RECOMMENDATIONS FOR A SOUTHERN CALIFORNIA REGIONAL EELGRASS MONITORING PROGRAM

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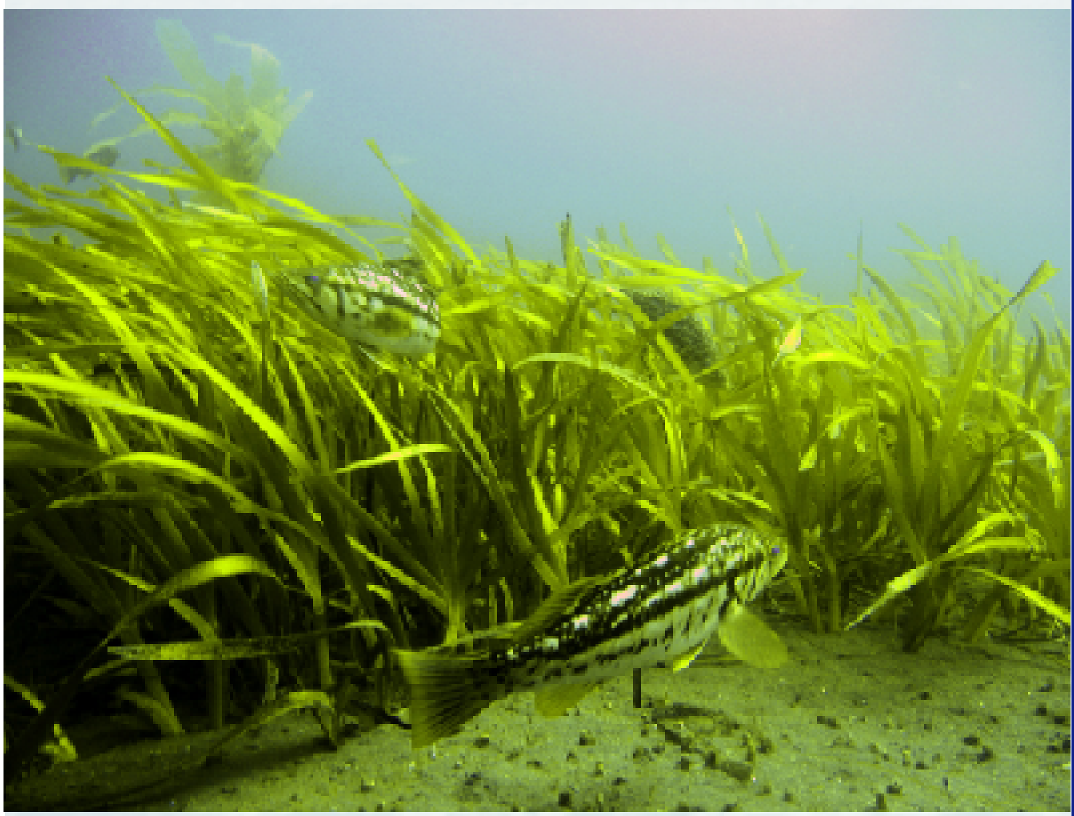

Southern California Coastal Water Research Project

Technical Report 632 - May 2011

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Acknowledgements

This project was funded by the National Marine Fisheries Service and managed through the Southern California Coastal Water Research Project (SCCWRP). The content of the report was developed over the course of 2009 by a workgroup consisting of regulated, regulatory, environmental, and research organizations. Members who participated for all or part of this effort included:

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In addition to these workgroup members, invited experts provided valuable information and advice on a number of key issues. We would also like to provide a special thank you to parties that have provided eelgrass survey data to support the preparation of our state of knowledge regarding eelgrass distribution in southern California as of 2010. These contributors by increasing latitude of survey data, include Mitch Perdue (U.S. Navy), Eileen Maher (Port of San Diego), Rick Ware (Coastal Resource Management), Sarah McFadden (Tetra Tech), Mike Curtis (MBC Applied Environmental Sciences), Kathryn Curtis (Port of Los Angeles), Tom Ford (Santa Monica Bay Restoration Commission), Jack Engle (U.C. Santa Barbara), Jesse Alstatt (Santa Barbara Channel Keeper), and Annie Gillespie (Morro Bay National Estuary Program).

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Executive Summary

This report presents a design for an integrated southern California Bightwide eelgrass monitoring program. It provides a framework for monitoring and assessment at the regional scale by:

- Identifying ways to improve coordination and comparability among existing eelgrass monitoring programs by addressing discrepancies in methods and survey timing
- Describing methods to fill key data gaps needed to complete the regional picture of eelgrass distribution and condition
- Identifying where new and/or improved methods would improve the accuracy, precision, reliability, and/or efficiency of monitoring approaches
- Describing adjustments to the management structures needed to support integrated regional monitoring and assessment

The program design was developed by a multistakeholder workgroup (see Acknowledgements) and addresses five core management questions, including:

- Question 1: What is the extent of eelgrass habitat and how is it changing over time?
- Question 2: Where does potential eelgrass habitat exist and where is eelgrass vegetation currently not persistent?
- Question 3: What is the condition of eelgrass habitat?
- Question 4: What are the effects of projects on regional eelgrass habitat?
- Question 5: What are the significant stressors on eelgrass habitat and what are their effects?

Having consistent and comparable answers to these questions available throughout the region will enable individuals and resource managers to more effectively predict, track, and manage the impacts of specific projects. In addition, this information will provide more complete information to management agencies about the overall status of the resource and trends in its condition, thus providing an overall regional context for making more informed decisions at the local and project scales.

An evaluation of the information available from existing eelgrass monitoring programs showed that it is currently not possible to answer any of the five questions for the Southern California Bight as a whole, although there are some well-monitored locations for which at least several of the questions may be answered. For example, some systems with eelgrass are not thoroughly and routinely monitored for eelgrass extent (Question 1), information (specifically bathymetry) needed to identify potential habitat is available for only a few systems (Question 2), and the mechanisms by which stressors affect eelgrass condition are not always well understood and/or accepted metrics do not exist to measure these effects (Question 5).

The workgroup determined that only Questions 1 – 4 can currently be addressed with routine monitoring approaches, while addressing Question 5 will require further research into the mechanisms through which various stressors affect eelgrass habitat and condition. For Questions 1 – 4, the program design provides the rationale for the recommended design approach, selection of indicators and monitoring frequency, appropriate data products, and coordination with other efforts where relevant. The design recommendations are summarized briefly in Table 1.

While the proposed program makes specific recommendations about the technical aspects of the regional monitoring design, issues related to implementation are envisioned to be dealt with through a subsequent process directed by a multistakeholder workgroup, perhaps operating as part of the periodic Southern California Bight Program. Implementation issues that such a workgroup could address over the next two years likely include:

- Survey methods
    - Supplement aerial data in Morro Bay with sidescan sonar surveys in deeper water areas that are not well represented by current multispectral mapping methods
    - Standardize eelgrass bottom coverage categories across all programs
    - Adjust timing of individual surveys to concentrate on the late summer – early fall time period
    - Develop protocols for integrating survey methodologies for maximized efficiency (e.g., blending aerial photography with sidescan sonar surveys)

- Data management
    - Create eelgrass webpage as part of the Wetlands data portal on the California Water Quality Monitoring Council's "My Water Quality" website
    - Load maps of current eelgrass extent into the eelgrass webpage
    - Complete revisions to the project tracking form to capture data appropriate to the five management questions
    - Develop data upload protocols for loading project tracking and routine survey data into the eelgrass webpage

- Filling key data gaps
    - Make provisions for surveys in eelgrass habitat that has not been surveyed
    - Make provisions for collecting bathymetric data as a part of routine surveys
    - Collect and organize currently available bathymetric data

- Program management
    - Empanel a more permanent regional workgroup to manage program implementation and regional assessments
    - Investigate the costs and benefits of including regional eelgrass surveys as a part of the Southern California Bight Program
    - Make necessary changes to regional environmental stewardship programs and regulatory structures to facilitate funding and implementation of the regional program

The proposed monitoring program furnishes a framework and guidance for this process by including clear statements of rationale and criteria for decision-making about design options. These building blocks provide tools that can be used to adapt the regional eelgrass monitoring program over time in response to improved knowledge and/or shifting management information needs.

Table 1. Summary of the recommended regional monitoring program design to address each of the five core management questions.

Question	Approach	Sites	Indicators	Frequency
Q1: Eelgrass extent	Systematic and exhaustive surveys of all systems	Every perennial system with more than 20 acres subtidal habitat	• Exterior boundary of bed • Percent of bottom coverage within defined beds, if available • Bathymetry in beds and adjacent bare bottom, if available	Every 5 years on mainland, 10 years on Channel Islands
Q2: Potential habitat	Transect surveys of all systems	Every perennial system with more than 20 acres subtidal habitat	• Bathymetry • Historical data on presence of eelgrass • Current eelgrass distribution and bottom coverage • Current eelgrass depth distribution curves • Distance from mouth of system • Distance from significant watershed inputs	Annually, in late summer / early fall
Q3: Eelgrass condition	Transect surveys of all systems	Every perennial system with more than 20 acres subtidal habitat	• Percent bottom coverage within beds • Change in lower depth distribution over time	Annually, in late summer / early fall
Q4: Project effects	Collect detailed information on each project	Every permitted project	Multiple descriptors	Before and after project implementation
Q5: Stressor effects	Special studies	To be determined, but likely sites that exhibit contrasts in the presence and/or severity of stressors	Wide range of indicators of condition, depending on the stressor(s) being investigated	As appropriate to the study

Introduction

Seagrass has long been recognized as an extremely valuable habitat in the marine and estuarine environment. Within southern California, four species of seagrass are known to occur: narrow-bladed eelgrass (*Zostera marina),* wide-bladed eelgrass (*Z. pacifica*), surfgrass (*Phylospadix torreyi* and *P. scouleri*), and widgeon grass (*Ruppia maritima*) (Talbot *et al*. 2006, Coyer *et al*. 2008). The two eelgrass species are likely the most dominant seagrass species in southern California and have been the subject of resource management for many years. Given eelgrass location in bays, estuaries, and the nearshore environment, the pressures of shoreline development and influences from coastal processes have the potential to significantly affect its distribution and abundance. Because of its significant contributions to a healthy ecosystem (described below) and susceptibility to anthropogenic activities, eelgrass warrants ongoing monitoring and assessment of its regional status.

Eelgrass ecological value

Eelgrass is a community structuring plant that forms expansive meadows or smaller beds in both subtidal and intertidal habitats in shallow coastal bays and estuaries as well as within semi-protected shallow soft bottom environments of the open coast. As a result, it is considered a "foundation", or habitat forming species that creates unique biological, physical, and chemical values and environments. Eelgrass is a major source of primary production in nearshore marine systems, underpinning detrital-based food webs. In addition, several organisms directly graze upon eelgrass or consume epiphytes and epifauna supported by eelgrass plant structures, thus contributing to the system at multiple trophic levels (Phillips and Watson 1984, Thayer *et al.* 1984). Eelgrass beds are also a source of secondary production and can have up to 15% greater secondary production (Heck *et al.* 1995) and greater species richness (Orth *et al.* 1984, Zieman and Zieman 1989) than mudflats, sandflats, and marshes.

Eelgrass beds function as habitat and nursery areas for commercially and recreationally important open ocean marine fish and invertebrates, and provide critical structural environments for resident bay and estuarine species, including abundant fish and invertebrates (Hoffman 1986, Kitting 1994). Eelgrass beds also provide habitat for juvenile fish (Hoffman 1986), including some anadromous fish such as salmon in the Pacific Northwest (Simenstad 1994). Besides providing important habitat for fish, eelgrass is considered to be an important resource supporting migratory birds during critical migration periods. Eelgrass is particularly important to waterfowl such as black brant that feed nearly exclusively on the plants and to a number of other species that make a diet of both eelgrass and the epiphytic growth that occurs on the leaves.

In addition to its habitat and resource value, eelgrass traps and removes suspended particulates, improves water clarity, and reduces erosion by stabilizing the sediment (Ward *et al.* 1984, Thayer *et al.* 1984, Wyllie-Echeverria and Rutten 1989, Merkel & Associates 2000). Eelgrass facilitates nutrient cycling, and oxygenates the water column during daylight hours. Eelgrass also has the potential to act as significant means of sequestering carbon (Laffoley and Grimsditch 2009, Mateo *et al.* 1997)

A number of prominent seagrass researchers and managers have emphasized the importance of monitoring seagrass ecosystems and incorporating seagrass as an indicator into large-scale programs assessing the health, functioning, and sustainable use of coastal ecosystems (Larkum *et al.* 2006, Duarte 2002). Seagrasses have been used in a number of significant, large-scale and multidisciplinary studies throughout the world and have frequently been used as an indicator of habitat condition in other regions such as Puget Sound (Gaeckle *et al.* 2009). In many instances, eelgrass has been identified and used as an indicator of water clarity and/or quality (Kenworthy and Haunert 1991, Dennison *et al.* 1993, Lee *et al*.

2004, Short and Burdick 2003). It has been evaluated as an indicator organism for tracking the fate of trace metals (Brix *et al*. 1983). Seagrass is a component of many National Estuary Program (NEP) environmental monitoring programs, including two NEP programs (Morro Bay National Estuary Program and Santa Monica Bay Restoration Commission) participating in this regional plan. On a global scale, SeagrassNet was recently established as a program that monitors and documents the status of seagrass resources worldwide. It now includes 70 monitoring sites in 23 different countries.

Management efforts

Despite the obvious value of seagrasses, nearly a quarter million acres of seagrass loss has been documented throughout the world over the last three decades. In order to address these widespread impacts, regulatory authorities have adopted various policies that reduce the impacts to this sensitive and valuable habitat. The U.S. Environmental Protection Agency (USEPA) has designated vegetated shallows (i.e., seagrasses) as special aquatic sites. This status provides special consideration when evaluating permits for dredged or fill material pursuant to Section 404 of the Clean Water Act.

In furtherance of efforts to curb losses and reduce the negative trends in seagrass habitat, resource and regulatory agencies around the nation have been developing resource management plans and resource protection policies addressing seagrasses. In southern California, the Southern California Eelgrass Mitigation Policy (NMFS *et al*. 1991, as revised) was developed by NOAA NMFS, U.S. Fish and Wildlife Service (USFWS), and California Department of Fish and Game (CDFG) to provide further guidance to regulatory programs on the necessary steps to compensate for unavoidable impacts to eelgrass resources. In addition to curbing losses through such regulatory mechanisms, eelgrass restoration efforts have been undertaken in southern California as mitigation for impacts, as banked resources for future mitigation uses, and as major elements of coastal wetland programs such as the Batiquitos Lagoon Enhancement Project and the Bolsa Chica Lowlands Restoration Project. Taken together, mitigation and restoration have achieved an expansion of eelgrass habitat significantly beyond the direct losses authorized by permit. However, it is still unknown whether eelgrass at the regional scale has increased or declined over the past several decades. This knowledge gap is due to inadequate data on regional eelgrass status and trends, as well as the effects of natural conditions and anthropogenic activities that may have indirect influences on eelgrass.

Provisions of the Southern California Eelgrass Mitigation Policy (SCEMP) require that any impacts to eelgrass be mitigated in a manner that compensates for direct habitat loss and loss of functions while mitigation habitat is becoming established. The SCEMP also requires monitoring of mitigation areas and suitable local reference sites for a period of five years to assess mitigation site performance against that of a natural reference bed. The SCEMP places the burden of mitigation performance on permittees who impact eelgrass to take those measures necessary to ensure that losses are offset. This is accomplished by clear language as to responsible parties and inclusion of building penalties for delays in accomplishing the mitigation.

Regulatory programs addressing direct impacts associated with filling, dredging, and placement of structures within eelgrass habitat have been highly effective at protecting eelgrass resources within the region. However, there remains a large void relative to protection and recovery of eelgrass resources that have been or are being lost or damaged as a result of the secondary influence of water quality impairments, changes in circulation patterns, sea-level rise, and/or other stressors. Mission Bay presents a striking example of this problem. It supports the second greatest areal extent of eelgrass within southern California, behind San Diego Bay, and over the past two decades has been the subject of only a handful of permitted fills, dredging projects, and placement of structures within open water areas and coastal shorelines. These permitted actions have resulted in less than 12 acres of loss of eelgrass, a reliable estimate based on pre- and post-construction eelgrass surveys. Mitigation and opportunistic restoration in the form of replacement eelgrass beds has actually created a net surplus of banked eelgrass mitigation credit at various in-bay sites. Despite this favorable picture from regulated project activities, the overall amount of eelgrass habitat within the bay fluctuates widely in a manner unrelated to localized, footprint-type regulated project activities. In fact, year-to-year eelgrass changes may exceed a few hundred acres as a result of a combination of climate and watershed influences, El Niño, sea-level rise (Hayward 1999, Jenkins and Inman 1999), or other regional factors that are still not fully understood. Such changes in eelgrass condition are outside the purview of most regulatory programs, yet they can dwarf the scale of regulated effects.

Recognition of the role of watershed effects, regional environmental stressors, and global climate concerns has led to a growing interest in resource management at a system rather than a project scale. Integrated natural resource management plans (INRMP), Special Area Management Plans (SAMPS), watershed management plans, and regional permits are becoming standard tools for addressing these broader concerns. Proponents of these tools hope that their use will assist regulators, industry, and environmental groups in focusing on non-point source problems, thereby leading to reduced nutrient and sediment loading, increased water clarity, and greater eelgrass habitat development within these systems. Such improvements from reduced loadings, however, may be swamped or obscured by normal environmental stochasticity and longer-term trends such as sea-level rise. As a result of expanding concern over non-point source effects and ecosystem-based management and regulation, it is believed that historic methods of monitoring discrete action areas and local reference sites are inadequate for assessing conservation progress at an ecosystem scale. As a result, a new set of monitoring tools and standards that can function and be integrated on a regional scale is called for.

Principles and Framework for Regional Monitoring

The regional monitoring design presented in the following sections focuses on addressing key management questions in accordance with a set of basic monitoring design principles:

- Monitoring should focus on decision making and only data helpful in making a decision about clearly defined regulatory, management, or technical issues should be collected
- The level of monitoring effort should reflect the value of the resource and/or the potential for impact, with more monitoring allocated to situations where the resource value and/or the potential impact (in terms of both the probability of an impact's occurrence and its extent and magnitude) is higher and less monitoring to situations where such value or potential is lower or where monitoring is not likely to provide useful information
- Monitoring should be adaptive in terms of its ability to both trigger follow-on studies as needed and make necessary midcourse corrections based on monitoring findings

The proposed regional program fits within a larger context for monitoring program design being adopted throughout the southern California region for both compliance and assessment programs. In this scheme, monitoring activities fall into three categories:

Core monitoring includes long-term, routine monitoring, intended to track compliance with specific regulatory requirements or limits, to conduct ongoing assessments, or to track trends in certain important conditions over time. Thus, core monitoring generally occurs at fixed stations or locations that are sampled routinely over time.

Regional monitoring includes cooperative studies that provide a larger-scale view of conditions and can be used to assess the cumulative results of anthropogenic and natural effects on the environment. Regional monitoring also helps to place particular impacts in perspective by comparing local results (i.e., core monitoring) to the breadth and depth of human impacts and natural variability found throughout a larger region.

Special projects include specific targeted studies included as adaptive elements within core or regional monitoring designs. These are shorter-term efforts, with a specified beginning, middle, and end, intended to extend or provide more insight into core monitoring results, for example, by investigating the specific sources that may be contributing to changes in eelgrass bed extent or condition.

The regional program presented below focuses primarily on improving the coordination of existing core monitoring programs, and filling gaps between them, in order to improve regional monitoring capacity. Special projects are identified, but no specific provisions are made for implementing them.

The workgroup articulated five key management questions related to assessing the status of eelgrass beds in the region:

- Question 1: What is the extent of eelgrass habitat and how is it changing over time?
- Question 2: Where does eelgrass habitat have the potential to exist and where is eelgrass vegetation currently not persistent?
- Question 3: What is the condition of eelgrass habitat?
- Question 4: What is the effect of projects on regional eelgrass habitat?
- Question 5: What are the significant stressors on eelgrass habitat and what are their effects?

The summary of existing monitoring in the watershed provided a basis for assessing the degree to which each key question is currently being addressed. This assessment formed the starting point for the development and description of regionalized monitoring designs targeted at the first three management questions. In some cases, this will require new designs where little or no effort currently exists. In others, questions can be answered through the improved coordination and standardization of existing efforts that have been implemented independently over a period of years or through conducting focused special studies.

System-wide Existing Monitoring History

Eelgrass habitat surveys within southern California have been conducted for many years. However, eelgrass is predominantly a subtidal resource in this region, making it difficult to monitor and track changes in its distribution. Moreover, comparisons between various eelgrass surveys are burdened by inconsistent application of significant advances in survey technology and in the precision and accuracy of mapping capabilities. Although there are many narrative references to eelgrass and evidence of the presence or absence of eelgrass within various coastal systems, early eelgrass mapping information is almost non-existent prior to the 1960s. Prior to the late 1990's, eelgrass surveys in San Diego Bay were performed using a variety of techniques including trawl and grab sampling, diver transects, and true color and infrared aerial imagery (Lockheed 1979; SDUPD 1979, 1990). In Morro Bay eelgrass maps were produced based on aerial photographs and brandt distribution patterns. A few smaller systems, such as Mugu Lagoon, were the focus of early ecological and coastal oceanographic study and were mapped by sketches produced during low tides. Early mapping was aided by estimation of locations based on various landmarks and, on rare occasion, some controlled survey points from which relative locations were visually approximated. Small-scale eelgrass mapping was conducted primarily through the use of grabs and divers, whereas the large-scale efforts tended to rely on aerial imagery. However, aerial imagery was not consistently capable of detecting eelgrass at increasing depths. As a result, shallow eelgrass beds were generally well mapped, but deeper eelgrass beds were often under-reported or missed entirely.

Beginning in the late 1980s, geopositional vessel tracking had advanced to the level of accuracy and accessibility needed for more widespread use in coastal ecological investigations; in 1988, sidescan sonar was used to map eelgrass throughout the full water area of the 2000-acre Mission Bay. The boat trackline was plotted using a microwave navigation system, and eelgrass density was hand mapped from paper sonagraphic charts while diver transects were used to ground-truth the work effort (Merkel 1988). This relatively arduous methodology was subsequently updated to make use of real-time differential GPS data to plot the centerline boat position as well as a CAD-based mapping effort (Merkel 1992). In 1993, the U.S. Navy applied this sidescan technology to San Diego Bay and provided the first comprehensive survey of eelgrass resources within San Diego Bay (U.S. Navy SWDIV 1994). The Navy and the San Diego Unified Port District (SDUPD) followed this effort with another baywide survey, in 1999, using single-beam sonar and aerial photographic survey methods (U.S. Navy SWDIV 2000). Subsequent to the 1999 surveys, the Navy reverted to the use of sidescan sonar for eelgrass mapping, and the two subsequent baywide surveys (2004 and 2008) employed this methodology (Merkel & Associates 2005, 2009).

Since the middle 1990s, eelgrass surveys employing various techniques have been conducted throughout many coastal waters of southern California. These include diver surveys, singlebeam fathometer surveys, towed video and ROV surveys, color and multispectral aerial photographic surveys, and sidescan sonar surveys. No single methodology has fully dominated the techniques employed to map eelgrass habitat within the region. However, for system-wide surveys with repeatable results, mapping methodologies have gravitated towards the application of two technologies, sidescan sonar and multispectral or true color aerial imagery, with data being managed in geographic information systems (GIS) software. While no standardization of field data collection equipment has occurred, spatial data management has generally been managed within the ESRI® suite of GIS software packages.

Recent eelgrass survey and monitoring activities conducted within coastal systems known to presently, or which have historically supported eelgrass are discussed briefly below. The systems examined extend from Morro Bay in the north to Tijuana Estuary in the south. The scope of this examination was based on the full extent of coastal bays and estuaries located within the jurisdictional area of National Oceanic and

Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Southwest Region, Long Beach office of the Habitat Conservation Division and the U.S. Army Corps of Engineers Los Angeles District. Table 2 summarizes the known extent of eelgrass within the surveyed systems and the survey method applied in these systems. The maximum mapped composite extent of known eelgrass from system-wide survey efforts is illustrated in Figure 1 and in somewhat more detail in a series of subregional maps (Figures 1-1 through 1-6). This composite coverage map of eelgrass is based on survey data that were readily available at the time of this report and may not be completely up to date. In addition, the survey results are not comprehensive because they are limited to system-wide or other large-scale efforts, which represent a restricted subset of all surveys conducted in the region. In some cases, comprehensive spatial surveys have not been conducted, but substantial evidence and point survey data exist that have documented the presence of eelgrass in locations that may support moderately extensive beds. Further variance in the number of surveys between systems, and in their respective timing, may significantly affect the eelgrass coverage depicted. Consequently, the maps presented here represent the best available data about large-scale eelgrass distribution, do not include all data on eelgrass in the region, and are intended only for regional planning purposes and not for site-specific analysis.

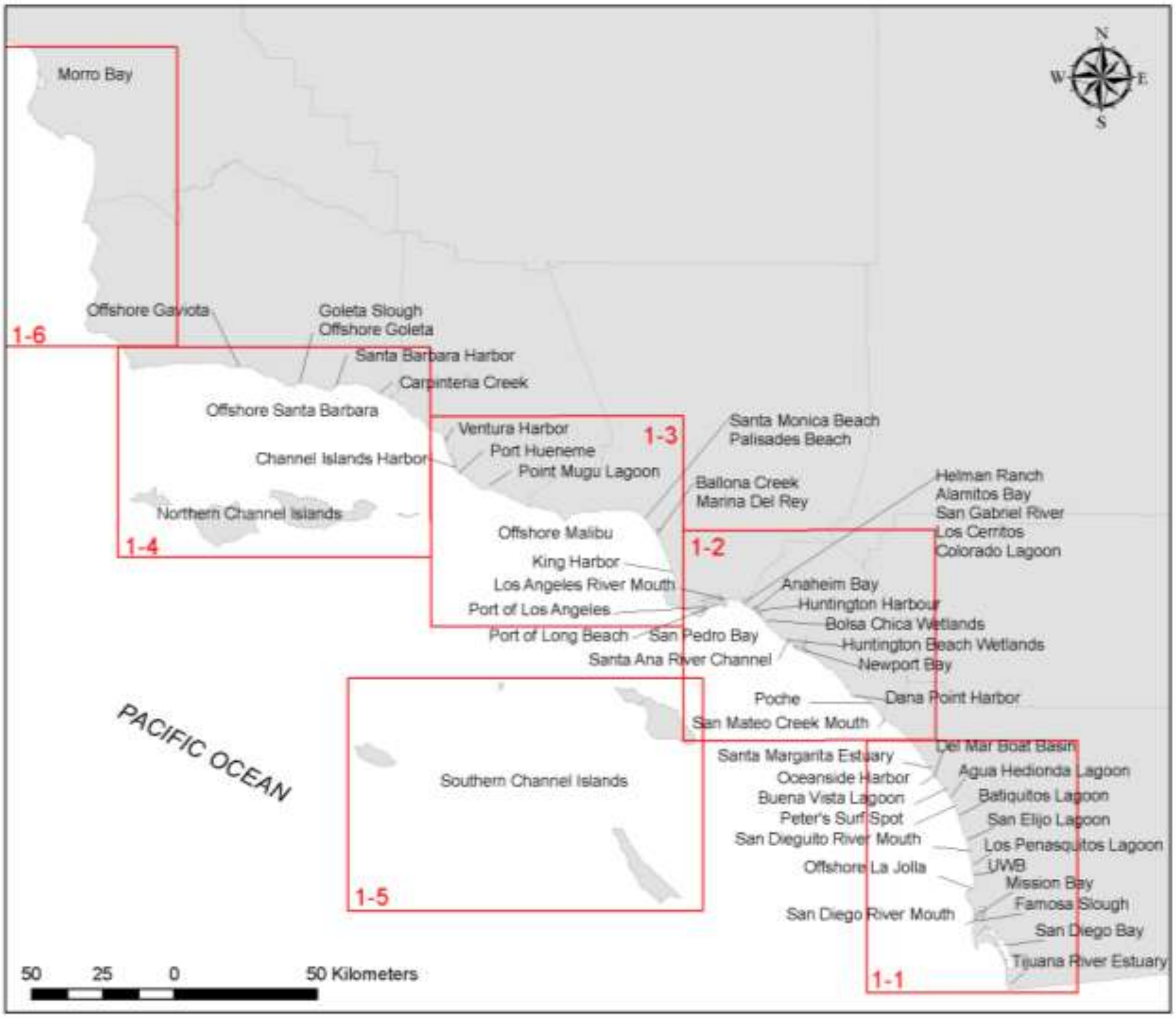

Figure 1. Key to mapped seagrass habitats in the Southern California Bight (2010).

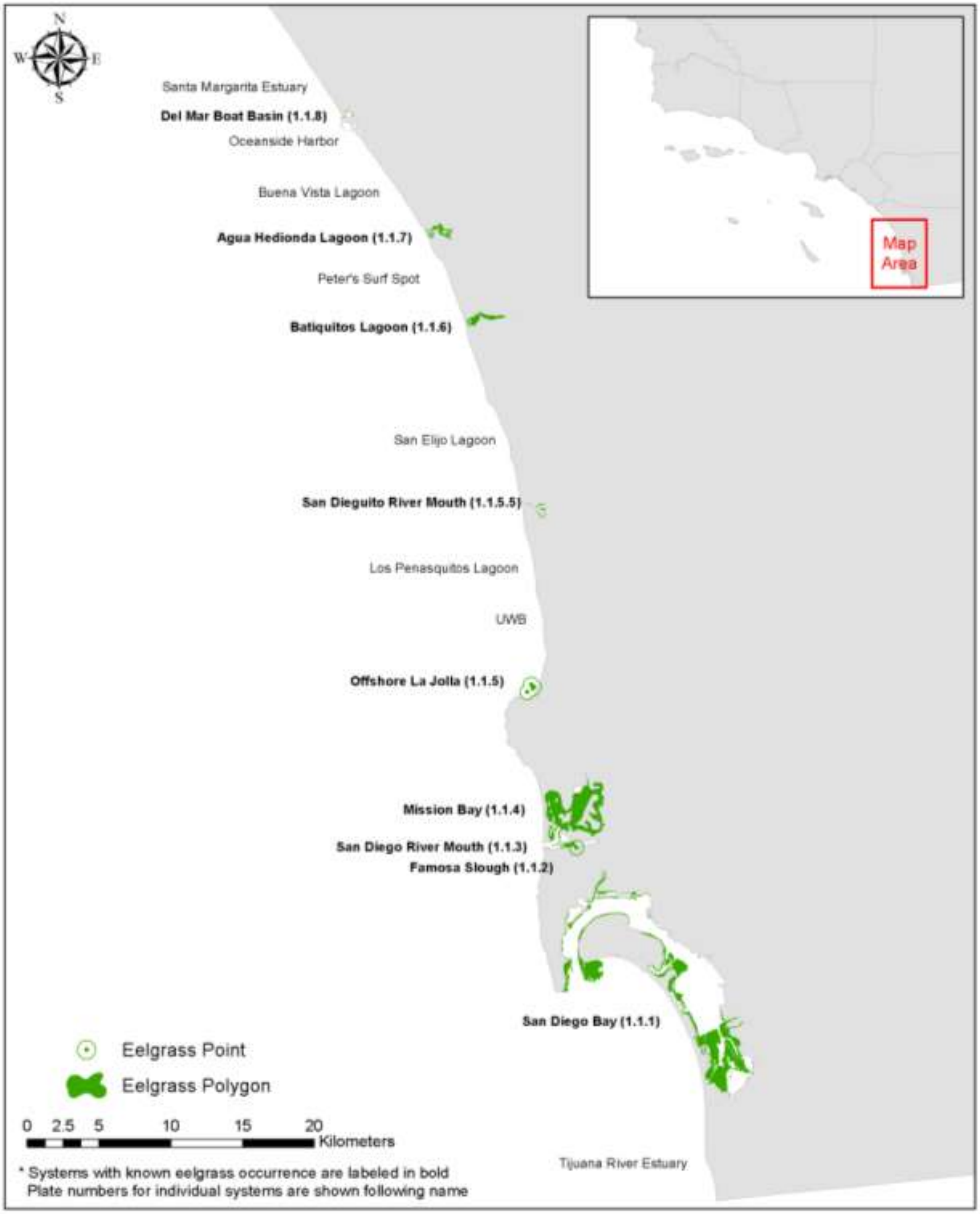

Figure 1-1. Maximum known eelgrass extent within the San Diego Subregion (2010).

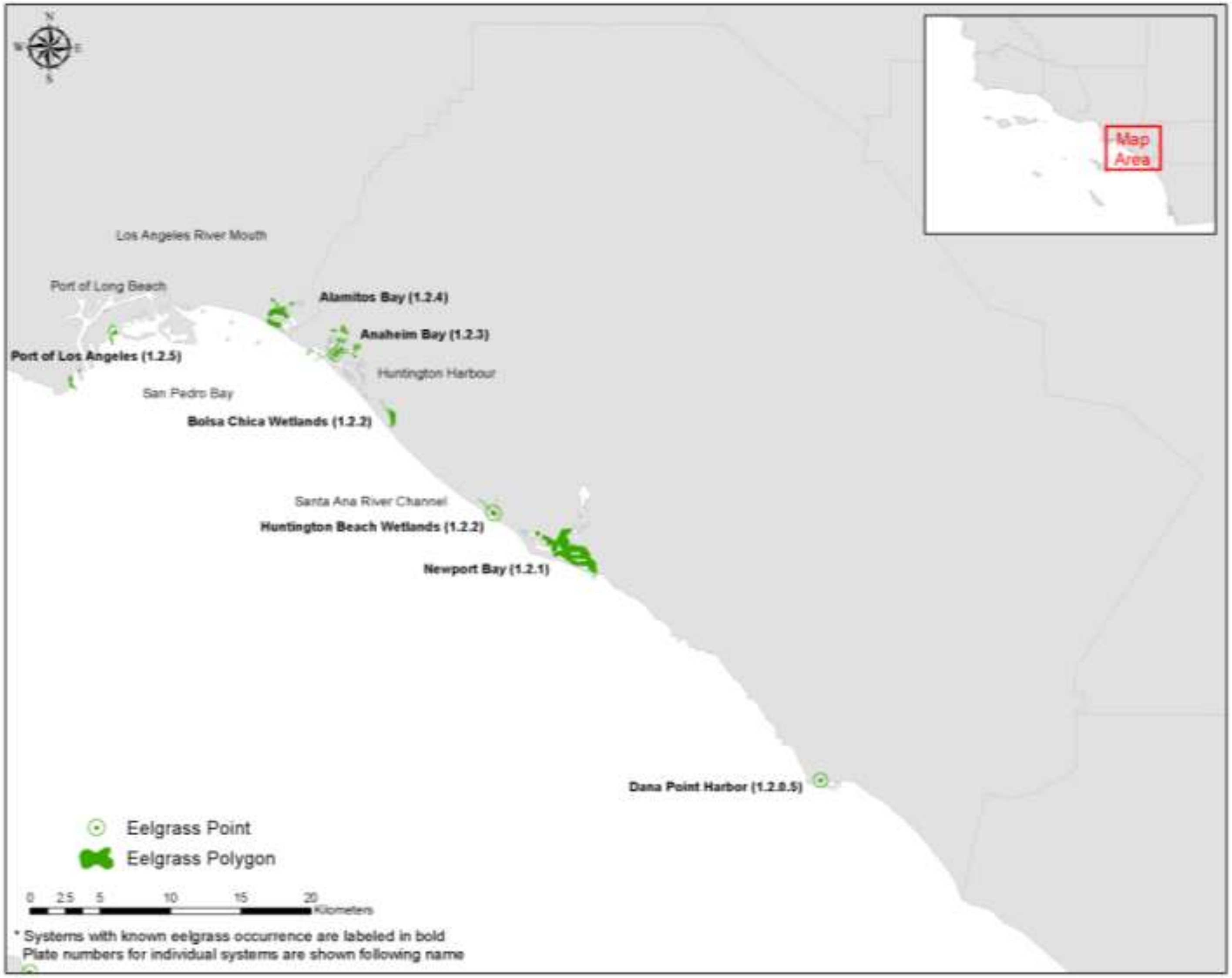

Figure 1-2. Maximum known eelgrass extent within the Orange County/Los Angeles Subregion (2010).

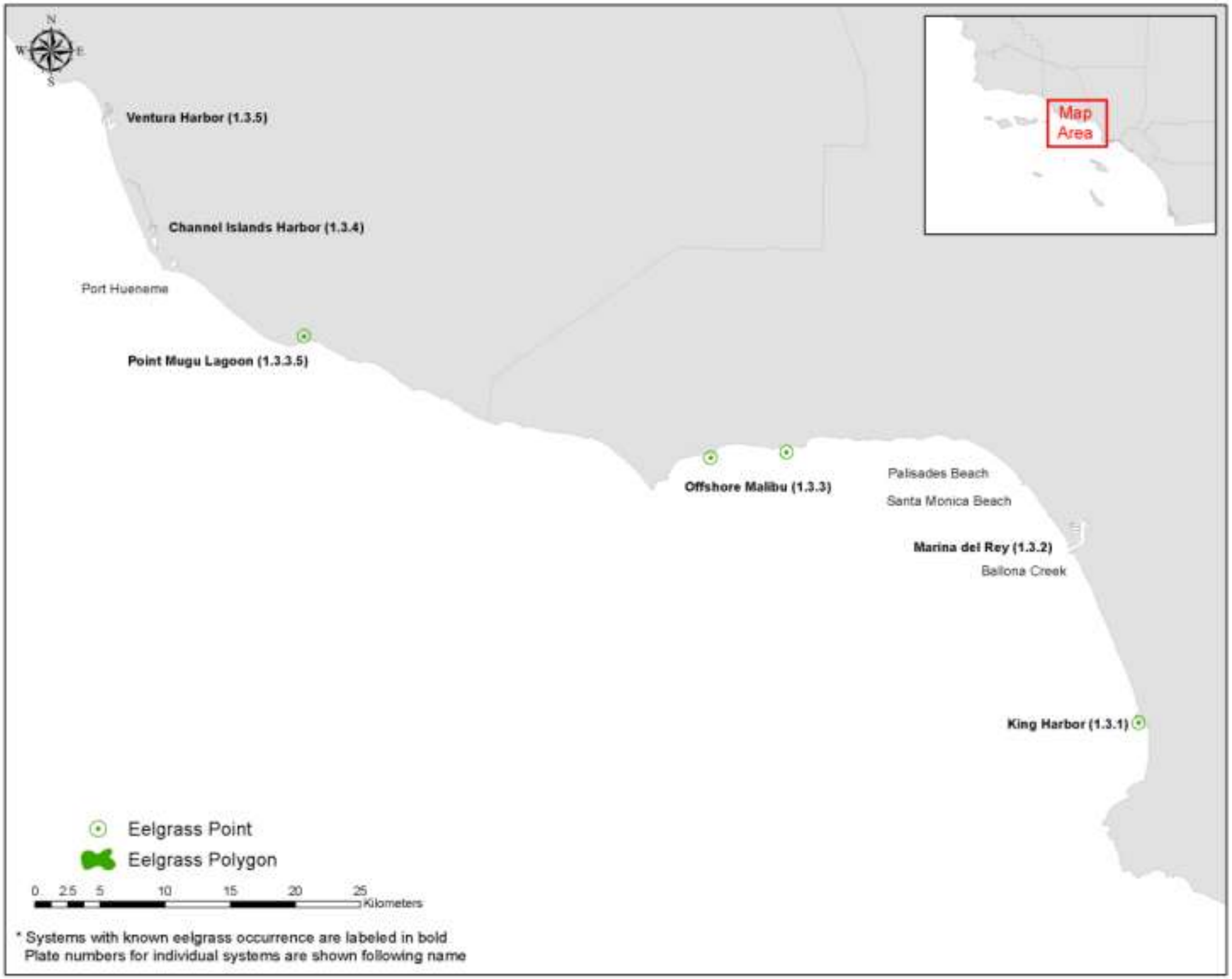

Figure 1-3. Maximum known eelgrass extent within the Los Angeles/Ventura Subregion (2010).

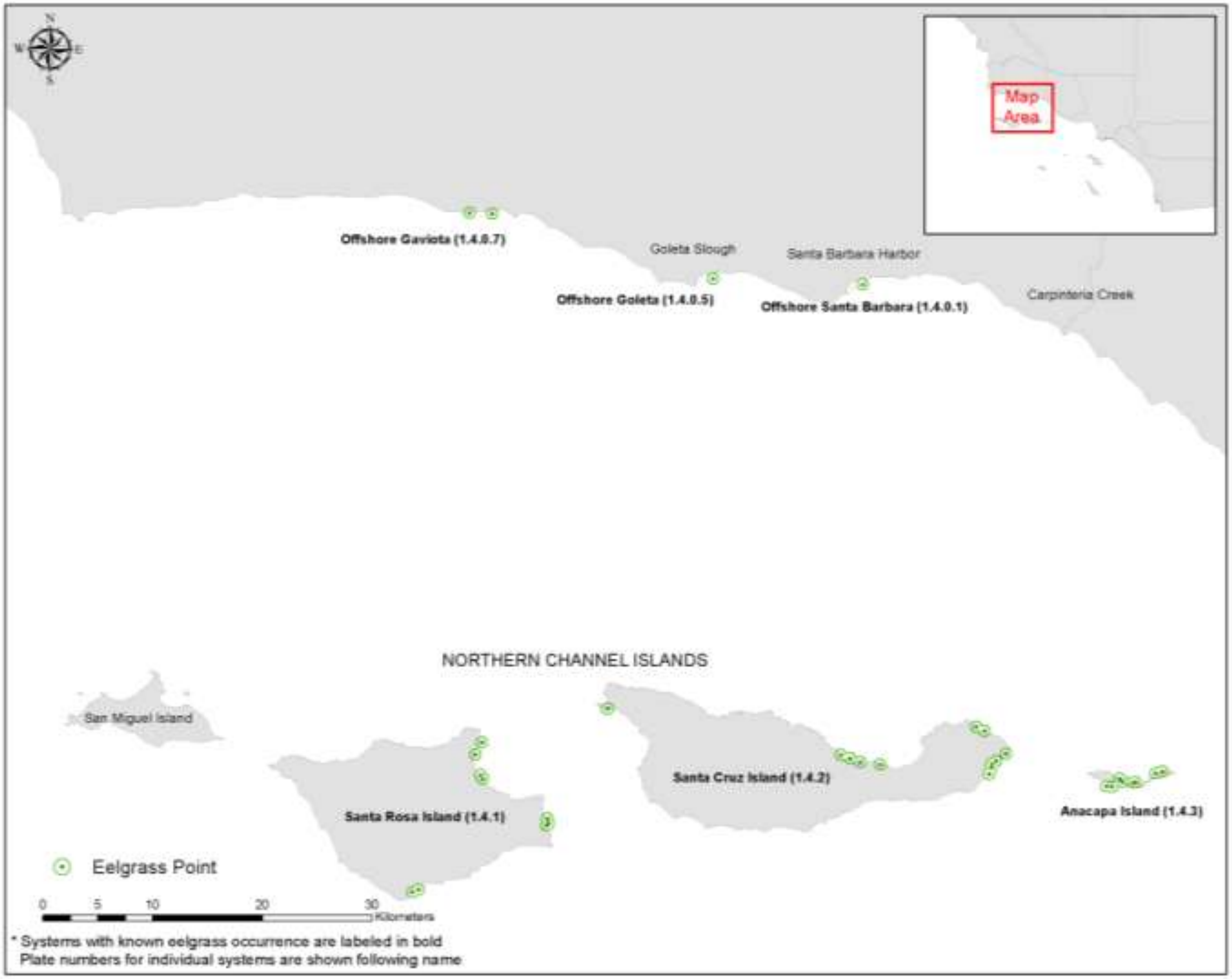

Figure 1-4. Maximum known eelgrass extent within the Santa Barbara/Northern Channel Islands Subregion (2010).

Figure 1-5. Maximum known eelgrass extent within the Southern Channel Islands Subregion (2010).

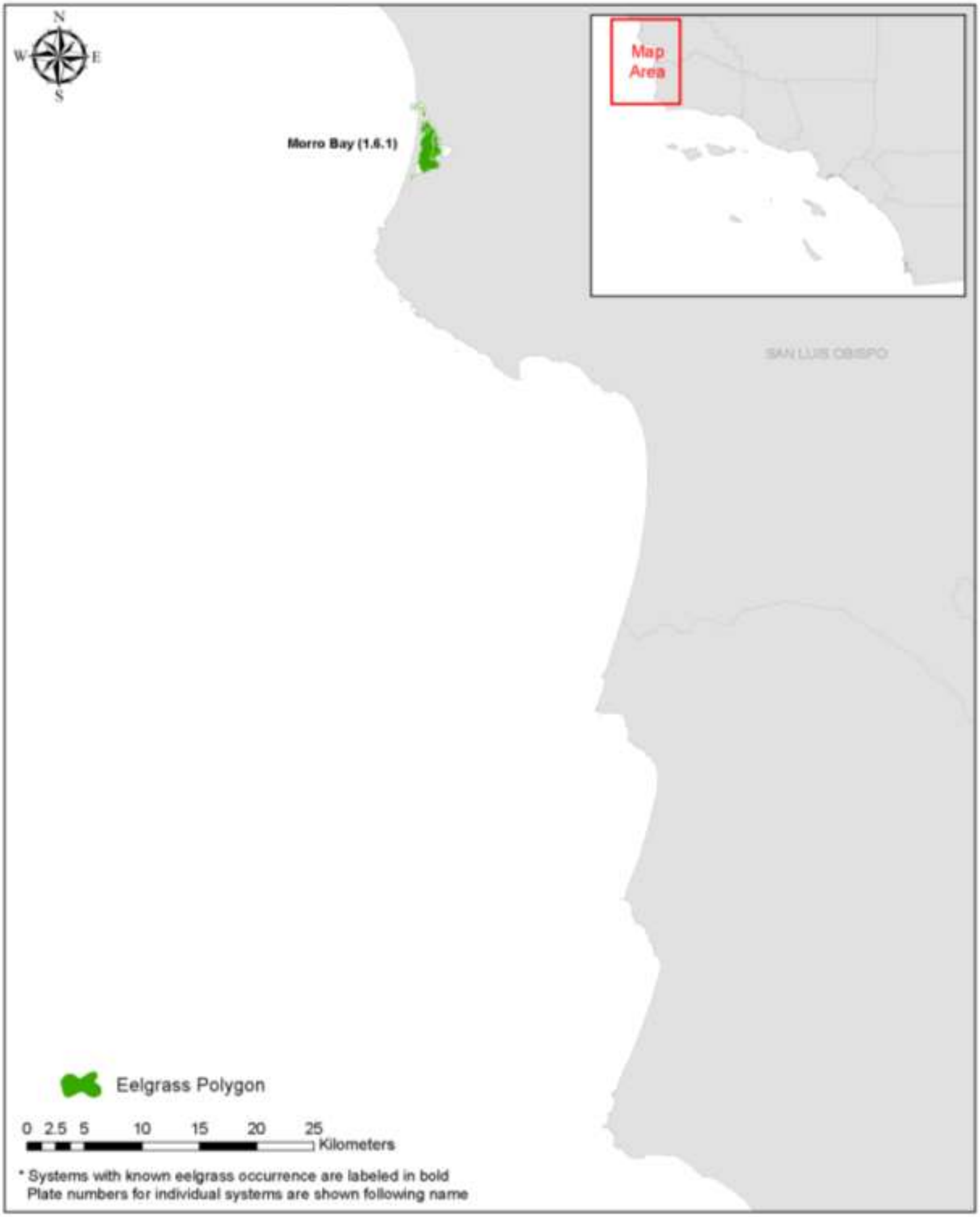

Figure 1-6. Maximum known eelgrass extent in the Santa Barbara/San Luis Obispo Subregion (2010).

All together, the documented maximum presence of eelgrass is less than 5,500 acres within the study region from Morro Bay to the U.S. – Mexico border. This total extent is dominated by a handful of systems, with San Diego Bay, Mission Bay, and Morro Bay collectively comprising over 90% of the known extent of mapped eelgrass. However, many areas have been comprehensively surveyed only once during 2005, a year when several well-investigated systems exhibited marked declines in eelgrass. Other systems have not been spatially mapped at all, although persistent eelgrass is known to exist in these areas (e.g., the Channel Islands and other offshore beds). As a result, significant potential for greater eelgrass habitat may exist in these lesser-investigated systems. However, it is anticipated that the three best-investigated systems will always dominate the total extent of known eelgrass habitat in the region.

Table 2. Known maximum extent of eelgrass distribution in Southern California coastal systems and mapping methodologies applied in system-wide inventories (2010)*.

Identity	*System*	*Acreage*	*Unquantified*	*Mapping Methods*
1.1 San Diego Subregion				
1.1.1	San Diego Bay	2,730.0		sidescan
1.1.2	Famosa Slough		present	low tide observations
1.1.3	San Diego River Mouth	28.1		aerial photography
1.1.4	Mission Bay	1,633.5		sidescan
1.1.5	Offshore La Jolla		present	diver observations
1.1.5.5	San Dieguito Lagoon	6.9	present	aerial photography
1.1.6	Batiquitos Lagoon	143.0		aerial photography/sidescan
1.1.7	Agua Hedionda Lagoon	58.4		sidescan
1.1.8	Del Mar Boat Basin	2.2		sidescan
1.2 Orange County/Los Angeles Subregion				
1.2.0.5	Dana Harbor	0.2		aerial photography
1.2.1	Newport Harbor	68.8		sidescan/diver perimeter
1.2.2	Huntington Beach Wetlands	3.4	present	sidescan/low tide perimeter tracking
1.2.3	Bolsa Chica Wetlands	33.8		sidescan
1.2.4	Anaheim Bay	108.9		sidescan
1.2.5	Alamitos Bay	16.2		sidescan
1.2.6	LA/LB Harbors	71.7		sidescan
1.3 Los Angeles/Ventura Subregion				
1.3.1	King Harbor	0.4		sidescan
1.3.2	Marina del Rey	0.6		sidescan
1.3.3	Offshore Malibu		present	ROV transects/diver report
1.3.3.5	Mugu Lagoon		present	diver observations
1.3.4	Channel Islands Harbor	1.2		sidescan
1.3.5	Ventura Harbor	1.0		sidescan
1.4 Santa Barbara/Northern Channel Islands Subregion				
1.4.0.2	Offshore Santa Barbara		present	diver observations
1.4.0.5	Offshore Goleta	>38	present	diver boundary/diver observations
1.4.0.7	Offshore Gaviota	>27	present	diver boundary/diver observations
1.4.1	Santa Rosa Island	>59	present	diver transect/diver observations
1.4.2	Santa Cruz Island	>100	present	diver transect/diver observations
1.4.3	Anacapa Island	>3	present	diver transect/diver observations
1.5 Southern Channel Islands Subregion				
1.5.1	San Clemente Island	>0.9	present	sidescan/diver observations
1.5.2	San Nicolas Island		present	diver transect/diver observations
1.5.3	Santa Catalina Island		present	diver transect/diver observations
1.6 Santa Barbara/San Luis Obispo Subregion				
1.6.1	Morro Bay	450.0		multi-spectral/singlebeam/sidescan
Maximum Total Eelgrass Known*		**5,561.5**	**Unknown**	

*Data reflect information available for large-scale eelgrass inventory and mapping efforts that were available and collected from numerous sources in 2010. Information does not reflect all data for project surveys or that which was not received during the data collection period.

Survey Methods

Much of the following discussion of monitoring approaches depends on a basic understanding of eelgrass survey methods. There is no single method that is best for all habitat types and all management questions; existing programs use a variety of methods, as illustrated in Table 2. The following discussion describes the strengths and weaknesses of the most commonly used methods and provides information about their comparability.

At present, a variety of methods are in use for monitoring eelgrass beds, including:

- Diver transect surveys
- Trackline boundary surveys
- Aerial photographs
- Single beam sonar
- Sidescan sonar

Because of differences in the characteristics of the specific measurements each method collects, the estimates of extent (and coverage, see Question 3, below) can vary widely and interpolation methods can result in inconsistent error generation depending on bed type and environmental condition.

In one investigation of the differences in eelgrass survey and spatial interpolation methods, it was found that eelgrass mapped during coincident surveys varied significantly in coverage based on the survey methods and interpolation techniques applied (Figure 2; Merkel In prep.). In this particular investigation, conducted in a portion of Agua Hedionda Lagoon, some methods, such as aerial photography, grossly under-estimated the extent of eelgrass due to water clarity at the time of survey. Other methods of diver transect and single-beam sonar over-estimated eelgrass extent based on methods of interpolation. Further, the spatial distribution of eelgrass was skewed in the diver transect surveys by survey bias, wherein divers reaching the apparent outer edge of an eelgrass bed stopped swimming the transect early and thus missed eelgrass at greater distance from shore. Notably, in the present case, diver transects and single-beam sonar both resulted in an over-estimation of eelgrass extent, however, from other comparisons in low bottom coverage eelgrass beds, single-beam sonar has resulted in under-estimations of eelgrass coverage. In the present circumstance, sidescan sonar yielded what is believed to be the best representation of eelgrass coverage, both for extent and spatial distribution. However, this mapping technique also has limitations, particularly in shallow water environments and areas with considerable acoustically reflective surfaces (e.g., uneven bottom terrain, mixed kelp and eelgrass, cobble and sand bottoms, or mixed seagrasses of similar stature). A new tool in eelgrass mapping is interferometric sidescan sonar that provides multibeam sonar-quality bathymetry, along with acoustic backscatter imagery. This allows for high resolution mapping of eelgrass integrated with bathymetry. It also allows better capacity to discern eelgrass in complex environments. Further investigations are planned to explore repeatability of sampling methods to evaluate the intrinsic error of each method of survey and interpolation.

Based on the readily available survey methodologies and the desire to minimize error and expense with large-scale mapping, the workgroup has agreed that the primary method for the initial systematic survey to fill data gaps, as well as for subsequent surveys, should be sidescan sonar, supplemented with multispectral and true color aerial photography where appropriate. For example, multispectral imaging is suited for Morro Bay, where eelgrass occurs in shallow water depths that do not obscure the presence of eelgrass, although further work may be needed to better couple different reflectance classes to eelgrass and to address issues with mixed vegetation classification and classification of submerged vegetation where color shift causes misclassification at a greater frequency. In addition, recent surveys in San

Francisco Bay have demonstrated the utility of a hybrid approach that combines aerial photography with sidescan sonar (Merkel & Associates 2010). In this approach, low-tide flown aerial photography is used to map shallow areas and assist in directing eelgrass survey efforts using sidescan sonar. The mapping results from the two methodologies are subsequently seamed together at areas of overlap to create a single survey map.

A suggestion was made that color infrared (CIR) photography should be considered. However, contrary to the benefits of CIR for detecting differences in transpiration rates of terrestrial plants due to differing reflective properties, water absorbs CIR thus resulting in a black image in clear water and a bluish image in more turbid water. Because most eelgrass occurs subtidally, the high absorption of infrared (IR) radiation by water makes detection of submerged vegetation more difficult than it is with true color photography. The application of aerial photographic techniques of any form is dependent upon water clarity, low tide timing, and limited and shallow bathymetric relief. More work is still needed in standardizing the application and integration of aerial survey with sidescan sonar survey.

Changes in eelgrass extent over multiple surveys can be used to generate eelgrass frequency distribution maps that provide information on the persistence of eelgrass within geographic areas of the system. This is accomplished by creating a summation of existing eelgrass occurrence using map overlays of available data and dividing the sum by the number of survey intervals used to generate the map. Over time and with enough survey periods, this provides a fairly accurate indication of both maximum extent of eelgrass habitat within a system and the stability of eelgrass in different areas. Figure 3 is one example of such a map for Mission Bay that relies on five late summer/fall surveys completed from 1988 through 2007 (Merkel & Associates 2008). With additional information, such as bathymetry, the frequency distribution over depth or other environmental gradients may be explored.

These tools allow for examination of not only static conditions, but also trends; however, such examination requires serial analyses of data, rather than composite evaluations. An example of such an application can be as simple as analyzing eelgrass extent and coverage over time, such as has been completed for Mission Bay surveys (Figure 4). Further, with available environmental gradient information, the causative agents of eelgrass change can begin to be examined. In San Diego Bay, long-term coincident monitoring of eelgrass distribution, water depth, photosynthetically active radiation (PAR), temperature, dissolved oxygen, and salinity through the 1997 El Niño period provided a demonstration that impacts of an El Niño Southern Oscillation (ENSO) event on eelgrass resulted from sea level rise and declining light availability rather than changing water temperature (Merkel & Associates 2000). Another example of the application of eelgrass distribution data coupled with environmental gradients is, again illustrated through the Mission Bay eelgrass monitoring program, which compared the eelgrass depth distribution of 2003 with that observed in 2007 (Figure 5). In this graph, it can be seen that in 2003 a normal unimodal distribution curve was present across a depth gradient in the Bay. This curve is typical for eelgrass in southern California and most other areas, where physical factors restrict distribution with the upper limit being defined by desiccation stress, and the lower limit being defined by light attenuation. However, in 2007, a bimodal distribution curve across a depth gradient was developed (Merkel & Associates 2008). This curve is typical where a biotic stressor impacts typically dense populations located in the core of a species suitability range. Density dependent biotic controls are generally manifested by a centric change in resource extent (e.g., disease spreads fastest through dense population centers), while physical environmental controls are often expressed as a range limitation within either tail of the distribution curve.

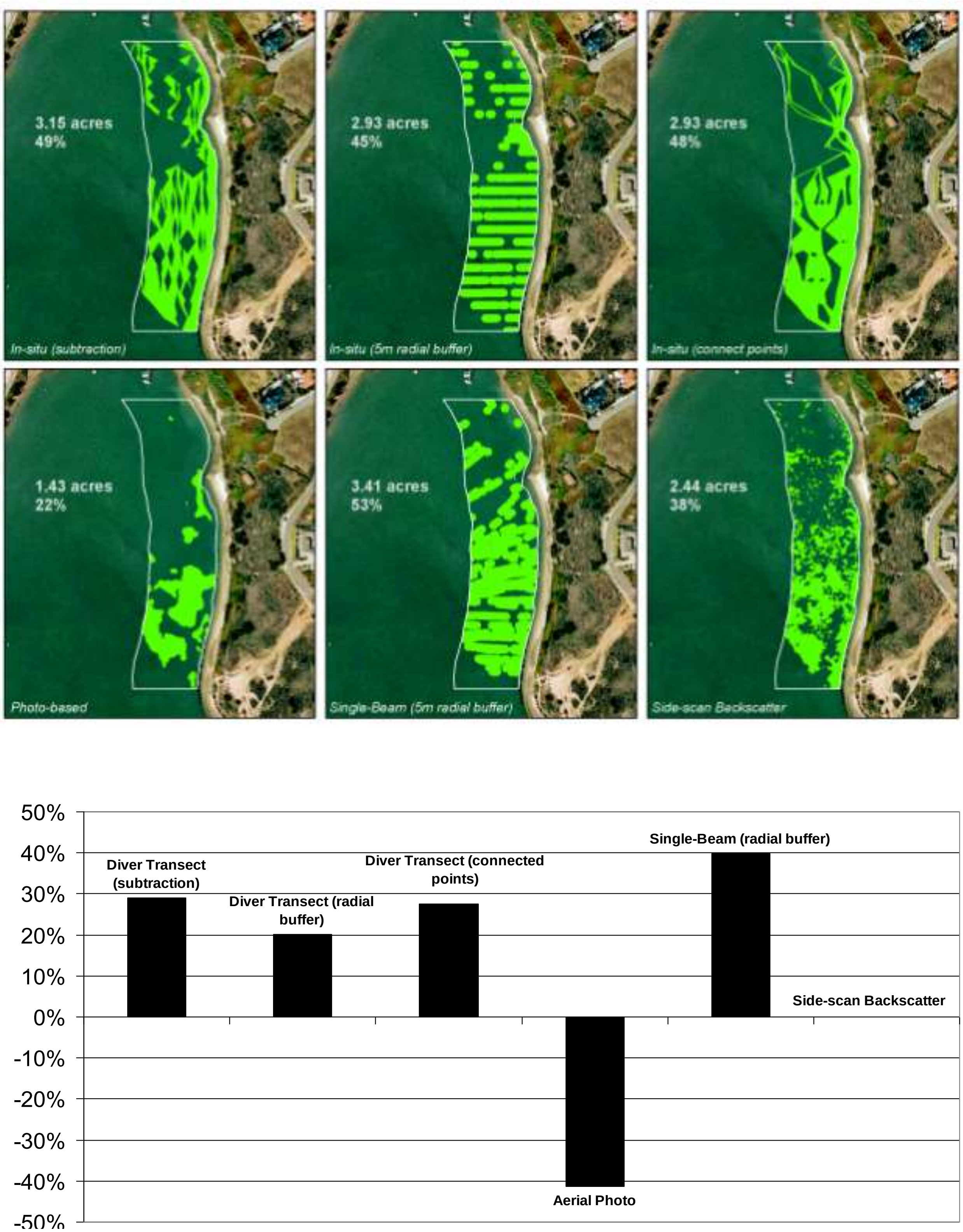

Figure 2. Comparison of eelgrass survey and mapping methods from coincident sampling (Source, Merkel, In Prep).

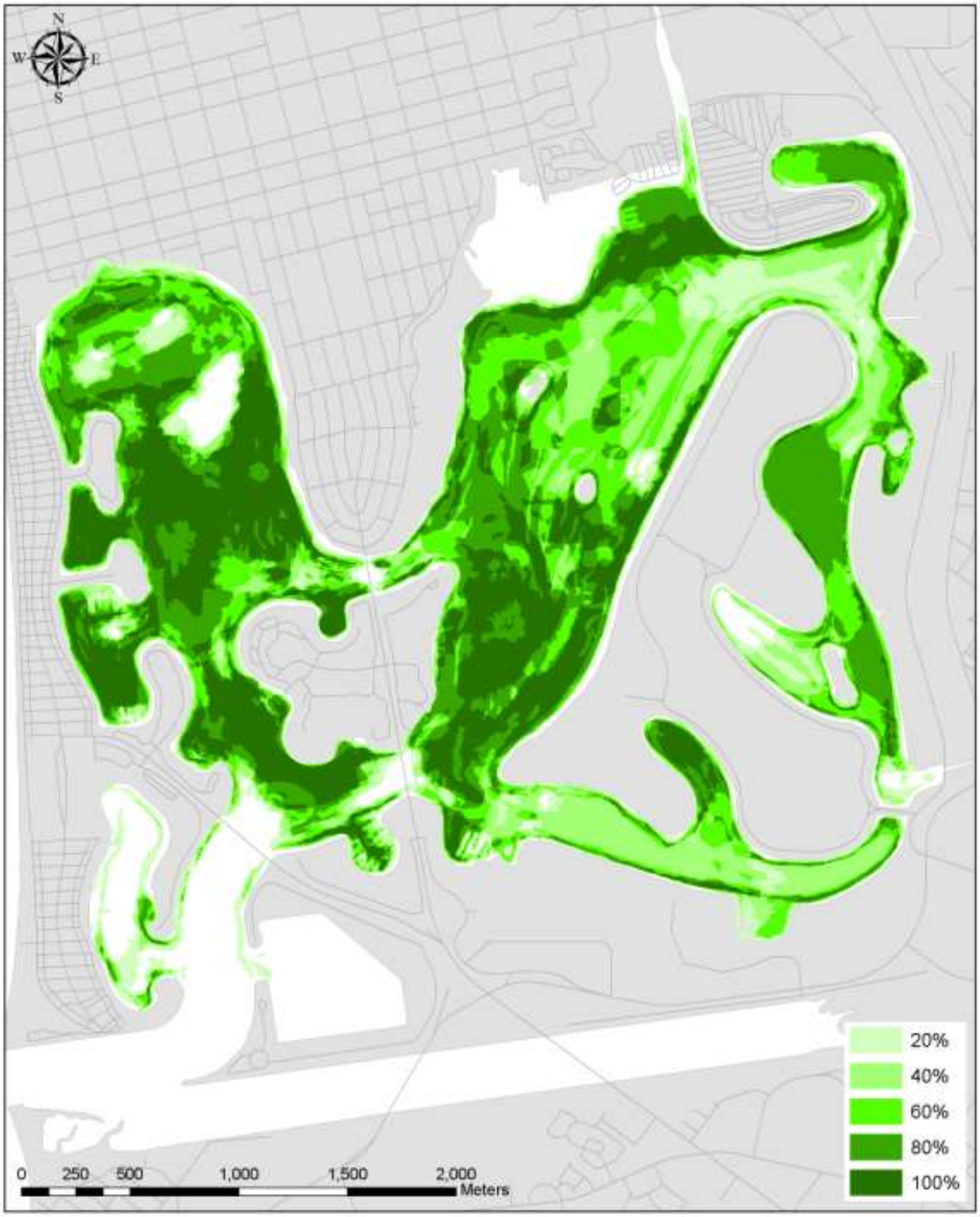

Figure 3. Eelgrass frequency distribution in Mission Bay (1998-2007).

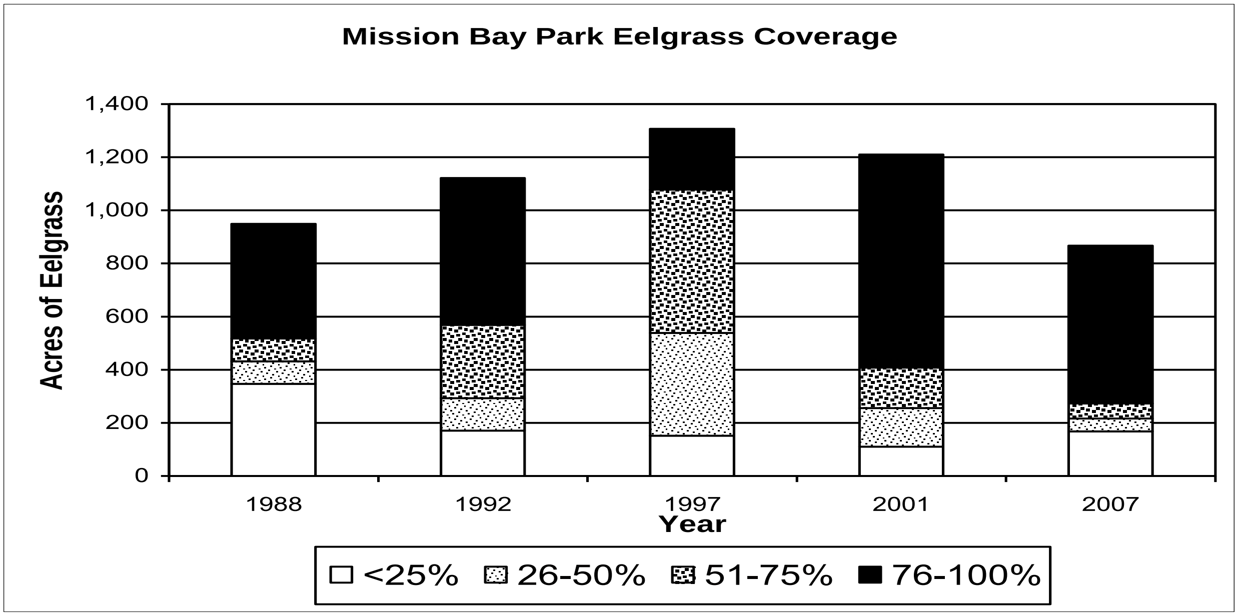

Figure 4. Eelgrass extent and bottom coverage in Mission Bay as a function of time.

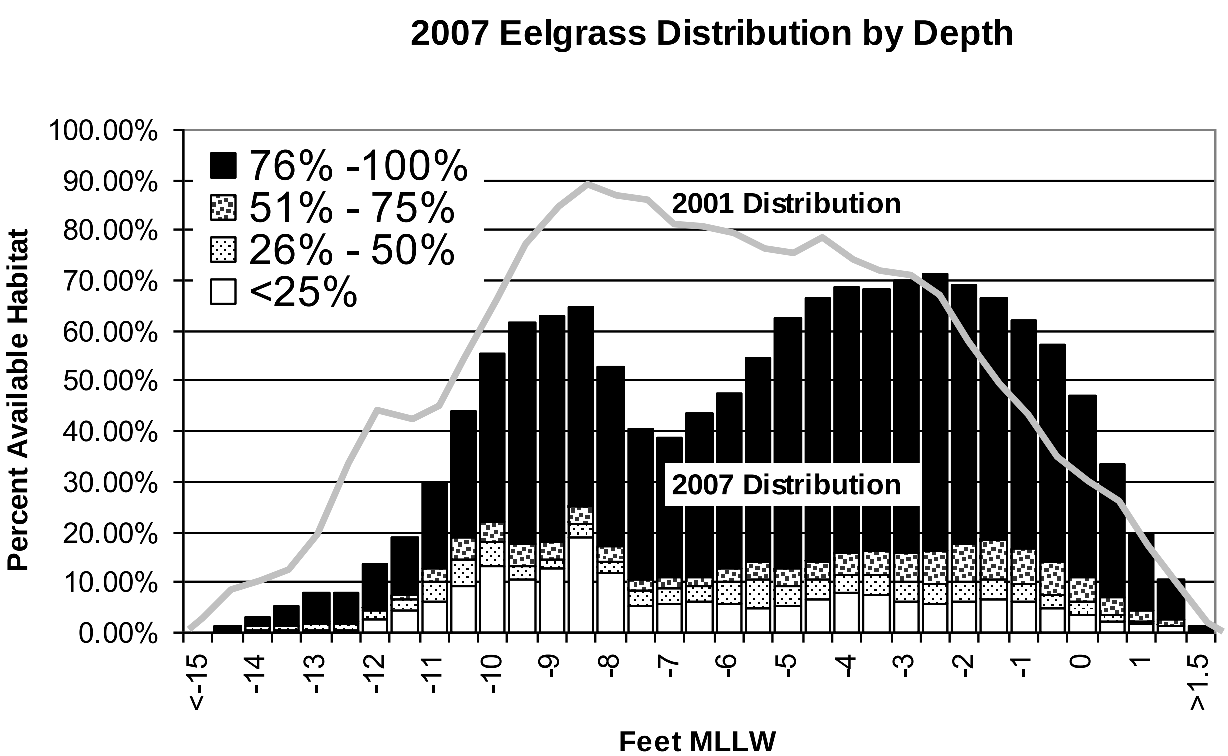

Figure 5. Eelgrass depth distribution patterns for 2007 monitoring year compared to 2003 depth distribution pattern.

Question 1: What is the extent of eelgrass habitat and how is it changing over time?

This question is the highest priority for resource managers. It focuses directly on defining the areal distribution and the actual extent of eelgrass habitat at a given point in time and how that distribution changes over time. This is a key metric essential for assessing the need for and the effectiveness of resource management actions.

Potential assessment questions that address such concerns include:

- Which bays, estuaries, and portions of the coastline support eelgrass beds?
- What are the boundaries of eelgrass beds in these systems at a given point in time?
- How do bed boundaries change over time, exhibiting localized expansion or contraction, as well as migration?
- What is the maximum extent and distribution of eelgrass that has been mapped within known beds?
- Are the changes exhibited by eelgrass directional along an environmental stressor gradient (e.g. depth (light))?

In overview, the monitoring design recommended to address such questions has the following elements:

- Comprehensive systematic surveys to fill data gaps in the larger systems, conducted using primarily sidescan sonar
- Periodic (every five years on the mainland and every ten years around the Channel Islands) systemwide surveys to update maps of eelgrass extent and track trends

The types of data products resulting from this monitoring design and appropriate for answering Question 1 may include:

- Maps of the areal extent of eelgrass beds in monitored systems
- Time series map overlays of extent monitoring at periodic intervals of five or ten years
- Estimates of the increase or decrease in overall extent, plotted over time as data accumulate
- Maps of eelgrass coverage as a frequency distribution plot that depict the persistence of eelgrass as a function of sampling intervals through time

The following subsections provide details on the design approach selected, as well as on the recommended indicators and the sampling frequencies.

Design approach

The basic design approach is to fill gaps in existing monitoring efforts to conduct a systematic survey of eelgrass beds in the Southern California Bight, followed by similar surveys at five-year intervals for the mainland eelgrass beds and ten-year intervals for the offshore beds on the Channel Islands. Monitoring will focus on larger systems that meet specific criteria and will be based primarily on sidescan sonar, supplemented with other compatible methods as may be most applicable to a specific system and bathymetry where practical to collect. Principally, additional data collection would be by aerial photography or multi-spectral aerial photography in shallow water systems where high accuracy of habitat classification and eelgrass boundaries may be achieved. There may be instances where funding or other constraints restrict the use of these preferred methods, particularly in less accessible and relatively poorly sampled areas such as the Channel Islands. In such cases, the regional program would accept data gathered by single beam sonar or diver surveys to fill key data gaps, while working over the longer term toward broader use of the preferred survey methods to garner greater accuracy and precision in mapping.

Indicators for this aspect of the regional monitoring program are the boundaries of eelgrass beds and measures of changes in these boundaries over time. The periodic comprehensive survey will build on existing programs by filling gaps in their spatial coverage and/or by making adjustments to survey methods and frequency, as is currently done for the periodic Bight Programs. In the case of San Diego Bay, Mission Bay, and Los Angeles/Long Beach Harbors, the five-year recurrent survey frequency and survey methodologies are reasonably consistent with programs already in place and changes requested are limited to coordinated seasonality and synchronizing annual intervals. For the present annual Morro Bay surveys, greater frequency of data collection than required for the present purpose does not pose a conflict and seasonal timing of surveys may or may not be of concern. More information on this program is necessary to assess potential integration needs. Field investigations conducted by NMFS using single-beam sonar and Merkel & Associates (in prep) using sidescan sonar have revealed that eelgrass generally extends deeper than can be adequately mapped using aerial surveys. This is especially true in the deeper north and central portions of Morro Bay and thus a sidescan survey component to the Morro Bay surveys is appropriate. The City of Newport Beach is in the early stages of development and implementation of an eelgrass monitoring program and as such, flexibility in survey frequency and timing may exist. This needs to be explored further. Other systems lack any continuous monitoring program that documents spatial distribution of eelgrass and it will be necessary to investigate means of implementing compatible efforts in these locations. Some short-term programs, such as that completed for Batiquitos Lagoon or underway at Bolsa Chica Wetlands may provide a few data points; however, these are restricted to short periods of time and will be non-continuous. As a result, any particulars regarding instituting a regular monitoring program in these systems are believed to be open.

In the case of the Channel Islands eelgrass survey and monitoring, extensive non-spatially explicit observations have been made for two decades in a fairly regimented monitoring approach. Based on the presence of this existing program, it is worthwhile to further investigate how a spatial monitoring element may be integrated in a manner that leverages the greatest benefits of the long-term record and best enhances the existing program. More discussion and evaluation of these issues is required.

Target population and sampling frame

The target population is the ecological resource about which information is desired. The target population for Question 1 is defined as:

> *All coastal features in the Southern California Bight, including the Channel Islands, where suitable eelgrass habitat is known or expected to occur. This includes perennially tidal coastal lagoons, partially-enclosed embayments, river mouth estuaries, and open coastal areas of shallow soft-bottom, including portions of the Channel Islands.*

Areas within the study region that meet the above definition are listed in Table 3 and are exhibited in Figure 1. Table 3 includes an indication as to the completeness of monitoring data, the status of eelgrass in the system, and the tools that have been applied for monitoring and surveying eelgrass. The completeness of monitoring data refers strictly to data collected that are comprehensive enough to serve a regional monitoring purpose. This means that various small surveys may have occurred within the system, but completeness of monitoring data can still be identified as “No data.” Further, the status of eelgrass and survey methods applied in the systems are reported as of the time of document preparation. Over time, conditions are expected to change as more surveys are conducted.

Table 3. Southern California coastal systems with potential to support eelgrass.

				Prior Monitoring or Comprehensive Survey Methods						
Systems	**Monitoring data completeness**	**Status of Eelgrass (acres)**	**System Subtidal (>20 acres)**	**Diver transects**	**Boundary Tracking**	**Video transects**	**Aerial photography**	**Multi-spectral photo**	**Single beam sonar**	**Sidescan sonar**
Morro Bay	Multi-year spatial monitoring	Major (400 +)	X				X	X	X	X
Northern Channel Islands	Limited, no spatial data	Intermediate (10 - 400)	X	X	X					
Offshore Gaviota	Limited spatial data	Intermediate (10 - 400)	X		X					
Offshore Goleta	No data	Intermediate (10 - 400)	X		X					
Goleta Slough	No data	Closed lagoon								
Santa Barbara Harbor	No data	Unlikely to be persistent	X							
Offshore Santa Barbara	No spatial data	Present	X	X		X				
Carpinteria Creek	No data	Closed lagoon	X							
Ventura Harbor	Limited system-wide spatial data	Minor (< 10)	X							X
Channel Islands Harbor	Limited system-wide spatial data	Minor (< 10)	X							X
Port Hueneme	Limited system-wide spatial data	Absent	X							X
Pt. Mugu Lagoon	Limited system-wide spatial data	Present	X							
Offshore Malibu	Limited, no spatial data	Present	X							
Palisades Beach-Montana Ave.	No data	Unlikely to be persistent								
Santa Monica Beach-Pico Blvd.	No data	Unlikely to be persistent								
Marina del Rey	Limited system-wide spatial data	Minor (< 10)	X							X
Ballona Creek	No data	Unknown	X							
King Harbor	Limited system-wide spatial data	Minor (< 10)	X							X
Colorado Lagoon	No data	Unlikely to be persistent	X							
Los Cerittos Wetlands	No data	Unlikely to be persistent								
Helman Ranch	No data	Unlikely to be persistent								
Port of Los Angeles	Intermittent spatial data collection	Intermediate (10 - 400)	X							X
Port of Long Beach	Intermittent spatial data collection	Minor (< 10)	X							X
Los Angeles River mouth	No data	Unknown	X							
San Pedro Bay	No data	Unknown	X							
Alamitos Bay	Limited system-wide spatial data	Intermediate (10 - 400)	X							X
Anaheim Bay	Limited system-wide spatial data	Minor (< 10)	X							X
Huntington Harbour	Limited system-wide spatial data	Minor (< 10)	X							X
Bolsa Chica Wetlands	Intermittent spatial data collection	Intermediate (10 - 400)	X							X
Huntington Beach Wetlands	Limited system-wide spatial data	Minor (< 10)	X				X			X
Santa Ana River channel	Limited, no spatial data	Unlikely to be persistent	X							
Newport Bay	Limited system-wide spatial data	Intermediate (10 - 400)	X	X	X					X
Southern Channel Islands	Limited, no spatial data	Present	X	X						
Dana Point Harbor	Limited system-wide spatial data	Minor (< 10)	X				X			X
Santa Margarita River Estuary	No data	Unknown	X							
Del Mar Boat Basin	Limited system-wide spatial data	Minor (< 10)	X							X
Oceanside Harbor	Limited system-wide spatial data	Unlikely to be persistent	X							X
Agua Hedionda Lagoon	Intermittent spatial data collection	Intermediate (10 - 400)	X				X			X
Encinas Creek mouth	No data	Unlikely to be persistent								
Bataquitos Lagoon	Intermittent spatial data collection	Intermediate (10 - 400)	X				X			X
San Elijo Lagoon	No data	Unlikely to be persistent	X							
San Dieguito River Estuary	Limited spatial data	Minor (< 10)	X				X			
Los Penasquitos Lagoon	No data	Unlikely to be persistent	X							
Offshore La Jolla	No data	Present	X							
Mission Bay	Multi-year spatial monitoring	Major (400 +)	X							X
Famosa Slough	Limited system-wide spatial data	Minor (< 10)					X			
San Diego River Estuary	Limited system-wide spatial data	Intermediate (10 - 400)	X				X			
San Diego Bay	Multi-year spatial monitoring	Major (400 +)	X						X	X
Offshore Coronado/Strand	Intermittent spatial data collection	Intermediate (10 - 400)	X							X
Tijuana River Estuary	No data	Unlikely to be persistent	X							

The sampling frame is a representation of the target population that is used to select the sample sites and may not include all elements of the target population. For Question 1, two additional criteria were applied to identify the sampling frame for the monitoring design:

- Perennially tidal systems that are open to the ocean for at least 11 months per year
- Systems with a minimum of 20 acres of subtidal habitat

The sampling frame was selected by listing all systems in the Southern California Bight that meet the target population definition (Table 3) and then applying the two criteria that further define the sampling frame.

Eelgrass occurs predominantly in perennially tidal systems. If systems are regularly closed for more than a month, then the likelihood that eelgrass will be persistent, or even present, drops to near zero. This criterion is interpreted to include systems that are naturally seasonally tidal but which are effectively perennially tidal because they are deliberately opened if they are closed for more than a short time. Salinity was considered as an element of the sampling frame, since salinity ranges and gradients are important in the definition of these systems. However, there is insufficient salinity data for the systems to be useful in further defining the sampling frame.

South of Point Conception, eelgrass grows primarily in subtidal habitat and the 20-acre minimum size criterion removes systems with marginal, ephemeral, and/or small amounts of habitat that do not contribute significantly to the overall regional estimate of extent. For example, the smallest systems are slough channels through marshes; such systems contain only small amounts of eelgrass, if any. However, there is no scientifically consistent method for applying the 20-acre criterion. For example, using the amount of open water and (possibly) mudflat measured in the National Wetlands Inventory (NWI) as the basis for determining the size of the system will not provide accurate and consistent results across systems. This is because the NWI estimates were snapshots at one point in time that did not take account of tidal elevation. Thus, the relative proportion of intertidal habitat in the NWI estimates that is either exposed or submerged is unknown and, because eelgrass does not grow much above approximately +0.5 feet MLLW in southern California, including intertidal habitat would overestimate the amount of available subtidal eelgrass habitat. Because of the difficulty in applying a generic criterion across all systems, the criteria were applied and then the results examined on a case-by-case basis, using expert knowledge of each system to assess their relative accuracy and suitability.

Spatial design and sampling requirements

The goal of the periodic systematic surveys is to fill all data gaps (Table 3) for every system with more than 20 acres of subtidal habitat and then to repeat this systematic survey over time. Within this general framework, there are four types of systems that will require somewhat different approaches to detailed monitoring design and implementation. These are:

- Systems about which there is little or no knowledge: Potentially large or spatially expansive systems, such as those at the Channel Islands, may require either initial reconnaissance or the delineation of a number of segments that systematically cover and represent eelgrass habitat over the whole area (surveys would need to sample beyond the entire area where eelgrass may occur to capture change represented by colonization processes rather than existing bed expansion)
- Smaller systems that are not currently surveyed but that can readily be sampled exhaustively
- Systems about which there is some knowledge, based on current or recent monitoring, that, combined with best professional judgment, can provide the basis for a monitoring design to better measure and characterize extent or change

- Systems (e.g., Morro and San Diego Bays) for which there are regular data collections from on-going monitoring programs that either collect the data needed to document patterns of change or can do so with minor modifications

Sampling frequency and intensity

Regional extent will be measured with a comprehensive systematic survey once every five years on the mainland and every ten years at the Channel Islands. The initial comprehensive survey will focus on filling data gaps in existing monitoring coverage (Table 3) and integrating these new data with existing information to create a regional map and estimate of extent. Subsequent comprehensive surveys could be rotated among systems to spread costs out over time. Seasonal timing of the surveys should be synchronized to the extent practical to a late-summer and fall (August through October) schedule to capture the maximum developed extent of eelgrass beds at depth. This timing sacrifices the winter-spring expansion of eelgrass upshore into the higher intertidal range and the deeper recruitment of seedlings that are dependent principally on stored reserves of the cotyledon and thus do not accurately depict the effects of environmental stressors. While these early season expansions in eelgrass presence are notable, they are of limited value in the use of eelgrass as an ecological indicator of system condition.

Indicators

Estimates of the areal extent of eelgrass beds will be based on the exterior boundary of the bed. Defining the location of the exterior boundary can be complicated by fragmentation and differences in coverage. The SCEMP currently defines the extent of vegetated cover as that area where eelgrass is present and where gaps in coverage are less than one meter between individual turion clusters. Similarly, the Puget Sound eelgrass monitoring program uses one shoot/sq. m. as the criterion for presence of eelgrass. Such definitions are adequate for continuous beds or for a focus on separate patches, but not always well suited the broader assessment of patchy, naturally sparse, or dynamic beds. Thus, where eelgrass is patchy, the locations or boundaries of individual patches are likely to change over time, even while the overall boundary of eelgrass habitat within the bay or estuary remains more stable. For this reason, a functional definition of "eelgrass bed" is required for the regional program to capture natural bed dynamics.

The definition for eelgrass beds proposed for the broader system assessment in this regional monitoring program is as follows:

> *An eelgrass bed is defined as the aggregated extent of eelgrass patches. This definition encompasses interstitial spaces between individual plants or plant clusters that are directly influenced by the proximity of plants (e.g., aggregation of fish, increased detritus generation and trapping, benthic community enrichment, local alteration of physical environmental conditions).*

An eelgrass bed may be characterized by a number of parameters that, collectively, describe the nature of the bed, its spatial and temporal distribution, and persistence through time. While many other parameters may be useful to define the bed condition (e.g., plant biomass, leaf length, shoot:root ratios, epiphytic loading), many are presently too labor intensive and variable to provide suitable metrics for broad resource inventories or management applications on a day-to-day basis. For this reason, four parameters have been identified for use in defining the extent and character of an eelgrass bed. These parameters are 1) the spatial distribution of the bed, 2) the areal extent of the bed, 3) the percentage of bottom cover within the bed, and 4) the turion (shoot) density within the bed. In some instances, an adequate monitoring history exists to include a fifth parameter that characterizes the occurrence frequency and distribution of eelgrass beds through time. The third and fourth of these indicators, percentage of bottom cover and turion density, respectively, are not measures of the extent of eelgrass beds, the primary focus of Question 1. If these parameters are readily available from the survey method used (e.g., sidescan sonar), then they provide useful additional information about the nature of the bed and its dynamics. However, if the preferred survey methods (i.e., sidescan sonar and multispectral or true color aerial imagery) are not available due to funding, logistical, or other constraints, then the other parameters would be sufficient to document the extent of the bed.

1. Spatial Distribution of Eelgrass Beds

The spatial distribution of an eelgrass bed is based on the exterior boundary of observed eelgrass patches persisting in a definable aggregation. A bed is defined as the area encompassed by this boundary excluding gaps within the bed that have individual plants greater than 20 meters from neighboring plants. Where such separations occur, either a separate bed is defined, or a gap in the bed is defined by extending a line around the void along a boundary defined by adjacent plants. Where depth, substrate, or existing structures limit bed continuity, the boundary of the bed is defined by the limits of habitat suitability to support eelgrass, clipping these restricting conditions from the bed.

2. Areal Extent of Eelgrass Beds

The aerial extent of eelgrass is defined as the total area of bottom that is bounded by the polygon defining the spatial distribution of eelgrass beds.

3. Percent Bottom Cover within Eelgrass Beds

The proportional bottom cover within an eelgrass bed is to be determined by totaling the area of eelgrass patches present within a defined bed and dividing this by the total bed area. For regional inventory purposes, the bottom cover is to be reported by cover classes that define a percentage range of bottom cover, thus allowing for subdividing the bed and estimating the percent eelgrass cover within subareas of the bed. In general, eelgrass will exhibit a vertical gradient of higher to lower coverage classes with changing elevation. Similar gradients may exist based on site energy exposure, circulation gradients, etc. Cover classes to be used in this regional program are as follows:

- Low Cover = 1 to 25 percent
- Moderate Cover = 26 to 50 percent
- Moderate/High Cover = 51 to 75 percent
- High Cover = 76 to 100 percent

4. Turion (Shoot) Density within Eelgrass Beds

Turion density is defined as the density of eelgrass leaf shoots per square meter occurring as a mean across eelgrass plants occurring within mapped eelgrass beds. Turion density shall be presented as shoots per square meter and shall be a density reported as a mean ± the standard deviation of replicate measurements. The number of replicate measurements (n) shall be reported along with the mean and deviation. Turion density characterizes the growth form of plants rather than coverage of beds. As such, turion densities are determined only within eelgrass patches comprising the bed and not within unvegetated interstitial spaces within the bed. As a result a turion count cannot equal zero.

5. Frequency and Distribution of Eelgrass Bed Occurrence

The occurrence frequency and distribution of eelgrass beds over time provides an indication of resilience and stability of the eelgrass beds. In some instances, several surveys have been completed over multiple years.

Coordination with other efforts

At the regional level, detailed planning for, and possibly implementation of, the periodic comprehensive survey could potentially be integrated with the Bight Program, which has an existing infrastructure for design, planning, implementation, and reporting. For example, planning for the first comprehensive survey to fill data gaps and integrate data from throughout the region could begin during the Bight Program year and monitoring conducted as a Bight Program special study.

Some systems and/or beds, especially the smaller ones that fall below the 20-acre minimum scale, could be sampled by volunteer groups, however a regimented survey methodology would need to be developed to maximize the value of such efforts. Beds at the smaller end of the size spectrum could be assessed in terms of simple presence/absence of eelgrass, which would provide useful long-term information if it were reported with point or polygonal spatial reference. A system specific, community-based monitoring program for volunteer implementation could be developed for these smaller systems.

Question 2: Where does eelgrass habitat have the potential to exist and where is eelgrass vegetation currently not persistent?

This question focuses on determining where eelgrass might reasonably occur and where increased management attention to habitat protection might therefore provide additional opportunities for expansion of eelgrass beds in the future. It is thus relevant to developing restoration and mitigation targets and to assessing benefits of water quality improvements and opportunity value of other lower quality habitats.

A consideration of potential habitat also supports growing interest among managers in an ecosystem-based, as opposed to a strictly project-based, approach to management and planning. Finally, an understanding of potential habitat and factors that may influence site suitability is inherently valuable in consideration of the net ecosystem effects of sea level rise or watershed level improvements.

Question 2 is based on empirical observations that eelgrass appears and disappears from certain locations, as well as on modeling results from South San Diego Bay and San Francisco Bay that indicate that at least in some systems, eelgrass should be more widespread than it actually is at any given time. Therefore it is likely that either pulsed stressful events act on the system to curtail eelgrass proliferation to all areas, or some environmental controls exist that limit eelgrass expansion on a broad scale. However, it also suggests that the absence of eelgrass in those locations where its presence is strongly predicted is potentially mediated by large-scale infrequent stressor events. Understanding where environmental conditions are suitable to support eelgrass would strongly benefit eelgrass restoration and introduction program success.

Potential assessment questions that address such concerns include:

- What is the location and extent of habitat potentially suited to future eelgrass expansion?
- What portions of these potential habitat areas contain no eelgrass, or only ephemeral eelgrass?
- How does the colonization and loss of eelgrass from these areas change over time?
- What mediates change and suitability of these areas relative to eelgrass occurrence?
- What mediates eelgrass colonization and at what frequency when an area exhibits suitable conditions?

In overview, the monitoring design recommended to address such questions has the following elements:

- Organization of existing bathymetric data and historical information on extent of eelgrass beds
- Assessment of the utility of coastal LIDAR data
- Collection of limited bathymetric data coincident with eelgrass surveys using single beam, multibeam, and interferometric sonar
- Partnering with other efforts engaged in bathymetric mapping
- Collection of additional data types needed to support the continued development and application of a predictive model to better define eelgrass habitat

The types of data products resulting from this monitoring design and appropriate for answering Question 2 may include:

- Bathymetric maps of coastal systems

- Delineation of potential eelgrass habitat in coastal systems
- Overlay of eelgrass extent on maps of potential habitat
- Time series map overlays of eelgrass extent compared to potential habitat
- A predictive model that produces a more accurate delineation of potential habitat for well studied systems
- Estimate of the proportion of potential eelgrass habitat where eelgrass beds occur, plotted over time as data accumulate

The following subsections provide details on the design approach selected, as well as on the recommended indicators and the sampling frequencies.

Design approach

Within the target systems, the single most important indicators related to delineating potential eelgrass habitat are bathymetry and soft bottom. For most enclosed bays and lagoons, the bottom environment is comprised of soft sediments and thus this factor does not become a substantial discriminator of suitability. However, due the key role of available light, more specifically hours of exposure by PAR above photosynthesis saturation intensity (H_{sat}), as a controlling factor to eelgrass growth, and the rapid attenuation of light intensity and quality with depth, bathymetry is a strong indicator of suitable conditions to support eelgrass. Unfortunately, there are large gaps in bathymetric data for the coastal systems that are the focus of the program. The basic design approach is to fill these gaps with limited bathymetric data collected coincident with sonar surveys for eelgrass and then to gradually gather more accurate and precise bathymetric data over time as opportunities present themselves. The recent development of low cost interferometric sidescan sonar may provide opportunities for integrated bathymetric data collection with acoustic eelgrass surveys.

Target population and sampling frame

The target population for this question is the same as for Question 1 (see Table 3 and Figure 1):

> *All coastal features in the Southern California Bight, including the Channel Islands, where suitable eelgrass habitat is known or expected to occur. This includes perennially tidal coastal lagoons, partially-enclosed embayments, river mouth estuaries, and areas of offshore soft-bottom, including portions of the Channel Islands*

The sampling frame is also the same as defined for Question 1:

- Perennially tidal systems that are open to the ocean for at least 11 months per year
- Systems with a minimum of 20 acres of subtidal habitat

The sampling frame was selected by listing all systems in the Southern California Bight that meet the target population definition (Table 3) and then applying the two criteria that further define the sampling frame.

Sampling design and sampling requirements

Within the defined sampling frame, the workgroup agreed that the best approach to delineating potential habitat is to compile existing bathymetric data and make the best assessment of suitable habitat possible with those data, then to develop a plan for acquiring additional bathymetric data over time as individual systems are monitored. At present, bathymetric data are only available for six to eight of the numerous systems in the Bight, and it would cost millions of dollars to acquire high-quality bathymetric data for all of the remaining systems, a task the workgroup does not believe this program can achieve on its own. Further, bathymetric data can become outdated due to sediment deposition, erosion, and dredging and as a result it must be updated regularly. The recently collected Laser Induced Differential Absorption Radar (LIDAR) data for the California coastline may be helpful in filling the bathymetry data gap, but is has not yet been fully processed and evaluated. However, LIDAR is typically not very useful in turbid nearshore environments that may dominate in many of the systems of interest.

The workgroup therefore recommends that limited bathymetric data be collected simultaneously during sonagraphic surveys of eelgrass beds. This can be accomplished by obtaining tidally corrected singlebeam sonar data coincident with sidescan sonar surveys. Single beam sonar surveys only provide bathymetry for the vessel trackline, while sidescan provides eelgrass distribution data for a much wider survey swath. As a result interpolation of depth is limited and dependent upon the survey density and evenness of the bathymetry across interpolated space. While crude, these data would start to fill this data gap and help in defining suitable habitat. Interferometric sidescan sonar resolves this problem by providing coincident bathymetric data with backscatter sidescan data. Given the cost of more extensive bathymetric surveys, the workgroup agreed to produce the best estimate possible with available data and best professional judgment and then to improve on the data over time; perhaps incrementally as resources become available.

Sampling frequency and intensity

Since the approach to gathering bathymetric data is to piggyback bathymetric measurement on routine sonar surveys of eelgrass beds, the sampling frequency and intensity would be identical to that described for eelgrass monitoring in Questions 1 and 3.

Indicators

Defining suitable potential eelgrass habitat depends on the availability of accurate bathymetric data and this is simply not available for more than a portion of the systems in the Bight. In many cases, it is available on a project by project basis, but not for the system as a whole, making it very difficult to define suitable habitat outside project boundaries. While sonar surveys could provide crude bathymetric data, most such survey methods do produce useful data at the shallower edges of systems.

As a result of these limitations, bathymetry, while a useful indicator in theory, will be of only limited use in practice until major data gaps are filled. Limited bathymetry data can be augmented to some extent with historical data and professional judgment, but descriptions of potential eelgrass habitat based on this approach will be uncertain. Where bathymetry data are available, they can be combined with historical data, information on current depth distribution, and distance from the mouth of the system to produce a simple predictive model of potential habitat. However, it is unlikely that Question 2 can be answered for the Bight as a whole anytime soon.

Coordination with other efforts

The state recently completed detailed bathymetry studies for coastal areas deeper than 30 meters and may eventually fill the data gap in this shallow zone, though there are no plans at present for conducting such surveys in shallow water. In addition, data from wetland monitoring programs might help to fill the data gap in shallow water.

Question 3: What is the condition of eelgrass habitat?

This question focuses on describing specific characteristics related to the morphology of eelgrass beds in order to assess their condition, which in turn can provide insight into their response to both natural and anthropogenic stressors. Questions about condition should be linked to specific management questions about the sources of impact and what can be managed, for example, water quality and sedimentation. Managers can control permitted actions that affect systemwide factors such as water quality and sediment loading.

Potential assessment questions that address such concerns include:

- What is the percentage of area of eelgrass beds in excellent, good, fair, or poor condition?
- What is the spatial distribution, both across and within systems, of the area of eelgrass beds in different condition categories?
- How is the condition of eelgrass beds, both regionally and within systems, changing over time?

In overview, the monitoring design recommended to address such questions has the following elements:

- Annual monitoring of eelgrass beds for coverage and changes in depth distribution

The types of data products resulting from this monitoring design and appropriate for answering Question 3 may include:

- Maps of coverage as a bottom cover class within eelgrass beds
- Maps of the deepest extent of eelgrass beds
- Measures of the change in coverage over time
- Measure of the change in deepest extent over time

The following subsections provide details on the design approach selected, as well as on the recommended indicators and the sampling frequencies.

Design approach

The basic design approach is to survey existing eelgrass beds on an annual basis to measure both their depth distribution and the coverage of eelgrass within the bed. As for Question 1, monitoring will focus on larger systems that meet specific criteria and will be based primarily on sidescan sonar, supplemented where necessary with other compatible methods. Annual surveys will build on existing monitoring programs and evaluate possible design changes needed to produce comparable data across the entire region.

Target population and sampling frame

The target population is the ecological resource about which information is desired. The target population for Question 3 is defined as:

> *All coastal features in the Southern California Bight, including the Channel Islands, where suitable eelgrass habitat is known or expected to occur, coastal lagoons, enclosed embayments, river mouth estuaries, and areas of offshore soft-bottom particularly at the Channel Islands (Table 3, Figure 1).*

The sampling frame is a representation of the target population that is used to select the sample sites and may not include all elements of the target population. For Question 3, three additional criteria were applied to identify the sampling frame for the monitoring design:

- Perennially tidal systems that are open to the ocean for at least 11 months per year
- Systems with a minimum of 20 acres of subtidal habitat
- Identified eelgrass beds

Sampling design and sampling requirements

There are three levels of spatial resolution considered in the design: regional or Bight-wide, individual systems or estuaries, and individual beds.

At the regional level, there is no need to select a randomized subset of estuaries to monitor during the periodic systematic surveys because the goal of these surveys is to fill all data gaps (Table 3) for every system with more than 20 acres of subtidal habitat and then to repeat this systematic survey over time. There is also no management purpose for monitoring a randomized subset of estuaries during the period between each regional comprehensive survey.

At the system or estuary level, the key design question is the overall distribution and frequency of sampling effort within the system as a whole. Many of the embayments and lagoons in southern California exhibit within-system variation due to varying land uses, fresh water inflow, sediment and nutrient loadings, and circulation patterns. Therefore, it was determined that portioning some of the systems into smaller segments according to similar conditions would be appropriate. While salinity gradients have been found to relate to eelgrass beds in wet temperate environments, very few southern California system have well established persistent salinity gradients. Further, where such gradients do exist, they are poorly documented and highly variable through time. One fairly stable gradient that has been identified in southern California systems is that of diminishing oceanic influence, or water circulation. Alternatively, this can be viewed as a gradient of increasing water residence time. In a simplified way this can be viewed as distance from the mouth of enclosed or semi-enclosed systems. However, in more complicated systems, it may be necessary to break out segments based on effective circulation, considering many forcing factors. The workgroup recommends that systems be broken into segments based on such factors as distance from the mouth or shared characteristics of circulation. The number of such segments will depend on the size and structure of the system, along with existing knowledge about the distribution of eelgrass along the gradient. Within each segment, beds will be selected for monitoring using a repeated belt-transect sampling design.

At the scale of individual beds, transects will be oriented across existing beds, usually from the shallowest to the deepest depths. To the maximum extent practical, transects should extend beyond the expansion capacity of the bed (i.e. well above and below the suitable depth range to support eelgrass). The number of transects needed for the entire system will be based on the goal of monitoring a minimum percentage (e.g., 5%) of the system's known total eelgrass coverage and transects will be allocated to individual beds based on each bed's proportion of the entire area of eelgrass occurring in the system. Transects will be located randomly within each bed, unless the bed is large enough to be broken into portions, each of which will receive an allocation of transects to be located randomly within each portion. Randomizing transect locations allows survey data to be applied to the bed as a whole.

Sampling frequency and intensity

The condition of eelgrass beds will be measured annually. Condition should be monitored at the end of the recognized eelgrass growing season when eelgrass remains at its stable peak condition (August through October).

Indicators

There are a number of indicators typically used to measure condition. Common indicators include depth distribution, percent cover and patch characteristics/dynamics, canopy height, maximum shoot length, shoot width, shoot density, biomass, leaf area index, and shoot-root ratios. Other indicators include community metrics, such as benthic and epiphytic fauna, the nature of the fish community, and net productivity.

Eelgrass bottom coverage by patches generally is reflective of the extent of disturbance or stressor influence on eelgrass bed development. The workgroup thus considered coverage to be a primary readily observable indicator of condition the program should focus on. Previous work with sidescan sonar has categorized coverage into three or four categories that serve as proxies for coverage, and a similar approach has been used with single beam sonar methods, although multiple single beam survey tracks would be needed to cover the same area as one sidescan sonar track. Diver transects have also been used to gather data for a patchiness index. For example, the Puget Sound monitoring program defined a patchiness index to be the number of transitions per 100 meters of straight-line transect length.

Another primary indicator selected by the workgroup is the change in depth distribution over time. Trends in the lower depth distribution could be used as a predictor for ecosystem health (Dennison *et al.* 1993). If good bathymetric data are available, changes in the depth of the deepest edge of the bed and in the bottom coverage with depth can provide insight into changes in condition and their relationship to potential stressors such as turbidity. Because coverage and distribution across a depth gradient can be readily measured with sidescan sonar, as well as single beam sonar and diver transects, and can be more readily interpreted and related to condition than other indicators, the workgroup selected these as the two primary indicators of condition. These primary indicators would be combined with measures of extent from Question 1 to develop an overall assessment of condition.

Although not currently proposed as an indicator to be used for the annual, regional surveys, shoot density will continue to be used as an indicator at a project level. Previous work has shown that eelgrass shoot density changes in response to various stressors (e.g., Olesen and Sand-Jensen 1994, Fonseca *et al.* 1990). In addition, shoot density is a common metric used in a variety of eelgrass studies and a performance criterion within the SCEMP. However, Evans and Short (2005) found only a weak correlation between fish utilization parameters and shoot density, but found a stronger correlation between fish species richness and eelgrass biomass, leaf area index (LAI), and canopy height.

The workgroup agreed that a fundamental problem in measuring condition is that there is no widely accepted definition of what *condition* means. It is used to refer to many different aspects of eelgrass beds and many different stressors. Because of the many potentially confounding factors affecting this range of possible indicators, special studies may be required to develop a more reliable understanding of condition.

Leaf area index and canopy height are two potential candidates for further study in the southern California region. Leaf area index is determined by mean shoot density and surface area per shoot and provides an estimate of the amount of areal habitat available for epibiota. Thus, it may be a functional attribute of habitat utilization. As stated above, Evans and Short (2005) found this to have a stronger correlation with fish utilization than did shoot density alone. Leaf area index has been used in Puget Sound and Gulf of Mexico eelgrass monitoring programs.

Canopy height is estimated as 80% of the mean maximum leaf length of ten shoots. It provides an estimate of the three-dimensional complexity of the habitat and, thus, may be a functional attribute of habitat utilization. As noted above, Evans and Short (2005) found this to be a useful metric for estimating habitat use. It also seems to be increasingly used in eelgrass monitoring programs (see Duarte and Kirkman 2001).

Coordination with other efforts

Opportunities may exist for an integrated effort to evaluate eelgrass condition and various metrics of condition in association with regional investigations of water quality stressors. The Bight Program's option for special studies may provide an appropriate context for such investigations.

Question 4: What are the effects of projects on regional eelgrass habitat?

Answering Question 4 depends first on having ready access to data on the location and nature of individual projects, as well as on the pre- and post-project monitoring data on the extent of eelgrass in the vicinity of the project. In the past, such data have been developed and submitted as part of the permitting process, but have not been input to a readily accessible database to allow for more comprehensive assessment of project effects.

The workgroup modified the existing project tracking form to collect additional information that will allow for tracking of the net effect of projects on the acreage of eelgrass habitat. However, this information will not include indicators needed to assess eelgrass condition. Data collected on the project tracking forms will be input to the California Water Quality Monitoring Council's Aquatic Resources Web Portal and made available on the portal's project tracking page. While this solution will provide access to the raw project data, data analyses for tracking net effects of projects on a regional basis have not been developed.

Question 5: What are the significant stressors on eelgrass habitat and what are their effects?

Eelgrass condition is affected by a number of physical, chemical, and biological stressors. Fully understanding changes in eelgrass extent and condition depends on an improved understanding of the direct, indirect, and cumulative effects of these stressors. While this is an important question for resource management, the workgroup agreed that developing a systematic approach to addressing the role of stressors was beyond the capability of this initial effort. They did anticipate, however, that expanded data collection and integration on a regional scale will allow for comparative and trend analyses that will begin to provide insight into stressors' effects on eelgrass habitat.

The workgroup also agreed that evaluating studies of stressor effects in other regions would provide a useful starting point for such studies in southern California. For example, an Eelgrass Stressor-Response Project (ES-RP) was initiated by the Washington Department of Natural Resources in 2005 to investigate and understand the nature of stressors that lead to declines of *Z. marina* in Puget Sound (Dowty *et al.* 2007). The overall goal of the ES-RP is to identify and understand *Z. marina* stressors by investigating sites in the greater Puget Sound area with observed stressed eelgrass. A key emphasis of the ES-RP is to deliver information to resource managers and decision makers that will guide management actions to protect and restore valuable habitats.

Table 4 identifies the primary stressors with the potential to affect eelgrass in southern California, along with the more evident indicators that could be used to measure their effects.

Several of the stressors identified above result in visible and rapidly assessable indicator conditions, while other stressors may not result in such immediately obvious changes. For example, high wave and current environments often result in exposure of typically buried rhizomes and the presence of loose water-roots and unanchored shoot growth at the margins of eelgrass patches. Sediment burial often results in evidence of buried leaf sheaths and upward migration of elongating turions. Sediment toxicity may not provide any evident indicator of effects on eelgrass due to the lack of any eelgrass presence. Many indicator affects may also be transitory in nature and thus not assessable at all times.

One of the primary needs in tracking the effects of stressors on eelgrass is to develop a unified assessment methodology such that when indicators of stress are noted, they are both recorded and recorded in a standard way. A rapid assessment for eelgrass condition and stressor indicator should be developed using a standardized scoring to rate the state of the eelgrass. A simplified rating format should be developed and incorporated into regional mapping programs as well as regulatory reporting data forms. This would allow for broad-based data collection on the eelgrass beds that would over-time facilitate understanding of the distribution of eelgrass in the Bight and would enhance the capacity to interpret change by examining eelgrass in the context of multiple stressor gradients.

Table 4. Major potential eelgrass stressors in southern California and indicators that could be used to measure their effects.

STRESSORS	*GENERAL INDICATORS*
Physical Stressors	
○ Wave and current energy	short and narrow leaved growth form; exposed turions at patch margins; coarse sand with ripples outside of bed; limited to no detritus accumulation
○ Sediment burial, instability	leaf sheath buried below sediment surface; upwardly migrating turions where burial is occurring; free rhizomes with water roots where sediment erosion is occurring
○ Dredging	direct bed removal; steep active slumping of adjacent side slopes; frequently, sliding eelgrass on slopes adjacent to cuts; uneven bottom due to recent cuts by dredging
○ Wake scour and prop scars	undercut rhizomes at patch margins; loose or free eelgrass plants with water roots; linear cuts in bed with loose sediment in trough
○ Animal grazing and bioturbation	apparent random pattern of rhizome exposure; forage pits in beds and adjacent bottom (rays); clipped leaves and bird waste (waterfowl)
Chemical Stressors	
○ Sediment toxicity	variable to unknown
○ Water contamination	variable to unknown
○ Oiling and other chemical fouling	observations of oils on leaves and soil; bleaching of leaves
Biological Stressors	
○ Metabolic Stressors	
▪ Photosynthetic limitation and light competition	
➢ Turbidity	low transparency in water; Sedimentation on plants; declining leaf density and chlorotic tissues
➢ Phytoplankton blooms	red tides or green water
➢ Macroalgal blooms	accumulation of sheet and tube alga (typically *Ulva*, *Enteromorpha, Porphyra*, and *Gracillaria* species); thinning of eelgrass beds in matted algae
➢ Epiphytic loading	heavy growth of epiphytes on leaves; high silt loading on plants
➢ Ambient water transparency	Gradual reduction in eelgrass cover over bottom; reduction in shoot density within patches at depth
▪ Heat and desiccation	bleaching of leaves at upper shore; loss of turgor in leaves; mottled light and dark splotches on leaves
▪ Osmotic regulation and other salinity stresses	loss of turgor in leaves; decline of bed in regions of prolonged elevated or depressed salinities
○ Disease and infection	pronounced decline of eelgrass in dense beds areas; black mottling and rot on leaves
○ Herbivory	evidence of consumption (leaf clipping, rasping, flooded lacunae)

Special Studies and Priority Research Questions

A number of questions have been identified by the workgroup that are either presently beyond the capacity to address through a regional monitoring framework or not suited to a monitoring program yet nevertheless important for resource management decision making. Such priority special studies and research questions are presented below as discrete elements that should be addressed irrespective of the monitoring program process.

Describe genetic relationships within the Southern California Bight

A NMFS-funded special study is presently underway to:

- Genetically characterize the population structure, diversity, and connectivity of eelgrass meadows along the Southern California Bight in order to establish baseline local and regional-scale data, that may assist in predicting "meadow health" in relation to other monitoring parameters
- Develop a collaborative link between the scientific community and coastal zone managers

Raw genotyping data will be provided and analyzed in a technical report that will include analyses of general diversity, population differentiation, and population connectivity. Another technical article will be developed that summarizes the results and provides suggestions on their application to ecosystem-based management. In addition, a draft manuscript will be developed with the intent of publication in a peer-reviewed journal.

Evaluate and standardize survey methodologies

Preliminary work has been completed to examine the differences between eelgrass survey methods. This work has determined that estimates of eelgrass and cover within eelgrass beds can vary widely depending upon survey and interpolation methodology. From a management perspective, the variability between differing survey methodologies creates some difficulty in assessing small-scale changes in eelgrass beds over time. From a regulatory perspective, the wide range in survey error based on methodology creates risk that an eelgrass impact from a regulated project may not be detected or may be falsely detected and a project proponent be required to mitigate damages that did not actually occur. Given the critical importance of accurate eelgrass surveys to assessing eelgrass from both management and regulatory standpoints, there is a critical need for development of standard survey methods with known error terms and repeatability in design.

Develop and analyze metrics for rapid assessment of eelgrass condition

The present monitoring program uses bottom coverage within eelgrass beds as a metric of eelgrass condition. However, there are many potential metrics that may provide a better assessment of the overall condition of eelgrass within the region. These metrics are generally cumbersome and expensive to implement on a large scale and have generally not been applied beyond an academic scale. In order to fully develop a regional monitoring program, it would be beneficial to garner a greater understanding of eelgrass condition over a broad spatial extent. This would facilitate the assessment and tracking of trends that result from of non-lethal stressors.

Carbon sequestration capabilities in eelgrass beds

Much research is still needed to understand the dynamics of carbon sequestration in eelgrass beds and its role relative to other carbon sources and sinks. Areas for further research include: the role of various processes in sequestering carbon from coastal vegetation, estimates of eelgrass habitat loss associated with sea level rise and corresponding reduction in carbon sequestration, the effects of tidal flushing on sedimentation in coastal estuaries, the effect of increased water temperatures on eelgrass growth rates, and potential ways to stimulate eelgrass growth or sequestration without harming the environment.

Faunal utilization of eelgrass meadows and trophic link between eelgrass and fisheries

Eelgrass beds provide habitat structure for a variety of fish and invertebrate species, refuge from predation, and foraging habitat. Various studies have shown that fish diversity and abundance within beds is greater than in adjacent non-vegetated areas. However, less is known about growth, reproduction, survival, and/or production rates within eelgrass habitat. Additional research on these issues would provide further information regarding the degree of importance of eelgrass habitat to fishery resources. In addition, eelgrass serves as the basis of a detrital food web. However, little research has been conducted in California examining the fate of detritus and the extent to which it may benefit the nearshore ecosystem.

Linkages between watershed inputs and eelgrass bed distribution and condition

Extensive coastal development of southern California has resulted in increased sediment and nutrient loads in many embayment systems. Research that examines the effects of these sediment and/or nutrient inputs on various environmental parameters (e.g., water clarity) will improve eelgrass management. In addition, research should focus on the efficacy of various efforts to mitigate increased sediment and nutrient inputs and, thus, improve environmental conditions for eelgrass habitat.

Quantify carbohydrate depletion in eelgrass under reduced light conditions to improve understanding of stresses from temporary or partial shading

The extent to which eelgrass may tolerate low light conditions is dependent upon the ability of eelgrass to maintain a positive plant carbon balance. In temporally variable light environments, the accumulation and mobilization of carbon reserves within the plant likely play a key role in eelgrass survival. Additional research should assess carbohydrate reserves in root and rhizome tissue over various environmental gradients in order to identify the potential early depletion of carbohydrate reserves and to better understand causes of *Z. marina* losses in stressed environments.

Next Steps

Implementing the regional program described above will involve, at a minimum, addressing recommendations in the following four areas:

- Survey methods
- Data management
- Filling key data gaps
- Regulation and program management

In particular, the workgroup agreed to pursue formal participation in the regional Bight Program because of the benefits this would provide for regional planning, monitoring, data management, and data analysis and reporting.

Survey methods

In general, methods used in the Southern California Bight are adequate to meet the basic goals of the regional program. However, there are several adjustments needed to ensure that data from existing programs can be successfully integrated to provide regional measure of extent and condition.

The largest concern is with the Morro Bay program, where aerial survey flights using multispectral imaging do not fully capture eelgrass at depth. These overflights should be supplemented with sidescan sonar surveys in deeper portions of the bay to ensure full coverage of eelgrass habitat in the Bay. In addition, the Morro Bay program maps eelgrass by raster pixels of three coverage categories for eelgrass density based on spectral reflectance, while other programs in the region use vector mapping and four cover categories based on a broader spatial mosaic across variable sized polygons. This difference will not affect estimates of extent or trends in extent, but will affect the ability to assess condition consistently across all programs. In the long run, regional standardization on four coverage categories would aid in the development of consistent maps. In the short term, the solution is to aggregate all eelgrass classified pixels in the Morro Bay monitoring program within vector polygons to simplify data to the same format of other regional mapping programs. This would require interpretation of raster maps in a manner exactly similar to interpretation of sidescan survey data.

The timing of surveys is another inconsistency among programs, with all programs ideally standardized on a late summer to early fall survey period. This would require adjustments primarily to the Newport Bay and Morro Bay programs. While this would reduce the consistency with historical data for these programs, these adjustments would produce a longer-term payoff by helping to create a regionally consistent dataset.

Recent regional mapping (2009) has been performed in San Francisco Bay that has employed a combination of purpose flown aerial photography, helicopter survey flights, and sidescan sonar to map large areas in an efficient and cost effective manner (Merkel & Associates 2010). This survey methodology has proven highly effective at acquiring data in a rapid manner. However, integration of data collected using multiple survey methods remains problematic and fraught with a need for interpretive data prioritization decision-making criteria. As a result, more work is needed to standardize the application and integration of aerial survey with sidescan sonar survey data.

Eelgrass mapping for regional monitoring purposes should employ sidescan sonar as the principal survey tool with supplemental data collection being comprised of aerial photography (true color or multispectral) where site conditions support the efficient application of these techniques. Coincident with collection of eelgrass spatial data, a rapid assessment of eelgrass condition parameters should be developed and tested. This rapid assessment must be robust and repeatable by a broad spectrum of individuals.

Data management

The workgroup identified several actions needed to provide streamlined access to data and to ensure that it is well maintained over the long term. The project needs a project web page to provide ready access to information about the program, as well as to data, reports, maps, and other products. The eventual logical home for this page is the California Water Quality Monitoring Council's system of web portals. Because the structure for the Council's ecosystem portals is still under development, a temporary home for the project's web page could be either on SCCWRP's website or as a subsection of the wetlands data portal. Once the web page is established, it will be loaded with the maps developed for the regional program design, as well as a document describing the proposed regional program.

In addition, the revised project tracking form should be tested to ensure that it accurately reflects the specific information needed for eelgrass projects and that its information can be readily loaded into the wetlands tracker system, which has offered to house eelgrass project information until a more permanent solution can be developed. Actual survey data will be housed at SCCWRP and accessible through the program's webpage.

Filling key data gaps

There are two key data gaps identified by the workgroup. The first is the lack of survey data for some systems with more than 20 acres of subtidal habitat in Table 3. The workgroup did not identify any source(s) of funding for conducting these surveys, but agreed that filling this data gap was an essential part of the periodic comprehensive regional survey described in the discussion for Question 1.

The second major data gap is regionwide bathymetry data needed to better define potential eelgrass habitat. Filling this data gap will involve organizing existing information, as well as collecting crude bathymetric data coincident with ongoing eelgrass surveys as described in the discussion for Question 2.

Regional program coordination

Implementing the next steps described above, as well as the longer-term adjustments described in the discussion for each of the five management questions, will require a more robust structure for regional program coordination. The regional workgroup organized for this report, or a similar entity with representation from the major monitoring programs and data users, will be needed to:

- Define specific adjustments to monitoring protocols required to improve comparability and consistency across programs
- Guide the development of improved methods
- Prioritize efforts to fill data gaps
- Contribute to the design and implementation of regional assessments

The workgroup examined the structure and process used by the periodic Southern California Bight Program and concluded this was a suitable framework for organizing and building a more coordinated eelgrass monitoring and assessment effort. Benefits of working through the Bight Program include the ability to begin with a smaller-scale pilot program, cost-sharing for the overall program infrastructure (including management, statistical support, and data management support), easier access to complementary data on related aspects of the ecosystem, and an established workgroup structure for data analysis and report preparation. In addition, participation in the Bight Program provides greater visibility and a ready vehicle for dissemination of results. The workgroup agreed to formalize its membership in the Bight Program through additional communication with the sponsors of existing eelgrass monitoring programs and concrete planning with SCCWRP Bight Program managers.

Regulatory program changes do not appear to be required for purposes of implementing the regional monitoring program. However, it is appropriate to alter the data collected and reporting formats for eelgrass surveys and mitigation slightly to accommodate integration into regional reporting formats and to improve continuity in survey reporting and interpretation of results.

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