Wildlife Society Bulletin 42(4):693–700; 2018; DOI: 10.1002/wsb.927

Tools and Technology

Track Plates Detect the Endangered New Mexico Jumping Mouse

RACHEL L. HARROW,[1] *School of Forestry, Northern Arizona University, Flagstaff, AZ 86011, USA*
VALERIE J. HORNCASTLE,[2] *School of Forestry, Northern Arizona University, Flagstaff, AZ 86011, USA*
CAROL L. CHAMBERS,[3] *School of Forestry, Northern Arizona University, Flagstaff, AZ 86011, USA*

ABSTRACT The New Mexico jumping mouse (*Zapus luteus luteus*, formerly *Z. hudsonius luteus*), an endangered subspecies found in the southwestern United States, inhabits riparian areas with tall, dense herbaceous vegetation as habitat. To detect presence of this species for use in defining life history and habitat use, we developed and tested 4 noninvasive track-plate methods, and selected the best for field use. New Mexico jumping mice have unique feet and toes that are readily distinguishable from other small mammals within their geographic range. We created reference photos of rodent tracks that confirmed the unique footprints of the jumping mouse and tested this method against detection with live traps in the Apache–Sitgreaves, Arizona, and Santa Fe, New Mexico, USA, National Forests, 2016 and 2017. When comparing the 2 detection methods, in only 1 of 16 comparisons did results differ, where we captured jumping mice in live traps, but did not detect them with track plates. Based on our success with this approach, we developed a 14-minute instructional video (https://www.youtube.com/watch?v=i2x0Ydc1XVM) on assembly, deployment, and interpretation of track plates. Although trapping provided specific information about individuals, the noninvasive nature of our track-plate design minimized risk of injury or mortality to animals and lowered study costs.

KEY WORDS Arizona, detection, endangered species, New Mexico, noninvasive methods, survey methodology, track plate, *Zapus hudsonius luteus*, *Zapus luteus luteus*.

The New Mexico jumping mouse (*Zapus luteus luteus,* formerly *Zapus hudsonius luteus;* Malaney et al. 2017; hereafter, jumping mouse) is a genetically and morphologically distinct subspecies of jumping mouse found in the southwestern United States (Miller 1911, Hafner et al. 1981, King et al. 2006, Malaney et al. 2017). Jumping mice have an unusual life history because they are active for only 3–5 months annually (May or Jun through Sep or Oct), hibernating the remaining months of the year (Quimby 1951, Morrison 1990, Frey 2015). The species is considered a riparian obligate that uses tall ($\geq$61 cm), dense herbaceous vegetation along perennial flowing water such as streams, ditches, and wet meadows (Morrison 1990, Frey and Malaney 2009, U.S. Fish and Wildlife Service 2014). Jumping mice also use adjacent dry upland areas beyond floodplains to nest, raise young, and overwinter (Morrison 1990).

Populations of jumping mice declined or disappeared throughout their range in the southwestern United States; this led to their listing as endangered in 2014 under the 1973 Endangered Species Act (50 CFR Part 17 2014, U.S. Fish and Wildlife Service 2014). Loss of habitat is attributed to livestock and water management, development, recreation (impacts from fishing, camping, off-road vehicles, human foot traffic), and stochastic events such as wildfires and drought (Morrison 1990, Allen et al. 2009, Frey and Malaney 2009, U.S. Fish and Wildlife Service 2014).

Limited information regarding distribution and habitat requirements for the jumping mouse make study of the species important for recovery efforts. Previous survey methods used trapping but risks to animals included stress, injury, and mortality (Morrison 1992, Wright and Frey 2015, Sikes et al. 2016). Track plates successfully distinguished species, communities, or activity of small mammals (Carey and Witt 1991, Glennon et al. 2002, Connors et al. 2005). Detecting tracks as an alternative method of identification could increase survey efficiency for the jumping mouse.

The only sympatric species overlapping the range of the New Mexico jumping mouse is the western jumping mouse (*Z. princeps*). These species co-occur in parts of northern New Mexico and southern Colorado, USA (Ramey et al. 2005, Cassola 2016). Other species captured with jumping mice such as deer and brush mice (*Peromyscus* spp.) and voles (*Microtus* spp.) have different footprints (Reid 2006, Halfpenny et al. 2009). The feet of abundant species such

Received: 22 August 2017; Accepted: 18 August 2018
Published: 4 December 2018

[1]*Current address: Arizona Game and Fish Department, 5000 W Carefree Highway, Phoenix, AZ 85086, USA*
[2]*Current address: Springerville Ranger District, 165 S Mountain Avenue, P.O. Box 760, Springerville, AZ 85938, USA*
[3]*E-mail: Carol.Chambers@nau.edu*

as chipmunks (*Tamias* spp.) and woodrats (*Neotoma* spp.) appeared substantially larger than those of *Zapus* (Halfpenny et al. 2009). Thus, we hypothesized that we could distinguish between tracks of jumping mice and nontarget species.

Our objective was to devise an alternative detection method to assist survey efforts for the New Mexico jumping mouse. Specifically, we 1) assessed the ability to differentiate tracks of jumping mice from sympatric species and created a track photo reference for field use; 2) developed and tested a design to collect tracks; and 3) compared the effectiveness of track-plating to standard live-capture methods. Our target species was the jumping mouse, so we did not attempt to identify to species or genus other species detected on track plates.

STUDY AREA

We conducted work on the Apache–Sitgreaves National Forests in Arizona, USA, and the Santa Fe National Forest in New Mexico. The Apache–Sitgreaves National Forests encompassed 1.05 million ha along the Mogollon Rim and the White Mountains in east-central Arizona. The Santa Fe National Forest included >600,000 ha in northern New Mexico. For these National Forests, annual precipitation averaged 57 cm with annual maximum and minimum temperatures of 14° and −2° C, respectively (Western Regional Climate Center 2017).

We surveyed along perennial and intermittent streams in meadows between 2,000 and 3,000 m elevation within the range of the jumping mouse (Morrison 1990, U.S. Fish and Wildlife Service 2014). Meadows frequently occurred along a gradient that included aquatic vegetation near the stream, mesic meadows, dry meadows, ponderosa pine (*Pinus ponderosa*), and mixed conifer forest. These vegetation gradients were closely associated with differences in flooding, depth to water table, and soil characteristics (Judd 1972, Dwire et al. 2006). Riparian meadows were typically dominated by sedges (*Carex* spp.), rushes (*Juncus* spp.), grasses (*Poa* spp.), and forbs (Patton and Judd 1970). Ponderosa pine with Gambel oak (*Quercus gambelii*), alligator juniper (*Juniperus deppeana*), and New Mexico locust (*Robinia neomexicana*) dominated at elevations closer to 2,000 m. Higher elevation areas included white fir (*Abies concolor*) and Douglas-fir (*Pseudotsuga menziesii*) with scattered spruce (*Picea* spp.).

METHODS

Track Comparison and Photo Reference

During a concurrent live-trapping project (Jun to Aug 2015), we obtained tracks of jumping mice for comparison with those of sympatric species and to create reference photos of commonly occurring species. We placed individuals in a covered plastic storage box (16.5 × 28.3 × 43.2 cm) partially lined with a track plate that consisted of a 15 × 28-cm piece of self-adhesive paper (e.g., clear matte Con-Tact Brand Clear Covering Self-Adhesive Privacy Film and Liner; Con-Tact, Pomona, CA, USA) placed sticky side up. We centered 1 felt inkpad (5 × 15 cm; 100% polyester craft felt fabric) on the self-adhesive paper and attached the track plate to the inside bottom of the box with double-sided tape or adhesive putty placed on the nonstick side of the track plate. When an animal stepped on the inkpad, ink would temporarily adhere to its feet. As the animal moved away from the inkpad, its tracks printed on the self-adhesive paper. Bait (a mixture of steel-cut oats and peanuts), which we placed along the edge of the felt pad and the wall of the box, served as an attractant for the animal (Fig. 1).

Holes drilled in the plastic storage box lid allowed airflow. Animals remained inside the box for ≤10 min before release at their point of capture. We next removed the inkpad and attached the sticky side of the self-adhesive paper with the collected tracks to white paper (22 × 28 cm), which we labeled with date and species. This paper was then stored in a plastic sleeve in a binder to preserve the tracks. Animals were captured and handled under guidelines of the American Society of Mammalogists (Sikes et al. 2016), with the approval of the Northern Arizona University Institutional Animal Care and Use Committee (#15-011), and under Fish and Wildlife Service Permit TE63202B.

We compared tracks of sympatric species with those of jumping mice using calipers to measure fore prints including length (from longest toe to heel), pad width and length (from the 2 points farthest apart), and toe lengths (from the inside of the foot to outside). We also measured hind print length (from longest toe to heel; Taylor and Raphael 1988). We tested whether mean ranks of tracks of fore prints and toes of sympatric species had the same distribution as those of jumping mice using Kruskal–Wallis tests (Conover 1980). We set alpha at 0.05. We selected tracks that contained examples of fore and hind prints where toes were clearly distinguishable for comparison of jumping mice to sympatric species in our track reference photos.

Development of the Track Plate for Field Use

To construct a track plate for field surveys we needed 4 parts: track plate, ink, enclosure (for shelter), and enclosure cover (to protect from inclement weather). The track plate consisted of self-adhesive paper sized to the enclosure,

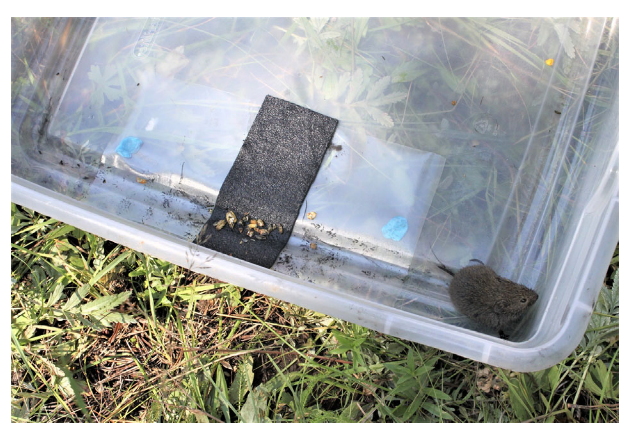

Figure 1. Collecting tracks from a Mogollon vole to create a photo reference for distinguishing New Mexico jumping mice from sympatric species. The felt ink pad, transparent self-adhesive paper, and Mogollon vole are visible in the plastic storage box.

placed sticky side up, and secured to the enclosure with double-sided tape. We saturated the inkpad with the same solution that we selected for track comparison; the inkpad covered approximately 20% of the track plate. Initially we tested placing the inkpad at the entrances (vs. center) of the track plate, but we observed these track plates saturated in tracks or smeared ink, leaving them unreadable. We thus placed the inkpad in the middle of the enclosure.

We tested ink solutions by mixing a solvent (water or mineral oil) with a pigmented powder as our solute (carpenter's chalk [e.g., Drennan et al. 1998], carbon black [e.g., Wiewel et al. 2007], graphite powder [e.g., Connors et al. 2005], and charcoal) to select the best for imprinting tracks. We discarded use of water as a solvent (it dried quickly and left powdery residue that failed to capture tracks) and graphite powder and charcoal as our solute (these inks did not print well so tracks were difficult to see or did not print). Although carbon black produced sharp, dark prints equivalent to carpenter's chalk, carbon black proved more expensive and difficult to obtain and was listed as potentially carcinogenic. We thus saturated the inkpads with a 1:1 solution of carpenter's chalk (Dewalt, Baltimore, MD, USA) and mineral oil.

From June to September 2015, we tested 4 enclosure designs for accessibility, protection from weather, and efficiency of data collection. We needed the jumping mouse to easily access and a technician to efficiently handle the enclosure. Wooden roofing or siding shingles (12 × 40 cm) or roofing felt (#30 smooth black asphalt felt 14.5-kg, cut to 30.5 × 48 cm) placed over the shelters blocked precipitation and provided shade and concealment. Enclosures included simple designs easily transported in the field (Fig. 2): a folding extra-large 7.6 × 9.5 × 30.5-cm Sherman trap (H. B. Sherman, Tallahassee, FL, USA); a double U-style gutter tube (12.7 × 25.4-cm vinyl, e.g., Geneva Products, Sicklerville, NJ, USA; modified from Drennan et al. [1998]); a single K-style gutter with acrylic base plate (12.7 × 30.5-cm vinyl, e.g., Geneva Products); and a plastic, see-through 33.0 × 20.3 × 12.7-cm modified shoebox with snap-on lid (e.g., ULINE, Pleasant Prairie, WI, USA). All designs included 2 entry points to reduce the likelihood of trapping jumping mice or other animals inside.

The folding Sherman trap required modification to secure its doors in an open position. We inserted a No. 2 pencil under the treadle and placed the enclosure upside down, so the original ceiling served as a smooth surface for the track plate. Two U-shaped pieces of fencing wire staked the enclosure in position and prevented it from folding. A wooden roofing shingle covered the Sherman trap.

We combined 2 U-style gutter pieces to form the double U-style gutter-tube oval design. The track plate attached to the smooth floor of the tube, and we covered the enclosure with a wooden roofing shingle. The single K-style gutter with acrylic base plate was held together by 2 rubber bands. The track plate attached to the acrylic base and the enclosure was covered with a wooden roofing shingle.

For the plastic modified shoebox design, we placed the enclosure upside-down with the lid in contact with the ground and the track plate attached to the lid. Holes drilled in the lip of the lid allowed for water drainage. Two 5 × 5-cm entrances cut offset from one another on the short sides of the enclosure and through the lip allowed entry by animals, but kept the locking snaps for the lid intact. Roofing felt covered the enclosure.

With each design, we prepared enclosures for track-plating by cutting self-adhesive paper to fit and taping the paper to the flat surface of the box so it covered the entire surface. We mixed carpenter's chalk and mineral oil in a gallon-sized plastic zipper bag, double-bagged to prevent leakage. We placed 30 felt pads in the ink mixture until saturated. This step was repeated until we prepared enough enclosures for testing.

In the field, we concurrently tested the 4 enclosure types at 3 sites, setting 20 track plates at each site for 1 week of track-plating. We removed the backing of the paper to expose the self-adhesive side, placed an inkpad in center of the enclosure, added bait, and set the enclosure on the ground. We covered each enclosure to prevent rain from splashing inside and affecting the inkpad or tracks. We checked enclosures every 24 hr to avoid overprinting (visitation

Figure 2. Four box designs for collecting tracks of New Mexico jumping mice on the Apache–Sitgreaves National Forests, Arizona, USA, during June–August 2015. Designs included (left to right) a K-style gutter with acrylic base plate, a double U-style gutter tube, a small folding Sherman trap, and a plastic modified shoebox. The modified shoebox was the most efficient and effective design.

leaving tracks too dense to detect prints of jumping mice) for 3–5 days. If a track plate contained tracks, we removed the cover, opened the enclosure, shook out any bait and feces, and extracted the self-adhesive paper. We attached the paper sticky side down on a piece of 21.6 × 27.9-cm white paper, uniquely labeled with date and location. When attaching, we smoothed the self-adhesive paper along the long side to remove air pockets, taking care not to smear any of the inkpad residue over tracks; tracks were unaffected by this process. We then replaced the self-adhesive paper in the enclosure. We also replaced or resoaked inkpads that appeared dry because they could not produce tracks. When track plates contained no tracks, we reset the enclosure without replacing the self-adhesive paper. We reviewed labeled track plates for jumping mouse tracks, recorded results on a data sheet, and then stored plates in plastic sleeves in a binder.

Comparing Methods: Track Plates and Live-trapping

We used the modified shoebox design to test efficacy of track-plating versus live capture. We sampled 16 sites on the Apache–Sitgreaves National Forests in 2016 and 2 sites on the Santa Fe National Forest in 2017 (Table 1). We established a transect at each site, placing flags at 80 points spaced 3–5 m apart along the riparian drainage. Flags for the first 2 points were placed upstream on the right side of the stream with the next 2 flags placed downstream on the opposite stream bank. We continued flagging points by alternating every 2 points working downstream along the transect to equally sample both sides of the stream. At each flag, we placed either a track-plate enclosure or a Sherman live trap. We randomized which method we tested first (track-plating or trapping), conducted comparison trials of the other method within 3 weeks, and used the same transect points for both trapping and track-plating. For both methods, we walked in the stream to set and check traps to avoid trampling vegetation used by the jumping mouse. For trapping, we set large Sherman live traps (8 × 9 × 23 cm) at each point on the transect baited with a mixture of steel cut oats and peanuts. We placed polyester batting in traps to provide insulation and covered each trap with a wooden shingle to protect from rain and solar insulation. We set traps each evening $\leq$2 hr before sunset and checked them $\leq$4 hr after sunrise each morning for 3 concurrent days. Captured animals were identified to species before release. When jumping mice were captured at a site with $<$3 trap nights, we discontinued trapping if additional trapping might put the species at risk. Our purpose was to detect occupancy and this was achieved at a site with $\geq$1 capture of a jumping mouse.

We deployed track-plate enclosures for 3 concurrent days, checking them daily. Track plates with tracks were collected, labeled, and attached to white paper and preserved in a binder for identification and permanent retention. We used our track photo reference to identify tracks of jumping mice. Three independent reviewers trained in identification of tracks reviewed each track plate for presence of jumping mouse tracks and recorded whether they detected tracks of jumping mice. Jumping mice were considered present at a point on the transect when 3 reviewers reported $\geq$1 track for the same track-plate enclosure.

We compared detection of jumping mice between track-plating and live-trapping at the site level. We considered the species present if $\geq$1 jumping mouse was captured or $\geq$1 track was identified at a site. We compared detectability between track-plating and live-capture methods with a Spearman correlation to test for strength and direction of association between methods (Myers et al. 2010). In addition, we compared relative abundance of jumping mice (no. of captures per 100 trap nights [TN] per site) with detection by track-plating (no. of track-plate enclosures

Table 1. Comparison of live-trapping and track-plating methods used to detect New Mexico jumping mice on the Apache–Sitgreaves, Arizona, and Santa Fe (SFNF), New Mexico, USA, National Forests, 2016 and 2017.

Site number	Year	Trap dates	Plate dates	Trap[a]	Plate[a]	First	No. animals/100 TN[b]	No. enclosures/100 TN[b]
13	2016	14–17 Jun	3–5 Jul	No	No	Trap	0	0
15	2016	21–23 Jun	8–10 Jul	No	No	Trap	0	0
16	2016	21–23 Jun	8–10 Jul	No	No	Trap	0	0
38	2016	21–23 Jun	8–10 Jul	No	No	Trap	0	0
39	2016	24–26 Aug	28–30 Jul	Yes	Yes	Plate	2	13
42	2016	24–26 Aug	28–30 Jul	Yes	Yes	Plate	2	5
48	2016	24–26 Aug	28–30 Aug	No	No	Trap	0	0
52	2016	16–17 Aug	17–19 Jul	Yes	Yes	Plate	1	8
60	2016	21–23 Jun	8–10 Jul	Yes	Yes	Trap	1	3
73	2016	21–23 Jun	30 Jun–2 Jul	Yes	Yes	Trap	2	19
77	2016	22–24 Jun	30 Jun–2 Jul	No	No	Trap	0	0
26	2016	14–16 Jun	29 Jun–1 Jul	Yes	Yes	Trap	5	20
63	2016	16–17 Aug	28–30 Jul	Yes	Yes	Plate	3	8
66	2016	16–17 Aug	28–30 Jul	Yes	No	Plate	1	0
0[c]	2017	2 Jul	28–30 Jun	Yes	Yes	Plate	11	10
4[c]	2017	2 Jul	28–30 Jun	Yes	Yes	Plate	4	1

[a] For "Trap" and "Plate," "No" indicated jumping mice were not detected by a method, "Yes" indicated they were. "First" identified the method tested initially (i.e., if "trap" then the site was trapped first and track-plated second); methods were not conducted simultaneously.
[b] Number of jumping mice captured/100 trap nights (TN) correlated with number of track-plate enclosures with jumping mice tracks (No. enclosures/100 TN).
[c] Site located on SFNF.

with jumping mouse tracks per 100 TN per site) to determine if greater track counts indicated greater relative abundance of jumping mice at a site. We used a Pearson correlation to compare capture rates between track plates and trapping (Myers et al. 2010). For all tests, we used an alpha level of 0.05.

RESULTS

Track Comparison and Reference Photos

We collected 1 to 13 tracks each from 21 individuals representing 6 species: New Mexico jumping mice ($n = 5$, mean no. of tracks per individual $\pm$ SE: 3.6 ± 0.7), long-tailed vole (*Microtus longicaudus; n* $= 3$, 7.3 ± 2.9), Mogollon vole (*M. mogollonensis;* $n = 3$, 7.3 ± 0.9), montane vole (*M. montanus;* $n = 5$, 4.4 ± 1.4), brush mice (*Peromyscus boylii;* $n = 2$, 9 ± 0), and deer mice (*P. maniculatus;* $n = 3$, 7.3 ± 1.8). The larger tracks of chipmunks and woodrats made them clearly distinguishable from tracks of jumping mice, so we did not statistically compare them. Although we did not capture shrews (*Sorex* spp.) during our project, we did capture them in subsequent tests. Their tracks, smaller than those of mice and voles, were easily distinguishable from those of jumping mice.

Tracks for sympatric species (voles and deer mice) were readily distinguishable from those of jumping mice. The toes on the forefoot of jumping mice were elongated compared with voles and deer mice ($\chi^2{}_5 \geq 13.49$, $P \leq 0.02$; Figs. 3 and 4) although we did not detect differences in forefoot pad width and length between jumping mice and sympatric species ($\chi^2{}_5 \leq 8.85$, $P \geq 0.12$). Hind prints of deer mice and voles lacked the heel and were thus incomplete; therefore, we did not statistically compare them. However, the elongated hind prints and toes of jumping mice (>20 mm; Fig. 4), made them easy to differentiate from those of sympatric species (<14 mm; Fig. 4), even when only partial tracks were recorded.

We selected the best tracks for jumping mice and sympatric species to create a track-field photo reference (Fig. 4). Technicians and those reviewing track plates used the photo reference for identification of tracks during or after field trials of track-plate enclosures and comparisons of track-plate enclosures with live-capture methods.

Development of the Track Plate for Field Use

After testing 4 track-plate enclosures to determine which most efficiently recorded tracks of jumping mice, we selected the modified shoebox as our preferred track-plate design. The folding Sherman trap was stable after placement only if we removed or flattened vegetation, rocks, or other debris under the enclosure to prevent it from rolling or collapsing. We found that the U-style gutter tube also rolled easily, making it difficult to place on steep slopes, rocky, or shrubby areas. Although the K-style gutter enclosure was stable, it remained assembled as one unit, so was bulky to transport in the field. The modified shoebox design provided a larger surface area than other designs, thus collecting more tracks and protecting the track plate from the environment better than the other 3 designs. It was stable, lightweight, did not compress vegetation, and could withstand heavy rainfall events and flooding. This design was also stackable and easy to assemble in the field.

Testing Effectiveness of Track Plate to Trapping Methods

We captured jumping mice at 10 of 16 sites and identified tracks of jumping mice at 9 of 16 sites (Table 1). Detection differed between the track-plate method and trapping at only 1 site, where we captured a jumping mouse but did not detect

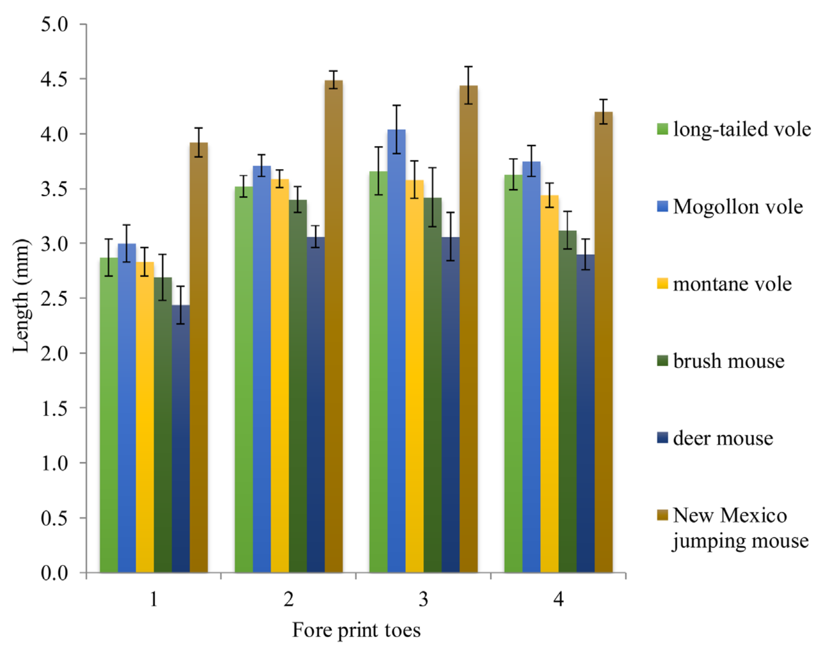

Figure 3. Average length (mm) of individual fore print toes for 6 rodent species on the Apache–Sitgreaves National Forests, Arizona, USA, during June–August 2015. Fore print toes (1 to 4) of New Mexico jumping mice were longer than those of voles (Mogollon vole, long-tailed vole montane vole) and deer mice (deer mouse, brush mouse).

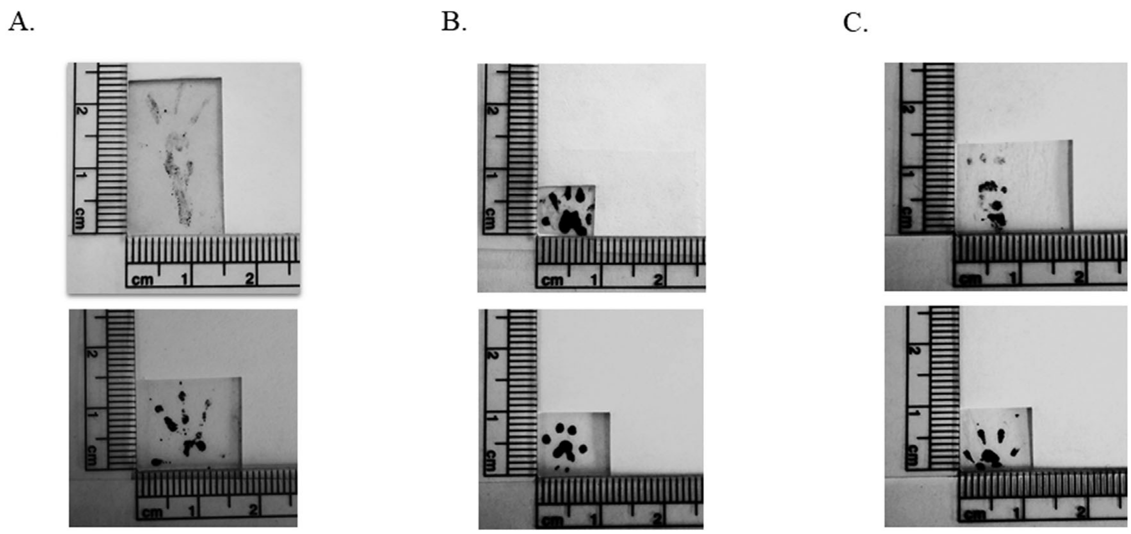

Figure 4. Elongated hind print (top) and length of the fore print toes (bottom) of A) jumping mouse, compared to B) deer mouse and C) vole. Rodent tracks were collected on the Apache–Sitgreaves National Forests, Arizona, USA, June–August 2015.

tracks. Thus both techniques detected jumping mice similarly, regardless of the technique we tested first (Spearman's rho $= 0.83$, $P < 0.0001$).

DISCUSSION

Our track-plate approach offered an effective, inexpensive, efficient, and noninvasive method for detecting jumping mice (Table 2). The modified shoebox design provided a large surface area for track collection and protected the track plate from the environment. It was stable, lightweight, easy to assemble in the field, did not compress vegetation, and could withstand flooding. In only one comparison did results differ between trapping and track-plating; low densities of jumping mice or inadequate ink could thus affect detectability. Although we had incidences of livestock or wildlife interfering with boxes (e.g., bumping, stepping on, or opening them) and flood events, we found no evidence that track-plating resulted in injuries to animals. In addition, the noninvasive nature of track plates lowered stress and risk of hypo- and hyperthermia to jumping mice. In contrast, live traps caused injury or death to jumping mice (C. L. Chambers, personal observation), resulting in take under the Endangered Species Act (Table 2).

Survey sites for track-plating could be more broadly dispersed than trapping because checking track plates was less time-sensitive (e.g., with live-trapping, animals must be removed from traps before temperatures rise and heat up the inside of traps; Table 2). In 2016, we successfully used track-plating at 66 sites to survey for jumping mice across the Apache–Sitgreaves National Forests (C. L. Chambers, unpublished data). Surveying such a large area ($>1{,}000\ km^2$) would not be possible if using live-trapping because of the time limitations of trapping (Table 2).

Materials were readily available in stores or online. We found that clear boxes worked well, as they did in another riparian study monitoring small and medium-sized mammals (Loukmas et al. 2003). Checking enclosures was less time-sensitive than trapping, although track plates needed daily checks to avoid overprinting on track plates. Track plates required fewer surveyors and visits per day and could be checked any time of the day (Table 2).

Table 2. Comparison of live-trapping versus track plating methods to detect New Mexico jumping mice in Apache–Sitgreaves, Arizona, and Santa Fe, New Mexico, USA, National Forests, 2016 and 2017.

	Trapping	Track plates
Identification	Difficult to misidentify	Possible to misidentify or miss tracks
	Can obtain demographic data, genetic samples	Only presence detected
Mortality or injury	Possible during flooding, cold or hot temperatures	Unlikely
Procedure	Checked daily to release animals	Checked daily to avoid overprinting
	Sites must be in close proximity	Sites can be broadly dispersed
	Larger teams to rapidly check traps	Smaller teams
	Work times inflexible (dawn and dusk)	Work times flexible
Trap	Must be moved outside of riparian area if flood events are likely	Can leave in riparian zone; track plates float so can be recovered
	Animal trapped until trap checked	Two entrances allow easy egress
Trap materials	Must be ordered	Locally available unless large numbers needed
	~$US28/trap	~$US5/track-plate enclosure
Regulatory	Chance of take	Little to no chance of take

Despite their advantages, track plates did not allow identification beyond genus, of individuals, or collection of demographic data. In areas where other species or subspecies of jumping mice overlap, our track-plate method should be used only when identifying to genus because differentiating tracks between species or subspecies of jumping mice may not be feasible. We also found that setting and checking track plates offered no substantial time saving over live-trapping.

Track plates improved our ability to detect and monitor jumping mice and determine distribution and habitat use (e.g., Clevenger et al. 2001, Cain et al. 2006, Ray and Zielinski 2008, Rytwinski and Fahrig 2011). They also make regional survey and monitoring approaches more feasible (Zielinski and Truex 1995). Based on our success with this technique, we developed a 14-minute video that demonstrated how to assemble, deploy, interpret, and archive results of track plates (Martínez-Fonseca and Chambers 2016).

ACKNOWLEDGMENTS

We thank R. Benford, G. Davis, J. M. Gladden, M. Hart, H. E. Hicks, S. M. Houlette, D. A. Kopp, P. Langle, S. Langle, L. K. LeSueur, K. L. Licence, R. A. Marroquin-Flores, J. G. Martínez-Fonseca, N. Meneses, A. Nemecek, W. O. Noble, M. C. Parker, J. E. Peiffer, C. A. Rozanski, and D. R. Smith for their assistance on this project. We thank P. Neuhaus and 2 anonymous reviewers for their comments that improved the quality of this manuscript. We received funding and support from the U.S. Forest Service, Natural Resources Conservation Service, Arizona Game and Fish Department Heritage Fund, and Northern Arizona University Hooper Undergraduate Research Award.

LITERATURE CITED

Allen, J. A., K. Ramstead, and A. Springer. 2009. Have wet meadow restoration projects in the southwestern U.S. been effective in restoring hydrology, geomorphology, soils, and plant species composition to conditions comparable to wet meadows with minimal human-induced disturbance? Collaboration for Environmental Evidence, Systematic Review No.75. http://openknowledge.nau.edu/2855/1/Allen_EBCFinalProtocol.pdf. Accessed 20 Aug 2017.

Cain, J. W. III, K. S. Smallwood, M. L. Morrison, and H. L. Loffland. 2006. Influence of mammal activity on nesting success of passerines. Journal of Wildlife Management 70:522–531.

Carey, A. B., and J. W. Witt. 1991. Track counts as indices to abundances of arboreal rodents. Journal of Mammalogy 72:192–194.

Cassola, F. 2016. *Zapus princeps*. (Errata version published in 2017) The IUCN Red List of threatened species 2016: e.T42614A115195084. https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T42614A22203482.en. Accessed 22 Aug 2017.

Clevenger, A. P., B. Chruszcz, and K. Gunson. 2001. Drainage culverts as habitat linkages and factors affecting passage by mammals. Journal of Applied Ecology 38:1340–1349.

Connors, M. J., E. M. Schauber, A. Forbes, C. G. Jones, B. J. Goodwin, and R. S. Ostfeld. 2005. Use of track plates to quantify predation risk at small spatial scales. Journal of Mammalogy 86:991–996.

Conover, W. J. 1980. Practical nonparametric statistics. Second edition. John Wiley & Sons, New York, New York, USA.

Drennan, J. E., P. Beier, and N. L. Dodd. 1998. Use of track stations to index abundance of Scurids. Journal of Mammalogy 79:352–359.

Dwire, K. A., J. B. Kauffman, and J. E. Baham. 2006. Plant species distribution in relation to water-table depth and soil redux potential in montane riparian meadows. Wetlands 26:131–146.

Frey, J. K. 2015. Variation in phenology of hibernation and reproduction in the endangered New Mexico meadow jumping mouse (*Zapus hudsonius luteus*). PeerJ 3:e1138.

Frey, J. K., and J. L. Malaney. 2009. Decline of the meadow jumping mouse (*Zapus hudsonius luteus*) in two mountain ranges in New Mexico. Southwestern Naturalist 54:31–44.

Glennon, M. J., W. F. Porter, and C. L. Demers. 2002. An alternative field technique for estimating diversity of small-mammal populations. Journal of Mammalogy 83:734–742.

Hafner, D. J., K. E. Petersen, and T. L. Yates. 1981. Evolutionary relationships of jumping mice (genus *Zapus*) of the southwestern United States. Journal of Mammalogy 62:501–512.

Halfpenny, J. C., M. Walla-Murphy, E. Rogers, and D. Tiller. 2009. Track plates for mammals. CreateSpace, Charleston, South Carolina, USA.

Judd, B. I. 1972. Vegetation zones around a small pond in the White Mountains of Arizona. Great Basin Naturalist 32:91–96.

King, T. L., J. F. Switzer, C. L. Morrison, M. S. Eackles, C. C. Young, B. A. Lubinski, and P. Cryan. 2006. Comprehensive genetic analyses reveal evolutionary distinction of a mouse (*Zapus hudsonius preblei*) proposed for delisting from the US Endangered Species Act. Molecular Ecology 15:4331–4359.

Loukmas, J. J., D. T. Mayack, and M. E. Richmond. 2003. Track plate enclosures: box designs affecting attractiveness to riparian mammals. American Midland Naturalist 149:219–224.

Malaney, J. L., J. R. Demboski, and J. A. Cook. 2017. Integrative species delimitation of the widespread North American jumping mice (Zapodinae). Molecular Phylogenetics and Evolution 114:137–152.

Martínez-Fonseca, J. G., and C. L. Chambers. 2016. Tracking big feet, *Zapus hudsonius luteus*, New Mexico meadow jumping mouse. https://www.youtube.com/watch?v=i2x0Ydc1XVM. Accessed 1 Nov 2016.

Myers J. L., A. D. Well, and R. F. Lorch Jr. 2010. Research design and statistical analysis. Third edition. Routledge, New York, New York, USA.

Miller, G. S. Jr. 1911. A new jumping mouse from New Mexico. Proceedings of the Biological Society of Washington 14:253–254.

Morrison, J. L. 1990. The meadow jumping mouse in New Mexico: habitat preferences and management recommendations. Pages 136–143 *in* P. R. Krausman and N. S. Smith, editors. Proceedings of the symposium on managing wildlife in the Southwest. Arizona Chapter, The Wildlife Society, Phoenix, USA.

Morrison, J. L. 1992. Persistence of the meadow jumping mouse, *Zapus hudsonius luteus*, in New Mexico. Southwestern Naturalist 37:308–311.

Patton, D. R., and B. I. Judd. 1970. The role of wet meadows as wildlife habitat in the Southwest. Journal of Range Management 23:272–275.

Quimby, D. C. 1951. The life history and ecology of the jumping mouse, *Zapus hudsonius*. Ecological Monographs 21:61–95.

Ramey, R. R. II, H.-P. Liu, C. W. Epps, L. M. Carpenter, and J. D. Wehausen. 2005. Genetic relatedness of the Preble's meadow jumping mouse (*Zapus hudsonius preblei*) to nearby subspecies of *Z. hudsonius* as inferred from variation in cranial morphology, mitochondrial DNA and microsatellite DNA: implications for taxonomy and conservation. Animal Conservation 8:329–346.

Ray, J. C., and W. J. Zielinski. 2008. Track stations. Pages 75–109 *in* R. A. Long, P. MacKay, J. Ray, and W. Zielinski, editors. Noninvasive survey methods for carnivores. Island Press, Washington, D.C., USA.

Reid, F. 2006. Peterson field guide to mammals of North America. Fourth edition. Houghton Mifflin, Singapore.

Rytwinski, T., and L. Fahrig. 2011. Reproductive rate and body size predict road impacts on mammal abundance. Ecological Applications 21:589–600.

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.

Taylor, C. A., and M. G. Raphael. 1988. Identification of mammal tracks from sooted track stations in the Pacific Northwest. California Fish and Game 74:4–15.

U.S. Fish and Wildlife Service. 2014. Species status assessment report: New Mexico meadow jumping mouse (*Zapus hudsonius luteus*). U.S. Fish and Wildlife Service, Albuquerque, New Mexico, USA.

Western Regional Climate Center. 2017. Western Regional Climate Center homepage. http://www.wrcc.dri.edu/. Accessed 15 Jul 2017.

Wiewel, A. S., W. R. Clark, and M. A. Sovada. 2007. Assessing small mammal abundance with track-tube indices and mark-recapture population estimates. Journal of Mammalogy 88:250–260.
Wright, G. D., and J. K. Frey. 2015. Habitat selection by the endangered New Mexico meadow jumping mouse on an irrigated floodplain. Journal of Fish and Wildlife Management 6:112–129.
Zielinski, W. J., and R. L. Truex. 1995. Distinguishing tracks of closely-related species: marten and fisher. Journal of Wildlife Management 59:571–579.

Associate Editor: Neuhaus.