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Current distribution of the California vole (*Microtus californicus*) in Baja California, Mexico

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Abstract.—We revisited 26 of the 28 known collection sites for the California vole, *Microtus californicus*, in Baja California, Mexico. With live trapping, we were able to confirm the continued presence of the vole at 7 of these sites, which include all 3 of the subspecies endemic to Baja California. At 14 of these sites, no viable habitat was found. These 14 sites included all known occurrences of *M. californicus sanctidiegi* in Baja California. Based on capture numbers or lack of habitat, population size may be drastically reduced at all sites except one. Effective conservation actions are required for recovery of California vole populations in Baja California.

Resumen.—Revisitamos 26 de los 28 sitios de colecta conocidos para el meteoro de California *Microtus californicus* en Baja California, México. A través de trampeo, pudimos confirmar la presencia del meteoro en 7 de estos sitios, que incluyen las 3 subespecies endémicas a Baja California. En 14 de estos sitios, no se encontró hábitat viable. Estos 14 sitios incluyen todos los registros de *M. californicus sanctidiegi* en Baja California. Los tamaños poblacionales parecen estar drésticamente reducidos en todos los sitios, excepto uno. Se requieren acciones efectivas de conservación para recuperar las poblaciones del meteoro de California en Baja California.

The California vole, *Microtus californicus*, is a small rodent and common resident of mesic habitats, ranging from southern Oregon to northern Baja California (Cudworth and Koprowski 2010, Conroy et al. 2016). Seventeen subspecies have been described: 13 are endemic to the United States, 3 are endemic to Baja California, and 1 is shared. In the United States, the species is considered secure; however, one subspecies is considered endangered by federal and California law and 5 further subspecies have conservation concerns (CNDDB 2019). In Mexico, all subspecies are considered in danger of extinction and are protected by the Mexican government (SEMARNAT 2010, 2018). The species appears to be declining in distribution in Baja California (Mellink and Contreras 2014), with earlier concern that some of its Mexican subspecies may already be extinct (Heske and Lidicker 1999). Recently the vole's continued presence in Baja California has been confirmed (Guevara-Carrizales et al. 2016, Harper et al. 2016), but little is known about its current distribution. This study was undertaken to locate the known historical sites of the California vole in Baja California and to determine the current habitat and occurrence at these sites.

The Baja California subspecies are distinguished qualitatively based on size, skull morphology, and pelage color, each based on average or typical values of adult specimens, because the range of characters between subspecies overlaps (Grinnell 1926). Hence, in the following discussion, the subspecies designation of historical specimens follows that of the museum with that specimen, and the designation of modern observations is based on the subspecies previously recorded from that site or nearby sites.

Microtus californicus sanctidiegi (Kellogg 1922) is known from 6 locations along the

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AH orcid.org/0000-0003-4437-4701 APG orcid.org/0000-0003-1214-1524 JHVV orcid.org/0000-0001-9612-0303
CJC orcid.org/0000-0001-7198-9651

coast as far south as Santo Tomás and along the U.S. border as far east as Macho Güero, from 0 m to 1040 m elevation. Prior to 2013, it was last collected in Baja California in 1974. This subspecies is widely distributed in Southern California (Mellink et al. 2017).

Microtus californicus grinnelli (Huey 1931) is known from 4 locations east and southeast of Ensenada from 200 m to 1560 m elevation. It was last seen in 1996 (Harper et al. 2016).

Microtus californicus huperuthrus (Elliot 1903) is found in the Sierra San Pedro Mártir at 9 locations, from 1295 m to 2425 m elevation. Prior to 2013, it was last collected in 1925.

Microtus californicus aequivocatus (Osgood 1928) is known from 9 locations in the western foothills of the Sierra San Pedro Mártir and coastal and inland wetlands to the south, from 0 m to 635 m elevation. It was last collected in 1953.

Methods

We used online databases (AMNH 2018, Arctos 2018, NMNH 2018, VertNet 2018) and museum records to generate a list of known collection sites of California voles in Baja California. These locations were georeferenced using modern maps (including Google Earth), historical maps, and field notes of the original collectors (details and citations in Supplementary Material 1).

We visited 26 of 28 sites with historical *Microtus* collections from June 2016 to December 2018. (Two sites, Aguaje de las Fresas and Las Cabras, could not be accessed due to security concerns at the first and a lack of permission at the second.) At each site we qualitatively evaluated the habitat by looking for fresh or brackish water (≤3‰), known food plants (especially saltgrass [*Distichlis* spp.] and spikerush [*Eleocharis* spp.]), and sign of voles (e.g., runs, feces, and chewed vegetation). At sites where we identified favorable or marginal habitat, we trapped using Sherman traps. Ideally we trapped for 3 nights, or until 11 animals were captured, up to 300 trap-nights; but many sites were trapped with fewer traps or nights due to logistical considerations or limited habitat (details in Supplementary Material 1). Tissue samples (ear clips) were taken from all animals trapped, and when the population appeared to be robust, a whole animal was collected (3 in total). Tissue samples were deposited at the Museum of Vertebrate Zoology, Berkeley, California; specimens were deposited at the mammal collection of the Universidad Autónoma de Baja California at Ensenada. Handling of live animals was in accord with the recommendations of Sikes et al. (2016).

Results

We identified 28 historical sites for *Microtus californicus* in Baja California and visited 26 of them (Fig. 1, Table 1). We use modern names for these sites, with historical names shown in Supplementary Material 1. Two sites have the same name, “La Grulla”: one is in the Sierra San Pedro Mártir (“SSPM”) at 2080 m elevation, while the other is south of Ensenada, near the settlement of Las Ánimas, at 210 m.

We confirmed the presence of voles at 7 sites (Table 2). An additional 5 sites had habitat that appeared to be consistent with the maintenance of, at least, a sparse population of voles (having some food plants and fresh water, often heavily grazed or limited in extent), but trapping was not successful at these sites.[1]

At 2 sites, La Grulla (SSPM) and Sangre de Cristo, we found abundant sign and had high capture rates (5%–15%). At the other 5 sites with voles, capture rates per trap-night were 0.5%–2%, which, combined with little sign of voles, suggests that these populations are depressed by poor habitat quality.

The habitat found at 14 sites did not appear to be compatible with the continued detectable presence of voles at those sites. It is clear that the California vole can survive in sparse numbers in disturbed sites for long time periods, even at sites where earlier intensive searches were unsuccessful (Bleich 1979, Harper et al. 2016). Hence, especially for this species, absence of evidence cannot be used alone as evidence of absence. Even if *Microtus* continues to exist at some of the sites where

[1]Note added in proof: On 30 July 2019, a California vole was found in a pitfall trap in Estero de Punta Banda, south of Ensenada (A. Peralta-García and J.H. Valdez-Villavicencio unpublished data). Given the location, we presume that this specimen was *Microtus californicus sanctidiegi*. It was found on a sand peninsula within a protected area about 2 km WSW of Planicie de Maneadero.

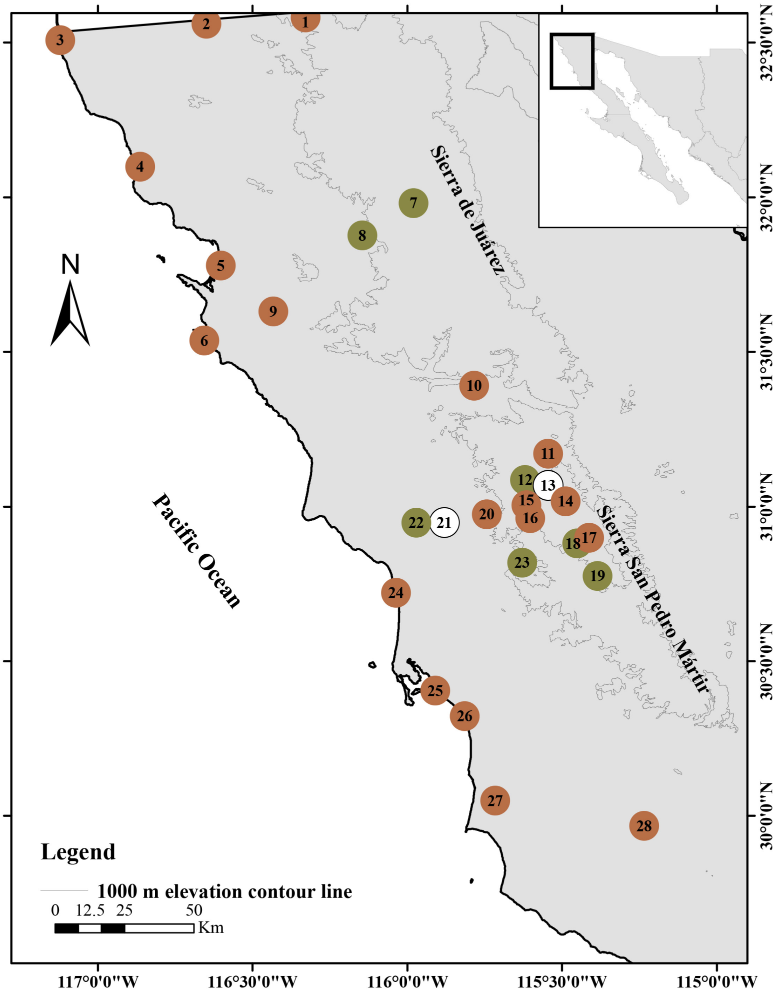

Fig. 1. Historical and current distribution of *Microtus californicus* in Baja California. Green circles are sites with confirmed occurrence; brown circles are sites where occurrence is unconfirmed; and white circles are sites that were not visited.

we found no habitat, it is now at such low levels that this once-common prey no longer contributes to the local ecology and food webs (Pearson 1966, Ackerman 2002, Evans et al. 2006, 2015, Johnson and Horn 2008).

All of these sites appear to have historically been wetlands with fresh or perhaps estuarine water, usually with permanent, shallow, slowly flowing streams. Unlike populations in California and Oregon (Heske and Lidicker 1999), nearly all known Baja California populations appear to be from areas with open water or wetlands. We think that this pattern occurs because, in the arid climate of Baja California, the vegetation required to maintain a detectable population almost always occurs in areas with open water. The one exception to this pattern is at Sangre de Cristo, where an abundant population has been known from a tule (*Schoenoplectus* sp.) wetland with no open water (Huey 1916–1953 [13 June 1927]).

In San Diego County, *Microtus californicus* is known to occur in upland habitats with no fresh water but with significant fog (e.g., Marine Corps Base Camp Pendleton, Marine Corps Air Station Miramar; Mellink et al. 2017, S. Tremor unpublished data), but currently no population in similar habitat is known from Baja California. Some of the coastal populations were associated with lagoons at the

TABLE 1. Known historical and modern collection sites of *Microtus californicus* in Baja California, with current status, latitude, longitude, and elevation (WGS84 datum). Symbols: –, not visited; †, no habitat seen, population probably critically reduced or extirpated; ?, habitat available (usually heavily impacted with no sign of *Microtus*) but presence not confirmed; and ✓, presence confirmed. For details see Supplementary Material 1. Museum collections: FMNH, Field Museum of Natural History; LACM, Natural History Museum of Los Angeles County; MVZ, Museum of Vertebrate Zoology, UC Berkeley; SDNHM, San Diego Natural History Museum; UABC, Universidad Autónoma de Baja California a Ensenada; UCLA, University of California, Los Angeles; UCM, University of Colorado Museum of Natural History; USNM, National Museum of Natural History, Smithsonian Institution. SSPM stands for Sierra San Pedro Mátir.

Site	Status	Site description
Microtus californicus sanctidiegi		
1	†	**Macho Güero Valley** (32.597°, −116.360°, 1040 m). 1927 MVZ. Targeted trapping by W.Z. Lidicker Jr. et al. in 1974 was unsuccessful. Now no habitat seen.
2	†	**Tecate Valley** (32.560°, −116.648°, 500 m). 1894 AMNH; 1894 & 1903 USNM. No habitat seen.
3	†	**Real del Mar** (32.449°, −117.105°, 2 m). 1927 MVZ. Now a sewage outfall, no habitat seen.
4	†	**La Misión** (32.097°, −116.863°, 2 m). 1958 PSM, 1974 MVZ. Now degraded habitat, infested with tamarisk, no sign.
5	†	**Planicie de Maneadero** (31.778°, −116.603°, 10 m). 2013 UABC. Subspecies assigned by continuity with the historical sites to the north and south. Specimen found in 2013 but habitat at site subsequently cleared (Erickson et al. 2019). After our study concluded, a specimen was found nearby.
6	†	**Boca del Río Santo Tomás** (31.535°, −116.659°, 2 m). 1947 LACM. Now degraded, high salinity, no apparent habitat.
Microtus californicus grinnelli		
7	✓	**El Rayo** (31.980°, −115.979°, 1560 m). 1905 USNM. El Rayo now heavily grazed. We trapped successfully at nearby Laguna Seca (31.930°, −115.917°, 1690 m) where grazing was less intense.
8	✓	**Sangre de Cristo** (31.874°, −116.144°, 820 m). 1927 SDNHM. A large tule swamp; *Microtus californicus* captured in 1996 by E. Mellink (Harper et al. 2016). Trapped successfully, abundant.
9	†	**La Grulla (Las Ánimas Canyon)** (31.632°, −116.430°, 210 m). 1925 SDNHM. Now degraded habitat, infested with tamarisk, no sign.
10	†	**Valle de la Trinidad, west end** (31.388°, −115.783°, 730 m) and **López Mateos** (31.410°, −115.735°, 830 m). 1927 SDNHM. First site now heavily grazed, saline stream, settlement nearby, degraded habitat, no sign; second site now an urban settlement.
Microtus californicus huperuthrus		
11	†	**Rancho Las Tinajas** (31.172°, −115.545°, 1695 m). 1905 USNM. Water has disappeared, no apparent habitat.
12	✓	**Río de San Rafael** (31.087°, −115.620°, 1295 m). 2013 UABC. Subspecies assigned by continuity with the historical sites to the north and south. Now heavily grazed, with appropriate habitat. Trapped 3 nights, unsuccessfully.
13	–	**Aguaje de las Fresas** (31.069°, −115.544°, 1970 m). 1902 FMNH. Did not visit due to security concerns.
14	†	**Vallecitos** (31.018°, −115.489°, 2425 m). 1902 FMNH, 1905 USNM, 1925 MVZ. Lower end of valley, where water came to the surface. Now heavily grazed, no water flow, no apparent habitat.
15	?	**Rancho Concepción** (31.005°, −115.615°, 1460 m). 1925 MVZ. Along the arroyo in front of the ranch. Now heavily grazed with limited appropriate habitat. Trapped 3 nights, unsuccessfully.
16	?	**La Corona** (30.962°, −115.603°, 1750 m), and **La Canoa Creek near La Jolla** (30.928°, −115.583°, 1560 m). 1923 AMNH, 1923 SDNHM. These 2 locations are about 4 km apart. We visited La Jolla about 800 m north of La Canoa Creek, and found favorable but heavily grazed habitat. Trapped 3 nights, unsuccessfully.
17	?	**La Encantada** (30.900°, −115.410°, 2125 m). 1893 AMNH & UCM. Now heavily grazed with limited appropriate habitat. Trapped 1 night, unsuccessfully.
18	✓	**La Grulla (SSPM)** and **Rancho Viejo** (30.884°, −115.439°, 2080 m). 1902 FMNH; 1923 AMNH, MCZ & SDNHM; 1925 MVZ & UCLA. Trapped successfully during 3-year break in otherwise heavy grazing by cattle.

TABLE 1. Continued.

Site	Status	Site description
19	✓	**Rancho Santo Tomás** (SSPM) (30.773°, −115.388°, 1775 m). 1905 USNM. Now moderate grazing with good habitat. Trapped successfully.
Microtus californicus aequivocatus		
20	?	**Rancho San José** (30.971°, −115.742°, 635 m). 1925 MVZ, 1926 SDNHM. Now appropriate habitat but heavily grazed and no sign. Trapped 1 night, unsuccessfully.
21	–	**Las Cabras** (30.950°, −115.882 W, 210 m). 1923 SDNHM. Unable to access.
22	✓	**San Telmo** (30.949°, −115.972°, 142 m). 1905 USNM, 1925 MVZ, 1925 UCLA, 1926 UMMZ. The MVZ specimens were collected in the valley above the narrows, which was then an extensive wetland but is now completely destroyed by agriculture. We found poor, but seemingly ungrazed, habitat downstream at 30.977°, −116.096°, 80 m, noted sign of voles, and trapped successfully.
23	✓	**San Antonio** (30.818°, −115.630°, 555 m). 1902 FMNH, 1905 USNM. Habitat appears to be good, moderately grazed. Trapped successfully.
24	†	**Boca del Río Santo Domingo** (30.720°, −116.040°, 2 m). 1925 MVZ. Terminal lagoon now saline, no habitat.
25	†	**Laguna Santa María** (30.402°, −115.909°, 2 m). 1902 FMNH, 1905 USNM, 1953 SDNHM. Now desiccated, no habitat.
26	†	**El Socorro** (30.317°, −115.822°, 2 m). 1905 USNM. Terminal lagoon now desiccated, no habitat.
27	†	**El Rosario** (30.054°, −115.725°, 20 m). 1906 MCZ, 1925 SDNHM, 1926 LACM, 1930 MVZ. No habitat found at historical collecting sites, but given the areal extent of the valley (>40 km^2), there may be some remnant habitat that we did not encounter.
28	?	**San Fernando Velicatá** (29.970°, −115.238°, 455 m). 1930 MVZ. Now moderately grazed with limited appropriate habitat but no sign. Trapped 3 nights, unsuccessfully.

TABLE 2. Summary of known occurrences of subspecies of *Microtus californicus* in Baja California (all except *M. c. sanctidiegi* are endemic to Baja). For each subspecies, the number of historical sites is shown, along with the number of sites visited in this study, the number at which we found habitat that appeared favorable for voles, and the number at which the continued presence of the species is confirmed.

Subspecies	Sites known	Visited	Potential habitat	Confirmed presence
sanctidiegi	6	6	0	0[a]
grinnelli	4	4	2	2
huperuthrus	9	8	6	3
aequivocatus	9	8	4	2

[a]Though the site Planicie de Maneadero was cleared in 2015 (Erickson et al. 2019), a specimen was found nearby in 2019 after the termination of this study (see text).

mouths of seasonal rivers, which may have become saline at certain times of year. Although there are few reports on the salinity, it seems that historical collections at these sites were made when the lagoons were fresh or estuarine. Today we find that these sites either do not have lagoons (Boca del Río Santo Domingo, Laguna Santa María, El Socorro), or have lagoons that appear to be saline year-round (Boca del Río Santo Tomás), with shorelines of typical salt-marsh vegetation and mudflats.

We used our surveys and the historical descriptions of the sites to try to understand the causes of the reduction of *Microtus californicus* in Baja California. At 15 locations, freshwater inputs have been reduced (La Misión; El Rayo; Valle de la Trinidad, west end; La Encantada, probably; San Telmo; El Rosario; and San Fernando Velicatá) or completely eliminated (Macho Güero Valley, Real del Mar, Boca del Río Santo Tomás, Rancho Las Tinajas, Vallecitos, Boca del Río Santo Domingo, Laguna Santa María, and El Socorro). At 11 locations, heavy grazing has negatively affected available food and cover for voles (El Rayo; Valle de la Trinidad, west end; Río de San Rafael; Vallecitos; Rancho Concepción; La Jolla; La Encantada; La Grulla (SSPM); Rancho San José; San Antonio; and San Fernando Velicatá). Urban, agricultural, and recreational developments have probably reduced or eliminated 6 populations (Tecate Valley, Real del Mar, Planicie de Maneadero, La Grulla [Las Ánimas Canyon], López Mateos, and Laguna Santa María).

DISCUSSION

We confirmed the continued survival of all 3 Baja California–endemic subspecies of voles, albeit at only 2 or 3 sites for each taxon. However, the subspecies *sanctidiegi* (not known to be threatened in the United States) could not be confirmed (see footnote on page 195).

At this time, only 1 of the 28 historical sites in Baja California is known to have an abundant population of voles (*M. c. grinnelli* at Sangre de Cristo). None of these populations are secure (even the populations in national parks are threatened by overgrazing).

We think that this apparent decline indicates a real and dramatic reduction in the actual density and distribution of voles in Baja California, and that it cannot be attributed to other known mechanisms, such as sporadic sampling of populations that cycle from dense to sparse. While no studies have been done in Baja California, in California this vole is known to have populations that exhibit dramatic changes in population density on an annual and superannual basis (Krebs 1966, Pearson 1966, Batzli and Pitelka 1971, Lidicker 1973, Garsd and Howard 1981, Bowen 1982, Cockburn and Lidicker 1983, Heske et al. 1984, Ostfeld et al. 1985, Ostfeld 1986). Nearly all of these studies were made in annual and perennial grasslands as well as inland coastal scrub, habitats that are dissimilar to the known occurrences of voles in Baja California. It appears that none of the study sites with population cycling were grazed by domestic animals, and 2 studies (Garsd and Howard 1981, Bowen 1982) specifically mention that the absence of grazing was necessary in order to allow the observed changes in population density. The one study made in a coastal environment that is arguably similar to that of coastal populations in Baja California (Brooks Island, Alameda County; Lidicker 1973) showed biennial cycles that moderated, but were much smaller than, the annual population cycle.

While we have no data about annual cycles in population size in Baja California, our current and historical samples were made at what seemed like seasonally appropriate times (i.e., late winter through early summer in lower-elevation sites, and after snow and frost were absent from higher-elevation sites). We do not believe that seasonal sampling differences can explain the dramatic differences in apparent population density reported here.

It has been amply demonstrated that grazing can depress vole (*Microtus* spp.) populations to low or undetectable levels (Eadie 1953, Jones et al. 2003, Steen et al. 2005, Evans et al. 2006, Johnson and Horn 2008, Johnston and Anthony 2008, Mellink and Contreras 2014, Evans et al. 2015, Horncastle et al. 2019, Lagendijk et al. 2019), and this is reflected by field scientists stating that the heavy grazing seen in Baja California, especially in mountain meadows, has depressed populations and made trapping unfruitful (Huey 1916–1953 [26 May 1922, 10 June 1923], Borell 1925 [6 June 1925], Grinnell 1925 [2 October 1925], Benson 1949 [24 July 1949], Mellink and Contreras 2014).

Cattle were introduced into the Sierra San Pedro Mártir when a mission was established in 1794 (Nieser 1960). Private herds of cattle (at one time perhaps numbering over 6000 head) have been driven in summer to the meadows of the Sierra San Pedro Mártir since at least 1828. Sheep were also grazed there until 1964 (Gabb 1869, Pleasants 1965, Henderson 1964, Meling 1991).

The loss of fresh water at many of the sites is also a likely reason for the decline in other California vole populations. This reason has been noted anecdotally by collectors who revisited historical locations in Baja California (Lidicker 1973–1974 [10 December 1974]), and in the field notes of nearly all Baja California collectors, which stress the need for water and wetland vegetation for success in trapping this vole.

It could be argued that the reason historical densities were high at some locations, where now the populations are undetectable, is due to natural cycles in this animal's numbers. The fact that we found little if any habitat at these locations suggests that the populations are permanently reduced or eliminated unless habitat is restored.

Although we do not have exact measures of historical trapping effort, it is illustrative to see how much more effective trapping was when apparent habitat was present than when it was absent: at Macho Güero Valley, Lamb (1927 [16–22 November 1927]) was able to trap 6 voles in 7 nights and 250 trap-nights. He described the habitat as follows: "This is not really a valley but is a very shallow depression. … At the north end … there is a large spring, or rather a series of springs, making a damp marshy area of about 75 yards in diameter from which a small stream flows." When Lidicker (1973–1974 [10 December 1974]) visited the valley 47 years later, he found a few willows but no marsh, sedges, or water. He noted, "We can imagine that these meadows and stream course could have had cover suitable for *Microtus* in the past, but not now." Lidicker set 39 traps in a nearby valley and caught no *Microtus*. When we visited in 2017, we found that the site appeared similar to Lidicker's description.

At Vallecitos, in the Sierra San Pedro Mártir, Heller (1902 [23 September–6 October 1902]) said, "*Microtus* common along the creek in grassy places & soft earth." In 1905, Nelson (1921) collected 5 animals in one night's trapping, and he described the habitat as "where in the arroyo a little water comes to the surface." Borell (1925 [1–11 June 1925]) trapped 3 animals over 11 d in 1925, noting, "The meadow and creek are all dry or nearly so and the cattle keep the scant grass grazed down very short." In 2018, we found only dry ground and no habitat or sign of *Microtus*.

At La Grulla (SSPM), only one of 3 early explorers found *Microtus*, even though all of them trapped for small mammals at this site—Heller was successful in 1902, but not Anthony in 1893 or Nelson in 1905 (Allen 1893, Heller 1902 [5–22 September 1902], Nelson 1921, NMNH 2018, VertNet 2018). Nelson and subsequent biologists noted poor, overgrazed habitat at La Grulla, and for this reason visitors after Nelson did not attempt to trap for *Microtus* at the west end of this large meadow (Nelson 1921, Huey 1916–1953 [with A.W. Anthony on 10 June 1923], Borell 1925 [12 June 1925], Grinnell 1925 [2 October 1925]), although Huey, Anthony, and Grinnell did find *Microtus* in a stream beyond the east end of this meadow, where grazing was described as less intense. In 2011, Mellink and Riojas-López searched intensively for *Microtus* for 9 d, in spite of heavy grazing and the absence of sign, but they did not detect any animals with either trapping or game cameras (Harper et al. 2016). In 2013 and 2014, A. Peralta-García and J.H. Valdez-Villavicencio visited this site and also noted intensive grazing and no sign of *Microtus*. In 2015, no cattle were found in this meadow due to a grazing quarantine; we searched this meadow intensively but saw no sign, but we were able to trap one vole in a nearby meadow. In 2017, the third year with apparently no grazing, we found tall grass and captured 13 animals in one night. We have been told that grazing returned to its previous intensity after 2017.

For all of these reasons, we think that the declines reported here are caused by changes in habitat, especially due to grazing pressure and the availability of surface water and forage and not due to natural fluctuations in population density.

While the relative importance of the reasons for declines can only be speculated at this time, it is clear that they interact; excessive grazing has been shown to cause increased evaporation and runoff, as well as the loss of wetland habitat, in many environments (Rich and Reynolds 1963, Gifford and Hawkins 1978, Warren et al. 1986, Greene et al. 1994, Evans 1998, Lovich and Bainbridge 1999, Mellink and Contreras 2014). We suspect that by this mechanism, grazing may have eliminated freshwater inputs at Macho Güero Valley and Vallecitos. At other sites, the reduction or elimination of fresh water (and salinization of the water that is available) can be attributed to irrigated agriculture upstream. The inflow of saline agricultural wastewater eliminates many of the food plants of *Microtus* and may also directly affect the survival of an animal that requires abundant drinking water (Church 1966, Coulombe 1970). The spread of weeds, particularly tamarisk (*Tamarix* spp.), probably also contributes to the loss of habitat.

The history at Rancho Las Tinajas is less clear; Nelson (1921) mentions that the ranch had already undergone a major loss of water by 1905. Today, even though there are no signs of disruption of flow, there is neither surface nor (we are told) subsurface water available. Perhaps this is a site that has been altered by natural geological processes or secular changes in climate and not by human and bovine disturbance.

Conclusion

We have documented a striking decline in the numbers of *Microtus californicus* in Baja California over the past century and more. The known occurrence of the species has declined from 28 sites to a minimum of 7 sites, many of which have sparse populations and low capture rates. We believe that *M. californicus* has been effectively or actually extirpated from at least 50% of the sites that it was known from. The diminishment and loss of these populations has removed a once-common, if localized, prey animal from much of its original range in Baja California.

Of the sites where we found voles, only one seems to support a healthy population that approaches its historical abundance: Sangre de Cristo, with the endemic subspecies *grinnelli*. Sangre de Cristo is privately owned, and, given that it appears to be one of the few relatively intact freshwater wetlands outside of the Sierra San Pedro Mártir, conservation of this site could benefit many species that are threatened in Baja California. The other site with high trapping success, La Grulla (SSPM), had a detectable population only when grazing was abated for 3 years. If grazing there has returned to its historically high level, the population has probably declined.

The California vole should be a prime target species for protection and restoration of habitat in Baja California. As has been stated many times, overgrazing is one threat to this species that could be easily minimized through controlling cattle and fencing wetlands. This is especially true in national parks, where commercial grazing is contrary to Mexican law (CONANP 2006).

Restoration of remnant wetlands is another mechanism to protect this species in Baja California. Currently, 2 of us (A. Peralta-García and J.H. Valdez-Villavicencio) are restoring ponds at Rancho San José in order to enhance red-legged frog (*Rana draytonii*) populations. We hope that these restoration efforts may have broader effects on bringing back many wetland species, including *Microtus californicus*.

Supplementary Material

One online-only supplementary file accompanies this article (https://scholarsarchive.byu.edu/wnan/vol80/iss2/7).

Supplementary Material 1. Twenty-eight historical collection sites for *Microtus californicus* (California vole, CAVO) in Baja California, Mexico, are georeferenced; historical collections and descriptions are summarized; and, when possible, sites were visited to evaluate habitat and possible continued presence of CAVO. When the habitat indicated that detection of CAVO seemed possible, we trapped for up to 3 nights to try to confirm the presence of voles.

Material Suplementario 1. Veintiocho sitios históricos de colecta para *Microtus californicus* (Meteoro de California, CAVO) en Baja California, México son georreferenciados, se resumen colectas y descripciones históricas, y cuando fue posible, los sitios fueron visitados para evaluar el hábitat y la posible presencia de CAVO. Cuando el hábitat indico la posible detección de CAVO, trampeamos hasta 3 noches para intentar confirmar la presencia de meteoros.

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Literature Cited

Ackerman, J.T. 2002. Of mice and mallards: positive indirect effects of coexisting prey on waterfowl nest success. Oikos 99:469–480.

Allen, J.A. 1893. On a collection of mammals from the San Pedro Martir region of Lower California: with notes on other species, particularly of the genus *Sitomys*. Bulletin of the American Museum of Natural History 5:181–202.

[AMNH] American Museum of Natural History. 2018. Vertebrate zoology collection database. [Accessed 8 September 2018]. http://sci-web-001.amnh.org/db/emuwebamnh/

Arctos. 2018. Specimen search. [Accessed 8 September 2018]. https://arctos.database.museum/

Batzli, G.O., and F.A. Pitelka. 1971. Condition and diet of cycling populations of the California vole, *Microtus californicus*. Journal of Mammalogy 52:141–163.

Benson, S.B. 1949. v535, Section 1: Journal Calif: Lassen-Modoc trip; Mexico: Baja [field notes]. MVZ Archives, Museum of Vertebrate Zoology, University of California, Berkeley, CA.

Bleich, V.C. 1979. *Microtus californicus scirpensis* not extinct. Journal of Mammalogy 60:851–852.

Borell, A. 1925. v540, Section 2: Journal: Lower California, Mexico [field notes]. MVZ Archives, Museum of Vertebrate Zoology, University of California, Berkeley, CA.

Bowen, B.S. 1982. Temporal dynamics of microgeographic structure of genetic variation in *Microtus californicus*. Journal of Mammalogy 63:625–638.

[CNDDB] California Natural Diversity Database. 2019. Special animals list. California Department of Fish and Wildlife, Periodic Publication. 67 pp.

Church, R.L. 1966. Water exchanges of the California vole, *Microtus californicus*. Physiological Zoology 39: 326–340.

Cockburn, A., and W.Z. Lidicker Jr. 1983. Microhabitat heterogeneity and population ecology of an herbivorous rodent, *Microtus californicus*. Oecologia 59: 167–177.

[CONANP] Comisión Nacional de Áreas Naturales Protegidas. 2006. Programa de conservación y manejo, Parque Nacional Sierra de San Pedro Mártir, México. Comisión Nacional de Áreas Naturales Protegidas, Mexico, DF. 174 pp.

Conroy, C.J., J.L. Patton, M.C.W. Lim, M.A. Phuong, B. Parmenter, and S. Höhna. 2016. Following the rivers: historical reconstruction of California voles *Microtus californicus* (Rodentia: Cricetidae) in the deserts of eastern California. Biological Journal of the Linnean Society 119:80–98.

Coulombe, H.N. 1970. The role of succulent halophytes in the water balance of salt marsh rodents. Oecologia 4:223–247.

Cudworth, N.L., and J.L. Koprowski. 2010. *Microtus californicus* (Rodentia: Cricetidae). Mammalian Species 42:230–243.

Eadie, W.R. 1953. Response of *Microtus* to vegetative cover. Journal of Mammalogy 34:263–264.

Elliot, D.G. 1903. Descriptions of apparently new species and subspecies of mammals from California, Oregon, the Kenai Peninsula, Alaska, and Lower California, Mexico. Zoological Series 3:153–173.

Erickson, R.A., E. Mellink, and G. Marrón. 2019. A new locality for the endangered *Microtus californicus* in Mexico, with clarification of the known distribution. Western North American Naturalist 79: 135–138.

Evans, D.M., S.M. Redpath, D.A. Elston, S.A. Evans, R.J. Mitchell, and P. Dennis. 2006. To graze or not to graze? Sheep, voles, forestry and nature conservation in the British uplands. Journal of Applied Ecology 43:499–505.

Evans, D.M., N. Villar, N.A. Littlewood, R.J. Pakeman, S.A. Evans, P. Dennis, J. Skartveit, and S.M. Redpath. 2015. The cascading impacts of livestock grazing in upland ecosystems: a 10-year experiment. Ecosphere 6(3):art42. 15 pp.

Evans, R. 1998. The erosional impacts of grazing animals. Progress in Physical Geography 22:251–268.

Gabb, W.M. 1869. Exploration of Lower California. Pages 82–122 *in* J.R. Browne, editor, Resources of the Pacific Slope: a statistical and descriptive summary of the mines and minerals, climate, topography, agriculture, commerce, manufactures, and miscellaneous productions of the states and territories west of the Rocky Mountains with a sketch of the settlement and exploration of Lower California. H.H. Bancroft, San Francisco, CA.

Garsd, A., and W.E. Howard. 1981. A 19-year study of microtine population fluctuations using time-series analysis. Ecology 62:930–937.

Gifford, G.F., and R.H. Hawkins. 1978. Hydrologic impact of grazing on infiltration: a critical review. Water Resources Research 14:305–313.

Greene, R.S.B., P.I.A. Kinnell, and J.T. Wood. 1994. Role of plant cover and stock trampling on runoff and soil-erosion from semi-arid wooded rangelands. Soil Research 32:953–973.

Grinnell, J. 1925. v1327, Section 3: Lower California, Mexico 1925 (Sept–Oct) [field notes]. MVZ Archives, Museum of Vertebrate Zoology, University of California, Berkeley, CA.

Grinnell, J. 1926. Critical examination of the meadow mice of Lower California. Journal of Mammalogy 7: 221–226.

Guevara-Carrizales, A.A., A. Peralta-García, J.H. Valdez-Villavicencio, C.R. Mahrdt, and G. Ruiz-Campos. 2016. Confirmation of the presence of *Microtus californicus* in Baja California, México. Western North American Naturalist 76:493–496.

Harper, A.B., E. Mellink, S. Tremor, and S. Vanderplank. 2016. Rediscovery of a high-altitude vole, *Microtus californicus*, in Baja California, Mexico. Southwestern Naturalist 61:333–338.

Heller, E. 1902. Baja California field notes, 1902, Feb. 16–Nov. 25 [field notes]. MSS 332, UCSD Library Special Collections, San Diego, CA.

Henderson, D.A. 1964. Agriculture and livestock raising in the evolution of the economy and culture of the state of Baja California, Mexico. Doctoral dissertation, University of California, Los Angeles, CA.

Heske, E.J., and W.Z. Lidicker Jr. 1999. California vole: *Microtus californicus*. Pages 626–628 *in* D.E. Wilson and S. Ruff, editors, Smithsonian book of North American mammals. Smithsonian Institution Press, Washington, DC.

Heske, E.J., R.S. Ostfeld, and W.Z. Lidicker Jr. 1984. Competitive interactions between *Microtus californicus* and *Reithrodontomys megalotis* during two peaks of *Microtus* abundance. Journal of Mammalogy 65:271–280.

Horncastle, V.J., C.L. Chambers, and B.G. Dickson. 2019. Grazing and wildfire effects on small mammals inhabiting montane meadows. Journal of Wildlife Management 83:534–543.

Huey, L.M. 1916–1953. Field notes [transcribed field notes]. Archives, San Diego Natural History Museum, San Diego, CA.

Huey, L.M. 1931. A new meadow mouse from Lower California, Mexico. Transactions of the San Diego Society of Natural History 7:47–50.

Johnson, M.D., and C.M. Horn. 2008. Effects of rotational grazing on rodents and raptors in a coastal grassland. Western North American Naturalist 68: 444–452.

Johnston, A.N., and R.G. Anthony. 2008. Small-mammal microhabitat associations and response to grazing in Oregon. Journal of Wildlife Management 72: 1736–1746.

Jones, Z.F., C.E. Bock, and J.H. Bock. 2003. Rodent communities in a grazed and ungrazed Arizona grassland, and a model of habitat relationships among rodents in southwestern grass/shrublands. American Midland Naturalist 149:384–394.

Kellogg, R. 1922. Change of name. Proceedings of the Biological Society of Washington 35:78.

Krebs, C.J. 1966. Demographic changes in fluctuating populations of *Microtus californicus*. Ecological Monographs 36:239–273.

Lagendijk, D.D.G., R.A. Howison, P. Esselink, and C. Smit. 2019. Grazing as a conservation management tool: responses of voles to grazer species and densities. Basic and Applied Ecology 34:36–45.

Lamb, C.C. 1927. v1420, Section 3: Lower California, Mexico, Expedition 8, Part 1 [field notes]. MVZ Archives, Museum of Vertebrate Zoology, University of California, Berkeley, CA.

Lidicker, W.Z., Jr. 1973. Regulation of numbers in an island population of the California vole, a problem in community dynamics. Ecological Monographs 43: 271–302.

Lidicker, W.Z., Jr. 1973–1974. v1442, Section 8: Catalogue #3305–#3391 California: Contra Costa, Kern Cos. Baja Calif. [field notes]. MVZ Archives, Museum of Vertebrate Zoology, University of California, Berkeley, CA.

Lovich, J.E., and D. Bainbridge. 1999. Anthropogenic degradation of the southern California desert ecosystem and prospects for natural recovery and restoration. Environmental Management 24:309–326.

Meling, D. 1991. La ganadería en la Sierra de San Pedro Mártir. Pages 9–12 *in* E. Franco-Vizcaíno and J. Sosa Ramírez, editors, Memorias de la conferencia internacional sobre la cordillera peninsular de las Californias como reserva de la biósfera [Resúmenes]: celebrada en Ensenada, Baja California, Marzo 18–19 de 1991. CICESE; Universidad Autónoma de Baja California; Universidad de California; Universidad Estatal de California, Ensenada.

Mellink, E., and J. Contreras. 2014. Impact of ranching on wildlife in Baja California. Pages 453–477 *in* E.V. Wehncke, J.R. Lara-Lara, S. Álvarez-Borrego, and E. Ezcurra, editors, Conservation science in Mexico's northwest: ecosystem status and trends in the Gulf of California. UC MEXUS, Riverside, CA.

Mellink, E., M. Riojas-López, and A.B. Harper. 2017. California vole, *Microtus californicus*. Pages 99–103 *in* S. Tremor, D. Stokes, W. Spencer, J. Diffendorfer, H. Thomas, S. Chivers, and P. Unitt, editors, The San Diego mammal atlas. San Diego Natural History Museum, San Diego, CA.

[NMNH] National Museum of Natural History, Smithsonian Institution. 2018. Mammals collection search. [Accessed 8 September 2018]. https://collections.nmnh.si.edu/search/mammals/

Nelson, E.W. 1921. Lower California and its natural resources. National Academy of Sciences, Washington, DC. Memoirs of the National Academy of Sciences. Manessier Publishing Company, Riverside, CA. 194 pp.

Nieser, A.B. 1960. The Dominican Mission foundations in Baja California. Doctoral dissertation, Loyola University, Chicago, IL. 349 pp.

Osgood, W.H. 1928. Why is a type specimen. Journal of Mammalogy 9:52–56.

Ostfeld, R.S. 1986. Territoriality and mating system of California voles. Journal of Animal Ecology 55: 691–706.

Ostfeld, R.S., W.Z. Lidicker Jr., and E.J. Heske. 1985. The relationship between habitat heterogeneity, space use, and demography in a population of California voles. Oikos 433–442.

Pearson, O.P. 1966. The prey of carnivores during one cycle of mouse abundance. Journal of Animal Ecology 217–233.

Pleasants, J.E. 1965. The cattle drives of Joseph E. Pleasants, from Baja California in 1867 and 1868. Baja California Travels Series, Volume 8. Dawson's Book Shop, Los Angeles, CA.

Rich, L.R., and H.G. Reynolds. 1963. Grazing in relation to runoff and erosion on some chaparral watersheds of central Arizona. Journal of Range Management 16:322–326.

[SEMARNAT] Secretaría de Medio Ambiente y Recursos Naturales. 2010. Norma Oficial Mexicana NOM-059-ECOL-2010, Protección ambiental—Especies nativas de México de flora y fauna silvestres—Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio—Lista de especies en riesgo. Diario Oficial Jueves 30 de diciembre de 2010:1–77.

[SEMARNAT] Secretaría de Medio Ambiente y Recursos Naturales. 2018. Proyecto de Modificación del Anexo Normativo III, Lista de especies en riesgo de la Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental—Especies nativas de México de flora y fauna silvestres—Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio—Lista de especies en riesgo, publicada el 30 de diciembre de 2010. [Accessed 21 August 2019]. http://dof.gob.mx/nota_detalle.php?codigo=5534594&fecha=13/08/2018.

Sikes, R.S., and the Animal Care and Use Committee of the American Society of Mammalogists. 2016. 2016 Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. Journal of Mammalogy 97:663–688.

Steen, H., A. Mysterud, and G. Austrheim. 2005. Sheep grazing and rodent populations: evidence of negative interactions from a landscape scale experiment. Oecologia 143:357–364.

VertNet. 2018. VertNet–Home. [Accessed 8 September 2018]. http://vertnet.org/

Warren, S.D., T.L. Thurow, W.H. Blackburn, and N.E. Garza. 1986. The influence of livestock trampling under intensive rotation grazing on soil hydrologic characteristics. Journal of Range Management 39: 491–495.

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