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Potential evidence of communal nesting, mate guarding, or biparental care in the salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*)

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The salt marsh harvest mouse (*Reithrodontomys raviventris*) is endemic to the saline and brackish marshes surrounding the San Francisco Estuary (Fisler 1965). There are two subspecies of salt marsh harvest mouse; the northern subspecies (*R. r. halicoetes*), which occurs primarily around San Pablo, Suisun and Grizzly bays, and the southern subspecies (*R. r. raviventris*), which occurs primarily around the South San Francisco Bay (Fisler 1965). Due to the loss of over 90% historic tidal marsh habitat in the San Francisco Estuary, both subspecies were listed as endangered by the U.S. Fish and Wildlife Service in 1970 and the California Department of Fish and Game in 1971 (U.S. Fish and Wildlife Service 2013). Very little research has directly addressed the behaviors of salt marsh harvest mice, and virtually none has investigated intraspecific interactions. Understanding animal behavior can improve conservation efforts (Berger-Tal et al. 2011), but until very recently, the only observations of social behaviors of the salt marsh harvest mouse (e.g., breeding behaviors) occurred *ex situ* (Fisler 1961).

Beginning in 2013, researchers from the California Department of Fish and Wildlife (CDFW), and University of California, Davis performed radiotelemetry seasonally as part of a three-year demographic and habitat use study on the northern subspecies. Once per season, at three study blocks consisting of paired tidal and diked managed wetlands, adult male and female salt marsh harvest mice were radiocollared and monitored for habitat use and other behaviors. Monitoring activities were concentrated during nocturnal hours but also encompassed some daylight hours. Researchers tracked and located mice throughout shifts with at least 30 minutes between sequential locations for individuals. Using this technique we were able to make observations of habitat use, feeding behavior, interactions between individual mice, and more.

During three years of radiotelemetry work, tracking hundreds of individual salt marsh harvest mice, we rarely observed mice remaining in one location for extended periods during nocturnal hours. However, on 30 August 2016 at CDFW's Goodyear Slough Unit in Benicia, California, between the hours of 0300 and 0600, we tracked a radiocollared adult male salt marsh harvest mouse to the same nest four times. The nest, made of harvested annual grasses (Figure 1), was located in pickleweed (*Salicornia pacifica*) about 0.5 m above the ground, and about 10 cm above standing water on a recently flooded diked managed wetland. At 0645 hrs, to confirm that the mouse was present and that the radiocollar had not slipped off, we uncovered the top of the nest. Upon pulling back the nesting material, we observed the adult male mouse and three well-haired juvenile mice huddled together in the nest. The juveniles were beneath the adult male's body (Figure 2). The mice did not flee and we replaced the nesting material promptly to minimize disturbance. The weather at the time was mild; the temperature was about 17.0° C, average wind speed was 2.6 miles per hour, and cloud cover was about 50% with no precipitation. Later that day, between 1900 hrs and 2300 hrs, we recorded the radiocollared male mouse moving about, presumably foraging. During this period the weather remained mild; the temperature dropped from about 28.5° C to 20.0° C, wind speed decreased from 2.5 to 1.0 mile per hour, and cloud cover increased from about 30% to 80% with no precipitation.

The following morning between 0300 hrs and 0600 hrs we tracked the mouse to the same nest three times. At 0640 hrs, we again checked on the mouse, pulling away the top nesting material to reveal the adult male and the three juvenile mice. This time

FIGURE 1.—Nest built out of dry annual grass in the upper branches of a pickleweed bush (*Sarcocornia pacifica*).

FIGURE 2.—A radiocollared adult male salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*) in a nest with three juveniles.

one juvenile was tucked under the adult's abdomen, while the other two lay on top of him. We removed the adult mouse from the nest and verified that the radiocollar was in place and was not restricting his movement. At this point we confirmed him to be a scrotal male and placed him back in the nest. The juvenile mice did not flee as we removed and replaced the male (Figure 3). The temperature was about 16° C, average wind speed was 2.4 miles per hour, and cloud cover was <5%. Monitoring during the following nights revealed that the radiocollared adult and juvenile mice were not using the nest.

This is the first time an adult male salt marsh harvest mouse has been observed nesting with juveniles in the wild, and we generated several potential explanations for the behavior. One possibility is that the radiocollared male was simply looking for a warm, dry place to rest and did not perceive any threat from the juvenile mice. Since the pond was recently flooded, the mice were forced into closer proximity with fewer resources. Flooding diked managed ponds for duck hunting can reduce the available habitat for salt marsh harvest mice and they may be forced to move vertically into emergent vegetation (Smith et al. 2014). However, this was during a relatively warm and dry period, so huddling for warmth was likely unnecessary.

FIGURE 3.—Three juvenile salt marsh harvest mice (*Reithrodontomys raviventris halicoetes*) huddling calmly in a nest after researchers removed an adult radiocollared male from the nest.

A second possible explanation is that the radiocollared male was mate guarding (Getz et al. 2003). There is some debate as to whether salt marsh harvest mice breed into August (Padgett-Flohr and Isakson 2003, Bias and Morrison 2006); however, we have observed reproductive females of the northern subspecies year-round during years of low precipitation. Female salt marsh harvest mice are capable of entering postpartum and/or lactation estrus (Gilbert 1984, Shellhammer et al. 1988) and we commonly capture pregnant females who are still lactating (suggesting post-partum estrus), so there is a strong possibility that the male was remaining near the juveniles to gain access to the mother for mating. Alternatively, the male could have been mate guarding the juveniles. While there are no published estimates of age to sexual maturity for female salt marsh harvest mice, female western harvest mice (*R. megalotis*) can reach sexual maturity in less than six weeks (Richins et al. 1974). Additionally, male western harvest mice are significantly more likely to be captured in traps with reproductively receptive females than pregnant or postpartum females (Blaustein and Rothstein 1978). We commonly observe this when sampling salt marsh harvest mice as well, often trapping older adult males and very young females together in the same trap. Unfortunately, to minimize disturbance, we did not remove the juveniles from the nest to determine their sex or take measurements for age estimation. However, since there were three individuals, it is likely that at least one of the juveniles was a female; hence, it is possible that this adult male was associating with these young mice as a means of guarding a female to ensure he was the first to breed her.

Our final possible explanation is that the radiocollared adult and three juvenile mice may have been genetically related. Northern salt marsh harvest mice have an average litter size of 4.21 (Fisler 1965), so this was potentially a litter of siblings. It is possible that the young were the male's offspring and he was participating in biparental care; he generally may have foraged for the first half of the night, and cared for the young during the latter half of the night while his mate foraged. The huddled position and nest guarding, which is typical of paternal care in mice (Gubernick and Teferi 2000), supports this possible explanation. Unfortunately, since the mice did not use the nest on subsequent nights, we were unable to collect hair samples to determine their genetic relationship.

Biparental care is rare among mammals, but relatively common in rodents (e.g., Silva et al. 2008; Schradin and Pillay 2003), where paternal care can significantly increase pup survival (e.g., Ophir et al. 2008; Gubernick and Teferi 2000). We observed radiocollared females in nests with young on a number of occasions, but this is the only observation we made of a male in a nest with young. However, we commonly tracked radiocollared adult males and females to the same location where they may have been sharing a nest. We were only able to confirm this visually with one pair because we did not regularly uncover nests unless radiocollars were stationary for extended periods or we were trying to capture mice for collar removal.

These observations have important implications for the conservation and management of the salt marsh harvest mouse. Understanding breeding behaviors such as communal nesting and biparental care can assist managers in conserving this endangered species by more accurately assessing habitat needs, demography, and densities. These types of data can also improve timing of habitat management activities to reduce negative effects on mice during peak breeding seasons. Observations of behaviors related to the life history of endangered species should be recorded when feasible, as they may prove valuable tools for conservation. Finally, collecting genetic samples from adult and juvenile salt marsh harvest mice captured in the same trap during routine surveys will improve our understanding of parental care and breeding behaviors for this critically endangered species.

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