Appendix D
Review of Subtidal and Intertidal Habitat Compensatory Mitigation Approaches

Prepared for:
California State Lands Commission

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ACRONYMS

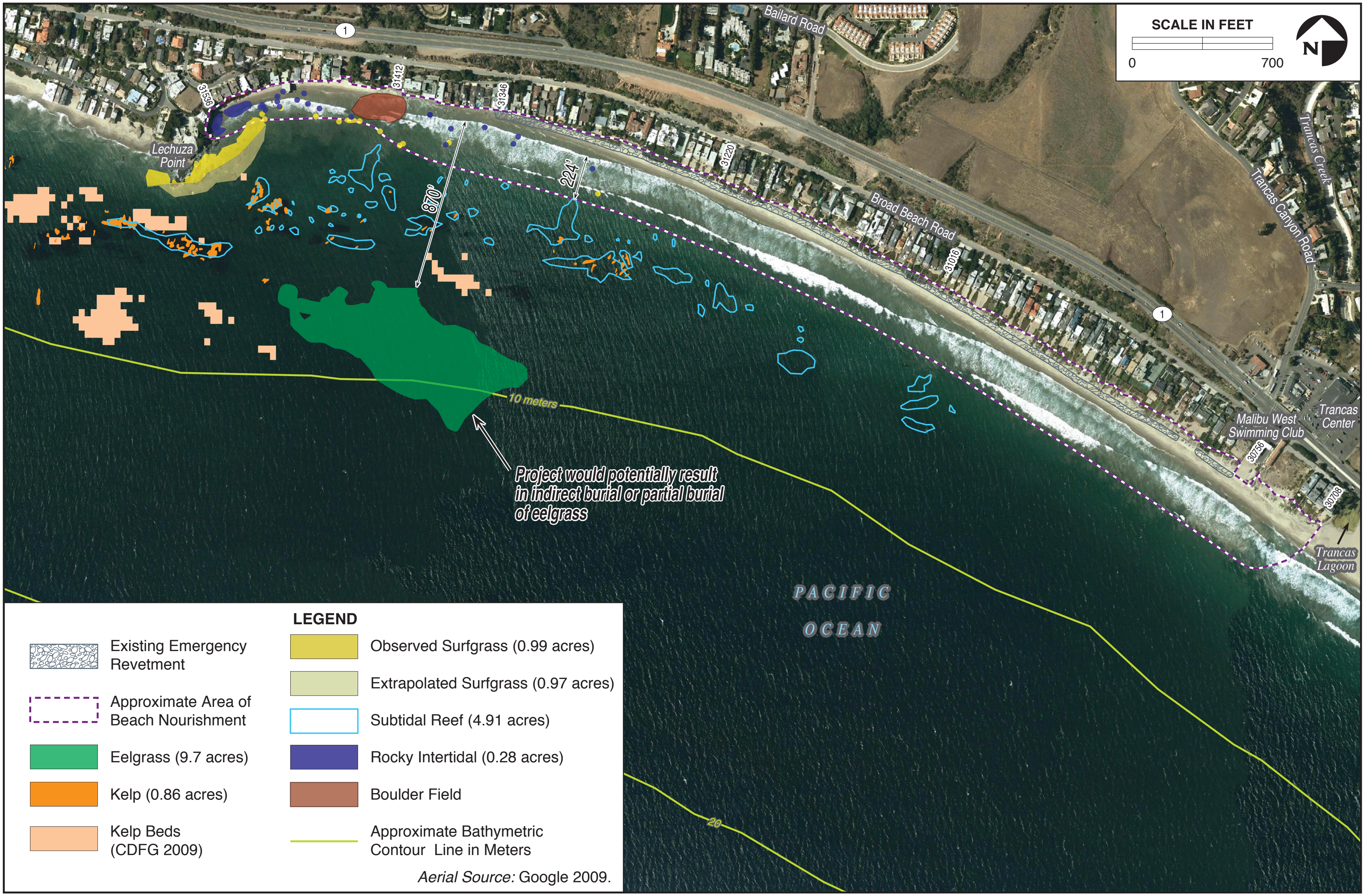
APTR	Analysis of Public Trust Resource
BBGHAD	Broad Beach Geological Hazard Abatement District
CCC	California Coastal Commission
CDFW	California Department of Fish and Wildlife
CINMS	Channel Islands National Marine Sanctuary
CIRP	Channel Islands Research Program
CSLC	California State Lands Commission
cy	cubic yards
HAPC	Habitat Area of Particular Concern
MBIRP	Marine Biological Impact Reduction Report
MLLW	Mean Low Low Water
MLPA	Marine Life Protection Act
MPA	Marine Protected Area
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRI	National Reef Indicator
MT	Metric Tons
SCE	Southern California Edison
SMCA	State Marine Conservation Area
SMR	State Marine Reserve
SONGS	San Onofre Nuclear Generating Station
SYU	Santa Ynez Unit
TWG	Technical Work Group
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service

INTRODUCTION

The California State Lands Commission (CLSC) is currently preparing a Draft Analysis of Public Trust Resources (APTR) to evaluate the potential impacts of the Broad Beach Restoration Project proposed by the Broad Beach Geological Hazard Abatement District (BBGHAD). The BBGHAD is seeking approval from the CSLC, through the issuance of a lease, to restore an approximately 46-acre area of beach and sand dunes and to authorize the continued use of an existing 4,100-foot-long emergency rock and sand bag revetment at Broad Beach in the city of Malibu, California. The proposed nourishment of Broad Beach would also require multiple additional local, state, and federal permits, including a Coastal Development Permit issued by the California Coastal Commission (CCC). This report is intended to provide an overview of past efforts to avoid or mitigate impacts to rocky intertidal and subtidal habitats resulting from development within such areas, in this case due to beach nourishment and restoration. However, because most available past projects and associated studies focus on subtidal habitats, so does this review.

Under the Project the BBGHAD would import an estimated 600,000 cubic yards (cy) of beach- and dune-quality sand to Broad Beach from inland quarries to re-establish a wide sandy beach berm up to 322 feet on the eastern end, backed by a restored dune system. The Draft APTR identifies potentially substantial and unavoidable direct and indirect impacts to rocky intertidal and subtidal habitats as a consequence of burial and increased turbidity resulting from implementation of the proposed beach nourishment. Impacts include loss of surfgrass (*Phyllospadix* sp.) in Lechuza Cove and potential increased turbidity and/or post-construction sand redistribution to affected subtidal reefs area and offshore eelgrass beds (*Zostera* sp.). Therefore, the Draft APTR includes avoidance and minimization measures as well as alternatives that would require the BBGHAD to address these potential impacts to sensitive marine biological resources; such measures range from limitations on the sand placement along the western end of the Project area as well as requirements to support habitat establishment, restoration/enhancement, or preservation.

More than two acres of rocky intertidal habitat occur within Lechuza Cove on the west end of Broad Beach. This complex habitat type supports a diverse community of sessile invertebrates (left), as well as surfgrass (Phyllospadix sp.) (right), which is designated as a habitat area of particular concern (HAPC) and is important for nearshore fish communities.



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Marine Biological Resources in the Project Area

FIGURE 1

This report briefly describes the issues surrounding each of the above approaches to compensatory mitigation and provides examples of past mitigation projects for impacts to intertidal and subtidal marine habitats. Each of these approaches include complex issues associated with biological science, public perception, and the existing regulatory environment.

- **Permittee-responsible Compensatory Mitigation**

  Permittee responsible for ensuring that compensatory mitigation is completed and successful.

- **Mitigation Banks**

  Widely used for impacts to wetlands, but not subtidal marine habitat types. Off-site compensation for impacts conducted by a third party, typically for profit, private entity.

- **In-lieu Fee**

  Such programs use collected fees to implement off-site compensation administered by state or local agencies with fees collected from permittees.

Given the ecological values of marine aquatic habitats such as surfgrass and rocky reefs, public resource management agencies generally stress avoidance of impacts where possible. Where avoidance is not possible, resource management agencies typically employ four approaches as compensatory mitigation for impacts to marine biological resources (U.S. Army Corps of Engineers [USACE] 2008; Yates 2014):

(1) **Restoration**: Returning a degraded or former aquatic habitat to a pre-existing condition or as close to that condition as possible.

(2) **Enhancement**: Increasing one or more of the functions performed by an existing aquatic habitat beyond what currently or previously existed.

(3) **Establishment**: The creation of rocky intertidal or subtidal habitat in a location where the habitat does not currently exist.

(4) **Preservation**: Protection of existing rocky intertidal or subtidal habitat from future degradation.

Additionally, there are three mechanisms for providing compensatory mitigation: (1) permittee-responsible compensatory mitigation; (2) mitigation banks; and (3) in-lieu fee mitigation. Permittee-responsible mitigation is the most traditional form of compensation and continues to represent the majority of compensation acreage provided each year (USACE 2008). As its name implies, the permittee retains responsibility for ensuring that required compensation activities are completed and successful, under the guidance of regulatory agencies (USACE 2008). A high-profile example of permittee-responsible mitigation in marine subtidal environment is the North Wheeler Reef, approximately 0.5 miles offshore of San Clemente, California, discussed in detail below.

Mitigation banks and in-lieu fee mitigation both involve off-site compensation activities generally conducted by a third party, a mitigation bank sponsor, or an in-lieu fee administrator. When a permittee's compensatory mitigation requirements are satisfied by a mitigation bank or an in-lieu fee program, responsibility for ensuring that required compensation is completed and successful shifts from the permittee to the mitigation bank or the in-lieu fee administrator.

Mitigation banks and in-lieu fee programs both conduct consolidated aquatic resource restoration, enhancement, establishment, and preservation projects; however, under current practice, there are several important differences. In-lieu fee programs rely on fees collected from permittees to initiate compensatory mitigation projects while mitigation banks usually rely on private investment for initial financing. Mitigation banks must achieve certain milestones, including site selection, plan approval, and financial assurances, before they can sell credits, and generally sell a majority of their credits only after the physical development of compensation sites has begun. In contrast, in-lieu fee programs generally initiate compensatory mitigation projects only after collecting fees, and there has often been a substantial time lag between permitted impacts and implementation of compensatory mitigation projects. Similar lag times can also occur with permittee-responsible mitigation as compensatory mitigation projects are generally initiated only after issuance of a permit for the proposed development. Further, in-lieu fee programs have not generally been required to provide the same financial assurances as mitigation banks. For all of these reasons, there is greater risk and uncertainty associated with in-lieu fee programs regarding the implementation of the compensatory mitigation project and its adequacy to compensate for lost functions and services (USACE 2008).

Habitat preservation has not historically been used as a means of compensatory mitigation in the marine environment (Ugoretz 2005). Establishing or restoring/enhancing the physical and chemical characteristics of aquatic habitat, including substrate quality and habitat complexity are complex undertakings and can require years to achieve desired results (Johnson et al. 2008; Yates 2014). Replicating and restoring the full ecological functions and values of aquatic habitat is a complex process and there are no assurances of success (Johnson et al. 2008). Each of the approaches to compensatory mitigation for impacts to marine habitats includes benefits and tradeoffs and have varying level of success and agency or community support.

COMPARISION OF COMPENSATORY MITIGATION TYPES

Mitigation approaches within rocky intertidal and subtidal habitats include a variety of management decisions and tradeoffs associated within marine biological resource protection and recreation. Over the last decade, preservation has become a widely used management tool for marine biological resource protection (e.g., Marine Protected Areas [MPAs]); however, difficulties associated with consensus building and coordination across multiple jurisdictions present challenges to this approach for mitigating impacts to marine biological resources. Consequently, state agencies such as the California Department of Fish and Wildlife (CDFW) generally do not support the development and implementation of MPAs as a primary compensatory mitigation measure (Ugoretz 2005). While habitat restoration/enhancement and establishment are more widely implemented to mitigate impacts to aquatic habitats, these approaches also present challenges associated with public perception and effectiveness.

Table 1: Comparison of Compensatory Mitigation Approaches

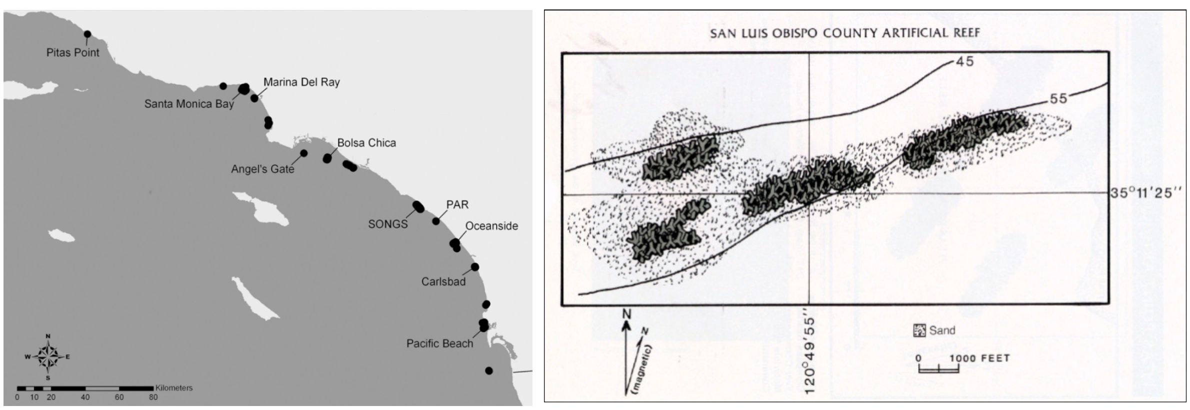
Mitigation Type	Benefits	Challenges
Habitat Establishment	• Potential for local increase in biomass and biological diversity • Potential for recruitment of special status or keystone species • Potential commercial and recreational benefits (e.g., fishing) • Potential opportunity for education or academic study	• Effectiveness in mimicking a natural ecosystem • Attraction of existing biomas versus production of biomass at the mitigation site • Public perception • Complex regulatory environment • High initial cost and large monitoring/maintenance efforts
Restoration/Enhancement	• Builds upon and enhances existing habitat areas • Potential long-term enhancement of existing ecosystems • Potential to reduce edge effects within an existing ecosystem	• May result in damages to existing natural habitat or function • Restoration methods may not be developed or may be difficult to implement • Transplant regimes may have indirect impacts on existing healthy ecosystems • Moderate cost for monitoring/maintenance efforts
Preservation	• Potential to prevent or reduce future impacts to a vulnerable ecosystem • Potential to allow natural recovery of a previously impacted habitat area • Potential to manage for multiple uses • Minimal direct cost	• Difficult to build consensus • Coordination across complex jurisdictions • Potential loss of commercial and recreational fishing opportunities

This report explores the approaches to compensatory mitigation described above in Table 1 and provides examples of their implementation. Compensatory mitigation proposals or projects for the San Onofre Nuclear Generating Station (SONGS), Exxon Santa Ynez Unit (SYU), and Diablo Canyon Nuclear Power Plant provide examples of permitee-responsible or in-lieu compensatory mitigation for impacts to rocky intertidal and subtidal habitats. Discussion regarding the proposed Port of Los Angeles Umbrella Mitigation Agreement and the proposed Colorado Lagoon Mitigation Bank provides the only readily available example of mitigation banking as a means of implementing compensatory mitigation for impacts to subtidal habitats (e.g., eelgrass and rocky intertidal). As the establishment of subtidal reef habitat as mitigation is a relatively new topic, this report also describes past artificial reef construction and restoration within the Southern California Bight.

ARTIFICIAL REEF CREATION IN THE SOUTHERN CALIFORNIA BIGHT

Rocky reefs are among the most important but least abundant habitats within the Southern California Bight (Cross and Allen 1993). The CDFW administers the California Artificial Reef Program (California Fish and Game Code Sections 6420–6425), which has a long history of designing and constructing artificial reefs. Approximately 30 artificial reefs have been constructed involving over 100 modules (i.e., structures or quarry rock piles) and a broad range of designs and goals (National Oceanic and Atmospheric Administration [NOAA] 2005).

CDFW began constructing artificial reefs off of Southern California in the late 1950s (Bedford et al. 2000). Early artificial reef building was aimed at determining materials best suited for creating artificial reefs that that would attract and produce fish biomass, particularly for popular sport fish species (Bedford et al. 2000). However, beginnings in the 1980s questions were raised regarding the functions of artificial reefs relative to natural reefs (Bedford et al. 2000).



Over 30 artificial reefs have been constructed within the Southern California Bight (left) since the 1960s with materials ranging from quarry rock to car bodies. Early artificial reefs along the California Coast, such as the San Luis Obispo County Artificial Reef (right) were constructed as a group of rock modules spaced closely together at a depth ranging from 30 and 165 feet below mean low low water (MLLW).

Additional information on reef productivity and community structure has been generated in the past two decades by construction of a series of "developmental" reefs specifically designed to evaluate and compare how various design elements affect biological productivity and marine community structure. Developmental reefs have been built at Pendleton, Pitas Point, Santa Monica Bay, Marina Del Rey #2, Oceanside #2, Pacific Beach, Carlsbad, and Topanga. These developmental reefs generally consist of a series of rock modules with different rock sizes, relief profiles, and depths (NOAA 2005).

Table 2: Artificial Reefs Established in California Prior to 1990

Artificial Reef (Construction Year)	Area (acres)	Depth (MLLW)	Materials	Notes
Early Artificial Reefs				
Hermosa Beach[1] (1960)	0.5	60	330 tons Quarry Rock, 44 Concrete Shelters, 14 Car Bodies, and 1 Streetcar	Some of the reef structure has since disintegrated. Still attracts large numbers of fishes, particularly in late September and early October.
Malibu (1961)	0.5	60	333 tons Quarry Rock, 44 Concrete Shelters, 14 Car Bodies, and 1 Streetcar	Some of the reef structure has since disintegrated, but the reef still provides good sculpin fishing, particularly in March and April.
Santa Monica (1961)	0.5	60	330 tons Quarry Rock, 44 Concrete Shelters, 4 Car Bodies, and 1 Streetcar	Some of the reef structure has since disintegrated. Some sandbass in fall. Occasional good sculpin fishing in the spring.
Redondo Beach (1962)	1.6	72	1,000 tons Quarry Rock	Reef is quite complex and provides habitat for many nearshore species.
Huntington Beach Artificial Reef 1-4 (1963)	3.67	60	Each of the 4 Reefs Consist of 1,000 tons Quarry Rock	N/A
Oceanside Artificial Reef 1[2] (1964)	4	82-100	2,000 tons Quarry Rock	Sportfishing has occasionally been reported good for barred sandbass, kelp bass, and sheephead.
Torrey Pines Artificial Reef 1[1, 2, 3] (1964)	N/A	67	1,000 tons Quarry Rock	Partially covered by sand and silt. Only a few scattered rock piles observed. Very low relief.
Mariana Del Rey Artificial Reef 1[1] (1965)	3.2	65	2,000 tons Quarry Rock	Occasional good sandbass angling.
Torrey Pines Artificial Reef 2[1, 2] (1975)	1	44	3,000 tons Quarry Rock and Concrete Dock Floats	This reef holds significant numbers of blacksmith sheephead, and kelp bass. Few barred sandbass have been seen.
Palawan (1977)	0.6	120	Sunken Ship	Few species of fish have been observed in large numbers. Occasional large halibut have been noted on the sand.
Newport Beach[1] (1979)	8	72	10,675 tons Concrete Blocks, Pilings, and Rubble	Sizable barred sand bass numbers have been surveyed at this reef.

Artificial Reef (Construction Year)	Area (acres)	Depth (MLLW)	Materials	Notes
Developmental Reefs				
Pendleton[1, 2, 4, 5, 6] (1980)	3.5	43	10,000 tons Quarry Rock	This is the pilot experimental reef of the developmental reef series. Very good sand bass fish in September and October. Sculpins are seasonally abundant and various surfperches are common year round. Lobster diving can be exceptional.
Pitas Point[1, 2] (1984)	1.1	28	7,200 tons Quarry Rock	Reef supports a healthy stand of giant kelp which forms a surface canopy. Feather boa kelp is also present forming a lower story canopy. Kelp bass, barred sandbass, olive and brown rockfishes and several species of surfperches are common.
San Luis Obispo County (1984)	13	42-52	27,000 tons Concrete Tribar and Rubble	Nursery ground for rockfish. Large numbers of adult blue rockfish . Very lush algae growth.
Atascadero (1985)	0.4	55	3,500 tons Quarry Rock	Divers have observed good concentrations of adult brown, gopher, and blue rockfish, and pile and striped surfperch around the rock piles.
Mariana Del Rey Artificial Reef 2[1] (1985)	6.9	65	10,000 tons Quarry Rock	Anglers have reported occasional good catches of sandbass and sculpin.
Bolsa Chica (1986)	220	85-100	140,00 tons Concrete Rubble and Quarry Rock as well as 8 Steel and Concrete Barges	Exceptional sculpin fishing in March and April. Good white croaker catches reported.
Mission Beach[4] (1987)	173	80-90	3 Sunken Vessels and Concrete Rubble	The focus of extensive research, prior to the construction of the Southern California Edison mitigation kelp reef off San Clemente, since the Mission Beach Reef represents the first time kelp has been sustained for more than a couple of years on an artificial reef in the U.S. Although the reef lost most of its kelp during the winter storms of the 1997–1998 El Niño event, kelp seemed to recover as the 1998–1999 La Niña progressed and the hard substrate of the reef has shown little change (Deysher et al. 2002).

Artificial Reef (Construction Year)	Area (acres)	Depth (MLLW)	Materials	Notes
Oceanside Artificial Reef 2[2] (1987)	256	42-72	10,000 tons Quarry Rock	Good numbers of barred sandbass have been observed on the reef.
Pacific Beach[2] (1987)	109	42-72	10,000 tons Quarry Rock	Reef supports a wide variety of kelp-rock habitat organisms. Excellent lobster diving has been reported. Also, good numbers of kelp and sandbass have been seen.
Santa Monica Bay (1987)	256	42-72	20,000 tons Quarry Rock	Very successful fishing reef. March and April good for sculpin. Sandbass all year, particularly early-late fall. Halibut on sand near rockpiles early summer. Lobster diving on shallow rockpiles can be productive early in season, deeper rockpiles in January and February.
Topanga (1987)	13	28	10,000 tons Quarry Rock	Designed to promote kelp habitat development. However, while giant kelp was observed in 1989, 1990, and 1993, it was not observed during the last known CDFW survey in 1995 (Bedford et al. 1996). Kelp bass and sandbass commonly observed. Good lobster diving early in season.
Carlsbad[2] (1991)	6	33-67	10,000 tons Quarry Rock	Carlsbad reef was built to complement the opening of the mouth of Batiquitos Lagoon and this lagoon's function as a nursery grounds for some popular sport fish species (e.g., California halibut; sand bass). The stability of the fish community at this reef has persisted even after the abundant giant kelp disappeared between 1994 and 1997 (Kashiwada 1998).
International Beach (1992)	75	165	25,000 tons Quarry Rock, Concrete, and Steel Missile Tower as well as 300 tons Concrete Rubble	Deepest of the fish and game reefs. This is an excellent fishing reef for sandbass and surface fishes in the summer months and rock fish in the winter months

Known studies that support discussion in this table and provide additional information regarding specific artificial reefs within the Southern California Bight include: [1]Ambrose and Swarbrick 1989; [2]Deysher et al. 2002; [3]Johnson et al. 1994; [4]Grove et al. 2002; [5]Grant et al. 1982; [6]Carter et al. 1985.
Source: Bedford 2001.

EARLY COMPARISONS OF ARTIFICIAL REEFS WITH NATURAL REEFS

Over 25 years ago Ambrose and Swarbrick (1989) examined a wide range of subtidal reefs in order to evaluate the similarities between fish assemblages on artificial and natural reefs. During this study all age classes of fish on 10 artificial and 16 natural reefs were censused along benthic and water-column transects, physical characteristics of the reefs were measured, and invertebrate as well as algal assemblages were assessed. Two types of artificial reefs were sampled including traditional artificial reefs, which were usually small, isolated, completely submerged, and with low to moderate height, and breakwaters, which were larger, steeper, emergent (i.e., projected above the surface of the water) and tall. Natural reefs ranged from small, high-relief reefs composed of boulders and bedrock to extensive, low-relief reefs composed of cobbles. Ambrose and Swarbrick (1989) found that the average size of artificial reefs was much smaller than natural reefs. Artificial reefs had significantly more benthic fish individuals, a greater density of benthic fishes, and a greater biomass density of benthic fishes; however, the diversity of benthic species (i.e., the variety or relative number of species) was similar for both artificial and natural reefs. Additionally, species richness, diversity, density and biomass density of fish in the water column were similar on artificial and natural reefs. In general, the same species were found on both reef types, although the relative abundances of some of the common species differed. However, artificial reefs were so much smaller than most natural reefs that, in spite of their greater densities of fish, the total abundance of fish was generally much higher on natural reefs. Estimated standing stocks on artificial reefs varied from 0.12 to 2.77 metric tons (MT). On natural reefs, estimated standing stocks varied from 2.08 to 276.05 MT, with a mean of 45.32 MT. Ambrose and Swarbrick (1989) asserted that these results have important implications for the use of artificial reefs in mitigation. Even under the assumption that all fish on an artificial reef are produced by the reef rather than attracted to it, the size of artificial reef needed to compensate for environmental impacts to natural reefs may be substantial.

Additionally, CDFW found that none of the early artificial reefs developed resilient or persistent kelp forest communities (Grove et al. 2002). The Mission Beach Artificial Reef, installed by CDFW in 1987, was the first artificial reef in the U.S. to mimic a natural kelp community for more than a few years (Grove et al. 2002).

Mission Beach Artificial Reef

This artificial reef was constructed in 1987 and consists of a low profile (one to five feet off the seafloor) field of concrete rubble. Approximately 1,800 tons of concrete slabs were placed on a sloping sand bottom at a depth of 80 to 90 feet. The Mission Beach Artificial Reef, approximately four arces in area, lies midway between the Point Loma and La Jolla kelp forests, with the nearest natural hard substrate (and kelp population) located approximately two miles to the south at Point Loma (Grove et al. 2002).

Lessons Learned

- El Niño events generally decrease kelp recruitment and increase mortality.
- Low-relief rock reef with a moderate level of sand cover would be the most likely candidate for a successful kelp reef.

The initial qualitative survey of the Mission Beach Artificial Reef in November 1994 showed that a dense population of giant kelp (*Macrocystis pyrifera*) had developed with fronds reaching the surface. During the first quantitative survey in 1995, a diverse and abundant algal population was also observed with adult kelp densities similar to those observed in natural kelp beds (Grove et al. 2002).

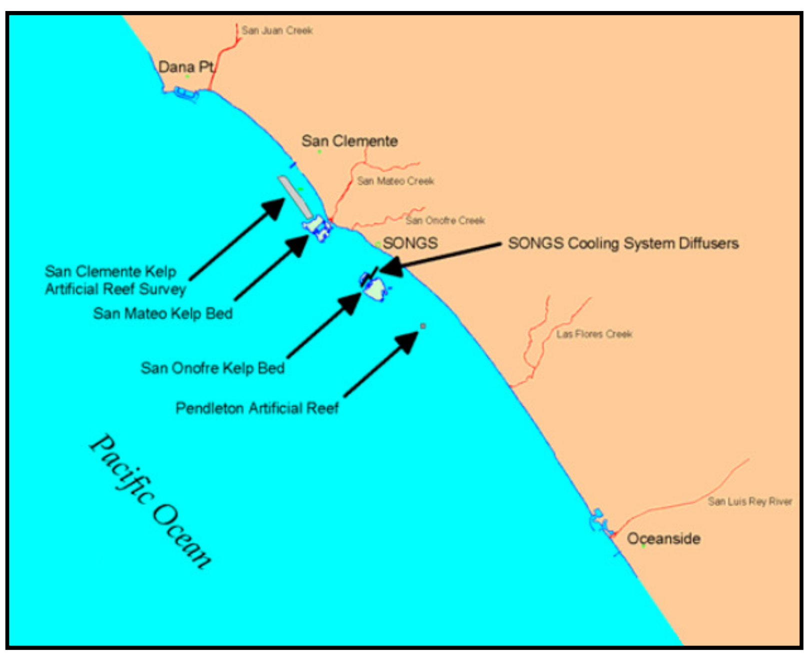
In contrast to the high-relief Pendleton Artificial Reef, discussed below, the low-relief Mission Beach Artificial Reef, the only artificial reef constructed prior to 1990 to persistently support giant kelp, appears to respond to the El Niño/La Niña events similarly to natural kelp beds. Prior to 1997, there had been speculation that a major El Niño event would eliminate kelp from this reef and that the concrete substrate might become buried in the sand bottom. Although the reef lost most of its kelp during the winter storms of the 1997–1998 El Niño event, kelp seemed to recover as the 1998–1999 La Niña progressed and the hard substrate of the reef has shown little change (Deysher et al. 2002).

Observations on both artificial and natural reefs indicate that a low-relief reef is the most favorable configuration to support kelp populations (Deysher et al. 2002). The most persistent beds appear to occur on solid rock substrate with moderately low relief and moderate coverage by sand. Very low reefs, with an abundance of sand, have less persistent kelp and high-relief reefs built in Southern California are dominated by sea fans, which exclude kelp. These conclusions are supported by observations of Patton et al. (1994) that adult plants were more common on hard substrates lying less than three feet above the surrounding sand than on higher relief substrate (Deysher et al. 2002).

ARTIFICIAL REEF CREATION AS MITIGATION

As described above, following the pulse of artificial reef creation during the 1960s and 1970s, in the early to mid-1980s CDFW focused its attention on determining if artificial reefs could function in a similar way to natural reefs. Debates regarding the attraction versus the production of biomass on artificial reefs, discussed below, still remain (Pickering and Whitmarsh 1997; Osenberg et al. 2002); however, the construction and multi-year study of Pendleton Artificial Reef, off northern San Diego County demonstrated that, in time, a well-constructed artificial reef can develop the same community structure as similarly configured natural reefs (Bedford et al. 2000). Consequently, artificial reefs have been constructed within the Southern California Bight to mitigate the loss of natural reefs resulting from development or habitat degradation (Ambrose 1994). Key examples of artificial reefs constructed as mitigation include the Pendleton Artificial Reef and the North Wheeler Artificial Reef in Southern California as well as the Elliot Bay Artificial Reef in Puget Sound, Washington. Additionally, artificial reefs are also being considered at Solana Beach and San Clemente in Southern California. These artificial reefs are all discussed in detail below.

Pendleton Artificial Reef



The Pendleton Artificial Reef was designed by CDFW and Southern California Edison (SCE) to determine the potential of artificial reefs for mitigating possible losses of kelp-reef habitat caused by operation of coastal power plants (Grant et al. 1982; Carter et al. 1985). The reef was constructed of 10,000 tons of quarry rock. Criteria used to determine the location for reef construction, included water depth, which was chosen as being adequate for kelp (*Macrocystis*) growth and kelp recruitment in that section of coast. The Pendleton Artificial Reef is approximately 3.5 acres in size and is located at a depth of approximately 43 feet below mean low low water (MLLW) with a relief of approximately 13 feet.

At the time of its construction, aside from the Mission Beach Artifical Reef, attaining a stable kelp bed on an artificial reef had not yet been accomplished. Kelp had preiovusly been recruited naturally to an artificial reef constructed by the CDFW off Hermosa Beach in Los Angeles County; however, the kelp bed was lost, probably due to poor water quality in the area and excessive depth. Kelp had also been previously recruited to Torrey Pines artificial reef in 40 feet of water near La Jolla in San Diego County. This kelp bed was also lost due to sea urchin grazing, but has since begun to return after removal of the sea urchins (Grant et al. 1982).

Lessons Learned

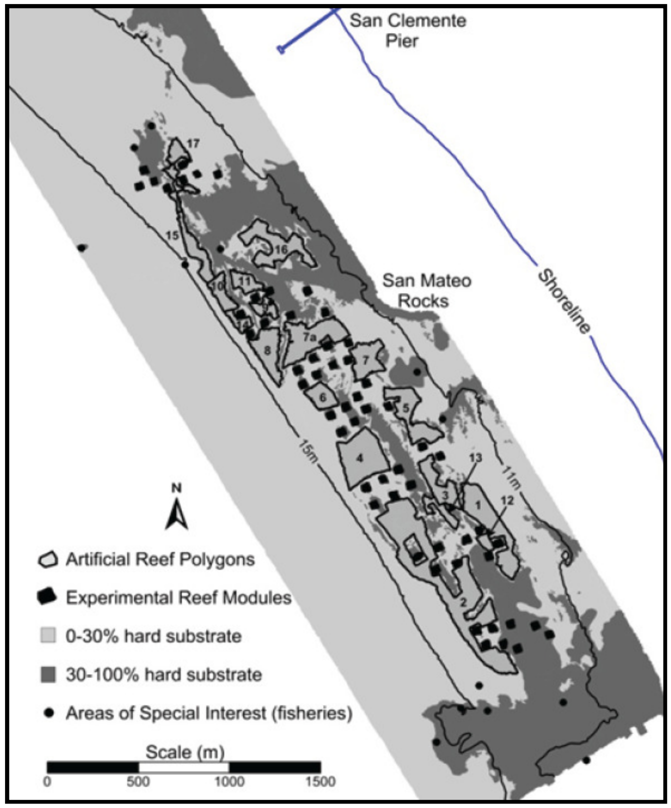
- Initial planning should consider physical and biological environment such as upwelling frequency and nutrient availability.
- Timing of reef installation is important.
- Post reef placement management techniques such as predator exclusion should be considered.

The Pendleton Artificial Reef was built as a prototype for a kelp mitigation reef. Hundreds of adult and juvenile kelp plants were transplanted to this reef soon after its construction; however, they were all lost to intense fish grazing (Grant et al. 1982). Natural recruitment was reported in the late 1980s, when kelp populations became established at many locations along the Southern California coast. The cause of this recruitment event appears to be a severe storm event that caused a great deal of disturbance and opened substrate for new settlement. The storm was followed by a period of La Niña conditions providing colder, nutrient-rich water that stimulated kelp growth and survival. This period of kelp recruitment, however, did not sustain a long-lived kelp population on the Pendleton Reef (Grove et al. 2002).

A long-term study of the successional development of the turf community (i.e., sessile invertebrates and understory algae) on the reef began one year after construction, from fall 1981 through fall 1986. To determine if the Pendleton Artificial Reef was developing a turf community characteristic of more mature reefs, the study was expanded in fall 1984 to include sampling of two reference reefs – Torrey Pines Artificial Reef and Las Pulgas (Natural) Reef. During the five-year study, the turf community on the Pendleton Artifical Reef became progressively more complex; it evolved from a few pioneer taxa into a diverse community (Palmer-Zwahlen and Aseltine 1994). Additionally, comparisons between the reefs revealed that the assemblage of taxa on the Pendleton Artificial Reef in fall 1986 was similar to those on the Torrey Pines Artificial Reef and Las Pulgas (Natural) Reef (Aseltine-Neilson et al. 1999).

Lessons learned from the construction of the Pendleton Artificial Reef include that initial planning should consider the physical and chemical environment, including depth, relief, substrate type nutrient availability, as well as the biological environment, including surrounding community structure that could influence dispersal and/or attraction of desirable or undesirable organisms. Factors that affect the quality of the subhabitats such as type and durability of construction material, structure complexity, and roughness of the substratum are also key to the success of an artificial reef. Additionally, after an artificial reef has been constructed, factors that can influence community development include timing of reef installation (e.g., availability of spores and larvae to colonize the reef) and possible post reef placement management techniques (e.g., transplantation or removal of select species to alter natural succession) (Carter et al. 1985).

Wheeler North Artificial Reef (San Onofre Nuclear Generating Station Mitigation)



In 1974, the CCC issued a permit to SCE for Units 2 and 3 of SONGS. A condition of the permit required study of the impacts of the operation of Units 2 and 3 on the marine environment offshore from San Onofre, and mitigation of any adverse impacts with a particular emphasis on offshore kelp beds. The SONGS coastal development permit required that a mitigation reef be constructed of rock, concrete, or a combination of these materials at a coverage that is suitable for sustaining giant kelp and associated kelp forest biota similar in abundance and diversity to nearby reference reefs, as determined by results from an experimental artificial reef. The permit conditions required that the total area of the mitigation reef be no less than 150 acres, two-thirds of which would be covered by exposed hard substrate (Reed et al. 2013).

Wheeler North is a low-relief artificial reef that supports 176 acres of kelp forest mitigating images from the operations of SONGS.

The purpose of the artificial Wheeler North Reef was to create a fully functioning kelp forest community with a minimum of 150 acres of medium- to high-density giant kelp (*Macrocystis pyrifera*) and associated biota (i.e., algae, invertebrates, and fish) to contribute as compensation for the loss of 179 acres of high-density kelp bed community. The kelp mitigation project area is located approximately 0.5 miles offshore of San Clemente, California, in water depths of approximately 35 to 50 feet. The mitigation reef consists of low-relief substrate grouped in modules and large polygon areas along approximately 2.5 miles of coastline. Wheeler North is the largest human-made reef constructed in the U.S., covering approximately 176 acres. The profile of Wheeler North consists of a single rock layer rising no more than approximately 1.5 feet off the existing sand seafloor. This rock configuration was used because previous studies had determined that kelp in the area is most persistent on very low profile natural outcroppings (Elwany et al. 2011).

Evaluation of the Wheeler North Reef is based on its performance with respect to four primary criteria, including:

(1) At least 90 percent of the exposed hard substrate must remain available for attachment by reef biota;

(2) The artificial reef(s) shall sustain 150 acres of medium- to high-density giant kelp;

(3) The standing stock of fish at the mitigation reef shall be at least 28 tons; and

(4) The important functions of the reef shall not be impaired by undesirable or invasive benthic species (e.g., sea urchins or cryptochnidium).

Lessons Learned

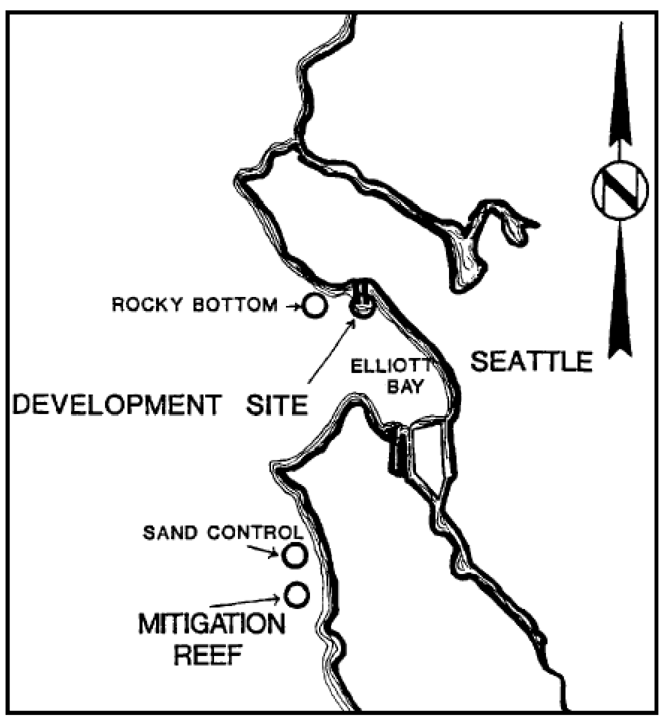
- This artificial reef supports previous studies that found low-relief reefs support kelp better than high-relief reefs.
- Monitoring has supported that fish biomass on artificial reefs is limited when compared to natural reefs.

Monitoring is completed annually to determine whether the Wheeler North Reef has met these standards (Reed et al. 2013). In 2012 the Wheeler North Reef met three of the four performance criteria. However, it failed to meet requirements to support a fish standing stock of at least 28 tons. To date the Wheeler North Reef has produced at most half of this amount, and there is no indication from the monitoring results that the artificial reef is on a trajectory to meet the fish standing stock standard any time soon. Results of analyses using longer-term data collected from the reference reefs and the smaller modules constructed during the initial experimental phase indicate that the present size and configuration of the Wheeler North Reef is not sufficient to consistently support 28 tons of kelp bed fish (Reed et al. 2013).

During the 2012 annual monitoring, 174 of Wheeler North Reef's 176 acres (i.e., 99 percent) were estimated to support medium to high densities of adult giant kelp since 2010. This indicates the Wheeler North Reef currently is meeting the objective of compensating for the loss of giant kelp caused by SONGS operations (Reed et al. 2013).

Elliot Bay Washington

The Elliot Bay Artificial Reef was constructed on a featureless sand bottom in the Puget Sound, Washington as mitigation for the direct loss of rocky-type subtidal habitat from a shoreline development (fill) project in Elliot Bay. National Reef Indicator (NRI) species were used to help select a site for the mitigation reef. A total of 200,000 tons of quarry rock was used to construct fourteen 20 foot tall reef structures in a seven acre area during May 1987. The 50-foot spacing between reef structures at the mitigation site provided natural open benthic foraging areas between structures. This spacing also maintained continuity of the reef fish community and the trophic level relationships normally occurring for fishes feeding from between the reef



Lessons Learned

- Open sand bottom surrounding a reef site can support infaunal organism, which have been shown to be important prey items.
- Some displacement of sand bottom fish species can occur with reef development.

structures and surrounding natural habitats (Hueckel et al. 1989). The open sand bottom at the mitigation reef site supports a diverse assemblage of infaunal organisms many of which have been shown to be important prey items for some reef fishes. During the reef's first eight months of submergence, the mitigation reef met the objective of developing a similar assemblage of economically important fish species as the development site, prior to its filling. Fish species diversity and densities on the mitigation reef have surpassed that observed on a rocky bottom adjacent to the development site (Hueckel et al. 1989). The mitigation reef is undergoing similar successional development as other productive artificial reefs in Puget Sound (Hueckel et al. 1989). The number of economically important fish species which colonized the mitigation reef is similar to those which colonized the three Puget Sound artificial reefs constructed at sites with similar numbers of NRI species as the mitigation reef site. Some displacement of resident fish appeared to have occurred as evidenced by the greater diversity and density of flounder observed on the adjacent sand bottom compared to those observed on the sand bottom between the mitigation reef structures (Hueckel et al. 1989).

Whittier Artificial Reef

The coastal habitats adjacent to Whittier, Alaska are increasingly stressed by recreational, industrial and fishery impacts. The area is a recreational destination for Anchorage residents and seasonal tourists, and a port for the Marine Highway Ferry System, cargo vessels, cruise ships, and commercial fishing vessels. As economic growth and development continues in Whittier, marine coastal habitat is increasingly altered by a variety of development activities such as harbor development, dredge and fill operations, sheet-pile dock structures, and log transfer facilities. These development activities alter the function of pristine marine coastal habitats principally by the removal, alteration, or elimination of existing living habitat structure including rocky reefs and aquatic vegetation.

The artificial reef at Smitty's Cove used pyramid shaped fish havens (left) and reef balls (right). Monitoring has demonstrated that the artificial reef structures have a marine community make up that is similar to nearby natural reefs (e.g., Bush Banks Pinnacle).

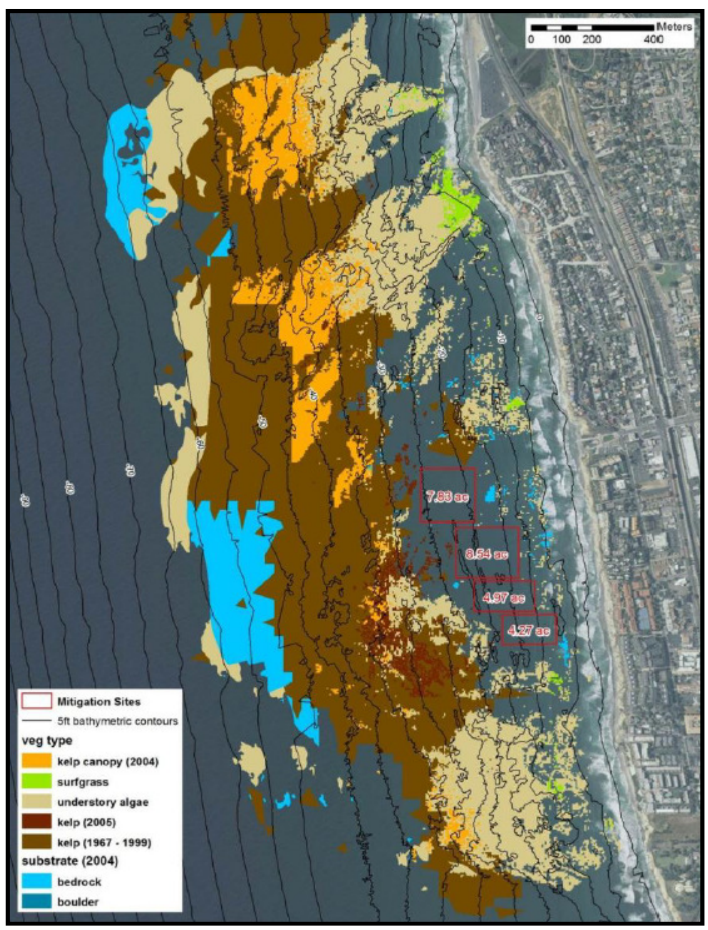
In May 2006, Alaska's first pre-planned artificial reef was installed in Smitty's Cove in northwestern Prince William Sound. The reef is a pilot research project funded by NOAA

Fisheries Alaska Regional Office, NOAA Fisheries Restoration Center, the U.S. Fish and Wildlife Service (USFWS) Alaska Coastal Program and the Alaska Marine Lines mitigation fund.

The artificial reef installation at Smitty's Cove consists of two parallel rows, each containing three, circular reef plots, 30 feet in diameter, consisting either of three-foot high pyramid-shaped fish havens or of three feet high spherical Reef Balls. The two rows are situated on a declining slope 40 to 65 feet in depth over a mixed soft and hard sediment substrate. At the beginning of the second year of a five year study, the artificial reef was developing the beginnings of an Alaskan nearshore community, including colonization by algae and kelp, invertebrates such as starfish, snails, tunicates, hermit crab, and shrimp, as well as dusky, copper, and quillback rockfish, juvenile lingcod, and sculpin. The results of monitoring demonstrate distinct fish communities between the low relief natural hard bottom site and the high relief natural and artificial reef sites. The data indicate a habitat preference by rockfish for sites with high relief, especially sites with high relief structure colonized by kelp. Overall, the data suggest similarities between artificial reef and natural reef community structure (Reynolds 2007).

NOAA Fisheries intends to monitor the artificial reef site for another three years to see if the expected ecosystem complexity develops, or if maturation of the ecosystem at the artificial reef is influenced by structural differences in the types of reefs used (NOAA 2013).

Solana Beach California (Encinitas-Solana Beach Coastal Storm Damage and Reduction Project Mitigation)



Similar to the nourishment project at Broad Beach the purpose of the Encinitas-Solana Beach Coastal Storm Damage Reduction Project is to effectively reduce risks to public safety and economic damages associated with shoreline erosion and to restore beaches along the shorelines of the cities of Encinitas and Solana Beach (USACE 2012). The tentatively recommended plan for Encinitas and Solana Beach includes the creation of a 100 foot wide beach for the City of Encinitas with renourishment cycles every 5 years and the creation of a 200 foot wide beach for the City of Solana Beach with renourishment cycles every 13 years (USACE 2012). This would result in an initial placement of 680,000 cy of sand at Encinitas within Swami's State Marine Conservation Area (SMCA) and 960,000 cy at Solana Beach, just south of the MPA (USACE 2012). Sand would be dredged from offshore, beyond the depth of closure, and would then be placed directly onto the two receiver sites within Encinitas and Solana Beach.

The linear extent of each receiver site was designed to maximize economic benefits while avoiding sensitive environmental resources (USACE 2012). Reaches were limited to existing sandy beaches, avoiding rocky intertidal areas. Reaches also avoided entrances to nearby coastal lagoons (Batiquitos and San Elijo Lagoons). The distance between the receiver sites and lagoon mouths are far enough that no impacts are expected. Post construction monitoring will include monitoring of the lagoon entrances to confirm that the project does not result in any closure or restrictions to lagoon entrances. Additionally, a lagoon sedimentation fee will be paid to offset the cost of dredging should the project result in closure or restrictions to lagoon entrances.

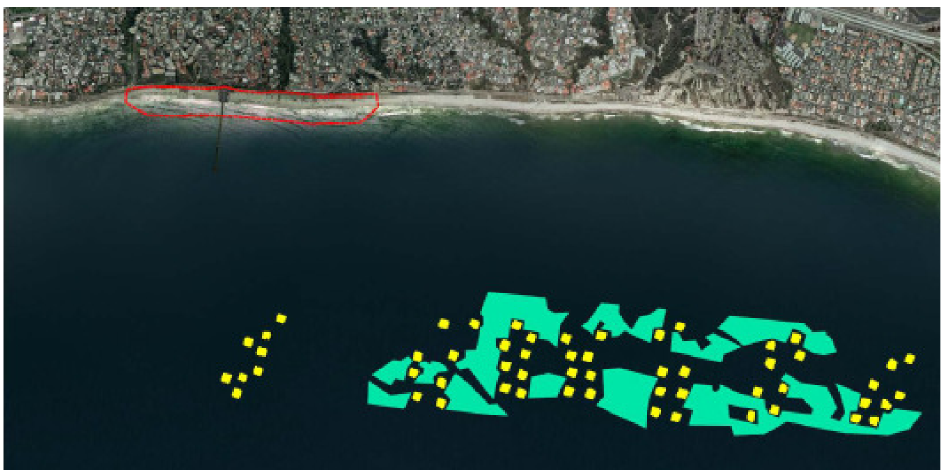
No impacts to marine biological resources were predicted for Encinitas and therefore no potential mitigation areas were identified offshore of Encinitas (USACE 2012). However, offshore of Solana Beach, sand introduced into the system would potentially indirectly impact up to 8.4 acres of marine biological resources (benthic habitat) as a result of burial or degradation of sensitive habitats and resources, under the low sea level rise scenario. If mitigation were required based on results of the post-construction monitoring, rocky reef and surfgrass mitigation would be implemented at a 2:1 functional equivalent (USACE 2012).

The creation of a mitigation reef would result in the conversion of 16.8 acres (maximum) of natural soft sandy seafloor substrate to rocky substrate. The mitigation area would include four potential sites just south of the Swami SMCA. The reef height would vary, but is generally expected to be approximately three feet in height, on average. The mitigation reef would be constructed offshore in waters of -30 to -40 feet below MLLW. Reef habitat would consist of shallow-water, mid-water, or deep-water reef at a 2:1 functional equivalent to the area of reef impacted. Shallow water reef would be for any surfgrass mitigation, mid-water reef would be located inshore of the existing kelp beds, and deep-water reef would be located offshore of the existing kelp beds. The mid-water reef would be the first priority as it is most like the reef that would potentially be impacted and is therefore closer to an "in-kind" mitigation (USACE 2012).

San Clemente California

Over the past 20 years, average beach widths in the San Clemente beaches have been gradually reduced to approximately 50 feet, a reduction of more than 50 percent compared to beach measurements from 1958 and 1981 (USACE 2011). San Clemente beaches were especially impacted by the El Niño storms of 1983 and 1998 (USACE 2011). Changes to the beach shoreline caused by erosion have reduced recreational opportunities and are threatening the stability of city facilities, private property, and a major Southern California commuter rail corridor. The purpose of the San Clemente Shoreline Protection Project is to provide shore protection through nourishment of the beach at the San Clemente Pier (USACE 2011).

The sand placement footprint for the nourishment project does not include any kelp beds, surfgrass, or rocky intertidal areas. Therefore, no direct impacts to sensitive habitats would occur from the placement of sand on the beach (USACE 2011). Following initial placement, the majority of the sand movement is expected to be downcoast and offshore. The nearest significant rocky intertidal area to the proposed beach fill location is at Mariposa Point, approximately 1,600 feet north of the northern end of the beach fill site. Therefore, the equilibrium footprint likely would result in a range of impacts between no burial of surfgrass on the larger rocks and partial burial on the smaller boulders. Additionally, considerable reef habitat that supports giant kelp, feather boa kelp, gorgonians, palm kelp, and sparse surfgrass is located approximately 1,000 to 1,300 feet offshore. Little or none of the fill from the beach nourishment site is expected to reach this area (USACE 2011). CRM and Moffatt & Nichol provided analysis that predicted less than 0.2 feet of sand from the San Clemente beach fill would accrete in the kelp beds (CRM 2000). Based on this information, it is unlikely that the nourishment project would result in the transport of enough sand into kelp bed areas to result in a long-term net loss of the habitat. All of the available evidence indicates that the project would have minor transitory effects, if any, on sensitive habitats in the vicinity of San Clemente Beach (USACE 2011). However, in a worst-case scenario, it is possible that the sand might not behave as predicted and that a large volume of sand could move into a sensitive biological habitat for a period long enough to result in permanent surfgrass loss or long-term cover of reefs (USACE 2011).



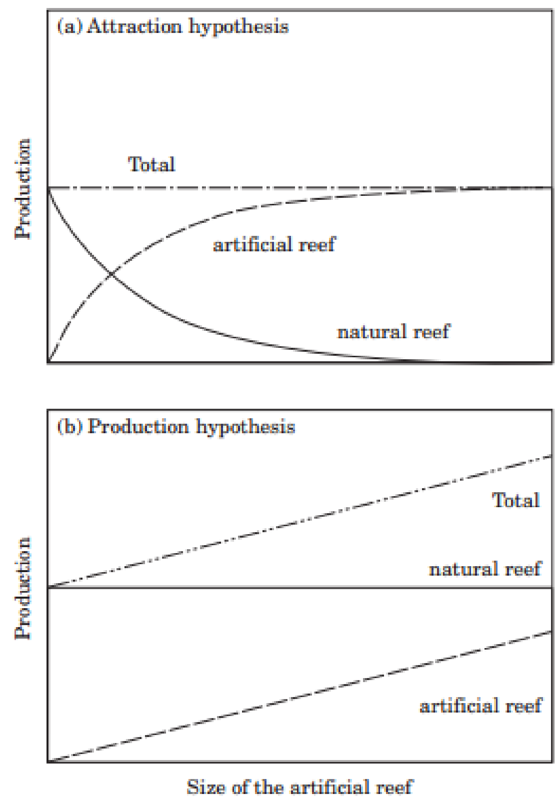
The San Clemente beach nourishment site (upper left) is located in close proximity to the Wheeler North Artificial Reef (bottom right). Implementation of the nourishment project would result in potential burial of surfgrass and kelp immediately offshore of the San Clemente Pier.

Consequently, shallow subtidal surfgrass beds in the vicinity of San Clemente Beach will be monitored to determine whether the nourishment project adversely affects shallow subtidal reefs and surfgrass. If adverse significant impacts to surfgrass and/or reef habitat compared to controls and baseline conditions are observed from the monitoring, subsequent nourishment activities will be modified to avoid or minimize these impacts as part of adaptive management. If adverse significant impacts still are observed after all reasonable attempts to avoid or minimize impacts have been exhausted, additional renourishment would not occur until impacted surfgrass has recovered or compensatory mitigation is completed. Compensatory mitigation would consist of the creation of shallow rocky habitat in the immediate vicinity of the project area at a site to be determined in consultation with NOAA Fisheries and CDFW (USACE 2011). Rocky reef habitat would be created at a ratio of one acre of habitat created for each acre of habitat buried (USACE 2011). If the monitoring determines that surfgrass has been affected by the project, an experimental surfgrass restoration would be implemented. Recent studies by researchers at the University of California, Santa Barbara, have demonstrated some success restoring surfgrass using sprigs (Bull et al. 2004; see below).

PRODUCTION VS. ATTRACTION

Artificial reefs have often been proposed as a tool to mitigate impacts to natural reefs. The efficacy of this strategy depends on the extent to which artificial reefs contribute to new production or simply redistribute fish and other biomass (e.g., invertebrates, kelp, etc.) during or after settlement (Pickering and Whitmarsh 1997). Past studies have concluded that artificial reefs likely both increase production and simply redistribute fish biomass without augmenting production. This is because they provide new habitat in an otherwise saturated benthic environment, but also attract fish that would have settled, survived, and grown at comparable rates on natural habitats in its absence (Osenberg et al. 2002).

Though some studies have apparently demonstrated that artificial reefs are capable of acting as production enhancers, others have not, for reasons which may be associated with the design of the reef itself (Pickering and Whitmarsh 1997).



The attraction hypothesis argues that fish are redistributed between natural and artificial reefs and that total biomass production remains the same while the production hypothesis argues that the introduction of artificial reefs raises the total carrying capacity.

- Larger reefs support larger fish and fewer individuals.
- Smaller reefs have greater fish population densities.
- Structural complexity of reefs contributes to biological productivity of reefs.
- Siting location must support the weight of the reef material and not be buried by sediment.
- Currents influence the distribution of pelagic, demersal, and benthic species.

The effectiveness of artificial reefs in increasing productivity depends on the design of a reef structure, in particular whether it meets the specific habitat requirements of individual target species (Pickering and Whitmarsh 1997).

Despite the number of artificial reefs built and evaluated, and the large body of literature on their effectiveness relatively few studies have been dedicated to determining the relative benefits of different designs for production purposes. A number of factors including structure type, design, size, depth of installation, and exposure to currents and nutrients have all been shown to have some at least some effect on the production of artificial reefs (Pickering and Whitmarsh 1997).

ENHANCEMENT AND RESTORATION

Review of enhancement and restoration of rocky subtidal reefs along the western coast of the U.S. has largely been limited to planting of kelp beds or the removal of sea urchins. For example, the Santa Monica Bay Restoration Foundation, with funding and technical assistance from NOAA's Montrose Settlements Restoration Program, began a large-scale kelp forest restoration project in July 2013, aimed at removing urchins from nearly 100 acres of reef habitat off of the Palos Verdes Peninsula, which has experienced a 75 percent decline in kelp canopy due to development, pollution, over-fishing, and a changing ocean climate (NOAA 2014), which has facilitated the development of an "urchin barren."

Similarly, there appear to be few examples of rocky intertidal restoration. A literature search revealed two examples of rocky intertidal habitat restoration, one associated with the Elliot Bay Marina project described above, and one at Colorado Lagoon located in Long Beach, California. The lack of rocky intertidal mitigation projects may be due to the dynamic, high stress environment of this zone, which is strongly influenced by wave action and periodic sand burial. Conditions including wave action, changes in salinity, thermal stress, alternating periods of exposure and submersion, which cannot be easily manipulated by management actions, have necessitated that organisms develop strategies to survive in this stressful environment. Breakwaters and rip rap have been shown to provide low to moderately suitable intertidal habitat; however, studies indicate that artificial intertidal structures do not typical support similar assemblages of mobile intertidal species (Chapman and Blockley 2009; Pister 2009; Davis et al. 2002). Consequently, rather than improving habitat or expanding habitat with artificial structures, the majority of management actions in this habitat type are focused on reducing additional anthropogenic stresses, such as trampling or over-harvesting. However, both the Elliot Bay and Colorado Lagoon projects do offer examples of rocky intertidal mitigation, which have achieved at least moderate success as summarized below.

ROCKY INTERTIDAL AND SURFGRASS ENHANCEMENT AND RESTORATION

Restoration of surfgrass and other rocky intertidal habitats appears to have rarely been attempted, and a literature search returned very few examples. In addition to the projects above that include potential seagrass restoration (e.g., Solana Beach and San Clemente Beach), a comprehensive review of seagrass restoration in the United States (Fonseca et al. 1998) was able to offer only limited guidance on restoration and transplantation of surfgrass. Recently, a few studies have begun to investigate methods to restore surfgrass species (Bull et al. 2004; Holbrook et al. 2002; deWit et al. 1998; Reed et al. 1998).

Exxon Surfgrass Restoration Plan

Exxon prepared a program for surfgrass restoration associated with the Exxon SYU Pipelines (Exxon 1993). The surfgrass restoration efforts described in the plan were designed to fulfill Exxon's obligation for mitigation as required through the Nearshore Marine Biological Impact Reduction Report (MBIRP), as well as specific permit conditions for the Exxon SYU Expansion Project relating to surfgrass restoration.

The field studies portion of the program consisted of implementation and monitoring of four different treatment methodologies designed to restore and promote surfgrass in the armor rock habitat overlying the pipelines in the intertidal and shallow subtidal water of the pipeline construction area offshore the mouth of Corral Creek, in the Santa Barbara Channel.

Lessons Learned

- Recovery of surfgrass following disturbance is slow.
- Long-term burial of hard substrate precludes recovery of surfgrass.
- Outplanting seeds/seedlings is more affective in the subtidal zone than the intertidal.

Monitoring and minor maintenance of treatment cells were set to continue for four years after initiation provided that the treatments demonstrated some level of success. Exxon also planned to fund a 2.5 year laboratory study program to a local research institution to test the viability of seed germination in a laboratory environment.

The field program involved a reconnaissance survey to observe and quantitatively describe the existing conditions with the treatment areas; ascertain the availability of boulders to be used in the treatments; observe and quantitatively describe the natural recover of surfgrass within the inter- and subtidal impact areas; and establish the boundaries of the treatment cells. The treatments consisted of four different treatments totaling approximately .03 acres and included rhizome mats, macroalgae removal, mesh netting to mimic coralline algae (which has been shown to trap surfgrass seeds in situ), and a control cell. Monitoring of the treatment cells and surfgrass mat donor sites was planned to be completed at regular intervals with eight quarterly monitoring surveys over two years and a third and fourth year anniversary survey to monitor continued success and re-establishment of surfgrass in the treatment area.

The results of the studies reinforced the concept that the best mitigation is to avoid impacts to surfgrass beds where possible because natural recovery is likely to be slow due to their annual clonal expansion (Reed et al. 1999). Disturbances that destabilize boulder fields will probably result in loss of surfgrass, even if the plants themselves are not initially damaged. Disturbances that result in long-term (or permanent) burial of the hard substrate in an area will preclude recovery. No amount of elapsed time since disturbance appears likely to compensate for destruction or covering of the necessary hard substrate for surfgrass (Reed et al. 1999).

The studies demonstrated that for a variety of reasons outplanting seeds/seedlings is likely to be more successful in the subtidal zone than the intertidal. The intertidal zone is less accessible for restoration efforts than the subtidal because access to the very low intertidal zones where surfgrass lives is gained only at very low tide. Further, the intertidal may be more stressful for plants and it might be harder for them to establish due to desiccation, thermal or wave stress, or disturbance by people. One possible strategy would be to restore only subtidal zones by outplanting, and let the bed grow upward into the intertidal zone as it matures. It is likely that no matter where restoration efforts take place it will be necessary to protect young seedlings from predation by crabs (e.g., shore crab [*Pachygrapsis crassipes*] and kelp crab [*Pugettia producta*]). Complete recovery (even with successful restoration) of a bed could take on the order of a decade or more, rather than months or a couple of years (Reed et al. 1999).

Surfgrass Restoration along the Western Coast of the United States

A literature search revealed only three sources that describe surfgrass restoration projects (deWit et al. 1998; Holbrook et al. 2002; and Bull et al. 2004), all located in central California. Plugs, sprigs, and seedlings have been used as planting units in these studies, which are described in detail below.

Table 3: Surfgrass Restoration Techniques

Restoration Technique	Study	Description
Plugs as Planting Units	deWit et al. 1998	Initial losses were very high. Of the 105 boulders that were used for transplants, only 22 could be relocated following the first winter's storms. The total area transplanted decreased by 45 percent, but remaining transplants expanded by 57 percent by the end of the study. Loss of transplant substrate (boulders) due to sand coverage, detachment of transplant units by turbulence, predation by urchins and shading by kelp were identified as the major limiting factors to transplant persistence and expansion.
	Bull et al. 2004	Most transplanted plugs survived after 6 months, but survival varied with size. Small and medium sized plugs had 100 percent survival during the experiment and rhizome coverage increased significantly in the intertidal for small plugs and in the subtidal for medium plugs. Five of the six large plugs in the intertidal zone were dislodged within days of the beginning of the experiment. Although survival of plugs was highest, the potential for donor bed degradation and the cost of preparing the transplanting unit make this technique the least promising.
Sprigs as Planting Units	Bull et al. 2004	This study near Santa Barbara, California compared the effectiveness of different types of surfgrass planting units. Sprigs were harvested from the periphery of an established bed with a knife and transplanted immediately after collection using marine epoxy putty. Loss of transplanted sprigs appeared to be from necrosis and loss of leaves rather than being dislodged. The number of leaves increased nearly 200 percent by the end of the 6- month experimental period. Rhizome coverage increased by 42 percent in the intertidal, and by 86 percent in the subtidal. By the end of the experiment, cut rhizomes at the donor site (where sprigs had been harvested from the edge of the bed) had re-grown to nearly equal the area lost to harvest.
Seedlings as Planting Units	Bull et al. 2004	Seedlings were sprouted in the laboratory and prepared for transplanting approximately one month after germination. Seedlings were secured to a double-braided nylon line, which was transported to the transplant site in plastic bags filled with sea water. Marine epoxy putty was used to attach each transplant unit onto rock that was cleared of algae and sand. Transplants occurred in both intertidal and subtidal zones; survival and growth of the transplants as well as recovery at the donor site were monitored for six months. Only one and two percent of the seedlings survived in the subtidal and intertidal zones, respectively. However, the number of leaves in the few surviving seedlings increased by nearly 300 percent and plants had developed small rhizomes by the end of the six-month study period.

Restoration Technique	Study	Description
	Hollbrook et al. 2002	This study compared survival rates of seedlings 1) recruited naturally; 2) placed on nylon string; and 3) placed on nylon mesh. Highest survival rates (30 percent) were observed in naturally recruited seedlings, followed by seedlings attached to nylon mesh (20 percent), and 10 percent for seedlings attached to nylon string. The increased survival of seedlings on the nylon mesh substrate may have been due to higher seedling densities and reduced losses to abrasion and dislodgement resulting from the direct attachment of the mesh to the substrate.

Selection of an appropriate site is probably the single most important decision in the surfgrass restoration planning process (Fonseca et al. 1998). If historical records indicate a lack of surfgrass presence at the proposed restoration site, the site should be considered marginal at best, and should probably be rejected. For further information on planning and implementing surfgrass restoration projects, see Fonseca et al. (1998). Incorporating research into individual restoration projects would allow for more rapid development of successful restoration techniques, and identify factors limiting restoration success. The results of these experiments could be used to improve the success of future surfgrass restoration projects.

Given the amount of information currently available, transplanting sprigs seems to be the most cost efficient and effective mode of transplanting surfgrass into both intertidal and subtidal zones in central California.

Elliot Bay Rocky Intertidal Habitat Mitigation

Development of a 1,200-slip marina in Puget Sound, Washington, including filling and loss of 10 acres of gravel/cobble beach, required the construction of rocky intertidal habitat to offset the loss of rearing habitat import to outmigrating juvenile salmon (Cheney 1994). A detailed habitat mitigation plan for the marina was prepared in 1987. Mitigation to compensate for losses of fish rearing habitat included creation of approximately eight acres of rocky beach and kelp habitat ranging between zero and eight feet below MLLW. The rocky habitats were constructed by spreading approximately 18,000 cy of cobbles four to eight inches in diameter (Cheney 1994). Project performance standards for the restoration effort were based on the aerial extent of mitigation habitats and the productive values of those habitats.

The principal measure of productivity was the abundance and diversity of epibenthic species (i.e., species living or associated with the bottom). These epibenthic species are consumed preferentially by juvenile salmonids, flatfish, other fish, and invertebrates. A process based on the USFWS Habitat Evaluation Procedure was used to calculate changes in epibenthic food resources due to project development, and to determine the area required for the mitigation habitat (Cheney et al. 1994). Post-project monitoring of all mitigation and control sites began in early 1991 and continued through 1996;

Lessons Learned

- Restoration of rocky intertidal habitat has demonstrated moderate success in mitigating impacts to anadromous fish species.
- Given the proximity of Trancas Creek and the Zuma Wetlands, both potential locations for southern steelhead habitat restoration, this type of compensatory mitigation could be particularly appealing for the proposed nourishment project at Broad Beach.

epibenthic samples were taken and analyzed using standard zooplankton sorting methods. Sampling demonstrated that various species of kelp and green algae were colonizing the mitigation rock in all areas and distribution and density of macro-algae generally increased where suitable uncolonized substrates were available. Additionally, fish were observed utilizing mitigation substrates, including several small groupings of juvenile chum salmon. The mitigation habitat met its performance criteria over the short-term by providing interstitial refuge for epibenthic organisms and structure for the attachment of algae. In fact, prey densities in the control area remained low in comparison with the mitigation areas during February and April 1991. Consequently, the project demonstrated that the mitigation goal to replace "in-kind" food resource production on intertidal and subtidal cobble and gravel habitats appears to be feasible, at least in the short term (Cheney et al. 1994).

Colorado Lagoon Mitigation Bank

The Port of Los Angeles has proposed a mitigation bank at the Colorado Lagoon as compensatory mitigation for future aquatic impacts incurred by other projects that would fall within the proposed service area from the Palos Verdes Peninsula to the Bolsa Chica Wetlands (USACE 2014). The mitigation bank would also functionally provide for the final restoration of the Colorado Lagoon. The proposed mitigation bank concept is to construct an open earthen tidal channel for the connection between Colorado Lagoon and Marine Stadium, to replace the existing underground culvert. Bridges would be constructed along both Eliot Street and Colorado Street, over the open channel. By constructing an open channel of sufficient size and depth, the tidal exchange between Colorado Lagoon and Marine Stadium would be improved. The proposed mitigation bank would result in the restoration of the following habitats and areas:

- Phase 2a Open Channel: approximately 2.4 acres of tidal habitat and 2.3 acres of buffer within the open channel footprint as well as 0.4 acre of intertidal habitat and 18 acres of enhancement at Colorado Lagoon.
- Phase 2b Lagoon Recontouring: approximately 1.8 acres of subtidal eelgrass habitat, 1.5 acres of intertidal and shallow soft-bottom subtidal habitat, 4.5 acres of shallow subtidal habitat for potential suitable eelgrass recruitment, and 1.8 acres of buffer.

The channel section under the bridges would be narrower with steeper slopes, so as to minimize the length and cost of the bridges. Therefore rock slope protection would be necessary; however, this rock slope area, which would cover approximately 0.4 acres, may support a variety of mobile and sessile invertebrate organisms and a variety of red, green, and brown macroalgal species (USACE 2014).

The proposed mitigation bank is still in the planning and design phases. The public comment period on the application for this mitigation bank closed in March 2014 (USACE 2014).

EELGRASS ENHANCEMENT AND RESTORATION

Eelgrass vegetated areas are recognized as important ecological communities in shallow bays and estuaries because of their multiple biological and physical values. Eelgrass habitat functions as an important structural environment for resident bay and estuarine species, offering both predation refuge and a food source. Eelgrass functions as a nursery area for many commercially and recreational important finfish and shellfish species, including those that are resident within bays and estuaries, as well as oceanic species that enter estuaries to breed or spawn. Eelgrass also provides a unique habitat that supports a high diversity of non-commercially important species whose ecological roles are less well understood (NOAA 1991).

NOAA Eelgrass Mitigation Policy

In order to standardize and maintain a consistent policy regarding mitigating adverse impacts to eelgrass resources, the following policy has been developed by the federal and state resource agencies (National Marine Fisheries Service [NMFS], USFWS, and the CDFW). While the intent of this policy is to provide a basis for consistent recommendations for projects that may impact existing eelgrass resources, there may be circumstances (e.g., climatic events) where flexibility in the application of this policy is warranted. As a consequence, deviations from the stated Policy may be allowed on a case-by-case basis (NOAA 1991).

Table 4: NOAA Eelgrass Mitigation Policy

Mitigation Requirements	
Mitigation Need	Eelgrass transplants shall be considered only after the normal provisions and policies regarding avoidance and minimization, as addressed in the Section 404 Mitigation Memorandum of Agreement between the Corps of Engineers and Environmental Protection Agency, have been pursued to the fullest extent possible prior to the development of any mitigation program. Mitigation will be required for the loss of existing vegetated areas, loss of potential eelgrass habitat, and/or degradation of existing/potential eelgrass habitat.
Mitigation Map	The project applicant shall map thoroughly the area, distribution, density, and relationship to depth contours of any eelgrass beds likely to be impacted by project construction. This includes areas immediately adjacent to the project site which have the potential to be indirectly or inadvertently impacted as well as potential eelgrass habitat areas. Potential habitat is defined as areas where eelgrass would normally be expected to occur but where no vegetation currently exists. Factors to be considered in delineating potential habitat areas include appropriate circulation, light, sediment, slope, salinity, temperature, dissolved oxygen, depth, proximity to eelgrass, history of eelgrass coverage, etc.
Mitigation Site	The location of eelgrass transplant mitigation shall be in areas similar to those where the initial impact occurs. Factors such as, distance from project, depth, sediment type, distance from ocean connection, water quality, and currents are among those that should be considered in evaluating potential sites.
Mitigation Size	In the case of transplant mitigation activities that occur concurrent to the project that results in damage to the existing eelgrass resource, a ratio of 1.2 to 1 shall apply. That is, for each square meter adversely impacted, 1.2 square meters of new suitable habitat, vegetated with eelgrass, must be created. An exception to the 1.2 to 1 requirement shall be allowed when the impact is temporary and the total area of impact is less than 100 square meters. Mitigation on a one-for-one basis shall be acceptable for projects that meet these requirements (see section 11 for projects impacting less than 10 square meters).

Mitigation Requirements	
Mitigation Technique	Techniques for the construction and planting of the eelgrass mitigation site shall be consistent with the best available technology at the time of the project. Donor material shall be taken from the area of direct impact whenever possible, but also should include a minimum of two additional distinct sites to better ensure genetic diversity of the donor plants. No more than 10 percent of an existing bed shall be harvested for transplanting purposes. Plants harvested shall be taken in a manner to thin an existing bed without leaving any noticeable bare areas. Written permission to harvest donor plants must be obtained from CDFW. Plantings should consist of bare-root bundles consisting of eight to 12 individual turions. Specific spacing of transplant units shall be at the discretion of the project applicant. However, it is understood that whatever techniques are employed, they must comply with the stated requirements and criteria.
Mitigation Timing	For off-site mitigation, transplanting should be started prior to or concurrent with the initiation of in-water construction resulting in the impact to the eelgrass bed. Any off-site mitigation project which fails to initiate transplanting work within 135 days following the initiation of the in-water construction resulting in impact to the eelgrass bed will be subject to additional mitigation requirements. For on-site mitigation, transplanting should be postponed when construction work is likely to impact the mitigation. However, transplanting of on-site mitigation should be started no later than 135 days after initiation of in-water construction activities. A construction schedule which includes specific starting and ending dates for all work including mitigation activities shall be provided to the resource agencies for approval at least 30 days prior to initiating in-water construction.
Mitigation Delay	If, according to the construction schedule or because of any delays, mitigation cannot be started within 135 days of initiating in-water construction, the eelgrass replacement mitigation obligation shall increase at a rate of seven percent for each month of delay. This increase is necessary to ensure that all productivity losses incurred during this period are sufficiently offset within five years.
Mitigation Monitoring	Monitoring the success of eelgrass mitigation shall be required for a period of five years for most projects. Monitoring activities shall determine the area of eelgrass and density of plants at the transplant site and shall be conducted at initial planting, six, 12, 24, 36, 48, and 60 months after completion of the transplant. All monitoring work must be conducted during the active vegetative growth period and shall avoid the winter months of November through February. Sufficient flexibility in the scheduling of the 6 month surveys shall be allowed in order to ensure the work is completed during this active growth period. Additional monitoring beyond the 60 month period may be required in those instances where stability of the proposed transplant site is questionable or where other factors may influence the long-term success of transplant.
Mitigation Success	Criteria for determination of transplant success shall be based upon a comparison of vegetation coverage (area) and density (turions per square meter) between the adjusted project impact area (i.e., original impact area multiplied by 1.2) and mitigation site(s). Extent of vegetated cover is defined as that area where eelgrass is present and where gaps in coverage are less than one meter between individual turion clusters. Density of shoots is defined by the number of turions per area present in representative samples within the original impact area, control, or transplant bed.

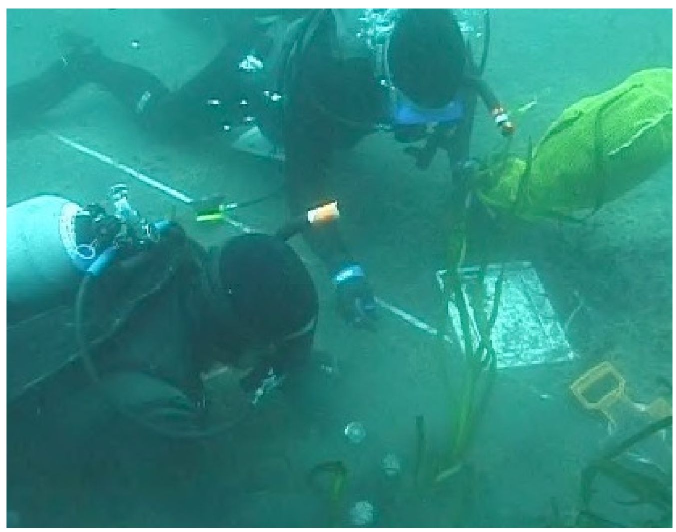
Source: NOAA 1991.

In Southern California, eelgrass has been severely impacted by increased turbidity, dredging, construction, and pollution within its habitat of shallow bays and coastal lagoons (Merkel 1991). Environmental laws such as the Clean Water Act require mitigation for any construction project that might impair eelgrass beds and wetland habitat, and eelgrass mitigation policies have required enhancement or restoration of beds at ratios of 1.2 to 1 (NOAA 1991). Between 1976 and 1997, there were 36 eelgrass transplant projects in California (NMFS 1997). Almost without exception these projects occurred as mitigation for coastal development. Unfortunately, the same pollution associated with growing development pressures that impacts the native beds or habitat also negatively impacts the transplanted or restored beds; some report that as few as 10 to 60 percent of transplantation efforts are successful (Goforth and Peeling 1978; NMFS 1997). Moreover, there have been no restoration efforts conducted in relatively pristine waters; all work has been associated with coastal pollution (Short and Wylie-Echeverria 1996).

In addition to the proposed Colorado Lagoon Mitigation Bank, discussed above, restoration of eelgrass has been accomplished in Frenchy's Cove and is proposed as a part of the Port of Los Angeles Umbrella Mitigation Agreement.

Frenchy's Cove

In a cooperative effort between the Santa Barbara Channelkeeper, the Channel Islands Research Program (CIRP), and NOAA Fisheries' Community-based Restoration Program, Frenchy's Cove, Anacapa Island, was chosen for a pilot restoration study of an eelgrass bed that had previously been decimated by white urchin overgrazing in the 1980s (Alstatt 2003). The primary objective of this pilot study was to test eelgrass restoration techniques in a relatively pristine habitat, free from human-induced disturbance. Both harvesting and transplanting work occurred in July 2002. Transplants were harvested by divers from large beds (i.e., Smugglers Cove and Prisoners Harbor) near the east end of nearby Santa Cruz Island (Alstatt 2003). These beds were selected based on their proximity to Anacapa Island, and their large size. Plants were harvested from three locations within each bed (i.e., shallow edge, middle of bed, and deep edge) to maximize genetic diversity (Williams and Davis 1996).



Eelgrass restoration at Frenchy's Cove demonstrated success in the absence of brittlestars, which unexpectedly affected the initial planting of eelgrass.

Eelgrass was planted into four different areas corresponding to depth using an adaptation of a planting technique developed by Orth et al. (1999). To prepare the sediment for the rhizome, divers used a knife or other objects to dig a small trench. Once this sediment was loosened by the knife, a shoot was pushed into the trench so that the root hairs and rhizome were in the loose sediment and the shoot was erect. The study site was visited every one to two months and numbers of shoots were counted. Sixteen months after transplanting, in the absence of disturbance from brittlestars, eelgrass shoots surpassed initial transplant densities in shallow plots. In the absence of disturbance from brittlestars and grazers, the transplanted shoots in shallow water spread quickly. Seedlings first found in March 2003 surveys continued to appear into early summer and survival was better than expected, although rhizomes exposed by sediment erosion appeared to be one potential cause or seedling loss. Monitoring will continue at the site at regular intervals to track survival and growth of the pilot bed, and to more closely track seedling survival in the future. Based on the findings thus far, it is expect that further expansion of the patches in shallow water will be observed in the future (Alstatt 2003).

Port of Los Angeles Umbrella Agreement

The majority of mitigation projects described in this report are permittee-responsible compensatory mitigation (e.g., SONGS) or in-lieu fee mitigation (e.g., Exxon SYU). While mitigation banks are widely used for wetland habitat types, to date none of the mitigation banks approved by USACE have been developed for offshore aquatic habitat, including eelgrass. However, in addition to the proposed Colorado Lagoon Mitigation Bank, discussed previously, the Los Angeles Harbor Department has proposed to develop a single-user umbrella mitigation bank agreement. The agreement would:

- Establish an umbrella mitigation bank agreement;
- Establish a mitigation credit valuation process for each proposed habitat typed base on an approved functional assessment methodology or direct impact/mitigation ration approach;
- Establish an approach to determining adequate financial assurances for long-term maintenance and management of each mitigation bank site;
- Establish requirements for long-term mitigation bank site protection; and
- Establish requirements for long-term mitigation bank site maintenance, monitoring, and adaptive management.

Habitats included in the agreement would include harbor habitat, wetlands, eelgrass, and other habitat types, potentially rocky subtidal reef habitat. Eelgrass habitat credits would compensate for impacts to eelgrass within the harbor and would be credited pursuant to current policy (Prickett 2013).

PRESERVATION

Passed by the California State Legislature in 1999, the Marine Life Protection Act (MLPA) required the California Department of Fish and Wildlife to redesign its system of MPAs to increase its coherence and effectiveness at protecting the state's marine life, habitats, and ecosystems. For the purposes of MPA planning, a public-private partnership commonly referred to as the MLPA Initiative was established, and the state was split into five distinct regions (four coastal and the San Francisco Bay) each of which had its own MPA planning process. All four coastal regions have completed these individual planning processes. As a result the coastal portion of California’s MPA network is now in effect statewide. Options for a planning process in the fifth and final region, the San Francisco Bay, have been developed for consideration at a future date (CDFW 2013).

There are different marine managed areas classifications used in California's MPA network including three MPA designations, a marine recreational management area, and special closures:

State Marine Reserve (SMR). In these areas it is unlawful to injure, damage, take, or possess any living geological, or cultural marine resource, except under a permit or specific authorization from the managing agency for research, restoration, or monitoring purposes. While, to the extent feasible, the area shall be open to the public for managed enjoyment and study, the area shall be maintained to the extent practicable in an undisturbed and unpolluted state. Access and use for activities including, but not limited to, walking, swimming, boating, and diving may be restricted to protect marine resources. Research, restoration, and monitoring may be permitted by the managing agency. Educational activities and other forms of nonconsumptive human use may be permitted by the designating entity or managing agency in a manner consistent with the protection of all marine resources (CDFW 2013).

State Marine Park. In these areas it is unlawful to injure, damage, take, or possess any living or nonliving marine resource for commercial exploitation purposes. Any human use that would compromise protection of the species of interest, natural community or habitat, or geological, cultural, or recreational features, may be restricted by the designating entity or managing agency. All other uses are allowed, including scientific collection with a permit, research, monitoring, and public recreation, including recreational harvest, unless otherwise restricted. Public use, enjoyment, and education are encouraged, in a manner consistent with protecting resource values (CDFW 2013).

State Marine Conservation Area (SMCA). In these areas, it is unlawful to injure, damage, take, or possess any living, geological, or cultural marine resource for commercial or recreational purposes, or a combination of commercial and recreational purposes, that the designating entity or managing agency determines would compromise protection of the species of interest, natural community, habitat, or geological features. The designating entity or managing agency may permit research, education, and recreational activities, and certain commercial and recreational harvest of marine resources (CDFW 2013).

State Marine Recreational Management Area. In these areas, it is unlawful to perform any activity that, as determined by the designating entity or managing agency, would compromise the recreational values for which the area may be designated. Recreational opportunities may be protected, enhanced, or restricted, while preserving basic resource values of the area. No other use is restricted. The Fish and Game Commission may designate, delete, or modify state marine recreational management areas for hunting purposes (CDFW 2013).

Special Closure. A special closure is an area designated by the Fish and Game Commission that prohibits access or restricts boating activities in waters adjacent to sea bird rookeries or marine mammal haul-out sites (CDFW 2013).

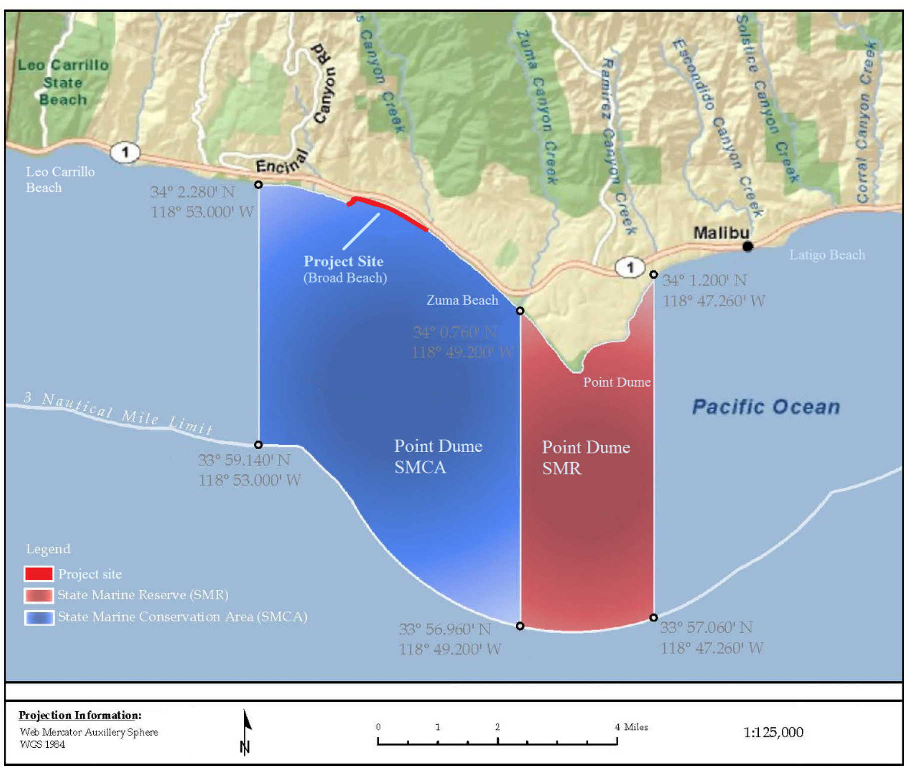
The Broad Beach project site is located within the South Coast Region, which covers approximately 2,351 square miles of state waters from Point Conception (Santa Barbara County) south to the California/Mexico border, including state waters around the Channel Islands. A network of 50 MPAs covers approximately 355 square miles of state waters or about 15 percent of the South Coast Region (see Table 5) (CDFW 2013).

Table 5: Marine Protected Areas in the South Coast

Type of Protected Area	Number	Area in South Coast State Waters (sq mi)	Percent of Total South Coast State Waters
SMR	19	241.5	10.3%
SMCA (no-take)	11	33.6	1.4%
SMCA	20	80.4	3.4%
Special Closures	2	1.9	0.1%
Total	50	355.4	15.12%

Source: CDFW 2013.

Broad Beach is located within one of two newly created MPAs encompassing the Point Dume area, established on 1 January 2012 and totaling approximately 23 square miles (CDFW 2013). The first area, the Point Dume State Marine Conservation Area SMCA, extends from Encinal Canyon in the north to Westward Beach in the south. The Point Dume State Marine Reserve (SMR) incorporates an area of offshore reefs, a submarine canyon (Dume Canyon), and a kelp forest that is popular with kayak fishers and the diving community. Although access to the entire Point Dume area remains open to scuba diving, boating, and other recreational activities, the take of all living marine resources within this area is prohibited. The second preserve, the Point Dume SMR begins at Westward Beach, and continues around Point Dume to the west end of Paradise Cove. Within the Point Dume SMCA, fishing activities are also restricted, but not banned entirely; the recreational taking of pelagic finfish (i.e., thresher sharks, barracuda, and dolphinfish) is allowed, as well as the take of white sea bass and Pacific bonito by spear fishing. Limited commercial fishing of coastal pelagic fish (like squid) is permitted in the SMCA but is restricted to capture by round-haul net.



Source: CDFW 2011.

Other nearby MPAs include 10 marine reserves and two conservation areas created within the Channel Islands National Marine Sanctuary (CINMS), a California Fish and Game Commission approved comprehensive marine zoning network.

However, as preservation (e.g., the establishment of reserves or MPAs) does not result in a net gain of aquatic habitats, public agencies generally only use this approach to compensatory mitigation in exceptional circumstances. Preservation is best applied in conjunction with restoration and/or enhancement of ecological functions and values and rarely as the sole means of compensation (Ugoretz 2005).

A literature search revealed no readily available examples of in-kind preservation of aquatic habitat as mitigation for offshore impacts. This may be attributed to the public ownership of offshore lands and/or difficulty in consensus building. The California Regional Water Quality Control Board Technical Work Group (TWG) evaluated several strategies for mitigation impacts resulting from the cooling water impacts associated with the Pacific Gas and Electric Company Diablo Canyon Nuclear Power Plant. The TWG evaluated aspects of the MPA option, including ecological benefits, likelihood of success, process for implementation, and costs. However, while the revised technical working group report continues to support the establishment of MPAs, the CDFW does not believe that the development and implementation of MPAs should be the primary mitigation measure associated with the operation of the cooling system. CDFW argued that while MPAs have been established for a variety of reasons in California, they have never as mitigation for direct or indirect damage caused by power plants. CDFW believes that MPAs could be an integral part of the overall mitigation package, but should not be considered as the primary form of compensatory mitigation (Ugoretz 2005).

COMPENSATORY MITIGATION RATIOS

According to the USACE Mitigation Rule, compensatory mitigation should be sufficient to replace the lost aquatic resource functions as assessed using an appropriate functional or condition assessment, when available.

33 CFR 332.3(f)

"If the district engineer determines that compensatory mitigation is necessary to offset unavoidable impacts to aquatic resources, the amount of required compensatory mitigation must be, to the extent practicable, sufficient to replace lost aquatic resource functions. In cases where appropriate functional or condition assessment methods or other suitable metrics are available, these methods should be used where practicable to determine how much compensatory mitigation is required. If a functional or condition assessment or other suitable metric is not used, a minimum one-to-one acreage or linear foot compensation ratio must be used."

If a suitable assessment method or other metric is not available, a minimum of a one-to-one acreage mitigation ratio must be used (USACE 2013). In most cases, the ratio used is the area of aquatic resource to be mitigated in relation to the area of aquatic resource impacted. While other ratios are possible (e.g., metrics of functional gain to loss), area has been the predominant ratio. However, commonly, agencies have required a ratio greater than 1:1 mitigation ratio, in part due to scientific observations that compensatory mitigation sites often provide reduced functions compared to the impacted aquatic resources, particularly in the case of in-lieu compensatory mitigation. Additional variables such as temporal loss, the difficulty of restoring the aquatic resource type, and the distance from the impact site also would affect how much compensatory mitigation would be required for specific projects (USACE 2013).

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