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Mammals of China Camp State Park and Rush Ranch Open Space Preserve

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ABSTRACT

China Camp State Park is primarily a forested area with a fringing saline marsh while the Rush Ranch Open Space Preserve has large brackish marshes backed by grass-covered hills. The emphasis of this chapter is on small mammals common to both areas, i.e. endangered salt marsh harvest mice and several rare shrews. Both China Camp and Rush Ranch contain significant stretches of intact marsh–upland ecotone that provide refuge for small mammals during periods of high water. This refuge habitat will become even more important as accelerating sea level rise increases marsh inundation and reduces other available cover. Future efforts to conserve populations of salt marsh harvest mice and shrews around San Francisco Bay should focus on protection and expansion of the marsh–upland ecotone.

KEY WORDS

Salt marsh harvest mouse; sudden oak death; Suisun shrew

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INTRODUCTION

China Camp State Park and Rush Ranch Open Space Preserve are components of the San Francisco Bay National Estuarine Research Reserve. While both areas contain marshes they are quite different in their overall plant cover. China Camp is predominately a forested area in the hills of the Marin Peninsula and is located on the saline San Pablo Bay while Rush Ranch is composed of marshes and grasslands located on the more brackish Suisun Bay. The objective of this chapter is to summarize what is known and what needs to be known about terrestrial mammals that live at each site. The mammals of the two areas are listed in Table 1. Some of the smaller mammals, especially the endangered salt marsh harvest mouse (*Reithrodontomys raviventris*) and several rare shrews (*Sorex* spp.), will be discussed in considerable detail in the sections on the two areas.

Neither of the two areas has a list of documented mammals. The nearest park or management unit with a mammal list to China Camp is Point Reyes National Seashore (*http://www.nps.gov/pore/naturescience/mammals.htm*) and while it is on the other, i.e., the western, side of the Marin Peninsula, that list offers some idea of what mammals can be found in China Camp. Based on that list and the type of vegetation present at China Camp, a number of the mammals listed for China Camp in Table 1 are listed as

Table 1 Land mammals of China Camp State Park and Rush Ranch

Scientific name	Common name	China Camp[1]	Rush Ranch	Status[2]
Didelphis virginiana	Virginia opossum	+	+	---
Sorex vagrans sonomae	Fog shrew	+		
Sorex trowbridgii	Trowbridge's shrew	+		
Sorex ornatus californicus	Ornate shrew	+	+	
Sorex ornatus sinuosus	Suisun shrew	+		
Scapanus latimanus	Broad-footed mole	+	+	
Tadarida braziliensis	Brazilian free-tailed bat	+		
Eumops perotis	Western mastiff bat		+	
Antrozous pallidus	Pallid bat	e	+	
Plecotus townsendii	Lump-nosed bat		+	
Corynorhinus townsendii	Townsend's big-eared bat	e		
Eptesicus fuscus	Big brown bat	e	+	
Lasiurus blossevillii	Western red bat	e	+	
Lasiurus cinereus	Hoary bat	e	+	
Lasiurus noctivagans	Silver-haired bat	e	+	
Pipistrellus hesperus	Western pipistrelle		+	
Myotis californicus	California myotis	e	+	
Myotis evotis	Long-eared myotis	e	+	
Myotis leibii	Small-footed myotis	e	+	
Myotis lucifugus	Little brown myotis	e	+	
Myotis thysanodes	Fringed myotis	e	+	
Myotis volans	Long-legged myotis	e	+	
Myotis yumanensis	Yuma myotis	e	+	
Lepus californicus	Black-tailed jackrabbit	+	+	
Sylvilagus audubonii	Audubon cottontail	+	+	
Erethizon dorsatum	Porcupine	+		
Thomomys bottae	Botta's pocket gopher	+	+	
Microtus californicus	California vole	+	+	
Mus musculus	House mouse	+	+	---
Neotoma fuscipes	Dusky-footed woodrat	+		

[1] e = expected, [2] dashes indicate non-native species

(continued next page)

"expected." A similar situation exists for Rush Ranch. A list of mammals has been prepared by the Suisun Marsh Natural History Association and is available online (*http://www.suisunwildlife.org/mammal.html*). It is assumed that the mammals on that list are present on Rush Ranch especially since the ranch has a small grove of eucalyptus trees and several barns or barn-like buildings. Those structures make it likely that the bats listed for the area on Table 1 can be found at Rush Ranch, at least occasionally.

It is likely that some of the mammals listed in Table 1 are not common in the two areas, and this is especially the situation with the shrews. Only one species of mammal, however, is listed as endangered by both California Department of Fish and Game and the U. S. Fish and Wildlife Service, and that is the salt marsh harvest mouse.

CHINA CAMP STATE PARK: UNIQUE MARSHES, A CHANGING FOREST AND A DEARTH OF INFORMATION

Mammals of the Park

While the marshes of China Camp State Park are somewhat unique the forests of the park are

Table 1 (Continued) Land mammals of China Camp State Park and Rush Ranch

Scientific name	Common name	China Camp[1]	Rush Ranch	Status[2]
Ondatra zibethicus	Muskrat	+	+	
Peromyscus maniculatus	Deer mouse	+	+	
Peromyscus boylii	Brush mouse	+		
Peromyscus truei	Pinyon mouse	e		
Rattus norvegicus	Norway rat	+	+	---
Rattus rattus	Black rat	+	+	---
Reithrodontomys megalotis	Western harvest mouse	+	+	
Reithrodontomys raviventris	Salt marsh harvest mouse	+	+	
Sciurus griseus	Western gray squirrel	+	+	
Sciurus niger	Eastern fox squirrel		+	
Tamias sonomae	Sonoma chipmunk	+		
Spermophilus beecheyi	California ground squirrel	+	+	
Dipodomys heermanni	Heermann's kangaroo rat	+		
Canis latrans	Coyote	+	+	
Canis domesticus	Domestic and feral dog	+	+	---
Urocyon cinereoargenteus	Gray fox		+	
Vulpes vulpes	Red fox	+		---
Felis silvestris	Domestic and feral cat	+	+	---
Puma concolor	Mountain lion	e		
Lynx rufus	Bobcat	e	+	
Mephitis mephitis	Striped skunk	+	+	
Spilogale putorius	Spotted skunk	+	+	
Lutra canadensis	River otter	+	+	
Mustela vison	Mink		+	
Mustela frenata	Long-tailed weasel	+	+	
Castor canadensis	Beaver		+	
Taxidea taxus	Badger	+	+	
Procyon lotor	Raccoon	+	+	
Odocoileus hemionus columbianus	Black-tailed deer	+		
Sus scrofa	Wild pig	+	+	---

[1] e = expected, [2] dashes indicate non-native species

very much like those in other parts of the Marin Peninsula. Most of the 1,640 acre park is made up of hillsides covered with mixed evergreen forest, oak woodland, and chaparral plus some native grassland. The upper portion of the park is a ridgeline covered by mixtures of chaparral and dry woodland containing manzanita, madrone, coast live oak and California black oak. The forests and other upland areas provide habitats for a diversity of mammals while the marsh provides the home for an endangered mouse and a rare shrew (see Table 1).

The Changing Forests of China Camp

The forested areas at China Camp are complex and diverse and they support a considerable variety of mammals. The forest of the park is changing, however, with the advent and spread of Sudden Oak Death (SOD) within it. Tempel, Tietje and Winslow (2006) and Tempel and Tietje (2005) studied the risk to small mammals and other species of SOD in San Luis Obispo County but there are not any published studies on the actual effects of SOD on mammals in China Camp. If many of the oaks die in China Camp the small mammals that eat acorns as part of their

diet likely will decline in numbers and the carnivores that prey on those small mammals will also decline. Apigian and others (2005) studying SOD in nearby Sonoma county suggested that the response to SOD by small mammals in coastal live oak woodlands in the San Francisco Bay Area may be varied, e.g., with wood rats being found only in the most heavily affected sites while the apparent response of deer mice and related species was varied. Deer mice were most common in heavily affected sites while Pinyon and brush mice were more common is less affected sites. The authors, however, noted that the apparent patterns of abundance could have been caused either by aspects of the SOD damage or to factors unrelated to SOD. It is also likely that without the larger trees in the forest many of the bats now present in China Camp's forest will move elsewhere with concomitant changes in the numbers and diversity of insects. The impact of SOD is very heavy in some portions of the park. What the actual effects of SOD on China Camp will be in the longer run await time and scientific study.

The Marshes of China Camp

The marshes of both China Camp and Rush Ranch are of special interest to the author because they contain the only endangered mammalian species in either area, i.e., the salt marsh harvest mouse, as well as several rare to very rare shrews. Much of the discussion of the marshes of both China Camp and Rush Ranch will concentrate on these species.

The marshes of China Camp are more or less unique in that they have transition areas connecting them to the grasslands above them and there are few other marshes around the San Francisco Bay that (1) have grassland adjacent to them and (2) have an ecotone between the highest zone of the marsh and the grassland. There are three primary regions of marsh separated from one another by Turtleback Hill and Chicken Coop Hill. For the location of these features and others at China Camp see the map on the California State Parks website (*http://www.parks.ca.gov/*). There is a wide, broad marsh with an extensive marsh plain that extends north and westward from Turtleback Hill to beyond the mouth of Gallinas Creek to the west. A second and smaller marsh is between Turtleback Hill and Chicken Coop Hill with the smaller Bullet Hill located between them. The third of the primary marshes extends east from Chicken Coop Hill and disappears before Buckeye Point. There are a few very small pocket marshes to the east of Buckeye Point but beyond the park boundaries there are no marshes around San Pedro Point and westward to the northeastern suburbs of San Rafael. This break in marshes between China Camp and the marshes east of Larkspur (and south of the Corte Madera Channel) is significant in the case of the salt marsh harvest mouse (SMHM). The more southern subspecies of this endangered species (*Reithrodontomys raviventris raviventris*) occurs south of the break and the northern subspecies (*R. r. halicoetes*) occurs to the north.

There has been some trapping for SMHM in the marshes in or near China Camp but it has not been either recent or extensive. The oldest trapping records are those of George Fisler, who did a major study of the SMHM in the early 1960s and wrote the monograph on the species (Fisler 1965). He trapped the southern, or raviventris, subspecies as far north as the marshes east of Larkspur, in what is today the Corte Madera Marsh Ecological Reserve. The farthest south he trapped in the range of the northern, or halicoetes, subspecies was on the south side of Gallinas Creek at its mouth, a point approximately a half mile to the west of the western boundary of the park. He captured 24 SMHM at the Gallinas location but he did not indicate the trap effort.

The park or the marshes near the park have been trapped three times. Cummings (1975) trapped in the general vicinity where Fisler trapped in 1965, i.e., the south side of Gallinas Creek and somewhat east of the mouth, but she captured just one SMHM in 100 trap nights, a trap night being one trap set for one night. Shellhammer and Simons (1980) trapped in the marsh off the northeast side of Turtleback Hill and captured 2 SMHM in 200 trap nights.

The character of the marsh extending from the mouth of Gallinas Creek eastward to the park at the west side of Turtleback Hill is, as mentioned previously, almost unique around the San Francisco Bay as it

exists today, so it seems unusual that so few SMHM have been captured there since the area was trapped by Fisler in1965. Little is known about SMHM populations in the China Camp marshes in the 2000s but it is likely that the large marsh extending westward from Turtleback Hill is still a productive habitat for SMHM. It is also possible that some SMHM move occasionally from that marsh into the two marshes in China Camp east of Turtleback Hill.

Although the Gallinas Creek/China Camp marsh is wide and broad in comparison with the smaller marshes within the park, most all of them are bisected by North San Pedro Road which limits marsh transgression. Turtleback Hill, Chicken Coop Hill, Bullitt Hill and Jake's Island are exceptions in that they have complete marsh–upland ecotones. The transition zone between marsh and grassland is narrow and steep on the sides of the smaller pocket marshes on the bay side of the road crossing them. The two marshes on the upland side of the road have gentler slopes and broader transition zones, features needed by SMHM as escape cover (Shellhammer 1982, 1989) when tides are high. Tides flow in and out of the upper part of each of those two marshes via culvert pipes beneath the road. The road bed and its barren edge is 20 feet wide where it crosses the marshes, a barren band that is likely to preclude SMHM from crossing the road (Shellhammer 1982, 1989) and hence the only likely access to the upper portions of these marshes is through the culvert pipe. These two smaller, brackish marshes could be improved as SMHM habitat if the present culvert pipes were removed and replaced with larger openings that would allow vegetation to grow on most of their surfaces and hence allow for the movement of SMHM beneath the road for a greater part of each tidal cycle, i.e., not just when the tides are low.

Little is known of the "fog" shrew (*Sorex vagrans sonomae*) that might inhabit these marshes. Cummings (1975) reported no shrew captures nor did Fisler (1965). Shellhammer and Simons (1980) captured no shrews at China Camp in 200 trap nights but Simons captured 19 shrews of various species in 2,986 trap nights at 6 of the 20 locations he trapped in the marshes around San Pablo Bay (Lee Simons, San Jose State University, pers. comm., 1979). It is assumed that shrews still exist in the China Camp marshes but only intensive trapping or fortuitous observation could verify if they are present. Trapping for shrews involves demanding trapping protocols including checking traps several times each night or using fewer, specially designed shrew traps (e.g., those described in Hays 1998) that contain food to keep the shrews alive through the night. It is also necessary to bait the traps with baits other than those used to trap SMHM. For these reasons there is seldom the support available to trap for shrews and hence little of it is done and little is known of their presence or their numbers anywhere around the Greater San Francisco Bay.

RUSH RANCH: HARVEST MICE AND SHREWS IN A CHANGING MARSH

Rush Ranch Open Space Preserve is ecologically different from China Camp State Park in that approximately half of its 2,070 acres is marsh and brackish rather than saline, and is a mixture of tidal, muted tidal, and diked marsh conditions. The rest of Rush Ranch is composed of the Potrero Hills, which are covered by grazed annual grasses. The only trees—mostly non-native eucalyptus—are those found around the preserve headquarters, the former home of the Rush family.

The subspecies of the salt marsh harvest mouse (SMHM) found in the Suisun Marsh, as well as the marshes of San Pablo Bay, is *R. r. halicoetes*. The mouse was originally described by Dixon (1908, 1909) who described the species as being restricted to salt marshes and primarily to areas of pickleweed (*Sarcocornia pacifica*). Fisler (1965) indicated that the *halicoetes* subspecies was found in both salt and brackish marshes, although the brackish marshes he trapped were described as being "characterized by the presence of the cattail (*Typha latifolia*) and several species of *Scirpus*. *Salicornia* and *Distichlis* are found in depressed areas, which are scattered throughout the marshes even to the landward edges. Natural and artificial levees support growth of *Grindelia cuneifolia* and *Baccharis pilularis*." That expectation as to the preferred habitat of the mouse being primarily saline vegetation continued until the late 1990s

when approximately 1,300 acres of SMHM conservation areas were established in the Suisun Marsh on California Department of Fish and Game (DFG) land.

In 1998, researchers from the DFG and the California Department of Water Resources (DWR) began monitoring those conservation areas; this monitoring continues today. In addition to pickleweed and upland grasses, some of the vegetation in the mouse reserves, and in Rush Ranch, which they trapped in 2002, 2003 and 2004, was composed of a mixture of halophytes including *Atriplex triangularis*, *Frankenia salina*, *Distichlis spicata*, *Juncus balticus*, and *Schoenoplectus americanus*. In some areas of the Suisun Marsh, the researchers placed trapping grids in monocultures or near monocultures of *Schoenoplectus* spp., usually *S. americanus* or Olney's three-square bulrush. Because the trapping grids were sometimes placed in either tidal or diked areas when the soil surface was flooded, researchers began to place their traps within, or on top of, the vegetation or thatch layer over two feet off the ground (Lorraine Barthman–Thompson, DFG, pers. comm., 2002). They consistently trapped SMHM in these brackish vegetative conditions, and have shown that SMHM use the complex stands of *Schoenoplectus americanus* as well as pickleweed and other halophytes. Their studies are summarized and analyzed in Sustaita and others (2011). They demonstrated that the thickness and complexity of the vegetation—be it pickleweed, mixed vegetation, or the layer of thatch in *Schoenoplectus* stands or in stands of *Schoenoplectus* mixed with *Juncus*—is important in promoting mouse numbers by providing cover from predators and refuge from high waters. Similarly, H. T. Harvey (2007) found SMHM in the deep thatch in mature alkali bulrush (*Schoenoplectus robustus*) in the southern-most end of the South San Francisco Bay.

Researchers at DFG and DWR often found many more SMHM in the Suisun Marsh than other investigators and trappers have found in marshes elsewhere in the greater San Francisco Bay area. The average capture efficiency (CE) of SMHM for all 252 projects carried out in the Suisun Marsh between 1998 and 2007 was 4.4 (i.e., the number of animals captured divided by the total number of traps set multiplied by 100), although some of their surveys were conducted in upland habitats where SMHM was not the targeted species. This index has been used for decades in SMHM trapping studies before modern computer-aided density-estimation programs were available. The sources for these and the following CEs are various yearly reports to agencies and the database for SMHM trapping projects developed by Shellhammer and available from the San Francisco Estuary Institute (*http://legacy.sfei.org/ecoatlas/smhm*). That database shows that most of the trapping efforts in the Suisun Marsh (in mouse conservation areas, on Rush Ranch, and other state and county properties) had CEs below 10.0, although some were in the low 20s, and one effort that yielded a CE of 25.0 (i.e., one mouse for every four trap nights). For comparison, the 201 projects carried out in south San Francisco Bay yielded an average CE of 1.4, while 74, or 36.8% of them yielded no SMHM. Few of these projects had capture efficiencies of 10.0 or more.

During 2002, 2003 and 2004, Sustaita and others (2011) carried out a SMHM study that investigated habitat use and demography in different vegetation types. Two of the study sites were tidal (one of which was Rush Ranch), and two were managed, diked areas. Three different vegetation types were trapped at each site: (1) pickleweed-dominated, (2) mixed-wetland marsh vegetation dominated by species other than pickleweed, and (3) upland grasses-dominated. Two trap grids were located in each vegetation type at each site. Researchers captured 648 SMHM in 9,384 trap nights in the mixed-wetland trapping grids for a CE of 6.9. In contrast, they captured 441 SMHM in 9,288 trap nights in the pickleweed-dominated trap grids for a CE of 4.7. The Rush Ranch CEs were comparatively lower than at most of the sites. At Rush Ranch researchers captured 117 SMHM in 2,352 trap nights in mixed-wetland vegetation for a CE of 6.9 and 59 SMHM in 2,304 trap nights in pickleweed-dominated vegetation for a CE of 2.6. The mixed-wetland areas in two of the three other sites had higher capture efficiencies than Rush Ranch (7.4 and 11.1), while one site was lower (CE 4.2), and all of the pickleweed-dominated areas in the other sites were higher (3.7 to 6.4).

The fact that the Suistata study, as well as their DFG and DWR annual monitoring, yielded high CEs in

mixed-wetland areas within the Suisun Marsh suggests that the habitat requirements for the northern subspecies of the mouse should be modified. These results further suggest that Rush Ranch has valuable mouse habitat. When more trapping is done in alkali bulrush areas in the southern end of the south San Francisco Bay, we expect that perceived habitat requirements for the southern subspecies of the mouse will also be modified.

Much has been learned about SMHM use of various habitats because of the DFG and DWR trapping studies, and specifically Sustaita and others (2011), but there are aspects that still need to be examined. For example, relatively little is known about the feeding ecology of SMHM. Fisler (1965) suggested that mice of the two SMHM subspecies will eat seeds but "prefer a great amount of either green or dry vegetation." He suggested that they will eat salty vegetation while the upland *R. megalotis*, the western harvest mouse, will not. Little more is known about the breadth of their diets, other than the statement by Fisler (1965) that "the three forms will eat a variety of food natural to their habitat as well as many artificial foods". We assume that the SMHM at Rush Ranch eat parts of various *Schoenoplectus* species and other halophytic species. Barthman–Thompson (DFG, pers. comm., 2002) noted that SMHM were captured repeatedly in stands of *Schoenoplectus*, and sometimes a hundred yards or more in one night from patches of pickleweed, suggesting that mice were not moving back to areas of pickleweed to eat, but were instead eating the vegetation of bulrushes and other brackish species.

Suisun Shrews

Suisun shrews have been found historically in tidal and brackish marsh communities from Sonoma Creek in Sonoma County to Collinsville in Solano County (Rudd 1955; Brown and Rudd 1981). Ornate shrews are found in the grasslands above tidal and brackish marshes throughout the range of the Suisun shrew, and because the two forms are so similar externally (except for coloration) it is difficult to differentiate between these two shrews in the field. Rudd (1955) suggested that Suisun shrews typically inhabit Pacific cordgrass (*Spartina foliosa*) and pickleweed in tidal salt marshes, and bulrush species and cattails (*Typha* spp.) in brackish water marshes. Rudd noted, however, that structure rather than species composition of the plant community determines the preferred habitat of these shrews. He suggested that dense, low-lying, plant cover where invertebrates are abundant was optimum habitat for shrews. Rudd also suggested that driftwood and other litter above the mean high-tide line were essential for both nesting and foraging. Such litter helps maintain the moist conditions needed by the invertebrates that the shrews eat. Hadaway and Newman (1971) reported that these shrews were most often captured at the ecotone between marshes of pickleweed and upland levees vegetated by coyote brush (*Baccharis* spp.) and grasses. In that sense, Suisun shrews have problems similar to the salt marsh wandering shrew (*Sorex vagrans halicoetes*) found in the southern parts of the San Francisco Bay, because the latter shrew needs increasingly rare marsh areas that are not flooded regularly by tidal waters (Johnston and Rudd 1957; Goals Project 2000). In addition to the great loss of marshes over the last century, there has been a dramatic reduction in the width of most tidal marshes (i.e., from upper edge to mudflats) and in the breadth of the zones of vegetation within those marshes. This latter phenomenon is much more obvious in tidal salt marshes, which historically had a low marsh zone of cordgrass, a middle zone of pickleweed, and an upper zone of peripheral halophytes that blended into the grasslands above the marshes (Shellhammer 1982, 1989). In most of the San Francisco Bay today, and especially in the south San Francisco Bay, diking and filling of marshes has reduced the middle zone by half or more, and has reduced the upper zone from a band between 100s of meters to as much as 2-km wide to a band of 2 m or less. The grasslands above the marshes, and the ecotone between the marshes and grasslands, have disappeared along almost the entire edge of the San Francisco Bay (Shellhammer 1982, 1989). There is little to no escape cover of almost any kind remaining and little to no litter or debris. Hence both the vagrant shrew and Suisun shrew have suffered greatly.

Trapping for marsh-dwelling shrews is not the same as trapping for SMHM, i.e., SMHM traps are not necessarily placed in the most appropriate locations for shrews, nor are they baited appropriately to attract shrews. There have been, however, a few studies of Suisun shrews carried out in the northern Suisun Bay in the 1980s. Williams (1983) trapped along 26 transects in the Grizzly Island area, using pitfall traps and captured 15 house mice and one ornate shrew; another shrew was found dead near one of the trapping transects. Hays and Lidicker (2000) were much more productive as they captured 161 shrews in the marsh ecotone in the southern portion of Rush Ranch in 1989 and 1990. They used a custom-made live trap that reduced trap mortality to 1% (Hays 1998). Their study area was dominated by pickleweed, *jaumea (Jaumea carnosa*), saltgrass, arrowgrass (*Triglochin maritimum*), perennial peppergrass (*Lepidium latifolium*), and dodder (*Cuscuta salina*), and was located between ungrazed annual grassland and undiked tidal marsh. Their study area was located in the center of a marsh ecotone that was 20 to 70 m wide and about 8 km long at the time of the study. It was flooded completely only a few times a year but remained moist throughout the period of their study. The plants of their trapping area formed a dense layer of matted vegetation that was riddled with runways most likely created by California voles. The tidal marsh below the ecotone was 100 to 500 m wide and dominated by bulrushes, arrowgrass, and *jaumea*. The other common species of small mammal in their study area was the SMHM.

In summary, it appears that Suisun shrews may be rare in some parts of their range but potentially more common in much of the marsh ecotone of Rush Ranch. The low numbers in other parts of their range are likely from the lack of appropriate habitat, which is still decreasing in the south San Francisco Bay (Shellhammer 1982, 1989). The vegetative conditions of the Rush Ranch ecotone favor Suisun shrews. Maintaining an adequate band of ungrazed grassland above the ecotone is important, because it is the home of the closely-related ornate shrew, with which the Suisun shrew can interbreed. Hays and Lidicker (2000) note that:

> ... interbreeding with the subspecies *californicus* may be caused by invasion of the marsh by this upland form, and not the reverse. It may be that provision of adequate upland and marsh habitats permits co-existence of both shrews with minimal contact between them.

The combination of extensive marsh ecotone and a wide band of ungrazed annual grassland above it are extremely rare. The maintenance of these two bands of vegetation at Rush Ranch is therefore extremely important.

The Changing Environment

While Rush Ranch is now a productive area for SMHM, potential changes may reduce mouse numbers in the future. One change is the increasing coverage by perennial peppergrass. H. T. Harvey (2007) found SMHM in mixtures of peppergrass and alkali bulrush, but the patch sizes of pure peppergrass were small enough even in areas dominated by this species to make it difficult to ascertain if the mice were consistently using pure stands of peppergrass for extended periods of time. The same general situation appears to be the case at Rush Ranch. Peppergrass has spread throughout the brackish portions of the southern part of the San Francisco Bay and is expanding rapidly at Rush Ranch. The density and area covered by peppergrass varies yearly, but the direction has consistently been toward increased coverage. Studies are needed to find out if SMHM and Suisun shrews use large monocultures of peppergrass regularly.

The other factor that bodes ill for both the mice and the shrews is sea level rise resulting from world climate change. Mean sea level in the San Francisco Bay is predicted to rise at least an additional 1.0 to 1.4 m by the year 2100 (Cayan and others 2009). Even a 0.5 m rise in sea level will likely be devastating to SMHM as most all of the marshes in the region, including one area at Rush Ranch, are backed by steep-sided dikes. The diked marsh at Rush Ranch has extensive uplands above it, as do the tidal marshes along the southern border of the property. This is not the case, however, in most of the Suisun

Marsh where roads and houses restrict the upward movement of marshes. As sea levels rise dikes will have to be raised and for economic restrictions it is likely that the new dikes will be just like the present ones, only higher, i.e., steep-sided dikes that are initially barren of vegetation. The new dikes will likely provide even less escape cover from tides for the salt marsh harvest mice or habitat for Suisun shrews. The diked marshes of Rush Ranch and the rest of the Suisun Marsh, however, may have an increasingly important role with respect to SMHM in a warmer world with higher sea levels. Barthman-Thompson and Quickert found high numbers of SMHM in diked, brackish marshes where water management has been effectively practiced. As sea levels rise, and if they rise slowly and do not rise more than about a meter, then the diked brackish as well as diked saline marshes throughout the San Francisco Bay are likely to become increasingly more important refugia for the mice. Should a more catastrophic sea level rise occur, it will be likely that much to most of the Suisun Marsh and most of the Suisun shrews will disappear while SMHM will decrease in numbers and distribution.

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