalone	CDFG 2007
	abundance of black abalone and incidence of disease	
	diseases in echinoderms	
	size structure of spiny lobster	on-going monitoring, CINP unpublished data, D. Kushner personal communication 2007
	abundance and size structure of sheephead and kelp bass	on-going monitoring, D. Kushner personal communication 2007
	nest failure rates of Cassin's Auklet	on-going monitoring, Carter et al 2007
	timing of nesting of Xantus's Murrelets	on-going monitoring, Whitworth et al 2006
	nesting rates of Ashy Storm-Petrels	on-going monitoring, Carter et al 2007
14) What are the levels of human activities that may influence living resource quality and how are they changing?		
	extraction rates for exploited species	
	number of recreational kayaker	
	trampling rates of nests and intertidal animals	
	amount of recreational boating/anchoring	
	amount of shipping traffic	
	runoff/storm events on mainland - pollutants and marine debris	

Table 12. Observing datasets that are being used by one or more of the on-going ecosystem assessment efforts in the California Current Ecosystem. Datasets that are currently hosted by PaCOOS (http://www.pacoos.org/DataMgt.htm) are indicated. A project identification number is provided for observing datasets identified by the West Coast Sanctuary Data Inventory project (see Appendix I).

Project Name	Project Description	Available though PaCOOS	ONMS SWiM Condition Reports	Module I, CCE IEA	Atlantis NCCE model	NCEAS CCME Human Impact Assessment	MBCORC Report Card	ID #
West Coast Observatories (WCObs)	WCObs deals with oceanographic data collected at the five west coast sanctuaries. The project began in 2004 and focuses on various data streams collected at instrument moorings.	X						1
Beach COMBERS	Beach COMBERS (Coastal Ocean Marine Mammal & Bird Education and Research Surveys) uses volunteers to survey beached marine birds and mammals monthly at selected beach segments in central and southern portions of Monterey Bay sanctuary.		MB				X	2
Center for Integrated Marine Technologies (CIMT)	CIMT simultaneously collected data on physical, chemical, and biological (from phytoplankton to marine mammals) via moorings, shipboard surveys, apex predator tagging and tracking, and satellite, aircraft, and land-based remote sensing in Monterey Bay from 2002-2007 and was built on a foundation of data collection initiated in 1997.	CTD & Chloro only	MB	X			X	3
MBARI Ocean Observing System (MOOS)	Since 1989 Monterey Bay Aquarium Research Institute (MBARI) has operated a mooring observing system in Monterey Bay.	X	MB				X	6
California Sea Otter Survey	Bi-annual aerial and land-based standardized surveys of Southern sea otters have been conducted in California (from Santa Barbara to Half Moon Bay) during late spring and early fall since 1983.		MB				X	7
Naval Postgraduate School HF Radar	HF radar hardware and software have allowed examination of circulation in Monterey Bay since 1994.	X						8
WA Annual Kelp Surveys	Aerial photographs taken in the late summer are used to monitor maximum bed extent of floating kelp along the Strait of Juan de Fuca and outer coast in the Olympic Coast sanctuary. Data collected by Washington State Department of Natural Resources in 1989-1992 and 1994-present.	X	OC					9
CA Annual Kelp Surveys	Aerial photographs taken in the late summer have been used to monitor maximum bed extent of floating kelp along the California mainland coast. Data collected by California Department of Fish and Game in 1989 and 1999-present.		MB			X		10
Land/Ocean Biogeochemical Observatory in Elkhorn Slough (LOBO)	The LOBO project uses in situ chemical sensors to determine chemical fluxes into, within, and out of Elkhorn Slough in the Monterey Bay sanctuary. The primary focus is to measure nutrients, such as nitrate, ammonium, and phosphate. Data collected since 2003.		MB					12
Coastal Observation and Seabird Survey Team (COASST)	COASST, which began in 1999, uses volunteers to survey beached marine birds at selected beach segments in Washington and northern Oregon. Beach segments are surveyed either monthly or	2006 data only	OC					15

Table 12

Project Name	Project Description	Available though PaCOOS	ONMS SWiM Condition Reports	Module I, CCE IEA	Atlantis NCCE model	NCEAS CCME Human Impact Assessment	MBCORC Report Card	ID #
	every two weeks.							
CSUMB Seafloor Mapping Lab (SFML)	The CSUMB SFML specializes in high-resolution acoustic remote sensing for coastal habitats. Data collection in coastal California began in 1993.		CB, MB					17
OCNMS Habitat Mapping	In August 2004 and May and July 2005, OCNMS imaged several regions of the sea floor in the northern OCNMS. Video from a towed camera sled, bathymetry data, sedimentary samples and side scan sonar mapping were integrated to describe geological and biological aspects of habitat.	X	OC					18
Cordell Bank Ocean Monitoring Program (CBOMP)	A monthly census of birds, marine mammals, krill and physical oceanographic conditions in the CBNMS began in 2004. Data collection methods were designed so that data could be integrated with CIMT.		CB					19
MBARI Monterey Bay Multibeam Survey	In June 1998 MBARI completed surveys of selected areas of the Monterey Bay sanctuary and surrounding features using a multibeam echo sounder.		MB					20
Essential Fish Habitat (EFH)	The EFH data set contains physical seafloor characteristics considered important for identifying essential habitat for groundfish. Seafloor feature data sets include side-scan sonar, bottom samples, seismic data, and multibeam bathymetry. The Active Tectonics and Seafloor Mapping Lab, College of Oceanic and Atmospheric Sciences, Oregon State University developed the data for Oregon and Washington. The Center for Habitat Studies, Moss Landing Marine Laboratories developed the data for California.	X	OC		X	X		21
OCNMS multi-agency census of sea otters	Monitoring the sea otter population in Washington state since 1995. Annual surveys in July.		OC					25
SCCWRP Southern California Bight Regional Surveys	Beginning in 1994 and repeating every 5 years, Southern California Coastal Water Research Project (SCCWRP) has led a consortium of 13 organizations in conducting a integrated, coordinated regional monitoring survey for the Southern California Bight. The surveys include measurement of chemistry, toxicity, benthic infauna, and fish assemblages at 261 sites between Point Conception and the Mexican border.		CI					26
Sanctuary Ecosystem Assessment Surveys (SEAS)	SEAS collect data on the abundance and distribution of bird, mammals, turtles, jellyfish, krill, vessel activities, harmful algal blooms, and location of surface fronts and convergent zones. 2005-2008 annual 10 day cruise		GF					28
Central Coast Ambient Monitoring Program (CCAMP)	A water quality monitoring and assessment program for the central California region that began in 1998.		MB					30

Table 12

Project Name	Project Description	Available though PaCOOS	ONMS SWiM Condition Reports	Module I, CCE IEA	Atlantis NCCE model	NCEAS CCME Human Impact Assessment	MBCORC Report Card	ID #
Central Coast Long Term Environmental Network (CCLEAN)	A long-term regional monitoring program for central California that began in 2000. Water quality is monitored in watersheds that flow into coastal regions, in estuarine coastal confluences, and at coastal sites. Monitoring persistent organic pollutants in water and sediment, nutrients, pathogens, and suspended sediments in rivers.		MB				X	31
National Estuarine Research Reserve (NERR) System-Wide Monitoring Program	Part of a system-wide long-term monitoring program that focuses on short-term variability and long-term changes in key properties of water quality. Monthly sampling in Elkhorn Slough since 1988 and in San Francisco NERR since 2005.		MB					32
Santa Cruz County Surface Water Quality Monitoring Program	The Santa Cruz County Surface Water Quality Monitoring Program began in 1975, and is conducted by the Santa Cruz County Environmental Health Services Agency. Measures baseline water quality and identifies sources of water quality degradation in the marine and fresh waters of Santa Cruz County.		MB					33
OCNMS intertidal monitoring	Bi-annual monitoring of baseline information and trends over time for intertidal living resources along the Olympic Coast began in 1996. Conducted by OCNMS and Olympic National Park.		OC					35
Central California Habitat Characterization	Starting in 2004, this project has been mapping the seafloor and characterizing habitats and associated benthic macroinvertebrates and fish assemblages in the three West Coast national marine sanctuaries.		MB, CB					37
Statewide Water Ambient Monitoring Program (SWAMP)	SWAMP data currently consists of field observations, discrete field measures and laboratory, bacteria indicators, and toxicity results for sediment and water samples throughout the state of California. Tissue, bioassessment (organisms and physical habitat) and time series data are being added to the database.		MB					41
OCNMS offshore cetacean and seabird surveys	Binocular and naked-eye surveys using ship-based line transects following permanent east-west tracklines; photo ID catalogue collected. Annual surveys in late May to July since 1995.		OC					42
Deep Sea Corals	Expeditions to inventory deep sea corals from Olympic Coast NMS (in 2006) and the Davidson Seamount (in 2002 and 2006).		OC					43
USFW seabird colony surveys	Annual surveys of seabird colonies in the Olympic Coast sanctuary conducted by USFW.		OC					46
USGS Pacific Coast habitat mapping program	Various remotely-sensed data available for download. Primarily sidescan.	X	MB					47
Long-term Monitoring Program & Experiential Training for Students (LiMPETS)	The LiMPETS program began in 2002. Middle school, high school, and other volunteer groups monitor rocky intertidal and sandy shore areas in four of the west coast National Marine Sanctuaries.		MB					48
Santa Barbara Coastal Long Term Ecological	The primary research objective of the SBC LTER is to investigate the relative importance of land and ocean processes in structuring		CI					51

Table 12

Project Name	Project Description	Available though PaCOOS	ONMS SWiM Condition Reports	Module I, CCE IEA	Atlantis NCCE model	NCEAS CCME Human Impact Assessment	MBCORC Report Card	ID #
Research Program (SBC LTER)	giant kelp forest ecosystems. This monitoring program began in 2000.							
Beach Watch	Beach Watch is a long-term shoreline monitoring project that was founded in 1993. Volunteers conduct monthly surveys of assigned beaches within the Gulf of the Farallones and Monterey Bay National Marine Sanctuaries. Data is collected on live and dead species of birds and marine mammals as well as oil pollution.		GF					54
Partnership for the Interdisciplinary Study of Coastal Oceans (PISCO)	PISCO conducts experiments & long-term monitoring of west coast nearshore ecosystems (e.g., rocky intertidal, kelp forest and rocky reef). Components include nearshore oceanography, larval dispersal, recruitment, physiology, ecological interactions, community structure. Began in 1999.		MB					59
SWFSC Shipboard Cetacean Survey	Survey to assess the abundance and distribution of marine mammals and to characterize the pelagic ecosystem off the U.S. West Coast out to a distance of approximately 300 nautical miles. Surveys occurred in 1991, 1993, 1996, 2001, 2005, and 2008. The 2005 cruise, called the Collaborative Survey of Cetacean Abundance and the Pelagic Ecosystem (CSCAPE), was a collaboration with ONMS and included additional fine-scale surveys within the NMS boundaries.	CTD data only	MB, CI		X			60
California Cooperative Oceanic Fisheries Investigations (CalCOFI)	CalCOFI are a series of shipboard surveys along fixed transect lines off central and southern California to collect physical and chemical oceanographic data and to census populations from phytoplankton to avifauna. Began in 1949. Some transects are still sampled annually through a partnership including SIO, SWFSC and CDFG	Biological data: Phytoplankton, fish eggs and larvae only		X	X			65
Monterey Bay Time Series (MBTS) Program	Shipboard measurements of physical, chemical and biological parameters are made during quarterly MBARI cruises. Data collection in Monterey Bay began in 1989. Data collection was expanded offshore into the California Current (along CalCOFI transect line 67) in 1997 under the name SECRET (Studies of Ecological and Chemical Responses to Environmental Trends).	X	MB	X			X	66
NWFSC Groundfish Surveys	Annual trawl groundfish surveys are conducted by NMFS NWFSC from the Canadian border to the Mexican border along the West Coast of the U.S. These surveys provide information about distribution, relative abundance, and age structure of important groundfish populations. Occurrence of structure-forming invertebrates in trawls is recorded when possible.	X	OC, MB	X	X		X	67
NOAA National Data Buoy Center (NDBC)	The NOAA NDBC collects recent and historical buoy data and observations from various types of buoys around the world, including the entire U.S. West Coast	X						68
Humboldt Line Survey	Monitoring of ocean structure and the spatial distribution of plankton species including egg and larval stages of fish and select invertebrate species along a 60 nautical mile cross-shelf transect off Trinidad Head. Quarterly sampling by NOAA and Humboldt State							69

Table 12

Project Name	Project Description	Available though PaCOOS	ONMS SWiM Condition Reports	Module I, CCE IEA	Atlantis NCCE model	NCEAS CCME Human Impact Assessment	MBCORC Report Card	ID #
	University starting April 2006.							
SWFSC Central California Aerial Surveys	Aerial surveys to quantify the spatial and temporal distribution of marine mammals, seabirds and leatherback turtles in coastal waters of central California. Began in 1997.		CB		X			71
Cooperative Research and Assessment of Nearshore Ecosystems (CRANE)	CRANE, which began in 2002, is a collaborative effort to gather data for fishery management and performance of marine protected areas in central and southern California. Data collection includes wide-scale survey of fish and invertebrate populations in shallow, rocky habitats accessible to divers (Monterey to San Diego, including the Channel Islands).		MB					76
Habitat Characterization and Biological Monitoring of Cordell Bank	In 2001, Cordell Bank sanctuary, in partnership with the SWFSC, USGS, and CDFG, initiated a long-term study to classify habitats and monitor fishes and macro-invertebrates on and around Cordell Bank. Underwater surveys of fishes, invertebrates, and their habitats are conducted on and around Cordell Bank using direct observation and video-transect methods from an occupied research submersible (Delta).		CB					77
Coastal Ocean Currents Monitoring Program (COCMP)	COCMP uses an integrated set of high frequency radar systems to measure and map surface currents over large areas of the coastal ocean in central and southern California.	Monterey Bay, San Francisco Bay and outlet						79
PRBO At-Sea Marine Mammal and Seabird Surveys	Surveys in the Gulf of the Farallones to determine the distribution and abundance of marine birds and mammals, to quantify the distribution and abundance of euphausiids and other bird/mammals prey, to characterize the zooplankton community in the upper water column, and to characterize the physical oceanographic conditions.		CB					81
Mussel Watch Program	The NOAA National Status and Trends Mussel Watch Program monitors chemical contamination in the coastal United States. Since 1986 mussels and oysters have been annually collected at more than 200 sites around the nation and analyzed for a suite of chemical contaminants.		OC, GF, MB				X	88
Multi-Agency Rocky Intertidal Network (MARINe)	MARINe monitors sites along the Pacific Coast using two different approaches—target assemblage monitoring (biannually at 80 locations in California and Oregon), and biodiversity community monitoring (less frequent at 91 locations from Alaska to Mexico). Sites are selected to provide data about different rocky habitats, different exposure variables, different public uses.		MB					91

Table 12

Project Name	Project Description	Available though PaCOOS	ONMS SWiM Condition Reports	Module I, CCE IEA	Atlantis NCCE model	NCEAS CCME Human Impact Assessment	MBCO RC Report Card	ID #
Santa Barbara Channelkeeper Stream Team monitoring program	Channelkeeper has run a volunteer-based water quality monitoring program - Stream Team - since 2001 in the Ventura River watershed (in partnership with the Ventura County chapter of the Surfrider Foundation), and since 2002 in the Goleta Slough watershed. Water quality is tested monthly at every major reach and junction to locate the 'trouble' spots.		CI					93
PRBO Snowy Plover monitoring	PRBO Conservation Science has two monitoring projects for Snowy Plover, one in Monterey Bay and one at Point Reyes. Since 1976, the Monterey project has monitored Snowy Plovers nesting in coastal habitats of Santa Cruz and Monterey counties. Since 1996, the Point Reyes project has been protecting and monitoring nesting Snowy Plovers within the Point Reyes National Seashore.						X	96
Line P	Department of Fisheries and Oceans Canada (DFO) & others. Oceanographic sampling off British Columbia, Canada. Hydrography, nutrients and lower trophic level productivity is measured. Seabirds and marine mammals are also surveyed. On-going monitoring began in 1949.	X		X				
SWFSC Rockfish Recruitment Survey	NMFS-SWFSC and other collaborators have conducted annual mid-water trawl surveys in the greater Gulf of the Farallones (Monterey Bay to Bodega Bay) region off central California. Hydrography and estimates of recruitment for young-of-the-year (age-0) *Sebastes* are priorities for this survey. On-going monitoring began in 1983. Data on abundance of seabirds and marine mammals is also collected.	CTD and Thermosal data only	CB, GF, MB	X			X	
Southeast Farallon Island Seabird Ecology Surveys	Under contract with USFWS, PRBO Conservation Science monitors and studies the ecology of 12 seabird species and 5 pinniped species at this site. Daily measurements of SST, salinity, and weather are also made. On-going monitoring began in 1971.		CB, MB	X	cenCA model only		X	
Channel Islands Seabird Ecology Surveys	The California Center for Environmental Studies initiated research on Brown Pelicans in the Channel Islands in the late 1960s. In 1985, the Channel Islands National Park initiated long-term studies of a variety of seabirds at Santa Barbara, Anacapa, and San Miguel islands. On-going monitoring began in 1968.		CI	X				
Vancouver Island Zooplankton	Since 1979, DFO Canada has measured zooplankton and hydrographic conditions on the Vancouver Island continental margin.			X				
Newport Hydrographic Line	Biweekly surveys of this line have been conducted by NMFS-NWFSC off Newport, Oregon since 1996. Priorities for this survey include hydrography and zooplankton (copepods and euphausiids) and more recently seabirds.	hydrography data		X	X			
Oregon and Washington Forage Fish	Hydrography, nutrients, chlorophyll-a, zooplankton and pelagic forage fish are sampled by NMFS-NWFSC at six stations along each of eight transects ranging from Newport, Oregon to the Washington-Canadian border. 1998 - present			X	TBD			

Table 12

Project Name	Project Description	Available though PaCOOS	ONMS SWiM Condition Reports	Module I, CCE IEA	Atlantis NCCE model	NCEAS CCME Human Impact Assessment	MBCO RC Report Card	ID #
Tatoosh Island Seabird Ecology Study	Studies of the breeding success and diet of seabirds that inhabit Tatoosh Island, WA, focused on Common Murres began in 1990 by University of Washington.			X				
Triangle Island Seabird Ecology	Canadian Wildlife Service and Simon Fraser University are studying the breeding success and diet of the seabirds that inhabit Triangle Island. Focus on Rhinoceros Auklet and Cassin's Auklet. On-going monitoring began in 1994.			X				
SWFSC Pinniped Aerial Surveys Project	SWFSC conducts censuses of five species of pinnipeds.. Pups and other age/sex classes are counted from color photographs taken at rookeries and haulouts during aerial surveys of islands and the mainland coast of California.		MB	X	X			
CINP Monitoring	Subsurface temperature and biological monitoring data at numerous subtidal sites in the Channel Islands National Park (CINP).	Temp, kelp, inverts and fish data	CI					
GLOBEC	GLOBEC (Global Ocean Ecosystem Dynamics) was initiated in 1991. Oceanographic data including temperature, salinity, oxygen, nutrients, phytoplankton, birds, cetaceans.	X			X			
World Ocean Database (WODB)	The World Ocean Database is a collection of scientifically quality-controlled ocean profiles from the National Oceanographic Data Center (NODC). This dataset contains measurements of temperature, salinity, oxygen, chlorophyll.	X						
NOAA Habitat Use Database (HUD)	This NWFSC database Includes Fish Occurrence Details, Fish Species Details, Predators and Prey, References.	X						
West Coast Groundfish Observer Program	This NWFSC Observer Program conducts sampling of groundfish discarded by commercial fisheries along the entire continental U.S. West Coast. The seventeen species included in this data product are those of most interest to fisheries management and commercial fishing communities. Data available for both trawl and fixed gear.	X			X			
Integrated Acoustic and Trawl Surveys of Pacific Hake	Shipboard acoustic Doppler current profiler data collected by NWFSC during the Integrated Acoustic and Trawl Surveys of Pacific Hake, years: 1995, 1998, 2001, 2003, and 2005.	ADCP data only			X			
NGDC Coastal Relief Gridded database	The National Geophysical Data Center (NGDC) Coastal Relief model provides bathymetry from the coastal state boundaries to as far offshore as the NOS hydrographic data will support a continuous view of the seafloor.	X	?					
WOCE	World Ocean Circulation Experiment (WOCE) in-situ tide gauge data (data on sea level) as part of the Global Sea Level Observing System (GLOSS) network	X						
POES	Polar Operational Environmental Satellites (POES) provide ocean surface temperature data.	X						

Table 12

Project Name	Project Description	Available though PaCOOS	ONMS SWiM Condition Reports	Module I, CCE IEA	Atlantis NCCE model	NCEAS CCME Human Impact Assessment	MBCORC Report Card	ID #
California Fish Landings	Database includes commercial landings of fish and invertebrates caught off California and landed in California. Landing receipt data began in 1928. Includes PacFIN database which began in 1981. Also includes length and age compositions.	X	MB		X	X	X	
SF-BEAMS	The San Francisco Bay Environmental Assessment and Monitoring Station (SF-BEAMS) continuously monitors San Francisco Bay water quality and weather conditions at a location approximately 200 ft offshore on the Romberg Tiberon Center pier. SF-BEAMS is part of CICORE.	X						
COADS	Comprehensive Ocean-Atmosphere Data Set (COADS) Project provides monthly time series (1854-1993) of atmospheric variables including SST, Sea Level Pressure, Wind.	X			X			
usSEABED	usSEABED provides data from seafloor samples on sediment and rock distributions in the waters off the United States. Part of the USGS Coastal & Marine Geology Program	X						
NMFS Cold Water Corals	The location of some observations of cold-water/deep-sea corals off the west coast of the United States. Records of coral catch originate from bottom trawl surveys conducted from 1980 to 2001 by the Alaska Fisheries Science Center (AFSC) and 2001 to 2005 by the Northwest Fisheries Science Center (NWFSC).	X	OC, MB					
EPA Toxic Release Inventory	The EPA Toxics Release Inventory contains information on toxic chemical releases and waste management activities reported annually by certain industries as well as federal facilities.					X		
California Recreational Fisheries Survey (CRFS)	CRFS is a coordinated sampling survey designed to gather catch and effort data from anglers in all modes of marine recreational finfish fishing. It can be used to estimate total marine recreational finfish catch and effort in California		GF			X		
VOS Scheme	World Meteorological Organization Voluntary Observing Ship (VOS) Scheme provides information on commercial shipping traffic patterns.					X		
FAO Fisheries time-series	The Food and Agriculture Organization (FAO) of the United Nations Fisheries and Aquaculture department collects data on demersal and pelagic fisheries					X		
DOT Ferry Traffic	Data on ferry traffic available from the state Department of Transportation (California and Washington)					X		
Shipping	Tonnage data available from the US Army Corps of Engineers Navigation Data Center					X		
Oil Rigs	Data available from Pacific States Marine Fisheries Commission					X		
Platts energy database	Location of power plants and desalination plants. Provided by Platts (part of McGraw-Hill Companies)					X		

Table 12

Project Name	Project Description	Available though PaCOOS	ONMS SWiM Condition Reports	Module I, CCE IEA	Atlantis NCCE model	NCEAS CCME Human Impact Assessment	MBCO RC Report Card	ID #
California Coastal Commission Public Education Program	Data on coastal pollution including marine debris (other than fishing gear) and oil, chemicals, etc.					X		
AVHRR Pathfinder Satellite data	Sea surface temperature data produced by NOAA's National Oceanographic Data Center and the University of Miami's Rosenstiel School of Marine and Atmospheric Science.				?	X		
Human access to beaches, intertidal	California: California Coastal Access Guide (MLPA); Oregon: Oregon Geospatial Enterprise Office; Washington: Washington State Department of Ecology BEACH (Beach Environmental Assessment, Communication and Health) Program					X		
PDO index	The Pacific Decadal Oscillation (PDO) index (1900-2006). Data courtesy Nate Mantua (Joint Institute for the Study of the Atmosphere and Ocean, UW). http://jisao.washington.edu/pdo/PDO.latest			X				
MEI	The Multivariate El Niño Index (MEI), 1950-2006. Data courtesy Klaus Wolter (NOAA-Earth System Research Laboratory). The MEI is a composite index constructed using 7 environmental variables. http://www.cdc.noaa.gov/people/klaus.wolter/MEI/table.html.			X				
SWFSC Upwelling Index	The SWFSC Pacific Fisheries Environmental Laboratory generates indices of the intensity of large-scale, wind-induced coastal upwelling and along-shore transport at 15 standard locations along the west coast of North America.	X		X	x		x	

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Appendix 1 - West Coast Sanctuary Data Inventory

A west coast sanctuary data inventory was built by identifying monitoring programs in the five west coast sanctuaries: Olympic Coast, Cordell Bank, Gulf of the Farallones, Monterey Bay, and Channel Islands National Marine Sanctuaries. Initial requirements for inventory inclusion were subjectively based on (in no particular order) geographic range, monitoring frequency, duration, future longevity, variables measured, and ONMS participation. Since PaCOOS primarily seeks to integrate data from the relatively large area of the U.S. Pacific west coast Exclusive Economic Zone (EEZ; from shore out to 200 nautical miles), monitoring efforts with a small footprint were considered lower priority. Emphasis was placed on monitoring efforts that were multi-year with frequent data collection. Future longevity of a project was also a key consideration.

ID	Project Name	Project Description	Charact. ID #	ONMS Site					Biological data											Physical data															Project URL
				OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile inverts	Adult inverts	Ichthyoplankton	Juvenile fish	Adult fish	Marine mammals	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents (ADCP)	Transmittance	Weather	Barometric pres	PAR	Wind	Wave direction	Aerial/sat photos	Sidescan	Multibeam	Habitat type	ADCP	Other-physical	
1	West Coast Observatories (WCObs)	WCObs deals with oceanographic data collected at all five sanctuary sites located on the west coast. The project began in 2004 and focuses on various data streams collected at instrument moorings.	1, 2	x	x	x	x	x		x												x	x	x	x	x		x										Turbidity, sigma-t	http://www.sanctuarysimon.org/regional_sections/obs/
2	Beach COMBERS	Beach COMBERS (Coastal Ocean Marine Mammal & Bird Education and Research Surveys) uses volunteers to survey beached marine birds and mammals monthly at selected sections of beaches in the central and southern portions of the Monterey Bay sanctuary.	8				x											x	x										x									tar balls	http://sanctuarysimon.org/monterey/sections/marineMammals/project_info.php?projectID=100143&sec=mm

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
3	Center for Integrated Marine Technologies (CIMT)	CIMT simultaneously collected data on physical, chemical, and biological (from phytoplankton to marine mammals) via moorings, shipboard surveys, apex predator tagging and tracking, and satellite, aircraft, and land-based remote sensing in Monterey Bay from 2002-2007 and was built on a foundation of data collection initiated in 1997.	1, 2, 8, 14, 15				x		x		x	x							x	x		x		x	x	x	x		x		x									harmful algal blooms	http://sanctuarysimon.org/monterey/sections/oceanography/project_info.php?projectID=100155&sec=o
4	R/V Fulmar and R/V Shearwater data logger	Weather and ocean surface variables measured continuously when the research vessel is moving greater than 1kt. Data collection began in 2006.	1		x	x	x	x														x	x		x		x			x		x							
5	USGS Stream Gauge Network	The US Geological Survey Stream Gauge Network provides historical and real-time river/stream level and flow information.	2, 5	x		x	x	x																	x														flow rate	http://waterdata.usgs.gov/nwis/rt
6	MBARI Ocean Observing System (MOOS)	Since 1989 Monterey Bay Aquarium Research Institute (MBARI) has operated a mooring observing system in Monterey Bay.	1				x																x	x	x		x		x		x	x							http://www.mbari.org/bog/Projects/MOOS/default.htm

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
7	California Sea Otter Survey	Bi-annual aerial and land-based standardized surveys of Southern sea otters have been conducted in California (from Santa Barbara to Half Moon Bay) during late spring and early fall since 1983.	12, 15			x	x	x										x											x				x							http://sanctuarysimon.org/monterey/sections/marineMammals/project_info.php?projectID=100172&sec=mm
8	Naval Postgraduate School HF Radar	HF radar hardware and software have allowed examination of circulation in Monterey Bay since 1994.	1, 2				x																				x													http://www.oc.nps.navy.mil/~radlab/radar.html
9	WA Annual Kelp Surveys	Aerial photographs taken in the late summer are used to monitor maximum bed extent of floating kelp along the Strait of Juan de Fuca and outer coast in the Olympic Coast sanctuary. Data collected by Washington State Department of Natural Resources in 1989-1992 and 1994-present.	9, 12	x																kelp														x			x			http://www3.wadnr.gov/dnrapp6/dataweb/metadata/dnr_kelp.htm
10	CA Annual Kelp Surveys	Aerial photographs taken in the late summer have been used to monitor maximum bed extent of floating kelp along the California mainland coast. Data collected by California Department of Fish and Game in 1989 and 1999-present.	9, 12			x	x	x												kelp														x			x			

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
11	MBARI cruise data	Monterey Bay Aquarium Research Institute (MBARI) vessels continuously record oceanographic variables.	1				x																x		x		x													
12	Land/Ocean Biogeochemical Observatory in Elkhorn Slough (LOBO)	The LOBO project uses in situ chemical sensors to determine chemical fluxes into, within, and out of Elkhorn Slough in the Monterey Bay sanctuary. The primary focus is to measure nutrients, such as nitrate, ammonium, and phosphate. Data collected since 2003.	2, 5, 8				x		x	x											x	x	x	x	x	x	x	x	x			x							NO4, PO4	http://www.mbari.org/lobo/
13	Structure of Populations, Levels of Abundance and Status of Humpbacks (SPLASH)	SPLASH conducted a dedicated sampling program of humpback whales in the entire North Pacific from 2003-2007. Subsequent analysis is determining a current estimate of overall abundance for the North Pacific (including estimates for specific wintering and feeding areas).	15	x	x	x	x	x										x		skin and blubber						x		x			x									http://www.cascadiaresearch.org/SPLASH/splash.htm
14	Coastal Data Information Program (CDIP)/ Wave Rider buoys	CDIP was established in 1975 to measure, analyze, archive and disseminate coastal environmental data including wave models and forecasts for the United States.	1, 2	x	x	x	x	x																	x		x					x	x							http://cdip.ucsd.edu/?nav=recent&sub=observed

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15	Coastal Observation and Seabird Survey Team (COASST)	COASST, which began in 1999, uses volunteers to survey beached marine birds at selected sections of beaches in Washington and northern Oregon. Beach segments are surveyed either monthly or every two weeks.	8	x															x											x			x	x							http://coasst.org
16	Network for Environmental Observations of the Coastal Ocean (NEOCO)	NEOCO, established in 2001, is a observing network that monitors coastal oceanographic conditions. Active sites are Bodega Head, La Jolla, Newport Beach, Santa Barbara, and Santa Cruz.	1, 2, 5, 8			x	x	x	x	x												x		x	x			x												http://www.es.ucsc.edu/~neoco/instruments.html
17	California State University Monterey Bay - Seafloor Mapping Lab (SFML)	The CSUMB-SFML specializes in high-resolution acoustic remote sensing for coastal habitats. Data collection in coastal California began in 1993.	4	x	x	x	x	x																		x										x	x	x		http://seafloor.csumb.edu/index.html
18	OCNMS Habitat Mapping	In August 2004 and May and July 2005, OCNMS imaged several regions of the sea floor in the northern OCNMS. Video from a towed camera sled, bathymetry data, sedimentary samples and side scan sonar mapping were integrated to describe geological and biological aspects of habitat.	4	x																						x										x	x	x		http://www.sanctuaries.noaa.gov/science/conservation/oc_mapping.html

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19	Cordell Bank Ocean Monitoring Program (CBOMP)	A monthly census of birds, marine mammals, krill and physical oceanographic conditions in the Cordell Bank NMS began in 2004. Data collection methods were designed so that data could be integrated with CIMT.	1, 14, 15		x				x			x							x	x				x	x	x	x	x			x		x								http://sanctuarysimon.org/cordell/sections/openOcean/project_info.php?projectID=84&sec=oo
20	MBARI Monterey Bay Multibeam Survey	In June 1998 Monterey Bay Aquarium Research Institute (MBARI) completed surveys of selected areas of the Monterey Bay sanctuary and surrounding features using a multibeam echo sounder.	4				x																			x											x	x			http://www.mbari.org/data/mapping/monterey/default.htm
21	Essential Fish Habitat (EFH)	The EFH data set contains physical seafloor characteristics considered important for identifying essential habitat for groundfish. Seafloor feature data sets include side-scan sonar, bottom samples, seismic data, and multibeam bathymetry. The Active Tectonics and Seafloor Mapping Lab, College of Oceanic and Atmospheric Sciences, Oregon State University developed the data for Oregon and Washington. The Center for Habitat Studies, Moss Landing Marine Laboratories developed the data for California.	4	x	x	x	x	x																			x												x			http://www.nmfs.noaa.gov/habitat/habitatprotection/efh/

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22	Tagging of Pacific Predators (TOPP)	Archiving tags collect data on the movements of pelagic nekton and seabirds in the North Pacific and record the physical conditions of their surroundings.	1, 14, 15	x	x	x	x	x						x			x	x	x	sea turtles			x	x	x	x			x											
23	Tracking Black-footed Albatross	This project uses satellite tracking to explore the post-breeding movements and ocean habitats of Black-footed Albatross tagged in National Marine Sanctuaries off central California during summer / fall. Started in 2004.	15		x	x	x												x																				http://www.toppcensus.org, http://sanctuarysimon.org/monterey/sections/marineMammals/project_info.php?projectID=100137&sec=mm http://www.oikonos.org/projects/albatross.htm, http://sanctuarysimon.org/monterey/sections/birds/project_info.php?projectID=100305&sec=ss
24	City of San Diego Ocean Monitoring Program	The City of San Diego's Ocean Monitoring Program has two distinct monitoring programs (beginning in 2004): 1) the National Pollutant Discharge Elimination System mandated program surrounding the Point Loma Ocean Outfall, and 2) the monitoring program surrounding the South Bay Ocean Outfall. 350 sampling days per year from 2 vessels	6, 13			x			x					x			x			bacterial samples		x	x	x		x		x										sediment, pH	http://www.sandiego.gov/mwwd/environment/oceanmonitor.shtml
25	OCNMS multi-agency census of sea otters	Monitoring the sea otter population in Washington state since 1995. Annual surveys in July.	12, 15	x														x															x						

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26	SCCWRP Southern California Bight Regional Surveys	Beginning in 1994 and repeating every 5 years, Southern California Coastal Water Research Project (SCCWRP) has led a consortium of 13 organizations in conducting a integrated, coordinated regional monitoring survey for the Southern California Bight. The surveys include measurement of chemistry, toxicity, benthic infauna, and fish assemblages at 261 sites between Point Conception and the Mexican border.	1, 5, 6, 7, 13, 14					x						x			x					x	x	x	x													x	toxicity, grain size	http://www.sccwrp.org/view.php?id=545
27	El Nino Coastal Erosion study	NASA's Wallops Flight Facility, NOAA's Coastal Services Center, and the USGS Coastal & Marine Program surveyed 1200 km of representative areas of the west coast both prior to and following the El Niño winter storms using scanning airborne laser altimetry to determine the magnitude, spatial patterns, and causative processes of El Niño-induced change.	4			x	x																												x			x		http://www.mbnms-simon.org/sections/geology/project_info.php?pid=100188&sec=g

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28	Sanctuary Ecosystem Assessment Surveys (SEAS)	SEAS collect data on the abundance and distribution of bird, mammals, turtles, jellyfish, krill, vessel activities, harmful algal blooms, and location of surface fronts and convergent zones. 2005-2008 annual 10 day cruise	1, 8, 14, 15		x	x	x			x	x	x			x			x	x	sounds			x	x	x	x	x			x									http://www.sanctuaries.noaa.gov/missions/2006gfnms/welcome.html
30	Central Coast Ambient Monitoring Program (CCAMP)	A water quality monitoring and assessment program for the central California region that began in 1998.	5				x	x													x																	various	http://www.ccamp.org/
31	Central Coast Long Term Environmental Network (CCLEAN)	A long-term regional monitoring program for central California that began in 2000. Water quality is monitored in watersheds that flow into coastal regions, in estuarine coastal confluences, and at coastal sites. Monitoring persistent organic pollutants in water and sediment, nutrients, pathogens, and suspended sediments in rivers.	2, 5, 6, 7, 8			x	x							x							x	x	x		x	x	x											various	http://www.amarine.com/information/cclean/cclean.html

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32	National Estuarine Research Reserve (NERR) System-Wide Monitoring Program	Part of a system-wide long-term monitoring program that focuses on short-term variability and long-term changes in key properties of water quality. Monthly sampling in Elkhorn Slough since 1988 and in San Francisco NERR since 2005.	2, 5			x	x														x	x	x			x	x	x											various	http://www.elkhornslough.org/research/waterquality_stations.htm
33	Santa Cruz County SWQMP	The Santa Cruz County Surface Water Quality Monitoring Program (SWQMP) began in 1975, and is conducted by the Santa Cruz County Environmental Health Services Agency. Measures baseline water quality and identifies sources of water quality degradation in the marine and fresh waters of Santa Cruz County.	2, 5				x														x	x	x			x	x	x											various	http://sccounty01.co.santa-cruz.ca.us/eh/
34	Central Coast Watershed Studies (CCoWS)	CCoWS, which began in 2001, is conducting watershed and landscape ecological research and education that supports sustainable land management in California's Central Coast region.	2, 5				x														x	x	x			x	x	x											various	http://ccows.csumb.edu/
35	OCNMS intertidal monitoring	Bi-annual monitoring of baseline information and trends over time for intertidal living resources along the Olympic Coast began in 1996. Conducted by OCNMS and Olympic National Park.	10	x										x	x																									

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36	Physical Oceanographic Real-Time System (PORTS)	PORTS provides real-time information to mariners, oil spill response teams, coastal managers, and others about San Francisco Bay water levels, currents, salinity, and winds. Includes nowcasts and predictions. NOAA/National Ocean Service CO-OPS				x																x		x		x	x			x		x							tides	http://tidesandcurrents.noaa.gov/ports.html
37	Central California Habitat Characterization	Starting in 2004, this project has been mapping the seafloor and characterizing habitats and associated benthic macroinvertebrates and fish assemblages in the three West Coast national marine sanctuaries.	4, 13		x	x	x							x			x							x	x									x		x			http://www.mbnms-simon.org/sections/sandyFloor/project_info.php?pid=100237&sec=sf
38	Plumes and Blooms (PnB Project)	The PnB project provides data on the Santa Barbara Channel's ever changing environment, including temperature, salinity, chlorophyll concentrations, and phytoplankton blooms. Since 1996.	1, 5, 8					x	x	x	x												x			x	x			x			x	x						http://www.icess.ucsb.edu/PnB/PnB.html

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39	EPA California Coastal Project	Various projects throughout California: Sediment samples taken from 80 estuaries in 1999; sediment samples from 50 stations in SF Bay taken in 2000; Los Angeles County dredging sediment samples taken since 1997; continental shelf sediment samples taken around Southern CA bight in 1998; several others				x								x	x		x	x				x	x	x		x			x												http://www.sccwrp.org/
40	CDFG/CINP White abalone surveys	Surveys in the 1980's	12					x						x											x	x														
41	Statewide Water Ambient Monitoring Program (SWAMP)	SWAMP data currently consists of field observations, discrete field measures and laboratory, bacteria indicators, and toxicity results for sediment and water samples throughout the state of California. Tissue, bioassessment (organisms and physical habitat) and time series data are being added to the database.	5, 6, 7			x	x							x						mussel tissue, bacteria		x	x	x	x				x										pH, sediment	http://www.swrcb.ca.gov/water_issues/programs/swamp/

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42	OCNMS offshore cetacean and seabird surveys	Binocular and naked-eye surveys using ship-based line transects following permanent east-west tracklines; photo ID catalogue collected. Annual surveys in late May to July since 1995.	15	x															x	x										x											
43	Deep Sea Corals	Expeditions to inventory deep sea corals from Olympic Coast NMS (in 2006) and the Davidson Seamount (in 2002 and 2006).	9	x			x							x	x								x		x	x												x			http://olympiccoast.noaa.gov/research/research_feat/welcome.htm
44	Sanctuary Aerial Monitoring and Spatial Analysis Program (SAMSAP)	Aerial surveys over the Channel Islands NMS from 1999-2004 primarily for looking at vessel use/traffic of all vessel, but marine mammal sightings are also taken.	15					x											x															x						
45	Coastal LIDAR Collection	Light Detection and Ranging (LIDAR) is being used by NOAA and NASA scientists to document topographic changes along shorelines. LIDAR data collected along the U.S. west coast since 1997.	2, 3	x			x	x	x																													x	x	
46	USFW seabird colony surveys	Annual surveys of seabird colonies in the Olympic Coast sanctuary conducted by USFW.	15	x															x																					
47	USGS Pacific Coast habitat mapping program	Various remotely-sensed data available for download. Primarily sidescan.	4	x	x	x	x	x																											x		x			http://kai.er.usgs.gov/regional/contusa/westcoast/

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48	Long-term Monitoring Program & Experiential Training for Students (LiMPETS)	The LiMPETS program began in 2002. Middle school, high school, and other volunteer groups monitor the rocky intertidal, sandy shore and offshore areas of the five west coast National Marine Sanctuaries.	10, 11	x		x	x	x						x						algae																				http://limpetsmonitoring.org/
49	USGS Water Quality Monitoring	The USGS collects and analyzes chemical, physical, and biological properties of water, sediment and tissue samples from across the Nation. The NWISWeb discrete sample data base is a compilation of over 4.4 million historical water quality analyses in the USGS district data bases through September 2005. 1958-present.		x		x	x	x													x				x	x														http://waterdata.usgs.gov/nwis/qw
50	Pacific Jets Experiment (PACJET)	The goal of PACJET was to understand land-falling winter storms and test the use of new observing systems to understand these storms and generate products to improve National Weather Service (NWS) predictions of rainfall and runoff. This project ran 3 storm seasons (2001-2003) in California and Oregon.				x	x	x																			x			x	x		x						precip	http://www.etl.noaa.gov/programs/2003/pacjet/

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51	Santa Barbara Coastal Long Term Ecological Research Program (SBC LTER)	The primary research objective of the SBC LTER is to investigate the relative importance of land and ocean processes in structuring giant kelp forest ecosystems. This monitoring program began in 2000.						x														x			x	x											x		flow	http://sbc.lternet.edu/
52	Automated Surface Observing System (ASOS)	ASOS stations are automated weather stations designed to provide pilots and meteorologists with near real-time weather conditions. This system began data collection in 1998.	1																								x			x			x							http://www.weather.gov/ost/asostech.html
53	Advanced Global Atmospheric Gases Experiment (AGAGE)	Continuous high-frequency gas chromatographic measurements of two biogenic/anthropogenic gases and five anthropogenic gases to determine the source and circulation. The stations are located at coastal sites around the world, with one site at Trinidad Head, California. 1995-present.				x																																atm gases	http://agage.eas.gatech.edu/

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54	Beach Watch	Beach Watch is a long-term shoreline monitoring project that was founded in 1993. Volunteers conduct monthly surveys of assigned beaches within the Gulf of the Farallones and Monterey Bay National Marine Sanctuaries. Data is collected on live and dead species of birds and marine mammals as well as oil pollution.	8, 11			x	x												x	x	human activity, dog activity, live bird and mammal counts						x		x										relevant stream conditions, tar balls	http://www.farallones.org/volunteer/beach_watch.htm
55	Spatial Ecological Analyses of Megavertebrate Populations (SEAMAP)	As part of Ocean Biological Information System (OBIS), SEAMAP is a digital database of marine mammal, seabird, and sea turtle distribution and abundance data. The web-based system allows the interactive display, query, and analysis of Digital Archive in conjunction with environmental data.	1	x	x	x	x	x											x	x			x	x	x	x		x		x											http://seamap.env.duke.edu/
56	First Flush	First Flush is a volunteer water quality sampling program run by the Monterey Bay Sanctuary Citizen Watershed Monitoring Network. Beginning in 2000, runoff has been sampled after the first rain each year at 12 different sites in the cities of Monterey, Pacific Grove and Capitola, CA.	5				x														x	x																	pH	http://www.coastal-watershed.org/Programs/First_Flush/index.htm

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57	Monterey Inner Shelf Observatory (MISO)	MISO is part of the Rapid Environmental Assessment Lab (REAL) at the Naval Postgraduate School in Monterey, California. The MISO instruments, which record nearshore oceanographic conditions, are located on shore and 600m out from the beach adjacent to the Naval Postgraduate School at the southern end of Monterey Bay.	2				x																		x		x	x		x			x	x						http://www.oc.nps.navy.mil/~stanton/miso/
58	Bodega Marine Laboratory Coastal Observing System (BML-COS)	Meteorological and oceanographic conditions on the Bodega Marine Reserve and adjacent coastal waters have been continuously monitored since 1988.	1			x																	x	x		x		x	x			x	x					CO	http://www.bml.ucdavis.edu/boon/
59	Partnership for the Interdisciplinary Study of Coastal Oceans (PISCO)	PISCO conducts experiments & long-term monitoring of west coast nearshore ecosystems (e.g., rocky intertidal, kelp forest and rocky reef). Components include nearshore oceanography, larval dispersal, recruitment, physiology, ecological interactions, community structure. Began in 1999.	9, 10, 12, 14	x		x	x	x					x	x		x	x								x													x		

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60	SWFSC Shipboard Cetacean Survey	Survey to assess the abundance and distribution of marine mammals and to characterize the pelagic ecosystem off the U.S. West Coast out to a distance of approximately 300 nautical miles. Surveys occurred in 1991, 1993, 1996, 2001, 2005, and 2008. The 2005 cruise, called the Collaborative Survey of Cetacean Abundance and the Pelagic Ecosystem (CSCAPE), was a collaboration with ONMS and included additional fine-scale surveys within the NMS boundaries.	1, 15	x	x	x	x	x											x	x											x										http://www.mbnms-simon.org/other/gen/project_info.php?pid=100273&query=cscape&form=kw
61	Aerial Monitoring of Kelp Canopy (CINMS)	CINMS discontinued this monitoring program that surveyed presence/absence of kelp canopy. See CDFG kelp monitoring for on-going monitoring effort.						x																										x		x			
62	Monterey Bay Cable Survey	Survey of infauna and epibenthic organisms for cable instillation, 10 - 2,000 m Monterey Bay					x							x																									

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63	USGS SF Bay and Delta monitoring	The US Geological Survey (USGS) has continuously monitored suspended-solids concentrations, temperature, salinity, and water level at many sites throughout the San Francisco Bay and Delta since 1989. Data availability varies among the sites and is limited to time series between 1989 and 2001.	5			x																	x		x														sediment	
64	CoastWatch	CoastWatch, a NOAA program that began in 1979, collects remotely sensed satellite and other environmental data along the west coast. Data is provided to government decision makers and academic researchers.	1	x	x	x	x	x	x																x															http://coastwatch.noaa.gov/cw_index.html
65	California Cooperative Oceanic Fisheries Investigations (CalCOFI)	CalCOFI are a series of shipboard surveys along fixed transect lines off central and southern California to collect physical and chemical oceanographic data and to census populations from phytoplankton to avifauna. Began in 1949. Some transects are still sampled annually through a partnership including SIO, SWFSC, and CDFG	1, 14				x	x	x									x				x	x		x	x	x		x				x	x					PO4 NO3	http://www.calcofi.org l

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66	Monterey Bay Time Series (MBTS) Program	Shipboard measurements of physical, chemical and biological parameters are made during quarterly MBARI cruises. Data collection in Monterey Bay began in 1989 and was expanded offshore into the California Current (along CalCOFI transect line 67) in 1997.	1, 14				x										x					x			x	x														http://www.mbari.org/bog/Projects/secret/default.htm
67	NWFSC Groundfish Surveys	Annual trawl groundfish surveys are conducted by NFMS NWFSC from the Canadian border to the Mexican border along the West Coast of the U.S. These surveys provide information about distribution, relative abundance, and age structure of important groundfish populations. Occurrence of structure-forming invertebrates in trawls is recorded when possible.	13			x	x									x	x																								http://www.nwfsc.noaa.gov/research/divisions/fram/survey.cfm
68	NOAA National Data Buoy Center (NDBC)	The NOAA NDBC collects recent and historical buoy data and observations from various types of buoys around the world, including the entire U.S. West Coast	1	x	x	x	x	x														x	x	x			x			x										http://www.ndbc.noaa.gov/

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
69	Humboldt Line	Monitoring of ocean structure and the spatial distribution of plankton species including egg and larval stages of fish and select invertebrate species along a 60 nautical mile cross-shelf transect off Trinidad Head. Quarterly sampling by HSU and SWFSC, starting April 2006.	1		x	x				x		x			x							x	x		x						x										www.pacoos.org
70	Remote Automated Weather Stations (RAWS)	There are nearly 2,200 interagency RAWS strategically located throughout the United States. These land-based stations collected meteorological data.																												x		x									http://www.fs.fed.us/raws/
71	SWFSC Central California Aerial Surveys	Aerial surveys to quantify the spatial and temporal distribution of marine mammals, seabirds and leatherback turtles in coastal waters of central California. Began in 1997.	15		x	x	x											x	x															x						

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
72	REEF Volunteer Survey Project	The Reef Environmental Education Fund (REEF) Volunteer Survey Project enlists volunteer SCUBA divers and snorkelers to collect and report information on marine fish populations (Fish Survey Project) as well as selected invertebrate and algae species (Invertebrate & Algae Monitoring Program) along the West Coast of the US and Canada. The Project was developed in 1990. Surveys are completed annually in MBNMS, OCNMS, and CINMS.	12	x			x	x						x			x																					x		http://www.reef.org/
74	CCSF Beach and Ocean Monitoring	The City and County of San Francisco (CCSF) owns and operates the Oceanside Water Pollution Control Plant that discharges municipal wastewater and storm water approximately 3.75 miles offshore of Ocean Beach. Approximately 55 stations are sampled annually for sediment quality and benthic infauna community analyses (sampled since 1997). Five stations fall within the GFNMS and ten stations fall within the MBNMS.	13			x	x							x			x				x																		PCB, metals	http://www.mbnms-simon.org/sections/sandyFloor/project_info.php?pid=100212&sec=sf

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
75	Center for Integrative Coastal Observation, Research and Education (CI-CORE)	CI-CORE examines watershed alteration, erosion, chemical contamination, depletion of fish stocks, toxic plankton blooms, marine-borne pathogens, and non-indigenous species along the California coast.	2				x																											x			x			http://www.cicore.org/
76	Cooperative Research and Assessment of Nearshore Ecosystems (CRANE)	CRANE, which began in 2002, is a collaborative effort to gather data for fishery management and performance of marine protected areas in central and southern California. Data collection includes wide-scale survey of fish and invertebrate populations in shallow, rocky habitats accessible to divers (Monterey to San Diego, including the Channel Islands).	12				x	x						x			x								x	x											x			http://sanctuarysimon.org/monterey/sections/kelpForests/project_info.php?projectID=100154&sec=kf

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
77	Habitat Characterization and Biological Monitoring of Cordell Bank	In 2001, Cordell Bank sanctuary, in partnership with the SWFSC, USGS, and CDFG, initiated a long-term study to classify habitats and monitor fishes and macro-invertebrates on and around Cordell Bank. Underwater surveys of fishes, invertebrates, and their habitats are conducted on and around Cordell Bank using direct observation and video-transect methods from an occupied research submersible (Delta).	9, 12	x										x			x					x	x	x	x													x		http://www.mbnms-simon.org/other/gen/project_info.php?pid=100163&proid=&form=pi
78	Love Lab subtidal surveys	Subtidal surveys at San Miguel and Santa Rosa Islands using the CRANE protocol. Includes monitoring of marine reserves. Began in 1995.	12					x									x																						
79	Coastal Ocean Currents Monitoring Program (COCMP)	COCMP uses an integrated set of high frequency radar systems to measure and map surface currents over large areas of the coastal ocean in central and southern California. Began in 2004.	1			x	x	x																				x											http://www.cocmp.org/

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
80	Pacific Whiting Conservation Cooperative (PWCC) surveys	To improve estimates of whiting recruitment, the PWCC partners with NMFS to conduct an annual survey. Started in 1999, this cooperative survey investigates the abundance and distribution of juvenile whiting and rockfish in the California Current.	14	x													x																								http://www.pacificwhiting.org/
81	PRBO At-Sea Marine Mammal and Seabird Surveys	Surveys in the Gulf of the Farallones to determine the distribution and abundance of marine birds and mammals, to quantify the distribution and abundance of euphausiids and other bird/mammals prey, to characterize the zooplankton community in the upper water column, and to characterize the physical oceanographic conditions.			x	x						x						x	x	x			x	x	x	x	x			x	x		x							http://www.sanctuarysimon.org/farallones/sections/marineMammals/project_info.php?projectID=91&sec=mm
82	PIER Acoustic Telemetry Monitoring	PIER has installed an array of acoustic receivers at Anacapa, Santa Rosa, west end of Santa Cruz Island to monitor the movement of tagged fishes (e.g., kelp bass, California sheephead). Began in 2004.						x									x																							

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
83	Pioneer Seamount Acoustic Observatory	A hydrophone array was installed on the summit of the Pioneer seamount (998m depth) and sounds from earthquakes, weather, whales, ships, etc. were continuously recorded between June 2001 and September 2002.			x	x																			x														sound	http://www.mbari.org/itd/retrospective/algal.html
84	Point Lobos Monterey Bay Time Series	Bio-optical, physical, meteorological, chemical, and biological time series data from moorings and ships are used document annual and ENSO-related variability. Began in 1997.	1				x															x	x		x	x													
85	Remote Sensing of CINMS	Various - multibeam and LiDAR Channel Islands and southern CA						x																	x									x	x		x		
86	San Francisco Estuary Research Institute's Regional Monitoring Program (SFEI RMP)	SFEI RMP monitors contaminant concentrations in water, sediments, and fish and shellfish tissue in San Francisco Bay and Delta. Began in 1994.	5, 6, 7			x											x																					sediment	

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
87	Shore Station Program	The Shore Stations Program, which began in 1916, collects and provides access to current and historical data records of sea surface temperature and salinity measurements observed at shoreline stations along the west coast of the United States. Historically, stations ranged from the southern most station in La Jolla, California, up to the northern most point on the western coast, Neah Bay, Washington. All active stations are located in California.		x		x	x														x	x																	http://shorestation.ucsd.edu/
88	Mussel Watch Program	The NOAA National Status and Trends Mussel Watch Project monitors chemical contamination in the coastal United States. Since 1986 mussels and oysters have been annually collected at more than 200 sites around the nation and chemically analyzed for a suite of chemical contaminants.	6, 8			x	x						x						mussel tissue																		grain/sediment, dioxin, PCB	http://www.sfei.org/camp/servlet/DisplayProgram?which=General&pid=1SF01NSTMW

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
89	MBARI Environmental Sample Processor (ESP)	The ESP was developed at the Monterey Bay Aquarium Research Institute (MBARI) and is designed to autonomously collect discrete subsurface water samples, concentrate microorganisms or particles, and identify and quantify the species captured. The ESP has also been used to detect the onset and development of a harmful algal bloom (HAB). One trial was conducted in Monterey Bay in 2002 and a second generation ESP was deployed in spring 2006.	8				x		x		x								DNA seq		x	x	x	x	x													HAB	http://www.mbari.org/ESP/
90	ESNERR bird monitoring programs	The Elkhorn Slough National Estuarine Research Reserve (ESNERR) has seven distinct, volunteer-run bird monitoring projects including: Monitoring the Rookery, Monitoring the Caspian Tern Colony, Shorebird and Waterfowl Monitoring on the Reserve (and Elkhorn Slough), Monitoring Habitat Use in the south marsh.	15				x											x																					http://www.elkhornslough.org/research/biomonitor_bird.htm

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91	Multi-Agency Rocky Intertidal Network (MARINe)	MARINe monitors sites along the Pacific Coast using two different approaches - target assemblage monitoring (biannually at 80 locations in California and Oregon), and biodiversity community monitoring (less frequent at 91 locations from Alaska to Mexico). Sites are selected to provide data about different rocky habitats, different exposure variables, different public uses.	10			x	x	x						x						algae																			wave exposure	http://www.marine.gov
92	ESNERR elasmobranch monitoring programs	Elkhorn Slough National Estuarine Research Reserve (ESNERR) has been monitoring the elasmobranch assemblage in Elkhorn Slough since 2002. The general focus is to investigate the affect of tides on elasmobranch assemblages and abundances at various points along the Elkhorn Slough. These sampling sites included the main channel at the mouth of the slough and several of the tidal creeks and lagoons throughout the reserve.	11				x											x								x	x														http://www.pelagic.org/slough/

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
93	Santa Barbara Channelkeeper Stream Team monitoring program	Channelkeeper has run a volunteer-based water quality monitoring program - Stream Team - since 2001 in the Ventura River watershed (in partnership with the Ventura County chapter of the Surfrider Foundation), and since 2002 in the Goleta Slough watershed. Water quality is tested monthly at every major reach and junction to locate the 'trouble' spots.	5, 6					x												bacteria		x	x			x		x													http://stream-team.org/index.html
94	PRNS Pinniped Monitoring	Six species of pinnipeds have been documented in the Point Reyes National Seashore (PRNS). Two species, Northern elephant seals and harbor seals, have been monitored on a regular basis during their breeding and pupping seasons since 1971. The other four species (California sea lions, Steller sea lions, Guadalupe fur seals, and Northern fur seals) have been censused weekly at the Point Reyes Headlands since 1995.	15			x												x																							http://www.mbnms-simon.org/sections/marineMammals/project_info.php?pid=100242&sec=mm

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Transmittance	Currents	Air temp	Depth	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
95	PRNS Intertidal Monitoring	The Point Reyes National Seashore (PRNS) intertidal monitoring program began in 1996. Sites are surveyed twice a year, usually around November and May, during a low tide series. Surveys are conducted on the rocky intertidal in three locations. The objective of this monitoring is to create a system for long-term tracking of the Point Reyes intertidal environment integrity.	10			x								x						algae																				http://www.nps.gov/archive/pore/science_current_resmgt.htm
96	PRBO Snowy Plover monitoring	PRBO Conservation Science has two monitoring projects for Snowy Plover, one in Monterey Bay and one at Point Reyes. Since 1976, the Monterey project has monitored Snowy Plovers nesting in coastal habitats of Santa Cruz and Monterey counties. Since 1996, the Point Reyes project has been protecting and monitoring nesting Snowy Plovers within the Point Reyes National Seashore.	11			x	x												x																					http://www.prbo.org/cms/index.php?mid=126

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Depth	Air temp	Currents	Transmittance	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
97	Olympic Region Harmful Algal Blooms (ORHAB)	Since summer 2000, ORHAB has been investigating the origins of blooms of toxic algae, monitoring where and when the blooms occur, and exploring methods that can be used to reduce HAB impacts on humans and the environment. The ORHAB project monitors plankton, toxins, and water quality along the WA coast to determine the environmental conditions associated with blooms.	1, 8	x						x			x																									demonic acid	http://www.orhab.org/index.html
98	MLML class trawls project	Since the early 1970s, faculty and students in Marine Ecology, Invertebrate Zoology, and Ichthyology courses at Moss Landing Marine Laboratories (MLML) have participated in class cruises aboard several research vessels to survey the fishes and invertebrates in shallow-benthic, deep-benthic and midwater habitats in Monterey Bay. All fishes and invertebrates were identified to the lowest possible taxon. The results of these surveys, originally recorded on data sheets, are available in a Microsoft Access database.	13, 14				x						x	x		x	x								x	x													http://www.mbnms-simon.org/other/gen/project_info.php?pid=100170&proid=&form=pi

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99	ESNERR invertebrate monitoring programs	The Elkhorn Slough National Estuarine Research Reserve (ESNERR) is monitoring crabs and large burrowing invertebrates (e.g., clams, fat innkeeper worms, ghost shrimp) - two groups of large, relatively easy to identify invertebrates. The goals are to detect dramatic changes in abundance, species diversity, and distribution.	11				x							x																									http://www.elkhornslough.org/research/biomonitor_invert.htm
100	Snapshot Day	Each years since 2003 watershed groups from across the state participate in the California Coast-Wide Snapshot Day, with the goal of collecting important information about the health of coastal waters flowing into the Pacific Ocean. Snapshot Day volunteers collected water samples at 565 creeks, rivers, wetlands, and beaches from the Oregon border to Ensenada, Mexico.	5, 6			x	x	x												x																			PO4, NO3	http://www.mbnms-simon.org/other/gen/project_info.php?pid=100142&query=snapshot&form=kw

ID	Project Name	Project Description	Charact. ID #	OC	CB	GF	MB	CI	Chlorophyll	Fluorescence	Phytoplankton	Zooplankton	Juvenile	Adult inverts	Ichthyoplankt	Juvenile fish	Adult fish	Marine	Seabirds	Other - bio	Nutrients	Dissolved O2	Salinity	Density	Water temp	Transmittance	Currents	Air temp	Depth	Weather	Barometric	PAR	Wind	Wave	Aerial/sat	Sidescan	Multibeam	Habitat type	LiDAR	Other-physical	Project URL
10 1	OSPR and MMS Santa Barbara Channel Aerial Surveys	These surveys are conducted as part of a program to maintain readiness for oil spill response. Aerial surveys are conducted frequently throughout the year to ensure that trained and experienced aerial observers are available in the event of an oil spill in California offshore waters. Data available 1994-1998 and 2001-present.				x	x	x											x																x						http://ccmaserver.nos.noaa.gov/products/biogeography/canms_cd/htm/birds/EFFLOC_aerial.htm

Appendix 2 – Background Information on IEA Efforts in CCE

Atlantis Model for CCE

Atlantis is a simulation modeling approach developed by Commonwealth Scientific and Industrial Research Organization (CSIRO) scientists in Australia (Fulton 2004, Fulton et al. 2005). In Atlantis, ecosystem dynamics are represented by spatially-explicit sub-models that simulate hydrographic processes (light- and temperature-driven fluxes of water and nutrients), biogeochemical factors driving primary production, and foodweb relations among functional groups. The Atlantis approach has been adapted to the California Current Ecosystem by scientists at the Northwest Fisheries Science Center (Brand et al. 2007). Currently, the Northwest Fisheries Science Center is creating an Atlantis ecosystem model at the Central California sub-regional scale. The central California model is including additional sub-regional scale data and monitoring information. The modeling team has built a network of collaborators and has identified management scenarios and data outputs that will be relevant to the management needs of their state and federal collaborators.

The CCE and central California Atlantis models are intended as a strategic management tools that will allow the identification of trade-offs and to identify direct and indirect effects of management policies. The Atlantis framework will be used in management strategy evaluation, in which management policies and assessment methods are tested against simulations that represent a real ecosystem and its complexities. The ecosystem model can serve as a filter to identify which policies (e.g., marine protected areas placement and monitoring) and methods (e.g., stock assessment techniques) are promising and which are flawed or likely to be ineffective. In addition the model can be used to develop a range of scenarios that consider tradeoffs and benefits of the multi-agency management of the fisheries (state, fisheries council, and National Marine Sanctuaries). Within the context of IEAs, the model will be used for performance testing of indicators, development of ecologically-based management targets, monitoring strategy evaluation, and possibly for semi-quantitative risk assessment.

Module I, CCE (Sydeman and Elliott 2008)

The Module I California Current Ecosystem IEA by Sydeman and Elliot (2008) takes a biological indicator approach to developing an IEA. They have compiled time-series data sets of both physical oceanography and key biological organisms. Key biological organisms include forage species (e.g., krill, plankton) top-level vertebrate predators of significant management concern, such as salmon and seabirds. The objectives of this effort are used to determine trends in the abundance of indicator species to understand both recent and long-term changes in the ecosystem. An additional goal of this initial effort was to identify gaps in knowledge. Module I does not include socio-economic data and other human-related data, though this type of data may be included in subsequent

modules. Module I did not forecast future conditions, but this is a likely direction for subsequent modules.

NCEAS CCME Human Impact Assessment (Halpern et al. 2009)

This project aims to understand and map how human activities are affecting marine ecosystems in the California Current, a region defined in this study as the coastal marine area between the U.S.-Canada border and central Baja, Mexico. The project builds upon previous work by collaborators from the National Center for Ecological Analysis and Synthesis (NCEAS) and Stanford University, which mapped human impacts on marine ecosystems globally. One objective of this study is the synthesis of spatial data on the distribution and intensity of human activities and the overlap of their impacts on marine ecosystems. The authors identified anthropogenic drivers of ecological change for 18 marine ecosystems in the California Current and then determined the availability of data sets to model the impacts of those drivers (Table 5). This project aims to help determine how to allocate conservation and management resources, to implement ecosystem-based management, and to inform marine spatial planning, education, and basic research.

ONMS SWiM Condition Reports

Each site in the Office of National Marine Sanctuaries (ONMS) is in the process of developing, reviewing and issuing their condition reports. The reports are part of the ONMS System-Wide Monitoring framework that facilitates the development of effective, ecosystem-based monitoring programs that address management information needs using a design process that can be applied in a consistent way at multiple spatial scales and to multiple resource types. The condition reports are developed based on a Pressure-State-Response framework (PSR) – they provide a summary of natural and anthropogenic pressures on resources in the National Marine Sanctuaries, the current status and trends of resource conditions, and management responses to the anthropogenic pressures affecting resources. The PSR framework allows managers to both prioritize management actions and evaluate their effectiveness in meeting conservation or restoration goals.

The “state” section of the condition reports centers on a set of questions used as evaluation criteria to assess resource conditions and trends within each sanctuary. The questions derive from the Office of National Marine Sanctuaries mission and a system-wide monitoring framework. Resource status relating to each question is rated on a scale from good to poor and trends in the status of resources are also reported. In order to address the set of questions and thereby evaluate the status and trends of resources, sanctuary staff selected and consulted outside experts familiar with water quality, living resources, habitat, and maritime archaeological resources.

The ONMS condition reports may be accessed from the ONMS Web site: http://sanctuaries.noaa.gov/science/condition.

Background Information on MBCORC Report Card and Virtual Monterey Bay

The mission of the Monterey Bay Crescent Ocean Research Consortium (MBCORC) is to promote the scientific understanding of coastal and marine systems and to facilitate the application of that knowledge for public policy, environmental awareness, and decision making. MBCORC achieves its objectives by creating, coordinating, promoting, and endorsing research, education, and outreach activities, using the Monterey Bay as a natural laboratory. This group meets periodically to discuss projects of joint regional effort. Two of those projects are:

- Monterey Bay Ecosystem Report Card: Producing an ecosystem report card/set of ecosystem indicators for the Monterey Bay region/Central California. This effort has been focused on identifying indicators of interest and determining the availability of associated monitoring data for the Monterey Bay area.
- Oceanographic Modeling Workshop: Conducting one or more oceanographic modeling workshops to foster sharing and transfer of knowledge and expertise among MBCORC members. The first workshop was held in 2007.

Appendix 3 – Acronyms and Abbreviations

AFSC: Alaska Fisheries Science Center
Beach COMBERS: Coastal Ocean Marine Mammal & Bird Education and Research Surveys
CalCOFI: California Cooperative Oceanic Fisheries Investigations
CBNMS: Cordell Bank National Marine Sanctuary
CBOMP: Cordell Bank Ocean Monitoring Program
CCAMP: Central Coast Ambient Monitoring Program
CCE: California Current Ecosystem
CCLEAN: Central Coast Long Term Environmental Network
CCSF: City and County of San Francisco
CIMT: Center for Integrated Marine Technologies
CINMS: Channel Islands
CINP: Channel Island National Park
COASST: Coastal Observation and Seabird Survey Team
COCMP: Coastal Ocean Currents Monitoring Program
CRANE: Cooperative Research and Assessment of Nearshore Ecosystems
CRFS: Recreational Fisheries Survey
CSUMB: California State University, Monterey Bay
DPSIR: Driver, Pressure, State, Impact, Response
DFO: Department of Fisheries and Oceans Canada
EAM: Ecosystem Approach to Management
EFH: Essential Fish Habitat
EPA: Environmental Protection Agency
FAO: Food and Agriculture Organization of the United Nations
GFNMS: Gulf of the Farallones National Marine Sanctuary
HABs: Harmful Algal Blooms
IEA: Integrated Ecosystem Assessment
IOOS: Integrated Ocean Observing System
LOBO: Land/Ocean Biogeochemical Observatory
MARINe: Multi-Agency Rocky Intertidal Network
MBARI: Monterey Bay Aquarium Research Institute
MBCORC: Monterey Bay Crescent Ocean Research Consortium
Monterey Bay Time Series (MBTS) Program
MBNMS: Monterey Bay National Marine Sanctuary
MEI: Multivariate El Niño Index
MOOS: MBARI Ocean Observing System
NCCE: Northern California Current Ecosystem
NCEAS: National Center for Ecological Analysis and Synthesis
NDBC: National Data Buoy Center
NERR: National Estuarine Research Reserve
NGDC: National Geophysical Data Center
NMFS: National Marine Fisheries Service
NMS: National Marine Sanctuary

NOAA: National Oceanic and Atmospheric Administration
NODC: National Oceanographic Data Center
NWFSC: Northwest Fisheries Science Center
OCNMS: Olympic Coast National Marine Sanctuary
ONMS: Office of National Marine Sanctuaries
ORHAB: Olympic Region Harmful Algal Blooms
PaCOOS: Pacific Coast Ocean Observing System
PDO: Pacific Decadal Oscillation
PISCO: Partnership for the Interdisciplinary Study of Coastal Oceans
PnB: Plumes and Blooms
POES: Polar Operational Environmental Satellites
PRBO: Point Reyes Bird Observatory
PSR: Pressure-State-Response
SCCWRP: Southern California Coastal Water Research Project
SEAS: Sanctuary Ecosystem Assessment Surveys
SECRET: Studies of Ecological and Chemical Responses to Environmental Trends
SF-BEAMS: San Francisco Bay Environmental Assessment and Monitoring Station
SFML: Seafloor Mapping Laboratory
SIO: Scripps Institution of Oceanography
SWAMP: Statewide Water Ambient Monitoring Program
SWFSC: Southwest Fisheries Science Center
SWiM: System-Wide Monitoring
USGS: United States Geological Survey
USFW: United States Fish and Wildlife
WCObs: West Coast Observatories
WOCE: World Ocean Circulation Experiment

ONMS CONSERVATION SERIES PUBLICATIONS

To date, the following reports have been published in the Marine Sanctuaries Conservation Series. All publications are available on the Office of National Marine Sanctuaries website (http://www.sanctuaries.noaa.gov/).

Reconciling Ecosystem-Based Management and Focal Resource Conservation in the Papahānaumokuākea Marine National Monument (ONMS-09-04)

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Automated, objective texture segmentation of multibeam echosounder data - Seafloor survey and substrate maps from James Island to Ozette Lake, Washington Outer Coast. (NMSP-07-05)

Observations of Deep Coral and Sponge Assemblages in Olympic Coast National Marine Sanctuary, Washington (NMSP-07-04)

A Bioregional Classification of the Continental Shelf of Northeastern North America for Conservation Analysis and Planning Based on Representation (NMSP-07-03)

M/V *WELLWOOD* Coral Reef Restoration Monitoring Report Monitoring Events 2004-2006 Florida Keys National Marine Sanctuary Monroe County, Florida (NMSP-07-02)

Survey report of NOAA Ship McArthur II cruises AR-04-04, AR-05-05 and AR-06-03: Habitat classification of side scan sonar imagery in support of deep-sea coral/sponge explorations at the Olympic Coast National Marine Sanctuary (NMSP-07-01)

2002 - 03 Florida Keys National Marine Sanctuary Science Report: An Ecosystem Report Card After Five Years of Marine Zoning (NMSP-06-12)

Habitat Mapping Effort at the Olympic Coast National Marine Sanctuary - Current Status and Future Needs (NMSP-06-11)

M/V *CONNECTED* Coral Reef Restoration Monitoring Report Monitoring Events 2004-2005 Florida Keys National Marine Sanctuary Monroe County, Florida (NMSP-06-010)

M/V *JACQUELYN L* Coral Reef Restoration Monitoring Report Monitoring Events 2004-2005 Florida Keys National Marine Sanctuary Monroe County, Florida (NMSP-06-09)

M/V *WAVE WALKER* Coral Reef Restoration Baseline Monitoring Report - 2004 Florida Keys National Marine Sanctuary Monroe County, Florida (NMSP-06-08)

Olympic Coast National Marine Sanctuary Habitat Mapping: Survey report and classification of side scan sonar data from surveys HMPR-114-2004-02 and HMPR-116-2005-01 (NMSP-06-07)

A Pilot Study of Hogfish (*Lachnolaimus maximus* Walbaum 1792) Movement in the Conch Reef Research Only Area (Northern Florida Keys) (NMSP-06-06)

Comments on Hydrographic and Topographic LIDAR Acquisition and Merging with Multibeam Sounding Data Acquired in the Olympic Coast National Marine Sanctuary (ONMS-06-05)

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Olympic Coast National Marine Sanctuary: Proceedings of the 1998 Research Workshop, Seattle, Washington (MSD-01-04)

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