Wildlife Society Bulletin 44(3):610–616; 2020; DOI: 10.1002/wsb.1103

Tools and Technology

Evaluation of Noninvasive Survey Methods for Detecting Endangered Shrews

ERIN N. TENNANT,[1] *California Department of Fish and Wildlife, Central Region, Lands Unit, 1234 E Shaw Avenue, Fresno, CA 93710, USA*
BRIAN L. CYPHER, *California State University, Stanislaus, Endangered Species Recovery Program, One University Circle, Turlock, CA 95382, USA*
LAWRENCE R. SASLAW, *California State University, Stanislaus, Endangered Species Recovery Program, One University Circle, Turlock, CA 95382, USA*
TORY L. WESTALL, *California State University, Stanislaus, Endangered Species Recovery Program, One University Circle, Turlock, CA 95382, USA*
JACKLYN L. MOHAY,[2] *California Department of Fish and Wildlife, Central Region, Lands Unit, 1234 E Shaw Avenue, Fresno, CA 93710, USA*
ERICA C. KELLY, *California State University, Stanislaus, Endangered Species Recovery Program, One University Circle, Turlock, CA 95382, USA*
CHRISTINE L. VAN HORN JOB,[3] *California State University, Stanislaus, Endangered Species Recovery Program, One University Circle, Turlock, CA 95382, USA*

ABSTRACT Using traditional capture methods, shrews typically have low capture and high trap-mortality rates. To reduce effects from live-trapping and attempt to increase detection success, we investigated 3 potential noninvasive survey methods for shrews (Soricidae): track tubes, scat tubes, and camera traps. These 3 techniques were tested in areas of the San Joaquin Valley, California, USA, with high detection rates of shrews during previous live-trapping surveys. We found that Reconyx camera traps specifically modified with a close focal distance resulted in the greatest number of positive detections and outperformed all other survey methods. Scat tubes also resulted in positive detections but were less reliable and required more expertise. Track tubes resulted in no positive detections. Use of camera traps is highly recommended for conducting presence–absence surveys for shrews.

KEY WORDS Buena Vista Lake shrew, camera trap, noninvasive survey, scat tube, shrew, *Sorex ornatus relictus*, track tube.

When surveying for any wildlife species, but particularly an endangered species, use of noninvasive survey techniques may be desirable to prevent possible injury or death. For small mammals, and particularly for shrews (Soricidae), live-trapping in Sherman-style box traps or using pitfall traps are common detection techniques (Kirkland and Sheppard 1994, Sikes et al. 2016). However, detecting shrews using these techniques is challenging because of low capture and high trap-mortality rates (e.g., Yunger et al. 1992, Kirkland and Sheppard 1994, Hays 1998, Do et al. 2013, Smith et al. 2017). Trap mortality rates as high as 93% (Shonfield et al. 2013), 90% (Getz 1961), and 68% (Greenberg et al. 2007) have been reported for *Sorex* species. Furthermore, capture-related mortalities are even more problematic when working with a rare and federally listed species where special permits are required for take (i.e., capture). To reduce impacts from live-trapping and attempt to increase detection success, we investigated 3 potential noninvasive survey methods for shrews: track tubes, scat tubes, and camera traps.

Our study species was the Buena Vista Lake shrew (*Sorex ornatus relictus*), which is 1 of 9 subspecies of the ornate shrew (*S. ornatus;* Merriam 1895, Maldonado et al. 2004). The historical range of *S. o. relictus* included the interconnected seasonal and permanent lakes, wetlands, sloughs, and marshes around historic Tulare, Kern, and Buena Vista lakes in the Tulare Basin of the San Joaquin Valley, California, USA. It is the only species of *Sorex* found in this region. By the early 1900s, when *S. o. relictus* was first described, diversion, draining, and dredging of the rivers and wetlands of the Tulare Basin for agricultural development had already begun to affect shrew populations (Grinnell 1932). Today, approximately 90–95% of riparian and wetland habitat in the San Joaquin Valley has been lost (Kelly et al. 2005, U.S. Fish and Wildlife Service [USFWS] 2011), leaving only isolated remnants of habitat where *S. o. relictus* still persists. Consequently, *S. o. relictus* was listed as endangered under the 1973 Endangered Species Act in 2002 (USFWS 2011). The rarity and difficulty in detection of *S. o. relictus* has contributed to a lack of information on basic aspects of their ecology, distribution, and status.

Received: 1 February 2019; Accepted: 2 January 2020
Published: 22 June 2020

[1]*E-mail: erin.tennant@wildlife.ca.gov*
[2]*Current affiliation: Moss Landing Marine Labs, 8272 Moss Landing Road, Moss Landing, CA 95039, USA*
[3]*Current affiliation: McCormick Biological, Incorporated, 3600 Pegasus Drive, Suite 12, Bakersfield, CA 93308, USA*

Shrews and other very small mammals (approx. <10 g mass) have been detected using noninvasive methods including track tubes and camera traps (Brehme et al. 2010, Soininen et al. 2015). Track identification stations have been successfully used to survey a wide range of taxa for many years, but the use of camera traps in wildlife studies has only recently become more widespread (Rowcliffe and Carbone 2008, Rovero and Zimmermann 2016). Although camera traps are most commonly used in studies of large mammals (Mills et al. 2016), the field is rapidly expanding to apply to small mammals, lizards, and even large invertebrates (e.g., Soininen et al. 2015, Diggins et al. 2016, Mills et al. 2016, Noble et al. 2016, Hobbs and Brehme 2017). However, the efficacy of these noninvasive techniques, especially for shrews, has not been previously evaluated. Based on our initial trials, we predicted that modified automated camera traps would be the best detection method for *S. o. relictus*.

STUDY AREA

This research took place in the southern San Joaquin Valley, California. This area was within the region known as the San Joaquin Desert (Germano et al. 2011). The regional climate was Mediterranean in nature, and characterized by hot, dry summers, and cool, wet winters with frequent fog. Mean maximum and minimum temperatures were 35° C and 18° C in summer, and 17° C and 5° C in winter. Annual precipitation averaged approximately 150 mm and occurred primarily as rain falling between October and April (National Oceanic and Atmospheric Administration 2002). Habitat types associated with *S. o. relictus* included wetland and riparian areas that have moist soil and dense cover of either herbaceous vegetation or leaf litter (USFWS 2011). Typical vegetation of sites with *S. o. relictus* included Fremont cottonwood (*Populus fremontii*), willows (*Salix* spp.), mulefat (*Baccharis salicifolia*), alkali heath (*Frankenia salina*), wild rye (*Elymus* spp.), saltgrass (*Distichlis* spp.), rushes (*Juncus* spp.), and cattails (*Typha* spp.). We used 3 sites with known *S. o. relictus* populations to test noninvasive techniques: Kern National Wildlife Refuge (KNWR), Northern Semitropic Ridge Ecological Reserve (NSRER) and adjacent private lands, and Wind Wolves Preserve (WWP; Fig. 1).

METHODS

We evaluated noninvasive survey methods for *S. o. relictus* while completing a range-wide status survey (Cypher et al. 2017). During the status survey, the detection technique we primarily used was live-trapping in small Sherman aluminum box traps (5.1 × 6.4 × 16.5 cm; H.B. Sherman Traps, Inc., Tallahassee, FL, USA). Once we established that *S. o. relictus* was present at a site, we deployed our noninvasive survey techniques to determine detection efficacy. All live-trapping of *S. o. relictus* was completed in accordance with the standard animal care and use principles of the American Society of Mammologists (Sikes et al. 2016) and a 10(a)(1)(A) Endangered Species Recovery Permit (TE-023496 to California State University, Stanislaus) or a Memorandum of Understanding (to the California Department of Fish and Wildlife) issued by the United States Fish and Wildlife Service.

Track Tubes

Track tubes consisted of 2 15-cm-long polyvinyl chloride (PVC) pipes (6-cm diameter) connected by a 10-cm-long 45° elbow. We used a 6-cm tube diameter and a 45° elbow to connect the 2 PVC pipes to provide some safety for shrews within the tube (the elbow prevented predators from seeing directly through the tube) and encourage shrews to spend more time investigating the tube. We placed a wood block (5 cm × 5 cm; flat on the top and curved on the bottom to conform to the shape of the tube) just inside each end of the tube. The block was held in place by a bolt through both the wood and the PVC tube and secured with a wing nut. We wrapped a piece of felt around each block and secured with duct tape. Using a syringe, we saturated each piece of felt with a tracking medium consisting of 2 parts lamp black and 5 parts mineral oil. We placed white notecards (7.5 × 12.5 cm) between the wood blocks and the elbow. We placed 6–12 dried mealworms in the elbow of the tube as bait. We used dried mealworms so that we did not have to contain live mealworms inside the tube. Shrews entering the tube to get the worms would need to cross the felt pieces, pick up tracking medium on their feet, and cross over the notecards, thereby recording their tracks. To aid in track identification, we obtained known *S. o. relictus* tracks by setting a captured *S. o. relictus* on one of the ink-soaked felt pieces or an ink pad, and then allowing it to run across a recording paper. To identify tracks collected in the field, we consulted several wildlife tracking guides (e.g., Kays and Wilson 2002, Lowery 2013).

We tested track tubes during August–October 2014 at the WWP. We set track tubes at 20 locations for 6 nights each. After 3 days, we replaced the notecards with new cards. We considered a track tube to have detected *S. o. relictus* if ≥1 track could be positively identified as a *S. o. relictus* track. Figures of track tubes and tracks can be found in the online supporting material for this article.

Scat Tubes

Scat tubes consisted of a modified design of the track tubes. We used 2 30-cm-long PVC pipe pieces (6-cm diameter) that were connected by a 10-cm-long 45° elbow. The longer length tubes gave shrews entering the device more time to deposit scats. We taped a piece of white paper 28.5 × 10.5 cm to the inside bottom of each tube. As with the track tubes, we placed 6–12 dried mealworms in the elbow when we placed the scat tube in the field.

To aid in scat identification, we obtained known *S. o. relictus* scats by allowing captured shrews to run around inside the tubes. Also, we collected scats from traps in which *S. o. relictus* had been captured. We used a dissecting microscope to identify *S. o. relictus* scats. We found that scats of *S. o. relictus* appeared to consist exclusively of invertebrate remains with no vegetation. Also, the scats seemed to be less well-formed compared with rodent feces.

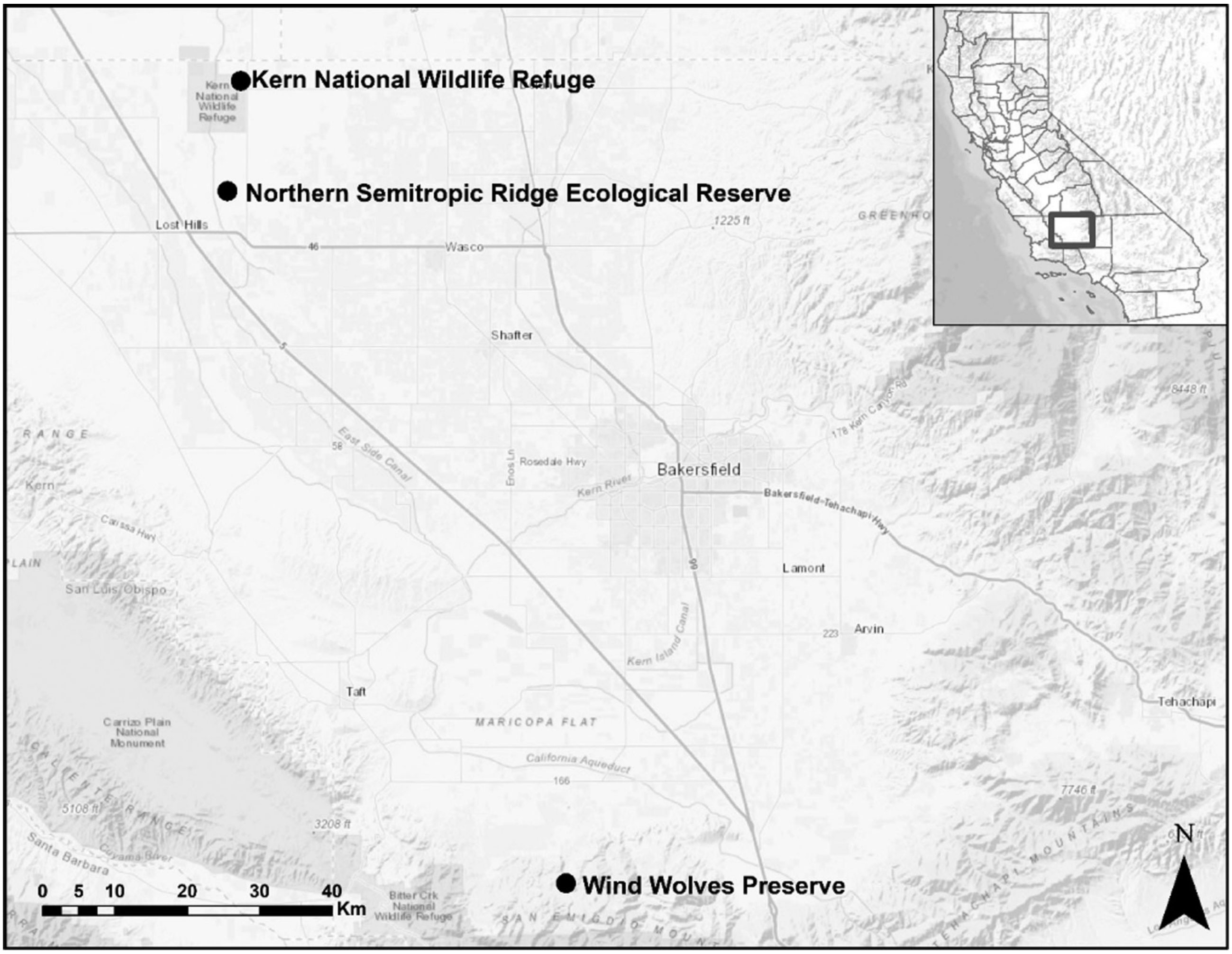

Figure 1. Locations of noninvasive survey technique tests for Buena Vista Lake shrew (*Sorex ornatus relictus*) in Kern County, California, USA. Surveys occurred during August–October 2014 and October 2016 at Kern National Wildlife Refuge, Northern Semitropic Ridge Ecological Reserve, and Wind Wolves Preserve.

We tested scat tubes in October 2016 at the WWP, NSRER, and KNWR. We set scat tubes at 10 locations at each site. We operated the tubes for 3 nights at Kern NWR and NSRER, and 2 nights at WWP. We considered a scat tube to have detected *S. o. relictus* if ≥1 scat could be positively identified as *S. o. relictus* scat. Figures of scat tubes and scats can be found in the online supporting material for this manuscript.

Automated Camera Stations

We experimented with several different camera models, including Reconyx HC800 Professional HyperFire Covert Camera Traps (Reconyx Inc., Holmen, WI, USA), Bushnell Trophy Cameras (several models; Bushnell Outdoor Products, Overland Park, MO, USA), Moultrie Wingscapes Birdcam Pros (EBSCO Industries, Inc., Calera, AL, USA), and a self-made camera trap built by a colleague. We were able to detect shrews on several of these camera models, but the quality of the images on the commercially available cameras was mediocre because the camera focal distance is set for larger wildlife typically detected at longer focal distances. After discussion with colleagues and completing a literature review, we determined that other studies were successfully detecting small mammals using cameras with a modified focal distance (McCleery et al. 2014, Soininen et al. 2015). We contacted Reconyx Inc. and requested that their standard Reconyx HC800 Professional HyperFire Covert Camera Trap, which is a motion-activated, infrared field camera, be altered to a close-focal distance of 40 cm (approx. 16 in) to obtain clearer images of small animals. We experimented with various settings on the cameras and found that the optimal setting to obtain multiple clear images of *S. o. relictus* was to capture 5 images in rapid-fire fashion on the fast shutter speed setting. The fast shutter setting programs the camera to reduce the range of the flash and reduce motion blur. We attached each camera to a 0.5-m metal t-post and positioned it approximately 20 cm off the ground. We trimmed or removed all vegetation in the area directly in front of the camera station so that we could place bait and get clear images of our target species (Fig. 2).

We experimented with several types of bait stations, including setting cameras without bait, using sunflower seeds, using only dried mealworms, and using a small

Figure 2. Example setup of a Reconyx close-focus automated camera station to detect Buena Vista Lake shrew *(Sorex ornatus relictus)* at Wind Wolves Preserve, Kern County, California, USA, in October 2016. The camera was attached approximately 20 cm off the ground to a 0.5-m metal t-post. To attract *S. o. relictus,* a small plastic container (approx. 9-cm diameter, approx. 7 cm deep) filled with polyester fiber batting and approximately 10 live mealworms was buried and pinned to the ground with a 15-cm nail. We placed approximately 30 dried mealworms on top of the container. Bait stations were positioned approximately 50 cm in front of each camera.

container to hold live mealworms (*Tenebrio molitor*). We found that the optimal bait station was a small plastic container with a lid (approx. 9 cm diameter, approx. 7 cm deep) that was buried in ground and pinned down with a 15-cm nail to inhibit removal by nontarget animals. We placed approximately 10 live mealworms and a small amount of polyester fiber batting inside the bait container. The bait container had a lid so that the mealworms could not escape, and we poked a few small holes in the lid to allow air to enter the container. The mealworms in the container provided scent and sound as an attractant for shrews, which was our intent because shrews may use both olfactory and auditory cues to find food (Pernetta 1977, Churchfield 1980). On top of the containers, we placed approximately 30 dried mealworms as an additional attractant. The dried mealworms also provided a food reward. Given the high metabolic rates of shrews, we felt that such a reward was important because *S. o. relictus* individuals were being distracted from their normal foraging patterns to investigate the bait stations. The bait container was buried so that the top was flush with the ground and would not obstruct the camera's view. We noticed that at some sites with very wet soils, the small plastic container would become filled with water. At these sites we found that using an additional bait container consisting of a metal tea infuser ball that was pinned to the ground with either a 15-cm nail or a landscape-style stake was effective. We positioned the bait stations approximately 50 cm in front of each camera.

We tested camera traps at the same times and locations as the scat tubes and placed them so that the scat tubes were in the view of the camera trap. We considered a camera trap to have detected *S. o. relictus* if ≥1 photo could be positively identified as the species.

RESULTS

We collected 40 notecards from the track tubes. We were unable to positively identify tracks of *S. o. relictus* on any of the notecards. We set 30 scat tubes and were able to positively identify *S. o. relictus* scats in 11 of the tubes (36.7%). We set 30 camera stations, but 2 cameras at KNWR and 1 camera at NSRER malfunctioned because of improper factory settings. Excluding these cameras from analyses, *S. o. relictus* was detected on 24 of 27 (88.9%) camera stations. Of the 24 stations with detections, *S. o. relictus* was detected on the first night at 21 stations (87.5%) and on the second night at the remaining 3 stations (12.5%). The 24 camera traps that detected shrews included the 11 scat tube stations that had positive detections.

DISCUSSION

As we predicted, camera traps proved to be a very effective technique for detecting *S. o. relictus*. Scat tubes also resulted in positive detections. Track tubes were the least effective method and had no positive detections.

Track tubes were a problematic detection technique for 2 reasons. First, positively identifying *S. o. relictus* tracks with any consistent confidence proved difficult, even if we were only assessing sets of sample tracks from captured shrews. We thought that because shrews have 5 toes on both front and hind feet, whereas mice only have 4 toes on the front feet, we might be able to discern between shrews and sympatrically occurring rodents. However, even with the reference materials, we did not feel confident that we could consistently identify *S. o. relictus* tracks, or conversely, to rule out that *S. o. relictus* tracks were not present. Another issue was that ≥1 *S. o. relictus* or other small mammal species, particularly deer mice (*Peromyscus maniculatus*), sometimes entered a tube multiple times to retrieve mealworms. As a result, the recording notecards commonly had a jumble of overlapping tracks that made it extremely difficult to single out and identify individual tracks.

Scat tubes proved to be an easier technique to employ compared with the track tubes, but still required a good deal of expertise to correctly identify shrew scats. The scat tubes were easier to construct and deploy compared with track tubes, primarily because of not having to construct or manage the felt ink pads. As with the track tubes, *S. o. relictus* appeared to readily enter the tubes and commonly left scats. We felt much more confident about identifying *S. o. relictus* scats compared with identifying *S. o. relictus* tracks. That said, there were a considerable number of scat samples deposited in tubes that we could not positively identify as *S. o. relictus* versus another species. Also, as indicated by camera images, *S. o. relictus* frequently entered the tubes without depositing scats. Thus, this technique also had a relatively high potential to not detect present *S. o. relictus*, resulting in false-negative data.

Cameras proved to be an extremely effective technique for detecting *S. o. relictus*, although detection efficacy varied among camera models. Although most cameras will capture images of small mammals, those with close-focus capability markedly facilitated the identification of shrews versus other small mammals (Fig. 3). Cameras were also very effective because in the San Joaquin Valley area only one species of shrew occurs. Thus, we were highly confident in identification of *S. o. relictus* from images produced by close-focus cameras. However, if multiple shrew species are present, modifications to camera trap setup such as placing a white background in the camera view to more accurately estimate size, or a similar strategy, should allow for detection of size and species differences (e.g., McCleery et al. 2014, Soininen et al. 2015, Mills et al. 2016).

The camera traps were relatively easy to set up, although some care must be taken to ensure that the cameras are correctly pointed at the bait container. We also found that it was critical to clear the patch of vegetation in the camera view to prevent obstruction in the images and false triggers from wind-blown vegetation. The species present could not always be identified in some of the images. However, each time an animal visited a bait station, the cameras obtained multiple images, which markedly enhanced the opportunity to reliably distinguish *S. o. relictus* from other species. In our estimation, no visits by *S. o. relictus* were missed by the cameras as a result of an inability to identify the visitor, as opposed to the track and scat tubes. The rate at which cameras missed capturing an image of a *S. o. relictus* visiting a bait station is unknown. However, given that 5 images were taken in rapid fire and, typically, ≥1 image of *S. o. relictus* was captured in a 5-image set, the potential for false-negatives at a given camera station is probably low, particularly if camera stations are operated for multiple nights. Also, given that *S. o. relictus* was detected on multiple cameras at each of the 3 sites, the probability that *S. o. relictus* would not be detected at a site where they are present is low if multiple cameras are used.

It appeared that the bait attraction system we used for camera traps was highly effective. Clearly, shrews were attracted to both the small plastic containers and tea infuser balls, and we did not notice a difference between these 2 container types. Typically, shrews would emerge from surrounding dense vegetation into the field of view of the camera trap and take one dry mealworm from the top of the bait container and immediately carry it back into the dense vegetation. This would happen repeatedly until the dry bait was consumed. Even after the dry bait was gone, shrews would often revisit the stations, possibly because they could smell the residual scent of the dried worms and also because they likely could hear and smell the live worms in the bait container.

The principal drawback to camera traps is the cost of the cameras. Currently, the only commercially available close-focus cameras we know of are those made by Reconyx, and each camera costs just over US$500. However, use of camera traps in wildlife studies is rapidly evolving, and other camera models may become available. For most project budgets, the cost of the cameras restricts the number of cameras that can be deployed. Furthermore, finding secure locations for camera deployment can sometimes be a concern. In areas where *S. o. relictus* distribution is unknown, or perhaps habitat is patchy, a limited number of cameras could result in *S. o. relictus* not being detected in the area. *Sorex ornatus relictus* is rare and the extent of their range, habitats, and seasonal variation in demography and habitat use are unknown; therefore, we recommend deploying multiple camera traps to cover all potential habitats to determine presence–absence.

The labor involved in organizing and identifying species captured in each photo detection is highly variable and depends on the number of small mammals attracted to the bait in a given area. During our study, we typically left our cameras in the field for a week or less. During that time, if the cameras were set properly, we never exhausted the battery life of our cameras or the capacity of a 16-GB memory card. Typically, we could organize and characterize the photos retrieved and determine if shrews were present from one camera in approximately 2 hours. Thus, in our study, the amount of effort for one technician to deploy

Figure 3. Images of Buena Vista Lake shrews (*Sorex ornatus relictus*) taken with a standard Reconyx PC800 Professional Hyperfire camera (left) and a modified close-focus Reconyx PC800 Professional Hyperfire camera (right). The close-focus camera focal distance was set to 40 cm. Both images were captured early August 2016 at Kern National Wildlife Refuge, Kern County, California, USA.

multiple camera traps at one site over the course of one week and characterize the photos would have been <20 hours.

During our research on *S. o. relictus,* we also completed several live-trapping efforts to establish occupied sites. We used small, aluminum Sherman live-traps, but often had problems with traps malfunctioning and not capturing shrews. In fact, when we conducted our trials with the scat tubes and camera traps, we also concurrently placed live-traps at the same locations. At the 24 locations where *S. o. relictus* was captured on camera, *S. o. relictus* entered live-traps 62 times, but only 1 shrew was captured (Cypher et al. 2017). High live-trap mortality is another common issue with shrews (Getz 1961, Greenberg et al. 2007, Shonfield et al. 2013). Thus, if the goal is simply detection, camera traps are a much better option than live-traps. Of course, live-trapping might be necessary for projects in which genetic samples or capture of live individuals is needed (e.g., abundance estimation, demographic parameters, home range studies). In these situations, time and effort might be optimized by operating camera stations first, and then deploying multiple live-traps at specific locations where *S. o. relictus* is detected on camera.

If genetic samples are desired from an area but individual shrews otherwise do not need to be captured, then scat tubes might be used instead of live-traps. We sent several scats to the Smithsonian Conservation Biology Institute and our colleagues were able to successfully extract *S. o. relictus* DNA from known and putative shrew scats collected (J. Maldonado, Smithsonian Conservation Biology Institute, personal communication). Use of scat tubes might be desirable for projects where the objective is simply to determine *S. o. relictus* presence–absence or obtain genetic samples for taxonomic or population studies.

One potential noninvasive sampling method for *S. o. relictus* that we did not test is recording ultrasonic acoustic vocalization. This method has been used successfully for detecting bats and other small mammals (Griffin 2004, Kalcounis-Rueppell et al. 2006, Gilley 2013, Diggins et al. 2016). Several species of *Sorex* are known to produce ultrasonic acoustic vocalizations, and acoustic monitoring for shrews has shown potential (Zsebők et al. 2015), but it is unknown whether *S. o. relictus* produces vocalizations.

Our investigation of noninvasive survey methods clearly demonstrated that automated camera traps, particularly those with close-focus capability, were highly effective in detecting *S. o. relictus* in a manner that presents minimal risk to the animals. Compared with the traditional survey method of live-trapping, cameras not only had better detection rates but also were safer and less labor-intensive. Scat tubes were also a successful method but were less reliable because we could not discern *S. o. relictus* scats 100% of the time. Track tubes were an ineffective method because we could never positively identify *S. o. relictus* tracks.

ACKNOWLEDGMENTS

We would like to acknowledge the U.S. Fish and Wildlife Service Section 6 Endangered Species Conservation and Recovery Program Grant to the California Department of Fish and Wildlife (CDFW) for funding. For field assistance and administrative support, we acknowledge staff at CDFW, the Endangered Species Recovery Program, The Wildlands Conservancy's Wind Wolves Preserve, and the Kern and Pixley National Wildlife Refuge Complex, particularly J. Battistoni, K. Tomlinson, S. Carey, E. Cypher, B. Paul, S. Phillips, K. Tabor, G. Grisdale, M. Jimenez, N. Stanley, and L. Peppel. We thank T. Jessen at the University of Arizona for track tube advice and K. Hickman, C. Wemmer, and C. Fiehler for camera-trapping advice. We also thank Associate Editor P. Neuhaus and 2 anonymous reviewers for providing helpful comments that greatly improved this manuscript.

LITERATURE CITED

Brehme, C. S., L. R. Albert, T. Matsuda, R. N. Booth, and R. N. Fisher. 2010. Pacific pocket mouse sampling methodology study, Marine Corps Base, Camp Pendleton. Data summary prepared for AC/S Environmental Security, Marine Corps Base, Camp Pendleton, California, USA.

Churchfield, S. 1980. Subterranean foraging and burrowing activity of the common shrew. Acta Theriologica 25:451–459.

Cypher, B. L., E. N. Tennant, J. Maldonado, L. R. Saslaw, T. L. Westall, J. L. Mohay, E. C. Kelly, and C. L. Van Horn Job. 2017. Conservation of endangered Buena Vista Lake shrews (*Sorex ornatus relictus*) through investigation of taxonomic status, distribution, and use of non-invasive survey methods. California State University, Stanislaus Endangered Species Recovery Program, Turlock, USA.

Diggins, C. A., L. M. Gilley, C. A. Kelly, and W. M. Ford. 2016. Comparison of survey techniques on detection of northern flying squirrels. Wildlife Society Bulletin 40:654–662.

Do, R., J. Shonfield, and A. G. McAdam. 2013. Reducing accidental shrew mortality associated with small-mammal livetrapping II: a field experiment with bait supplementation. Journal of Mammalogy 94:754–760.

Germano, D. J., G. B. Rathbun, L. R. Saslaw, B. L. Cypher, E. A. Cypher, and L. Vredenburgh. 2011. The San Joaquin Desert of California: ecologically misunderstood and overlooked. Natural Areas Journal 31:138–147.

Getz, L. L. 1961. Factors influencing the local distribution of shrews. American Midland Naturalist 65:67–88.

Gilley, L. M. 2013. Discovery and characterization of high-frequency calls in North American flying squirrels (*Glaucomys sabrinus* and *G. volans*): implications for ecology, behavior and conservation. Dissertation, Auburn University, Auburn, Alabama, USA.

Greenberg, C. H., S. Miller, and T. A. Waldrop. 2007. Short-term response of shrews to prescribed fire and mechanical fuel reduction in a Southern Appalachian upland hardwood forest. Forest Ecology and Management 243:231–236.

Griffin, D. R. 2004. The past and future history of bat detectors. Pages 6–9 *in* R. M. Brigham, E. K. V. Kalko, G. Jones, S. Parsons, and H. J. G. A. Limpens, editors. Bat echolocation research: tools, techniques, and analysis. Bat Conservation International, Austin, Texas, USA.

Grinnell, J. 1932. A relic shrew from central California. University of California Publication in Zoology 38:389–390.

Hays, W. S. 1998. A new method for live-trapping shrews. Acta Theriologica 43:333–335.

Hobbs, M. T., and C. S. Brehme. 2017. An improved camera trap for amphibians, reptiles, small mammals, and large invertebrates. PLoS ONE 12:e0185026.

Kalcounis-Rueppell, M. C., J. D. Metheny, and M. J. Vonhof. 2006. Production of ultrasonic vocalizations by *Peromyscus* mice in the wild. Frontiers in Zoology 3:3.

Kays, R. W., and D. E. Wilson. 2002. Mammals of North America. Princeton University Press, Princeton, New Jersey, USA.

Kelly, P. A., S. E. Phillips, and D. F. Williams. 2005. Documenting ecological change in time and space: the San Joaquin Valley of California. Pages 57–78 *in* E. A. Lacey and P. Myers, editors. Mammalian diversification: from chromosomes to phylogeography. Publications in Zoology Series, University of California Press, Berkeley, USA.

Kirkland, G. L., Jr., and P. K. Sheppard. 1994. Proposed standard protocol for sampling small mammal communities. Pages 277–281 *in* J. F. Merritt, G. L. Kirkland, Jr., and R. K. Rose, editors. Advances in the biology of shrews. Special publication 18. Carnegie Museum of Natural History, Pittsburgh, Pennsylvania, USA.

Lowery, J. C. 2013. Tracker's field guide: a comprehensive manual for animal tracking. Second edition. Falcon Guides, Guilford, Connecticut, USA.

Maldonado, J., F. Hertel, and C. Vilá. 2004. Discordant patterns of morphological variation in genetically divergent populations of ornate shrews (*Sorex ornatus*). Journal of Mammalogy 85:886–896.

McCleery, R. A., C. L. Zweig, M. A. Desa, R. Hunt, W. M. Kitchens, and H. F. Percival. 2014. A novel method for camera-trapping small mammals. Wildlife Society Bulletin 38:887–891.

Merriam, C. H. 1895. Synopsis of the American shrews in genus *Sorex*. North American Fauna 10:57–98.

Mills, C. A., B. J. Godley, and D. J. Hodgson. 2016. Take only photographs, leave only footprints: novel applications of non-invasive survey methods for rapid detection of small, arboreal animals. PLoS ONE 11:e0146142.

National Oceanic and Atmospheric Administration. 2002. Local climatological data, Bakersfield, California. National Climatological Data Center, Ashville, North Carolina, USA.

Noble, T. J., C. J. Lortie, M. Westphal, and H. S. Butterfield. 2016. A picture is worth a thousand data points: an imagery dataset of paired shrub-open microsites within the Carrizo Plain National Monument. GigaScience 5:40.

Pernetta, J. C. 1977. Anatomical and behavioral specialisations of shrews in relation to their diet. Canadian Journal of Zoology 55:1442–1453.

Rovero, F., and F. Zimmermann, editors. 2016. Camera trapping for wildlife research. Pelagic, Exeter, England, United Kingdom.

Rowcliffe, J. M., and C. Carbone. 2008. Surveys using camera traps: are we looking to a brighter future? Animal Conservation 11:185–186.

Shonfield, J., R. Do, R. J. Brooks, and A. G. McAdam. 2013. Reducing accidental shrew mortality associated with small-mammal livetrapping I: an inter- and intrastudy analysis. Journal of Mammalogy 94:745–753.

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.

Smith, T., J. Van Gunst, M. R. Jeffress, K. Lunn, R. E. Lamp, and M. S. Enders. 2017. The taming of the shrew: preliminary results from testing a shrew live trapping protocol. Abstract. The Wildlife Society, Western Section, 2017 Annual Conference, 6–10 Feb 2017, Reno, Nevada, USA.

Soininen, E. M., I. Jensvoll, S. T. Killengreen, and R. A. Ims. 2015. Under the snow: a new camera trap opens the white box of subnivean ecology. Remote Sensing in Ecology and Conservation 1:29–38.

U.S. Fish and Wildlife Service [USFWS]. 2011. Buena Vista Lake ornate shrew (*Sorex ornatus relictus*) 5-year review: summary and evaluation. U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Office, Sacramento, California, USA.

Yunger, J. A., R. Brewer, and R. Snook. 1992. A method for decreasing trap mortality of *Sorex*. Canadian Field-Naturalist 106:249–251.

Zsebők, S., D. Czabán, J. Farkas, B. M. Siemers, and S. von Merten. 2015. Acoustic species identification of shrews: twittering calls for monitoring. Ecological Informatics 27:1–10.

Associate Editor: Neuhaus.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site and includes figures of a track tube, scat tube, shrew scat, and track sample.