Critique of Present Wetlands Mitigation Policies in the United States Based on an Analysis of Past Restoration Projects in San Francisco Bay

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ABSTRACT / A detailed evaluation of past wetland restoration projects in San Francisco Bay was undertaken to determine their present status and degree of success. Many of the projects never reached the level of success purported and others have been plagued by serious problems. On the basis of these findings, it is debatable whether any sites in San Francisco Bay can be described as completed, active, or successful restoration projects at present. In spite of these limited accomplishments, wetland creation and restoration have been adopted in the coastal permit process as mitigation to offset environmental damage or loss of habitat. However, because the technology is still largely experimental, there is no guarantee that man-made wetlands will persist as permanent substitutes for sacrificed natural habitats. Existing permit policies should be reanalyzed to insure that they actually succeed in safeguarding diminishing wetlands resources rather than bartering them away for questionable habitat substitutes. Coastal managers must be more specific about project requirements and goals before approval is granted. Continued research on a regional basis is needed to advance marsh establishment techniques into a proven technology. In the meantime, policies encouraging or allowing quid pro quo exchanges of natural wetlands with man-made replacements should proceed with caution. The technology and management policies used at present are many steps ahead of the needed supporting documentation.

In recent years the meaning of mitigation in coastal permits in the United States has expanded from its strict sense of "alleviating or lessening" damages on-site to a more liberal interpretation allowing compensation, off-site substitution, or replacement of habitats. The latitude in interpretation of coastal regulations has allowed coastal managers and prospective developers to negotiate the detailed mitigation conditions of each permit. The result has often meant trading away natural wetlands in exchange for restoring, replacing, or creating wetlands elsewhere. Ideally, this mitigation by habitat exchange could result in a net gain of wetland area since permittees are often required to replace more acres than were lost at the original permit sites. However, because establishment of man-made marshes is unpredictable, this environmental bartering system may not result in all the benefits envisioned by its proponents. Discussions with coastal managers and review of projects elsewhere (Race and Christie 1982) suggest that the problem is not limited to one area of the country. In this report, experiences in San Francisco Bay are discussed to highlight some of the problems encountered when marsh establishment technology is used in the permit process.

KEY WORDS: Marsh restoration; Man-made marshes; Coastal zone management; Mitigation; Coastal wetlands

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Background

After more than a decade of experience, the technology of marsh building in the United States is still largely experimental. Although many projects have been undertaken nationwide, few detailed reports are available which document the establishment of entire marsh/wetland biotic communities in man-made marshes. In San Francisco Bay, despite the fact that over a dozen sites have been referred to as marsh enhancement, restoration, or establishment projects, field work indicated that a comparative study between man-made and natural marshes was impossible for a number of reasons. These included the almost total lack of suitable natural control sites in a highly urbanized estuary; the great variability in sizes, tidal conditions, substrate characteristics and other physical factors within and among sites; and the early successional stage or unusual conditions at many sites.

For these reasons, crucial questions about marsh restoration and mitigation by habitat exchange on the West Coast, and in San Francisco Bay in particular, cannot be answered from a strictly biological perspective at this time. At present, to determine whether mitigation by habitat exchange is an appropriate long-term coastal management strategy, an analysis of the question from a policy and management perspective is required. This report is designed for that purpose.

Methods

To assess the success and persistence of marsh restoration and establishment efforts, data were gathered for all past projects in San Francisco Bay involving restoration, enhancement, mitigation, experimental plantings or marsh establishment. Where possible, information for each site included a chronological profile, permit history, quantitative or qualitative field data, and photographs. Many purported restoration projects listed by various authors (see Josselyn and Buchholz 1982, Harvey and others 1982) were deliberately excluded from further analysis because they involved neither marsh establishment technology nor planting of vegetation, or were unfinished.

Permits issued by the Bay Conservation and Development Commission (BCDC) for the years 1977 to 1982 were analyzed to determine the frequency of different types of wetland restorations required as conditions of permits. BCDC has jurisdiction over projects and developments in tidal areas and/or within 100 feet of the line of highest tidal action in San Francisco Bay.

Detailed Review of Past Wetland Projects

Because it is difficult for government decision makers to follow the latest developments and technical details of environmental research, they must rely on review articles, government summary reports, and information from the professional scientists with whom they interact. At present, coastal managers are unable to critically analyze the success of previous restoration projects because of the great variability in nature and scope, and the inconsistency in classification schemes and definitions used in the literature. In addition, many published reports of success have been premature or misleading, giving coastal managers an inaccurate picture of the status of previous restoration attempts.

Past restorations projects in San Francisco Bay provide examples of all these problems. Of the 33 past restoration projects in California (Josselyn and Buchholz 1982), 16 are located in San Francisco Bay. Excluding freshwater marshes, sites with no substantive work done to date, and projects enhancing only water flow, only 11 projects can be described as past wetlands projects. Because information on many of these projects is unavailable in the literature, details are provided below about the work performed and eventual results at each site. The reader interested in only a summary of this detailed information should refer to Tables 1 and 2.

Experimental Vegetation Plantings

Of the 11 projects in San Francisco Bay, six (Table 1) involved the experimental planting of vegetation on 0.2 ha (0.5 acres) or less. These projects focused on the establishment of *Spartina foliosa* on dredge spoil or bare areas for one or more of three objectives: (a) to evaluate planting techniques, (b) to develop cost estimates for larger projects, and/or (c) to attempt to control erosion.

Bay Bridge site. One of the earliest experimental plantings in the bay was undertaken between 1969 and 1971 in conjunction with a freeway construction project near the Bay Bridge Toll Plaza in Oakland. Neither the planting scheme nor detailed data on vegetation persistence are available (Harvey 1983). As reported in a nationwide survey of restoration projects (Appendix B in Garbisch 1977), only 10% of the *Spartina* transplants survived at this site after one year. Transplants, plugs, and seeds of *Salicornia pacifica, Distichlis spicata,* and *Grindelia humilis* were also tried. After one year, 70% of an unspecified number of *Salicornia* plugs survived, though no *Salicornia* survived from seeding. Survival of the *Distichlis* plugs was 20%, and 100 plants of *Grindelia* were established from seed.

Marin Country Day School site. In 1974, 594 plugs of *Spartina foliosa* were planted on an area of 467.3 m^2 (5000 ft^2) in Corte Madera, California. The project was "set up as an empirical effort, not as a scientific project, because the ultimate objective was to retard erosion rather than measure plant growth." (Kingsley and Boerger 1976). Plugs were transplanted from the nearby Larkspur Ferry Terminal site and placed at 3-m intervals in a strip 9.15 m wide (30 ft) along 76.2 m (250 ft) of shoreline. Qualitative monitoring for survival was done from the time of planting in May 1974 to September 1975, at which time 235 of the original 594 plugs remained. "No apparent abatement of shoreline erosion had occurred by fall of 1976" although the remaining vegetation was reported to be similar in appearance to a nearby control marsh. Since that time considerable spread of vegetation has occurred, although the stated objective of erosion control has not been met (Josselyn 1983).

Anza Pacifica lagoon. Planting at the edge of this rip-rapped lagoon was required by a court decision as mitigation for unpermitted fill and construction activities nearby. In 1974, four edge areas of the lagoon were each planted with 125 *Spartina* plugs, seedlings or cuttings, and 1 liter of seeds. Following the failure of all experimental plots, replanting took place in June 1978 with 448 plugs divided over six plots (Harvey 1983). After 18 months, fewer than a third of the original cordgrass plugs remained (Harvey 1979). By 1981, all that remained of the plantings were sparse remnant patches of plugs at three locations in the lagoon.

Table 1. Past experimental plantings in San Francisco Bay.

Location	Date	Actual area restored	Results	Bank enhancement or erosion control	Mitigation for wetlands loss	Mitigation for other habitat loss	Post construction repair	Experimental	Published reports of success/ completion
Bay Bridge approach, Oakland	1969–1971	—	10% survival of *Spartina* @ 1 year; mixed results for other species				X	X	G, J
Marin Country Day School, Corte Madera	1974	594 plugs on 467.3 m^2	< 40% survival @ 18 months	X				X	G, J
Anza Pacifica lagoon, Burlingame	1974	4 plots of 125 plugs and 1 liter seeds ea.	Failure		X			X	G, J
	1978	448 plugs on 6 plots	< 33% survival @ 18 months		X			X	G, J
Alameda Creek channel, Fremont	1974–1976	1600 m^2 (66 5 × 5 m plots)	< 50% survival of *Spartina* on transects and ⅓ to ¼ vegetative cover on best plots @ 18 months	X				X	G, J, K
Point Pinole[a]	1975–1978	6 4 × 4 m plots	4% survival of plugs with wave-breakers @ 17 months; 0% survival of all other experiments @ 8 months	X				X	G, J, N
San Mateo[a]	1975–1978	150 × 15 m plot; 6 4 × 4 m plots	Immediate failure of seeded area; 0% survival of plugs and sprigs @ 5 months; 4% survival of plugs with wave-breakers @ 17 months	X				X	G, J, N
Alameda Creek[a]	1975–1978	Vegetation: 150 × 15 m plot; 10 4 × 4 m plots	Immediate failure of seeded area; 0% survival of plugs and sprigs @ 8 months; 0% survival of plugs with wave-breakers @ 18 months	X				X	G, J, N
		Bioconstructs: 5 5 × 5 m plots	2 "successful" plots in areas of low wave shock; 1 plot with increased *Spartina* @ 13 months	X				X	G, J, N
Muzzi Marsh experimental, Corte Madera	1976	39 4-m^2 plots	All vegetation disappeared by 5 months; average survival @ 3 months for north section: 8.43 seedlings m^{-2}; for south section: 0.8 m^{-2}		X			X	—

[a]US Army Corps of Engineers Bank erosion control project.

G, Garbisch 1977; J, Josselyn and Buccholz 1982; K, US Army Corps of Engineers 1976; N, Newcombe and others 1979.

Alameda Creek Channel. This experimental planting project involved 66 5 × 5 m plots and seven "linear transects" of unspecified lengths on 500 m of unconfined dredge material along the north bank of the Alameda Creek Flood Control Project (US Army Corps of Engineers 1976). A total area of 1650 m^2 was planted in May 1974 using rooted and unrooted cuttings, seeds, seedlings, or plugs of *Spartina* and *Salicornia*. The area covered by the 48 cordgrass plots was 1200 m^2, while the 18 *Salicornia* plots covered 450 m^2. In addition, "almost 300 plugs of *Spartina* were planted along transects at various elevations." Data on survival and growth of vegetation were reported for six months (Newcombe and Pride 1976) and 18 months (Floyd and Newcombe 1976) after planting.

After two growing seasons, average survival of *Spartina* on experimental plots ranged from one to nine plants m^{-2}, with the worst results from cuttings, and the best from plugs. The average height of plants was about one-third that of nearby natural *Spartina* stands, and the best plots had ¼ to ⅓ of the sediment surface covered with *Spartina* after 18 months. The transects of *Spartina* averaged 48% survival after 18 months (Harvey 1975). An analysis of *Salicornia* growth was complicated by the invasion of numerous volunteers. The final report for the project predicted the experimentally planted *Spartina* would establish densities equivalent to mature stands in about three years, a prediction that has never been documented. Spread of *Spartina* beyond the original planted area has not occurred. A proposed dredging and levee repair project is expected to destroy this channel wetland in the near future (US Army Corps of Engineers, San Francisco District, Public Notice no. 14510E98C, 13 January 84).

US Army Corps of Engineers bank erosion control projects. Three experimental sites, at Alameda Creek, Point Pinole, and San Mateo, were studied between 1975 and 1978 as part of a research program of the Army's Coastal Engineering Research Center to provide "information on the use of intertidal salt marsh vegetation for erosion control on the open shores of the San Francisco Bay system" (Newcombe and others 1979). Field plantings with *Spartina foliosa* seeds, sprigs, plugs, and "bioconstructs" (cordgrass plugs with attached ribbed mussels, *Ischadium demissum*) were undertaken during the summers of 1976 and 1977 on nonreplicated plots. Quantitative monitoring of vegetation survival was conducted for up to eight months after planting.

All attempts at seeding, either by hydroseeding or by hand, failed completely within two days at both San Mateo and Alameda Creek. Plantings with sprigs were unsuccessful at both sites as well. At San Mateo, only 6% of the 360 sprigs survived one month and none were alive five months after planting. At the Alameda Creek site, 2% of the 628 sprigs survived five months, with none alive at eight months after planting.

Results with plugs were only marginally better. Of the 108 plugs planted at San Mateo, 54% survived one month, but none were alive at five months after planting. At Alameda Creek, 13% of the 54 plugs survived five months but none survived eight months. In summary, no vegetation persisted longer than eight months on any experimental plots, regardless of starter type.

Further testing of plugs, with and without wave breakers, was also generally unsuccessful at all three locations. Although *Spartina* plugs protected by wooden shingles survived better during the early months after planting, they too eventually died. After 17 months, no more than 4% of the plugs survived at any of the three sites.

In another experiment at Alameda Creek, bioconstructs were planted in 1977 on five dissimilar plots of 5 × 5 m each, using 25 bioconstructs per plot. Survival was monitored for up to 13 months after planting. Although 100% survival was noted for three plots after one year, unusual conditions existed. One plot was established within an existing cordgrass-mussel community, thus demonstrating that transplanting had no lasting detrimental effects on bioconstructs. The two other surviving plots were actually within the creek, not on the outer banks of marsh exposed to the bay. The plot furthest up the creek demonstrated good growth and total survival in an area devoid of wave shock. In the partially sheltered plot closer to the bay, bioconstructs had 100% survival, but with average height and number of stems decreasing over time. These unreplicated results indicated that bioconstructs could be transplanted to areas with little or no wave stress, and presumably little erosive force. The results do not indicate that bioconstructs are useful for either stabilizing eroding banks or establishing marsh habitat.

Muzzi Marsh experimental planting. An experimental planting program was authorized by BCDC in 1976 for Muzzi Marsh in Corte Madera prior to the full restoration of this site as mitigation for construction of the Larkspur Ferry Terminal. In June 1976, several weeks after the dikes were breached, experimental planting of *Spartina foliosa* occurred on 39 4-m^2 plots, half in the north section and half in the south section of the site (Kingsley and Boerger 1976). Seeds collected in November 1975 from San Pablo Bay underwent various storage and rinse treatments before planting in late June. An additional six plugs of *Spartina* were planted in a transect at each plot. Vegetation establishment and survival were monitored six times between late June and November 1976. After three months (the last quantitative data), an average of 0.8 seedlings m^{-2} was found in the south section where 12 of the 19 plots had no survival,

Table 2. Wetlands restoration with major substrate alteration.

Location	Date	Reported size	Actual area restored	Bank enhancement or erosion control	Mitigation for wetlands loss	Mitigation for other habitat loss	Post-construction repair	Experimental	Published reports of success/ completion
Faber Tract Palo Alto, CA	1968–1971	38.4 ha (95 acres)	450 plugs *Spartina* planted on 3 transects			X			G, J, H
Salt Pond III Newark, CA	1975–1976	44.5 ha (110 acres)	4.78 ha (11.8 acres)					X	J, S, H
Creekside Park Kentfield, CA	1976–1978	11 ha (27.2 acres)	4.05 ha (10 acres)			X			J, L, H
Muzzi Marsh Corte Madera, CA	1976–present	site = 214.5 ha (530 acres); 50.6 ha (125 acres) to be restored	<60% of marsh restored to date		X				J, B, H
Hayward Marsh/ Johnson Landing Hayward, CA	1980–present	89 ha (220 acres)	Restoration still underway; site is in early successional stage with large areas of mud		X				J, H

G, Garbisch 1977; J, Josselyn and Buccholz 1982; H, Harvey and others 1982; L, ASLA 1979; S, Saucier and others 1978; B, Beeman and Benkendorf 1978.

five had 2.5 seedlings m^{-2} or fewer, and the two best plots had fewer than 5 seedlings m^{-2}. Establishment of seedlings was slightly better in the north section after three months, with an average of 8.4 seedlings m^{-2}. Two plots had over 25 seedlings m^{-2}, but the remaining 17 plots had between 4 and 12.5 seedlings m^{-2}. Subsequent field observations in October and November indicated that no growth was evident on any of the plots in either section and that all vegetation had disappeared. The final report in 1976 concluded that "no large scale planting of seeds in San Francisco Bay wetlands has been successful to date" and, contrary to previous assertions, that cord-grass seeds planted during the summer do not grow successfully.

Restoration Projects with Major Substrate Alterations

Five sites in San Francisco Bay with reported sizes ranging from 11 to 215 ha (27 to 530 acres) can be categorized as wetland restoration projects with major substrate alterations (Table 2). Detailed analysis of these sites indicated that the areas actually restored to marsh are considerably less than the reported sizes.

Faber Tract. On this 38.4-ha (95-acre) site in Palo Alto, a total of 450 plugs of *Spartina* were planted in 1971 along three transects following use of the site for dredge spoil disposal (Harvey 1983). The site is vegetated and open to tidal flow at present, although some back portions appear to have limited tidal circulation. Natural colonization by *Salicornia,* rather than plantings of *Spartina,* has been responsible for revegetating the area.

Salt Pond III. This 44.5-ha (110-acre) former salt pond and dredge disposal site in Newark was one of the early, large-scale habitat creation attempts of the Army Corps of Engineers Dredge Material Research Program. Following grading and dike breaching in 1976, experimental planting was undertaken in the bayward portion of site. The total planted area of experimental plots amounted to 4.78 ha (11.8 acres). An additional area of about 2 ha (5 acres) at a higher elevation was used for an experiment with 27 species of seeds, none of which became established. In the lower elevations, experimental plots were established for various combinations of starter types of *Spartina* (sprigs or seeds), spacing between plants (0.5–0.3 m), plant elevation, planting season (45-day intervals between April 1976 and November 1977), and planting method (tractor or hand-planting).

No quantitative data are presented in the final report (Morris and others 1978), although descriptive information suggests mixed results. Aerial photographs of the site in 1978 show an irregular patchwork of test plots and large expanses of open mud. At that time, the planted plots covered less than 10% of the site. The remaining area, in excess of 38.4 (95 acres), showed little vegetative cover. In spite of this, the program's summary report asserted that the study "demonstrates that a *Spartina foliosa* marsh can be established within two years" (Saucier and others 1978). Aerial photographs from subsequent years and field sampling of the site by the author six years after the original restoration attempts show a marsh dominated by *Salicornia* and large patches of dried mud over much of the site. In the bayward 6.1 ha (15 acres), *Spartina* persists and has spread, although the outlines of some of the original experimental plots are still discernible.

Creekside Park. Work done in 1976 on this 11-ha (27.2-acre) spoil disposal site in Corte Madera returned it to tidal action, but restored only 4.05 ha (10 acres) of marsh. The remaining portions are upland park or were already existing marsh. The original plans called for creating a marsh with high species diversity by planting a dozen species of vegetation at various locations in the marsh (Royston and other 1976). Problems such as poor tidal circulation, extremely saline soils, exotic vegetation, and large unvegetated islands of spoil have occurred. No data are available on the fate of the original plantings. Recent studies at the site indicate that larval fish and shorebirds regularly feed in the area (Josselyn 1983).

Muzzi Marsh. This large restoration project in Corte Madera was undertaken as mitigation for habitat loss of 12.8 ha (31.7 acres) of mudflat, 0.45 ha (1.1 acres) of *Salicornia* marsh, and an unspecified amount of dredged subtidal area resulting from the construction of the Larkspur Ferry Terminal. The original permit required the acquisition of a 214.5-ha (530-acre) area consisting of 157.8 ha (390 acres) of marsh habitat, tidal and submerged lands, of which 56.7 ha (140 acres) of diked land would be restored to tidal action. The planned restoration of marsh habitat actually amounted to 50.6 ha (125 acres), because of existing dikes. As the project progressed, plans were repeatedly modified and information from other restoration attempts in the bay was incorporated. Early experimental plantings by seed were unsuccessful (Kingsley and Boerger 1976), and much of this site has been vegetated by natural recruitment. Quantitative data tracing the early colonization by *Salicornia* and *Spartina* (Faber 1979 and 1980) are available. In 1981, a project was undertaken to regrade and modify channels to increase tidal flow to landward portions of the marsh. However, only about 60% of the planned regrading was completed, owing to difficulty of using heavy construction equipment on unconsolidated spoil. Since the channel improvement project, vegetative cover has continued to increase, especially in areas with formerly restricted tidal flushing and high elevations. By 1982, percent cover of the dominant species, *Salicornia virginica,* was reported as high as 70%–95% in many areas, and cordgrass areas were continuing to expand (Faber 1983). Research and monitoring are expected to continue at this site and should provide additional information about marsh and wetland development.

Hayward Marsh/Johnson Landing. This 89-ha (220-acre) site was created as mitigation for a loss of 30.1 ha (76.3 acres) of wetlands and other adverse environmental impacts associated with the construction of the Dumbarton Bridge. Prior to dike breaching in May 1980, considerable planning and site renovation were undertaken to create a wetland with diverse habitats including open water, mudflats, tidal channels, upland islands, and high and low marshes. The intention was to diversify the environmental conditions and allow natural processes to develop the site over time. Vegetation would be planted, if necessary, at a later time (Madrone Associates 1978). After one year, the site was still dominated by large expanses of mudflat with *Salicornia* spp. and other wetland vegetation species occurring in sporadic clumps around the margins of the restoration, particularly in the vicinity of the wrack line. No natural recruitment of *Spartina* was observed in spite of the fact that over 70% of the site is at an elevation appropriate for its establishment (Niessen and Josselyn 1981). Subsequent descriptive reports indicate that some *Spartina* became established the second yar after dike breaching (Cuneo 1982). Although the site is incomplete at present, those involved with the project are optimistic about the probability of its eventual success. No estimates are available for the time required for complete restoration and vegetation establishment on the site.

Findings Concerning Past Projects

Although many projects in San Francisco Bay have been categorized as completed or partially completed wetlands projects, they do not demonstrate an ability to establish marsh habitats in a predictable manner. More than half of the projects were experimental and involved either plantings on very small areas or limited planting on large areas. None of these experimental projects intended to establish marsh habitat and all of them were largely unsuccessful in meeting their stated objectives. Actual acreages of marsh restored at most large restoration projects have been only a fraction of each site's total area. Projects have been plagued by multiple problems such as high soil salinities, incorrect slope, improper tidal elevations, incomplete vegetation establishment, channel erosion, sedimentation or poor tidal circulation. On the basis of these findings, it is debatable whether any sites in San Francisco Bay can be described as completed, active, or successful restoration sites at present. Considering the limited accomplishments to date, published information about restoration projects has been somewhat misleading.

Coastal managers are faced with a confusing and inconsistent combination of summary lists that do little to help them determine either the total numbers of past restoration attempts or their degree of success. As noted by Josselyn and Buchholz (1982), compiling information on wetland restorations from previous summary listings is difficult because synonyms for projects abound and listing criteria are not usually given. Summary listings for San Francisco Bay range from a report of eight "generally successful" active experimental sites (Garbisch 1977), to nine salt marsh restoration projects (Harvey and others 1982) and 16 completed or partially completed restoration projects (Josselyn and Buchholz 1982). Still other reports list anywhere from seven to 12 different restoration projects for San Francisco Bay (see Table 1 in Josselyn and Buchholz 1982). Because of the inconsistencies between recent and previous lists, it is impossible to determine whether earlier projects were omitted from later lists because they failed or were abandoned, or because they were overlooked or did not meet the author's listing criteria. No consistent definitions or criteria have been used for the various kinds of marsh establishment work, which range from postconstruction repair to complex habitat creation de novo. Some reportedly successful projects no longer exist or are so unusual that they should not be cited as examples of an ability to establish marshes. In most cases, published reports do not provide an accurate picture of the great variability in type, size, local conditions, and other physical features of the sites. Consequently, it is difficult to distinguish between failures, limited successes, and ongoing projects.

More serious than insufficient or inconsistent information are the inaccurate reports of success. For example, in 1978 Muzzi Marsh was described as a successfully restored waterfront recreation park (Beeman and Benkendorf 1978) when, in fact, vegetation colonization was just beginning and major channelization work had not started. Salt Pond III was described as a success in 1978 at a time when experimental plantings covered less than 10% of the site (Saucier and others 1978). Creekside Park received a landscape design award and was described as a "completely restored" salt water marsh and natural reserve in 1979 (ASLA 1979) when large areas of the site were still bare dredge spoil and problems with exotic vegetation were apparent. The widespread notion that marsh establishment is a technologically sound proposition has been derived from a relatively small number of projects with only partial success, incomplete information, or anecdotal reports.

Recent attempts to provide guidelines for enhancement, restoration, or stabilization of marshes and shorelines (Harvey and others 1982, Knutson 1977, Knutson and Woodhouse 1983) also contribute to the perception of a proven technology by including preferred planting techniques based largely on the early experimental plantings in the bay that failed. For example, all guidelines indicate that bioconstructs are more effective where strong wave action is prevalent, in spite of the fact that only one experiment has ever been undertaken in San Francisco Bay using this method and that no vegetation in plots subject to strong wave action survived more than 13 months. The use of *Spartina* is suggested as an alternative means of protecting levees and dike breaches from erosion and undercutting, although no project in the bay has successfully demonstrated such an application. Optimal planting time for Pacific cordgrass is listed as February to April, yet only one project in the bay has ever been planted during that period and the results have never been published. Finally, guidelines for shore stabilization (Knutson and Woodhouse 1983) appear to be extrapolations from East Coast work combined with data from the unsuccessful experimental plantings in San Francisco Bay. Information such as fertilization rates, plant spacing, seed harvesting requirements, and planting width have only an indirect relationship to any previous plantings in the bay. Rather than providing principles for establishment of marshes and marsh vegetation, the various guidelines may actually mislead professionals as they attempt to design and implement future marsh restoration and enhancement projects in this region.

Present and Future Trends

The history of marsh establishment technology has repeatedly involved the premature adoption of ideas before the necessary supporting data were available. The results of the Army Corps of Engineers innovative experiments to establish vegetation on dredge spoil were extrapolated by some to mean that entire habitats could be created. On the basis of the presumption that experimental projects would succeed, policy makers have adopted the technology as a mitigation measure in the permit process. At present, although it is apparent that earlier projects were not entirely successful, coastal policies frequently require some form of marsh establishment and restoration as mitigation for development. If attempts at restoring marshes were limited to several pilot projects or experimental sites, there would be little cause for criticism. It is normal to have setbacks and problems in the early stages of any new technology. However, marsh creation policy has become institutionalized and continues to play an important role in the permit process in many coastal states. As a result, natural habitats are being replaced incrementally by artificial substitutes whose long-term value and survival are questionable. Experiences in San Francisco Bay illustrate how this unproven technology has been adopted prematurely in the permit process.

Mitigation involving the use of marsh establishment technology has repeatedly been required in both major and minor permits issued by BCDC. Between 1977 and 1982, approximately one-third of all major permits issued by BCDC involved wetlands (Table 3). Every permit associated with wetlands involved special considerations such as public dedication, postconstruction repair, or the creation, restoration, or enhancement of habitat either on- or off-site. Postconstruction repair

Table 3. Number of major permits by category executed by BCDC, 1977–1982 (permit numbers in parentheses).

Date	Total no. of permits	No. wetland related	Enhancement: Shore	Enhancement: Marsh	Mitigation for wetlands loss: Restore	Mitigation for wetlands loss: Create	Mitigation for wetlands loss: Acquire	Mitigation for other habitat loss: Restore	Mitigation for other habitat loss: Create	Mitigation for other habitat loss: Acquire	Post-construction repair	Public dedication: Marsh	Public dedication: Subtidal
1977	21	6	1 (13–77)	0	0	0	0	1 (5–77)	1 (27–77)	0	0	1	4
1978	30	10	0	0	0	2 (32–78) (11–78)	1 (8–78)	1 (2–78)	0	0	0	0	6
1979	26	9	0	0	1 (22–79)	3 (35–79) (30–79) (8–79)	2 (37–79) (35–79)	0	0	0	2 (37–79) (35–79)	3	4
1980	17	4	1 (1–80)	0	3 (24–80) (21–80) (4–80)	1 (21–80)	0	0	0	0	0	0	0
1981	19	4	0	1 (2–81)	0	0	0	2 (11–81) (7–81)	0	0	0	1	0
1982	11	3	1 (19–82)	0	1 (18–82)	0	0	0	0	0	1 (11–82)	0	0
Totals	124	36	4			14			5		3	19	
Percent[a]			11			39			14		8	53	

[a]Percents do not add to 100% because some permits required more than one type of mitigation.

Table 4. Wetlands-related minor permits by category executed by BCDC, 1977–1982.

	No. wetlands related	Enhancement	Mitigation for wetlands loss	Mitigation for other habitat loss	Postconstruction repair	Public dedication
Total	27	3	5	1	16	2
	Percent[a]	11	18.5	3.7	59	7.4

[a]Percents do not add to 100% because some permits required more than one type of mitigation.

on-site was required in 8% ($n = 3$) of the major permits, and habitat enhancement in 11% ($n = 4$). Mitigation by creation or restoration of marsh habitats was found in nearly half of the permits (17 out of 36). In total, 64% (23 out of 36 permits) required the use of some type of marsh establishment work, ranging from replanting or reseeding to restoring, enhancing, or creating wetlands. In the same period, 27 of the 598 minor permits involved marsh or wetland habitats (Table 4). Of those 27 permits, 25 required some form of postconstruction repair, enhancement, creation, or restoration of habitat. Of these, postconstruction repair on-site was required most often in minor permits (16 out of 27).

Many of these projects are only partially completed or have not yet begun. This backlog means that more uncontrolled experimentation with marsh restoration technology will occur in San Francisco Bay. In many cases, these approved permits mean the certain loss of existing wetland areas. Admittedly, the number of permits associated with wetlands is small. Considering the paucity of wetland areas in San Francisco Bay and most West Coast estuaries, however, the loss of even small amounts poses potentially serious environmental consequences. Even if replacement acreage is greater than the original amount lost, there is no assurance of a net gain in wetlands, given the present state of marsh establishment technology.

General Recommendations and Conclusions

A review of previous restoration projects in San Francisco Bay combined with information from sites in other coastal states indicates that marsh establishment technology is still in an experimental stage. There is no doubt that the technology is potentially useful for restoring degraded marsh areas, for establishing vegetation on small bare areas, or for repairing small portions of extant marshes. Any of these situations would probably result in a gain of wetland areas and demonstrate sound coastal management. When the same techniques are coupled to the permit process as mitigation for the certain loss of wetland acreage, however, we risk the loss of more wetland area if restoration projects are unsuccessful. With this potential loss in mind, a mitigation site should be viewed not simply as a man-made or restored marsh, but as a permanent substitute for a sacrificed area. Although the details vary for sites in San Francisco Bay and elsewhere, a repeated pattern of findings has emerged. If mitigation by habitat exchange and marsh establishment is to be considered an acceptable wetlands management strategy, coastal managers should consider the following points:

1) Coastal managers must address and resolve a number of potentially serious problems associated with permits. In particular, they must specify detailed goals and requirements for each project and include time constraints for habitat development. As yet, coastal managers have resolved neither what is desired nor what is required of man-made marsh sites. Specific goals are rarely stated at the outset of most projects or in permit requirements. Because of the experimental nature of marsh establishment work, requirements for many projects continue to change as the projects proceed. Since different vegetation and techniques may be required for different site objectives, it is imperative to plan restoration projects with specific goals at the outset. It must be clear whether the habitat is to be designed to maximize species diversity, to provide high productivity, to create habitat for particular rare or endangered species, or simply to establish vegetation. Without specific goals and criteria, it is impossible to monitor a project and determine its success.

Permits have rarely addressed the question of development time, either short or long term. Reseeding or replanting requirements have often been specified for one or two years after project completion, with nothing further required if the initial plantings fail or if the site does not develop as planned. Because most consultants and landscape architects guarantee their work for only one year after planting, there is no responsible party to assume liability for problems after that time. In addition, most permits ignore the question of how long it should take for the habitat to develop to the desired extent. Alternatively, some permits have required the maintenance of marshes in perpetuity, ignoring the fact that even natural marshes are dynamic, ever-changing habitats subject to the vagaries of nature. Clearly, these inconsistencies about time must be addressed to insure fair application of regulations to all permittees.

2) Marsh establishment techniques should continue to be developed and information made available on a regional basis. Previous attempts to apply technology from the East Coast directly to the West Coast have had only limited success. Recent published guidelines for West Coast marsh restoration are helpful, but are based largely on projects of limited success. They do not provide a proven technology for large-scale application. In many cases, natural colonization by *Salicornia,* rather than planting of *Spartina* by consultants, has revegetated so-called man-made marshes. This calls into question the wisdom of requiring planting or seeding in so many cases.

Questions about the source of plant materials have not been addressed, especially on the West Coast. Extracting plant stock from existing marshes should be discouraged, especially for large sites (Garbisch 1977) because of probable damage to natural marshes through the removal of vegetation, and unavoidable impacts caused by work crews and their equipment. At present, nursery stock of marsh vegetation is available from only one source on the entire West Coast [Marine Research Center (MRC), San Rafael, CA]. MRC deals in large quantity orders and by contract only, requiring about one year's lead time to develop stock for projects. According to MRC, the number of contracts for marsh restoration work have been few during recent years, calling into question the source of vegetation for the many permits already approved.

3) Continued research is needed on man-made marshes and wetlands. Coastal agencies should insist that future projects provide adequate documentation to assist ongoing evaluation of the technology. Whenever possible, carefully designed and documented experiments should be included as part of projects (Zedler 1983). All too often, data and information have been totally unavailable or only partially reported in the "grey literature" of government and consultants documents. Most previous studies have documented only the very early successional stages of marsh development without any indication of long-term persistence. Rather than requiring expensive monitoring at every site, it may be advisable to conduct detailed pilot studies over a long period at several selected, representative marsh establishment projects. Finally, while comparative studies between man-made and natural marshes would be ideal, it might be necessary to compare man-made marshes against a theoretical standard of previously formulated project goals if suitable control sites are unavailable in urbanized estuaries.

4) It may be time to evaluate the cost-effectiveness of many small marsh establishment projects. Over the years, considerable money has been spent on marsh establishment projects with dubious gains to estuarine systems. At present, developers are forced to accept the widespread application of an expensive and unpredictable technology that offers no guarantee of wetlands gain. The conditions of a permit constitute legally binding obligations for the permittee and require monitoring and enforcement by coastal agency staffs to insure com-

pliance, yet manpower and budgetary constraints make it difficult or impossible to fulfill adequately this overseer function. The long-term result may be the further degradation of wetland areas if permit conditions are improperly implemented or inadequately enforced. In light of this situation, it would be advisable to require, as mitigation, that permittees contribute to a fund for land banking and research. This would be especially advantageous in areas where there are considerable amounts of degraded wetland for potential restoration. In this way, acquisition of large areas, suitable for future restoration, could be made in anticipation of a time when the technology has been developed to a more predictable level. Continuing the present policy of forcing each permittee to apply an experimental technology in a piecemeal fashion only contributes to poor results and wasted mitigation dollars.

This critical review of past projects does not intend to suggest the abandonment of marsh establishment work. The technology is an important tool for balancing the demand for coastal development with the need for conservation of wetland habitats. Future policies encouraging the quid pro quo exchange of natural marshes with man-made habitats should proceed slowly and with caution until stronger supporting documentation is available. Existing permit policies should be analyzed and reformulated, if necessary, to insure that our coastal permit policies are both fair and cost-effective for developers. More important, those policies must truly safeguard the diminishing wetlands resources in the coastal zone of the United States.

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Literature Cited

ASLA. 1979. Creekside Park. ASLA awards issue, July 1979. *Landscape Architecture* 69:380–382.

Beeman, O., and A. Benkendorf. 1978. Productive land use of dredged material areas. *In* Coastal zone '78. American Society of Civil Engineers, New York.

Cuneo, K. 1982. Natural invasion and establishment of *Spartina foliosa* Trin. on the site of a San Francisco Bay salt marsh restoration at Hayward, Ca. *In* Pacific estuaries: recent research in science and management. Proceedings of the 10th meeting of the Pacific Estuarine Research Society, California Academy of Sciences, San Francisco.

Faber, P. 1979. Report on the current status of the Muzzi Marsh, 1979. Prepared for Golden Gate Bridge, Highway and Transportation District by Phyllis Faber, 212 Del Casa, Mill Valley, CA.

Faber, P. 1980. Report on the current status of the Muzzi Marsh, September, 1980. Prepared for Golden Gate Bridge, Highway and Transportation District by Phyllis Faber, 212 Del Casa, Mill Valley, CA.

Faber, P. 1983. Marsh restoration with natural revegetation: a case study in San Francisco Bay. *In* Coastal zone '83. Proceedings of the 3rd symposium on coastal and ocean management, San Diego.

Floyd, K., and C. Newcombe. 1976. Marsh development study, phase two, pilot study. Inclosure 2 *in* Dredge disposal study, Appendix K. US Army Corps of Engineers, San Francisco.

Garbisch, E. 1977. Recent and planned marsh establishment work throughout the contiguous United States: a survey and basic guidelines. DRMP contract report D-77-3. US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MI.

Harvey, H. T. 1975. Memo to Dr. Curtis L. Newcombe, November 14, 1975. *In* Dredge material disposal study, appendix K. US Army Corps of Engineers, San Francisco.

Harvey, H. T. 1979. Anza Pacifica Lagoon marsh restoration study. Draft report submitted by H. T. Harvey to John Briscoe, Deputy Attorney General, San Francisco.

Harvey, H. T. 1983. Personal communication. San Jose State University, San Jose, CA.

Harvey, H. T., P. Williams, J. Haltiner, and BCDC Staff. 1982. Guidelines for enhancement and restoration of diked historic baylands. A technical report prepared for San Francisco Bay Conservation and Development Commission, 30 Van Ness Street, San Francisco.

Josselyn, M. 1983. Personal communication. Tiburon Center for Environmental Studies, PO Box 855, Tiburon, CA.

Josselyn, M., and J. Buchholz. 1982. Summary of past wetland restoration projects in California. Pages 1–10 *in* Wetland restoration and enhancement in California, California Sea Grant report T-CSGCP-007.

Kingsley, R. B., and F. C. Boerger. 1976. Experimental marsh planting programs, Marin Country Day School and Muzzi Marsh. Prepared for Golden Gate Bridge, Highway and Transportation District by Madrone Associates, Environmental Consultants, Pamaron Way, Novato, CA.

Knutson, P. L. 1977. Planting guidelines for marsh development and bank stabilization. Coastal Engineering technical report 77-3. US Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA.

Knutson, P.L., and W. Woodhouse. 1983. Shore stabilization and salt marsh vegetation. Report 9. US Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA.

Madrone Associates. 1978. Open file: Hayward shoreline marsh restoration project. Prepared by Madrone Associates, Environmental Consultants, Pamaron Way, Novato, CA.

Morris, J. H., C. L. Newcombe, R. T. Huffman, and J. S. Wilson. 1978. Habitat development field investigation, salt pond no. 3, marsh development site, South San Francisco

Bay. Summary report. US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MI.

Newcombe, C. L., J. H. Morris, P. L. Knutson, and C. S. Gorbics. 1979. Bank erosion control with vegetation, San Francisco Bay, CA. Misc. report 79-2. US Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, VA.

Newcombe, C. L., and C. Pride. 1976. Marsh development study, phase three, final investigation. Inclosure 3 *in* Dredge disposal study, Appendix K. US Army Corps of Engineers, San Francisco.

Niessen, T., and M. Josselyn (eds.). 1981. The Hayward regional shoreline marsh restoration: biological succession during the first year following dike removal. Technical report 1. Tiburon Center for Environmental Studies, Tiburon, CA.

Race, M. S., and D. R. Christie. 1982. Coastal zone development: mitigation, marsh creation, and decision-making. *Environmental Management* 6:317–328.

Royston, R., A. Hanamoto, E. Beck, and K. Abey. 1976. Creekside Park, phase II, marsh planting plan, June 1, 1976. Prepared by Royston, Hanamoto, Beck, and Abey, Landscape Architects and Planners, 225 Miller Avenue, Mill Valley, CA.

Saucier, R. T., C. C. Calhoun, R. M. Engler, T. R. Patin, and H. K. Smith. 1978. Executive overview and detailed summary. Dredge Material Research Program, US Waterways Experiment Station, Vicksburg, MI.

US Army Corps of Engineers. 1976. Dredge disposal study. San Francisco Bay and Estuary. Appendix K: marsh development. Available from US Army Corps of Engineers, San Francisco.

Zedler, J. 1983. Salt marsh restoration: the experimental approach. Pages 2578–2586 *in* Coastal zone '83. Proceedings of the 3rd symposium on coastal and ocean management, San Diego.