INTERIM ACTION PLAN
for Protecting and Restoring California's Kelp Forests

February 2021

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OCEAN PROTECTION COUNCIL

Executive Summary

Kelp forests are fundamental to California's marine biodiversity and its ocean economy. Both giant kelp (*Macrocystis pyrifera*), a perennial alga that dominates in southern and central California, and bull kelp (*Nereocystis luetkeana*), an annual alga that dominates in northern California, are foundational species that provide a variety of ecological functions and ecosystem services. In general, California's nearshore environment has supported healthy kelp forests for decades; satellite imagery dating back to 1984 shows significant interannual variability but a stable overall trend in kelp canopy area across the state prior to the onset of a marine heatwave in 2014. The marine heatwave had variable effects on kelp in each of California's major geographic regions: northern California (California/Oregon border to San Francisco Bay), central California (San Francisco Bay to Point Conception), and southern California (Point Conception to the California/Mexico border, including the Channel Islands). Bull kelp forests in northern California were devastated, experiencing greater than 95% loss in kelp canopy from 2014 to 2019 and limited recovery in 2020. Giant kelp forests in central California have exhibited patchy declines since 2014, but no discernible region-wide trend. The marine heatwave generally had no strong effects on giant kelp forests in southern California.

Given the ecological and socioeconomic importance of kelp, the severity of kelp declines on the north coast, and the anticipated impacts of changing ocean conditions, the protection and restoration of California's kelp forests has emerged as a top priority for the California Ocean Protection Council (OPC) and the California Department of Fish and Wildlife (CDFW). Efforts initiated in 2019 and 2020 are providing resource managers with critical monitoring data, an enhanced understanding of the drivers of kelp loss and persistence, and science-based evaluations of potential kelp restoration approaches. However, significant knowledge gaps remain. In support of OPC's Strategic Plan to Protect California's Coast and Ocean 2020-2025, (Objective 3.2, Target 3.2.1), this Action Plan is intended to summarize current state-supported kelp research and restoration initiatives, as well as other relevant efforts in California; highlight key knowledge gaps; and outline priorities for action in kelp research and monitoring, policy development, restoration, and community engagement. Those priorities include: completing pilot efforts; developing science-based metrics for tracking kelp forest ecosystem health; implementing statewide kelp forest monitoring based on those metrics; initiating the development of a kelp restoration and management plan, which will include a restoration "toolkit"; and engaging with California's coastal communities and Native American Tribes.

OPC has developed this interim Action Plan in partnership with CDFW to serve as a starting point for discussion between resource managers, the academic community, California Native American Tribes, coastal stakeholders (including the diving and fishing communities), and members of the public. OPC will offer opportunities for engagement on this draft throughout 2021, and a final version of the Action Plan will be presented to the Council for consideration and possible adoption in Spring 2022. That version will incorporate results from research and restoration projects currently underway, as well as scientific, Tribal, and public input.

1. Introduction

California's iconic kelp forests are among the most productive and biodiverse ecosystems on the planet. Both giant kelp (*Macrocystis pyrifera*), a perennial alga that dominates in southern and central California, and bull kelp (*Nereocystis luetkeana*), an annual alga that dominates in northern California, are foundational species that provide a variety of ecological functions and ecosystem services. Kelp forests form complex three-dimensional habitat and host a diverse array of invertebrates, fishes, marine mammals, and birds. Kelp is an important food source for herbivores and detritivores and underpins nearshore food webs. Additionally, kelp buffers shorelines against waves and storms, plays an important role in coastal nutrient cycling, and may help to mitigate ocean acidification at local scales (Steneck et al. 2002, Springer et al. 2010, Carr & Reed 2016, Miller et al. 2018, Nielsen et al. 2018, Hirsh et al. 2020, Lamy et al. 2020).

Kelp is also critical to the well-being of California's coastal residents and the state's $44 billion ocean economy (NOAA 2015). California's indigenous peoples, who have inhabited and stewarded the coast since time immemorial, continue to rely on kelp forest ecosystems for food, medicine, and ceremony. Kelp supports a variety of commercially and recreationally important fisheries, including recreational red abalone (*Haliotis rufescens*), commercial red sea urchin (*Mesocentrotus franciscanus*), and groundfish, including rockfishes (*Sebastes* spp.). Kelp itself is harvested commercially and recreationally in California, both for human consumption and as feed for aquaculture operations. Finally, kelp forests are a major coastal attraction for many Californians, offering unparalleled opportunities for skin and scuba diving, kayaking, surfing, and wildlife viewing.

Globally, kelp forests naturally fluctuate from year to year, and the significant interannual variability of kelp canopy area on the California coast has been well documented (Dayton et al. 1992, Springer et al. 2010, Krumhansl et al. 2016). However, in general, California's nearshore environment has supported healthy kelp forests for decades; Landsat imagery dating back to 1984 shows a stable overall trend in kelp canopy area across the state prior to a marine heatwave in the Northeast Pacific that started in 2014 and persisted through 2016 (Reed et al. 2011, Bell et al. 2020).

Indicators of kelp forest ecosystem "health" include species-level metrics (e.g. canopy area, biomass, genetic diversity), community-level metrics (e.g. functional diversity, species composition), and socioeconomic metrics (e.g. fisheries landings, tourism revenue). Threats to kelp include overgrazing (often by sea urchins, which can proliferate when populations of their predators are reduced), poor water quality, sedimentation, invasive species, and nutrient limitation, which is typically associated with elevated water temperatures. Disturbance in the form of wave events can also control kelp abundance. These metrics and drivers vary substantially across California's 1,200-mile coastline (Reed et al 2016, Cavanaugh et al 2019, Beas-Luna et al 2020). Accordingly, the 2014-2016 marine heatwave had varying impacts on kelp forest ecosystem health in the state's three major geographic regions: northern California (California/Oregon border to San Francisco Bay), central California (San Francisco Bay to Point Conception), and southern California (Point Conception to the California/Mexico border, including the Channel Islands) (Fig 1).

Bull kelp forests in northern California have declined substantially since 2014. Surveys conducted by CDFW and The Nature Conservancy (TNC) show that more than 90% of the bull kelp canopy off Mendocino and Sonoma Counties was lost between 2014 and 2016 (Rogers-Bennett & Catton 2019) (Fig 2), with an additional 85% decline between 2016 and 2019 (TNC 2020). The scale, magnitude, and speed of the 2014-2019 decline, and the subsequent lack of recovery, are unprecedented (Rogers-Bennett & Catton 2019).

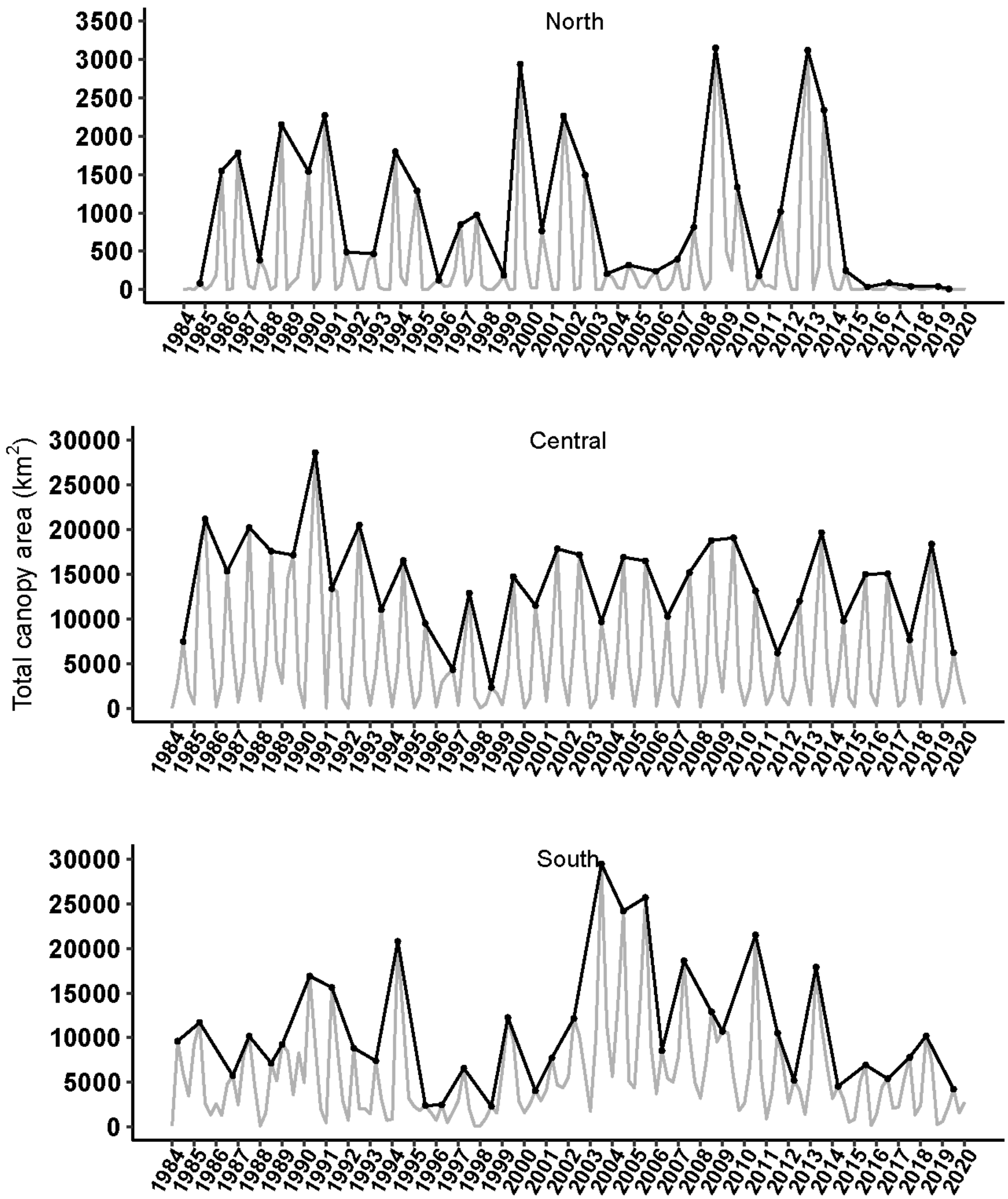

Figure 1. Kelp canopy area 1984-2020 in CDFW Administrative Kelp Beds in northern California, central California, and southern California. Black lines show maximum quarterly area and gray lines show total quarterly area. Preliminary estimates generated from Landsat imagery (Bell et al. 2020). From CDFW in prep.

The loss of bull kelp has been attributed to a "perfect storm" of changing ocean conditions in northern California (Rogers-Bennett & Catton 2019, McPherson et al. in press). The 2014-2016 marine heatwave, which included both the 2014-2015 "Warm Blob" temperature anomaly and a strong El Nino-Southern Oscillation event in 2015-2016, resulted in warm, nutrient-poor waters that reduced kelp productivity and limited the ability of new kelp to establish and grow. Just prior to the marine heatwave, sea star populations were decimated by Sea Star Wasting Syndrome, a disease that resulted in the disappearance of the sunflower star (*Pycnopodia helianthoides*), a predominant urchin predator, from California waters. The sunflower star is now listed as critically endangered by the International Union for Conservation of Nature (Gravem et al. 2020). While the initial occurrence of Sea Star Wasting Syndrome may not have been linked to ocean temperatures, it is possible that warmer waters exacerbated its effects (Harvell et al. 2019).

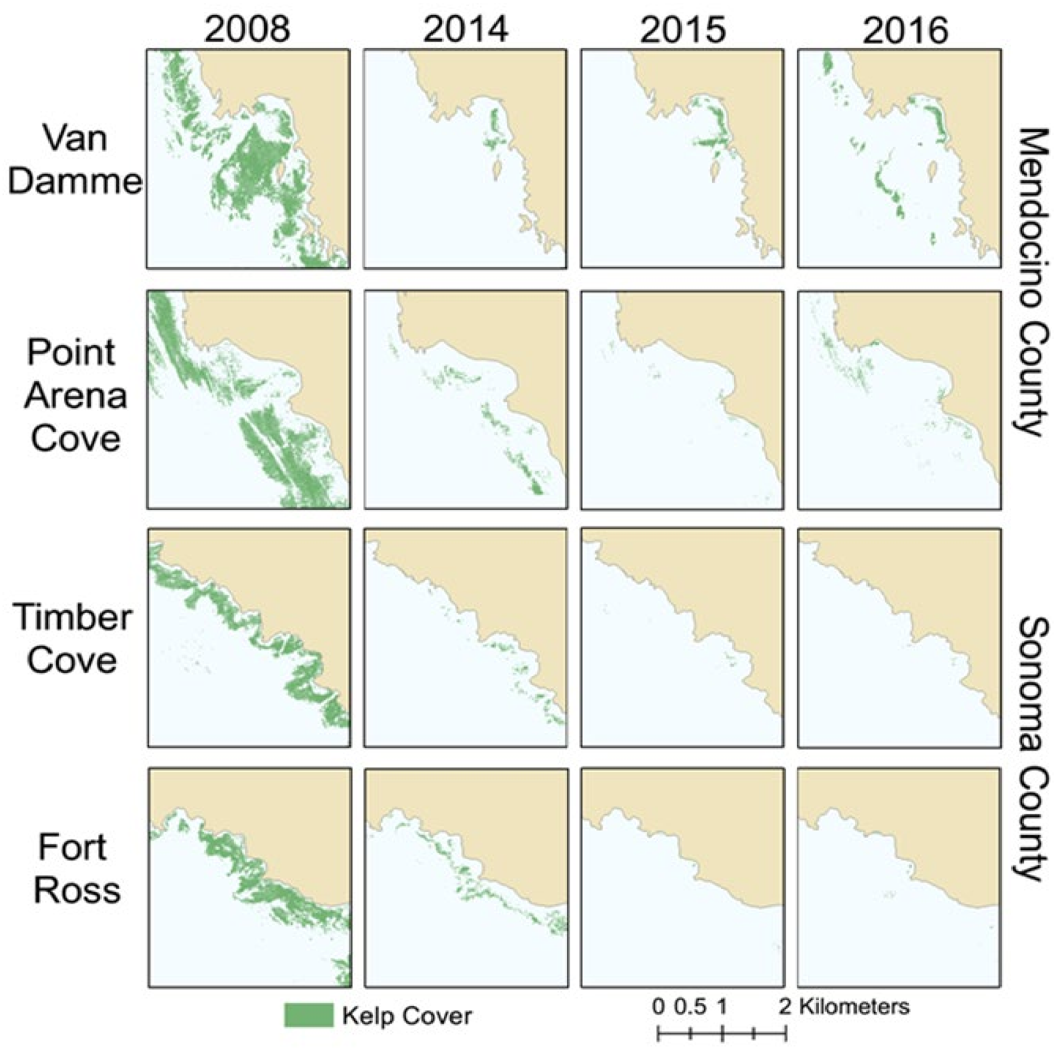

Figure 2. Kelp canopy cover at various sites in Mendocino and Sonoma Counties, derived from aerial surveys conducted by CDFW in 2008 and from 2014-2016. From Rogers-Bennett & Catton 2019.

In the absence of sunflower stars, purple sea urchin (*Strongylocentrotus purpuratus*) populations exploded in northern California, grazing once-lush kelp forests down to bare rock or "urchin barrens" (Rogers-Bennett & Catton 2019); warm waters linked to the marine heatwave may have increased purple urchin recruitment in this region (Okamoto et al. 2020). Even as the marine heatwave has subsided, purple urchin densities remain up to 60 times higher than normal levels at many locations on the north coast (Fig 3). This is consistent with a phenomenon known as hysteresis, or discontinuous phase shift, between kelp and urchins. The threshold urchin density for a shift from kelp forest to urchin barren is much higher than the threshold for the reverse shift from urchin barren to kelp forest. In other words, kelp forests can quickly transform into urchin barrens, but once established, urchin barrens can persist for extended periods as alternative stable states (Filbee-Dexter & Scheibling 2014, Ling 2015, Caselle et al. 2020).

Drone surveys conducted along the Mendocino and Sonoma coast in fall 2020 have documented bull kelp at locations from which it has been absent since 2014 (Norah Eddy, Vienna Saccomanno, and Rietta Hohman, personal communication). However, a potentially depleted spore bank, the persistence of urchin barrens, the local extinction of the sunflower star, and the lack of other urchin predators in northern California will likely constrain the ability of the system to naturally recover to pre-2014 levels (McPherson et al. in press).

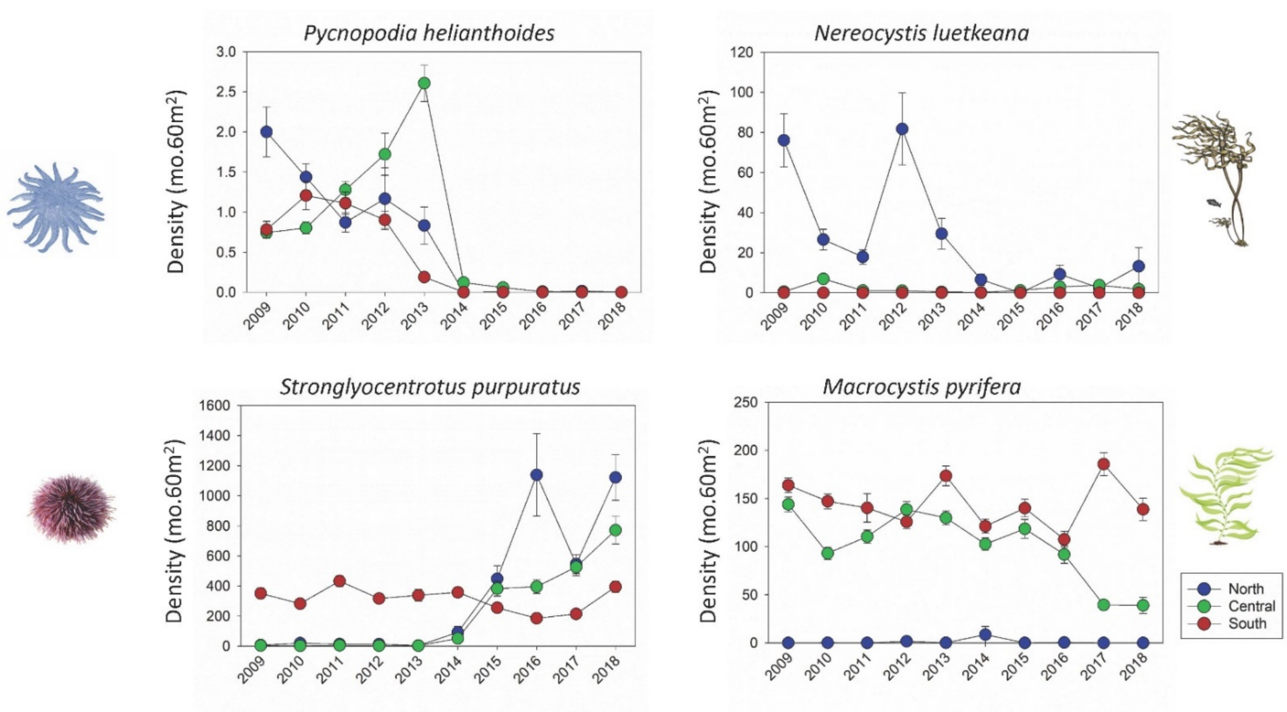

Figure 3. Dive survey data showing (number/60 m^2) of key kelp forest species in northern (blue), central (green) and southern (red) California from 2009-2018. Clockwise, plots show: sunflower stars (*Pycnopodia helianthoides*), bull kelp (*Nereocystis luetkeana*), giant kelp (*Macrocystis pyrifera*) and purple urchins (*Strongylocentrotus purpuratus*). Beginning in 2014, sunflower stars were lost in all regions and purple urchins showed increases of variable magnitudes across regions with the greatest increase in northern California. Bull kelp showed a large decline in northern California while giant kelp showed patchy declines in central California. Data are courtesy of J. Caselle and come from two long-term datasets (Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) and Reef Check California).

The loss of bull kelp has had significant impacts on ecological function and ecosystem services in northern California. Commercial red sea urchin landings in 2016 were 80% lower in northern California than the 2006-2015 average, leading the U.S. Secretary of Commerce to issue a federal fishery disaster declaration for the northern California red sea urchin fishery in 2019 (Teck et al. 2018, CDFW 2019). Populations of red abalone, California's only remaining abalone fishery, have declined so substantially that the $44 million recreational red abalone fishery was closed by the California Fish and Game Commission in 2017 and will likely remain so until the population begins to recover. The north coast's dive tourism industry, which has historically depended on abalone fishing, has been heavily impacted.

In contrast to the devastation observed on the north coast, patterns in giant kelp abundance along California's central coast are more complex (Beas-Luna et al. 2020, Cavanaugh et al. in prep, Smith et al. in press) (Fig 4). In general, from 2014-2019, central California has been characterized by patchy kelp distribution, with no discernible overall trend. Kelp has persisted in some locations but appears to have declined in others; one area of particular concern is the Monterey Peninsula, where kelp has exhibited significant losses since 2014. In contrast to the region-wide dynamics on the north coast, factors at smaller spatial scales likely drive kelp persistence on the central coast. These factors include temperature, local urchin densities, and the foraging behavior of sea urchins and southern sea otters. Urchin grazing pressure has increased in some areas, including Monterey; however, it is not currently clear if that increased grazing pressure is a function of increased abundance from high recruitment, or if initial heatwave-driven declines in kelp triggered a shift to the more aggressive urchin feeding behavior associated with insufficient food supply (CDFW in prep, Smith et al. in press). Although sea otters readily forage for urchins in kelp forests, recent studies indicate that otter predation on urchins contributes to the persistence of remnant forests but is ineffective at reducing urchin abundances in barrens, likely because of the poor body condition of those urchins (Smith et al. in press). This limits the ability of sea otters to facilitate kelp recovery on the central coast.

Reed et al. (2016) found that the 2014-2016 marine heatwave had no strong effects on giant kelp in southern California. Kelp canopy area in southern California declined following the onset of the marine heatwave in 2014, but these losses were within the normal range of variability and kelp quickly recovered (Reed et al. 2016). Importantly, however, some areas where kelp has historically persisted in the Channel Islands, such as San Miguel Island and the west side of Santa Rosa Island, have been converted to urchin barrens (Kyle Cavanaugh and Tom Bell, personal communication). As with the central coast, smaller-scale factors likely drive kelp abundance on the south coast; in particular, the presence of urchin predators such as California Sheephead and California spiny lobsters may provide kelp forests with a measure of functional redundancy that has increased the resilience of these systems to the loss of the sunflower star (Eisaguirre et al. 2020). Furthermore, wave disturbance is consistently lower in southern California than in central or northern California, potentially contributing to kelp persistence (Reed et al. 2011). Tracking top-down drivers (e.g. herbivory), bottom-up drivers (e.g. nutrients) and disturbance regimes (e.g. waves) over space and time, as well as assessing the role of other factors (e.g. invasive species, proximity to kelp spore sources, freshwater input, water quality/sedimentation, and management measures such as marine protected areas (MPAs)), will be critical to conserving kelp across California.

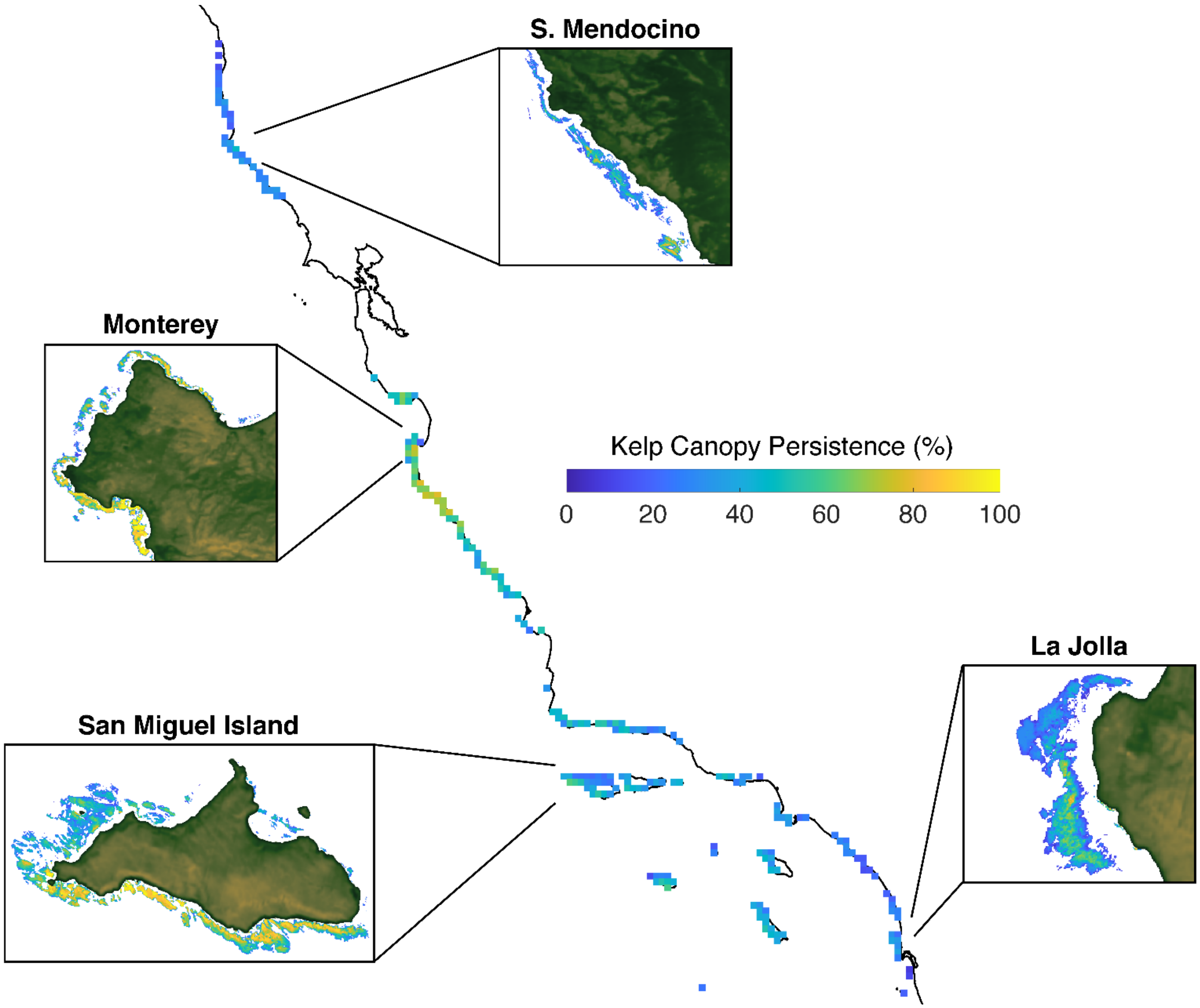

Figure 4. Kelp persistence for all coastal areas of California using kelp canopy data derived from Landsat satellite sensors. Boxes along the coast show the mean kelp persistence for all 30 x 30 m pixels within a 5 x 5 km area from 1984-2020. Persistence is defined as the percentage of years where kelp canopy was identified in a pixel at least once during a calendar year. The mean persistence for each box is shown if at least 100 Landsat pixels have been classified as kelp canopy during the 37-year period of assessment. The four insets show kelp persistence in selected areas along the coast of California at the native 30 x 30 m resolution of the Landsat data. Data used to create this figure is available at: https://sbclter.msi.ucsb.edu/data/catalog/package/?package=knb-lter-sbc.74

Given the ecological and socioeconomic importance of kelp, the severity of the crisis on the north coast, and the anticipated impacts of changing ocean conditions (Beas-Luna et al. 2020), the protection and restoration of California's kelp forests has emerged as a top priority for OPC and CDFW. In support of OPC's Strategic Plan to Protect California's Coast and Ocean 2020-2025 (Objective 3.2, Target 3.2.1) (OPC 2020), this Action Plan is intended to summarize current state-supported kelp research and restoration initiatives, as well as other relevant efforts in California; highlight key knowledge gaps; and outline priorities for action in kelp research and monitoring, policy development, restoration, and community engagement.

2. Current Research and Restoration Efforts

Building on recommendations contained in the Sonoma-Mendocino Bull Kelp Recovery Plan (Hohman et al. 2019), OPC and CDFW have recently initiated several projects to monitor kelp forest ecosystems, better understand drivers of kelp loss and persistence, and test potential kelp restoration approaches. These efforts represent an investment of more than $3 million in 2019-2020. They are summarized below.

Kelp canopy monitoring and mapping. Historically, aerial surveys of kelp canopy were the primary method of monitoring kelp forest extent; however, aerial surveys are expensive and have several logistical constraints. Due to funding limitations and the lack of availability of suitable contractors, CDFW has not conducted aerial surveys of kelp canopy in northern California since 2016. Resource managers therefore lack a consistent and timely understanding of kelp abundance and spatial distribution in the region.

TNC and UCLA are currently working to address that knowledge gap on the north coast by conducting aerial surveys of kelp canopy from Monterey to the Oregon border. Imagery from those aerial surveys will be compared to high-resolution Planet satellite imagery, which may be a more cost-effective and robust strategy for long-term kelp canopy monitoring. This project will result in recommendations for a scalable, statewide effort that will use remote sensing platforms to provide monthly kelp cover estimates. These recommendations are anticipated by Spring 2021.

In 2020, the Greater Farallones Association (GFA) launched a collaborative mapping project to improve the accuracy and efficiency of kelp canopy monitoring in West Coast National Marine Sanctuaries. OPC and CDFW are committed to working with GFA, TNC, and other partners to share data and lessons learned in pursuit of improved kelp canopy monitoring.

Experimental determination of urchin threshold densities. There is considerable scientific evidence that the reduction of sea urchin grazing pressure can facilitate kelp regrowth in urchin-dominated habitats (Steneck et al. 2002, Ford & Meux 2010, Watanuki et al. 2010, Filbee-Dexter & Scheibling 2014). To date, kelp restoration efforts in California have largely focused on the removal or in-water culling of purple urchins. Urchin threshold densities are generally known for giant kelp systems (approximately 14 urchins per square meter to convert a kelp forest to an urchin barren, and 2-3 urchins per square meter to restore an urchin barren back to a kelp forest (see discussion of hysteresis above; Filbee-Dexter & Scheibling 2014)), and recent modeling efforts have generated preliminary estimates of threshold densities in bull kelp systems (Arroyo-

Esquivel et al. in prep). However, for both systems, further study is needed to empirically validate threshold densities, understand whether or not threshold densities can be maintained without constant human intervention, and assess the scales at which threshold densities apply. These questions are critical for informing larger-scale restoration efforts.

Reef Check California (RCCA), a nonprofit organization dedicated to the conservation of California's rocky reefs and kelp forests through community science, is currently working to experimentally validate urchin threshold densities on the central coast, a giant kelp system, and will soon set up a similar project on the north coast, a bull kelp system. The north coast work will also include a comparison of the effectiveness, or catch per unit effort, of physical removal of urchins vs. in-water culling of urchins. Results are anticipated by December 2021.

Urchin removal by commercial fishermen. Commercial sea urchin fishermen are skilled at harvesting urchins underwater and can be extremely effective at clearing urchin barrens, which may facilitate kelp regrowth. However, the efficacy of this potential kelp restoration tool has yet to be scientifically investigated in California. In 2020, OPC, CDFW, and RCCA initiated a partnership with north coast commercial red sea urchin fishermen, who have largely been unable to fish since the collapse of their fishery in 2016, to remove purple urchins in support of kelp restoration at Noyo Bay and Albion Cove in Mendocino County. RCCA is tracking changes in ecological metrics (including urchin density, kelp density, and community composition) at these restoration sites to evaluate the efficacy of large-scale urchin removal as a kelp restoration tool. This project will also result in the development of best practices and lessons learned, which can be used to scale up commercial urchin removals on the north coast and statewide should this method prove effective. Furthermore, by directly engaging stakeholders who have been severely impacted by the kelp crisis, this project is providing significant social and economic benefit to Mendocino County and the broader north coast community. Results are anticipated by December 2021.

In-water urchin culling by recreational divers. In-water urchin culling (i.e. smashing or crushing sea urchins *in situ*) has the potential to be an effective method of kelp restoration, if sufficient focused effort can be sustained and ocean conditions are favorable for algal regrowth. The Bay Foundation, for example, has engaged in in-water culling of purple urchins off the Palos Verdes Peninsula since 1997, and has documented increased giant kelp canopy cover and stipe density across approximately 50 acres of reef where culling has been conducted (Ford & Meux 2010, The Bay Foundation & Vantuna Research Group 2018). California's recreational diving community has advocated for changes in state regulations to allow in-water urchin culling, and recreational divers have potential to serve as valuable partners in kelp restoration efforts. However, before in-water urchin culling by recreational divers can be broadly supported by resource managers as a kelp restoration tool, further study is needed on 1) the efficacy of such efforts at reducing urchin densities to the level required for kelp regrowth, including how long such efforts need to be maintained, and 2) ecological effects, including potential unintended negative impacts such as bycatch or damage to underlying reef structure.

California has recently permitted in-water urchin culling by recreational divers at two specific locations: Caspar Cove in Mendocino County, a system dominated by bull kelp, and Tanker Reef in Monterey County, a system dominated by giant kelp. Divers are following established protocols and are encouraged to report their efforts through online forms. To assess ecological effects, culling is being monitored by RCCA at both locations via the same approach being used for the commercial removal effort. Together, the Caspar and Tanker projects will help to answer the following questions:

- Can recreational divers operating under sea urchin sport harvest regulations reduce sea urchin densities to levels expected to facilitate kelp regrowth via in-water urchin culling?
- Does reduction of sea urchin grazing pressure via in-water urchin culling facilitate natural kelp regrowth?
- Are there negative impacts associated with in-water urchin culling (e.g. bycatch, damage to underlying reef structure, disturbance to marine mammal populations)?
- How can potential negative impacts to the commercial red sea urchin fishery be avoided?
- Can recreational divers collect, analyze, and communicate data/results in a way that is informative to resource managers?

Preliminary results are anticipated by Winter 2021.

Statewide Kelp Recovery Research Program. As the kelp crisis has unfolded, resource managers have been constrained by a variety of knowledge gaps surrounding kelp forest ecosystem dynamics. In order to more effectively mitigate the kelp crisis at broad spatial and temporal scales, and to promote the resilience of kelp ecosystems into the future, OPC, CDFW, and California Sea Grant have initiated a partnership with California's leading kelp forest researchers to create a statewide Kelp Recovery Research Program. This partnership is supporting six innovative, solutions-oriented research projects aimed at informing kelp management efforts. Results for all projects are anticipated by Fall 2022.

- *Jennifer Caselle, Tom Bell (UC Santa Barbara), Mark Carr (UC Santa Cruz): Where, when and how? A guide to kelp restoration in California using spatio-temporal models of kelp dynamics.* This project will use cutting-edge modeling techniques to identify key ecological, oceanographic, geographic, and management-related drivers of kelp persistence at local and regional scales. Model results will be used to produce a restoration guide. This guide will enable resource managers to choose optimal locations, times, and methods for kelp restoration activities statewide.
- *Michael Graham, Scott Hamilton (Moss Landing Marine Laboratories): Assessment of practical methods for re-establishment of northern California bull kelp populations at an ecologically relevant scale.* Re-establishing kelp populations via seeding or outplanting is a promising restoration tool that, when paired with urchin removal efforts, may lead to more successful restoration outcomes than urchin removal alone. This project will test the efficacy of various methods for 1) culturing bull kelp in the lab and 2) outplanting cultured kelp to reefs following sea urchin removal in northern California. Investigators will monitor the growth, survival, and reproduction of bull kelp following outplanting.
- *Joleah Lamb, Matthew Bracken (UC Irvine): Scaling a new cost-effective intervention tool to restore and future-proof coastal kelp forests.* This project will complement Graham's project (described above) by testing the efficacy of various methods for culturing and outplanting giant kelp in southern California. In addition, investigators will

pursue an "assisted evolution" approach that will acclimatize young kelps to warmer waters, helping to ensure future restoration success in the face of climate change.

- *Brian Gaylord, Marissa Baskett, Aurora Ricart (UC Davis), Matt Edwards (UC San Diego), Mackenzie Zippay, Brent Hughes, Sean Place (Sonoma State University), Jason Hodin (University of Washington): A multi-pronged approach to kelp recovery along California's north coast.* This multi-pronged project will accomplish the following: 1) culture heat-tolerant strains of bull kelp and test their outplanting success; 2) model bull kelp spore dispersal to help inform site selection for restoration on California's north coast; 3) assess the reproductive viability of malnourished purple urchins in urchin barrens, helping to determine whether in-water urchin culling may inadvertently cause urchins to spawn; 4) quantify the predation rate of juvenile sunflower sea stars on juvenile purple urchin; and 5) develop a dynamic model of the kelp-urchin-sea star system, to help isolate the best policy levers for management action.
- *Alison Haupt (CSU Monterey Bay), Jan Freiwald (Reef Check California): Informing restoration and recovery of central coast kelp forests – understanding the dynamics of urchin recruitment, reproduction and density.* This project will examine the reproductive potential of intertidal and subtidal purple urchin populations, helping to determine potential reproductive sources of sea urchins that may play a role in maintaining urchin barrens. Investigators will also assess spatial patterns in kelp and sea urchin recruitment by collecting larvae at a variety of central and north coast sites, including sites where purple urchin removal is currently being conducted. An improved understanding of kelp and urchin demographics will assist resource managers in restoration site selection.
- *Felipe Alberto (University of Wisconsin – Milwaukee), Peter Raimondi (UC Santa Cruz), Sergey Nuzhdin (USC): Conservation genomics and gametophyte banking of bull kelp in California.* This project will create a bull kelp "seed bank" that will include both spores and living kelps, helping to preserve the species and its genetic diversity for decades into the future. Investigators will also assess genetic variation in bull kelp populations over time and space, enhancing resource managers' understanding of why bull kelp is persisting at certain locations but not others, and helping to optimize restoration site selection on the north coast.

The Kelp Recovery Research Program may be complemented by other research initiatives currently underway in California and elsewhere. For example, TNC is currently supporting several scientific research projects that address emerging questions of management relevance, such as the feasibility of a sunflower star captive breeding and reintroduction program. To the extent practicable, OPC and CDFW will work to ensure communication between Kelp Recovery Research Program scientists and other researchers and partners, to identify potential overlap between efforts, maximize information sharing, and facilitate uptake of the best available science into policy and management discussions.

<u>3. Knowledge Gaps</u>

The research and restoration efforts described above are exploring a substantial number of knowledge gaps surrounding kelp forest ecosystem dynamics and the efficacy of various restoration approaches. However, resource managers still face a variety of broader scientific, policy, and management questions, including:

- What are the most important metrics of kelp forest ecosystem health?
- How can kelp monitoring results be integrated with environmental datasets to forecast short-term changes in kelp abundance?
- How will kelp distribution change long-term under predicted climate scenarios? What are the potential ecological and socioeconomic effects of these changes?
- What are the most effective and efficient methods of kelp restoration in California? When and where should they be pursued?
- What are the risks and potential unintended consequences of different kelp restoration methods?
- What are the ecological baselines to which resource managers should seek to restore kelp forests? Are these baselines realistic given predicted climate scenarios? How do they translate into science-based goals, objectives, and metrics of success for restoration?
- How should kelp protection and restoration efforts be integrated with existing management measures, such as MPAs?
- How can resource managers identify reliable funding streams and institutional support to implement kelp restoration and resilience efforts, particularly given the urgency of other resource management needs?
- How can alternative "ways of knowing"—including both local knowledge and indigenous traditional knowledge—complement scientific efforts and contribute to our understanding of kelp resilience?

4. Priorities for Action

In support of the protection and restoration of California's kelp forests, and to address the knowledge gaps highlighted above, OPC has identified the following priorities for action. OPC views these as efforts that can and should be undertaken collaboratively with agency, Tribal, academic, nongovernmental/nonprofit, and community partners. Lead entities and timelines for individual actions will be identified as the final draft of this Action Plan is developed.

Research and monitoring

- Continue the suite of six Kelp Recovery Research Program projects. Work closely with researchers to ensure that scientific findings contribute to policy and management outcomes, in particular the final draft of this Action Plan and the development of a statewide Kelp Restoration and Management Plan (see below).
- Develop agreed-upon, science-based metrics for tracking kelp forest ecosystem health.
- Develop and implement a standardized statewide kelp monitoring program (including both kelp canopy and subtidal monitoring) to track metrics of kelp forest ecosystem health. Leverage existing monitoring efforts where possible.
- Develop methods to reliably forecast changes in kelp abundance and distribution based on known drivers.

- Initiate scientific projects to better understand the connection between physical oceanography and dispersal/recruitment of kelp forest species.
- Further explore the role of grazer predators in providing kelp forest ecosystem resilience.

Policy development

- Complete Enhanced Status Report (ESR) for bull kelp and giant kelp. The ESR should provide a comprehensive overview of both species and fisheries, along with current management and monitoring efforts and future management needs.
- Initiate the development of a statewide, ecosystem-based Kelp Restoration and Management Plan (KRMP).
- Update commercial harvest regulations for bull kelp and giant kelp.
- Ensure that aquaculture efforts related to kelp restoration (e.g. kelp sporophyte culturing, land-based "ranching" of harvested purple urchin for human consumption, etc.) are consistent with the state's interagency guiding principles for aquaculture and upcoming Aquaculture Action Plan.
- In collaboration with state MPA managers and partners, develop a clear policy outlining the circumstances under which kelp restoration methods could be considered in MPAs.

Restoration

- Continue pilot restoration projects and use results to develop a preliminary kelp restoration "toolkit" for inclusion in the KRMP.
    - The toolkit should consist of kelp restoration options available to resource managers in California, as well metrics of restoration success and a summary of the ecological and socioeconomic conditions under which various options are likely to be most effective.
    - The toolkit should contain methods for evaluating the risks and benefits of restoration actions. A precautionary approach should be adopted, and restoration methods with a high likelihood of unintended ecological consequences should be avoided.
- Engage with the commercial red sea urchin fishery to develop restoration incentives and explore potential markets for purple urchin.
- Engage with the global kelp forest restoration community to share best practices and lessons learned.

Community engagement

- Initiate projects to improve access to kelp forests for Californians from underserved communities, through both field-based and virtual programs.
- Continue engagement with California's Native American Tribes.
    - Ensure that Tribal perspectives are represented in policy and management conversations.
    - Include Tribes in research and monitoring efforts, potentially through California's recently launched Tribal Marine Stewards Network.
    - Begin development of a pathway for the consideration of Indigenous Traditional Knowledge in state policy and management decisions related to kelp.

- Engage stakeholders to ensure California's coastal communities are represented in policy and management discussions, including the development of the KRMP.
- Utilize knowledge and capacity of diving and fishing communities, as well as kelp and algae harvesters, to assist with kelp monitoring and restoration efforts.

5. Conclusion

Kelp forests are fundamental to California's marine biodiversity and its ocean economy. However, the ocean is rapidly changing, and kelp faces an uncertain future. Marine heatwaves are predicted to become more frequent and more severe. Changing ocean conditions may also lead to more intense storm and wave activity, and marine disease may become more prevalent. While such threats are generally beyond the control of resource managers, steps can be taken to support healthy kelp forests in California. For example, some stressors such as harvest, pollution, sedimentation, and urchin grazing may be managed to promote resilience in the face of an increasingly hostile ocean. Robust research and monitoring, science-informed policy, the development of effective restoration methods, and meaningful partnership with California Native American Tribes and stakeholder communities will help resource managers craft proactive, "climate-ready" strategies for kelp management, protecting our state's underwater forests for the benefit of current and future generations.

OPC, in partnership with CDFW, has developed this interim Action Plan to serve as a starting point for discussion between resource managers, the academic community, California Native American Tribes, coastal stakeholders (including the diving and fishing communities), and members of the public. OPC will offer opportunities for engagement on this draft throughout 2021, and a final version of the Action Plan will be presented to the Council for consideration and possible adoption in Spring 2022. That version will incorporate results from research and restoration projects currently underway, as well as scientific, Tribal, and public input.

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