Sonoma-Mendocino Bull Kelp Recovery Plan

For Greater Farallones National Marine Sanctuary and California Department of Fish & Wildlife

April 2019

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Citation:
Hohman, R., Hutto, S., Catton, C. and F. Koe. 2019. Sonoma-Mendocino Bull Kelp Recovery Plan. Plan for the Greater Farallones National Marine Sanctuary and the California Department of Fish and Wildlife. San Francisco, CA. 166 pp.

This work was made possible with support from:

National Marine Sanctuaries Greater Farallones
Greater Farallones Association
California Department of Fish & Wildlife
Tomberg Family Philanthropies
The Campbell Foundation

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EXECUTIVE SUMMARY

The Bull Kelp Recovery Plan (Recovery Plan) is a guidance document that outlines management strategies to address the extensive loss of bull kelp forests along the Sonoma and Mendocino counties coastline. Bull kelp (*Nereocystis luetkeana*) forms dense underwater forests that marine organisms depend on for shelter and food along the rocky nearshore habitat of the Northeast Pacific Ocean. Since 2014, bull kelp forests along northern California have been decimated due to an unusual combination of climatic conditions and ecological stressors. These stressors include a large-scale persistent marine heatwave, a lack of vital nutrients from upwelling, the massive die-off of sea stars due to a wasting syndrome, and a population boom in purple sea urchins. It is estimated that greater than 90% of bull kelp beds in this region were lost. The loss of bull kelp forests has led to the decline of the commercial red urchin fishery in the region by 80% and the complete closure of the recreational red abalone fishery, which has a $44 million non-market value.

In order to understand and proactively respond to the drastic loss of bull kelp, the Greater Farallones National Marine Sanctuary Advisory Council (GFNMS AC) convened the Kelp Recovery Working Group (Working Group), chaired by the Greater Farallones Association (GFA), and the California Department of Fish and Wildlife (CDFW) to develop recommendations to comprehensively address kelp loss in Sonoma and Mendocino counties and facilitate management and recovery of bull kelp populations. Using the GFNMS AC recommendations and with the generous support of the Campbell Foundation and Tomberg Family Philanthropies, GFA produced the Recovery Plan for GFNMS and CDFW. The Recovery Plan contains strategies for active kelp recovery, restoration site selection, monitoring and research, and community engagement and includes supporting literature references and summaries of current recovery actions and research.

Active Kelp Recovery

The Active Kelp Recovery chapter outlines recommended restoration efforts to be taken in the field. The primary goal for recovery efforts is to preserve the local nearshore spore bank to facilitate natural recovery of bull kelp forests once ocean conditions improve. The most immediate need is reducing purple urchin grazing pressure. Active Kelp Recovery includes two primary strategies, 1) reduce grazing pressure of herbivorous urchins and 2) enhance kelp growth. Each strategy is divided into two tiers. Tier 1 actions should be investigated and assessed immediately, and Tier 2 actions should be considered at a future date and are dependent on ocean conditions. Several actions evaluated by the Working Group were deemed to have consequences that could be too severe and were removed from the active recovery options. The strategies and respective tiers are outlined in Table 1. Initial recovery efforts were conducted in 2018 by CDFW, the Waterman's Alliance, and the Noyo Center for Marine Science to reduce urchin population density using commercial and recreational harvesting techniques. These studies should inform future recovery actions. Information about the pilot studies is included in the Recovery Plan.

Table 1. Active Kelp Recovery strategies to be investigated and implemented immediately as funding and feasibility allow (Tier 1), considered at a future date (Tier 2), and actions that were proposed but were removed from recovery options.

Tier 1 - Actions to be Investigated and Implemented Immediately	
Reduce Grazing Pressure	
Commercial urchin harvest	The reduction of urchin population density in the ecosystem through consistent efforts by commercial urchin divers.
Recreational urchin harvest	The reduction of urchin population density in the ecosystem through periodic community-led events.
Support Sea Star Wasting Disease (SSWD) Strategic Action Plan Recommendations	Collaborate with SSWD Task Force to identify areas of greater sea star population density and support sea star reintroduction efforts.
In-Situ sacrifice (culling) of urchins	Pilot studies may be conducted by CDFW outside of GFNMS borders.
Enhance Kelp	
Seeding kelp	Placing reproductive sori, blades of kelp containing spores that have not been released yet, in areas cleared of grazing pressure. These efforts should be informed by settlement plate studies of kelp spores.
Tier 2 – Actions to be Considered at a Future Date	
Grazing Pressure	
Reintroduction of sea otters	Not considered a viable option at this time; urchin barrens will not support sea otter reintroduction.
Harvesting urchins with specially-designed Remotely-Operated Vehicles (ROVs)	Current studies are underway in Tasmania, Australia and Norway. Feasibility, cost and scale should be assessed for the northern California coastline when more information is available.
Enhance Kelp	
Outplanting kelp microspores	Culturing of kelp spores in a laboratory and outplanting them to areas cleared of grazing pressure.
Transplanting kelp sporophytes	Transplanting sporophytes from wild populations of existing bull kelp forests to areas cleared of grazing pressure.
Actions That Should Not be Considered at Any Time	
Urchin disease introduction	Consequences may be too severe. The full eradication of purple urchins is not the desired result.
Genetic Modification of purple urchins	Consequences may be too severe. The full eradication of purple urchins is not the desired result.

Placement of artificial urchin barriers	This action is not cost-effective nor feasible for ocean conditions on the northern California coastline.

Restoration Site Selection

The Restoration Site Selection chapter outlines the strategies used to prioritize recommended candidate regions for restoration and recovery actions in Sonoma and Mendocino counties based on available data and contains a geospatial analysis of the characteristics of these regions. Actions for kelp recovery per region are not provided and should be determined once specific sites within each region are chosen and field surveys of each site are conducted. The Restoration Site Selection chapter includes five strategies that together create a selection process based on weighted categories of specific criteria. The strategies are as follows:

(1) Group site selection criteria into three categories of priority, within each of the criteria are ranked by relevance (Table 2);
(2) Consider multiple layers of kelp canopy persistence based on available data from plane-based aerial surveys, historical (1999, 2002-2005, 2008) and current (2014-2016), while providing maximum historical canopy extent for reference;
(3) Give priority to sites with nearby subtidal ecosystem survey data, historical (pre-2014) and current (2014-2016);
(4) Choose a corresponding reference site, where no recovery actions would take place, once specific recovery sites are chosen within candidate regions;
(5) Determine different types of recovery actions for different sites based on the criteria for which they were selected and field verification surveys to identify certain elements of the criteria.

Table 2. Restoration site selection criteria separated by categories.

Category 1 – Ecological Significance	
Criteria	**Description**
Maximum historical kelp canopy extent	Layer created from all canopy shapefiles from aerial surveys conducted in 1999, 2002-2005 and 2008.
Historical persistence of kelp canopy	Persistence layer created from canopy shapefiles from aerial surveys where at least four of the following six years overlapped in 1999, 2002-2005, and 2008.
Current persistence of kelp	Persistence layer created from canopy shapefiles from aerial surveys conducted in 2014, 2015 and 2016
Subtidal ecosystem survey areas and sites	Sites and areas surveyed historically (pre-2014) and/or currently (2014-2018) by PISCO, Reef Check, and CDFW, and other MPA baselinde monitoring programs such as Humboldt State University (HSU). Current PISCO survey sites will be managed in the future by HSU.

Historically isolated kelp beds	Sites that support kelp beds that are isolated either due to benthic composition (surrounded by sand), depth (pinnacles) or orientation (small coves).
Sediment impacts	Movement of sediment along the coast, especially near freshwater outputs. Highly turbid or sediment-impacted sites should be avoided, as there may be an impact on kelp survival.
Freshwater output sites	Locations where freshwater drains to the ocean via rivers, streams, estuaries, lagoons. Purple urchin populations may not be able to persist as strongly due to vulnerability to freshwater input at these sites, resulting in more robust kelp - natural locations to consider for restoration.
Category 2 – Areas in Need of Further Assessment	
Areas of cultural significance	Culturally significant fishing and collecting sites. Tribal representatives should be consulted on locations of culturally sensitive areas.
Presence of anthropogenic stressors	Oil spills, run off, development, shipping lanes, etc. should be evaluated further.
State-designated MPAs where urchin harvest is allowed (SMCA, SMP, SMRMA)	Areas established for conservation of natural resources. Avoid conducting recovery actions in MPAs even where urchin harvest is allowed, in order to allow for opportunity as reference sites.
State-designated MPAs where urchin harvest is prohibited (SMR, no-take SMCA)	Areas established for conservation of natural resources. Avoid sites that currently do not allow urchin take as they provide opportunities for reference sites.
Category 3 – Positive Additional Aspects	
Sites of value to the red abalone fishery	Sites that historically have had the highest catch in the recreational abalone fishery.
Proximity to boat launch sites, ports and harbors, coastal access sites.	Areas of the coast where boats and vessels can be launched or coastal areas can be accessed by foot to allow logistical ease of recovery efforts.
Protection from wave exposure	Areas determined to have less mechanical wave action/currents when the dominant direction comes from the Northwest to provide greater safety of divers and vessels during recovery efforts, as well as logistical ease.
Areas (fishing blocks) of value to the red urchin fishery.	Sites that historically have had the highest catch in the red urchin fishery.

The site selection process was applied to identify candidate regions in Sonoma and Mendocino counties. A framework is provided for the site selection process. Active recovery options are not recommended per site, but rather field verification surveys are recommended to finalize specific restoration sites and the type of recovery actions per site. A series of maps are provided to show characteristics of candidate regions.

Monitoring and Research

The Monitoring and Research chapter identifies the most critical knowledge gaps and outlines recommended actions to be taken to conduct future monitoring efforts and identifies areas of potential research. This section includes seven strategies needed to inform kelp recovery management. A summary of techniques and limitations is provided as well as case study examples and current research. The strategies are as follows:

(1) Development of a long-term kelp canopy monitoring program to characterize broad-scale and fine-scale kelp forest dynamics and restoration efficacy, making use of new technologies such as satellites and Unmanned Aerial Vehicles (UAVs);
(2) Expedite the processing and analysis of satellite data for bull kelp canopy along the Sonoma and Mendocino counties' coastline;
(3) Investigate characteristics that may confer persistence and resilience of kelp beds, such as lower urchin population densities, natural urchin barriers such as sand bars, exposure to waves and currents, and proximity to freshwater outputs;
(4) Evaluate the potential for state-designated MPA network monitoring and other ecological monitoring efforts to understand kelp dynamics and recovery;
(5) Conduct consistent monitoring to inform all ongoing and future recovery efforts;
(6) Coordinate monitoring events and disseminate the information gathered from monitoring studies through existing websites of citizen science organizations such as Reef Check and Citizen Kelp;
(7) Implement a kelp spore distribution study with settlement plates to determine extent of dispersal and survival to inform recovery efforts.

Community Engagement

The strategies for Community Engagement are intended to bridge the gap between ongoing research and restoration efforts with passionate community members that are eager to be involved in active recovery. The strategies are as follows:

(1) Engage a range of community members, organizations and agencies to raise awareness about kelp recovery efforts with consistent messaging tailored to each target audience and their level of engagement and areas of focus,
(2) Develop consistent messaging with scientific elements of the story;
(3) Communicate the role of urchins in the ecosystem - ecological, social, and economic impacts resulting from purple urchin barrens - and opportunities for urchin harvest and use;
(4) Connect with key organizations about kelp loss and recovery efforts to engage more stakeholders in finding solutions;
(5) Produce a range of informational outreach materials with consistent messaging for specific audiences;
(6) Share consistent messaging and information including videos on social media channels;

(7) Encourage commercial urchin divers to film the underwater habitat and stream through videos and make connections with existing partners that have ROVs or ROV footage related to kelp to develop videos that tell the kelp loss and recovery story;
(8) Connect how human activities have contributed to kelp loss and how human activities can help kelp recovery.
(9) Engage community members and students in citizen science programs such as Reef Check, Citizen Kelp, and LiMPETS.

Specific guidelines to develop consistent messaging and engage audiences are provided alongside examples of ongoing community engagement efforts. Opportunities for public involvement in citizen science are outlined with links to relevant organizations.

Kelp Recovery Network

The drastic decline in bull kelp has garnered the interest of multiple stakeholders ranging from commercial red urchin fishermen, recreational divers, CDFW, academic researchers, non-governmental organizations, and NOAA's Greater Farallones National Marine Sanctuary. In order for active recovery efforts to be effective, stakeholder actions must be coordinated, interventions monitored to ensure unintended consequences are avoided and successful action documented, and accurate information is communicated to all interested parties.

The Recovery Plan recommends GFNMS coordinate efforts to create a Kelp Recovery Network in order to establish strong lines of collaboration and communication across all entities contributing to kelp recovery along the northern California coastline as well as integrating the Recovery Plan's recommendations into relevant action plans for GFNMS, CDFW, the Sea Star Wasting Syndrome Task Force, and the Ocean Protection Council. A Kelp Recovery Project should be established in partnership with GFA and supported by collaboration with CDFW to manage the Kelp Recovery Network and implement the strategies outlined in the Recovery Plan.

Conclusion and Next Steps

The Conclusion and Next Steps outline the actions necessary for a Kelp Recovery Network and Project to comprehensively and immediately address this pressing issue. Success would be dependent on a well-coordinated synergistic effort in which all interested parties are working together toward a common goal. Recommended next steps are as follows:

(1) GFNMS and CDFW adopt the recommendations and strategies in the Recovery Plan and facilitate implementation in partnership with each other;
(2) GFNMS and CDFW in partnership with GFA establish a consistent funding stream to facilitate the formation of the Kelp Recovery Project and Kelp Recovery Network and support active recovery efforts;

(3) CDFW take the recommended steps to determine specific restoration sites within the priority candidate regions and evaluate active recovery efforts to be taken for each site;
(4) GFNMS immediately investigate opportunities to collaborate with CDFW to conduct restoration and monitoring efforts within the recommended sites with available NOAA vessels, divers and equipment;
(5) GFA in partnership with CDFW and GFNMS build upon connections and efforts taken by partners in 2018 to inform, grow and implement recovery actions in 2019 and 2020;
(6) GFA in partnership with CDFW and GFNMS determine specific roles, coordination efforts, pathways for communication and avenues to facilitate the implementation of these strategies in conjunction with members of the Kelp Recovery Network;
(7) GFA in partnership with CDFW and GFNMS work with members of the Network to begin developing a comprehensive outreach plan with effective and consistent messaging and materials that can be used by all partners to increase participation and awareness;
(8) GFA in partnership with CDFW and GFNMS begin developing pathways to establish a kelp canopy monitoring program for the Sonoma and Mendocino counties coastline and expedite the processing of satellite data for bull kelp canopy monitoring being conducted by the University of California Santa Cruz.

This plan and the strategies within provide an opportunity to comprehensively address the issue of severe kelp loss in Sonoma and Mendocino counties. It is the result of a strong, interdisciplinary collaborative effort to address community engagement, monitoring and research, restoration site selection and active recovery options. These guidelines provide the necessary foundation to strengthen partnerships and cohesively pursue funding and implementation pathways immediately and efficiently. The establishment of the Kelp Recovery Project and Network would facilitate short-term recovery efforts and ensure effective long-term management of bull kelp forests.

1.0 Introduction

The Bull Kelp Recovery Plan (Recovery Plan) is a guidance document that outlines kelp recovery management strategies to address the extensive loss of bull kelp forests along the Sonoma and Mendocino counties coastline. In 2018, the Greater Farallones National Marine Sanctuary Advisory Council (GFNMS AC) established a Kelp Recovery Working Group (Working Group) composed of researchers, community members, stakeholders and agency representatives to develop bull kelp recovery management recommendations for the Sonoma and Mendocino counties rocky nearshore habitat. The Working Group was comprised of local stakeholders and representatives from academic institutions, nonprofit organizations and tribal governments and the Greater Farallones Association's participation was supported by the Tomberg Family Philanthropies and the Campbell Foundation. Working Group members reviewed the state of the science regarding kelp loss in the region, evaluated restoration and recovery methods used in other regions, discussed applications for the northern California coastline, determined a set of selection criteria for restoration sites, identified data and knowledge gaps and reviewed opportunities for education, outreach and community engagement.

The GFNMS AC reviewed and revised the working group recommendations and forwarded them to the GFNMS Superintendent for consideration. Greater Farallones Association (GFA) staff, in partnership with the California Department of Fish and Wildlife (CDFW), compiled the recommendations revised by the GFNMS SAC and developed strategies with pathways to implementation contained within this plan. The Recovery Plan includes background information on the environmental and ecological stressors contributing to bull kelp forest loss along the coastline of Sonoma and Mendocino counties, describes the process of the Working Group, and outlines strategies for restoration efforts, restoration site selection, long-term monitoring, and community engagement.

Recovery actions include strategies to reduce grazing pressure and to enhance kelp, each of which are divided by tiers to identify efforts that should be immediately investigated and implemented as funding and feasibility allow, such as purple urchin harvesting through commercial and recreational efforts; and efforts that should be evaluated at a future date, such as the reintroduction of sea otters and purple urchin harvesting by ROVs. A restoration site selection process is outlined with weighted criteria including historical and current kelp canopy persistence and proximity to subtidal ecosystems survey sites, and a list of recommended priority sites is included for recovery actions. Pathways for establishing a robust kelp canopy monitoring program utilizing a mixture of satellite imagery and Unmanned Aerial Vehicle (UAV) surveys are provided. Guidelines are provided to develop effective messaging to convey pertinent information to the public and engage members of coastal communities in citizen science efforts is provided. A critical part of the implementation of these strategies includes the establishment of a Bull Kelp Recovery Project and a Bull Kelp Recovery Network, to be managed by GFA in close partnership with GFNMS and supported by CDFW.

2.0 Background

The nearshore marine habitat of the northern California coastline hosts some of the most biodiverse and productive ecosystems in the world. Wind-driven upwelling brings cold, nutrient-rich waters to the ocean's surface, which in turn shape and support rocky subtidal ecosystems (Teagle et al. 2017). Kelp forests are recognized as highly dynamic ecosystems that harbor rich and complex communities of marine plants and animals (Gerard 1976). Kelp forests form biogenic habitat that hosts dense populations of fishes, invertebrates and other algal species. Healthy and productive kelp forests support economically significant commercial and recreational fisheries as well as culturally significant practices and resources (Bertocci et al. 2015). The nearshore rocky habitat of the Sonoma and Mendocino counties is dominated by bull kelp (*Nereocystis luetkeana*) forests. An annual species, bull kelp exhibits strong spatial and temporal variability in distribution and abundance and under ideal conditions can grow up to 25-30 cm per day (Springer et al. 2010). Overall growth is highly susceptible to ocean conditions (Schiel and Foster 2015). Climate and ecological stressors can cause long-term kelp forest loss and subsequently impact nearshore ecosystems (Krumhansl et al. 2016). Compounding climate and ecological stressors over the last decade significantly impacted kelp forests along the Northeast Pacific Ocean. Since 2011, a combination of mass mortality events and persistent marine heatwaves led to widespread bull kelp recruitment failure and increased herbivorous grazing pressure in many regions. Bull kelp forests along the Sonoma and Mendocino coastline in particular suffered a substantial decline, which led to the deterioration of local nearshore fisheries (Rogers-Bennett et al. 2019).

2.1 Description of the Study Region

The Area of Interest (AOI) is the rocky nearshore region of Northern California that stretches 206 miles (331 kilometers) from the southern tip of Sonoma County to northern Mendocino County (Figure 1). Bull kelp forests exist along rocky nearshore habitat throughout northern California. The Kelp Recovery Working Group considered recovery actions impacting bull kelp forests within the AOI, which historically contained 95% of the bull kelp canopy area in northern California. Marin was not included in the AOI due to the predominance of sandy or eelgrass habitat, with sparse rocky habitat supporting only a few small kelp beds. The borders of the Greater Farallones National Marine Sanctuary are included for reference.

Figure 1. Area of Interest (AOI) for the Recovery Plan is the nearshore habitat of Sonoma and Mendocino counties suitable for bull kelp forests (blue line), and area of the coastline that is 206 miles (331 kilometers) long.

A substantial part of the AOI falls within Greater Farallones National Marine Sanctuary (GFNMS or sanctuary) from Sonoma County through the southern part of Mendocino County. GFNMS extends from the 39th parallel at Manchester Beach in Mendocino County to Rocky Point in Marin County and includes the waters surrounding the Farallon Islands. The sanctuary encompasses 3,295 square miles and extends from the mean high-water line to the continental margin depth contour of three kilometers (GFNMS 2014). Designated in 1981, the sanctuary expanded from a previous 3,312 square kilometers in 2015. The habitats protected within the sanctuary include open ocean, coastal beaches, rocky intertidal areas, kelp forests, nearshore tidal flats, estuarine wetlands and subtidal reefs. Prior to 2015, the area managed by the sanctuary contained relatively sparse kelp forests in Sonoma, Marin and San Mateo Counties. With the sanctuary's expansion, kelp forests became a more prevalent habitat within sanctuary borders along the Sonoma and southern Mendocino coastline.

2.2 Upwelling

Upwelling is a critical process for successful recruitment and growth of kelp forests in California. The coastline of northern California is part of one of the world's four major wind-driven upwelling systems. Upwelling is the process that occurs when winds drive the surface layer of the coastal ocean offshore (GFNMS 2014). The movement of this surface layer results in the upwelling of cold, nutrient-rich waters from deeper with the ocean up to the surface (Figure 2). Sunlight and nutrients support a food-rich environment and promote the growth of organisms at all levels of the marine food web. The Point Arena region serves as an area that originates upwelled, nutrient-rich waters that are transported throughout the region over a period of five to seven days (Halle and Largier 2011). Upwelling may be widespread at times or localized at upwelling regions such as Point Arena. During the spring-summer upwelling season, typically March to August, strong northwest winds drive surface waters offshore and cold deep waters are upwelled to the surface over the continental shelf (Largier et al. 2010). The California Undercurrent carries cold high-salinity waters north at depth along the shelf-edge and is a source for upwelled waters. Phytoplankton blooms are the foundation of rich nearshore food webs, involving zooplankton, benthic and pelagic invertebrates, fishes, birds, and mammals. Spring and summer currents over the middle and outer shelf flow strongly southward parallel to the shore during upwelling, but nearshore flow patterns are mixed. Nutrients brought to the ocean's surface via upwelling, primarily nitrogen and phosphorous, act as fertilizers that stimulate rapid growth of kelp and are essential for prolific kelp forests.

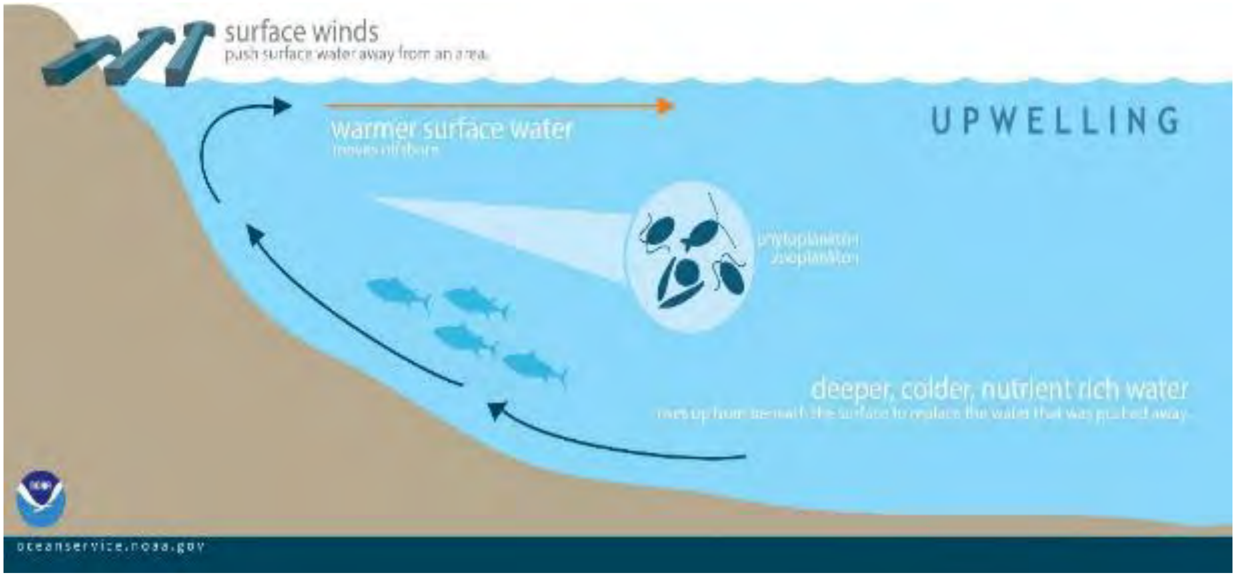


Figure 2. Upwelling is the process by which surface waters are pushed away from the coastline by surface winds and are replaced by cold, nutrient-rich water that wells up from the bottom of the ocean (NOAA). Upwelling is critical for kelp recruitment and growth.

2.4 Marine Protected Areas

There are 21 State-designated Marine Protected Areas (MPAs) that include rocky nearshore habitat along the Sonoma and Mendocino coastline. These include the following types of MPAs:

- Seven State Marine Reserves (SMR), that prohibit damage or take of all marine resources (living, geologic, or cultural) including recreational and commercial take.
- 12 State Marine Conservation Areas (SMCA), that may allow some recreational or commercial take of marine resources;
- Two Special Closure Areas designated by the Fish and Game Commission that prohibit access or restricts boating activities in waters adjacent to sea bird rookeries or marine mammal haul-out sites.

State MPAs are not recommended for restoration and recovery efforts. However, they may serve as reference sites for nearby restoration activities and continue to provide critical insights into the environmental factors influencing kelp recovery.

2.4 Bull Kelp Forests

2.4.1 Range

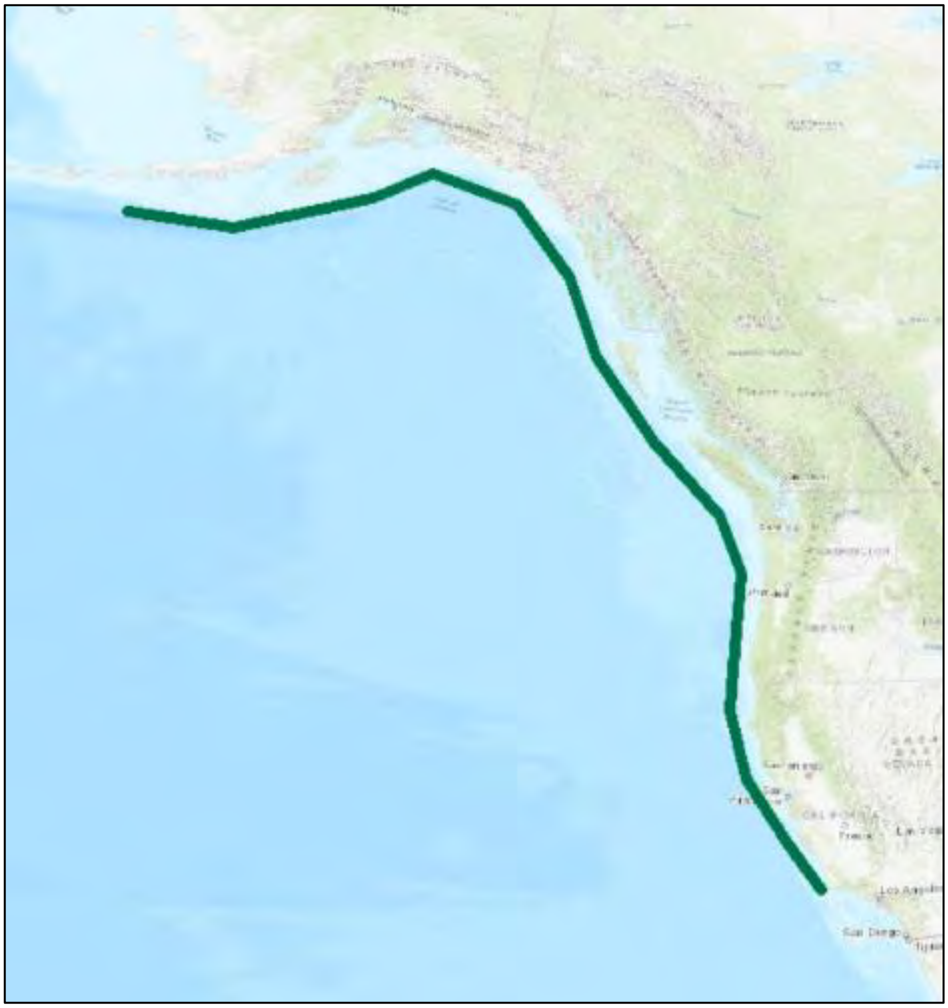


Figure 3. Geographic distribution of *Nereocystis luetkeana.*

Bull kelp is a canopy-forming laminarian algae found in nearshore rocky habitat from Point Conception, California, to Unmak Island, Alaska (Figure 3). Bull kelp and understory algal species attach to hard substrate along coastal areas, thus kelp forests are associated with bedrock reefs and boulder fields. The rocky nearshore environment of the Sonoma and Mendocino counties coastline is characterized by dense forests of bull kelp that grow at depths from two to 20 meters (Springer et al. 2010). Other canopy-forming species found in the shallow areas of this region include the feather boa kelp, *Egregia menziesii*, and *Pterygophora californica* (Schiel and Foster 2010). Along the southern portion of bull kelp range, where more coastal protection from wave exposure occurs, bull kelp forms mixed kelp forests with giant kelp, *Macrocystis pyrifera*. North of Santa Cruz, bull kelp is most often the sole or dominant canopy-forming kelp in both exposed and protected areas. In British Columbia, bull kelp and giant kelp occur in mixed kelp forests similar to Central California (GFA 2018).

2.4.2 Morphology and Reproduction

Bull kelp attaches to the benthic substrate with a structure termed the holdfast (Figure 4). A long, thin hollow stipe extends from the holdfast to the ocean surface, where long blades grow from a central, spherical, air-filled pneumatocyst (also called a float). Blades can grow up to 4 meters long in adult plants and form the canopy layer. The tissue of bull kelp is extremely elastic and can stretch more than 38% when exposed to waves (Koehl and Wainwright 1977). All algal species are photosynthetic, but they differ from plants in that they lack true roots, stems, leaves, cellulose cell walls and differentiated internal tissues such as xylem and phloem. Photosynthesis and nutrient uptake occur primarily in the canopy layer where biomass is concentrated, and light intensity is higher.

Similar to other kelp species, *Nereocystis sp.* exhibits an alternation of generations between a large, diploid sporophyte stage and a microscopic haploid gametophyte stage. In July through November, bull kelp forms sporophylls, which produce reproductive sori that then fall to the ocean floor and release spores (Figure 4). *Nereocystis* spores are thought to travel short distances from the adult, on the scale of tens of meters (Springer et al. 2010). The density and proximity of settling spores is vital for successful recruitment. Critical spore density for *Nereocystis* recruitment is not known but may be similar in scale to giant kelp (1–10 spores mm^{-2}). Spores germinate and grow into male and female gametophytes, which produce eggs and sperm. Kelp eggs release pheromones that attract sperm, but the distance for successful fertilization occurs is small. Once eggs are fertilized, they grow into young sporophytes in early spring, typically reaching the surface by late spring or early summer. Individuals grow until the pneumatocyst reaches the water surface, up to 10-17 meters in height.

2.4.3 Ecosystem Services

In California, bull kelp forests provide numerous ecosystem services (Table 1). Kelp forests provide structurally complex biogenic habitat, or habitat formed by a living organism and contribute important primary production for pelagic and nearshore food webs. Birds and marine mammals utilize kelp forest canopies and wrack created by loose kelp. Gulls, terns, Snowy Egrets, Great Blue Herons and cormorants are commonly associated with kelp forests and feed on the plankton and fish larvae associated with kelp (GFNMS 2014). Harbor seals (*Phoca vitulina*) and California sea lions (*Zalophus californianus*) feed on fishes in kelp forests off northern and Central California and Southern sea otters (*Enhydra lutris)* feed on mollusks and crustaceans as well as some species of fish in central California.

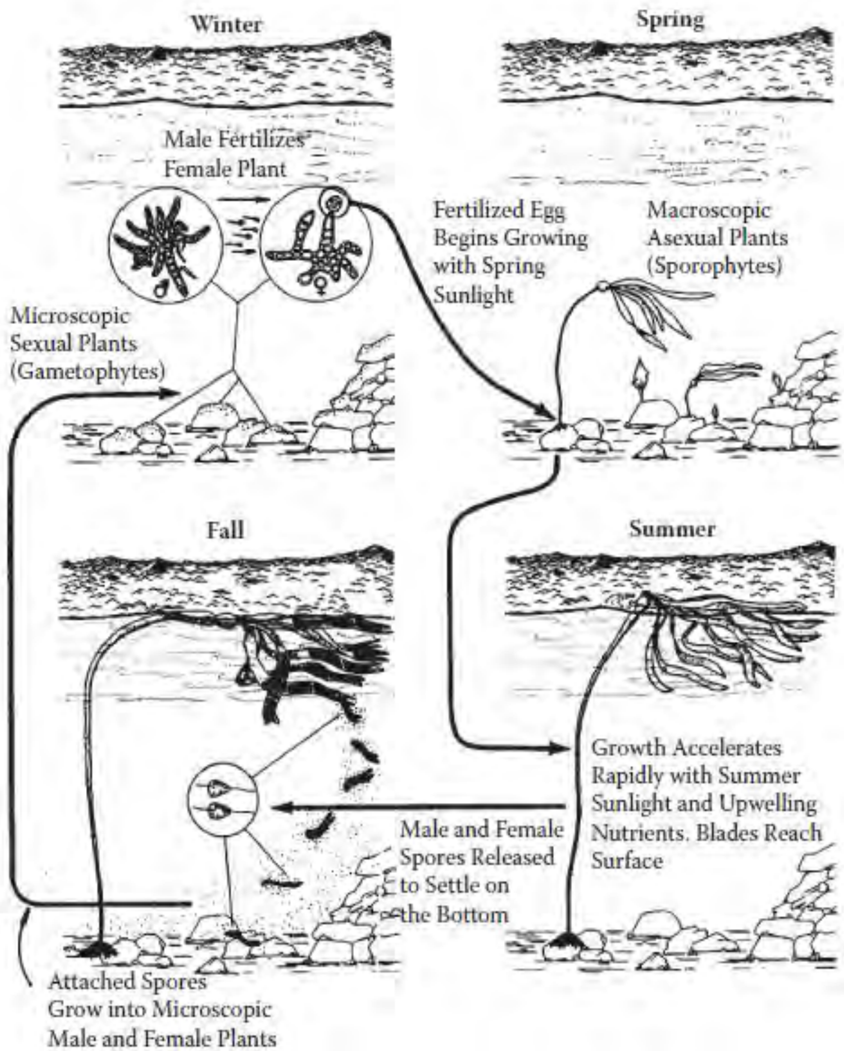


Figure 4. Annual life cycle of bull kelp (Springer et al. 2010).

Both giant kelp and bull kelp are harvested for a variety of purposes (Springer et al. 2010). These include human consumption, pharmaceutical production, and mariculture. Bull kelp forests contribute important primary production to pelagic and nearshore food webs. Due to their high productivity and biomass relative to other algal species, giant kelp and bull kelp may contribute to localized amelioration of ocean acidification (Nielson et al. 2018). Floating kelp rafts provide refuge for larval and juvenile fishes and invertebrates, providing a means of transport between spatially isolated adult populations.

Bull kelp forests on the northern California also enrich recreational opportunities such as SCUBA diving, kayaking, surfing, swimming, bird watching and fishing, and support important cultural resources. Economically and culturally-important fished species such as abalone, sea urchins, groundfish, and other seaweeds are dependent upon healthy kelp ecosystems (Steneck et al. 2002). Bull kelp is also harvested in small amounts, both commercially and recreationally, primarily for human consumption.

Current research is investigating the contribution of bull kelp forests to carbon sequestration, localized amelioration of ocean acidification (Nielson et al. 2018), and prevention of coastal erosion.

Table 1. Ecosystem services and functions provided by bull kelp forests (Springer et al. 2010).

Ecosystem function	Ecosystem service
Trophic functions	
Primary production	Source of carbon sequestering
Fuels secondary production: grazers (crustaceans, gastropods, echinoderms)	Production of culturally and recreationally important species (abalone), minor harvest for recreational and commercial consumption by humans
Fuels secondary production: detritivores (crustaceans, gastropods, echinoderms)	Production of commercially fished species (abalone, sea urchins), harvested for commercial mariculture of abalone
Fuels tertiary production: invertivores	Production of commercially fished species (crabs, fishes)
Structural functions	
Biogenic 3-dimensional habitat	Provides structural framework for nearshore ecosystems
Source of habitat for epiphytes	Increased local species diversity
Source of recruitment and nursery habitat for juvenile invertebrates and fishes	Production of recreationally and commercially fished species (rockfishes, salmon)
Physical structure dampens inshore swell and turbulence	Reduces swell and coastal erosion
Ecosystem connectivity	
Export of primary production to coastal marine ecosystems (sandy beaches, rocky intertidal, offshore soft-bottom and submarine canyons)	Fuels secondary production of detritivores in other coastal ecosystems

2.4.4 Natural Variability and Abundance of Bull Kelp

Krumhansl et al. (2016) provides the first globally comprehensive analysis of changes in kelp forests over the past 50 years, which indicates a high degree of variation in the magnitude and direction of change across all kelp forests. Some kelp forests experience major losses during El Niño events and the rate of recovery is highly dependent on local drivers of kelp abundance (Dayton et al. 1992). Physical factors influencing growth, distribution and abundance include light, substrate, sedimentation, nutrients levels, temperature, water motion and salinity. The interactions and effects of these factors can be complex and challenging to understand because they do not act in isolation. Consistent with an annual life history, bull kelp exhibits even stronger spatial and temporal variability in abundance and distribution than other kelp species (Springer et al. 2010). Due to the challenges of monitoring bull kelp populations (see section 6.2), a long-term time-series depicting bull kelp canopy dynamics does not exist, unlike for giant kelp. However, evidence from ecosystem and aerial surveys from CDFW since the 1980s indicates that this is the first time the current extent of loss of bull kelp forests has been documented.

2.5 Problem Background

The decline of kelp forests results in a loss of habitat for numerous species of fish, invertebrates and algae. Due to compounding environmental and ecological stressors, bull kelp forests along the Sonoma and Mendocino counties coastline have deteriorated dramatically since 2014. Starting in 2013, the Sea Star Wasting Syndrome let to widespread mass mortalities of all sea star species in northern California, many of which are primary predators of urchins (Eisenlord et al. 2016). The following year (2014) was the start of a persistent warm-water condition caused by a combination of a multi-year large-scale marine heatwave (2014-2015) (Di Lorenzo and Mantua 2016) and a strong El Niño condition (2015-2016). Bull kelp showed widespread recruitment failure throughout the AOI, resulting in the development of a food-limited condition for purple urchins (*Strongylocentrotus purpuratus*) and other herbivores. Purple urchin populations grew in numbers to more than sixty times normal levels, and shifted behavior toward more aggressive grazing on kelp and other seaweeds, effectively outcompeting other herbivores like abalone (Catton 2018).

Areas where dense productive kelp forests historically thrived are now largely replaced by urchin barrens and bare rock. Understory kelp, or species that form midwater and benthic communities such as *Pterygophera californica*, were also significantly impacted (Figure 5 and 6). The California Department of Fish and Wildlife estimated that greater than 90% of bull kelp forests was lost (Figure 7).

Kelp forests are naturally dynamic ecosystems exhibiting high interseasonal variation (Springer et al. 2010); however, a persistent loss of this magnitude may have severe long-term impacts on the nearshore ecosystem. An annual species, bull kelp must complete its entire life cycle, growing from a spore to a mature adult, within a single year. Persistently poor ocean conditions can potentially devastate the entire population of an annual species by inhibiting the sporophyte cohort (Schiltroth 2018). The conditions on the northern California coastline may have led to low spore availability and intense grazing pressure, which would threaten recovery even when ocean conditions improve. Areas where patches of bull kelp forests still exist are relatively small and isolated.

Figure 5. Understory species of kelp have declined significantly in the AOI in addition to canopy-forming bull kelp (Catton 2018). Photo credits: L. Rogers-Bennet, CDFW (left), A. Weltz CDFW (right).

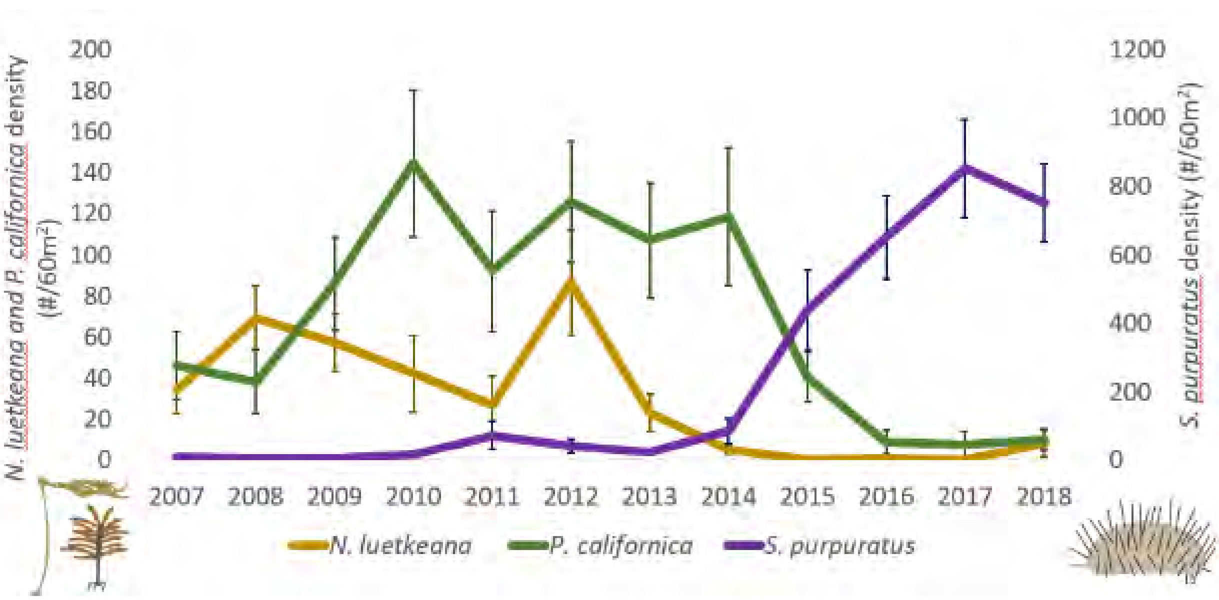


Figure 6. Reef Check surveys showing population density of purple urchins increasing while population density of bull kelp and *P. californica*, an understory species, decreased beginning in 2014 (McHugh et al. 2018).

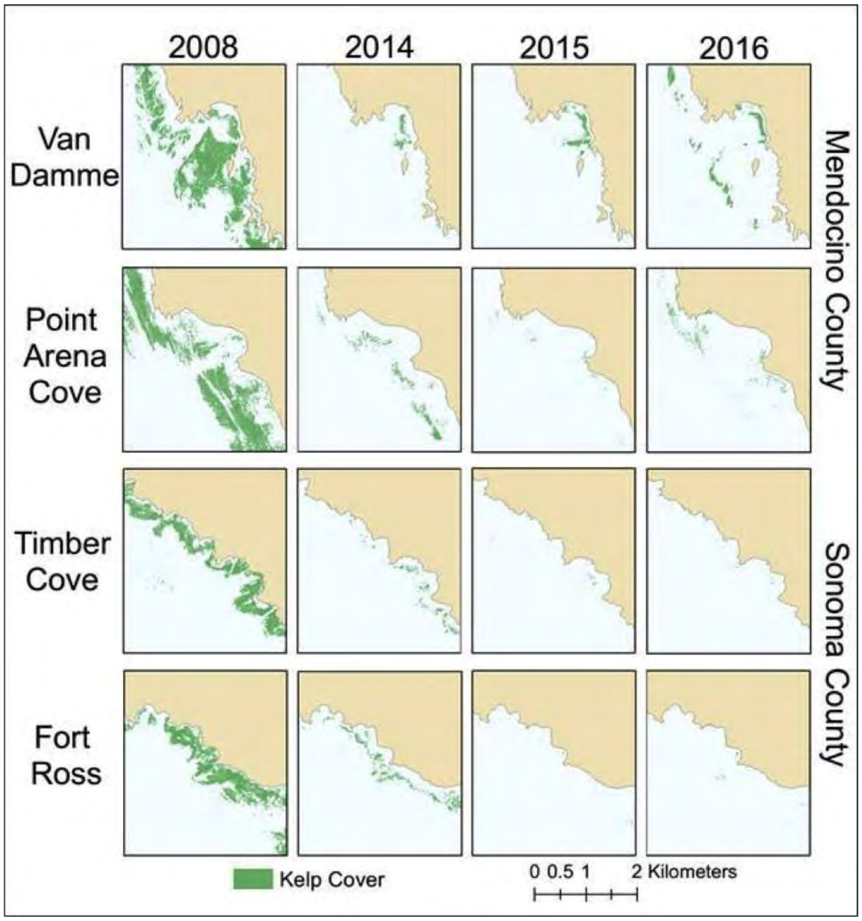


Figure 7. Kelp canopy cover from aerial plane-based surveys shows a loss of greater than 90% over the last few years in the AOI (Catton 2018).

3.0 Climatic and Ecological Stressors Contributing to Kelp Forest Loss

Substantial kelp forest loss occurs in many regions because of changing climates, overfishing, pollution and invasive species and other regional stressors (House et al. 2017). For Sonoma and Mendocino counties, the main stressors were determined to be persistent marine heatwaves, the prevalence of the sea star wasting syndrome and substantially increased grazing pressure. Both large-scale climatic stressors and regional-scale influences can lead to unbalanced ecosystems and compounding stressors increase vulnerability and impacts. Active management of local, smaller-scale stressors is an achievable and effective goal to increase resilience of kelp forest communities to both climatic and ecological stressors. The following describes the primary climatic and ecological stressors associated with the recent dramatic loss of bull kelp forests.

3.1 Persistent Marine Heatwaves

Extreme climate and weather events are increasing in frequency and duration due to climate change (Di Lorenzo and Mantua 2016). Studies of climate change on terrestrial ecosystems show that these events have dramatic impacts on ecosystem health and the services provided for society. However, there is a significant knowledge gap regarding marine ecosystems and the long-term impacts of persistent intense marine heatwaves. Satellite observations and Earth system model simulations show that the number of marine heatwave days doubled between 1982 and 2016 (Figure 8). In 2013, the Northeast Pacific Ocean (NPO) experienced the greatest Sea Surface Temperature (SST) anomaly, or marine heatwave, since the 1980s (Bond et al. 2015). The magnitude and intensity of this event led to it being termed "The Blob" and it persisted strongly over 711 days. The International Working Group on Marine Heatwaves categorized this anomaly as an extreme heatwave, rate a three on a scale of four in terms of duration and intensity (EBM Tools Network 2018). Offshore measurements of SST during this time showed a peak of 2.5ºC above average (Di Lorenzo and Mantua 2016). Coastal SST along the Washington, Oregon, and California coasts were significantly warmer than usual, reaching a maximum of 6.2°C above average off Southern California (Gentemann et al. 2017). In Sonoma and Mendocino counties, elevated water temperatures began in late spring of 2014 and persisted through 2016 (Figure 9). The temperature anomaly was likely the compounding result of the persistent high-pressure ridge over the Northeast Pacific Ocean and the El Niño Southern Oscillation (ENSO) event. Marine heatwaves are predicted to increase in severity, duration and intensity due to climate change in the future (EMB Tools Network 2018).

Kelp forests are vulnerable to both rapid and prolonged changes in ocean conditions and the existence and tremendous productivity of kelp forests are highly dependent on upwelling (Barth et al. 2007). Fluctuations in atmospheric conditions cause changes in the timing, location and intensity of coastal winds, and this can alter the distribution and magnitude of upwelling, changing the environmental conditions required to sustain kelp forests. Along the coast of California, ENSO events impact the thermocline and the California Current, which may lead to suppressed upwelling. This in turn reduces primary productivity and leads to large-scale disturbance or mass mortality of kelp forest communities (Dayton et al. 1992). ENSO is a natural fluctuation that follows a regular pattern, occurring every 2-10 years. Kelp forests are naturally resilient to these fluctuations and typically recover quickly. However, kelp forests cannot recover as efficiently when other significant stressors are present, or if the fluctuations or stressors persist for long periods of time such as the recent multi-year persistent marine heatwave.

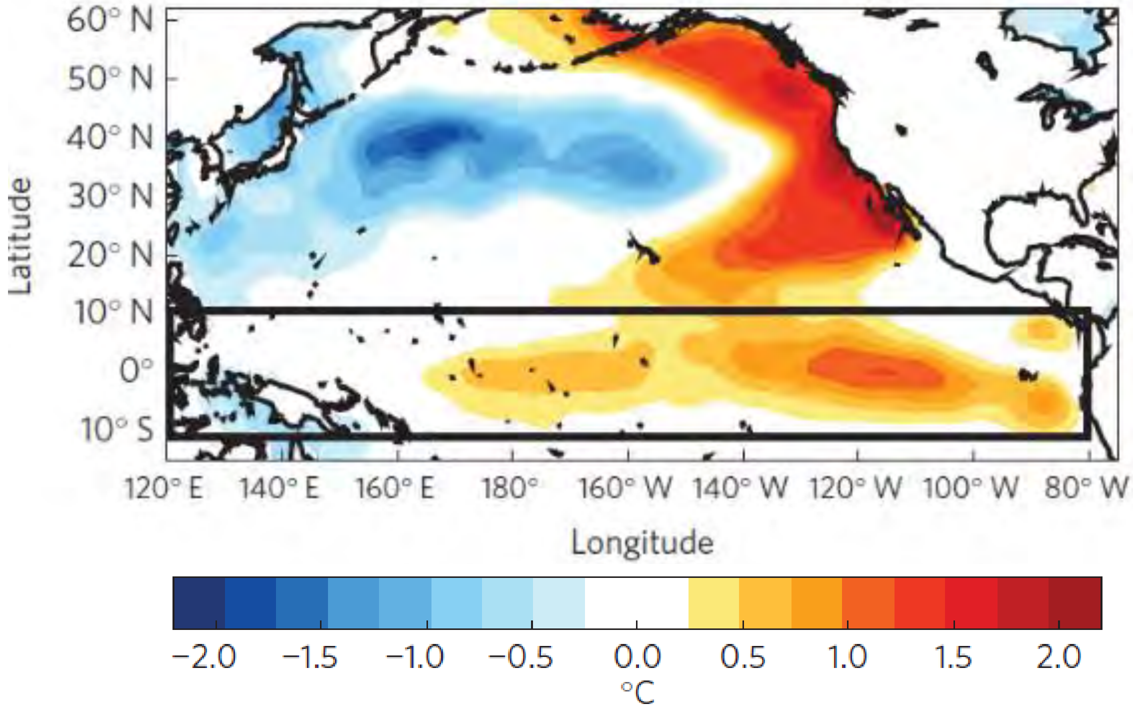


Figure 8. Map depicting the Sea Surface Temperature anomaly (SSTa) that occurred in the Fall of 2014. The warm temperature anomaly developed in the upper ocean along the North Pacific Current beginning in 2013 and persisted through 2015. It reached a record-breaking amplitude with SSTa exceeding three standard deviations (Di Lorenzo and Mantua 2016).

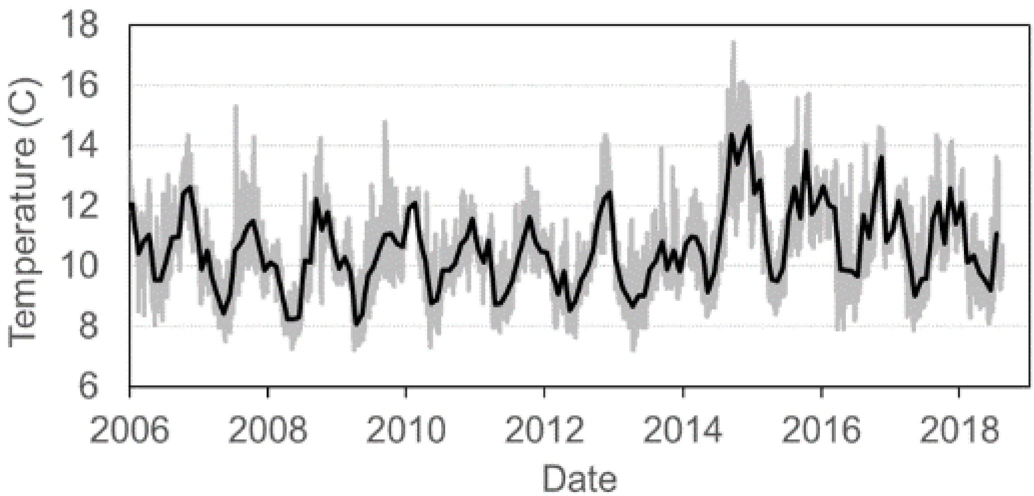


Figure 9. Subtidal (10 meter depth) nearshore temperature time series in a Mendocino County kelp forest (unpublished data from CDFW).

3.2 Sea Star Wasting Syndrome

In 2013 and 2014, sea stars along the Northeast Pacific Coast suffered a massive die-off due to a wasting syndrome. The sea star wasting syndrome (SSWS) is one of the largest marine epizootics ever recorded (SSWSTF 2018). The outbreak is considered global, although the most devastating impacts occurred along the West coast of North America. At least 20 species of sea stars experienced extremely high mortality during this period (Hewson et al. 2014). Similar die-offs occurred several times over the last 50 years of recorded data, but never to such a magnitude or to such a geographic extent. There is evidence that there is a viral pathogen involved and that environmental conditions contributed to the rapid and extensive spread of the disease (Hewson et al. 2018). As of the time of the Recovery Plan, the disease is still active in many areas and sea stars are still being impacted according to the SSWS Task Force (see http://www.piscoweb.org/sea-star-wasting-syndrome-task-force for updated information). Sea stars are among the few main predators of juvenile purple urchins along the northern California coastline, especially *Pycnopodia helianthoides*. The mass mortality of this species in particular likely contributed significantly to the increase in population and density of purple urchins between 2014 and 2018 (Figure 10 and 11). A recent time-series analysis of SST along the NPO showed a negative association with abundance of *P. helianthoides* due to SSWS with anomalously warm SST (Harvell et al. 2019). With the likelihood of increasing frequency and intensity of marine heatwaves with climate change, there could be significant lasting negative implications for *P. helanthoides*.

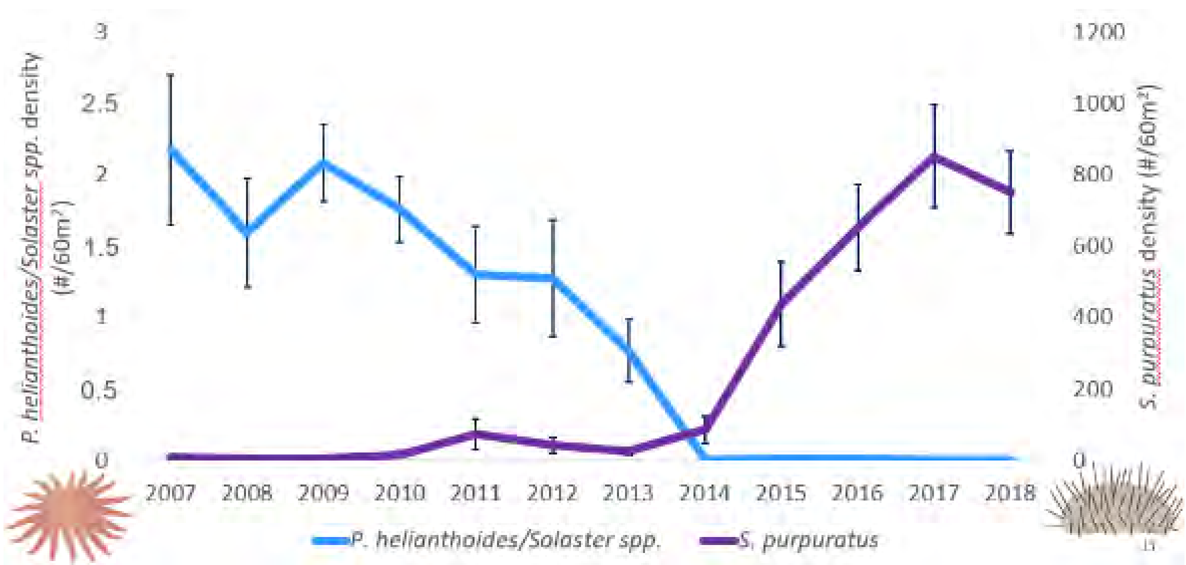


Figure 10. Reef Check surveys in Sonoma and Mendocino show population densities decreasing for sea stars *P. helianthoides* and *Solaster spp.* and increasing for purple urchins in recent years (McHugh et al. 2018).

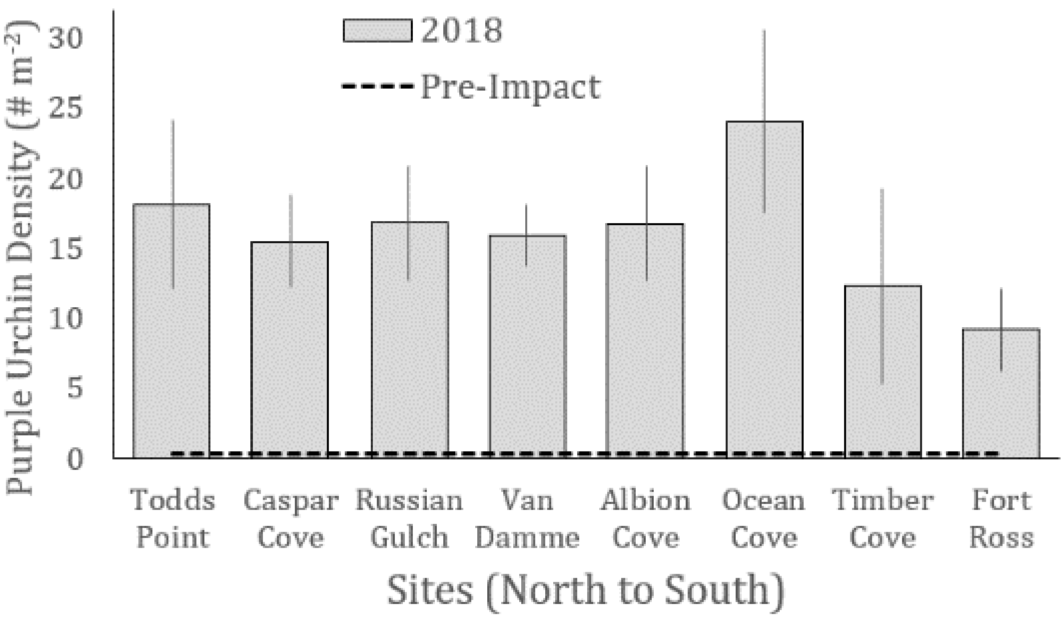


Figure 11. CDFW surveys in Sonoma and Mendocino counties show average purple urchin population density (0-60 ft depths) in 2018 was 26 – 64 times the historic average purple urchin density (0.36 purple urchins m^{-2}; SE = 0.18) (unpublished data from CDFW).

3.3 Purple Sea Urchin Population Increase

Overgrazing by herbivores is an important factor which can maintain persistent urchin barren conditions in areas that once supported productive kelp forests (House et al. 2017). Purple sea urchins (*Strongylocentrotus purpuratus*) and red urchins (*Mesocentrotus franciscanus*) may aggregate and graze large expanses of both giant and bull kelp forests under food-limited conditions and in the absence of keystone species such as sea otters and sea stars. When starved, populations of purple urchins shift to a more aggressive grazing behavior and may denude a reef of macroalgae. Urchin barrens are characterized by low productivity leading to food limitation and dense, persistent populations of urchins (Figure 12). Feeding fronts of urchins may be seen at the boundaries of kelp forests, or piles of urchins may form on drift algae or other non-traditional food items (Figure 13). Urchin barrens exist as an alternative stable-state to kelp forests, with high levels of grazing preventing new algal growth. Barrens may persist as a mosaic of small patches on the scale of 10-100 square meters but can extend up to several thousand kilometers of coastline (Filbee-Dexter and Scheibling 2014).

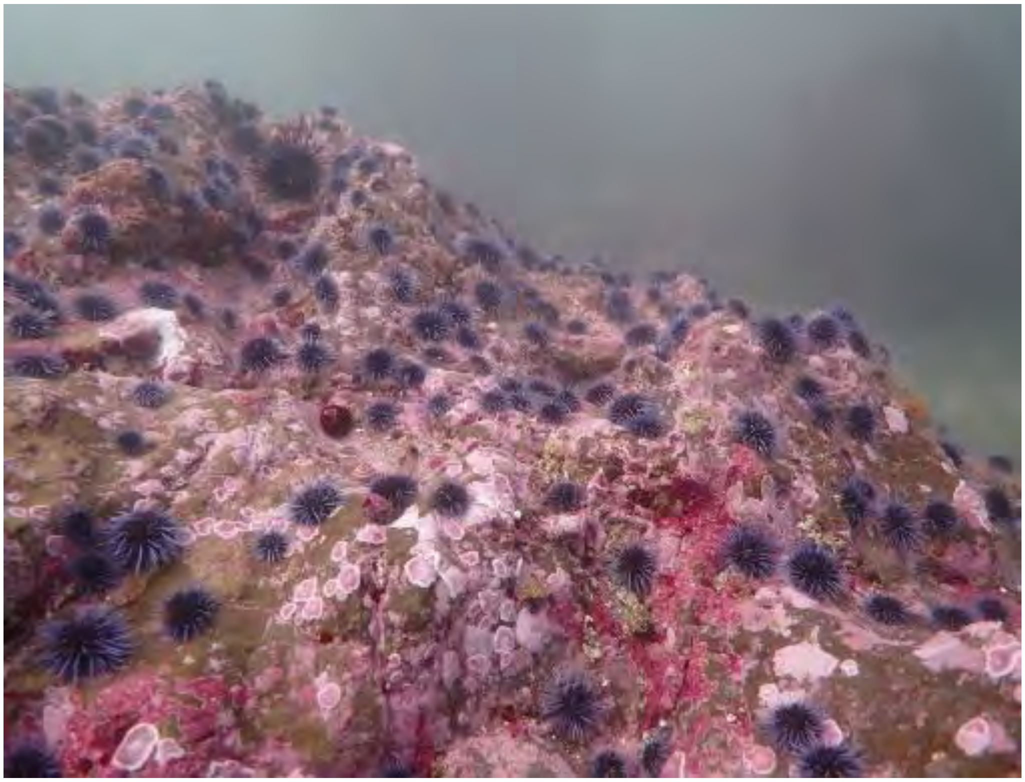


Figure 12. Urchin barren on the Sonoma-Mendocino counties coastline. Photo by C. Catton.

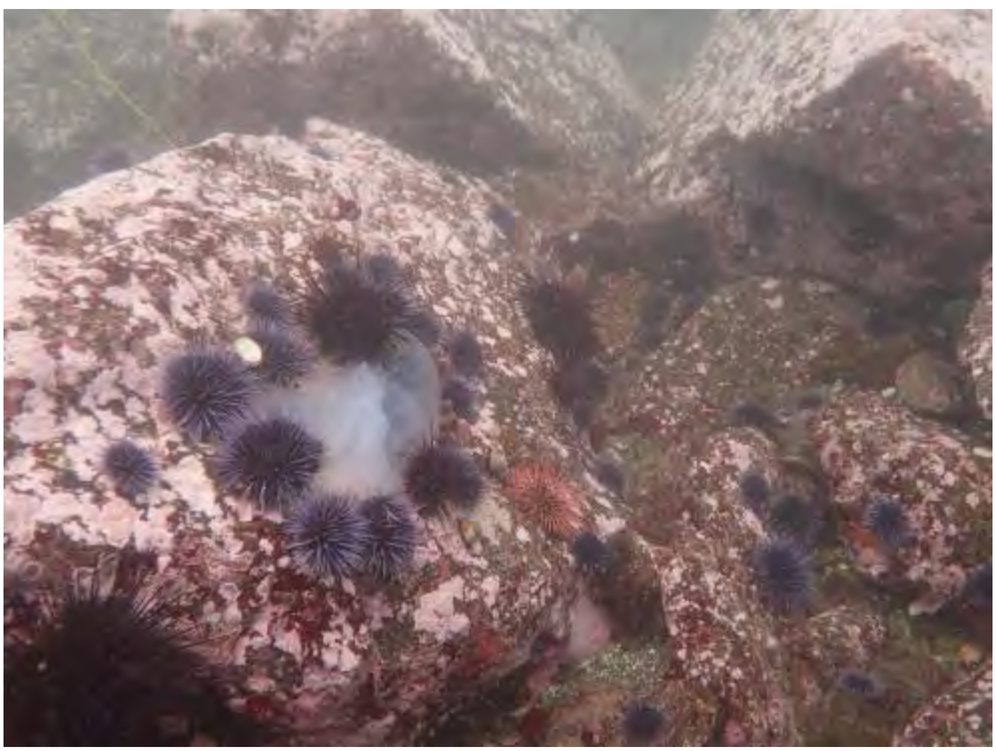


Figure 13. Purple urchins in food-limited conditions aggregating on a moon jelly (*Aurelia aurita*), which is not considered a typical food item for the species. Photo by C. Catton.

Since 2014, urchin barrens have largely replaced kelp forest ecosystems throughout the AOI. Invertebrate surveys were conducted regularly by CDFW in this region since the 1990s. Purple urchin populations reached 26-64 times their historic yearly average density in 2016 at CDFW survey sites (Catton 2018). The increase in urchin population density persisted into 2017 and 2018 with no reported decrease in any of the areas surveyed, despite starvation conditions. The persistent population density of purple urchins puts tremendous grazing pressure on adult bull kelp and bull kelp sporophytes, inhibiting recruitment and growth. Purple and red urchins compete directly with other herbivores, including abalone. Both feed on drift algae, but under normal conditions urchins actively seek attached kelp where abalone tend to be more passive grazers. Under starvation conditions, abalone actively seek out food; however, urchins are more aggressive in feeding behavior and are more opportunistic. Sea urchins can also survive on less algae than abalone and thus outcompete them when algal food resources are low in an ecosystem (Ling et al. 2015). There is emerging concern that purple urchins are grazing through crustose coralline algae, exposing large areas of bare rock. Coralline algae release a chemical known as gamma aminobutyric acid (GABA) that induces larval abalone and other invertebrates to settle on a substrate to grow. When this compound is absent or present in low levels, larvae are less likely to be successful in finding suitable habitat to settle. Urchin barrens have been known to persist for decades until disease or recovered predator populations reduce urchin numbers enough to allow kelp to recover.

3.4 Sea Otter Extirpation

Early studies in Alaska, British Columbia and Monterey suggest that Northern and Southern sea otters may control herbivorous invertebrate populations and their presence may increase stability of a healthy kelp forest ecosystem (Larson et al. 2015). The absence of otters may lead to increased herbivory and eventual significant loss in macroalgal communities and kelp forests (Estes and Palmisano, 1974). The sea otter was extirpated from the northern California coastline and throughout much of their historic range in the Northeast Pacific following the fur trade in the 1900s (Larson et al. 2015). A remnant population along the central coast of California persisted and eventually grew abundant, particularly in Monterey Bay. Although sea otters have occasionally been sighted north of San Francisco Bay in the AOI, the central coast population has primarily expanded southward into the Santa Barbara area. Despite the long-term near-absence of sea otters in the AOI for over a century, the region maintained highly productive robust kelp forests until 2014. Kelp forests in Monterey Bay, where sea otters are abundant, have also been impacted in recent years, although urchin barren conditions in Monterey Bay are less extensive than in the AOI. These recent observations highlight the need for additional regionally-specific studies on the role of sea otters in kelp forest-urchin barren systems.

3.5 Harmful Algal Blooms

Harmful Algal Blooms (HABs) may impact ecosystems and fisheries by causing mass mortalities of species or through trophic accumulation of toxins associated with the HAB. In the OAI, large algal blooms occur annually but have rarely resulted in harm to the nearshore ecosystem or associated fisheries. In 2011, an unprecedented HAB of *Gonyaulax* sp. Released a yessotoxin along the Sonoma County coastline, causing a mass mortality of abalone and other invertebrates (Rogers-Bennet et al. 2014). Ecosystem surveys indicated significant changes in the density of red abalone following the HAB (Figure 14). Red abalone (*Haliotis rufescens*) populations showed a 40% decline in density between 2010 and 2011 (Carr et al. 2013). This large-scale mortality of multiple key taxa may have made the ecosystem more vulnerable to subsequent ecological and environmental stressors.

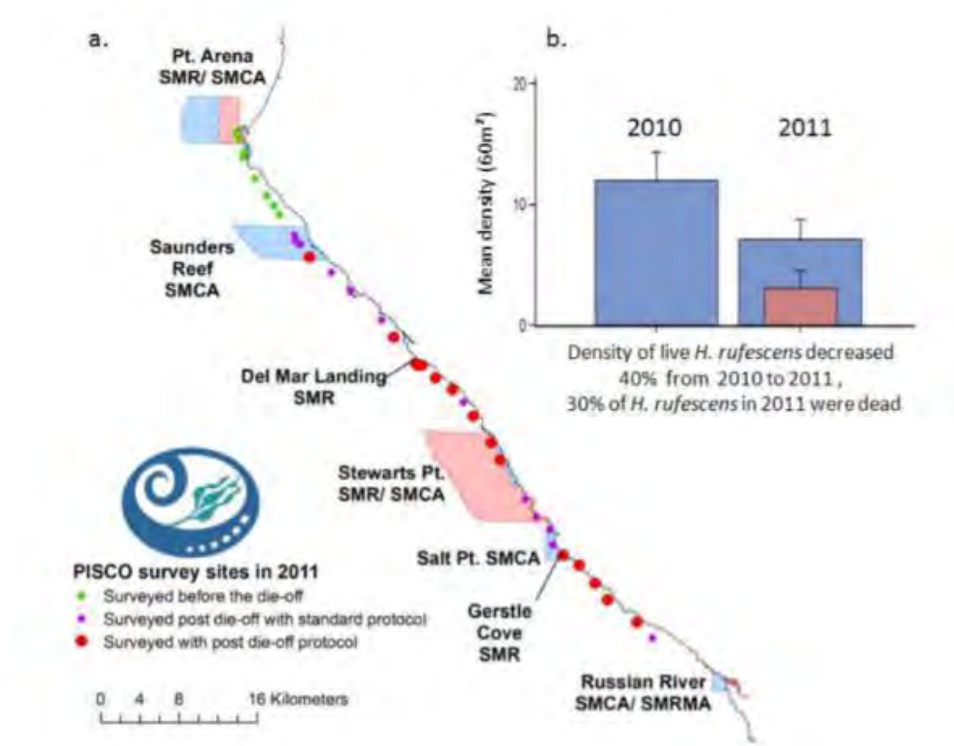


Figure 14. a) Locations of kelp forest surveys conducted by PISCO in 2010 and 2011 and b) average density of live red abalone in 2010, then live and dead abalone in 2011 (Carr et al. 2013).

3.6 Anthropogenic Stressors

Kelp forests in California are subject to harmful anthropogenic impacts that can impair the functions and services they provide. The other potentially major stressors may include harvesting, coastal pollution in the form of nutrient discharge from urban and agricultural sources, and thermal pollution associated with cooling water outflow from coastal power plants (House et al. 2017). Nutrient discharge and thermal pollution are greater concerns in Southern California and other areas closer in proximity to coastal urban development. In Northern California, there is less coastal development relative to other regions and no coastal nuclear powerplants are located in the AOI.

4.0 Economic and Cultural Impacts of Kelp Forest Loss

Bull kelp forests in northern California provide critical habitat for species that have commercial and recreational fishery value. Two of the fisheries impacted by the loss of kelp so far that are economically important in the region are the commercial red urchin fishery and the recreational abalone fishery. The primary target of the commercial urchin fishery is the larger red urchin, with very low fishing pressure on purple urchins historically. Due to the persistent widespread starvation conditions, most legal-sized red urchins have had low food value (low reproductive condition), and fishers have been diving deeper (>90 ft depths) to encounter patches of marketable red urchins (Catton 2018). Since 2015, the commercial red urchin fishery landings have declined by 60-80%, with near collapse of red urchin harvests in 2018. The ex-vessel value of the fishery in Sonoma and Mendocino counties is $3 million, lending to a significant economic loss for the statewide commercial urchin fishery.

The recreational red abalone fishery in the AOI has had important cultural and traditional value for centuries. Since the collapse of the abalone fisheries in central and southern California in the 1990s, the northern California red abalone fishery provided the only opportunity for abalone fishing in California and it was the largest recreational abalone fishery in the world. Prior to the recent impacts, more than 3,000 fishers participated in the fishery annually and derived more than $44 million per year of recreational value (Reid et al. 2016). Since 2011, subtidal surveys of abalone populations conducted by CDFW and Reef Check showed marked declines in abundance throughout the historic depth range in the AOI since the 2000s (Figure 15 and 16). In 2018, the California Fish and Game Commission closed the recreational red abalone (*Haliotus rufescens*) fishery due to evidence of mass mortalities associated with starvation, resulting in population densities declining below the fishery closure threshold (0.3 abalone m^{-2}). Most of the surviving abalone in the region were observed in the shallowest habitats (0-3 meters), where the abalone could access a narrow band of algal growth in the intertidal and shallow subtidal zones. Because the remaining abalone are weakened due to starvation and their habitat compressed within the shallow depths, the population is more vulnerable to fishing pressure and to other environmental impacts such as exposure to large waves, runoff and pollution. The fishery closure is currently extended until 2021, when conditions will be reevaluated.

The AOI includes many areas that are historically, traditionally and culturally important for tribal nations. Ocean organisms play a central role in tribal songs, ceremonies, rituals and dances. In California, tribal people harvest and collect numerous organisms from coastal areas for subsistence and cultural practices. Species important to coastal tribes include over 150 types of marine fishes as well as seaweeds and shellfish such as crabs, mussels, abalone, clams, oysters, chitons, and other gastropods (McGinnis et al. 2004). The majority of these species are reliant on healthy nearshore kelp forest ecosystems and are likely to be negatively impacted by a significant loss in kelp forests.

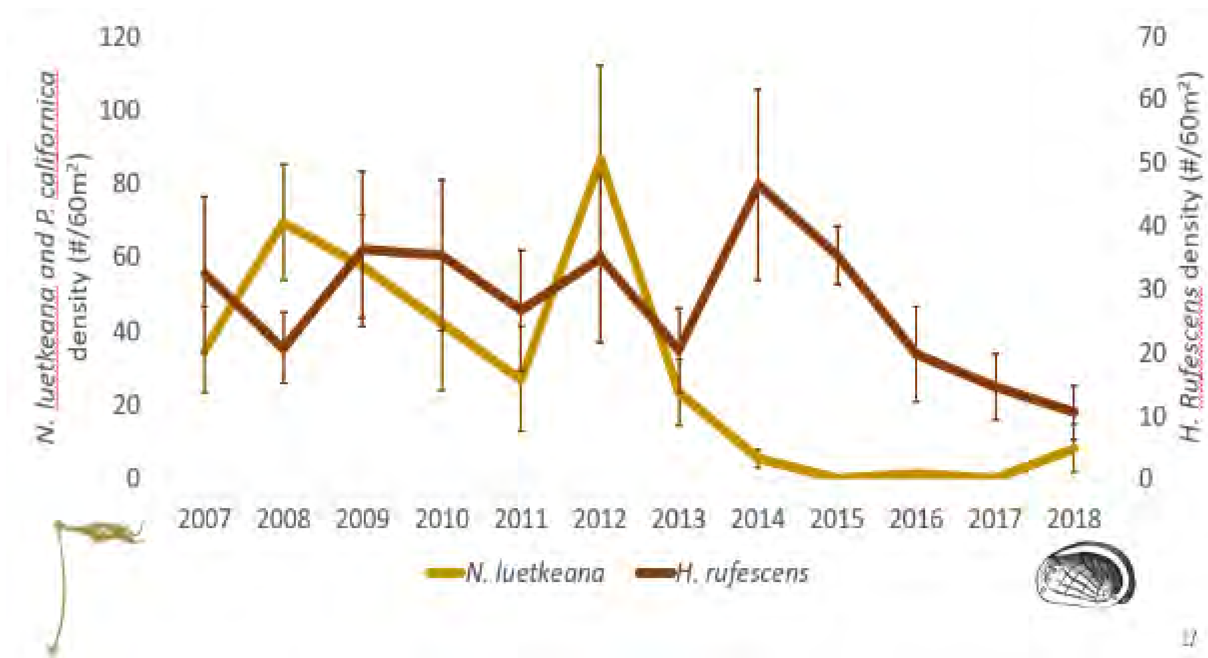


Figure 15. Red abalone populations declined significantly over the last few years alongside bull kelp populations (McHugh et al. 2018). It was noted by Reef Check that the population increase in 2014 was likely due to abalone emerging from sheltered spaces, such as cracks and crevices, and moving to shallower waters in search of kelp.

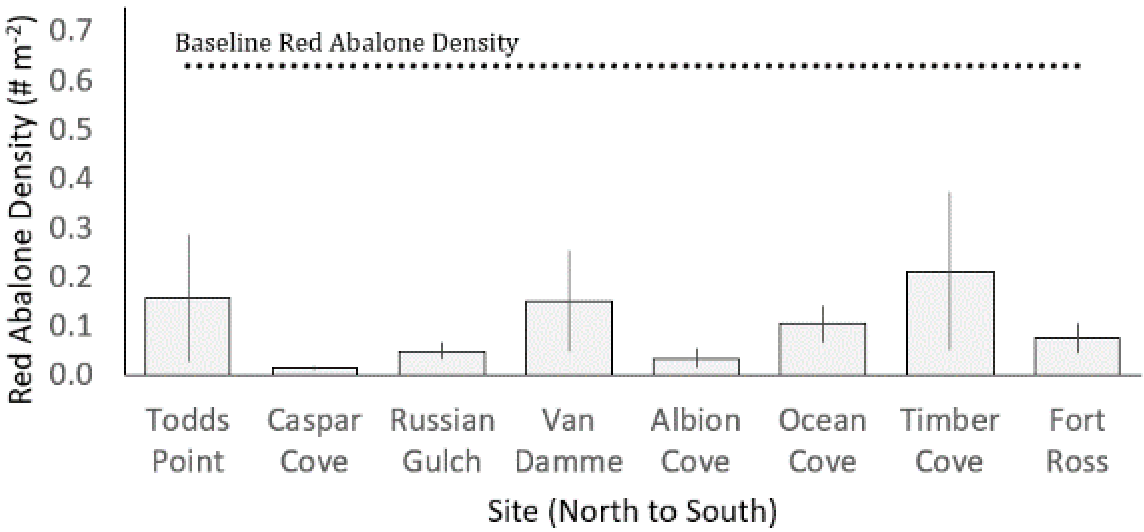


Figure 16. Red abalone density estimates from CDFW subtidal surveys in Sonoma and Mendocino counties in 2018 (grey bars). Dotted line is the baseline density estimate for the region in the 2000s (0.63 abalone m^{-2}). The fishery closed in 2018 when density averaged across all 10 index sites declined below 0.3 abalone m^{-2} (unpublished data from CDFW).

5.0 Kelp Recovery Working Group

On January 10, 2018, Greater Farallones Association staff presented the known causes, scope and associated impacts of the loss of bull kelp forests to the Greater Farallones National Marine Sanctuary Advisory Council (GFNMS AC) and the Council unanimously approved the formation of the Kelp Recovery Working Group (Working Group). The working group was formed in partnership with, and co-chaired by, the California Department of Fish and Wildlife. The working group was a collaborative, multi-stakeholder effort, engaging regional scientists representing government agencies and universities, recreational and commercial users, and non-governmental and education representatives. The purpose of the group was to examine existing research and current case studies outside of the region to develop recommendations for monitoring and research, community engagement, and a selection process for restoration sites to facilitate management and recovery of bull kelp forests.

5.1 Purpose Statement, Goals and Scope

The Working Group developed the following purpose statement:

"Our mission is to promote healthy bull kelp ecosystems along the northern California coast, foster collaborative kelp recovery and conservation efforts, and bring the best information and data to bear on adaptive management of this vitally important resource."

The goals of the Working Group included taking a collaborative approach to develop research, monitoring, community engagement, and management recommendations for the recovery of bull kelp populations along the North-Central California coastline. Objectives to achieve these goals included synthesizing available data and identifying knowledge gaps; identifying ways to streamline and enhance scientific collaboration and monitoring; evaluating restoration and recovery efforts implemented in similar ecosystems across the US West coast; developing effective management recommendations for the coastal region of northern California; documenting the direct and indirect importance of kelp to coastal communities and the socio-ecological impacts of widespread declining kelp forests; and identifying pathways for community engagement and outreach. Kelp forests along both the Sonoma and Mendocino counties coastline in the AOI were considered. Relevant trends, stressors, restoration, monitoring and management actions in other regions such as Monterey Bay, Southern California and the Puget Sound were discussed and evaluated for application to the AOI.

5.2 Working Group Process and Timeline

Meetings for the Working Group took place over a span of six months. Throughout 2018, the Working Group met three times in-person at the GFNMS headquarters in San Francisco, participated in one webinar and held multiple conference calls (see Appendix B for working group meeting summaries). The first meeting on April 25th focused on outlining the working group expectations and objectives, reviewing the state of the science for bull kelp forests, identifying knowledge gaps, reviewing restoration and recovery methods used elsewhere and begin discussion of possible options for Sonoma and Mendocino counties. A webinar was hosted on June 6th by the Greater Farallones Association titled "*Kelp Canopy Monitoring Methods and Technologies*" and focused on guest speakers discussing their research utilizing aerial plane-based surveys, remote sensing techniques and satellite imagery to monitor kelp canopy (see Appendix B for speaker biographies and section 8.2 of the Recovery Plan for a synthesis of their presentations). On June 26th, members participated in a conference call to discuss criteria for restoration site selection and a survey was distributed to determine rankings of priority. The second in-person meeting took place on August 4th with the objectives to review the results of the restoration site selection survey, identify immediate and near-term bull kelp recovery options in the context of variable future conditions, form topic teams to focus on specific recommendations, and begin drafting recommendations to facilitate recovery of bull kelp forests. In August and September, conference calls were scheduled for each of the topic teams to further discuss recommendations in preparation for the final meeting. On September 13th, the last in-person meeting focused on crafting a purpose statement for the group, reviewing the draft recommendations, finalizing general components of all recommendations and identifying intersections across topics, assessing the "big picture" with respect to alternative scenarios, identifying agency and individual leads for each recommended action and identifying the most critical next steps.

The Kelp Recovery Working Group presented their final recommendations to the GFNMS AC on November 14th, 2018, and the Council unanimously approved the recommendations with minor edits and forwarded to the Sanctuary Superintendent and CDFW staff. This plan builds upon the GFNMS AC recommendations and lays out a course for implementation.

6.0 Strategies for Active Kelp Recovery

The following active recovery options should be considered based on the characteristics of specific restoration sites once they have been identified. The recovery actions below are organized first by the type of action (no action, enhance bull kelp, and reduce grazing pressure) and second by the GFNMS AC's recommendation for how each action should be approached moving forward.

Tier 1: Action should be investigated and assessed immediately (within 1-2 years).

Tier 2: Action should be considered at a future date and is dependent on conditions.

Reduce Grazing Pressure

Tier 1 – Immediate Investigation

Commercial urchin harvest

- Needs: ideally create a market for urchins, consider payment for collection, ensure coordinated and directed harvest informed by Kelp Recovery Project
- Benefit: skilled, effective, less limited geographically than recreational divers
- Lead: CDFW in collaboration with Kelp Recovery Network partners

Recreational urchin harvest

- Needs: coordinated and directed harvest informed by Kelp Recovery Program
- Recognize utility of existing, individual efforts
- Benefit: capacity and enthusiasm
- Lead: CDFW, in collaboration with Kelp Recovery Network partners

Support Sea Star Wasting Disease Strategic Action Plan Recommendations

- Needs: Review recommendations and identify potential synergies
- Lead: Greater Farallones Association in collaboration with CDFW
- Scientific expertise: Sea Star Wasting Syndrome Task Force

In-situ *Sacrifice (Culling) of urchins*

- Investigate unintended consequences, such as induced spawning, damage to the reef and impacts on other species
- Needs: ensure communication around this action clearly portrays urchins as a native species important to a balanced ecosystem; efforts should be coordinated and highly

controlled in specific, focused areas
- Lead: CDFW, in close partnership with the tribes

Tier 2 – Possible Future Consideration

Reintroduce sea otters

- Issues: barren urchins do not have enough calories to sustain otters, many otters do not consume urchins; this is not considered a viable option at this time
- Should be reevaluated at a later time, as reintroduction of otters may be a long-term option for increasing ecosystem resilience to future stressors

Urchin harvesting by Remotely-Operated Vehicles (ROVs)

- Method currently being tested by Universities of Tasmania and Sydney, Australia, and Nofima in Norway

Enhance Kelp

Tier 1 – Immediate Investigation

Bull kelp seeding

- Need to investigate source information and feasibility at scale
- Opportunity to explore resilient ecotypes to assist adaptation
- Agency lead: CDFW
- Scientific expertise:
  - Michael Graham at Moss Landing Marine Labs for population dynamics of macrophytes and associated communities;
  - Felipe Alberto at University of Wisconsin-Milwaukee for molecular ecology of algae and has specific expertise in California giant kelp seascape genetics.

Tier 2 – Possible Future Consideration

Outplanting and transplanting sporophytes

- Need: evaluation of feasibility at scale, suitability in coastal environment
- Opportunity to install artificial reefs as refuges in sandy habitat (Mendocino county only outside of Sanctuary waters)

Actions that Should Not be Pursued

There are several actions that were considered by the working group that were deemed to have consequences that could be too severe and were removed from the viable active recovery options. These options are included below and should not be considered for implementation:

Urchin disease introduction

- Issues: the full eradication of urchins is not the desired result

Genetic modification of purple urchins (sterilization)

- Issues: the full eradication of purple urchins is not the desired result

Artificial urchin barrens

- Issues: not cost effective for an annual species, not feasible for ocean conditions on the north coast

Areas of Potential Future Research for Data Gaps and Site Selection
Genetic testing of bull kelp beds (eDNA) and the surrounding biological community selected for restoration may help determine if local biome affects recovery of species during restoration efforts. Genetic diversity in the future may be able to play a part in the selection of sites for restoration and recovery actions.

6.1 Reduce Grazing Pressure

Grazing pressure reduction is the restoration method receiving the most consideration by managers for kelp forest restoration in California (OPC 2018). For bull kelp forests in Sonoma and Mendocino counties, the most immediate issue is the high density of purple urchins and the persistence of urchin barrens, which places tremendous grazing pressure on existing kelp stands and new growth (Catton 2018). Chenelot and Konar found that herbivores selectively choose to graze younger cohorts, placing even greater grazing pressure on sporophytes (2007). Methods to enhance kelp may prove unsuccessful if grazing pressure is not reduced substantially beforehand. When a productive kelp spore bank is available and oceanographic conditions are favorable, reducing urchin densities has a high likelihood of restoring the integrity of kelp forest ecosystems (OPC 2018). Areas where extensive urchin barrens exist persist as an alternative stable state to kelp forests and reducing urchins to average densities before the urchin barren state was formed may not be adequate to facilitate kelp recovery (OPC 2018). It may be necessary to sacrifice or harvest enough urchins to reduce populations to lower-than-normal densities to encourage new kelp growth (OPC 2018). The following review of the literature and summary of ongoing harvesting efforts should be referenced when considering methods for removing grazing pressure. Urchin harvesting in the context of the Recovery Plan refers to targeted efforts focused on the reduction of purple urchin numbers from urchin barrens as a recovery action. Urchins would be collected manually by divers and taken to land, where they may be incorporated into commercial-scale compost as a calcium supplement, or they may be taken into an aquaculture facility for commercial ranching. Future active restoration efforts should be informed by the commercial and recreational harvesting efforts outlined below.

Initial recovery efforts to reduce grazing pressure were led in 2018 by partners of the Kelp Ecosystem Landscape Partnership for Research for Resiliency (KELPRR), a broad partnership of stakeholders, scientists and government agencies focused on developing science-based solutions to supporting recovery of the bull kelp forest ecosystem.

Limitations: For kelp bed loss at a regional scale, it would be challenging to scale up urchin harvesting efforts to achieve region-wide restoration of kelp forests due to labor, intensity and scalability limitations (OPC 2018). However, harvesting on a smaller scale with targeted efforts positioned strategically across a region may lead to patches of restored kelp forest habitat, creating distributed sources of kelp spore production that could serve to expedite broad-scale recovery once ocean conditions improve or there is a large-scale decline in urchin populations by natural processes. This type of effort has not been conducted before however, and there is no guidance for the minimum area required for reducing urchin densities to facilitate recovery of kelp forest habitat on a regional scale. Another significant challenge to urchin harvesting is the utilization of harvested purple urchins. Initial recovery efforts led by KELPRR partners in 2018 are providing guidance for determining best practices, and the scalability of processing and composting purple urchins.

Commercial Urchin Harvest

The red sea urchin fishery had historically been one of the top five most valuable commercial fisheries in the State of California for nearly two decades, prior to 2015 (CDFW). In the AOI, the red sea urchin fishery had an estimated ex-vessel value of $3 million. The loss in regional landings for this fishery indicates significant economic incentive for commercial urchin divers to support kelp restoration efforts. The expertise and resources available by partnering with the commercial urchin divers is invaluable to restoration efforts because harvesting may be accomplished efficiently and restoration sites that are accessible by boat may be targeted. Commercial urchin divers are also likely to have more robust equipment, including a boat, dive equipment and potentially an urchin airlift, a modified underwater vacuum designed to take up urchins at a higher rate than other mechanical forms of harvesting. A video demonstrating the urchin airlift can be viewed at https://www.youtube.com/watch?v=AaXExXw4R0A. Sites that are more exposed to higher ocean swell and currents require more experience and greater expertise to ensure feasibility and safety of diving conditions. In these cases, it may not be practical to implement recreational harvesting. As options for utilizing purple urchins for commercial purposes are developed, ongoing coordinated commercial harvest of purple urchins in the urchin barrens may be supported by market sales.

The Waterman's Alliance, a union that represents over 1,000 divers in spearfishing clubs throughout California, raised $120,000 in 2018 in grants and donations to coordinate urchin harvesting in Sonoma and Mendocino counties. A significant portion of the funds raised by the Waterman's Alliance in 2018 were allocated to pay commercial divers to harvest purple urchins in between the volunteer harvesting events. Get Inspired and the Noyo Center for Marine Science also contributed over $15,000 in donations and in-kind support to the commercial harvesting efforts (trained volunteer citizen scientists, coordinated dockside sampling during the events, developed education and outreach materials, and assisted with managing the composting process for harvested urchins). Over a period of eight months, 17 commercial urchin divers conducted targeted harvesting efforts in 2018 in three locations: Noyo Harbor, Caspar Cove and Albion Cove. A total of 41.5 metric tons, approximately 1,281,559 purple urchins, were harvested. Table 2 outlines time spent underwater, number of diving days, number and fresh weight of urchins harvested and the rate of purple urchins harvested per hour.

Table 2. Summary of commercial urchin harvest efforts in 2018 in the AOI.

Urchin harvest site	Diver days	Hours spent underwater	Fresh weight of harvested urchins (metric tons)	Number of urchins harvested	Rate of harvest (number of urchins/hour)
Noyo Bay	69	263	16.4	418,276	1,591
Caspar Cove	80	366	21.7	772,963	2,111
Albion Cove	16	62	3.3	90,320	1,451

In southern California, the kelp forest restoration project also collaborated strongly with local commercial sea urchin divers to reduce purple urchin numbers (House et al. 2017). With a steady income to pay for fuel and dive time, commercial urchin divers offered a strong measure of consistency to supplement volunteer events. Claisse et al. (2013) found that restoration of giant kelp forests in southern California had the potential to increase red urchin gonad biomass available to the commercial fishery by 864%. This experience provides further incentive for coordination with commercial urchin divers to harvest urchins in order to facilitate kelp forest recovery. Efforts to mitigate purple urchin barrens may lead to more profitable red urchin landings in the future, as the red urchin fishery benefits once a healthier ecosystem is established.

Recreational Purple Urchin Harvest

Throughout 2018 there were multiple urchin harvesting events coordinated by the Waterman's Alliance and supported by numerous KELPRR partners. Recreational harvesting events occurred in May at Ocean Cove, in July at Albion Cove, in September at Ocean Cove again, then in November at Caspar Cove. On the first day of these community events, 100 volunteer divers harvested 60,533 purple urchins, a total fresh weight of 3,400 kilograms. This is approximately equal to the take that a commercial urchin fisherman would collect over 15 diving days. When asked if they would participate in a similar event again, 100% of divers said yes. On the subsequent dates, 50-100 divers volunteered and more than 139,000 purple urchins were harvested.

The recreational urchin harvesting events in 2018 provide a successful example of collaboration, community engagement and participation. Partners that contributed greatly to these events in addition to the Waterman's Alliance included CDFW, Reef Check California and the Noyo Center for Marine Science. CDFW created the sampling protocol to estimate total harvests and coordinated on-site data collection. The Noyo Center for Marine Science organized additional community volunteers to support the on-site sampling. CDFW and Reef Check conducted subtidal surveys of harvest sites prior to and after the events to assess reductions in purple urchin densities and to provide baseline data for evaluating future ecosystem responses. These events would be used as a model for future community harvesting events and targeted purple urchin harvesting for restoration sites in 2019. Volunteer harvesting events can be scheduled regularly and months in advance if weather and ocean conditions cooperate. Collaboration between the KELPRR partners ensures broad community engagement efforts are conducted, best practices are upheld, and data collection is comprehensive and accurate.

Sea Star Wasting Disease Strategic (SSWD) Action Plan

In 2018, a Strategic Action Plan was developed by the Sea Star Wasting Syndrome Task Force, a group designated to identify gaps in knowledge, research goals and action items, and potential conservation strategies at a national scale (SSWST 2018). The action plan provides recommendations for diagnostics and epidemiology, surveillance and ecology, management, conservation, recovery, communication, outreach and citizen science. There are significant opportunities for collaboration between the SSWST and bull kelp recovery actions in Sonoma and Mendocino counties. Current information about the status of sea star populations, and the presence and severity of the sea star wasting syndrome, for specific regions would be critical to urchin and kelp forest management and may help determine specific areas to focus recovery efforts. Likewise, kelp recovery actions can serve to inform the SSWST with ecosystem monitoring efforts on locations and densities of sea stars.

In-situ *Purple Urchin Sacrifice (Culling)*

Purple urchin *in-situ* sacrifice, commonly referred to as urchin culling, is the on-site crushing or culling of urchins to support restoration of kelp forests. The most comprehensive study using this method to reduce urchin grazing pressure is from the Palos Verdes Restoration Project in Southern California. Multiple stressors have contributed to the formation of urchin barrens in place of giant kelp forests near the Palos Verdes Peninsula (Foster and Schiel 2010). Localized stressors on southern California giant kelp forests include commercial and recreational fishing, sedimentation, urban runoff and pollution (Dojiri et al. 2003). Aerial surveys revealed that between 1911 and 2015, nearly 80% of the canopy extent of giant kelp in this region was lost (House et al. 2017). Subtidal surveys in 2010 showed approximately 0.62 km^2 of kelp forest were dominated by urchin barrens. Subsequent surveys show relatively low biodiversity and productivity relative to other areas of the Palos Verdes Peninsula. These data indicated that urchin barrens persisted even with favorable conditions for giant kelp recruitment and growth. To coordinate kelp recovery in this region, the nonprofit organization The Bay Foundation initiated a restoration project in 1997 to reduce the density of urchins on nearshore rocky reefs.

By 2009, they had demonstrated that reducing urchin density from 100 urchins per square meter to less than two sea urchins per square meter allowed the natural development of macroalgae at restoration sites in Malibu and Palos Verdes. The reduction of purple urchin densities between the years of 1997 and 2009 in restoration efforts led to a rapid recovery of giant kelp (Ford and Meux, 2010). Between 2013 and 2017, restoration and monitoring efforts were conducted in restoration and reference sites. Total diving efforts between June 1, 2013 and June 30, 2017 included 1,333 hours for monitoring and 5,965 hours for active restoration. These efforts were spread across six sites, a total of 44 acres, with an estimated 3,359,669 urchins culled. The average purple urchin density was reduced from 18.46/m^2 to 1.32/m^2 across the 44 acres. One of the most powerful El Niño signatures ever recorded occurred in 2015-2016, greatly limiting the opportunities for restoration and monitoring. When conditions shifted in the winter of 2016-2017, juvenile purple urchin recruitment increased in new areas around the peninsula. Five restoration sites were chosen alongside five control sites, all of which were monitored by divers according to CDFW protocols.

Limitations/concerns: There are several limitations and concerns voiced by Working Group members regarding *in-situ* urchin sacrifice as a kelp recovery action on the northern California coastline. Culling large densities of urchins in targeted areas may have unintended and undesired consequences. There may be a possibility of mechanical damage to the reef through the physical action of crushing or hammering urchin tests. If urchins are reproductively viable, crushing or culling them *in-situ* may facilitate artificial fertilization and recruitment of larger numbers of urchins. Fertilization experiments under laboratory settings demonstrate viability in urchin reproductive material in diluted seawater, supporting the caution against *in-situ* culling when large amounts of reproductive material may be released. If *in-situ* sacrifice is considered for Sonoma and Mendocino counties, the timing and location of culling should be coordinated to occur only if purple urchins have low reproductive condition. Recovery and reference sites should be carefully monitored for impacts to the reef and to track changes in urchin population densities and recruitment.

Reintroduction of Sea Otters

Although urchin barrens provide more abundant urchin prey, individual urchins have much lower food value compared to urchins in healthy kelp forests (Stewart and Konar 2012). A kelp forest ecosystem in a degraded state may therefore not support the energy and habitat requirements for sea otters to survive. The majority of the nearshore habitat of Sonoma and Mendocino counties consists of urchin barrens with few kelp forest patch areas. There is also concern that sea otter presence on the north coast could pose an additional threat to the remaining red abalone population, which has been rapidly declining due to multiple years of mass mortalities caused by persistent starvation conditions. This action is not considered viable at this time, but may be reevaluated if kelp forests recover to an extent that may support sea otter survival.

Urchin Harvesting by Remotely-Operated Underwater Vehicles (ROVs)

Initial studies testing the usage of ROVs to cull urchins has been promising in Tasmania, where kelp forests have been severely impacted by a single urchin species, and an urchin fishing industry has not yet been established. ROVs can be deployed underwater for longer periods of time than divers. However, operation, maintenance and trouble-shooting require a high level of expertise and competence and the equipment can be expensive (Nofima 2014). Currently this technology is not yet advanced enough to be considered a feasible option but may be reevaluated at a future date if more studies are conducted on ROVs as urchin harvesting tools and appropriate funding becomes available.

6.2 Enhance Kelp

Kelp enhancement encompasses techniques used to outplant and transplant kelp sporophytes, or juvenile kelps, and the artificial introduction of male and female kelp spores, or seeding, and gametophytes.

Kelp Seeding

Kelp seeding has a strong potential to be a viable option for kelp recovery following the reduction of grazing pressure and there are several considerations that must be factored into the planning process. There are typically short "recruitment windows" where ocean conditions are conducive for the survival of spores (Hernandez-Carmona et al. 2000). The maximum distance that male and female gametophytes can be separated to allow for fertilization should be studied and documented for *Nereocystis*. Experiments with *Macrocystis pyrifera* and *Pterygophera californica* demonstrated that a minimum density of at least 1-10 spore/mm^{-2} was needed for successful recruitment (Reed 1990). Critical spore density for *Nereocystis* is not known but is likely to be similar. An effective option is placing fertile kelp sporophylls in mesh bags and attaching them to the substrate (Hernandez-Carmona et al. 2000).

Transplanting and Outplanting

Kelp sporophytes are relatively easy to cultivate and they have an extremely fast growth rate (Heath et al. 2017). Unlike vegetative restoration, sporophytes cannot be planted in the benthic habitat. Kelp holdfasts of outplanted and transplanted sporophytes must attach to a hard substrate, which in turn must be a stable structure that would not be dislodged by currents or degraded by saltwater. The attachment substrate may be natural material such as rocks or shells, or an artificial material such as ceramic. In areas where water movement is high, the substrate must be attached to the reef in a fashion that causes little to minimal damage to the natural habitat. It is important to consider the influence of herbivorous grazing pressure as well as light and nutrient availability. Young sporophytes tend to attract grazers and survival rate is negatively impacted in areas where competition with other algae species is high. Carney et al. examined and compared techniques for bull kelp restoration in Washington State (2005). These techniques included out-planting recently settled zoospores and microscopic sporophytes grown in a laboratory culture, as well as transplanting juvenile sporophytes from natural populations. This study evaluated the costs associated with small-scale restoration efforts. It was found that juvenile transplants had a higher survival rate and were less expensive and logistically less taxing than outplanting of microscopic stages. The main causes of mortality included grazing pressure from herbivorous snails and the degradation of the epoxy attaching the substrate to the reef. They developed a technique to attach juvenile kelps to the natural substrate using rope and a plastic clip. It was found that this attachment method decreased mortality significantly.

Hernandez-Carmona et al. investigated techniques to transplant and seed giant kelp in Mexico following El Niño in 1982-83 (2000). Large storms during that time devastated giant kelp forests along 50 kilometers of the coastline and the region had still not fully recovered at the time the study was conducted. The restoration site of Isla Asunción was chosen due to moderate wave action and proximity to a sea lion colony which might control fish grazing on transplanted kelp. The giant kelp sporophytes were anchored to cut holdfasts of *Eisenia arborea*, an understory kelp species, using thick rubber bands and the surrounding area was observed for natural recruitment. It was observed that understory kelp increased after the loss in giant kelp, likely due to the absence of light and competitors for space. The highest recruitment occurred when all understory algae were removed, followed by treatments with giant kelp attached to *Eisenia arborea*. Giant kelp recruitment occurred only in treatments with added sporophylls; results suggest that a lack of spores and the presence of understory algae were the main factors inhibiting giant kelp recruitment. The study found that a combined approach of transplanting juveniles and seeding during spring would be most effective for restoring giant kelp forests.

7.0 Restoration Site Selection

7.1 Strategies to Identify Candidate Regions and Sites for Restoration

The following restoration site selection framework outlines the process by which sites should be selected for recovery actions. Specific recovery actions for specific sites are not identified and should be evaluated once specific restoration sites are chosen. Rankings of site selection criteria can be referred to in Appendix D. A preliminary compilation of recommended sites based on this framework are included in the Recovery Plan (see Section 7.0).

1. Site selection criteria are grouped into three categories of priority, within which site selection criteria are ranked by relevance.

All of the site selection criterion data are grouped and weighted using the following three categories

- **Category 1 - Ecological Significance:** This category includes criteria that have some element of ecological significance. Criteria include maximum historical extent, historical and current persistence, historical and current subtidal ecosystem surveys and influences of freshwater flow and sedimentation. Persistence layers are given the greatest consideration when choosing priority sites.
- **Category 2 - Areas in Need of Further Assessment:** Areas where further consideration and/or assessment is needed, such as MPAs and culturally sensitive areas. Tribal representatives should be consulted on locations of culturally sensitive areas.
- **Category 3 – Positive Additional Aspects:** Positive additional aspects such as ease of public access, protection from wave exposure and sites of value to the recreational abalone fishery and the red urchin commercial fishery are considered.

2. Multiple layers of persistence of kelp canopy, historical and current, should be considered.

3. Priority should be given to sites with nearby subtidal survey data (historical and current) and sites should be assigned based on the resolution of those data.

4. When specific recovery sites within candidate regions are chosen, a corresponding reference site would be chosen at the same time.

5. Different types of recovery actions should be determined for different sites depending on the criteria for which they were selected.

7.2 Guidelines for Applying Site Selection Criteria

During the final restoration site selection process, criteria may be weighted differently within the three categories outlined in Strategy #1 on a case by case basis. Clear reasoning on weighting within categories should be provided on a case-by-case basis. Local and traditional knowledge should be incorporated whenever available. If site selection criteria result in regional grouping of priority sites, additional positive aspects should be taken into greater consideration and higher weight should be applied to certain criteria to avoid site congregation. An effort would be made to determine why grouping may have occurred. The evaluation of these criteria in this section determined 'candidate areas', or regions of the coastline where potential recovery efforts could be made, then specific sites should be chosen within these candidate areas, based on the recovery action being implemented. Tribal representatives should be consulted before final restoration sites and recovery actions are chosen.

Maximum Extent and Persistence

Multiple analyses of the kelp canopy survey data would contribute to the site selection criteria – maximum historic extent, historical persistence, and current persistence. The analyses presented in the Recovery Plan uses the kelp canopy data available from the CDFW airplane-based surveys (2m x 2m resolution). Maximum historic extent identifies the area within the region where restoration actions may be considered. The historical persistence layer identifies areas where kelp was observed for at least 4 out of the 6 years of kelp canopy observations prior to 2014 (1999, 2002-2005, and 2008). The current persistence layer identifies areas where kelp has been observed during the most recent years since the severe decline in 2014 (2014-2016). Both historical and current persistence of kelp canopy are used to refine candidate regions for restoration, which is assumed to coincide with high quality habitat. Persistence may occur at different sites for different reasons. This should be taken into consideration when developing the type of recovery action.

Ecosystem Surveys and Data Resolution

Candidate regions that are nearby areas with historic or current subtidal ecosystem surveys would be prioritized. Historical surveys (< 2014) by CDFW, Reef Check, PISCO and any other scientific or citizen science organization provides a baseline for better understanding ecosystem dynamics and responses to recovery efforts. Sites with current subtidal survey effort provide opportunities to leverage existing resources and knowledge to identify specific sites to target for restoration and to monitor ecosystem responses. The resolution of each data set and the maps in Section 7.0 of the Recovery Plan would be referenced when identifying final candidate areas and specific restoration sites. The resolution of each data set should be referenced. Once a site is chosen, further surveys should be conducted to determine restoration actions on a finer scale.

Reference Sites

Learning from the recovery process is essential. Reference sites allow more effective monitoring to determine success or failure of recovery efforts. Marine Protected Areas should be prioritized as reference sites to minimize the influence of human activities on ecosystem dynamics and responses. The size of a site chosen should depend on the resolution of the data available, accessibility limitations, and the recovery efforts that would take place.

Other Considerations

It is critical to understand marine community composition and dynamics in order to determine appropriate recovery actions and ecosystem responses. The site selection criteria should be used as a guide to identify candidate areas for restoration work, followed by additional field evaluation and verification to finalized specific restoration sites and the type of recovery actions that should be taken. Restoration site selection and recovery actions should be informed by the ongoing commercial and community organized urchin harvest efforts conducted in 2018 and 2019.

Anthropogenic stressors will vary in type and magnitude depending on the region where candidate areas are selected and should be evaluated separately for each restoration site selected. The potential vulnerability of sites to stressors including pollution, oil spills, and sedimentation should be considered. Due to a minimal amount of coastal development along Sonoma and Mendocino, the magnitude of anthropogenic stressors on the nearshore environment is relatively low when compared to other regions such as southern California and the Puget Sound.

Summary of Criterion Datasets

Table 2 provides the criterion datasets considered by the Kelp Recovery Working Group with descriptions, reasoning, ranking by the working group members and categorization. Areas of cultural significance are not included due to the sensitive nature of traditional resources. As the selection process for specific restoration sites and recovery actions per site progresses, tribal representatives should be consulted before final sites and actions are decided.

Table 3. Descriptions, reasoning, ratings and categories for site selection criteria considered by the Working Group.

Criteria	Description	Reasoning	Category
Maximum Historical Canopy Extent	Layer created from all canopy shapefiles from aerial surveys conducted in 1999, 2002-2005 and 2008.	Shows total suitable habitat for bull kelp and total potential area for restoration consideration.	1
Historical persistence of kelp	Persistence layer created from canopy shapefiles from aerial surveys where at least four of the six years overlapped between 1999, 2002-2005, and 2008.	May have greater potential of supporting a large persistent bed, indicates suitable habitat.	1
Current persistence of kelp	Persistence layer created from canopy shapefiles from aerial surveys conducted in 2014, 2015 and 2016	May indicate natural resilience, provide spore sources, higher potential of responding positively to recovery actions. Consider sites that either currently support kelp or are nearby existing kelp patches in recovery efforts.	1
Subtidal survey sites	Sites surveyed historically (pre-2014) and/or currently (2014-2018) by PISCO, Reef Check, and CDFW, and other MPA baseline monitoring programs such as Humboldt State University.	Align recovery actions with sites that have subtidal survey information to better understand ecosystem responses and recovery.	1
Areas of cultural sensitivity to be avoided	Culturally sensitive sites.	Areas of cultural significance that should be avoided (no disturbance).	2
Areas of cultural significance	Culturally significant fishing and collecting sites.	Areas where natural resources that have current and historical cultural significance for coastal tribes and should be supported through recovery efforts.	3
Historically isolated kelp beds	Sites that support kelp beds that are isolated either due to benthic composition (surrounded by sand), depth (pinnacle) or orientation (small cove).	Identify patches that may have natural protection from urchins, either to monitor or to target reduction of urchins to ensure persistence.	1

Sediment impacts	Movement of sediment along the coast, especially near freshwater outputs.	Avoid highly turbid or sediment-impacted sites. Higher sediment input/changes may have an impact on kelp survival.	1
Sites of value to red abalone fishery	Sites that historically have had the highest catch in the recreational abalone fishery.	Potentially prioritize sites with higher catch	3
Presence of anthropogenic stressors	Oil spills, development, etc.	Sites considered less vulnerable to certain anthropogenic stressors (e.g. choosing a site that is further away from shipping lanes).	2
Proximity to boat launch sites, ports & harbors, coastal access sites	Areas of the coast where boats and vessels can be launched or coastal areas can be accessed by foot.	Greater logistical ease of recovery efforts.	3
Marine Protected Areas where urchin harvest is allowed (e.g. SMCA, SMP, SMRMA)	Areas established for conservation of natural resources.	Avoid conducting recovery actions in MPAs even where urchin harvest is allowed, in order to allow for opportunity as reference sites.	2
Protection from wave exposure	Areas determined to have less mechanical wave action/currents when the dominant direction comes from the Northwest.	Provides greater safety of divers and vessels during recovery efforts, as well as logistical ease.	3
Areas (fishing blocks) of value to red urchin fishery	Sites that historically have had the highest catch in the red urchin fishery.	Potentially prioritize sites with higher historical catch.	3
Marine Protected Areas where urchin harvest is prohibited (e.g. SMR, no-take SMCA)	Areas established for conservation of natural resources.	Avoid sites that currently do not allow urchin take; provide opportunity for reference sites.	2
Freshwater output sites	Locations where freshwater drains to the ocean via rivers, streams, estuaries, lagoons.	The urchin population may not be able to persist as strongly due to vulnerability to freshwater input at these sites, resulting in more robust kelp - natural locations to consider for restoration.	1

7.3 Methods

GIS was used to conduct an assessment of potential candidate regions and sites for recovery actions. Terminology references:

- *Persistence* is defined as areas where kelp canopy growth occurred consistently in one location throughout the years data are available. Persistence may potentially indicate some element of natural resilience to stressors for either or both historical and current persistence.
- *Near* is used to describe map features within 1000 meters of each other.
- *Kelp patch* is used to describe distinct individual or clustered shapefiles that compose the kelp canopy persistence layers.

Specific steps for the analysis included the following:

- Restoration site selection criteria were evaluated from the three categories:
    - Ecological significance: presence, absence and area of historical and current persistence, historical and current ecosystem survey areas and sites and proximity to freshwater outputs are included.
    - Areas to be Avoided: Candidate regions that are partially or completely inside MPAs are identified as potential reference sites or sites to be avoided for restoration action.
    - Additional Positive Aspects: Coastal access sites are identified; however, proximity and ease of access should be determined by field verification.
- Historical canopy persistence is defined as areas where kelp was observed for at least 4 out of the 6 years of kelp canopy observations prior to 2014 (1999, 2002-2005, and 2008).
- Current persistence was determined by intersecting observed kelp canopy and subsurface layers from surveys conducted in 2014, 2015 and 2016.
- Candidate regions for recovery actions with either or both layers of persistence are identified. Isolated areas with less than 50 square meters of persistent kelp patches were not included, unless they are already within the candidate region. Regions are identified by nearby landscape features. GPS locations are given at the top and bottom of each map to provide a reference for the location of each candidate region.
- Locations of subtidal survey sites are identified within each candidate area:
    - Survey sites for Reef Check California were identified as being current (2014-2018), historical (2008-2014) or both.
    - Survey sites for PISCO were identified as having historical data if surveys were only conducted in 2010 and 2011, and having current data if surveys were conducted in 2016-2018. PISCO sites with current data will be surveyed by Humboldt State University beginning in 2019.

- All CDFW sites have current and historical data sets; specific transect survey locations vary within the polygon each year. Historic surveys were conducted so that all index sites were surveyed within a 3-4 year period. Current surveys are conducted annually at most sites so that recent rapid changes in the ecosystem are documented.
- Each candidate region is considered to have historical and/or current data if they are within or near an ecosystem survey area or site.

- Maps are provided below for each candidate region in Sonoma and Mendocino counties for reference when selecting sites and recovery actions.

7.4 Site Selection Analysis

An initial assessment of candidate regions for recovery actions is provided in this section based on the tiered decision tree determined by the Kelp Recovery Working Group. The following categories outline which aspects of the decision tree are evaluated in this assessment with guidance to determine other criteria on a case-by-case basis:

- Category 1 – Ecological Significance: Criteria that have ecological significance are given priority. All candidate regions should be located within the area where kelp canopy was observed historically (maximum historic extent). Within this area, sites that supported historical and/or current kelp canopy persistence are given the greatest consideration.
    - Maximum historic extent is assessed.
    - Historical and current kelp canopy persistence are identified.
    - Ecosystem survey sites available from CDFW, Reef Check, PISCO, and other MPA baseline monitoring programs are identified by location, historical (pre-2014) and current (2014-present) data.
    - Location of nearby coastal freshwater outputs are identified.
- Category 2 – Areas to be Avoided: Areas where recovery efforts should be avoided are considered next, such as MPAs and culturally sensitive areas.
    - MPAs are mapped and included.
    - Tribal representatives should be consulted on locations of culturally significant and sensitive areas.
- Category 3 – Positive Additional Aspects: Sites of value to the recreational abalone fishery are identified in Table 5 for reference. Positive additional aspects such as ease of public access and protection from wave exposure should be identified with field surveys.

The purpose of this assessment is meant to provide guidance for the site selection process and provide recommendations for priority candidate regions, not to select final recommendations for locations of specific restoration sites, or recovery actions per site. Once potential priority regions are chosen based on this guidance, the following steps should be taken before final restoration sites are chosen:

- Resolution of data available from specific ecosystem surveys near recommended regions and sites should be evaluated, including what years they were surveyed, what protocols were used and which species were monitored.
- Guidance should be taken from ongoing commercial and recreational urchin harvesting events.
- Additional field verification surveys should be conducted to determine proximity and flow of freshwater outputs, sediment impacts, accessibility, appropriate boat launch sites, protection from wave exposure and presence/vulnerability of anthropogenic stressors.

This assessment provides a series of recommended priority regions for recovery actions based on the site selection criteria. Specific sites should be selected by managers after evaluating priority regions with field surveys. Criteria are weighted as follows:

Category 1:

- Maximum historic extent (provided for visual reference, but not weighted)
- Presence of historical persistence = 5
- Presence of current persistence = 4
- Presence of historical data = 3
- Presence of current data = 2
- Proximity to freshwater output = 1

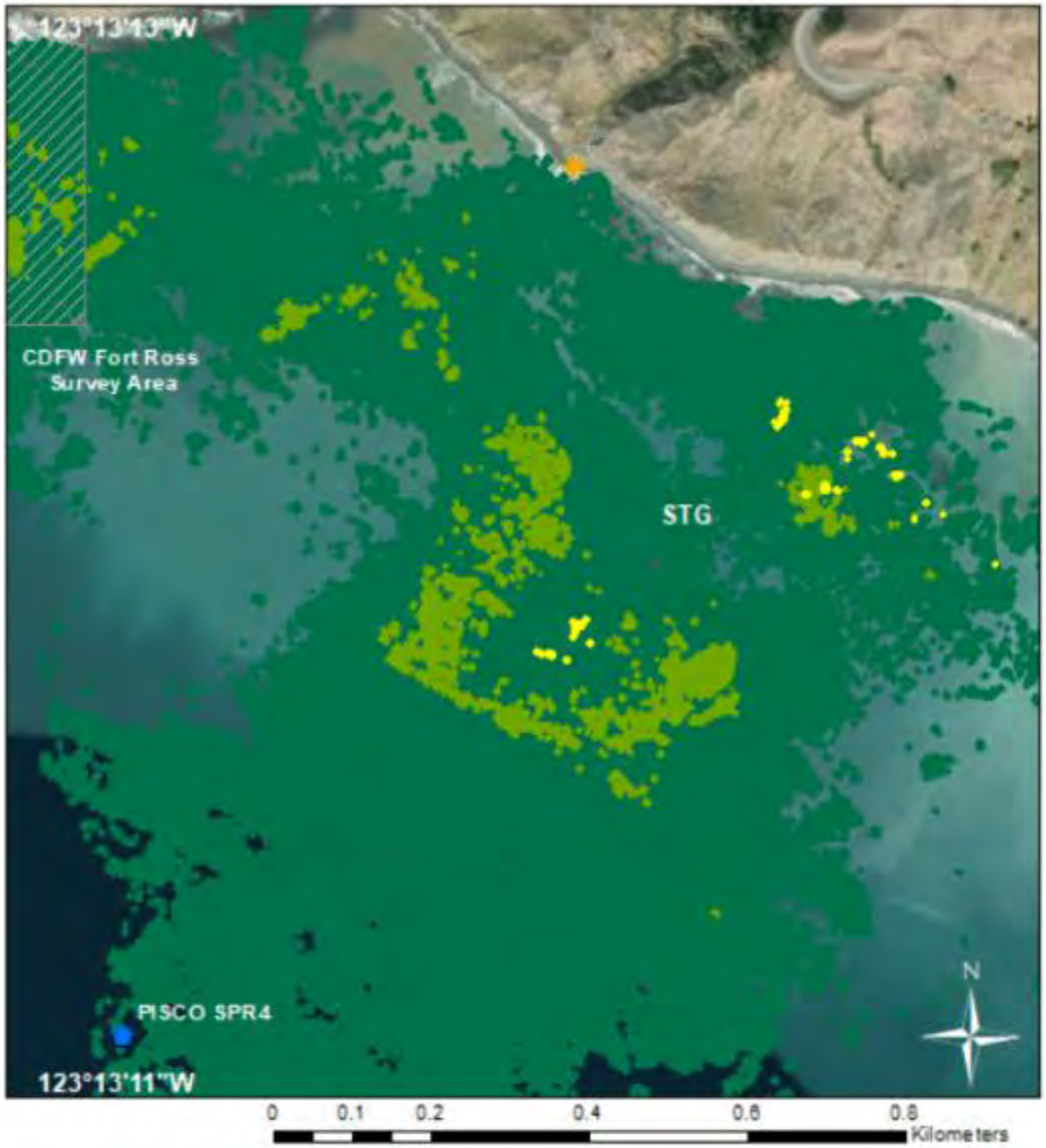
Category 2:

- Near MPA = 0.5 for potential of establishing a reference site
- Inside MPA = 0.5 and assigned as a potential reference site
- Sites identified as culturally sensitive by tribal representatives should be avoided

Category 3:

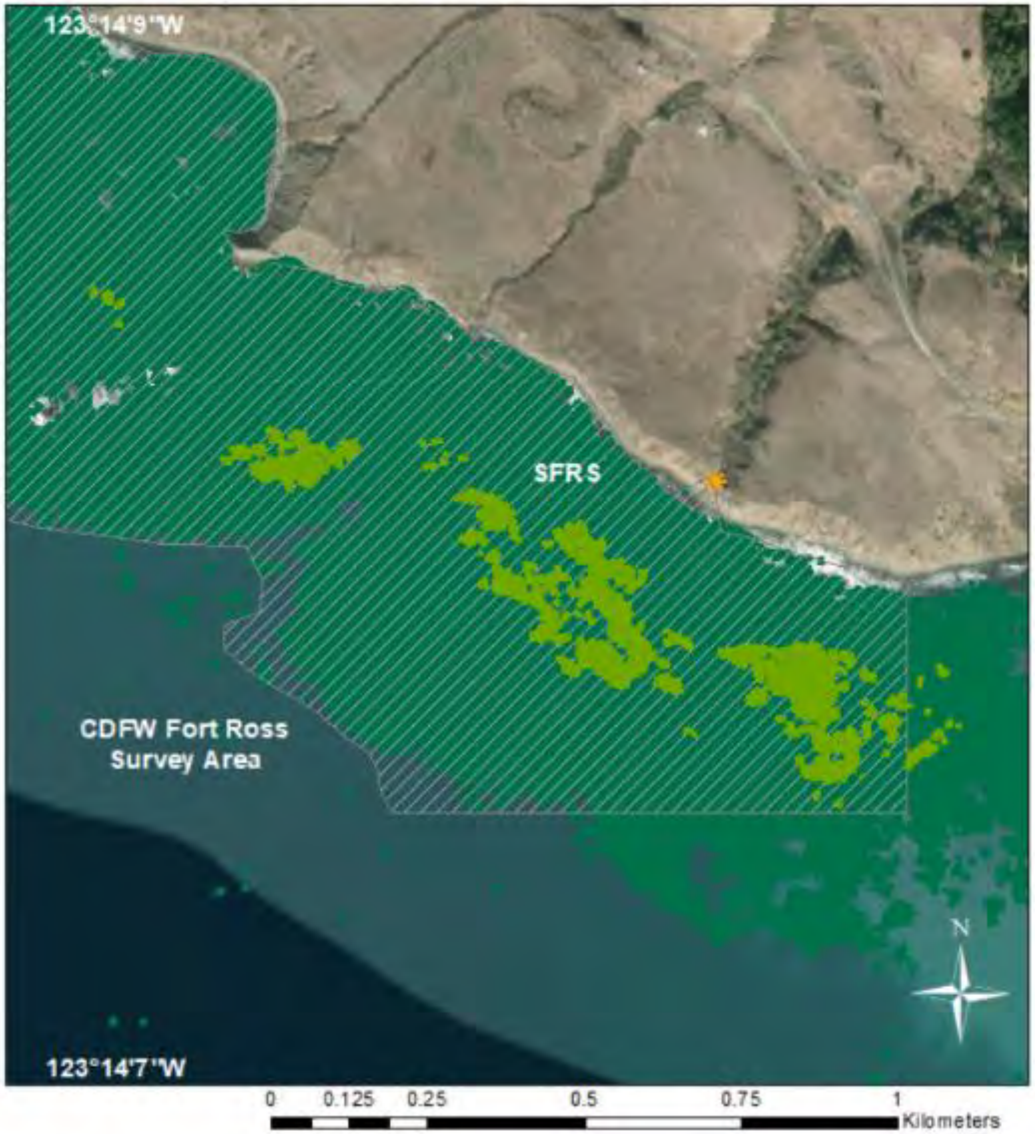
- Tables 5 is provided for reference for managers when determining specific sites for recovery actions.

Figures 17 through 53 represent candidate regions, sites and assessment of site selection criteria. Table 4 applies the weighted rating system above to determine recommendations for priority regions and sites. The weighted criteria provide a framework for further management decisions regarding restoration site selection. For example, it may be decided to give higher weight to sites based on the total area of either layer of persistence, or weighting may be applied to the distance of each region from a coastal access point or a boat launch ramp.



Sonoma Timber Gulch (STG)	
Kelp Patch Area ID	STG
Historical Persistence (m^2)	15636
Current Persistence (m^2)	372
Proximity to Ecosystem Surveys/Areas	Near CDFW Fort Ross Survey Area, near PISCO SPR4
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

Figure 17. Sonoma Timber Gulch candidate region.



Sonoma Fort Ross South (SFRS)	
Kelp Patch Area ID	SFRS
Historical Persistence (m^2)	16384
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Inside CDFW Fort Ross Survey Area
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

Figure 18. Sonoma Fort Ross South candidate region.

Sonoma Fort Ross (SFR)	
Kelp Patch Area ID	SFR
Historical Persistence (m^2)	2056
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Inside CDFW Fort Ross Survey Area, near RC Fort Ross survey site
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

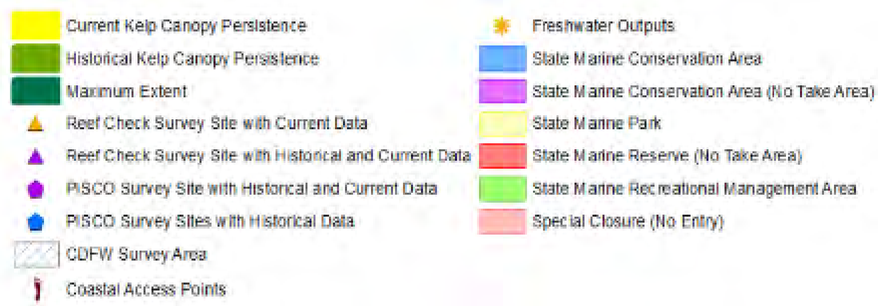
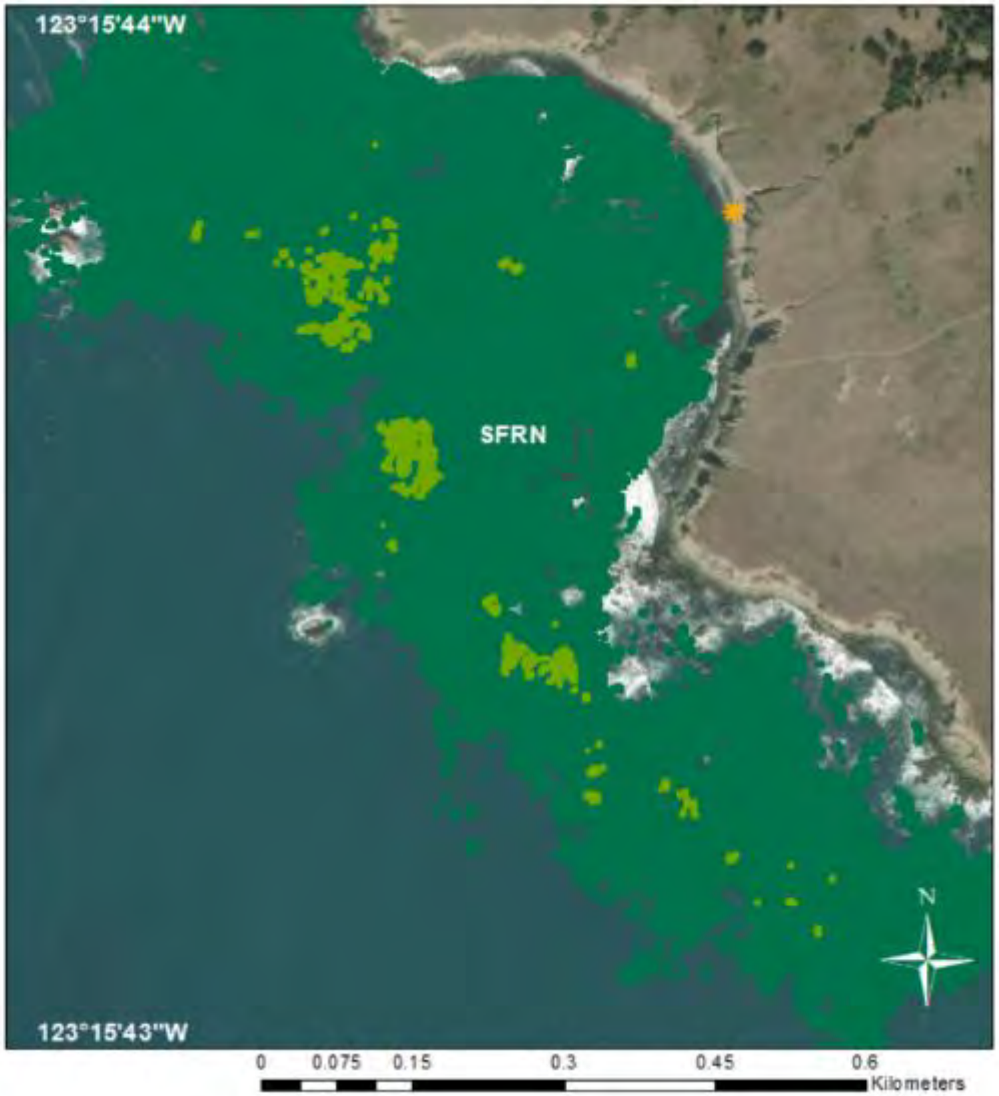


Figure 19. Sonoma Fort Ross candidate region.



Sonoma Fort Ross North (SFRN)	
Kelp Patch Area ID	SFRN
Historical Persistence (m^2)	2795
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

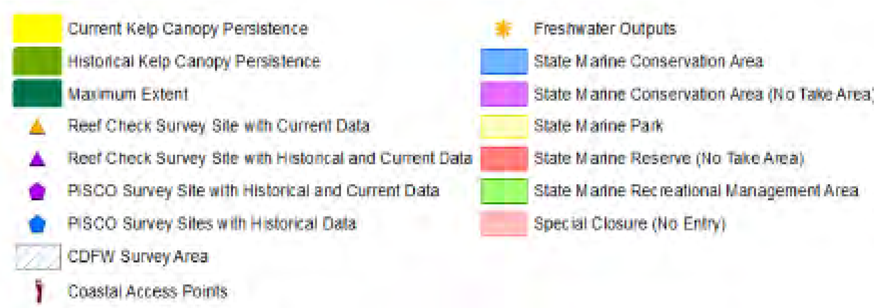
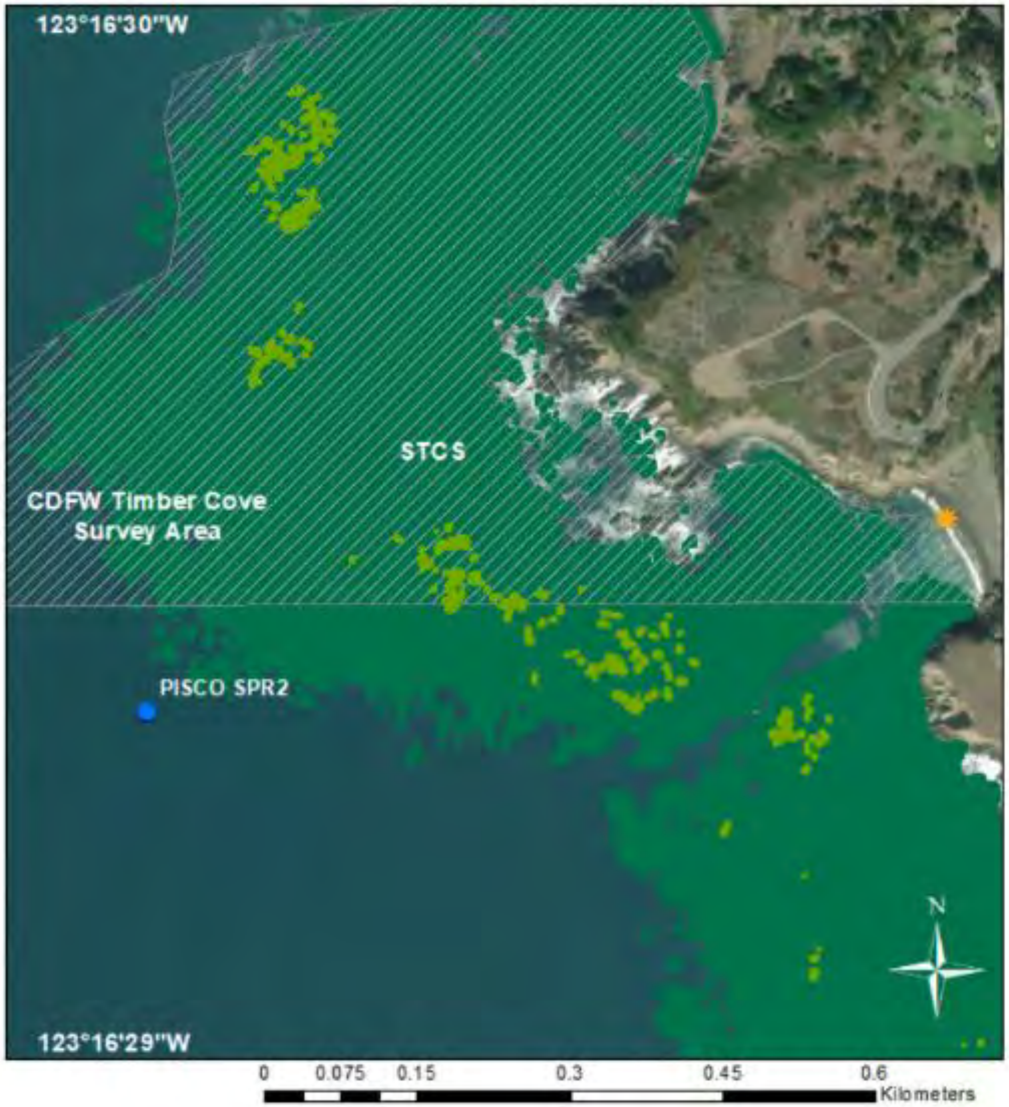


Figure 20. Sonoma Fort Ross North candidate region.



Sonoma Timber Cove South (STCS)	
Kelp Patch Area ID	STCS
Historical Persistence (m^2)	1945
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Inside/near CDFW Timber Cove Survey Area, near PISCO SPR2
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

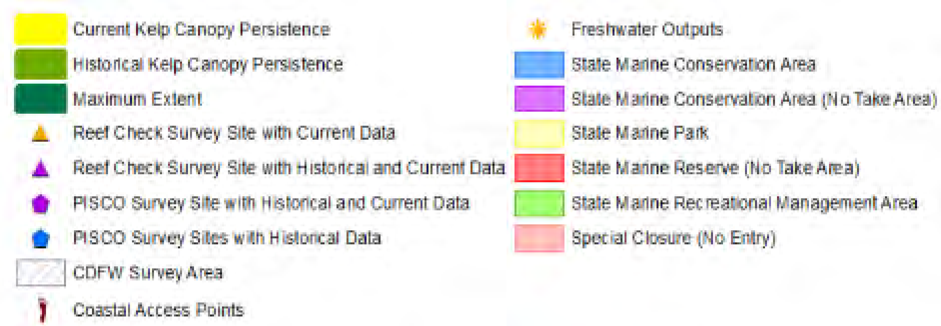


Figure 21. Sonoma Timber Cove South candidate region.

Sonoma Timber Cove Rosson (STCR)	
Kelp Patch Area ID	STCR
Historical Persistence (m^2)	1105
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Inside CDFW Timber Cove Survey Area
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

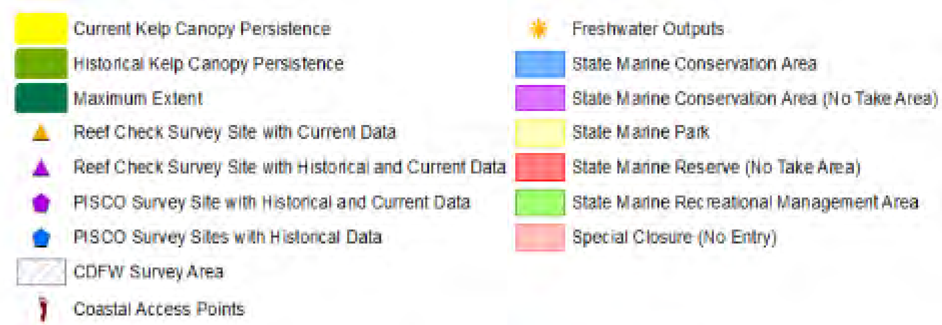
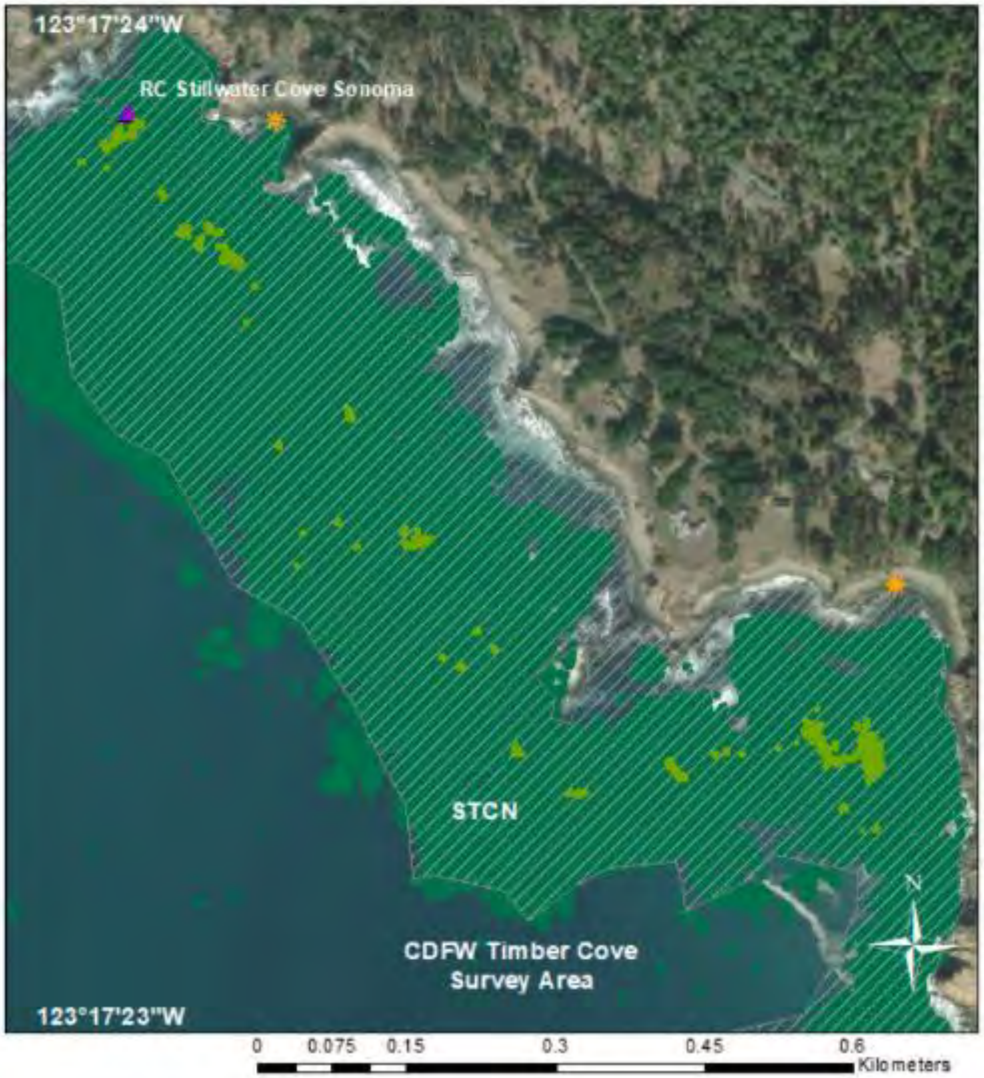


Figure 22. Sonoma Timber Cove Rosson candidate region.



Sonoma Timber Cove North (STCN)	
Kelp Patch Area ID	STCN
Historical Persistence (m^2)	1481
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Inside CDFW Timber Cove Survey Area, near RC Stillwater Cove Sonoma
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

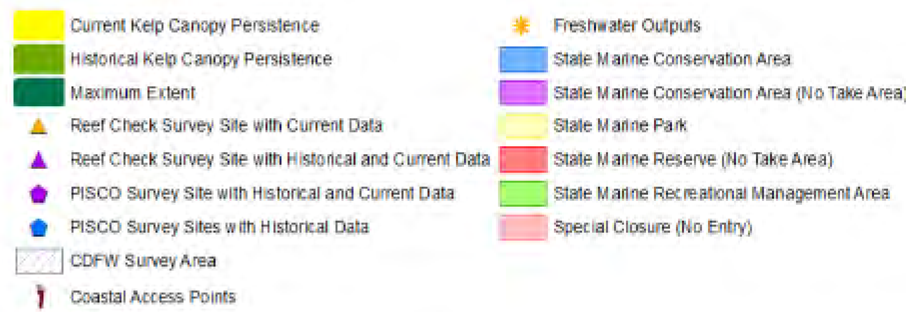
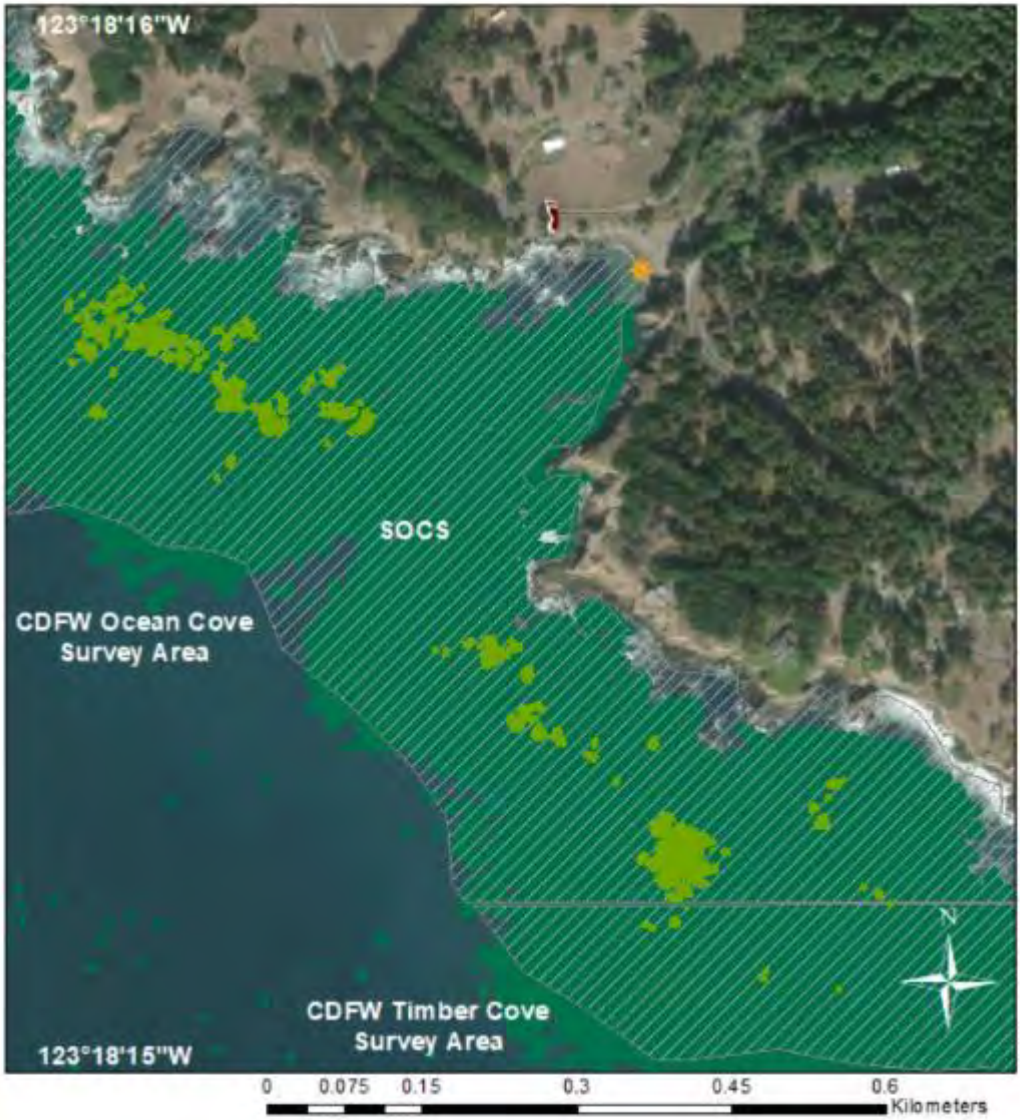


Figure 23. Sonoma Timber Cove North candidate region.

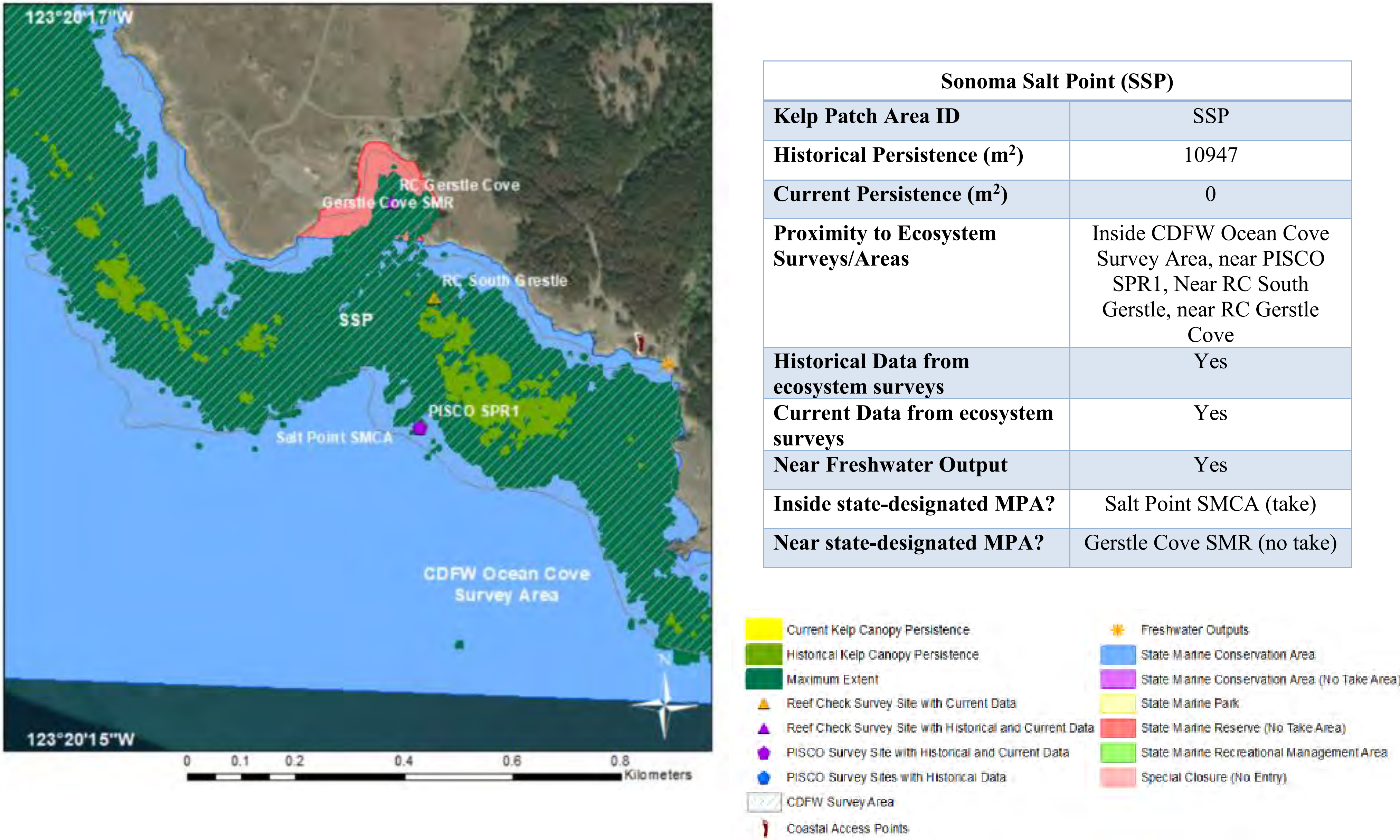


Sonoma Ocean Cove South (SOCS)	
Kelp Patch Area ID	SOCS
Historical Persistence (m^2)	4677
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Inside CDFW Ocean Cove Survey Area
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

Figure 24. Sonoma Ocean Cove South candidate region.

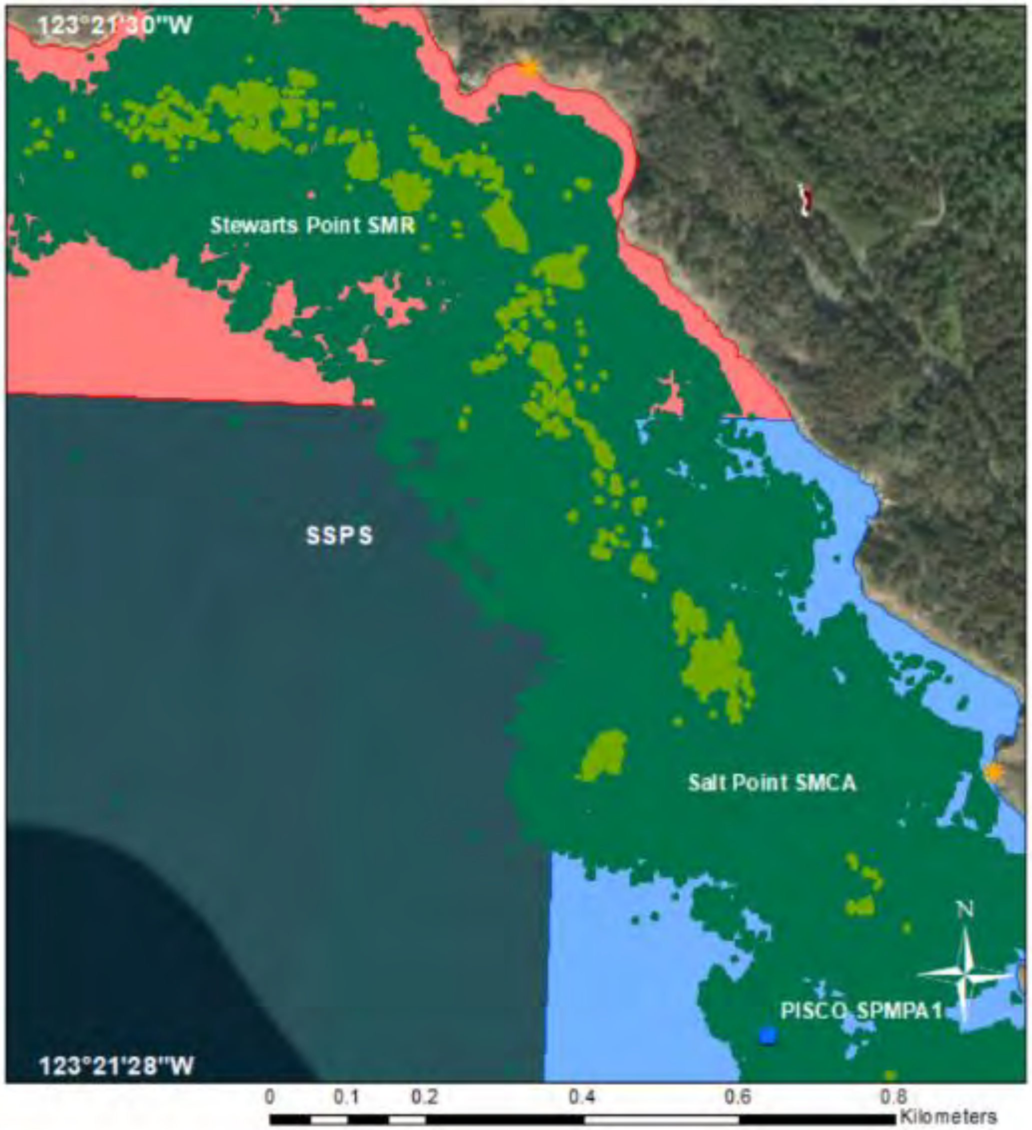
Sonoma Ocean Cove (SOC)	
Kelp Patch Area ID	SSC
Historical Persistence (m^2)	2847
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Inside CDFW Ocean Cove Survey Area, near PISCO SPR5, near RC Ocean Cove
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	Salt Point SMCA (take)

Figure 25. Sonoma Ocean Cove candidate region.



Sonoma Salt Point (SSP)	
Kelp Patch Area ID	SSP
Historical Persistence (m^2)	10947
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Inside CDFW Ocean Cove Survey Area, near PISCO SPR1, Near RC South Gerstle, near RC Gerstle Cove
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	Salt Point SMCA (take)
Near state-designated MPA?	Gerstle Cove SMR (no take)

Figure 26. Sonoma Salt Point candidate region.



Sonoma Stewarts Point South (SSPS)	
Kelp Patch Area ID	SSPS
Historical Persistence (m^2)	13586
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Near PISCO SPMPA1
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	Salt Point SMCA (take), Stewarts Point SMR (no take)
Near state-designated MPA?	Salt Point SMCA (take), Stewarts Point SMR (no take)

Figure 27. Sonoma Stewarts Point South candidate region.

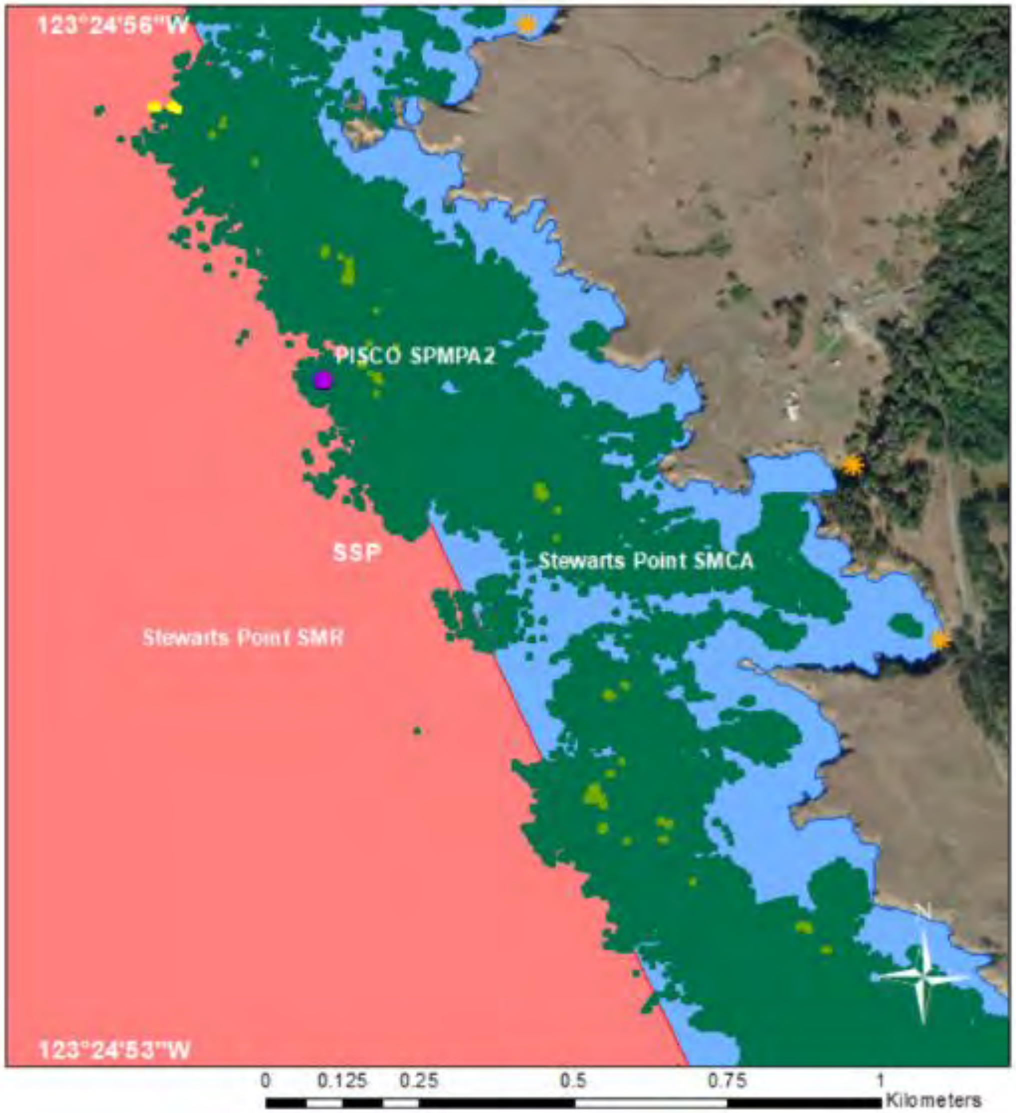


Figure 28. Sonoma Stewarts Point candidate region.

Sonoma Stewarts Point (SSP)	
Kelp Patch Area ID	SSP
Historical Persistence (m^2)	512
Current Persistence (m^2)	76
Proximity to Ecosystem Surveys/Areas	Near PISCO SPMPA2
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	Stewarts Point SMR (no take), Stewarts Point SMCA
Near state-designated MPA?	Stewarts Point SMR (no take), Stewarts Point SMCA

Sonoma Stewarts Point North (SSPN)	
Kelp Patch Area ID	SSPN
Historical Persistence (m²)	322
Current Persistence (m²)	8
Proximity to Ecosystem Surveys/Areas	Near PISCO SPMPA1
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	Stewarts Point SMCA
Near state-designated MPA?	Stewarts Point SMR (no take)

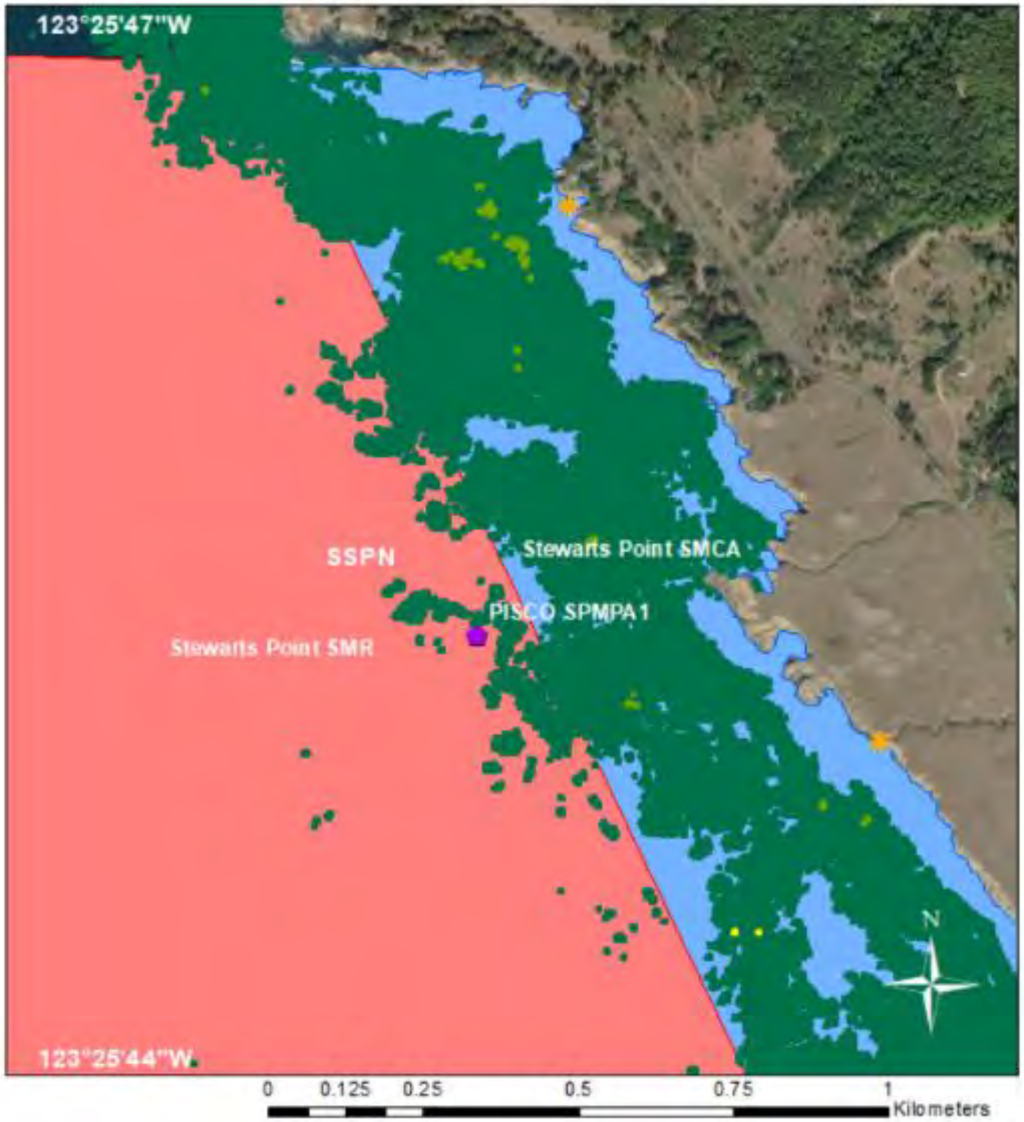
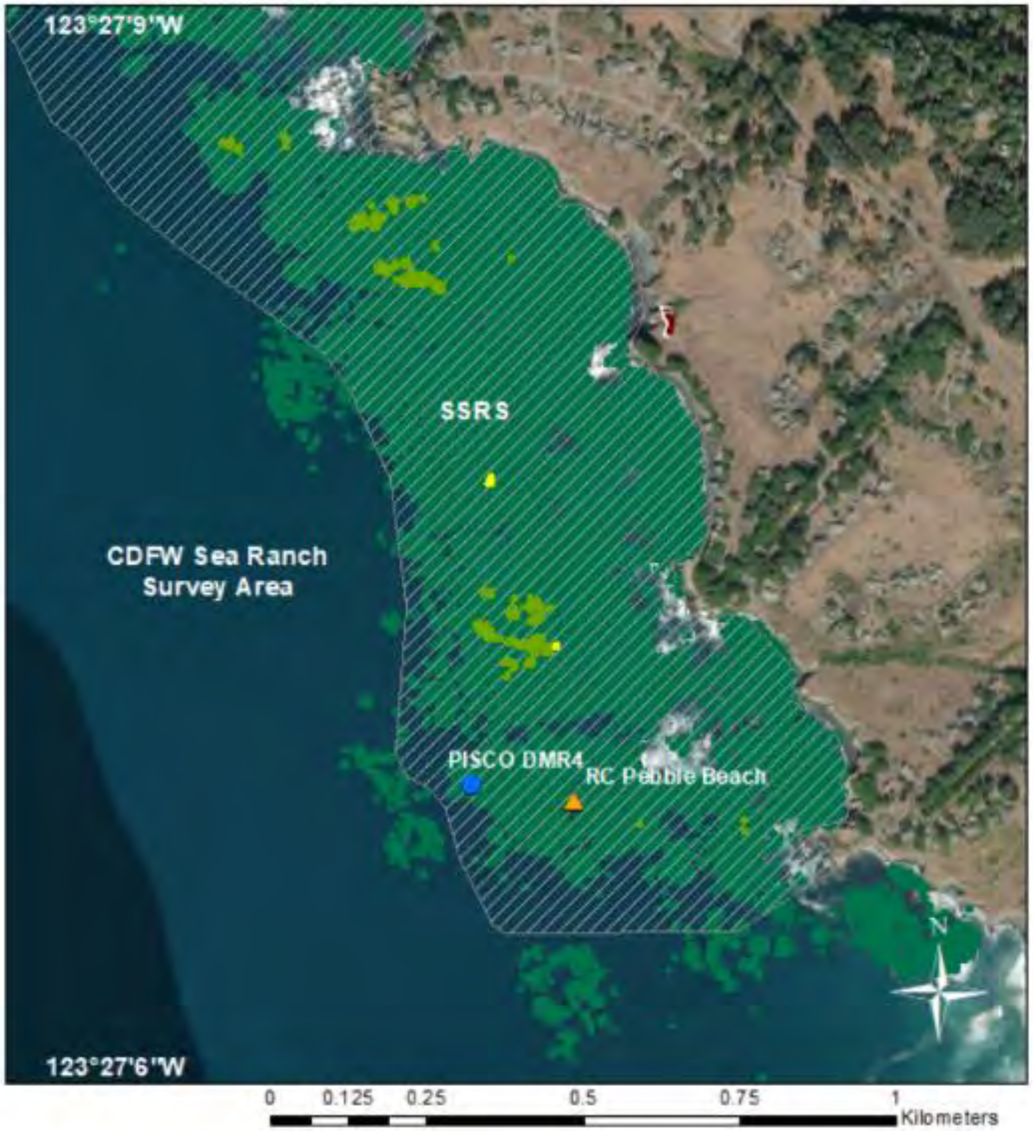


Figure 29. Sonoma Sea Ranch candidate region.

Sonoma Sea Ranch South (SSRS)	
Kelp Patch Area ID	SSRS
Historical Persistence (m^2)	2128
Current Persistence (m^2)	16
Proximity to Ecosystem Surveys/Areas	Inside CDFW Sea Ranch Survey Area, near PISCO DMR4, near RC Pebble Beach
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	No
Inside state-designated MPA?	No
Near state-designated MPA?	No



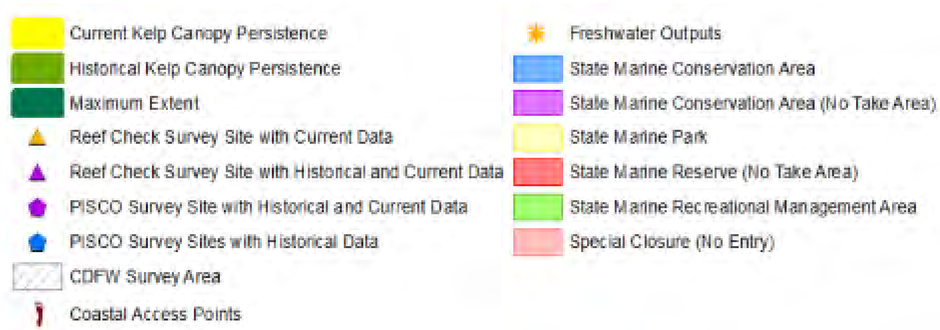
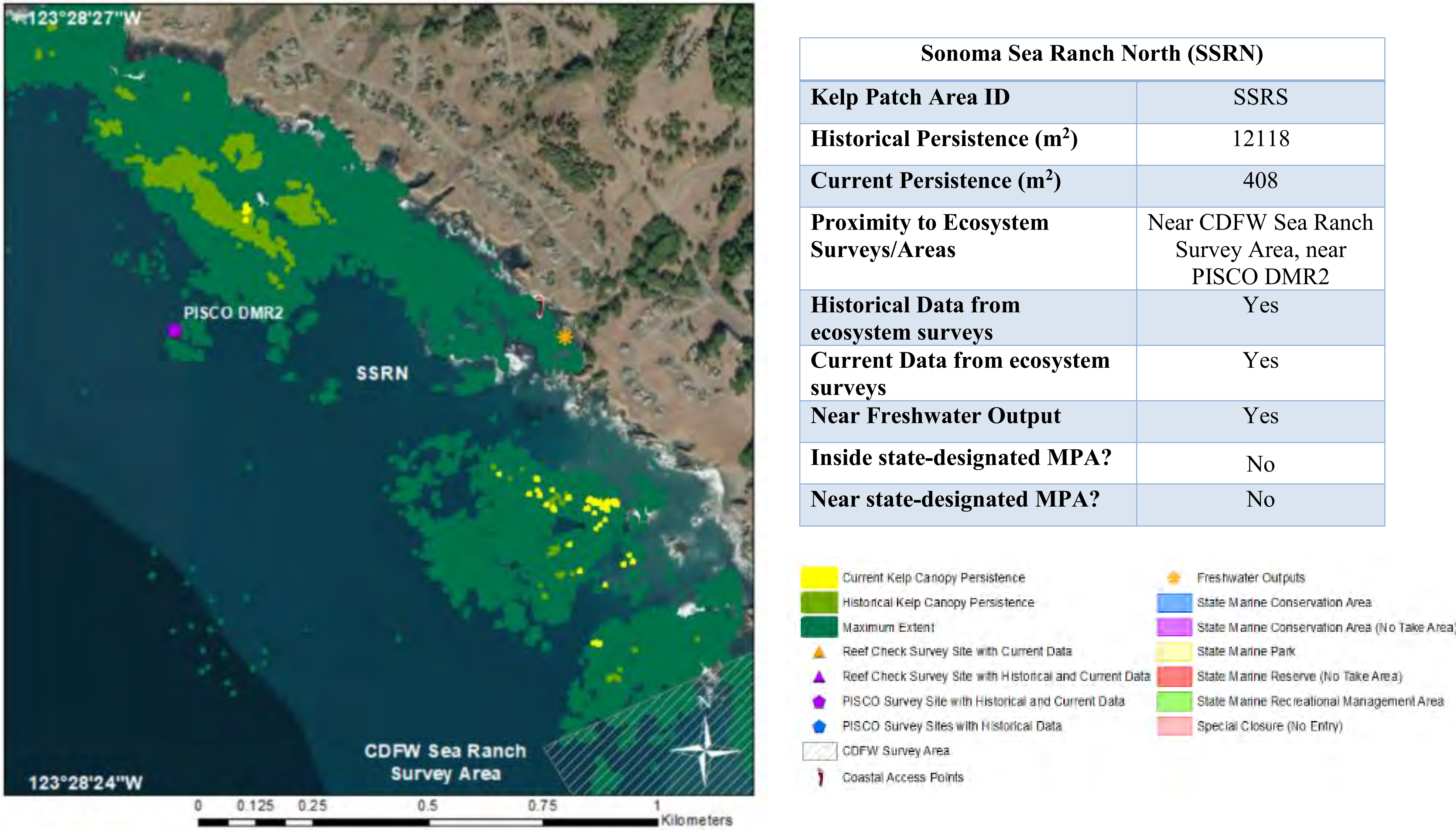
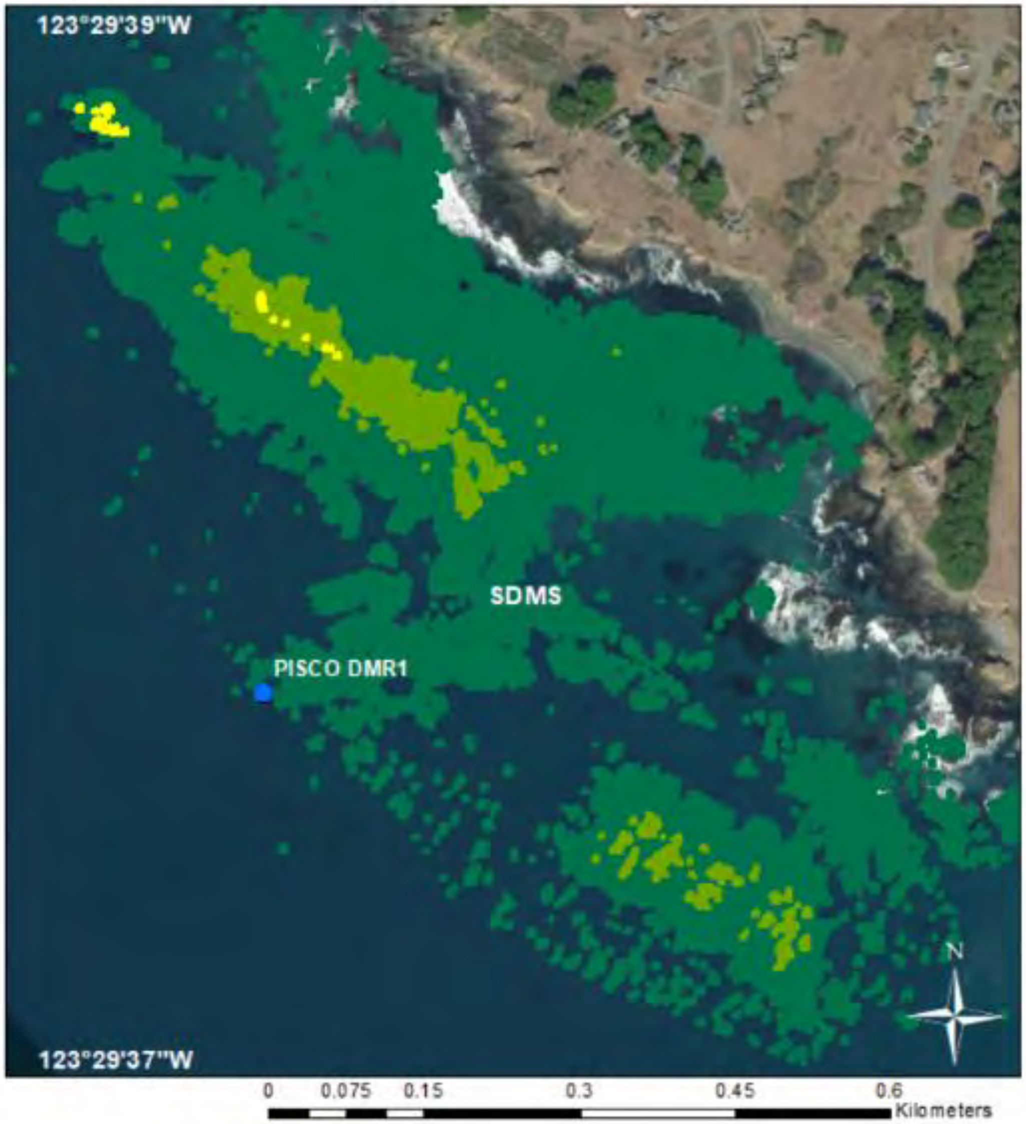


Figure 30. Sonoma Sea Ranch South candidate region.



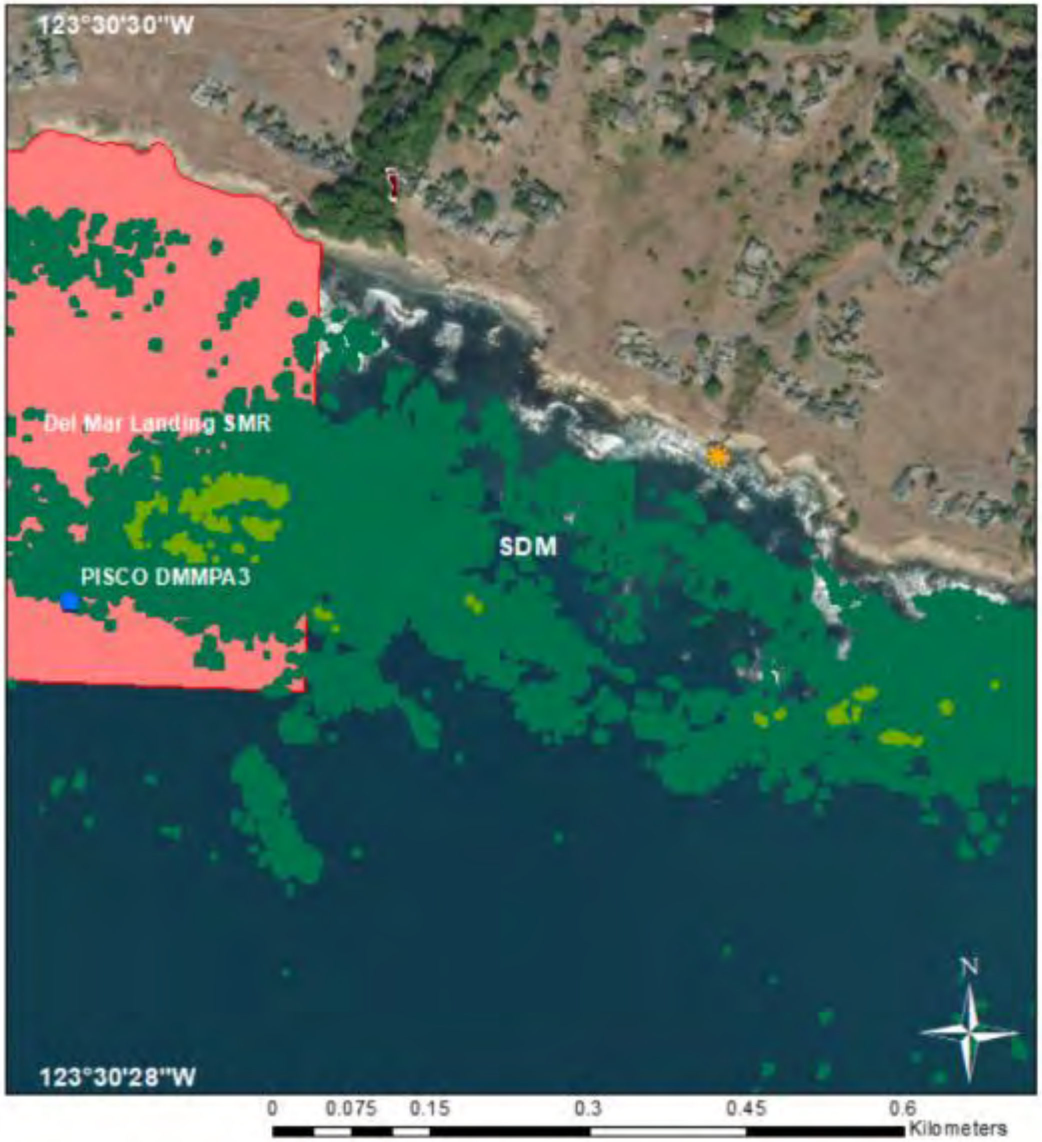
Sonoma Sea Ranch North (SSRN)	
Kelp Patch Area ID	SSRS
Historical Persistence (m^2)	12118
Current Persistence (m^2)	408
Proximity to Ecosystem Surveys/Areas	Near CDFW Sea Ranch Survey Area, near PISCO DMR2
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

Figure 31. Sonoma Sea Ranch North candidate region.



Sonoma Del Mar South (SDMS)	
Kelp Patch Area ID	SDMS
Historical Persistence (m^2)	12474
Current Persistence (m^2)	264
Proximity to Ecosystem Surveys/Areas	Near PISCO DMR1
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	No
Near Freshwater Output	No
Inside state-designated MPA?	Yes
Near state-designated MPA?	No

Figure 32. Sonoma Del Mar South candidate region.



Sonoma Del Mar (SDM)	
Kelp Patch Area ID	SDM
Historical Persistence (m^2)	2086
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Near PISCO DMMPA3
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	Del Mar Landing SMR
Near state-designated MPA?	Del Mar Landing SMR

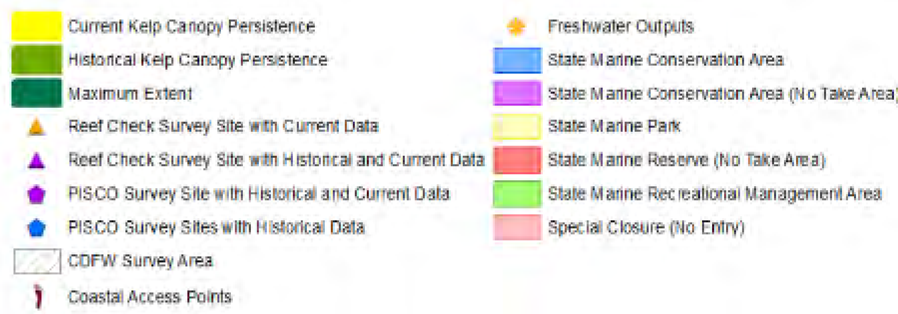
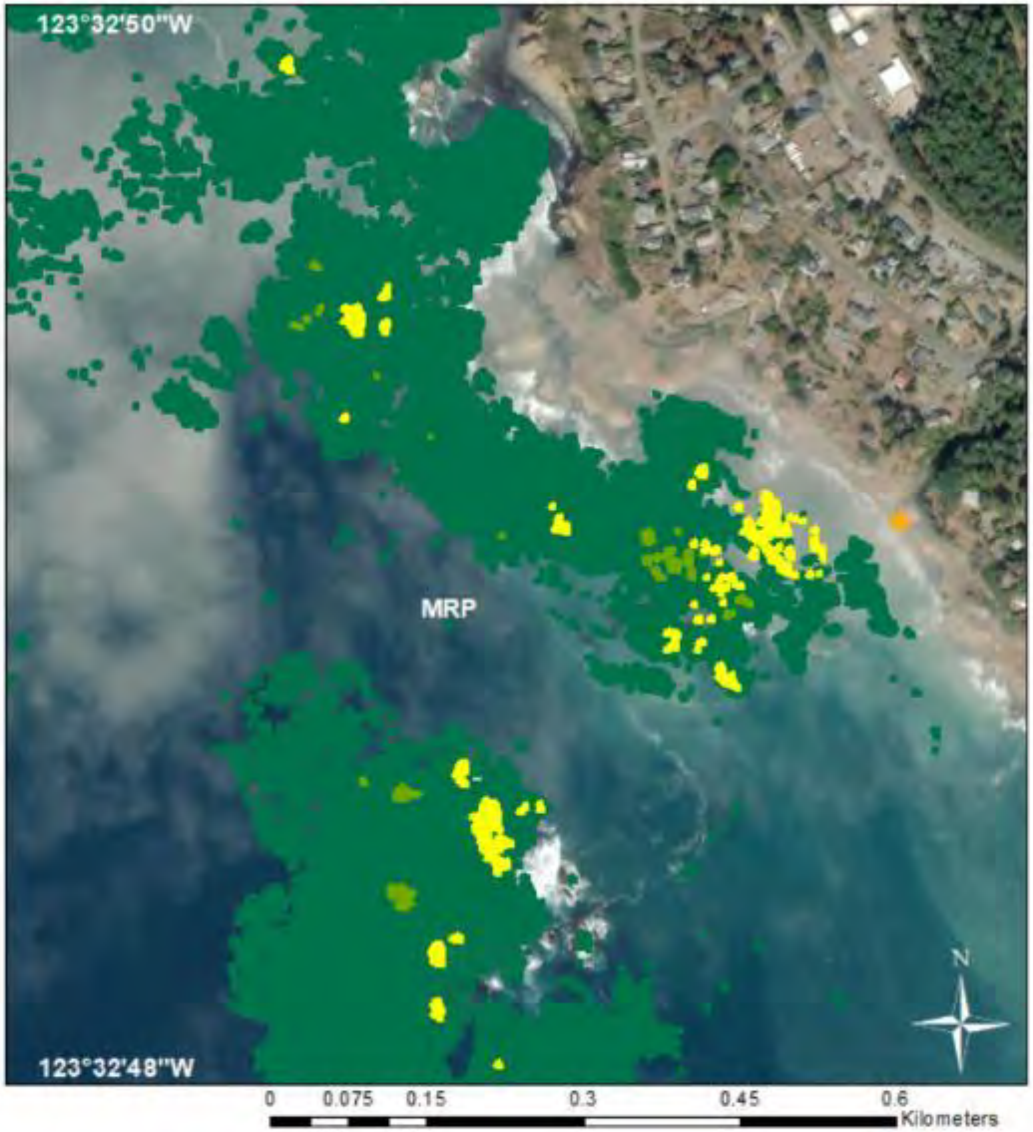
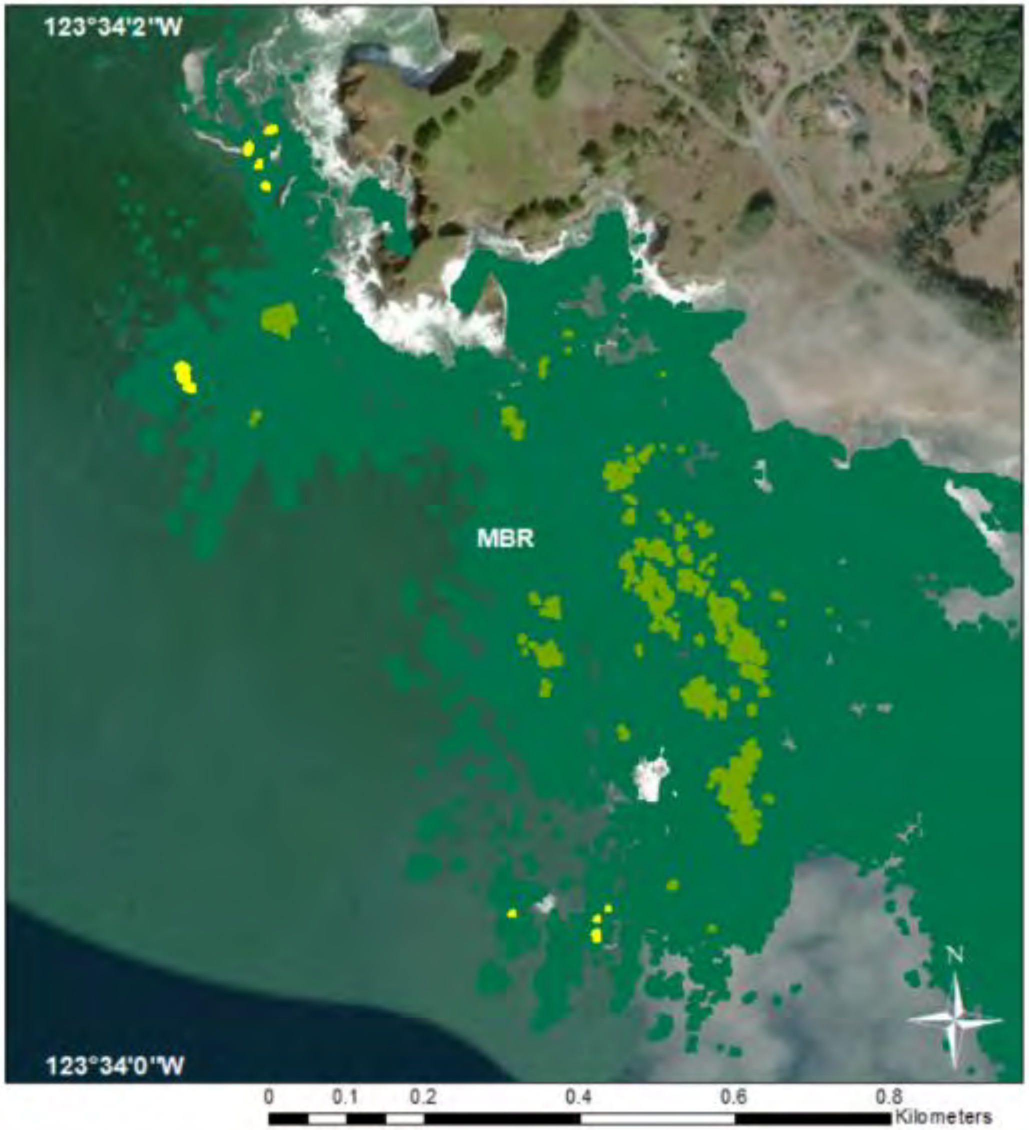


Figure 33. Sonoma Del Mar candidate region



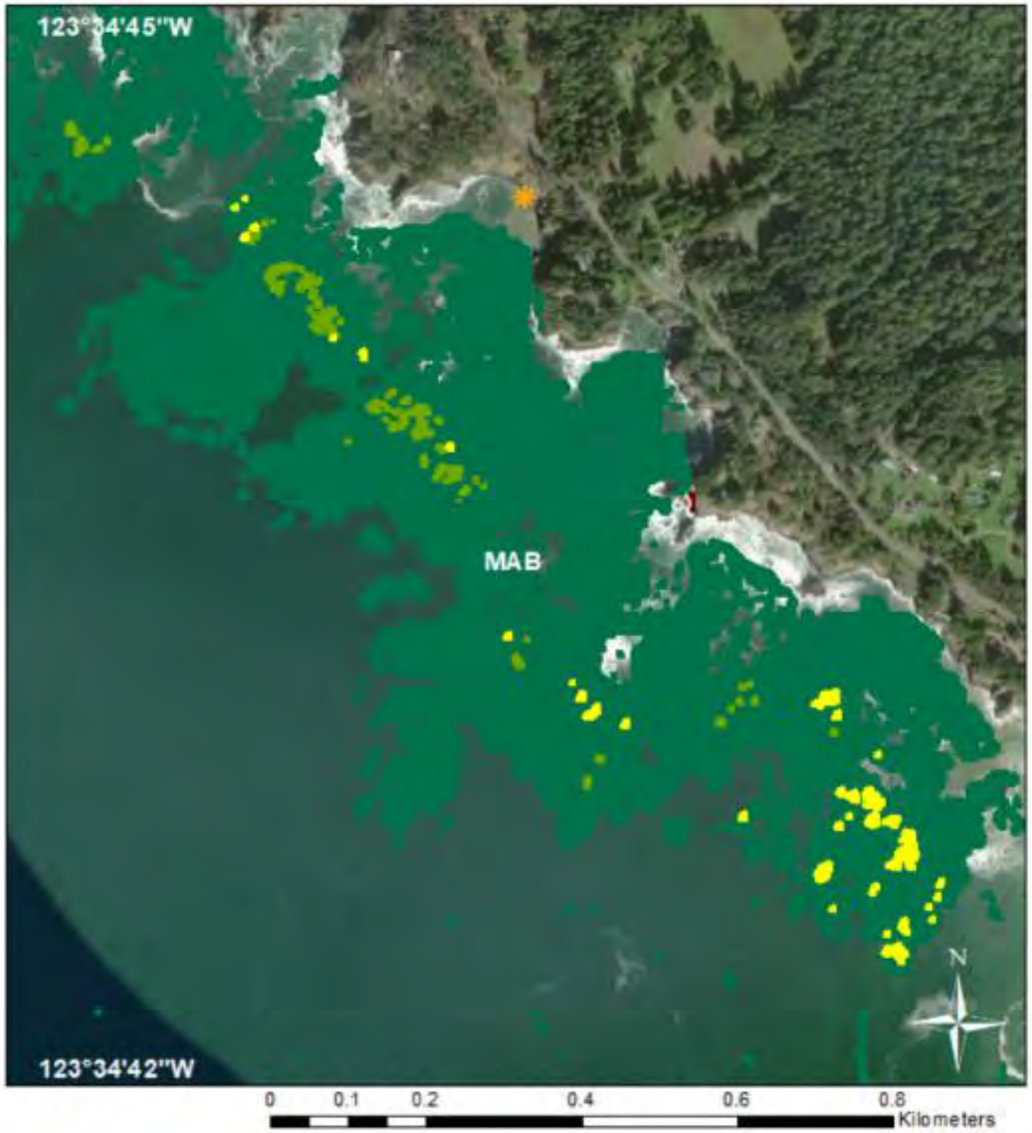
Mendocino Robinson Point (MRP)	
Kelp Patch Area ID	MRP
Historical Persistence (m^2)	599
Current Persistence (m^2)	2768
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

Figure 34. Mendocino Robinson Point candidate region.



Mendocino Bourns Rock (MBR)	
Kelp Patch Area ID	MBR
Historical Persistence (m^2)	5353
Current Persistence (m^2)	292
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

Figure 35. Mendocino Bourns Rock candidate region.



Mendocino Anchor Bay (MAB)	
Kelp Patch Area ID	MAB
Historical Persistence (m^2)	1148
Current Persistence (m^2)	1864
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

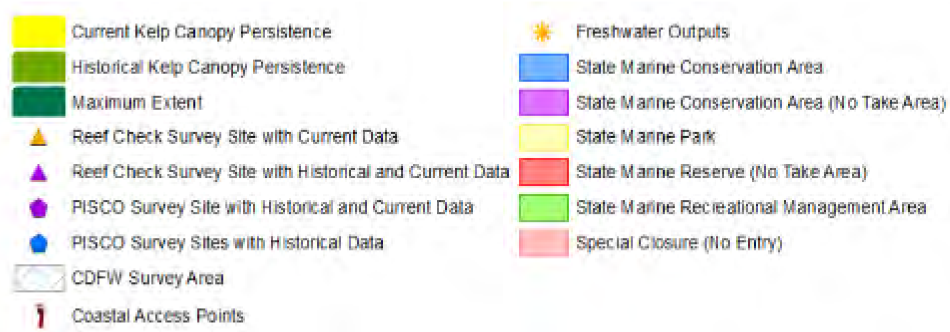
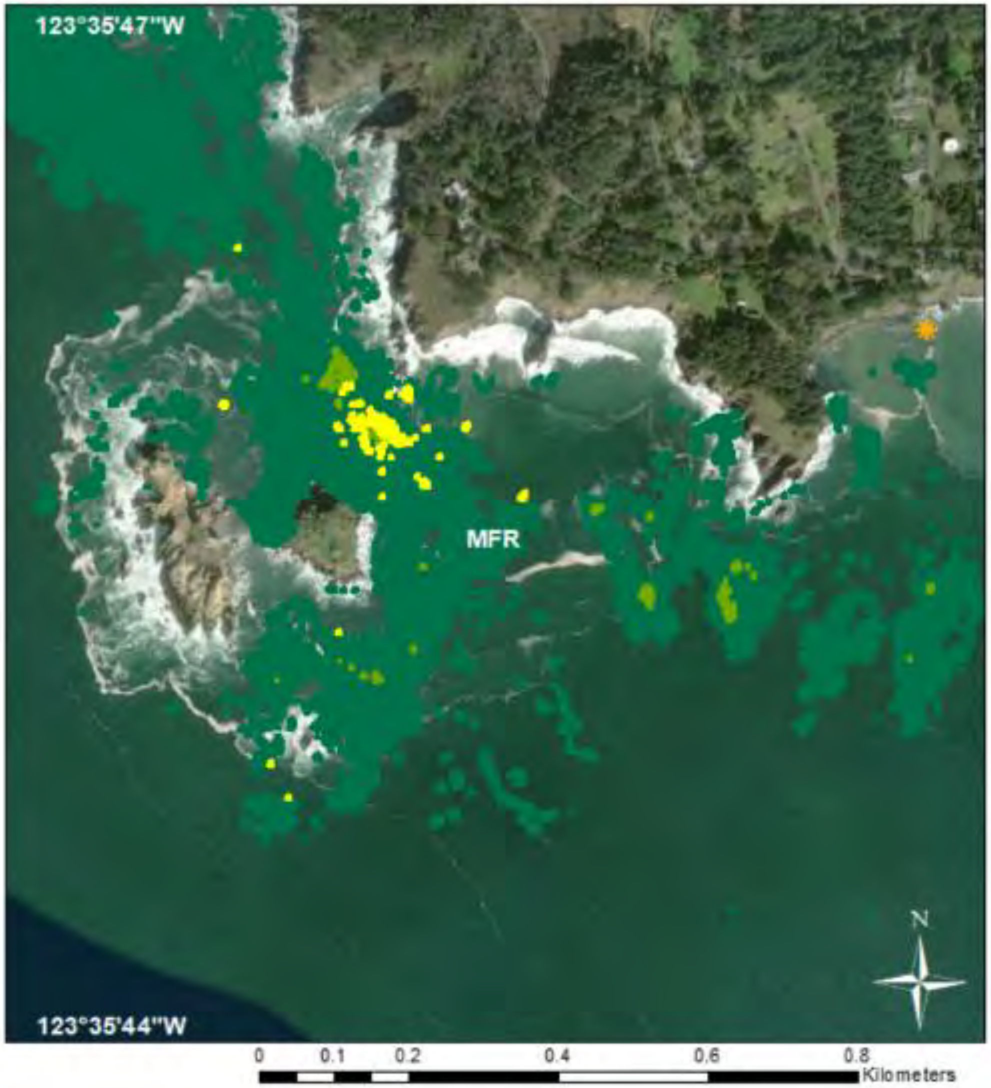
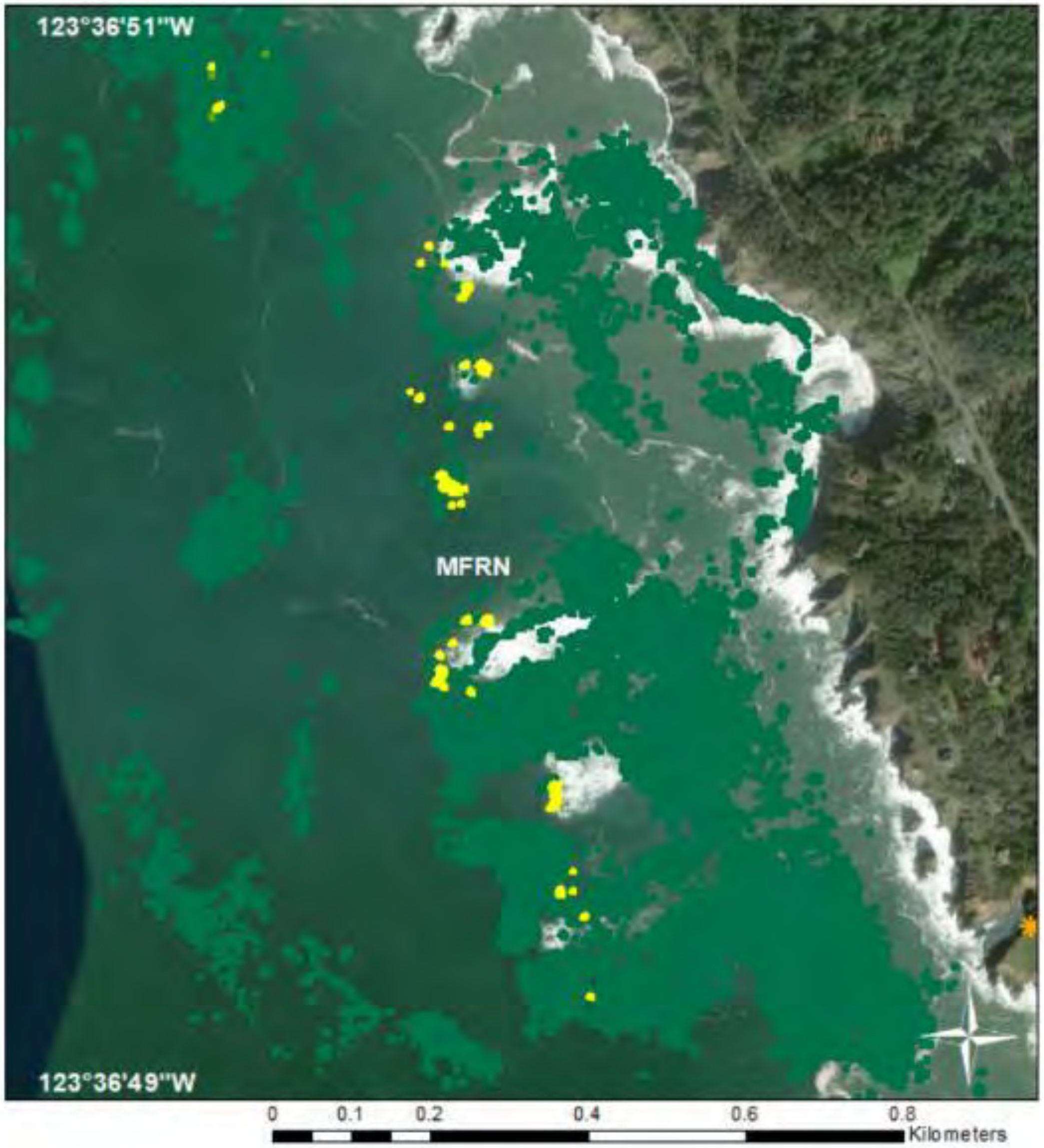


Figure 36. Mendocino Anchor Bay candidate region.



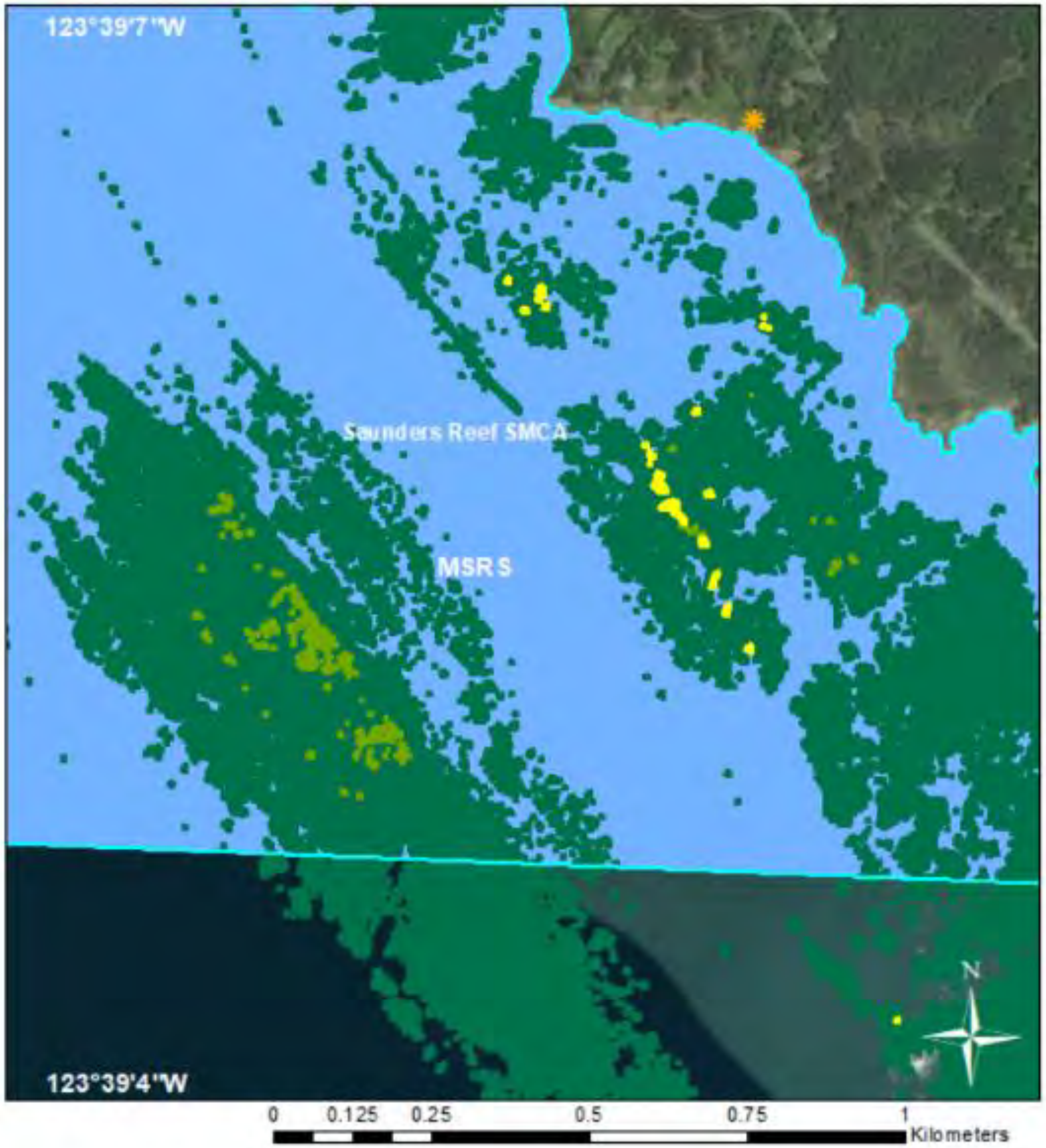
Mendocino Fish Rock (MFR)	
Kelp Patch Area ID	MFR
Historical Persistence (m^2)	1359
Current Persistence (m^2)	1075
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

Figure 37. Mendocino Fish Rock candidate region.



Mendocino Fish Rock North (MFRN)	
Kelp Patch Area ID	MFRN
Historical Persistence (m^2)	12
Current Persistence (m^2)	878
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

Figure 38. Mendocino Fish Rock North candidate region



Mendocino Saunders Reef South (MSRS)	
Kelp Patch Area ID	MSRS
Historical Persistence (m^2)	1547
Current Persistence (m^2)	912
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	Saunders Reef SMCA (take)
Near state-designated MPA?	No

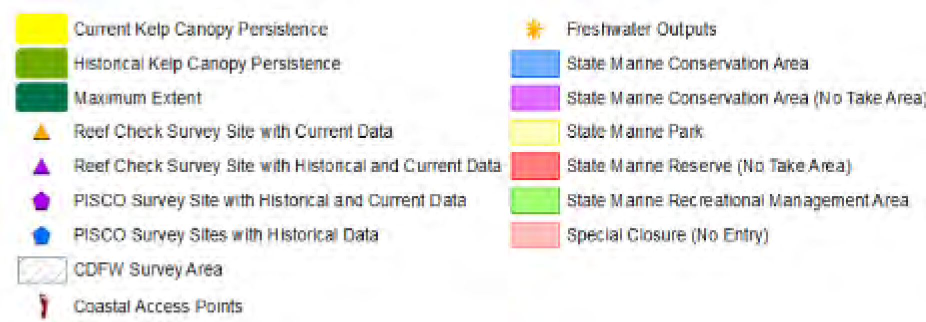


Figure 39. Mendocino Saunders Reef South candidate region.

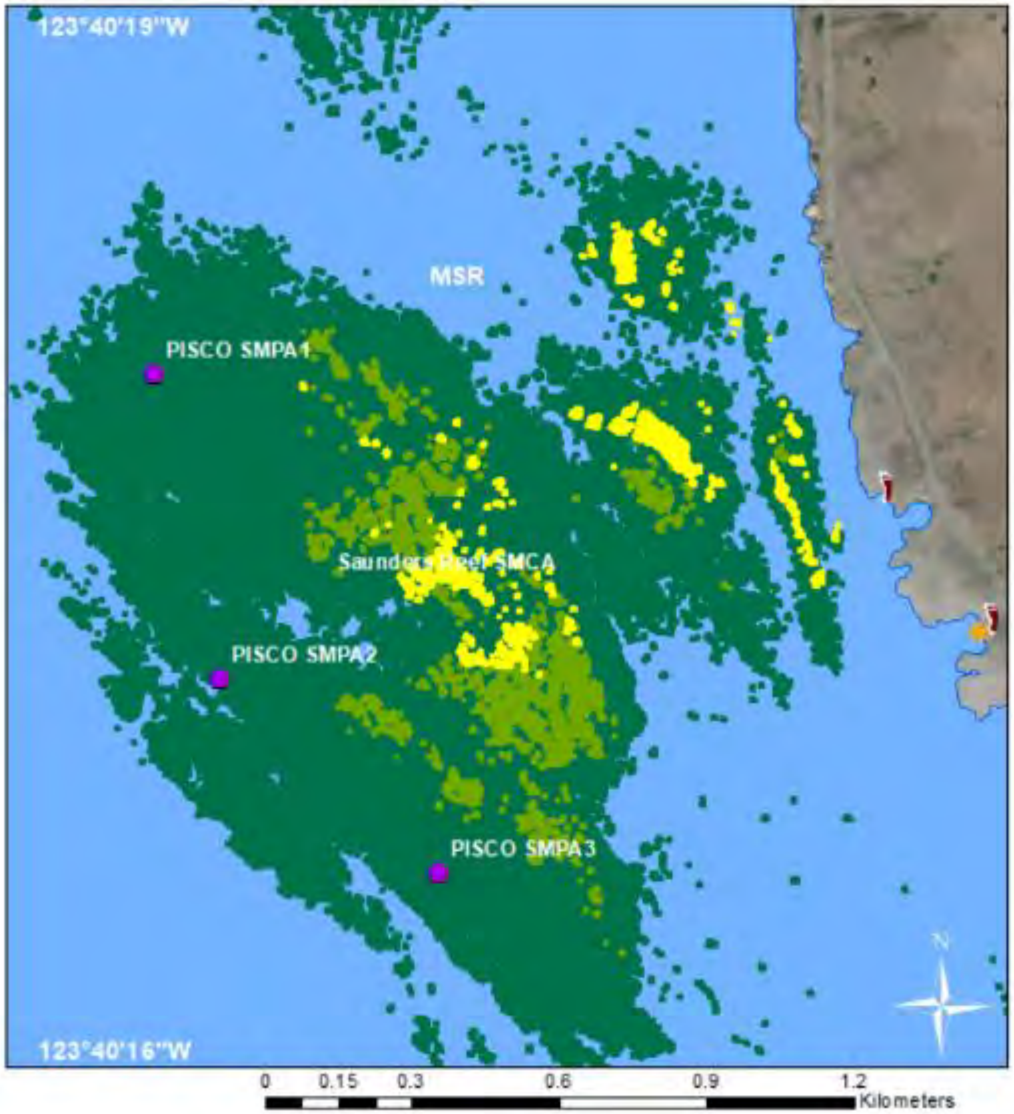
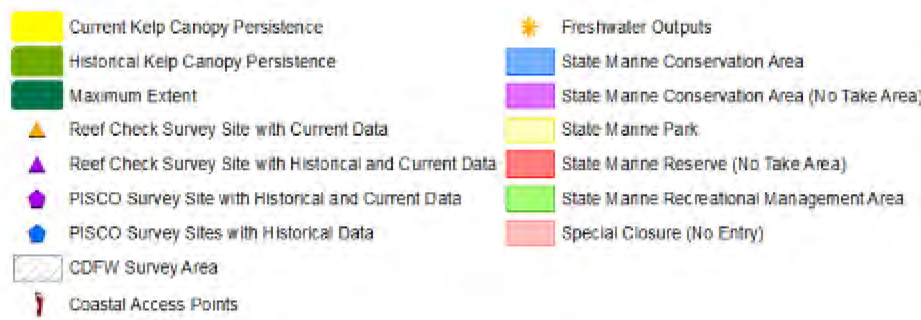
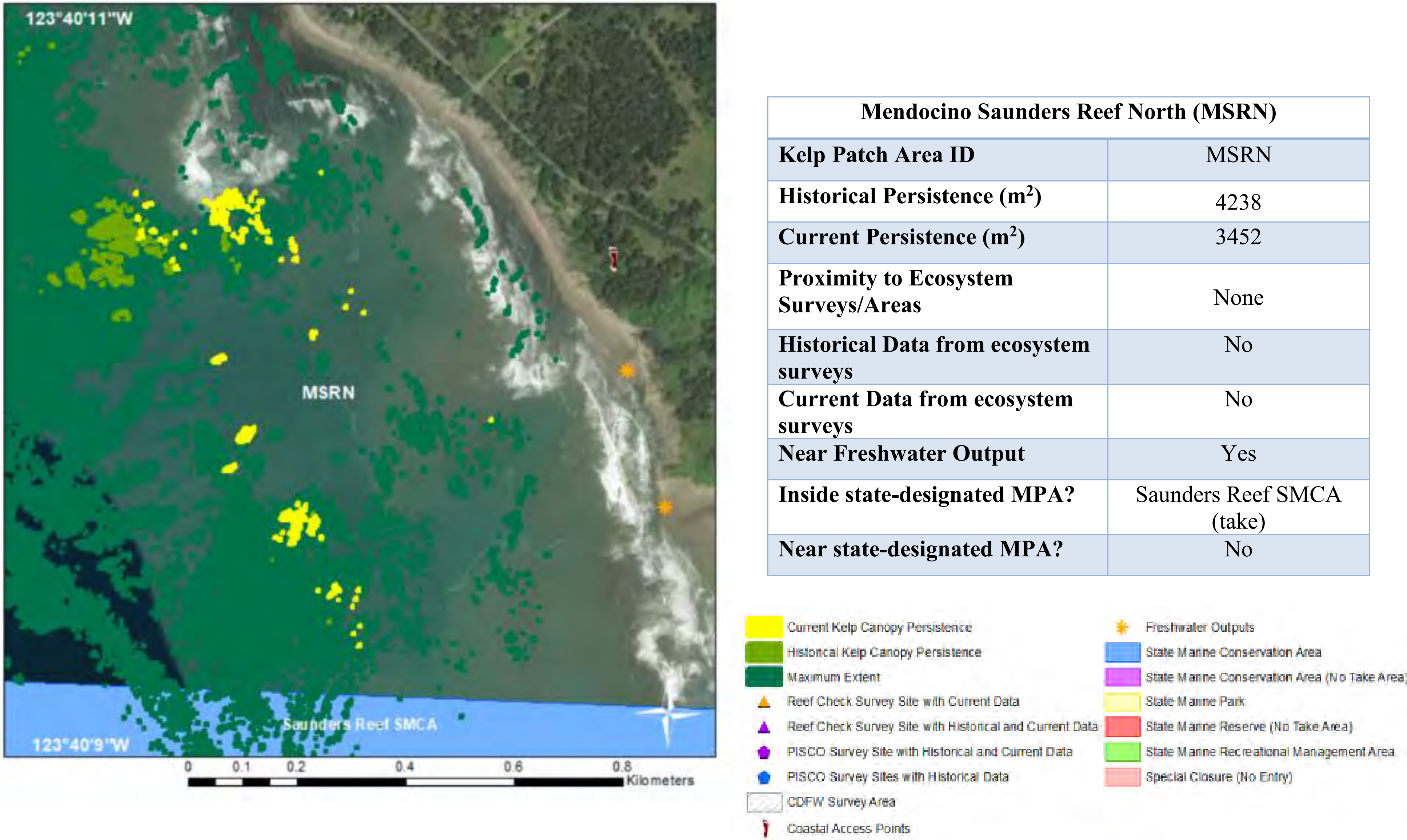


Figure 40. Mendocino Saunders Reef candidate region.

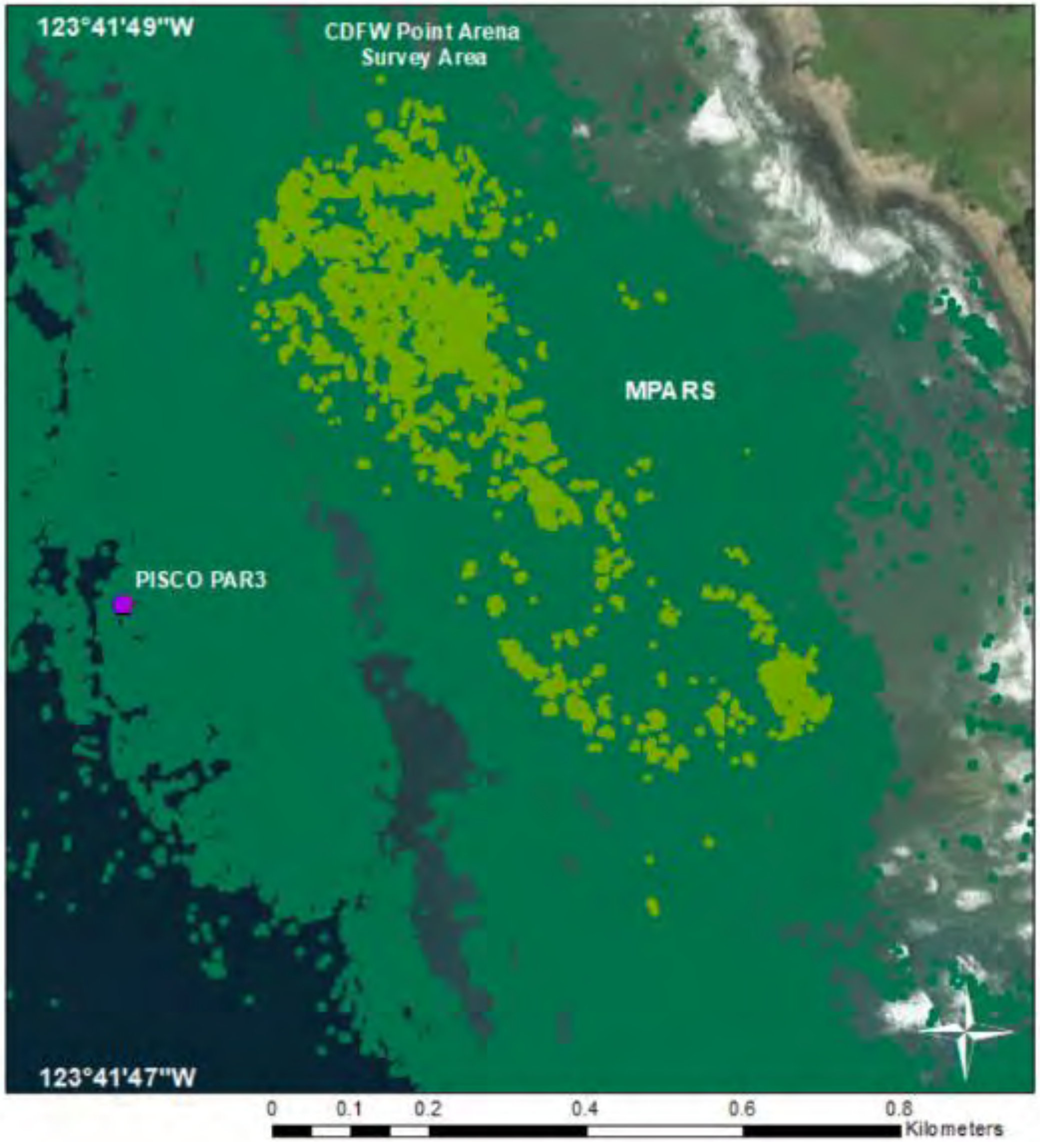
Mendocino Saunders Reef (MSR)	
Kelp Patch Area ID	MSR
Historical Persistence (m²)	16774
Current Persistence (m²)	12312
Proximity to Ecosystem Surveys/Areas	Near PISCO SMPA1, PISCO SMPA2, PISCO SMPA3
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	Saunders Reef SMCA (take)
Near state-designated MPA?	No





Mendocino Saunders Reef North (MSRN)	
Kelp Patch Area ID	MSRN
Historical Persistence (m^2)	4238
Current Persistence (m^2)	3452
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	Saunders Reef SMCA (take)
Near state-designated MPA?	No

Figure 41. Mendocino Saunders Reef North candidate region.



Mendocino Point Arena South (MPARS)	
Kelp Patch Area ID	MPARS
Historical Persistence (m^2)	30559
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Near PISCO PAR3
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

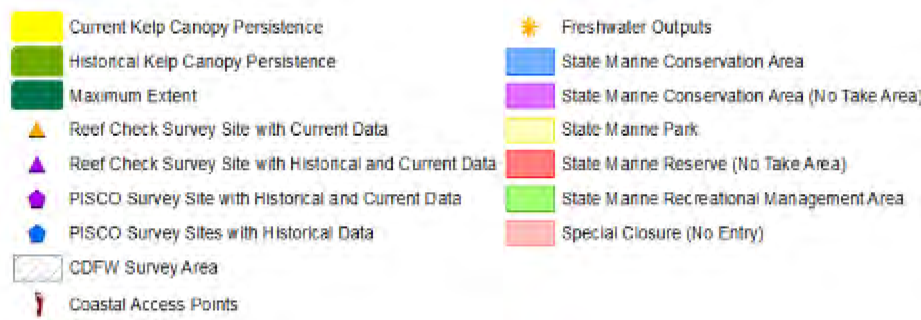
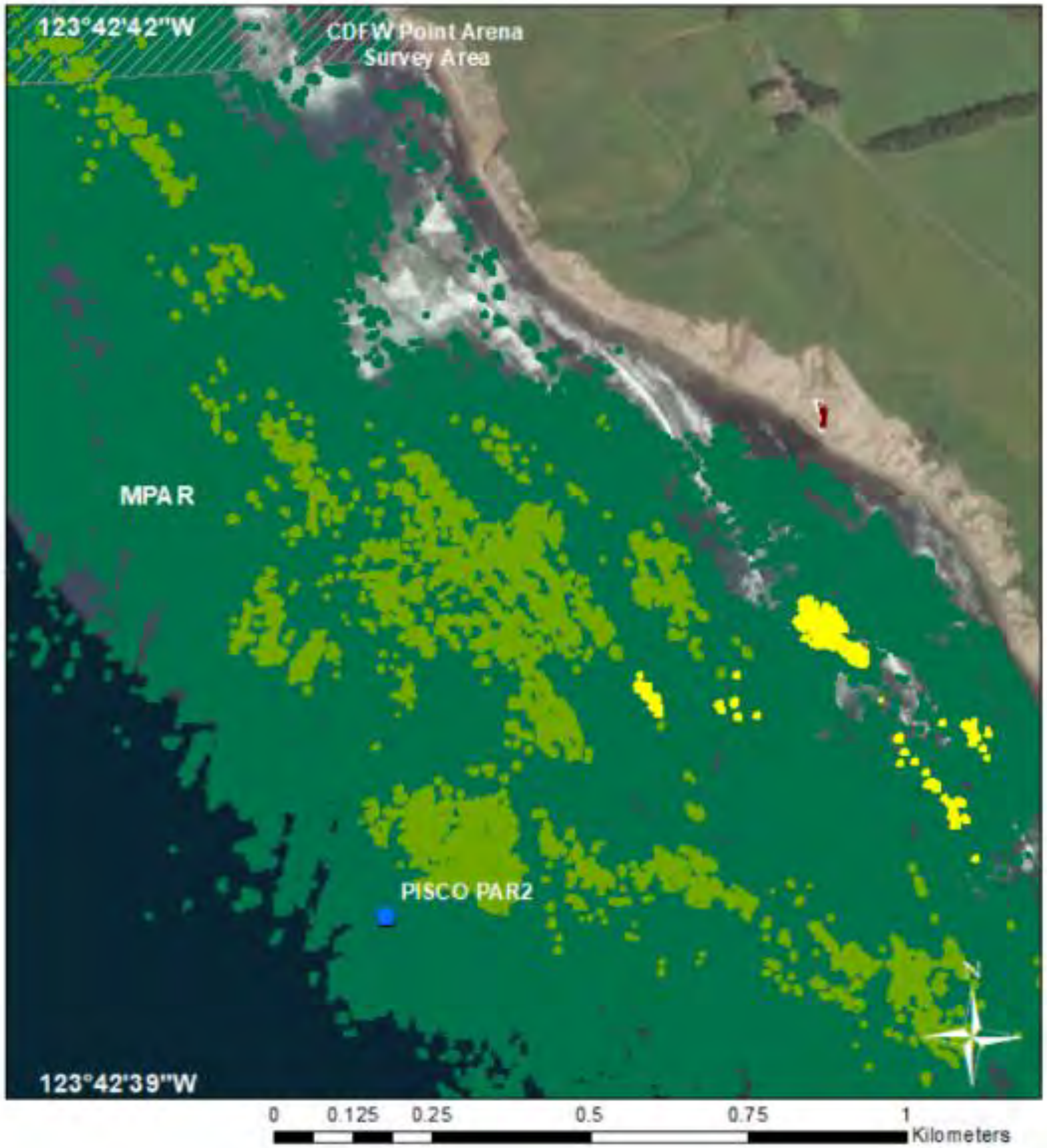


Figure 42. Mendocino Point Arena South candidate region.



Mendocino Point Arena (MPAR)	
Kelp Patch Area ID	MPAR
Historical Persistence (m^2)	43419
Current Persistence (m^2)	3079
Proximity to Ecosystem Surveys/Areas	Near CDFW Point Arena Survey Area, near PISCO PAR2
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

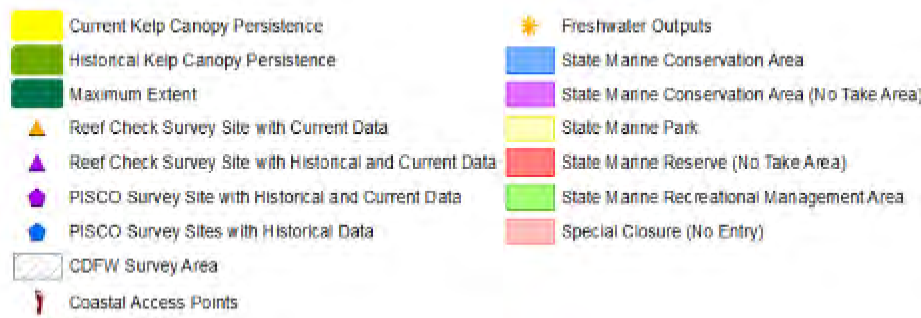
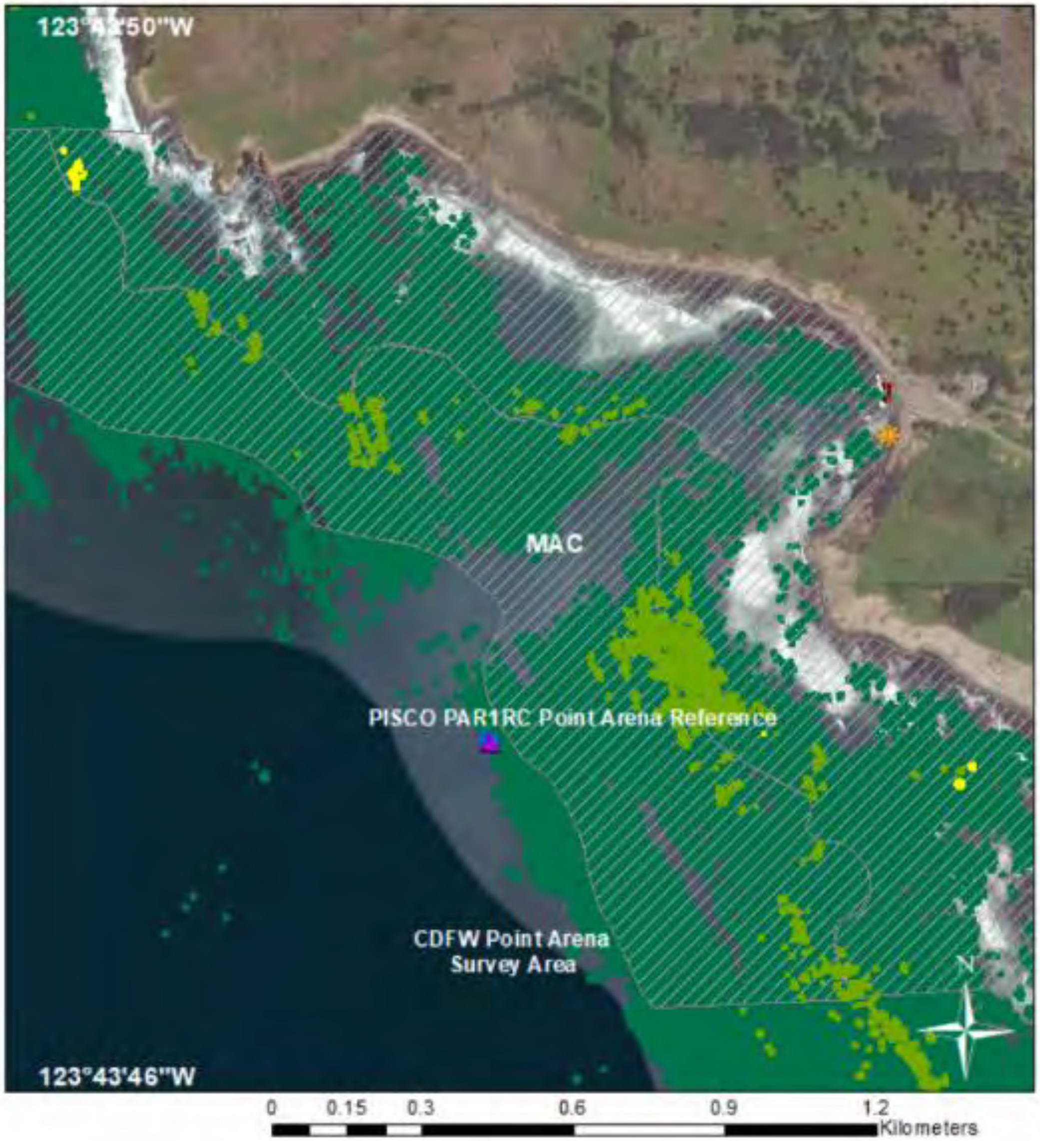


Figure 43. Mendocino Point Arena candidate region.



Mendocino Arena Cove (MAC)	
Kelp Patch Area ID	MAC
Historical Persistence (m^2)	12168
Current Persistence (m^2)	192
Proximity to Ecosystem Surveys/Areas	Inside CDFW Point Arena Survey Area, near PISCO PAR1, near RC Point Arena Reference
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

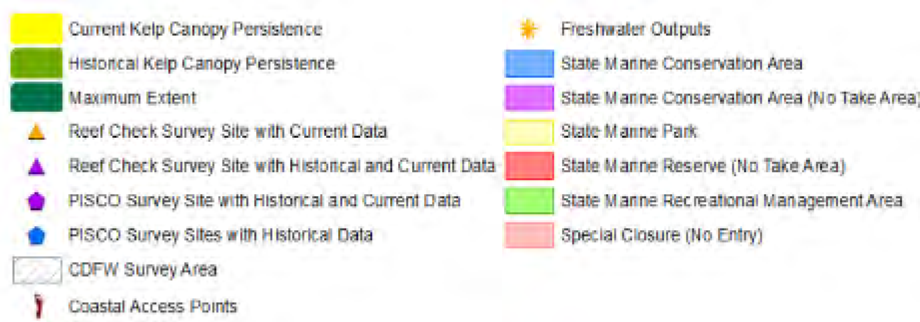
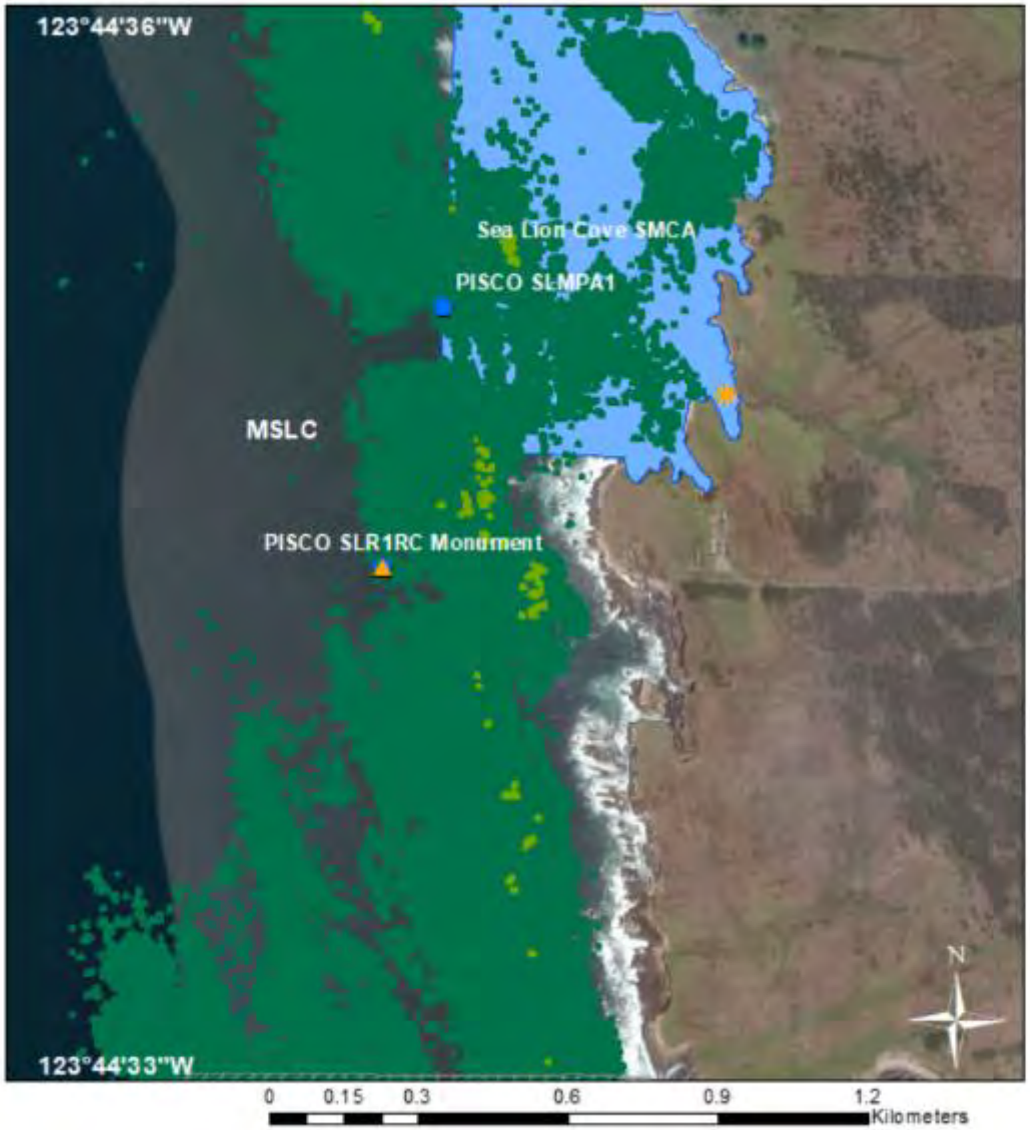


Figure 44. Mendocino Arena Cove candidate region.



Mendocino Sea Lion Cove (MSLC)	
Kelp Patch Area ID	MSLC
Historical Persistence (m^2)	860
Current Persistence (m^2)	0
Proximity to Ecosystem Surveys/Areas	Near CDFW Point Arena Survey Area, PISCO SLR1, PISCO SLMPA1, RC Monument
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	Sea Lion Cove SMCA (take)

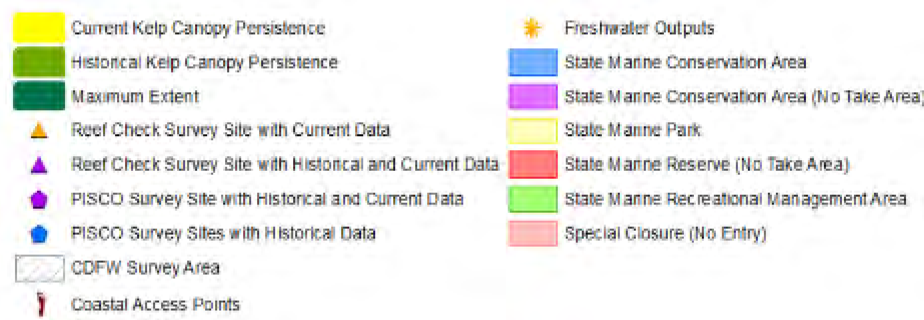


Figure 45. Mendocino Sea Lion Cove candidate region.

Mendocino Greenwood Creek (MGC)	
Kelp Patch Area ID	MGC
Historical Persistence (m^2)	2700
Current Persistence (m^2)	16
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	No
Inside state-designated MPA?	No
Near state-designated MPA?	No

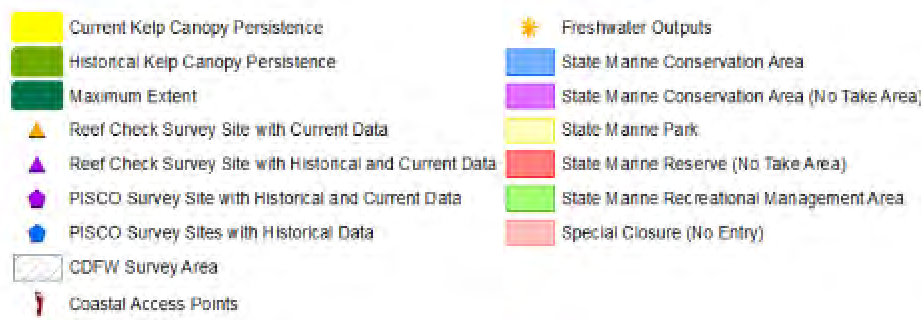
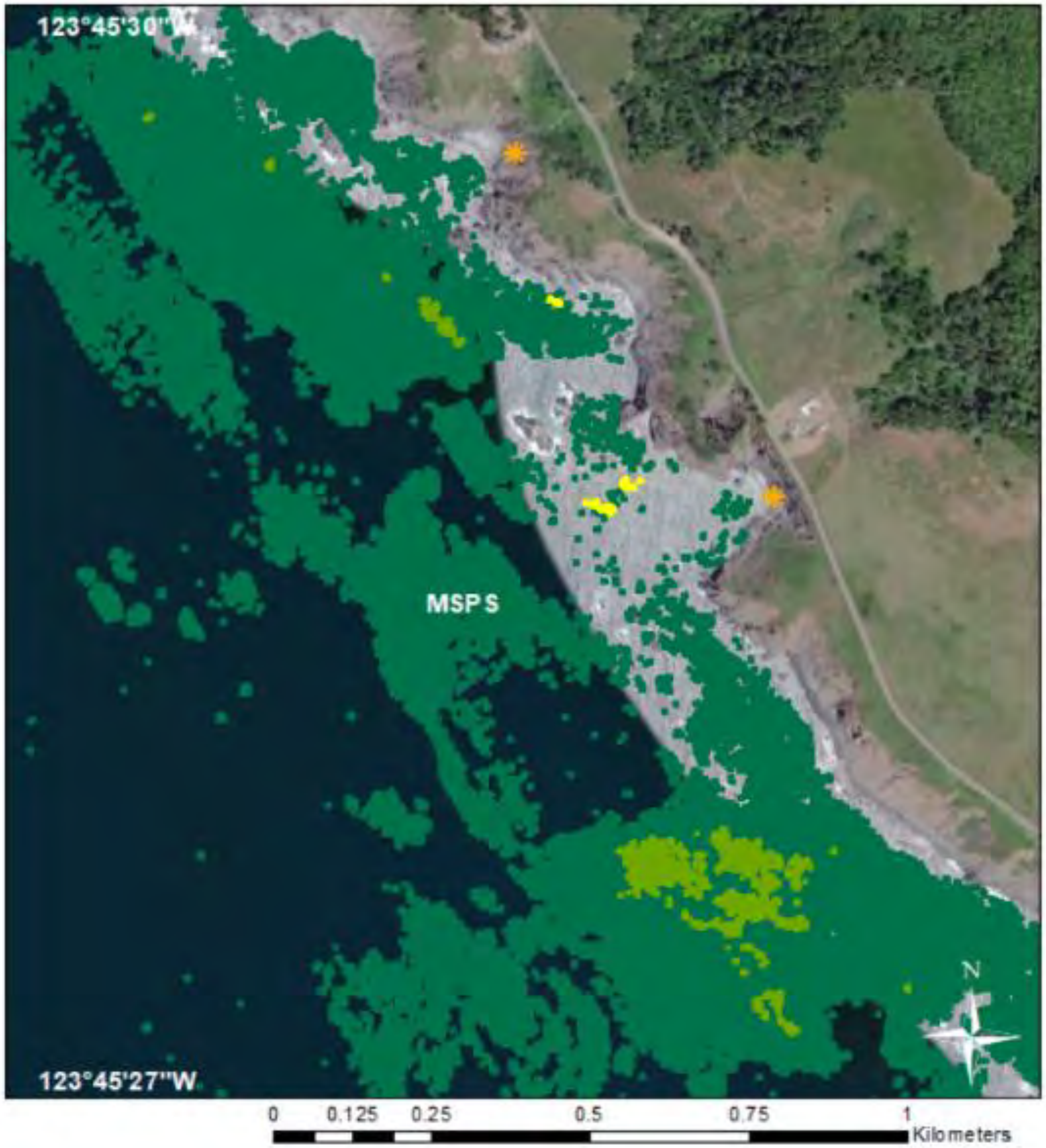
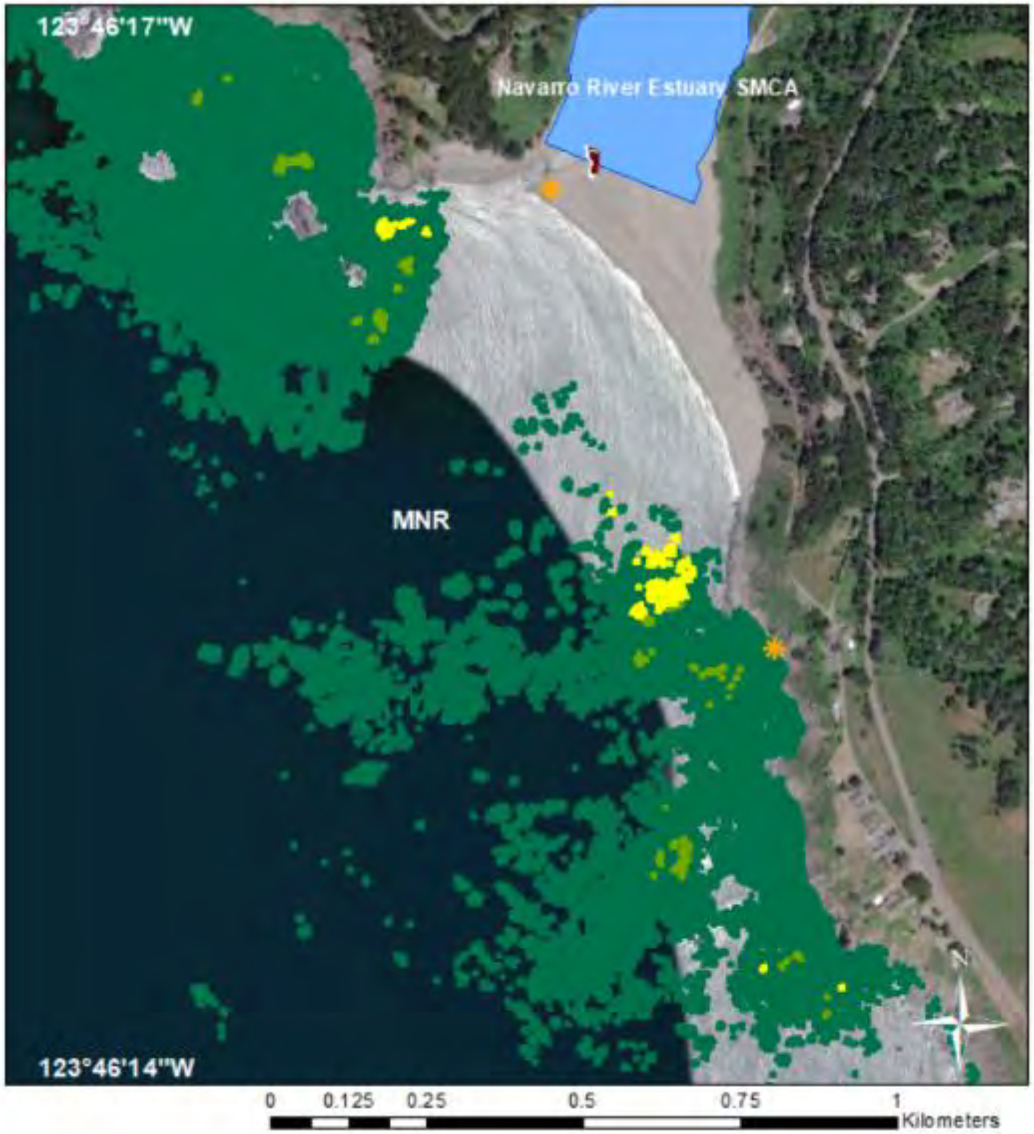


Figure 46. Mendocino Greenwood Creek candidate region.



Mendocino Saddle Point South (MSPS)	
Kelp Patch Area ID	MSPS
Historical Persistence (m^2)	7417
Current Persistence (m^2)	151
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

Figure 47. Mendocino Saddle Point South candidate region.



Mendocino Navarro River (MNR)	
Kelp Patch Area ID	MNR
Historical Persistence (m^2)	1200
Current Persistence (m^2)	1456
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	Navarro River Estuary SMCA (take)

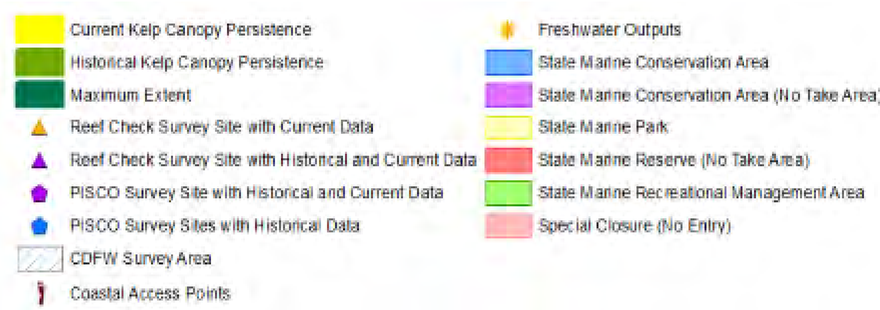
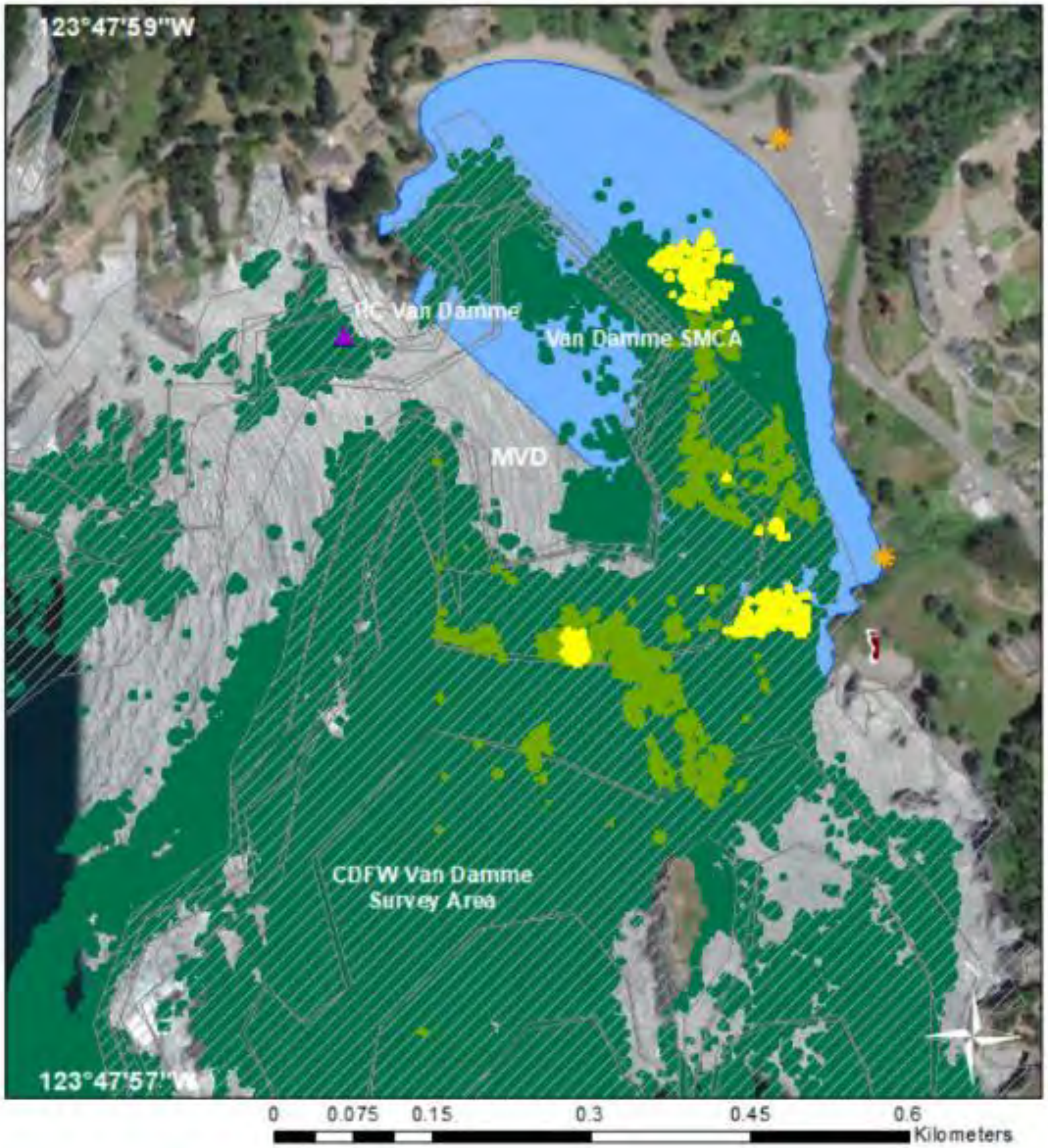
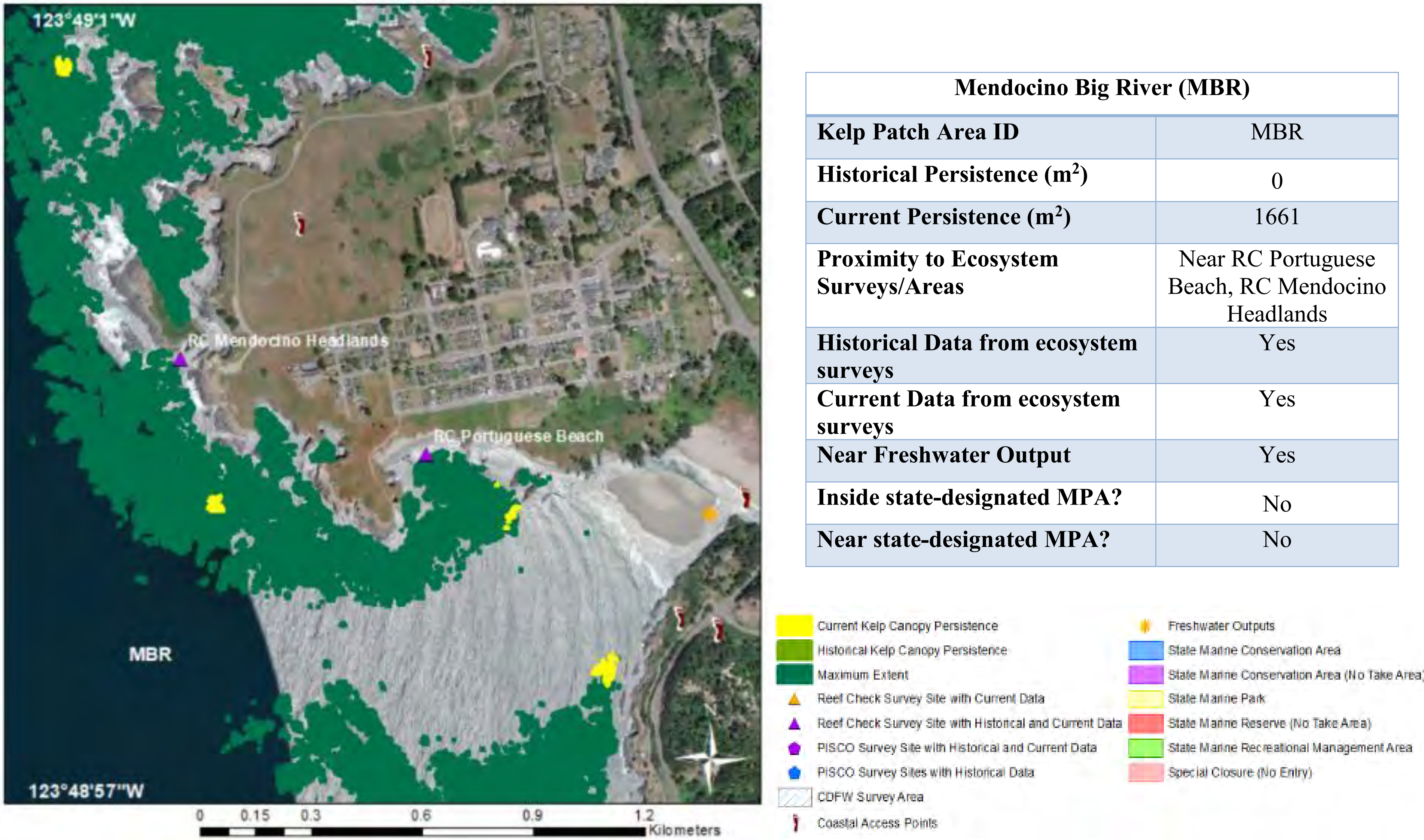


Figure 48. Mendocino Navarro River candidate region.



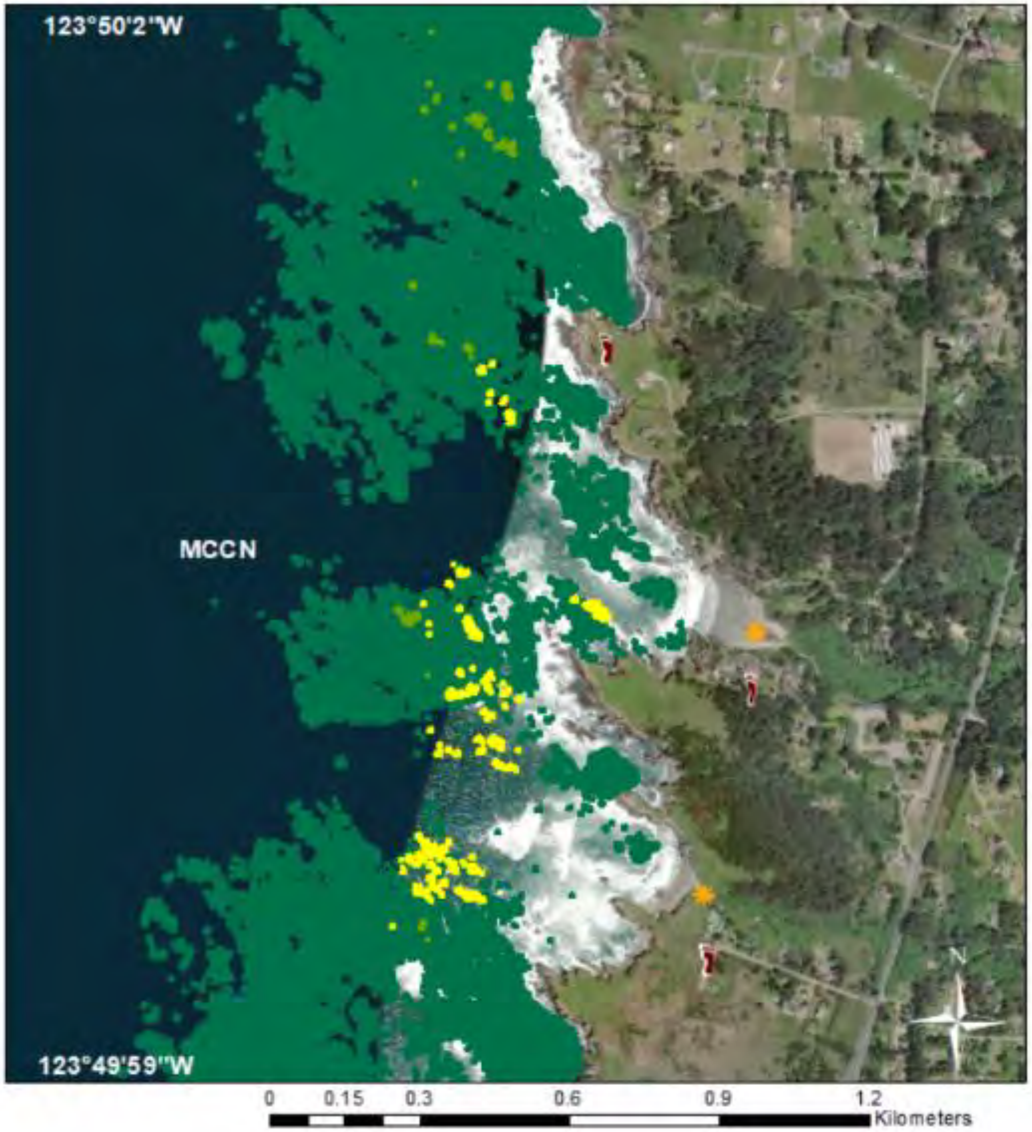
Mendocino Van Damme (MVD)	
Kelp Patch Area ID	MVD
Historical Persistence (m^2)	6037
Current Persistence (m^2)	2601
Proximity to Ecosystem Surveys/Areas	Inside CDFW Van Damme Survey Area, near RC Van Damme
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	Van Damme SMCA (take)
Near state-designated MPA?	Van Damme SMCA (take)

Figure 49. Mendocino Van Damme candidate region.



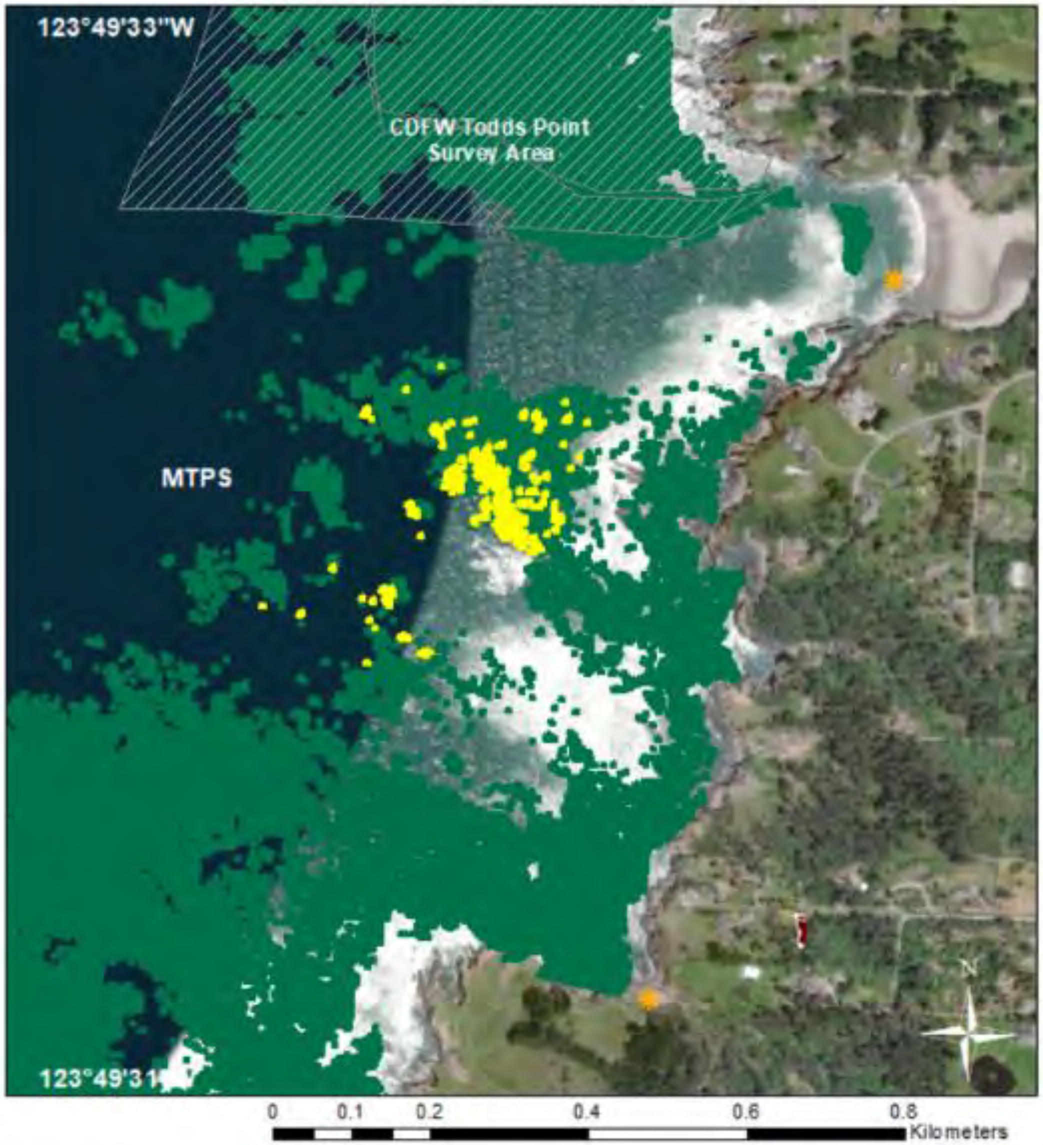
Mendocino Big River (MBR)	
Kelp Patch Area ID	MBR
Historical Persistence (m^2)	0
Current Persistence (m^2)	1661
Proximity to Ecosystem Surveys/Areas	Near RC Portuguese Beach, RC Mendocino Headlands
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

Figure 50. Mendocino Big River candidate region.



Mendocino Caspar Cove North (MCCN)	
Kelp Patch Area ID	MCCN
Historical Persistence (m^2)	397
Current Persistence (m^2)	2652
Proximity to Ecosystem Surveys/Areas	None
Historical Data from ecosystem surveys	No
Current Data from ecosystem surveys	No
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

Figure 51. Mendocino Caspar Cove North candidate region.



Mendocino Todds Point South (MTPS)	
Kelp Patch Area ID	MTPS
Historical Persistence (m^2)	0
Current Persistence (m^2)	2788
Proximity to Ecosystem Surveys/Areas	Near CDFW Todds Point Mendocino Survey area
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

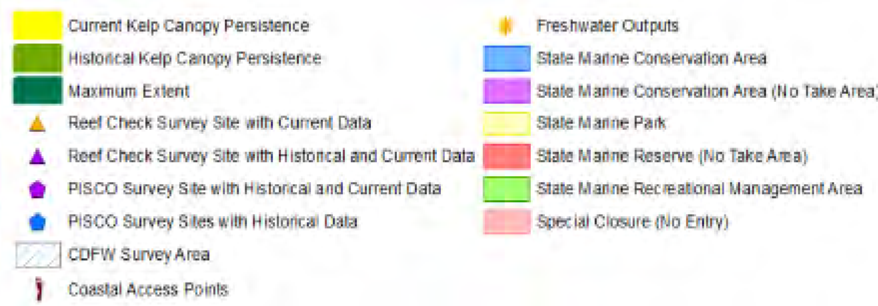
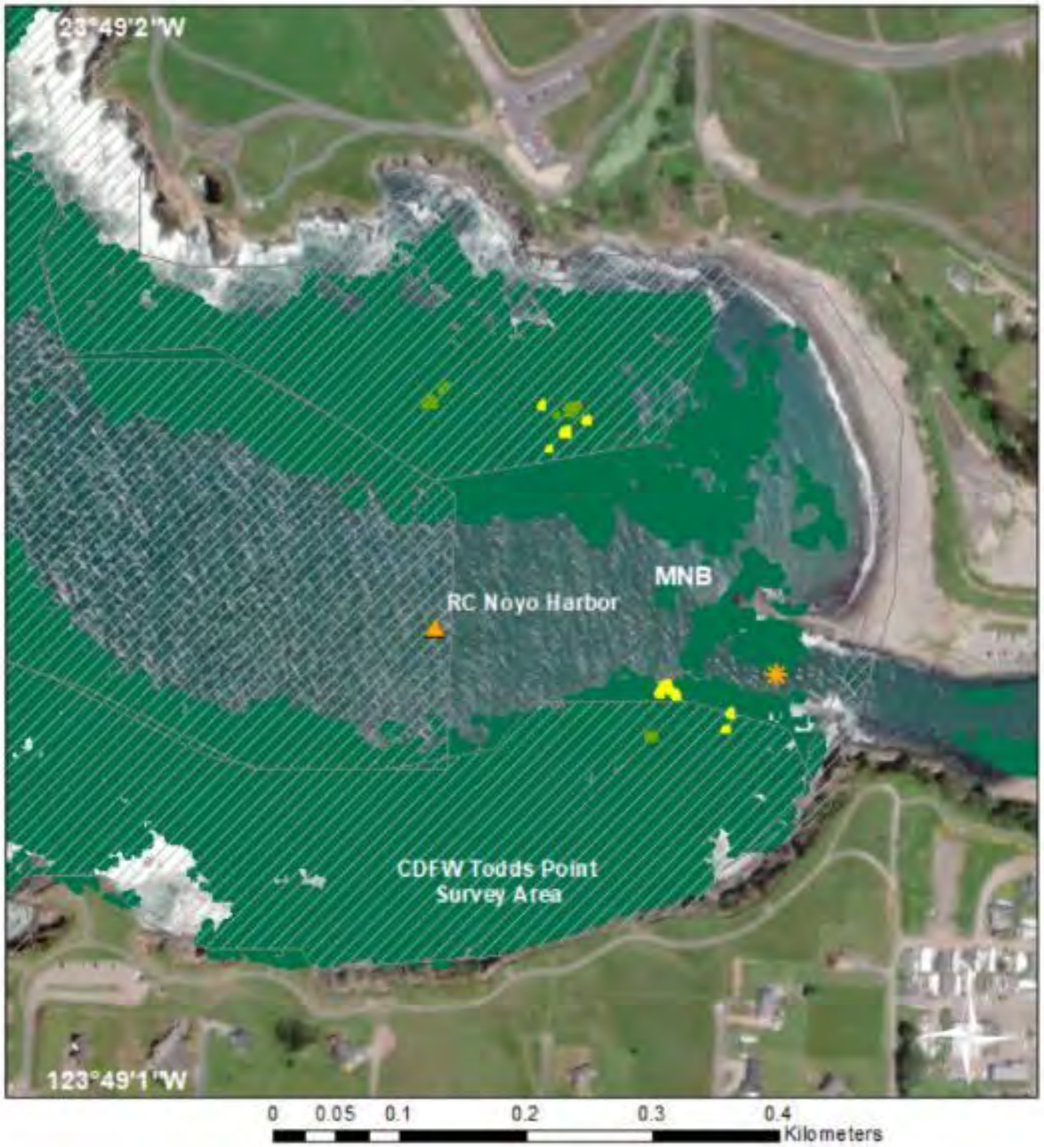


Figure 52. Mendocino Todds Point South candidate region.



Mendocino Noyo Bay (MNB)	
Kelp Patch Area ID	MNB
Historical Persistence (m^2)	60
Current Persistence (m^2)	80
Proximity to Ecosystem Surveys/Areas	Inside CDFW Todd's Point Survey area, near RC Noyo Harbor
Historical Data from ecosystem surveys	Yes
Current Data from ecosystem surveys	Yes
Near Freshwater Output	Yes
Inside state-designated MPA?	No
Near state-designated MPA?	No

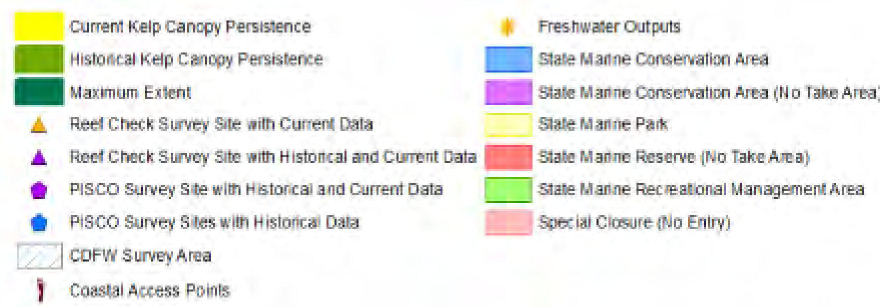


Figure 53. Mendocino Noyo Bay candidate region.

Table 4. Rankings used to determine recommendations for priority regions and sites based on selection criteria.

Candidate Region	Kelp Patch ID	Historical Persistence	Current Persistence	Historical Data	Current Data	Near Freshwater Output?	Inside MPA ?	Near MPA ?	Total	MPA
Sonoma Timber Gulch	STG	5	4	3	2	1	0	0	15	0
Sonoma Fort Ross South	SFRS	5	0	3	2	1	0	0	11	-
Sonoma Fort Ross	SFR	5	0	3	2	1	0	0	11	-
Sonoma Fort Ross North	SFRN	5	0	0	0	1	0	0	6	-
Sonoma Timber Cove South	STCS	5	0	3	2	1	0	0	11	-
Sonoma Timber Cove Rosson	STCR	5	0	3	2	1	0	0	11	-
Sonoma Timber Cove North	STCN	5	0	3	2	1	0	0	11	-
Sonoma Ocean Cove South	SOCS	5	0	3	2	1	0	0	11	-
Sonoma Ocean Cove	SOC	5	0	3	2	1	0	0.5	11.5	-
Sonoma Salt Point	SSP	5	0	3	2	1	0.5	0.5	12	Reference or Avoid
Sonoma Stewarts Point South	SSPS	5	0	3	0	1	0.5	0.5	10	Reference or Avoid
Sonoma Stewards Point	SSP	5	4	3	2	1	0.5	0.5	16	Reference or Avoid
Sonoma Stewards Point North	SSPN	5	4	3	2	1	0.5	0.5	16	Reference or Avoid
Sonoma Sea Ranch South	SSRS	5	4	3	2	0	0	0	14	-
Sonoma Sea Ranch North	SSRN	5	4	3	2	1	0	0	15	-
Sonoma Del Mar South	SDMS	5	4	3	0	0	0	0	12	-

Sonoma Del Mar	SDM	5	0	3	0	1	0.5	0.5	10	Reference or Avoid
Mendocino Robinson Point	MRP	5	4	0	0	1	0	0	10	-
Mendocino Bourns Rock	MBR	5	4	0	0	1	0	0	10	-
Mendocino Anchor Bay	MAB	5	4	0	0	1	0	0	10	-
Mendocino Fish Rock	MFR	5	4	0	0	1	0	0	10	-
Mendocino Fish Rock North	MFRN	5	4	0	0	1	0	0	10	0
Mendocino Saunders Reef South	MSRS	5	4	0	0	1	0.5	0	10.5	Reference or Avoid
Mendocino Saunders Reef	MSR	5	4	3	2	1	0.5	0	15.5	Reference or Avoid
Mendocino Saunders Reef North	MSRN	5	4	0	0	1	0	0.5	10.5	-
Mendocino Point Arena South	MPAR S	5	0	3	2	1	0	0	11	-
Mendocino Point Arena	MPAR	5	4	3	2	1	0	0	15	-
Mendocino Arena Cove	MAC	5	4	3	2	1	0	0	15	-
Mendocino Sea Lion Cove	MSLC	5	0	3	2	1	0	0.5	11.5	-
Mendocino Greenwood Creek	MGC	5	4	0	0	0	0	0	9	-
Mendocino Saddle Point South	MSPS	5	4	0	0	1	0	0	10	-
Mendocino Navarro River	MNR	5	4	0	0	1	0	0.5	10.5	-
Mendocino Van Damme	MVD	5	4	3	2	1	0.5	0.5	16	Reference or Avoid
Mendocino Big River	MBR	0	4	3	2	1	0	0	10	-

Mendocino Caspar Cove North	MCCN	5	4	0	0	1	0	0	10	-
Mendocino Todds Point South	MTPS	0	4	3	2	1	0	0	10	
Mendocino Noyo Bay	MNB	5	4	3	2	1	0	0	15	

Table 5. Sites of economic value to the recreational abalone harvest. Economic value is derived by the reduction per trip in dollars predicted by Reid et al. that would be lost due to the closure of the recreational abalone fishery (2016).

Recreational Abalone Fishing Site	Economic Value	Nearby Candidate Region
Point Arena (Arena Cove)	6.58	Mendocino Point Arena
Moat Creek	5.74	Mendocino Point Arena
Russian Gulch State Park	5.04	None
Albion Cove	5.54	None
Van Damme State Park	4.86	Mendocino Van Damme
Elk	4.53	None
Mendocino Headlands	4.29	Mendocino Big River
Navarro River	3.67	Mendocino Navarro River
Georgia Pacific Mill	3.14	Mendocino Todds Point
Hare Creek	3.06	Mendocino Jughandle South
Bodega Head	2.92	None
Caspar Cove	2.88	None
Stillwater Cove	2.87	Sonoma Ocean Cove South
Glass Beach	2.78	None
MacKerricher State Park	2.61	None
Todd’s Point	2.41	Mendocino Todds Point
Anchor Bay	2.18	Mendocino Anchor Bay, Mendocino Fish Rock
Fisk Mill Cove	2.07	Sonoma Stewarts Point South
Salt Point State Park	2.00	Sonoma Ocean Cove North, Sonoma Gerstle Cove
Abalone Point	1.99	None
Dark Gulch	1.97	None
Jughandle State Reserve	1.95	Mendocino Jughandle South
Schooner Gulch	1.89	Mendocino Saunder's Reef
Usal	1.86	None
Timber Cove	1.86	Sonoma Timber Cove North

Fort Ross	1.85	Sonoma Fort Ross South, Sonoma Fort Ross, Sonoma Fort Ross North
Point Arena Lighthouse	1.68	None
Hardy Creek	1.51	None
Salmon Creek	1.53	Mendocino Navarro River
Reef Campground (Pedotti)	1.47	Sonoma Fort Ross South
Jack Peters Gulch	1.41	Mendocino Big River
Westport	1.39	None
Mitchell Creek	1.21	Mendocino Jughandle South
Horseshoe Cove	1.13	Sonoma Stewarts Point South
Sea Ranch	1.09	Sonoma Sea Ranch
Stewart's Point	0.93	Sonoma Stewarts Point
Gordon Lane (Spring Ranch)	0.88	Mendocino Van Damme
Black Point	0.79	Sonoma Sea Ranch
Jenner	0.76	None
Gualala Point	0.63	Sonoma Sea Ranch, Sonoma Sea Ranch North, Mendocino Gualala
Bruhel Point	0.52	None
Rocky Point	0.42	None
Robinson Point	0.40	Mendocino Gualala

7.5 Recommended Priority Regions for Recovery Action

The following categorizes regions and sites into four tiers of prioritization – primary, secondary, tertiary and reference or avoid sites.

Recommended Primary Regions (Ranking of 14-16)

- Sonoma Timber Gulch (STG)
- Sonoma Sea Ranch North (SSRN)
- Sonoma Sea Ranch South (SSRN)
- Mendocino Point Arena South (MPARS)
- Mendocino Point Arena (MPAR)
- Mendocino Arena Cove (MAC)
- Mendocino Van Damme (MVD) *Area outside of MPA*
- Mendocino Noyo Bay (MNB)

Recommended Secondary Regions (Ranking of 11-13)
- Sonoma Fort Ross South (SFRS)
- Sonoma Fort Ross (SFR)
- Sonoma Ocean Cove (SOC)
- Sonoma Timber Cove South (STCS)
- Sonoma Timber Cove Rosson (STCR)
- Sonoma Timber Cove North (STCN)
- Sonoma Del Mar South (SDMS)
- Mendocino Sea Lion Cove (MSLC)

Recommended Tertiary Regions (Ranking of 6-10):
- Sonoma Fort Ross North (SFRN)
- Mendocino Robinson Point (MRP)
- Mendocino Bourns Rock (MBR)
- Mendocino Anchor Bay (MAB)
- Mendocino Fish Rock (MFR)
- Mendocino Saunders Reef North (MSRN)
- Mendocino Caspar Cove North (MCCN)
- Mendocino Greenwood Creek (MVD)

Reference or Avoid Sites:
- Sonoma Stewarts Point (SSP)
- Sonoma Stewarts Point North (SSPN)
- Sonoma Salt Point (SSP)
- Sonoma Stewarts Point South (SSPS)
- Sonoma Del Mar (SDM)
- Mendocino Saunders Reef South (MSRS)
- Mendocino Saunders Reef (MSR)
- Mendocino Van Damme (MVD) *Area inside of MPA*

Recommended Next Steps to Finalize Sites

The recommended regions and sites are ranked by alignment with the weighted site selection categories and criteria. Field verification surveys are critical for further planning and implementation. Depending on accessibility, these sites may be targeted by community harvest events, commercial harvesting efforts, other targeted active recovery options or a mixture of these.

A Kelp Recovery Project Coordinator is recommended to implement the following next steps to finalize restoration sites:
- Consult tribal representatives on the locations of primary recommended sites and, once determined, the recovery actions per site.
- Coordinate with CDFW and other members of the Network to determine additional analysis, monitoring needs and other steps needed implement active recovery.

- Coordinate with CDFW to conduct field verification surveys.
- Coordinate ongoing expertise and guidance on feasibility of active recovery options for each recommended site.
- Coordinate analysis of feasibility and scalability of recovery actions based on 2018 harvesting efforts.
- Coordinate a cost analysis based on 2018 purple urchin harvesting efforts.
- Coordinate Network ecosystem surveys of restoration sites.
- Pursue uses for harvested urchins.
- Pursue funding opportunities to support urchin harvesting coordination and other recovery actions.

It is recommended that urchin harvesting efforts continue in the same locations (Noyo Harbor, Caspar Cove, Albion Cove and Ocean Cove; see *Recreational Urchin Harvest* on page 28) in addition to sites selected from the recommended regions. This would allow managers to better associate rate of recovery with dive time, number of volunteers, amount of urchins harvested and rate of harvesting as well as provide a baseline for harvesting as a recovery action. Purple urchin harvesting should continue to be the primary restoration method moving forward, but other actions should be considered and evaluated using Section 6.0 as guidance.

The primary goal for recovery efforts is to preserve the local nearshore spore bank to facilitate recovery of bull kelp forests once ocean conditions improve. Regions with historical and current persistence may facilitate more efficient recovery due to existing kelp patches to provide spores, or elements of natural resilience. The number of sites chosen largely depends on available funding, but there is no specified distance between sites to indicate faster recovery of the larger population. Restoration efforts should not be clustered to any one specific region, but spread out along both the Sonoma and Mendocino counties coastline as accessibility and feasibility allow.

8.0 Strategies for Monitoring and Research

The scope of these strategies includes only the monitoring needed to inform kelp recovery management, and not the actions pertaining to management of bull kelp and the ecosystems they support. The focus of the following strategies is on the types of studies and key elements of those studies and not the specifics of study design and methods. The establishment of the following strategies would contribute to the priority recommendation from the working group to establish a cost-effective, sustainable kelp monitoring program, expanding on existing efforts.

1. Develop a long-term coordinated kelp canopy monitoring program to characterize broad-scale and fine-scale kelp forest dynamics and restoration efficacy, making use of new technologies such as satellites and Unmanned Aerial Vehicles (UAVs).

2. Expedite the processing and analysis of satellite data for bull kelp canopy along the Sonoma-Mendocino counties coast, annually at a minimum.

3. Investigate the key characteristics that confer persistence and resilience of kelp beds.

4. Evaluate the potential for MPA network monitoring and other ecological monitoring efforts to understand kelp dynamics and recovery.

5. Consistently conduct monitoring to inform all ongoing and future recovery efforts.

6. Coordinate monitoring events and to disseminate the information gathered from monitoring studies through existing websites of citizen science organizations such as Reef Check and Citizen Kelp.

7. Implement a kelp spore distribution study with settlement plates to determine extent of dispersal and survival to inform recovery efforts.

8.1 Techniques and Limitations

Kelp Canopy Monitoring

Bull kelp is an annual species and the canopy layer can only be detected during the months between August and November (GFA 2018). Bull kelp biomass is concentrated in the canopy layer, so that aerial survey data may accurately represent the available extent of bull kelp forest habitat along the coast. Kelp canopy monitoring has been conducted statewide in California by CDFW with airplane-based surveys since the 1980s and has been critical for tracking historic extent and fluctuations of kelp canopy as well as the scale of recent impacts. The Working Group identified a need to explore the use of new technologies to support continued tracking of broad-scale and fine-scale kelp canopy dynamics. In addition to airplane-based surveys, aerial imagery may be obtained from satellites (broad coverage, lower resolution) and from UAVs (small coverage, higher resolution).

Airplane-based surveys have been the standard method to track kelp canopy in many regions because the timing of surveys may be adjusted to accommodate seasonality, environmental conditions, and tidal height. The resolution of airplane-based images are sufficiently fine to detect small bull kelp patches.

Satellite imagery provides broad geographic coverage but at a low resolution that may not detect small patches of bull kelp or in areas immediately adjacent to shore, though the resolution of satellite imagery has improved with recent satellites. The timing of satellite images occurs on a regular (predictable) schedule but cannot be adjusted to accommodate specific needs of the surveys. Due to the narrow timeframe for bull kelp canopy surveys, many of the satellite images may be obscured by clouds, fog, smoke. The benefits of using satellite imagery is the relative low cost of acquiring and analyzing imagery to potentially track coast-wide dynamics. Satellite imagery and data from remote sensing may be used to evaluate large-scale annual fluctuations in kelp forest growth and recovery in response to changes in environmental conditions. The survey results would inform resource managing agencies of potential future impacts to the bull kelp forest ecosystem and dependent fisheries, such as abalone and urchins.

UAVs also provide a lower-cost option for obtaining higher resolution imagery with flexibility of scheduling the timing of surveys. The fine resolution UAV images may be used to characterize species-specific kelp growth in priority kelp restoration sites. It may also be possible to equip UAVs with a multispectral sensor that can detect chlorophyll and carbon to monitor kelp forest health a high spatial resolution (Meredith McPherson, *personal communication*, December 3, 2018). Obtaining UAV imagery covering a broad geographic scale, comparable to airplane-based or satellite imagery, would require a dedicated effort to coordinate multiple simultaneous UAV flights. Partnerships with researchers and contractors may be leveraged to identify best practices and a plan for engaging with and coordinating UAV enthusiasts through a citizen science program with the goal of standardizing site surveys to support efficient analysis at a specified frequency. The development of this program may allow scaling up UAV monitoring efforts to support broader high-resolution coverage of Sonoma and Mendocino counties.
The development of a UAV monitoring program should include the following actions:

- Best practices should be established for data collection, required permits, spatial data for survey lines and altitude, and guidance for tidal fluctuations to capture accurate and consistent kelp canopy extent across all surveys. The UAV monitoring program should take clear guidance from GFNMS and adhere to low overflight restriction zones (Figure 54).
- Methods for image processing and analysis should be developed and lead agencies from the Kelp Recovery Network should be designated to undertake processing.
- A phased approach for locations should be implemented so that data collection methods can be modified if needed based on accessibility, weather and ocean conditions.
- Specific UAV pilots, such researchers, contractors, volunteers and members of nongovernmental agencies should be identified to participate initially.
- Managers should be engaged with specific product outputs for bull kelp recovery actions.
- The three primary data collection methods between UAVs, planes and satellites should be implemented over the span of one year to calibrate results as funding allows.
- Applications for equipping UAVs with multispectral sensors should be explored and implemented if and when possible.

Limitations: UAVs cannot be used to monitor spatially large regions that manned aircraft can survey (Colefax et al. 2018). However, UAVs can be used to conduct intensive sampling and surveying on a smaller spatial scale and for specific sites. There have been developments in recent years to improve UAV sensor resolution and alternative sensor types such as multispectral cameras, increasing area coverage, reducing perception error and increasing water penetration for better visibility. Auto-detection software is being developed that will greatly improve image processing and reduce human observer error. UAV users would also need to adhere to overflight restriction zones (Figure 15) and any other civil aviation restrictions. Aerial surveys using UAVs should be coordinated and managed by a scientific lead with a Remote Pilot Certification from the Federal Aviation Administration (FAA).

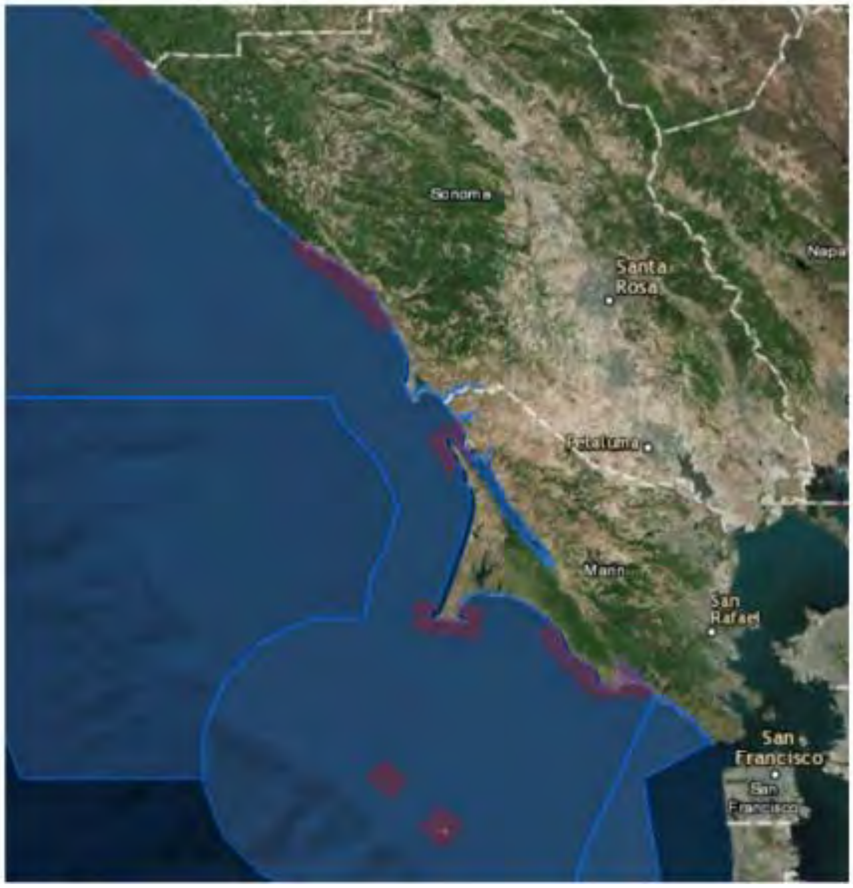


Figure 54. NOAA Regulated Overflight Zones in the Greater Farallones National Marine Sanctuary, shown in purple.

Persistence and Resilience

Understanding factors that contribute to historical kelp forest persistence and current resilience should be assessed by analyzing a combination of remotely-sensed oceanographic and kelp canopy data, and fine-scale *in situ* biophysical surveys. Large-scale oceanographic data includes sea surface temperature, upwelling, nutrient availability, turbidity, and wave exposure. Fine-scale biophysical data includes salinity, subtidal nearshore water temperature, dissolved oxygen, salinity, as well as abundance of key species (e.g. seastars, urchins, abalone) and habitat features (algal coverage, substrate type, and depth). Ongoing kelp forest ecosystem monitoring at key restoration and reference sites (including nearby MPAs) would provide critical input to the models of kelp persistence and resilience. The result of these analyses would be used to:

- Evaluate current kelp restoration efforts and inform decisions about future priority site selection for restoration actions.
- Enhance understanding of the biophysical conditions that led to kelp loss, resilience, and recovery.
- Evaluate the role of MPAs in kelp forest resilience.

The following information would contribute to a better understanding of bull kelp persistence and resilience:

- Collaborative ecosystem surveys (CDFW, the Office of National Marine Sanctuaries, and partners) at key restoration and reference sites would be pursued yearly when possible.
- Marine Protected Areas with and without persistent kelp beds would be identified as priority locations for leveraging current ecosystem monitoring studies.
- Landsat imagery collected since 1984 should be analyzed to establish a baseline and evaluate historic variation in kelp canopy data.
- Traditional Ecological Knowledge should be collected and utilized. A socioecological analysis may be conducted by a member of the Kelp Recovery Network.
- Efforts to identify data which would further contribute to an understanding of persistence should be pursued. These data may include bathymetry, a model reanalysis output such the Regional Ocean Modeling System (ROMS), nutrient sampling, temperature-salinity-oxygen moorings, High Frequency (HF) Radar surface current, and buoy wave data.
- The possibility of a potential long-lived or resilient “spore bank” to support future recovery of forests should be investigated. The extent of these spore banks should be determined through the development of methods and a study design to test whether they are sufficient to explain or contribute to patterns of recovery.

Ecological Monitoring Efforts

Data from long-term comparative ecosystem monitoring surveys, including sites inside and outside of MPAs, is critical for decoupling the role of environmental and anthropogenic impacts to kelp forests. Currently, patterns of resource and ecosystem dynamics are similar across sites, suggesting that broad-scale environmental stressors are primarily contributing to the recent impacts to kelp growth. Future evaluation of ecosystem responses to active restoration efforts should require continued monitoring across sites with different levels of human activity. The results would inform future restoration strategies (e.g. location, timing, and technique). Monitoring studies inform the design and evaluation of recovery efforts, as well as future recovery efforts by determining how the design of a recovery program did or did not lead to a successful recovery of kelp and associated resources. Parameters of monitoring restoration sites may include but are not limited to: algal abundance and distribution within the site prior to restoration efforts; presence and proximity of urchin predators and competitors; presence of other key species such as abalone and sea stars; and environmental conditions.

Blade Biomass and Spore Production

Determining the relationship between blade biomass and bull kelp spore production would advance our knowledge of the biology of bull kelp and help guide recovery planning by revealing sources and sinks related to spore production and dispersal. It is not currently clear if dense patches of kelp forest contribute disproportionately to colonization beyond that source area. High resolution imagery and multispectral data from UAV surveys can be used to explore these relationships and conduct research on spore dispersal dynamics. A coordinated approach that combines remote and field verification surveys is required to test for these relationships.

Web Platforms for Data

All existing and future non-sensitive data, excluding Personally Identifiable Information and sensitive tribal information, related to these strategies would be publicly available on CNRA Open Data. Other relevant websites hosted by Network partners such as CDFW, the Noyo Center for Marine Science, and the Greater Farallones Association used to disseminate the information would be coordinated with explanations of the purpose of the monitoring programs and who was involved in data collection. Detailed explanations would be provided at one website and the same text can be shared and posted across all partner websites. Information presented on the partner websites would be coordinated to contribute to a unified messaging strategy.

8.2 Case Studies and Current Research

The following case studies and synopses of current research are summarized from a webinar on June 6th hosted by GFA for the Kelp Recovery Working Group to explore case studies with relevant applications for monitoring bull kelp canopy in Sonoma and Mendocino. Biographies from each speaker can be viewed in Appendix B and the full webinar can be viewed at www.farallones.org/kelp.

Aerial Plane-Based Surveys in California
Rebecca Flores Miller, California Department of Fish and Wildlife

Airplane-based aerial surveys are performed along the West Coast from Mexico up to Oregon, including the Channel Islands in southern California (GFA 2018). The surveys are annual and take place between August and October. Digital images are collected with a two-meter spatial resolution and are multispectral with an infrared band to detect kelp canopy on the surface of the ocean. The images are then geoprocessed and classified to distinguish kelp. The first survey was completed and digitized in 1989, but they were not performed again until 1999. The California Department of Fish and Wildlife conducted surveys in 2002 through 2007, then contracted other organizations to conduct surveys from 2008 through 2016. These surveys are not entirely complete; 2009-2010 do not provide coverage for the entire coastline and 2011-2012 surveys did not cover the northern California coastline at all. 2013 was also incomplete. Surveys were not conducted in 2017 or 2018. The data that was gathered show a significant decline in canopy cover during the years of 2014-2016.

Aerial data from other organizations and projects may also supplement available data for limited spatial analysis. These other data have been used by CDFW to inform the planning process for Marine Protected Areas throughout California. In Central and Southern California, aerial survey data have been used to inform kelp bed lease and harvest management. The two-meter resolution of the data from airplane-based surveys is valuable, as it allows the detection of small patches of bull kelp canopy. However, surveys are planned to be conducted annually and would not reflect seasonal variation in growth. Consistency of surveys in northern California has historically been impacted by poor weather, malfunctioning equipment, understaffing, and limited funding. To better understand kelp forest dynamics and responses to both stressors and restoration efforts, a long-term consistent monitoring strategy is needed.

Remote Estimation of Giant Kelp Canopy Density in California
Tom Bell, University of California Santa Barbara

Landsat 5, 7 and 8 were utilized to create a continuous 35-year time series of giant kelp canopy dynamics in southern California. Landsat 5 was launched in 1984 and flew until 2011. Landsat 7 and 8 are currently functional and together provide an image every eight days regardless of cloud cover. The resolution of the images was 30-meter by 30-meter. Data were verified using SCUBA diver biomass estimates from the Santa Barbara Coastal Long-Term Ecological Research Project (LTER), dating back to 2002. LTER developed an allometric relationship between the number and lengths of frond segments to estimate biomass of giant kelp in 40-meter by 40-meter plots in the Santa Barbara Channel.

The study region stretched from the Mexican border to north of Santa Cruz and included the Channel Islands. The total coastal area was 1500 kilometers where giant kelp is the dominant canopy-forming macroalgae, or eight Landsat scenes. Each Landsat scene, or tile, is 185 kilometers long by 185 kilometers wide (Figure 55). Landsat data to map kelp canopy was initially classified manually and a new automation procedure was created that can transform a Landsat image into an estimate of kelp canopy biomass in a fraction of the time. When compared, the automated protocol slightly underestimated canopy biomass. In manual surveys, intertidal surf grass, algae or waves were sometimes identified as kelp, which are not identified by the automated process. Therefore, the automated process is not only more efficient, but also slightly more accurate.

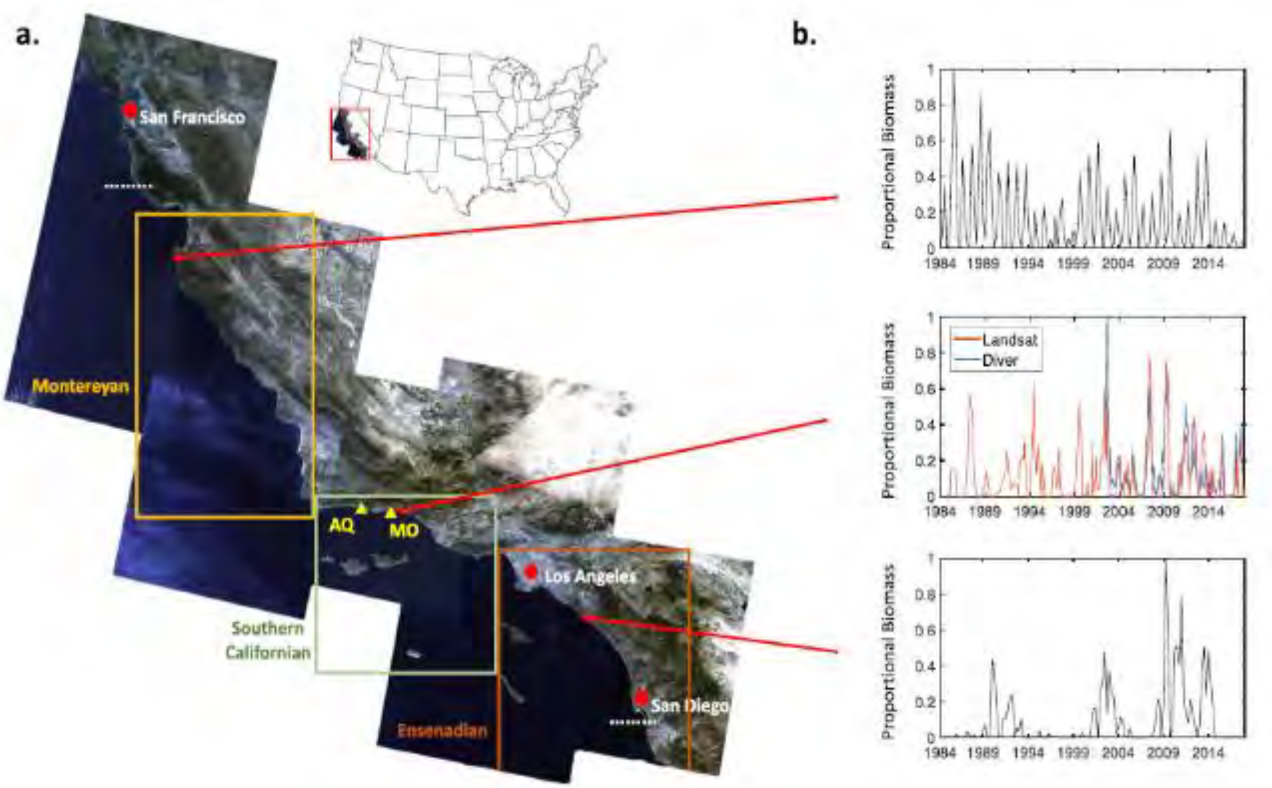


Figure 55. Landsat tiles (a) and biomass surveys (b). The top graph shows the extreme seasonality of kelp canopy typical of the Monterey peninsula and the central coast. The bottom graph shows interannual patterns typical of areas around Orange county. The middle graph shows the correlation between the diver estimated canopy biomass and the Landsat estimated biomass, where blue represents the LTER surveys and red is the Landsat data (Bell et al. 2018).

A collaboration between the Oregon State University and the University of California Los Angeles began in early 2018 to determine the feasibility of mapping bull kelp canopy using Landsat. Landsat estimates of bull kelp canopy were compared to aerial surveys done by the Oregon Department of Fish and Wildlife. Initial data processing revealed a strong correlation between satellite and aerial imagery and the automated protocol is being adapted for bull kelp detection. Research is being conducted on the use of UAVs in Alaska as a potentially more cost-effective way to map kelp canopy.

Detection of Bull Kelp in the Salish Sea Using High Resolution Satellite Imagery
Maycira Costa, University of Victoria

Research on kelp canopy extent in the Salish Sea stemmed from a collaborative project evaluating the habitat for juvenile Chinook and Coho salmon populations (GFA 2018). Detecting kelp with satellite imagery depends on a variety of factors. These included kelp density, exposure, tide height, time of year, water surface reflection and the spatial and spectral resolution of the satellites. Kelp is exposed at tides below 1.2 but is submerged and undetectable above this height. The maximum growth and extent are in July and August. Close to the coastline, kelp imagery can be confused with rocks and vegetation, which is called pixel-mixing. Pixel-mixing can happen relatively often at a 30-meter spatial resolution. Sunlight reflecting off of water at the same angle as a satellite view can obscure kelp on the surface and can be difficult to correct. To correct for some of these challenges, a coordinated effort was made to gather additional data on the ground. Ferries and research vessels were equipped with sensors. Citizens on the beach, in boats and on kayaks were also encouraged to report sightings of kelp with GPS coordinates. Sightings on the ground provided correlation with the satellite imagery, although they were not as robust or structured as the LTER surveys in Santa Barbara. The University of Victoria is also working on digitizing historical maps from the early 20th century that were hand-drawn and included kelp.

Floating Kelp Trends and Issues in Washington State
Helen Berry, Washington State Department of Natural Resources

Washington state has about 20 species of kelp, only 10% of which is on the rocky outer coast. The majority is found within and throughout the Puget Sound. Both bull kelp and giant kelp are found along the coast, but only bull kelp is located within the Sound. The Sound is a fjord system with large tides, strong currents and an estuarine circulation. Stressors in the Puget Sound tend to be regionally distinct. Anthropogenic influences are stronger due to the proximity and magnitude of urban development. Main stressors include elevated temperatures, urbanization, sedimentation, overfishing, marine ecosystem community shifts, grazing from kelp crabs and invasive species such as sargassum. They have used a variety of methods to map kelp. These include aerial photography, airborne multispectral surveys, surveys from a kayak, small boats and underwater videography. The most complete data comes from aerial photography. However, consistency with aerial photography remains a challenge in regards to using the same methods and handling tides, currents and seasons. Satellite imagery was determined to not be an effective tool because most kelp forests were too small to be detected. The Puget Sound region experiences high variability in overall kelp canopy similar to other regions. The exception was an extensive loss of kelp during warm-water years of 1997 and 2014.

Potential for Satellite Imagery and Remote Sensing of Bull Kelp
Meredith McPherson, University of California Santa Cruz

Landsat can detect the relatively larger canopy extent of giant kelp, but it is unclear whether it can be used as a tool to detect small patches of bull kelp. A high resolution is needed for accurate measurement of the impact of multiple stressors and better estimation of biomass. Meredith McPherson, a PhD candidate with the University of California Santa Cruz, is currently investigating various platforms to determine the best techniques to detect bull kelp canopy extent on the northern California coastline. Meredith has compared RapidEye and Landsat imagery to the CDFW aerial surveys to determine accuracy. RapidEye is a commercial satellite with a five meter by five-meter spatial resolution and has provided continuous images since 2009. Whereas CDFW and Landsat matched up well, RapidEye overestimated canopy cover, likely due to the absence of atmospheric correction. However, that RapidEye may still be a useful tool if certain challenges are addressed, including manual atmospheric correction, decreasing signal-to-noise ratio and addressing the computational expense of processing many more pixels than Landsat.

Meredith's ongoing research includes investigating the influence of environmental factors on relative change in bull kelp canopy since 1984 to develop a timeseries analysis of Landsat 5 and 8 data (Meredith McPherson, personal communication, January 16, 2019). Meredith also plans to determine the feasibility and spatial requirements to reliably identify bull kelp canopy and patch biomass during low biomass conditions through a sensory comparison analysis and quantify the errors associated. Biomass estimates of bull kelp canopy in the field were conducted in the fall of 2018 to ground-truth satellite imagery. Protocols for biomass estimation involved sampling a 30-meter by 30-meter plot to correspond with a Landsat pixel. Within the plot, measurements of morphology such as the longest blade length and average bulb diameter were taken. Further research is being conducted to take *in-situ* measurements on chlorophyll and carbon and develop a relationship in which they can be detected from a remote sensing platform.

9.0 Strategies for Community Engagement

Strategies for community engagement would bridge the gap between ongoing research and restoration efforts and public accessibility of current information. Community engagement materials should be developed with insight from all partners of the Kelp Recovery Network to engage coastal communities and convey relevant information about kelp recovery actions being taken.

1. Engage range of community members, organizations and agencies to raise awareness about kelp recovery efforts with consistent messaging tailored to each target audience and their level of

engagement & areas of focus. Specific messaging should be crafted for public education, partner recruitment and monitoring outcomes.

2. Develop meta-messaging with correct and consistent scientific elements of the story.

3. Communicate the role of urchins in the ecosystem; ecological, social, and economic impacts resulting from purple urchin barrens; and opportunities for urchin harvest and use.

4. Connections with key organizations about kelp loss and recovery efforts to engage more stakeholders in finding solutions.

5. A range of informational outreach materials with consistent messaging should be produced to increase engagement in coastal communities. Outreach materials or presentations should be translated into other languages as needed.

6. Share consistent message and information including videos on social media channels of Network partners.

7. Encourage commercial urchin divers to film the underwater habitat and stream through videos. Connections with existing partners that have ROVs or ROV footage related to kelp to develop videos that tell the kelp loss and recovery story. The 3-dimensional element and visual impact of video is powerful and shows the true extent of the problem.

8. Connect how human activities have contributed to kelp loss and how human activities can help kelp recovery.

9.1 Guidelines to Develop Consistent Messaging and Engage Audiences

Consistent messaging and a comprehensive outreach plan should be developed with the goal of raising awareness of kelp forest loss in Sonoma and Mendocino counties and increasing efforts to recovery to kelp. Agency, academic, NGOs, and community members should be brough together to develop a cohesive plan with common goals on how to recover lost kelp habitat. Messaging should be tailored to specific audiences to increase understanding, engagement and relevancy. Concepts of adaptive restoration and learning should be incorporated. The following provides a guideline for engaging audiences and developing consistent messaging.

Crafting of a "meta-message"

There are many levels of messaging depending on the audience and community engagement. There should be one overarching message, a "meta-message" that shares four important aspects.

The following is a four-step guideline that can be used to develop the meta-message:

1. Place: Northern California bull kelp forests are underwater communities with ecological, historical, economic, and cultural significance on which our way of life depends. Analogies and metaphors using places of significant natural elements with historical and cultural

context (e.g. redwood forests) can increase understanding. It is important to capture what the historical environment was like compared to the current state of the ecosystem.

2. Problem: The "Perfect Storm" can be described as multiple compounding stressors that impacted kelp forests. These stressors included the sea star wasting disease, a major purple urchin predator, coupled with extremely warm ocean conditions caused by El Niño and a persistent multi-year marine heatwave titled "the Blob" in the Northeast Pacific Ocean. All of these factors have resulted in an unprecedented, dramatic, and startling decrease of bull kelp forest in the last five years. The problem statement should tailored to each specific audience.

3. Why it matters: Human health is dependent on a healthy ocean environment. The ocean provides the air we breathe, food and recreation. In particular, the ocean is vital to the North-Central California coastal economy. Local kelp forests are nurseries for commercial and recreational fish, are vital to the recreational abalone industry and provide culturally important resources. The local economy depends on healthy kelp forests to provide these benefits that result in jobs, tourism, food, recreation and cultural practices

4. Action: You can join us in helping the kelp forest recovery!
    a. Get involved: Volunteer with citizen science programs that monitor kelp health and recovery: Noyo Center for Marine Science, Reef Check, and Citizen Kelp.
    b. Get giving: Donate to organizations that help fund recovery efforts
    c. Get talking: Act as an ambassador for kelp recovery and share the story on social media and with family, friends, and colleagues.
    d. Get clever: Think about innovative uses for harvested purple urchins
    e. Get learning: Discover how your community impacts the land and water.
    f. Get active: Change habits that negatively impact the ocean. Save water, reduce the use of fertilizers and pesticides. List five ways to reduce your carbon footprint to keep the ocean cool!

Outreach Materials

Potential products to be developed include some or all of the following:

- Talking points on the background science and current recovery efforts.
- A shareable presentation such as the one created and used by the Noyo Center for Marine Science, which can be found at https://noyocenter.org/wp-content/uploads/2018/05/HtK-training-all-how-we-got-here.pdf.
- A community listserve with upcoming events.

- A laminated, weatherproof “Kelp Binder” with relevant information, photos, and visuals. This binder can be provided to docents, vessels, public facilities, libraries, etc. to share the story in a consistent manner.
- A shared information portal that is updated with ongoing community events hosted by a member of the Network or the GFNMS Ocean Climate Program.
- A shared drive of visual assets or image and video library that includes iconic social media-worthy photos and videos.
- A “traveling roadshow” presentation for public facilities. These presentations may have a target date or time frame. The goal of the traveling presentation would be to have a large number of people spreading the same message to different communities.
- A YouTube channel to share a digital version of the presentation and other video content.
- Informational cards and additional outreach materials when printed materials are necessary or appropriate.

Labeling Purple Urchins

Purple urchins are a native species and as such are an important component of kelp forest ecosystems. Messaging used by members of the Kelp Recovery Network should not label purple urchins as a “villain” or “evil”. It is important to prevent a situation of unintended consequences when bull kelp forests recover. Reduction of urchins by commercial divers and community events should be labeled as “urchin harvesting”. A case-specific and targeted effort of “culling” may arise under carefully coordinated and managed circumstances. This may include an incentive-based prize or reward for an innovative use of harvested urchins.

Communicating Anthropogenic Environmental Change

Part of this messaging should highlight how land development and other uses are drivers of stressors to open-coast environments and how we need to consider better practices here to minimize impacts. It should be communicated that humans are contributing to local anthropogenic environmental change. It is important to increase understanding of the larger picture and interconnectivity of actions and not focus on purple urchins as the main causal factor. Encourage reasonable actions that people can do in their daily life to provide climate resiliency. Topics should be adjusted for different audiences to increase understanding and relevancy. Lists of recommended behavior changes to reduce negative anthropogenic impacts can be useful for members of the public to reference. One list could include the top five actions the general public can take to help the kelp recovery project. Another list could include changes that people can make in their lives to address broader climate impacts on the ocean.

Audiences and Partnerships

The list below outlines audiences and partnerships with examples of identified organizations, members, or agencies that can be engaged in Sonoma and Mendocino counties.

Community organizations and the general public:

- Kayak companies (e.g. WaterTreks Ecotours)
- Arts centers (e.g. Gualala Arts Center)
- Activist organizations
- Nature/Education Centers (e.g. Bay Model)
- Libraries (e.g. Point Arena Library)
- Public facilities such as campgrounds, parks, and lighthouses
- Chambers of Commerce
- General public partaking in recreation

Governmental entities and representatives:

- Tribal: Resource management departments, seaweed gatherers and indigenous harvesters, tribal water consortium in Northern CA, North Coast Resource Partnership tribal representatives
- State: California Department of Fish & Wildlife, Ocean Protection Council.
- Federal: GFNMS, NOAA
- Local governments
- Legislators

Fundraisers:

- Funders (e.g. private, corporate funding opportunities)
- Foundations and associations (e.g. Greater Farallones Association, The Sea Ranch Association)
- Local, state, federal government grants
- Crowdfunding Opportunities

Resource stakeholders:

- Tribal groups (seaweed gatherers and indigenous harvesters, tribal water consortium in Northern CA, North Coast Resource Partnership tribal representative)
- Recreational fishers
- Commercial fishers
- Charter party boats
- Commercial and recreational fleet captains
- Academic/science institutions
- Processors
- Abalone Divers
- Chambers of Commerce

Groups that engage in novel urchin use:

- Urchinomics: a Norway-based business that works worldwide to preserve kelp forests and boost rural communities by creating a lucrative market for sea urchins
- Composters
- Farms
- Craftspeople
- Public input and crowdfunding: potentially facilitate a public challenge to crowdsource ideas regarding novel urchin use
- Chambers of Commerce via visitor centers
- Restaurants

Research and scientific agencies:
- Monitoring groups/labs (e.g. Bodega Marine Lab)
- Citizen science groups
- Other (national/international) groups addressing urchin barrens

Classroom education:
- Noyo Center for Marine Science
- GFNMS and GFA school-age programs
- The Long-Term Monitoring and Experiential Training for Students (LiMPETS)

Media and public outreach outlets:
- Newspapers (SF Chronicle, NYT, Point Arena Light, Ukiah, Press Democrat, Marin IJ)
- Magazines
- Radio
- Television

9.1.1 Ongoing Community Engagement Efforts

The Noyo Center for Marine Science in Fort Bragg has been a leading force in engaging audiences and leading numerous community engagement efforts regarding kelp recovery. Efforts taken by the Noyo Center can be built upon by partners in the Kelp Recovery Network. Staff at the Noyo Center initiated a grass-roots public campaign titled "Help the Kelp" in 2018 that has been successful in conducting outreach and recruiting volunteers for community events (Sheila Semans, personal communication, January 23, 2019). The campaign engaged members of the community through the following efforts:

- Selling Help the Kelp merchandise with proceeds supporting recovery efforts.
- Establishing partnerships with local businesses to raise awareness and funds.
- Promoting the program through videos, merchandise sales and donations.
- Labeling and selling Thanksgiving coffee bags with the Help the Kelp logo.

- Working with local businesses, including a hotel and a restaurant, to include information about the campaign on the bill with an option to donate when paying.

The Noyo Center received an underwater drone with a 3-dimensional 360-degree camera to use in monitoring urchin harvesting sites with the goal of eventually obtaining footage showing the transition from an urchin barren to a kelp forest. They have conducted other public outreach efforts including the development of an informative website, found at https://noyocenter.org/help-the-kelp/, tailored to target commercial divers, recreational divers, and the public. The website outlines the background science clearly and concisely with relevant links to user portals and partner websites. Noyo hosted a series of public events in 2018 to raise awareness about kelp forest loss, including a panel discussion and public speaking events. They have given a total of 13 presentations throughout 2018 to local civic groups, the Fort Bragg city council, the Coastal Commission and the Western Society of Naturalists conference. They offer youth programs focused on kelp forest ecosystems, participate in science and art fairs, and have written numerous articles for the local paper. The Noyo Center is in the process of improving their interactive exhibits, which include a geodesic dome that will create a virtual experience of being underwater (Figure 56). They have designed and built a 5-meter diameter dome to showcase the footage from the 360-degree camera mounted on the drone to provide members of the public with more personal experience to increase understanding of the critical conservation issues. The goal is to compel more action, greater participation and more funding for kelp recovery efforts.

Figure 56. The Noyo Center is in the process of designing a geodesic dome that will create a virtual experience of being underwater. Credit: Sheila Semans.

9.1.2 Opportunities for Public Involvement in Citizen Science

Reef Check California

Reef Check California monitors rocky reefs at over 100 sites inside and outside of California's MPAs and works with marine managers, researchers and the public to provide the scientific data needed to make informed, science-based decisions for the sustainable management and conservation of California's ocean environment. Reef Check has monitored kelp forests along the northern California coastline since 2007, including 18 long-term monitoring sites in Mendocino and Sonoma counties and are currently monitoring sites where recovery actions are taking place. All Reef Check site locations and date collected over time can be viewed on the Global Reef Tracker website at http://data.reefcheck.us/. Reef Check trains volunteers to become citizen scientists and their audience includes fishermen, divers, kayakers, surfers, boaters and other Californians who want to take a proactive role in the conservation and management of kelp forests. Reef Check kelp forest monitoring protocols are modeled after PISCO methods and data are collected on fish, invertebrates, algae and the habitat. Surveys target ecologically and economically important species that help indicate ecosystem heath and all data is made publicly available on their Global Reef Tracker (http://data.reefcheck.us/) website. Reef Check California Ecodiver Training involves a mixture of classroom lectures, pool-based practice surveys, species identification testing and ocean dives. Trainings and recertifications are held frequently in the spring and summer in various locations.

Citizen Kelp

Citizen Kelp is a citizen science program recently established by The Nature Conservancy in partnership with CDFW. The goal of the program is to involve the public in kelp forest conservation by reporting observations in several ways when visiting the beach, diving, boating and/or kayaking. Four categories of observation are reported, including: 1) urchin barren conditions; 2) bull kelp observations; 3) abalone health; and 4) urchin health. Observations are reported on the Citizen Kelp web portal (go to www.citsci.org and search for Citizen Kelp).

Community Urchin Harvesting Events

In 2018, the Waterman's Alliance began coordinating recreational divers that have skills in freediving and SCUBA diving at all levels to participate in urchin harvesting events. Kayakers and boaters are also needed to ferry collection bags from divers to dockside samplers. Urchin harvesting events are posted on the Waterman's Alliance Facebook page (https://www.facebook.com/groups/158992911481142/). Volunteer dockside samplers are coordinated by the Noyo Center for Marine Science (https://noyocenter.org/help-the-kelp/) to collect data on urchins for these events. See *Recreational Urchin Harvest* on page 28 for more information.

10.0 Integration with Relevant Action Plans

Greater Farallones NMS Climate Adaptation Plan

The Sanctuary Climate Adaptation Plan (CAP), published in November 2016 by the Sanctuary's Ocean Climate Program, WAS the result of a 2-year process to characterize climate impacts and vulnerabilities to Sanctuary resources along the North-Central California coast and ocean, and to develop management strategies to respond to and decrease those vulnerabilities. The CAP presents 26 final adaptation strategies to improve climate resilience of coastal and nearshore habitats to climate impacts. Two of these strategies are directly relevant to the recommended actions in the Recovery Plan. Strategy H-6 calls for the restoration of subtidal bull kelp forests to help buffer the coastline from increased storm activity and erosion by identifying locations in need of restoration and carrying out feasibility studies and demonstration projects to test the viability of bull kelp restoration. Strategy SN-5 calls for the extensive mapping of bull kelp habitat along the Sanctuary coastline and ground-truthing aerial kelp canopy cover with diver-based estimates of kelp biomass. The proposed actions in the Recovery Plan, therefore, support the work of the Sanctuary's Ocean Climate Program and would further ensure the critical resources of the Sanctuary are more resilient to the impacts of climate change.

Research and Management Priorities to Address Sea Star Wasting Syndrome: A Collaborative Action Plan

The Sea Star Wasting Syndrome Strategic Action Plan was developed by the Sea Star Wasting Syndrome Task Force in 2018 to address gaps in knowledge, research goals and action items, and potential conservation strategies at a national scale for recovery of sea stars. The action plan contains recommendations for (1) diagnostics and epidemiology, (2) surveillance and ecology, (3) management, conservation, recovery, and (4) communication, outreach and citizen science. There are multiple recommendations in this action plan that have implications for collaboration with the strategies outlined in the Recovery Plan. The decline of *Pycnopodia helianthoides* is linked to increases in urchin densities and decreases in kelp densities along the Northeast Pacific Ocean. Actions taken to manage, conserve and recover sea star species has an indirect impact on kelp forest management and recovery. Survey sites where greater numbers of sea stars are observed may be considered priority areas for kelp recovery actions due to a higher possibility of urchin population management. The strategic plan also outlines a socioeconomic study to determine impacts of kelp forest loss resulting from decreases in sea star populations. A joint study would be valuable for managers to determine comprehensive socioeconomic impacts.

California State Wildlife Action Plan (CDFW)

The State Wildlife Action Plan is a document funded through the Wildlife Conservation and Restoration Program and the State Wildlife Grants Program centered around conserving California's wildlife resources while responding to environmental challenges. In the plan, numerous species dependent on healthy kelp forests are listed as Species of Greatest Conservation Need, including seven species of abalone and numerous other invertebrates and fishes.

Marine Life Management Act Master Plan (CDFW)

The Marine Life Management Act (MLMA) is California's primary fisheries management law and CDFW developed a Master Plan to guide implementation. The Master Plan includes an interim list of prioritized species for management action and describes a comprehensive approach to prioritization within a framework for MLMA-based management. The goal of the plan is to allow CDFW to focus limited management resources on fisheries with the greatest need and opportunities for resource and ecosystem benefits to the state of California. Bull kelp is actively managed by CDFW as are numerous kelp-dependent species.

Abalone Recovery and Management Plan (ARMP)

The Abalone Recovery and Management Plan provides a cohesive framework for the recovery of depleted abalone populations in southern California, and for the management of the northern California fishery and future fisheries. All of California's abalone species are included in this plan. A recovery and management plan for abalone species is needed to manage abalone fisheries and prevent further population declines throughout California, and to ensure that current and future populations would be sustainable. Kelp forest communities are vital to abalone populations. In northern California, the predominant food source for abalone is bull kelp; subsequently, in recent years red abalone populations in the AOI were significantly impacted by kelp loss.

Northern California Red Abalone Fishery Management Plan (CDFW)

The Northern California Red Abalone FMP is currently being developed to further refine and implement the long-term management objectives in the ARMP. The recent rapid collapse of the recreational red abalone fishery due to kelp loss has highlighted the need to incorporate direct measures of potential environmental impacts and population productivity measures to inform management of this iconic resource. The data needs to inform the red abalone fishery recovery and management in northern California align strongly with the monitoring activities outlined in the bull kelp recovery plan. The recovery of the red abalone fishery would be highly dependent on the widespread successful recovery of bull kelp forests.

Ocean Protection Council (OPC) Plan for Strategic Priorities to Protect California's Coast and Ocean

The Ocean Protection Council's Plan for Strategic Priorities to Protect California's Coast and Ocean for 2019-2024, in draft form at the time this Recovery Plan was published, sets a five-year course for addressing the broad range of challenges facing California's ocean and marine ecosystems while guiding targeted investments focused on critical issues and policy changes with the potential for greatest impact. Objective 2.3 cites the need the promote healthy kelp forest ecosystems along the California coast by funding research and monitoring projects, supporting citizen science and volunteer restoration efforts, developing a cost-effective and robust strategy to map the current extent of kelp to inform adaptive management, collaborate with CDFW and the California Fish and Game commission to develop coordinated state policy for kelp management, leverage partnerships with state agencies and stakeholders to implement a collaborative and multi-pronged strategy for kelp forest protection and resilience and fund science-based pilot projects to explore kelp forest ecosystem restoration and management approaches. The plan also identifies the need to improve scientific understanding of how climate change alters coastal and marine ecosystems, citing the proposed action to quantify the role of aquatic vegetation, including kelp forests, in mitigating ocean acidification and storing carbon. The strategies outlined in the Recovery Plan support all of the proposed actions in the OPC Strategic Plan and close collaboration is recommended.

California Ocean Acidification Action Plan (OPC)

The California Ocean Acidification Action Plan was produced by the Ocean Protection Council in collaboration with the Ocean Science Trust and articulates a 10-year vision for addressing ocean acidification and a series of pragmatic actions to work towards that vision. It is designed for integration into public agency operations and to inform decisions made by members of the private sector and scientific community. It serves as a model for other jurisdictions seeking to undertake concrete actions to better understand, mitigate, and adapt to ocean acidification. The Recovery Plan supports Action 4.1 to implement a coordinated and strategic statewide approach to restoring, conserving, enhancing and assisting in the migration of seagrass meadows, kelp forests, and salt marshes to achieve multiple state goals.

Marine Protected Area (MPA) Monitoring Action Plan (CDFW)

The MPA Monitoring 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. This Action Plan prioritizes metrics, habitats, sites, and species to target for long-term monitoring in order to inform the evaluation of California's MPA Network. The Recovery Plan supports continued monitoring at key MPAs to evaluate the relative influence of environmental and anthropogenic effects on kelp forest recovery.

11.0 Conclusion and Next Steps

The Conclusion and Next Steps outline the actions necessary for a Kelp Recovery Network and Project to comprehensively and immediately address this pressing issue. Success will be dependent on a well-coordinated synergistic effort in which all interested parties are working together toward a common goal.

11.1 Establish a Kelp Recovery Project and Network

The overarching recommendation from the Sanctuary Advisory Council to implement the strategies in the Recovery Plan was to establish a Kelp Recovery Project and collaborative Kelp Recovery Network. The Greater Farallones Association would designate a Kelp Recovery Project Coordinator to manage the Project and Network and work in close partnership with GFNMS and CDFW to carry out the priority strategies outlined below.

11.1.1 Build on Existing Partnerships

The Kelp Recovery Network would facilitate partnerships, collaborations and communication across all entities involved in kelp recovery along the Sonoma and Mendocino counties coastline. The formation of the Network should build from the successful collaborations already established by the Kelp Recovery Working Group and the Kelp Ecosystem Landscape Partnership for Research for Resiliency (KELPRR) spearheaded by CDFW. KELPRR is a broad partnership of stakeholders, scientists and government agencies focused on developing science-based solutions to supporting recovery of the bull kelp forest ecosystem. Conference calls are currently held monthly by KELPRR members to discuss efforts by partners to conduct recovery efforts, identify and fill knowledge gaps, assess recovery potential of bull kelp forests, support rapid widespread kelp recovery through efforts to maintain spore production along the coast and support development of commercial markets for purple urchins. After the establishment of the GFA Kelp Recovery Project, efforts will focus on supporting the coordination of and expansion of KELPRR with the goal of strengthening and advancing cross-sector collaboration within a broader Kelp Recovery Network.

11.2 Implement the Strategies

Recommended next steps towards implementation, with identified agency leads, are as follows:

(1) GFNMS and CDFW adopt the recommendations and strategies in the Recovery Plan and facilitate implementation in partnership with each other;
(2) GFNMS and CDFW in partnership with GFA establish a consistent funding stream to facilitate the formation of the Kelp Recovery Project and Kelp Recovery Network and support active recovery efforts;
(3) CDFW take the recommended steps to determine specific restoration sites within the priority candidate regions and evaluate active recovery efforts to be taken for each site;
(4) GFNMS immediately investigate opportunities to collaborate with CDFW to conduct restoration and monitoring efforts within the recommended sites with available NOAA vessels, divers and equipment;
(5) GFNMS in partnership with CDFW and GFA build upon connections and efforts taken by partners in 2018 to inform, grow and implement recovery actions in 2019 and 2020;
(6) GFNMS in partnership with CDFW and GFA determine specific roles, coordination efforts, pathways for communication and avenues to facilitate the implementation of these strategies in conjunction with members of the Kelp Recovery Network;
(7) GFA in partnership with CDFW and GFNMS work with members of the Network to begin developing a comprehensive outreach plan with effective and consistent messaging and materials that can be used by all partners to increase participation and awareness;
(8) GFA in partnership with CDFW and GFNMS begin developing pathways to establish a kelp canopy monitoring program for the Sonoma and Mendocino counties coastline and expedite the processing of satellite data for bull kelp canopy monitoring being conducted by the University of California Santa Cruz.

This plan and the strategies within provide an opportunity to comprehensively address the issue of severe kelp loss in Sonoma and Mendocino counties. It is the result of a strong, interdisciplinary collaborative effort to address community engagement, monitoring and research, restoration site selection and active recovery options. These guidelines provide the necessary foundation to strengthen partnerships and cohesively pursue funding and implementation pathways immediately and efficiently. The establishment of the Kelp Recovery Project and Network would facilitate short-term recovery efforts and ensure effective long-term management of bull kelp forests.

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Appendix A. Working Group Membership

Name		**Affiliation**	**Contact**
Catton	*Cynthia*	*Working Group Co-Chair; CDFW*	*Cynthia.Catton@wildlife.ca.gov*
Koe	*Francesca*	*Working Group Co-Chair; Sanctuary Advisory Council (SAC)*	*Francesca.Koe@gmail.com*
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Staff to the Working Group

Name		**Role**	**Contact**
Gamurot	Jenn	Advisory Council Coordinator; logistics lead	Jenn.Gamurot@noaa.gov
Hohman	Rietta	Science lead	Rietta.Hohman@noaa.gov
Hutto	Sara	Project lead	Sara.Hutto@noaa.gov

Appendix B. Working Group Meeting Summaries

Three in-person Working Group Meetings, one webinar and multiple conference calls were held throughout 2018 to engage stakeholders, community members, organizations, research institutions, agencies and tribal representatives. This appendix summarizes each meeting, the webinar and the conference calls. Linked text in this appendix provides access to presentations given during each meeting and the working group's recommendations.

Working Group Meeting 1 Summary
April 25, 2018 9:00am-4:00pm
3rd Floor Conference Room at the Greater Farallones NMS Headquarters on Crissy Field, San Francisco

Meeting Objectives:
- Outline working group expectations, objectives, deliverables, and timeline
- Review the state of the science for bull kelp and help identify knowledge gaps
- Review restoration and recovery methods used elsewhere and begin discussion of possible options for the north coast region
- Discuss next steps moving forward
- Participants confirm assignment to one of three topic teams for future meetings

All working group presentations can be found here.

In attendance:
Working Group members: Sarah Allen, Mark Carr (by phone), Cynthia Catton, Barbara Emley, Michael Esgro, Mike Graham (by phone), Frank Hurd, Francesca Koe, John Largier, Abby Mohan, Josh Russo, Sheila Semans, Javier Silva, Bibit Traut, Jan Freiwald, Tom Ford
Technical advisors: Steve Lonhart, Rebecca Flores-Miller (by phone)
Staff members: Rietta Hohman, Sara Hutto, Jenn Gamurot

Welcome:
Maria Brown, Sanctuary Superintendent, opened the meeting and welcomed working group members to the Sanctuary offices. She thanked everyone for their time and energy in addressing kelp loss along the north coast and emphasized the critical need for solutions.

Project Orientation

Presentation: "Introduction to the Kelp Recovery Working Group"

Rietta Hohman, Greater Farallones Association

Sara Hutto, Greater Farallones Association

Francesca Koe, Sanctuary Advisory Council, Working Group Co-chair

Rietta and Sara, staff to the working group, provided a brief introduction to the Kelp Recovery Project, spearheaded by Greater Farallones National Marine Sanctuary and Greater Farallones Association, in partnership with California Department of Fish and Wildlife. The Kelp Recovery Working Group was convened by the Sanctuary Advisory Council to better understand the issue of kelp loss along the north coast and to develop recommendations for management, education/outreach, and science/monitoring actions to enhance kelp resilience. The project goals, working group timeline, and working group objectives were reviewed. Francesca discussed working group operating guidelines.

Discussion

Steve Lonhart - may be helpful to provide a toolkit of things that can be done and a list of what GFNMS and CDFW assets are available including vessels, funding, partners, etc. to understand what we're working with, particularly regulatory topics.

Francesca clarified this meeting will identify the gaps, take inventory of what we have to work with, look at resources we have.

Francesca noted that she will maintain online presence through blogs and #kelprecoveryproject to highlight the important work this group is doing.

State of the Science Presentation

Presentation: "Causes and Consequences of Recent Large-Scale Kelp Loss in Northern California"
Cynthia Catton, California Department of Fish and Wildlife, Working Group Co-chair

Cynthia presented on the "Perfect Storm" of multiple large-scale stressors that led to severe impacts to the kelp forest ecosystem in northern California. Stressors included a harmful algal bloom (2011), Sea Star Wasting Disease (2013-), persistent warm water (2014-2016), and urchin population boom (2014-). Herbivorous benthic invertebrates were first species to show impacts of long-term starvation due to the large-scale loss of algal growth. Introduced concerns over recovery potential of bull kelp (annual life history) after multiple years of very low growth.

Discussion

Mike G - Bull kelp is an annual, different than giant kelp, a perrennial. Bull kelp relies on previous year for reproductive outputs for recruitment. There are not too many holdouts for refuge for microscopic bull kelp. Need to establish a reproductive crop of bull kelp spores to avoid allee effect, enough spores to saturate the substrate.
Steve - Do we know how far their spores can travel and their life expectancy? Mike G - It drops

its actual spores to bottom, has broader dispersal range of tens to hundreds of meters. In that way, it is different than giant kelp. Bull kelp is less prolific than giant kelp. There is nothing to keep them in the dormant state because they are not resource limited.
It is critical to address bull kelp this year due to inability for spore "bank" to replenish. Should consider refuge areas due to broad dispersal, lower reproductive potential.
Cynthia - less productivity on the north coast, greater visibility/warmer temperatures, fewer nutrients.
Nutrients are very low - but may be more than sufficient still
Abby - experiments to see how abalone recover - have you looked at extent of population size we would need to have them recover? Cynthia - no, haven't done that math yet. We just fed the abalone as much as they would eat, didn't measure the amount of food we were feeding them.

Bibit - Restoring kelp forests - are you planning to introduce sori? Have you considered oceanographic conditions? Southern warm water tolerance? Cynthia - In the afternoon we'll discuss more of this topic; much of the discussion currently will direct our movement forward. We are focused on areas that had spore production last area - many areas in Sonoma did not have spore production (lack of kelp), so clearing an area may not be enough to have bull kelp come back. Understory species perhaps could recover. We want to minimize the amount that we are manipulating and allow nature to take over, but there are ways we can help facilitate recovery.

Jan - Experiment w/abalone - do you have any thoughts as to why it takes so long for them to recover their reproductive status? Cynthia - would really like to talk to a physiologist! Looking at doing some research on ocean acidification impacts on larval abalone. Wanted to get a huge number of abalone spawning to get a diverse genetic pool, so we did a beach spawn with 50 animals but none of them spawned. In 2014 - prior to when we were aware of oceanographic conditions, the following year we gave them more time to become reproductive. Took some back to the lab to fatten them up, but it took 1.5 years to get them to spawn. Red abalone are relatively easy to spawn normally, but not this time.

Jan - are we going to talk about fish? Fish depend on kelp too, but have not seen any decline in fish populations. Many studies have been inconclusive, would expect them to decline because they are losing their habitat with kelp loss. Now that we can't fish for abalone anymore, there might be more spear fishermen.

Regional sampling - have you seen effects near Russian River sampling for abalone/kelp due to influx of nutrients/freshwater/pollutants? No, much of the habitat around Russian River mouth is sand, not rocky reef. For abalone fishery, historically we have the most robust populations north of Jenner. Probably has to do turbidity and sandy habitat. Recent reports of mortality on the north coast, may have to do with salinity. Nutrient load is likely to not be a major factor (John L.).

Tom Ford - if there are stands of bull kelp, be tactical - help existing stands persevere. Find refugia for juvenile gametophytes and sporophytes, examine substrate type on a small scale may have influence on management decisions.

Francesca - past two years in harvesting abalone in headlands in Mendocino down through Sea Ranch. Purple urchin barrens are everywhere. Bull kelp around double point is more present, possible to transplant? Saw a shallower foot in collecting abalone, also they did not grip the substrate as strongly as they normally had to (didn't have to sneak up on them). Last year we were able to just pick them up in shallow areas, didn't have to dive. Very different patterns close to each other. Cynthia - will be important to look at those dynamics. Heard about a robust bull kelp population off of Half Moon Bay, Reef Check did a couple of surveys but it's a dicey place to dive. Bull kelp is popping up in weird places and not present where it's supposed to be.

Answer may be complicated, influence from drought, less turbidity, very interesting dynamics.

Cynthia - Shrinkage scores that we've been using are from looking straight now at abalone, have to squash them down a bit to see thickness. There is some pretty extreme starvation, wide potential range inclusive of a lot of different conditions. Found deeper pockets of abalone, but they were the exception rather than the rule. Other sites - we saw abalone up very high in shallow areas on top of each other because any algal growth will be in shallow areas.

Depth threshold for purple urchins and bull kelp? Cynthia - purples are more abundant in shallow areas, red urchins are more abundant at depth (around 60 feet). Several years ago would not have seen hardly any purple urchins past 55 ft (1-2 individuals) now will see dozens, sometimes hundreds. Bull kelp on good years can get much deeper than 60 feet.

Josh - worried about what it will do to the fish, already getting reports from some recreational fishermen that they are not seeing fish. Fishermen have mostly stopped fishing in Sonoma (has been much more heavily impacted than Mendocino). Some spear fishermen have moved from Sonoma up to Mendo. Recreational abalone fishermen transferring to spear fishermen? Many ab divers come from Sac and valley. Easier for them to get to and fish in Monterey; so many folks may not want to travel to Sonoma/Mendo. Hook and line, kayakers fishing deeper.

Bibit - we want to be careful with our messages to the public - want to make sure we're not saying that we'll just let nature recover (nature does it best). It's alright to say that we are doing active management. Cynthia - there are certain processes that if there is a certain way forward for it to happen on it's own, we may get more robust results than if we try to force it (i.e. spore availability). If we are selecting just a few individuals to put in an area, how can we do that in the best way, a more organic way than what we would create artificially?

Meredith - anyone doing any ecological modeling that takes into account climate change and if it would impact the frequency of sea star wasting disease, etc? Do we have any forecast on modeling for kelp forest ecosystems when it comes to multiple stressors? There are some forecasts and interesting dynamics on things we haven't considered before; we need to consider different scenarios, including worst case scenario (making recommendations for weathering the transition away from bull kelp). Will Macrocystis become the dominant species in northern CA, and what would that transition look like?

Think about critical knowledge gaps that we need to address.

Restoration and Recovery

Presentation: "The Growth of a Kelp Project: Informing the Physical, Chemical, and Biological Characteristics of Coastal Management in Southern California"

Tom Ford, Executive Director of the The Bay Foundation

Tom discussed this collaborative project with UC Davis Bodega Marine Lab and LMU LA Frank

R. Seaver College of Science and Engineering to conduct restoration of giant kelp off of the Palos Verdes peninsula, considering both ecological and economic recovery. To date they have restored 44 acres of kelp forest habitat and culled 3.4 million urchins over a period of four years. Results showed a 250% increase in kelp canopy and a significant increase in reef diversity within restoration sites. They also measured a 168% increase in red urchin gonad biomass. He also discussed the initial project to outplant red urchins in preparation for white abalone recovery, as well as some work that has been done on kelp forest hydrodynamic research.

Discussion

Tom shared that using hammers to remove the urchins was the best path forward in the Southern California project. Steve asked Tom about funding for his program. It was funded by a restoration site from a company that dumped contaminants into the Santa Monica Bay (similar to a Superfund site underwater). It was also a threat to public health. Cost about 2.5 million to implement.

Mike E. asked about the scalability of Tom's program. Tom's program was hugely labor intensive to reduce urchins and they had to set up strategic harvesting methods.

Mike Graham mentioned anecdotal reports of synchronized spawning when the urchins were being smashed. Also, how do you deal with the invasive Sargassum horneri? In Southern California, Macrocystis has pushed it out.

In Southern California, the work was permitted with a scientific collecting permit from CDFW, which ensured pre-and post-monitoring.

Presentation: "Salish Sea Bull Kelp Restoration Research"

Braeden Schiltroth - MsC candidate, Simon Frazier University

Braeden discussed some global trends in kelp forest dynamics, namely regime and range shifts and influences of temperature changes and other stressors. Their project goals include identifying temperature limits for early reproductive success in bull kelp, evaluate whether certain kelp populations exhibit a resiliency to warm temperatures and establish/continue restoration in the Salish Sea by monitoring kelp performance and determining how to establish a self-sustaining kelp bed. They grew kelp by seeding spools of string around culture rope, which were then attached to a grid and monitored over time. So far they can get good growth and reproduction at restoration sites, but cannot as of yet recolonize. Much of Braeden's work was on evaluating stress resiliency in kelp and they found that 17 degrees C in SST appears to be around the upper limit for spore production and is the temperature at which germination decreases significantly, whereas 20 degrees C kills off spores. Warm conditions lead to a shortened reproductive season for bull kelp.

Discussion

Mike G asked if the adult densities were long enough to stimulate recruitment on the mooring lines. Are the sporophytes showing up on the lines? Braeden clarified yes, but undetermined where they are coming from. It is suspected that they are growing on the lines.

Braeden- focusing on sea surface temperature, compared with bottom temperatures.

Cynthia noted there may be some subpopulations that are more heat resistant than others. Are they investigating into genetic analyses? Braeden said the warm and cool sites acted pretty similar in terms of temperatures. He is looking at metabolic byproducts as stress markers and different reactions to warm temperatures. Looking to collect from the Stanley Park site in the future.

Presentation: KELPRR Program: Protecting the Bull Kelp Spore Bank

Cynthia Catton, California Department of Fish and Wildlife; Working Group Co-chair

Cynthia described KELPRR (Kelp Ecosystem and Landscape Partnership for Research for Resiliency), the partnership of stakeholders, scientists, and resource managers that has formed in response to the recent bull kelp loss in northern California. She described the program goals on multiple time scales. In 2018, the goals of the program are to assess the potential for enhancing kelp growth at strategic locations within Sonoma and Mendocino counties, through focused reductions of purple urchin populations. Future work, including additional site selection, will be informed by the Kelp Recovery Working Group recommendations. The long-term goals include developing viable commercial markets for purple urchin materials, to provide future opportunities for commercial divers to control urchin barren conditions.

Discussion

How are they dealing with long-term effects of urchins in terms of stakeholder prioritization? Looking at the larger patches of kelp. The effort was initially focused on one cove; now that there is more interest, there is an opportunity to spread the effort out.

Jan asked about seed banks and the best way to choose a site. Tom shared that in Southern California, the efforts averaged 25 urchins per square meter. They did not spread largely after the harvesting efforts in Southern California. The die off did not help with killing them all off.

Sarah asked about the sites chosen. Cynthia said that some sites are chosen through the CDFW monitoring program. Jan has some of the same sites as well. We want to choose sites we have information on to compare with what we're seeing this year. Important to monitor sites that are also not manipulating.

Mike E shared that this fall, the long term MPA monitoring action plan from CDFW/OPC will be released which can be tied in to these efforts.

Frank asked if there was a general sense of the scale in terms of hours. Josh said they paid for 27 dive days. They are clearing 2,000 feet a day and have cleared 50,000 square feet so far.

Steve noted that now that there are recreational fishers with a sport fishing license, they can collect 20 gallons per day, but how is that effort being captured? There is a need for control and monitoring in terms of unleashing people to collect the urchins, to ensure that the efforts are being documented. Are there mechanisms in place for this to account for what's happening?

Cynthia clarified that the 20 gallon collection is an emergency rulemaking for 180 days; it is a time period to make an observation if it is successful. Sheila noted that there is a lot of outreach into the harvesting efforts for the community. CDFW works with diver groups to add data to the website. It is important to educate diver groups about the messaging.

Josh has talked with dive shops to coordinate harvesting efforts and generally everyone is on board. Looking for long term data on what they were like, what they will be in the future. Without the recreational component, the commercial cannot happen. The abundance of urchins is mostly in the smaller shore areas. He will be trying to hold more frequent harvesting events. Hoping to have a large sized workforce of volunteers going forward.

Francesca added that people are gravitating towards organized events, which serves the community.

Javier shared concerns about extraditing urchins as a species. Tribes look to use them as resources.

Francesca noted that once we have a list of sites, some sites may be better suited for recreational, some may not be. If we do arrive at a list of sites appropriate for volunteers it can be provided to other agencies to coordinate efforts.

Sarah suggested collecting data from visitors - the messaging makes a difference and should be communicated as "volunteers". Also, safety should be first priority.

Javier noted that cultural resources also include archeological sites, and to look at all resources as coastal resources as a whole.

Reflections Roundtable

Working Group members were invited to reflect on what was discussed today, their individual perspectives, and priorities moving forward.

Mike Graham - comments: it's such a great story to think about collecting hundreds of thousands of urchins and utilizing them for some type of resource that isn't wasted. There is activity going on in Moss Landing to see if they can develop a non-sushi related uni product and how to develop marketing. Connect with Cynthia on this! Recovery potential - limited genetic structure north of SF in the bull kelp population, similar to several other species of kelp, a positive when thinking about bringing bull kelp spore material from another region to the north coast because they are genetically similar. Much is at stake - livelihoods, aesthetics, economics, if the current state persists. Cynthia - have you seen any recruits in areas w/high waves, urchins, etc on north coast? Commercial urchin divers haven't reported any, but soon CDFW/Noyo will get an ROV in the water to monitor, Reef Check will also soon be monitoring. Diablo nuclear power plant - warmer water output caused shifts in bull kelp beds.

Mark Carr - concerned based on discussion today that cart is before the horse, there are pre-existing efforts in place but the role of this working may need to step back and look at the overarching goals. Two spatial scales - 1: just go to particular areas and re-establish kelp forests in those areas; 2: identify areas that can be restored to create spore sources that will then re- establish populations along the coast when conditions approve. High swell disturbance and disease are two natural processes that act at broad spatial scales; one of these ways may be the way that we get coast-wide restoration. Should establish these "spore islands" that can quickly react and provide spores when conditions improve. This solution really impacts spatial objectives

- Let's get clarity. Braeden discussed how they are raising Nereo and then outplanting it, which may have low success. Other way, how to increase natural predators such as sea stars. Have there been discussions to raising sea stars (Pycnopodia) and outplanting them? Then there's mechanical harvesting of urchins. Size of clearing and isolation of clearing? If you're not doing this in isolated areas, we might be destined for failure. Most effective way to reduce urchins - how far do spores disperse from Nereocystis beds? How far apart do we separate these areas so we've blanketed as much of this coastline as we can? Bottom line - there's a whole lot of questions to address. This group needs to think about all of these things and implications of each approach and how to utilize really great resources (urchin divers, recreational divers).

**See Mark C's notes here for greater detail on these thoughts.

Rebecca - if urchins are going to move after clearing an area, should intertidal area be considered? Then a lot more folks could be involved. Cynthia - the regulations specify a gear type, not intertidal or subtidal. Deliberate decision made to encourage people to work within the area that we want them to to minimize damage (can dive at high tide & reduce trampling). Want to work with partners w/outreach and convey the right message - urchins are a resource and we are using this resource to help the ecosystem and minimize damage to the ecosystem.

Tom Ford - Agree with Mark Carr, but at the same time there is a swell of interest that can and should be utilized. Would be happy to continue to play a role and assist as needed, since they have navigated many of these issues already. Benefits of integrating these partners is very high.

John Largier - great seeing this working deal with this issue, there's a lot of work to do, much work is being done. How do we know if anything like this has happened before? Is it realistic to do nothing? We have to consider this alternative and what it would look like. Not advocating that we do nothing, but we should develop that thinking a little more than we did today. Kelp patches are not all the same; we need to know how they differ in chemistry/topography/composition/etc. Should have an idea of what the sites look like on local scale. If we have a recovery opportunity when urchins get knocked out, how do we utilize it. Don't want to suppress enthusiasm from interested people, we can talk about ways to address the error.

Barbara - coming into it knowing very little about the issue heading into it. For Tom Ford - is there a big enough difference between south of Point Conception and northern conditions? Tom - Yes.

Steve Lonhart - are these urchins the result of one or two recruitment events and we're just looking at a cohort? What are the dynamics of larval transport? If there had not been a coinciding warm water event, would we be seeing these? Is it an acute or persistent problem? Are there new urchins entering the system? This will be fundamental to addressing the approach to the problem.

Frank Hurd - lots of information together, this going around the circle is really bringing forward important questions and will be thinking these over.

Jan Freiwald - agree with Steve, need to consider urchin larval dynamics and potentially re-introducing predators (sea stars).

Mike Esgro - OPC is very aware of the issue, recognize the severity and extent of the issue, ready to help in whatever way they can, very supportive of local efforts. OPC mandate - make science-informed decisions. There are a lot of knowledge gaps we need to address. Also do need to consider that this is an alternative stable-state.

Francesca Koe - Loved seeing Tom's presentation because it showed that when people come together, great things can happen.

Sarah Allen - Don't let the science get in the way of the good. Really enjoyed all the discussion today.

Josh Russo - Appreciates all the knowledge in this room from researchers and their perspectives. Fairly confident that this was a single recruitment event. Goal for the Watermen's Alliance is to raise as much money as possible to clear coves as soon as possible. Intention is not to kill all the urchins, just to clear these specific sites to help kelp persist.

Meredith McPherson - Learned a lot today. Mark made a lot of good points about the types of environmental influences that can reduce urchin population density, we should look at the cost of maintaining these sites until those influences occur. Should look at those patches of kelp and determine why they have persisted.

Javier Silva - Supportive of kelp recovery, not many tribal people have seen the scale of the issue, learned a lot today and wants to stay involved and determine a way of helping the kelp. Many tribal folks are concerned about the quality of resources from the ocean.

Wrap-up and Next Steps

The meeting was adjourned after the group decided the same meeting location will be used for the remaining in-person meetings (August 2, Sept 13) and that staff would work on convening a second conference call for continued discussion (in addition to the scheduled webinar on June 6 at 10am).

Information and Data Gaps Identified:

- Genetic variability of abalone and possible variation in response to kelp loss
- Biomass estimates of urchins as related to kelp extent
- Potential impact to fish – both from kelp decline and increased fishing pressure (as harvesters switch from inverts)
- Shrinkage score to estimate abalone health may not be most appropriate – thinner and weaker anecdotally
- Impact of climate change – are there any forecasts for kelp?
- What are source populations of larvae?
- What are the coastal oceanographic processes that transport larvae?
- Are persistent Nereo patches due to lack of urchins or resilience of kelp?
- Is there economic data on the locations that produce the most red abs and red urchins?
- Sample size and distribution – core tons term sample locations pair with random sites with broader distribution. Review sampling design.
- Test effects of cages over Nereocystis holdfasts

Working Group Meeting 2 Summary
August 2nd , 2018 9:00am-4:30pm
3rd Floor Conference Room at the Greater Farallones NMS Headquarters on Crissy Field, San Francisco

Meeting Notes

Attendees: Cynthia Catton, Sarah Allen, Tom Ford, Francesca Koe, Bibit Traut, Rebecca Flores-Miller, Cyndi Dawson, Javier Silva, Barbara Emley, Yann Herrera, Sheila Semans, Mark Carr, Tom Bell, Abby Mohan, Steve Lonhart, Jan Freiwald, John Largier (phone)
Staff: Sara Hutto, Rietta Hohman, Jenn Gamurot

Meeting Objectives:

- Reflect on what has been discussed and learned thus far; provide relevant updates
- Review the results of the site selection criteria survey and the information/data gaps
- Identify immediate and near-term bull kelp recovery options in the context of variable future conditions (scenarios)
- In topic teams, develop draft recommendations for facilitating the recovery of bull kelp populations along the Sonoma/Mendocino coast

Reflections Roundtable
Need to provide some clarity and refinement to what can be done with resources in hand now, versus what we would like to be done if more resources become available, especially for Sanctuaries, we have to be realistic. However, some other organizations like OPC do have pots of money available, so it is very important to outline what needs to be done to advance kelp recovery even if it is not currently feasible.

Cynthia is excited for this meeting to discuss and map out the recommendations and begin the foundation of the report. What we are doing will be critical for informing future steps. Just had joint CDFW/Sanctuaries survey on the north coast; it was an incredible week of diving and discussions between the two groups. Got feedback from a bull kelp geneticist; looking at diversity. Had recreational harvesting event in Albion, recreational divers got 60,000 purple urchins, commercial got 78,000, got a commercial composting facility involved.

Mark Carr asked about the purpose of the site selection group. When identifying application of criteria, are you identifying the purpose and management question? Cynthia said it was specifically for recovery actions, not necessarily for monitoring. The idea is about the combined satellite drone monitoring program. Restoration could include enhancing spore production. An interesting opportunity is to look at persistent kelp beds and asking why they are distinct from the other sites.

Must also look at who addresses that question, as the drone won't tell you what aspects of those sites make them different. We will have to look at seafloor maps and ecology. Cynthia sees it as an analysis of data that we already have. It's not just about where they are, also looking at if there are other sites that we could identify with similar characteristics that we could focus on.

Cyndi asked if we have physical, biological data on why those beds are there? Cynthia - we have drone monitoring. We have a host of other data that can be brought in to analyze.

Javier asked if there has there been monitoring of urchin harvesting projects in Albion and Ocean Cove. Cynthia said that they have been tracking the effort, though there are still lots of urchins on Ocean Cove. Jan from Reef Check is going out also. It's a little early to see bull kelp popping up in response to that. This is the start of a continual harvest at these sites to create an area where bull kelp can thrive. Attempts are being made to make a clearing in the area to ensure that nothing else is coming in Let's also make sure that nothing else is coming in.
Javier suggested that there may be something else to be looked at in addition to just taking out the urchins. Cynthia is working with Mike Graham to be able to check if there are spores in the are; it is a question of whether spores can be dispersed to the cleared area.

Sheila noted that the amount of bycatch from commercial divers is small. Cynthia estimated multiple hectares. The urchins vary in size. Having some kelp bycatch may be typical.

Francesca noted that the events galvanize a community and bring people together to help with recovery. 96 recreational divers and 9 commercial divers participated. Commercial divers got smaller ones than the rec divers. Cynthia didn't see a big change from last year to this year.

Tom Ford asked about the density; it is about 500-1,000 per square meter. Peak abundance is within 20 feet. The areas that the commercial divers are clearing are smaller.

Cynthia noted that this was the first event at Ocean Cove; the divers were not as focused and didn't get as much accomplished as at Albion. At Albion they have commercial and recreational divers working together to expand on an area. It is a process to lower the density and maintain them. Recreational harvesting is one tool to get us there; in combination with commercial is a better route.

Cyndi noted that the recommendations are going to matter and will set expectations in the community. There is a worry that the emergency regulations will set an expectation. We should be aware that the recommendations will be uptaken by the community.

Mark noted that this group should produce recommendations that engage the community in working on the problem. The groups will mostly work together as the 3 topic teams have a lot of overlap. Bibit noted that as a working group we need to talk about the system including climate change and genetics to put more teeth to the recommendations

Abby noted that there are rumors and miscommunication in the maritime community often with misinformation. Therefore, it is helpful to have organized community involvement for events. We should ensure there is a good place to direct people to and to have consistent messaging.

Scenarios and Recovery Options

Cynthia led the discussion about scenarios and recovery options, with best case, worst case, and interim case scenarios. This can inform the context and provide some bounds for the recommendations. Lot of uncertainty in the ocean and our future.

Best case scenario (2019-2020)

- "Urchin crash". Mark noted that urchin barren areas are losing their urchins in central CA. Best case would be that life takes its course and urchins are wiped out; a storm comes through; disease. We are seeing signs of distressed urchins. We are now in this phase where additional recruitment dynamics will play into sites. The timing of the crash relative to spore production is important in terms of how the kelp will rebound. This may lead to bull kelp recovery (in 2019-2020) if urchins were the only thing hindering kelp.
- Sufficient nutrients, favorable conditions for kelp, unfavorable conditions for predators.
- Recent "perfect storm" was unfortunate fluke. The larvae side has to be a component of the best case scenario.
- Comes down to three aspects: supply of urchin larvae, existing urchins, and growth of kelp
- Kelp come back indefinitely after 2020, persist into the future

Worst Case Scenario (for bull kelp)

- Persistent adult urchins and continual recruitment
- Persistent warm water/more frequent warm water conditions (Link to "Increasing Coupling Between NPGO and PDO Leads to Prolonged Marine Heatwaves in the Northeast Pacific" (provided by Tom Bell) http://www.o3d.org/manu/papers/PDFs/Joh-2017-Increasing-Coupling-Between-NPGO-and.pdf
- Non-native algal and other space-occupying species
- No refugia for kelp (no pockets with favorable conditions)
- Insufficient spore bank
- Spore limitation from local refugia/exclusion
- Managerial efforts and restoration are ineffective (*must define what that means)

- Ecosystem services provided by a kelp forest are gone

Interim Scenario
- Locally persistent islands of kelp refugia needing maintenance
- Episodic oceanographic conditions (different than historic)
- Move towards nutrient availability following this new trajectory of ocean climate conditions (bottom up); moving towards incompatibility
- Expect more variability (frequency and amplitude)
- More uncertainty about kelp forest resilience (Performance metrics important here)
- Shifts in ecological dynamics (coupling and decoupling of ecological relationships

When do we know which scenario we are going down? (Question for monitoring folks)

Topic Teams Discussion Notes

Community Engagement (Jenn)

1. *Document current community engagement efforts and develop recommendations for how to involve the community in recovery efforts (consider citizen science, community-led urchin harvesting events, tribal engagement, etc.) and document current efforts*
   Current and future Community Engagement Efforts/agencies/messaging audiences

- Community and public recreational fleet captains (Abby)
- Tribes - Seaweed gatherers and indigenous harvesters, tribal water consortium in Northern CA, North Coast Resource Partnership tribal representative (Javier)
- Tribal communications with government agencies (Javier)
- The Sea Ranch Association
- Campgrounds/State Parks
- Gualala Arts Center, Point Arena Library
- CDFW
- GFA (Francesca)
- Bodega Marine Lab
- OPC
- Chamber of Commerce
- General public/recreation
- Abalone divers
- Newspapers (SF Chronicle, NYT, Point Arena Light, Ukiah, Press Democrat, Marin IJ, do editorial, consistent messaging/story, educating the community as a whole

- Bay Model
- Fisherman areas/locations
- Suki Waters/kayaking locations
- Kids in the classroom
- TNC- project for citizen science, link on Noyo site, to get people who are seeing and doing things to report it (dead abalone, stand of bull kelp, rec divers taking urchin, commercial diver take) this is not working very well- Francesca says this might be a few steps beyond where we are now…..

Draft Recommendations

- Provide consistent messaging to all organizations/agencies
- Create a "Kelp Binder" with information, docent book with photos/visuals
    - Here is a great example of the docent book presentation binder we need printed to pass out to relevant organizations: https://noyocenter.org/wp-content/uploads/2018/05/HtK-training-all-how-we-got-here.pdf
- Create an image library (Sheila has some PDFs; put more images, photos in)
- Help other organizations understand how the kelp issue is connected/related to issues they care about (i.e. Audubon Society). Draft a blurb about how the kelp issue impacts other species
- Create an internal kelp group shared Drive/portal with internal information, to continually update community with events etc; GFNMS/Ocean Climate program to own? State has started an open data portal/library. Assets could be in there. Cyndi has this.
- Information portal for outreach materials (CDFW has one; Cyndi can share).
- Share consistent information/messaging/videos through partner social media channels
- Find beneficial uses for urchins
- Translate outreach materials/presentations into various languages to reach out to wider audience
- Commercial divers can film what is happening underwater; stream through videos. 3D element is powerful. Shows the problem and how we can use that. Check with MARE/other partners for ROV footage that they may already have related to kelp
- Connection to climate change as part of the problem; showing land development/uses as drivers of stressors to estuaries/etc. Identify that humans are contributing; looking at better practices. Trying to get people to understand the larger picture; not considering urchins as the main villain. Encourage what people can do in their daily life

Products

- Talking points
- Shareable presentation
- List serve with community events/information portal
- Shared drive of visual assets

- Iconic social media-worthy photos and videos
- "Traveling roadshow" presentations to have a large number of people spreading the same message. Could do targeted date/time frame for peak interest (spring), dive shops
- Youtube channel to show/digital version of the presentation

2) Identify lead groups/agencies/stakeholder groups for community engagement/governance/who are the players, who needs to be involved, etc

See above

3) Develop consistent messaging, identify correct and consistent scientific elements to the story.

- o *Identify target audiences for messaging*
- o *Identify best methods to reach target audiences*

- Many levels of messaging. Target audiences include
  - Public,
  - Larger community,
  - Recreational divers
- Informational cards, outreach materials
- Creating "buckets" for community to be involved with.
- "Urchinomics" - fatten up the urchins to be commercially useful. Our job is to make them usable

<u>Meta message: 4 building blocks to create the take-aways we want to deliver (the below is an example of the construct -- not *yet* wordsmithed)</u>

1. Place: Ecological, historical, cultural, economic significance for humans and species

a. Northern California bull kelp forest is an underwater community with ecological, historical, economic, and cultural significance chock full of marine life

b. Analogies/metaphors "what would California be without redwoods? Kelp forest?"

2. "Problem" *word to be changed: "Perfect storm: wasting disease of major purple urchin predator coupled with warming ocean conditions (warm water blob, El Niño, "the blob" - a heat wave in our marine ecosystem) resulting in an unprecedented, dramatic, and startling 95% decrease of bull kelp forest in the last five years.
3. Why it matters: The kelp forest sustains and supports over hundreds of species, many of which are harvested and the tribes and fishermen rely on kelp forest for human subsistence, recreation, and entire economies.
4. Action: (how you can help), list organizations, Donate, Dive, Dine.

Discussion:

- Based on audience needs, note where printed vs. electronic materials would be more effective.
- In messaging, highlight "adaptive restoration". We don't know the cause but we are trying to understand it more. Learning as we go. Being explicit with regulations. Want to tie in

with climate change; meeting people where they are. “Increasing variability”. Transparency in this adaptive learning. Public audience piece.

- Eliminate barriers for public to receive research, make research more accessible to public
- In terms of our topic team recommendations - the HOW we do it would mainly remain consistent but the WHAT would be driven out of directions provided by SITE SELECTION and MONITORING TEAMS (substantive content)

Site Selection (Rietta)

Major points of discussion:

1. Prioritize sites based on weighted categories:

a. First - ecological significance (current and historical significance, isolated kelp beds, sediment, freshwater output sites), then areas to avoid (MPAs, culturally sensitive areas), then take into account positive additional aspects (public access, wave exposure, citizen science).

b. Consider specific sites based on funding availability using weighted categories.

c. If criteria group is weighted differently, provide clear reasoning.

d. Confirm with local and traditional knowledge.

2. Consider multiple layers of persistence - both historical and current - when looking at specific sites. Especially for Sonoma - rely on historical rather than current persistence.

. Consider that persistence may occur at different sites for different reasons.

a. Need to define what constitutes the “persistence” layer.

3. If site selection criteria result in regional grouping, take additional positive aspects into greater consideration/apply higher weight.

. Make persistence criterion less stringent if necessary.

4. When specific recovery sites are chosen, a corresponding control site should be chosen at the same time.

. Learning from the recovery process is essential.

a. MPAs may be considered controls to minimize influence of commercial and recreational take on monitoring.

5. Different types of recovery actions should be identified for different sites depending on the criteria for which they were selected.
6. Critical to keep both sport and commercial divers involved.
7. Proximity to public access points, or areas that could reasonably be reached by boat, are of significant importance.
8. Determine how best to link with data gaps and monitoring.
9. Genetic samples of kelp from Alaska through northern CA – despite the bottleneck we saw high genetic diversity.
10. Further discussion needed to identify specific process for recommendations.

Monitoring and Information Gaps (Sara)

At a bare minimum, the group agreed that scientists and managers must have annual remote-sensed surveys of kelp canopy cover (mechanism not specified) – ideally, we would develop satellite and drone methods in tandem to achieve required data frequency and resolution.

Satellite-based data:
- 10 meter resolution at least through European *Sentinel 2* satellite
- 30 meter resolution through Landsat – seasonal (4x per year)
- With both satellites, could have data every 2-3 weeks

UAV-based data:
Because satellites don't provide the resolution and scale of data needed to ask some critical questions, we also need drone data to verify satellite data and provide finer resolution
UAVs provide:

- Improved spatial resolution
- Ability to ID vulnerable areas that are not captured by satellite imagery – tied to specific locations (kelp refugia, urchin harvesting)
- Ability to ID areas that Landsat can't capture, or in areas where you need more information, inform the MLPA process
- Spatial heterogeneity of reef structure
- Help identify persistent pockets of kelp for spore supply
- Species-specific resolution

The main constraint with drones is coastal access and permitting issues (primarily with Sanctuaries); liability would reside with the individual flying the drone. Though we are at least a decade away from being able to "mow the lawn" per se and collect large-scale data along the coast autonomously, the most effective way to gather drone-based data would be to decentralize the data collection and leverage 1) Scientists and contractors (experts) OR 2) drone enthusiasts (citizen science) to run specific tracks at a specified frequency. Scientists (Tom Bell, Kyle Cavanaugh) would provide best practices and methods to the users, and the users would submit their images on a drop box for analysis. This could be all web-based to prioritize sites and contact folks to get their images in. Tom Bell and his lab are already running the infrastructure – the desire is to scale up the collection. Track files can actually be sent to individuals with a log-in and the drone can run on autopilot collecting and transmitting the data.
If we go the "enthusiast"/citizen science route, we would have two options:
1. Creating an organization like Reef Check to actually run a drone imagery program with training, etc.
2. Develop a crowd-sourcing website – this would be much more hands-off, less investment, less risk if the whole thing doesn't really catch on

We recommend a phased approach:
1. Create a post-doc opportunity to create best practices (info the users need including methods), build infrastructure (for receiving data), and develop the process.

2. Determine the best user

   a. “experts” – academics, contractors (different sensors – higher tech)
   b. Crowd-sourcing as an initial push and test
   c. Consider a “reefcheck” option depending on how b goes

Data Gaps:

1. Data to explain why some kelp patches are persistent when others are not (detailed biophysical, chemical, biological coupled monitoring)
   a. Landsat data
   b. Bathymetric data
   c. Chris Edwards (Rom’s model)
   d. Need: in situ nutrient data – CTD moorings
2. Identify MPAs with and without persistent bull kelp beds as priorities for this monitoring
3. Explore potential for MPA network monitoring and any other monitoring efforts (e.g. Laura Rogers-Bennett) to fulfill science needs/objectives in understanding kelp dynamics and recovery.

Recommendations:

1. Expedite the processing and analysis of annual (at a minimum) satellite data for bull kelp along the Sonoma/Mendocino coast – engage CDFW and ONMS with what data products they need
2. Develop a large-scale drone monitoring program to complement satellite imagery
   1. Develop best practices for data collection including specific track-lines, altitude; advance image processing and analysis
   2. Identify the user (UC scientists/experts, contractors, drone enthusiasts via crowd-sourcing, NGOs)
   3. Specify product outputs that are needed to manage for bull kelp – engage the managers (CDFW, ONMS)
3. Identify MPAs with and without persistent beds as priority locations for investigating the key characteristics that confer persistence of kelp beds.
   - Process landsat data since 1984 to establish a baseline and evaluate deviation from the baseline – all to define persistence
   - Identify data to help answer the question of persistence (Landsat, Bathymetric, Chris Edwards’ ROM model, *in situ* nutrient data - CTD moorings)
4. Explore the potential for MPA network monitoring and other ecological monitoring efforts (e.g. Laura Rogers-Bennett abalone program) to fulfill science needs/objectives in understanding kelp dynamics and recovery.
5. For current urchin harvesting events:
   - ensure pre and post monitoring efforts
   - be explicitly clear in writing as to the methods of reducing urchins and what is being monitored.
   - Ensure effort is focused (commercial and recreational harvesting are conducted at the same locations)

- Ensure effective reduction of urchins (completely clear a designated area)
- Ensure frequent urchin harvesting so designated clearings remain clear

6. All existing and future non-sensitive data (i.e. PII, tribal) related to these recommendations should be publically available, for example on data.cnra.ca.gov.
7. Use high-resolution drone canopy data to explore relationships of blade biomass with spore production (size of sori).
8. Leverage an existing website (Noyo? GFA?) to compile all public outreach information and data for scientists, and to coordinate urchin harvesting events.

<u>Agree on first draft recommendations/Discussion</u>

Steve - one of the most important things is to have a central website with public information. Contains outreach materials, consistent place to do that. (shows partnerships. Holds press releases, all pertinent information, report, etc)

Recommendations for restoration action will change. What will the recovery options look like? We may not know which scenario we're in until we do some restoration activities and document the response. Could also use monitoring data as a defining metric for which scenario we're in.
- In the near-term, activities should be scenario-independent and focused on how to leverage the community interest with sound scientific design incorporated into future harvesting events. We have to make the urchin harvesting events effective in order to answer the question of being spore limited or not. Need to design the reduction of urchins in a manner to answer that question – focus on isolated rocky outcrops vs broadscale harvesting.

Leverage reduction of purple urchins to answer question of spore limitation. Impossible to answer this question right now due to seasonality of bull kelp recruitment – goal of this season is to figure out methods, and form relationships to set ourselves up for effective work in late winter/spring. The next "round-up" will be to test effective, long-term urchin harvesting. Messaging should be clear – summer harvesting is for purple urchin control, late winter/early spring harvesting is to test spore availability. Recreational harvesting at Ocean Cove (Sonoma) and Albion (Mendo); Commercial divers are working at 3 spots in Mendo (Noyo, Casper, Albion).

Working Group Meeting 3 Summary
September 13, 2018 9:00am-4:00pm
3rd Floor Conference Room at the Greater Farallones NMS Headquarters on Crissy Field, San Francisco

Meeting Notes

In attendance: Rebecca Flores-Miller, Barbara Emley, Cynthia Catton, Meredith McPherson, Jan Freiwald, Sarah Allen, Frank Hurd, Abby Mohan, John Largier, Mike Esgrow, Bibit Traut, Francesca Koe, Josh Russo
On the phone: Mark Carr, Steve Lonhart, Sara Azat

Meeting Objectives:

- Craft a purpose statement for the group
- Review draft recommendations, finalize general components of all recommendations and identify intersections across topics
- Assess the "big picture" and identify recovery actions through time and across scenarios
- Identify agency/individual leads for each recommended action
- Identify most critical next steps and discuss funding opportunities

Welcome and Agenda Overview
Francesca Koe, Working Group Co-Chair, opened the meeting and asked for brief updates from working group members:
Steve Lonhart: Keith Rootsart with Monterey Bay NMS Advisory Council received permission to do limited urchin manipulations.
Mark Carr - Monitoring data continue to be gathered over the summer by Reef Check, PISCO (Jan, Mark, Steve). There has been some recovery down in Monterey/central coast, so there may not be action needed in that area. Is CDFW monitoring the condition of red urchins along the coast? Cynthia - yes, not every year, but we do have data pre/post kelp loss. This year we've been focused on purple urchin reproductive condition. Want to continue doing this to learn about seasonality and conditions that make big changes with the urchins. Want to determine places or time of year to avoid smashing. Mark - would be good to document the red urchin impacts, esp for commercial fishery. Good to understand social and economic consequences with respect to that fishery. Cynthia - have a Sea Grant proposal in with undergrads at Humboldt State to do a socioeconomic analysis. Divers have had to dive deeper and deeper to find urchins (90+ ft) which is very dangerous. Need to have urchin data documented. Josh - red fishery is closed due to gonad index. Frank - should have specific objective facts on socioeconomics.
Cynthia Catton - added Albion as a site because it is a critical commercial and recreational urchin site. CDFW will be finishing up surveys next week, then diving Sonoma and finishing up

work for the season. They will be working to get all the data summarized. Based on personal observations, things have not improved.

Sara Hutto - Will be presenting as part of a panel at Aquarium of the Bay on MPAs and climate change, and briefly discuss the kelp loss issue and what the Sanctuary and partners are doing to address the issue. Also Point Blue on the panel, hosted by David McGuire of Shark Stewards.

Purpose Statement

Cynthia introduced this item as a necessary step to identify the purpose of the Kelp Recovery Program and supporting working group. She encouraged the group to think more big picture, and to draw from the series of strong discussions on the group's priorities. Francesca presented a draft purpose statement that the group reviewed and finalized:

> To protect, preserve and promote healthy and abundant bull kelp and healthy ecosystems along the northern California coast, fostering collaboration among communities, resource managers and scientific/educational institutions to bring the best information and data to bear on our adaptive management of a vitally important habitat.

Cynthia added that it is good that we are talking about ecosystems and not just bull kelp. This is a building block of what makes this place special. Abundant kelp = healthy ecosystem. Because there has been such a decline, we want to restore it to abundance.

Topic Team Presentations and Recommendation Review

Sara Hutto began this discussion by indicating that the goal is to present and bring everyone up to speed on each topic team's recommendations. Live editing occurred within each topic team document; Sara presented the Data Gaps & Monitoring recommendations; Francesca presented the Community Engagement recommendations, and Cynthia presented the Site Selection recommendations.

A few questions/comments came up during discussion:

- Can CDFW leave markers for restoration sites?
- Recovery action will depend on the characteristics of the site - there will not be a "one size fits all" approach
- We have the processes outlined, now we should talk about how they should be applied.
- Bob Bertelli mentioned that urchins right now don't have any reproductive material and fish eat what is left when they are crushed. Cynthia added that CDFW is evaluating urchin gonadal mass for different seasons to determine best time of year to cull urchins.

The Big Picture

Cynthia facilitated the group through a discussion of overlapping priorities across topic teams:

1. Digital platforms/Communications
    a. Need approved, consistent messaging
    b. OPC's open data platform
2. Citizen Science opportunities

. Comes up in multiple areas of recommendations (data collection, outreach/interpretation, harvests) but not fully developed

A. Through the Kelp Recovery Program, provide list of opportunities and direct interested people (e.g. Reef Check for scuba monitoring, Noyo Science Center for harvesting, Tom Bell for drone monitoring TBD) - via the "Get Involved: Volunteer" action

B. More fully develop a network for information dissemination and collaboration - dedicated person to liaison with all citizen science programs to coordinate activities and priority sites

Francesca added that in terms of digital platforms, recommendations should include that when we are conducting monitoring/citizen science, there should be universal approval on the messaging between partners (central website/database).

- Create a universal consistent way of describing the work being done
- We've discussed the resources that we have available, but it's important to recognize when we have opportunities to address some additional layer that we don't have yet (teachers, dive shops, etc).
- To the degree that we have surveys/citizen science, we need to develop the protocols on how to do it

Citizen science opportunities:

- With citizen science we need to develop a specific plan so as not to encourage the public to engage in the same work that may be against regulations or may be unsafe
- Are they under the umbrella of - who? The sanctuary? KELPRR? Need to identify a central place where citizens can go to find out about opportunities.
- Suggest to the SAC that we reopen the conversation about drones? Develop maps of where drones can or can't go?
- Drones can include software that already have no-fly zones (merges w/site selection)
    - These are special closures and sensitive areas
- Recommend an umbrella program through the Kelp Recovery Program? (so that it is not scattered to the wind?). Or are all of these citizen science programs so different they should be managed differently? Or could they be grouped/managed together?
- May not have infrastructure to create a kelp-specific program?
- Have both - have a central place, then break out into areas of specialization
- Link them all through a specific entity, then get them funded
- There can be cross-promotion between sites "Kelp Forest Recovery Group Approved Citizen Science Programs"

Much of what we are recommending will require much collaboration across the groups/partnerships

- Will require a centralized structure that is funded
- Need a "kelp recovery network", could be an existing person or a new role, but there needs to be dedicated coordination.
- Faster analysis of areas that are overlapping
- Connecting more of satellite data with site selection criteria - Different resolution in satellite versus aerial (30 m versus 2 m)
- Coordinator will need to know each group and their capacity, but also their limitations; less dictating, but more suggesting

Based on this discussion, the group developed a set of primary, overarching recommendations to accompany the topic area recommendations. These are available here: Final Draft Working Group Recommendations.

Active Recovery Options

Cynthia then facilitated discussion on identifying recommendations for the immediate time-frame, which first required the group to brainstorm as many active recovery options for bull kelp as possible. They organized these options by type of action (no action, enhance bull kelp, reduce urchins) and identified which of those options that should be immediately pursued, those options that should be considered in the future, and those options that should not be considered. This information is available in Appendix B. The group reached consensus on each of the recovery options, with the exception of urchin culling. Because the tribal representative was not available for this meeting to help with the discussion, it was decided to table the decision on this particular recovery option until tribal input could be attained.

Funding kelp recovery

Sara then led the group through a discussion of funding opportunities to support these recommendations. She added that it is possible to recommend to the sanctuary that they keep momentum and re-deploy some staff to address immediate needs until a full-time coordinator is hired. Sara and Rietta are currently pursuing funding through the Greater Farallones Association and will build funding proposals around these recommendations. The group identified the following funding possibilities that should be investigated and pursued if relevant:

- The National Marine Sanctuary Foundation may be interested in this issue in particular
- X-prize to generate ideas and crowdsource info for some of our tougher problems (market for urchins, urchin-eating robot, etc)
- Approach OPC to discuss funding sources
- NOAA Fisheries; matching (in-kind) funding is key, consider 2020 S-K grant
- Resources Legacy Fund

- Disaster relief funding
- Packard
- The Nature Conservancy - citizen science to generate management-ready datasets
- Rapid response grants through Sea Grant
- NFWF Coastal Resilience Grant
- KEEN Critical Coastlines Grant
- Josh and GFA work together on private donations
- Moore Foundation
- Consider tribal-specific funds - Bureau of Indian Affairs
- A "foodie" fundraiser
- Benioff

Next Steps

Finally, the following next steps were identified, and the meeting was concluded.

- Jan will send information along to the group regarding their activity in the Monterey area
- Working group evaluations - please complete now or over google forms
- Urchin harvesting event Sept 29/30 at Ocean Cove
- Sara will compile and clean up all recs - circulate with WG on the 27th - WG has first week of October to review
- Jenn send out mtg notes from today
- Jenn will organize a phone call with George, John, Francesca and others on WG to discuss drone issue and how to head it off with the SAC
- Let Cynthia know if you'd like to join the monthly KELPRR calls - Kelp Ecosystem and Landscape Partnership

June 6 Webinar: Objectives and Speaker Biographies
Kelp Monitoring Methods and Technologies
June 6th, 2018 10:00am - 12:30pm

Full notes on the webinar can be found here.

Webinar Objectives

- Learn from guest speakers: the various efforts to survey kelp beds using different methods and technologies, the challenges of remote sensing and aerial mapping, and ways to address challenges
- Discuss implications for our region; what technologies seem most promising and effective? What could be applied in our region to better understand changes to kelp forests?
- Begin crafting monitoring recommendations based on what was learned - take detailed notes to revisit at 2nd working group meeting

Rebecca Flores Miller is an Environmental Scientist with the California Department of Fish and Wildlife (CDFW). Rebecca is the CDFW lead for marine algae management, including: managing the statewide aerial kelp surveys, tracking commercial kelp and other marine algae harvesting, reviewing and providing guidance on marine algae related permit requests, and providing recommendations to the Fish and Game Commission (Commission) on kelp harvest plans, kelp bed lease requests, and potential regulation changes. Rebecca is the lead on the three-phase process to review and amend the commercial kelp and other marine algae harvest regulations. She has overseen the completion of Phase One, focusing on the kelp regulations which included updating Administrative Kelp Bed boundary descriptions and kelp harvest plan requirements. Rebecca is currently working on the Phase Two review, focusing on marine algae management policies including harvest methods.

Presentation title: California Department of Fish and Wildlife Aerial Kelp Surveys

Rebecca will be presenting information on the California Department of Fish and Wildlife's aerial kelp surveys. The presentation will include the survey background, how to access the data, uses of the dataset, an overview of the north coast kelp surveys, and the value and limitations of the surveys.

Tom Bell is a postdoctoral researcher with the University of California Los Angeles and the University of Alaska SE. He completed his Ph.D. in Marine Science from UC Santa Barbara in 2016 under the guidance of Dr. David Siegel. Tom has been working on the remote estimation of giant kelp biomass and physiological conditions since 2011 and has published many papers on the topic with several additional manuscripts in preparation and in various states of review.

Presentation title: Remote Estimation of Kelp Canopy Density along the California Coast

Presentation summary: Tom will present an overview of the methods to estimate kelp canopy density from multispectral satellite imagery, such as the Landsat sensors. This process can be summarized as two main steps: the identification of kelp containing pixels using supervised classification techniques and the estimation of the kelp canopy density within a pixel using multiple endmember spectral mixture analysis. Successful implementation of this method can be used to produce a 30+ year time series of kelp canopy dynamics for most areas of the globe. Tom will also present recent results using these data linking giant kelp dynamics to various environmental drivers and the application of this method to bull kelp canopies in the NE Pacific.

Meredith McPherson is a third year Ocean Sciences PhD student in the Kudela Lab at UC Santa Cruz. Meredith studies kelp in northern California using a variety of remote sensing technologies, and is interested in understanding the effects of oceanographic, ecological, and biogeochemical processes on radical changes in kelp biomass in Sonoma and Mendocino counties over the past decade. Previously, she completed her BS and MS in Ocean, Earth, and Atmospheric Sciences at Old Dominion University (ODU). Her research at ODU focused on studying the effects of in situ water column optical properties on seagrasses in Florida Bay as an undergrad and developing a mechanistic model to predict the impact of environmental conditions on carbon uptake and isotope discrimination in Eelgrass (Zostera marina) as a masters student, both under Dr. Richard Zimmerman.

Presentation title: Re-thinking our approach to observation and monitoring of Bull kelp after large scale ecological and environmental perturbations on the North Coast

Presentation summary: The CDFW has historically monitored kelp canopy area using aerial surveys, but temporal and spatial coverage is intermittent in northern California across the bull kelp die-off. Landsat imagery has proved to be a fantastic tool for detecting relatively large giant kelp beds in southern California, however it is unclear whether Landsat can accurately estimate bull kelp after the die-off in northern California, which reduced canopy diameters to <10 m. Relatively high spatial resolution sensors may be necessary to accurately capture Bull kelp. I will discuss the suite of sensors we are exploring to understand the spatial requirements of Bull kelp using remote sensing, and some challenges we've encountered in utilizing commercial satellite imagery with higher spatial resolution than Landsat. Furthermore, I will present upcoming field work to quantify bull kelp biomass and kelp health (expanding on research published by Tom Bell), which is important for linking remotely sensed data to bull kelp physiological conditions through space and time.

Maycira Costa is a professor at the University of Victoria, Canada and she is the coordinator of the Remote Sensing Laboratory in the Department of Geography. Her expertise is in oceanography and ocean remote sensing.

Presentation title: Detection of Bull Kelp (Nereocystis luetkeana) in the Salish sea Using High Resolution Satellite Imagery.

Presentation summary: Bull kelp (Nereocystis luetkeana) is an important feature of the nearshore environment, forming structural habitat for marine species, protection from wave energy and nutrient entrainment. In the Salish Sea, reports that kelp beds are in decline due to factors such as warming sea temperatures and deterioration of ocean conditions have raised concern amongst the scientific community. This talk will present some of the benefits and challenges of using long-term data set of satellite imagery to detect kelp and understand how its distribution may be changing over time. A framework for using high-resolution satellite imagery acquired by SPOT and WorldView will be demonstrated.

Helen Berry is a marine ecologist who maps and monitors nearshore habitat for the Washington State Department of Natural Resources, the state steward of intertidal and subtidal aquatic lands. Helen's current projects include long-term monitoring of kelp, seagrasses and intertidal biotic communities. Findings from these projects are used to track habitat condition for DNR, the Puget Sound Partnership and other organizations. Helen has an MS in Oceanography from Oregon State University.

Presentation title: An Overview of Floating Kelp Trends and Issues in Washington State.

Presentation summary: Helen will discuss what is known about long-term trends in floating kelp in Washington and patterns in kelp canopy area since 2013, which encompasses the time-period of extreme changes in Northern California. She will also discuss the progress of the Washington Kelp Recovery Plan, which is currently under development.

June 26 Conference Call Summary
Site Selection Criteria

On the call:
Sara, Rietta, Jenn (staff)
Cynthia, Francesca (chairs)
Sarah Allen, Sheila Semans, Sara Azat, Jan Freiwald, Barbara Emley, Bibit Traut, Bob Bertelli, Josh Russo, Rebecca Flores-Miller, Cyndi Dawson, Javier Silva, John Largier (members)

Introduction:
Cynthia opened the meeting by providing an introduction to the call and stating the goal - to confirm site selection criteria that would enable the group to identify locations along the coast for management action to retain spore production for the bull kelp population overall. There may also be a need to create criteria for other purposes - like sites to monitor, for example, which would be separate from this list. We have put together a draft list of criteria for this group to review and discuss.

Criteria overview:
Aerial survey data of kelp canopy - as a way to identify areas of persistent, robust kelp forests contrasted with where current forests are and finding overlap - there are different ways to approach this dataset. If we are thinking about a network of spore production, we can look at the distance between current patches. Feasibility is captured in a few criteria - how protected a site is from dominant swell/wind for diving feasibility, and proximity to access points.

Working Group input:
Francesca:
1 - Curious about the freshwater output sites - what changes in productivity would be expected with proximity to freshwater sites? Cynthia: this criterion is aimed at places where the urchin population may not be able to persist as strongly due to vulnerability to freshwater input - natural locations to consider for restoration. Francesca - good to consider, but maybe not a foundational criterion.

2 - Also, what about considering existing monitoring sites (e.g. reefcheck). Cynthia: will want to select sites that do have historic monitoring - add a criterion for subtidal monitoring sites.

3 - Aside from predominance of growth in the summer, in our region, are there sites doing different things across seasons? Cynthia: there are interesting seasonal dynamics happening but hard to detect with such sparse biomass right now. Seasonality is very narrow - shows up at the

surface in the fall. We do not have much information on seasonal dynamics, but a good point to identify this as a knowledge gap that would be helpful to fill.

Cyndi: current policy of the state does not support manipulations within MPAs, so would need to ensure sites are outside of MPAs. Connectivity between sites will be critical. Will need a design that allows us to answer some critical questions - a challenge on the north coast to allow for replication and robust scientific design. Ensure that we are proceeding with caution and not getting out in front of scientific design.

Bob: important to find places where the understory algae are coming back - bull kelp may have a better chance to establish (indicates better health and other food options for inverts). Freshwater input should not be overstated - there are healthy urchin populations in areas with freshwater input. Cynthia: maybe add a criterion for commercial diver info on urchins - citizen science project.

Rebecca: Equally important in maintaining spore connectivity is maintaining spore availability in isolated kelp beds to facilitate persistent kelp beds (that are naturally isolated) - to see if those are being reduced to get at the notion of finding patches that may be protected from urchins (surrounded by sand like in Southern CA). Cynthia: these areas are harder to find on the north coast, but maybe places isolated for other reasons (like at the top of a pinnacle). Urchin divers are keen to identify small coves to target for urchin harvesting as they may be more easily defended.

Sarah: industrial infrastructure adjacent to kelp beds leading to runoff. When we've worked with Redwood National Park on culverts - with more intense storms, we may see larger inputs from those (sediment, contamination from roads and ag, etc.). Cynthia: we have major river outlets associated with sandy habitat. Rietta: no large-scale industrial development that would impact habitat - more of an issue further south, less development on the north coast.

Sheila: spreadsheet is really good. Sediment is much more of an issue than any kind of contaminants - definitely consider sediment. Divers are seeing nice little kelp patches this year where there is some protection from snd bars (less area to defend). Size of kelp patches is important to consider as well. Proximity to popular dive sites - a positive or a negative? We aren't getting people to input data into the citizen science website right now - urchin harvests going on that we aren't capturing or knowing about. Do we want areas that are more accessible for people to go in and reduce urchins, or a more pure, non-accessible site for science reasons. Bathymetry is key - need to follow up with Mark and Paulo on filling in the white zone. A lot of info coming back now from divers - how to integrate the diver input? Sheila has been asking divers for lat/longs when they see new patches. Cynthia: don't want a site so small to be trivial, but maybe a much larger area to be able to select within to apply recovery actions. Site scale is something to consider - what is logistically and financially feasible?

Rebecca: will we be attempting to rank these criteria? Cynthia: would be great for WG members to send to staff how they would rank them. And we can follow up with a discussion at the August meeting.

Javier: can provide a document that shows some of those sites for Mendocino County. And can get this info from folks in Sonoma County. Current use areas - where tribal folks are going - paired with historical use, could provide some insight. Some areas we will want to avoid disturbing, some areas we want to support with active restoration/recovery actions. Cynthia: this conversation can be more of a start, we just want to finalize our thoughts by the August meeting. More detail about what this criterion might be to better inform how the criterion is used - we will need to work closely with Javier and his colleagues to identify culturally significant areas to avoid and areas to support with active restoration.

Bibit: site selection vs. restoration design. From webinar discussion, learned that temperature really affects recovery - something to think about when selecting sites is considering temperature-tolerant variants of bull kelp (can we do this? Incorporating sporophylls from more southern populations that are exposed to warmer water) - if this possible now or in the future, should consider for site selection. Upstream, active forest management can contribute to inputs to the system through rivers and streams.

Cyndi: white zone has been filled in - published and available. Water quality on the north coast - upstream agriculture and septic systems lead to significant water quality issues even though it is more rural - key to consider. Citizen science - learned that the interface is really important and having a mobile component to that interface (satellite service on phones) to take GPS locations and associated data. Always a balance - there are detailed science questions to answer vs. quality/quantity of data from the users. Is the idea to select the site, do treatment manipulations and replicate across sites or within sites? Cynthia: the citizen kelp interface does have a mobile app - but getting people to participate is the difficulty. Would like to take this to the next level, this is just a start. Purpose of what we're talking about today is getting us to the longer-term goal of identifying sites that we want to ensure have healthy kelp habitat - independent of whether we think we can accomplish but what is our goal. Additional discussions on what are our science questions to ask and address with targeted experiments, maybe at these sites, to help inform how we do this. Scientific design to come later - right now, we just want to identify where we want kelp to be.

Sarah: thinking ahead to possible future impacts and extreme events (like a vulnerability assessment) - how we might respond to an extreme event impacting our sites. Parking lot this - as something to consider in discussions moving forward. Cynthia: there are some different, unusual stressors that we can think about (e.g. sites closer to SF Bay may be more vulnerable to oil spills). Are there certain stressors we are particularly concerned about and we may want to choose sites that are less vulnerable to those stressors?

Jan: criteria of exposure - clearly we need to access the sites, but sites that are more exposed are likely to be more protected from urchins (though not much info on this). Cynthia - if we are able to overlay aerial survey data with wave exposure then we can find those sites and determine if some of them may be accessible. Within fish and wildlife survey sites would have baseline data to inform as well. These criteria, once prioritized, are meant to build on each other - what are the foundational pieces of information that we want to build on and add additional criteria to in order to narrow down list of sites. Jan: maybe should expand criteria to other oceanographic conditions - temperature, OA, upwelling, etc. Criteria of proximity to MPAs is skirting the issue - we should really discuss if we want to work within MPAs or not - could inform the policy. This group needs to decide if we want to pursue that to help change the policy. Francesca: would need to lay out the reasons for why we may want to conduct activities within an MPA. In the spirit of the collaborative nature of MPA design (and SAC input on that) - if there is something that can be collaborated on within an MPA that can inform all parties involved, then we should not shy away from that. Cynthia - this is discussion we can have at the August meeting.

Bob: Probably more flexibility in a SMCA (allow some take) than an SMR - when it comes to a scientific permit, even more flexibility. May be a good diea to take one MPA and see what happens - however, as a consumptive user, in the future managers would need to be explicity regarding any manipulations that take place and how that is perceived if successful.

Josh: we've been targeting easily accessible sites by boat and shore - clearing index sites and trying to connect them, could continue this strategic clearing. What this working group recommends is different than urchin fishers are doing now, they are leading the way and experimenting. Cynthia - yes, we are learning a lot this year and want to build on the work everyone is doing.

John:
1 - sites should be somewhat isolated (sand run, rock outcrop)
2 - spacing of sites distributed through range but close enough to other places for seeding (not all clustered, but good potential to seed nearby areas).

3 - Select across diverse physical settings, not all protected in coves.
4 - Same with temperature - select across diverse temperatures.

Mark (via email):
Great restoration sites would be: shallow, protected, close access for divers, historically supported substantial, persistent beds, in close proximity to existing beds as sources of spores, with mixed rock and sand substratum to create more persistent clearings of urchins, and separated from one another by spore dispersal distance in order to cover as much of the coast with spores as possible.

<u>Data</u>:
Rietta then demonstrated some of these data layers that she has been able to pull together in ArcGIS - including:
- persistent kelp canopy (from various years - growth in 2014 overlayed with persistent beds),
- bathymetry,
- coastal termini (not magnitude and flow which is what is needed, just where freshwater output meets the coastline),
- boat launch sites, with a 5nm buffer to indicate how far boats may want to travel
- MPAs

<u>Next Steps</u>:
1 - Before July 6th, review the updated criteria list and call notes, and provide edits/comments to the google doc.
2 - After criteria have been finalized by staff (~July 9), each working group member will insert a column within the modified spreadsheet to rank the criteria (more instructions to follow on this!)
3 - Staff will provide a summary of those recommendations at August 2nd meeting
4 - August 2nd meeting - you'll initially be working in topic teams to develop recommendations for 1) monitoring/scientific design of experimental studies; 2) management actions for specific sites; 3) community outreach and engagement strategies. We'll either convene in the afternoon as one group or rotate through the recommendations first. Details TBD!

Additional info:
- The next recreational harvesting event of urchins is July 21, 22 in Albion campground, meeting by the boat ramp by the bridge - just show up, could dive, kayak, watch
- Greater Farallones Association (which supports the work of the Sanctuary) has a Kelp Recovery webpage where we'll soon start posting updates and can link to any partner pages - let me know if you'd like us to highlight any of your work or links related to kelp recovery (and there's a "donate" button on the page to support our work!)

Appendix C: Established Partnerships

Listed below are the agencies, organizations, and stakeholder groups that would be engaged and leveraged in the development of a Kelp Recovery Program and Kelp Recovery Network. This list will be continually expanded as new partnerships are formed.

- California Department of Fish and Wildlife
- Greater Farallones National Marine Sanctuary
- Greater Farallones Association
- The Nature Conservancy
- North Coast Resource Partnership Tribal Representatives
- Sherwood Valley Band of Pomo and Noyo Tribal Community
- Round Valley Tribes
- Coyote Valley Band of Pomo
- Manchester/Point Arena Tribe
- Potter Valley Tribe
- Kashia Tribe
- Inter-Tribal Sinkyone Council
- Noyo Center for Marine Science
- Urchinomics
- Surfrider Foundation
- Watermen's Alliance
- Get Inspired, Inc
- Reef Check California
- California Sea Urchin Commission
- University of California, Bodega Marine Lab
- Lift Economy
- Nutiva
- North Coast Brewing
- Fortunate Farm
- Humboldt State University
- University of Santa Cruz
- San Diego State University Coastal and Marine Institute
- Farallon Institute
- Waves of Compassion Association

Appendix D: Restoration Site Selection Criteria Rankings

Rankings as determined by the Kelp Recovery Working Group for restoration site selection criteria. The weighted criteria used in the site selection analysis in Section 7.0 are based on the the rankings below.

	Site Selection Criteria, in order of importance (n = 16)	**Average Rating** (1 = Very important; 5 = Not important)
1	Current persistence of kelp	1.13
2	Historical persistence of kelp	1.25
3	Subtidal survey sites	1.63
3	Areas of cultural sensitivity to be avoided	1.63
4	Areas of cultural significance to be recovered	2
5	Historically isolated kelp beds	2.19
6	Sediment Impacts	2.25
7	Presence of anthropogenic stressors	2.31
8	Sites of value to red abalone fishery	2.34
9	Proximity to public access points	2.44
10	MPAs where urchin harvest is allowed	2.56
11	Protection from wave exposure	2.63
11	Sites of value to red urchin fishery	2.63
12	MPAs where urchin harvest is prohibited	2.88
13	Freshwater output sites	3.25