Science Foundation Chapter 3
Appendix 3.1 – Case Study
Submerged Aquatic Vegetation

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DESCRIPTION OF THE GROUP

Submerged aquatic vegetation (SAV) includes, going from salt to freshwater: eelgrass *Zostera marina*, several species of pondweed (*Stuckenia* spp.), and the Brazilian waterweed *Egeria densa* as well as several other freshwater invasive species. The freshwater species are largely outside the domain of this report.

CRITERIA FOR SELECTION OF THE GROUP

SAV generally is regarded as an important component of estuarine ecosystems and an indicator of ecological condition. SAV is generally in short supply in the lower estuary and a nuisance in the Delta (e.g., invasive species such as *Egeria densa*). Eelgrass in particular is vulnerable to several aspects of climate change, particularly rising sea level. In addition, eelgrass restoration, alone or as part of a living shoreline, may be useful in protecting shorelines and marshes.

OTHER INFORMATION ABOUT THE GROUP

Most of this discussion concerns eelgrass beds, because eelgrass is the predominant SAV in the lower estuary, has the greatest potential both for climate effects and for adaptation to rising sea level, and is better known than the other SAV forms. Much of this information comes from Boyer and Wyllie-Echeverria (2010) and the Subtidal Habitat Goals Report (2010).

Eelgrass beds form in shallow areas of sandy-mud bottom, where they trap and stabilize sediments, alter hydrodynamics, and alter sediment chemistry, all of which can enhance conditions for the maintenance of the beds. They also add structure to otherwise bare areas, providing habitat for many species that may use the eelgrass for protection or feed on the eelgrass or associated biota.

Eelgrass beds occur in the saline areas of the estuary, covering about 1500 ha or 1% of the area of San Pablo, Central, and South Bays. The largest bed is just north of Point San Pablo in San Pablo Bay, but most of the other major beds are in Central Bay (Merkel and Associates 2009). These beds occur mostly within 2m of mean lower low water, presumably because of light limitation (Zimmerman et al. 1991). Most of the beds are perennial, reproducing vegetatively and also through annual seed production resulting in new shoots, except for one bed near Alameda that primarily reproduces annually by seeds. Reproduction from seeds appears to be inhibited by high winter flows accompanied by high turbidity, as occurred in 2006 (K. Boyer, SFSU, pers. comm.).

Despite their close proximity, major beds within the Bay are genetically differentiated, possibly as a result of local selection (Ort et al. 2012). This may imply adaptation to local conditions, and the authors recommended care in selecting sources of plants to be used in restoration.

A current research project (K. Boyer, SFSU, PI) is investigating the salinity tolerance and other characteristics of pondweeds, *Stuckenia* spp.. Both *S. pectinata* and *S. filiformis* are present, and they may hybridize. These species have only recently been documented in the open waters of Suisun Bay and the west Delta, although *S. pectinata* has long occurred in ponds behind levees (Jepson 1905). New beds and patches have established in the open Suisun Bay in the last five years according to aerial imagery, suggesting that conditions are becoming more favorable. Although the reason for this is unknown, salinity penetration in summer-fall has increased, apparently because of changed operations of the large water projects in the Central Valley (USFWS 2008) and light penetration may be increasing due to a now-limited supply of erodible sediment (Kimmerer 2004, Schoellhamer 2011). There are now about 400 ha of *Stuckenia* beds in Suisun Bay and the western Delta, and in some places the density of the beds is high enough to be a nuisance for boating. The plants senesce each winter and grow back from belowground tissues in spring.

The Brazilian waterweed *Egeria densa* forms large beds throughout much of the freshwater Delta. In places it chokes waterways, reduces current speeds, and traps sediment, possibly making the water clearer. Its distribution is largely outside of the scope of this report, but it probably has had a substantial impact on the Delta pelagic foodweb and therefore that of Suisun Bay . In addition, *Stuckenia* spp. overlap in distribution with *Egeria* in the western Delta and competition between these species may influence responses to changes in salinity, temperature, or water clarity (Borgnis 2013).

REVIEW OF LONG-TERM EFFECTS

Eelgrass beds are most vulnerable to rising sea level, which would reduce light levels at the beds and possibly also increase current speeds over the beds, reducing the efficiency with which beds capture sediments.

If suspended sediment concentrations continue to decline, eelgrass beds may be less able to trap sediments, reducing their capacity for self-maintenance and for maintenance of a sediment pool that might protect marshes and shorelines. This effect would interact with that of rising sea level, inhibiting both upward growth of the beds to maintain a constant depth through accretion and lateral growth up-slope. Lateral growth will also be inhibited in places with steep shorelines, especially where levees and seawalls reflect waves.

Water clarity is probably a limiting factor for the maximum depth of eelgrass beds, and reduced local sediment supply will allow water clarity to increase, possibly offsetting the other effects. However, the limit on depth may occur during winter-spring, when floods bring pulses of highly turbid water at the same time when new shoots are beginning to grow. High turbidity and possibly reduced salinity may explain a recruitment failure of eelgrass in San Pablo Bay during winter-spring of 2006.

A landward shift of the salinity gradient in summer may allow eelgrass beds to expand up the estuary. The other SAV species may already be responding to a landward shift in salinity in summer-fall, which is likely to increase (see section 2.1F).

Rising temperature is less likely than other changes to affect eelgrass, except possibly in some beds in shallow areas protected from waves and currents. To the extent that dissolved CO_2 increases relative to background, this may favor the growth of eelgrass and other SAV.

OTHER STRESSORS

Oil spills can cause severe damage to eelgrass beds. The effect of contaminants on SAV is unknown, except that the Department of Boating and Waterways uses herbicides to reduce SAV buildups near boat harbors and these herbicides may have effects beyond the areas of application. Experimentally elevated nutrients do not appear to affect eelgrass (G. Santos, SFSU thesis in progress).

FACTORS THAT MAY AFFECT SPECIES RESILIENCE

Probably high; eelgrass plants can grow clonally or through seed dispersal, and substantial belowground biomass can allow for recovery from periods of unfavorable conditions such as low salinity.

LIKELY CLIMATE CHANGE IMPACTS AND RISKS

Increased sea level and reduced sediment availability are likely to have negative effects, possibly offset by increasing water clarity.

MANAGEMENT ACTIONS TO BE CONSIDERED

Continue actions to protect eelgrass beds. continue investigations into the functions of eelgrass beds, particularly their ability to trap sediments, reduce waves and currents, and protect shorelines. Continue pilot restoration projects at an intermediate scale using a scientific approach to learn about methods for restoration as well as the functions of the beds.

UNCERTAINTY AND KNOWLEDGE GAPS

The uncertainties for SAV are summarized here from those enumerated in the Subtidal Habitat Goals Report (2010):

- Specific ecosystem functions supported by eelgrass beds
- Extent of functions contributed by plants vs. physical structure
- Scaling of functions to area of restored eelgrass beds
- Response of eelgrass beds to local biotic and abiotic environment
- Limits on establishment of new beds, naturally or as restoration.
- Effect of tidal and wind-driven circulation, wakes, and suspended sediment on persistence of beds and on dispersal of seeds and recruitment.
- Ecological and genetic connectivity among beds
- Effects of bed size, fragmentation, and density of plants in an eelgrass bed on persistence and expansion
- Extent of exogenous mortality of eelgrass and controls on die-back and recovery.

- The most effective methods for restoration and maintenance of eelgrass beds with minimal intervention
- Interactions between oyster and eelgrass beds
- Distribution, abundance, and limiting factors for other SAV species

LITERATURE CITED AND RESOURCES

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