National Marine Sanctuary Foundation

10 Challenges and Opportunities for Climate-Smart Restoration in Marine Protected Areas

Protecting Coral and Kelp in a Changing Ocean

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Cover Photos: Oceanography Team/CRED/PIFSC/NMFS/NOAA (coral) and Nathan Coy/NOAA (kelp)

CONTENTS

CLIMATE CHANGE, MARINE PROTECTED AREAS, AND RESTORATION

Marine ecosystems occupy the majority of Earth's surface and are invaluable to humans, as they help regulate our climate, provide food for billions of people, and offer opportunities to connect with nature. Ocean and coastal places also have indelible ties to the heritage of many peoples; however, the marine environment is increasingly facing pressures from human activities, including pollution, overfishing, and modification of natural shorelines. In light of these pressures, marine protected areas (MPAs) have been established globally to manage human activities in order to maintain ecological integrity, ecosystem services, and more in valued ocean places. One such example is the National Marine Sanctuary System, a network of 16 underwater parks that encompasses more than 620,000 square miles of marine and Great Lakes waters (Office of National Marine Sanctuaries [ONMS], n.d.-a). This network overlaps with the homelands and traditional waters of Indigenous Peoples, including lands and waters that many Indigenous cultures continue to steward today (ONMS, n.d.-b).

Although MPAs have some success in managing local human activities, climate change has emerged as a dominant, global-scale threat to marine ecosystems. Climate change exacerbates many management issues within MPAs, and creates new, complex challenges. Given the global scale of climate change and the human activities that cause it, MPAs do not have the ability to manage it directly at the local level. Corals and kelps, foundational habitat-forming species groups found in the majority of national marine sanctuaries and other MPAs worldwide, have been particularly impacted by climate change and are experiencing unprecedented declines.

 Photo: Claire Fackler/NOAA

Living coral cover has declined globally by approximately 50% since the 1950s, largely due to increasing ocean temperatures (Eddy et al., 2021), which trigger a stress response known as bleaching. When prolonged, bleaching can result in mortality. The loss of coral has already had measurable effects on ecosystem services, such as coral-reef-associated fisheries and shoreline protection.
Over the past 50 years, 40–60% of kelp forests globally have experienced declines (United Nations Environment Programme, 2023), and estimates suggest that global kelp abundance is declining at a rate of about 2% per year (Krumhansl et al., 2016). Warming temperatures are also implicated as a factor in kelp decline, along with environmental imbalances driven by disease and overfishing (United Nations Environment Programme, 2023). Coral and kelp losses have been particularly profound in some national marine sanctuaries. For example, Florida Keys National Marine Sanctuary has lost 90% of its coral cover since the 1970s (Scott, 2023), while Greater Farallones National Marine Sanctuary in central California has lost over 90% of its kelp since 2014 (ONMS, 2024a). Given these dramatic and ongoing losses, sanctuary and other MPA managers have increasingly recognized an urgent need to conserve and restore these habitats.

In recent decades, restoration has emerged as a key tool for MPAs to complement management of human activities and aid in the recovery of degraded ecosystems. Restoration in marine environments may include passive activities, such banning harvest of certain species to aid ecosystem recovery, or active activities, such as removing nuisance or invasive species or placing propagules of key species in areas where they have been depleted or extirpated. Marine habitat restoration has become an important management strategy in many MPAs, particularly in areas where key habitat-forming species have been rapidly lost and have exhibited little to no natural recovery.

Climate change has increasingly challenged the success of traditional restoration activities that seek to return an ecosystem to a prior state. In April 2024, the National Oceanic and Atmospheric Administration (NOAA) confirmed the fourth global coral bleaching event (NOAA, 2024). This event, which began as early as February 2023 in some areas, resulted in the loss of as much as 78–95% of branching corals outplanted to restore targeted reefs in Florida Keys National Marine Sanctuary (Thiem, 2024), raising questions about the effectiveness of traditional habitat restoration techniques in light of worsening climate change. It is imperative that the planning and implementation of restoration strategies for both coral reefs and kelp forests consider ongoing climate change and future climate scenarios, including the need for rapid response when acute climate pressures, such as coral bleaching events, occur. As areas that are a focal point for research, monitoring, management, and community engagement, MPAs can be well suited for testing and applying innovative, climate-informed restoration approaches, when these approaches align with a given MPA's conservation objectives.

To understand how to best move marine ecosystem restoration forward in light of climate change, particularly for the increasingly threatened coral reef and kelp forest ecosystems in MPAs, the Climate-Informed Ecosystem Restoration in MPAs Symposium was convened in March 2024. This symposium brought together 60 coral reef and kelp forest experts, including MPA managers, representatives from Indigenous governments and organizations, academic scientists, restoration practitioners, and other community members to discuss synergies between coral reef and kelp forest climate threats, and to generate actionable recommendations for advancing climate-informed restoration practices for these critical habitats.

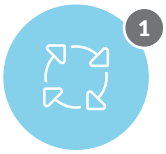
The objectives of the symposium were to:

- Identify research needs and effective strategies for climate-informed restoration in kelp forest and coral reef ecosystems in national marine sanctuaries and other MPAs;
- Evaluate decision-making frameworks and best practices for addressing governance, equity, and social considerations in climate-informed restoration efforts;
- Share experiences in restoration planning, permitting, funding, community engagement, and communications; and,
- Generate actionable recommendations for advancing climate-informed restoration practices.

The event resulted in the identification of 10 challenges and opportunities for climate-smart restoration in MPAs.

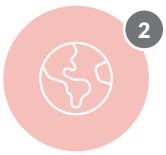
 Photo: G.P. Schmahl/NOAA

10 CHALLENGES AND OPPORTUNITIES FOR RESTORATION IN MPAS



MEANINGFUL AND EQUITABLE ENGAGEMENT OF INDIGENOUS PEOPLES

Involving Indigenous governments, peoples, and communities from the beginning will lead to more successful restoration efforts. As rightsholders with long-standing relationships with marine ecosystems, meaningful and equitable partnerships with Indigenous Peoples, including through co-management and co-stewardship, are essential to sustainable and successful restoration.



EQUITABLE INCLUSION OF INDIGENOUS KNOWLEDGE

Multiple-knowledge-based approaches that include Indigenous Knowledge will lead to more effective solutions for the restoration of degraded ecosystems. Co-production of knowledge approaches to bring together Indigenous Knowledge and Western science have been highlighted as necessary to achieve shared conservation and restoration goals.

MORE INCLUSIVE RESTORATION CONVERSATIONS

Involving diverse disciplines, such as economics, social science, and education, in restoration activities from the start, along with early partnership with local communities and inclusion of local knowledge, can make restoration activities more successful and enduring. Additionally, despite regional distinctions (e.g., levels of recruitment, oceanographic variation), inclusion of diverse regional perspectives in restoration planning can leverage experience within and across regions for better outcomes.

REDUCTION OF NON-CLIMATE STRESSORS

Reducing non-climate stressors to systems (e.g., overfishing, destructive fishing methods) through a holistic restoration plan that includes upstream sources and potential point source pollution can set climate-informed restoration up for success.

ADAPTIVE GOAL-SETTING

Adaptive goal-setting is necessary to ensure flexibility in restoration strategies as environmental conditions change. This approach supports restoration that focuses on priority outcomes, identified in partnership with rightsholders and stakeholders, even when dealing with irreversible change.

STREAMLINED AND FLEXIBLE PERMITTING

Streamlining the process of permitting restoration activities by increasing collaboration among permitting authorities and building flexibility into permitting processes to be responsive to climate-driven changes are critical for implementing climate-smart restoration.

POLICY AND LEGISLATIVE TOOLS FOR EMERGENCY RESPONSE

Policy and legislative tools for responding to disasters could be better designed to support climate-informed restoration. For example, the ability to declare emergencies across multiple levels of government for bleaching events and kelp loss may streamline processes, increase access to funding, and facilitate spending to enable restoration in at-risk ecosystems.

MONITORING AND TECHNOLOGY

Developing and monitoring more robust restoration indicators, including bio-cultural, socioeconomic, and ecological indicators, can facilitate more climate-responsive restoration. Investing in new monitoring methods and technologies for remote sensing, automation, and artificial intelligence, as well as significantly scaling up operations, is critical for the marine restoration field to work in a changing ocean.

SCALING UP AND SECURING LONG-TERM FUNDING

The scale of the climate crisis requires significant increases in restoration funding (and an associated shift in strategy for and mindset toward securing such funding), exploring new funding sources, and building knowledge among funding partners on the need for flexible and long-term funding that promotes learning from both successes and failures.

CAPACITY BUILDING AND TRAINING THE NEXT GENERATION

Restoration success requires capacity building among MPA staff and their partners, through action planning, training, citizen engagement, and resource sharing. It also requires the involvement of the next generation in restoration efforts through education and training, and assuring that historical perspectives of experienced practitioners and scientists are appropriately incorporated in restoration decisions.

CHALLENGES AND OPPORTUNITIES FOR RESTORATION IN A CHANGING OCEAN

The 10 challenges and opportunities identified in the graphic on page 5 represent levers for change in coral and kelp restoration within MPAs. If pulled, these levers could shift the trajectory, pace, and scale of the field in a way that is more aligned with the trajectory, pace, and scale of climate change. These are areas for concurrent progress, where advancing climate-informed restoration across these many fronts can foster exponential improvements. While inherently abstract, the potential to address these challenges and seize opportunities becomes significantly more concrete when viewed through the place-based lens of existing MPAs.

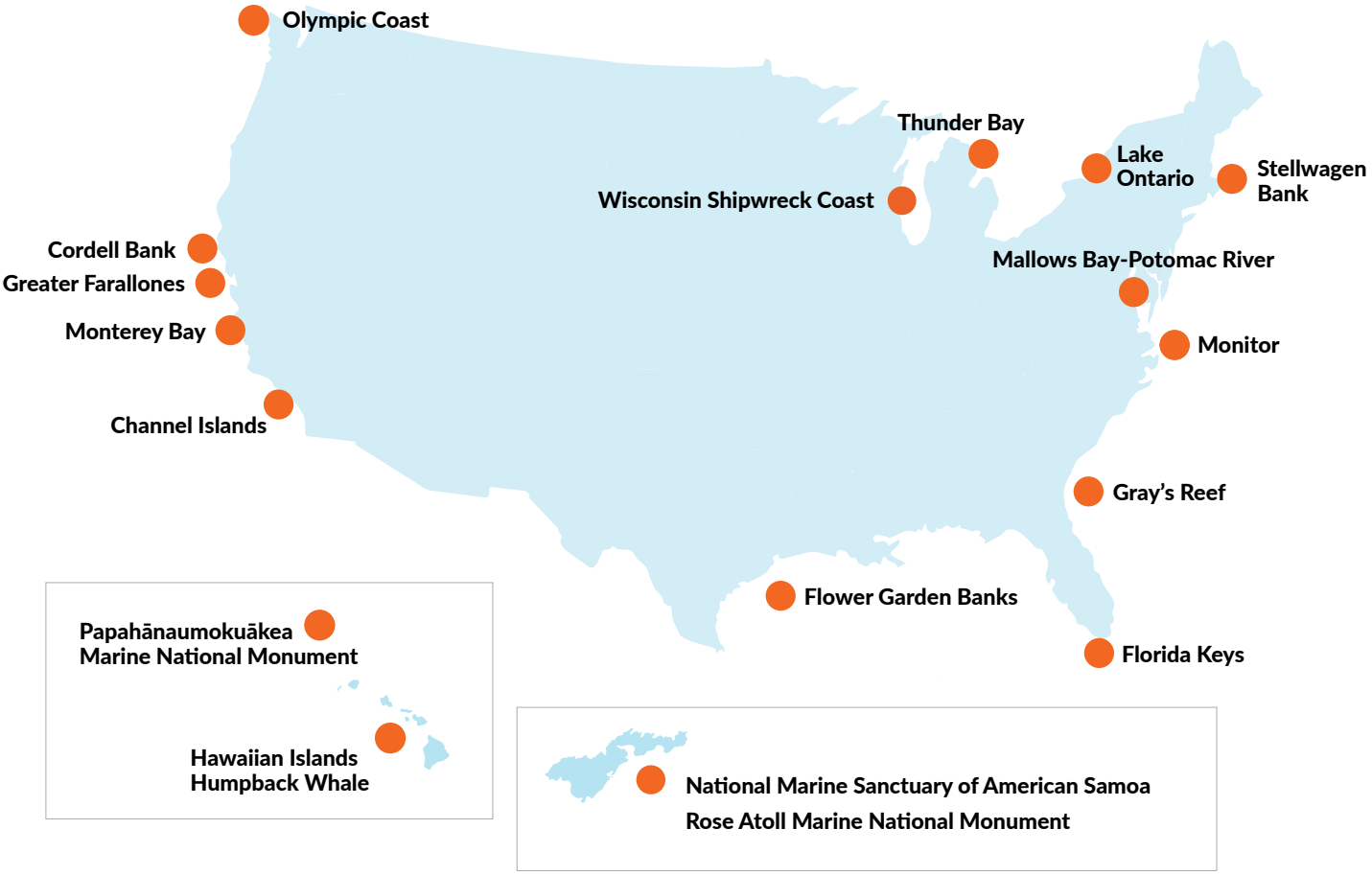
Here, the 10 challenges and opportunities are described in greater detail and made tangible through a discussion of relevant past, present, and future activities relevant to coral and kelp restoration and conservation across the National Marine Sanctuary System. National marine sanctuaries, as a network of U.S. protected areas stewarding coral reefs and kelp forests, among other resources and ecosystems, allow us to conceptualize how action on these 10 challenges and opportunities directly impact communities and conservation goals. Although these challenges and opportunities are not unique to national marine sanctuaries, examples centered on sanctuaries are used here to illustrate specific challenges and opportunities for coral and kelp restoration in MPAs, as well as efforts to address them, even when those efforts are imperfect, incomplete, or unsuccessful.

While the 10 challenges and opportunities described here were developed based on the experiences of experts who study and/or manage coral and kelp habitats (and are described specifically in the context of these ecosystems), they often also reflect and resonate with the ongoing dialogues around restoration for other ecosystem types.

 Photo: Wendy Cover/NOAA (purple coral)

NATIONAL MARINE SANCTUARY SYSTEM MAP

As of October, 2024



Map: National Marine Sanctuary Foundation;
Photo: Douglas Croft/NOAA (otter)

1

MEANINGFUL AND EQUITABLE ENGAGEMENT OF INDIGENOUS PEOPLES

Involving Indigenous governments, peoples, and communities from the beginning will lead to more successful restoration efforts. As rightsholders with long-standing relationships with marine ecosystems, meaningful and equitable partnerships with Indigenous Peoples, including through co-management and co-stewardship, are essential to sustainable and successful restoration.

Challenges to non-Indigenous institutions equitably engaging Indigenous Peoples in restoration include, but are not limited to, a legacy of land dispossession; systemic exclusion and sidelining in decision-making processes; chronic disinvestment in Tribal Nations and communities; and insufficient knowledge and capacity within non-Indigenous organizations to create inclusive spaces for multiple cultures, world views, and knowledge systems (Yua et al., 2022; Kimmerer & Artelle, 2024). However, investing in genuine partnerships grounded in trust, respect for Indigenous rights and sovereignty, and shared decision-making power can start to address these challenges while supporting collaborative restoration projects. These relationships require frequent, consistent communication and engagement from the early stages of connection and throughout the partnership. Developing such relationships can allow for more just and sustainable restoration activities that are effective, deliver for Indigenous Peoples, and authentically meet local communities' needs.

The Office of National Marine Sanctuaries (ONMS) has made commitments to more meaningful and equitable engagement of Indigenous Peoples (e.g., the *Imila-alpa Commitments*, developed during the second Cross-Pacific Indigenous Exchange in April 2024), but is still working to deliver on those commitments. ONMS has developed principles and standard operating procedures for Tribal/Indigenous consultation, such as *Government-to-Government Consultation with Federally Recognized Tribes/Nations: An ONMS Field Guide*, but still needs to fully utilize available guidance and further develop system-wide capacity for all forms of meaningful and equitable engagement of Indigenous Peoples (ONMS, 2024b; n.d.-b).

CORAL EXAMPLE

Papahānaumokuākea Marine National Monument Co-Management

Papahānaumokuākea Marine National Monument, part of the National Marine Sanctuary System, includes extensive coral reefs and significant cultural sites on the islands of Nihoa and Mokumanamana, and holds special significance for Native Hawaiians. The management structure currently consists of three co-trustees and seven managing agencies, including the Office of Hawaiian Affairs, and exemplifies a model of co-management. This framework ensures that cultural stewardship and environmental protection are integrated into monument operations (Papahānaumokuākea Marine National Monument, 2022). As discussed further in the upcoming section on the equitable inclusion of Indigenous Knowledge in climate-informed restoration, Papahānaumokuākea also supports the inclusion of Native Hawaiian knowledge and values in monument management via a historic guidance document, *Mai Ka Pō Mai*, which informs federal and state agencies on how they can further consider Native Hawaiian culture within all areas of management (Office of Hawaiian Affairs et al., 2021). A successful outcome of the co-management structure is the development of the Papahānaumokuākea Native Hawaiian Cultural Working Group, active since the monument's inception, which uses Hawaiian knowledge and perspectives to assist in selecting Hawaiian and scientific names for newly identified species within the monument (Office of Hawaiian Affairs et al., 2021).

KELP XAMPLE

Olympic Coast National Marine Sanctuary and the Intergovernmental Policy Council

At Olympic Coast National Marine Sanctuary, the Hoh Tribe, Makah Tribe, Quileute Tribe, and Quinault Indian Nation, collectively known as the Coastal Treaty Tribes, along with the State of Washington and NOAA, established the Intergovernmental Policy Council (IPC). This council serves as a policy-level forum for jointly managing resources on the Olympic Coast. While the IPC facilitates interactions between resource co-managers and the sanctuary, it does not replace direct government-to-government consultations with individual tribal governments. The creation of the IPC, with its commitments from tribal governments, the state, and NOAA, offers a potential model of partnership for other regions who have MPAs where management intersects with Tribal and Indigenous sovereignty (Marine Protected Areas Federal Advisory Committee, 2024).

Photos: Paola Ayotte/NOAA (coral example); Andy Collins/NOAA (kelp example)

2

EQUITABLE INCLUSION OF INDIGENOUS KNOWLEDGE

Multiple-knowledge-based approaches that include Indigenous Knowledge will lead to more effective solutions for the restoration of degraded ecosystems. Co-production of knowledge approaches to bring together Indigenous Knowledge and Western science have been highlighted as necessary to achieve shared conservation and restoration goals.

Indigenous Knowledge, which stems from deep and multigenerational cultural and ecological ties, provides distinct and living insights into marine environments, how they behave and adapt, and how we can address current concerns about their health (Yua et al., 2022). However, Indigenous Knowledge has historically not been equitably included in marine management, conservation, or restoration efforts (Reid et al., 2022). Achieving equitable inclusion of Indigenous Knowledge requires a systemic change in how non-Indigenous institutions conduct restoration, genuine partnerships that respect Indigenous Peoples' knowledge systems, and a realization of Indigenous Peoples' rights to marine resources and more broadly to sovereignty, security, and self-determination (Kimmerer & Artelle, 2024; Yua et al., 2022). This requires developing relationships and equal partnership from the very beginning of a project, and working collaboratively from the design phase through to analysis and outputs. Including Indigenous Knowledge alongside other scientific approaches can enhance restoration outcomes both within and outside of MPAs.

ONMS is committed to institutional and operational changes to foster the equitable inclusion of Indigenous Knowledges in conservation and restoration, as well as greater explicit recognition and respect for Indigenous Knowledges (ONMS, 2024b). While the examples here discuss Indigenous Knowledge and coral and kelp restoration within the context of sanctuaries, it should be acknowledged that the ONMS will need to take additional steps to meet its commitments in this space.

CORAL EXAMPLE

Papahānaumokuākea Marine National Monument and *Mai Ka Pō Mai*

Designated a mixed natural and cultural World Heritage Site by UNESCO in 2010, Papahānaumokuākea Marine National Monument has the distinct responsibility to steward resources with tremendous community value and of particular importance to Native Hawaiians. Equitable inclusion of traditional Hawaiian knowledge systems, values, and practices in national monument management were elevated in Papahānaumokuākea in 2021 via the historic release of *Mai Ka Pō Mai*. *Mai Ka Pō Mai* is a guidance document that helps federal and state agencies further consider Native Hawaiian culture within all areas of management, and it will inform future iterations of monument management plans (Office of Hawaiian Affairs et al., 2021). This guidance on Indigenous Knowledge and management does not reflect the actual inclusion of Indigenous Knowledge in restoration. However, *Mai Ka Pō Mai* is an example of the kinds of resources that can support the equitable inclusion of Indigenous Knowledge and multiple world views in all aspects of protected area management, including restoration. This in turn bolsters conservation outcomes while advancing broader societal goals of environmental justice and cultural preservation.

KELP EXAMPLE

The California Coast and Kashia Band of Pomo Indians Kelp Canopy Surveys

Indigenous Peoples' ability to maintain and pass on Indigenous Knowledge is greatly undermined by a legacy of relocation and rights dispossession, along with current barriers to accessing ancestral waters and broader inequities in coastal access. In California, one Indigenous-led initiative that seeks to address this issue is the Tribal Marine Stewards Network, which includes the Tolowa Dee-ni' Nation, Resighini Rancheria, Kashia Band of Pomo Indians, Amah Mutsun Tribal Band, and Santa Ynez Band of Chumash Indians. This network seeks to return stewardship and management of ocean and coastal territories to California Tribes and advance Indigenous Knowledges in decision-making (Tribal Marine Stewards Network, n.d.-a). The Kashia Band of Pomo Indians is both a member of the network and one of three federally recognized tribes along the coastline of Greater Farallones National Marine Sanctuary. In collaboration with the Greater Farallones Association Kelp Restoration Program, the Kashia Band of Pomo Indians conduct yearly kelp canopy surveys on the Kashia Coastal Reserve (Tribal Marine Stewards Network, n.d.-b). Co-developed and Indigenous-led efforts in kelp restoration can bolster tribal stewardship of coastal and marine areas, as a component of supporting Indigenous Knowledge while informing kelp restoration initiatives.

Photos: Greg McFall/NOAA (coral example); Robert Schwemmer/NOAA (kelp example)

3

MORE INCLUSIVE RESTORATION CONVERSATIONS

Involving diverse disciplines, such as economics, social science, and education, in restoration activities from the start, along with early partnership with local communities and inclusion of local knowledge, can make restoration activities more successful and enduring. Additionally, despite regional distinctions (e.g., levels of recruitment, oceanographic variation), inclusion of diverse regional perspectives in restoration planning can leverage experience within and across regions for better outcomes.

Restoration projects are more likely to be successful at achieving targeted outcomes when they engage experts from diverse disciplines and across multiple knowledge systems, including Indigenous Peoples, as well as local partners (Higgs, 2005). Additionally, restoration practitioners benefit by learning from those working in different regions and ecosystem types. This is particularly true for restoration in MPAs, where the impacts and interests in restoration are complex and multifaceted. Restoration projects that are holistic and leverage a breadth of expertise are best positioned to preempt and respond to challenges that may arise. Similarly, projects that learn from the experiences of those in other regions and ecosystems can benefit from their successes and failures. Resilient and adaptive restoration projects are those grounded in local knowledge, and bolstered by genuine community support. Some federal entities already have frameworks to evaluate restoration funding proposals based on their commitment to meaningful engagement with communities. These restoration activities are designed to meet local needs and engage local experts to foster their success.

Resilient and adaptive restoration projects are those grounded in local knowledge, and bolstered by genuine community support.

CORAL EXAMPLE

Community-Based Coral Restoration Areas in Hawai'i

In Hawai'i, Kuleana Coral Restoration has developed community-based coral restoration areas (CBCRAs). These restoration planning initiatives are driven by diverse, place-based knowledge and are contingent on approval from the local community before any restoration is conducted. By partnering directly with local community organizations, Kuleana can identify goals and train local partners to actively support restoration, mapping, and monitoring efforts. Two of these CBCRAs are within the boundaries of the Hawaiian Islands Humpback Whale National Marine Sanctuary (Kuleana Coral Restoration, n.d.). CBCRAs are one tool for making restoration more inclusive, by establishing projects on the support and engagement of local communities and local knowledge.

KELP EXAMPLE

Knowledge Sharing for Kelp Ecosystems

Dialogue across regions is an important component of fostering inclusive restoration discussions and knowledge sharing. Exchanging restoration experiences across the globe can be particularly useful for identifying innovative ways to build climate change resilience in restoration and to grow more nascent forms of ecosystem restoration, such as North American kelp restoration. Organizations like the Kelp Forest Alliance support inclusive, global thinking by curating information on restoration projects and resources, making them easily available restoration practitioners (Kelp Forest Alliance, n.d.). Local or regional working groups, such as the Kelp Node, help foster local collaborations and place-based knowledge sharing. National marine sanctuaries also amplify these efforts by publishing and sharing NOAA's work on kelp restoration. One example, the ONMS Kelp Forest Ecosystem Resource Collection, includes diverse multi-media resources, from lesson plans to virtual reality videos, about kelp ecosystems, including their conservation and restoration (ONMS, n.d.-c).

Photos: Greg McFall/NOAA (coral example); Chad King/NOAA (kelp example)

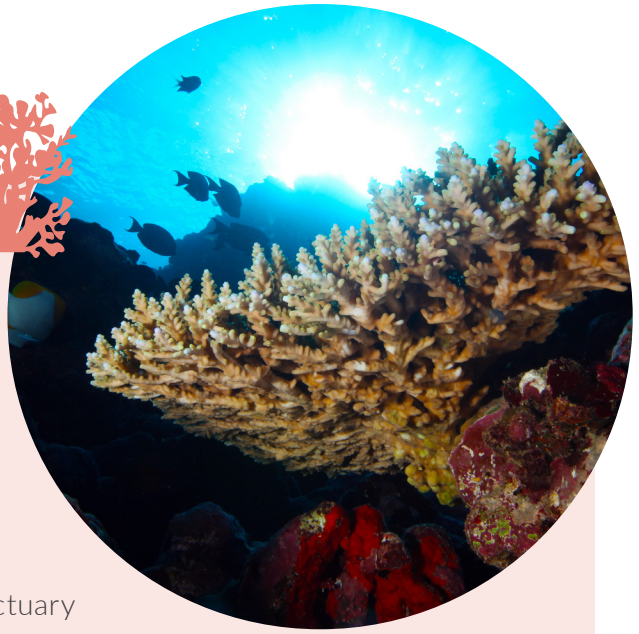
4

REDUCTION OF NON-CLIMATE STRESSORS

Reducing non-climate stressors to systems (e.g., overfishing, destructive fishing methods) through a holistic restoration plan that includes upstream sources and potential point source pollution can set climate-informed restoration up for success.

Many local non-climatic stressors, such as overfishing, coastal development, pollution, and unsustainable tourism practices, significantly contribute to marine ecosystem degradation, undermining restoration efforts despite climate impact mitigation. MPAs employ education and outreach tools to inform local communities, stakeholders, and visitors about the importance of marine ecosystems and promote sustainable practices to minimize environmental impacts. MPAs can also play a role in mitigating these stressors through management actions such as regulatory protections to restrict harmful activities either across the entire MPA or in special zones.

MPAs employ education and outreach tools to inform local communities, stakeholders, and visitors about the importance of marine ecosystems and promote sustainable practices to minimize environmental impacts.



CORAL EXAMPLE

Regulations to Reduce Human Impacts on Reefs in the National Marine Sanctuary of American Samoa

A number of regulations are in place to reduce human pressures on coral reefs in the National Marine Sanctuary of American Samoa (National Marine Sanctuary of American Samoa, 2019). Fishing and other extractive uses are prohibited in Fagatele Bay, which supports some of the highest biological diversity within the National Marine Sanctuary System. These regulations reduce the risk of negative impacts on living resources from fishing, including entanglement and biodiversity loss. Reducing these pressures boosts resilience, which could increase the success of future restoration activities. While other areas within the sanctuary allow some types of harvest, destructive fishing methods (e.g., poisons, explosives) are not allowed, helping to safeguard reef health.

KELP EXAMPLE

Protecting Predators to Aid in Balancing Kelp Forest Ecosystems

MPAs can have a crucial role in preserving trophic connections that enhance the resilience of ecosystems, including kelp forests. Studies from the Western Pacific have shown that MPAs that limit or prohibit fishing can enhance kelp cover by protecting large-bodied fish and lobsters that prey on sea urchins (Peleg et al., 2023; Kawamata & Taino, 2021), which are major predators of kelp and significant contributors to its decline and slow recovery in some areas. Similarly, a negative relationship was found between the abundance of urchins and predatory fish and lobsters in California no-take MPAs that overlap Channel Islands National Marine Sanctuary (Eisaguirre et al., 2020). Protections that maintain ecological integrity and support healthy trophic relationships can provide a foundation that increases resilience to climate stressors and supports restoration efforts. MPAs, such as national marine sanctuaries, can help foster such healthy trophic relationships by working with partners to research and develop strategies for reducing and responding to human pressures that threaten key predatory species, supporting climate-informed restoration within and beyond their boundaries.

Photos: Greg McFall/NOAA (coral example); Ed Lyman/NOAA (kelp example)

ADAPTIVE GOAL-SETTING

Adaptive goal-setting is necessary to ensure flexibility in restoration strategies as environmental conditions change. This approach supports restoration that focuses on priority outcomes, identified in partnership with rightsholders and stakeholders, even when dealing with irreversible change.

Marine ecosystem restoration in the context of a changing ocean, where the degree and duration of change is yet to be fully determined, requires plans that are adaptable. Adaptive goal-setting in MPAs involves establishing flexible objectives that can adjust to evolving environmental conditions, changes in resource use, and other new information. In some cases, goals may shift to focus on a co-developed priority for ecosystem users, such as ecosystem function or services, rather than restoring a particular species or assemblage that has been degraded. Key ecosystem services of interest may include habitat provision for fishery species harvested for ceremonial and subsistence, commercial, and/or recreational purposes; tourism opportunities; shoreline protection or sediment stabilization; and carbon sequestration.

However, in many circumstances, adaptive goal-setting around ecosystem services specifically may not be appropriate to deliver on the priorities of all those who value and use a habitat. The priorities that MPAs adaptively manage and set goals around should be developed through equitable and inclusive processes, and must evolve out of long-standing partnership and collaboration with Indigenous Peoples that have long stewarded the waters and species of interest.

CORAL EXAMPLE

A Proactive Management Strategy for Flower Garden Banks National Marine Sanctuary

Flower Garden Banks National Marine Sanctuary has developed a proactive strategy to prevent and respond to stony coral tissue loss disease, anticipating potential impacts and responses prior to the first observation of the disease in the sanctuary (Johnston, 2021). This strategy, along with a recently published climate vulnerability assessment for the sanctuary (Dias et al., 2023), reflects adaptive management to prepare for future scenarios based on current understanding and available scientific knowledge. This approach allows sanctuary managers to be more responsive to emerging threats by identifying prevention, education, preparedness, early warning, response, and intervention strategies, thereby enhancing the ability to protect and conserve sanctuary coral reefs in the face of uncertain and evolving environmental challenges. For example, the careful planning and rapid response actions Flower Garden Banks National Marine Sanctuary and research partners took during a 2022 disease outbreak allowed for timely sampling of affected colonies and generation of histological results (Rossin, 2024). This model could also be applied to preparedness for anticipated climate change impacts, such as bleaching events.

KELP EXAMPLE

State-Wide Kelp Planning

The California Department of Fish and Wildlife, in collaboration with the California Ocean Protection Council, is developing a comprehensive statewide plan for giant kelp and bull kelp, the Kelp Restoration and Management Plan. This plan ecompasses three main components: establishing a harvest management framework and other fishery management plan elements, introducing an innovative ecosystem-based management framework tailored for kelp forests, and implementing a restoration toolkit (California Department of Fish and Wildlife, n.d.). The Kelp Restoration and Management Plan aims to provide a resilient and adaptable approach to managing California's kelp forests amid shifting ocean conditions, and will be an important resource for three of California's four national marine sanctuaries.

Photos: G.P. Schmahl/NOAA (coral example); Chad King/NOAA (kelp example)

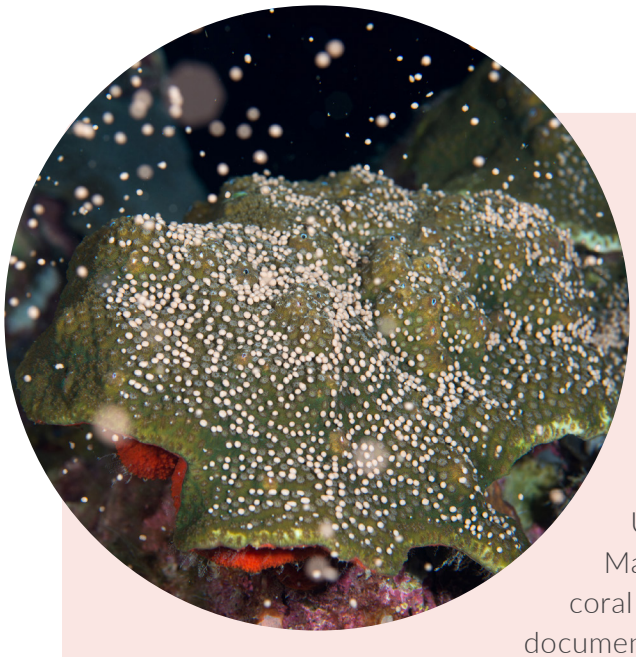
6

STREAMLINED AND FLEXIBLE PERMITTING

Streamlining the process of permitting restoration activities by increasing collaboration among permitting authorities and building flexibility into permitting processes to be responsive to climate-driven changes are critical for implementing climate-smart restoration.

Delays in obtaining permits can hinder timely interventions needed to address acute climate stressors, and overly onerous permit processes can deter the development of innovative restoration techniques and approaches. This is a particular concern for MPAs, where there is often an additional, rigorous level of scrutiny applied to proposed activities within protected area boundaries. Streamlined permitting across federal and state authorities, clear communication about permitting requirements, and processes for obtaining permits that recognize how climate change is shifting the need for active intervention in MPAs can accelerate the deployment of novel restoration practices and enable quicker responses to emerging challenges, including climate-induced stressors.

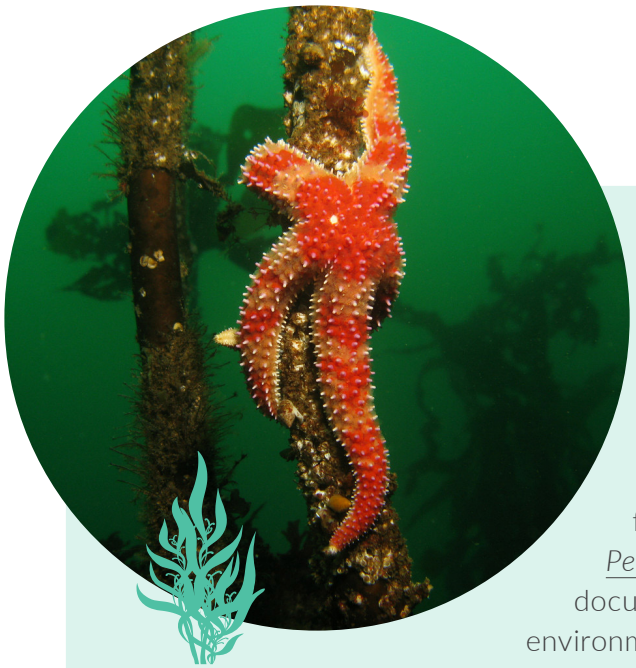
Delays in obtaining permits can hinder timely interventions needed to address acute climate stressors, and overly onerous permit processes can deter the development of innovative restoration techniques and approaches.



CORAL EXAMPLE

Streamlined Restoration Permitting Guidance

As an initial effort to streamline the permitting process for coral restoration, the U.S. Coral Reef Task Force Restoration Working Group (2023) produced a document offering guidance to coral restoration managers and partners on the legal procedures associated with obtaining permits for coral restoration activities within U.S. jurisdictions. At the MPA level, Florida Keys National Marine Sanctuary (2019) published guidance on permitting for coral restoration activities within the sanctuary. This guidance document clarifies the level of review required for a variety of restoration activities, and includes a list of well-established coral restoration activities for which permitting is likely to be expedited. Efforts like these can improve operationalization of permitting regimes, help make the permitting process more transparent and navigable, and allow prospective permittees to more effectively and confidently pursue restoration activities, including within MPAs.



KELP EXAMPLE

An Example of Efficient Permitting Guidance for North-Central California

To tackle issues surrounding permitting and sediment management, the North-Central California Coastal Sediment Coordination Committee compiled insights from 17 federal, state, and local agencies into an *Efficient Permitting Roadmap* (Kordesch & Delaney, 2024). This document includes guidance on streamlining the permitting and environmental review process for coastal sediment management, including beach habitat restoration. This resource equips project planners with the information they need to navigate regulatory requirements efficiently, potentially reducing delays. While sediment-specific, the roadmap serves as a model for addressing permitting challenges that may be faced as kelp restoration grows in the region.

Photos: G.P. Schmahl/NOAA (coral example); NOAA (kelp example)

7

POLICY AND LEGISLATIVE TOOLS FOR EMERGENCY RESPONSE

Policy and legislative tools for responding to disasters could be better designed to support climate-informed restoration. For example, the ability to declare emergencies across multiple levels of government for bleaching events and kelp loss may streamline processes, increase access to funding, and facilitate spending to enable restoration in at-risk ecosystems.

Restoration efforts must be responsive to the impact of extreme events like marine heatwaves, disease outbreaks, nuisance species outbreaks, and storm impacts. When such events occur, immediate interventions are crucial. These efforts may include rapid health assessments, damage mitigation or repair, removal of invasive or nuisance species, and deployment or removal of artificial structures. Emergency response teams, which may include scientists; Indigenous Knowledge holders; Indigenous governments, organizations, and communities; local community members; businesses; and government agencies, must deploy resources quickly and effectively to minimize ecological impacts and improve opportunities for recovery.

However, current policies, regulations, and laws are often not designed to allow for the rapid and flexible response necessitated by climate-driven emergencies and changes. Climate change is likely to continue to produce changes and disasters that are not only unexpected, but unprecedented in scale and form. As such, there is a need for policy and legislative tools that are more flexible and responsive to these events, allowing for rapid and novel response.

CORAL EXAMPLE

FEMA Hazard Mitigation and the Coral Emergency Response Fund

In 2023, the Federal Emergency Management Agency (FEMA) allocated $3 million in hazard mitigation funds for coral restoration in Puerto Rico as part of Hurricane Maria recovery efforts (Federal Emergency Management Agency, 2023). These funds will support restoration of reefs in San Juan Bay because the restored reefs will reduce flooding in adjacent communities. This historic allocation recognizes the value of coral reefs for coastal hazard risk reduction (Storlazzi et al., 2021), and establishes a precedent for considering coral reef restoration as part of a comprehensive post-disaster mitigation strategy. Models suggest that reef restoration could have similar shoreline protection benefits for MPAs within the National Marine Sanctuary System, particularly Florida Keys National Marine Sanctuary (Storlazzi et al., 2021). Another example of emergency response funding that supports coral reef interventions is the Coral Emergency Response Fund. Administered by NOAA's Coral Reef Conservation Program and the National Fish and Wildlife Foundation, this funding program supports activities in response to damage, disease, and other unanticipated stressors to coral reefs (NOAA Coral Reef Conservation Program, 2023). In 2021 and 2022, the Coral Emergency Response Fund supported the treatment of coral colonies with active stony coral tissue loss disease in Dry Tortugas National Park, which is adjacent to Florida Keys National Marine Sanctuary (NOAA Coral Reef Conservation Program, 2023).

KELP EXAMPLE

Emergency Urchin Culling in California

The national marine sanctuaries along the West Coast have faced significant challenges in maintaining healthy kelp populations, including sea star wasting syndrome, prolonged marine heatwaves, and a surge in the purple urchin population (Greater Farallones National Marine Sanctuary, 2024; Ocean Protection Council, 2021). The elevated number of purple sea urchins has made it difficult to restore any kelp forests, as urchins continue to overgraze kelp. In response to this threat, the California Department of Fish and Wildlife implemented an emergency regulation in 2020 that allowed recreational divers to cull purple sea urchins in Caspar Cove in Mendocino County and Tankers Reef in Monterey County, which is located in Monterey Bay National Marine Sanctuary. This temporary change in legislation to facilitate emergency response to an ongoing problem could serve as an example for other locations looking to conserve and restore kelp forests in the future, especially as environmental conditions continue to worsen.

Photos: Matt McIntosh/NOAA (coral example); Douglas Croft/NOAA (kelp example)

8

MONITORING AND TECHNOLOGY

Developing and monitoring more robust restoration indicators, including bio-cultural, socioeconomic, and ecological indicators, can facilitate more climate-responsive restoration. Investing in new monitoring methods and technologies for remote sensing, automation, and artificial intelligence, as well as significantly scaling up operations, is critical for the marine restoration field to work in a changing ocean.

Advanced monitoring techniques that are restoration-relevant are essential for accurately assessing ecosystem health and dynamics amid environmental changes like ocean warming and acidification. Technological innovations (e.g., photomosaics and artificial intelligence/machine learning) can enhance monitoring efficiency, reduce costs, and enable monitoring in challenging environments, and technology can also directly accelerate or enhance restoration itself (Knowlton et al., 2021). However, access to reliable data, technological infrastructure, and skilled personnel can be limited, particularly in remote or under-resourced areas where many MPAs, and some coral reefs and kelp forests, are found. Fortunately, opportunities to innovate and enhance restoration and monitoring capabilities are expanding with advancements in remote sensing, underwater robotics, and artificial intelligence. These technologies offer potential improvements in real-time data collection, predictive modeling, and early warning systems. Sharing technologies, monitoring data, and expertise across knowledge systems, agencies, and organizations can also strengthen conservation efforts to enhance marine ecosystem resilience amid climate change.

CORAL EXAMPLE

Forecasting to Support Coral Reef Management

Since 2000, NOAA's Coral Reef Watch has leveraged remote sensing, modeled data, and in situ observations to effectively forecast, monitor, and alert reef managers globally about threats to coral reefs (Coral Reef Watch, 2024). The program's near-real-time satellite products and modeled forecasts form a robust early-warning system for coral reef environmental changes. Coral Reef Watch has consistently and accurately predicted all major mass coral bleaching events worldwide since 1997, providing vital information during periods of severe ocean heat stress and other critical environmental conditions. Coral bleaching response plans, incident action plans, and restoration strategies worldwide utilize NOAA Coral Reef Watch's bleaching alert levels. These levels serve as crucial tools for guiding management decisions and urgent interventions, such as relocating corals to deeper water or land-based nurseries during high thermal stress, which occurred during the summer 2023 bleaching event in Florida Keys National Marine Sanctuary (Thiem, 2024). Florida Keys and Flower Garden Banks national marine sanctuaries have also supplemented satellite-based monitoring data and forecasts with Sofar Spotter buoys, new technology that helps monitor temperature in real time (Sofar Ocean, n.d.), supporting activities such as coral nursery management and bleaching response.

KELP EXAMPLE

Remote Sensing Informs Kelp Restoration in West Coast Sanctuaries

Increasingly, remote sensing technologies have been deployed to identify areas of kelp loss and sites for possible kelp restoration. A recent study highlighted the applications of several tools, technologies, and data portals available to managers for remote sensing of kelp forest ecosystems (Hohman et al., 2023). The study specifically assessed satellite imagery, plane-based aerial imagery, and uncrewed aerial systems, providing recommendations to enhance managers' capacity for data acquisition and management. Case studies from three national marine sanctuaries in California illustrated the practical applications of these technologies and highlighted areas for continued coordination across the West Coast Region as state and federal partners consider future restoration actions. Further north, the Washington State Floating Kelp Indicator uses aerial imagery to track kelp canopy cover across coastal Washington (Washington State Department of Natural Resources, 2024). This tool aids in understanding of the status and trends of kelp within the state, including in Olympic Coast National Marine Sanctuary, informing science and management actions.

Photos: Tane Casserley/NOAA (coral example); Nick Tolimeri/NOAA (kelp example)

SCALING UP AND SECURING LONG-TERM FUNDING

The scale of the climate crisis requires significant increases in restoration funding (and an associated shift in strategy for and mindset toward securing such funding), exploring new funding sources, and building knowledge among funding partners on the need for flexible and long-term funding that promotes learning from both successes and failures.

Securing long-term funding for restoration, at the scale needed to address current and anticipated climate change impacts, remains a significant challenge for MPAs. The high costs and long timelines associated with large-scale restoration projects necessitate sustained financial support amid competing conservation priorities. Uncertainty in funding streams and donor fatigue, along with preferences for shorter funding cycles and "quick wins," can impede progress. Additionally, there is a need for an increase in funder tolerance for failure and shifting strategies in the restoration space to promote innovation. Finally, growing funders' understanding of how they can and should work with approaches that bring together multiple knowledge systems, such as co-production of knowledge approaches, will support more equitable and inclusive projects and outcomes. However, opportunities exist in leveraging public-private partnerships, innovative financing mechanisms, and international collaboration to diversify funding sources and meet targets. Demonstrating the economic, social, and environmental benefits of healthy coral reefs and kelp forests, educating funders on long-term investment value, and advocating for restoration as a priority within marine conservation policies can enhance funding security.

CORAL EXAMPLE

Mission: Iconic Reefs in Florida Keys National Marine Sanctuary

Mission: Iconic Reefs, launched in 2019, is one the of the world's largest investments in coral reef restoration. Led by a coalition of government agencies, nonprofit organizations, and academic institutions, the initiative aims to restore seven iconic reef sites within the Florida Keys National Marine Sanctuary over the next several decades (Weinberg, 2019). To date, $52.5 million has been directly invested in Mission: Iconic Reefs, with NOAA as the lead funder. Mission: Iconic Reefs has used innovative restoration techniques, community engagement, and strategic planning around diversified funding to make the funding case for coral restoration and secure the support needed for this multi-year restoration effort. However, despite the considerable resources dedicated to the project, Mission: Iconic Reefs is also evidence of the funding gaps in coral restoration. The funding allocated for the projects remains insufficient to address the magnitude of the crisis in the Florida Keys. While this funding and project specifically targets seven reefs, there are numerous others that urgently require attention (Weinberg, 2019).

KELP EXAMPLE

Investment into Kelp Restoration in Greater Farallones National Marine Sanctuary

Across Greater Farallones National Marine Sanctuary, bull kelp has declined by over 90% in the last 10 years (ONMS, 2024a). Kelp loss in the sanctuary led to the loss of vital habitat for marine life and the collapse of fisheries valued at tens of millions of dollars, which were crucial for local economies (NOAA Fisheries, 2024). Through funding from NOAA's Office of Habitat Conservation under the Bipartisan Infrastructure Law and Inflation Reduction Act, the Greater Farallones Association has been awarded $4.9 million to restore bull kelp, in partnership with NOAA (NOAA Fisheries, 2024). The team is pioneering kelp restoration techniques, partnering with Moss Landing Marine Labs and Sonoma State University to develop practical and cost-effective methods for planting and maintaining kelp, targeting three sanctuary locations. Given that kelp restoration techniques are in relatively early stages of development, this funding from the federal government represents one of the few examples of substantial investment into such efforts in California. Significant, additional funding is needed to adequately address the extensive losses along the California coast.

Photos: Bill Goodwin/NOAA (coral example); Robert Schwemmer/NOAA (kelp example)

10

CAPACITY BUILDING AND TRAINING THE NEXT GENERATION

Restoration success requires capacity building among MPA staff and their partners, through action planning, training, citizen engagement, and resource sharing. It also requires the involvement of the next generation in restoration efforts through education and training, and assuring that historical perspectives of experienced practitioners and scientists are appropriately incorporated in restoration decisions.

Comprehensive training is crucial to equip MPA staff and restoration practitioners with the specialized skills in biology, restoration techniques, marine conservation practices, and cross-knowledge system and collaborative work necessary to successfully implement ecosystem restoration. Capacity building around working with Indigenous Peoples is a specific area of need in coral and kelp restoration. Challenges such as limited access to educational resources, funding constraints, and geographical barriers impede efforts to develop a skilled workforce capable of addressing complex ecological and planning challenges. However, collaborative partnerships among MPAs, academic institutions, NGOs, and local communities present significant opportunities to bolster capacity. Initiatives like mentorship programs, workshops, paid internships, and hands-on field experience empower young scientists and conservationists with practical knowledge and expertise.

CORAL EXAMPLE

Building Managers' Restoration Capacity

As climate change hastens the decline of coral reefs across the world, restoration has increasingly become the responsibility of natural resource managers. However, coral restoration is a relatively young area of work that has had rapid growth in recent years, and involves numerous diverse projects and novel techniques. Some coral reef managers have lacked the capacity to fully engage with this nascent field, and integrate it into their ongoing management actions. In response, the NOAA Coral Reef Conservation Program developed *A Manager's Guide to Coral Reef Restoration Planning and Design* (Shaver et al., 2020). This resource provides reef managers with a six-step adaptive management planning process for developing restoration action plans, enabling them to both begin and assess ongoing restoration work. The manager's guide is a particular asset to protected area managers, including those working across NOAA's national marine sanctuaries. It is also a model for the kind of resources that can be produced, customized, and deployed within MPAs to support assessing existing coral restoration action plans, and developing new plans where needed. Additionally, the Coral Restoration Consortium, a holistic coral restoration community of practice, provides resources and facilitates knowledge sharing among researchers, managers, and practitioners around the world.

KELP EXAMPLE

Kelp Forest Education

Sanctuaries and their partners are developing educational programming that can inspire curiosity, passion, and personal investment from students in their local kelp forests. For example, Channel Island National Marine Sanctuary has developed a 360-degree virtual reality video tour of a kelp forest off the coast of Southern California. The video, called *Explore the Blue: 360° Sea Lion Encounter*, brings the viewer through a kelp forest from the perspective of a sea lion. It has a complementary lesson plan that can be used to teach students about the plants and animals featured in the video (ONMS, n.d.-d). Educational assets like this can be used to engage new generations of young scientists and conservationists, and encourage them to care about conserving and restoring kelp forests.

Photos: Alicia Farrer/NOAA (coral example); Robert Schwemmer/NOAA (kelp example)

CONCLUDING STATEMENT

The challenge of restoring coral and kelp ecosystems within MPAs and in the face of a changing ocean is complex. However, meeting these challenges through a strategic and integrated approach also unlocks opportunities to better deliver on MPAs' commitment and value to their communities. Effective restoration will depend on scaling up and diversifying funding, streamlining permitting processes, and addressing non-climate stressors, while fostering innovation through advanced monitoring technologies and adaptive management. The inclusion of Indigenous Knowledge and the equitable engagement of Indigenous governments and communities are vital for ensuring holistic, adaptive, resilient, culturally appropriate, and effective restoration practices. Additionally, robust monitoring, capacity building, and adaptive goal-setting will enhance the resilience and responsiveness of restoration efforts. Moving forward, a coordinated effort that combines public-private partnerships, improved policy frameworks, and inclusive practices will be essential to securing necessary resources and achieving long-term success in restoring and protecting marine ecosystems amid a rapidly changing climate.

> *When I think of climate leadership, two words come to mind: risk and speed. We need to be willing to take risks, and do it now.*
>
> - Sarah Fangman, Superintendent, Florida Keys National Marine Sanctuary

While some successful examples of supporting climate resilient coral and kelp ecosystems are highlighted in this report, it is clear that more progress is needed to effectively conduct climate-informed restoration of coral reefs and kelp forests. The scale and urgency of climate change necessitates a robust response. We urge MPA managers, in partnership with Indigenous communities; federal, state, local, and Indigenous governments; academic partners; and nonprofit organizations, to tackle these critical challenges and seize key opportunities to align the trajectory of restoration efforts more closely with the pace of climate change. It is imperative that MPA managers and their partners, including funding organizations, commit to pursuing these goals to advance climate-smart restoration. Meeting these challenges through a strategic and integrated approach will enhance the ability of MPAs to meet conservation and restoration goals, while also enhancing the value of these places to their communities.

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THE CLIMATE-INFORMED ECOSYSTEM RESTORATION IN MPAS SYMPOSIUM

The Climate-Informed Ecosystem Restoration in Marine Protected Areas (CERM) Symposium convened in Santa Cruz, California from March 25–27, 2024. The symposium was funded by the Lenfest Ocean Program and co-hosted by the National Marine Sanctuary Foundation and ONMS.

The objectives of the symposium were to:

1. Identify research needs and effective strategies for climate-informed restoration in kelp forest and coral reef ecosystems in national marine sanctuaries and other marine protected areas (MPAs);

2. Evaluate decision-making frameworks and best practices for addressing governance, equity, and social considerations in climate-informed restoration efforts;

3. Share experiences in restoration planning, permitting, funding, community engagement, and communications; and,

4. Generate actionable recommendations for advancing climate-informed restoration practices.

The event brought together 60 MPA managers, representatives from Indigenous governments, academic scientists, restoration practitioners, and other community members. Participants were initially identified based on input from national marine sanctuary staff and their partners, and almost every sanctuary with kelp and coral ecosystems had at least one representative at the convening. Specifically, representatives from Florida Keys, Flower Garden Banks, Channel Islands, Cordell Bank, Greater Farallones, Monterey Bay, Olympic Coast, and Hawaiian Islands Humpback Whale national marine sanctuaries, as well as the National Marine Sanctuary of American Samoa and Papahānaumokuākea Marine National Monument, attended.

The symposium itself was divided into three days, each with a guiding concept: deciding to restore, holistic restoration, and taking action.

Photo: Christina Funck/National Marine Sanctuary Foundation

DAY 1: Deciding to Restore

Chairman Valentin Lopez, Chair of the Amah Mutsun Tribal Band, opened the event with remarks on Indigenous history and stewardship in the Santa Cruz area. These remarks were followed by a grounding discussion about what Indigenous Knowledge is and the importance of working from a multi-knowledge based approach. A series of presentations highlighted the scale of the climate change challenge and the breadth of possible solutions, including overviews of climate impacts and resource interventions in sanctuaries; community-led coral restoration in Fiji; restoration on the Kashia Coastline in California; the history of restoration in national marine sanctuaries; holistic approaches to the restoration of herbivores and corals in the Florida Keys; and community-based coral restoration in Hawai'i. Later, participants split into coral and kelp breakout groups to identify key considerations around deciding to restore and the viability of restoration options.

DAY 2: Holistic Restoration

Day two began with a review of commonalities and differences between the day one ecosystem breakout group discussions. Participants then engaged in a conversation about holistic restoration, what "holistic" means, what holistic approaches involve, and challenges or opportunities around implementation. Participants discussed scaling restoration efforts and approaching restoration in the context of MPA networks, including regional considerations for restoration. The conversation was guided by presentations on kelp recovery research in Mendocino, California; kelp remote sensing; data tools for restoration; and the state MPA network and kelp restoration in California.

DAY 3: Taking Action

Day three began with reflections on the previous days, followed by presentations on coral and kelp ecosystem restoration approaches. Subsequent presentations addressed permitting in national marine sanctuaries. Follow-up conversation revolved around streamlining permitting, improving communication and collaboration among permitting agencies, and ensuring Indigenous Peoples' access to lands and waters. Participants also discussed communication strategies relevant for restoration. Presentations focused on emergency response planning at Flower Garden Banks National Marine Sanctuary and a new tool to mitigate coral bleaching at restoration sites. Dr. Randy Kosaki, Research Ecologist for Papahānaumokuākea Marine National Monument, closed by reflecting on how the monument has benefitted from increased engagement with multiple knowledge systems. The symposium concluded with a discussion of next steps to further the field of climate-informed ecosystem restoration.

 Photos: Jillian Neuberger/NOAA/National Marine Sanctuary Foundation

SHARING KNOWLEDGE ON CLIMATE AND RESTORATION

As part of the Climate-Informed Ecosystem Restoration in MPAs Symposium, participants recommended the resources they would most like their colleagues to read. Below is a list of those resources.

Please note, inclusion of a resource on this list does not equate to endorsement of the content by the National Marine Sanctuary Foundation or their partners.

CLIMATE-INFORMED ECOSYSTEM RESTORATION

Journal Articles

Mauser, W., Klepper, G., Rice, M., Schmalzbauer, B. S., Hackmann, H., Leemans, R., & Moore, H. (2013). Transdisciplinary global change research: The co-creation of knowledge for sustainability. Current Opinion in Environmental Sustainability, 5(3–4), 420–431. https://doi.org/10.1016/j.cosust.2013.07.001

Rogers-Bennett, L., Yang, G., & Mann, J. D. (2022). Using the Resist-Accept-Direct management framework to respond to climate-driven transformations in marine ecosystems. Fisheries Management and Ecology, 29(4), 409–422. https://doi.org/10.1111/fme.12539

Thompson, L. M., Lynch, A. J., Beever, E. A., Engman, A. C., Falke, J. A., Jackson, S. T., Krabbenhoft, T. J., Lawrence, D. J., Limpinsel, D., Magill, R. T., Melvin, T. A., Morton, J. M., Newman, R. A., Peterson, J. O., Porath, M. T., Rahel, F. J., Sethi, S. A., & Wilkening, J. L. (2021). Responding to ecosystem transformation: Resist, accept, or direct? Fisheries, 46(1), 8–21. https://doi.org/10.1002/fsh.10506

Timpane-Padgham, B. L., Beechie, T., & Klinger, T. (2017). A systematic review of ecological attributes that confer resilience to climate change in environmental restoration. PLoS ONE, 12(3), e0173812. https://doi.org/10.1371/journal.pone.0173812

Reports

Kordesch, W. K., & Delaney, M. (2024). Efficient permitting roadmap: A guide to the regulatory process for coastal sediment management actions. North-Central California Coastal Sediment Coordination Committee. https://nccscc-noaa.hub.arcgis.com/pages/roadmap

Schuurman G. W., Hawkins-Hoffman, C., Cole, D. N., Lawrence, D. J., Morton, J. M., Magness, D. R., Cravens, A. E., Covington, S., O'Malley, R., & Fisichelli, N. A. (2020). Resist-accept-direct (RAD)—a framework for the 21st-century natural resource manager. Natural Resource Report NPS/NRSS/CCRP/NRR—2020/2213. U.S. Department of the Interior, National Park Service. https://doi.org/10.36967/nrr-2283597

RESTORATION ACROSS MARINE PROTECTED AREAS

Journal Articles

Carr, M. H., Robinson, S. P., Wahle, C., Davis, G., Kroll, S., Murray, S., Schumacker, E. J., & Williams, M. (2017). The central importance of ecological spatial connectivity to effective coastal marine protected areas and to meeting the challenges of climate change in the marine environment. Aquatic Conservation: Marine and Freshwater Ecosystems, 27(S1), 6–29. https://doi.org/10.1002/aqc.2800

RESTORATION ACROSS MARINE PROTECTED AREAS CONT.

Reports

Gittings, S. R., Lohr, K. E., Quiocho, K., Symons, L., & Van Tilburg, H. (2024). Intervention: An evolving priority in national marine sanctuaries. National Marine Sanctuaries Conservation Series ONMS-24-03. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of National Marine Sanctuaries. https://sanctuaries.noaa.gov/science/conservation/intervention-an-evolving-priority.html

Websites/Other Resources

Office of Habitat Conservation. (2015). Restoration Center programmatic environmental impact statement. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Habitat Conservation. https://www.fisheries.noaa.gov/resource/document/restoration-center-programmatic-environmental-impact-statement

TRIBAL PERSPECTIVES AND INDIGENOUS KNOWLEDGE

Journal Articles

Kimmerer, R. W., & Artelle, K. A. (2024). Time to support Indigenous science. Science, 383(6680), 243–243. https://doi.org/10.1126/science.ado0684

Long, J. W., Goode, R. W., & Lake, F. K. (2020). Recentering ecological restoration with tribal perspectives. Fremontia, 48(1), 14–19. https://www.fs.usda.gov/research/treesearch/61600

Reid, M., Collins, M. L., Hall, S. R. J., Mason, E., McGee, G., & Frid, A. (2022). Protecting our coast for everyone's future: Indigenous and scientific knowledge support marine spatial protections proposed by Central Coast First Nations in Pacific Canada. People and Nature, 4(5), 1052–1070. https://doi.org/10.1002/pan3.10380

Yua, E., Raymond-Yakoubian, J., Daniel, R. A., & Behe, C. (2022). A framework for co-production of knowledge in the context of Arctic research. Ecology and Society, 27(1), 34. https://doi.org/10.5751/ES-12960-270134

CORAL RESTORATION

Journal Articles

Caruso, C., Hughes, K., & Drury, C. (2021). Selecting heat-tolerant corals for proactive reef restoration. Frontiers in Marine Science, 8, 632027. https://doi.org/10.3389/fmars.2021.632027

Guest, J., Baria-Rodriguez, M. V., Toh, T. C., Dela Cruz, D., Vicentuan, K., Gomez, E., Villanueva, R., Steinberg, P., & Edwards, A. (2023). Live slow, die old: Larval propagation of slow-growing, stress-tolerant corals for reef restoration. Coral Reefs, 42(6), 1365–1377. https://doi.org/10.1007/s00338-023-02440-1

Hein, M. Y., Vardi, T., Shaver, E. C., Pioch, S., Boström-Einarsson, L., Ahmed, M., Grimsditch, G., & McLeod, I. M. (2021). Perspectives on the use of coral reef restoration as a strategy to support and improve reef ecosystem services. Frontiers in Marine Science, 8, 618303. https://doi.org/10.3389/fmars.2021.618303

Hoegh-Guldberg, O., Skirving, W., Dove, S. G., Spady, B. L., Norrie, A., Geiger, E. F., Liu, G., De La Cour, J. L., & Manzello, D. P. (2023). Coral reefs in peril in a record-breaking year. Science, 382(6676), 1238–1240. https://doi.org/10.1126/science.adk4532

Shaver, E. C., McLeod, E., Hein, M. Y., Palumbi, S. R., Quigley, K., Vardi, T., Mumby, P. J., Smith, D., Montoya-Maya, P., Muller, E. M., Banaszak, A. T., McLeod, I. M., & Wachenfeld, D. (2022). A roadmap to integrating resilience into the practice of coral reef restoration. Global Change Biology, 28(16), 4751–4764. https://doi.org/10.1111/gcb.16212

Webb, A. E., Enochs, I. C., Van Hooidonk, R., Van Westen, R. M., Besemer, N., Kolodziej, G., Viehman, T. S., & Manzello, D. P. (2023). Restoration and coral adaptation delay, but do not prevent, climate-driven reef framework erosion of an inshore site in the Florida Keys. Scientific Reports, 13(1), 258. https://doi.org/10.1038/s41598-022-26930-4

Reports

Boch, C. A., DeVogelaere, A., Burton, E. J., King, C., Lovera, C., Buck, K., Lord, J., Kuhnz, L., Kaiser, M., Reid-Rose, C., & Barry, J. P. (2020). Guide to translocating coral fragments for deep-sea restoration. National Marine Sanctuaries Conservation Series ONMS-20-10. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries. https://sanctuaries.noaa.gov/science/conservation/translocating-coral-fragments-for-deep-sea-restoration.html

Knowlton, N., Grottoli, A. G., Kleypas, J., Obura, D., Corcoran, E., de Goeij, J. M., Felis, T., Harding, S., Mayfield, A., Miller, M., Osuka, K., Peixoto, R., Randall, C. J., Voolstra, C. R., Wells, S., Wild, C., & Ferse, S. (2021). Rebuilding coral reefs: A decadal grand challenge. International Coral Reef Society and Future Earth Coasts. https://coralreefs.org/publications/rebuilding_coral_reefs/

Websites/Other Resources

National Academies of Sciences. (n.d.). Interventions to increase the resilience of coral reefs. https://www.nationalacademies.org/our-work/interventions-to-increase-the-resilience-of-coral-reefs

KELP RESTORATION

Journal Articles

Eger, A. M., Marzinelli, E. M., Christie, H., Fagerli, C. W., Fujita, D., Gonzalez, A. P., ... & Vergés, A. (2022). Global kelp forest restoration: Past lessons, present status, and future directions. Biological Reviews, 97(4), 1449–1475. https://doi.org/10.1111/brv.12850

Reports

Eger, A. M., Layton, C., McHugh, T. A., Gleason, M., & Eddy, N. (2022). Kelp restoration guidebook: Lessons learned from kelp projects around the world. The Nature Conservancy. https://kelpforestalliance.com/TNC-KFA-Kelp-Guidebook-2022.pdf

Giraldo-Ospina, A., Bell, T., Carr, M. H., Malone, D., & Caselle, J. E. (2023). Where, when and how? A guide to kelp restoration in California using spatio-temporal models of kelp dynamics. Final report to California Sea Grant. https://caseagrant.ucsd.edu/sites/default/files/R_HCEOPC-18_2023_final_report_.pdf

Gleason, M. G., Caselle, J. E., Heady, W. N., Saccomanno, V. R., Zimmerman, J., McHugh, T. A., & Eddy, N. (2021). A structured approach for kelp restoration and management decisions in California. The Nature Conservancy. https://www.scienceforconservation.org/assets/downloads/Kelp_StructuredDecisionMaking_Final_Report_April_2021.pdf

Websites/Other Resources

West Coast Ocean Alliance. (n.d.). West Coast Ocean Alliance. https://www.westcoastoceanalliance.org

National Marine Sanctuary Foundation

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