ASSESSING SALT MARSH HARVEST MOUSE MOVEMENTS DURING HIGH TIDES, SAN PABLO BAY, CALIFORNIA

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The salt marsh harvest mouse (*Reithrodontomys raviventris*) is endemic to salt marshes surrounding the San Francisco Bay, California. Both subspecies of salt marsh harvest mouse (*R. r. raviventris*, the southern salt marsh harvest mouse, and *R. r. halicoetes*, the northern salt marsh harvest mouse) were listed as endangered by the United States Department of the Interior (Office of the Federal Register 1970) and the California Department of Fish and Game (California Department of Fish and Game 1972). Loss of habitat was the principal reason for the listing of the mouse as endangered (Shellhammer 1977). Shellhammer et al. (1982) reported that pickleweed (*Salicornia virginica*) was the predominant plant in salt marsh harvest mouse habitat. They also reported that back-filled pickleweed marshes or those bordered by dikes might not support mice because these marshes lack upper marsh zones with thick cover. Upper marsh zones are thought to be used by salt marsh harvest mice as refugia from high tides (Fisler 1965, Shellhammer et al. 1982, Geissel et al. 1988), although few studies have evaluated this conjecture (Johnston 1957, Hadaway and Newman 1971).

Many of the marshes of the San Francisco Bay are subject to daily tidal submergence, but these tides generally are not high enough to completely submerge marsh vegetation and force mammals from the area. However, from November to January the combined effects of extremely high tides, wind, rain, and increased inflow from rivers can increase tides by as much as 1.5 m (Fisler 1961). Reports vary, however, on the response of small mammals to marsh flooding during the highest tides of winter. Although Johnston (1957) reported that small mammals remained in nearly the same marsh locations during high winter tides, Hadaway and Newman (1971) found a slight increase in the number of salt marsh harvest mice on upper marsh levees during winter inundation of a marsh in San Pablo Bay, Sonoma County, California. Further work is needed to assess the extent to which salt marsh harvest mice depend on upper marsh zones, such as levees, during the highest tides of winter.

We conducted a winter livetrapping study of the northern subspecies of salt marsh harvest mouse at 2 locations, Tolay Creek and Cullinan Ranch, in San Pablo Bay National Wildlife Refuge, to assess upper-marsh levee use by the mouse and to investigate movements from frequently flooded marsh fragments to diked bayland areas. Knowledge of levee and diked-area use by the species will enable restoration planners to assess the importance of these zones in restored marshes for the benefit of the salt marsh harvest mouse.

Tolay Creek is located in Sonoma County, California, at the northern end of San Pablo Bay. It is bounded on the north by State Highway 37 and on the south by San Pablo Bay. The Tolay Creek Restoration Project, a collaborative partnership involving federal, state, and local agencies, restored 180 ha of saline emergent wetlands in the Tolay Creek floodplain within the boundaries of the San Pablo National Wildlife Refuge and the Tolay Unit of the Napa/Sonoma Wildlife Area (Ducks Unlimited, Inc. 1997*a*). The restoration project, which restored tidal action to the creek and to 2 agricultural fields, was completed in December 1998.

Cullinan Ranch is a 605-ha diked bayland located at the northeastern edge of San Pablo Bay in Solano County, California, that was acquired in 1991 as a unit of the National Wildlife Refuge. Restoration plans include breaching the levee that separates the property from the tidal waters and salt marsh fragments of adjacent Dutchman Slough (Ducks Unlimited, Inc. 1997*b*).

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At Tolay Creek, mice were live trapped on 2 trap grids using large Sherman small-mammal traps. One trap grid was a 7 by 7 configuration with 10-m trap spacing, and the other trap grid was a 5 by 10 configuration with 10-m trap spacing. Trap grids differed in size and number of traps due to space constraints posed by standing water in the salt marsh. Pickleweed accounted for an average of 96% of the vegetation cover on the trap grids (Hulst 2000).

Two trap lines, composed of 25 traps each, were established on the levee adjacent to each of the trap grids at Tolay Creek. Trap spacing within and between the lines of traps was about 2 m. This trap spacing increased the probability of capturing animals that might have moved onto the levee during inundation of the marsh. Shrubs such as coyote bush (*Baccharis pilularis*) accounted for an average of 75% of the vegetative cover on the levee (Hulst 2000).

The Tolay Creek grids were trapped for a 3-night session prior to the highest tide of November 1999 to determine the presence or absence of salt marsh harvest mice in the marsh. The levee trap lines for each grid also were run simultaneously to determine the presence or absence of salt marsh harvest mice on the levee in non-flood conditions. Afterward, the Tolay Creek trap lines on the levee were trapped during a 2-day period (22-23 November 1999) encompassing the highest tide (2.07 m) of the month to assess the movement of salt marsh harvest mice from the marsh to the levee. The high tide trapping effort also included establishment of a line of 9 floating Sherman live traps with 10-m spacing on each trap grid. Each floating trap consisted of a trap fastened to a Styrofoam (and wood platform with a hole in 1 end. A piece of pipe driven into the ground through the hole prevented the platform from floating away. The purpose of the floating traps was to assess the activity of salt marsh harvest mice in the marsh during the high tide. High tide trapping was conducted during the day because winter high tides in San Pablo Bay are diurnal and would likely force animals to move during the day.

At Cullinan Ranch, 2 trap grids were established in the diked area, adjacent to the salt marsh fragments. Both grids were approximately square, but differed in size and shape due to space constraints posed by standing water. One trap grid contained 47 traps with 10-m spacing, and the other trap grid contained 30 traps with 10-m trap spacing. Annual grasses accounted for an average of 72% of the vegetation cover on the trap grids (Hulst 2000).

Two trap lines, established on the Cullinan Ranch levee between each of the trap grids and the edge of Dutchman Slough, were composed of 25 traps each. Trap spacing within and between the lines of traps was approximately 2 m. The purpose of the trap lines was to capture any mice that might have moved out of the marsh fragments and into the diked areas of Cullinan Ranch during tidal inundation of the salt marsh fragments in Dutchman Slough. Annual grasses accounted for an average of 84% of the vegetation cover on the levee (Hulst 2000).

The Cullinan Ranch grids and accompanying trap lines were trapped for a 4-night session prior to the highest tide of December 1999 to determine the presence or absence of salt marsh harvest mice at Cullinan Ranch in the absence of tidal flooding in the adjacent salt marsh fragments. Nine floating traps were then placed in the salt marsh fragments adjacent to each trap grid and all traps were checked for a 3-day period (20-22 December 1999) encompassing the highest tide (2.08 m) of the month.

All captured mice were marked by fur clipping in a pattern that indicated the location where the animal was first captured, which allowed determination of movement upon recapture. All age classes and sexes were combined for this analysis. Standard characteristics used to identify salt marsh harvest mice were measured (Shellhammer 1984). However, there were marked differences between those that we identified as western harvest mice (*R. megalotis*) and those that we identified as salt marsh harvest mice.

The numbers of animals captured during all trapping efforts were converted into indices of abundance (new animals captured/100 trap nights) before analyzing them because the number of trap nights differed between grids. A trap night was defined as 1 trap open for 1 night, or, in the case of high tide trapping, 1 afternoon. Each sprung trap that was empty was counted as half of a trap night (Nelson and Clark 1973).

During low tide, we captured 7.2 new salt marsh harvest mice/100 trap nights (21 animals, 292.5 trap nights) in the salt marsh trap grids at Tolay Creek, and 0.3 new salt marsh harvest mice/100 trap nights (1 animal, 296 trap nights) in the trap lines on the levee at Tolay Creek. No salt marsh harvest mice were captured, however, on the levee or in the floating traps at Tolay Creek during the high tide. During low tide at Cullinan Ranch, we captured 2.4 new salt marsh harvest mice/100 trap nights (7 animals, 286 trap nights) in the trap grids and 2.7 new salt marsh harvest mice/100 trap nights (10 animals, 372 trap nights) in the trap lines on the levee. No salt marsh harvest mice were captured at Cullinan Ranch during high tide.

Tidal flooding in the marsh at Tolay Creek and in the marsh fragments adjacent to Cullinan Ranch did not appear to be severe enough to cause salt marsh harvest mice to seek refuge on the levee at Tolay Creek or on the levee and the diked areas at Cullinan Ranch. During flooding, it is probable that the salt marsh harvest mice present in the marsh climbed vertically through the vegetation, moving into areas above the water line, rather than moving horizontally out of the marsh. This was a possibility because low levels of flooding at both sites left a considerable amount of vegetation unsubmerged (25-150 cm, depending on the height of the vegetation at the trap locations).

The high tides at a marsh are influenced by local conditions such as bay and marsh configurations, rainfall, size of inflowing streams, and onshore winds (Fisler 1965). The low level of tidal flooding at Tolay Creek and Cullinan Ranch in 1999 was likely the result of below-average rainfall, and thus stream inflow into San Pablo Bay, for the period of 1 October - 31 December 1999.

Although radio telemetry might be needed to confirm or refute Johnston's (1957) claim that small mammals remain in nearly the same marsh locations during the high winter tides at Tolay Creek or Cullinan Ranch, our data fail to support Hadaway and Newman's (1971) finding of a slight increase in the number of salt marsh harvest mice on upper levees during winter inundation of a marsh in San Pablo Bay (Newman and Hadaway did not provide flood levels during their study). However, the lack of levee and diked area use by salt marsh harvest mice during the high tides of our study might not be the case for the entire winter season or from year to year, especially during times in which high winter tides and heavy rainfall coincide. Furthermore, we acknowledge that our sampling efforts were not extensive and additional work is needed to clarify the influence of high tides on mouse movements, including work in other locations and vegetative types.

Our capture of salt mash harvest mice in grassy, diked areas and on levees during non-flood conditions supports the suggestion by some researchers (e.g., Rice 1974, Zetterquist 1977, Botti et al. 1986, Bias 1994) that salt marsh harvest mice use areas other than thick pickleweed, regardless of tidal flooding. Therefore, levees and grassy areas should not be dismissed as non-habitat for the salt marsh harvest mouse. Incorporating such areas in tidal marsh restoration projects might be beneficial for the species.

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