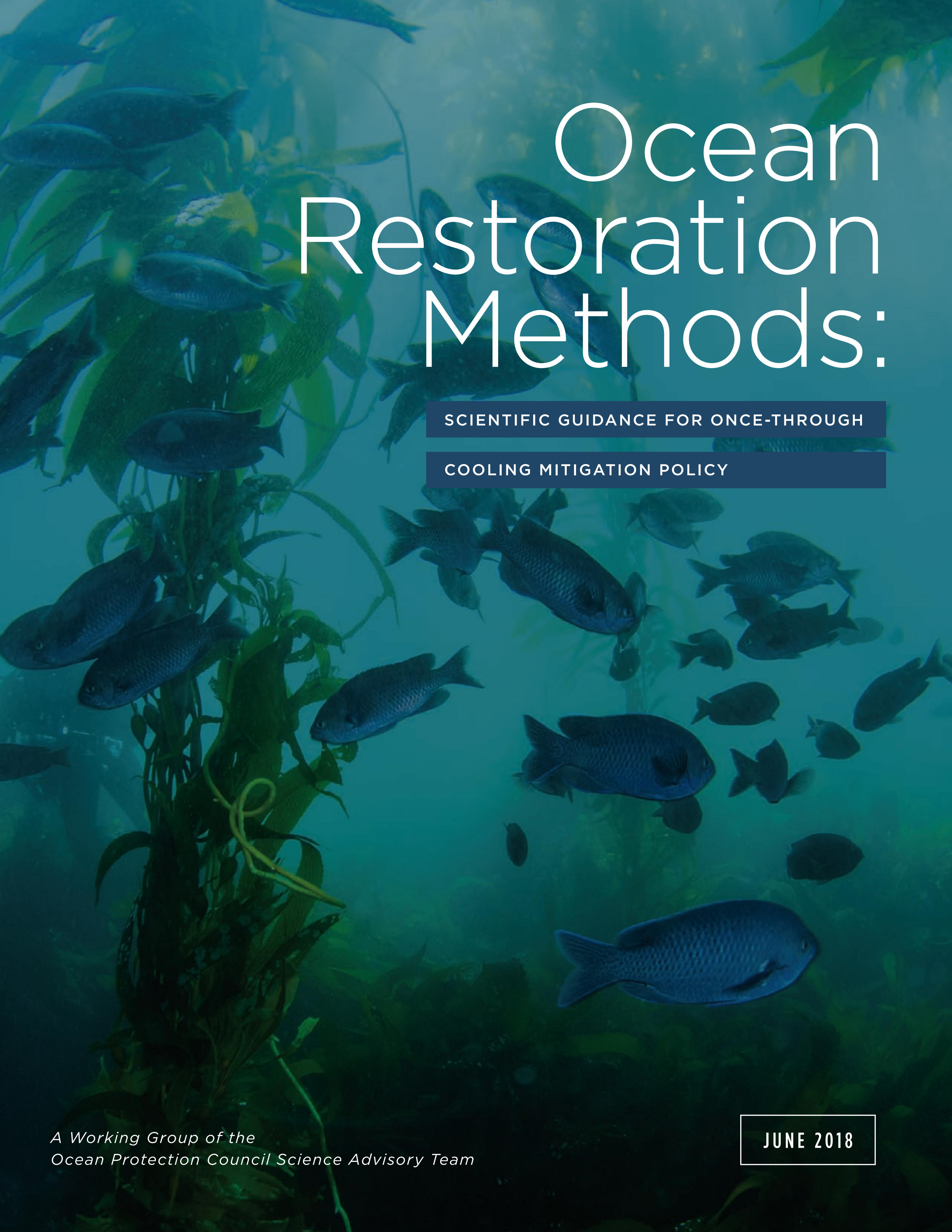

# Ocean Restoration Methods:

## SCIENTIFIC GUIDANCE FOR ONCE-THROUGH COOLING MITIGATION POLICY

*A Working Group of the*
*Ocean Protection Council Science Advisory Team*

JUNE 2018

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### Ocean Protection Council Science Advisory Team Working Group

The role of the Ocean Protection Council Science Advisory Team (OPC-SAT) is to provide scientific advice to the California Ocean Protection Council (OPC). The work of the OPC-SAT is supported by the California Ocean Protection Council and administered by Ocean Science Trust. OPC-SAT working groups bring together experts from within and outside the OPC-SAT with the ability to access, analyze, and interpret the best available scientific information on a selected topic.

### California Ocean Science Trust

California Ocean Science Trust is an independent, non-profit organization that brings together governments, scientists, and citizens to build trust and understanding in ocean and coastal science issues. We empower participation in the decisions that are shaping the future of our oceans. We were established by the California Ocean Resources Stewardship Act to support managers and policymakers with sound science. For more information, visit our website at www.oceansciencetrust.org.

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California Ocean Protection Council
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# About this Report

## CALIFORNIA MANAGEMENT CONTEXT

California's Once-Through Cooling Policy (Policy) was adopted by the State Water Resources Control Board (State Water Board) in 2010 and amended in 2011, 2013, 2016, and 2017. The Policy establishes technology-based standards to implement federal Clean Water Act section 316(b) and reduce the harmful effects associated with cooling water intake structures on marine and estuarine life. The Immediate and Interim Requirements Section 3(e) of the Policy states, "It is the preference of the State Water Board that funding is provided to the California Coastal Conservancy[1], working with the California Ocean Protection Council, for mitigation projects directed toward increases in marine life associated with the State's Marine Protected Areas in the geographic region of the facility" (State Water Board, 2015). As the OPC considers how to design a funding program, they seek scientific guidance from the OPC-SAT on where restoration efforts should be targeted and how to evaluate potential restoration strategies.

## GOAL OF THIS REPORT

This report was produced by an OPC-SAT working group and California Ocean Science Trust on behalf of the OPC and the broader community of California managers. This report applies the latest scientific data and expertise to inform the implementation of the adopted Once-Through Cooling (OTC) Policy. The working group focused on tractable scientific questions embedded in the Policy language regarding defining the spatial extent of OTC impacts around each facility, the spatial extent of association with the State's marine protected areas (MPAs), and building a framework to define increases in marine life. The Ocean Protection Council's OTC Interim Mitigation Program includes four components that guide the implementation of the OTC Policy related to California's MPA Network; 1) enforcement; 2) outreach to improve compliance; 3) research to understand how existing MPAs may be mitigating for OTC impacts (Dawson et al., 2016); and 4) restoration that increases marine life in the geographic region of the facility. This report is narrowly focused on applying the best science available to inform the implementation of the restoration component.

1. In 2013, the Ocean Protection Council moved to be housed in the California Natural Resources Agency which is the successor agency to the California Coastal Conservancy in this case.

# Executive Summary

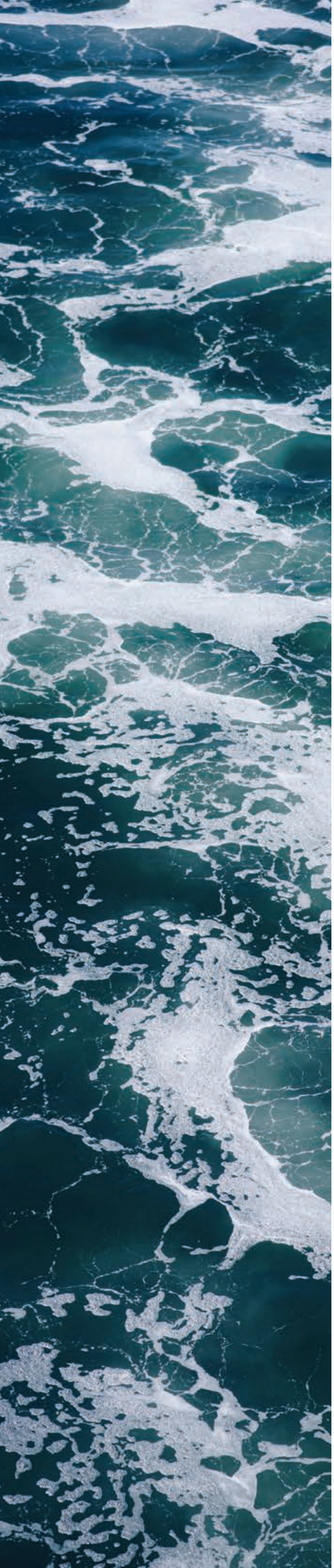
California's Once-Through Cooling Policy (Policy) was adopted by the State Water Resources Control Board (State Water Board) in 2010 and amended in 2011, 2013, 2016, and 2017. The Policy establishes technology-based standards to implement federal Clean Water Act section 316(b) and reduce the harmful effects associated with cooling water intake structures on marine and estuarine life. The Immediate and Interim Requirements Section 3(e) of the Policy states, "It is the preference of the State Water Board that funding is provided to the California Coastal Conservancy, working with the California Ocean Protection Council, for mitigation projects directed toward increases in marine life associated with the State's Marine Protected Areas in the geographic region of the facility" (State Water Board, 2015). The working group of the OPC-SAT was charged with answering the following questions where current scientific knowledge and understanding could provide key insights and guidance to OPC in designing a funding program to disburse OTC funds.

1. **The Policy states that it is the preference for mitigation funds to be directed towards projects that are within the "geographic region of the facility." However, the Policy does not define that geographic range. What is the "geographic region" specific to the ten power plants that are part of the program?**

2. **The Policy states that it is the preference for mitigation funds to be directed towards projects that may lead to "increases in marine life associated with the State's Marine Protected Areas." How do we evaluate if common open coast restoration methods will lead to increases in marine life associated with the State's MPA Network based on currently available scientific evidence?**

In this report, we define clear boundaries for the geographic range in Section 2 which can bound the areas where impacts can be assumed to occur based on our current scientific knowledge. We also encourage the State to revisit these boundaries as more advanced models become available in the near-term. These models will help to better understand and refine the area of impact due to their ability to tell us about not just where the organisms were coming from, but their destination had they not been impinged or entrained by an OTC power plant.

We also provide a scientific definition of "associated with the State's marine protected areas" and "increases in marine life" in Section 3. These definitions should be the umbrella with which the framework in Section 4 is applied. We utilize these definitions and the framework for evaluating restoration methods in the examples in Section 5 to better illuminate how the State can determine if common open coast restoration methods will lead to increases in marine life associated with the State's MPA Network using best available science. Through applying the framework, we are able to refine it and feel confident that it will serve to examine the scientific rigor and ability of projects to meet the scientific elements of the Policy.



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# 1. Introduction

Once-through cooling (OTC) technology pulls water from the ocean to cool power plants. The sea water taken in is itself habitat with a high biodiversity of zoo- and phytoplankton, including billions of eggs and larvae of marine fishes and invertebrates, and the gametes, spores, and seeds of seaweeds and marine plants, such as eelgrass and kelp. These organisms are killed in the process. Small organisms are entrained in circulated water, subjected to thermal, physical, and/or chemical stresses as the water is brought from the ocean to the plant. Larger organisms can also be be harmed, even though they do not pass through intake screens into the plant, by being pinned against the sea water intake screens (a process known as impingement) (Raimondi, 2011). These impacts contribute to the decline of fisheries and the degradation of marine habitats in the vicinity of power plants using OTC (State Water Board, 2008).

## 1.1 Policy Directive

California's Once-Through Cooling Policy (Policy) establishes technology-based standards to implement federal Clean Water Act section 316(b) and reduce the harmful effects on marine and estuarine life associated with cooling water intake structures. The Policy requires that power plants that have not met the technology-based standards by October 2015 mitigate the impacts of their non-compliance. Plant operators may meet this obligation either by undertaking mitigation projects or paying into a mitigation fund (State Water Board, 2015). This interim mitigation obligation ends when the plant achieves compliance with the technology-based standards, which require that plant operators reduce water intake rates or impingement mortality and entrainment to levels equivalent to those achieved by plants using closed cycle cooling.

The Policy directs the California Ocean Protection Council (OPC) to spend interim mitigation funds on mitigation projects (see Box 1). OPC is not obligated to spend the funds as direct compensatory mitigation, where projects would have to target the precise species lost at a particular plant. Rather, the Policy states, "It is the preference of the State Water Board that funding is provided to the California Coastal Conservancy,[2] working with the California Ocean Protection Council, for mitigation projects *directed toward increases in marine life associated with the State's Marine Protected Areas (MPAs) in the geographic region of the facility*" (State Water Board, 2015)(emphasis added). The facilities still operating along with their proximity to MPAs are shown in Figure 1.

**BOX 1**

### MITIGATION OR RESTORATION?

A "mitigation project" is defined in the Policy as a project "to restore marine life lost through impingement mortality and entrainment. Restoration of marine life may include projects to restore and/or enhance coastal marine or estuarine habitat, and may also include protection of marine life in existing marine habitat, for example through the funding of implementation and/or management of Marine Protected Areas" (State Water Board, 2015). This is different from compensatory mitigation in that the payments into the OTC Interim Mitigation Program may be used to increase marine life associated with the State's MPAs in the geographic region of the facility.

Although the Policy language refers to "mitigation projects," for clarity in this report, we will use the term "restoration methods" to describe these projects. This OPC-SAT working group was asked to give scientific guidance on restoration methods.

2. In 2013, the Ocean Protection Council moved to be housed in the California Natural Resources Agency which is the successor agency to the California Coastal Conservancy in this case.

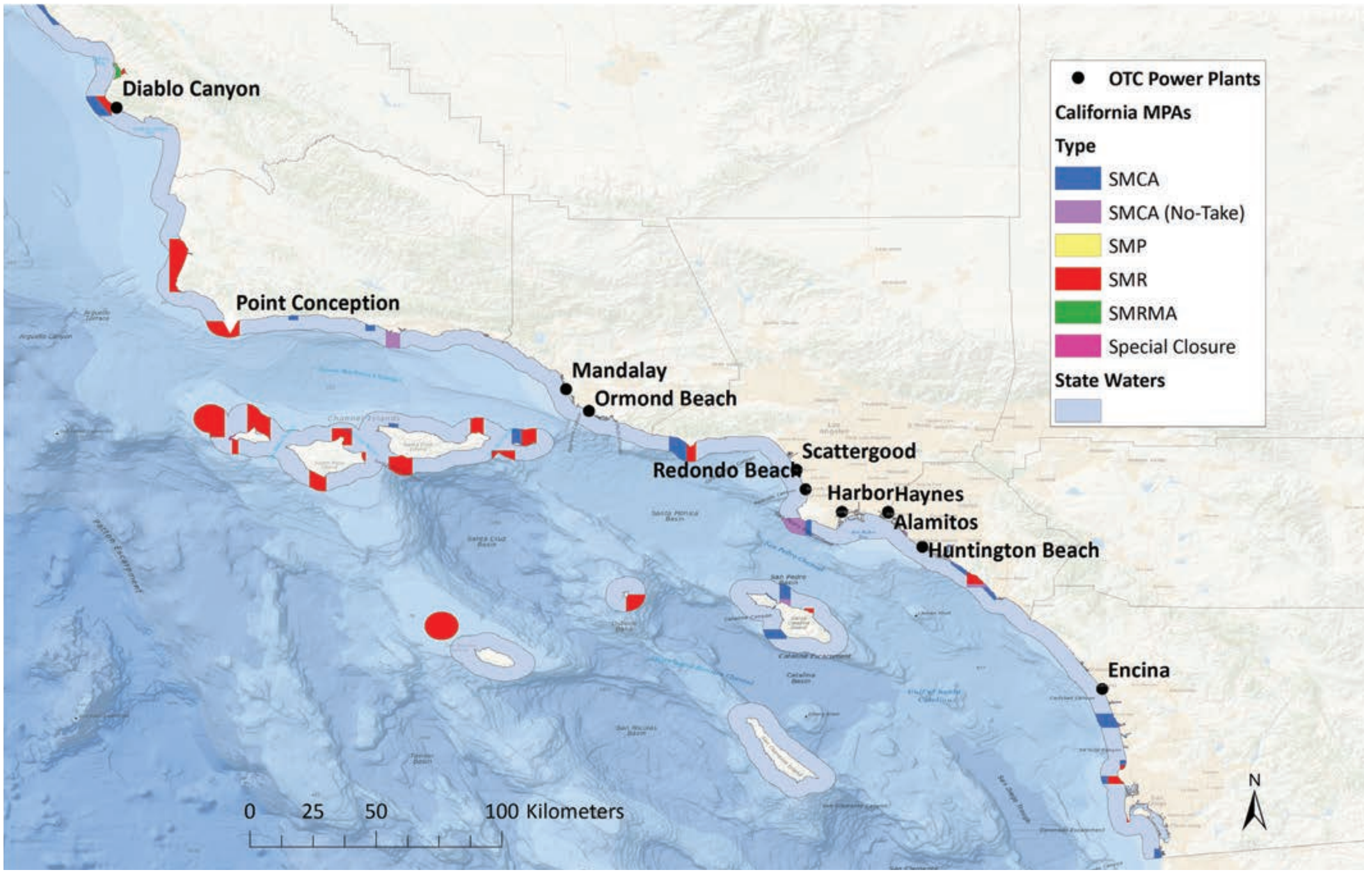



**Figure 1.** There are ten power plants in the OTC Interim Mitigation Program (the other OTC plants have either come into compliance with the guidelines in the Policy or have ceased operations): Alamitos, Diablo Canyon, Encina, Harbor, Haynes, Huntington Beach, Mandalay, Ormond Beach, Redondo Beach, and Scattergood.

## 1.2 Scientific Guidance on OTC Policy

The Policy recommends that OPC directs funds towards mitigation projects (or "restoration methods") likely to lead to increases in marine life associated with MPAs (see Box 1). OPC's OTC Interim Mitigation Program has four components for implementing the Policy related to California's MPA Network. The four components were chosen due to their ability to increase marine life associated with MPAs. They are: 1) enforcement; 2) outreach to improve compliance; 3) research to understand how existing MPAs may be mitigating for OTC impacts (Dawson et al., 2016); and 4) restoration that increases marine life in the geographic region of the facility. There is significant scientific consensus and guidance for how enforcement, education, and research can improve MPA functions and lead to increases in marine life (IUCN, 2008; Sheehan et al., 2013; Botsford et al., 2014; Starr et al., 2015). However there is less scientific syntheses and guidance from the literature for how to define the area of impact in California and what types of restoration methods are likely to lead to increases in marine life associated with MPAs.

**For this reason, the OPC asked the OPC-SAT working group to answer the following questions where current scientific knowledge and understanding could provide key insights and guidance.**

1. **The Policy states that it is the preference for mitigation funds to be directed towards projects that are within the "geographic region of the facility." However, the Policy does not define that geographic range. What is the "geographic region" specific to the ten power plants that are part of the program?**

2. **The Policy states that it is the preference for mitigation funds to be directed towards projects that may lead to "increases in marine life associated with the State's Marine Protected Areas." How do we evaluate if common open coast restoration methods will lead to increases in marine life associated with the State's MPA Network based on currently available scientific evidence?**

To help answer question 2, we have established a scientific framework of guiding principles for evaluating a restoration method's likelihood of success (Section 4), and we provide three examples to illustrate the use of the framework (Section 5).

# 2. Geographic Region of the Facility

Here we define the section of the Policy that directs payments toward restoration methods in the geographic region of the facility, or what we will refer to as the "area of impact." See Figure 1 for a map of the power plants subject to the Policy.

In order to assess the area of impact, we want to consider every possible combination of organisms that could have been lost to the MPA N etwork from OTC plant operations. We want to consider both where the organisms have come from and where they might have gone had they not been entrained or impinged. There are a variety of mechanisms for understanding this. Models are the main tool scientists use to study and predict the movement of all sizes of organisms. One way to geographically assess the impacts is to use an Empirical Transport Model (ETM), a model used previously in work related to OTC impacts. As defined in Raimondi (2011), an ETM estimates "the portion of a larval population at risk to entrainment" by determining both the amount of larvae from that population that will be entrained as well as the size of the larval populations found in the source water body based on data collected from the source water body. The source water body is "the area where larvae are at risk of being entrained and is determined by biological and oceanographic factors" (Raimondi, 2011). ETM is a model that is fully developed (i.e. ready to use right now) that can take field sampling data and use it to predict where the entrained organisms may have come from.

To define the geographic region, the working group looked for a scientifically rigorous technique that is currently usable. While other methods are under development, and still being tested, the timeline for their completion (including rigorous scientific peer review) will not meet the timelines for which OPC needs to initiate their program. The ETM uses sampling data of target species from the intake water, which are collected at regular intervals (Raimondi, 2011). One step of the ETM is to estimate the source water body; this estimation closely aligns with our understanding of the area of impact. For these reasons, and because this methodology has been determined by the State Water Board as the preferred method to determine impacts of OTC to organisms, we used the results of the ETM and the source water bodies for each power plant to define the geographic area of impact. Results of the ETM generated a source water body for each target species. Additionally, the results of the ETM are also in close alignment with theoretical models that include the observation that nearshore water motion decreases toward shore, often in the vicinity of intakes (White et al., 2010b; Nickols et al., 2012). For this report, we considered the largest source water body to define the area of impact because it will include all possible combinations of entrained and impinged species that could be lost from the MPA Network.

## 2.1 Results: Areas of Impact

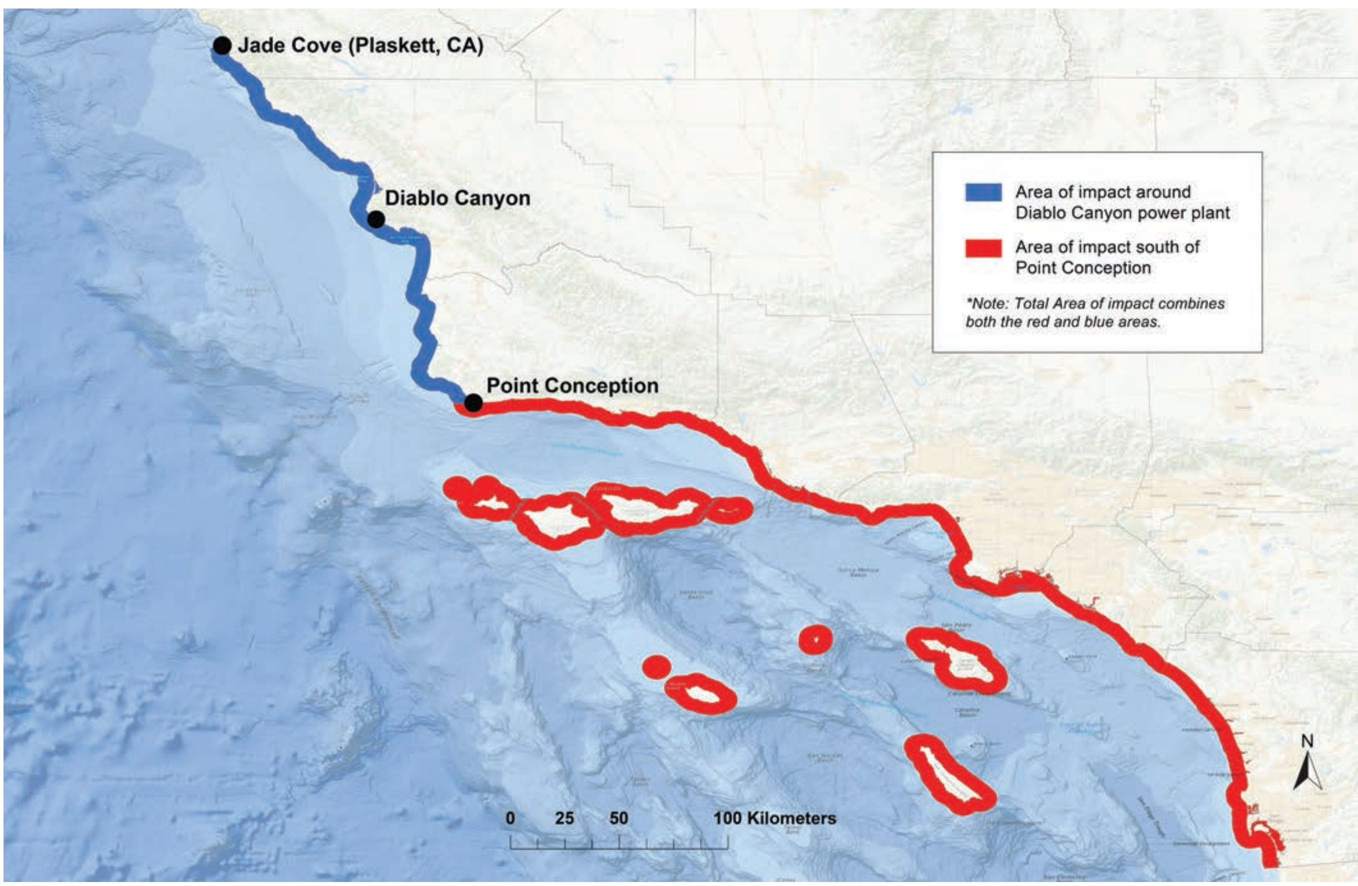



**Figure 2.** The areas of impact for the ten power plants complying with the interim mitigation requirements of the OTC Policy (red areas and blue area combined).

Figure 2 is a map of the areas of impact for the ten power plants that are operating under the interim mitigation requirements of the Policy. The power plants are clustered closely together in Southern California, and their source water bodies overlap, creating an area of impact that spans the entirety of State waters (3 nautical miles from the coastline, the extent of this analysis) from Point Conception in the north, to the California/Mexico border to the south (Figure 2, red areas). Although outside the ETM results, we also include the waters around the Channel Islands, as research shows these waters to be connected to the mainland through the larval transport of species of interest (Mitarai et al., 2009; Watson et al., 2010).

North of Point Conception, the Diablo Canyon power plant determines the area of impact, which extends roughly 100km north of and south of the plant in State waters (Figure 2, blue area). The northern limit is in the vacinity of Jade Cove, near Plaskett, California.

## 2.2 Near-term Considerations

ETM was the chosen method for this report for a number of reasons: 1) it is the model currently used by the State, 2) the data used are from samples taken from a location adjacent to or in the intake, 3) the results provide a method that has been vetted, and 4) the results provide species-specific estimation. However, more sophisticated methods using state-of-the-science numerical models that represent realistic ocean currents and their variability along the entire coast of California are increasingly available. When coupled to particle transport algorithms, such models can predict larval transport within the MPA Network.

One advanced numerical ocean model that is widely used in the California Current and other locations worldwide is the Regional Ocean Modeling System (ROMS) (Shchepetkin & McWilliams, 2005). This model is similar in structure and complexity to weather forecast models used to predict atmospheric winds. Driven by realistic atmospheric fields at the surface, various applications resolve the California Current in its entirety at coarse resolution (2 km - 10 km) (Marchesiello et al., 2003; Veneziani et al., 2009; Kurapov et al., 2017) and nest higher resolution grids down to km scale or hundreds of meters in more localized regions (Dong et al., 2009; Suanda et al., 2016). Ocean currents produced by these models are used to model the transport of larvae throughout the California Current. While some dispersal studies are generic (Mitarai et al., 2009; Drake et al., 2011), others are more targeted with species-specific emphasis (Watson et al., 2009; Drake et al., 2013; Johansson et al., 2016).

Studies such as these may provide a better understanding in the near-term for the State on the areas of impact from OTC, allowing the State to consider not just where organisms came from, but also where they might have gone. We recommend that the State consider using these models as they mature.

# 3. Scientific Definitions for Interpreting OTC Policy

In order for us to provide the needed scientific guidance for the questions outlined in Section 1, we determined that there was a need to define two of the phrases from the Policy in scientific terms. We note that these definitions are for the purposes of interpreting and applying the questions given to this OPC-SAT working group.

Section 2 above defines the geographic region of the facility and those boundaries are based on the best available scientific information. OPC also asked us what types of projects will lead to increases in marine life associated with MPAs. However, in order to answer that question, we need to apply a scientific definition to two discrete phrases from the Policy: "associated with the State's Marine Protected Areas" and "increases in marine life."

## 3.1 Key Definition: "Associated with the State's Marine Protected Areas"

The Marine Life Protection Act (MLPA) (Marine Life Protection Act, 1999) directed the State to design a network of MPAs to be created and managed using sound science and stakeholder input. As of December 19, 2012 (after a rigorous and multi-year planning and implementation process that included stakeholders, tribes, scientists, decision makers, and the public) the MPA Network is in effect for the entire coast of California.

California's MPA Network was designed to be ecologically connected through ocean currents that transport eggs, spores, larvae, and individuals across the Network both into MPAs and into the spaces in between. Different species spend different amounts of time and are transported different distances by ocean currents before settling in their juvenile habitats. Here we refer to this period as "transport time." Most abalone, for example, have transport times of about 5-10 days (Haaker et al., 2001). Other species, like California spiny lobster (*Panulirus interruptus*), can have much longer transport times of 7-10 months (Pringle, 1986). The connectivity across the MPA Network is a core principle of both the design of the MPA Network itself and the related performance evaluation monitoring. Due to this connectivity, we consider that "associated with MPAs" includes both the areas inside and outside of individual MPA boundaries (White et al., 2010a). Therefore, the area of impact is the entire area as defined in Section 2.1 above, not just the discrete MPAs that are within that area of impact.

The mandates in the MLPA for design and performance evaluation strongly align with this definition as well. The MLPA focus on the importance of connectivity both in design and evaluation is being reflected in the forthcoming MPA Monitoring Action Plan (California Ocean Protection Council, 2018). All these factors taken together, both from the best available ecological science and existing policy, provide robust alignment with the definition of California's MPA Network being inclusive of the MPAs themselves as well as the spaces in between for the area of impact as defined in Section 2.1.

## 3.2 Key Definition: "Increases in Marine Life"

California's MPA Network was established with many goals, which include protecting and sustaining diversity and abundance of marine life populations, protecting the structure, function, and integrity of marine ecosystems, and rebuilding marine populations that are depleted (California Department of Fish and Wildlife, 2016). The OTC Policy has language that is in alignment with California's MPA Network goals as well as other MPAs across the globe: "increases in marine life associated with the State's MPAs." We have provided our scientific interpretation of this language in order to inform our guidance of restoration methods that are likely to lead to these types of increases.

Increases in marine life could come from a variety of mechanisms; they are not just about numerical changes in particular species, but about improving the ecosystem functions within the MPA Network as a whole, and is in alignment with the goals in the MLPA (Marine Life Protection Act, 1999). Our definition of increases in marine life is drawn from ecological first principles about population dynamics and the ecosystem features that support them (Marquet et al., 2015).

The following metrics, and therefore species we refer to below in the metrics, are those that are important to perpetuating the structure and integrity of a healthy, functioning ecosystem through time and therefore lead to increases in marine life as stated in the Policy. While we don't expect every project to meet every metric, we do recommend that they should be considered together, not discretely, and should have reference points (discussed below) associated with each one when applying to a particular method or approach.

**In each of these metrics the types of species we are referring to are those that are important to perpetuating the structure and integrity of a healthy, functioning ecosystem through time and therefore lead to increases in marine life[1,2].**

**DENSITY[3]:** increases in the density of a particular species or suite of species. This could mean methods that directly increase density of native species or include indirect methods, such as removal of invasive species, indirectly leading to increases in density of species that enhance ecosystem health.

**BIODIVERSITY[4]:** increases in diversity of species, populations, communities, ecosystems, and/or functions. This includes increasing the diversity of age or size classes or other ecologically-relevant traits within a population, genetic representation, community and/or habitats in an ecosystem, etc.

**BIOMASS[5]:** increases in biomass of a particular or suite of species.

**FUNCTION[6]:** increases in the functionality of ecosystem components such as connectivity, resilience of species, functional groups or habitat, productivity, water quality, etc.

**POPULATION SIZE[8]:** increases in a species population either spatially or genetically.

These metrics seek to create a definition of "increases in marine life" that is quantifiable and measurable. We recommend the use of reference points[9] for each of these metrics, in order to not only better measure these metrics, but also to answer the question: What are we restoring to and/or from? The reference point should be in the same unit of measurement as the goal or metric. The reference point could be based on that metric from a different time, specific species, population, or ecosystem state, or a new reference point due to changing ocean conditions, etc. Additionally, other metrics, like resiliency, have been difficult to measure or to define reference points, and even more difficult to render successful. We know that these other metrics are important and should not be ignored when considering restoration methods. However, we recommend that they be considered together with the above metrics, rather than in isolation.

1-Ecosystem health- condition of the ecosystem. A healthy ecosystem is defined as being 'stable and sustainable'; maintaining its organization and autonomy over time and its resilience to stress (Costanza 1994; Rapport et al., 1998).
2-Ecosystem function- "the flow of energy and materials through the arrangement of biotic and abiotic components of an ecosystem" (Diaz & Cabido 2001).
3-Density- is usually used to refer to the number of items per unit area, for example, barnacles/$m^2$.
4-Biodiversity- includes four main components:
- Genetic diversity refers to the genetic variation that occurs among members of the same species.
- Species diversity (taxonomic diversity) refers to the variety of species or other taxonomic groups in an ecosystem.
- Ecosystem diversity refers to the variety of biological communities found on earth, usually consider at two levels, communities and ecosystems.
- Functional diversity refers to the variety of biological processes, functions, or characteristics of a particular ecosystem (Thorne- Miller 1999).

5-Biomass- is the mass of living biological organisms in a given area or ecosystem at a given time. Biomass can refer to species biomass, which is the mass of one or more species, or to community biomass, which is the mass of all species in the community (IUPAC, 1997). Biomass therefore considers the size structure of the species or community, in addition to abundance or density.
6-Function- role, or function, that a species plays in the community or ecosystem in which they occur (e.g. primary producer, consumer, top predator, etc.).
7-Resilience- can include both engineering resilience (how quickly a system returns to the original state from disturbance) and ecological resilience (likelihood of a state switch following disturbance).
8-Population size- amount (number or area) of individuals of the same species, and can include increases in functionality of the role of the population in the ecosystem.
9-Reference point- basis or standard for evaluation, assessment, or comparison; a criterion.

# 4. Framework for Evaluating Restoration Methods

We have taken an ecological first principles (Marquet et al., 2015) approach for creating a scientific framework for evaluating restoration methods in alignment with the goals outlined in the Policy. The guiding principles that make up this framework are intended for use in evaluating whether or not a restoration method is likely to reach the goal of increasing marine life associated with MPAs from a scientific perspective. They are meant to be taken in conjunction with the definitions described in Section 3 and the geographic confines described in Section 2. Restoration methods should be assessed for alignment with these definitions and within the defined geographic scope before applying these principles to assess whether they are scientifically likely to lead to increases in marine life associated with MPAs.

## 4.1 Guiding Principles

**Principle 1** *Restoration method has a high likelihood of restoring the integrity of the coastal ecosystem.*

Integrity of an ecosystem is defined here as the natural structure and functions of an ecosystem, including the populations, communities, and habitats that constitute the ecosystem, which exist in the absence of or prior to industrial-era anthropogenic influences. Restoration methods should seek to facilitate and protect the integrity of the MPA Network and demonstrate a long-term outcome for increasing marine life at the community level rather than species level. Restoration methods that have a high likelihood of restoring the integrity of the coastal ecosystem are likely to increase marine life both inside and outside of MPAs, even if the approach is not applied within an MPA itself.

This principle takes into account that restoring to a pre-industrial-era anthropogenic status may not be possible or appropriate given our current understanding of how our ocean ecosystems may be and are changing (species range shifts, ocean acidification, harmful algal blooms, sea surface temperature changes, etc.). A component of ecosystem integrity is the capacity for a system to respond to change (e.g. across locations, maintain the capacity for range shifts to occur), and within a location, maintain ecosystem function as some of the underlying community composition changes.

We recommend methods that may produce community wide benefits, rather than single species benefits. This can mean either enhancement at the level of ecosystems or communities (e.g., increases in species biodiversity, habitat diversity, community-wide productivity) or enhancement at the level of species populations. Population level enhancement of a single species should target those species that have broader community-wide influences, or those that are threatened or endangered by human impacts. However, single-species approaches might have ramifications for other species, but would not have as high priority as approaches with broad community benefits.

**Principle 2** *Restoration method has a high likelihood of success at a scale that can provide meaningful ecological benefits.*

Scale here refers to both spatial and/or temporal aspects of a proposed method. If approaches are too spatially restricted, or are done for too short a period of a time, they might not increase marine life in a meaningful way. This includes both methods that can be executed at a large scale (at least hundreds of meters) or executed in a small area but have larger impacts, or reverberate through a system. For example, removal of an invasive species at an early stage in a pristine long-protected environment could have large scale impacts over time by preventing establishment of an irreversible invasion that could decrease the integrity of a pristine marine habitat. Feasibility of success at scale also includes the potential for the approach to be implemented on short enough time scales and small enough spatial scales to be realistically possible while still having ecosystem level outcomes.

**Principle 3** *Restoration method has a high likelihood of being self-sustaining.*

Restoration method is able to maintain benefits over a long time period with minimal external inputs or maintenance. The method is likely to be highly resistant or resilient to natural and anthropogenic disturbances over time and space. The method will have demonstrated a high likelihood of being able to maintain its desired effects after a disturbance through demonstrating either minimal effects or recovery over space and/or time.

## 4.2 Using the Framework

Applying these three principles to proposed restoration methods will help to determine if the method is scientifically likely to be effective at increasing marine life associated with MPAs. We anticipate that some restoration methods will be shown to be effective through previous work in particular habitats while other habitats or methods will have little to no previous applications. In these areas, we recommend and believe that innovative research and development will be a key tool to achieving long-term success in reaching the goals that are outlined in the Policy. It is essential that any new restoration methods proposed are designed to inform the utility of the new method. Regardless, all restoration methods should be grounded in science and include scientifically rigorous and specific predictions of ecosystem responses to the restoration method. In the following section, we provide some examples on how the framework can be applied.

# 5. Applying the Framework

Here we apply the framework and guiding principles, presented in Section 4, to three restoration methods to demonstrate how the framework can be used. Our goal was to both test and refine the guiding principles themselves in addition to demonstrating their application. These examples also document current scientific understanding of how these methods may or may not be likely to lead to increases in marine life associated with MPAs. We chose three broad categories for review, and present a specific restoration method for each category to bound the exercise:

**REDUCING NOVEL STRESSORS:** mitigating anthropogenically-driven elements (both biotic and abiotic)

**COMMUNITY ENHANCEMENT:** manipulating naturally-occuring biotic elements

**STRUCTURAL MANIPULATION:** enhancement of abiotic elements

The following demonstrations are by no means a comprehensive list of restoration categories or methods. The examples presented here are not meant to limit the types of restoration or projects that should be considered for funding under OPC's OTC Interim Mitigation Program. We chose restoration methods for which there is not necessarily a deep body of scientific evidence demonstrating outcomes. Other restoration methods, like wetland restoration, are well documented.

## 5.1 Reducing novel stressors: Marine and estuarine invasive macroalgae removal

### INTRODUCTION

Given the difficulties in establishing effective measures to prevent the spread of marine and estuarine invasive species, management options fall under control and eradication (Williams & Grosholz, 2008). There are currently no ready-made protocols for invasive species control or eradication, rather, methods must be tailored to the specific physical and biological conditions of the impacted area as well as characteristics of the invader (Anderson, 2007). Eradication can be accomplished using physical removal, applying biocides, biological control by introducing predators, parasites or viruses, or through genetic modification techniques (Thresher & Kuris, 2004). For the purposes of this case study, we chose to focus on physical (i.e. mechanical) removal of invasive macroalgae from rocky marine environments, as this approach has been most commonly used to control and eradicate invasive species (Thresher & Kuris, 2004). Physical methods include manipulations in or around the impacted area with the objective of either removing, burying, or killing the invasive macroalgae.

**Principle 1** *Restoration method has a high likelihood of restoring the integrity of the coastal ecosystem.*

A review of impacts by introduced macroalgae indicates that these species most commonly alter community composition or monopolize space; other documented ecological impacts include reduced abundances, richness, and diversity of native macroalgae and associated fauna, altered habitat characteristics due to changing sediment accumulation by introduced macroalgae, and changing food web linkages (Davidson et al., 2015). Thus, the expectation is that removal of invasive macroalgae would help restore the impacted ecological functions of the coastal ecosystem. However, in many cases we know little about the ecological impacts of invasive species, and ecosystem processes and functions are among the most overlooked effects of invasive species in estuarine and coastal environments (Williams & Grosholz, 2008). Furthermore, while restoring ecological integrity is often the ultimate goal of an eradication program, most simply score success by proximate goals such as invasive species removal (Prior et al., 2018). Studies also indicate that the ecological consequences of an invader depend on the degree to which a habitat is degraded (Tamburello et al., 2015). For example, removal of an invasive marine alga had positive ecological effects on native algae at sites with little exposure to anthropogenic influences (Bulleri et al., 2016).

**Principle 2** *Restoration method has a high likelihood of success at a scale that can provide meaningful ecological benefits.*

The few documented cases of total eradication of a marine invasive algae occurred when the invasion was caught early, the invasion scale was small or in an isolated area, the response was rapid and well-coordinated by cooperating government agencies, and the biological and ecological characteristics of the invader were well understood (*Caulerpa taxifolia*, Anderson, 2005; *Ascophyllum nodosum*, Miller et al., 2004).

Physical removal is unlikely to result in complete eradication unless the invasion is limited to a relatively small area. The studies of hand removal (and 'super sucker' suction device) from Kaneohe Bay, HI and Catalina Island, CA, both made estimates of the human-hours (people-time) required to remove measured amounts of algae but neither study extrapolated to the total time or cost for complete eradication at the scale of the respective invasions (Conklin & Smith, 2005; Marks et al., 2017). Most eradication programs require multiple years for completion, making it difficult to evaluate the ecological benefits of removing an invasive macroalgae.

**Principle 3** *Restoration method has a high likelihood of being self-sustaining.*

Total eradication might be possible with early detection, when the invader is in small or isolated areas, and when efficient removal methods are applied. Complete eradication is preferable rather than invasion control because it is likely to be more self-sustaining. To be sustainable, a physical removal method needs to make sure that algal gametes, zoospores, and fragments (for asexually-reproducing forms) are contained so that dispersal to other areas does not occur during removal (example of such recolonizations following removal: *Kappaphycus spp.*, Conklin & Smith, 2005; *Caulerpa taxifolia*, Ivesa et al., 2006; *Sargassum horneri*, Marks et al., 2017).

Monitoring to ensure that recolonization following removal does not take place is also important.

### DISCUSSION

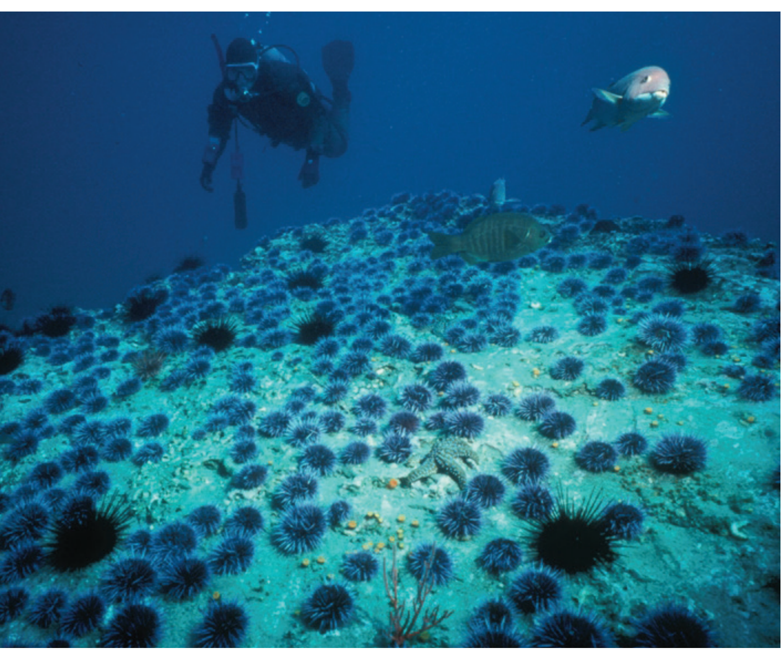
Most studies indicate that eradication of invasive species is almost impossible and always expensive. In a review of 151 studies on the efficacy of invasive species removal (across terrestrial and aquatic habitats), there were 1) positive or mixed effects on ecological recovery for most studies, although 31% of studies lacked ecological recovery, or observed negative effects such as increases in non-target invasive species; 2) ecological recovery was more likely in areas with less anthropogenic disturbance and fewer other invaders; 3) ecological recovery was more likely for animal rather than plant populations and communities; and 4) the likelihood of ecological recovery did not change if invaders were completely removed or strongly suppressed (at least 90% removal) (Prior et al., 2018). In general, examples of eradication successes have occurred when the introduced populations were small and restricted, human and financial resources were available, there was existing knowledge about the ecological characteristics of the invader, and early action was taken. To help gauge success, invasive macroalgae removal projects should consider the following:

- How conspicuous is the invasive species? How easily can it be identified?
- The timing of removal relative to reproduction of the invasive species and relative to environmental conditions.
- The mode of reproduction of the invasive species. Will the method of removal cause spread via dispersal of reproductive parts or can fragmented parts recolonize and asexually reproduce?
- Is the species susceptible to changing ocean conditions (i.e. changing water temperature)?
- What stage is the invasion? What is the spatial scale of the colonization?
- How degraded or 'healthy' is the habitat?

## 5.2 Community enhancement: Urchin removal for kelp-bed restoration

### INTRODUCTION

When disturbances to an ecosystem or habitat occur simultaneously with other changes, such as loss of a foundational species or increases in consumers, it can limit the options for restoration. For example, recent widespread loss of several species of surface canopy-forming giant and bull kelp (*Macrocystis*, *Nereocystis*) and sub-canopy forming kelps (*Pterygophora*, *Laminaria*, *Pluerophycus*) in central and northern California has co-occurred with increases in densities of exposed purple sea urchins (*Strongylocentrotus purpuratus*). Past research strongly suggests that the presence of high densities of sea urchins can prevent or delay recovery of kelp forests (Ling et al., 2015). Two potential methods for ecosystem restoration or enhancement of kelp forests where purple sea urchin densities have increased are 1) to increase the consumer's predator(s) or 2) manually reduce the density of the consumer. Of the potential methods of reducing sea urchin grazing (e.g. increasing urchin predators, manual reductions of sea urchins, etc.), we chose manual reductions for this review, as it is currently receiving much consideration in California.



**Principle 1** *Restoration method has a high likelihood of restoring the integrity of the coastal ecosystem.*

Under the right circumstances, manual reduction of sea urchin densities has a high likelihood of restoring the integrity of kelp forest ecosystems. Where high urchin densities have resulted in overgrazing of kelp ("urchin barrens"), reduction of urchin densities can result in recovery of kelp (Wilson et al., 1979; Ling et al., 2010) along with the species associated with it (Graham, 2004). However, not all instances of kelp decline are driven by overgrazing urchins. Kelp declines can be driven by other factors, such as poor water quality/high turbidity, sedimentation, and oceanographic conditions (Catton et al., 2016; Foster & Schiel, 2010). In these cases, reducing urchin densities may not help a kelp forest to recover. Thus, for each location, the efficacy of sea urchin removal will depend on the causes of kelp decline and whether those causes will persist.

Even in cases where reducing urchin densities can result in kelp recovery, the magnitude of density reduction needs to be determined based on the characteristics of the system. The urchin-dominated system is often considered an alternate stable state, and it is possible that reducing urchins to "normal" densities won't be sufficient to facilitate kelp recovery. In those cases, urchin densities might need to be reduced to much lower-than-normal densities for kelp to recover (Ling et al., 2015).

**Principle 2** *Restoration method has a high likelihood of success at a scale that can provide meaningful ecological benefits.*

For localized kelp bed loss, it is feasible to reduce urchin densities to achieve local restoration that would provide meaningful ecological benefits at that location (Ford & Meux, 2010). If the loss of kelp forest is associated with a localized anthropogenic impact, then reducing urchin densities at that location has a high likelihood of being done at the scale that would provide meaningful ecological benefits.

For kelp bed loss at a regional scale, it would be very difficult to scale up manual removal of urchins to achieve a region-wide restoration of kelp forests. For example, in northern California, where the loss of kelp forests has been coast-wide and the aim may be to facilitate broad scale recovery, manual removal of urchins along the entire coast is not likely due to the amount of effort it would take. However, local removals could be positioned strategically across a region, creating distributed sources of kelp spore production to expedite broad-scale recovery upon regional declines in urchins by natural processes (e.g. disease, storms), providing some regional benefit by having spatially distributed kelp forests. However, to our knowledge, this approach has never been applied.

It is unknown what the minimum area required would be for local urchin reduction and kelp recovery to persist at a scale that is meaningful or beneficial. Recent patch dynamic and metapopulation studies of giant kelp forests (*Macrocystis*) in southern California (Castorani et al., 2015; 2017) and central California (Young et al., 2016) may inform the relationship between the spatial scale of forests and their persistence. Depending on the specific goals of the restoration (i.e. local or regional), there may be a minimum restoration area for those goals to be realized. However, these relationships may differ between the two kelp forest-forming species in California, giant kelp (*Macrocystis*) and bull kelp (*Nereocystis*), given their very different life histories (perennial and annual, respectively).

**Principle 3** *Restoration method has a high likelihood of being self-sustaining.*

In theory, manual reduction of urchin densities has a high likelihood of being self-sustaining. The concept behind this method is that reducing urchin densities to an appropriate level would allow a kelp forest to re-establish and be self-sustaining. In practice, many factors will determine whether manual reduction of urchins is self-sustaining. Although there are suggestions that manual reduction of sea urchins may lead to the return of canopy-forming kelps (Ford & Meux, 2010), there is limited peer-reviewed literature available documenting lasting success in California rocky reef ecosystems. If the kelp forest is not likely to be self-sustaining after the initial reduction of urchin densities and future intervention is likely to be required to maintain the forest, then the frequency and extent of the intervention needed to sustain the kelp needs to be considered.

### DISCUSSION

The likelihood of restoring kelp forests over the long term using manual removal of urchins requires careful consideration of other factors, including:

- *The cause of the kelp loss and increase in sea urchin grazing.* If changes were associated with a short-term natural or anthropogenic perturbation such as an unprecedented storm event, then reestablishment of the forested reef might persist for a prolonged period with little subsequent intervention. If the decline in kelp or increase in sea urchins was caused by a chronic perturbation, such as a change in water quality or reduction in urchin predators, manual reductions in urchins may not result in kelp increases, but even if they do, kelp still might not persist without continual maintenance efforts.

- *Ecological feedbacks needed to maintain the reestablished forest are intact.* For example, there must be sufficient numbers and diversity of sea urchin predators to continue to control the number of sea urchins subsequent to urchin density reduction. With sufficient ecological feedbacks and no chronic perturbations, a restored kelp forest should be as resilient to future perturbations as a natural forest.

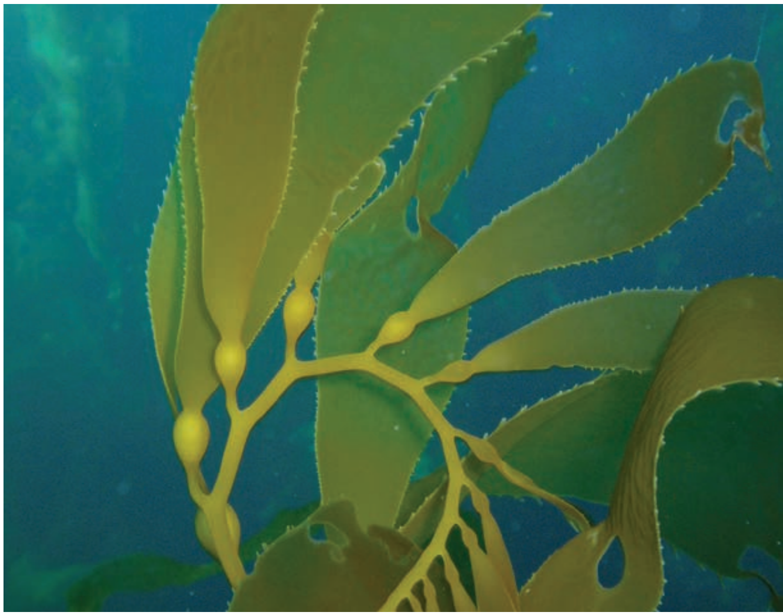
- *Disturbances that may impact the ability of a site to maintain the restoration application.* These might include, but are not limited to, the frequency and magnitude of disturbances, known future disturbances such as nutrient-poor temperature anomalies or storms, changes in water quality, or disturbances that occur before the kelp forest has fully recovered. These types of disturbances may mean that a restoration site is not likely to maintain the effects of urchin removal.

- *Timing of episodes of strong sea urchin recruitment relative to the rate of recovery of a forest.* Once recovered, an intact forest can likely resist subsequent strong episodes of sea urchin recruitment. However, if an episode of strong sea urchin recruitment occurs prior to the recovery of a forest, it could preempt successful reestablishment of a forest. Therefore, the likelihood of an episode of a strong sea urchin recruitment event occurring during the recovery period of a forest should be considered in forecasting the necessary duration of sustained sea urchin removal.

## 5.3 Structural manipulation: Artificial reefs in shallow water

### INTRODUCTION

Structural manipulation refers to creating change in the bottom substrate, for example, the creation of artificial reefs to increase rocky bottom habitat availability or to convert upland areas to coastal estuarine habitat. Artificial reefs are human-made structures that are submerged under the water and can be placed intentionally or unintentionally. Artificial reefs have been placed in the water for a wide variety of purposes, including increasing recreational opportunities such as fishing and diving, enhancing commercial and recreational fisheries, reducing beach erosion, mitigating habitat loss from anthropogenic actions, ecosystem restoration, and research. Here, we will concentrate the discussion on shallow (<30 m) artificial reefs that mimic rocky reef habitat for ecosystem restoration. While there are many examples of artificial reef installation across the globe (Jackson et al., 2004, 2007; Harris, 2006; Bicudo et al., 2008), there are few that have been done for the explicit purpose of ecosystem enhancement.



**Principle 1** *Restoration method has a high likelihood of restoring the integrity of the coastal ecosystem.*

Because artificial reefs are so diverse in terms of purpose, design, construction material, and placement, there is an equally wide diversity of outcomes (Baine, 2001). Many artificial reefs (especially those created a few decades ago when interest in artificial reefs began) were constructed from non-natural materials such as tires, coal ash, sunken ships, oil platform structures, and concrete (Bohnsack et al., 1991). However, while there is still interest in using concrete in reef construction, the deficiencies in reef sustainability or the biological communities occurring on these reefs led to the current focus on natural materials such as rock.

In California, which has a long history of artificial reef construction starting in the 1950s (Carlisle et al., 1964; Turner et al., 1969), a series of artificial reefs were constructed from quarry rock in the 1980s, and the biological communities of these reefs resembled communities on natural reefs (Ambrose, 1987; Ambrose & Swarbrick, 1989). Besides similar community structure, quarry rock reefs in southern California have been shown to support fish growth and production (DeMartini et al., 1989; Johnson et al., 1989). Biological communities on some artificial reefs constructed from concrete have also been shown to be similar to natural reefs (Ambrose & Swarbrick, 1989; Reed et al., 2006).

The most intensively studied artificial reef in the world is the Wheeler North Artificial Reef (WNAR), a 71-ha reef constructed from quarry rock in a low-relief design (i.e., a single layer of rocks ~1 m high). This reef has had benthic algae, invertebrates, and fish assemblages with abundance and species richness similar to nearby natural reefs, as well as similar fish production (Reed et al., 2017).

In addition to construction material, reef design is likely to be an important factor determining the degree to which an artificial reef enhances marine resources. WNAR was designed to mimic nearby low-relief natural reefs and evidence indicates it functions like those natural reefs. It is not clear that designs that differ from natural reef structure will function like natural reefs, so evidence of reef function would need to be provided before it could be concluded that they provide a high likelihood of restoring the integrity of the coastal ecosystem.

After an extensive literature review, Baine (2001) concluded that many of the problems associated with artificial reefs have been related to general planning and management issues. Although artificial reefs constructed of human-made materials or with designs focused on attracting fish cannot be assumed to support reef communities with structure and function similar to natural reefs, artificial reefs that are carefully designed to provide productive habitat have a high likelihood of restoring the integrity of coastal ecosystems (Baine, 2001).

**Principle 2** *Restoration method has a high likelihood of success at a scale that can provide meaningful ecological benefits.*

Artificial reefs can be constructed at a scale that can provide meaningful ecological benefits. For example, the WNAR, at 71 ha, is larger than many natural reefs. However, in order to be done at a meaningful scale, there needs to be enough habitat available for reef creation. For example, assuming the goal is a shallow rocky reef that could support kelp, the target area would be a shallow (8-20 meters depth depending on location and water visibility) sandy habitat with a narrow lens of sand over bedrock (typically the goal is not more than ~.5 - .75 meters of sand over bedrock with appropriate water clarity and sediment movement/scour for kelp establishment).

Note also that any habitat addition to an area results in destruction or, at the least, substantial modification to the pre-existing habitat. It is important to assess what species and processes will be disturbed as a result of reef creation and an assessment of whether the tradeoff is appropriate. This is particularly important for large-scale habitat creation. In areas such as southern California, subtidal rocky reef habitat is much less common than sandy bottom habitat, so replacement of sandy habitat by rocky reef habitat has been judged environmentally beneficial and this is unlikely to change, even with extensive artificial reef construction. However, in other regions, or after extensive construction of artificial reefs, sandy bottom habitat might be judged so valuable that replacement by rocky reef habitat would not be desirable.

**Principle 3** *Restoration method has a high likelihood of being self-sustaining.*

Careful design and placement of an artificial reef will result in a high likelihood of it being self-sustaining, both physically and ecologically. The design and location of the reef must take into account the oceanographic and geomorphological context in which the reef will be placed, paying particular attention to avoid excessive scour or sinking of reef materials. As noted above, construction on a thin layer of sand over bedrock ensures that the artificial reef will not sink below the sand surface. A properly designed and located artificial reef will persist indefinitely if constructed of long-lasting materials such as quarry rock or concrete.

In addition to physical persistence, connectivity to other reefs would ensure that the biological community is sustained. Although isolated artificial reefs can support rich biological communities (Ambrose & Swarbrick, 1989), stronger connections to natural reefs should help artificial reefs recover from disturbances. Thus, placement near other reefs should increase the likelihood that an artificial reef would be self-sustaining.

**DISCUSSION**

Globally, there are a number of examples where the goals of an artificial reef were aligned with ecosystem-level restoration and metrics of success were well defined. In cases where artificial reefs have successfully persisted and met their goals, they went through a thorough planning process followed by ongoing monitoring and management (Baine, 2001). In southern California, the WNAR has demonstrated that a carefully planned artificial reef constructed from quarry rock can persist and provide valuable marine resources comparable to those provided by natural reefs.

To help gauge success, artificial reef projects should consider the following:

- Does reef design match the goals for the reef (e.g., development of an ecological community similar to other reefs in the region)?
- Does the placement of the reef consider the oceanographic and geomorphologic conditions of the area to ensure reef persistence?
- Does the reef location affect socioeconomic or cultural value (e.g., surf breaks, fishing opportunities, accumulation of kelp wrack on beaches, etc.)?
- Are there nearby natural reefs from which propagules or adults can colonize the artificial reef?
- Is the artificial reef robust to changes in ocean conditions (e.g., increased storm activity with climate change)?
- Will the creation of an artificial reef lead to destruction of habitat that outweighs the benefits of the artificial reef?

# 6. Conclusions

Throughout the process for providing scientific guidance we kept the main charge given to us by OPC in mind.

1. **The Policy states that it is the preference that mitigation funds be spent on projects that are within the "geographic region of the facility." However, the Policy does not define that geographic range. What is the "geographic region" specific to the ten power plants that are part of the program?**

**Conclusion:** We defined clear boundaries for the geographic range in Section 2 which can bound the areas where impacts can be assumed to occur based on our current scientific knowledge. As noted previously, we also encourage the State to revisit these boundaries as more advanced models become available in the near-term. These models will help to better understand and refine the area of impact due to their ability to tell us about not just where the organisms were coming from, but also their destination had they not been impinged or entrained by an OTC power plant.

2 **The Policy states that it is the preference that mitigation funds be spent on projects that may lead to "increases in marine life associated with the State's Marine Protected Areas." How do we evaluate if common open coast restoration methods will lead to increases in marine life associated with the State's MPA Network based on currently available scientific evidence?**

**Conclusion:** We provided a scientific definition of "associated with the State's marine protected areas"  and "increases in marine life" in Section 3. These definitions and the geographic scope should be the umbrella with which the framework in Section 4 is applied. We utilized these definitions and the framework in the examples in Section 5 to better illuminate how the State can determine if common open coast restoration methods will lead to increases in marine life associated with the State's MPA Network using best available science. Through applying the framework we were able to refine it and feel confident that it will serve to examine the scientific rigor and likelihood of projects to lead to increases in marine life associated with MPAs.

Lastly, we note that restoration and research in California's marine systems are increasingly important, especially given changing ocean conditions. All restoration and other types of proposals considered should be grounded in science and scientifically rigorous methods of evaluation of responses by the ecosystem. However, many open coast restoration methods and other research are relatively new and others are untested under changing ocean conditions. Because of this, innovative scientific research and development will be a key tool to achieving long-term success in reaching the goals that are outlined in the Policy as well as the MPA's themselves.

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# 8. Appendices

## APPENDIX A:
## Workshop Agenda, March 6, 2018

**OPC-SAT WORKING GROUP: OTC WORKSHOP**

Room 118, Center for
Ocean Health Building,
115 McAllister Way,
Santa Cruz, CA

**WORKSHOP OUTCOMES:**

- **Select model to use for geography question and define next steps**
- **Complete draft framework to evaluate open coast mitigation approaches**
- **Begin process of applying framework to the four mitigation approaches**
- **Decide upon next steps to prepare for report drafting and Webinar #3**

### Agenda:

**9:30-10 am:** Light Breakfast and Chit Chat

**10:00 am:** Welcome and Overview

- Welcome
- Agenda and Outcomes overview
- Short introductions
- State agency thoughts and perspective

**10:30-12 pm:** ETM vs. ROMS as options for evaluating geographic range of impact

**12:00-12:30 pm:** Lunch provided

**12:30-1:30 pm:** Key questions and Framework design discussion

- Key questions
    - *What does it mean to be associated with an MPA?*
    - *What does it mean to increase marine life associated with MPAs?*
- Framework design discussion

**1:30-2:30 pm:** Breakout groups: Applying the draft Framework to an open coast mitigation approach

**2:30-2:40 pm:** Break

**2:40-4:00 pm:** Report out and group discussion about all four open coast mitigation approaches

**4:00-5:00 pm:** Wrap up and Next Steps

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