RESTORING SUSTAINABLE COASTAL ECOSYSTEMS ON THE PACIFIC COAST

Establishing a Research Agenda

Summary of a Sea Grant Workshop

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RESTORING SUSTAINABLE COASTAL ECOSYSTEMS ON THE PACIFIC COAST

Establishing a Research Agenda

Summary of a Workshop
Sponsored by the California Sea Grant College
at the meeting of the Estuarine Research Federation
San Francisco, November 1991

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EXECUTIVE SUMMARY

A workshop on "Research Needs for Restoring Sustainable Coastal Ecosystems on the Pacific Coast" was held at the meeting of the Estuarine Research Federation in San Francisco in November 1991. The workshop was convened by the California Sea Grant College in recognition of a significant gap in the understanding of Pacific coastal ecosystems.

Coastal ecosystems on the Pacific Coast are characterized by their great diversity and their uniqueness, particularly when compared to better-known coastal ecosystems on the Atlantic and Gulf of Mexico. The result of the workshop was a listing of critical research needs for Pacific coastal ecosystems, particularly in estuaries. The research needs were ranked by workshop participants in order of highest priority within each of four categories: 1) hydrology, 2) habitat function, 3) habitat requirements of organisms, and 4) population dynamics.

INTRODUCTION

The purpose of this report is to identify research needs for Pacific coastal ecosystems, particularly estuarine wetlands. The research needs were derived from a fundamental recognition of: 1) the unique physical environment of the estuaries, 2) the paucity of data, and 3) the highly disturbed and fragmented condition of the estuaries. A brief background for these points is provided below.

The report is the result of a workshop sponsored by the California Sea Grant College on "Research Needs for Restoring Sustainable Coastal Ecosystems on the Pacific Coast" held during the Estuarine Research Federation (ERF) meeting in San Francisco in November 1991. This workshop was convened between two sessions on "Coastal Habitat Restoration: Submerged Aquatic and Saltmarshes" in which invited workshop participants presented papers. The San Francisco meeting was a part of the Ecological Society of America's (ESA) "Sustainable Biosphere Initiative" (SBI, Lubchenco et al., 1991). Members of ESA developed the Initiative to help prioritize ecological research efforts in the closing decade of this century in the face of a rapidly deteriorating environment and limited financial resources. Three broad topics of concern were given the highest priority for research: 1) global change, 2) biological diversity, and 3) sustainable ecological systems. The ERF meeting was one of the first actions taken by the ESA to foster implementation of the Sustainable Biosphere Initiative.

Sustainable ecological systems that lack a current market value, such as wetlands, have received the least research attention. The Sustainable Biosphere Initiative recommended that a focus be placed on "understanding the underlying ecological processes in natural and human-dominated ecosystems in order to prescribe restoration and management strategies that would enhance the sustainability of the Earth's ecological systems." Invited workshop participants were provided with a copy of the Initiative prior to the workshop in order to address the problems associated with ecosystem sustainability and restoration.

DISCUSSION SUMMARY

Sixteen scientists, primarily from the Pacific Coast, presented recommendations on research needs for Pacific coastal habitat restoration during the Sea Grant workshop (see List of Participants).

A general consensus was that ecosystem research on Pacific estuaries lags behind that of Atlantic and Gulf Coast efforts by several decades. This lack of understanding of the region's estuaries is reflected by the fact that the West Coast estuaries were not included in EPA's National Estuary Program until mid-1990 (NOAA, 1990). Mandated by Congress in 1987, the estuarine inventory for the program was initiated as early as 1984. San Diego Bay, which was not included, has been called one of the most polluted estuaries in the nation.

Wetland acreage is known for only 29% of California's major estuaries in contrast to 69% for the rest of the nation's NOAA-classified estuaries (Basta, 1990). The lack of the most basic information (e.g., what is the acreage of estuaries and their historical development, what are the habitat requirements of Pacific estuarine plant species, what is the specific habitat dependency of fish and wildlife species?) seriously hampers understanding of coastal ecosystems, thus impeding our ability to sustain or restore them. Yet, the need to sustain existing systems and restore or construct others is most critical on the Pacific Coast because of habitat fragmentation and loss.

Few West Coast estuaries remain in their original state. The percentage loss of original acreage for the longest stretch of the continental West Coast (California) is the highest in the nation at 75%. Wetland loss in Pacific Northwest estuaries was estimated to be 50-95% by the 1970s (Boule and Bierly, 1987). Most remaining estuaries are highly urbanized and many are in danger of total elimination in the face of pressures associated with rapidly accelerating population growth. As a result, recreational use of the nation's estuaries is highest on the Pacific Coast. The highly modified and threatened condition of these estuaries represents one future scenario for those of other coasts. The challenge for scientists and managers is thus to use these highly modified estuaries as a window to the future. Carefully conceived research on these estuaries now will be applicable for future management needs in the rest of the country. The assumption that extrapolation from the understanding of estuaries outside the region can substitute for Pacific estuarine research carries the risk of losing the remaining West Coast estuaries, as does poorly conceived research. It is difficult to transfer information between coasts on processes such as primary productivity and nutrient cycling because the forcing functions are quite site-specific. In contrast, the effects of habitat loss and biodiversity are universal.

The scientific and management issues at stake on the West Coast are fundamentally different from those on the East and Gulf coasts for three basic reasons: 1) the physical environment of the estuaries is very diverse and different from those of other coasts, 2) the database is very incomplete, and 3) the estuaries are highly disturbed and fragmented. Workshop participants stressed that a national estuarine research initiative must be regionalized and that West Coast sub-regions must be recognized (three to five were suggested) to accommodate the uniqueness of the physical environment along the coast.

The Physical Environment of Pacific Coast Estuaries

The salient features of the uniqueness of Pacific estuaries lie in the coast's geomorphology and in climate, with its effects on hydrology and physical oceanography.

As a result of geological constraints, West Coast estuaries in their unaltered state were small with high land/water ratios. They were also relatively isolated in the landscape, making them and their associated organisms particularly vulnerable to disturbances. Some are "reversed deltas" with a dendritic system of freshwater sources inland of a relatively closed bay. All occur in relatively active seismic zones.

The variability of West Coast estuaries is the highest in the nation. For example, rainfall ranges from among the highest in the nation (Pacific Northwest) to the least (southern California). Within the arid estuaries of southern California, the intensity of rainfall is the highest within the continental United States, as well as the most variable (Zedler, 1982).

Although major storm (tropical cyclonic) events occur with a fairly predictable frequency on the Atlantic and Gulf coasts, comparable major storms on the Pacific are highly unpredictable, in part due to their correlation with El Niño events. The ecosystem responses to such storms also are different. The resistance of various seagrass communities to major storm events on the Atlantic Coast is well documented. In contrast, a large eelgrass bed in southern California was destroyed by a major storm. The mechanism underlying this quite different response was based in geological and meteorological differences (Onuf and Quammen, 1983).

Upwelling and associated nutrient supplies are also fairly unpredictable. Circulation in many Pacific estuaries is dominated by freshwater influx, not by tides, with the exceptions of Puget Sound and San Francisco Bay. Freshwater influx is highly variable, even intermittent, and thus so are salinity regimes. The influx varies seasonally, year-to-year, and geographically. For example, freshwater influx to southern California estuaries is rare and hypersalinity results, yet in some years (e.g., those associated with El Niño events) the estuaries can be virtually nonsaline. Freshwater discharge also determines whether long-shore sediment transport processes cut off the mouth of southern estuaries. Superimposed upon this natural variability in the physical environment in small estuaries is the effect of highly modified watersheds. Modification of freshwater discharge has resulted in documented replacement of native Pacific estuarine plant species with exotics.

The uniqueness of the Pacific estuarine environment requires a specific regional approach. For example, freshwater discharge in East and Gulf Coast estuaries is typically considered as a term in a nutrient budget or as a pollutant source. Although the same is true for Pacific estuaries, the importance of freshwater discharge is far more fundamental. The amount and timing of the discharge drives circulation and vegetation distributions, which in turn affect distributions of endangered species. The primary research questions, therefore, are not how much nitrogen or herbicides enter the estuary, but: What is the optimal freshwater discharge that will maintain the wetlands? What is the critical temporal pattern in the influx that maintains the dominant plant communities? and What is the effect of extreme events? Extrapolation from the larger database available for East and Gulf coast estuaries is not sufficient to address these questions because tidal flows, not freshwater influx, generally drive circulation in Eastern estuaries. There, vegetational patterns are not principally a function of the degree and variability of the freshwater influx.

Information Gaps for Pacific Coast Estuaries

That few data are available for Pacific Coast estuaries is an impediment to management. Sufficient data are considered to exist on the climate, vegetation, water chemistry, and aquatic organisms to define subregions along the coast. Subregionalization is critical for effective restoration. Beyond this structural information, tremendous gaps in knowledge exist at all levels of biological organization from population dynamics to ecosystem development, as well as in physical estuarine processes. There have been relatively few studies of wetland primary productivity and virtually no studies of nutrient dynamics. The habitat specificity of organisms has not been identified; for example, neither salinity tolerances of marsh plant species nor estuarine utilization by fish and wildlife. Only recently did research suggest that nesting of the endangered light-footed clapper rail depends on the canopy architecture of the vegetation (Zedler, accepted 1992).

The trophic dynamics of Pacific estuaries are poorly understood, particularly in southern California. Over the region the variability in the environment, particularly in freshwater influx, suggests there may be important shifts between sources of organic matter for consumers (Simenstad and Wissmar, 1985). In southern California estuaries, primary productivity of epibenthic microalgae can be higher than that of vascular plant communities. This simple fact indicates that using the primary productivity of salt marsh *grasses* as a surrogate for habitat trophic function, as is practiced for Atlantic Coast marshes, is clearly inappropriate for many Pacific marshes. Altered hydrology in turn affects the relative abundance of algae versus vascular plants, as do unpredictable extremes in freshwater inflow (in part through introduction of exotic species). Emergent insect communities may be critical prey for salmon and endangered bird species, yet trophic dependencies of insects are unknown. Secondary production of economically valuable species is an objective of estuarine management on other coasts, but along much of the Pacific Coast a more appropriate goal is maintenance of biodiversity, with provision of migratory bird and endangered species habitat.

Studies of population and community dynamics are also rudimentary. Information on the basic biology of common species such as surfgrass (*Phyllospadix* spp.) and *Zostera japonica* (an introduced species) and endangered species is lacking. Fundamental processes such as dispersal mechanisms, the relative importance of sexual versus vegetative propagation, population genetic structure, regional population growth models, and below-ground vegetation processes are poorly understood for even the better-known species such as *Salicornia virginica* and *Spartina foliosa*.

Exotic species are a major disturbance to Pacific estuaries and were recently cited as a primary threat to marine biodiversity in the region. In San Francisco Bay where there are estimated to be over 100 introduced species, the exotic clam *Potomocorbula amurensis* has shifted the estuarine trophodynamics from planktonic- to benthic-based. All four National Estuarine Research Reserves on the continental West Coast suffer from problems associated with the introduction of exotic species. Exotic species seem to establish very readily in constructed wetlands. Extremes in freshwater discharge have been implicated in the establishment of many exotic species, but research on this and other factors, such as their effect on estuaries, is required.

Physical processes in Pacific estuaries are as poorly understood as the biological processes, in part due to the complexity imposed by the high variability in the climate, meteorology, and rainfall. In addition to the typical research gaps (e.g., sediment transport, marsh erosion and accretion, and hydrology), an understanding of West Coast systems requires an understanding of how extreme events affect marsh morphology and how the alternation of prolonged and seasonal periods of wetting and drying affects soil-sediment processes (compaction, biogeochemistry).

Pacific Estuarine Management Questions

Although the structure of the biological communities of Pacific Coast estuaries superficially resembles that of estuaries on other coasts, the uniqueness of the region's geology, climate, and physical oceanography leads to fundamentally different mechanisms underlying community dynamics and requires that these differences be addressed for effective management strategies. Extrapolation from models of estuaries on other coasts is not a viable alternative to filling the research gaps that exist for the West Coast. To be useful for management, estuarine models need to be precise and realistic at the expense of being general (Costanza et al., 1990) and thus, site-specific data are required. For example, parallel studies on the use of organic amendments to accelerate constructed marsh development yielded dramatically different results on the Atlantic and Pacific coasts (Broome, research in progress). An even greater limitation to extrapolation from other coasts is that the questions are not appropriate for the western regions.

Discussions of pressing management needs among West Coast estuarine scientists contrast markedly from those on other coasts. Here, where the remaining estuaries are few, small, isolated, and highly modified, the relevant questions concern effects of habitat fragmentation on biogeography and biological diversity. How can biodiversity be sustained in coastal ecosystems on the West Coast? Such questions are very different from the traditional ones that have driven estuarine research on other coasts and are prevalent as mission objectives from federal agencies, e.g., what is the coupling between primary and secondary production, and what are the terms in nutrient budgets?

Biodiversity involves all levels of biological organization from ecosystems and habitat types to genes. Biodiversity has been woefully ignored in the marine environment. The West Coast has led the nation in research on coastal biodiversity. Here, marine biodiversity was historically the highest in the nation, and may be eroding fastest due to extreme habitat loss and modification and the prevalence of exotic species. A very different set of specific questions falls from this management need. For example: What is the habitat dependency of the species involved, from algae and vascular plants to insects and migratory birds? What are the population dynamics of rare, endangered, and exotic species and how do they interact within their communities? What is the minimum viable population size and the habitat size needed to support it? Is there a critical landscape configuration for fragmented habitats to facilitate utilization by desired species? Obviously, the problem of managing fragmented habitats requires a very different and broader approach to estuarine management than the traditional one derived from coastal oceanography (energy and material fluxes, coupling of production). The approach for the West Coast must rely heavily on conservation ecology and has its analogy in the questions that are being directed to management of tropical rainforests. These questions and this approach rarely appear in estuarine management strategies for other coasts. Thus, it should be clear that management strategies developed for other coasts are insufficient for the needs of the Pacific Coast and that a Pacific regional research initiative is critical and cannot wait.

Recommendation for Pacific Region Estuarine Reference Sites

Workshop participants strongly recommended that a system of Pacific estuarine reference sites be initiated. The sites chosen should represent the diversity of estuarine systems along the coast, include intact ecosystems for comparative studies, and be of sufficient size to encompass significant estuarine processes and to allow replicated experimental manipulation. Existing National Estuarine Research Reserve sites and possibly Land-Margin Ecological Research sites could provide the core of the system, but the number of sites must be increased. The reference site system would provide long-term databases on natural and restored or mitigated sites, help to focus coordinated research efforts along the coast, help develop regionalized restoration protocols, and serve as demonstration areas.

PRIORITIZATION OF RESEARCH NEEDS FOR SUSTAINABLE PACIFIC ESTUARIES

The following hierarchies of research needs were developed from responses to a research priority questionnaire made by scientists participating in the workshop on "Research Needs for Restoring Sustainable Coastal Ecosystems on the Pacific Coast." This list focuses on estuaries but other coastal habitats (rocky intertidal areas, coastal dunes, coastal scrub) are also important, fall through gaps in environmental legislation, and have specific research needs.

The list is divided into four subject areas of equal importance: conservation of biodiversity, physical processes, water quality, and restoration. The categories were ranked by workshop participants with (1) designating a higher and (3) a lower priority. The tally below represents the mean ranking by fifteen respondents.

Conservation of Biodiversity Research Needs

1.30 Habitat requirements/habitat specificity of organisms
- primary determinants of habitat utilization (trophic/reproduction requirements)
- structure (e.g., habitat heterogeneity, canopy height)
- function (e.g., productivity)

1.27 Habitat function determinants
- structural (marsh edge, canopy height)
- functional (productivity, trophic support)

1.90 Trophic dynamics
- food web analysis
- emergent insect communities

1.42 Population dynamics
- genetic structure and diversity
- minimum viable population sizes
- community development processes (rates, rate-limiting processes)
- below-ground vegetation processes

2.10 Endangered species biology

2.02 Exotic species biology
- dispersal mechanisms
- competitive effects
- trophic effects

2.65 Effects of rare events

1.89 Linkages between communities and habitats

2.09 Habitat inventory
- determination of estuarine acreage and habitat types
- 'community-profiles' on sites with long-term database

Physical Processes Research Needs

1.23 Hydrology
- effects of altered hydrology

effects of vegetation
effects of marsh morphology (channel vs. overmarsh flow)
effects of alternating wet-dry cycles
models

1.78 Erosion/accretion responses
- role of organic vs. inorganic matter in accretion
- integration with hydrological effects
- sediment supply processes

2.36 Marsh morphology
- role of extreme events
- comparisons between marsh types

1.97 Model of salinity dynamics (modal and extreme)

2.22 Effects of anticipated sea level rise

Water Quality Research Needs

1.51 Nutrient dynamics
- process rates
- budgets
- organic matter accumulation and decomposition rates
- effects of alternating wet-dry cycles
- effects of altered hydrology

1.53 Criteria for vegetation

1.81 Impacts of development

1.71 Urban runoff

1.90 Treatment strategies

Restoration Research Needs

1.59 Site selection critieria
- identification of potential sites
- consideration of regional habitat biodiversity
- urban problems

1.29 Habitat architecture
- habitat size to sustain minimum viable population sizes and functionality
- habitat heterogeneity
- landscape linkages and corridors
- buffer zone requirements

1.94 Methodology
- identification of desired initial conditions
- establishment of desired initial conditions
- independent tests of design strategies
- acceleration of functional development trajectory
- incorporation of effects of rare/stochastic events in design

1.65 Monitoring and evaluation of success
- assessment and standardization of functionality evaluation criteria
- assessment of appropriate temporal scales of monitoring
- assessment critieria for urban projects where no natural sites remain for comparison
- assessment of structure (e.g., canopy height) as surrogates for function

1.17 Inventory of projects and monitoring

2.48 Economic evaluation of adequacy of mitigation/restoration options as compensation for loss

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APPENDIX

Individual Responses to Research Priority Questionnaire

QUESTION	Rank 1 (higher) to 3 (lower)														
Habitat requirement	1	1	1	2	2	1	1	1	1	1.5	1	1	1	3	1
Habitat function	1	2	1	1	1	1	1	1	1	2	1	1	2	1	2
Trophic dynamics	2		2	2	2	2	1	2	2	2	1.6	1	2	3	2
Population dynamics	1	1		1	3	2	2	1	1	2	1.9	1	1	1	1
Endangered species	1			2		2		3	2	3	2.1	2	2	3	1
Exotic species	2			2	1	2	2	3	1	1	2.3	2	2	3	3
Rare events	3	3	3	3	3	2	3	3	3	3	2.7	3	2	2	1
Comm. and habitats	2	2		2	3	1	1	2	3	3	1.4	2	1	2	1
Habitat inventory	1	3		1	3	2	1	2	3	2	2.3	2	2	2	3
Hydrology	1	2	1	1	1	1	1	1	1	1.5	1	1	1	1	3
Erosion	1	1	3	2	2	2	1	2	1	2	1.7	2	2	2	2
Marsh morphology	2	3		3	3	1	2	3	3	3	2.1	3	2	2	1
Model of salinity	2		2	3	3	1	2	1	2	2.5	2.1	2	1	3	1
Sea level rise	3			3	3	2	1	3	1	2	2.9	1	2	3	2
Nutrient dynamics	1	3		2	3	2	1	1	1	1	1.1	1	2	1	1
Veg. criteria	2			2		1	1	1	2		1.3	1	2	2	
Development impact	3	2	1	1	1	2	2	3	2	2.5	1.7	1	1	3	1
Urban runoff	3		2	1	2	1	2	2	1	2	2	1	1	3	1
Treatment strategy	1	1	3		3	1	2	3	2	3	2.6	1	1	2	1
Site selection	2	1	1	1	3	1	2	1	1	2	1.9	2	1	2	2
Habitat architecture	2	1		2	1	1	1	1	1	2	1	2	1	1	1
Methodology	2	2	2	2	3	1	1	2	1	2	1.1	2	2	3	3
Monitoring and eval.	1	3	3	1.5	2	1	1	2	1	2	1.3	1	2	2	1
Inventory of project	1			2.5	3	2	2	3	3	2	2.7	1	2	1	3
Economic evaluation	3			1	3	2	2	3	3	3	2.3	1	3	3	3