Science Foundation Chapter 5
Appendix 5.1 – Case Study
Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*)

Authors: Howard Shellhammer[1] and Laureen Barthman-Thompson[2]
[1] *H.T. Harvey& Associates, 983 University Ave, Los Gatos, CA 95032*
[2]*California Department of Fish and Wildlife, 2109 Arch Airport Road, Stockton, CA 95206*

DESCRIPTION OF THE SPECIES

Salt marsh harvest mice (SMHM) (*Reithrodontomys raviventris*) are endangered (at the State and Federal level) because of habitat loss, fragmentation and alteration (Shellhammer, 2000). These mice are endemic to the marshes of the San Francisco Bay and include two subspecies. The Southern subspecies (*R. r. raviventris*) is found in the South San Francisco Bay, the Corte Madera area and Richmond area in the Central Bay; and the Northern subspecies (*R. r. halicoetes*) is found in the Marin Peninsula, as well as San Pablo and Suisun Bays.

In most of their range, SMHM are found in the upper half of tidal salt marshes, i.e. in the middle to high marsh or peripheral halophyte zone. Where it is present the mice may also utilize the ecotone between the marshes and the adjacent uplands as escape cover during high to extremely high tides. In addition, they are also found in some of the relatively rare brackish marshes in the South Bay (Shellhammer, Duke and Orland, 2010).

Population sizes of the two subspecies differ, likely due to differences in available habitat throughout its range. SMHM numbers are low in most marshes throughout the range of the southern subspecies with numerous marshes devoid of mice. Mouse numbers are higher, however, in the more brackish marshes of northern and western Suisun Marsh where Sustaita et al. (2011) reported large populations in both pickleweed (*Salicornia virginica*) areas and areas with mixed halophytes such as fat hen (*Atriplex triangularis*), alkali heath (*Frankenia salina*), Baltic rush (*Juncus balticus*), Olney's threesquare bulrush (*Schoenoplectus americanus*) and other halophytic species. It was reported that mixed vegetation not dominated by pickleweed was often equally productive for mice as pickleweed areas. A positive correlation between density and height of the vegetation in the mixed vegetation areas and mouse numbers was also noted.

CRITERIA FOR SELECTION OF THE SPECIES

The loss of SMHM habitat is especially severe in the South San Francisco Bay. Most of the tidal salt marshes of the S. F. Bay have lost the upper half of their mid marsh (pickleweed) zones and almost all of their high marsh (peripheral halophyte) zones as well as almost all of their marsh/upland edges or ecotones. The two latter areas can provide escape cover to the mice during the higher and highest high tides. Many marshes in the South Bay are very narrow and movement of mice is reduced or absent (Shellhammer and Duke, 2010). As a result, the distribution of the mouse is becoming increasingly fragmented in the South Bay. However, Sustaita et al. reported that SMHM are numerous in both diked and tidal marshes of the Suisun Marsh with diked marshes supporting more mice than tidal marshes (2011).

This species was declared endangered because its population numbers were small and decreasing throughout most of its range and because of the continued loss, separation and degradation of its habitat and those threats continue in much of its range.

REVIEW OF CLIMATE CHANGE EFFECTS ON THE SPECIES

Sea level rise due to climate change will greatly impact this species, especially in the South Bay. In much of the mouse's range marshes are backed by development. Hence there is no areas into which marshes can migrate into. The few areas of undeveloped upland available for new marshes are the Coyote Hills in the South Bay, the Sears Point area in the San Pablo Bay. There are protected areas along the eastern side of the Marin Peninsula, but many of these areas rise steeply from the bay waters. The Suisun Marsh provides a larger opportunity for marsh migration where not barred by freeways and infrastructure.

In most tidal marshes dramatic sea level rise will result in narrower marshes with little to no upper zones or marsh/upland ecotone. Because of their narrowness and increasingly common stretches of poor vegetative cover such marshes will tend to have more, smaller populations of salt marsh harvest mice than do larger and deeper marshes (Shellhammer and Duke, 2010) and experience higher random genetic drift.

Climate change includes scenarios such as warmer air, less rainfall, earlier runoff, and increased frequency of extreme environmental conditions. In the Suisun Marsh SMHM are known to survive high inundation, catastrophic flooding, and fire, with most populations returning to pre-event levels within a year (CDFW unpublished data). However, if high inundation rates occur in areas without tall escape cover or upland refugia then reproduction could be reduced or eliminated. This could be especially devastating in the South Bay where little habitat remains.

While the two subspecies can tolerate drinking sea water the southern subspecies, *raviventris*, has been subject to relatively high and stable salinity levels. The northern subspecies, *halicoetes*, has evolved with a much greater range of salinity (Fisler 1965). There is no documentation on how long SMHM could tolerate the increased salinity. Increased salinity with lower precipitation could also lead to areas devoid of vegetation, or salt scalds, further degrading remaining SMHM habitat as Paddett-Flohr and Isakson (2003) noted that harvest mice key to the salinity levels of pickleweed.

Other potential impacts of sea level rise include changes and shifts in vegetation composition and the overtopping of all intertidal vegetation by higher storm surges. Such severe inundation is likely to increase predation (Johnston, 1957) as well as decrease reproductive success by flooding out nests (Hadaway and Newman, 1971).

FACTORS THAT MAY AFFECT SPECIES RESILIENCE

Resilience is heavily dependent on the composition, height, and depth of vegetation (Sustaita et al., 2011) as deep, complex plant structure allows mice to avoid predation and tall, complex plant structure allows them to remain in tidal marshes during most periods of inundation (Smith, 2012). The potential resilience of the marshes of the San Pablo and Suisun Bays are greater than that of the South San Francisco Bay as there are more deeper marshes and broader ecotones in the northern bays. Most of the South Bay marshes have narrow pickleweed (i.e. mid marsh) zones and little to no high marsh or ecotones as they are backed by dikes. While it is true for much of the entire bay there is less area adjacent to the marshes in the South Bay into which can migrate as sea level rise.

Population resilience can be increased in tidal salt marshes by increasing marsh size, connectivity, and especially marsh completeness, i.e. the expansion or recreation of high marsh and ecotone areas. It will also be improved by more effectively connecting marshes so that genetic exchange is maintained and inbreeding depression is avoided.

MANAGEMENT ACTIONS TO BE CONSIDERED

Short term goals for preserving the mouse, i.e. those in the next 20 to 30 years, include restoring more marshes to tidal action such as South Bay Salt Pond Restoration Project has done in the first two decades of this century. Recreating large marshes increases the chances that complex channel systems will develop within them and hence the development of raised overflow berms along their intermediate channels, areas where marsh gumplant (*Grindelia stricta*) can grow and offer small mammals escape cover from high tides. Some of these restored marshes will have sloping upper edges where high marsh and transition zone vegetation can develop although such slopes will be relatively narrow and seldom connected to adjacent uplands because either the marshes are backed by large dikes or there is development and no where for new marshes to develop. Connecting revegetated marshes will allow for larger populations of small mammals, including SMHM, and protect populations from the loss of genetic variability.

It is very important that wherever possible that land adjacent to existing marshes be acquired and protected as the success of SMHM and other small mammals by 2100 will depend on the upslope movement of the tidal marshes over time as sea levels rise. Decreased sediment loads (Cloern and Jassby, 2012), particularly in the South Bay, will likely result in narrowing of marshes. Increased marsh size, complexity, and the possibility for extension landward are critical to mouse survival. Therefore adjacent slopes to areas such as Sears Point in the San Pablo Bay and the Western uplands and Hills in the Suisun Marsh should be purchased and protected. If sea level rise by the end of the century is severe it is likely that most of the remaining habitat will be adjacent to such hilly areas.

Mice will disappear where marshes, and the ecotone areas adjacent to them, cannot move landward with sea level rise And that will be the case around much of the bay, especially if sea level rise more than three feet. As such marshes compress, become increasingly narrow and become dominated by frequently inundated low marsh vegetation mouse habitat will disappear. In such areas practically the only solution will be to retain the habitat as diked marshes or muted wetlands with the primary dike protecting landward infrastructure being established on the bay side of the diked marshes. Such diked marshes will be more exposed to terrestrial predators that marshes are in the early 2000's and efforts should be made to reduce such predation.

Recommendations from highest to lowest priority are:

- Conduct genetic studies to determine bottlenecks for genetic dispersal and boundaries for each sub-species (2nd stage is currently underway by CDFW and UCD).
- Protect high marsh and upland habitats in existing tidal and managed marshes.

- Identify bottlenecks/ infrastructure barriers, especially roads as barriers to upward tidal marsh movement (Hwy 37 in San Pablo Bay; Hwy 4 in Martinez, Pittsburg; Hwy 680 & Hwy 12 in Suisun.

- Provide upland and wetland (diked or muted tidal) connectivity between marshes where existing marshes may be lost due to flooding with sea level rise.

- Protect existing diked/muted tidal wetland where all habitat could be lost (i.e. permanent levees needed to protect infrastructure) (example is DFW property at Eden Landing), and manage as a habitat levee or horizontal levee (the Bay Institute).

- Adjacent to tidal restoration projects maintain diked marshes as interim reserves (USFWS 2009) and evaluate for muted tidal restoration.

- For tidal restoration designs, incorporate wide and gently sloping high marsh and upland bands. Ideally, these areas should include upland edges with sufficient space to accommodate sea level rise; include tidal berms, mounds, habitat levees, or other elevational raising actions.

- Monitor SMHM populations, distribution, and diversity.

- Encourage tall thick stands of vegetation as high tide refugia and cover along upland edges or habitat levees.

- Control invasive plants, and non-native or artificially abundant predators.

- Reduce access of mammalian and non-native predators to tidal and diked marshes.

- Monitor changes in vegetation species and complexity.

- Continue with research to answer species specific questions such as those identified by the USFWS 2009.

UNCERTAINTY AND KNOWLEDGE GAPS

With climate change, it is certain that the SMHM will need to be protected from possible impacts such as habitat loss. However it is uncertain how SMHM will react to climate change and whether management efforts to protect SMHM habitat will help to preserve the species. In order to protect the mouse and better manage existing populations in the face of climate change, it will be important to continue studying the mouse and increase knowledge about its ecology. In addition, more in-depth analysis of current data sets may help to increase knowledge about how shifts in climate may impact the mouse.

Important Data Gaps

While SMHM have been studied since they were first described in 1908, there are many gaps in knowledge that will be important to fill in order to protect the mouse from emerging threats such as climate change.

Unanswered questions about habitat use by the mouse include their potential use of brackish marshes in the southern San Francisco Bay, principally areas near Alviso freshened by the effluent of the nearby San Jose Water Treatment Control Plant. The marshes south of Drawbridge supported a third as many salt marsh harvest mice than in nearby salt marshes in a mixture of alkali bulrush (*Bolboschoenus maritimus*) and invasive perennial pepperweed (*Lepidium latifolium*), with more captures in bulrush than peppergrass (Shellhammer, Duke and Orland, 2010). Shellhammer (trapping records) trapped no harvest mice in pure pepperweed in the 1960's and 70's so the question of what percentage mixture of pepperweed and alkali bulrush will support harvest mice is also unanswered. Another uncertainty is whether areas of alkali bulrush in the South Bay could play a role in the survival of the mouse, e. g. as a refuge while changes are occurring in adjacent salt marshes and whether pepperweed should be eradicated.

It will also be important to understand the impacts of upland predators on the mice in the high marsh and marsh/upland ecotone and how it can be reduced and controlled. In addition, more needs to be known about the conversion of heavily grazed grasslands adjacent to marshes, like those in the Suisun Marsh, to small mammal and other species' use as part of the marsh/upland ecotone.

DFW and UC, Davis investigators are currently looking at SMHM genetics to estimate how recent anthropogenic disturbances have affected the sub-structuring of this species, and identify natural and manmade barriers to gene flow/dispersal. Mitochondrial and microsatellite analyses will allow us to assess the validity of the currently recognized subspecies. It is also hoped that further genetic analysis can contribute habitat use and population dynamics information that may be used to address species and habitat management, climate change response, and species recovery efforts.

Additionally, further research partnered with other species should be conducted. Loss of foraging habitat for waterfowl is a big concern in the Suisun Marsh. Any enhancement for waterfowl foods could also benefit the SMHM. Studies of what SMHM are eating in diked and tidal wetlands should be looked at.

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