Submerged Aquatic Plants

Eelgrass

Introduction

Worldwide there are more than 50 species of vascular plants capable of inhabiting the shallow saline waters of the estuarine environment. The most common of these species, occurring in full-strength seawater, are the seagrasses. One of the most studied seagrasses in temperate and tropical regions is eelgrass (*Zostera* spp.). The eelgrass commonly found in North America, *Z. marina,* is widely distributed in the temperate zones of both coasts. Along the U.S. Pacific Coast, *Z. marina* occurs from Alaska to Baja California. Another species, *Z. asiatica,* is also found in a number of locations on the west coast of North America including offshore of the Santa Barbara area in California at depths up to 45 feet.

Eelgrass beds are generally regarded as highly productive habitats that support a rich assemblage of fish species and provide a refuge area for larval and juvenile fishes. Eelgrass habitat is also a very important resource for a variety of birds. It is associated with rich bottom fauna important to waterbirds, especially diving birds and mollusc-eaters. In California's bays and estuaries north of Monterey Bay, eelgrass provides spawning habitat for Pacific herring. Large numbers of waterbirds such as scoters, bufflehead, scaup, goldeneyes, American coots, eat eggs deposited onto eelgrass by Pacific herring during the mid-winter spawn. In addition, many birds such as surface-feeding ducks and other waterfowl, including the black brant, feed directly on eelgrass.

The location, abundance and health of eelgrass appear to be highly sensitive to changes in environmental conditions. For example, in the decade of 1935 to 1945, eelgrass beds on the north coasts of America and Europe suffered a substantial decline in abundance. The cause of this decline remains unknown but has been ascribed to a variety of causes ranging from parasitic infection by slime mold and fungus to greater than normal changes in rainfall or seawater temperature. A population decline in a wide variety of marine organisms dependent on eelgrass habitat was also seen during this period. Additionally, changes in bottom topography occurred in the affected eelgrass bed areas as currents and wave action reworked formerly stable bottom sediments. Recovery occurred slowly, due to the diminished and scattered distribution of individual plants resulting in reduced vegetative propagation and seed production.

Aside from its interaction in the marine and estuarine food webs, eelgrass assumes an important role in cycling nutrients. Organic material from natural decomposition processes or human influences are filtered and collected by eelgrass leaves and turions, providing a nutrient source for the eelgrass bed community. Nutrients that otherwise would accumulate in the sediments or be flushed out to sea may thereby be retained and recycled within the estuarine ecosystem.

The decline in eelgrass communities during the 1930s and 1940s encouraged the initiation of studies to gain a better understanding of this vital estuarine habitat. In recent years, the importance of eelgrass communities has resurfaced as a significant measure of the health of bays and estuaries. Some protection of this ecosystem has been afforded over the years through management practices that protect it through disturbance avoidance or in-kind replacement mitigation. In southern California further protection as also been provided by the implementation of the multi-agency Southern California Eelgrass Mitigation Policy of 1991 which is routinely included within permit conditions of both the U.S. Army Corps of Engineers and California Coastal Commission. While this policy was specifically designed to address eelgrass impacting projects in southern California, its principals have, at times, also been applied permit conditions for projects occurring in

Eelgrass, *Zostera marina*
Credit: DFG

northern California. The continued decline of important fish species may serve to offer additional protection for the state's eelgrass communities by designation of this habitat type as critical habitat under federal laws, administered by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service.

Status of Biological Knowledge

The recognition of the importance of eelgrass within the bay and estuarine ecosystem has provided a focus of scientific research and resource management for several decades. Early last century researchers on both coasts collected an array of information on water and air temperatures along with plant data over a several year period. Additionally, measurements of eelgrass standing stock have been conducted throughout the Northern Hemisphere including the West Coast of North America.

The distribution of eelgrasses within bay and estuarine ecosystems is dependent on a variety of parameters, including light, temperature, salinity, substrate, waves and currents, nutrients, and availability of seed. Most commonly, estuarine seagrasses are found in soft sediments of semi-sheltered areas where depth and turbidity conditions allow sufficient light. The typical depth distribution of eelgrass is throughout the inter- and subtidal-zones. The maximum standing crop occurs just below mean low water. Maximum biomass occurs at depths corresponding to 20 to 30 percent surface-light intensity. Distribution and abundance of eelgrass also appear to be influenced along the land-sea axis of estuaries by the relative abundance of nutrients. Nutrient availability is higher at the riverine end of an estuary. However, the mixing zone within estuaries also tends to be more turbid. Thus, the relationship between light penetration and nutrient availability acts with other factors to define the areas within estuaries where eelgrass beds become established and thrive.

Eelgrass is a flowering marine plant that grows from rhizomes in soft sediment. The establishment and expansion of eelgrass beds occur through seed production and asexual rhizome propagation. Although their roots and rhizomes help to stabilize sediments where they are established, eelgrass beds are highly susceptible to anthropogenic disturbances, particularly substrate disturbances and reduced light penetration. Eelgrass beds are also susceptible to adverse impacts from non-native invasive species. Studies looking at the response of eelgrass to a non-indigenous mussel (*Musculista senhousia*) found that eelgrass beds showed a negative response to colonization of this invasive bivalve, particularly where the eelgrass bed was sparse or fragmented, or in beds that had been reestablished. The recent discovery of the invasive algae *Caulerpa taxifolia* (Mediterranean strain) in Agua Hedionda Lagoon in southern California has also demonstrated the ability of an invasive species to displace eelgrass.

Once disturbed, eelgrass bed recovery or recolonization is slow and may not be possible without reestablishment of favorable growth conditions. The decline of seagrass and related aquatic vegetation has reached and alarming state worldwide. Studies show documented plant losses in the United States that have approached or exceeded three-quarters of the historic distribution. Further, the importance of genetic distribution in the population dynamics of aquatic plants has in the past largely been ignored in restoration and conservation efforts. Studies in southern California found significantly reduced genetic diversity in eelgrass beds that were reestablished through transplants or that otherwise became established in previously disturbed locations. Reduced genetic diversity in the transplanted sites corresponded in general to a smaller size and younger plant age than in undisturbed sites, although this characteristic effect on the eelgrass community is not fully understood. However, there was no evidence that genetic diversity increased in transplanted sites over time. It is likely that this genetic diversity problem occurs in many areas of the state where eelgrass bed disturbances commonly take place.

Status of the Beds

Along the Pacific coastline of California, eelgrass is found to some degree in all of the larger bays and estuaries, from the Oregon border to San Diego, including Humboldt Bay, Tomales Bay, San Francisco Bay, Monterey Bay, Morro Bay, and San Diego/Mission Bay. Additionally, eelgrass is well established in several of the smaller open estuarine embayments along the state's coastline. The historical presence of eelgrass along the California coast was much greater than it is today. Although few records exist that measure the areal extent of eelgrass within the state's small coastal estuaries, the condition that existed prior to human disturbances in many of these locations were no doubt favorable to eelgrass bed communities.

Humboldt Bay

Measurements of eelgrass standing stock in Humboldt Bay were conducted in 1972. Distribution was determined by mapping the eelgrass beds through field surveys and light aircraft. Eelgrass standing stock values determined through density analyses ranged from 3.1 million pounds dry weight in April 1972, to 15.2 million pounds dry weight in July 1972, with South Humboldt Bay accounting for 78 to 95 percent of the total eelgrass stock. These results were similar to an earlier assessment in 1962.

The differences in densities between the north and south bays appear to be persistent. A wet-weight density range (depending on location) of 0.06 to 0.43 pounds per square foot for Humboldt Bay winter eelgrass was estimated in 1979. The study attributed eelgrass density differences between the two regions of the bay to variations in sediment composition, and dredging activities in North Humboldt Bay associated with the commercial cultivation and harvest of oysters, rather than light availability or tidal flushing. Localized eelgrass bed density surveys conducted by the Department of Fish and Game in an effort to evaluate the biomass of Pacific herring utilizing Humboldt Bay eelgrass beds for spawning substrate also noted significantly lower eelgrass densities in North Humboldt Bay compared to South Bay during the 2000-2001 commercial herring season. Total eelgrass coverage within Humboldt Bay was determined to be 3,053 acres in 1984. Since that time, a detailed bay-wide eelgrass survey has not been conducted. However, the California Department of Fish and Game, U.S. Fish and Wildlife Service, Humboldt State University, and others have proposed initiating biannual bay-wide eelgrass surveys to begin during the summer of 2001.

Small North Coast Estuaries

It is likely that at one time eelgrass predominated along the seaward edge of many of the small estuaries at the mouth the north coast river systems. Today, due to human alterations, such as channelization, dredging, and upstream disturbances that cause increase turbidity and siltation, eelgrass is limited to but a few such ecosystems. Remnant populations are documented within the North Coast estuaries that remain open to seawater influence year-round, such as the Big River estuary where eelgrass forms large beds along muddy banks within the first three miles of the estuary, and the Albion River Estuary, which also has a well-established eelgrass community.

Tomales Bay

Eelgrass is the most abundant marine flora in Tomales Bay. Surveys conducted by the California Department of Fish and Game in 1985, determined the areal extent to be 965 acres. Although eelgrass distribution is relatively stable from year to year in Tomales Bay, densities of eelgrass beds are highly variable within and between individual beds seasonally. The density and distribution of eelgrass within Tomales Bay are determined annually by the California Department of Fish and Game as part of the seasonal herring spawning-ground surveys. Extensive eelgrass beds are located within Tomales Bay throughout the intertidal and subtidal areas, generally in waters less than 12 feet mean lower low water between Sand Point and Nicks Cove, and around the immediate bay perimeter on both shorelines to the vicinity of Millerton Point.

The general locations of the Tomales Bay eelgrass beds appear to have been consistent since the early 1970s, although there is some annual fluctuation. The density of eelgrass during the winter of 1987-1988 was 0.04 0.55 pounds per square foot. Similar densities were observed 1973 and 1976. Such densities represent between 70 and 100 percent bottom-coverage. The long-term evaluation of Tomales Bay eelgrass beds indicates that one bed near the mouth of the estuary is more ephemeral than any other.

San Francisco Bay

San Francisco Bay, the largest of California's estuaries, is also the most impacted by human development. An estimated one third of the historic extent of the bay has been lost to fill and development. While estuarine systems are by nature highly turbid, poor water clarity within San Francisco Bay is further exacerbated by human activities including direct treated industrial and wastewater discharges, non-point source runoff, urban-associated atmospheric deposition, and riverine inflow containing urban and agricultural discharges. Data on the historic areal extent of eelgrass within San Francisco Bay are limited, although it is believed that it supported extensive eelgrass meadows in the past. Reduced light penetration due to extremely high bay turbidity has been found to limit the development of eelgrass and may be the principal cause of its decline in San Francisco Bay. Eelgrass beds in the bay today are limited to relatively small patches located in the central bay, Richardson Bay, and the eastern northern-most portions of the south bay. In 1989, the areal extent of eelgrass beds in San Francisco Bay was estimated to be 316 acres. Since that time, some eelgrass beds have increased in size and new patches have been sited.

Eelgrass densities are far lower than those of the larger, healthier beds found in Tomales and Humboldt Bays. Although the eelgrass beds appear to be stressed, they have remained persistent in the bay and are heavily utilized by estuarine organisms.

Southern California

The eelgrass communities found south of San Francisco are more heavily impacted by human alteration than those in northern California. Historical records suggest that eelgrass was a predominant plant species in the state's south coast estuaries. However, the majority of southern California's remaining eelgrass habitat exists primarily due to replanting or recolonization of eelgrass beds in new or historic locations. Patchy eelgrass communities found within the Monterey Bay Area and Morro Bay are two exceptions. The eelgrass beds within the Monterey Bay Area are limited to the estuarine environment of Elkhorn

Slough and its entrance to the bay. These areas make up a total of approximately 50 to 75 acres of eelgrass habitat.

Eelgrass remains the dominant plant in the beds of Morro Bay. The beds there are the largest and least impacted of any in the southern portion of the state. Nevertheless, there are wide fluctuations in areal extent. By 1997, eelgrass distribution reached a historic low of 50 total acres. Further studies in 1998 showed an improvement in eelgrass distribution ranging from 81 to 120 acres, depending on the season of survey.

Eelgrass bed communities also exist in Los Angeles Harbor, Huntington Harbor, and in adjacent coastal areas. Many of these have been established through transplant activities associated with specific development mitigation requirements. Due primarily to suitable light conditions, many of the reestablished areas have met their intended mitigation goals. However, some reestablishment attempts have been unsuccessful. A complete survey of the areal extent of eelgrass and associated density assessments within this location of the state has not been conducted. The National Marine Fishery Service and other state and federal resource agencies have conducted cursory surveys of eelgrass in these locations. While formal surveys and reports have not been completed, areas that support eelgrass have been identified.

The eelgrass bed communities within San Diego County coastal areas have been heavily impacted by urbanization. All of the bays in this area of the state have been intensively modified. Attendant stresses are evidenced by very low eelgrass densities. Additionally, many of the eelgrass communities in San Diego County coastal areas have been derived through reestablishment efforts or, as in Mission Bay, through natural colonization of dredged sediments. The most comprehensive survey conducted for eelgrass in the San Diego Bay was completed in 2000. This survey followed an early bay-wide survey conducted in 1994. Similar surveys have been completed for Mission Bay, Batiquitos Lagoon, and Agua Hedionda. The location of eelgrass present within Oceanside Harbor has also been documented by the National Marine Fishery Service.

Management Considerations

See the Management Considerations Appendix A for further information.

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Gracilaria and Gracilariopsis

History of Harvest

Although species in the red algal genera *Gracilaria* and *Gracilariopsis* have been harvested throughout the world for agar production and as a food source for humans and cultured shellfish, only small amounts have been harvested from the wild in California during the last few decades. Between 1965 and 1970, several applications were made to the Fish and Game Commission for permission to harvest Pacific herring eggs deposited on edible seaweeds for export to Japan, where it is considered a luxury food item. In 1970, Department of Fish and Game divers conducted a survey to determine the quantity and composition of the aquatic vegetation in Tomales Bay. The commission decided to establish one five-ton harvest permit each for Tomales and San Francisco bays. However, siltation, which occurs in both bays during the winter months, lowered the market quality of a large portion of the eggs-on-seaweed harvest; as a result, the five-ton quota was never reached in either bay. The harvest of herring eggs on wild edible seaweed in Tomales and San Francsico bays is now prohibited.

Status of Biological Knowledge

Gracilaria pacifica and *Gracilariopsis lemaneiformis* are commonly found in California's bays and estuaries. Both species have numerous brownish-red thin branches loosely connected to the substrate by a small holdfast and grow to a maximum height around three feet. Because they are so similar in appearance and frequently found growing in the same area, they are often difficult to distinguish. *Gracilaria pacifica* is commonly found in sheltered intertidal to subtidal locations from Alaska to the Gulf of California, Mexico. *Gracilaria lemaneiformis* occurs in areas exposed to ocean currents as well as protected intertidal and subtidal areas from Vancouver Island, British Columbia, Canada, to Santa Catalina Island in the Southern California Bight. Both species are fast growing and, when detached from the substrate, often form large dense mats in estuarine areas protected from strong currents. In Tomales and San Francisco bays, where annual vegetation density studies are conducted in conjunction with Pacific herring spawning surveys, *Gracilaria* and *Gracilariopsis* densities fluctuate considerably from year to year.

Little is known about the significance of these species in bay and estuary ecosystems. One study conducted in Jarvis Bay, Australia, found relatively low numbers of fish and decapod species inhabiting drifting *Gracilaria spp.* beds when compared to adjacent seagrass beds, suggesting that these beds may not be a critical habitat for estuarine macrofauna. However, *Gracilaria* and *Gracilariopsis* appear to be among the preferred spawning substrates for Pacific herring in California waters and may be essential to herring when other aquatic vegetation is not available. These beds with herring eggs are an important feeding area for a variety of marine animals.

Management Considerations

See the Management Considerations Appendix A for further information.

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