Science Foundation Chapter 5
Appendix 5.1 – Case Study
Pacific cordgrass (*Spartina foliosa*)

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DESCRIPTION OF THE SPECIES

In the San Francisco Bay, the low salt marsh zone has historically been typified by a single plant species, Pacific cordgrass (*Spartina foliosa*), which also is a co-dominant species in the mid-marsh plain. In recent decades, San Francisco Bay tidal marsh has been invaded by an introduced relative from the eastern coast of the United States, Smooth cordgrass (*S. alterniflora*), and subsequently by even more invasive hybrids formed between the Pacific and Atlantic species *(*Dahler & Strong 1997, Ayres et al 1999*)*.

This case study describes the ecological role played by native Pacific cordgrass in providing habitat structure for a variety of species in San Francisco Bay, and the substantial changes in habitat structure and benthic invertebrate community composition caused by invasive *Spartina alterniflora x foliosa* hybrids (Levin et al. 1998, Levin and Talley 2002, Neira et al. 2006, Janousek et al. 2007, Brusati and Grosholz 2009, Grosholz et al. 2009a, Grosholz et al. 2009b).

The genus *Spartina* (cordgrass) is widely dispersed throughout temperate salt marsh systems of the world. It has been well-studied globally, both because it is a highly valued, habitat-forming foundation species within salt marshes to which it is native (Pennings and Bertness 2001, Warren et al. 2002), and because of the negative ecosystem consequences associated with human-facilitated introductions of *Spartina* species to areas in which they do not naturally occur (Neira et al. 2006, Strong 2009).

Species Description: Native *Spartina*

Spartina foliosa is a clonal grass species found from Baja California to Bodega Bay, that grows in tidal salt marsh in the San Francisco Bay (Hinde 1954, Callaway and Josselyn 1992, Daehler and Strong 1995, 1997, Vasey 2010). In the low elevation salt marsh zone that extends from mean high water to mean sea level, *S. foliosa* is the dominant native plant species (Mahall and Park 1976b). This foundation species forms the structure of the low marsh zone forming uniform fringes on tidal creek banks and broad, uniform plains on the edge of

marshes adjacent to tidal mudflats (Hinde 1954, Atwater et al. 1979, Baye et al. 1999). Midway through its tidal range, *S. foliosa* can be found co-occurring with annual pickleweed (*Salicornia depressa*), the only other native emergent plant species to occur at this range (Baye et al. 1999). As elevations approach mean high water, *S. foliosa* intergrades onto the middle marsh plain and is mixed in with stands of *Sarcocornia pacifica* (perennial pickleweed). However, *S. foliosa* presence quickly disappears above mean high water as pickleweed becomes the dominant plant species (Mahall and Park 1976a, b).

S. foliosa has a minimal presence in the brackish portions of the estuary, despite the fact that cordgrass grows faster in fresher waters (Watson and Byrne 2009). It is more productive at lower salinities with an increased growth rate, height, and germination success (Phleger 1971). Indeed, seeds of this species germinate at the highest rates in nearly fresh water (Crispin 1976). The lack of presence in fresher parts of the estuary is likely due to the increased presence of better competitors not tolerant of higher salinities (Atwater et al. 1979).

Spartina foliosa was historically abundant in all intertidal marshes from North Bay (San Pablo Bay) to South Bay (Atwater et al. 1979). Diking and filling of the marshes since the 1800s eliminated 85-90% of the tidal marsh habitat (Goals Project 1999). Since the 1970s, the spread of the *S. alterniflora x foliosa* hybrid swarm has caused additional decline of native *S. foliosa* populations in the South and Central Bays, as the native is directly displaced or assimilated by hybridization (Ayres et al 1999, 2004, 2009; Sloop et al 2009, 2011). Native cordgrass was essentially extirpated from some large areas of the East Bay, including the marshes of the Eden Landing Ecological Reserve. Large areas of *S. foliosa* are still intact in the North Bay and throughout the Don Edwards National Wildlife Refuge (DENWR) in the far South Bay, where only small patches of invasive *Spartina* hybrids have been found and treated (Ayres et al 2004a). *Spartina foliosa* does not currently have special regulatory status, but it is considered a critical part of the ecological functions of the native tidal marsh ecosystem (Vasey 2009).

Low marsh provides essential habitat for a variety of fish and wildlife species, such as Chinook salmon, Dungeness crab, bat rays, ducks, and wading and shore birds (Goals Project 2000). *S. foliosa* , the sole vascular plant in the native low salt marsh zone, provides foraging cover and nesting substrate for the endangered California clapper rail, *Rallus longirostris obsoletus* (Albertson and Evens 2000). None of these wildlife species, including the California clapper rail, are restricted to *S. foliosa*. Improved wetland conditions and increased availability of wintering habitat is proven to increase winter survival and improve body condition and subsequent reproductive success for waterfowl (Sedinger et al., 2011 and references listed therein) and other species. Native habitat with abundant, high quality foraging, and protected roosting qualities is an important attribute for birds and other species. Unvegetated mudflats provide critical shorebird feeding areas (Stralberg at al 2004). Native cordgrass habitat has been shown to result in a greater diversity of benthic organisms compared to areas dominated by invasive Spartina (Grosholz et al. 2009a,b); which in turn improves diet resources for motile invertebrates, which in turn enhances resources for forage fish and multiple trophic feed levels in the bay.

Due to its ability to colonize at low elevations, *S. foliosa* is an important component of tidal marsh restoration. It quickly recruited passively at many newly breached tidal restoration projects in San Francisco Bay. In Carl's Marsh in Petaluma and in Muzzi Marsh in Corte Madera, recruitment of *S. foliosa* occurred within four years of tidal breaching (Faber 2004, Tuxen et al. 2008). As low marsh establishes, a site can begin to support a suite of species that rely on native salt marsh vegetation to provide food web services and habitat structure (Dawson and Foster 1982, Vasey 2010). Vasey (2010) notes that as a foundation species, *S. foliosa*

has "a profound effect on tidal wetland functions such as succession, productivity, and habitat structure". Vasey further states that Pacific cordgrass functions to "facilitate the occupation of tidal wetlands by a myriad of microbial, algal, plant, invertebrate, fish, and bird species."

Species Description: Non-native *Spartina*

Spartina alterniflora (smooth cordgrass) is widely dispersed on the eastern portion of the United States, occupying a home range that extends from Maine to Texas. It was initially introduced to the San Francisco Bay by the U.S. Army Corps of Engineers in the 1970s as part of a restoration experiment aimed at stabilizing dredge spoils (Williams and Faber 2001). By the 1980s, *S. alterniflora* had expanded beyond the original planting site, and sometime after began to hybridize with the native *S. foliosa* (Callaway and Josselyn 1992, Ayres et al. 2003, Ayres et al. 2004). First generation hybrids soon backcrossed with one or both parents, and with other hybrids, creating a broad range of hybrids, sometimes termed a "hybrid swarm." Members of the hybrid swarm exhibit a range of phenotypes, with some individuals closely resembling one or the other of the parental species, and many others expressing traits that allow them to exceed either of the two parental species in their ability to colonize new areas and spread rapidly. It is the hybrids with these emergent properties that have become the most highly invasive.

Some well-documented emergent traits of the most invasive members of the *Spartina* hybrid swarm include:

1. Higher vegetative growth rates than native *Spartina,* achieving both greater heights (Ayres et al. 2003) and faster rates of lateral vegetative growth and clonal expansion (Ayres et al. 2003, Ayres et al. 2004). Several studies have documented hybrid *Spartina* to have 4-times greater above and below ground biomass than native *Spartina* (Neira et al. 2006, Brusati and Grosholz 2009).

2. Capability of growing over a greater tidal range than either of its parental species, thriving both above and below mean high water (Callaway and Josselyn 1992, Ayres et al. 2003), making these hybrid phenotypes able to invade and expand in tidal flats.

3. Higher fecundity than its parental species in terms of pollen production (Anttila et al. 1998) and viable seed production (Ayres et al. 2008b). Unlike either parental species, many highly fecund hybrids are also self-fertile (Sloop et al. 2009).

4. Tolerance to higher levels of variability in environmental conditions such as higher salinity, higher sulfide levels, and higher water resident time than its native counterpart (Callaway and Josselyn 1992, Ayres et al. 2003).

High rates of lateral and reproductive spread allowed for accelerating rates ofexpansion of these hybrid *Spartina* throughout the San Francisco Bay, as did their ability to pollen swamp stands of native cordgrass to create hybrid seeds. By the time full-scale control efforts by the Coastal Conservancy's Invasive *Spartina* Project began in 2005 (Ayres et al. 2008a, Hogle 2008), hybrid *Spartina* had invaded over 800 acres throughout the estuary with the central and southern portions of the bay experiencing the densest infestations (Hogle and Olofson Environmental Inc. 2011). Newly breached restoration marshes and tidal flats, which are initially devoid of biotic resistance and competition from established native marsh plants, were among the areas most impacted by these invasive phenotypes. In tidal flats, hybrids resistant to tidal inundation and other pressures established self-fertile clones that then spread clonally and through seeds (Sloop et al 2011). . In restoration areas in which hybrids were allowed to establish, valuable shorebird

habitat was converted to a less diverse, hybrid *Spartina*-dominated marsh, similar to the *S. alterniflora* invasion of Willapa Bay, WA (Davis 2005). Hybrid *Spartina* formed dense monocultures with an absence of the channel complexity and the diverse zonation of mid-marsh that would likely develop in the absence of hybrid *Spartina* (**Figure 1**; Impact of Hybrid *Spartina* on restoration marshes: 47 projects totaling 1,600 hectares; ISP 2007a, 2007b, Ayres and Strong 2004a, 2004b, Ayres et al 2004b, Sloop et al. 2009, 2011).

CRITERIA FOR SELECTION OF THE SPECIES

The genus *Spartina* has been chosen for this case study due to the importance of native Pacific cordgrass, *Spartina foliosa*, in providing habitat structure in the low intertidal for a variety of species in San Francisco Bay, and the substantial habitat changes that the invasive *Spartina alterniflora x foliosa* hybrids have caused. *S. foliosa* is the foundational native plant species in the low salt marsh zone of San Francisco Estuary, providing critical habitat structure for many native and migratory fish, birds, and other wildlifeIt is directly and immediately at risk from sea level rise at the same time that it is imminently threatened by extinction due to displacement by, and hybridization with, a non-native relative, *S. alterniflora*. State and Federal agencies, and other restoration advocates in the San Francisco Estuary, have invested approximately 24 million dollars to date and much effort to protect *S. foliosa* and the native marsh structure by eradicating the introduced *S. alterniflora* and controlling the highly invasive hybrids (*S.alterniflora x foliosa*). Adding complexity to this situation is that populations of the California clapper rail (*Rallus longirostris obsoletus*), an endangered marsh bird, have increased in the taller, denser patches of hybrid *Spartina*, leading some to speculate that the loss of *S. foliosa* and major changes to the tidal marsh structure caused by the spread of the hybrids might be justified, if it leads to recovery of this single endangered species. Finally, in recent years, as the expected rate of sea level rise has been adjusted upward, it has been suggested that the desire to preserve native *S. foliosa* and or restore a specific vision of tidal marsh should be abandoned, with the faster growing and more adaptive hybrid *Spartina* being allowed to dominate the marsh, accrete sediment, and raise marsh surface elevations at a rate potentially more in step with the rate of sea level rise.

Conscientious planning and management will be critical in the coming decades if we are to maintain and expand a healthy tidal marsh ecosystem in the face of sea-level rise. Without careful forethought, *S. foliosa* could be at risk of extinction due to loss of low-salt marsh habitat and genetic assimilation by the invasive hybrids.

Several studies characterize some of the impacts (physical effects, food web effects, etc.) in San Francisco Bay (Neira et al. 2005, 2006 Ecol Applications, 2007 Biological Invasions; Levin et al. 2006). Salt marshes on the Pacific coast generally consist of wide swathes of succulent pickleweed fringed with native Pacific cordgrass (*Spartina foliosa).* This is in stark contrast to Atlantic and Gulf Coast salt marshes which are typified by wide plains of smooth cordgrass, *Spartina alterniflora* (Macdonald and Barbour 1974). The introduction of *S. alterniflora* to San Francisco Bay and subsequent formation of hybrid *Spartina* with the native *S. foliosa* directly threatens the survival of the native Pacific cordgrass (Ayres et al. 2009), and has resulted in marshes that have been altered to more closely resemble eastern U.S. marshes, with both mudflat and pickleweed habitat supplanted by the hybrid *Spartina* invaders (Callaway and Josselyn 1992, Ayres et al. 2003).

The well-documented ecological consequences of the rapid expansion of hybrid *Spartina* is may be exacerbated by climate change. On the lower end of its tidal elevation range, there is a serious threat of conversion of mudflat habitat to hybrid meadows. Loss of mudflat equates to loss of foraging habitat for >500,000 migratory shorebirds that annually flock to the mudflats of the bay (Josselyn et al. 1990, Bildstein et al. 1991, Stralberg et al. 2004). Stralberg (2004) predicted between a 27 and 80 percent reduction in

mudflat area associated with uncontrolled hybrid *Spartina* populations. However, as we continue to reduce the acreage occupied by hybrids and control the most invasive phenotypes, it is not clear how hybrids that more closely resemble *S. foliosa* will respond to climate change and related impacts.

On the higher end of its elevational range, hybrid *Spartina* reduces marsh diversity by displacing perennial pickleweed, gumplant (*Grindelia stricta*), and saltgrass (*Distichlis spicata*) (Baye 2004, Point Blue 2013). The altered structure of the high marsh affects the distribution of resident songbirds (Nordby et al. 2009) and causes loss of habitat for an endangered species reliant on pickleweed, the salt marsh harvest mouse (*Reithrodontomys raviventris*) (Shellhammer et al. 1982). Avoidance of such hybrid *Spartina*-caused ecosystem stresses would likely benefit native species.

Hybrid *Spartina* also changes physical processes and food web structure in invaded marshes. Aboveground structure of hybrid *Spartina* slows water flow, trapping sediment and causing rapid rates of accretion not typical to native marshes (Neira et al. 2006). Plentiful detritus from hybrid *Spartina* is more abundant and decays more slowly than native detritus (Brusati and Grosholz 2009). Slower decay rates result in altered soil chemistry since native *Spartina* marshes have higher sediment respiration rates, shorter periods of ammonium resident time, and faster carbon turn over than their non-native counterparts (Grosholz et al. 2009a). These altered environments of hybrid marshes have been noted to change benthic invertebrate communities in terms of biomass, diversity, and functional group identity (Neira et al. 2006, Neira et al. 2007, Brusati and Grosholz 2009). The shift is most marked in converted tidal mudflat where the infaunal invertebrate community shifts from surface feeders that primarily consume microalgae to being dominated by belowground feeders that primarily consume plant detritus (Levin et al. 2006).

Because of concerns about multiple negative ecosystem effects of *Spartina* hybrids, the California State Coastal Conservancy and the US Fish and Wildlife Service's Don Edwards San Francisco Bay National Wildlife Refuge prioritized eradication of invasive cordgrass from the San Francisco Estuary through the formation of the Invasive *Spartina* Project (ISP; Strong 2009). In 2005, over 800 net acres of hybrid *Spartina* covered the estuary, but persistent control efforts by a region-wide coalition of ISP partners have reduced the hybrid presence by an order of magnitude (Hogle and Olofson Environmental Incorporated 2011), down to 39 net acres as of 2012 treatment. "Net acres" refers to the total footprint of invasive *Spartina* that is remaining bay-wide across the 25,000 acres of tidal marsh and 20,000 acres of mudflats that are monitored each year.

The endangered California clapper rail is an obligate tidal marsh bird found primarily within the San Francisco Bay Estuary. Clapper rail numbers increased from 1,040–1,264 in 1992-1998 (Albertson and Evens, 2000) to 1,425 (±22) in 2005-2008 (Liu *et al.*, 2009). The increase in clapper rail numbers occurred at a time when a hybridized, invasive *Spartina* spread rapidly throughout the Bay. Hybrid *Spartina* likely affected clapper rail numbers positively for two reasons: tall, dense hybrid *Spartina* provided increased cover for clapper rails reducing exposure to predators and tides; and hybrid *Spartina* converted mudflat to marsh habitat, allowing clapper rail populations to grow and expand into new areas. The subsequent reduction in hybrid *Spartina* has been accompanied by declines in California clapper rail populations, particularly in the Central and Southern San Francisco Bay. Review of the relation between hybrid *Spartina* cover and California clapper rail numbers suggests that the two are highly correlated, particularly at sites that lack natural features known to support clapper rails, such as channel networks and native *Spartina foliosa*. In the wake of the successful control of over 96% of the hybrid *Spartina* in the Bay, clapper rail numbers have since stabilized at most sites in the Bay (McBroom 2013).

REVIEW OF CLIMATE CHANGE EFFECTS ON THE SPECIES

Climate change predictions suggest that present-day marshes in the San Francisco Estuary will experience increased inundation times as a result of sea level rise (Parker et al. 2011). At the same time, the Estuary's salinity will become increasingly variable due to greater extremes in annual rainfall, decreased summer snow pack, and water divergence (Knowles and Cayan 2002). Salinity fluctuations causing alteration of plant communities is a well-documented phenomenon in historic records of San Francisco Bay. Soil cores and seed banks show an increase in native cordgrass presence during drier, warmer time periods over the past 5000 years (Goman et al. 2008). Additionally, an increase in the *S. foliosa* footprint was noted over the short time frame of 30 years during a survey of historic transects (Watson and Byrne 2012) in the estuary (prior to invasion). Currently, *S. foliosa* has a minimal presence in the brackish portions of the estuary despite the fact that it grows faster in fresher waters (Watson and Byrne 2009). It is more productive at lower salinities with an increased growth rate, height, and germination success (Phleger 1971). Indeed, seeds of this species germinate at the highest rates in nearly fresh water (Crispin 1976). The lack of presence in fresher parts of the estuary is likely due to the increased presence of better competitors and not tolerance of higher salinity (Atwater et al. 1979). Longer inundation times and greater water level fluctuations will likely increase and/or shift the footprint of *S. foliosa* and any remnant uncontrolled hybrid *Spartina* into the upper portions of the San Francisco Estuary..

While it is generally well understood how *S. foliosa* will likely respond to increased inundation and salinity, it is less understood how they may respond to increased carbon dioxide and increased temperatures that may result from climate change. Experimental studies have indicated that increased carbon dioxide in the atmosphere seems to favor plants with C4 metabolism, as does increased temperature (Rasse et al. 2005). Most wetland plants have this type of metabolism, including *Spartina*.

On the site level, differences in inundation, salinity, and plant interactions may impact patterns of plant zonation. Thus on a marsh to marsh basis, *S. foliosa* may decrease in abundance, and hybrids may or may not deviate from this pattern, depending on whether their intermediate characteristics confer an advantage over the native *Spartina*, especially in light of these added climate change-related stressors. It is not well understood what will happen to *S. foliosa* and *foliosa*-like hybrids within the confines of existing salt marshes. Mahall and Park (1976) suggest that Pacific cordgrass is excluded from the high marsh by increasing salinity while *Sacrocornia pacifica* is excluded from the low marsh by tidal flooding effects on seedling survival. However, if inundation increases, it would be expected that *S. foliosa* would increase in ecological footprint (Watson and Byrne 2009). It is not known how hybrids closer to *S. foliosa* on the morphological spectrum will respond, compared to either *S. foliosa* or more aggressively invasive hybrids.

The hybrid swarm initially contained four to six times greater genetic diversity than *S. foliosa*. As the invasion and subsequent treatment have progressed, there is some evidence that genetic diversity among the hybrids has declined, but average heterozygosity in the hybrids is still two to three times higher than in *S. foliosa* (Sloop et al 2011). This suggests that the hybrid swarm may still have an advantage over native cordgrass when it comes to adaptive potential in response to changing environmental conditions.

As sea level rises in reaches of the estuary with sediment supply deficits, it is likely that higher marsh zones will submerge to lower marsh zones (Warren and Neiring 2002). However, there are portions of the San

Francisco Bay that, because of the invasion and subsequent eradication of hybrid *Spartina,* have little to no native low marsh zones. As climate changes the San Francisco Bay and sea level rises, it will also be important to monitor *S. foliosa* in areas of the bay that are unaffected by hybrid *Spartina.*

OTHER STRESSORS

In addition to future projected climate change impacts, native *S. foliosa* is already under extreme pressure from existing stressors, including displacement by hybrid *Spartina* invasion. Additional stressors include habitat loss and fragmentation from development activities, urban sources of runoff and pollution, and nutrients.

Anthropogenic effects such as nutrient loading may variably affect *S. foliosa* as compared to hybrids. Tyler et al. (2007) found little response of *S foliosa* to nutrient addition, while finding a significant response from hybrid *Spartina* at some sites and not others. Above-ground biomass did not respond to nitrogen addition along the marsh edge at Robert's Landing, and at Elsie Roemer Marsh there was no response to nitrogen in the meadow. There was also very little response in the below-ground biomass of hybrids. Ryan and Boyer (2012) found that enhanced nitrogen levels increased the height and cover of *Sarcocornia pacifica* and will likely further increase its dominance, as will increased salinity, to the detriment of co-occurring marsh plain species (e.g. *Distichlis* and *Jaumea*) (Ryan and Boyer 2012).

FACTORS THAT MAY AFFECT SPECIES RESILIENCE

In the absence of hybrid *Spartina* and other anthropogenic stressors, native cordgrass is a resilient species capable of growing at higher salinities and lower inundations than the majority of marshland species of San Francisco Bay. However, invasion pressure and pollen transfer from remaining hybrid *Spartina* still threatens this resiliency. Thus, controlling hybrid *Spartina* is key to maintaining native marsh structure. Genetic introgression, habitat degradation, and sea level rise are the biggest factors affecting native cordgrass populations in the Bay. Resilience can be substantially increased by continuing to invest in protection of existing marshes, continuing the eradication of hybrid *Spartina*, and restoration of new sites in order to increase the footprint of native cordgrass in the bay.

LIKELY CLIMATE CHANGE IMPACTS AND RISKS

Likely climate change impacts include drowning of native cordgrass due to sea level rise. This would occur at a bay-wide scale and has a high likelihood of occurring if there aren't actions to allow the migration of the marsh to higher elevations that meet native cordgrass habitat requirements.

As the Bay salinity becomes more variable, there will likely be a shift in geographical distribution, and *Spartina foliosa* may displace brackish plant species in the fresher parts of the estuary, such as Suisun Bay (Byrne et al 2001).

Precipitation and temperature extremes and/or changes will affect the timing of annual emergence and seed set success for plants, including *Spartina foliosa* and remaining hybrid genotypes.

Changes in climate conditions, hydrology and phenology will likely cause major shifts in tidal marsh community composition, potentially creating new competitive challenges for the native *Spartina* with new arrivals of low elevation tidal wetland species or *Spartina* hybrids (Ayres et al. 2008).

MANAGEMENT ACTIONS TO BE CONSIDERED

- Develop a long-term funding strategy to complete elimination of non-native and hybrid *Spartina* from the San Francisco Estuary, thereby restoring native *Spartina foliosa* to its dominant position in the lower marsh zone.

- Develop an efficient and effective annual, long-term monitoring and rapid-response program to assure protection from re-emergence of the invasive.

- Strategically assist establishment of native low marsh (structure and vegetation) on the leading tidal edge of the bay during sea level rise. This may include assuring establishment of non-vegetated areas of low gradient where *Spartina foliosa* can readily establish as the Bay expands.

- Establish and maintain a diverse array of *Spartina foliosa* stock and managed tidal marsh reserves to hedge against the possibility that sea level rise could occur too rapidly to allow survival of natural *Spartina* marshes.

- Continue aggressive revegetation of tidal marsh restoration projects with *Spartina foliosa* to assure establishment of an ample and robust source of native propagules.

- In areas in which native cordgrass has been extirpated, implementing revegetation efforts with native cordgrass is a critical management action to enhance marsh biodiversity and native structure. Native cordgrass provides high-value native habitat at the lower tidal elevations.

- Work with current living shoreline projects that seek to buffer shorelines from wave attenuation, sediment stabilization and accretion. Determine how native *Spartina* can be incorporated into these designs.

- Conduct research to gain a better understanding of how *S. foliosa* and extant hybrids will interact with climate change effects in both the north and south bay.

UNCERTAINTY AND KNOWLEDGE GAPS

There are no existing data that document the ability of invasive *Spartina* to provide *long-term* habitat benefits for California Clapper Rails, or the long-term ability of *Spartina* to keep pace with a projected six to eight feet of sea level rise over the next 100 years.

Knowledge Gaps

- ability of hybrid *Spartina alterniflora x foliosa* and native *Spartina foliosa* to keep pace with sea level rise
- value of plant height vs. stem density
- value of much reduced root and rhizome density which does not exclude infaunal invertebrates like hybrid roots and rhizomes
- deposition rates in *S. foliosa* marshes vs. extant hybrid *Spartina*
- unanticipated impacts from planting/not treating invasive hybrid *Spartina*
- issues with comparing east coast systems/alterniflora to west coast systems
- long-term negative impact of hybrid on clapper rails

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