Science Foundation Chapter 5
Appendix 5.1 – Case Study
Longjaw mudsucker (*Gillichthys mirabilis*)

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DESCRIPTION OF THE SPECIES

The longjaw mudusucker (*Gillichthys mirabilis*) is a resident estuarine fish, ranging from Mexico to Humboldt Bay, California, USA, and is one of the most abundant fishes in high intertidal salt-marsh habitat (Desmond et al., 2000; Talley 2000; West and Zedler 2000). The Longjaw mudsucker depends on high intertidal complex dendritic creeks within salt marsh primarily "pickleweed" [*Salicornia virginica* now taxonomically known as (*Sarcocornia pacifica*)]. The fish reside within burrows in soft sediments and is the only fish species that can remain in intertidal creeks during low tide when the creeks completely de-water. The mudsucker can tolerate life out of water by having vascularized buccal cavities for uptaking oxygen from the air. Mudsuckers have a wide environmental tolerance, and are able to tolerate freshwater and salinities as high as 90-ppt for periods of a few days to a week, and temperatures from 9-35 C° (Lonzarich and Smith 1997, Moyle 2002). Longjaw mudsuckers are benthic consumers, most commonly eating bottom-dwelling invertebrates, such as amphipods, isopods, and small fish. Males will guard burrows and display their long maxillae, hence their common name, to attract females. Spawning occurs predominantly from late winter to early spring, with pelagic larvae settling to the benthos approximately two months after hatching. Juveniles (<80mm) spread out into many different habitats during summer, while adults tend to spend most of their lives in a single creek habitat, not straying more than a few meters from their burrows (Hobbs *unpublished data*). With such a high degree of site fidelity, the longjaw mudsucker completes its life cycle in a single marsh making it an excellent candidate as a sentinel species of saltmarsh habitat quality (Yoklavich et al., 1992).

CRITERIA FOR SELECTION OF THE SPECIES

Since the longjaw mudsucker depends on sinuous intertidal creeks in pickleweed marsh habitats, it may be especially vulnerable to sea level rise and thus a good candidate species when considering effects of climate change on tidal marsh habitats of San Francisco Bay. Like the other species depending on pickleweed marsh habitats such as the salt marsh harvest mouse and clapper rail, the species is particularly vulnerable to sea level rise because most remnant salt marsh habitats in South San Francisco Bay are backed by large levees, and thus limited in ability to adapt or move upland as sea level rises. The species could be considered a sentinel of salt marsh habitat health as it is the only fish species that occurs in intertidal creeks, taking refuge in burrows or in soft sediments during low tide when the creeks are dewatered. The longjaw mudsucker is rarely found outside of intertidal pickleweed marsh, primarily only after larvae settle from the water column and fish search out available creek habitats (Hobbs et al 2012). While the species does occur outside of San Francisco Bay, it is of conservation concern, as in many estuaries the salt marsh habitats have been highly altered, contaminated and invaded by non-native species. Moreover because the larvae appear to remain in upstream slough habitats, and are sensitive to high salinities, it is unlikely that connectivity among adjacent estuaries along the California coast is sufficient to sustain populations that are lost, and genetic distinctness is likely to exists among different estuaries.

OTHER INFORMATION ABOUT THE SPECIES

Because the species utilizes intertidal creeks for the majority of their life are often found within a few meters of original capture in subsequent recapture events, and males have been observed to guard burrows, the population dynamics can be characterized to be highly density dependent. This was apparent in mark-recapture studies conducted in south bay among creek habitats of different length. While catch per trap would often be much higher in the shorter creeks, abundance estimates from the mark-recaptures studies revealed similar or greater abundance in the longer creeks as in the short creeks, individuals were much more likely to be recaptured during subsequent surveys (Hobbs et al. 2012). The creation of new marsh habitat could result in an increase in total population abundance. This was evident in the south bay salt pond restorations, as ponds were restored to tidal inundation, new recruits could be found in newly opened pond habitats such as A6 and in ponds that had been open for several years and begun to return to pickleweed marsh habitats like pond A21, similar numbers of adults and juveniles could be found inside the pond relative to adjacent sites (Hobbs et al. 2012).

The species is also a very important component of the food web as they are a sought after prey item for many predatory species such as leopards sharks, bat rays and striped bass. Body morphology and lipid content would support this supposition as they are soft bodied, without any spinous rays for defense and contain high body lipid content relative to similar prey species such as the yellowfin goby and staghorn sculpin (Hobbs *unpublished data*). Longjaw mudsucker as prey would form a very important linkage between the intertidal marsh habitats and adjacent slough habitats, as they feed exclusively in marsh habitats and are preyed upon by benthic and pelagic slough oriented predators. Indeed the species is a favorite among bait fisherman in San Francisco Bay.

The status of the population is currently unknown; however considering their obligate dependence on pickleweed marshes, and the significant loss of this habitat in the last 100 years the population is surely a remnant of what it once was in San Francisco Bay. While pickleweed marsh extent is thought to be 10% of its pre-industrial range (Atwater et al. 1979), not all marshes have abundant longjaw mudsucker populations. In 2006, (Hobbs *unpublished data*) conducted a bay-wide survey including the Napa-Sonoma Marsh in the north bay, China Camp (Muzzi) Marsh, Stege Marsh in central bay and the Newark Slough marsh, the largest remaining pickleweed marsh in San Francisco Bay. They found the Napa-Sonoma Marsh to be devoid of longjaw mudsucker and only found the invasive yellowfin goby, the China Camp population to be small but present, the Stege Marsh population to have disappeared (McGourty et al 2009), and only the Newark marsh to have large numbers of longjaw mudsuckers. From 2010-2012 several sites within the Alviso Marsh complex, Ravenswood Marsh, Bair Island outer marsh and Eden Landings Whales Tale Marsh, were monitored monthly. Large numbers of fish were found in the Alviso complex, fewer in the Ravenswood Marsh and very few in the Whales Tale Marsh, but only a few individual longjaw mudsuckers were found in the Bair Island outer marsh over the two year study (Hobbs et al 2012). These surveys suggest that the population status is likely to be poor overall with only a few marshes harboring significant, but fragmented populations.

REVIEW OF CLIMATE CHANGE EFFECTS ON THE SPECIES

Current sea level rise predictions for San Francisco Bay by 2030 given the current observed rate of sea level rise (Stralberg et al. 2011), places the pickleweed marshes in jeopardy due the dual effects of increased inundation and salinity (Woo and Takekawa 2012; Schile et al. 2011). By 2050 many of the marshes may succumb to inundation due to the leveeing of most upland habitats surrounding these marsh habitats. Some salt marsh habitats may keep pace with sea level rise through sediment and organic material accretion, however this could lead to further fragmentation of populations and leave them even more vulnerable to other population drivers (Stralberg et al. 2011).

It is less clear how sea level rise and variable salinity and freshwater outflow will influence recruitment of the species. Recruitment appears to be greater during years of higher freshwater outflow (McGourty et al. 2009, Hobbs et al. 2012, however future climate may have increased variability of freshwater outflow and earlier timing of freshwater outflow which would have unpredictable effects on reproductive timing. They spend other than that month or two in the plankton and sloughs trying to find a burrow. The future climate may also have higher air temperatures leading to higher shallow water temperatures which may have a significant effect on shallow intertidal habitats where the longjaw mudsucker lives. While the species is tolerant of extreme temperatures for short periods of time, longer term changes to the intertidal habitats due to increased air temperatures could lead long term thermal stress to the fish, which could have negative effects on the long term condition of the fish (Somero 2010). However a concomitant rise in sea level could ameliorate intertidal temperature effects with flooding of cooler water, but again the interplay of these two effects is unpredictable at this moment. Moreover, it is predicted that along the California coast ocean water temperatures maybe cooler due to increased ocean upwelling (Snyder et al 2003).

OTHER STRESSORS

The longjaw mudsucker, being a species with a wide physical environmental tolerance, suggests that habitat availability is the driver of the species population dynamics. Indeed the longjaw mudsucker being the only fish obligate to picklweed marsh habitats, have likely undergone significant long-term population declines in the San Francisco Bay-Estuary as most of the pickleweed marsh habitat was dyked and utilized for salt production in the early 1900's. (Atwater 1979) The population of longjaw mudsucker may also be jeopardized by contaminants in salt marsh habitats. In the San Francisco Bay-Estuary populations of longjaw mudsucker have been shown to be much lower in abundance in highly contaminated marshes relative to less contaminated marshes (McGourty et al. 2009). The species may also be susceptible to disease induced by a parasitic microsporidian protozoan (Kabatana newberryi) that was first found in the tide water goby and has also been observed in high prevalence in populations of longjaw mudsucker in San Francisco Bay (McGourty et al. 2007. Hobbs *personal observations*). The species also appears to compete for limited habitat space with or be preyed upon by the invasive species the yellowfin goby (Acanthogobius flavimanus) (Brooks dissertation 1999, Hobbs *unpublished data.*).

FACTORS THAT MAY AFFECT SPECIES RESILIENCE

Given the species wide range of environmental tolerance, the persistence of the species in San Francisco Bay is dependent upon the existence of pickleweed marsh habitats, which in at least some place in the San Francisco Bay may be able to accrete enough sediment and organic material to keep pace with sea level rise.

MANAGEMENT ACTIONS TO BE CONSIDERED

The South Bay Salt Pond Restoration Program is currently restoring former salt pond habitats to tidal marshes, which could have major ameliorating effects on many of the potential negative impacts of climate change on the longjaw mudsucker population in San Francisco Bay as well as many other marsh dependent species. The project goal is to restore over 15,000 acres of salt ponds to tidal action which could have a significant impact of the rate of sea level rise for South San Francisco Bay and increase salt marsh habitat significantly (South Bay Salt Pond Restoration Program Adaptive Management Plan 2007). However the project is in dire need of long-term funding to meet the restoration goals, and funding of the project is highly recommended. Also acquiring more salt pond habitat from Cargill to restore to tidal marsh.

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