


MARINE PROTECTED AREA MONITORING

Action Plan

California Department of Fish and Wildlife
California Ocean Protection Council



2018

Acknowledgments

The California Department of Fish and Wildlife developed the Marine Protected Area Monitoring Action Plan in close collaboration with the California Ocean Protection Council. Insightful input was also received from a peer review panel, California Fish and Game Commission, other academic, state, and federal agencies, and the general public.

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Executive Summary

RECOGNIZING THE IMPORTANCE OF CALIFORNIA'S DIVERSE MARINE SPECIES AND ECOSYSTEMS as vital to the state's coastal economy, public well-being, and ecological health, the California Legislature passed the Marine Life Protection Act (MLPA) in 1999. The MLPA required the state to redesign its pre-existing system of marine protected areas (MPAs) to function as a statewide network to increase its coherence and effectiveness at protecting the state's marine life, habitats, and ecosystems. The MLPA also required the adoption of a Marine Life Protection Program (now called the MPA Management Program) with six primary goals to improve the design and management of California's MPAs. An extensive public planning process for MPA design and siting was implemented across California's coast incrementally through four regional, science-based and stakeholder-driven processes, ending in December 2012 and resulting in the creation of an ecologically connected network of 124 new or redesigned MPAs and 15 special closures.

California's MPAs are adaptively managed as a network through the MPA Management Program which consists of four focal areas: 1) outreach and education, 2) enforcement and compliance, 3) research and monitoring, and 4) policy and permitting. Within the research and monitoring focal area, the California Department of Fish and Wildlife (CDFW) and California Ocean Protection Council (OPC) collaboratively direct California's MPA Monitoring Program which includes a two-phased, ecosystem-based approach. Regional baseline monitoring (Phase 1, 2007 – 2018) characterized ecological and socioeconomic conditions near the time of regional MPA implementation and improved our understanding of a variety of representative marine habitats and the associated biodiversity. CDFW and OPC are now designing and implementing statewide long-term monitoring (Phase 2, 2016 – present) to reflect current priorities and management needs.

The MPA Monitoring Action Plan (Action Plan) informs next steps for long-term MPA monitoring in California by aggregating and synthesizing work to date, as well as by incorporating novel, quantitative, and expert-informed approaches. The Action Plan prioritizes key measures, metrics, habitats, sites, species, human uses, and management questions to target for long-term monitoring to inform the evaluation of California's MPA Network. For example, the Action Plan includes select species-level, community-level, physical, chemical, and human use measures and metrics identified to advance understanding of conditions and trends across the MPA Network. MPA index monitoring sites are prioritized based on scoring MPAs against four defined criteria that evaluated various aspects of individual MPAs, including 1) MPA design features, 2) historical coastwide monitoring, 3) habitat-based connectivity modeling, and 4) local recreational fishing effort prior to MPA implementation. These index sites are recommended using a tiered approach across three bioregions to create scalable monitoring options based on available resources and capacity. The Action Plan also provides lists of species and species groups to target for long-term monitoring, and highlights examples of existing programs that can contribute to long-term monitoring in California. In addition, the Action Plan incorporates long-term monitoring approaches to inform adaptive management. Specifically, quantitative analyses focused on detecting population responses to MPAs over time, incorporating spatial differences in fishing mortality rates, informing sample design for deep-water surveys, and comparing various fish monitoring techniques used for nearshore marine ecosystems and MPAs.

The primary intended audiences of the Action Plan include existing and potential partners interested in applying for funding to conduct MPA monitoring, as well as other entities with mandates, or interests relating to California's MPA Network. This is a living document and may be updated as needed to ensure the latest understanding of MPA network performance evaluation is reflected in the priorities of the MPA Monitoring Program.

1. Introduction

1.1 California's MPA Network

Recognizing the importance of California's marine resources to the state's coastal economy, public well-being, and ecological health, the California Legislature passed the Marine Life Protection Act (MLPA, Chapter 10.5 of the California Fish and Game Code [FGC], §2850-2863) in 1999. The MLPA required the state to redesign its pre-existing system of marine protected areas (MPAs) to meet six goals (Box 1).

BOX 1: Goals of the Marine Life Protection Act (MLPA)

>> **GOAL 1:** *Protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems.*

>> **GOAL 2:** *Help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted.*

>> **GOAL 3:** *Improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and to manage these uses in a manner consistent with protecting biodiversity.*

>> **GOAL 4:** *Protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic value.*

>> **GOAL 5:** *Ensure California's MPAs have clearly defined objectives, effective management measures, and adequate enforcement, and are based on sound scientific guidelines.*

>> **GOAL 6:** *Ensure the state's MPAs are designed and managed, to the extent possible, as a network.*

To read the full text of the MLPA, please visit
www.wildlife.ca.gov/Conservation/Marine/MPAs/MLPA

GUIDED BY THESE SIX GOALS, the MLPA was implemented incrementally across four planning regions through science-based and stakeholder-driven processes, resulting in the creation of an ecologically connected network of 124 MPAs. Implemented regionally, the new and revised MPAs went into effect in the central coast (Pigeon Point to Point Conception) in September 2007, the north central coast (Alder Creek near Point Arena to Pigeon Point) in May 2010, the south coast (Point Conception to U.S./Mexico border) in January 2012, and the north coast (California/Oregon border to Alder Creek) in December 2012. California's MPA Network (Figure 1) now spans the state's entire 1,100-mile coastline and encompasses approximately 740 square nautical miles (16% of California's jurisdictional waters). It is the largest network of MPAs in North America and one of the largest in the world.

FIGURE 1: California's MPA Network

The MPAs that comprise the Network are under several designations that reflect various management objectives (Table 1). Nine percent of state waters are no-take state marine reserves and approximately six percent of state waters are state marine conservation areas in which limited take is permitted. Special closures are not MPAs, but they do contribute to the goals of the MLPA by restricting access to waters adjacent to seabird rookeries or marine mammal haul-out sites.

TABLE 1: MPA and marine managed area (MMA) map color, classification, number of sites, percent of California state waters protected, and summary. For full definitions and a complete overview of MPA classifications, please refer to CDFW (2016).

MAP COLOR	CLASSIFICATION	NUMBER OF SITES	%	SUMMARY
Red	State Marine Reserve	49	9.0%	An MPA designation that prohibits damage or take of all marine resources (living, geologic, or cultural) including recreational and commercial take.
Purple	State Marine Conservation Area	60	6.5%	An MPA designation that may allow some recreational and/or commercial take of marine resources (restrictions vary)
Blue	State Marine Conservation Area (no-take)	10	0.6%	An MPA designation that generally prohibits the take of living, geological, and cultural marine resources, but allows potentially affected and ongoing permitted activities such as dredging and maintenance to continue.
Green	State Marine Recre-ational Management Area	5	0.1%	An MMA designation that limits recreational and commercial take of marine resources while allowing for legal waterfowl hunting to occur; provides subtidal protection equivalent to an MPA (restrictions vary)
Pink	Special Closure	15[1]	0.1%	An area designated by the Fish and Game Commission that prohibits access or restricts boating activities in waters adjacent to sea bird rookeries or marine mammal haul-out sites (restrictions vary)

Eight key habitats and two types of human uses (called “ecosystem features” in regional monitoring plans) were identified during Phase 1, and continue to help guide monitoring efforts: Rocky Intertidal, Kelp and Shallow Rock (0-30 m), Mid-depth Rock (30-100 m), Estuaries, Soft-bottom Intertidal and Beach, Soft-bottom Subtidal (0-100 m), Deep Ecosystems & Canyons (>100 m), Nearshore Pelagic (i.e., the water column habitat within state waters in depths >30 m), Consumptive Uses, and Non-Consumptive Uses.

1. The Commission repealed Rockport Rocks Special Closure on August 22, 2018, effective upon approval of Office of Administrative Law by January 1, 2019.

1.2 Management of the MPA Network

Management of California's MPA Network is guided by the 2016 MLPA Master Plan for MPAs (CDFW 2016) and the MPA Statewide Leadership Team Work Plan (OPC 2015). The MPA Management Program (Management Program) is a collaboration between the California Department of Fish and Wildlife[2] (CDFW) the California Fish and Game Commission[3] (Commission), the California Ocean Protection Council[4] (OPC), the MPA Statewide Leadership Team[5] (Leadership Team), California Native American Tribes, and non-governmental partners. This novel partnership-based approach is guided by "The California Collaborative Approach: Marine Protected Areas Partnership Plan[6]" (OPC 2014) and ensures that California's MPA Network is adaptively managed with active engagement across the ocean community.

MPA Management Program Focal Areas

California's MPAs are managed as a statewide network through the Management Program. The Management Program is composed of four programmatic focal areas that require active engagement to ensure the MPA Network is adaptively managed and informed by engaged partnerships (Gleason et al. 2013, CDFW 2016).

Outreach and education. Outreach and education efforts primarily focus on encouraging compliance with MPA regulations. The dissemination of MPA-based regulatory, interpretive, and educational materials is a collaborative effort with partners across the state. Collaboration with CDFW and local groups on these materials improves outreach efforts by helping to tailor messaging and delivery mechanisms to reach out to California's diverse public in a consistent, cohesive, and effective manner.

Enforcement and compliance. The success of any MPA or MPA network relies, in part, on proper enforcement of and compliance with MPA regulations (Gleason et al. 2013, CDFW 2016). The MLPA emphasizes the importance of enforcement as a primary goal of the Management Program and identifies CDFW as the primary agency responsible for MPA enforcement. CDFW occasionally receives assistance from other allied agencies such as the National Oceanographic and Atmospheric Administration (NOAA), the California Department of Parks and Recreation, the United States Coast Guard, local sheriffs, and the California Highway Patrol. In 2016, CDFW's Law Enforcement Division established a Marine Enforcement District, which includes 40 wildlife officers focused solely on enforcing marine regulations including MPAs.

Research and monitoring. The MLPA requires the MPA Network be monitored to evaluate progress toward meeting its goals, and that the results of monitoring inform adaptive management decisions. The Monitoring Program (detailed in Section 2) integrates across existing science, policy, and management needs to inform the adaptive management of the MPA Network. The Monitoring Program is carried out by multiple state partners, is scientifically rigorous, addresses the mandates of the MLPA, and informs other California coastal and ocean policy priorities.

Policy and permitting. Consistent policy and permitting is a critical component of MPA Network governance. The Management Program uses scientific data and expert knowledge to inform management recommendations to the Commission to aid in their rule-making decisions. For example, goal three of the MLPA states that the MPA Network provide study opportunities in marine ecosystems that are subject to minimal human disturbance. However, unregulated research activities have the potential to negatively impact marine environments. To address these potential adverse effects, in 2017 CDFW began utilizing an ecological framework (Saarman et al. 2018) for informing scientific collecting permitting decisions in MPAs.

2. https://www.wildlife.ca.gov/
3. http://www.fgc.ca.gov/
4. http://www.opc.ca.gov/
5. http://www.opc.ca.gov/programs-summary/marine-protected-areas/partnerships/
6. http://www.opc.ca.gov/webmaster/ftp/pdf/docs/mpa/APPROVED_FINAL_MPA_Partnership_Plan_12022014.pdf

MPA Governance

MPA governance in California is rooted in a partnership-based approach to facilitate design, implementation, and adaptive management of the MPA Network to achieve the goals of the MLPA (CDFW 2016). The Commission is the primary regulatory decision-making authority for regulations related to California's MPAs. CDFW implements and enforces the regulations set by the Commission, and is the lead managing agency for the MPA Network. OPC is responsible for the direction of policy for California's MPAs.

By tapping into the specialized knowledge of partners at other state and federal agencies, California Native American Tribes, non-governmental organizations, academic institutions, and fishing communities, CDFW and OPC leverage existing capacity to help ensure efficient, cost-effective management of the MPA Network. In 2014, the Secretary for Natural Resources directed OPC staff to convene the Leadership Team to encourage effective communication and collaboration among these partners. The Leadership Team is a standing advisory body made up of state, federal, nonprofit, and Tribal members that ensures communication and collaboration among entities that have regulatory authority, responsibility, or interests related to California's MPA Network. By building and maintaining active partnerships, the Leadership Team works to engage a diverse range of stakeholders in the management of the MPA Network. In particular, the Leadership Team plays a critical role in helping to support the MPA Monitoring Program.

Partnership with California Native American Tribes

Both informal discussions and formal Tribal Consultation are important to the ongoing management of MPAs (CDFW 2016). As the traditional users and stewards of California's marine resources, California Native American Tribes are particularly important to the success of the Management Program. The US Government recognizes some Native American Tribes as separate and independent sovereign nations, and these federally recognized Tribes have trust relationships with the US Government and interact with it on a government-to-government basis. Non-federally recognized Tribes also play an important role in natural resource management. The State of California does not have a formal trust relationship with federally recognized or non-federally recognized Tribes. However, the state is committed to engaging in meaningful collaborations with California Native American Tribes.

Guided by the Executive Order B-10-11 established by Governor Edmund G. Brown Jr. and demonstrating California's commitment to improving collaboration and communication with Tribes, CDFW, OPC through the California Natural Resources Agency[7] (CNRA), and the Commission developed and adopted formal Tribal Consultation policies to enable California Native American Tribes to provide meaningful input for natural resource management.

7. http://resources.ca.gov/

2. MPA Monitoring Program

SCIENTIFICALLY SOUND MPA MONITORING is a critical component of the adaptive management process required by the MLPA (CDFW 2016). The state and its partners have designed a scientifically rigorous and robust Monitoring Program. The Monitoring Program draws from best available science regarding MPA performance evaluation and uses best practices in science, policy, and management, recognizing the uniqueness of California's marine environment (CDFW 2016).

The Monitoring Program consists of a two-phase approach. Phase 1, which was completed in early 2018, focused on regional baseline monitoring and established a "snapshot" of ecological and socioeconomic conditions near the time of MPA implementation. Phase 2 is focused on statewide long-term monitoring to track changes in selected performance metrics inside and outside MPAs over time. Underpinning both phases are three core elements necessary for generating meaningful monitoring results: science, communication, and evaluation (Figure 2).

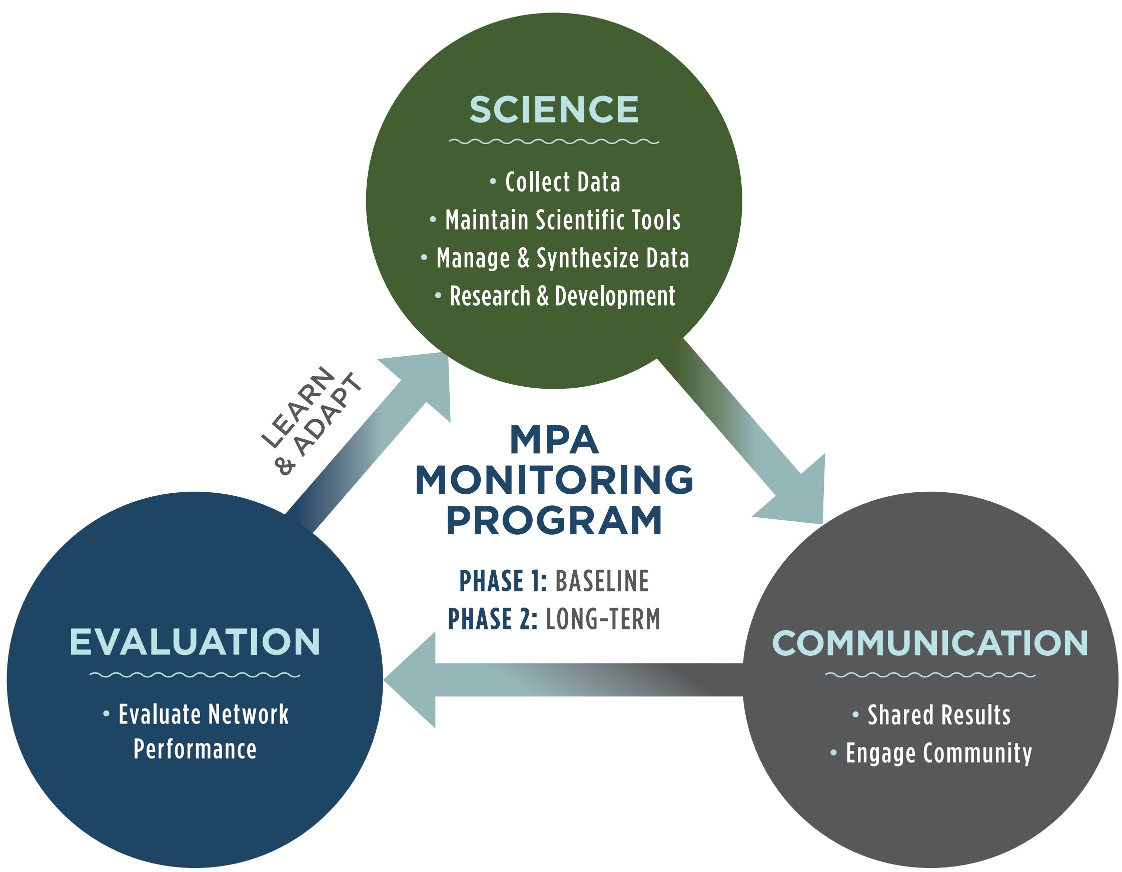


FIGURE 2: Science, communication, and evaluation elements that help inform adaptive management of California's MPA Monitoring Program.

2.1 Phase 1: Regional Baseline Monitoring

Regional baseline monitoring established a comprehensive snapshot of ecological and socioeconomic conditions at or near the time of MPA implementation in each of four planning regions across California's coast (Table 2). Baseline monitoring projects were guided by regional priorities funded in each region through a competitive peer review process, and covered eight habitats and two human uses, guided by recommendations from the MLPA Science Advisory Team (SAT) during the MPA design and siting process (CDFW 2008, MLPA SAT 2008, 2009, 2011, White et al. 2013):

- Rocky Intertidal
- Kelp and Shallow Rock (0-30 m)
- Mid-depth Rock (30-100 m)
- Soft-bottom Intertidal and Beach
- Soft-bottom Subtidal (0-100 m)
- Deep Ecosystems and Canyons (>100 m)
- Nearshore Pelagic (i.e., the water column within state waters 0-3 nm)
- Estuaries
- Consumptive Human Use
- Non-consumptive Human Use

TABLE 2: MPA baseline monitoring regions, number of projects, data collection period, analysis and sharing information period, and year of the initial regional 5-year management review.

COASTAL REGION	NUMBER OF PROJECTS	DATA COLLECTION PERIOD	ANALYZE, SYNTHESIZE, & SHARE INFORMATION	5-YEAR MANAGEMENT REVIEW
CENTRAL *(Pigeon Pt. to Pt. Conception)*	5	2007 - 2010	2010 - 2013	2013
NORTH CENTRAL *(Alder Creek to Pigeon Pt.)*	11	2010 - 2012	2012 - 2016	2016
SOUTH *(Pt. Conception to US/Mexico Border)*	10	2011 - 2013	2013 - 2017	2017
NORTH *(California/Oregon border to Alder Creek)*	11	2013 - 2016	2016 - 2018	2018

Data and results are found in raw data packages and individual technical reports for each funded project, as well as in summary "State of the Region" reports (Table 3). Baseline products informed an initial 5-year management review of regional MPA implementation, and provide a benchmark against which future changes can be measured. All baseline monitoring data and reports can be accessed at **https://data.cnra.ca.gov.**

TABLE 3: MPA baseline products by coastal region.

COASTAL REGION	PRODUCT
NORTH	Baseline Monitoring Projects[8] State of the Region Report[9] CDFW's Management Review[10]
NORTH CENTRAL	Baseline Monitoring Projects[11] State of the Region Report[12] CDFW's Management Review[13]
CENTRAL	Baseline Monitoring Projects[14] State of the California Central Coast Report[15] CDFW's Management Review[16]
SOUTH	Baseline Monitoring Projects[17] State of the California South Coast Report[18] CDFW's Management Review[19]

8. https://caseagrant.ucsd.edu/news/north-coast-marine-protected-areas-project-summaries
9. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=151828&inline
10. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=155713&inline
11. https://caseagrant.ucsd.edu/news/north-central-coast-marine-protected-areas-project-summaries
12. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=133100&inline
13. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=133098&inline
14. https://caseagrant.ucsd.edu/news/central-coast-marine-protected-areas-project-summaries
15. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=133101&inline
16. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=80499&inline
17. https://caseagrant.ucsd.edu/news/south-coast-mpa-baseline-program
18. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=144357&inline
19. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=144356&inline

2.2 Phase 2: Statewide Long-Term Monitoring

Statewide long-term monitoring focuses on gathering the required information necessary to assess MPA Network performance. Major components supported or identified to date include:

- Maintaining or expanding the geographic scope of data collection in selected key habitats and on human uses,
- Maintaining the capacity of CDFW to collect data through scientific equipment upgrades,
- Supporting the development of an Open Data Platform[20] (ODP), a comprehensive, publicly accessible information management system hosted by CNRA and connected to existing data platforms, and
- Conducting integrated analyses across sites, regions, and scientific disciplines to inform adaptive management.

This document informs next steps for long-term monitoring. It does this by aggregating and synthesizing work from the MPA design and siting process, baseline monitoring projects, and additional scientific study in California on MPAs over the past decade, as well as incorporating novel, quantitative, and expert informed approaches. ***This Action Plan prioritizes metrics, habitats, sites, species, and human uses for long-term monitoring to inform the evaluation of the MPA Network.*** The primary intended audiences include existing and potential partners interested in applying for funding to conduct MPA monitoring, as well as other entities with mandates, or interests relating to California's MPA Network. This is a living document and may be updated as needed to ensure the latest understanding of MPA Network performance evaluation is reflected in the priorities of the Monitoring Program.

Funding for Long-Term Monitoring

A variety of funding sources, disbursement mechanisms, and administrative processes have been identified to ensure the successful implementation of the Monitoring Program. Currently, the Monitoring Program receives a $2.5 million annual General Fund appropriation into the Secretary for Natural Resources budget that is designated for MPA monitoring. This amount is supplemented with other types of funds when available, but these monies are not available every year and the amount available for the Monitoring Program fluctuates annually. OPC's Once-Through Cooling (OTC) Interim Mitigation Program identifies research to determine the degree to which the MPA Network is mitigating OTC impacts as one of the designated uses for those funds[21]. The OTC Program will sunset in 2029. Payments to the program will decrease each year as power plants come into compliance with the policy or shut down. A general portfolio of potential funding disbursement mechanisms has been identified that will inform and enable state investments to strategically target maximum cost-effectiveness, transparency, and efficiency across the breadth of activities within the Monitoring Program (Appendix A). The MPA Management Program's adaptive management process includes a decadal management review, the first of which is anticipated in 2022 (marking 10 years since statewide MPA Network implementation in 2012; CDFW 2016). Some key elements of the process, specific to funding the Monitoring Program prior to the first review in 2022, are discussed below.

CURRENT TIMELINE

November 2018
Open call for proposals released

January 2019
Scientific peer review of submitted proposals

February 2019
Recommend proposals brought to OPC

March – May 2019
Approved project agreements executed

April 2019 – 2021
Data collection and analyses

December 2022
Ten-year management review brought to Commission

20. https://data.cnra.ca.gov/
21. Dawson C.L., Worden S., Whiteman L. 2016. Once-Through Cooling Mitigation Program Policy and Science Framework Linking California's Marine Protected Area Network to OTC Impacts. http://www.opc.ca.gov/webmaster/_media_library/2016/10/FINALScience_PolicyFramework_LinkingMPAstoOTCmitigation_8.30.16.pdf

RESEARCH CONSORTIUMS

The MPA Network spans more than 1,100 miles along California's coastline, excluding San Francisco Bay. Research programs are often clustered around academic institutions, and many focus on conducting monitoring studies within their local geographic region (see monitoring dashboard[22] for more information). Few monitoring programs have a statewide focus and fewer still work at broader scales. The Monitoring Program supports consortiums of principal investigators (PIs), often from multiple institutions or organizations, to conduct some elements of the Monitoring Program. Administratively, a single lead-PI and their associated institution/organization submits a single proposal during open call periods that identifies their geographically distributed co-PIs as sub-awardees. If a proposal is successful, the lead-PI will be awarded funds and they are responsible for using their institution's accounting practices to disburse funds to their co-PIs. In practice to date, most of the consortium awards have been organized around habitat types along the coast, e.g., Rocky Intertidal, Kelp and Shallow Rock (0-30 m), Mid-depth Rock (30-100 m). This prevents the state from absorbing the administrative burden of awarding monitoring projects on a regional basis, which significantly increases the number of overall awards being administered and allows for a more efficient leveraging of existing resources. Another major advantage of this approach is collaborators can share training resources and equipment across the state, when feasible, to increase efficiency and keep costs as low as possible.

OPEN CALL COMPETITIVE PROCESS

The state will, in most cases, release Requests for Qualifications (RFQs) soliciting proposal bids for monitoring projects. An RFQ lays out a highly specific project plan and is appropriate for many of the key habitat types that already have very clearly defined consensus approaches to monitoring the key metrics (see section 2.3). Long-term monitoring RFQs and submissions will undergo full scientific peer review. Successful applicants will enter into an agreement with the state and will be funded in arrears by reimbursement. Reimbursements will require ongoing written progress updates and a percentage of the total award (usually 10%) will be held back and released upon the submittal of all the required deliverables delineated in the agreement. The RFQ process will last a total of 12-14 weeks plus time for agreement execution. Steps include an open call period (4-6 weeks), peer review (4 weeks), applicant revisions based on reviewer comments (1-2 weeks), and final state review and decisions on recommended projects to fund (2 weeks). Although most open calls will likely be for new RFQs, other funding mechanisms identified in Appendix A can be deployed at any time as appropriate. For instance, specific questions regarding key habitats without clearly defined consensus approaches may be considered through Expressions of Interest (EOI).

Incorporating Existing Approaches

The Monitoring Program utilizes a partnership-based approach to leverage existing capacity. This approach has established a foundation for generating novel scientific information, tools, and strategies through partnerships with academic institutions, local, state, Tribal and federal governments, citizen science, other organizations, fishermen, and others across the state and beyond (CDFW 2016). For example, CDFW, OPC, and the Commission collaborated with over 60 organizations to conduct comprehensive baseline monitoring across all four coastal planning regions from 2007– 2018. Moving forward, the Monitoring Program will continue to identify opportunities to align monitoring approaches to leverage resources, capacity, and expertise.

To enhance our understanding of the magnitude of ocean monitoring and research along California's coastline, an interactive dashboard was developed to explore who is monitoring what and where. The dashboard is the result of information collected from a survey conducted following baseline monitoring in each of the four planning regions and represents a key step in planning for long-term monitoring. Survey participants included government agencies, non-government organizations, and academics involved in conducting or managing monitoring efforts.

22. http://oceanspaces.org

In 2018, 134 entities were actively monitoring and researching at 8,228 sites off California's coast. Some of these entities have long-term monitoring sites that may help fill data gaps and address data collection limitations related to the Monitoring Program. It should be noted that not all the projects described in the survey are on-going or monitoring the selected sites, metrics, and indicators identified by the Monitoring Program.

EXAMPLES OF IMPORTANT EXISTING PROGRAMS

The programs below have been in existence for often over a decade and are contributing data to statewide long-term monitoring. Though not a comprehensive list, the following programs include extended time series or novel monitoring of under-sampled metrics (e.g., human use metrics) that can contribute to long-term MPA monitoring in California.

- **Multi-Agency Rocky Intertidal Network (MARINe)**
  Established in the 1980s, MARINe[23] is a partnership of agencies, universities, and private research groups working together to collect data in rocky intertidal habitats. Surveys by MARINe partners follow standardized protocols and occur throughout the year at over 200 sites ranging from Southeast Alaska to Mexico, with more than 187 in California. With over 20-30 years of data at some California sites, long-term data will be invaluable to assessing MPA effectiveness, performance, and network connectivity.

- **Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO)**
  Established in 1999, PISCO[24] is a long-term, ecosystem-based scientific monitoring program involving marine scientists at four universities along the U.S. West Coast. The monitoring program was designed to enhance understanding of the California Current Large Marine Ecosystem (CCLME), with research focusing on physical oceanographic conditions of the coastal ocean (5-10 km from shore and less than 25 m deep), as well as the ecology of kelp forests and rocky shorelines. PISCO's broad-scale research, monitoring, data management, training, and outreach will continue to improve the understanding of how MPAs and surrounding areas respond to long-term protections.

- **National Science Foundation (NSF) Long-Term Ecological Research (LTER)**
  In 1980, to address ecological questions that cannot be resolved with short-term observations or experiments, NSF established the LTER program.[25] This program has designated specific sites to represent major ecosystem types or natural biomes, with two in southern California. The Santa Barbara Coastal LTER[26] project was established in 2000 and investigates the relative importance of land and ocean processes in structuring giant kelp forest ecosystems in the Santa Barbara Channel. The California Current Ecosystem LTER[27] project was established in 2004, and focuses on the oceanographic mechanisms leading to changes and dynamics of the pelagic ecosystem. Both sites have the potential to contribute greatly to our understanding of long-term change because of spatial protection.

- **California Cooperative Oceanic Fisheries Investigations (CalCOFI)**
  Established in 1949 to study ecological aspects of the sardine population crash, CalCOFI[28] is a partnership between CDFW, NOAA, and Scripps Institution of Oceanography that today focuses on the study of the marine environment off the coast of California through data collection on a wide array of marine indicators. CalCOFI conducts four seasonal oceanographic cruises a year to collect hydrographic and biological data in waters out to 300 nautical miles (nm) at various set stations from San Diego to Point Arena that are designed to improve the overall understanding of the fluctuations and long-term changes of the CCLME through continuous investigation.

23. https://www.eeb.ucsc.edu/pacificrockyintertidal/index.html
24. http://www.piscoweb.org/
25. https://lternet.edu/
26. http://sbc.lternet.edu/
27. http://cce.lternet.edu/
28. http://calcofi.org/

- **Integrated Ocean Observing System (IOOS)**
  Created in 2001, IOOS[29] is a national-regional partnership intended to integrate ocean observing systems to enable NOAA and partners to provide new tools and forecasts to improve safety, enhance the economy, and protect the environment through improved ecosystem and climate understanding. California waters are divided into two IOOS regions, the Southern California Coastal Ocean Observing System (SCCOOS) and the Central and Northern California Ocean Observing System (CeNCOOS). Created in 2002, SCCOOS[30] is a regional component of the IOOS that works with local, state, and federal agencies to provide scientific data and information to inform decision making and to understand the changing Southern California coastal ocean conditions. SCCOOS activities include marine operations, coastal hazards, climate variability and change, and ecosystems, fisheries, and water quality in waters from Point Conception south to the Mexico border. Since 2004, CeNCOOS[31] has been regional partner with IOOS to develop long-term environmental conditions monitoring (e.g., water quality, productivity, and connectivity) to support MPA management in waters from the California/Oregon border south to Point Conception. CeNCOOS activities include scientific and technical expertise in ocean surface circulation measurements, shore stations that measure biological conditions, atmospheric and oceanographic forecasting, ocean acidification monitoring, seafloor mapping, and data serving.

- **U.S. National Park Service Kelp Forest Monitoring (KFMP)**
  Channel Islands National Park established the Kelp Forest Monitoring Program[32] (KFMP) in 1982 to collect baseline data on the Park's kelp forest ecosystems. The protocol was formally adopted in 1987 and two formal reviews and revisions of monitoring protocol have occurred since. This is now one of the longest continuous datasets on the nearshore ecosystem in California and provides baseline data prior to the 2003 MPA establishment at the Northern Channel Islands to compare against for context. Each year, KFMP divers collect size and abundance data for algae, invertebrates, and fish along permanent transects. Currently 33 sites are surveyed annually, including 15 sites within the Northern Channel Islands MPAs and their associated reference sites. Information from the KFMP program has been used alongside PISCO data to detect changes in size and density of fishes, invertebrates, and algae in response to MPAs.

- **Citizen Science Programs**
  The capacity for citizen science to play a role in MPA monitoring is increasing, as multiple programs improve and standardize their sampling methods to meet traditional scientific standards. Citizen science can take many forms, from casual observations of marine life onshore to organized surveys of offshore reefs. Though citizen science is not a substitute for academic research, when suitable, citizen science has the potential to generate large amounts of reliable, cost-effective data while simultaneously creating more informed and invested communities.

  - **Reef Check California (RCCA)**
    Since 2005, RCCA[33] has conducted a statewide program that monitors and reports on subtidal rocky reefs throughout California. Trained volunteer SCUBA divers conduct surveys of fish, algae, and invertebrate species and document underwater topography. RCCA has established high expectations for volunteer entry, including extensive training requirements and a hierarchy of survey skills that develop over time through continued participation in the program. Due to the rigorous training requirements, RCCA has shown its data collection standards to be on par with those collected by academic and agency scientists, and as such received funding to collect data as part of regional baseline monitoring projects.

29. https://ioos.noaa.gov/about/about-us/
30. https://ioos.noaa.gov/regions/sccoos/
31. https://ioos.noaa.gov/regions/cencoos/
32. https://science.nature.nps.gov/im/units/medn/monitor/kelpforest.cfm
33. http://www.reefcheck.org/california/ca-overview

- **California Collaborative Fisheries Research Program (CCFRP)**
  CCFRP[34] is a partnership of researchers and local fishing communities interested in fisheries sustainability. Established in 2007 as part of baseline monitoring on California's central coast, the program uses local charter boats to take volunteer anglers out to conduct fishery-independent, hook-and-line, catch and release surveys of offshore rocky reefs inside and outside MPAs. Volunteer anglers participate in research cruises under the oversight of scientists who are on hand to help with measurements, tagging, and fish identification. The program has now expanded statewide. Researchers attribute the success of this program to its collaborative nature, which helps to create an open and collaborative dialogue between scientists and recreational fishermen.

- **Long-term Monitoring Program and Experiential Training for Students (LiMPETS)**
  Created in 2002, LiMPETS[35] is a youth-based citizen science program that works primarily with middle and high school students to collect data from more than 60 sites across California's coast. Volunteers are taught to identify, count, and measure marine species in rocky intertidal and sandy beach habitat. Participation in the LiMPETS program help increase students' understanding of California's coastal ecology while also providing publicly accessible, long-term data.

- **MPA Watch**
  MPA Watch[36], established in 2010, monitors both consumptive and non-consumptive human use of coastal resources. The program is overseen by ten different organizations, which collectively train and support volunteers to collect data on how coastal usage is changing as a result of MPA implementation. All volunteers utilize standardized data collection and reporting methods, which helps to increase the scientific rigor of the program. MPA Watch began collaboration with the State in 2013.

While established long-term monitoring programs will be of vital importance in tracking the MPA Network's progress towards meeting the goals of the MLPA, additional programs may also play important roles.

- **Mid-depth (30-100 m) and deep rocky reefs (>100 m) visual surveys**
  Mid-depth and deep rocky reefs comprise more than half of the rocky reef habitat within California's jurisdictional waters (0-3 nm from shore and around offshore islands and rocks). CDFW has performed extensive surveys inside and outside of MPAs using a remotely operated vehicle (ROV) since 2004. Recently, CDFW collaborated with Marine Applied Research and Exploration[37] (MARE) to survey 148 locations in a three-year, statewide effort revisiting historic baseline monitoring sites and adding many new locations. Synthesis of this data set with fine scale seafloor mapping products, through the use of spatial models, has demonstrated ability to quantify fish and invertebrates across these reef systems. Ongoing development of these techniques and refinement of sampling methodology will provide the ability to detect change in these important ecosystems. A series of workshops to explore the full range of sampling methods used in this habitat were held in 2017. The workshop focused on using expert input to develop consensus recommendations on metrics, sites, and indicators which will be used to inform (along with other emerging analyses), long-term monitoring in this habitat (Appendix E).

- **Seabird surveys**
  While seabirds are generally highly migratory, during breeding and nesting season, many species are central place foragers requiring frequent returns to their nests for roosting or feeding young throughout the day. This behavior dictates a more limited foraging range that could

34. https://www.mlml.calstate.edu/ccfrp/
35. http://limpets.org/
36. http://www.mpawatch.org/
37. https://www.maregroup.org/

benefit from nearby MPAs providing reduced competition with humans for prey resources. Continued monitoring of seabirds and their utilization of special closures and MPAs may potentially provide an indirect approach to study nearshore fish and invertebrate recruitment at spatial scales relevant to MPA establishment (McChesney & Robinette 2013, Robinette et al. 2015, Golightly et al. 2017, Robinette et al. 2018).

INCORPORATING TRADITIONAL ECOLOGICAL KNOWLEDGE

Another important component of long-term monitoring is the incorporation of Traditional Ecological Knowledge (TEK). Since time immemorial, California Native American Tribes have stewarded and utilized marine and coastal resources in the region. The foundation of their management is a collective storehouse of knowledge about the natural world, acquired through direct experience and contact with the environment, and gained through many generations of learning passed down by elders about practical, as well as, spiritual practices (Anderson 2005). This knowledge, which is the product of keen observation, patience, experimentation, and long-term relationships with the resources, today is commonly called TEK (Anderson 2005).

While no single definition of TEK is universally accepted, it has been described as "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes 1999). Traditional Knowledge (TK) and Indigenous Traditional Knowledge (ITK) encompasses TEK, science, and other relevant information from Tribes. Many California Native American Tribes continue to regularly harvest marine resources within their ancestral territories and maintain relationships with the coast for ongoing customary uses.

The Monitoring Program is committed to learning from and collaborating formally with California Native American Tribes on ways to integrate TEK into the long-term monitoring of MPAs. One of the baseline monitoring projects for the North Coast MPAs, *Informing the North Coast MPA Baseline: Traditional Ecological Knowledge of Keystone Marine Species and Ecosystems*, provided recommendations (Box 2) on management and policy that could act as a springboard for conversation.

BOX 2: North Coast Keystone Species

The North Coast TEK baseline project identified five keystone species of cultural importance to several North Coast Tribes including abalone, clams, mussels, seaweed, and smelt. These species are represented as key indicators for long-term monitoring on the North Coast, and species from other regions could be added once identified and discussed with respective Tribal nations.

2.3 Selection of Key Measures and Metrics, Sites, and Species

The MLPA Master Plan for MPAs directed the development of evaluation questions to help guide monitoring and adaptive management. Informed by existing science and policy, this broad list of evaluation questions (Appendix B) represent the key elements regarding the design, performance, and functioning of the MPA Network in relation to the goals of the MLPA. In order to provide a contextual framework for the key measures and metrics, sites, and species identified in this section, a sub-set of these evaluation questions are shown below as examples:

- **GOAL 1:** Do indicator species inside of MPAs differ in size, numbers, and biomass relative to reference sites?
- **GOAL 2:** Do California Monitoring Program indicator species, including those of economic importance, experience positive population level benefits (e.g. increase in abundance, larger size, increased reproductive output, increased stock size) in response to MPA implementation?
- **GOAL 3:** How are the frequency of non-consumptive use, knowledge, attitudes, and perceptions regarding the MPAs changing over time?
- **GOAL 4:** Have endangered species and culturally significant species benefited from the presence of California's MPAs?
- **GOAL 5:** How has the level of compliance changed over time since the MPAs were first implemented and what factors influence variation in compliance within and among MPAs?
- **GOAL 6:** How do other stressors impact the performance of MPAs over time (e.g., water quality, oil spills, desalination plants, ocean acidification, sea level rise)?

Inquiry into the additional evaluation questions listed in Appendix B by Monitoring Program partners is encouraged. It is important to note that the overarching questions listed above in many cases will provide insights into the other evaluation questions listed in Appendix B.

The priorities selected below are meant to guide the Monitoring Program. The Action Plan purposefully does not address the types of data collection methods or analytical approaches that should be used to evaluate the performance of California's MPA Network because methods and analytical approaches are rapidly evolving. This approach will help ensure our scientific partners have the ability, in collaboration with the state through the proposal solicitation process, to use their expertise to select the most effective and efficient procedures. The Monitoring Program will continue to incorporate opportunities to explore emerging methods and analytical approaches through proposal solicitations focused on pilot or research and design studies as appropriate.

Key Performance Measures and Metrics

To meet California's adaptive management objectives (CDFW 2016), a prioritized list of key measures and metrics have been selected to advance understanding of conditions and trends across the MPA Network as well as inform network evaluation[38]. Decades of MPA performance studies from around the world indicate that these ecological, physical, chemical, human use, and enforcement measures and metrics are the most important for evaluating and interpreting MPA performance (e.g., Claudet et al. 2008, Lester & Halpern 2008, Cinner et al. 2009, Caselle et al. 2015, Cinner et al. 2016, Giakoumi et al. 2017).

Species-level

- Abundance
- Density/cover
- Size/age frequency
- Biomass

Community-level

- Functional diversity--tracking the population dynamics of those species and organismal traits that influence ecosystem functioning
- Stability

Physical

- Temperature
- Depth
- Substrate *(e.g., rock or sediment size, type, and rugosity)*
- Wave exposure

Chemical[39]

- pH
- Total alkalinity
- Dissolved oxygen

Human Use[40]

- **Commercial Passenger Fishing Vessel**
  - Annual license renewal and vessel registration
  - Port of departure
  - Number of anglers
  - Target species
  - Trip length
  - Fishing location
  - Average price paid per angler
  - Number and pounds of fish caught by species
  - Number of crew on trip
  - Effort and catch per unit effort (CPUE)
  - Annual operating costs
  - Number of crew employed
- **Commercial Fisheries**
  - Annual license and vessel renewal
  - Number of fishermen making landings
  - Landings: catch, price, and revenue by species
  - Gear type
  - Landings port location
  - CPUE
  - Harvest location
  - Annual operating costs
  - Number of crew employed
- **Recreational Fisheries**
  - License purchases
  - Catch amount
  - Catch location
  - Catch effort
  - Type of gear/mode
- **Coastal Recreation and Tourism**
  - Location of residence
  - Demographic information *(i.e. age, gender, education, etc. See Appendix D for further detail)*
  - Income
  - Employment status
  - Frequency and type of visit
  - Location of visit
  - Type of activities
  - Trip expenditures
- **Enforcement (location specific)**
  - Patrol hours
  - Citations
  - Warnings
  - Cal TIPs received related to potential MPA violations[41]

38. Proposal solicitations will contain additional details on priorities.
39. Note total maximum daily load (TMDL) and other water quality parameters are addressed in complementary monitoring programs lead by the State and Regional Water Quality Control Boards
40. Appendix D contains a detailed plan for human use monitoring and proposal solicitations will contain additional details on priorities. It is important to note, existing data collection efforts like landing receipts, logbooks, report cards, and citizen science monitoring provide much of the required data to track key human use trends. Additional monitoring will be required and included in the Monitoring Program.
41. CalTIP (Californians Turn In Poachers and Polluters) is a confidential secret witness program that encourages the public to provide CDFW with factual information leading to the arrest of poachers and polluters. 1-888-334-CalTIP (888-334-2258).

The common approach to MPA performance evaluation is to compare the responses of these metrics inside and outside MPAs over time to distinguish responses to MPA protection from natural temporal variation (Lester et al. 2009, Fox et al. 2014, Caselle et al. 2015, Soykan & Lewison 2015). ***State-funded long-term monitoring projects will compare changes in the above performance measures inside and outside MPAs over time.*** Some projects may not measure all the key measures and metrics but where feasible, it will be important to measure as many of the key measures and metrics as possible at priority sites and their associated reference sites.

Index Site Selection

BIOREGIONS FOR LONG-TERM MONITORING

This Action Plan identifies three bioregions for long-term monitoring: the north coast (California/Oregon border to San Francisco Bay, including the Farallon Islands), the central coast (San Francisco Bay to Point Conception), and the south coast (Point Conception to the U.S./Mexico border, including the Channel Islands) (Figure 3). It is important to note these bioregions are not the same as the four historical MLPA planning regions and subsequent baseline monitoring regions. The four MLPA planning regions were identified in order to allow for a design approach that could reasonably take into account the unique character of different regions in developing the statewide network of MPAs (CDFW 2016), while the three bioregions in the Action Plan are in large part designated based on data collected during baseline monitoring that identified clusters of similar biota, ecological communities, and key habitats.

TIERED APPROACH

The MPA Network consists of 124 MPAs that span the state's entire 1,100-mile coastline including offshore islands, from the U.S./Mexico border to the California/Oregon border. It is both logistically and financially infeasible to monitor all marine species at all MPAs and their associated reference sites. This Action Plan prioritizes long-term MPA monitoring sites by identifying tiers: required (Tier I), secondary (Tier II), and tertiary (Tier III). These monitoring priority tiers, which are based on best available science, will enable efficient data collection by researchers while still allowing for a broad evaluation of network performance by CDFW. A key advantage of the tiered priority groupings is providing managers and partners a discrete list of index sites to inform the performance evaluation of the MPA Network. State-funded long-term monitoring projects should prioritize the Tier I index sites that align with monitoring project methods. Tier I sites should provide the ability to infer observed conditions to the broader evaluation of Network performance. When feasible, projects are encouraged to monitor sites from Tier II and Tier III lists (Appendix F). Sites not identified in Tier I still play a critical role in the functioning of the Network.

The MLPA requires the MPA Network include a variety of marine habitats and communities to be represented and replicated across a range of depths and environmental conditions (FGC §2857(c)). Habitat type, complexity, and depth are all known to be important drivers of community structure (Allen et al. 2006, Love et al. 2009, Schiel & Foster 2015, Starr et al. 2015, Fulton et al. 2016). Subsequent analyses indicate that most of the habitats targeted by the MPA design and siting process were successful in achieving representation and replication targets (Young & Carr 2015). MPA index sites were prioritized based on scoring each of the 102 coastal and island MPAs against four defined criteria that evaluated different aspects of individual MPAs ensuring a good representation of multiple habitats in the selected sites. The four criteria used to determine site selection are based on the best readily available science, and serve as a starting point for determining whether the Network is meeting the six goals of the MLPA. However, within each of the criteria there are limitations that are noted.

Only one of the four quantitative methods, MPA design features, could be applied to the 22 estuarine MPAs. Therefore, to assign estuarine MPAs into one of three tiers, they were separated from coastal MPAs and only evaluated on their ability to meet the SAT recommended MPA design features. See Appendix F for tiered list of estuary index sites.

The scoring approach for each quantitative method are summarized below, with detailed methodology located in Appendix F.

CRITERIA 1: MPA Design Features

During the MPA design and siting process, the MLPA SAT provided regional stakeholders with MPA science design guidelines, such as MPA size, level of protection, and habitat representation within MPAs. SAT guidelines also included identifying co-locating MPAs with existing water quality protection (e.g., Areas of Special Biological Significance (ASBS)) and areas that had historical protection as priorities. **MPAs that meet SAT guidelines are expected to realize more significant conservation benefits, and therefore should be prioritized for long-term monitoring.** All MPAs were scored against SAT guidelines as follows:

- **MPA size.** MPA size points = 2 if an MPA met the SAT recommended size of 18 square statute miles (sm^2) or larger; MPA size points = 1 if an MPA met the SAT recommended minimum area of 9 sm^2; MPA size points = 0 if an MPA was smaller than the SAT recommended minimum area of 9 sm^2.
- **Threshold of habitat representation and replication within an MPA.** MPAs received 1 point for each of 12 key habitats that met minimum size guidelines for representation/replication, and 0 points for key habitats that did not meet minimum size guidelines. See Appendix F, Table F1 for SAT-recommended minimum size guidelines by habitat.
- **Level of protection (LOP) within an MPA.** LOP points = Habitat threshold points * LOP multiplier. See Appendix F, Table F2 for LOP multiplier values by habitat.
- **MPA Overlap with Areas of Special Biological Significance.** MPAs were assigned a point value from 0 to 1 representing percent overlap with ASBS, e.g. if ASBS overlapped with 72% of the MPA area, point value = 0.72.
- **MPA Overlap with historically protected area.** MPAs were assigned a point value from 0 to 1 representing percent overlap with historically protected area, e.g. if historically protected area overlapped with 64% of the MPA, point value = 0.64. This point value was added to a second term representing protection, assigned 1 if the historical MPA prohibited all take and 0 if the historical MPA allowed take. The two terms were then summed for a final historical MPA points score.

Design scores were calculated as follows:

Total Design Score = MPA size + habitat threshold + LOP + ASBS + Historical MPA points

A key design metric outlined by the SAT during the MLPA planning process, spacing of MPAs, was not included in this criteria. There was uncertainty on how to properly score spacing guidelines for MPAs, and was therefore not included in the design score. However, the connectivity modeling done through the Regional Oceanographic Modeling System (ROMS, criteria 3) model helps to fill in this gap.

CRITERIA 2: MPA Historical Monitoring

Responses of targeted fished species to MPA implementation can occur on the order of years to decades, and community responses tend to occur over longer time scales (Babcock et al. 2010, Caselle et al. 2015, Starr et al. 2015). Moreover, change in and of itself is not sufficient evidence of an MPA effect. The ability to compare MPA trends to both control (no MPA regulations yet other fishing regulations apply) reference sites and to periods where protection was absent is more informative. Hence historical monitoring efforts that uniformly and consistently conducted monitoring statewide prior to and following MPA implementation will allow for a more objective evaluation of MPA effects using 'before-after' and 'control-impact' (BACI) analyses. BACI design allows for controlling for the effects of temporal and spatial variation (e.g., recruitment variability in time, habitat variability in space), and coupled dynamics inside and outside MPAs (i.e., larval connectivity and adult spillover) (White et al. 2011).

For more informative and successful network evaluation, it is essential to prioritize MPAs with the longest possible time series of available data to allow for statistically robust BACI analyses - in other words, a greater understanding of change over time.

The following three ecosystem features and associated monitoring programs were assessed for historical monitoring:

- Rocky intertidal monitoring: MARINe biodiversity and fixed plot surveys
- Nearshore (0-30 m) subtidal kelp forest monitoring: PISCO and RCCA scuba surveys
- Mid-depth (30-100 m) ROV monitoring: CDFW/MARE

In order to offer an unbiased assessment of the statewide monitoring we used very specific criteria in order to include monitoring as part of "historical monitoring." Specifically, the monitoring had to occur consistently throughout the state both before and after MPA implementation. There are a multitude of programs that offer long-term monitoring data (see section 2.2 "Examples of Important Existing Programs"), but were ultimately not included due to either temporal or spatial limitations. The approach to only include historical monitoring consistently conducted statewide limited the analysis to only rocky substrate programs. However, data collected by spatially limited survey programs such as the National Park Service's KFMP at the Northern Channel Islands will be integrated in future analyses.

All non-estuarine MPAs were scored for level of historical monitoring according to the following rule: for each of the five monitoring programs, MPAs received a single point for an annual survey replicate conducted since the beginning of the monitoring program. As an example, Point Lobos SMR has been surveyed for biodiversity by MARINe in 2001, 2005, 2014, and 2017, so receives a point value of 4. These individual survey points for all five monitoring programs are then summed for an MPA to create an initial score. To account for the importance of monitoring multiple habitats over time, initial scores were multiplied by a "monitoring multiplier" that ranged from 0 to 3 representing the number of habitats, of the three listed above, that were monitored over the date range considered.

Historical monitoring scores were calculated as follows:

Total Historical Monitoring Score = (rocky intertidal biodiversity + rocky intertidal fixed plot + PISCO kelp forest monitoring + RCCA kelp forest monitoring + mid-depth ROV) * monitoring multiplier

CRITERIA 3: Habitat Based Connectivity

The spatial connectivity among sites through larval dispersal within the MPA Network was examined for key habitats excluding estuaries. This was accomplished using a set of outputs from the ROMS model coupled to a coastwide habitat model. ROMS is a four dimensional (space over time) general circulation model that is widely used by the scientific community for simulating currents and tracking particle movement throughout the CCLME. Connectivity is modeled by tracking the simulated movement of passive particles released into the ROMS-derived nearshore ocean circulation patterns through time.

The nearshore habitat model was applied to ROMS to "convert" particles into simulated larvae. The key simulation was done using a 30-60 day pelagic larval duration (PLD) period. PLDs represent the dispersal period for larvae and 30 to 60 days is a PLD representative for most non-algal species (algae have propagules like spores as a dispersal stage) along the California coast. Habitat extent (e.g. area of rock in a location) was used in two ways: (1) as proxy for number of larvae produced for species associated with a particular habitat in a source location, and (2) as a target for species associated with a particular habitat in a sink location. Hence, the coupled model tracks the larval production (source) from a given location to a settlement location (sink) within the modeling domain (U.S. West Coast). Sites were ranked based on their level of larval connectivity to areas both inside and outside MPAs. Areas that are highly connected (both sources and sinks) across habitats were prioritized.

Summed source and sink numbers served as connectivity scores for individual MPA sites. The scores represent an individual MPA's level of connection to the entire California coastline. Sites that were significant sources and/or sinks received higher scores than areas that were less connected. It is important to note that the ROMS output can be considered a measure of connectivity among cells (locations) but should not be considered an estimate of one cell's contribution of larvae (propagules) to other cells. This is because cells in ROMS grids are only characterized by oceanographic factors. To estimate the level of larval contribution, propagule production for donor cell, and amount of suitable habitat for receiving cells, high resolution habitat information must be incorporated as a sub-model. For detailed information on ROMS methodology, habitat sub-model integration, and results, see Appendix F.

CRITERIA 4: High Resolution Mapping of Recreational Fishing Effort

Recovery trajectories of fished populations following MPA implementation are highly dependent on the level of fishing mortality (F) to which those populations were subjected prior to protection (Micheli et al. 2004, White et al. 2013, Casselle et al. 2015, Starr et al. 2015, White et al. 2016). In other words, more pronounced ecological change should be expected inside MPAs where F was once high, and these sites should be prioritized for long-term monitoring. However, many populations lack direct estimates of F. For these populations, fishing effort can provide a reasonable proxy for F.

To attribute fishing effort at a spatial scale appropriate for determining influence on MPAs, data collected by CDFW's California Recreational Fisheries Survey (CRFS) was used to calculate a relative index of fishing pressure by standardizing the sampled historical fishing effort (angler boat trips) over time and at sites, excluding estuaries, statewide. The analysis focused on recreational fishing trips targeting common nearshore rocky reef dwelling species (Appendix F). While there are many other types of target species and fishing modes, including commercial fisheries, the recreational private and rental boat support mapping at the high spatial resolution needed for this analysis. It presents an index of historical recreational bottom fishing pressure on MPAs prior to implementation, independent of fishing pressure from other modes of fishing. Results suggested that relative recreational fishing effort was concentrated in coastal areas surrounding major ports and surrounding island areas closest to these ports. Relative index numbers served as comparative fishing effort scores calculated within one-minute-by-one-minute areas (blocks) which were then summarized as maximum values for individual MPAs. For detailed information on methods, see Appendix F.

INTEGRATING QUANTITATIVE METHODS

For each of the four criteria listed above, a rank-order list of MPAs within each bioregion was generated based on final scores (Appendix F, Table F3). The four

individual rank-order values were then averaged to generate a final integrated rank-order value. MPAs were sorted into tiers based on these values, with cutoffs for each tier varying by bioregion to ensure equal representation of the bioregion's MPAs within each of the three tiers (Table 4). For example, the 34 north coast MPAs were sorted so that 11 MPAs fell into Tier I, 11 MPAs fell into Tier II, and 12 MPAs fell into Tier III (Appendix F, Table F3).

These rankings do not reflect the relative importance of a given MPA to the Network, but rather how well an MPA meets the specific quantitative criteria previously outlined.

Tier I MPAs received the highest integrated rank-order values. They meet many of the design criteria needed for effective protection, are well connected components of the MPA network, and may have long time series of monitoring data and/or have experienced high historical fishing effort, which make these MPAs good candidates for detecting the potential effects of protection over time. Many of the MPAs on the Tier I index site list are state marine reserves, which were designated during the design process to be the backbone of the network (CDFW 2016), thus providing "an improved marine life reserve component consistent with the guidelines for the preferred siting alternative" (FGC §2853(c)(1)).

Tier II MPAs received the second-highest integrated rank-order values. Many of these MPAs ranked high in one or two of the quantitative methods and may be considered valuable index sites for more specific research questions. Tier II MPAs can be considered for long-term monitoring when funding permits, when an MPA cluster is split between tiers, or to help answer more regionally focused questions.

Tier III MPAs received the lowest integrated rank-order values. While valuable to the Network's integrity, many of these MPAs are limited for monitoring purposes at this time due to features such as smaller size, fewer representative habitats, are difficult to access, have limited or no long-term monitoring data, or have more allowable take within their boundaries. Tier III MPAs are recommended for long-term monitoring only to answer very specific or localized research questions.

TABLE 4: Recommended MPA tiers within each bioregion (MPAs listed north to south). Abbreviations: SMR = state marine reserve, SMCA = state marine conservation area, SMRMA = state marine recreational management area.

TIER I	TIER II	TIER III
NORTH COAST		
Reading Rock SMCA	Point St. George Reef Offshore SMCA	Pyramid Point SMCA
Reading Rock SMR	South Cape Mendocino SMR	Samoa SMCA
Sea Lion Gulch SMR	Big Flat SMCA	Mattole Canyon SMR
Ten Mile SMR	Double Cone Rock SMCA	Ten Mile Beach SMCA
MacKerricher SMCA	Point Cabrillo SMR	Russian Gulch SMCA
Saunders Reef SMCA	Point Arena SMR	Van Damme SMCA
Stewarts Point SMR	Point Reyes SMCA	Point Arena SMCA
Salt Point SMCA	Duxbury Reef SMCA	Sea Lion Cove SMCA
Bodega Head SMR	North Farallon Islands SMR	Del Mar Landing SMR
Bodega Head SMCA	Southeast Farallon Island SMR	Stewarts Point SMCA
Point Reyes SMR	Southeast Farallon Island SMCA	Gerstle Cove SMR
		Russian River SMCA
CENTRAL COAST		
Montara SMR	Pillar Point SMCA	Portuguese Ledge SMCA
Año Nuevo SMR	Natural Bridges SMR	Edward F. Ricketts SMCA
Greyhound Rock SMCA	Soquel Canyon SMCA	Lovers Point - Julia Platt SMR
Carmel Bay SMCA	Pacific Grove Marine Gardens SMCA	Carmel Pinnacles SMR
Point Lobos SMR	Asilomar SMR	Point Lobos SMCA
Piedras Blancas SMR	Point Sur SMR	Point Sur SMCA
Point Buchon SMR	Big Creek SMR	Big Creek SMCA
Point Buchon SMCA	Cambria SMCA	Piedras Blancas SMCA
Vandenberg SMR		White Rock SMCA
SOUTH COAST		
Point Conception SMR	South Point SMR	Kashtayit SMCA
Campus Point SMCA	Gull Island SMR	Naples SMCA
Harris Point SMR	Begg Rock SMR	Richardson Rock SMR
Carrington Point SMR	Santa Barbara Island SMR	Judith Rock SMR
Scorpion SMR	Point Vicente SMCA	Skunk Point SMR
Anacapa Island SMCA	Abalone Cove SMCA	Painted Cave SMCA
Anacapa Island SMR	Arrow Point to Lion Head Point SMCA	Footprint SMR
Point Dume SMCA	Long Point SMR	Blue Cavern Offshore SMCA
Point Dume SMR	Crystal Cove SMCA	Casino Point SMCA
Blue Cavern Onshore SMCA	Laguna Beach SMCA	Lover's Cove SMCA
Laguna Beach SMR	San Diego-Scripps Coastal SMCA	Farnsworth Onshore SMCA
Dana Point SMCA	Matlahuayl SMR	Farnsworth Offshore SMCA
Swami's SMCA	South La Jolla SMCA	Cat Harbor SMCA
South La Jolla SMR	Cabrillo SMR	Tijuana River Mouth SMCA

Although soft-bottom habitat makes up the majority (85%) of substrate along California's coast, MPA size and spacing design guidelines largely influenced designs which focused around the patchy distributions of limited rocky substrate (Saarman et al. 2013). *Because rocky substrate is associated with a higher density of fished species (Bond et al. 1999, Stephens et al. 2006), presence of highly productive kelp forests (Carr & Reed 2015, Schiel & Foster 2015), and significant human use (CDFW CRFS database 2005-present, CPFV logbook data), these areas are a primary focus for monitoring.* Tables 5 and 6 provide area and linear extent of habitats within each MPA.

Prioritized sites in all Tiers include a variety of habitat types.

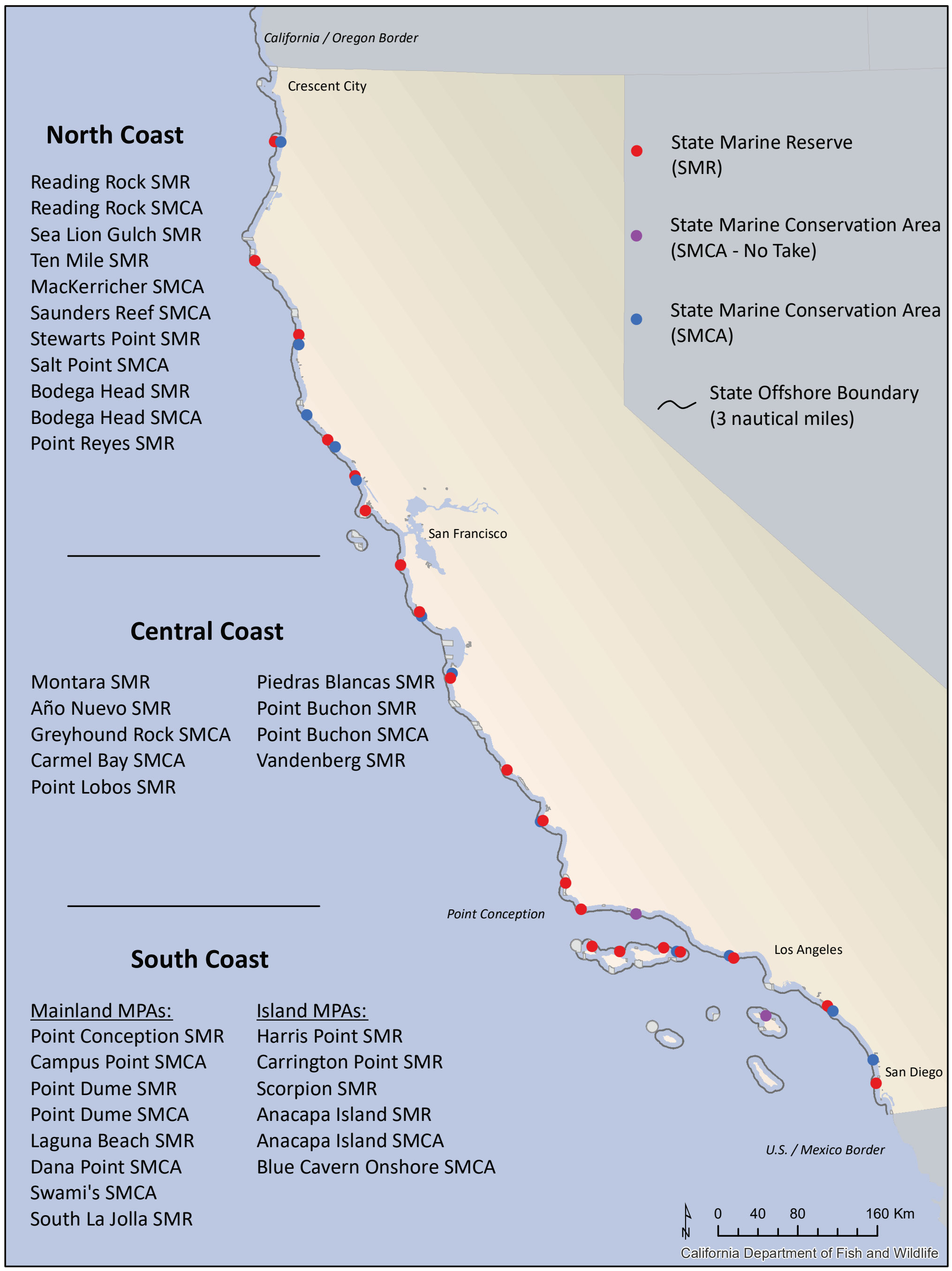


FIGURE 3: Tier I MPA sites by Marine Protected Area Monitoring Action Plan sampling bioregion.

TABLE 5: Soft bottom habitats - Area or linear extent of coastline and percentage of available habitats within each bioregion - Tier I MPA sites. Abbreviations: SMR = state marine reserve, SMCA = state marine conservation area, SMRMA = state marine recreational management area.

MPA	BIOREGION	TOTAL AREA (mi^2)	BEACHES (linear mi)	SOFT SUBSTRATE 0-30m (linear mi)	SOFT SUBSTRATE 30-100m (area mi^2)	SOFT SUBSTRATE 100-3000m (area mi^2)	ESTUARY (area mi^2)	EELGRASS (area mi^2)	COASTAL MARSH (area mi^2)
READING ROCK SMCA	NORTH	11.96	2.96	2.82	3.77	0.00	0.00	0.00	0.00
READING ROCK SMR		9.60	0.00	0.00	9.43	0.00	0.00	0.00	0.00
SEA LION GULCH SMR		10.42	2.42	2.01	3.86	1.09	0.00	0.00	0.00
TEN MILE SMR		11.95	2.63	2.00	8.13	0.46	0.00	0.00	0.01
MACKERRICHER SMCA		2.48	4.40	0.00	0.06	0.00	0.00	0.00	0.01
SAUNDERS REEF SMCA		9.36	1.83	0.19	5.25	0.00	0.00	0.00	0.00
STEWARTS POINT SMR		24.06	0.89	0.18	21.89	0.00	0.00	0.00	0.00
SALT POINT SMCA		1.84	0.59	0.36	0.37	0.00	0.00	0.00	0.00
BODEGA HEAD SMR		9.34	1.32	0.26	5.38	0.00	0.00	0.00	0.00
BODEGA HEAD SMCA		12.31	0.00	0.00	6.31	0.00	0.00	0.00	0.00
POINT REYES SMR		9.55	8.38	2.07	1.20	0.00	0.00	0.00	0.00
MONTARA SMR	CENTRAL	11.81	2.14	0.95	7.75	0.00	0.00	0.00	0.01
AÑO NUEVO SMR		11.15	10.46	3.34	1.63	0.00	0.00	0.00	0.05
GREYHOUND ROCK SMCA		12.00	2.79	0.70	8.61	0.00	0.00	0.00	0.00
CARMEL BAY SMCA		2.20	3.09	1.58	0.36	0.07	0.02	0.00	0.02
POINT LOBOS SMR		5.50	2.10	1.36	2.05	0.33	0.00	0.00	0.01
PIEDRAS BLANCAS SMR		10.44	5.48	4.43	2.25	0.00	0.01	0.00	0.06
POINT BUCHON SMR		6.68	1.46	0.73	4.56	0.00	0.00	0.00	0.00
POINT BUCHON SMCA		12.19	0.00	0.00	8.11	3.02	0.00	0.00	0.00
VANDENBERG SMR		32.91	13.33	12.82	10.11	0.00	0.04	0.00	0.09
POINT CONCEPTION SMR	SOUTH	22.52	2.73	1.83	15.79	3.26	0.00	0.00	0.01
CAMPUS POINT SMCA		10.56	3.02	1.21	7.08	1.48	0.01	0.00	0.01
HARRIS POINT SMR		25.40	2.71	5.60	15.93	2.54	0.00	0.00	0.00
CARRINGTON POINT SMR		12.78	0.82	3.32	3.82	0.00	0.00	0.00	0.00
SCORPION SMR		9.64	0.89	2.28	4.88	0.18	0.00	0.01	0.00
ANACAPA ISLAND SMCA		7.30	0.19	1.74	6.21	0.18	0.00	0.00	0.00
ANACAPA ISLAND SMR		11.55	1.12	2.59	7.25	0.78	0.00	0.00	0.00
POINT DUME SMCA		15.92	4.09	3.14	5.95	7.18	0.00	0.00	0.00
POINT DUME SMR		7.53	2.77	1.81	1.07	4.30	0.00	0.00	0.00
BLUE CAVERN ONSHORE SMCA		2.61	1.66	1.89	0.79	1.43	0.00	0.00	0.00
LAGUNA BEACH SMR		6.72	3.48	3.65	2.82	1.79	0.00	0.00	0.00
DANA POINT SMCA		3.47	3.60	1.90	0.79	0.00	0.00	0.00	0.00
SWAMI'S SMCA		12.71	3.77	1.29	3.85	5.52	0.00	0.00	0.00
SOUTH LA JOLLA SMR		5.04	2.33	0.07	0.85	0.00	0.00	0.00	0.00
NORTH BIOREGION TOTAL		1618.90	391.45	227.31	820.08	75.93	60.84	13.31	136.88
CENTRAL BIOREGION TOTAL		1317.84	272.90	231.37	602.63	158.19	7.02	1.94	45.02
SOUTH BIOREGION TOTAL		2350.87	441.29	362.57	672.08	392.73	43.30	19.64	60.78

*All miles are statute.

TABLE 6: Rocky habitats - Area or linear extent of coastline and percentage of available habitats within each bioregion - Tier I MPA sites. Abbreviations: SMR = state marine reserve, SMCA = state marine conservation area, SMRMA = state marine recreational management area.

MPA	BIOREGION	TOTAL AREA (mi²)	ROCKY INTERTIDAL (linear mi)	KELP (linear mi)	HARD SUBSTRATE 0-30m (linear mi)	HARD SUBSTRATE 30-100m (area mi²)	HARD SUBSTRATE 100-3000m (area mi²)
READING ROCK SMCA	NORTH	11.96	0.22	0.00	0.08	0.00	0.00
READING ROCK SMR	NORTH	9.60	0.00	0.00	0.00	0.16	0.00
SEA LION GULCH SMR	NORTH	10.42	2.32	0.19	0.56	2.86	0.12
TEN MILE SMR	NORTH	11.95	6.77	2.43	1.10	0.50	0.00
MACKERRICHER SMCA	NORTH	2.48	3.91	2.23	0.00	0.05	0.00
SAUNDERS REEF SMCA	NORTH	9.36	4.29	1.11	2.52	1.65	0.00
STEWARTS POINT SMR	NORTH	24.06	4.57	3.00	3.03	0.88	0.00
SALT POINT SMCA	NORTH	1.84	4.03	3.84	2.46	0.54	0.00
BODEGA HEAD SMR	NORTH	9.34	2.74	0.00	2.27	1.85	0.00
BODEGA HEAD SMCA	NORTH	12.31	0.29	0.00	1.33	5.11	0.00
POINT REYES SMR	NORTH	9.55	5.37	0.00	1.49	0.09	0.00
MONTARA SMR	CENTRAL	11.81	3.45	0.55	2.73	0.72	0.00
AÑO NUEVO SMR	CENTRAL	11.15	6.86	0.24	1.83	0.79	0.00
GREYHOUND ROCK SMCA	CENTRAL	12.00	3.39	0.08	2.38	0.03	0.00
CARMEL BAY SMCA	CENTRAL	2.20	2.66	2.57	1.15	0.12	0.02
POINT LOBOS SMR	CENTRAL	5.50	13.70	4.61	3.91	1.38	0.02
PIEDRAS BLANCAS SMR	CENTRAL	10.44	6.09	4.18	2.10	0.54	0.00
POINT BUCHON SMR	CENTRAL	6.68	2.71	1.85	2.59	0.47	0.00
POINT BUCHON SMCA	CENTRAL	12.19	0.00	0.00	0.00	0.32	0.04
VANDENBERG SMR	CENTRAL	32.91	10.21	0.63	1.45	0.08	0.00
POINT CONCEPTION SMR	SOUTH	22.52	3.13	1.29	1.84	0.32	0.10
CAMPUS POINT SMCA	SOUTH	10.56	1.37	1.62	1.85	0.04	0.00
HARRIS POINT SMR	SOUTH	25.40	8.18	2.30	1.96	2.40	0.25
CARRINGTON POINT SMR	SOUTH	12.78	5.35	1.24	1.97	0.27	0.00
SCORPION SMR	SOUTH	9.64	4.07	0.05	0.69	0.33	0.01
ANACAPA ISLAND SMCA	SOUTH	7.30	3.50	0.00	0.54	0.03	0.00
ANACAPA ISLAND SMR	SOUTH	11.55	6.50	0.65	0.65	0.10	0.00
POINT DUME SMCA	SOUTH	15.92	0.44	0.85	1.05	0.00	0.00
POINT DUME SMR	SOUTH	7.53	1.54	0.57	0.47	0.00	0.89
BLUE CAVERN ONSHORE SMCA	SOUTH	2.61	1.68	1.40	0.88	0.01	0.00
LAGUNA BEACH SMR	SOUTH	6.72	2.48	0.00	1.13	0.00	0.00
DANA POINT SMCA	SOUTH	3.47	2.06	0.80	1.67	0.00	0.00
SWAMI'S SMCA	SOUTH	12.71	1.20	1.44	1.43	0.02	0.04
SOUTH LA JOLLA SMR	SOUTH	5.04	1.45	0.72	1.95	0.50	0.00
NORTH BIOREGION TOTAL		1618.90	301.58	104.23	114.65	79.24	0.76
CENTRAL BIOREGION TOTAL		1317.84	238.83	151.07	95.97	46.60	29.98
SOUTH BIOREGION TOTAL		2350.87	280.71	253.51	191.62	47.79	6.05

*All miles are statute

REFERENCE SITE CRITERIA

Comparison of ecological metrics between MPA index sites and reference sites outside of MPAs, or inside/outside comparison, has been well established as a method of assessing the progress of MPAs toward conservation goals (Paddack & Estes 2000, Gell & Roberts 2003, Lester & Halpern 2008, Lester et al. 2009). However, differences between MPA sites and sites outside of MPAs unrelated to protection status (e.g. habitat quality, physical oceanographic conditions) are also identified as common confounding factors when assessing the effects of protection (Charton & Ruzafa 1999, Charton et al. 2000). Therefore, effective MPA monitoring requires informed selection of reference sites outside of MPAs so that inside/outside comparison is meaningful.

For long-term monitoring, selection of reference sites will be the responsibility of individual PIs. Although this Action Plan does not mandate monitoring at specific reference sites, the state requires that reference sites be selected, and data be provided, that supports compatibility with the corresponding MPA index sites they are being compared to. Compatibility is based on the following criteria:

Biotic Factors

- **Ecological conditions at the time of MPA implementation:** Detection of ecological divergence between MPA and reference sites requires similar initial conditions at both sites (Starr et al. 2015). Key metrics to consider include functional biodiversity, species composition, species density and biomass, and size frequency distributions.

Human Uses

- **Fishing pressure at time of MPA implementation:** Responses of fished populations to MPA implementation are highly dependent on the level of fishing pressure to which those populations were exposed before being protected (Micheli et al. 2004, Kaplan et al. in prep, Yamane et al. in prep). Key metrics to consider include: local fishing mortality (F) for targeted species, if available; historical fishing effort; and/or regional proxies for fishing effort (e.g., distance from port).
- **Non-consumptive human use:** While generally less significant than fishing, non-consumptive human use (e.g,. boating, tidepooling, scuba diving) affects marine ecosystems. Examples of deleterious effects associated with non-consumptive use include trampling, accidental take, and habitat alteration (Tratalos & Austin 2001, Davenport & Davenport 2006, Lloret et al. 2008). Key metrics to consider include: type and level of non-consumptive use (e.g. from MPA Watch beach surveys), water quality, and frequency of boat anchoring.

Abiotic Factors

- **Geography:** Biogeographic boundaries play an important role in driving marine community structure, and California's coastline encompasses several distinct marine ecoregions. It is therefore crucial to group index sites and reference sites at the correct geographic scale (Hamilton et al. 2010). Furthermore, a reference site adjacent or proximate to an MPA may be ecologically connected to that MPA through larval dispersal or spillover of adult organisms, potentially confounding inside/outside comparison (Moffitt et al. 2013). Key metrics to consider include: presence of biogeographic barriers and distance between MPA and reference sites.

- **Habitat features:** Habitat/microhabitat type, quality, and availability are critical drivers of marine species distribution and community composition, in some cases more influential than the presence or absence of protection (Lindholm et al. 2004, Oliver et al. 2010, Starr et al. 2015, Fulton et al. 2016). Key metrics to consider include: depth, percent rock, rugosity, habitat complexity, macroalgal cover, and distribution of habitat types.

- **Geology:** Seafloor sediment and benthic communities both play important roles in driving marine community structure (Snelgrove 1997). Key metrics to consider include: underlying rock type (e.g., shale, granite), grain size, benthic community structure, and proximity to major geologic features such as submarine canyons.

- **Physical and chemical oceanography:** Physical and chemical oceanographic conditions have significant impacts on marine communities. For example, by driving patterns of larval dispersal or influencing nutrient availability in an ecosystem (Menge et al. 1997, Ruzicka et al. 2012, Nickols et al. 2013). Key metrics to consider include: primary productivity/nutrient availability, wave exposure (including direction, extent, and intensity), and variability and spatial distribution of relevant dynamics and processes, such as upwelling, fronts, river plumes, ocean acidification, and hypoxia.

State-funded long-term monitoring projects will be required to justify reference site(s), based on the above criteria and using quantitative methods whenever possible. Qualitative comparisons are acceptable in situations where data are limited and potential reference sites are logistically difficult to access. Quantitative methods to address this question include: statistical comparison of habitat metrics (e.g., rock rugosity), habitat suitability modeling (Young et al. 2010), covariate analysis with matching models (Ahmadia et al. 2015), oceanographic observations, and oceanographic circulation models such as the ROMS (Moore et al. 2011).

BOX 3: Examining oceanographic and biogeographical conditions across MPAs and reference sites on the north coast.

Along the California coast, marine ecosystems exist in a highly energetic and variable oceanographic environment that shapes the dynamics of populations and communities (Checkley and Barth, 2009, Bjorkstedt et al. 2017). Understanding how ocean conditions vary over space and time is therefore essential for interpreting ecological responses to spatial management. A diverse suite of ocean observations can be synthesized to characterize historical conditions and spatial context to inform adaptive management strategies for the MPA Network that account for changing ocean conditions due to climate change.

For example, analysis based on oceanographic data for MPAs and reference sites along the north coast of California suggests that in most cases, MPA-reference pairs share similar oceanographic influences across seasons, while also highlighting factors that may contribute to MPA-reference site differences as the ecosystem changes over time (Robinson et al, in prep). Successful development of oceanographic context for the north coast and its application, drawing on observation systems (e.g., CeNCOOS and NANOOS), might serve as a template for a statewide synthesis in support of broader, long-term monitoring, evaluation, and adaptive management of California's MPA Network.

Indicator Species Selection

California's MPA Network was implemented, in part, to help conserve ecologically and economically important marine species, as well as to protect the structure and function of marine ecosystems. To that end, this Action Plan provides lists of species and species groups to target for long-term monitoring at MPA and reference sites (Tables 7-10). These lists of fishes, invertebrates, algae, and birds were compiled using the following sources (in the tables, "Y" indicates that the species is listed in the corresponding source, "N" indicates that it is not).

MPA Regional Monitoring Plans.
These plans were developed during MPA baseline monitoring and include regionally-focused lists of ecologically and economically important marine species. Plans and associated species lists were developed for each of the four coastal planning regions in which the MLPA was implemented (north, north central, central, and south). However, it is important to note that long-term MPA monitoring will take place in three broader-scale bioregions, or clusters of similar biota, ecological communities, and key habitats, as discussed in section 2.3 above.

Deepwater MPA Monitoring Workshop.
This 2017 workshop convened experts from across the state to discuss monitoring of deep marine ecosystems (>100 m depth) in California's MPAs. The species list developed at this workshop and included in Action Plan Appendix E represents these experts' best understanding of which species and species groups should be targeted for monitoring in deep ecosystems in order to meaningfully assess MPA performance.

Marine Life Management Act.
The Marine Life Management Act (MLMA) Master Plan (CDFW 2018) identifies 36 species of finfish and invertebrates, which are the targets of 45 distinct fisheries, as priority species for fishery management. These species represent the majority of commercial landings value in California as well as species of particular recreational importance.

Special Status Species.
For the purposes of this Action Plan, "species of special status" is any fish, invertebrate, algae, plant, or bird native to California that is identified in one of the four MPA regional monitoring plans, deepwater MPA monitoring workshop recommendations, or MLMA Master Plan, and currently satisfies one or more of the following criteria:

- Is listed as threatened or endangered under the Federal Endangered Species Act[42]
- Is listed as threatened or endangered under the California Endangered Species Act[43]
- Is identified as a species of concern[44] by the National Marine Fisheries Service. These species are not currently listed under an Endangered Species Act, but are identified as species to take proactive measures to address conservation needs in hopes of preventing the need to protect them under an Endangered Species Act
- Listed as overfished by the Pacific Fishery Management Council[45]
- Considered by CDFW to be a Species of Special Concern[46]. Currently experiencing a fishing moratorium, meaning this species was once targeted for commercial and/or recreational harvest, but now all direct take is prohibited

42. https://www.fws.gov/endangered/
43. http://www.dfg.ca.gov/wildlife/nongame/t_e_spp/
44. https://www.fws.gov/endangered/
45. https://www.pcouncil.org/
46. https://www.wildlife.ca.gov/Conservation/SSC

TABLE 7: Indicator fish species.

COMMON NAME	SCIENTIFIC NAME	Regional Monitoring Plans				DEEPWATER WORKSHOP	MLMA SPECIES
		NORTH	NORTH CENTRAL	CENTRAL	SOUTH		
ANCHOVY, NORTHERN	*Engraulis mordax*	N	N	Y	N	N	N
BASS, BARRED SAND	*Paralabrax nebulifer*	N	N	N	Y	Y	Y
BASS, GIANT SEA [1]	*Stereolepis gigas*	N	N	N	Y	Y	N
BASS, KELP	*Paralabrax clathratus*	N	N	N	Y	N	Y
BASS, SPOTTED SAND	*Paralabrax maculatofasciatus*	N	N	N	Y	N	Y
BLACKSMITH	*Chromis punctipinnis*	N	N	N	Y	N	N
CABEZON	*Scorpaenichthys marmoratus*	Y	Y	Y	Y	N	N
CROAKER	Sciaenidae	N	N	N	Y	N	N
CROAKER, WHITE SEABASS	*Atractoscion nobilis*	N	N	N	Y	N	Y
FLATFISH	Multiple spp.	Y	Y	Y	Y	Y	N
FLATFISH, CALIFORNIA HALIBUT	*Paralichthys californicus*	N	Y	Y	Y	N	Y
FLATFISH, DIAMOND TURBOT	*Pleuronichthys guttulatus*	N	N	Y	N	N	N
FLATFISH, DOVER SOLE	*Microstomus pacificus*	N	N	Y	N	N	N
FLATFISH, ENGLISH SOLE	*Parophrys vetulus*	N	N	Y	N	N	N
FLATFISH, PACIFIC HALIBUT	*Hippoglossus stenolepis*	Y	N	N	N	N	N
FLATFISH, PACIFIC SANDDAB	*Citharichthys sordidus*	N	N	Y	N	N	N
FLATFISH, PETRALE SOLE	*Eopsetta jordani*	N	N	Y	N	N	N
FLATFISH, STARRY FLOUNDER	*Platichthys stellatus*	Y	Y	Y	N	Y	N
GOBY	Gobiidae	N	N	Y	Y	N	N
GOBY, BLACKEYE	*Rhinogobiops nicholsii*	N	N	Y	N	N	N
GREENLING, KELP	*Hexagrammos decagrammus*	Y	Y	Y	N	N	N
GREENLING, PAINTED	*Oxylebius pictus*	N	Y	Y	N	N	N
GUITARFISH, SHOVELNOSE	*Rhinobatos productus*	N	N	N	Y	N	N
HAGFISH, PACIFIC	*Eptatretus stoutii*	N	N	Y	Y	N	Y
HERRING, PACIFIC	*Clupea pallasii*	Y	N	N	N	N	Y
LINGCOD	*Ophiodon elongatus*	Y	Y	Y	Y	Y	N
OCEAN WHITEFISH	*Caulolatilus princeps*	N	N	N	Y	Y	Y
PERCH	Embiotocidae	Y	Y	Y	Y	N	N
PERCH, BLACK	*Embiotoca jacksoni*	N	N	Y	N	N	N
PERCH, PILE	*Rhacochilus vacca*	N	N	Y	N	N	N
PERCH, SHINER	*Cymatogaster aggregata*	N	Y	Y	N	N	Y
PERCH, STRIPED SEA	*Embiotoca lateralis*	Y	Y	Y	N	N	N
PRICKLEBACK, MONKEYFACE	*Cebidichthys violaceus*	N	Y	Y	N	N	N
PRICKLEBACK, ROCK	*Xiphister mucosus*	N	Y	N	N	N	N
RATFISH, SPOTTED	*Hydrolagus colliei*	N	N	Y	N	Y	N
RAY, BAT	*Myliobatis californicus*	N	Y	Y	Y	N	N
ROCKFISH	*Sebastes* spp.	Y	Y	Y	Y	Y	N
ROCKFISH, AURORA	*Sebastes aurora*	N	N	N	N	Y	N
ROCKFISH, BANK	*Sebastes rufus*	N	N	Y	Y	N	N
ROCKFISH, BLACK	*Sebastes melanops*	Y	Y	Y	N	N	N
ROCKFISH, BLACK-AND-YELLOW	*Sebastes chrysomelas*	Y	Y	Y	N	N	N

COMMON NAME	SCIENTIFIC NAME	Regional Monitoring Plans				DEEPWATER WORKSHOP	MLMA SPECIES
		NORTH	NORTH CENTRAL	CENTRAL	SOUTH		
ROCKFISH, BLUE	*Sebastes mystinus*	Y	Y	Y	Y	N	N
ROCKFISH, BOCACCIO [2]	*Sebastes paucispinis*	N	Y	Y	Y	Y	N
ROCKFISH, BROWN	*Sebastes auriculatus*	Y	Y	N	N	Y	N
ROCKFISH, CANARY	*Sebastes pinniger*	Y	Y	Y	N	Y	N
ROCKFISH, CHINA	*Sebastes nebulosus*	N	Y	Y	N	N	N
ROCKFISH, COPPER	*Sebastes caurinus*	Y	Y	Y	N	Y	N
ROCKFISH, COWCOD [2,3]	*Sebastes levis*	N	N	Y	Y	Y	N
ROCKFISH, DWARF	*Sebastes* spp.	Y	Y	Y	Y	Y	N
ROCKFISH, GOPHER	*Sebastes carnatus*	N	Y	Y	N	Y	N
ROCKFISH, GREENSPOTTED	*Sebastes chlorostictus*	N	N	N	N	Y	N
ROCKFISH, GREENSTRIPED	*Sebastes elongatus*	Y	N	N	N	Y	N
ROCKFISH, KELP	*Sebastes atrovirens*	Y	Y	Y	Y	N	N
ROCKFISH, OLIVE	*Sebastes serranoides*	N	N	N	Y	N	N
ROCKFISH, QUILLBACK	*Sebastes maliger*	N	N	N	N	Y	N
ROCKFISH, ROSY	*Sebastes rosaceus*	N	N	Y	N	N	N
ROCKFISH, SHORTBELLY	*Sebastes jordani*	Y	Y	Y	Y	N	N
ROCKFISH, SPLITNOSE	*Sebastes diploproa*	N	N	N	N	Y	N
ROCKFISH, VERMILION	*Sebastes miniatus*	Y	Y	Y	Y	Y	N
ROCKFISH, WIDOW	*Sebastes entomelas*	Y	Y	Y	Y	Y	N
ROCKFISH, YELLOWEYE [3]	*Sebastes ruberrimus*	Y	Y	Y	N	Y	N
ROCKFISH, YELLOWTAIL	*Sebastes flavidus*	Y	Y	Y	N	N	N
SABLEFISH	*Anoplopoma fimbria*	Y	N	Y	Y	Y	N
SALMONIDS	*Oncorhynchus* spp.	Y	N	Y	N	N	N
SARDINE, PACIFIC	*Sardinops sagax*	N	N	Y	N	N	N
SCORPIONFISH, CALIFORNIA	*Scorpaena guttata*	N	N	N	Y	Y	N
SCULPIN	Cottidae	Y	N	Y	N	N	N
SEÑORITA	*Oxyjulis californica*	N	N	Y	Y	N	N
SHARK, LEOPARD	*Triakis semifasciata*	Y	Y	Y	Y	N	N
SHARK, PACIFIC ANGEL	*Squatina californica*	N	N	N	Y	Y	Y
SHEEPHEAD, CALIFORNIA	*Semicossyphus pulcher*	N	N	N	Y	Y	Y
SILVERSIDE, CALIFORNIA GRUNION	*Leuresthes tenuis*	N	N	Y	Y	N	N
SILVERSIDE, JACKSMELT	*Atherinopsis californiensis*	N	N	N	Y	N	Y
SILVERSIDE, TOPSMELT	*Atherinops affinis*	Y	N	Y	Y	N	N
SKATE, CALIFORNIA	*Raja inornata*	N	N	Y	N	N	N
SKATE, LONGNOSE	*Raja rhina*	N	N	Y	N	Y	N
SMELT, NIGHT	*Spirinchus starksi*	N	N	Y	N	N	Y
SMELT, SURF	*Hypomesus pretiosus*	Y	Y	Y	N	N	N
STICKLEBACK, THREESPINE	*Gasterosteus aculeatus*	Y	N	N	N	N	N
THORNYHEAD	*Sebastolobus* spp.	Y	N	Y	N	N	N
TUBESNOUT	*Aulorhynchus flavidus*	N	N	Y	N	N	N
YOUNG-OF-YEAR	Multiple spp.	Y	Y	Y	Y	N	N

1. Special status: Fishing moratorium (no direct commercial or recreational fishing allowed)
2. Special status: Identified as a species of concern by the National Marine Fisheries Service
3. Special status: Listed as overfished by the Pacific Fishery Management Council, as of 8/24/2018

TABLE 8: Indicator invertebrate species.

COMMON NAME	SCIENTIFIC NAME	Regional Monitoring Plans				DEEPWATER WORKSHOP	MLMA SPECIES
		NORTH	NORTH CENTRAL	CENTRAL	SOUTH		
ABALONE	Haliotidae	N	N	N	Y	N	N
ABALONE, BLACK [1,2]	*Haliotis cracherodii*	N	Y	Y	Y	N	N
ABALONE, RED [2]	*Haliotis rufescens*	Y	Y	Y	N	N	Y
AMPHIPOD, GAMMARID	Gammaridae	N	N	Y	N	N	N
ANEMONE, FISH-EATING	*Urticina piscivora*	N	N	Y	N	N	N
ANEMONE, LARGE SOLITARY	Multiple spp.	N	N	N	N	Y	N
ANEMONE, PLUMOSE	*Metridium* spp.	Y	Y	Y	Y	Y	N
BARNACLE	*Balanus spp. Chthamalus fissus/dalli*	Y	N	Y	Y	N	N
BARNACLE, ACORN	*Balanus glandula*	N	N	Y	N	N	N
BARNACLE, GOOSENECK	*Pollicipes polymerus*	N	N	Y	N	N	N
BARNACLE, PINK VOLCANO	*Tetraclita rubescens*	N	N	Y	N	N	N
BARNACLE, THATCHED	*Semibalanus cariosus*	N	N	Y	N	N	N
CLAM	Multiple spp.	Y	N	N	N	N	N
CLAM, BEAN	*Donax gouldii*	N	N	N	Y	N	N
CLAM, GEODUCK	*Panopea generosa*	Y	Y	Y	N	N	Y
CLAM, PACIFIC GAPER	*Tresus nuttallii*	Y	Y	Y	Y	N	N
CLAM, PACIFIC LITTLENECK	*Leukoma staminea*	Y	Y	Y	Y	N	N
CLAM, PACIFIC RAZOR	*Siliqua patula*	Y	Y	N	N	N	N
CLAM, PISMO	*Tivela stultorum*	N	N	N	Y	N	Y
CLAM, WASHINGTON	*Saxidomus nuttalli*	N	N	N	Y	N	N
CORAL, BLACK	*Antipathes* spp.	N	N	Y	N	N	N
CORAL, LOPHELIA	Lophelia	N	N	N	N	Y	N
CORAL, MUSHROOM SOFT	*Anthomastus ritteri*	Y	N	N	N	N	N
CORAL, SOFT	Octocorallia	N	N	Y	N	N	N
CRAB, BROWN BOX	*Lopholithodes foraminatus*	N	Y	Y	N	Y	N
CRAB, DUNGENESS	*Metacarcinus magister*	Y	Y	Y	N	N	Y
CRAB, GALATHEID (SQUAT LOBSTER)	*Munida quadrispina*	N	N	Y	N	N	N
CRAB, ROCK	*Cancer* spp. *Metacarcinus* spp.	Y	Y	Y	Y	Y	N
CRAB, SAND	*Emerita* spp.	Y	Y	Y	Y	N	N
CRAB, SHEEP	*Loxorhynchus grandis*	N	Y	Y	N	Y	N
CRAB, YELLOW SHORE	*Hemigrapsus oregonensis*	Y	N	N	N	N	N
CRINOID	Crinoidea	N	N	Y	N	Y	N
GORGONIAN, SHORT RED	*Muricea* spp.	Y	N	N	N	N	N
HYDROCORAL [2]	*Stylasterina* spp.	N	Y	Y	Y	N	N
ISOPOD, EELGRASS	*Pentidotea resecata*	N	N	Y	N	N	N
LIMPET, GIANT KEYHOLE	*Megathura crenulata*	N	N	N	Y	N	N
LIMPET, OWL	*Lottia gigantea*	N	Y	Y	Y	N	N
LOBSTER, CALIFORNIA SPINY	*Panulirus interruptus*	N	N	N	Y	N	Y
MUSSEL	*Mytilus* spp.	Y	Y	Y	Y	N	N

COMMON NAME	SCIENTIFIC NAME	Regional Monitoring Plans				DEEPWATER WORKSHOP	MLMA SPECIES
		NORTH	NORTH CENTRAL	CENTRAL	SOUTH		
OCTOPUS, RED	*Octopus rubescens*	Y	N	N	N	N	N
OYSTER, OLYMPIA	*Octopus rubescens*	Y	Y	Y	N	N	N
PRAWN, RIDGEBACK	*Sicyonia ingentis*	N	N	N	Y	Y	Y
PRAWN, SPOT	*Pandalus platyceros*	N	N	Y	Y	N	Y
SAND DOLLAR	*Dendraster excentricus*	N	Y	Y	N	N	N
SEA CUCUMBER, CALIFORNIA	*Parastichopus californicus*	Y	N	Y	Y	Y	Y
SEA CUCUMBER, WARTY	*Parastichopus parvimensis*	N	N	N	N	Y	Y
SEA PEN	Multiple spp.	Y	N	Y	N	N	N
SEA WHIP	Multiple spp.	Y	N	Y	N	N	N
SHRIMP, BAY GHOST	*Neotrypaea californiensis*	N	Y	Y	Y	N	N
SHRIMP, MUD	*Upogebia pugettensis*	N	Y	Y	Y	N	N
SNAIL, EMARGINATE DOG WINKLE	*Nucella emarginata*	N	N	Y	N	N	N
SNAIL, TURBAN	*Tegula* spp.	Y	N	Y	Y	N	N
SNAIL, WAVY TURBAN	*Megastraea undosa*	N	N	N	Y	N	N
SPONGE	*Porifera* spp.	N	N	Y	N	Y	N
SQUID, MARKET	*Doryteuthis opalescens*	N	N	Y	Y	N	Y
STAR	Multiple spp.	Y	Y	Y	Y	Y	N
STAR, BASKET	Multiple spp.	Y	N	Y	N	N	N
STAR, BAT	*Patiria miniata*	Y	N	Y	N	N	N
STAR, BRITTLE	Ophiuroidea	N	N	Y	Y	Y	N
STAR, DEEP SAND	*Thrissacanthias penicillatus*	N	N	Y	N	N	N
STAR, OCHRE SEA	*Pisaster ochraceus*	Y	Y	Y	Y	N	N
STAR, RED SEA	*Mediaster aequalis*	N	N	Y	N	N	N
STAR, SAND	*Luidia foliolata*	N	N	Y	N	N	N
STAR, SUNFLOWER SEA	*Pycnopodia helianthoides*	Y	Y	Y	Y	N	N
TUNICATE, COMPOUND	Multiple spp.	N	Y	N	N	N	N
URCHIN, FRAGILE PINK SEA	*Strongylocentrotus fragilis*	N	N	Y	N	N	N
URCHIN, PURPLE SEA	*Strongylocentrotus purpuratus*	Y	Y	Y	Y	N	N
URCHIN, RED SEA	*Mesocentrotus franciscanus*	Y	Y	Y	Y	N	Y
URCHIN, WHITE SEA	*Lytechinus pictus*	N	N	N	N	Y	N
WHELK, KELLET'S	*Kelletia kelletii*	N	N	N	Y	N	Y
WORM, FAT INNKEEPER	*Urechis caupo*	N	Y	Y	N	N	N
WRACK ASSOCIATED INVERTEBRATES	Multiple spp.	Y	N	Y	Y	N	N

1. Special status: Listed as federally endangered under the Federal Endangered Species Act
2. Special status: Fishing moratorium (no direct commercial or recreational fishing allowed)

TABLE 9: Indicator algae and plant species.

COMMON NAME	SCIENTIFIC NAME	*Regional Monitoring Plans*				DEEPWATER WORKSHOP	MLMA SPECIES
		NORTH	NORTH CENTRAL	CENTRAL	SOUTH		
ALGAE, CORALLINE	*Corallina* spp.	Y	N	Y	Y	N	N
ALGAE, ENCRUSTING NON-CORALLINE	Multiple spp.	Y	N	N	Y	N	N
ALGAE, FOLIOSE RED	Multiple spp.	Y	Y	N	Y	N	N
ALGAE, GOLDEN ROCKWEED	*Silvetia compressa*	N	N	Y	N	N	N
ALGAE, RED	Multiple spp.	Y	N	Y	N	N	N
ALGAE, ROCKWEED	*Fucaceae* spp.	Y	Y	Y	Y	N	N
ALGAE, SEA LETTUCE	*Ulva* spp.	Y	Y	Y	N	N	N
ALGAE, SUB CANOPY	Multiple spp.	Y	Y	N	Y	N	N
ALGAE, TURF	Multiple spp.	Y	Y	Y	Y	N	N
BEACH WRACK	Multiple spp.	Y	N	Y	Y	N	N
EELGRASS	*Zostera marina*	Y	Y	Y	Y	N	N
KELP, BROAD-RIBBED	*Pleurophycus gardneri*	N	N	Y	N	N	N
KELP, BULL	*Nereocystis luetkeana*	Y	Y	Y	N	N	N
KELP, ELK	*Pelagophycus porra*	N	N	N	Y	N	N
KELP, FEATHER BOA	*Egregia menziesii*	Y	Y	N	Y	N	N
KELP, GIANT	*Macrocystis pyrifera*	N	Y	Y	Y	N	N
KELP, KOMBU	*Laminaria setchellii*	N	N	Y	N	N	N
KELP, SEA PALM	*Postelsia palmaeformis*	Y	N	Y	N	N	N
KELP, SOUTHERN SEA PALM	*Eisenia arborea*	N	N	Y	N	N	N
KELP, STALKED	*Pterygophora californica*	Y	N	Y	N	N	N
PICKLEWEED	*Salicornia* spp.	Y	Y	N	Y	N	N
SURFGRASS	*Phyllospadix* spp.	Y	Y	Y	Y	N	N

TABLE 10: Indicator bird species.

COMMON NAME	SCIENTIFIC NAME	*Regional Monitoring Plans*				DEEPWATER WORKSHOP	MLMA SPECIES
		NORTH	NORTH CENTRAL	CENTRAL	SOUTH		
AUKLET, CASSIN'S	*Ptychoramphus aleuticus*	N	Y	N	Y	N	N
BIRD, PISCIVOROUS	Multiple spp.	Y	Y	Y	Y	N	N
BIRD, PREDATORY	Multiple spp.	Y	Y	N	N	N	N
BIRD, SHORE	Multiple spp.	Y	Y	Y	Y	N	N
CORMORANT, BRANDT'S	*Phalacrocorax penicillatus*	Y	Y	Y	Y	N	N
CORMORANT, PELAGIC	*Phalacrocorax pelagicus*	Y	Y	Y	Y	N	N
GUILLEMOT, PIGEON	*Cepphus columba*	Y	Y	Y	Y	N	N
MURRE, COMMON	*Uria aalge*	Y	Y	N	N	N	N
OYSTERCATCHER, BLACK	*Haematopus bachmani*	N	Y	Y	N	N	N
PELICAN, BROWN	*Pelecanus occidentalis*	N	N	N	Y	N	N
PLOVER, WESTERN SNOWY [1,2]	*Charadrius nivosus nivosus*	N	N	Y	N	N	N
SHEARWATER, SOOTY	*Puffinus griseus*	N	N	N	Y	N	N
SURFBIRD	*Calidris virgata*	N	N	Y	N	N	N
TERN, CALIFORNIA LEAST [3,4]	*Sterna antillarum browni*	N	N	N	Y	N	N
TURNSTONE, BLACK	*Arenaria melanocephala*	N	N	Y	N	N	N
WATERFOWL (DABBLING AND DIVING DUCKS)	Multiple spp.	N	N	Y	N	N	N

1. Special status: Listed as federally threatened under the Federal Endangered Species Act
2. Special status: CDFW Species of Special Concern
3. Special status: Listed as federally endangered under the Federal Endangered Species Act
4. Special status: Listed as state endangered under the California Endangered Species Act

OTHER SPECIES OF SPECIAL INTEREST

Although the primary goal of this Action Plan is to outline a long-term MPA monitoring strategy that will directly address the goals of the MLPA, the state is also working to integrate MPAs into other resource management efforts, such as climate change adaptation and invasive species programs. To that end, the following species of special interest should be targeted for long-term monitoring inside and outside MPAs when feasible.

Invasive Species

The impact of aquatic invasive species is not widely understood, especially related to MPAs. Available management options vary depending on characteristics of both the impacted site and the invasive species, and are generally limited to either control or eradication of invaders (Anderson 2007, Williams & Grosholz 2008). The Monitoring Program will work to identify opportunities to link MPAs and marine invasive species management, both internally and with other agencies responsible for managing invasive species, such as the California State Lands Commission (SLC) and California Coastal Commission. In addition, CDFW's Office of Spill Prevention and Response Marine Invasive Species Program[47] (MISP) conducts biological monitoring in coastal and estuarine waters to determine the level of invasion by non-native species and works to coordinate with the SLC. The Monitoring Program will work to integrate MPA considerations into future biological monitoring by MISP and help to detect new introductions that may impact MPAs.

Climate Change Species Indicators

Species that may act as good indicators for studying the effects of climate change should be considered when developing monitoring priorities. Although the MLPA does not require consideration of climate change in MPA management, the Monitoring Program recognizes that climate change is affecting oceanographic conditions along the California coast, including within MPAs. Research is continually emerging regarding the effects of climate change stressors, such as ocean acidification and hypoxia, and shifts in upwelling and temperature regimes on marine species (Bruno et al. 2018). The Monitoring Program is building partnerships with groups that have aligned and complementary expertise and missions regarding the impacts of climate change on indicator species and the MPA Network.

47. https://www.wildlife.ca.gov/Conservation/Invasives

Monitoring In Other Habitat Types

At this time, the Monitoring Program focuses sampling on shallower (<100 m depth) hard substrate along the open coast. However, that does not preclude sampling in the other habitat types, despite some challenges. Sandy beaches are highly dynamic and heavily affected by land-based factors (Dugan & Hubbard 2016). Due to the lower density of emergent benthic species in soft-bottom habitats, robust sampling of these environments to track change over time can be costly. However, emerging methods are making sampling more cost efficient.

The water surrounding deeper canyons and pelagic environments are highly dynamic and many non-benthic populations that use these areas are highly mobile (Block et al. 2011, Zwolinski et al. 2012, Bograd et al. 2016). Ecosystems deeper than 100 m have also traditionally presented significant challenges to monitor in both logistics and cost (for more information on monitoring deep ecosystems, see Appendix E). In addition, the increasing effectiveness of remote sensing and ocean circulation models will be key factors in interpreting the results of monitoring for all habitat types, as physical and chemical oceanographic factors within the CCLME are primary drivers of the structure and function of marine communities (McGowan et al. 2003, Menge et al. 2003, Broitman & Kinlan 2006, Blanchette et al. 2016, Lindegren et al. 2018).

At the land and ocean interface, estuaries are highly productive ecosystems that support important habitats (e.g., eelgrass, salt marshes, tidal mudflats) and provide critical refugia and nursery functions for a wide variety of species including those of economic value (Beck et al. 2001, Sheaves et al. 2015). Estuaries are sensitive habitats, and their natural function and associated area of wetlands have decreased significantly with increased coastal development (Allen et al. 2006, Cloern et al. 2016). The estuaries in California range widely from brackish lagoons that breach every several years to river mouth estuaries and oceanic-dominated embayments (Cloern et al. 2016). California's estuaries are generally highly modified, particularly in southern California, and each has a unique suite of stressors and marine, freshwater, and geomorphological conditions (Allen et al. 2006, Hughes et al. 2015, Cloern et al. 2016, Shaughnessy et al. 2017, Toft et al. 2018). A recent review of existing monitoring in California's 22 estuarine MPAs identified core indicators regularly monitored statewide, including 1) eelgrass areal coverage, 2) clams abundance, 3) marine/shorebird abundance, 4) marine mammal abundance, 5) dissolved oxygen, and 6) pH (Hughes 2017, Appendix C). Hughes (2017) also prioritized additional indicators for long-term MPA monitoring in estuaries across the state, including additional vegetation types (e.g., salt marshes) and macroalgae (e.g., *Ulva* and *Gracilaria* spp.), salinity, nutrients (e.g., nitrate, ammonium, and phosphate), invasive species, Olympia oysters (*Ostrea lurida*), and standardized beach seining for fish communities.

There are numerous existing long-term estuarine monitoring programs in California[48]. For example, San Francisco Bay monitoring efforts represent among the world's longest observational programs in an estuary and serve as a model system to better understand how ecosystems between land and ocean are structured, function, and change over time (Cloern & Jassby 2012, Raimonet & Cloern 2016, Cloern et al. 2017). Another example is NOAA's National Estuarine Research Reserve System-wide Monitoring Program which generates systematic water quality and weather monitoring data for 29 estuaries across the United States, including three in California (San Francisco Bay, Elkhorn Slough, and Tijuana River)[49]. However, many estuarine monitoring programs outside of San Francisco Bay are generally limited in duration, to particular estuaries, or to certain indicators (Hughes 2017). For example, existing long-term monitoring efforts in California take place at specific sites (e.g., Malibu Lagoon, Ballona Wetlands, Santa Clara River estuary), for relevant metrics in larger estuaries (e.g., Morro, Humboldt, San Diego, Tomales Bays), and regionally (e.g., across the southern California bight led by the Southern California Coastal Water Research Project[50]). These types of well-planned and robust monitoring sites and efforts can address questions related to MPA performance in areas that overlap with the MPA Network. However, monitoring

48. California Estuary Portal: https://mywaterquality.ca.gov/eco_health/estuaries/index.html.
49. NOAA National Estuarine Research Reserves: https://coast.noaa.gov/nerrs/research/.
50. Southern California Coastal Water Research Project regional monitoring: http://www.sccwrp.org/ResearchAreas/RegionalMonitoring.aspx.

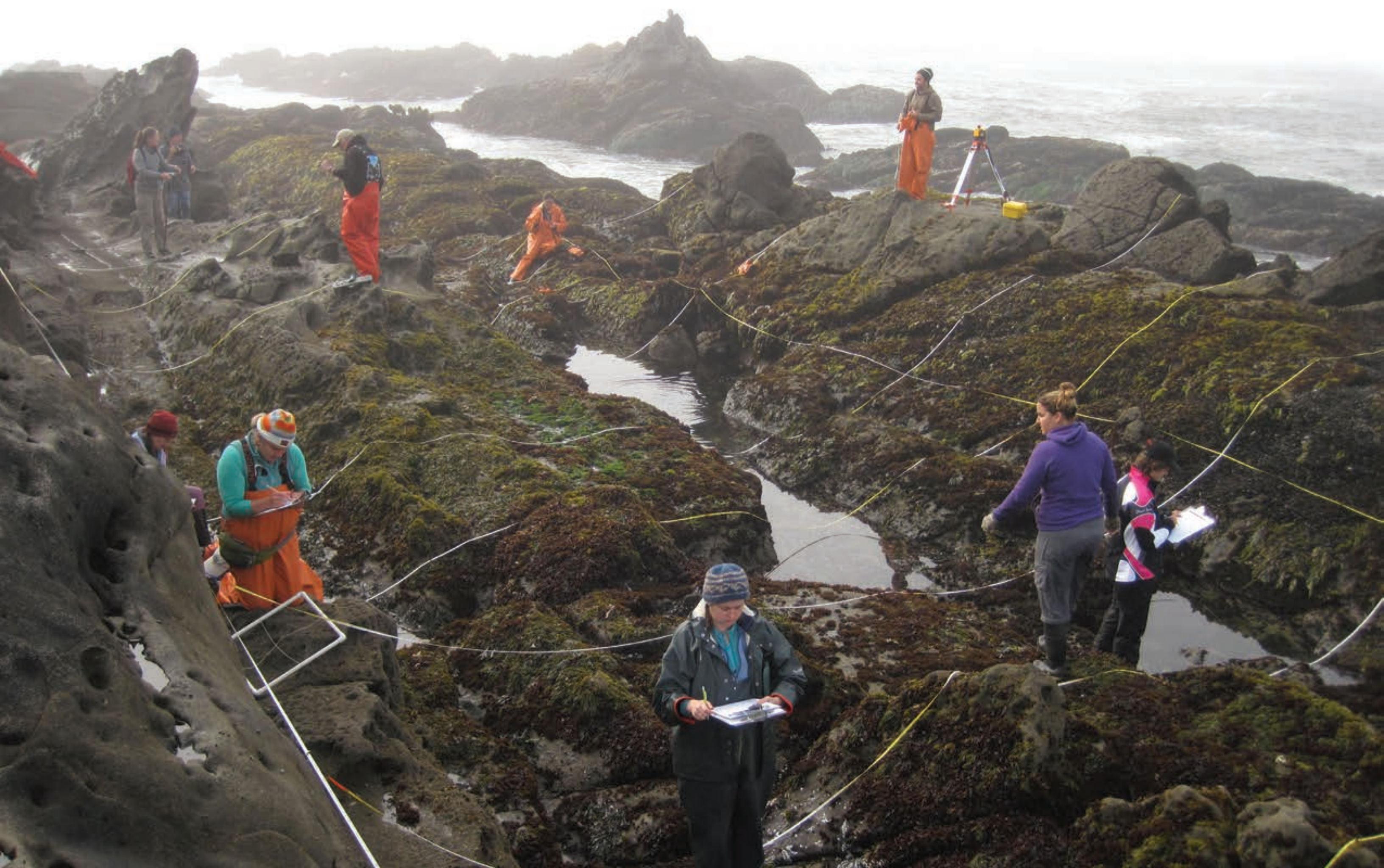
estuarine reference sites is challenging due to the unavailability of a similar site or because monitoring is focused on site based questions only. There is a need to further standardize metrics and develop coordinated, cost-effective, and repeatable methods across California estuaries to track key indicator species and habitats over time. For example, other wetland-associated assessment tools may be potentially adapted to certain estuarine habitats to expedite monitoring across the state (e.g., California Rapid Assessment Method[51]). The Monitoring Program will continue to track these efforts to determine the best approach to estuarine long-term monitoring within the MPA Network. See Appendix C for more information on estuarine MPA monitoring site recommendations.

While MPAs encompass some nearshore pelagic habitat within state waters (i.e., the water column overlying the continental shelf at depths greater than 30 m), monitoring specifically focused on the effects of protection of this habitat is difficult to implement. Many pelagic species are highly transient and may not spend significant amounts of time within MPA boundaries. However, pelagic species could be indicators of food web dynamics and shifts in ecological and physical factors in nearshore pelagic habitat within MPAs. These species will continue to be monitored within fisheries management context and their abundance and stock structure can be reported along with species monitored specifically within this plan.

51. California Rapid Assessment Method: https://www.cramwetlands.org/.

3. Approaches For Network Performance Evaluations

ADAPTIVE MANAGEMENT, as defined by the MLPA, is a process that facilitates learning from program actions and helps evaluate whether the MPA Network is making progress toward achieving the six goals of the MLPA (FGC §2852[a]; see Glossary for the full definition of adaptive management). California has set a 10-year MPA management review cycle as a mechanism to gather sufficient information for evaluating network efficacy and to inform the adaptive management process (CDFW 2016). Beginning in 2017, CDFW and researchers at University of California, Davis (UC Davis) co-mentored three postdoctoral researchers on MPA specific research projects intended to help inform long-term monitoring and the adaptive management process, including better understanding expectations of changes in highly dynamic temperate ecosystems such as the CCLME. Such expectations can inform adaptive management because they enable testing of species responses to MPA implementation, which provide updates in knowledge or management strategies. Quantitative analyses focused on examining the ability to detect population responses to MPAs over time, including incorporating spatial differences in fishing mortality rates. Analyses also focused on informing sample design for deepwater surveys and comparisons of various fish monitoring techniques being used for nearshore marine ecosystems and MPAs.



ANALYSIS 1: Projecting Changes And Their Statistical Detectability Following MPA Implementation

Modeled projections, or future estimates, of the timing and magnitude of marine life population responses to MPAs can inform adaptive management. This approach serves as a comparison between actual observations in the field and models of population responses to MPAs for evaluation of MPA performance at ecologically relevant time frames. Here we use two of the species level metrics mentioned in Section 2.3: abundance (which is the same as density here) and biomass. Globally, there are many reported levels of increase in these metrics with the implementation of MPAs (Lester et al. 2009). The increase in abundance and biomass are likely due to the effects of MPA protection on the age and size structure of the targeted species. Once an MPA is implemented, the expected response is that a population "fills in" over time with a greater proportion of older, larger individuals as a population approaches its stable age distribution after fishing mortality ceases (Baskett & Barnett 2015). This is essentially the first detectable effect of an MPA, and other longer-term potential effects (e.g., increased recruitment, changes in community structure) depend on this filling in effect (Baskett & Barnett 2015). Expected responses in abundance and biomass may be predicted from a species' life history and historical fishing rates (White et al. 2013). For example, Figure 4 demonstrates the filling in mechanism for blue rockfish (*Sebastes mystinus*), an abundant and important recreational and commercial species in California, where the age distribution moves from left to right, from red to gray over time.

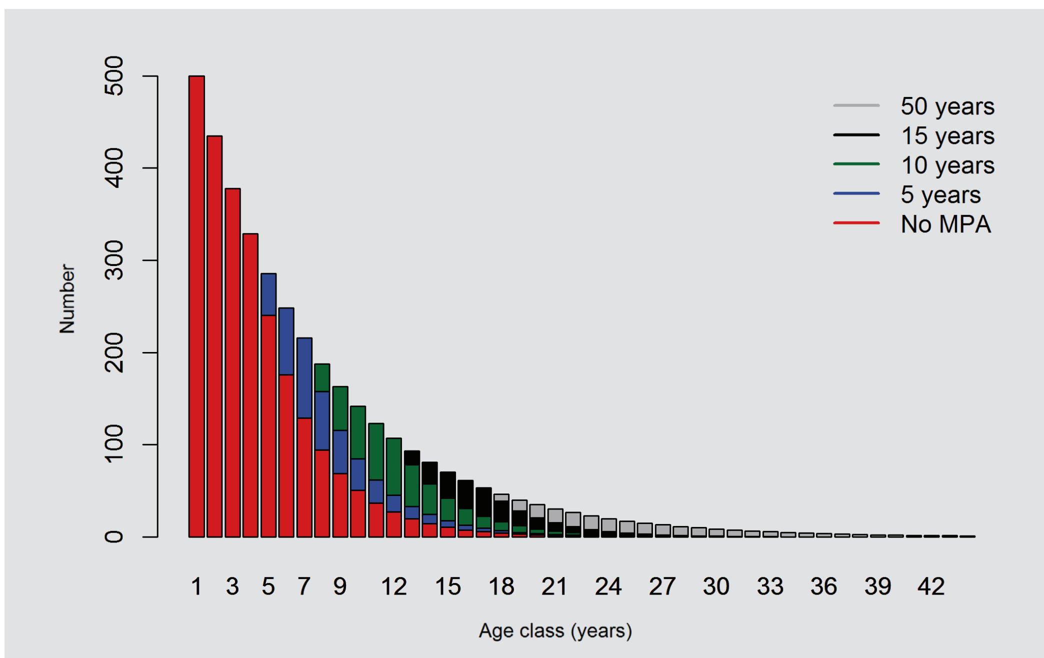


FIGURE 4: Number of individual blue rockfish *(Sebastes mystinus)* per age class increases in an MPA over time as compared to no MPA (fished state, red). Results shown for 5, 10, 15, and 50 years since MPA implementation, demonstrating the "filling-in" effect that occurs in an MPA for a previously harvested population. (This figure shows preliminary analyses by the UC Davis/CDFW postdoctoral researchers. Manuscripts detailing methodology and results are in preparation.)

The filling in and associated increase in abundance and biomass responses occur rapidly at first and then level off over time. The expected time frame to level off depends on the inverse of the natural mortality rate, which is a measure of the lifespan of the species. Thus, longer lived species take more time to observe population level responses to MPAs compared to short-lived species. The final population response to MPA implementation in terms of the change in the ratio of total abundance is dependent on the ratio of the fishing mortality rate (F) to the natural mortality rate (M) and will be proportional to (M+F)/M. In other words, the final expected gain in species abundance due to implementing an MPA depends on how heavily the population was fished before the MPA was put in place relative to the species natural mortality rate. The expected saturation level for the eventual abundance relative to its pre-MPA value is the ratio of the total pre-MPA mortality, fishing (F) plus natural mortality, to the post-MPA mortality, natural mortality M (i.e., ending abundance = (M+F)/M * starting abundance; White et al 2013). The relative biomass increase is always greater than the relative abundance increase because biomass also includes weight and age increases as individuals survive to be larger and older (Figure 5; Kaplan et al in prep.). Variable recruitment will lead to variation around this expected average (lighter colored "clouds" surrounding each line in Figure 5). Initially, this uncertainty can make an MPA effect difficult to detect (i.e., where the clouds of variability overlap).

However, as the potential MPA response increases through time, the clouds become more separated, and we can be more confident in deciding whether the MPA is working as expected. Statistical analysis of simulations of expected trajectories with and without an MPA, illustrated in Figure 5, can project the detectability of response over time (Kaplan et al in prep.).

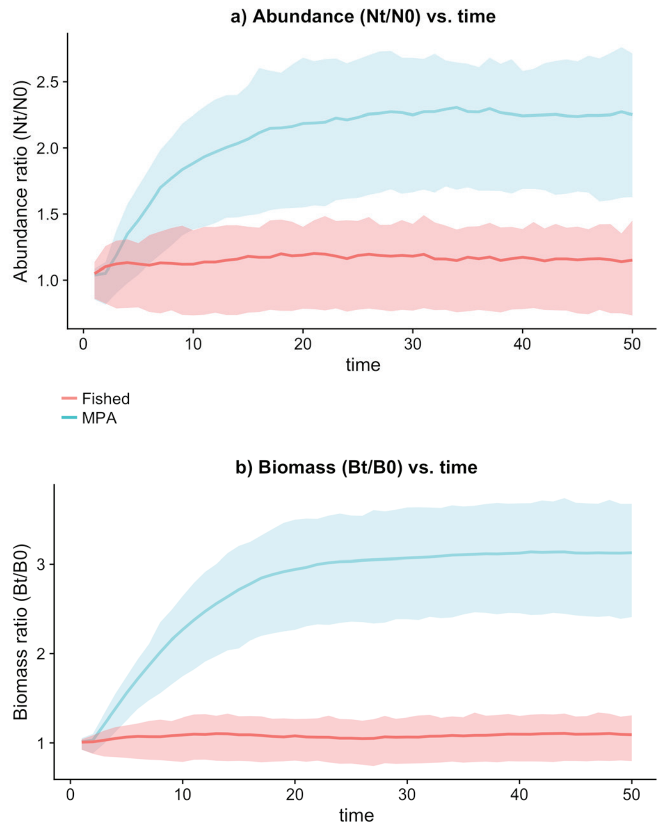


FIGURE 5: Blue rockfish population response projection with variable recruitment. Population projection in abundance (a) and biomass (b), relative to the initial value at MPA establishment, within an MPA (blue) and without an MPA (red). Nt=measure of abundance in each size class over time. N0=initial abundance at time of MPA implementation. Bt=measure of change in biomass over time. B0=population biomass at time of MPA implementation. Note difference in y-axis values. (This figure shows preliminary analyses by the UC Davis/CDFW postdoctoral researchers. Manuscripts detailing methodology and results are in preparation.)

ANALYSIS 2: Incorporating Spatial Differences in Fishing Mortality to Project Population Responses to MPAs

Because abundance and biomass responses depend directly on the fishing mortality rate prior to MPA implementation, measuring local fishing mortality is crucial for accurate predictions against which to compare monitoring data. In addition, as noted above, measuring local fishing mortality can identify target locations for monitoring prioritization. For example, coupling a monitoring site with an area recognized to have a relatively high local fishing mortality rate could result in a more detectable expected increase in abundance and biomass inside an MPA.

Fishing mortality rates for an individual species vary over space (Ralston & O'Farrell 2008). For example, Nickols et al. (in review) estimated local fishing mortality rates for blue rockfish in central California and found that it varied over tens of kilometers (Figure 6). In this example, the higher pre-MPA fishing mortality (F = 0.29) in Vandenberg SMR compared to White Rock SMCA (F = 0.10) means that responses will be more detectable in the Vandenberg SMR. In addition, the lack of significant fishing mortality at Big Creek means that this location is unlikely to provide short-term detectable responses to MPA establishment (Figure 6). A method for estimating local per-species fishing mortality is to apply a population model that accounts for the changes in fish size before and after fishing (Figure 6; White et al. 2016). The UC Davis/CDFW postdoctoral researchers evaluated the performance of this method across species and sampling protocols to inform monitoring efforts and index site selection (Yamane, et al in prep.).

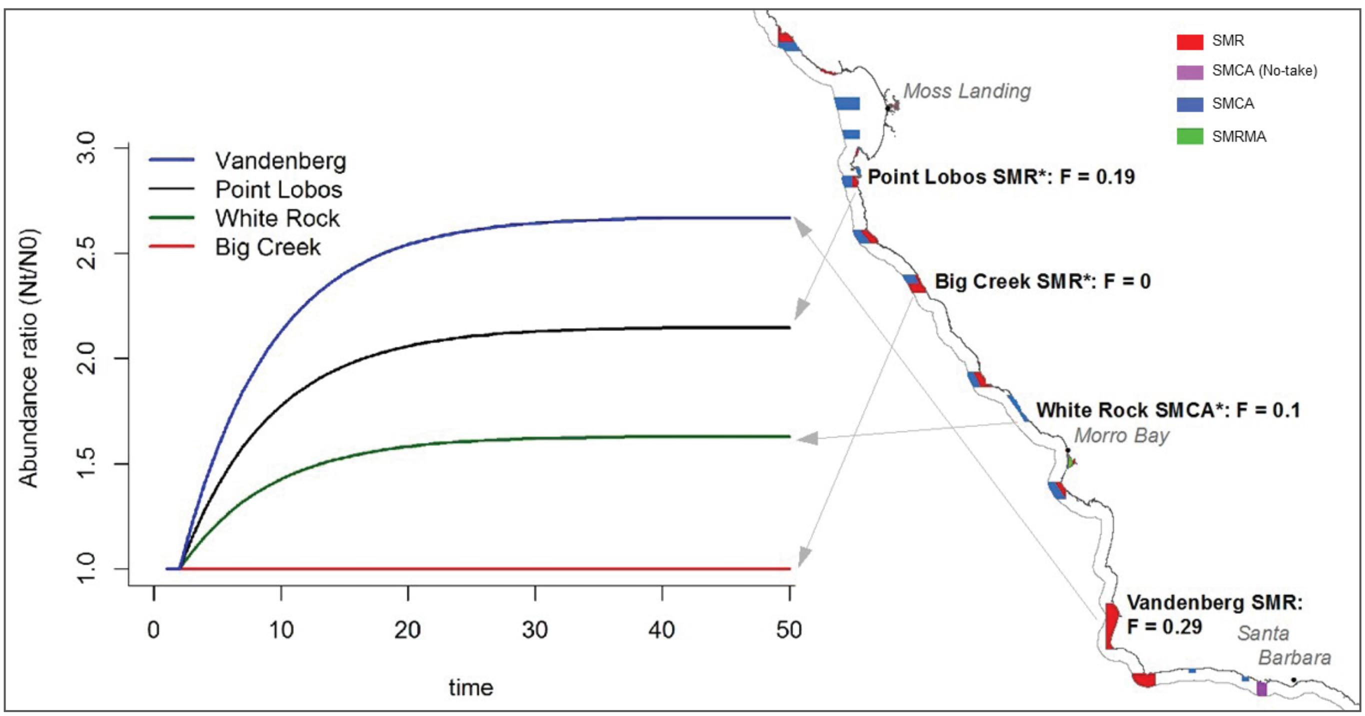


FIGURE 6: Spatial differences in fishing rates on blue rockfish populations before MPA implementation result in differences in expected population responses to MPAs along the central coast. Fishing rates with asterisks are from White et al. (2016); the remainder is from Nickols et al. (in review). (This figure shows preliminary analyses by the UC Davis/CDFW postdoctoral researchers. Manuscripts detailing methodology and results are in preparation.)

ANALYSIS 3: Estimating the Time Frame of Response for Different Species

The time frame for select species population responses to MPA protection depends on a variety of factors, including, but not limited to, species life history traits, rates of fishing mortality before MPA implementation, unique ecological characteristics of the MPA, and unexpected ecological events (Lester et al. 2009, Babcock et al. 2010, Gaines et al. 2010, Moffitt et al. 2013, White et al. 2013, Caselle et al. 2015, Starr et al. 2015, White et al. 2016). The time frame for reaching the maximum expected changes in abundance and biomass for 19 commonly targeted nearshore species was generated using an age-structured open population model (Figure 7, Kaplan et al. in prep). The model relies on individual species life history traits and expected harvest rates (i.e., averaged fishing mortality rates from stock assessments across years prior to MPA implementation). In addition to the factors noted above, the time frame for responses depends on monitoring program design and feasibility (i.e., sufficient sample size and scale, where species densities will inevitably set a limit on sampling). Figure 7 therefore provides initial insight into when monitoring might detect expected effects to inform adaptive management. Ongoing investigations by the UC Davis/CDFW postdoctoral researchers are further elucidating the roles of recruitment variability and sampling (Kaplan et al in prep., Perkins et al in prep., Yamane et al in prep.).

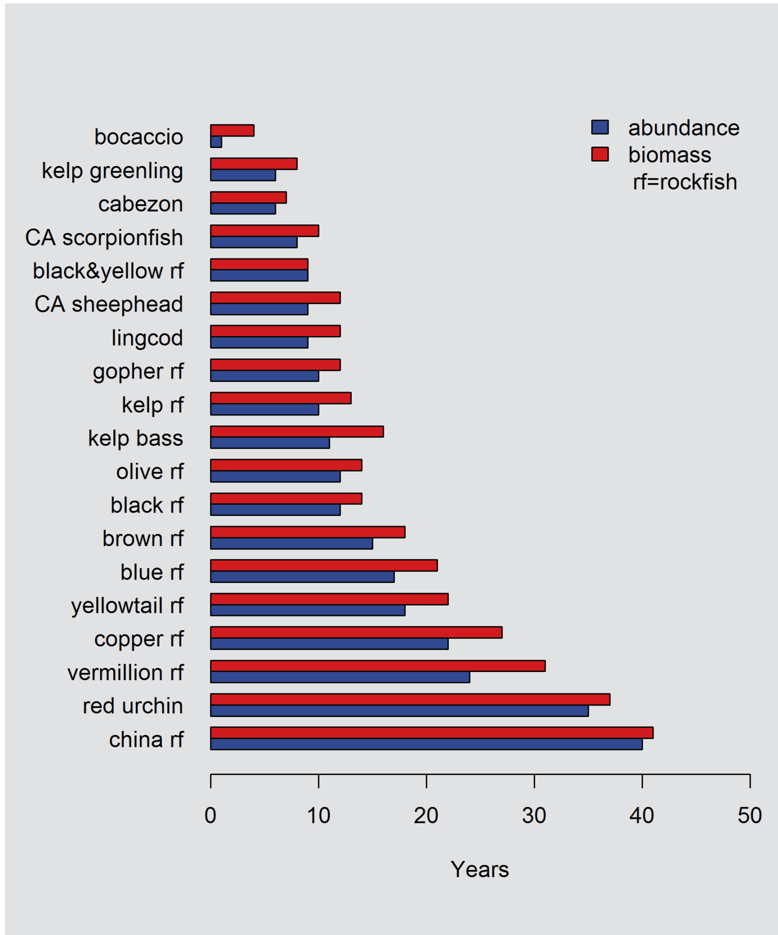


FIGURE 7: Estimated time to reach 95% of final abundance (unfished state), and biomass ratio increase in response to MPA implementation based on a deterministic open population model. rf = rockfish. (This figure shows preliminary analyses by the UC Davis/CDFW postdoctoral researchers. Manuscripts detailing methodology and results are in preparation).

ANALYSIS 4: Informing Long-Term Monitoring Sampling Design

Informing Sample Design for Deep-Water Surveys

Understanding the relationship between sampling effort and the ability to detect change is an additional component of establishing an effective monitoring program (Urquhart 2012). Ecological systems are inherently variable, and additional variability introduced through sampling methods can make detecting long-term trends (e.g., recovery of populations inside MPAs) more difficult. Simulation approaches provide a powerful tool that enables researchers to incorporate the best available scientific knowledge about the system under study, and explore how various factors (i.e. spatial distributions, habitat associations, recruitment variability and likely rates of recovery of populations) interact with the level of sampling effort likely required to detect change.

Mid-depth (30-100 m) and deep (>100 m) habitats, which lie outside of practical SCUBA diving depth limits, comprise more than half of California's MPA Network. Visual tools such as ROVs provide a means of collecting geo-referenced data about biological communities at these depths. For example, combining ROV data with fine-scale data from seafloor mapping projects allows models of habitat associations to be built for species of interest (Young et al. 2010, Wedding & Yoklavich 2015). These models can be used to predict the abundance and distribution of species across larger areas, such as an entire MPA. Moreover, combining this information with projections of expected species recovery inside MPAs compared to reference sites (see section 2.2) allows for realistic simulation of changing population abundance and size structure through time. By utilizing simulation-based approaches to explore the influence of using different numbers of ROV transects during monitoring to detect projected changes, this type of work can result in practical recommendations regarding the level of sampling required for effective long-term monitoring of California's MPA Network using ROVs (Figure 8).

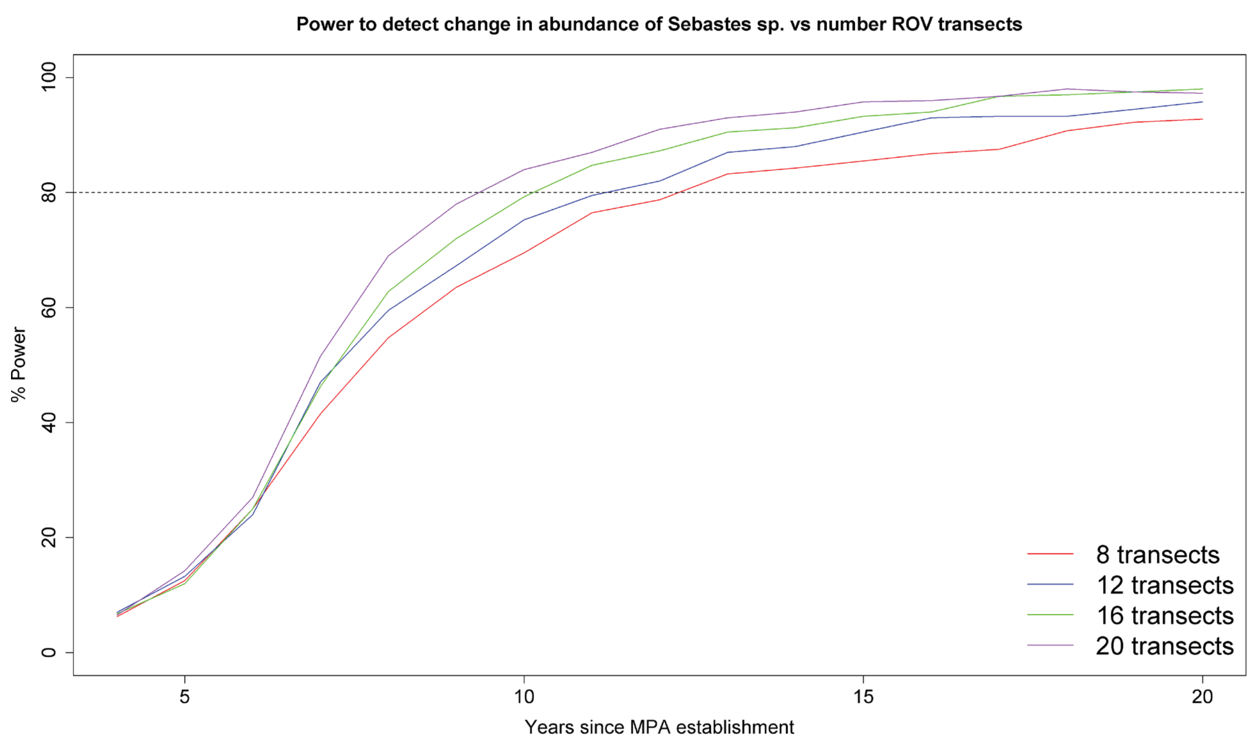


FIGURE 8: Statistical power to detect change in abundance of *Sebastes* spp. vs number of remotely operated vehicle transects. Example plot showing the trade-off between sampling effort (number of transects) and the ability to detect statistical difference in abundance of an example rockfish species over time in an MPA compared to a paired reference site. (This figure shows preliminary analyses by the UC Davis/CDFW postdoctoral researchers. Manuscripts detailing methodology and results are in preparation.)

Comparisons of Various Fish Monitoring Techniques

In California, various types of techniques are being used for monitoring nearshore marine ecosystems and MPAs, including SCUBA surveys, experimental fishing, ROVs, manned submersibles, and drop cameras/landers. These monitoring techniques are utilized at different depths and may capture species, or particular life history stages of species, that are unique to a certain monitoring technique or common with other monitoring techniques.

Performing a methodological comparison of various fish monitoring techniques will provide information regarding the species commonly captured by these techniques, potential species dynamics such as ontogenetic habitat shifts where individuals spend their early life in shallow areas then move to deeper areas as they grow bigger, potential depth and latitudinal range of the species, and so on. This information will be useful to ensure that any particular monitoring technique is effective for selected indicator species. Ideally, methodological comparisons will enable managers to identify a suite of techniques that can be used to monitor certain indicator species or identify synergies among different monitoring techniques to collectively inform statuses of indicator species. Combining complementary data from different monitoring techniques that often operate at different time periods, geographic regions, and depths may enhance monitoring frequency and extent in cost-effective ways while potentially providing more meaningful information for assessment and management.

BOX 4: Key Conclusions for Monitoring Expectations

- Simulating the abundance and biomass responses to MPAs, as they arise from a “filling in” of older ages and larger sizes, can inform the choice of indicator species (Figure 7), sampling locations (Figure 6), and estimation of decision timing (Figure 7) for monitoring and adaptive management.
- Response of biomass is always greater than response of abundance.
- The ability to correctly detect differences in population dynamics within and outside MPAs increases over time, where the projected time scales of 19 species responses range from 5 to 40 years.
- Abundance and biomass responses to MPA implementation increase with greater local fishing mortality, which can vary on scales of tens of kilometers (Figure 6).
- The level of monitoring sampling effort determines the statistical power needed to detect change in populations over time (Figure 8).

4. Conclusion

SINCE MPA IMPLEMENTATION, there has been ongoing work to develop quantitative and expert informed approaches to long-term monitoring (CDFW 2016). Using knowledge from the MPA design and siting process, baseline monitoring projects, additional scientific studies in California's MPAs over the past decade, and other emerging scientific tools, the Action Plan identifies a priority list of metrics, habitats, sites, and species for long-term monitoring to aid in the evaluation of the Network's progress towards meeting the goals of the MLPA.

Key MPA Performance Metrics

MPA monitoring from around the world has identified certain ecological, physical, chemical, and human use metrics as the most important for evaluating and interpreting MPA performance. The metrics identified in Section 2.3 are recommended for long-term monitoring to help advance the understanding of conditions and trends across the MPA Network.

Key Habitats and Human Uses

Analyses have indicated that the habitats targeted in the MLPA planning process were successful in achieving representation and replication targets. These habitats are therefore recommended for long-term monitoring, as are both consumptive and non-consumptive human uses (Section 2.3).

Index Sites

Using MPA design criteria, historical monitoring, connectivity modeling, and high resolution recreational fishing effort, MPAs were sorted into one of three tiers to identify which MPAs are good candidates for detecting the potential effects of protection over time (Section 2.3). This tiered approach was designed to create scalable monitoring options, allowing projects to be tailored to available resources and capacity.

Indicator Species

California's MPA Network was implemented, in part, to help conserve ecologically and economically important marine species, as well as to protect the structure and function of marine ecosystems. To that end, this Action Plan provides lists of species and species groups to target for long-term monitoring at MPA and reference sites (Tables 7-10). These lists of fishes, invertebrates, algae and plants, and birds were compiled using several sources, including regional monitoring plans, results from workshops, and the MLMA Master Plan.

This Action Plan should be viewed as a living document. Developed based on the best available science, and informed by peer-review and public input, the document can and will be updated as needed to serve as a guide for long-term monitoring across the entire state (CDFW 2016). These updates will ensure the latest understanding of MPA Network performance evaluation is reflected in the priorities of the Monitoring Program.

5. Glossary

Abiotic: Non-living, physical components of the environment that influence organisms and their habitats. Examples include temperature, wind, sunlight, and other physical oceanographic factors such as water density and movement, wave action, salinity, and nutrient availability.

Abundance: The total number of individual organisms present in a given area.

Adaptive Management: With regard to the marine protected areas, adaptive management is a management policy that seeks to improve management of biological resources, particularly in areas of scientific uncertainty, by viewing program actions as tools for learning. Actions shall be designed so that, even if they fail, they will provide useful information for future actions, and monitoring and evaluation shall be emphasized so that the interaction of different elements within marine systems may be better understood (FGC §2852(a)).

Areas of Special Biological Significance (ASBS): Ocean areas that are monitored and maintained for water quality by the State Water Resources Control Board. Currently, there are 34 ASBSs in California that support a variety of aquatic life and are primarily focused on regulation of coastal discharges.

Before-After Control-Impact Analyses (BACI): Type of study design that examines the conditions of an area(s) before and after protection ("impact") and compares these conditions over time to those at a reference site(s) ("control") that is not protected (Stewart-Oaten et al. 1986, Block et al. 2001).

Benthic: Organisms and communities that live on and in the ocean floor.

Biodiversity: A component and measure of ecosystem health and function. It is the number and genetic richness of different individuals found within the population of a species, of populations found within a species range, of different species found within a natural community or ecosystem, and of different communities and ecosystems found within a region (PRC §12220(b)).

Biomass: The total mass of organisms in a specified area.

Biotic: Components of the environment that are attributed to living organisms. Examples include plants, animals, algae, primary production, predation, parasitism, competition, etc.

California Current Large Marine Ecosystem (CCLME): A marine region in the North Pacific Ocean from southern British Columbia, Canada to Baja California, Mexico. The CCLME is one of only four temperate upwelling systems in the world, considered globally important for biodiversity because of its high productivity and the large numbers of species it supports.

Community Structure: The types and number of species present in a community, which is influenced by interactions between species and other environmental factors.

Density: The number of individual organisms per unit area or volume in a specified area.

Dissolved Oxygen: Oxygen that dissolves into ocean water, absorbed from the atmosphere or the release of oxygen during photosynthesis of marine plants and algae. Dissolved oxygen is critical for marine organisms; levels in the nearshore environment are affected by physical factors such as changes in temperature and salinity.

Ecosystem: The physical and climatic features and all the living and dead organisms in an area that are interrelated in the transfer of energy and material, which together produce and maintain a characteristic type of biological community (CDFW 2002).

Fishing Mortality: The removal of fish from a population due to fishing activities. Denoted as “F” in fisheries stock assessment and other related models.

Functional Diversity: The components of biodiversity that influence ecosystem function. It is a measure of value and range of traits attributed to an organism or groups of organisms and how that influences ecosystem dynamics such as stability, productivity, and trophic pathways (Tilman 2001, Laureto et al. 2015, Soykan & Lewison 2015).

Measure: ascertain the size, amount, or degree of (something) by using an instrument or device marked in standard units or by comparing it with an object of known size.

Metric: a calculated or composite measure or quantitative indicator based upon two or more indicators or measures.

Natural Mortality: Removal of fish from a population due to causes unrelated to fishing, such as predation, diseases and other natural factors, or pollution. Denoted as “M” in fisheries stock assessment models.

Pelagic: The zone in the ocean composed of the water column above the ocean floor.

pH: A measurement (from 0 to 14) of how acidic or basic a substance is. The lower the pH of a substance, the more acidic; the higher the pH, the more basic.

Size Frequency: The number of individual organisms that fall into a specific size class.

Stability: For the purposes of this Action Plan, ecosystem stability is a measure of ecosystem response over time. A “stable” ecosystem does not experience large changes in community structure and function due to disturbances or effects of other abiotic and biotic factors. Population stability applies to a single species, and refers to changes to a population’s abundance and biomass over time (McCann 2000, Worm et al. 2006, Stachowicz et al. 2007).

Total Alkalinity: The concentration of alkaline substances in ocean water, such as bicarbonate (HCO3-), which denotes the water’s ability to resist changes in pH.

Trophic Cascade: Indirect interactions that occur when changes in abundance of a predator alter the behavior of organisms at lower trophic levels, which can in turn cause dramatic changes in ecosystem structure and function (Pinnegar et al. 2002).

Upwelling: A process that occurs when winds push ocean surface water offshore and cold, nutrient-rich water from the deep sea rises up to the surface to replace it.

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