16 Eelgrass, *Zostera marina*

Eelgrass, *Zostera marina*: (left) a close-up photo of eelgrass blades; (right) an eelgrass meadow in Humboldt Bay. Photo Credit: UC Sea Grant Extension, Eureka/Annie Eicher.

Introduction

Seagrasses, a group of about sixty species, are unique amongst flowering plants in that they have adapted to live immersed in seawater. Seagrasses grow in shallow marine bays and estuaries around the world and form the basis of a specialized coastal and estuarine habitat of great ecological value. One of the seagrasses that is widely distributed throughout temperate estuaries of both coasts is the native eelgrass, *Zostera marina*. Along the west coast, eelgrass is found from southeastern Alaska to southern Baja California, Mexico.

Eelgrass beds are important ecological communities of shallow bays and estuaries because of the multiple ecosystem values that they provide. Eelgrass is a major source of primary production in nearshore marine systems, supplying detrital-based food chains. In addition, several organisms directly graze upon it, thus contributing to the system at multiple trophic levels. For example, certain waterbirds feed directly on the eelgrass plants, such as brant geese that use eelgrass almost exclusively as a food resource. Eelgrass meadows are also of vital importance as habitat and have an important role in the life cycle of many ecologically and economically important aquatic species by serving as nursery areas. In California bays and estuaries north of Monterey, eelgrass provides spawning habitat for Pacific herring. Eelgrass beds provide habitat for juvenile fish including Pacific salmonids, lingcod, and rockfish, and invertebrate species such as Dungeness crab.

In addition to the habitat and resource values that eelgrass provides, it also functions to trap and remove suspended particles, thus improving water clarity, reduces erosion by providing sediment stabilization, adds oxygen to the surrounding water, and cycles nutrients. Extensive eelgrass canopies absorb wave shock, thereby protecting adjacent shorelines.

Worldwide there has been a decline in eelgrass abundance over the past 20 to 30 years, which concerns natural resource managers. These changes have been

attributed to increased anthropogenic effects, such as coastal development, dredging, pollution, fishing practices and boating activities. Besides human disturbances, declines in eelgrass communities have been caused by outbreaks of disease, particularly by the eelgrass wasting disease during the 1930s on the Atlantic coasts of both Europe and the United States. The disease resulted in the loss of over 90 percent of the North Atlantic eelgrass population, which had a catastrophic effect on estuarine productivity. There was a drastic reduction in brant geese populations, as well as the disappearance of the scallop fishery. In addition, it resulted in the only known case of extinction of a marine gastropod, the eelgrass limpet. Wasting disease continues to affect eelgrass beds in North America and Europe with variable degrees of loss; however, none to date have been as catastrophic as the outbreak in the 1930s.

In response to the decline, the importance of eelgrass communities has been realized and they have received increasing attention from scientists and natural resource managers. There has been an increase in protection through management practices throughout the world. In the United States, eelgrass habitat is protected by federal and state law under their respective Clean Water Acts; the Magnuson-Stevens Fishery Conservation and Management Act; the California Coastal Act; and Title 14, California Code of Regulations. According to these laws and regulations, any activities which may potentially impact eelgrass habitat must mitigate for those impacts. This requires mitigation for harmful impacts to existing eelgrass beds as well as potential eelgrass habitat.

Status of Biological Knowledge

Some of the earliest research on seagrasses occurred with the native eelgrass. To gain a better understanding of this vital estuarine habitat, there has been a major increase in research into the detection and assessment of eelgrass threats. Researchers on both coasts have collected an array of information on 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 eelgrass within bay and estuarine systems is defined by several variables, including light, temperature, salinity, substrate, wave exposure, currents and nutrient availability. Eelgrass forms extensive meadows in soft-bottom habitats from the low intertidal to depths of about 20 feet (6 meters), and from sheltered areas to exposed coasts. In southern California, eelgrass has been reported to occur as deep as 98 feet (30 meters). Optimum temperatures for eelgrass growth seem to lie between 50 and 68°F (10 and 20°C). However, eelgrass is known to survive with a lower tolerance level of 21°F (-6°C) and an upper level of 104.9°F (40.5°C). Eelgrass is a euryhaline species (able to live in a wide range of salinities) that is capable of growing near stream mouths when the water is fresh at low tide, but does not grow in persistent fresh water. A salinity range of 10 to 30 parts per thousand is optimum for growth.

Eelgrass morphology consists of horizontal rhizomes that are buried in substrate and long leafy shoots that extend vertically in the water column. Shoots typically consist

of three to five ribbon-like leaves. Leaf lengths can vary from less than 1.5 feet (0.5 meters) to nearly 13 feet (4 meters) and leaf width ranges from 0.05 to 0.5 inches (1.5 to 12 millimeters). Eelgrass colonizes substrate ranging from firm sand to soft mud. Leaf growth is very rapid—typically 0.2 inches/day (5 millimeters/day) and in some circumstances growth can reach 0.4 inches/day (10 millimeters/day). This high productivity results in large biomass input into the ecosystem, fueling dynamic energy systems.

Not only does eelgrass provide high ecosystem value, but it also is used as an indicator of estuarine health because it responds to environmental factors by changing in distribution and abundance. Because of the susceptibility of eelgrass to stresses such as pollution, it is used as one of the five sensitive indicators of pollution in the NOAA National Estuarine Eutrophication Assessment. Eelgrass requires some of the highest light levels of any plant group worldwide which means it is acutely responsive to water clarity changes.

Status of the Population

Eelgrass is found in the nearshore waters of every continent except Antarctica. In California, eelgrass is found to some degree in all of the larger bays and estuaries, including Humboldt Bay, Tomales Bay, Drakes Estero, San Francisco Bay, Monterey Bay, Morro Bay, San Diego Bay and Mission Bay. Additionally, eelgrass is established in several of the smaller estuarine embayments along the state's coastline.

Humboldt Bay

In Humboldt Bay, eelgrass is the dominant macrophyte of the shallow subtidal and lower intertidal zones. The eelgrass beds here represent the third largest eelgrass meadows found along the west coast and host over 60 percent of the total brant goose population each year. Eelgrass contributes more than 40 percent of the primary production in the bay, indicating that it is quite likely the most important primary producer.

The seasonal and temporal fluctuation in distribution and standing stock of eelgrass was studied in Humboldt Bay for two years from 2001 to 2003. For the purpose of the study, the bay was divided into three regions, North Bay, Central Bay and South Bay. Total distribution was determined using aerial photography and on the ground verification with handheld GPS. Aerial imagery showed large continuous eelgrass meadows in North and South Bays with narrow bands along Central Bay. The total areal distribution of eelgrass in Humboldt Bay was determined to be 4670 acres (1890 hectares), which represents a substantial portion of California's eelgrass population (approximately 41 percent).

Eelgrass density in South Bay is greater and shoot lengths are shorter compared to North Bay. The population in Central Bay is intermediate in density and shoot length. Factors such as weather variability, flushing rate, temperature and turbidity, or

differences in the genetic composition of Humboldt Bay eelgrass may account for differences in shoot density, but need to be investigated further. Given Humboldt Bay's large eelgrass population and the role it serves in the bay's ecology, there is little doubt that it warrants specific management efforts to understand the dynamics of this important and valuable resource.

Tomales Bay

Eelgrass is the dominant marine flora in Tomales Bay and the primary spawning habitat for the Pacific herring, thus eelgrass distribution and density data are essential for calculating Pacific herring spawning population estimates. Bay-wide eelgrass surveys were conducted in 1987, 1992, 1993 and 1994 with eelgrass distribution along the entire 12 mile (20 kilometer) length of the bay estimated at 965 acres (391 hectares), 654 acres (265 hectares), 884 acres (358 hectares) and 865 acres (350 hectares), respectively, for those years. Many of the eelgrass beds are intertidal, becoming completely exposed during low tides. Eelgrass distribution is relatively stable from year to year; however, density is highly variable and can fluctuate seasonally.

San Francisco Bay

A comprehensive baywide eelgrass survey was completed in 2003 to identify and map existing eelgrass beds and identify conditions under which eelgrass can occur throughout San Francisco Bay. Eelgrass surveys were conducted from June to October using both acoustic and aerial survey methods. Survey techniques utilized a combination of aerial visual surveys, photography, side-scan sonar, single-beam sonar and diver ground-truthing to search for eelgrass beds.

The coverage area of eelgrass in San Francisco Bay was determined to be 2881 acres (1166 hectares), which represents approximately 1 percent of the total area of the bay. While the eelgrass resources here account for only a small portion of the total bay habitat, San Francisco Bay ranks second only to Humboldt in eelgrass coverage.

The largest eelgrass bed with 1505 acres (605 hectares) was located between Point Pinole and Point San Pablo north of the Richmond-San Rafael Bridge. The second largest bed with 437 acres (177 hectares) was found in Richardson Bay near Sausalito in Marin County. The majority of eelgrass was located on the east shoreline between Point Pinole and Bayfarm Island.

San Francisco Bay is greatly impacted by human development, thus an estimated one third of the historic extent of the eelgrass in the bay has been lost. Extremely high turbidity has resulted in reduced light penetration and may be the principle cause of the decline of eelgrass in San Francisco Bay.

Central California

The eelgrass beds within Monterey Bay 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 (20 to 31 hectares) 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 an historic low of 50 total acres (20 hectares). Further studies in 1998 showed an improvement in eelgrass distribution ranging from 81 to 120 acres (33 to 49 hectares), depending on the season of survey. A recent study conducted by the Morro Bay National Estuary Program found that eelgrass distribution had increased in the bay since the late 1990s. Total eelgrass in coverage in 2006 and 2007 was estimated at 288 acres (117 hectares) and 347 acres (140 hectares), respectively.

Southern California

In southern California, coastal wetlands are more heavily impacted by human alteration than those in northern California, thus approximately 90 percent of this habitat has been lost. Recent estimates reveal that 40 percent of the world's population lives within 60 miles (96 kilometers) of the coastline. As coastal use and development continues, it seems unavoidable that coastal habitats will continue to experience adverse stress.

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.

Eelgrass bed communities exist in Los Angeles Harbor, Huntington Harbor, Channel Islands 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.

Small Coastal Estuaries

It is likely that at one time eelgrass predominated along the seaward edge of many of the small estuaries along the coast. Today, due to human alterations, such as channelization, dredging, development and upstream disturbances that cause increased turbidity and siltation, eelgrass is limited to a few such ecosystems. Remnant populations are documented within California's north coast estuaries that remain open to seawater influence year round, such as the Big River estuary (Mendocino County) where eelgrass forms large beds along muddy banks within the first 3 miles (5

kilometers) of the estuary, and the Albion River Estuary (Mendocino County), which also has a well-established eelgrass community.

Management Considerations

In order to standardize and maintain a consistent policy regarding mitigating adverse impacts to eelgrass resources in southern California, the Southern California Eelgrass Mitigation Policy (Policy) was developed by federal and state resource agencies (National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service, and the California Department of Fish and Game (Department). The Policy provides a basis for consistent recommendations for projects that may affect existing eelgrass resources. The Department's future management goals for eelgrass include:

1. Carry out and maintain a comprehensive eelgrass inventory for the state.
2. Develop a Northern California Eelgrass Mitigation and Monitoring Policy in collaboration with NMFS.
3. Include maintenance of plant stock genetic diversity as an important parameter within eelgrass mitigation plan requirements.
4. Evaluate the potential impacts of anticipated sea level rise and coastal erosion on eelgrass bed communities. Because the natural, often gently sloping shorelines around many of California's bays have been replaced by revetments, a study of the potential loss of eelgrass habitat due to the lack of intertidal refuge from increased water depth and reduced light penetration should be undertaken. The results of such a study would then be added to the analyses of potential impacts and preparations for the anticipated rise in sea level.

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Further Reading

Engle JM and Miller KA. 2005. Distribution and morphology of eelgrass (*Zostera marina* L.) at the California Channel Islands. In: Garcelon DK and Scwemm CA, editors. Proceedings of the Sixth California Islands Symposium. National Park Service Technical Publication CHIS-05-01, pp 405-414

Ferson SL. 2008. Manipulation of food quality and quantity by black brant geese. [MSc thesis]. Arcata, CA: Humboldt State University. 61 p. Available from: Humboldt State University library, Arcata, CA.

Green EP and Short FT. 2003. World atlas of seagrasses. Berkeley: University of California Press; 298 p.

Larkum AWD, Orth RJ and Duarte CM, editors. 2006. Seagrasses: biology, ecology, and conservation. Amsterdam: Springer. 691 p.

Merkel and Associates, Inc. 2004. Baywide eelgrass (*Zostera marina* L.) inventory in San Francisco Bay: Pre-survey screening model and eelgrass survey report. Prepared for California Department of Transportation. 51 p. Available from: California Department of Fish and Game, Eureka, CA.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KL, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M and Williams SL. 2006. A global crisis for seagrass ecosystems. Bioscience. 56:987-996.

Phillips RC. 1984. Ecology of eelgrass meadows in the Pacific northwest: A community profile. US Fish and Wildlife Service Technical Report FWS/OBS-84/24. 85 p. Available from: NTIS, Springfield, VA, PC A05/MF AO1.