Managing Seagrass Systems in Western North America

RESEARCH GAPS AND NEEDS

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Alaska Sea Grant
College Program
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Sea Grant is a unique partnership with public and private sectors combining research, education, and technology transfer for public service. This national network of universities meets changing environmental and economic needs of people in our coastal, ocean, and Great Lakes regions.

Contents

The Authors

Sandy Wyllie-Echeverria is a Visiting Scholar at the School of Marine Affairs, University of Washington, where he is a member of the Interdisciplinary Seagrass Working Group (ISWG). The ISWG formed in fall 1992 to examine seagrass management programs in the Pacific Northwest using an interdisciplinary approach. Wyllie-Echeverria's research interests include seagrass population dynamics, restoration of damaged seagrass systems, subtidal seagrass mapping techniques, effects of light environments on seagrass distribution, history of seagrass science and policy, and traditional use of seagrass resources. For most of the last decade, at several locations along the West Coast of North America, he has given public lectures, participated in university classes, and made presentations at scientific meetings in an effort to craft a policy toward sound management of the seagrasses of the Northeast Pacific. He initiated the work for this booklet while a graduate student at the University of Alaska Fairbanks.

Dr. Ronald M. Thom is a Senior Research Scientist at Battelle's Marine Sciences Laboratory in Sequim, Washington. Prior to moving to Battelle in 1990, Thom was a researcher in the Fisheries Research Institute at the University of Washington. His 21 years of professional experience include employment as a biologist for Los Angeles County and the Seattle District Corps of Engineers. His research interests include benthic primary production, the effects of pollution on nearshore marine communities, habitat restoration, the effects of climate change on nearshore systems, the ecology of fisheries resources in nearshore systems, and biodegradation of petroleum. Most of his work has been conducted in Puget Sound, southern California, and Alaska. Thom has served on numerous committees, including a five-year appointment as Chair of the Technical Advisory Committee to the Puget Sound Estuary Program.

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Dedication

This booklet is dedicated to R.C. Phillips, whose pioneering seagrass research has been an inspiration to all seagrass scientists. Dr. Phillips continues to be active in seagrass research from his post at Battelle-Pacific Northwest Laboratory in Richland, Washington.

Introduction

This report summarizes the history and direction of efforts to connect scientists and resource managers along the West Coast of North America, to develop a regional seagrass management plan. These activities began in the 1980s and reached a plateau at the West Coast Seagrass Symposium in December 1990. Second, it summarizes seagrass research gaps and needs in this region. Information is derived from research priorities identified by two seagrass working groups and by seagrass scientists in this region (see Contributors).

Six species of temperate and cold-water seagrasses grow on the West Coast (Figure 1). All species belong to the family Potomogetonaceae but are differentiated into two genera: *Zostera* and *Phyllospadix* (Phillips and Menez 1988). The genus *Zostera* has three species: *Z. asiatica, Z. japonica,* and *Z. marina,* eelgrass. The genus *Phyllospadix,* surfgrass, also has three species: *P. serrulatus, P. scouleri,* and *P. torreyi*. Most probably, four of the species *(Z. marina, P. serrulatus, P. scouleri,* and *P. torreyi)* have been growing along the rocky shores and soft-bottom habitats of this region since the Pliocene (Phillips and Menez 1988, Domning 1977). *Z. japonica* probably was introduced in the 1930s and early 1940s (Harrison and Bigley 1982), while *Z. asiatica* was only recently described in this region (Phillips and Wyllie-Echeverria 1990). In some accounts the brackish water plant *Ruppia maritima* is classified as a seagrass (e.g., den Hartog 1970). This plant grows in western North America (Mason 1957, Steward et al. 1963, Brayshaw 1985); however, it has not often been considered a seagrass in this region by either research science or resource management and is not referenced in this report.

Development pressure in the coastal habitats of the world's oceans is intense, and seagrasses are often impacted by resulting coastal modification. Along the West Coast, it is common for developers to be dismayed at the disarray of opinion on the relative ecological importance of seagrass meadows, factors that may cause significant injury to the meadows, and the possibility of restoring impacted meadows or creating new ones. This

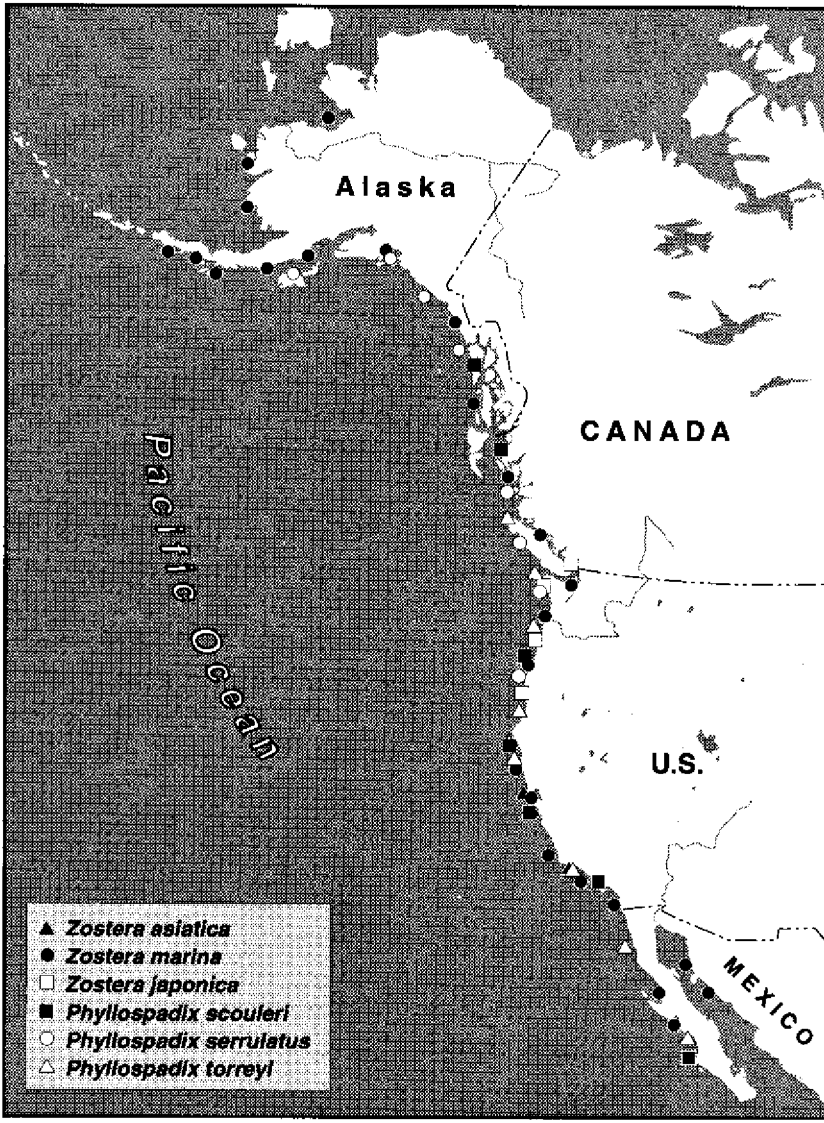

Figure 1. Seagrass distribution in the temperate waters of the Northeast Pacific (Phillips and Menez 1988, Phillips and Wyllie-Echeverria 1990). Symbols represent general ranges.

disarray is a function of several phenomena. Most notable are (1) lack of data on some fundamental questions concerning seagrass biology, autecology, and community structure; (2) ineffective communication of the reliable scientific information that does exist; and (3) the difficulty of making reasonable, rational decisions in resource management and development. Investigators in turn are concerned because the management of seagrass systems is carried out in the absence of adequate scientific information. In the final analysis, developers, resource managers, and scientists feel powerless to chart a course toward sound management.

Yet a spirit of cooperation exists among researchers studying seagrass on the West Coast. This cooperative spirit should lend itself to the development of coordinated research projects along the entire coast, encompassing long time-series data sets and collaborative investigations. In addition, there is intense interest in developing a better understanding of the importance of seagrass to fisheries resources.

History of the West Coast Seagrass Group

Two seagrass working groups formed in the 1980s in California and Washington, and two regional meetings organized by working group members were held. These activities are described below.

California Efforts

William Albert Setchell began seagrass studies while at the University of California, Berkeley, in the 1920s. Setchell (1929) was able to establish an informal network to facilitate his studies on eelgrass. Although he had two study sites on the shores of San Francisco Bay, he relied on contributions from individuals in several states to complete his analyses. Setchell's work was thorough and comprehensive, and his studies provided a baseline for other seagrass work in the United States. Unfortunately, this promising beginning did not provide strong impetus for continued seagrass research in San Francisco Bay, where research activities have resumed only recently (Nichols and Pamatmat 1988, Zimmerman et al. 1991, Kitting and Wyllie-Echeverria 1992).

In 1984, an eelgrass transplant was initiated in San Francisco Bay. The transplant team reported that lack of data on local eelgrass autecology, coupled with water quality conditions, limited transplant success (Fredette et al. 1988). The team recommended that eelgrass studies be initiated and maintained and that issues of water quality be addressed. In response to these recommendations, an interdisciplinary group of scientists and managers was formed in 1985 to outline eelgrass research priorities for San Francisco Bay. This group, known as the "ad hoc eelgrass working group," identified the following priorities:

- New and updated surveys to determine the distribution and density of eelgrass.
- Field research to determine the value of eelgrass as a habitat in San Francisco Bay.
- Field research and laboratory studies to determine the physical parameters that might limit plant distribution.
- Detailed investigations of the biology and autecology of eelgrass in San Francisco Bay.
- Continued studies to evaluate effective transplant techniques.

The working group met for two years and continued to discuss possible research projects and mechanisms for funding. In May 1987, the first California Eelgrass Symposium was held at the Paul F. Romberg Tiburon Center for Environmental Studies (RTCES), San Francisco State University, Tiburon, California. An initial report of resource inventory results was presented and it was agreed that a survey of San Francisco Bay eelgrass should become the top research priority. The National Marine Fisheries Service, Southwest Region, agreed to provide limited funding, and a survey project began in the summer of 1987. The project had two objectives: (1) provide a map depicting the geographic range and distribution of eelgrass in San Francisco Bay, and (2) provide estimates of total acreage at individual sites (Wyllie-Echeverria 1990, Wyllie-Echeverria and Rutten 1989).

Commensurate with the third research priority, a research team from the University of Chicago stationed at Hopkins Marine Station, Pacific Grove, California, and RTCES, was funded to assess the environmental suitability of San Francisco Bay for eelgrass. The objectives of the study were to: (1) determine the relationship between turbidity and light available for eelgrass growth and reproduction, and (2) determine the effect of this light environment on the depth distribution of eelgrass in the bay (Zimmerman et al. 1991).

During the first eelgrass symposium in 1987, a panel of resource managers concluded that the symposium format should be continued but that wider geographic participation should be encouraged. Accordingly, a second California Eelgrass Symposium, organized by Pacific Southwest Biological Services, was held in Chula Vista, California, in May 1988. Symposium participants came from British Columbia, Washington, California, and Mexico. Speakers addressed research and management priorities identified at the Tiburon symposium. The issues, summarized in Merkel and Hoffman (1990), include: (1) case studies from experimental and compensatory transplants in this region, (2) descriptions of the contribution of eelgrass to coastal food web dynamics, and (3) discussion of the primary factors limiting eelgrass distribution and abundance.

Washington Efforts

In autumn 1986, the Washington Department of Natural Resources (WDNR) invited researchers and resource managers to join in a cooperative effort to evaluate the functional value of eelgrass. At the first meeting, Thomas Mumford, group coordinator from WDNR, explained that federal, state, and local decision-makers needed scientifically valid information on site-specific and regional functional values of seagrass systems. Urgently needed were (1) maps of the distribution of seagrasses, (2) identification of the functional values of seagrass systems, and (3) methods for mitigating loss of functional values. It was recognized that there was growing pressure on seagrass systems and a lack of understanding of the importance of these systems to natural resource management.

The group met several times in 1987 and developed a list of functional attributes characteristic of seagrass systems. The topics on the list, which included physical, biochemical, and biological functions as well as management factors, were developed into a five-phase research approach designed to systematically acquire information needed by decision-makers. The priorities were:

- Aerial photographic analysis to map seagrass distributions.
- Subsample surveys to select representative patches for further research.

- In-depth studies on plant biology, faunal and floral structure, carbon energetics, and mechanics.
- Studies to optimize transplant techniques and assess the functionality of constructed seagrass systems.
- Data synthesis to provide information to decision-makers in a form that would maximize their ability to manage the resources.

The work of the group was not published, and documentation remains in the form of meeting notes. Although funding for conducting the outlined research was not made available, the first phase of the study plan was partially accomplished by another effort, the Puget Sound Monitoring Plan (PSMP). PSMP, part of the Puget Sound Estuary Program and partially funded by the Environmental Protection Agency, resulted in the development and implementation of a nearshore habitat monitoring program that included seagrass meadows (Puget Sound Water Quality Authority 1989). The program has collected distribution data on eelgrass in Puget Sound since 1988 and now has the beginnings of a comprehensive database on seagrass distribution in that area. Data and summaries of the studies are available from Thomas Mumford, Aquatic Lands Division, Department of Natural Resources, P.O. Box 42027, Olympia, WA 98504-7027. Data from Washington other than Puget Sound are largely lacking.

Management of eelgrass in Washington continues to be a major concern, and the Washington State Department of Fisheries (WDF) formed in 1989 an intra-agency working group to define eelgrass policy. This group has met periodically but to date has not published a formal statement regarding eelgrass resource research or management needs. At present, the WDF seagrass working group is the most active entity pursuing eelgrass issues in the state with regard to resources and management.

Development impacts on eelgrass and mitigation of these impacts currently are the most pressing environmental issues facing the U.S. Army Corps of Engineers, Seattle District, as well as the regional shipping ports. Approximately $100 million in development projects have been stopped or stalled in Washington State from 1990 to 1993 because of these issues (R. Thom, unpublished data). A perception that eelgrass cannot be successfully transplanted as mitigation has largely been responsible for denial of development permits (Thom 1990).

Pacific Coast Seagrass Newsletter

Production of the *Pacific Coast Seagrass Newsletter* was an effort to merge the goals of the California and Washington seagrass groups and develop a more regional approach. After several months of discussion and a commitment by the University of Washington Fisheries Research Institute (FRI), the first issue was mailed in spring 1990.

The newsletter had three goals: to announce meetings and workshops on seagrass-related topics, to communicate information between seagrass scientists and resource managers on a regional scale, and to provide a link between seagrass scientists and resource managers along the West Coast, including Mexico and Canada. Reasons for focusing on the West Coast were: (1) links between seagrass scientists and resource managers, although established locally, were not well developed on a regional scale; (2) much of the funding for seagrass research seemed concentrated in the eastern United States, and the newsletter editors believed that more attention should be focused on West Coast systems; and (3) limited resources demanded focusing efforts on one region.

In 1992, the Pacific Estuarine Research Society (PERS), a regional society of the Estuarine Research Federation, requested that we consider reformatting the newsletter as a column in the PERS newsletter. The column continues to fulfill the goals of the original seagrass newsletter.

Monterey Symposium

With a small budget from Alaska Sea Grant, a seagrass symposium was held as part of the annual meeting of the Western Society of Naturalists (WSN) in December 1990 in Monterey, California. The goal was to clarify previously identified research questions and suggest regional research priorities; therefore, invited participants focused on issues of general concern to the region. Approximately 25 individuals attended and 12 papers were presented.

Seagrass Research Needs on the West Coast

In an effort to capture the insights of West Coast seagrass scientists, the authors of this report asked each participant in the Monterey seagrass symposium to provide a list of knowledge gaps and research priorities. We also requested contributions from researchers who were unable to attend the symposium. We have synthesized the remarks of this body of scientists (see Contributors), whose primary research focus has been the seagrasses of the West Coast of North America. The intent of this summary is to inspire new research proposals and activities which, in turn, should guide seagrass policies and management in the next century.

PHYSIOLOGY

A thorough understanding of seagrass physiology is essential to fully comprehend the mechanisms by which seagrasses persist in existing meadows. This knowledge may also facilitate the development of effective transplant techniques throughout the region. Important research topics include: thermal requirements and tolerances, light requirements, nutrient requirements, grazer interactions, carbon and nitrogen cycling, sediment requirements, salinity regimes, and environmental toxicology. Knowledge of how these factors affect or interact with the maintenance of viable, healthy, and functional seagrass systems is required. Although physiological studies have been done for eelgrass, these need to be expanded. In addition, this work should be initiated on the other five species in the region. There is a vast array of literature on seagrass physiology in other regions of the world, and this literature and research can provide a foundation for West Coast studies. However, the distribution of *Phyllospadix torreyi, P. scouleri,* and *P. serrulatus* is limited to the West Coast of North America, and *Zostera japonica and Z. asiatica* grow only in temperate Pacific waters. Basic research to describe the physiological expressions of these plants is necessary before complete and comprehensive understanding will be achieved. Research on the following topics is critically needed:

- ***Root and shoot nutrient physiology***

It is established that seagrasses can assimilate inorganic nutrients through both roots and leaves. However, the factors controlling uptake rates and processes are not well established. Interactions between nutrient availability in the water column and sediment and uptake rates by leaves and roots are not understood for all species. Information on this topic is critical to understand the effects of eutrophication and nutrient limitation. In addition, this information would help establish guidelines for optimal transplanting.

- ***Carbon and nitrogen allocation and nutrient pool size***

Conversion of inorganic nutrients and carbon to organic compounds, and the storage, transport, and utilization of these compounds, is not well known. In particular, carbon and nitrogen sinks within vegetative and reproductive shoots as well as species-specific carbon and nitrogen distributions have not been established for all species. An understanding of nutrient pool sizes and the physical, chemical, and biological controls on interstitial nutrient pool size and composition is needed to describe pathways of energy allocation and storage. These data also have implications for modes of energy transfer to coastal food webs.

- ***Interactions of nutrients and light***

Human activities resulting in a reduction of light energy in aquatic systems (e.g., eutrophication and suspended sediment from dredging and filling) can result in large-scale declines of seagrasses. Studies are needed to sort out the relationships between epiphytes stimulated by nutrient additions and the seagrasses to which they are attached. Overabundant epiphyte loads can cause severe reductions in seagrass growth. This phenomenon, coupled with declines from reduced light environments, gives cause for concern.

Population Dynamics and Reproduction

The population dynamics of all species occurring on the West Coast are poorly understood. Research is needed to describe the similarities and differences between small, fragmented patches and continuous stands. Studies should also examine genetic structure and diversity and relate these features to performance and ecological success. Although recent studies have clarified seagrass breeding systems, more work is necessary. Work is especially needed to determine possible effects of human-induced disturbance (e.g., non–point source contamination resulting from agriculture, industry, logging, and urbanization) on pollination systems and mechanisms. Finally, detailed maps describing distributions and characterizing populations are needed for all species throughout the region.

Although some maps exist for eelgrass, information for the other species is very limited.

- ***Density-dependent features***

Currently no research allows us to determine the relationship between shoot density, patch size, and modifications in substrata and sediment biogeochemistry. This information is necessary to judge the point at which a small patch begins to function as a seagrass system, and it has direct consequences on proper management. For example, guidelines in Washington now state that a patch of eelgrass with a density of 50 shoots per m^2 is a functioning patch. This criterion is based on qualitative observations of the persistence of patches over several years. Three problems arise from this type of policy: (1) Before the policy can be adopted in other locations along the West Coast, adequate field tests at several locations are necessary; (2) criteria should be based on quantitative as well as qualitative analysis; and (3) although persistence is an ecologically sound measurement of functionality, other parameters such as modified sediment processes, higher infauna and epifauna densities, and enhanced organic composition of the sediments are also important indices.

- ***Turnover rates***

To date, we have no data to determine the fundamental population parameters of birth rate, death rate, and longevity for seagrass populations on the West Coast. There is also a need to determine the nutrient requirements of seedlings and to clarify their role in structuring patch size. In addition, there are no data to document the life expectancy of rhizome tissues or short shoot tissues. Finally, there is insufficient evidence to conclude whether plants in small patches are replaced more rapidly than plants in large, continuous stands. Without a basic understanding of these population parameters, there is no rigorous way to evaluate limiting factors or to estimate the true carrying capacity of a system for a seagrass species.

- ***Role of genetic diversity and gene flow within populations***

It is generally known that higher diversity leads to stability in natural systems. This is undoubtedly true for seagrass systems; nevertheless, we have only recently begun to understand the role of genetic diversity in maintaining seagrass populations. Major questions to be answered include: (1) Is disease resistance dependent on increased diversity? (2) Are certain genetic strains more tolerant of particular disturbance events (e.g., low light resulting from increases in suspended sediment)? (3) What are the rates and processes of gene flow between disjunct populations? (4) Does increased genetic diversity render a population more resilient to invasion by exotic species? and (5) Do seagrass meadows with higher genetic diversity offer enhanced ecological support to animal populations?

- ***Pollination studies***

Real progress has been made in the last decade in the understanding of seagrass pollination biology, and this research has collapsed the notion that seagrasses are largely asexual or rely on crude or inefficient pollination mechanisms. Research questions that warrant further attention include: (1) exploration of the physiological mechanism involved in pollen-stigma interactions, (2) clarification of the relationship between tidal and current activity and the timing of pollen and seed dispersal, and (3) elucidation of the relationship between seagrass morphology, pollination systems, and population structure.

- ***Distribution maps***

Several human activities threaten the growth and survival of seagrass in this region, including dredging and filling, industrial and agricultural runoff, and erosion from increased logging. Before we can begin to assess impacts, however, we need a working knowledge of the amount of seagrass present in the region as a whole. On this score we have little data. Although seagrass resources have been mapped at a few locations, these maps are usually one-time efforts and involve only one species, eelgrass. Some efforts have been made to map *Z. japonica*, but these activities are very localized. *Phyllospadix* spp. and *Z. asiatica* have received less attention. In sum, we have limited knowledge of the regional distribution and abundance of all species and are thus unable to assess the relative and cumulative impact of human activities over time.

Given the continued pressure to develop the margins between land and sea, accurate and comprehensive knowledge of seagrass distribution and abundance is essential for prudent and wise management of the resource. It is no longer necessary to validate the relative worth of seagrasses within the context of coastal food webs. This work has been and continues to be done. To preserve and conserve the resource, it is mandatory to know how much seagrass is present and, further, to determine the rate of relative loss or gain both locally and regionally. Any "no net loss" criterion is meaningless if distribution and abundance maps are missing.

Environmental Studies

Long-term management of natural systems demands an understanding of the effect of environmental fluctuations on these systems. For example, the impact—both immediate and cumulative—of coastal development on seagrass-dominated systems cannot be correctly interpreted until the physical and chemical characteristics necessary for plant growth and reproduction are fully understood. Although information is available for eelgrass, it is lacking for other species on this coast. Also, rates of change in population size and characteristics within coastal waters near areas of urban, industrial, or agricultural activity can be more easily explained when we have comprehensive knowledge of the effect of random natural disturbances on seagrass systems. Moreover, the relationship between changing environmental conditions, seagrass patch size, and animal distribution and density needs to be clarified. Finally, seagrass transplanting has been marginally successful along the West Coast. This is a critical issue. For example, some Superfund sites (highly contaminated sites designated for special attention and cleanup by the U.S. Environmental Protection Agency) located in estuaries and coastal areas demand restoration of viable seagrass systems as part of overall project goals. To comply with these goals, managers and scientists must develop the best configuration of preserved or created habitats. Unless transplants become more successful, this will not be possible.

- ***Coastal development and seagrass distribution and abundance***

Some human activities (e.g., dredging and filling and dock construction) directly impact seagrasses in this region. Also, non–point source contaminants and suspended sediment resulting from activities connected with agriculture, logging, and industry affect the condition of soft-bottom and rocky coast habitats. The cumulative effect of these phenomena on the distribution and abundance of seagrasses remains unknown. Long time-series environmental data sets are needed in a variety of seagrass environments so that models describing the impacts of human activity can be generated and tested and rational management decisions can be made.

- ***Natural disturbance and patch size***

The impact of stochastic events (e.g., winter storms and ice scour) on the long-term viability of seagrass meadows has not been determined. Consequently, we have little knowledge of long-term variation in the boundaries of meadows or patches. More information is needed from areas where the effects of human-induced disturbance is reduced. These types of data will enable us to interpret more accurately the responses of seagrasses to chronic stress.

- ***Patch size and animal distribution and density***

Efforts must be made to discern the relationship between patch or meadow size and animal distribution and density. Above-ground biomass is important not only for shelter and foraging but also as substrate for grazing and spawning. It is clear that seagrasses are an important link in the continued survival of many nearshore animals. What is not clear is the quantitative link between seagrass patch size and many animal species. Consequently, researchers are not able to state with confidence the critical patch size necessary to sustain important commercial species such as Pacific herring *(Clupea harengus pallasi)* or Dungeness crab *(Cancer magister)*. This information is necessary to realistically assess the functional equivalence of restored or newly established seagrass meadows.

- ***Seagrass transplant requirements***

Results from reports of failed eelgrass mitigation transplants (especially transplants greater than 1 hectare), particularly in the Pacific Northwest, suggest that these plants cannot be successfully transplanted (Thom 1990). This may be based on false assumptions. Many projects failed because the site was inappropriate. Commonly, eelgrass was not growing at the transplant site and no modifications were made to create conditions that would promote the growth and reproduction of transplanted stock (Thom 1990).

It is also necessary to identify appropriate transplant techniques (e.g., bare root, anchored shoot bundles, sediment plugs containing whole plants, or seeds). Information imported from studies outlined above in the sections on Physiology (e.g., root and shoot nutrient physiology) and Population Dynamics and Reproduction (e.g., role of genetic diversity and gene flow within populations) is necessary before we can confidently advocate transplant techniques to achieve maximum restoration efficiency.

There is a clear need for transplant guidelines for all species of seagrass on the West Coast. These guidelines should be regionally specific and should suggest monitoring programs and reporting protocols. Directed research necessary to achieve this goal includes: (1) complete understanding of environmental conditions (e.g., sediment, nutrient, and light environments) necessary for successful transplant, (2) relative importance of genetic composition and diversity for transplants, and (3) evaluation of the most appropriate techniques for large-scale transplants.

Concluding Remarks

As illustrated in this report, an informal network exists between seagrass scientists and resource managers along the West Coast. In addition, we have summarized research gaps and needs identified by the scientists most intimately connected with seagrass systems in this region. The job of seagrass researchers now is to link these separate but related phenomena in an effort to promote sound seagrass management for the region as a whole.

We thank all contributors for providing thoughtful, measured responses toward an understanding of research gaps and needs for West Coast seagrasses. We are confident that these comments, grounded in years of observation and analysis, can lend themselves to coordinated research projects built on time-series data collection and collaborative investigations. If such is the case, the formula necessary to compute the effects of human development on the preservation and creation of healthy seagrass systems in this region might be achieved.

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Appendix

The following sections describe seagrass research since 1985 in Southwestern British Columbia, Canada, and in Baja California, Mexico.

Seagrass Research in Southwestern British Columbia, Canada

Paul G. Harrison

Studies have focused on three levels of the ecological hierarchy: community, ecosystem, and population. Population-level studies began with basic demographic questions (e.g., Bigley and Harrison 1986), developed into applied areas (transplantation), and recently returned to basic aspects of population establishment and growth.

Initially, community-level studies focused on areas where two *Zostera* species overlap *(Zostera marina* and *Z. japonica)*. This phenomenon was due in part to port construction, which modified the physical environment and resulted in the expansion of *Z. marina* into a zone formerly occupied by *Z. japonica*. This in turn led to major changes in infaunal populations (Harrison 1987). Later, ecosystem-level studies explored the details of detritus production from *Z. marina* leaves and its consumption by microbes and invertebrates (Harrison 1989). As an adjunct to this research, some physiological studies were made on translocation and nutrient dynamics (Heminga et al. 1991).

Finally, loss of *Z. marina*, principally caused by erosion related to port construction, led to transplant technique experiments (Harrison 1990a, 1990b). These transplants were successful in that patches persisted or expanded during the monitoring period (5 years). However, several years later some transplants had perished. Consequently, recent studies have again focused on detailed demographic topics (e.g., shoot initiation and longevity, seed banks, germination) in an attempt to understand the mechanisms that control population dynamics (Nomme and Harrison 1991a, 1991b; Harrison 1990c). In addition, clonal structure (Harrison and Durance 1992), recognized as a basic but poorly understood aspect of seagrass populations, will be the subject of future studies.

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SEAGRASS RESEARCH IN BAJA CALIFORNIA, MEXICO

Silvia E. Ibarra-Obando

Dawson (1962) was the first to describe the presence of extensive eelgrass *(Zostera marina* L.) meadows in Baja California, specifically in San Quintín Bay on the Pacific Coast of Baja California. Barnard (1970) conducted detailed investigations of the invertebrates associated with eelgrass. Further descriptions are included in reports by Neuenschwander et al. (1979) and Kramer (1976). Kramer noted that maximum eelgrass biomass occurs during winter and spring, coinciding with the arrival of the black brant *(Branta bernicla nigricans)* from its summer feeding and breeding grounds in the Arctic. Eelgrass is an important food for wintering brant at several sites in Baja California (Kramer 1976, Ward 1983).

On the Pacific side of Baja California, *Zostera marina* extends south as far as Bahía Magdalena (24°N) (Saunders and Saunders 1981). In these temperate waters, eelgrass is perennial (Harrison 1982); however, in the warm waters of the Gulf of California, an annual variety grows (Phillips and Backman 1983). Descriptive and functional information on eelgrass beds in Baja California is currently only fragmentary.

With limited funding, my laboratory in 1982 began a complete descriptive study of the seagrasses in Baja California. For several years, we collected data for a number of plant characteristics (e.g., above and underground biomass, blade production, and shoot dynamics) and environmental parameters (e.g., tidal elevation and sediment characteristics) as well as epiphyte identification and biomass. These findings, summarized in Ibarra-Obando (1989), allow us to theorize that eelgrass prairies in San Quintín Bay are highly dynamic communities with a distinctive seasonal cycle that appears to differ from other eelgrass systems at more northerly locations along the West Coast of North America.

Current efforts focus on the role seagrass prairies play as nursery grounds for juvenile fish and invertebrates. To date, no studies have described the relationship between fish and eelgrass beds in Baja California.

Based on past and current studies, the following research gaps have been identified for seagrass systems in Baja California, Mexico: (1) characterization of the relationship between eelgrass and macro- and microalgae with respect to light and space; (2) determination of the relative contributions of eelgrass, salt marsh systems, and macro- and microalgae (phytoplankton included) to organic matter production; (3) determination of the relative influence of various sediment regimes (e.g., sand, silt) on plant morphology; (4) comparison of the structure and function of annual versus perennial eelgrass meadows; (5) descriptions of root and rhizome morphology across tidal elevations and determination of the relative functions of the various morphs; (6) detailed descriptions of the reproductive cycle in Baja waters; and (7) initiation of comprehensive research projects, similar to the studies in San Quintín Bay, at more southerly locations.

Compared to other locations along the Pacific Coast of North America, the Baja California coast is still relatively undisturbed. Scientific interest in this geographic region turns on the fact that undisturbed communities can provide basic information on ecosystem structure and functioning. These data are useful for regional seagrass management. Also, international efforts to study and preserve eelgrass beds in Mexico are needed. Establishing binational research projects would not only accomplish this goal but also provide the kind of information needed to meet existing knowledge gaps.

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