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Analysis of Eelgrass and Shallow Water Habitat Restoration Programs Along the North American Pacific Coast: Lessons Learned and Applicability to Oakland Middle Harbor Enhancement Area Design

Prepared for:

MIDDLE HARBOR ENHANCEMENT AREA HABITAT TECHNICAL ADVISORY COMMITTEE

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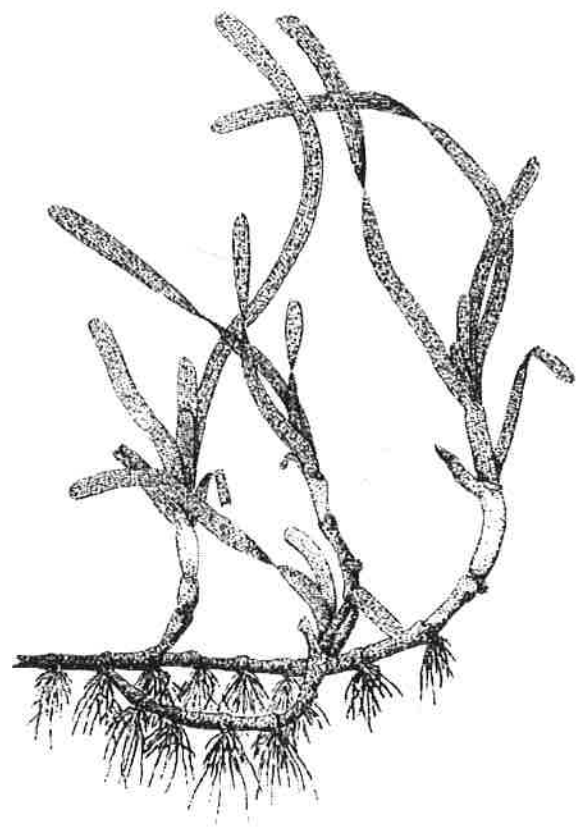

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INTRODUCTION

The Port of Oakland proposes to make a beneficial reuse of some of the dredged material from its 50-foot Harbor deepening project to restore habitat within the approximately 190 acre Oakland Middle Harbor. A restoration plan was developed for the site by Merkel & Associates acting under the direction of the Middle Harbor Habitat Technical Advisory Committee, a multi-agency, environmental group, and citizens advisory. This work would involve placement of approximately 7 million cubic yards of dredged sediments to create a gradually sloping shallow flat and channel array with the objective to create shallow water habitat and promote eelgrass habitat within San Francisco Bay. A portion of the site would also yield mudflat and intertidal marsh, beaches, rocky shore habitat and bird roosting areas (both island and shoreline locations).

Restoration projects similar to several of the smaller elements of the project, including marshes, beaches, and bird roosting areas have been successfully demonstrated throughout the bay area and within other regions. Further, these elements are relatively small components of the overall restoration proposed at Middle Harbor. However, no substantive efforts have been undertaken within San Francisco Bay to restore shallow flats, and only one known effort has been made to restore eelgrass in the bay. Due to a lack of experience with shallow water restoration projects and the past poor performance of the Richmond Harbor Training Jetty transplant experiment, there is reasonable concern that restoration techniques be demonstrated to be adequate. Further, the Middle Harbor Enhancement Area (MHEA) design, engineering, and construction processes should make use of information gained from prior restoration programs to improve the overall benefits returned from this project.

This document explores prior project records and analyzes the successes and failures of restoration on the Pacific coast. Lessons learned from these efforts have also been summarized to provide guidance for appropriate design and construction of the MHEA. In addition to individual projects, review articles addressing restoration efforts have been reviewed for added insight into restoration project successes and failures.

METHODS

The evaluation of the successes and failures of prior shallow water and eelgrass restoration projects, was based on information contained in review articles, project design reports, permits, and monitoring reports addressing such projects. Additional information was obtained by directly contacting restoration experts, regulatory agency staff, and researchers. These personal contacts, were made with the added objective of soliciting additional sources of information. To develop a document scope of manageable size from the hundreds of available projects, review was restricted to those in the Pacific Coast of North America. Of those, only projects of commercial size (not necessarily commercial projects), with the goal of restoration of eelgrass or shallow water habitats were reviewed. Excluded were transplants that were extremely small or which were performed for the purpose of ecological research not related directly to restoration objectives. Projects that resulted in an ancillary byproduct of eelgrass or shallow water restoration were also excluded.

For shallow water restoration projects not involving eelgrass, only those which significantly altered bottom elevations and which created subtidal shallow water habitat as a major restoration element were considered in this review. This analysis criteria excluded several deep disposal sites and shallow water confined aquatic disposal (CAD) sites which were capped by only a few feet of sediment, as well as marsh and mudflat restoration projects which had only ancillary shallow water creation associated with the projects.

Experimental projects and ancillary restoration projects were not considered proper for analysis because they lacked focused information assessing the restoration aspects of the work and had limited applicability to assessment of success or failure of the restoration techniques as a whole. Initially, only restoration efforts in excess of 10 acres were intended for analysis, however, so few examples existed that such a restriction would have sacrificed the value of the document as an information and teaching tool. Additionally, through this analysis it appears that size of the restoration project has more effect on the economics of restoration than on the intrinsic science and design. As such, any size project, whether successful or unsuccessful, has valuable information.

RESULTS

When project screening was completed, 45 eelgrass restoration projects (13 involving shallow water fills), and 2 shallow water restoration sites (not including eelgrass), were included in this review (Table 1). The location of projects identified and included in this review are exhibited in Figure 1 and are denoted by numbers corresponding to Table 1 identification numbers. Eelgrass projects were reviewed for several factors including compliance with permit requirements, successful eelgrass restoration, net changes in eelgrass cover, and successes and failures based on site selection and manipulation methods. Both shallow water habitat creation projects reviewed in this paper were port mitigation projects. These were reviewed for permit compliance and success or failures in design, construction, or physical and biological performance.

Table 1 is organized by year in which restoration was conducted. Thus, multi-phase projects may span several years. The table also identifies the type of project followed by a short description of the restoration work. Where applicable, permit objectives are noted. These objectives may be based on formal permits, memoranda between agencies, consistency determinations, or biological opinion terms and conditions. In addition, other objectives are also included which reflect non-compulsory goals of a project. These frequently include research and studies integrated into a project as an adjunct to the primary purpose.

The relevant results of the reviewed project are briefly summarized. Short reference document identification corresponds to more formal citations found within the References section of this report (Table 1). Analyses of project restoration approaches and general themes to the successes and failures are discussed within the Analysis and Discussion section of this paper.

Projects examined ranged a period of 22 years from 1976 through 1998 and the extent and quality of information available ranged from as little as faint recollection to detailed project background, permits, construction plans and specifications, and a full set of monitoring reports. In general, but not always, more recent projects had better and more complete files available for analysis. Projects presently being completed or which have recently been completed have been excluded from some analyses on success achievement since it is too early to fully assess the monitoring outcome. Notwithstanding on-going monitoring for projects which were completed one or more years ago, probable results have been included in trend analyses based on the current reported project status and a prognosis by experts.

All eelgrass restoration projects reviewed in this document have included transplantation of eelgrass from native donor beds. However, the methods of transplant have varied and have included sediment plugs (native sediment blocks cut from a native bed and containing intact root-rhizome complexes), individual shoots (eelgrass shoot-rhizome units harvested from sediment and moved bareroot), and bareroot units (anchored or unanchored bundles of individual shoots. The relative frequency at which the various planting units have been used has changed over time with a reduction in the number of sediment plug units and an increase in the number of projects completed with bareroot units. Individual shoot transplants have generally been limited to smaller restoration efforts and have not been widely used in any capacity at any time in the history of transplanting. However, experimental tests of new transplant techniques are being conducted as an adjunct to the Navy Eelgrass Mitigation Site - 5 (NEMS-5) project, #39 in Table 1. Single shoot and individual rhizome transplant materials are being investigated as a means to improve efficiency in restoration of large sites. Some of the projects have made use of small pilot restoration programs to determine the best locations for conducting larger scale transplants within the same site. This has been done to minimize program inefficiencies, reduce costs and impacts on donor beds, and to aid in selecting specific key sites to target efforts to promote natural expansion from seed and vegetative growth of transplants. This approach has been taken within Batiquitos Lagoon (#34 in Table 1).

Table 1. Eelgrass and Shallow Water Habitat Restoration Programs Conducted Along the North American Pacific Coast (1976 to 1998).

	SITE	YEAR	DESCRIPTION	OBJECTIVES	RESULTS	REFERENCES
1	Pier Bravo Munitions Pier Eelgrass Mitigation Project San Diego Bay, CA	1976	*Eelgrass Transplant Unmanipulated Site* The Navy conducted eelgrass mitigation for dredging impacts to eelgrass resulting from pier construction. This is the first commercial scale eelgrass restoration that we are aware of on the west coast. Plants were planted in unvegetated and unmanipulated shoreline sites in northern San Diego Bay. Plants were sediment plugs that were planted as both 'bare plugs as well as plugs in peat pots.	**Permit:** Attempt to transplant one-third (approx. 700 square feet of the eelgrass within the proposed dredging area. **Other:** Assessment of the cost and techniques employed in the work.	1. Restoration was not successful. Plugs and peat pots were eroded from high energy areas while deep sites suffered due to steep slope erosion and light limitations 2. Restoration costs were $25/planting unit.	Transplantation of Eelgrass in San Diego Bay Robilliard, G.A. and P.E. Porter 1976
2	Delta Beach Expansion Eelgrass Mitigation Coronado Island, San Diego Bay, CA	1977	*Eelgrass Restoration on Shallow Beach Fills* A Navy training beach on the Silver Strand was widened impacting 3.5 acres of eelgrass. As a term of a MOU developed under Fish and Wildlife Coordination Act Section 2B, a 6 acre shallow flat was created as a part of the widening and was planted with 12,000 eelgrass sediment plugs.	**Permit:** Create shallow flat and plant eelgrass following recommended methods of Robilliard and Porter pilot study, underway at the time. Conduct monitoring at 6 months and annually thereafter until eelgrass is established.	1. The shallow flat was not constructed as large as it should have been and elevations were not well controlled 2. Eelgrass restoration was moderately successful but failed to meet the targeted 3.5 acre goal.	MOU Among the Dept. of Navy, Dept. of Army, USFWS, NMFS, and CDFG June 10, 1976 Hoffman, R.S.. 1998, pers. Comm.
3	Newport Bay, West Jetty Newport Beach, CA	1980	*Eelgrass Restoration on Unknown Substrate* A small eelgrass transplant was conducted using sediment plugs for mitigation of a U.S. Army Corps of Engineers project	**Permit:** Un-locatable	Partial success no net change in eelgrass coverage	Summary of Eelgrass (Zostera marina) Transplant Projects, California 1976-1997. Hoffman, R.S.. 1998.
4	Humboldt Bay, CA	1982	*Eelgrass Transplant Unmanipulated Site* A small eelgrass transplant using individual shoots was conducted within an area in outer Humboldt Bay that lacked eelgrass. Habitat was intertidal.	**Permit:** Un-locatable	Eelgrass survived for several months and was subsequently wiped out by winter storms.	Thom, R.M. 1990. A Review of Eelgrass (Zostera marina L.) Transplanting Projects in the Pacific Northwest The Northwest Env. Journal 6:121-137
5	Roberts Bank Superport, Vancouver, B.C.	1982-83	*Eelgrass Transplant on Damaged Intertidal Site* An eelgrass transplant using a variety of planting units and techniques was done as a pilot to a large scale restoration program.	**Permit:** No conditions beyond study project was to serve as pilot for future mitigation **Other:** Research on restoration options, success/failures, and economies of transplant	Transplants grew and expanded well in some plots transplants in some plots suffered from desiccation Erosion and sedimentation was a problem. Economics favor bareroot transplants, and eelgrass restoration appears viable . Large-scale restoration not yet been completed.	Experimental Eelgrass Transplants in Southwestern British Columbia, Canada Harrison, P.G., 1988 Proceeding of the California Eelgrass Symp. May 1988
6	Bodega Harbor, CA	1984	*Eelgrass Transplant Unmanipulated Site* Eelgrass was planted on a shallow subtidal flat and channel bank to mitigate for dredging impacts to 3.3 acres of eelgrass. A total of 11,000 sq. meters was planted. Plantings were monitored for 2 years.	**Permit:** Un-locatable	1. Plantings on shallow flats had 40% survival and achieved 90% cover over a 74% greater area than planted. A rich biotic community developed in the transplant site. Channel banks had only 5% survival and 10% cover.	Thom, R.M. 1990. A Review of Eelgrass (Zostera marina L.) Transplanting Projects in the Pacific Northwest The Northwest Env. Journal 6:121-137 Connors, P. 1986. Large-Scale Eelgrass Transplant Studies, Bodega Harbor, California

	SITE	YEAR	DESCRIPTION	OBJECTIVES	RESULTS	REFERENCES
7	Pier 300 Los Angeles Harbor Shallow Water Mitigation Area Los Angeles Harbor	1984-85	*Deep Water Fill to Shallow Depths for Habitat* As mitigation for 190 acres of fastland fill, the Port of L.A. constructed a 190 acre shallow water plateau (<20 ft. deep) within deep waters (-30+ ft.) of L.A. Harbor. The fill was constructed near the Terminal Island least tern site to serve as an enhancement to tern foraging	**Permit:** Create shallow water from deep water on a 1:1 areal extent basis and provide least tern colony management to mitigate for losses of harbor surface area foraging opportunities	The project was successful in meeting objectives shallow water was created and has proven to be an enhanced foraging area for least terns, particularly during post hatching when smaller fish are needed and shorter trips from the nest are critical to provide food and protection to young Shallow water was determined to be more productive for fish than deeper waters of the harbor	J. Fancher, USFWS, pers comm. 8/98 R. Appy, POLA, pers. comm. 8/98 K. Keane, pers. comm. 7/98 Biological Baseline and Ecological Evaluation of Existing Habitats in Los Angeles Harbor and Adjacent Waters MEC Analytical 1988
8	City of Morro Bay Anchorage Area Eelgrass Mitigation Program Morro Bay, CA	1985	*Eelgrass Transplant Unmanipulated Site* An eelgrass transplant was conducted to compensate for eelgrass lost as a result of dredging activity in an anchorage area. The transplant used bareroot units with staple anchors. Transplant was conducted under direction of agencies. Monitored by agencies	**Permit:** Transplant 2,700 sq. ft. of eelgrass as mitigation for impacted area.	1. The initial transplant was the only requirement The transplant area had increased to 6,739 sq. ft. by 1986 and increased further to 9,461 sq. ft. by 1988. Leaf shoot density averaged 12.3 per sq. ft., representing an increase in density by 2.5 times that of the original transplant density.	Morro Bay Eelgrass Transplant Nitsos, R. (CDFG) 1988. Proceeding of the California Eelgrass Symp. May 1988
9	Gibsons Marina Transplant, Gibsons Harbour, B.C., Canada	1985	*Eelgrass Transplant on Damaged Intertidal Site* An eelgrass transplant was conducted on a poor site dominated by coarse gravel and cobbles and strongly undulating topography. Plantings used peat pots and anchored rhizomes with shoots.	**Permit:** No conditions beyond study project was to serve as pilot for future mitigation **Other:** Research on restoration options, success/failures, and economies of transplant	Growth within gravel was poor although plants survived in peat pots, they did not expand beyond pot. Where sand accretion occurred plants were successfully established. Successful plots were indistinguishable from native materials and summer transplants rapidly attracted fish and invertebrates Long-term survival of plants was not determined	Thom, R.M. 1990. A Review of Eelgrass (Zostera marina L.) Transplanting Projects in the Pacific Northwest The Northwest Env. Journal 6:121-137 May 1988
10	Sequim Bay, WA	1985	*Eelgrass Transplant Unmanipulated Site* Eelgrass mitigation for marina dredging was conducted using shoots, bareroot planting units, and sediment plug transplants. A total of 8,000 sq. m. was transplanted and monitored over 5+ years. A total of 11,000 shoots were planted.	**Permit:** unknown	After 5 years, 800 sq. meters remained as a very dense eelgrass bed. All planting methods gave similar survival results. Finer sediments with pooling water within intertidal areas had greatest survival results.	Thom, R.M. 1990. A Review of Eelgrass (Zostera marina L.) Transplanting Projects in the Pacific Northwest The Northwest Env. Journal 6:121-137
11	Boy Scout Camp Eelgrass Transplant Los Angeles Harbor	1985	*Eelgrass Transplant Unmanipulated Site* As mitigation for project impacts, 250 eelgrass planting units were planted on an existing recreational beach.	**Permit:** Create eelgrass to mitigate impacts to eelgrass in Huntington Harbor. The site was one of several areas planted	The project was successful in creating eelgrass in that the transplanted bed ranged from 3-4 acres in 1996. The project serves to identify the need for coordination between parties since it was approved by agency staff and not the Port on whose land it was completed. This has been a problem at this site.	R. Appy, POLA, pers. comm. 8/98 R. Hoffman, NMFS, pers. comm. 7/98
12	Richmond Harbor Training Jetty Eelgrass Transplant Program San Francisco Bay, CA	1985	*Eelgrass Transplant Unmanipulated Site* An effort was made to tranplant eelgrass into bare areas within and near existing eelgrass beds along both sides of the Richmond Training Jetty. Transplants were made with bareroot planting units.	**Permit:** Conduct a feasibility study for the restoration of eelgrass within San Francisco Bay	The project yielded differential survival of planting units depending upon planting location and maturity of donor material. Flowering of plants following transplant appeared to limit shoot density increases and likely were a response to both seasonal timing and transplant shock of plants. Both control and transplant areas failed to expand vegetatively in the spring and summer of 1985. Additional restoration attempts on sites engineered for eelgrass restoration are warranted given the results of this study.	Fredette, T.J. 1988. An Investigation of Eelgrass (Zostera marina) Transplanting Feasibility in San Francisco Bay, California

	SITE	YEAR	DESCRIPTION	OBJECTIVES	RESULTS	REFERENCES
13	Sail Bay Eelgrass Restoration Mission Bay, San Diego, CA	1986	*Eelgrass Restoration on Shallow Beach Fills* This project included the planting of 6 acres of eelgrass using 36,000 bareroot planting units. The eelgrass was planted on newly constructed 0.22 mm sand beaches at a 15:1 slope.	**Permit:** Eelgrass mitigation required the achievement of 11.0 acres of eelgrass within 5-years to off-set equivalent losses to habitat Also required was the 1:1 replacement of shallow water habitat loss **Other:** This site has served as a study area for a number of research projects addressing management concerns. These include rate of fish community recovery in transplanted eelgrass. The rate of eelgrass expansion from planting units. The importance of planting unit size to restoration success.	Over the 5 years of monitoring, the transplant exceeded the required 11 acres and grew to a total size of 38 acres wherein it merged with native eelgrass beds and could no longer be individually tracked. The rate of fish recovery in this bed was used to establish eelgrass mitigation ratios under the Southern California Eelgrass Mitigation Policy Planting unit type, size, and spacing data derived from this project were used as guides for many of the subsequent restoration projects performed over the last decade.	Growth and Survival of Transplanted Eelgrass: The Importance of Planting Unit Size and Spacing. Merkel, K.W., 1988 Proceeding of the California Eelgrass Symp. May 1988 Sail Bay Monitoring reports (Merkel, K.W. 1987-1992)
14	Humboldt Bay, Indian Island	1986	*Eelgrass Transplant Unmanipulated Site* Transplant of less than 0.25 acre to unmanipulated site	**Permit:** unknown	Transplant was completed in accordance with permits but failed to result in an increase or replacement of impacted eelgrass.	Summary of Eelgrass (Zostera marina) Transplant Projects California 1976-1997. Hoffman, R.S.. 1998.
15	Bangor, WA	1987	*Eelgrass Transplant Unmanipulated Site* Eelgrass mitigation for marina dredging was conducted on 46 sq. meters in 5 plots. Four intertidal and one subtidal plot. Monitoring was conducted for one year.	**Permit:** unknown	All intertidal plots failed. Steep topography was blamed. The fifth plot was subtidal and survived over the course of the one year monitoring.	Thom, R.M. 1990. A Review of Eelgrass (Zostera marina L.) Transplanting Projects in the Pacific Northwest The Northwest Env. Journal 6:121-137
16	Hidden Harbour Marina, Vancouver, B.C.	1987	*Eelgrass Transplant* An eelgrass transplant was conducted to compensate for eelgrass lost as a result of dredging activity. Eelgrass was transplanted to a mud bottom using unanchored shoots	**Permit:** Restoration of 1,900 sq. meters of eelgrass	Project was partially successful with 28% shoot survival and 23% decrease in transplant area size over slightly more than 1 year monitoring	Thom, R.M. 1990. A Review of Eelgrass (Zostera marina L.) Transplanting Projects in the Pacific Northwest The Northwest Env. Journal 6:121-137
17	Chula Vista Wildlife Reserve Island Eelgrass Restoration San Diego, CA	1987	*Eelgrass Transplant Unmanipulated Site* Eelgrass restoration was conducted on the shoreline of a dredged material disposal island that was constructed in the 1970's. The transplant was to mitigate port impacts. The work included a two phase transplant which identified means to minimize stingray bioturbation to planting units and then planted a larger area (0.13 ac.) with bareroot units and sediment plugs.	**Permit:** Restoration of 0.13 acre of eelgrass	1. Transplants into firm sands only resolved stingray foraging impacts to young planting units. 2. Eelgrass survived and expanded to a solid bed within 4 months. 3. At the one year interval, and in less than 3 mos. the site was buried in sediment more than 10 cm deep. 4. A resurgence has taken coverage to over 11 acres. 5. The site remains unpredictably vegetated today	Merkel, K.W. 1990. Eelgrass Transplanting in South San Diego Bay, California. Proceeding of the California Eelgrass Symp. May 1988 Merkel & Associates. 1995.
18	Navy Eelgrass Mitigation Site-1 (NEMS-1) Naval Amphibious Base Coronado Island, San Diego Bay, CA	1987-90	*Eelgrass on Shallow Water Fill* A 13 acre submerged plateau was create using Navy dredged material as a beneficial reuse alternative to ocean disposal. The purpose of the work was to meet outstanding mitigation obligations and to create an eelgrass mitigation bank. In constructing the site, the Navy construction contractor placed material on 6.3 acres of existing eelgrass along the nearshore edge of the constructed plateau. Efforts to use Navy SEALs to plant the site were less than effective and a private contractor was retained in 1989 to complete the transplant using bareroot units.	**Permit:** Restore 4.20 ac. of eelgrass to mitigate P-141/154 Impacts and to compensate for fill placement impacts associated with this site. **Other:** Site is to serve as a mitigation bank for other Navy projects within San Diego Bay	1. Eelgrass within shoreline implementation area recovered fully by December 1990 (6.3 acres) 2. A total of 7.64 acres of eelgrass restored to 6.28 acres originally believed available at the mitigation site. 3. Mean shoot density was found to be generally higher than in native control beds 4. Over 41,000 planting units were used to restore the NEMS-1 site. 5. Formal mitigation bank development at this site is still pending.	MBC Eelgrass Transplant Report 1990 NMFS Monitoring Report April 12, 1991 NMFS Monitoring Report March 15, 1994

	SITE	YEAR	DESCRIPTION	OBJECTIVES	RESULTS	REFERENCES
19	Dakota Creek, WA	1988	*Eelgrass Transplant* Eelgrass was transplanted from intertidal to subtidal environments on coarse substrate. The transplant unit was individual shoots. Monitoring was conducted for one year.	**Permit:** unknown	1. Eelgrass at lower elevations had an 80% survival rate; eelgrass at higher elevations had <30% survival. 2. Boat damage occurred to higher elevation eelgrass on tideflats.	Thom, R.M. 1990. A Review of Eelgrass (Zostera marina L.) Transplanting Projects in the Pacific Northwest The Northwest Env. Journal 6:121-137
20	Harbor Island Marina, Eelgrass Mitigation Harbor Island, San Diego Bay, CA	1988	*Eelgrass on Shallow Water Fill* A shallow fill was placed using materials dredged from the entrance channel to a major marina. Eelgrass totaling 0.25 acre. Transplants were conducted using bareroot units.	**Permit:** Restore eelgrass habitat totaling 0.25 ac. as mitigation for habitat suited to the support of eelgrass.	1. Eelgrass restoration died back substantially after planting and recovered during the subsequent 6 month period. 2. Acreage goals were met by the planting and exceeded the 0.25 acre target.	Summary of Eelgrass (Zostera marina) Transplant Projects California 1976-1997. Hoffman, R.S.. 1998. R. Hoffman, NMFS, pers. comm. 7/98 Merkel, K.W. pers. obs.
21	Huntington Harbor Entrance Channel Eelgrass Restoration	1989	*Eelgrass Transplant on Shallow Channel Cut* A small bare-root transplant was conducted along the fringes of the Huntington Harbor Entrance Channel using bareroot planting units.	**Permit:** Unavailable	1. Eelgrass restoration was partially successful with areas of heavy clay and large clay blocks precluding full establishment of eelgrass in deeper areas for several years. 2. Eventually the full mitigation acreage was exceeded.	Summary of Eelgrass (Zostera marina) Transplant Projects California 1976-1997. Hoffman, R.S.. 1998. R. Hoffman, NMFS, pers. comm. 7/98 'Merkel, K.W. Pers. Obs.
22	Port of Long Beach, Pier J Shallow Water Mitigation Port of Long Beach, CA	1990	*Shallow Water Habitat Created by Upland Excavation* As mitigation for a 147 acre fill for the Pier J facilities a 116 acre shallow water basin was excavated from weedy uplands in Anaheim Bay Naval Weapons Station	**Permit:** Create shallow water at an area ratio of 1.32 (impacted deep water) to 1.00 (created shallow water). Mitigation ratios were based on predicted biological values drawn from comparison of deep harbor with shallow waters.	The project was successful in meeting mitigation requirements based on physical parameters. Subsequent biological monitoring and habitat valuation testing against pre-agreed criteria proved success on a biological basis.	J. Fancher, USFWS, pers comm. 8/98 R. Appy, POLA, pers. comm. 8/98
23	North Bend Airport Expansion Project Coos Bay, Oregon	1990	*Eelgrass on Shallow Water Fill* As mitigation for the expansion of the runway, eelgrass was transplanted to an engineered site designed to divert flows through a sandy fill island shoal. Eelgrass planting made use of both plugs and bareroot transplant units.	**Permit:** Attempt restoration of eelgrass habitat by construction of a mitigation area at the end of the airport runway.	The island design was a failure in a hydrodynamic sense. Too much flow was diverted and the site was unstable. Pre-review modelling identified specific changes that would result in bathymetry. These occurred and an adjacent grass bed was impacted by th mitigation site. Following site stabilization an eelgrass transplant was conducted and was partially successful in mitigating impacts. A net loss in eelgrass area remained.	D. Hancock, OIO, pers. comm. 6/98
24	Sea World Lagoon, Mission Bay, CA	1990	*Eelgrass on Shallow Water Fill* Dredged materials excavated to remove navigation obstructions were placed to create a submerged plateau for eelgrass restoration. An eelgrass transplant was conducted to meet mitigation requirements and create excess eelgrass habitat.	**Permit:** Revegetate 3,970 sq. ft. of dredged bottom and 8,730 sq. ft. of bay bottom where tidal circulation has been restored.	1. Eelgrass met and exceeded the mitigation requirements with the creation of 26,952 square feet of new eelgrass habitat being created. An informal bank is in existence at this site	ACOE Permit #90-271-RS CCC Permit #6-90-140 PSBS #B14 M&A #95-028-01
25	Fifth Avenue Pier Eelgrass Mitigation Site. San Diego Bay, CA	1991	*Eelgrass Transplant on Site Cleared of Mussels* To mitigate for impacts to 0.13 acre of eelgrass, the Port of San Diego conducted a restoration at a site along the embarcadero waterfront. The site was cleared of heavy Japanese mussel mats and planted.	**Permit:** Restoration of 0.13 acre of eelgrass Eelgrass restoration at this site was a back up to the Chula Vista Wildlife Island transplant.	1. Eelgrass initially faired very well but expansion slowed as mussels reinvaded the area and outcompeted eelgrass for primary space. The site was partially successful in meeting the area requirements. 2. Success at the initial made moot the status of this site.	Merkel , K.W. 1990.

	SITE	YEAR	DESCRIPTION	OBJECTIVES	RESULTS	REFERENCES
26	Le Meridien Submerged Plateau, San Diego Bay, CA	1991	*Eelgrass on Shallow Water Fill* A rock crescent was constructed along the edge of deep navigation channels and backfilled with sand to raise bottom elevations from as much as -20 feet MLLW up to -6 feet MLLW in order to restore eelgrass. Eelgrass was planted on fill.	**Permit:** Restore 4,771 sq. ft. of impacted eelgrass from pier construction projects. **Other:** Site was used for study area investigating fertilizer effects on eelgrass and to examine fish community benefits associated with multiple habitat restoration designs.	1. Eelgrass surpassed permit restoration goals with the creation of 5,586 square feet total vegetated area. 2. Fertilizer treatment effects were not observed 3. Multiple habitat enhancement was beneficial to fish community diversity and richness as well as density.	ACOE Permit #86-074-BB, 87-079-RH, 88-220-LS Merkel, K.W. 1990-94 (PSBS #838) Merkel & Associates 1994 (M&A #94-008) Hoffman and Merkel, unpublished data
27	Metro-Seattle North Beach Mitigation Plan Puget Sound, WA	1991	*Eelgrass Transplant on Artificially Protected Shore* An eelgrass transplant was completed using both bareroot and sediment plug transplant units. A total of 6,000 square feet of restoration was conducted.	**Permit:** Restore 3,268 sq. ft. of eelgrass as mitigation for temporary losses associated with placement of a construction barge loading terminal. Conduct monitoring over a 10 year period	1. The transplant was successful in deeper waters but suffered some tugboat propwash impacts in shallow water. Signage at the barging facility appeared to resolve much of this problem. 2. Area requirements for interim habitat creation were met.	Merkel, K.W. 1991. Transplanting Program for Restoration of the North Beach Eelgrass Habitat, Puget Sound, WA. Parametrix. 1991. North Beach Mitigation Plan and Specification Document
28	Crown Isle, San Diego Bay, CA	1992	*Eelgrass Transplant Unmanipulated Site and Eelgrass on Shallow Water Fill* An eelgrass transplant was conducted to meet mitigation requirements. Portions of the restoration were on unmodified bottom in an area where applicant was warned was likely to fail. Partial success was met by the initial transplant. A subsequent submerged fill area was required.	**Permit:** Restore 3,042 sq. ft. of eelgrass as mitigation for dock and gangway construction.	1. The initial transplant was partially successful and met all but 312 sq. ft. of the mitigation requirements. '2. Supplemental transplant on created submerged fill plateau is being monitored	ACOE Permit #85-189-BB, 85-189-EW PSBS 1992, 94, 95 (PSBS #G65) Merkel & Associates 1997(M&A #94-017)
29	Agua Hedionda Lagoon Outer Lagoon Dock Mitigation Agua Hedionda Lagoon, CA	1993	*Eelgrass Transplant on Unmanipulated Site* A 700 square foot eelgrass transplant was conducted using bareroot materials	**Permit:** Restore 400 square feet of eelgrass as mitigation for shading impacts to eelgrass within outer Agua Hedionda Lagoon.	1. The restoration was successful and it is no longer possible to distinguish the transplant from the adjacent native beds. A net increase in eelgrass was realized.	Merkel, K.W. 1993. Eelgrass Restoration Plan for the Agua Hedionda Lagoon Aqua Farm Boat Dock
30	Navy Eelgrass Mit. Site 2 (NEMS-2) SPAWAR Marine Mammal Facility San Diego Bay, CA	1993	*Eelgrass Transplant on Unmanipulated Site* A transplant of 0.39 acre was completed on a sandy shoal in north San Diego Bay. The transplant was conducted with bareroot transplant units.	**Permit:** Restore 0.26 acre of eelgrass	1. Eelgrass has performed extremely well at this site and has resulted in an area that is indistinguishable from native beds. 2. The site has met all criteria for success.	Hoffman, R.S. NMFS, pers. comm. 1998 Perdue, M. 1998. SWDIV NAVFACENGCOM NAT RES, pers. comm. ACOE Permit #94-017-DZ
31	South Shores Boat Basin, Mission Bay, CA	1994	*Eelgrass Transplant on Shallow Basin Cut* A recreation beach and boat launch basin were created . Eelgrass was planted over 4.6 acres of the basin. Over 6 vegetated acres are ultimately expected	**Permit:** Restoration of 0.48 acre of eelgrass to mitigate for 0.40 acre of impacted eelgrass. Plus creation of 12 acre basin to mitigate for prior fills associated with beach restoration in Sail Bay	1. The eelgrass transplant successfully met the mitigation requirements and is anticipated to create a eelgrass mitigation bank of 3.7 acres. At 24 months post planting the site supported 4.18 acres of eelgrass	ACOE Permit #87-128-EW M&A #94-016-01
32	Navy Eelgrass Mit. Site 4 (NEMS-4) Delta Beach Region south-central San Diego Bay, CA	1994	*Eelgrass on Shallow Bay Fill Subtidal Plateau* This site was constructed by placement of dredged material into waters approximately 13 feet deep to create a shallow plateau at a depth of approximately -4 to -8 feet MLLW. The site was planted with bareroot eelgrass units on 1 meter centers. A total of 1.1 acres was planted and monitored for 5 years.	**Permit:** Beneficial reuse of dredged materials and restoration of 0.87 acre of eelgrass. Five year monitoring program.	1. The site sloped to deeper depths than those designed and extended to -8 feet from a deeper edge target of -6 ft. 2. Deep soft sediments were not conducive to plants and high mortality occurred in these areas. 3. Eelgrass coverage of 0.9 acres during monitoring 4. Site has been heavily impacted during present El Nino and eelgrass is way down in both mitigation area and control site. Additional monitoring is being performed.	Merkel, K.W. 1993. Eelgrass Planting Plan for U.S. Navy, Delta Beach Mitigation Area, San Diego Bay, CA ACOE Permit #92-436-DZ Coastal Consistency Det. (CD-48-92)

	SITE	YEAR	DESCRIPTION	OBJECTIVES	RESULTS	REFERENCES
33	De Anza Cove Launching Ramp, Mission Bay, CA	1994	<u>Eelgrass Transplant on Shallow Cut</u> An eelgrass transplant was conducted to meet mitigation requirements. A transplant of 9,846 sq. ft. was performed on bay sands	**Permit:** Create 1,482 square feet of eelgrass pursuant to SCEMP	1. The replanting efforts were successful in establishing eelgrass in previously disturbed areas. A total of 9,571 sq. ft. exists.	ACOE Permit #90-353-EW CCC Permit # 6-90-29 PSBS#G04 Merkel & Associates 1997
34	Batiquitos Lagoon Enhancement Project Batiquitos Lagoon, Carlsbad, CA	1994-97	<u>Shallow Water Restoration and Eelgrass Introduction</u> The Batiquitos Lagoon restoration project was a 500 plus acre comprehensive restoration project to revitalize a deteriorating lagoon system. It involved dredging, creation of shallow water basins, tern colonies, and pilot restoration of eelgrass and cordgrass habitats. Opening and maintaining the mouth of the lagoon was a major portion of the project.	**Permit:** Restore shallow water habitat as mitigation for deep water terminal fills at Pier 400 Restoration required a mitigation exchange ratio of 1.062 (impacted deepwater) to 1.000 (enhanced shallows). A ten year physical and biological monitoring program was required to document changes and support establishment of maintenance programs for the restored system. **Other:** The Batiquitos Lagoon eelgrass restoration is serving as a controlled laboratory for examining the role of population genetics in eelgrass restoration projects. Because eelgrass was completely absent from the system, materials from various populations were planted in an experimental layout to evaluate performance and genetics of the establishing daughter populations	To date the project has proven to be extremely successful for fish, benthic invertebrates, endangered species. Overall bird use is certainly not diminished, but strong trends cannot be drawn from the first year monitoring. Recorded fish species are up from 8 to 52 between pre- and post-restoration conditions. Benthic infauna are represented by greater diversity and abundance than observed prior to restoration. Least terns have increased by over 800% from pre-const. conditions (298 pairs in 1997); snowy plovers have similarly increased by over 700% (38 pairs in 1997) Waterfowl and shorebirds appear to be meeting or exceeding pre-construction conditions, however high seasonal and survey variability makes it difficult to evaluate change on the basis of the one year of post-restoration monitoring	Merkel & Associates. 1998. <u>Long-term Monitoring and Pilot Vegetation Program for the Batiquitos Lagoon Enhancement Project Annual Report Jan-Dec 1997</u>
35	Mission Bay Shoreline Protection Project Mission Bay, San Diego, CA	1995	<u>Eelgrass Transplant on Shallow Water Cut</u> The City of San Diego has conducted a comprehensive restoration of failing shorelines along the 23 mile shore of Mission Bay. As a part of this work, eelgrass impacts have occurred and mitigation has been incorporated into project design. Five different sites have received eelgrass transplants. These include an island that has been cut down to a submerged plateau, a shoal area that has been dredged out, and 3 shoreline sites that have been recontoured to accept eelgrass. A 7 acre marsh has also been restored and supports eelgrass within its tidal channels. A total of 7.08 acres of eelgrass have been impacted and 11.78 acres have been restored.	**Permit:** Restore shallow water and eelgrass habitat at a 1.2:1 areal ratio of restoration to impact in accordance with the Southern California Eelgrass Mitigation Policy. Monitor restoration areas for 5 years to demonstrate success. **Other:** Excess mitigation credits for eelgrass and intertidal wetlands and mudflats are being banked under a formal Mitigation Banking Agreement MOU	To date, the project has met its restoration requirements and is being monitored to establish success conditions. Eelgrass on the submerged plateau and all shoreline sites has achieved full coverage of the mitigation areas. Eelgrass on the shoal has been partially impacted by high flow velocities and shifting sands. This area is not anticipated to yeild excess eelgrass beyond that required to mitigate project impacts. Eelgrass on the submerged plateau (East Ski Island) will likely result in excess banked eelgrass credit. A mitigation banking agreement is presently circulating and receiving agency signatures and estimates 3.28 acres of bankable eelgrass.	ACOE #94-00054-DZ ACOE #20857-DZ Merkel & Associates, Inc. 1994 Merkel & Associates, Inc. 1998
36	Talbert Marsh Experimental Eelgrass Introduction to Flood Control Channel Huntington Beach, CA	1995	<u>Eelgrass Transplant In Flood Control Channel</u> Eelgrass and cordgrass were transplanted into the Talbert Marsh as an experimental introduction under the USFWS Bays and Estuaries Program.	**Permit:** N/A, This was an experimental transplant to determine if eelgrass could be successfully introduced into a marshland area of a large flood control channel	Eelgrass persisted and expanded until heavy storms filled the channel with sandy sediment washed in from the adjacen beach. Cordgrass responded well and has expanded considerably within the site.	Merkel & Associates, 1995 Hoffman, R.S. NMFS, pers. comm. 1996
37	Santa Clara Point, Mission Bay, CA	1996	<u>Eelgrass Transplant on Shallow Cut</u> An eelgrass transplant was conducted to meet mitigation requirements.	**Permit:** Transplant 6,120 sq. ft. of bay bottom in mitigation of impacted eelgrass habitat.	1. The eelgrass performed well and to date has met all mitigation requirements. Five year monitoring will continue	M&A #94-001-01
38	Ventura Cove, Mission Bay, CA	1996	<u>Eelgrass Transplant on Shallow Cut</u> A gradual slope was created off a shallow beach where sand had accumulated over many years. It was graded to create a large transplant area.	**Permit:** Restoration of 68,825 sq. ft. of newly created eelgrass habitat.	1. The planting efforts presently meets and exceeds the mitigation requirements. Continued monitoring is required for 5 years. Beach erosion may threaten the site over this period	ACOE Permit #96-20054-DZ CCC Permit #6-97-64 M&A #95-006-03

	SITE	YEAR	DESCRIPTION	OBJECTIVES	RESULTS	REFERENCES
39	Navy Eelgrass Mitigation Site-5 NEMS-5 CVN Mitigation Site North Island, San Diego Bay, CA	1996-98	<u>*Eelgrass Transplant on Shallow Water Cut Basin*</u> A 14.0 acre upland area of North Island was cut down to shallow subtidal and intertidal elevations. This cut resulted in creation of 17.4 acres of plantable area area for eelgrass restoration. Four artificial reefs were also constructed to enhance fisheries resources. A bareroot eelgrass transplant is being conducted in two large basins.	**Permit:** As mitigation for impacts from the CVN Homeporting project in San Diego Bay, the Navy was required to create 13.4 acres of shallow water and to mitigate the loss of 6.1 acres of eelgrass associated with project construction and creation of shallow water mitigation areas. **Other:** The NEMS-5 site is benefiting from a considerable amount of research ranging from studies of the rock reef fish community development to studies of eelgrass population performance, transplanting techniques, and multi-element habitat values.	1. Planting and natural recruitment are rapidly covering primary space within the excavated basins. 2. Rock reef colonization has been rapid but is susceptible to sedimentation if energies are not high enough.	Merkel & Associates. 1998. <u>Mitigation Implementation Plan, North Basin, NEMS-5, In Support of the Navy CVN Homeporting (MILCON P-700) Project at NAS North Island, Coronado.</u> ACOE Permit #96-2061-DZ Coastal Consistency Det. (CD-95-95)
40	Morro Bay, Target Rock Morro Bay, CA	1997	<u>*Eelgrass Transplant on Shallow Fill*</u> A sand berm eroded into the bay and covered eelgrass beds. A bareroot transplant was conducted to restore the damaged area.	Permit: No permit issued. U.S. Army Corps of Eng. Maint. Dredging. Damage to existing bed was not anticipated and requirements were restoration of damaged area by contractor.	Eelgrass restoration was successful and is presently being monitored for a 5 year period.	Merkel & Associates, Inc. 1996 Merkel & Associates, Inc. 1998
41	Navy Eelgrass Mitigation Site-6 NEMS-6 (MILCON P-211) south central San Diego Bay, CA	1998	<u>*Eelgrass Transplant on Shallow Water Fill Plateau*</u> This is a small eelgrass restoration program being constructed on a submerged plateau following the design of NEMS-1 and 4. A set-back from existing native beds has been included to protect these areas from construction period impacts.	**Permit:** The fill plateau is being constructed as an enhancement and beneficial reuse of dredged sediments. Eelgrass will be banked for other project impact mitigation	Plateau fills have been generally placed. The site is substantially smaller than designed. The site will require additional material to reach design criteria and elevations for planting	Merkel, K.W. 1998, pers. obs. Perdue, M. 1998. SWDIV NAVFACENGCOM NAT RES pers. comm.
42	Agua Hedionda Lagoon Tidal Prism Restoration Dredging Program Eelgrass Mitigation Agua Hedionda Lagoon, CA	1998	<u>*Eelgrass Transplant on Shallow Cut*</u> As mitigation for impacts to eelgrass within the footprint of dredging to restore tidal prism to this coastal lagoon, shallow water benches and shoal area are being created to support eelgrass revegetation. Eelgrass transplantation is being done using bareroot transplant units.	**Permit:** Mitigate eelgrass loss of 9.3 acres through restoration at a 1.2:1 areal cover ratio.	Planting of approximately 1.1 acre has recently been completed	ACOE #95-20135-DZ Merkel & Associates, 1998
43	Convair Lagoon CAD Site Eelgrass Restoration Program	1998	<u>*Eelgrass Transplant on Shallow Water Fill Over CAD*</u> As mitigation for impacts to eelgrass associated with placement of a sediment containment cap over a contaminated site, eelgrass restoration of the cap was required. Approximately 6 acres were restored using bare-root anchor units.	**Permit:** Mitigate eelgrass loss associated with capping by restoration of eelgrass. Monitor eelgrass for a 5 year period for successful re-establishment.	Planting of approximately 6 acres has been completed in 1998. Restoration was significantly delayed due to delays in the CAD capping program.	Hoffman, R.S. 1998. pers. comm.
44	Oyster Shell Bed Impact Eelgrass Restoration Project Grays Harbor, WA	1990	<u>Eelgrass Restoration at Damaged Site</u> In completing an enhancement of habitat for dungeness crabs, oyster shell was placed on flats of Gray's Harbor. Impacted eelgrass was restored by clearing shell and replanting using bareroot plant materials. Six sites were replanted. Plant survival and expansion were success criteria. Shoot density and lengths were also monitored.	**Permit:** none. Corps of Engineers was required to attempt restoration of eelgrass damaged.	Cambell Slough had a partial success in that plants survived but did not substantially expand. Five of six plots resulted in viable and expanding eelgrass that resembled native control beds in density and shoot lengths.	Thom, R.M. 1993. Wyllie-Echeverria, S., pers. comm.

	SITE	YEAR	DESCRIPTION	OBJECTIVES	RESULTS	REFERENCES
45	La Conner - Swinomish Channel, Port of Skagit County Fuel Pier Eelgrass Mitigation Padilla Bay Region, WA	1992	*Eelgrass Transplant on Le Meridien Type Shallow Water Plateau* An eelgrass transplant was conducted to meet dock coverage mitigation. Because of limited land a project was completed modelled on Le Meridien design guidance. Soft bare-root anchors used at the Le Meridien site were also used for this project. The site was approximately 1,500 square feet. Epibenthic invertebrates were monitored to determine if juvenile salmonid food resources were replaced by restored eelgrass.	**Permit**: Restore impacted eelgrass. In the the event that eelgrass failed, an alternative type of habitat enhancement was to be performed	1. The transplant was successful and met area requirements. 2. Shoot counts between transplant and control areas were comparable 3. Epibenthic prey resource densities between control and transplant areas were comparable.	Wyllie-Echeverria, S. et al. 1995 Wyllie-Echeverria, S., pers. comm.
46	Shaw Island Trench Restoration Orcas Power & Light San Juan Islands, WA	1995-97	Eelgrass Transplant onto Shallow Sand Backfill A utility trenchcut to bring power to Shaw Island damaged eelgrass and left a deep linear scar. To mitigate damage, the trench was backfilled with sand and planted with bare-root eelgrass units. A total of approximately 4,500 square feet of eelgrass was planted	**Permit:** Remediate the trench scar.	The restoration has been successful to date. Eelgrass is filling in over the sand cap. Anoxic sediments were a problem that is being remediated by the sand and eelgrass.	Wyllie-Echeverria, S., pers. comm.
47	Curtis Wharf Eelgrass Mitigation Anacordes, WA	1997	Eelgrass Transplanted on Previously Impacted Shoreline A small dock expansion was completed in an area supporting eelgrass. A total of approximately 4,500 square feet of eelgrass was impacted. To mitigate damage, a debris field of rock rubble, tires, fishing nets, and other rubbish was removed from a beach and shallow water area. A plug transplant was used to restore the site.	**Permit:** Mitigate impacts to eelgrass loss.	The transplant has taken very well and has filled in to levels resembling those found in adjacent control beds. A five year monitoring continues to be completed.	Wyllie-Echeverria, S., pers. comm.

Figure 1. Location of eelgrass and shallow water habitat restoration projects evaluated in this review.

ANALYSIS AND DISCUSSION

EELGRASS RESTORATION PROJECTS

Temporal Trends In Eelgrass Restoration Success and Failure

Permit Compliance

The success or failure of a restoration project is generally measured as performance against some established criterion or criteria. For most projects, permit conditions provide the standard against which the site is evaluated. Unfortunately, permit conditions do not always provide biologically meaningful criteria, nor do they regularly result in measurement of successes or failures beyond the requirements of the permit. Further, the conditions of permits have varied markedly over time. Earlier permits and permits in regions where eelgrass restoration is not widely employed tend more frequently to require good faith efforts at restoration leaving much of the risk on agencies and the resource. In areas where eelgrass restoration has been completed with extensive success, the burden for achieving restoration goals as mitigation is allocated to the applicant causing the impact to eelgrass beds. Due to these variable criteria, achievement of permit conditions has actually been quite high over time with nearly 100% of the projects meeting permit requirements during most years (Figure 2). This was true even where the actual restoration effort failed. Where permits included language such as "attempt an eelgrass transplant...," the criteria for success consisted generally of good-faith efforts to establish eelgrass or completion of studies designed to provide better information for future management or permit conditions. In such cases, data that would suggest the transplants were completed and reports prepared, has been deemed as successful compliance under the permit.

Eelgrass Transplant Success

Not all projects that were in compliance with permit conditions successfully replaced lost habitat or achieved *a priori* restoration goals. To further clarify, there is, in some instances, a distinction between meeting restoration objectives and replacing lost habitat in total. For some projects, the mitigation area required for restoration under the permit was smaller than the actual impact area. In such circumstances, habitat restoration was considered successful if it met the replacement requirements of the permit rather than full restoration of habitat by area (Figure 3). Since it is generally unclear as to what the specific circumstances were with respect to the individual project permitting decisions, this analysis is not intended to evaluate whether the specific conditions imposed by the regulatory agencies were appropriate. Where restoration success was reported as partial success, projects were arbitrarily given half credit in the Figure 3 evaluation.

Interestingly, the distribution successes based on permit compliance does not correlate with actual transplant success. In fact, many failed transplants successfully met permit requirements and some successful transplant projects failed to meet permit conditions. However, examples of these discrepancies were greater a decade ago than today. This can be attributed to several factors. First, there has been an improvement in restoration techniques such that fewer transplant failures presently occur. Second, there has been the development of a formal eelgrass mitigation policy (Southern

Figure 2. Permit Compliance Success of Eelgrass Restoration Projects Completed on the West Coast of North America (1976-1998)

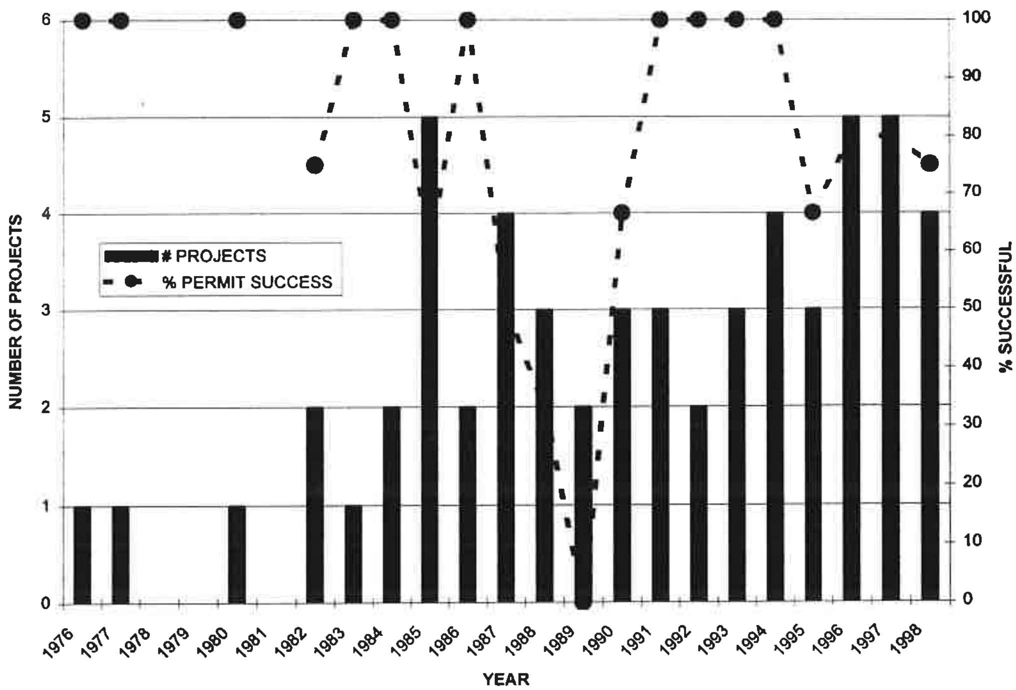
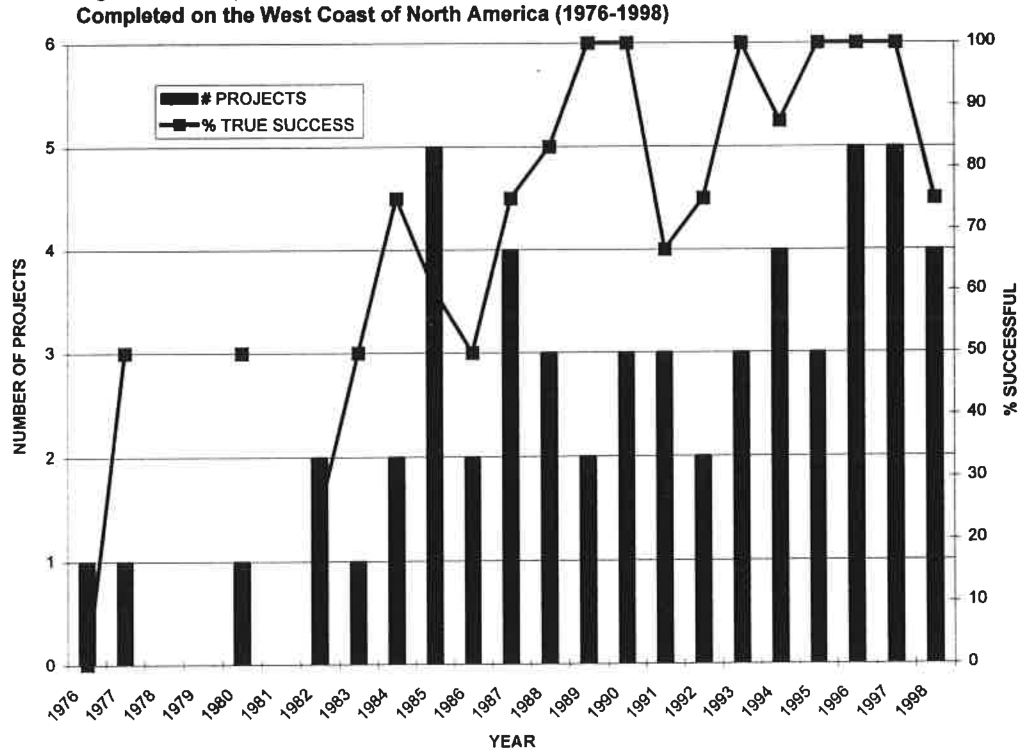


Figure 3. Transplant Success of Eelgrass Restoration Projects Completed on the West Coast of North America (1976-1998)



California Eelgrass Mitigation Policy) over a large portion of the U.S. coast (Hoffman, R.S., NMFS, ed. 1991, as amended). Third, through adoption of policy and improved development of permit conditions, there has been a general trend shifting performance-based obligations to the project proponent.

The number of restoration projects conducted annually ranged from zero to five with some projects extending over multiple years due to the size of the project or phasing of implementation (Figures 2 and 3). While unclear in the data, it is believed that the number of projects occurring during each year is less indicative of patterns of impact distribution than it is of historic treatment of eelgrass issues and regional differences in eelgrass management under state and federal regulatory programs.

Eelgrass Restoration Program Success

Aside from the analysis of project performance relative to meeting permit conditions and achieving transplant success (as defined by permit criteria), a second factor explored was how eelgrass has fared with respect to net gains and losses in restoration programs over the past two decades. To evaluate this, project impacts as reported in permits and monitoring reports were considered to be losses and any success in restoration was considered to be a gain. Where the restoration area exceeded the impact area for a single year, there was a net gain for that year. Alternatively, net losses would occur if the opposite were true for a single year. Based on the accumulated performance for each year of the last two decades, an accumulated restoration performance curve has been generated (Figure 4).

Several explanatory notes are required relative to the interpretation of Figure 4. First, the graph only addresses projects in which eelgrass restoration or an attempt to restore eelgrass was required. During this period, numerous permits were issued without regard to mitigating eelgrass impacts. This rarely occurs today. Second, this figure only addresses specific identified impacts of a project on eelgrass resources. Historically, and to a far lesser degree today, impact identification associated with secondary effects on water quality, sedimentation, and hydrodynamic changes to the environment have not been performed well (Merkel 1991, Lessons Learned from 15 Years...). This has especially been the case for marina developments. Finally, eelgrass distribution in marginal environments is extremely dynamic on many time scales. As a result, several projects have been constructed in areas which were devoid of eelgrass at the time of surveys, but may support eelgrass at other periods. To date, no equitable solution has been derived to address this problem, although information suitable for accurately modeling predicted eelgrass habitat is building and this may soon be resolvable in better studied systems. Unfortunately, it is not possible to address losses that were not originally contemplated by permits or project documents. For these reasons, it is important that Figure 4 not be misinterpreted to suggest that eelgrass habitat resources are well-off. Indeed, some of the greatest challenges to managing this resource are not found within the bays and estuaries, but within the watersheds that feed them, and on this issue, the stage of the science is still in its infancy.

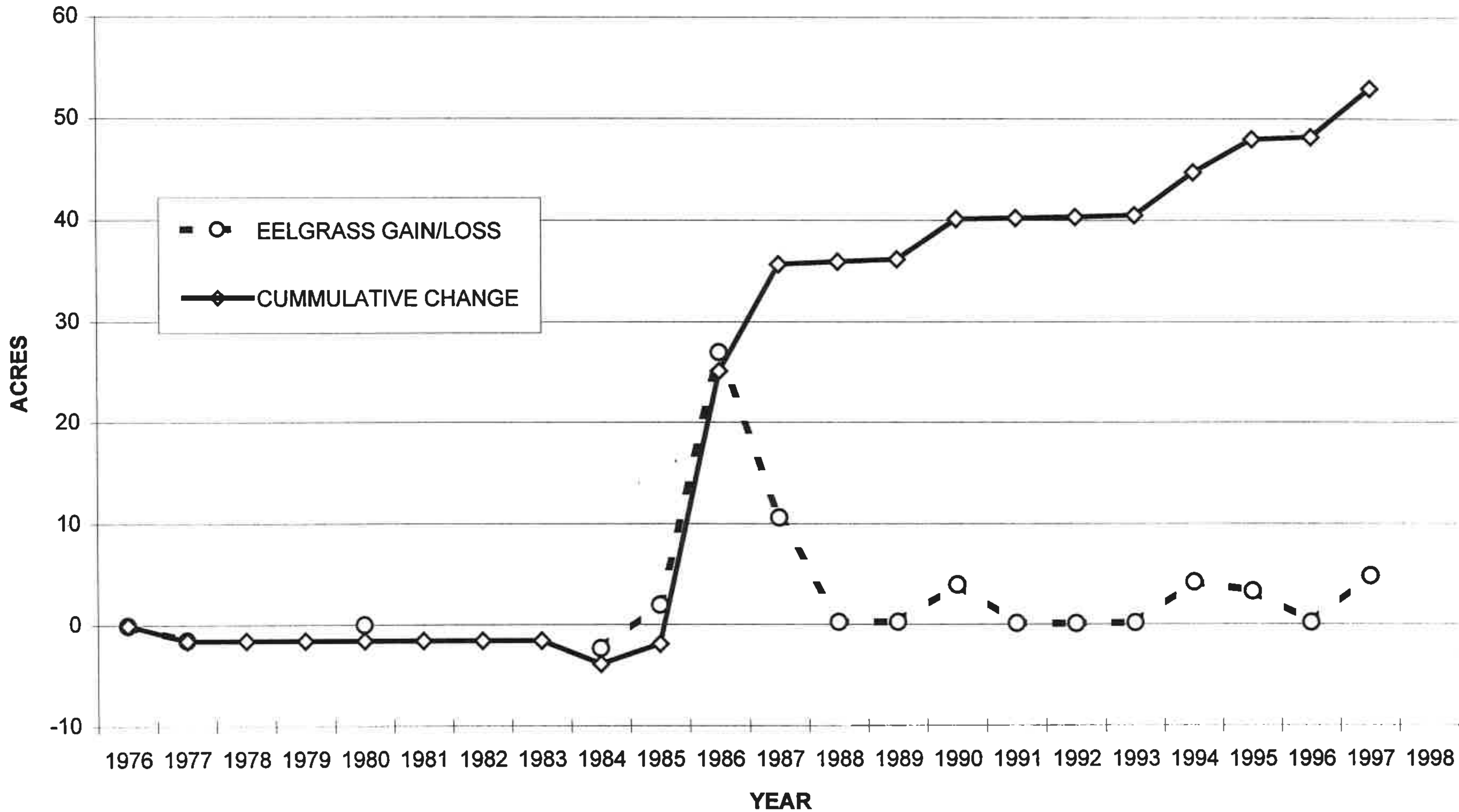


Figure 4. Assessment of Annual and Cummulative Net Gains and Losses of Eelgrass on the North American Pacific Coast Associated With Focused Mitigation and Enhancement Programs (1976-1998)

The results presented in Figure 4 would suggest that, for the projects involving some level of eelgrass restoration effort, a net deficit in eelgrass occurred through 1985 with a maximum deficit occurring in 1984 during which year project-associated losses totalled 3.85 acres. In 1985 and through subsequent years, eelgrass resulting from restoration projects has reversed this trend and no year has failed to generate a net gain in eelgrass. A tremendous gain was realized in 1986 by the Sail Bay eelgrass restoration project in Mission Bay, San Diego (project #13). Because of both the project design and a general improvement in water quality in southern California bays and estuaries, this project exceeded its 11 acre replacement goal by 27 acres. Other big gains came in 1990 from the Navy Eelgrass Mitigation Site -1 in San Diego Bay (project #18), the South Shores Basin, Mission Bay (project #31) in 1994, and the Mission Bay Shoreline Protection Program mitigation (project #35). As of 1997, the NEMS-5 site (project #19) has yielded approximately 3 acres through natural recruitment to an engineered mitigation site. An additional 14 acres is being added through restoration planting, of this, approximately 8 acres will be in excess of impacts. As of 1997, there has been a 52.91 acre documented gain in eelgrass habitat through restoration efforts.

One factor resulting in regular gains has been the transfer of obligation onto a permittee to perform to a standard which requires full resource replacement as well as supplemental habitat creation to off-set temporal loss of habitat values (see Southern California Eelgrass Mitigation Policy, Hoffman 1991). From the projects reviewed, it is clear that all major gains in eelgrass have resulted from sites specifically engineered to support eelgrass habitat. Two other significant factors have lead to major habitat gains. The first is recognition of "mitigation banking" for eelgrass as a viable means of addressing harbor development or maintenance needs by major entities such as the Navy, ports, and municipalities. The second is acceptance of opportunistic re-use of dredged materials to create sites suitable for eelgrass habitat development. This has been done at NEMS - 1 (project #18), 4 (project #32), and 6 (project #41), Batiquitos Lagoon (project #34), and Sea World Lagoon (project #24). To date, these opportunistic dredged materials re-use programs have generated approximately 5 acres of eelgrass beyond obligatory off-set. Given that NEMS-6 has yet to be planted and the outstanding potential at Batiquitos Lagoon, these sites may ultimately result in the net gain of well over 50 to 100 acres of eelgrass.

Success and Failure Rates Based on Restoration Design

While there are subtleties to every eelgrass restoration project, a few fundamental elements regularly define the transplant. The first is the type of site being planted and the type of modifications which have occurred to make the site suitable for eelgrass, if any. The second defining characteristic is the type of planting unit employed in the transplant. The final element that appears as a regular variable is the textural quality of the surface sediment within the receiver site. While photosynthetically active radiation (PAR) and turbidity are frequently discussed, few projects have ever done a real credible job at linking measured PAR and turbidity levels with suitable site criteria. As such, and even though they are considered critical to the success of a restoration project, these parameters are not extremely useful tools for exploring success rates in past eelgrass restoration efforts.

Site Selection and Manipulation Approach

Eelgrass is a fairly prolific and opportunistic species which can spread rapidly from source areas given appropriate conditions. In fact, there is a common generality that if eelgrass could grow on a site, it most likely would be there already. However, in reviewing the 41 eelgrass restoration efforts (42 actual count due to two planting efforts at Crown Isle (project #28)), a full 17 (37.8%) were transplants on unmanipulated sites that simply lacked eelgrass (Figure 5). References to the fact that the site appears suitable for the establishment of eelgrass are common, however, few papers explain the probable reasons why eelgrass is not already present within the unmanipulated area. Some projects note attempts to establish eelgrass marginally above or below the band of eelgrass which normally rings the low intertidal and shallow subtidal contours of the shoreline. An example of this is seen in the first Crown Isle transplant in San Diego Bay (project #28). These projects have been intermittently successful depending upon the precise timing of the restoration and the length of monitoring performed. However, the success or failure of such transplants likely are less attributable to the transplant itself than with the state of expansion or contraction that the native bed is in at the time of the planting. Such transplants performed while a native bed is contracted in its distribution, may be successful, but in fact, the transplant does little for the overall status of the resource since a natural expansion phase in the native bed would render the same results.

Of the various planting site conditions, unmanipulated sites had the lowest overall rate of success at 38.2% successful transplants (Figure 5). Other planting site treatments which exhibited relatively low success included attempts at biological manipulation, represented by a single project at the Fifth Avenue Pier, San Diego Bay (project #25). This site was partially successful, defined as a 50% success rate, following removal of heavy mats of Japanese mussels. Attempts to restore seriously damaged eelgrass beds impacted by changes in hydrology and erosional patterns failed 50% of the time, although damaged sites that were substantially remediated as part of the restoration effort brought this success rate up to 75% overall for 4 sites. A 75% success rate was observed for projects with unknown site manipulations. Very high rates of success were observed for sites on fill (92.3%) and cut (93.8%). These success rates come from relatively high numbers of projects, 13 total for fill and 8 total for sites on excavations. Finally, the highest success rate observed was 100% for protection of a site against storm damage exposure. Unfortunately, this success is represented by a single project (Metro-Seattle North Beach, project #27) and thus a true indication as to risks of failure under this type of project cannot be adequately assessed.

While the failure rate at unmanipulated sites has been recognized as high for many years, the lure of relatively low-cost restoration continues to bring this option back as a favored approach employed by project proponents. In San Francisco Bay, the Richmond Harbor Training Wall Tranplant (project #12) on unmanipulated sites has generally served as the only indicator of eelgrass restoration potential within San Francisco Bay. However, what is often overlooked from this study are the conclusions drawn with respect to the potential for future restoration in San Francisco Bay. These are best exemplified by the study findings themselves:

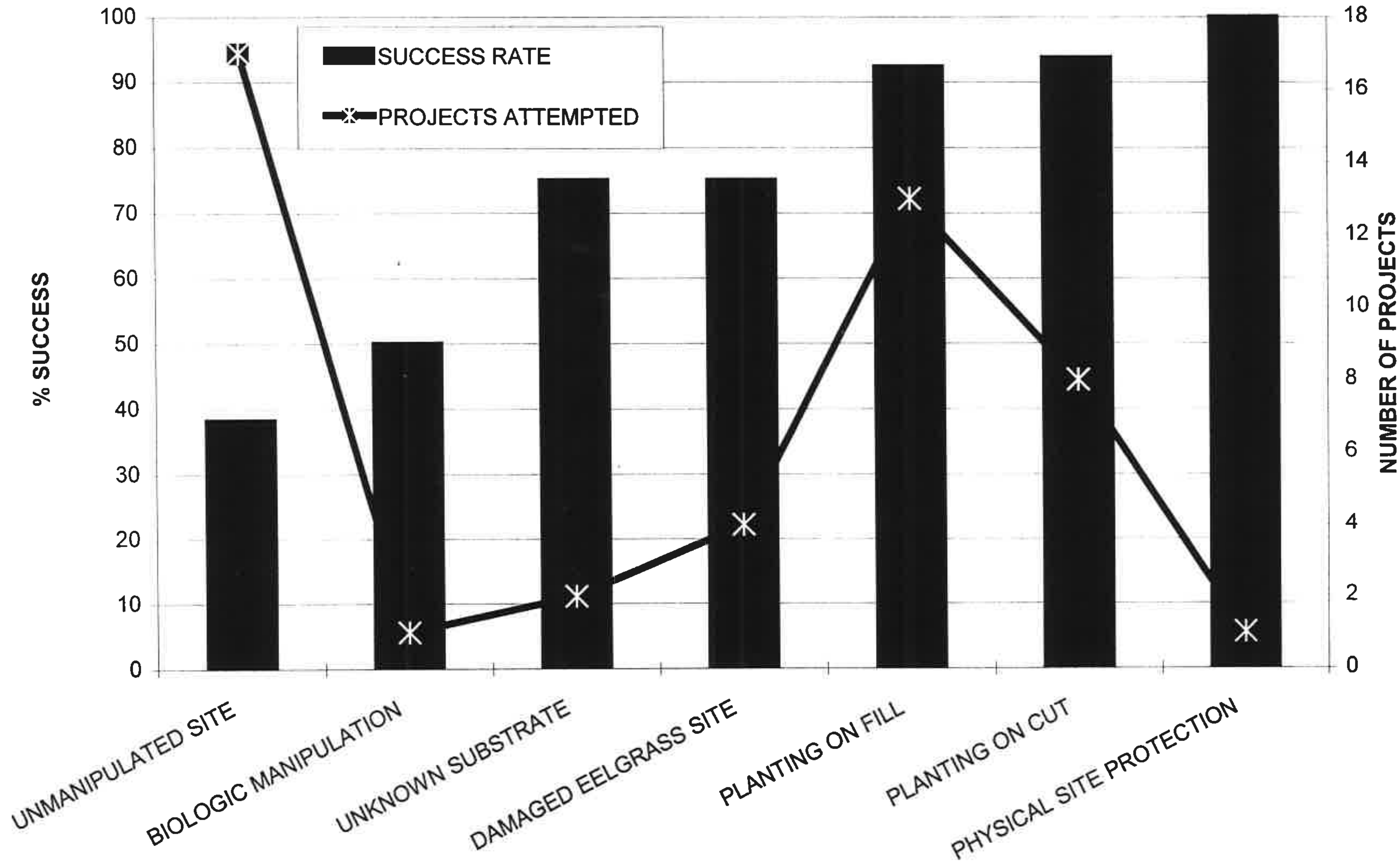


Figure 5. Rate of Success for Eelgrass Transplants Conducted with Different Site Manipulations

> Habitat restoration of creation using eelgrass in San Francisco Bay should not be eliminated from consideration based on the results of this study. Other options should be pursued before such a conclusion is reached, including conducting other trial transplants in different times of the year (the fall is recommended) or specifically engineering sites to provide proper depths, and wave protection for the establishment of either plantings or natural recruits (seed or drifting shoots).
>
> (Fredette *et al.* 1988)

The major transition from transplants to unmanipulated sites to the use of more appropriate cut and fill engineered sites have occurred both as a result of the establishment of success requirements as well as the increased interpretation of eelgrass and shallow water habitat restoration as a beneficial reuse of dredged materials under the Coastal Zone Management consistency requirements and the California Coastal Act.

Planting Unit Selection

One of the most consistently reported elements of a transplant has to be the type of planting unit used. Globally, these have included everything from free seed to sod. However, on the west coast of North America, the only units that have been used to any degree have been individual shoots, sediment plugs, and anchored bare-root planting units. Individual shoot transplant methods are not sufficiently well-represented at a commercial transplant scale to provide a suitable evaluation of this approach based on west coast experience. However, this technique has been successfully used on an experimental scale for many years. In commercial applications, sediment plugs were the most widely used transplant units through 1985 at which time anchored bareroot units became dominant on the west coast.

Sediment plugs historically have exhibited a high instance of failures related both to planting site selection and problems with the plugs themselves. While the relatively high rate of plug transplant failures may generally be attributed to coincident poor site selection, other problems with plugs have been identified and have contributed to failures in some areas. Most of the plug failures have occurred as a result of incorporating plugs of differing sediment consistancy into bottom sediments within areas exposed to erosive currents and waves. With plugs of a more firm material than the ambient sediments, sediments around the plugs tended to erode away. Where plugs were of a finer sediment consistency, the plugs themselves would erode away. In an attempt to resolve some of the handling difficulties associated with plugs as well as the plug sediment erosion problem, plugs in peat pots were planted for some early projects such as that at the Pier Bravo Munitions Pier Eelgrass Mitigation Project (project #1). The result was a two-fold failure. Not only did the ridged pot material exacerbate the erosion problems from both outside and within the pot, but the peat pots never decayed enough to allow plant rhizome extension into adjacent sediments.

Because of the theoretical benefits that plugs should have in maintaining the plant root system intact, this planting approach continues to be used on a rare and typically experimental basis. Plug plantings were used as a minor portion of the Chula Vista Wildlife Island Eelgrass Restoration (project #16), and in the Metro-Seattle North Beach Mitigation (project #25). The success of plugs was compared to the newly designed soft anchor bareroot planting units in early, pre-planting studies at Sail Bay (project #12). It should be noted that plug transplants conducted at a good site and with appropriate plug sediments can and do perform well. However, to date no substantial benefits to plugs over bareroot units remain proven within any significant restoration context. Further, given the substantially greater handling cost over bareroot units there is little to suggest a benefit to this approach for transplants. other than within experimental plots.

Bare-root planting units were introduced into eelgrass habitat restoration approximately two decades ago and was first made efficient in the early 1980's (Fonseca, *et al.* 1982). On the west coast, bare-root transplant units were introduced in 1982 in Vancouver, B.C. as one of many types of planting units being tested for restoration at the Roberts Bank Superport site (project #5). In 1985, soft anchor bare-root planting units were introduced (projects #11 and 12). These planting units have been used most extensively in subsequent transplant efforts. Success of these units has been demonstrated in a variety of environments and studies of these units have been optimized for southern California to obtain maximum plant survival with minimal amounts of donor material (Merkel 1990).

Planting Site Substrate

Several authors have noted the textural qualities of substrate onto which eelgrass is transplanted. Sediments on which eelgrass naturally occurs range from fine silts to coarse sand or fine gravels. Transplants have occurred across this entire range of substrates with mixed success. Unfortunately, there is no clear distinction between sediments which promote success and those which result in failure of eelgrass restoration. Further, few projects report actual specifications of receiver substrate so it is difficult to know how definitions such as "silt", "sand", "medium sand", etc. are used. To further complicate the defining characteristics of receiver site sediment evaluation, eelgrass lowers the boundary layer energies and results in a depositional environment and one supporting finer and more organically enriched sediments as beds mature. The result of this fact is that sediments from intact eelgrass beds are not generally good indicators of sediment conditions appropriate for transplant reciever areas.

From transplant projects there is some empirical data that may be used to identify preferable eelgrass planting environments. At Sail Bay (project #12), the receiver area was dominated by very low organic beach sand with a tight particle graduation around a mean of 0.22 mm diameter. Within this site, eelgrass grew vigorously, although sediment compaction frequently made planting difficult. Interestingly, eelgrass within this site eventually grew over storm drain bedding gravels of a 1-inch minus size class, however at the time this occured, gravel had already accumulated a heavy dusting of fine sediments capable of supporting eelgrass. At the Le Meridien site (project #24), clean river sand with zero organic content was used to create a submerged plateau. Within this well graded sand, 64% of the material ranged between 0.1mm and 0.4mm with other materials ranging to a size greater than 2mm. Again, eelgrass growth and survival was high.

At the extremes of the spectrum, eelgrass plantings have been performed in deeper waters within very fine sediments of nearly a gelatinous consistency. This was done at South Shores Boat Basin (project #29) and NEMS-4 (project #30). Early transplant mortality in these sediments was high, but surviving units grew and expanded, albeit more slowly than those in sand. It is unclear whether the retarded rate of expansion was due to sediment conditions or light limitation. At South Shores these sediments were eventually overgrown by eelgrass, while at NEMS-4 these deeper fringe sediments ultimately failed to support eelgrass. Within fine sediments, rhizomes generally grow very near the sediment surface, perhaps to foster greater gas exchange along roots. The poor oxygen penetration into fine sediments may suggest the reason for higher unit mortality in silts than in sands.

In coarse sediments, eelgrass grows reasonably well provided other physical conditions are suitable. Coarse sediments are generally indicative of high energy environments no normally conducive to eelgrass growth. At the successful Metro-Seattle transplant (project #25), reciever site mean sediment grain size exceeded 0.85mm within an area that had recently been protected from winter storms. Finally, on Admiralty Island, Alaska, an experimental transplant was done on an unmanipulated beach with nearly 100% of the sediments exceeding 2.0mm in size. This transplant survived from May through at least September 1987 and showed signs of growth and expansion. Unfortunately the transplant did not survive the winter storms that pound the cove in which planting was done (Merkel, unpubl. data). There is no indication that this transplant would have failed, absent the heavy storms. In northern regions, eelgrass regularly grows in sediments in excess of 0.6mm and is believed to be restricted by environmental energies rather than the sediment grain size.

For the purpose of conducting transplant projects, it has generally been found that sandy sediments are superior to silty materials. This is driven by the relative differences in initial transplant unit survival and growth as well as for logistical considerations. Logistics of working within a sandy sediment site versus a silty site include the increased ability to perform post-placement site modifications and improved water and sediment conditions for planting the site. Medium to coarse sandy sediments (0.2mm-0.6mm) have yielded the best results in transplant projects. However most successful transplants have occurred with sediments at the lower end of this spectrum, principally due to the normal, 0.2-0.3 mm, particle size that dominates in southern California bays and harbors where most planting has occurred.

Shallow Water Habitat Restoration Projects

While 19 of the eelgrass restoration projects reviewed included the creation of shallow water as a supporting element for eelgrass (11 on fill and 8 on cut), only two of the projects reviewed were constructed with the principal objective of creating shallow water, exclusive of eelgrass habitat. These projects were both constructed as mitigation for port development fills. The Port of Los Angeles's Pier 300 shallow water mitigation area (project #7) included the creation of a 190 acre shallow water mitigation site by filling a deep water portion of Los Angeles Outer Harbor using dredged materials. The site was raised to a mean depth of approximately -18 feet MLLW as mitigation. The second project is the Port of Long Beach's Pier J shallow water mitigation area (project #21) mitigation site. The Pier J site is a 116 acre shallow water basin cut from uplands to mitigate a 147 acre deep water fill. Both of these projects have been deemed successful by resource and regulatory agencies.

More recently, the Port of Los Angeles has completed the Batiquitos Lagoon Enhancement Program (project #32). This project has included significant dredging, filling, jetty construction, shoreline armoring, island construction, and other marine construction work. Because the project includes eelgrass restoration, it is not considered uniquely shallow water restoration, however it does provide some key insights into shallow water design and large-scale marine habitat construction programs.

Shallow Water Fills

The Pier 300 project (project #7) is perhaps the best example of a deep water port fill to create shallow water habitat. The Port of Los Angeles (Port) expanded the Pier 300 facilities located on Terminal Island in Los Angeles Harbor. Pier 300 consists of a container terminal (which includes a four-berth wharf, 200 acres of container storage, an intermodal container transfer facility, and a California least tern nesting site). Expansion of the site included dredging 30 million cubic yards of material to deepen navigation channels (to -63 feet MLLW) along the south side of the pier, and placement of 38,000 linear feet of rock dike and armor to construct 191.5 acres of new land and 65.1 acres of access corridor. In order to mitigate the loss of shallow water habitat due to the channel deepening along the south side of Terminal Island, the Port created 190 acres of shallow water habitat along the eastern edge of the island. Fill was placed using standard bulk dredging practices. However, because the fill topped out at approximately -16 to -18 feet the majority of the complications of placing materials in shallow waters were not realized in this project. A relatively small amount of material was placed with this project. Approximately 800,000 cubic yards of dredge material from the channel deepening in addition to 450,000 cubic yards of clean fine-grained material along the eastern edge of the existing Pier 300 in order to create shallow water habitat no deeper than -20 feet MLLW. Channel dredging materials included some sediments of low level contamination that was placed in the deep fill. The permits and memoranda recognized shallow waters to be preferable to deep waters and success was deemed to have been met with the physical construction of the site. No biological monitoring was required for the project.

Although not related to the fill itself, the Port of L.A. has been maintaining its least tern nesting colony for several years and has made its colony available and funded research on tern foraging which has provided some interesting results relative to the shallow water fill. It has been determined that the shallow water mitigation area serves as valuable feeding area for the federally and state endangered California least tern, which nests annually at a created site located on Terminal Island, adjacent to the shallow water mitigation area. Keane (1987) conducted least tern foraging studies at multiple sites in Los Angeles Harbor, CA. She determined that the majority of foraging activity occurred in shallow water areas adjacent to the nesting colony. In addition, shallow water habitat was used most heavily when least terns were feeding chicks. Preliminary radio tagging studies conducted by Massey in 1986 and 1987 at the Terminal Island nesting colony generally supported the earlier findings of Keane (1987). However, Massey conclude that the birds primarily foraged outside the breakwater, in the nearshore ocean, while eggs were incubating. However, individuals showed a marked shift in foraging location after chicks were hatched, foraging almost entirely in the shallow areas of the harbor nearer the colony and where smaller fish were more abundant.

A less compelling argument for shallow water restoration was made by assembling data from fisheries studies conducted prior to, during, and after the construction shallow water mitigation area. Unfortunately the study objectives and methods were very different between studies and comparisons are weakened by these differences. The United States Fish and Wildlife Service used gill net and otter trawl to characterize the fish community prior to construction activities. The USFWS otter trawl collections contained an average catch of 321 fish weighing 6.3 kg and comprised of 8.2 species. A total of 25 species were captured over the course of the study. The Southern California Ocean Studies Consortium used beach seine, gill net, purse seine, and otter trawl to characterize the fish community during and immediately following the creation of the habitat. The SCOSC otter trawl collections (during the same months as the USFWS surveys) contained an average catch of 116 individuals weighing 6.4 kg per trawl. A total of 26 species were captured over the course of the study. MEC Analytical Systems, Inc. (MEC 1988) completed post-construction fisheries surveys at the mitigation area that were comparable to the previous two studies. MEC otter trawl collections contained an average catch of 89 individuals, weighing 8.0 kg per haul and comprised of 8.8 species. A total of 22 species were captured over the course of the study. MEC (1988) argued that although the results from the fisheries surveys indicated a reduction in abundance of fish in the mitigation area after construction, the total number of species captured remained comparable to previous surveys. Further, the created shallow water habitat provided an important nursery area, particularly for queenfish, California grunion, northern anchovy, and California halibut. No more recent surveys of this area have been conducted to provide an updated status of the area.

While achieving the required mitigation goals set forth in permits, comparisons of this area with such sites as Cabrillo Beach, the Port of Long Beach's Pier J mitigation area, and the Batiquitos Lagoon Enhancement Project would suggest some design change benefits that could have further enhanced the values of the mitigation area. First, an even shallower site would likely have yielded higher habitat benefits. A shallow water/shoreline beach transition area has been identified by the Port of L.A. as one of the valuable habitat elements that they wish they could have created at the site, having now observed the benefits at other restoration sites (R. Appy, Port of LA, pers. comm.). Given the exposure of the site, a substantially shallower site would require greater protection against storm damage.

Shallow Water Habitat from Excavations

The Port of Long Beach has constructed the largest, non-marina, shallow water basin along the west coast through excavation of uplands (project #22). In 1990, a 116 acre shallow water basin was excavated from weedy uplands in the Anaheim Bay NWS Refuge lands. The purpose of the excavation was mitigation of a 147 acre deep water fill for the Pier J port facilities within Long Beach Harbor. A mitigation credit exchange rate of 1.32 acres of deep harbor fill to 1 acre of shallow water creation was required by permits and memoranda of agreement. This rate was determined by habitat valuation modeling. Follow-up biological monitoring was required to verify success of the project in achieving predicted habitat objectives. A five year monitoring program was completed and the same *a priori* valuation criteria used to generate habitat credit exchange ratios, were applied to observed data. The mitigation site met the desired objectives and achieved the values predicted. The site has turned out to be more heavily used by birds than was originally predicted and supports extensive nursery area values for such species as deepbody and slough anchovy.

Mixed Habitat Restoration Projects

One recent project stands out as having a number of values as a model for assessing design, construction, and maintenance aspects of shallow marine habitat restoration. While the Batiquitos Lagoon project has been previously discussed for its eelgrass restoration program, the site perhaps serves an even greater value as a tool for evaluation of shallow water habitat restoration. The Batiquitos Lagoon Enhancement Project was a nearly complete restoration of a degraded lagoon area along the southern California coast. The mouth of the lagoon was generally closed and much of the inner lagoon had filled with sediment. Restoration included construction of a pair of entrance jetties to minimize beach formation across the mouth of the Lagoon, dredging of extremely shallow flats to improve tidal prism, and construction of bird nesting islands to support and enhance nesting by California least terns and western snowy plovers. The dredging work included an elaborate sediment management program wherein sandy sediments were exported to the beaches for replenishment, fine undesirable sediments were placed in a deep hole excavated for beach replenishment, and a second source of sand was used to cap the borrow site to contain fine sediments.

The project was unique in several respects. It was the first major restoration of an existing marine system that was not principally a tidal marsh. It included a number of restoration design elements including marshes, mudflats, shallow water, bird nesting islands, and eelgrass. It was one of the few restoration projects that was based on a MOU that would result in future transfer of management and maintenance to the State along with a maintenance account. Finally, the project includes a 10 year long-term monitoring program designed to document physical and biological changes in the site over time.

The long-term post-restoration monitoring program has provided considerable insight into site stabilization processes and how development occurs within vegetation, invertebrate, fish, and bird communities. The project has generally been very successful for invertebrate and fish community development. Birds appear to have also been benefitted, however after only one year of monitoring, it is too early to be able to fully sort out habitat improvement effects from seasonal and interannual variability. However, it is clear that the restoration has been phenomenally successful with respect to enhancement of terns and plovers at the site. These species have increased their breeding pair numbers by 800% and 700% respectively over the past four years. While tern nesting site creation at Batiquitos has been extremely successful, this restoration element has the potential to be the second most significant maintenance area behind maintenance dredging within the channels.

Islands were manufactured by hydraulically placing dredged sands. Presently these sites remain generally unvegetated, however weedy plants may eventually colonize these areas as they have many of the tern colonies throughout the state.

The project provides valuable insight into what levels of control and specification tolerances are achievable using dredging equipment. The project monitoring program provides insight into habitat recovery processes following major restoration efforts. The Batiquitos Lagoon restoration revealed that tight dredging specifications can be met, however it was also clear that intensive contractor monitoring and guidance is critical to ensuring that material placement and phasing are executed properly to ensure that desired materials are available and used where appropriate. The Batiquitos Lagoon monitoring program has identified the need for comparable pre- and post-construction monitoring. One failing of the Batiquitos Lagoon restoration is the limited data collection completed prior to and during restoration. While data collection programs were conducted during these periods, they were not intensive and comparable to the post-construction sampling effort. Because of these differences in sampling programs, it has been necessary to reduce data comparisons between pre-, during, and post-construction to only a minor subset of the data available from the post-restoration monitoring.

Another element for mitigation projects that became clear from the Batiquitos Lagoon program is the need for a well funded early performance guarantee period. In the Batiquitos Lagoon mitigation and financing memoranda, two components of the project were identified. The first was the construction phase under which initial work was completed. The second was the maintenance program under which a self sustaining fund was established to address maintenance actions. However, no separate funding was established to address design flaw corrective measures that were manifested over the first year following construction. These included the need for additional shoreline erosion protection and remedial fencing. Such a warranty period will most certainly be a factor of future large-scale mitigation projects to address these potentially significant cost corrective measures (R. Hoffman, pers. comm.). Such an approach based on specific permit guarantees or bonding would resolve the need to address these one time costs through the use of maintenance funds.

LESSONS FOR MIDDLE HARBOR ENHANCEMENT

The Middle Harbor Enhancement Area has not been designed without substantial knowledge of prior restoration project successes and failures. Of the projects reviewed in this paper, Merkel & Associates and its staff have performed design, restoration, monitoring, or agency consulting work on 25 (53.1%) of the projects reviewed. Merkel & Associates staff have worked on 73.5% of all identified west coast restoration projects conducted since 1986.

The Richmond Harbor restoration project results have long been identified as a reason not to attempt additional eelgrass mitigation or restoration projects in San Francisco Bay. However, in the aftermath of the Richmond Harbor project, one specific conclusion that was reached was that those results should not preclude future restoration attempts. Further, the project report suggested that future efforts should be conducted at sites specifically engineered to support eelgrass. The Middle Harbor Enhancement Area is precisely such a site. In 1993, in-bay terraces supporting eelgrass were identified as potential mitigation opportunities for several California ports, including the Port of Oakland and Richmond. Principally this determination was based on the presence of nearby eelgrass habitat and reasonably suitable conditions to restore eelgrass habitat through placement of fills to elevate the bottom to appropriate conditions (MEC 1993).

Clearly from the data collected at 45 other eelgrass restoration sites, eelgrass transplant success is favored in areas which are engineered to support this habitat. Taken in total, 93.2% of the 22 sites engineered to support eelgrass were successful. These include sites that were filled, excavated, and protected from physical storm damage. Middle Harbor includes both a fill to create appropriate depths, and channels and a jetty to meet hydrodynamic requirements and to provide site protection against storm damage to enhance eelgrass restoration potential.

One aspect of the restoration proposed is a two step restoration including a pilot planting within the finished Middle Harbor site. This pilot project will provide information on performance of plantings in different portions of the site. A subsequent larger planting effort would make use of the data collected in this pilot effort to restore a number of strategically placed beds to provide a seed source for natural colonization of the larger site. The Richmond Harbor project made a recommendation for a fall season transplant based on heightened growth during this period. In the Metro-Seattle project the spring was selected to provide the maximum period for root structure development prior to winter storms. Other projects have favored summer season transplants. Based on the various preferences for different planting periods, it is appropriate to expand the pilot planting effort to include transplants during at least the three seasons that have been used regularly (spring, summer, and fall). Another notable consideration in the pilot transplant is the selection of donor sites for the restoration. Experimental common garden transplants conducted by Wyllie-Echeverria and Phillips (unpublished data) in which plants were moved from Point Melote to Keil Cove and reciprocally transplanted, indicated that plants from the more turbid Pt. Melote site were well able to colonize in Keil Cove, however Keil Cove plants could not withstand the conditions of Pt. Melote. Wyllie-Echeverria and Phillips argue that this is an indication of differences in environmental tolerances between populations within San Francisco Bay. While this is not surprising, it does suggest that a number of donor sites should be used and separately tracked in the pilot restoration effort.

There has been a suggestion that a smaller pilot transplant be conducted prior to completing the larger Middle Harbor Enhancement Area. However, such a unmanipulated pilot program is not believed to be warranted given the fact that experimental transplants within San Francisco Bay have demonstrated that eelgrass can be moved where conditions are favorable. Other restoration efforts have demonstrated that eelgrass can be effectively restored to created sites with high levels of success. What cannot be determined from an additional transplant in San Francisco Bay is how eelgrass will perform within the Middle Harbor site once the site has been modified for eelgrass restoration. This will only be determinable following completion of the site.

One factor of created sites that results in substantial risk at the Middle Harbor site is found in predicting appropriate bulking to address site consolidation and stabilization. The Batiquitos Lagoon project included a fill over a 38 foot deep borrow site which was backfilled with fine sediments. This site was not surcharged with fill that reached supra-tidal conditions and therefore weights were substantially less than in terrestrial surcharged sites and consolidation has been slower. Similarly consolidation rates were slowed in the construction of the Sail Bay site. Because of the critical elevations that must be attained to support eelgrass, it is necessary to fully understand the bulking factors and consolidation rates and processes within Middle Harbor early in the site construction process. This will allow an appropriate amount of fill to be placed during construction to achieve target elevations after settlement. This will also aid in establishing the schedule for transplantation.

The Middle Harbor Enhancement Area project draws guidance from a number of other projects and would result in a unique reclamation of San Francisco Bay habitat to near historic shallow water conditions. The fact that the work may be performed as an enhancement rather than serving significantly as mitigation is, in itself, very unique opportunity. However, to fully provide all benefits that can be achieved, it is critical that a well devised monitoring program for physical and biological resources be incorporated into the project such that future projects may benefit from what is learned here. In specific, it is critical that a monitoring program provide both pre-construction and post-construction data collection of a comparable form. This was a short-fall of nearly all of the prior projects reviewed.

Construction period lessons have been derived throughout the history of eelgrass and shallow water restoration projects. These have illustrated several generalities. First, contractors need both tight specifications and a clear understanding that they will be held to the specifications in order to perform as desired. Second, contractors are capable of working within relatively tight specifications when required, however there is a cost. Finally, contractors need to be closely monitored during the project work to avoid the emergence of undesirable conditions that cannot be rectified without considerable effort or cost. The greatest number of problems encountered have been poor site construction, material footprint misplacement, and inadequate control of material reuse phasing to obtain proper layering and bulking factors.

In discussions with agency staff and project managers, including port staff that have had considerable experience with large-scale restoration efforts, three key recommendations arose with respect to administrative element of a project. The first was that projects include a warranty period during which design flaws could be corrected without tapping into maintenance funds. The second was to carefully consider the long-term management program and who will manage the area after restoration. Both resource agencies and restoration project proponents have had less than desirable results with resource agency management. Where agencies are to receive the management obligations, at a minimum, management requirements and mandatory staffing needs to be clearly addressed. Understaffing, lack of expertise with contracting and land-use issues, and burdensome administrative procedures can be nearly crippling factors for agency management programs. Finally, permits and authorizations should incorporate flexibility to address construction period design changes governed by sound decisions and should also include coverage for maintenance predicted to be required over the life of the project.

The results of prior projects would suggest that the Middle Harbor is likely to yield the success desired. During the final engineering process, a physical and biological monitoring program and pilot transplant program should be developed. This program should generally follow the program employed at Batiquitos Lagoon. A specific program to monitor bulking factors for fill placed early in the project should also be developed. Data collection on eelgrass habitat should continue. This includes review of natural beds throughout stressful seasons to characterize dynamics of San Francisco Bay eelgrass beds. In addition, efforts should be continued to characterize the physical tolerances of eelgrass in various beds that may be used as donor sites. Finally, the nature and distribution of annual and perennial populations within the Bay should be explored. It is not clear whether genotypically annual populations exist in the Bay or whether poor site conditions result in a phenotypic expression of an annual life-history in genetically perennial plants.

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