Out-Of-Kind Mitigation Guidance for Coastal California:
Phase 1 Report

Coastal Mitigation
tools for our next coast

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Preface

Our work herein is the product of a long-term interest in better supporting our resource managers and policy makers seeking to build a more sustainable and just California. This report seeks to build a practical foundation for planning, decision making, and assessment of mitigation efforts across the broad swath of California's expansive coastal zone.

Background: Our Project

Our resource managers are progressively being asked to determine if and when out-of-kind or off-site mitigation is an appropriate management response all while lacking concise, clear guidance for how to do so. The need for clarity and guidance exists across our state but is particularly acute for compensatory mitigation across California's immediate coastal zone where overlapping stressors and resource users concentrate across diverse systems to manifest some of the most contentious and complex stewardship challenges now and over the coming decades.

The California State Science Information Needs Program (SSINP) was funded by a state appropriation to focus directly and exclusively upon supporting California's highest priority marine, coastal, and coastal watershed-related needs for scientific information. Our particular project (**Improved Mitigation Frameworks: Guidance for Improved Restoration Efficacy Across California's Coastal Zone**) was funded by the third and final round of funding designed to support Informing Ocean and Coastal Compensatory Mitigation and Associated Restoration.

Our central goal is to provide an updated conceptualization of what compensatory mitigation could be in the coming decades. We have approached this by exploring priorities, approvals, and assessments outside of traditional jurisdictional or policy boundaries. In particular, we seek to provide a guiding framework for off-site and out-of-kind mitigation. We are working to provide the science needed to undergird informed policy development and evidence-based decision making in a timely and actionable manner.

We are approaching our work via a series of phases with reinforcing goals and distinct groups of experts brought together for each particular phase.

Goal/Phase 1: Establish Compensatory Mitigation Theory
Goal/Phase 2: Provide Discrete Tests Of Theory Via Application Case Studies
Goal/Phase 3: Synthesis, Revision

This report presents the results from Phase 1 of the project.

A Living Document

We hope this document provides rich fodder for discussions within agencies and practitioner groups. That said this is a living document which can and should grow over time as our initial guidance is vetted and adapted to various settings. Comments and feedback are always welcomed.

Executive Summary

Compensatory mitigation efforts aim to heal a damaged ecosystem harmed by an anthropogenic impact. Across California's wider coastal zone such compensatory mitigation efforts have traditionally focused on in-kind and on-site or adjacent-site mitigation. However, as opportunities for these approaches become increasingly limited, resource managers are faced with exploring out-of-kind and off-site mitigation as potential alternatives. This report provides a guiding framework for considering out-of-kind and off-site mitigation to ensure these approaches are implemented effectively and responsibly to maximize ecological benefits.

Out-Of-Kind Mitigation

Out-of-kind compensatory mitigation replaces resources impacted from a permitted impact with a different resource type. For example, using a stream restoration as compensation for impacts to a coastal terrace wetland would constitute an out-of-kind mitigation project. Foundational to a general framework for compensatory mitigation is the proposition that resource losses must be completely balanced by resource gains resulting from the mitigation efforts.

With in-kind mitigation, the quantification is simplified because the resource losses and gains can be measured using the same metric. These are most typically habitat-based metrics (*e.g*. areal extent of kelp canopy), although species-based metrics (*e.g*. number of butterflies) are used when impacts to an individual species need to be mitigated. With out-of-kind mitigation, the resources gained in the wake of the mitigation project are not the same type as the resources originally lost, so determining equivalency (to ensure full compensation) is more complicated. Finding a metric that can be used to measure the seemingly heterogeneous losses and the gains of out-of-kind efforts is difficult. The solution is to find a "common currency" that can be used to measure both the losses and the gains despite the differences in the types of resources. Thus, losses would be converted into some other type of currency, and then that currency used to determine what full compensation would be in a different community or for a different species.

Assessment Components

Two core components form the basis for our common currency framework needed to determine the equivalency between resources originally impacted and resources subsequently created in the context of a candidate out-of-kind mitigation project:

1) Ecological Structure/Function, and
2) Ecosystem Services.

Ecological structure refers to the organization of an ecosystem, including its biotic and abiotic components, while ecological function encompasses the processes and interactions that occur within a given ecosystem, such as energy flow, nutrient cycling, and primary production. Mitigation efforts have traditionally focused on primarily (or, more typically, exclusively) recovering the structure and function of impacted systems.

In recent years, the concept of ecosystem services has emerged as an equally important consideration in recovery planning and assessment. Ecosystem services are the benefits that humans derive from properly functioning ecosystems, usually categorized into four main types: provisioning (*e.g.*, food, water), regulating (*e.g.*, climate regulation, water purification), supporting (*e.g.*, nutrient cycling, soil formation), and cultural (*e.g.*, recreation, aesthetic value) services. These ecosystem services are intrinsically linked to biodiversity and ecosystem dynamics, as the complex interactions between species and their environment support the delivery of these essential benefits to human well-being. They are also inherently dependent upon the human community which is deriving the particular benefits.

This report provides details about each of the two core components, including descriptions of representative elements, metrics, utility, and research needs.

Out-of-Kind Mitigation Framework

As noted above, determining equivalency for out-of-kind mitigation depends on finding a common currency describing both the resources lost due to the impact and the resources gained by the associated mitigation project can be expressed in. The two core components, ecological structure/function and ecosystem services, could form the basis for the common currency. Our proposed out-of-kind framework considers how those components could be combined to determine the appropriate amount of mitigation.

Three different calculation approaches are considered:

1) **Single metric**. If a single metric is used to determine the amount of compensatory mitigation required, the metric could be chosen *a priori* based on relevance, with the amount of mitigation determined by that metric. Alternatively, a number of different metrics could be chosen based on their relevance to the project impacts, with all of them measured individually and the metric that yields the largest amount of degradation from the impact being used to determine the amount of mitigation required. This approach would come closer to ensuring that the mitigation project fully compensated the lost resources. An example of a single metric being used to determine the size of mitigation is the Area of Production Foregone, which is a modeling approach used to estimate the area required to compensate for the impacts to a population caused by, for example, once-through cooling systems for coastal power plants and other water intakes.

2) **Combination of metrics**. If a combination of metrics is used to determine the amount of compensatory mitigation required, an approach could use all possible metrics, or a subset of metrics could be selected. For example, an existing functional assessment method might be used, possibly with only a subset of the metrics being used, or a set of ecosystem services could be assessed. Alternatively, full compensation might be determined based on **both** the functional assessment score and the set of ecosystem services.

3) **Dollar equivalence**. The dollar equivalence approach determines the amount of compensatory mitigation needed based on the cost to restore the damaged habitat to replace lost resources if in-kind mitigation were possible. In many ways, the dollar

equivalence approach is similar to the Natural Resource Damage Assessment (NRDA) at the federal level. A NRDA determines the damages (*i.e.*, dollar amount) for the injuries caused by an accident, and then a panel of experts (the Resource Trustees) decide how to spend that money to restore the injured resources. Although the particular methods used to determine the damages might differ, the idea of using a "pool" of money to support one or more restoration projects is the same.

Any of the calculation options could be used to determine the amount of mitigation needed to fully compensate for lost resources, but the scope of the resources considered in the calculations differ considerably, so the best approach will depend on the agency mandate and desire to be comprehensive.

For an agency that is primarily concerned with one dimension of resource loss, say lost productivity, using a single metric could satisfy the agency's mitigation needs. An example of this might be lost fish productivity due to once-through cooling system intakes. The Area of Production Foregone analysis used by the California water quality boards focuses on fish productivity, and by using that "currency" can calculate how large a wetland mitigation project must be in order to compensate for fish productivity losses. Similarly, an agency with a strong focus on environmental justice might have more focus on ecosystem services, particularly those aspects related to environmental justice. (This could be one metric reflecting environmental justice, though it might also be a suite of metrics.) Those agencies would focus on that aspect, just like a fisheries agency would focus on fisheries.

Although it could be appropriate to focus on only one dimension of resource loss in some circumstances, in general a more comprehensive, multidimensional perspective would be most appropriate. As a general principle, any mitigation project, whether in-kind or out-of-kind, should provide resources (both biological and ecosystem services) that are equivalent to the full suite of lost resources. Since biological resources and ecosystem services are multidimensional, the most appropriate assessment would include a number of important dimensions. Moreover, both ecological functions/structure and ecosystem services would be impacted by most developments, so **both** need to be replaced by the corresponding mitigation project. These two resource dimensions are related but independent, so neither can be replaced solely by the other. For out-of-kind mitigation, there needs to be some effort to quantify the ecological functions/structure and some effort to quantify the ecosystem services.

Although both ecological function/structure and ecosystem services need to be considered in determining equivalency of out-of-kind mitigation, the criteria for establishing equivalency could depend on how similar the resources produced by the mitigation project are to the resources lost by a project. This might be viewed as a sliding scale. For out-of-kind mitigation producing resources that are quite similar to the lost resources, we might assume that the ecosystem services will be quite similar and only a qualitative assessment of ecosystem services would be necessary. (A quantitative assessment of ecological functions/services would still be required.) But as the resources produced by mitigation become more dissimilar to the lost resources, more rigorous assessments will be needed to ensure the services are similar and are provided in a similar amount. For example, a qualitative assessment of ecosystem services might be sufficient for a project that produces a seagrass bed as mitigation for kelp loss, but a more rigorous assessment would be required to a project restoring coastal dunes as mitigation for kelp loss.

In a similar way, a sliding scale might be useful for determining the number of ecological dimensions that need to be included in an assessment of out-of-kind mitigation equivalency. For out-of-kind mitigation that provides resources that are similar to the lost resources, an analysis based on a single metric or a simple index such as the California Rapid Assessment Method (CRAM) might be appropriate. However, as the resources produced by mitigation become more dissimilar to the lost resources, more different components will need to be included in an assessment to ensure that the resources produced by the out-of-kind mitigation project are fully equivalent to the lost resources.

Even though in-kind mitigation might not be possible, we recommend that out-of-kind mitigation generally prioritize projects that produce resources and services that are as similar as possible to the lost resources and services. “Nexus” is an important concept in mitigation policy and it should apply to out-of-kind mitigation, too. One example of this would be mitigation for impacts to a plant alliance that cannot be replaced in-kind; out-of-kind mitigation should prioritize restoration of a plant alliance that is closely related to the impacted alliance. The nexus could also be spatial or related to energy/material flow. For example, impacts to riverine resources (that could not be replaced in-kind) might be mitigated by restoring the estuary into which the river flows.

There might also be a sliding scale for how appropriate out-of-kind mitigation is based on how dissimilar the replacement resources are and how large the magnitude of the impact is. For example, mitigation by a more dissimilar resource might be more acceptable for a small impact, whereas a very large impact might need to be mitigated by replacement resources and services that are more similar to the lost resources and services.

The mitigation framework recommended above addresses the issue of dissimilarity of resources by applying different criteria for establishing equivalency depending on how similar the resources produced by the mitigation project are to the resources lost by a project. However, that framework does not set any limit on how dissimilar the mitigation resources can be. Yet it does seem like some nexus to the lost resources must be maintained for the mitigation to be appropriate. We propose that out-of-kind mitigation should generally occur within the same large ecosystem categories, such as marine, freshwater and terrestrial, as the lost resources. However, there are connections between these large categories so that out-of-kind mitigation might be appropriate in a different category if there is a significant connection to the lost resources. Thus, restoration of a degraded river would provide benefits to an associated estuary, so river restoration would be considered appropriate out-of-kind mitigation for estuary impacts. In addition, the compensatory services should benefit the same community that was served by the impacted resources.

Finally, we note that, just as for in-kind mitigation projects, uncertainty needs to be incorporated into analyses about out-of-kind mitigation projects. Despite the best efforts to design a compensatory mitigation project, there is uncertainty about whether the project will be successful. There is also often a lag between when a development impacts resources and when a mitigation project produces the replacement resources. Agencies have frequently used mitigation ratios to account for uncertainty and time lags (as well as other aspects of compensatory mitigation). The application of the framework for calculating the amount of out-of-kind mitigation needed to compensate fully to an impact could easily incorporate mitigation ratios to account for uncertainty of success or a time lag in the production of replacement resources. Increased mitigation ratios might also be used to accommodate the greater risk to mitigation projects from changing coastal conditions, such as climate change.

Off-site mitigation

When it is feasible and would result in a successful mitigation project, mitigation should occur near the impact site. However, when on-site mitigation is not feasible or off-site mitigation is preferable (as with an in-lieu fee program or mitigation bank), steps can be taken to ensure complete mitigation occurs off site. Most important is the consideration of ecosystem services, which have generally not been considered historically but are more likely to be lost with off-site mitigation. The general approach of applying a sliding scale to determining the amount of mitigation required could also be applied to off-site mitigation, based on how close the mitigation site is to the impact site. As distance increases from the impact site, more quantitative and rigorous analyses of mitigation could be required.

For example, for off-site mitigation producing resources that are quite close to the impact site, we might assume that the ecosystem services will be quite similar and only a qualitative assessment of ecosystem services would be necessary. (A quantitative assessment of ecological functions/services would still be required.) However, as the resources produced by mitigation occur farther away from the impact site, more rigorous assessments would be needed to ensure the services are similar and are provided in a similar amount.

Conclusions and Next Steps

Our proposed framework to guide out-of-kind mitigation is flexible enough to deal with the diverse systems and stressors spanning California's diverse coastal zone. Factoring in both ecological systems and the human communities that benefit from those systems affords a pathway through an otherwise uncertain decision-making process of determining appropriate compensatory mitigation. This framework incorporates a **Compensatory Out-of-kind Mitigation Evaluation Tool (COMET)** that evaluates potential mitigation projects based on multiple criteria, including equivalency/nexus and derived community benefits.

COMET could eventually employ scoring rubrics to more easily standardize how different mitigation options offset impacts and provide value to both ecosystems and human communities. While this tool is too new and untested to currently provide such uniform yardsticks across all coastal settings with which we might hope to compare diverse mitigation proposals under any given setting, COMET still holds promise for regulators and project proponents who currently lack out-of-kind compensatory mitigation solution scaffolding that maximizes ecological and social benefits.

The adaptability of this approach should make it relatively easy to align with extant mitigation approaches in various agencies. It also supports more strategic mitigation site selection and project design to enhance overall coastal resilience in the face of climate change and other diffuse, chronic stressors. In short, the COMET framework represents a promising step towards a more holistic, equitable, and ecologically sound compensatory mitigation decision-making process for California's coastal zone.

Our next steps (Phase 2 of this project) will be to deploy COMET within the context of specific representative ecosystems experiencing a likely type of impact. We will turn towards a suite of the most commonly referenced coastal mitigation challenges from recent decades. We will apply our mitigation guidance to representative coastal zone projects to illustrate how a discrete, compensatory project could be designed and assessed wherein some or all implementation could happen off-site and/or out-of-kind. This phase will produce the most tangible short-term value for state agencies currently dealing with compensatory mitigation challenges.

Although there is a need to develop new tools to assist out-of-kind and off-site mitigation decisions, such as habitat-independent functional assessments, some of the recommendations in this report can be implemented immediately. For example, consideration of ecosystem services can happen now, even though better tools for a quantitative comprehensive assessment may be developed in the future.

Key Terminology

California Rapid Assessment Method (CRAM): A rapid assessment method for monitoring and assessing the ecological conditions of wetlands throughout California. CRAM is designed to evaluate the condition of a wetland based on its landscape setting, hydrology, physical structure and biological structure.

Coastal Zone: Numerous state, federal, international, and academic definitions of the coastal zone exist. Herein we use a general conceptualization of an inclusive coastal zone; the terrestrial region proximate to and directly influenced by the sea and the nearshore oceanic regions proximate to and directly influenced by the land.

Compensatory Mitigation: legal or policy framework for offsetting adverse impacts which remain after all appropriate and practicable efforts to minimize their harm. Achieved by replacing or providing substitute resources or processes.

Ecological Functions: The physical, chemical, and biological processes that occur within ecosystems, such as nutrient cycling, water filtration, and fishery productivity.
Environmental offsets: Measurable actions taken to compensate for or neutralize the harm of an environmental impact.

Ecosystem Services: The benefits humans obtain from ecosystem functions; often organized by provisioning, regulating, cultural, and supporting services.

Ecological Structure: The composition and arrangement of biotic and abiotic elements within an ecosystem, such as species diversity, habitat complexity, and landscape connectivity.

Habitat: The classic definition of a habitat is in reference to the needs of a particular species (e.g. the snake's habitat). Herein we most commonly use the convention of using "habitat" to refer to an ecological community or ecosystem, rather than being defined by the needs of a particular organism.

Habitat Equivalency Analysis (HEA): A method that scales compensatory restoration actions to match the spatial and temporal extent of natural resource injuries. The key concept underlying this approach is that the public can be compensated for past losses of habitat resources through habitat replacement projects providing additional resources of the same type. This idea was first conceptualized by the US Army Corps of Engineers to deal with injuries to aquatic systems.

Hydrogeomophic Approach (HGM): An assessment of the functioning of a wetland's ecosystem via measuring interactions between structural components and the surrounding landscape. Developed by the US Army Corps of Engineers for focal wetland types, since expanded to most freshwater aquatic ecosystems.

In-Lieu Fee Program: A program involving the restoration, establishment, enhancement, and/or preservation of resources through funds paid to a governmental or non-profit natural resources management entity to satisfy compensatory mitigation requirements.

In-Kind Mitigation: Replaces the impacted resource with a resource of an identical or similar structural and functional type.

Natural Resource Damage Assessment (NRDA): The federal process of collecting, compiling, and analyzing information to determine the extent of injuries to natural resources and services in order to ascertain the restoration actions needed to bring injured natural resources and services back to their reference or pre-disturbance condition and thereby make the public whole for interim losses. It is most commonly deployed in the wake of pollutant releases following oil spills, discovery of hazardous waste sites, and vessel groundings.

Nexus: Direct connection or common currency between impacted resource and the proposed recovery response.

No Net Loss: Policy aiming to balance loss of ecosystem extent from an impact economic with reclamation, mitigation, and/or restoration efforts to ensure that the total extent of the system remains constant or increases. This is most commonly deployed to address habitat loss and fragmentation of wetlands.

Off-Site Mitigation: A project implemented at an alternative location that can potentially offer equivalent or greater ecological functioning or ecosystem service provisioning. While recovery projects frequently take place in a location different than then exact impact site, this term in practice is taken to mean a location geographically distant from the impact site in question.

Payment for Ecosystem Services: Direct payments or other incentives offered to farmers or landowners in exchange for managing their landscapes to provide and protect some sort of ecological service into the future.

Mitigation Bank: A permanently protected terrestrial and/or aquatic site conserved and managed for its natural resource values. In exchange for permanently protecting, managing, and monitoring the community, the bank may sell or transfer resources and/or species/habitat credits to permittees/project proponents that need to meet compensatory requirements for the environmental impacts of projects. The banker may be a government, non-profit, or for-profit entity. These are most commonly used to address wetland and riparian impacts.

On-Site Mitigation: A project implemented directly at or very near (“adjacent”) to the impact site.

Out-Of-Kind Mitigation: Replaces the impacted resource with a different resource type.

Stream Quality Index: A method developed for southern California streams that integrates physical, chemical and biological indicators into a unified assessment of stream quality.

1. Introduction

1.1 Our Challenge

California's coastal zone (herein defined as the terrestrial region proximate to and directly influenced by the sea and the nearshore oceanic regions proximate to and directly influenced by the land) harbors a dizzying array of species, communities, and ecosystem functions that in turn provide a wide range of ecosystem services from provisioning to regulating which makes life in California what it is. California's coastal system has been transformed over millennia of human interactions. Despite their remnant diversity, coastal systems are vulnerable to chronic coastal development activities that fragment and destroy habitat (Griggs and Patsch 2019), novel introductions of invasive species (California State Lands Commission 2023) and pollutants (Li and Zhang 2019), overextraction (Karpov et al. 2000), increasingly frequent natural and anthropogenic disasters (Warrick et al. 2022), and the gamut of other synergistic threats of the Anthropocene (Lambrinos, John 2024).

With the emergence of our modern suite of environmental policy tools in the 1970s, we have generally sought to avoid environmental impacts when we can and mitigate any impacts that could not be avoided. Unfortunately, our traditional approaches to mitigating these impacts (*i.e.* habitat restoration), all too often have significant shortcomings. These include too few opportunities for implementation (Zedler 1994), difficulties in achieving success (Turner et al. 2001), high cost (Kimball et al. 2015), and artificial or arbitrary time frames (Grenier et al. 2021). Beyond these challenges for extant, discrete projects, a growing list of significant coastal impacts outside of development have not historically been viewed through a mitigation lens. This is changing. Increasingly, resource managers are seeking to bring these "new" impacts of the Anthropocene and climate crisis (sea level rise, ocean acidification, *etc.*) under a consistent umbrella of management response (Hanak and Moreno 2011) such that we proffer a unified approach to recovery from disturbances broadly writ (California Natural Resources Agency 2022).

1.2 Compensatory Mitigation

This report focuses on compensatory mitigation, where the production of substitute resources is closely tied to resource degradation or outright loss due to a specific project/discrete impact. Compensatory mitigation exists within the overarching suite of environmental offset harm reduction approaches wherein some environmental impact is compensated for by a counterbalancing action. Internationally, carbon offsets (World Bank 2023) might be the best known example of environmental offsets, but interest has also been growing around various other compensatory approaches including biodiversity, water quality, discrete ecosystem (*i.e.* wetland) extent, and ecosystem service offsets (Moore et al. 2023).

Biodiversity offsets have been some of the more popular categories of environmental offset where actions are taken to create biodiversity gains chiefly as compensation for losses caused by development (Bull et al. 2013). Traditional compensatory mitigation in California most commonly can be categorized as a type of biodiversity offset. In the case of compensatory mitigation, the offset is typically legislatively mandated, but voluntary offsetting can also play a role with biodiversity offsets often components enacted as part of voluntary programs. The goal of biodiversity offsetting is to achieve no net loss of biodiversity (viewed through a genetic, species, phylogenetic, or landscape lens). As with compensatory mitigation more generally, biodiversity offsetting is controversial (Maron et al. 2016, Conti and Seele 2024). Popular concern with offsets frequently centers on out-of-kind trading (Corbera and Brown 2010) when like-for-like options are not available (see below). In particular, offsetting of any kind frequently struggles with the perennial problems of determining appropriate metrics for the design (pre-implementation) and assessment (post-implementation) of appropriate offsets.

1.2.1 Mitigation Overview

Environmental mitigation for impacts to coastal organisms or ecosystems is a complex topic embedded in a web of federal and state regulations and laws, social values, and scientific theory and practice. While numerous definitions of “mitigation” are in play, the most widely accepted comes from the U.S. Council on Environmental Quality (*40 CFR § 1508.20 - Mitigation* 2021) wherein mitigation spans five domains (with lower number/rank of alternatives generally preferred over the higher number/ranking in a preferential hierarchy of options):

1. **Avoiding** the impact altogether by not taking a certain action or parts of an action.
2. **Minimizing** impacts by limiting the degree or magnitude of the action and its implementation.
3. **Rectifying** the impact by repairing, rehabilitating, or restoring the affected environment.
4. **Reducing** or eliminating the impact **over time** by preservation and maintenance operations during the life of the action.
5. **Compensating** for the impact by replacing or providing substitute resources or environments.

For the purposes of our work–and indeed much of the practical application of mitigation principles–these domains can effectively be binned into two broad, overarching categories of efforts:

- **Preventing** or reducing impacts, or

- **Compensating** for an impact by replacing or providing resources or systems that substitute for the loss of that impact.

Our study focuses on this second category of mitigation, true *compensatory mitigation*. While prevention is strongly preferred over compensation, and we should always strive to avoid impacts in the first place, the fact remains that we live in a state and world dominated by impacted systems (Rees 2022). California remains the most populous state (home to 39.5 million people as of July 1, 2024; US Census Bureau 2024) with human-dominated landscapes ascendent. Only 24.4% of our terrestrial regions and 16.2% of our coastal waters are durably protected and managed to sustain functional ecosystems via strong conservation structures or statutes (California Nature 2022); simply preventing impact is unrealistic for such an intensely and continually modified system as coastal California.

Mitigation conceptually applies to all ecosystems, but we have the clearest guidance for systems and resources whose functions are protected under specific statute or regulation such as aquatic systems. The specific example of California mitigation illustrates the general pattern with mitigation more broadly; while we have no comprehensive inventory of compensatory mitigation projects enacted across California in any given year, the state sees thousands of property owners each year undertaking projects that impact aquatic resources alone (US Army Corps of Engineers 2024). Mitigation projects in California have previously employed the spectrum of prevention/reduction measures like restoration, establishment, enhancement, or preservation (*e.g.* for wetlands or other aquatic resources, US Environmental Protection Agency 2023) but increasingly are utilizing replacement or substitution approaches. Indeed, many classes of impacts along California's coastal zone (once through cooling impacts, altered hydrology-driven habitat loss, *etc*.) primarily rely upon compensatory mitigation responses via tools such as mitigation banking or in-lieu fee approaches (see section 1.2.5). California broadly follows the same patterns of other regions wherein in-kind mitigation efforts are typically evaluated based on species or habitat comparisons and out-of-kind mitigation applying more amorphous, broader parameters to assessing ecological quality (Burton 2002).

1.2.2 Common Mitigation Categories

In-kind and out-of-kind compensatory mitigation refer to the type of resources used to offset permitted impacts:

- **In-kind compensatory mitigation** replaces the impacted resource with a resource of the identical or similar structural and functional type. For example, if a project impacts a seasonal wetland on a coastal terrace, in-kind mitigation would involve restoring, creating, enhancing, or preserving a coastal terrace pond to compensate for those injuries.

- **Out-of-kind compensatory mitigation** replaces the impacted resource with a different resource type. For example, using a stream restoration project as compensation for impacts to a coastal terrace wetland.

All mitigation requires a connection (nexus) to the impacted resource, but interpretations of nexus for any given setting or project can vary substantially, often depending on a given entity's interests and mandates. We have found a wide range of agency and practitioner perspectives on nexus and therefore what might be appropriate mitigation foci. This diversity is perhaps most evident when defining in-kind vs. out-of-kind efforts. For instance, agencies focused on recovering species of concern (*e.g*., an endangered passerine) may consider reducing egg predators at distant breeding grounds—to boost subsequent fledgling success—as out-of-kind mitigation. However, agencies with broader mandates may view the same intervention as in-kind mitigation.

Table 1. Traditional Compensatory Mitigation Project General Categories

Historic guidance strongly favors in-kind and on-site projects, but projects spanning the range of category combinations have been enacted across California's coastline. Illustrative examples (in blue) are individual mitigation projects funded in the wake of the 2007 *Cosco Busan* Oil Spill (proximate injuries were incurred in/around central San Francisco Bay following the release of 53,569 gallons of fuel oil following a ship collision with the Bay Bridge). Examples drawn from Pawlak (2012).

	On-Site	**Off-Site (but Adjacent)**	**Off-site**
In-Kind	Traditionally preferred mitigation (*e.g.* SF Bay Eelgrass Restoration)	Traditionally accepted mitigation (*e.g.* Farallon Islands bird nest site improvements)	Mitigation bank In-lieu fee program (*e.g.* Tule Lake Grebe habitat enhancement)
Out-Of-Kind	Substitute resources (*e.g.* Torpedo Wharf Safety Improvements)	Substitute resources (*e.g.* Golden Gate National Recreation Area Beach Webcams)	Substitute resources (*e.g.* Stinson Beach Junior Lifeguard Program)

1.2.3 Mitigation Complexity

Mitigation efforts can range from simple to complex in their implementation, depending on the type of function or ecosystem service being replaced or provided as compensation. As we move from simple, discrete efforts (*e.g.* recovering vegetation at a particular density) to more complex undertakings (*e.g.* recovering recreational value of a reef), implementation is more likely to include a blend of in-kind and out-of-kind efforts. Similarly, as our mitigation efforts expand beyond our traditional cornerstones of ecological structures and functions to include recovery of ecosystem services, out-of-kind efforts are more likely to be on our palette of mitigation options being considered. As the number and complexity of the nexuses grow, the likelihood that recovery includes out-of-kind measures grows to almost a certainty in our coastal zone.

1.2.4 Compensatory Mitigation

Compensatory mitigation programs, including out-of-kind measures, present challenges with varying levels of complexity and uncertainty, often lacking clear solutions to achieve intended ecological outcomes (White et al. 2021). However, following the traditional mitigation hierarchy (see above) can significantly enhance biodiversity outcomes (Fargione et al. 2010). Studies have explored the outcomes of restoration projects aimed at compensating for environmental impacts, assessing their success in meeting regulatory objectives and broader mitigation goals (Palmer and Hondula 2014).

While the likelihood of success of compensatory mitigation strategies is a critical concern at all times, it is a particular concern in contexts where we have limited practical mitigation experience, such as subtidal marine ecosystems where the feasibility of mitigation activities for certain species remains limited due to insufficient understanding of their early life stages (*e.g.* Finkelstein et al. 2008). Additionally, managers are increasingly coming to the realization that particular mitigation efforts also need to respond to/counteract more continuous stressors (*e.g.* San Francisco Public Utilities Commission 2018) if they wish a project to succeed and continue to compensate for lost resources over the long-term. Determining the likelihood of success of such long-term climate change mitigation or adaptation projects is a challenge and may have diverse implications (*e.g*. mental health and wellbeing of populations historically left out of impact calculations; Flores et al. 2023).

1.2.5 Compensatory Mitigation in California

Compensatory Mitigation strategies in California aim to address environmental impacts proactively and strategically, at times consolidating future mitigation needs for multiple injuries to achieve better economic and environmental outcomes while meeting conservation goals and regulatory requirements. Compensatory mitigation strategies of California agencies most commonly employ creating, restoring, or preserving ecological communities to compensate for discrete anthropogenic environmental damage. The state has implemented policies that (when fully implemented) prioritize compensatory mitigation projects implemented in advance of impacts to reduce risks and uncertainties inherent in stochastic recovery of often complex systems (Montoya 2021), demonstrating a commitment to conservation efforts that go beyond mere compliance with regulations (agency-independent Regional Conservation Investment Strategies Program, Caltrans' Advance Mitigation Program, *etc*.). Additionally, California's focus on consolidated compensatory mitigation mechanisms like conservation banks and in-lieu fee programs emphasize the importance of landscape-level conservation strategies (e.g. Monterey County Transportation Agency 2021), cost-effective options for offsetting cumulative adverse effects (e.g. Ventura County Planning Commission 2021), and fostering public-private partnerships (DeMarco 2022) to ensure sustainable conservation efforts.

Compensatory mitigation approaches across California's coastal zone have historically been driven by two overarching frames of reference/operational concerns:

- Geographic scale and setting

- Replacement of conspicuous ecological resources

Along the spatial dimension, our focus has been to either conduct mitigation at the same location as the injury or to do so adjacent to the impact site (see Table 1), with a large literature developing to help determine what we mean by "adjacent." Often "adjacent" has emphasized watersheds (Doyle and Shields 2012), littoral cells (Walsh et al. 2016), dispersal distances (Nogales et al. 2024), biogeographic breaks (Blanchette et al. 2008), or other factors which define discrete geographic processes or quantified population-level genetic diversity (Bischoff et al. 2008). A large, related literature/debate emerged in the late 1980s and early 1990s centering on how large in spatial extent any particular project needs to be to recover from the focal injury. Initially poor functional equivalence of coastal wetland mitigation projects with their pre-impact or reference conditions (e.g. Zedler 1994), sparked much of this debate. Exploratory mitigation ratio work (Simenstad and Thom 1996) ultimately evolved into the current practice of setting ratios that determine the amount of compensatory mitigation required to offset impacts to wetlands, stemming from the key observation that functional equivalency of particular dimensions of the ecosystem were not routinely being met and the quantity of mitigation was increased to produce something approaching a net equivalency (*e.g*. if we can only make vegetative assemblages half as dense as in our pre-impact communities, we should set out to restore as area twice as large an area as we originally measured or estimated to recover from the impact). After several decades of use, mitigation ratios now play a foundational role in ensuring that the ecological impacts to wetlands from development are adequately offset through more effective restoration (Coastal Commission Transportation Program Staff 2022). These ratios are determined based on factors such as land- or seascape quality, location, and heterogeneity to achieve no net loss (sensu Gasca 2004; see below) of wetland functions and values, an approach which is used only infrequently outside of wetland systems. In the wake of the popularization of mitigation ratios for wetlands, we now are beginning to see this approach tentatively considered in other ecosystems from grasslands (e.g. US Fish & Wildlife Service 2021) to oak woodlands (e.g. Santa Clara County Planning Office 2011).

Replacement of conspicuous resources is most commonly manifest via projects focused on recovering the habitat or species of concern (in particular threatened or endangered species). Mitigation for impacts often specifies a particular community (e.g. eelgrass for salmonid injuries; NOAA Fisheries 2024) or a population size (e.g. sea otters; US Fish & Wildlife Service 2022) be recovered. This line of thinking seeks to implicitly or explicitly push projects towards a design to achieve no net loss (typically with rare habitats, Bull et al. 2013) or a net gain in ecological function (often when species-driven recovery goals are forefronted, Akçakaya et al. 2020). As with mitigation ratios, the overall goal remains one of crafting post-mitigation conditions of ecological equivalence to those that existed/exist at pre-impact/reference sites in mitigated habitats.

Over the past three decades, compensatory mitigation in California is generally binned into one of three common approaches (with multiple approaches sometimes used for a particular impact):

- **“Traditional” On-Site (or Adjacent) Mitigation**: Involves implementing restoration or enhancement activities directly at (or near to) the location where the impact occurred. This could include habitat restoration, re-vegetation, invasive species control, or other measures that aim to restore or improve the affected ecosystem on-site.

- **In-Lieu Fee Programs**: These programs allow project proponents to pay a fee instead of directly implementing on-site mitigation. The collected fees are then used to fund off-site restoration or conservation projects that provide compensatory benefits equivalent to or greater than the impact caused by the original project.

- **Mitigation Banking**: Involves the restoration, creation, enhancement, or preservation of a habitat or ecosystem in advance of anticipated future impacts. Mitigation banks are set up as credit systems, where developers can purchase credits corresponding to the ecological value of the restored or protected area. These credits can then be used to offset impacts at the site of the development.

1.2.6 Insights from Wetland Compensatory Mitigation

Owing to the U.S. Clean Water Act and subsequent federal policy clarifications providing specific protections for jurisdictional wetlands (those meeting the established criteria), thinking and actions around compensatory mitigation are most developed in the context of wetland ecosystems. Compensatory wetland mitigation programs have slowed the rate of wetland loss in California but mostly not offset losses of ecosystem function (Turner et al. 2001, Ambrose et al.

2007), failing to meet both our stated federal (codified in 1989; Sibbing 2005) and state (codified in 1993; Wilson 1993) no net loss wetlands policy goals. In California, 91% of our wetland extent has been obliterated since 1850 (US Fish & Wildlife Service 2020). Recent compensatory mitigation mandated by the California Coastal Commission (primarily in-kind and on-site) seems to have resulted in a gain of coastal wetland acreage, but that actual net gain appears to be lower than reported and functional equivalency preforms more poorly yet (Alexander 2020). If our in-kind mitigations are failing to hold the line for wetlands, our beaches, reefs, and kelp forests are indeed in trouble under our business as usual approach.

While on-site and in-kind mitigation are generally preferred, the waters have been muddied a bit in recent years in the wake of the so-called 2008 Mitigation Rule issued by the U.S. Army Corp of Engineers and U.S. Environmental Protection Agency. The 2008 Mitigation Rule suggested that under certain conditions off-site mitigation could not only be adequate but even potentially preferable to on-site (US CFR 2021b; 33 CFR § 325 & 332, 40 CFR § 230) efforts. For example, this may be the case when projects occur as part of a larger, more contiguous manipulation and the mitigation is therefore subjected to more rigorous safeguards or assessments or when there is more flexibility where they can be located (Ambrose et al. 2016).

Taken together, the dearth of guidance and assessments for out-of-kind and off-site efforts means any such projects proceed extremely haphazardly. For example, an informal survey of nascent wetland mitigation projects in Ventura County watersheds in mid-2021 found nine (9) projects were then exploring/debating out-of-kind options and/or purchasing credits at a distant mitigation bank (Anderson 2021, unpublished data).

1.3 The Need

A robust compensatory mitigation strategy for our coastal zone should include guidance for all forms of mitigation. Any such guidance should ideally consider:

- **what kind** of mitigation will be done,

- **where** those efforts should occur,

- **how much** mitigation should be required, and

- **what components/metrics** should be utilized for performance evaluation.

Taken together, these decisions provide a framework for guiding principles that could be used to evaluate existing and new approaches to mitigation as well as planning and permitting for future impacts.

2 Out-Of-Kind Mitigation

2.1 General Framework for Out-of-Kind Mitigation Guidance

Foundational to a general framework for compensatory mitigation is the proposition that resource losses must be completely balanced by resource gains resulting from the mitigation efforts. Although compensatory mitigation is not always determined using a quantitative approach, the simplest framework is:

Compensatory Mitigation Axiom: Quantified Losses = Quantified Gains

Note that the gain from a mitigation project could come from an active restoration, for example, or the reduction in a stressor bolstering the resource in question.

With in-kind mitigation, the quantification is simplified because the resource losses and gains can be measured using the same metric. These are most typically habitat-based metrics (*e.g*. areal extent of kelp canopy), although species-based metrics (*e.g*. number of butterflies) are used when impacts to an individual species need to be mitigated. As a simple example, compensation could be based on acres of habitat loss and acres of the same habitat gained. Because the quality (= functioning) of habitats can vary, compensation is often determined based on a habitat functional assessment. For example, using the Hydrogeomorphic (HGM) assessment method, impacts will be fully compensated when the Functional Capacity Units (FCUs) gained in the mitigation project equal the FCUs lost due to the development (Hauer and Smith 1998). With in-kind mitigation, the FCUs of the mitigation and development projects are assumed to be equivalent because the habitats are the same.

With out-of-kind mitigation, the resources gained due to the mitigation project are not the same type as the resources lost, so determining equivalency (to ensure full compensation) is more complicated. Finding a metric that can be used to measure the seemingly heterogeneous losses, and the gains of out-of-kind efforts is difficult. The solution is to find a “common currency” that can be used to measure both the losses and the gains despite the differences in the types of resources. Thus, losses would be converted into some other type of currency, and then that currency used to determine what full compensation would be in a different community or for a different species.

2.1.1 Examples of other relevant approaches

To date, we have most frequently used two distinct management approaches to grapple with mitigating an impact with out-of-kind and off-site mitigation: Payment for Ecosystem Services (PES) and Natural Resource Damage Assessments.

2.1.1.1 Payment for Ecosystem Services

In Payment for Ecosystem Services (PES), the owner of an area that provides certain services is paid money to continue to provide those ecosystem services. PES agreements are typically voluntary and occur when the payer determines that it is useful to pay for particular ecosystem services. PES approaches aim to compensate landowners or providers for managing their land in a way that maintains or enhances the provision of valuable ecosystem services (Jack et al. 2008). The general rationale is that the beneficiaries of any given ecosystem service (*e.g.* water purification, flood control, carbon sequestration) should pay the providers of those services and therefore proponents seek to craft a market-based mechanism to address the “market failure” wherein ecosystem services are not properly valued and–ultimately–degraded. PES programs have grown globally in recent decades (Yan et al. 2022) with over 550 active programs supporting an estimated US$36–42 billion (as of 2018) in annual transactions pre-pandemic (Salzman et al. 2018). That global growth has been driven by motivated buyers, sellers, metrics, and low-transaction-cost institutions, gaining their most traction in water supply, biodiversity support, and forest/land-use carbon sectors.

Valuation of any particular coastal ecosystem services in California is a challenge (Ballard et al. 2016), but typically employs some form of willingness-to-pay and/or avoided cost analysis (Raheem et al. 2009, 2012, Blandon and zu Ermgassen 2014). For example, one study found that coastal wetlands provide \$2,500 acre^{-1} year^{-1} in water purification services alone (Raheem et al. 2009, 2012). PES programs as a whole hope to provide direct financial incentives to stem the loss or degradation of ecosystem services and therefore increase the supply of ecosystem services (Yang et al. 2023).

Some PES programs already being implemented in or explored in coastal California include:

- The Williamson Act (California Department of Conservation 2024) allowing landowners to receive tax breaks for keeping their land in agricultural or open space use, which can provide ecosystem services (Cheatum et al. 2011).

- In the San Francisco Bay Area, a \$12 parcel tax was recently approved by voters to specifically fund conservation and restoration of coastal habitats (Rogers 2016).

- Researchers are working with land managers to develop programs that compensate ranchers for practices that support native biodiversity and other ecosystem services on their lands (O’Connell and Livingston 2011).

While the conservation potential of PES is promising, additional funding or management mechanisms may well be needed to effectively support services such as biodiversity maintenance (Hein et al. 2013, Plantinga et al. 2024). While there are some natural alignments of impact and potential mitigation in these early examples, it is unclear if this will work at scale and across the wider coastal zone.

2.1.1.2 Natural Resources Damage Assessment

Although driven by different legislation and in response to a different kind of environmental impact, a Natural Resource Damage Assessment (NRDA) has a number of similarities with compensatory mitigation. In both cases, the goal is to fully compensate for the loss of natural resources by creating replacement resources. In the case of NRDA, the resource loss is caused by an unexpected impact such as an oil spill. The NRDA process determines the loss relative to a baseline level of resources. The harm, termed "injuries," are translated into the "damages," which is a monetary value to be provided by the responsible party. There are different methods that can be used to determine damages, but the Habitat Equivalency Method is commonly used. The damages are typically determined by a settlement between the Natural Resource Trustees (often helmed by NOAA or CDFW) and the responsible party, although sometimes the damages are determined through court action. Once damages have been determined, the Trustees decide collaboratively on which projects to fund (with the damages money from the responsible party) to restore the injured resources.

One distinction between compensatory mitigation and a NRDA is that restoration projects funded by a NRDA settlement typically are not determined ahead of time, although part of the NRDA process could consider the cost of particular types of restoration efforts, sometimes as an element of determining the appropriate damages. Essentially, a "pool" of money is recovered from the responsible party and a coordinating group (the Trustees) subsequently determines how to allocate that money to a range of different projects in order to restore the injured resources fully. Another contrast between compensatory mitigation and a NRDA is that ecosystem services are often a primary focus in determining damages and selecting the restoration projects.

General NRDA approaches to compensatory mitigation include:

- Habitat Equivalency Analysis (HEA) attempts to compensate for services lost over time from the impacted habitat (Strange et al. 2004, National Oceanic and Atmospheric Administration 2006).

- Resource Equivalency Analysis (REA) employs population modeling and a scaling equivalency (using biological rather than spatial units; Desvousges et al. 2018).

- Habitat-Based Resource Equivalency Method (HaBREM), which integrates elements of REA's with HEA (Baker et al. 2020).

Representative NRDA mitigations implemented across coastal California include:

- intertidal and subtidal estuarine habitat restored as compensation for sediment ecotoxicity (to amphipods) via an HEA in San Pablo Bay following oil refinery wastewater discharge (US EPA 2017)

- restored tidal marsh and upland habitat with abundant pedestrian and bike paths to close a 1.5 mile gap in the San Francisco Bay Trail, alongside public parking, restrooms, picnic facilities, and interpretive exhibits at Richmond's Dotson Family Marsh following oil refinery wastewater discharge (East Bay Regional Parks 2018)

- coastal sage scrub enhancement along the San Diego River in the wake of wildfire-induced expansion of non-native vegetation which had in turn harmed threatened California gnatcatcher (Kershner et al. 2017)

- shorebird foraging habitat restoration via control of non-native cordgrass in San Francisco Bay in the wake of the 1996 *Cape Mohican* oil spill after conducting an REA (Golden Gate National Recreation Area et al. 2008)

- camping and shore-based recreation improvements along the Santa Barbara coast in the wake of the 2015 Plains All American Pipeline oil spill (NOAA 2024)

2.2 Key Components / Ecological Themes for Assessment

The two core components discussed in the following sections form the basis for our common currency framework needed to determine the equivalency between impacted resources and resources created in the context of a candidate out-of-kind mitigation project.

Mitigation efforts have traditionally focused on primarily (or, more typically, exclusively) recovering the structure and function of impacted systems. However, in recent years, the concept of ecosystem services - the benefits that humans derive from healthy, well-functioning ecosystems - has emerged as an equally important consideration in recovery planning and assessment. To effectively design and evaluate the potential success of out-of-kind projects, it is crucial to understand and quantify the interrelated dimensions of these two components: 1) ecological structure and function, and 2) ecosystem services.

During initial discussions with the working groups, we identified five potential components, three of which were judged to be core components. Sub-groups were formed around these three components to explore them in more detail in the context of out-of-kind mitigation. The work group reports are provided in the Appendix to this report. We have combined two of these components, ecological structure and ecological functions, into one core component for this report.

2.2.1 Ecological Structure and Function Components

Ecological structure refers to the physical, biotic and abiotic components of an ecosystem, such as species composition, habitat complexity, and landscape connectivity. Ecological function encompasses the ecological processes that maintain the system. Functions are rates which play out over time and include processes such as nutrient cycling, primary production, and species interactions. While structure and function are clearly related (often intimately) to one another, we treat them separately below for clarity of our thinking around components. We discuss their integration in Section 2.2.1.3.

2.2.1.1 Ecological Structure Component

2.2.1.1.1 Definition-Ecological Structure

Ecological structure is the particular arrangement and organization of both biotic and abiotic elements within an ecosystem. Biotic components include all living organisms, such as plants, animals, fungi, and microorganisms, while abiotic components encompass the non-living physical and chemical aspects of soil, water, air, and climate. These structural components collectively are the physical underpinnings and products of the complex network of interactions and functions that define an ecosystem's character and health.

When applied to mitigation, ecological structure signifies the intentional management and restoration of these fundamental elements to counteract the most conspicuous environmental damage caused by human impacts. It typically involves strategies such as reforestation, wetland restoration, suppression of grazers, and soil rehabilitation to rebuild or preserve key aspects of the system. Commonly stated goals for the structural element management include enhancing biodiversity, setting the stage to facilitate other target ecosystem functions, and increasing resilience against further disturbances.

2.2.1.1.2 Representative Components

Understanding how different components contribute to ecological stability and resilience is crucial for effective mitigation. In this context, trophic complexity, habitat composition, and biodiversity have emerged as particularly significant factors over the past few decades. Each plays a distinct (and possibly central) role in maintaining ecological condition and requires specific focus to guide mitigation efforts.

Trophic Complexity: Refers to the organization and interaction of organisms in a food web (Hui 2012), illustrating the flow of energy and materials through different trophic groups. It is directly linked to the ecological functioning of trophic support and productivity. Trophic complexity was first recognized in coastal California with the lower than expected performance of many wetland mitigation projects in the late 1980's/early 1990's wherein habitat complexity had the knock-on effect of reduced trophic complexity across restored sites post-intervention.

- **Habitat Composition**: This considers the spatial arrangement and distribution of various habitat types across the scale of an entire landscape or seascape. In the context of out-of-kind mitigation, county-wide or regional scales are increasingly seen as crucial for assessing habitat distribution and goal setting for future persistence. An example of using Habitat Composition as guiding principle in the coastal zone is the Southern California Wetland Recovery Project's focus on the historic, current, and future distribution of wetland archetypes over the region spanning Point Conception (Santa Barbara County) to the international border with Mexico (San Diego County, SCWRP 2024).

- **Habitat Complexity**: This encompasses the physical structures and features that provide habitat for organisms. Anthropogenic structures can add to habitat complexity but may induce non-natural functioning, potentially presenting an added mitigation challenge. An example of the primacy of habitat complexity can be seen in various efforts to recover giant kelp reef communities in recent years (e.g. Burdick et al. 2024). The structural complexity added by robust forests of kelp create a completely different physical space relative to non-rocky or non-kelp dominated nearshore reef systems. Mitigation efforts in such management settings often focus on kelp stipe density, surface canopy extent, *etc*.

- **Biodiversity:** Measures the variety of life forms within an ecosystem, often assessed at the species level but also encompassing functional groups. Assessments might need to consider native versus non-native species diversity and contextual factors like urbanization and climate change. This dimension is one of the most widely articulated recovery goals across numerous mitigation projects in the coastal zone over decades. Often this is expressed as a targeted (usually elevated) species richness or species heterogeneity of natives (with the target being a high value) or exotics (with the targeted value being zero or dramatically lower than existing conditions). Examples of diversity-focused mitigation performance metrics include compensatory efforts for seawater movement (intakes which entrap larval assemblages, *etc*.) for routine operation of the San Onofre Nuclear Generating Station (Reed et al. 2023) and Carlsbad (Poseidon Water 2022) desalination facilities.

2.2.1.1.3 Utility

Ecological structure can play an important role in out-of-kind ecological mitigation by providing measurable and consistent metrics that allow for the comparison of different habitats. These metrics, such as species composition, habitat complexity, and physical characteristics, offer a standardized way to evaluate both the impact of development and the success of restoration efforts, even when the habitats involved differ significantly. However, the effectiveness of this approach may vary depending on the specific context, but focusing on structural attributes ensures that mitigation efforts are based on tangible ecological qualities.

In the context of out-of-kind mitigation, this methodology allows for meaningful comparisons between different ecosystems, ensuring that the mitigation delivers equivalent or greater ecological value. While the primary focus of this section is on ecological structure, aligning these metrics with ecosystem services ensures that the mitigation efforts not only restore but potentially enhance the services lost due to development.

2.2.1.1.4 Relevance/Importance

In the context of mitigation, understanding the ecological structure provides a foundation for assessing ecosystem health and functionality. This knowledge aids in the development of management plans and frameworks that prioritize preserving or restoring an ecosystem's structural integrity, ensuring that key ecological functions, such as nutrient cycling, habitat provision, and biodiversity support, are maintained. An accurate understanding of the ecological structure also facilitates decision-making by identifying critical areas for conservation or restoration and determining appropriate mitigation measures.

2.2.1.1.5 Example/Representative Metrics

Metrics for assessing ecological structure are some of the easiest to assess and therefore some of the measures with the longest track record of application in a mitigation context. For example, in salt marsh ecosystems, specific attributes of canopy architecture in intertidal cordgrass (*Spartina foliosa*) marshes have been linked to habitat suitability for the endangered Light-footed Clapper Rail (*Rallus longirostris levipes* Zedler 1993). Habitat assessments typically focus on cordgrass height distributions and density, as these metrics are critical for nesting success. Research suggests that a cordgrass height of >60 cm is necessary for constructing nests that float with the tide, minimizing nest failure due to inundation. Metrics such as the density of stems per square meter and the proportion of stems taller than 60 cm are central to distinguishing between suitable and unsuitable habitats for this endangered bird species. Such detailed canopy metrics provide a robust framework for habitat restoration success in salt marsh ecosystems.

2.2.1.2 Ecological Function Component

2.2.1.2.1 Definition-Ecological Function

Ecological Function encompasses the intricate network of physical, chemical, and biological processes inherent to ecosystems. They are rates and so measured as accumulation, loss, or other changes over time. These functions persist independently of human valuation, manifesting within ecosystems regardless of whether humans attribute value to them or recognize their potential to provide services. Physical functions involve the dynamic movement of energy, water, and nutrients, while chemical functions encompass transformations and interactions of substances vital for ecosystem health. Biological functions encompass the roles of organisms in processes such as pollination, decomposition, and nutrient cycling. While humans may value these functions for the services they provide (see below), such as water purification or climate regulation, their occurrence remains fundamental to ecosystem stability and resilience. Understanding and preserving ecological functioning is central to ecological mitigation efforts, aiming to mitigate the impacts of human activities on ecosystems and sustain their health and functionality over the long term.

2.2.1.2.2 Representative Components

Out-of-kind mitigation that focuses on ecological function involves restoring or creating ecosystem elements that provide similar environmental benefits as those lost to impacts, but not necessarily by restoring the exact same ecosystem type. There is a commonality in many of the variables targeted to evaluate ecosystem functioning, though they may be categorized differently between institutions (Shafer and Yozzo 1998, Fennessy et al. 2004, Blanchette et al. 2008). Here we suggest the useful aggregate ecosystem function categories crafted by the US Army Corps of Engineers and the Environmental Protection Agency:

- **Biogeochemical Functioning**: This category of functions encompasses processes related to the chemical and biological composition of ecosystems. It includes processes such as carbon fixation, denitrification, and contaminant transformation. While these components are most frequently associated with edaphic health and microbial physiologies, they have an immediate impacts across the entire ecosystem.

- **Material Flow Functioning**: This category of functions focuses on the movement and transformation of water and materials. These processes influence water (e.g. groundwater recharge, water availability), earthen material (e.g. soil erosion, sediment transport), and nutrient (e.g. nutrient upwellings, eutrophication) composition and abundance across the region in question.

- **Ecological Functioning**: This category of functions encompasses the capacity of ecosystems to support diverse organisms and assemblages. Popular examples include wildlife connectivity, resistance to invasion by non-native species, and productivity (often measured as biomass or individual accumulation over time). Biodiversity/species support, promoting a diverse range of species within ecosystems.

Inquiry of a system via the framework of these functional components can free investigators to focus on processes rather than the specifics of any one particular habitat type.

2.2.1.2.3 Utility

Ecological functions such as productivity rates, water flows, biodiversity, and connectivity serve as a form of currency to evaluate any potential nexus ecosystem processes. For instance, connectivity can be assessed by gene flow or species reliance on corridors for movement across landscapes. Aquatic resources are often linked to adjacent upland areas, which provide refuge during high flows and future habitat opportunities as sea levels rise.

Fully restoring ecosystems to their original function levels is often impractical, even with in-kind mitigation efforts. Offsite mitigation presents additional challenges due to varying site conditions. As already highlighted, attempts to establish new nesting sites for the light-footed clapper rail in San Diego Bay failed due to inadequate soil conditions for suitable vegetation growth.

2.2.1.2.4 Relevance/Importance

Ecological functions can provide a standardized framework for assessing and comparing different ecosystems' contributions. These functions encompass both biotic and abiotic processes that are fundamental to ecosystem health and resilience. For instance, the essential process of nutrient cycling occurs across various habitats, such as coastal sage scrub and kelp reefs, despite their structural differences. By focusing on ecological functions rather than specific habitat types, we can effectively gauge the relative importance of different ecosystems in supporting vital processes.

In situations where in-kind mitigation options are limited or unavailable, understanding the relative contribution of each ecosystem's functioning becomes essential. This understanding allows us to quantify the ecological value of diverse habitats and determine the appropriate level of out-of-kind mitigation required to compensate for resource losses adequately. By establishing a quantitative basis grounded in ecological functions, decision-makers can make informed choices to mitigate environmental impacts effectively, ensuring the preservation and restoration of ecosystem services across diverse landscapes.

2.2.1.2.5 Example/Representative Metrics

Many functional assessments relevant for mitigation work focus on a single measure. Here, that single dimension of the ecosystem is deemed of key or even overriding importance and so any ensuing assessments rely on this single process. Examples include:

- **Productivity** has been central to estimates of impacts as varied as acute oil spills and chronic power plant intake systems. Such stressors affect the productivity of ecosystem by reducing the populations of key species and altering food webs. Deployments of productivity impact/in mitigation contexts include:
    - Ecosystem productivity measurement: Productivity, often measured as biomass production or energy flow through trophic levels, has been used to estimate ecosystem impacts and determine appropriate mitigation measures (Borja et al. 2010).
    - Oil spill impact assessment: In cases of acute oil spills, productivity losses in affected ecosystems have been calculated to determine the scale of required restoration or compensation (Peterson et al. 2003).
    - Power plant intake systems: For chronic impacts like those from power plant cooling water intakes, reductions in fish and invertebrate populations due to entrainment and impingement have been quantified in terms of lost productivity to inform mitigation requirements (Barnthouse 2013).
    - Food web alterations: Productivity changes across trophic levels have been used to assess how stressors affect entire food webs, not just individual species (Rooney and McCann 2012).
    - Population dynamics: Reduced productivity of key species populations (e.g., decreased reproduction or survival rates) has been used to estimate overall ecosystem impacts (Rose et al. 2001).
    - Habitat Equivalency Analysis: This method often uses productivity metrics to quantify ecosystem service losses and gains when determining appropriate compensatory restoration (Dunford et al. 2004).
    - Restoration scaling: The amount of restoration required is often calculated based on matching the productivity losses from an impact with productivity gains from mitigation actions (Strange et al. 2002).
    - Mitigation banking: Credits for mitigation banks may be partially determined by assessing the productivity potential of restored or created habitats (Bendor 2009).
    - Long-term impact assessment: Productivity measures help in estimating the duration and severity of impacts over time, informing the temporal aspect of mitigation planning (Munns Jr et al. 2009).
    - Cross-ecosystem comparisons: Productivity metrics allow for comparisons between different ecosystem types when determining equivalent mitigation for impacts (Craven et al. 2020).

- **Resilience** refers to the capacity of an ecosystem to absorb existing and/or future disturbances by quickly recovering to their original or reference state. Our California Marine Protected Area (MPA) network and still-evolving 30x30 plan (California Natural Resources Agency 2022) to establish and bolster existing terrestrial and freshwater protected areas should play a crucial role in enhancing resilience by conserving biodiversity and providing ecological baselines. Examples of resilience to guide in mitigation planning or interpretation include:

  - Enhancing coastal wetland resilience: Projects have aimed to increase the ability of estuaries to withstand sea level rise and storm surges by improving sediment accretion rates and vegetation structure (Craft et al. 2009).
  - Promoting reef resilience: Mitigation efforts focus on enhancing subtidal reef resilience have been conceptualized to simultaneously reducing local stressors, increasing genetic diversity, and protecting herbivorous fish populations (Mumby and Steneck 2008) to bolster system-level resilience.
  - Strengthening riverine resilience: Successful restoration of natural flow regimes and connectivity in riparian systems has been defined by boosting a riverway's resilience to hydrological changes and extreme events (Palmer et al. 2009).
  - Bolstering grassland resilience: Mitigation in grassland ecosystems often focuses on maintaining existing species-level diversity and (apparent) functional redundancy to increase resilience to climate variability and predicted/likely land-use changes over the near-term (Isbell et al. 2015).
  - Enhancing urban ecosystem resilience: Mitigation efforts in urban areas involve creating green infrastructure and improving habitat connectivity to enhance the resilience of urban ecosystems to environmental stressors and climate change (McPhearson et al. 2015).

- **Nutrient loading** is a particular material flow with obvious, direct consequences for the ecosystem in question. Measures of nutrient loading have been increasingly utilized in compensatory mitigation efforts in California since the 1970s when excessive loading has been deemed particularly problematic, especailly in aquatic and coastal ecosystems downstream of heavily urbanized or agricultural landscapes. Nutrient measures most commonly focus on quantifying inputs of nitrogen and phosphorus (Howarth and Marino 2006). In wetland and stream restoration projects, nutrient loading assessments have been used to establish baseline conditions and set restoration targets for decades (e.g. Zedler and Callaway 1999). Nutrient loading as a mitigation tool include:
  - San Francisco Bay-Delta nutrients: compensatory mitigation projects have incorporated nutrient reduction goals to offset urban and agricultural runoff impacts (Novick and Senn 2014)
  - SoCal Coastal Lagoons: nutrient loading metrics often are used to gauge mitigation measures aimed at improving water quality and habitat conditions (Sutula et al. 2007).

One disadvantage of functional assessments is that many require intensive, and potentially longer-term, measurements than assessments based on ecological structure.

Single-function assessments could be combined to provide a more comprehensive assessment of ecological functions of a mitigation site. Although this could be done in an *ad hoc* manner based on the functions considered to be most relevant for a particular situation, there have been a number of functional assessments developed to provide a standardized, comprehensive view of site functions. These are mostly developed as relatively quick assessments, and as such they rely on measurements of ecological structure as indicators of ecological function. They are discussed in more detail in the next section (Section 2.2.1.3).

2.2.1.3 Integrating Ecological Structure and Function

To calculate equivalency for out-of-kind mitigation projects, the crosswalk between structural metrics and ecological functions is indispensable. This alignment helps determine if a proposed mitigation effort adequately replaces or enhances the ecological services lost due to development. For instance, a restoration project in one habitat type, such as kelp forests, can be evaluated against the loss in another, like oyster beds, by measuring and comparing the structural aspects that underpin key ecosystem services. This methodology ensures that mitigation projects deliver equivalent or greater ecological value, even if the specific habitat types differ. It is essential for the consistency and effectiveness of out-of-kind mitigation decisions, guiding efforts toward meaningful environmental outcomes.

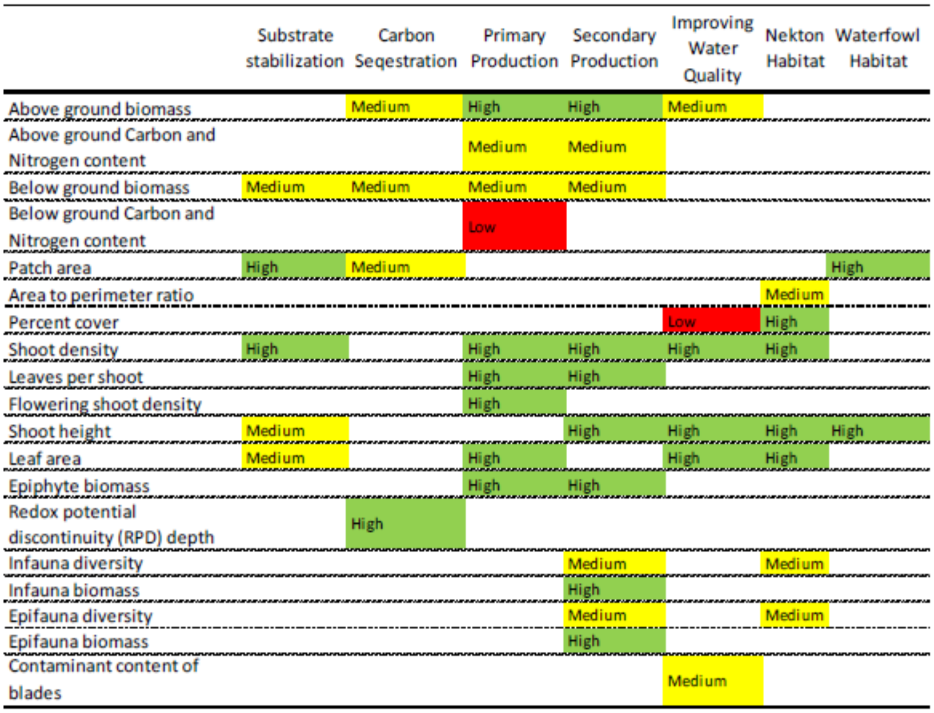
Although structural components are frequently used in planning and assessing mitigation projects, ecosystem structure is often tied directly to key ecological functions and services, facilitating nexus discussions when planning potential mitigation responses. Using Table 1 from McCune, *et al*. (2020, see below) baseline, we can explore a broader range of structural metrics and their association with other component categories (*i.e*. functions).

Key structural metrics which are commonly used in an eelgrass bed assessment include shoot density, shoot length, leaf area, and aerial extent of the bed. These metrics are generally regarded as central for a robust assessment of the health and stability of a given seagrass stand. For instance, shoot density can be closely linked to sediment stabilization and nutrient cycling, providing high strength of linkage (green). Similarly, shoot length and leaf area relate to habitat complexity, which supports a variety of marine life and particularly promotes invertebrate biodiversity. This habitat complexity, in turn, contributes to fish nursery functions and biodiversity enhancement, leading to a high or medium strength of linkage (yellow). Coverage, representing the spatial extent of the seagrass bed, directly influences water filtration and sediment trapping functions, reinforcing its ecological role in water quality maintenance and coastal protection.

One key advantage of structure measures is the potential to hind cast condition. For something such as aerial extent or species richness, archival documents can be used to quantify structural conditions decades (or even centuries) into the past (Shein et al. 2020). While most mitigation may not feel the need to assess conditions in the 1950s, such having such historic legacies opens up the possibility of collecting pre-disturbance data even if a structured, robust monitoring program did not exist at the time of the impact.

While Table 1 provides a solid crosswalk between structural metrics and ecological functions, these examples can be expanded to consider other habitat types, such as salt marshes, mangroves, or coral reefs. Metrics like vegetation type, vertical zonation, and substrate composition in salt marshes can be indicators of flood protection and carbon sequestration. In mangroves, root structure and canopy height could be linked to shoreline stabilization and biodiversity support. By building a comprehensive understanding of these structural-to-function relationships, decision-makers can better design and implement out-of-kind mitigation efforts that restore key ecological services even in different habitat contexts.

Table 1. Example structure-to-function crosswalk for eelgrass (McCune et al. 2020). A matrix illustrating the links of the SAV indicators (vertical axis) to prioritized ecological functions (horizontal axis) for an idealized SAV ecological function monitoring program. The color and the text at the intersections describe the strength of the linkage between indicator and the function as determined by the Technical Advisory Committee, with empty cells indicating no anticipated linkage. Green = a high strength relationship, yellow = medium strength, and red = low strength.



	Substrate stabilization	Carbon Seqestration	Primary Production	Secondary Production	Improving Water Quality	Nekton Habitat	Waterfowl Habitat
Above ground biomass		Medium	High	High	Medium		
Above ground Carbon and Nitrogen content			Medium	Medium			
Below ground biomass	Medium	Medium	Medium	Medium			
Below ground Carbon and Nitrogen content			Low				
Patch area	High	Medium					High
Area to perimeter ratio						Medium	
Percent cover					Low	High	
Shoot density	High		High	High	High	High	
Leaves per shoot			High	High			
Flowering shoot density			High				
Shoot height	Medium			High	High	High	High
Leaf area	Medium		High		High	High	
Epiphyte biomass			High	High			
Redox potential discontinuity (RPD) depth		High					
Infauna diversity				Medium		Medium	
Infauna biomass				High			
Epifauna diversity				Medium		Medium	
Epifauna biomass				High			
Contaminant content of blades					Medium		

Most popularly, various tools and guidebooks have emerged in recent decades to help practitioners assess ecological function by focusing on individual metrics to measure overall ecosystem health. These suite of assessments for terrestrial, aquatic, and wetland systems which seek to characterize the aggregate level of functioning of a particular site, by pulling together a suite of (sub)metrics and then integrating them into an aggregate assessment of the system. The California Rapid Assessment Methodology (CRAM, CRAM Steering Committee n.d.), Hydrogeomorphic (HGM, e.g. Hauer and Smith 1998) Approach, and Southern California Stream Quality Index (SQI, Beck et al. 2019) primarily sample snapshots of ecological structure before integrating these into an overall index interpreting the level of functioning ongoing across the site in question.

- **CRAM** collects structural information on 1) the structure Buffer and Landscape Context, 2) the structure and function of Hydrology, 3) the structure of the Physical Structure (pardon the repetition here), and 4) the structure of the Biological Structure of the system.

- **HGM** guidebooks are often region-specific and assess various ecosystem functions through different structural and functional components. These guidebooks provide specific metrics and Functional Capacity Index (FCI) equations to estimate ecosystem functioning for the respective community. Commonly assessed functions and their related (sub)metrics include 1) Hydrogeomorphic (via tidal surge attenuation, sediment deposition, and Organic Carbon exchange), and 2) Habitat Functions (via maintenance of community composition, nekton utilization, and potential wildlife habitat).

- **SQI** was designed to systematically integrate abiotic and biotic indicators using a stressor-response empirical model to quantify the expected likelihood that chemical and physical stressors will degrade biological condition, indicating that internal system functioning cannot resist the pressures from the impact.

All of these methods combine indicators that represent a range of different community aspects into an integrated assessment. The indicators are structural aspects of the assessed community. Their explicit links to ecological functions varies; HGM very explicitly developed indicators to have a clear link to functions, as reflected in the use of the term “Functional Capacity Index,” whereas CRAM and SQI are considered assessments of biological condition rather than explicitly ecological functions.

2.2.1.4 Research Needs

The main hurdle for assessing ecological function is that we rarely observe or measure functions in the field, which would entail detailed studies or experimentation. Instead, we observe indicators or biotic or abiotic features or attributes that are correlated with underlying processes occurring at the assessed site. Furthermore, the relationship between an indicator or set of indicators and an underlying function is often not well understood; in fact, in many cases, it is not linear. Current functional assessments, such as HGM, CRAM and SQI, have tackled to challenge of using indicators as proxies for ecological functions, but many habitat types lack a similar type of assessment method.

In out-of-kind mitigation cases, the functions assessed at a mitigation site are often different in type and degree relative to functions at the impact site. For example, floodplain storage at an impact site with a low-order/headwater stream at the top of a watershed would typically be less than a mitigation site located in a high-order stream with well-developed floodplains closer to the outlet of the watershed. As an example of starkly different marine habitat types, tidal surge attenuation and vascular plant communities occurring at a salt marsh impact site would not occur in open tidal water areas. Both habitats, of course, perform functions, but the functions each provides and the degree of performance differ. From strictly a functional assessment perspective, a highly functioning tidal water can be considered equivalent to a highly functioning salt marsh site. The challenge is to develop a method to assess these functional differences in a way that can show their equivalence. Because current functional assessment methods are designed to be applied to only one habitat type, new approaches must be developed to incorporate habitat-independent measures of function and structure.

2.2.2 Ecosystem Services Component

2.2.2.1 Definition

Ecosystem services are the essential benefits that humans derive from the ecological structures and functions of natural environments (Millennium Ecosystem Assessment 2005). These services encompass a wide range of tangible and intangible advantages that are critical for supporting and enhancing human wellbeing. Ecosystem services are the benefits humans derive from well-functioning ecological structures and functioning which we would have to otherwise craft for ourselves were they to be degraded or eliminated. Ecosystem services include the provisioning of vital resources such as food, freshwater, timber, and medicines. They also regulate important environmental processes which create the stable world in which humans have thrived for millennia, such as climate regulation, water purification, pollination of crops, flood control, and disease dynamics. Moreover, ecosystems provide spiritual, cultural, and recreational benefits that enrich our lives and connect us to the natural world and each other.

The term "ecosystem services" is often poorly articulated or vaguely defined (Schröter et al. 2021), leading to ambiguity in both application and interpretation (La Notte et al. 2017). Seppelt et al. (2011) suggested a robust characterization and praxis of ecosystem services should include:

- articulation of biophysical data and models grounded in ecological realism;
- consideration of local trade-offs;
- recognition of off-site effects; and
- comprehensive–but critical–involvement of stakeholders throughout assessment studies.

Our conceptualization herein adheres to these facets and dovetails well with our concept of a robust approach towards out-of-kind mitigation.

2.2.2.2 Diverse Benefits Provided by Ecosystems

Ecosystem services include the provision of vital resources such as food, freshwater, timber, and medicines. They also modulate important environmental processes like climate regulation, water purification, pollination of crops, flood control, and disease dynamics. Moreover, ecosystems provide spiritual, cultural, and recreational benefits that enrich our lives and connect us to the natural world.

Ecosystem services encompass a wide array of diverse benefits that nature provides to humanity, spanning multiple, interconnected categories. These include:

- **Provisioning services** supply essential resources directly consumed for human survival and essential economic activities. These include food production from agricultural lands and fisheries, drinkable freshwater from rivers and aquifers, timber and other structural fibers from forests, and medicinal compounds derived from plants and microorganisms. For instance, compounds isolated from approximately 50,000-70,000 plant species are used across both traditional and modern medicine worldwide (Schippmann et al. 2002) and insect pollination often underpins cultivation, with an estimated 75% of global crops depending on animal pollination (Bartomeus et al. 2014).

- **Regulating services** maintain environmental stability and mitigate hazards. For example, climate regulation via carbon sequestration by forests and oceans helps moderate global temperatures (Griscom et al. 2017), intact wetlands and soil microorganism assemblages remove contaminants and improves water quality (Wang et al. 2022), flood control afforded by intact floodplains and mangroves reduce the impact of extreme weather events (Narayan et al. 2016), and predator-prey relationships often mediate potential disease outbreaks and thereby limit the spread of pathogens (Renzi et al. 2022).

- **Cultural services** provide non-material benefits that contribute to human well-being and societal development (Yang and Cao 2022). These include spiritual fulfillment derived from sacred natural sites, cultural identity tied to traditional landscapes, educational opportunities through nature-based learning, and recreational experiences in parks and wilderness areas. For example, studies have shown that exposure to nature can reduce stress, improve cognitive function, and enhance overall mental health (Jimenez et al. 2021).

- **Supporting services** directly and indirectly underpin all other ecosystem services by maintaining fundamental ecological processes. These include nutrient cycling, soil formation, and primary production, which are essential for long-term ecosystem functioning.

2.2.2.3 The Importance of Recognizing Ecosystem Services

Often, the value of ecosystem services is overlooked until they become threatened or significantly degraded (Holzman 2012). However, these services play a crucial role in sustaining human societies and economies. Recognizing, quantifying, and appropriately valuing ecosystem services is essential for informed decision-making, sustainable development, and effective natural resource management.

As human activities continue to impact the natural world, the need to understand, protect, and restore ecosystem services has become increasingly urgent. Maintaining the integrity and resilience of ecosystems is vital for ensuring the long-term provision of the services that are fundamental to human health, prosperity, and quality of life.

2.2.2.4 Importance of Community

The synergetic relationship between community engagement and ecological mitigation cannot be overstated, as ecosystem services are inherently defined by the human communities that interact with them. For example, the value of a stable, large population of nearshore fish will be much higher to a local community of subsistence fisherfolk than that identical population offshore of a large private island serving as the summer home of occasional residential family. Similarly, the recreational value of an easily accessible beach in urbanized San Diego is much higher than the identical beach located along California’s lost coast. Given that services are a derived value, how that human community interacts any benefits in question are central to any such quantification.

Involving local communities not only ensures a deeper understanding of how more comprehensive understanding of how ecosystems contribute to human well-being but also highlights how these services are shaped by and directly benefit those communities. This shared responsibility fosters a sense of ownership and commitment, making project success more likely and sustainable. Recognizing and respecting the knowledge and perspectives of local communities in decision-making processes is crucial, as ecosystem services should not be divorced from the people they serve. Ultimately, the importance of community involvement extends beyond conventional ecological considerations, representing a more inclusive and collaborative approach to environmental conservation.

2.2.2.5 Representative Components

Here we highlight representative components for four different categories of ecosystem services; provisioning, regulating, cultural, and supporting services.

Provisioning is a vital ecosystem service with many goods and resources that benefit humanity. These tangible benefits are essential in sustaining society and supporting various economic activities because many provisions are sold in the market.

Here are some examples of provisioning ecosystem services:

- ○ *Food:* Ecosystems are the primary source of food production, supplying various crops, livestock, and fisheries. Traditional and modern agriculture heavily relies on the fertile soils, water availability, and climatic conditions provided by ecosystems to cultivate crops and raise livestock.
- ○ *Raw Materials:* Ecosystems are abundant reservoirs of raw materials used in various industries. Forests, for instance, provide timber and non-timber products like latex, resins, and gums, which are fundamental to the construction, manufacturing, and pharmaceutical sectors.
- ○ *Fresh Water:* Ecosystems are critical in regulating the water cycle, ensuring a continuous fresh water supply. Rivers, lakes, and aquifers sourced from natural ecosystems fulfill communities' water needs for drinking, irrigation, and industrial purposes.
- ○ *Medicinal Resources:* Many medicines are derived from plant and animal species found in ecosystems. Indigenous communities, for centuries, have relied on traditional knowledge of medicinal plants, and modern pharmaceutical industries continue to explore natural sources for potential drug development.
- ○ *Wood and Fiber:* Forest trees provide wood for construction, furniture, and paper products. Additionally, plant fibers, such as cotton and jute, sourced from ecosystems, are used in the textile industry.
- ○ *Fuel:* Biomass from forests and other ecosystems is a fuel source for cooking, heating, and electricity generation, especially in rural and resource-limited regions.

Regulating is an ecosystem service that involves the natural processes that help maintain and balance the environment, ensuring the continuous provision of various ecosystem services. These regulatory services play an essential role in safeguarding the health and stability of ecosystems and contribute significantly to human well-being.

Here are some examples of regulating ecosystem services:

- *Air Quality:* Ecosystems, particularly forests, play a pivotal role in regulating air quality by absorbing pollutants and releasing oxygen through photosynthesis. Trees and vegetation act as natural filters, mitigating air pollution and enhancing the overall air quality in their surroundings.
- *Carbon Sequestration and Storage:* Forests, wetlands, and other ecosystems serve as carbon sinks, sequestering and storing carbon dioxide from the atmosphere. This process helps mitigate climate change by reducing the concentration of greenhouse gasses in the atmosphere.
- *Wastewater Treatment:* Wetlands and aquatic ecosystems have a natural ability to treat and purify wastewater. Through a combination of physical, chemical, and biological processes, these ecosystems remove pollutants and nutrients from the water, making it safe for human consumption or release back into water bodies.
- *Erosion Prevention:* Vegetation, such as grasslands and forests, prevents soil erosion. Plant roots bind the soil, reducing erosion caused by wind and water and maintaining soil fertility for agriculture and other land uses.
- *Pollination:* Ecosystems, particularly pollinator habitats like bee colonies, butterflies, and birds, facilitate the pollination of plants. This process is essential for reproducing many flowering plants, including crops, ensuring the continuation of food production.
- *Biological Control:* Natural predators and beneficial organisms in ecosystems help control pest populations, reducing the need for chemical pesticides in agriculture. This ecological balance promotes sustainable and resilient agricultural practices.
- *Regulation of Water Flow:* Wetlands and forests act as natural buffers against flooding by absorbing excess water during heavy rainfall and slowly releasing it, thus regulating water flow in river systems and reducing the risk of flood events.

Supporting ecosystem services provide the foundation for life on Earth by offering habitats and maintaining biodiversity for plants, animals, and microorganisms. These services include essential ecological functions like soil formation, nutrient cycling, and the regulation of ecological processes that enable ecosystems to thrive.

Here are some examples of supporting ecosystem services:

- *Habitat*: Ecosystems provide living spaces for plants and animals. Habitats range from forests and grasslands to coral reefs and deep-sea vents, each supporting unique communities of organisms.
- *Biodiversity*: High biodiversity enhances ecosystem resilience/homeostasis and adaptability to environmental changes.
- *Photosynthesis*: Primary productivity by plants, algae, and cyanobacteria produces oxygen and removes carbon dioxide from the atmosphere, playing a crucial role in both climate regulation and energy provisioning for most life on earth.
- *Nutrient Cycling*: Ecosystems facilitate the movement and recycling of nutrients through biological, chemical, and geological processes. This cycling ensures that

essential elements like carbon, nitrogen, and phosphorus are available for organisms to use and reuse.

- *Water Cycle*: Ecosystems play a vital role in the movement and storage of water through evaporation, precipitation, and runoff. Forests, wetlands, and other ecosystems help regulate water availability and maintain water quality.
- *Soil*: Healthy ecosystems contribute to soil formation and maintenance. Soil provides a medium for plant growth, filters water, and hosts a diverse community of microorganisms essential for nutrient cycling.

Cultural ecosystem services are non-material benefits that people obtain from ecosystems through recreation, aesthetic experiences, spiritual enrichment, and cultural identity. These services enhance well-being by fostering a connection to nature and supporting practices like education, tourism, and heritage conservation.

Here are some examples of cultural ecosystem services:

- *Recreation*: Ecosystems provide spaces for an array of outdoor activities from hiking and camping to wildlife photography and surfing. These recreational opportunities not only offer enjoyment but also foster a deeper connection with nature, promoting environmental stewardship.
- *Mental Health*: Exposure to natural environments reduce stress, anxiety, and depression. Even brief interactions with nature, such as a short walk on the beach, can improve mood and cognitive function.
- *Physical Health*: Intact, natural landscapes and shorelines encourage physical activity and exercise, contributing to overall health and fitness. Green spaces in more urbanized areas have been linked to lower rates of obesity, cardiovascular disease, and other improved health outcomes.
- *Tourism*: Natural land- and seascapes populated with abundant, diverse species attract visitors and in turn support local and regional economies through ecotourism. This form of tourism can also promote conservation efforts when managed sustainably, creating one of the clearest positive feedback loops between economic benefits and environmental protection.
- *Artistic Inspiration*: Nature is perhaps the oldest source of inspiration for artists, writers, and musicians. The beauty and complexity of ecosystems continue to influence creative expression across various media, from landscape paintings and nature-inspired poetry to contemplative music and jewelry crafted from the shells of invertebrates.
- *Spiritual Experience*: Many find spiritual fulfillment and a sense of connection to something greater than themselves when immersed in nature. Sacred natural sites and landscapes often hold deep cultural and religious significance for communities around the world.

2.2.2.6 Utility

The approaches to valuing ecosystem services are traditionally driven by the rationale behind the valuation, such as a site restoration or cost-benefit analysis. When undertaking restoration projects, the valuation of ecosystem services becomes instrumental in assessing the overall benefits obtained from natural processes. Ecosystem services, including provisioning, regulating, cultural, and supporting services, are quantified and integrated into cost-benefit analyses to evaluate the ecological, social, and economic impacts of mitigation efforts. This approach ensures that restoration strategies not only address specific site damages but also contribute to broader understanding of the value of intact ecosystems. By identifying ecosystem services, and incorporating valuations when possible, into the decision-making process, stakeholders can make informed choices that prioritize sustainable practices. This approach allows stakeholders to maximize the long-term benefits of ecological mitigation while considering the diverse values ecosystems provide.

2.2.2.7 Relevance/Importance

Ecosystem services play a crucial role in assessing ecological impacts for out-of-kind mitigation planning and decision-making due to their direct relevance and importance in maintaining ecological integrity and human well-being. These services, encompassing provisioning, regulating, cultural, and supporting functions, serve as the foundation upon which human societies rely for sustenance, health, and economic prosperity. When assessing ecological impacts, understanding the potential effects on ecosystem services provides valuable insights into the broader implications of proposed actions.

By considering ecosystem services in mitigation planning and decision-making, stakeholders can accurately evaluate the trade-offs involved in various courses of action. This comprehensive approach ensures that mitigation strategies not only address immediate ecological concerns but also safeguard the benefits that ecosystems provide to society. Furthermore, recognizing the importance of ecosystem services fosters a more holistic understanding of the interconnectedness between human activities and the natural environment, guiding sustainable development practices that prioritize the conservation and enhancement of these vital services for present and future generations.

2.2.2.8 Example/Representative Metrics

The examples provided discuss various ecosystem services and how they are measured and valued, both monetarily and non-monetarily, with specific examples related to out-of-kind ecological mitigation.

Supporting Service - Habitat:

- What: Habitat service supports biodiversity and ecosystem function.
- Measurement: Quantitative methods include biodiversity assessments, while qualitative methods involve stakeholder interviews.
- Beneficiaries: Beneficiaries include wildlife, ecosystems, and humans who depend on biodiversity for resources and services.

Supporting Service - Fisheries/Food Production:

- What: This service provides food resources through fisheries.
- Measurement: It can be measured monetarily through market value assessments and non-monetarily through ecological surveys.

- Beneficiaries: Beneficiaries include commercial fisheries, coastal communities, and consumers who rely on seafood.

Regulating Service - Erosion Protection:

- What: Ecosystems protect against erosion, benefiting landscapes and communities.
- Measurement: Methods include cost comparisons with artificial infrastructure and property value assessments.
- Beneficiaries: Beneficiaries include coastal communities, agriculture, biodiversity, and infrastructure.

Cultural Service - Recreation:

- What: Recreation in natural areas provides physical, mental, and social benefits.
- Measurement: Methods include visitor surveys, market valuation, and health indicators.
- Beneficiaries: Beneficiaries include individuals, families, communities, tourism industries, and future generations.

Overall, these ecosystem services play critical roles in supporting human well-being and environmental sustainability, and their measurement helps inform decision-making for conservation and management efforts.

2.2.2.9 Research Needs

Incorporating ecosystem services into out-of-kind mitigation assessments, planning, and decision-making processes requires addressing several critical research needs and hurdles. Firstly, there's a pressing need to establish a robust understanding of the interconnections and dependencies between different ecosystems and their associated services. This requires comprehensive research to identify the complex relationships and feedback loops between habitats or ecosystem services that are being mitigated for and those that may be impacted indirectly. Developing a broad understanding of these ecological linkages is essential for effective decision-making and ensuring that mitigation efforts do not inadvertently harm other critical ecosystems or services.

Additionally, there's a need to develop methodologies for quantifying and valuing ecosystem services across various spatial and temporal scales. This involves not only assessing the direct benefits provided by specific habitats but also considering the broader implications for ecosystem functioning and the services they support. Integrating these diverse perspectives into mitigation assessments requires interdisciplinary research and the development of standardized tools and metrics that can account for the multifaceted nature of ecosystem services. For ecological functions and structure, resource managers have found it useful to use comprehensive assessments that integrate a wide range of different attributes into a simple index, and a considerable amount of effort has been devoted to developing and testing these assessment methods. No similar assessment exists for ecosystem services, though it would likely be useful to evaluating equivalency in out-of-kind mitigation efforts.

Finally, fostering collaboration and communication among stakeholders is crucial for establishing a "nexus" between different habitats or services and ensuring that mitigation efforts are coordinated and aligned with broader conservation goals. Building consensus among stakeholders and promoting transparency in decision-making processes are essential for achieving sustainable outcomes and maximizing the effectiveness of ecological mitigation efforts.

2.3 Application of the Out-of-Kind Mitigation Framework

As discussed in Section 2.1, determining equivalency for out-of-kind mitigation depends on finding a common currency the resources lost by a project and the resources gained by associated mitigation project can both be expressed in. The components discussed in the previous sections could form the basis for the common currency. This section considers general approaches for how those components could be combined to determine the appropriate amount of mitigation.

Note that there are many different approaches to quantifying ecosystem attributes for market-based conservation (Chiavacci and Pindilli 2022). Details of some of these methods could be useful for the calculation approaches described below.

2.3.1 Calculation approaches

2.3.1.1 Single metric

If a single metric is used to determine the amount of compensatory mitigation required, the metric could be chosen *a priori* based on relevance, with the amount of mitigation determined by that metric. Alternatively, a number of different metrics could be chosen based on their relevance to the project impacts, with all of them measured and the metric that gives the largest amount of mitigation being used to determine the amount of mitigation required. This approach would come closer to ensuring that the mitigation project fully compensated to the lost resources.

The following are examples of single metrics:

Lost fish productivity = Gain in fish productivity

Lost recreational opportunities = Gain in recreational opportunities

In these examples, one of these metrics might be chosen *a priori* because it is relevant to the type of project or an agency’s mandate. Alternatively, if both were measured but one, say lost recreational opportunities, would yield a larger mitigation project, that metric could be used to determine the size of the mitigation project, since this would be most protective of the resources.

An example of a single metric being used to determine the size of mitigation is the Area of Production Foregone, which is a modeling approach used to estimate the area required to compensate for the impacts to a population caused by, for example, once-through cooling systems for coastal power plants and other water intakes. This method adapts the concept of Production Foregone due to the entrainment and impingement of fish in a water intake (Rago 1984, Jensen et al. 1988) to consider the area of a habitat that would be required to produce that amount of fish. This approach has been used to determine the amount of habitat needed to be replaced to compensate for once-through cooling impacts and is the basis for California's fee-based approach for once-through use of seawater (Raimondi 2011; see also Raimondi 2013).

2.3.1.2 Combination of metrics

If a combination of metrics is used to determine the amount of compensatory mitigation required, an approach could use all possible metrics, or a subset of metrics could be selected.

The following are examples of combinations of metrics:

Reduction in CRAM score = Increase in CRAM score

Lost set of ecosystem services = Gain in the set of ecosystem services

CRAM has a wide range of uses, including evaluating the general condition of wetlands for assessment of wetland status and trends as well as assessing wetland restoration and mitigation projects. CRAM has been used to evaluate wetland compensatory mitigation projects in California (Ambrose et al. 2006).

Even within each of the preceding examples, only a subset of the metrics might be used. For example, only some of the CRAM attributes might be assessed, or only a few ecosystem services might be measured. By its nature, it would be easy to combine CRAM components into a modified index. There is no equivalent structure for combining ecosystem service components.

Alternatively, full compensation might be determined based on BOTH the CRAM score and the set of ecosystem services.

Note that existing assessment methods, such as CRAM, are designed for a particular habitat type and would not be suitable for application beyond that habitat type. CRAM is designed for wetlands, so it could be applied in different kinds of wetlands, which could be considered out of kind, but it would not be suitable for a non-wetland habitat, such as rocky intertidal or dune system. In this example, CRAM is useful as an example of how different ecological components could be combined, but actually implementing this idea in disparate habitats would require the development of an assessment method that incorporated metrics that could be measured in a habitat-independent way.

2.3.1.3 Dollar equivalence

The dollar equivalence approach determines the amount of compensatory mitigation needed based on the cost to restore the damaged habitat to replace lost resources if in-kind mitigation was possible. Thus:

Cost to restore the damaged habitat to replace the lost resources = Use this amount to fund related out-of-kind habitat restoration project

Dollar value of lost ecosystem services	=	Creation of ecosystem services worth the value of the lost services

When applied to habitat restoration, the dollar equivalence approach is the same as the Habitat Replacement Cost (HRC) assessment (Strange et al. 2004, Steinbeck et al. 2007). HRC estimates the cost of restoring habitat to the level necessary to offset resource losses through natural production (Strange et al. 2004).

In many ways, the dollar equivalence approach is similar to a Natural Resource Damage Assessment (NRDA). An NRDA determines the damages (*i.e.*, dollar amount) for the injuries caused by an accident, and then the Resource Trustees decide how to spend that money to restore the injured resources. Although the methods used to determine the damages might differ, the idea of using a "pool" of money to support one or more restoration projects is the same. In an NRDA, the restored resources should be the same as the injured resources, although in practice there is some flexibility about how that similarity is achieved. With an explicit out-of-kind compensatory mitigation project, there would be no expectation that the restored resource would be the same as the lost resources.

One advantage of the dollar equivalence approach is that there is no need to calculate the losses and gains in a common ecological currency; dollars would be the common currency. Although there would be no ecological measure of the amount of resources produced, equivalence would be assumed to occur when all of the money collected for (1) the lost resources is spent on a habitat restoration project(s), or (2) the lost ecosystem services is spent on an ecosystem services project(s). As with the combination of metrics approach, full compensation might be determined based on BOTH the lost resources and the lost ecosystem services.

Determining the cost to restore the damaged habitat to replace the lost resources could be problematic. In an actual habitat restoration project, initial estimates of cost are often unrealistically low; it isn't until the restoration project is planned in detail that more realistic cost estimates can be made. However, a detailed restoration plan is very time-consuming and expensive to produce - which would be especially challenging for a project that wasn't actually going to be completed. Some effort would need to be made to ensure a realistic restoration cost estimate with only minimal planning cost; this might be accomplished in part by using past experiences with restoration projects to adjust the initial cost estimate.

Similarly, estimating the dollar value of lost ecosystem services would be problematic. There are many different ideas about how to put a dollar value to ecosystem services but there is no generally accepted approach. Despite this impediment, economists could provide a value for lost ecosystem services. Over time, a more generally accepted approach for valuing ecosystem services might be developed for adoption by the State or individual agencies.

2.3.2 Uncertainty

2.3.2.1 Uncertainty and time lags

Despite the best efforts to design a compensatory mitigation project, there is uncertainty about whether the project will be successful. For example, many assessments of wetland mitigation projects find that they have failed to produce an ecologically successful project (Sudol and Ambrose 2002, Ambrose et al. 2006, etc.).

In addition to uncertainty about the success of a mitigation project, there is often a lag between when a development impacts resources and when a mitigation project produces the replacement resources. This time lag is explicitly accounted for in NRDA calculations but is rarely incorporated explicitly into compensatory mitigation calculations. Ideally, there would be no lag between impacts and producing replacement resources, and that might be the case for impacts that are mitigated using an established mitigation bank or in-lieu fee program. However, for most permittee-responsible mitigation projects and for projects using a newly established mitigation bank or in-lieu fee program, there will be a delay in the production of replacement resources.

Agencies have frequently used mitigation ratios to account for uncertainty and time lags (as well as other aspects of compensatory mitigation). A mitigation ratio is essentially a multiplier, where Y amount of resource lost (most simply expressed as area) is replaced by X times Y amount of mitigation. Mitigation ratios are commonly 4:1 but could be 10:1 or higher.

The application of the framework for calculating the amount of out-of-kind mitigation needed to compensate fully to an impact could easily incorporate mitigation ratios to account for uncertainty of success or a time lag in the production of replacement resources.

One problem with mitigation ratios is that they rarely are explicit about their basis. That is, there is rarely an explicit explanation for how much of the ratio is based on uncertainty of success, how much is based on time lag, and how much is based on other factors. The application of mitigation ratios, for both in-kind and out-of-kind mitigation, would be improved by having a more explicit and quantitative basis.

2.3.2.2 The Changing Coast

Past mitigation decisions have mostly ignored our climate and biodiversity extinction crises. However, we now realize that as these the changing conditions across our coastal zone are likely to influence mitigation projects (in-kind and out-of-kind alike) during the lifetime of those projects. Thus, decisions about the amount of mitigation required for full compensation should incorporate projection of changes expected due to climate change.

The probable unpredictability of the coast in the coming decades makes it difficult to plan and implement effective restoration strategies, as the injuries that a particular restoration projects is designed to address may rapidly and unexpectedly worsen (perhaps with a local pollinator collapse or excessive desiccation levels). We have seen this scenario play out most recently with our recent multi-year drought. In coastal grasslands and woodlands, traditional restoration plans, and husbandry techniques were no match for the intense drying experienced by woody planting (Anderson, personal observation). Numerous sites in Santa Barbara, Ventura, and Los Angeles Counties had well over 2/3 mortality of even hardy oak species with some sites effectively seeing complete survivorship failure of planted individuals. Most of these projects were mitigation for housing and other municipal development projects.

These projected changes due to climate change or changed community composition will necessarily be uncertain. Adapting restoration strategies to accommodate shifting conditions will almost certainly require additional resources and innovative approaches involving multi-benefit solutions that can increase resilience in the face of a wider range of impacts. The state's leaning into its "30 x 30" land use goal to protect (the potentially to restore) more ecosystems is partly a response to this. More broadly, these conditions might mean that we need to accept greater risk as we embark down a particular mitigation pathway. That greater risk might be accommodated by employing mitigation ratio that is greater than 1:1, for example.

Regardless, pulling ecosystem services more explicitly into our assessment criteria might afford novel mitigation paths which have not been considered or which might bolster the probability of success of more traditional ecological restoration-style responses to injury.

2.3.3 Recommendations

Any of the calculation options could be used to determine the amount of mitigation needed to fully compensate for lost resources, but the scope of the resources considered in the calculations differ considerably, so the best approach will depend on the agency mandate and desire to be comprehensive.

For an agency that is primarily concerned with one dimension of resource loss, say lost productivity, using a single metric could satisfy the agency's mitigation needs. An example of this might be lost fish productivity due to once-through cooling system intakes. The Area of Production Foregone analysis used by the California water quality boards focuses on fish productivity, and by using that "currency" can calculate how large a wetland mitigation project must be in order to compensate for fish productivity losses. Similarly, an agency with a strong focus on environmental justice might have more focus on ecosystem services, particularly those aspects related to environmental justice. (This might be one metric reflecting environmental justice or a suite of metrics.) Those agencies would focus on that aspect, just like a fisheries agency would focus on fisheries.

Although it could be appropriate to focus on only one dimension of resource loss in some circumstances, in general a more comprehensive, multidimensional perspective would be most appropriate. As a general principle any mitigation project, whether in-kind or out-of-kind, should provide resources (biological and ecosystem services) that are equivalent to the full suite of lost resources. Since biological resources and ecosystem services are multidimensional, the most appropriate assessment would include a number of important dimensions. Moreover, both ecological functions/structure and ecosystem services would be impacted by most developments, so **both** need to be replaced by the corresponding mitigation project. These two resource dimensions are related but independent, so neither can be replaced solely by the other. For example, biological impacts cannot be mitigated by ecosystem services projects alone, and vice versa. For out-of-kind mitigation, there needs to be some effort to quantify the ecological functions/structure and some effort to quantify the ecosystem services.

Although both ecological function/structure and ecosystem services need to be considered in determining equivalency of out-of-kind mitigation, the criteria for establishing equivalency could depend on how similar the resources produced by the mitigation project are to the resources lost by a project. This might be viewed as a sliding scale. For out-of-kind mitigation producing resources that are quite similar to the lost resources, we might assume that the ecosystem services will be quite similar and only a qualitative assessment of ecosystem services would be necessary. (A quantitative assessment of ecological functions/services would still be required.) But as the resources produced by mitigation become more dissimilar to the lost resources, more rigorous assessments will be needed to ensure the services are similar and are provided in a similar amount. For example, a qualitative assessment of ecosystem services might be sufficient for a project that produces a seagrass bed as mitigation for kelp loss, but a more rigorous, quantitative assessment would be required to a project restoring coastal dunes as mitigation for kelp loss.

In a similar way, a sliding scale might be useful for determining the number of ecological dimensions that need to be included in an assessment of out-of-kind mitigation equivalency. For out-of-kind mitigation that provides resources that are similar to the lost resources, an analysis based on a single metric or a simple index such as CRAM might be appropriate. However, as the resources produced by mitigation become more dissimilar to the lost resources, more different components will need to be included in an assessment to ensure that the resources produced by the out-of-kind mitigation project are fully equivalent to the lost resources.

Even though in-kind mitigation might not be possible, we recommend that out-of-kind mitigation generally prioritize projects that produce resources and services that are as similar as possible to the lost resources and services. “Nexus” is an important concept in mitigation policy, and it should apply to out-of-kind mitigation, too. One example of this would be mitigation for impacts to a plant alliance that cannot be replaced in-kind; out-of-kind mitigation should prioritize restoration of a plant alliance that is closely related to the impacted alliance. The nexus could also be spatial or related to energy/material flow. For example, impacts to riverine resources (that could not be replaced in-kind) might be mitigated by restoring the estuary into which the river flows.

There might also be a sliding scale for how appropriate out-of-kind mitigation is based on how dissimilar the replacement resources are and how large the magnitude of the impact is. For example, mitigation by a more dissimilar resource might be more acceptable for a small impact, whereas a very large impact might need to be mitigated by replacement resources and services that are more similar to the lost resources and services.

2.3.4 Out-of-Kind Mitigation Domain

By definition, out-of-kind mitigation creates different resources to compensate for resource losses. But how different can the mitigation be and still be considered appropriate? In general, there is little legal or regulatory support for “very out-of-kind” forms of mitigation, such as funding for education or research (McKenney and Kiesecker 2010). However, determining how “out-of-kind” something is can be complicated. For example, is it appropriate to create soccer fields (thus creating a recreational opportunity) as mitigation for lost fishing opportunities when a kelp forest is destroyed? From the perspective of ecological functions, it is clear that a soccer field does not provide the same ecological functions as a kelp forest. On the other hand, from the perspective of recreational ecosystem services, the soccer field provides recreational opportunities (*i.e.*, playing soccer) that might be considered compensation for the recreational opportunities (*i.e.*, fishing) lost when the kelp forest is destroyed. One question, then, is whether it is appropriate to mitigate lost fishing opportunities by increasing soccer opportunities. Although both are recreation, they encompass different communities.

The mitigation framework recommended above addresses the issue of dissimilarity of resources by applying different criteria for establishing equivalency depending on how similar the resources produced by the mitigation project are to the resources lost by a project. However, that framework does not set any limit on how dissimilar the mitigation resources can be. Yet it does seem like some nexus to the lost resources must be maintained for the mitigation to be appropriate. In this section, we provide some guidance about the domain for appropriate mitigation.

Out-of-kind mitigation should generally occur within the same large ecosystem categories, such as marine, freshwater and terrestrial, as the lost resources. However, there are connections between these large categories so that out-of-kind mitigation might be appropriate in a different category if there is a significant connection to the lost resources. Thus, restoration of a degraded river would provide benefits to an associated estuary, so river restoration would be considered appropriate out-of-kind mitigation for estuary impacts.

We also need to consider the ecosystem services provided, and in particular the specific community benefitting from the services. In general, the compensatory services should benefit the same community that was served by the impacted resources. In the hypothetical example given in the first paragraph, even if a soccer field and a kelp forest both provide recreational opportunities, the community benefitting from the soccer field is different from the community benefitting from the kelp forest, so the soccer field would not be appropriate out-of-kind mitigation for the lost kelp forest ecosystem services.

3 Off-Site Mitigation

3.1 General Themes of Off-Site Mitigation

Off-site mitigation aims to provide compensatory mitigation at alternative locations that can potentially offer equivalent (if not potentially greater) ecological functioning or ecosystem service provisioning while adhering to regulatory requirements, policy priorities, and emphasizing all the typical monitoring and verification of outcomes.

While it is possible to restore a system in the same exact location where in the injury occurred, this is rarely an option. For an unplanned, discrete impact (*e.g.* chemical spill, wildfire-induced mudslide) it often is possible to mitigate on-site. Temporary impacts from projects also can often be mitigated on site. However, the vast majority of impacts we commonly encounter across the coastal zone are more permanent in nature (*e.g.* freeway widening, infrastructure installation) and so it is rarely possible to recover the system in the same exact location. The general philosophy has been to strongly prefer the mitigation occur adjacent to the impact. “Near” in this context is often defined by a particular ecological (*e.g.* routine dispersal distance) or biogeochemical process (*e.g.* watershed) directly impacting the site of injury. So while the vast majority of mitigations are not technically on-site, in effect they are often very near spatially. As such and for clarity in our report, “off-site” herein refer to mitigation that is beyond the typical adjacent (farther than “near”) siting.

We note that siting mitigation projects off-site has particular negative connotations in the regulatory community (but see below for a different perspective from the 2008 Mitigation Rule), often causing concern that the ecological process may be lost from the impact site. As with out-of-kind mitigation, off-site mitigation may be a necessity, even if it is not the preferred option, given the increasing constraints of locations where mitigation can occur.

3.2 Prioritization of Off-Site Mitigation in an Historical Context

Historically, on-site compensatory mitigation was prioritized over off-site mitigation. This prioritization was consistent with the general philosophy of replacing lost resources with resources that were as similar as possible to the losses. On-site mitigation ensures that the spatial distribution of natural resources and ecological processes remain the same. One example of an ecological function with a spatial component is connectivity.

Spatial proximity is likely to be even more important for ecosystem services, where the community that benefits from the lost ecosystem services would be likely to benefit from replacement ecosystem services.

In contrast to this historical prioritization, the 2008 Mitigation Rule prioritizes off-site mitigation over on-site mitigation. This is not based on a preference for off-site replacement of resources but rather a consequence of preferring third-party mitigation such as mitigation banks and in-lieu fee programs over permittee-responsible mitigation. The 2008 Mitigation Rule bases the preference for third-party mitigation on many studies showing the poor performance of permittee-responsible mitigation.

Even though the 2008 Mitigation Rule has an extensive discussion about ecosystem services, it does not consider the consequences of off-site mitigation for the delivery of ecosystem services. In many cases, services lost due to a development project would not be replaced by a habitat restoration at an off-site location. For example, a mitigation bank (a preferred mitigation approach in the 2008 Mitigation Rule due to the perceived likelihood of increased mitigation success) might be established in the upper reaches of a watershed, where land is more available/less expensive and ecological functions might be easier to establish. Mitigation of the impacts to an urban stream in the lower watershed might preferably occur in the upper-watershed mitigation bank according to the 2008 Mitigation Rule priorities, and the ecological structures/functions of the impacted stream could be replaced there. However, the ecosystem services provided by the urbanized stream, such as water quality improvement and recreational opportunities, would not be replaced by using the mitigation bank because the upper watershed likely would not have impaired water quality and the community near the urbanized stream could not easily recreate in the upper watershed. Thus, replacement of lost ecosystem services is particularly important for off-site mitigation and should be an explicit analysis when planning off-site mitigation.

3.3 Recommendations

When it is feasible and would result in a successful mitigation project, mitigation should occur near the impact site. However, when on-site mitigation is not feasible or on balance off-site mitigation is preferable (as with an in-lieu fee program or mitigation bank), then some steps can be taken to ensure complete mitigation occurs off site. Most important is the consideration of ecosystem services, which have generally not been considered historically but are more likely to be lost with off-site mitigation.

This needs to take place with clear attention to ecosystem services. Such services are crucial when evaluating mitigation options, to ensure that the mitigation strategy ultimately selected maintains or enhances both overall ecological value and benefits to local communities. Off-site mitigation could be preferable when such an effort provides greater ecosystem services than on-site options. For example, off-site mitigation might allow for the restoration of larger, more contiguous habitats that offer enhanced watershed-level water quality improvements, better support wildlife corridors alongside recreational trail networks, or provide greater long-term resilience from wildfire impacts to neighborhoods and croplands.

By carefully considering ecosystem services in the mitigation planning process, we can maximize the ecological and societal benefits of mitigation efforts, ensuring that the chosen approach not only compensates for immediate impacts but also contributes to broader landscape-scale conservation goals

The general approach described in Section 2.3.3 of applying a sliding scale to determining the amount of mitigation required could similarly be applied to off-site mitigation, based on how close the mitigation site is to the impact site. As distance increases from the impact site, more quantitative and rigorous analyses of mitigation could be required.

For example, for off-site mitigation producing resources that are quite close to the impact site, we might assume that the ecosystem services will be quite similar and only a qualitative assessment of ecosystem services would be necessary. (A quantitative assessment of ecological functions/services would still be required.) But as the resources produced by mitigation occur farther away from the impact site, more rigorous assessments would be needed to ensure the services are similar and are provided in a similar amount.

4 Conclusions

We are at something of an inflection point in our thinking about how California can craft a more broadly resilient coastal zone and specifically evolve our approach towards compensatory mitigation efforts. This inflection point is emerging as a consequence of both constraints and opportunities. Our tightening constraints were forged by historic development and management choices across our State’s coastal zone. Those mounting local hinderances have been further intensified by our broader, society-wide priorities and resource decisions across our state and nation over the past century. Together these local and distant factors are conspiring to limit our traditional options in space. The “easy” mitigation options and targets are dwindling fast. Alongside these ever-narrowing traditional mitigation options, new frames of reference and appreciation for additional perspectives have arrived in the form of the rising prominence of ecosystem services (a dimension historically deprioritized or explicitly ignored within most traditional coastal management approaches) across agencies and resource managers more broadly.

Our proposed approach towards out-of-kind compensatory mitigation is an outgrowth of our recognition of these twin sea changes and our effort to be more explicit in grappling with coastal zones in the future.

4.1 Framework for the Future

Our proposed framework to guide out-of-kind mitigation is flexible enough to deal with the diverse systems and stressors spanning California's diverse coastal zone. Factoring in both ecological systems and the human communities that benefit from those systems affords a pathway through an otherwise uncertain decision-making process of determining appropriate compensatory mitigation. This framework is building towards a nascent **Compensatory Out-of-kind Mitigation Evaluation Tool (COMET)** that evaluates potential mitigation projects based on multiple criteria, including equivalency/nexus and derived community benefits.

COMET could eventually employ scoring rubrics to more easily standardize how different mitigation options offset impacts and provide value to both ecosystems and human communities alike. While this nascent tool is too new and untested to currently provide any such uniform yardsticks across all coastal settings with which we might hope to compare diverse mitigation proposals under any given setting, COMET still holds promise for regulators and project proponents who currently lack out-of-kind compensatory mitigation solution scaffolding that maximizes ecological and social benefits.

The adaptability of this approach should make it relatively easy to align with extant mitigation approaches in various agencies. It also supports more strategic mitigation site selection and project design to enhance overall coastal resilience in the face of climate change and other diffuse, chronic stressors. In short, the COMET framework represents a promising step towards a more holistic, equitable, and ecologically sound compensatory mitigation decision-making process for California's coastal zone.

4.2 Out-Of-Kind: New Tool Needing Refinement

COMET centers on encouraging practitioners and the management community to proactively explore out-of-kind ecological restoration approaches when appropriate, rather than waiting until they are forced into it due to site- or impact-specific constraints. The rationale behind beginning to experiment with this tool now include:

1. Fewer Options: The limited current extent of remnant coastal ecosystems (e.g. coastal marsh, eelgrass beds) and the projected major decline in abundance of others (e.g. sandy

beaches, mudflats) paired with the continued popularity of this limited real estate for homes, farms, and other uses which convert these land- and seascapes to human-dominated systems set the stage for limited options. Scenarios wherein out-of-kind mitigations are the only or best options are only likely to become more frequent as **traditional in-kind opportunities become more limited** along our crowded, fragmented, and stressed coast.

2. Explicitness: Much mitigation policy has relied on a mix of explicit and implicit assumptions about how systems function and the most effective way to modify that functioning. As we begin treading a relatively untested pathway, being **explicit about our assumptions** about how the natural world works and our the methodologies we deploy to manage those workings is both necessary intellectually and a best practice to educate newcomers about these still-evolving tool sets.

3. Test Drives: It is better to pilot methodologies before jumping in as this allows for the identification of potential challenges, the refinement of approaches based on real-world feedback, and the optimization of resources, ultimately leading to more effective and sustainable project implementation. Piloting out-of-kind project frameworks now will allow for lessons learned and **best practices to be developed before widespread adoption is necessary**, rather than going into it with untested tools.

4. Refinement: Phased, experimental approaches allow for **adaptive management and learning**, adjusting methodologies accordingly in subsequent phases. Complex ecosystems and human perception/use of them often respond unpredictably (and sometimes uniquely) to interventions. Monitoring system performance over limited spatial and temporal scales is a wise and cost-effective investment before scaling up effort. Such informed refinement is also a central ask of organizations and practitioners skeptical of out-of-kind approaches on principal.

5. Habitat-Independent Assessments: Develop habitat-independent assessment methods that can **quantify and compare ecosystem services across different ecosystems**. This quantification in likely to be context (and possibly metric) dependent. And while more traditional ecological measures remain important, a focus on ecosystem services is a key research need to enable more robust out-of-kind evaluations. Traditional compensatory mitigation often relies on habitat-specific assessment methods. While these are of great value and utility, their exclusive use can make it challenging to compare the ecological value of different habitat types in the context of a given human community. Developing habitat-independent assessment methods would allow for more practical (and possibly more accurate) comparisons of ecosystem services across those diverse ecosystems, facilitating better decision-making under a range of out-of-kind mitigation scenarios. That said, we acknowledge that incorporating new assessment methods into existing regulatory frameworks will require careful consideration and potential policy adjustments. Such approaches also likely necessitate engagement beyond the typical ecologists, chemists, and environmental engineers that routinely engage with pre- and post- implementation assessments. That wider net is likely include (as a starter) economists, sociologists, and policy experts as those comprehensive assessment methodologies are developed and vetted in detail.

6. CRAM-like Multifactorial Assessment Tool. Our ultimate tool which can aid **tradeoff and optimization decisions** does not yet exit. Key elements of such a multidimensional tool will be 1) the capacity to deal with ecosystem services alongside more traditional ecological dimensions of a system being evaluated and 2) the ability to crosswalk apparent disparate facets of the system. Exploring a swath of factors rather that a single aspect (*e.g*. a single ecosystem services) of the system, is necessary to fully capture the value and tradeoffs of different mitigation options. As such, this tool will employ a "sliding scale" approach that weighs the degree of difference between the impacted and mitigated site against the ability to maintain key ecosystem services. The sliding scale approach within COMET would allow for nuanced evaluations that recognize the inherent trade-offs in out-of-kind mitigation while prioritizing the maintenance of critical ecosystem services and as well as ecological rarity, *etc*. This approach may help ensure that mitigation efforts result in the best possible outcomes for both ecological integrity and human well-being.

In essence, we are encouraging a proactive and controlled exploration of out-of-kind mitigation leveraging pilot projects and a phased approach to gain valuable experience and develop standardized approaches. This is a preferable alternative to being forced into out-of-kind mitigation without prior knowledge or established best practices.

4.3 Proper Context for Out-Of-Kind Mitigation

While agencies have traditionally avoided out-of-kind and off-site mitigation efforts due to concerns about potential negative impacts and aggregate degradation or outright loss of ecological functions (*e.g*. Loss Aversion), there are numerous instances where such approaches could be beneficial for our coastal systems and resources even if existing constraints didn't exist. Key elements for any effective out-of-kind ecological restoration effort include:

7. Foregrounding Ecosystem Services: Evaluating and prioritizing the maintenance or enhancement of **ecosystem services should be a core consideration of out-of-kind mitigation** decisions and take its place alongside more traditional ecological considerations (biodiversity, invasive species management, ecological functioning, *etc*.). Historically rarely considered in compensatory mitigation project implementation, considering ecosystem services going forward should provide a more holistic view of the ecological and societal impacts of mitigation choices. Ecosystem services may often resonate more with the public and decision-makers, given they directly relate to human well-being. Explicitly incorporating ecosystem services into our mitigation work can help better prioritize environmental justice goals and are more likely to produce projects that meet broader community and economic objectives alongside ecosystem improvements.

8. No One-Size-Fits-All Solution: The COMET framework acknowledges that there is **no universal approach suitable for all ecosystems and situations** in every instance. The framework's flexibility allows it to be adapted to various regulatory contexts, ecological conditions, and community needs. By avoiding a rigid, standardized approach, COMET enables practitioners to consider local ecological dynamics, socio-economic factors, and specific restoration goals when designing, implementing, and assessing mitigation

projects. This adaptability ensures that the framework can be effectively applied across different scales, from small local projects to large regional initiatives, while still maintaining scientific rigor and consistency in evaluation methodologies.

9. Agency Mandates and Priorities Are Not Universal: Some agencies may prioritize specific aspects of our coastal ecosystems (*e.g*. U.S. Fish and Wildlife potentially emphasizing single species of concern), while others may have broader mandates (*e.g*. California Coastal Commission's goals of enhancing both ecosystem functioning and public access) necessitating a more comprehensive approach. **Each agency must internalize these guidelines** and develop or adapt policies tailored to their specific mandates and contexts.

10. Limited In-Kind Restoration Potential: In certain (increasingly common) cases and locations, **opportunities for in-kind mitigation may be seriously constrained**, and by strictly adhering to in-kind approaches, agencies may fail to achieve the best possible outcomes for ecological resources coast-wide. Some heavily degraded coastal areas may now have limited potential for in-kind restoration due to (effectively) irreversible changes in hydrology, soil composition, shifted species ranges, or other factors.

11. Controlled Out-of-Kind Approach: While historical examples of poorly executed out-of-kind mitigation projects certainly exist, our proposed framework aims to establish guidelines and safeguards to ensure that such efforts are undertaken responsibly and effectively. Out-of-kind efforts may achieve **equivalent or greater ecological lift** than traditional in-kind efforts and have the potential to improve ecosystem resilience, address landscape-level conservation goals, and enhance ecosystem services.

12. Balanced Perspective: For clarity, our recommendation is **not to indiscriminately pursue out-of-kind mitigation by default**, but rather to recognize that there may be situations where it could be the most appropriate course of action for maximizing ecological benefits, provided it is implemented within a well-defined and controlled framework. Our thinking on out-of-kind approaches emphasizes the need for agencies and practitioners to carefully evaluate the trade-offs and potential opportunities associated with out-of-kind ecological restoration, while explicitly and repeatedly acknowledging the complexities and challenges involved. A balanced and context-specific approach, guided by our proposed COMET framework, could help make better informed decisions that prioritize the long-term health and sustainability of coastal zone resources.

4.4 Off-Site Mitigation

Off-site mitigation is already a common dimension of compensatory mitigation through the use of in-lieu fee programs and mitigation banks. While geographic awareness is inherent in most (if not all) of our compensatory mitigation work, implemented projects frequently extend well beyond the oft-touted "local" or "immediately impacted" area. These are most commonly represented by stated project goals or explicit interest in working within a given littoral cell or watershed. "How far away is *too* far away?" is a common refrain amongst practitioners. These concerns are most acute around ecosystem services and functions wherein the impacted human community should receive benefits from the compensatory mitigation project. As we move farther away (farther off-site), ecosystem services become a greater concern as we work towards accounting for the full suite of impacts as the valuation of that project will change (*i.e.* become less valuable to those community members experiencing the original impact).

5 Next Steps

Our next steps, in Phase 2 of this project, will be to deploy COMET within the context of specific representative ecosystems experiencing a representative impact. We will first turn towards a suite of the most commonly referenced coastal mitigation challenges from recent decades. We will next apply our mitigation guidance to representative coastal zone projects to illustrate how a discrete, compensatory project could be designed and assessed wherein some or all implementation could happen off-site and/or out-of-kind. This phase will produce the most tangible short-term value for state agencies currently dealing with compensatory mitigation challenges.

Although there is a need to develop new tools to assist out-of-kind and off-site mitigation decisions, such as habitat-independent assessments of ecosystem, some of the recommendations in this report can be implemented immediately. For example, consideration of ecosystem services can happen now, even though better tools for a quantitative comprehensive assessment may not be fully developed at the moment.

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