Box and Bucket Camera Traps Yield Similar Detection Results for Small Terrestrial Mammals

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Abstract - Small terrestrial mammals are vital to ecosystems but receive less conservation attention than larger species. Camera trapping offers a non-invasive monitoring method but faces challenges in detecting small terrestrial mammals. We compared 3 camera-trap designs—open, box, and bucket—across 15 sites in Pennsylvania, deploying 45 cameras for 3375 trap nights. Box (n = 625) and bucket traps (n = 399) obtained significantly more images than open traps (n = 229) (P < 0.01). Open traps detected mice faster (1 median day to first detection, P < 0.01) but failed to detect voles or shrews. Box traps recorded the most mice (n = 537) and voles (n = 71), while bucket traps detected the most shrews (n = 23). Our findings highlight the effectiveness of enclosed designs in improving detection of small terrestrial mammals.

Introduction

For the last 35 years, small mammals in North America have declined (Medd et al. 2025), and in the last 20 years, research publications on shrews and rodents have been declining in the US (Readyhough et al. 2025). Currently, *Mustela nivalis* L. (Least Weasel) is a species of conservation concern in over half the states and provinces in which it occurs, and there is limited knowledge on its abundance and distribution (Jachowski et al. 2021). Small, terrestrial, secretive, and cryptic mammals, such as Least Weasels, mice, shrews, and voles are important herbivores, seed dispersers, prey species, predators, pollinators, and indicators of overall ecosystem health (Avenant and Cavallini 2007, Keesing 2000, Manson et al. 2001, Monadjem and Perrin 2003, Mychajliw et al. 2024). Despite their ecological importance, these small mammals are subject to proportionally little research and conservation attention compared to larger and more charismatic mammal species (Ceballos and Brown 1995, Roberge 2014, Sitas et al. 2009). In the past, research efforts for small terrestrial mammals, including mice, shrews, and voles, relied on labor-intensive and often pernicious sampling methods, such as live trapping, pitfall trapping, and kill trapping. Recently, camera traps have become an effective alternative method for small-mammal research.

Camera trapping is the use of motion- and heat-triggered cameras to detect and photograph species, including small mammals, for surveying and management purposes (Gracanin et al. 2022, Rovero et al. 2013, Thomas et al. 2020). As a

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passive monitoring method requiring no human–animal contact, camera traps can effectively monitor target species with little impact to small-mammal populations and minimize human risks associated with handling wild mammals (Gracanin et al. 2022). Furthermore, camera trapping can be deployed over large spatial and temporal scales, even in remote locations with relatively low fieldwork effort, and is less costly than in-person observation or live trapping (Gracanin et al. 2022, Littlewood et al. 2021, Mölle et al. 2021). For terrestrial small-mammal research efforts, camera traps have been used to determine presence (Gracanin and Mikac 2022, Littlewood et al. 2021, McCleery et al. 2014, Porter and Dueser 2024, White et al. 2023), estimate home ranges and track movements (Gracanin and Mikac 2022), estimate abundance (Kleiven et al. 2022, Littlewood et al. 2021), and track activity patterns (Gray et al. 2017). Other research applications of camera traps include surveying populations or communities over time, disease monitoring, surveilling wildlife crossings, and observing phenotypically abnormal individuals (Rovero et al. 2013). In addition, camera traps can enable monitoring in environments where the use of other methods would be challenging, such as in subnivean environments (Soininen et al. 2015).

Conventional camera traps are typically designed to obtain images of larger mammal species; therefore, a unique mix of challenges arise when using camera traps to survey for terrestrial small mammals. For example, the target species may be too small to reliably trigger the camera sensor, or it may be difficult to accurately identify the photographed species (Littlewood et al. 2021). Moreover, cameras with limited focal ranges may take low-resolution images, which can inhibit accurate species identification (Gracanin et al. 2022). Multiple strategies exist to overcome these challenges. To obtain higher-quality images, some studies use bait to attract animals closer to the camera, while others position the camera traps above ground, facing down to take photos from above (De Bondi et al. 2010, Littlewood et al. 2021). Another method involves placing a camera equipped with a close-focus lens within a protective structure through which the animal passes (Gracanin et al. 2022, Littlewood et al. 2021).

Several studies have demonstrated the benefits of camera trapping, especially in comparison to live trapping. De Bondi et al. (2010) compared small-mammal detections between an open camera-trap design and live trapping and found that camera trapping was more effective in terms of cost and number of species detected. Littlewood et al. (2021) utilized a baited-tunnel design with an attached camera trap equipped with a close-focus lens and reduced flash intensity to obtain quality small-mammal images. They found that this camera-trap design was a more cost-effective, less labor-intensive, and safer alternative than live trapping to monitor small mammals (Littlewood et al. 2021). A similar camera-trap design known as the "selfie trap", consists of a close-focus lens placed on a trail camera with a bait holder affixed in front of the camera, all housed in a PVC pipe. The "selfie trap" was successfully used by Gracanin et al. (2022) to detect arboreal small mammals and estimate population density and abundance. McCleery et al. (2014) and Porter and Dueser (2024) took top-down images of small mammals using a bucket design to determine small-mammal diversity and occupancy. McCleery et al. (2014) found this camera-trap design to be ideal for small mammals because it reduced the number of photos of non-target species (that were too large to enter the bucket) and permitted the determination of species presence and diversity, community composition, activity levels, habitat selection, and species distributions. Additionally, Soininen et al. (2015) and Kleiven et al. (2022) used a bucket-based camera-trap design to monitor small-mammal communities and abundances in the Arctic.

Multiple camera-trap designs have been developed to survey small mammals, but effective methods and best practices remain unclear. Fink and Jachowski (2025) encouraged researchers to test, evaluate, and compare camera-trap designs to advance the understanding of understudied small mammals. The objective of our study was to compare detections of secretive, cryptic, small terrestrial mammals, specifically Least Weasels, between 3 separate, low-cost camera-trap designs (i.e., open, box, and bucket designs). We determined the success of the camera-trap types by quantifying the total number of detections and time to first detection for Least Weasels, mice, shrews, and voles. Because all 3 camera-trap designs have been successful in small-mammal detection in the field, we tested the null hypothesis that there would be no significant difference in the total number of detections or time to first detection between the open, box, and bucket camera-trapping techniques.

Field Site Description

Our study sites were concentrated in the Southwest Region of Pennsylvania and at Hawk Mountain Sanctuary, located in eastern Pennsylvania (Fig. 1). We selected general camera-trap locations within these study sites based on previous observations or suspected habitat of Least Weasels. We chose specific trap sites within the study areas once on-site and targeted areas providing structural cover for small terrestrial mammals, including fence rows, rock piles, pinch points, and linear features on the landscape within mixed farmland and grassland adjacent to woodlands. At each of our 15 camera-trap setup sites (Fig. 1), we deployed 3 camera-trap designs, open, box and bucket, that were run simultaneously for a total of 45 cameras.

Methods

At each study site, we positioned the open, box, and bucket camera-trap designs (Fig. 2) 3–5 m apart and deployed them to run simultaneously so the number of trap days for each camera design was the same. In the open camera-trap design, we positioned cameras facing a capped PVC pipe (no animals could enter) that was 31 cm in length and 3–4 cm in width such that the pipe was ~30–100 cm in front of the camera and affixed with a scale bar anchored to the ground with a 22-cm metal gutter spike. We mounted the cameras on trees with varying perspectives, at a height of about 50 cm, with differing fields of view, depending on the landscape (Fig. 2A). We modified the design of the box camera trap from that of

Mos and Hofmeester (2020), also referred to as the Mostela camera trap, which was originally intended to target small mustelids (Fig. 2B). We fashioned our box

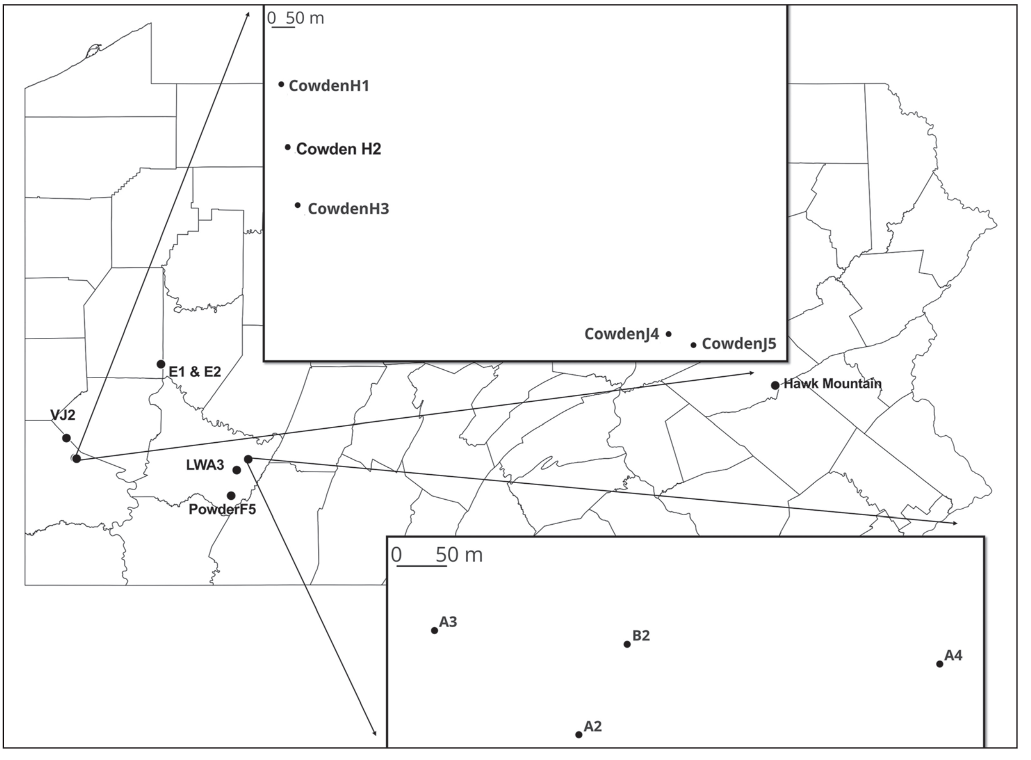

Figure 1. Locations of 15 camera-trap sites across Pennsylvania selected to photo-detect small terrestrial mammals.

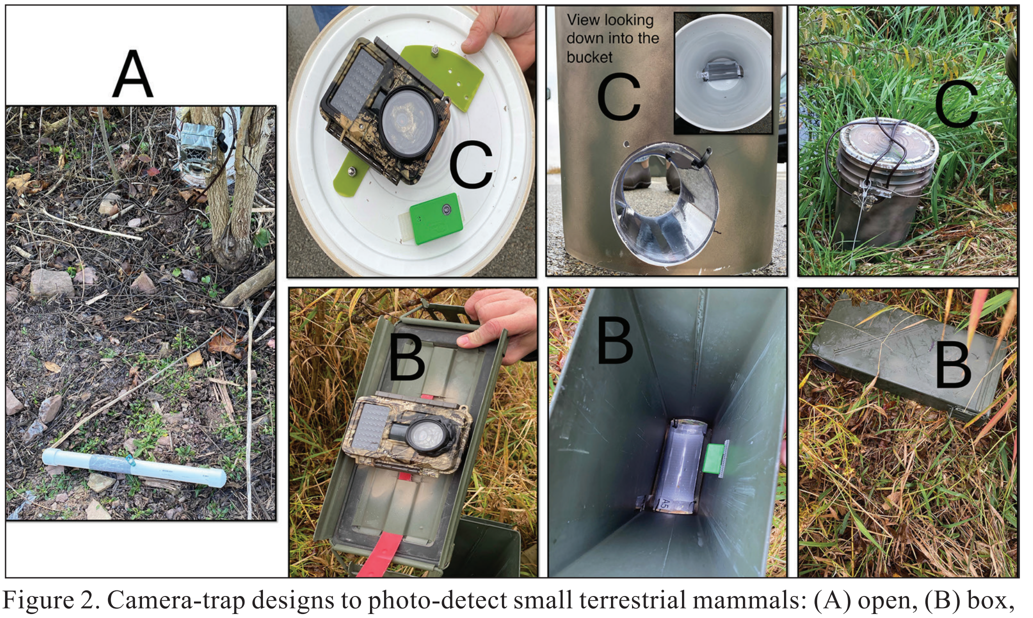

Figure 2. Camera-trap designs to photo-detect small terrestrial mammals: (A) open, (B) box, aand (C) bucket.

traps out of durable ammunition boxes measuring ~74 cm tall, 35.5 cm long, and 13 cm wide with the infrared motion-triggered camera housed inside the box. We set boxes flat on their long side on level ground, and we cut 2 entrances measuring 10 cm in diameter parallel to one another. Between the entrances, we fitted a modified PVC pipe to create a tunnel and cut a hole through the tunnel for a better view of the animal and scale bar. We attached the camera to the lid of the box, facing the tunnel and a scale bar behind the tunnel. Our bucket camera-trap design was modified from McCleery et al. (2014), also referred to as the Hunt camera trap, and the design of Porter and Dueser (2024) to study small mammals (Fig. 2C). We cut entrance arches into the bucket parallel to each other at ground level, measuring ~13–15 cm in diameter, and connected these arches using a modified PVC pipe to create a tunnel. We cut a hole through the PVC tunnel for a better view of the animal and scale bar. We mounted an infrared motion-triggered camera to the inside of the bucket lid, facing down toward the tunnel and scale bar behind the tunnel. The bucket camera traps measured a volume of 19 L and were approximately 44.5 cm tall and 30.5 cm in diameter.

To detect Least Weasels, camera-trap designs had combinations of scent lures, audio-call lures, and small-mammal carcasses. We placed scent and audio lures within box and bucket camera traps; for open camera traps, we placed small-mammal carcasses, scent lures, and audio lures above or alongside the PVC pipe. We did not use small-mammal carcasses in box or bucket camera traps, nor did we use baits or lures for other small mammals (i.e., mice, voles, or shrews). We assumed the lures used to attract Least Weasels did not influence the detection rates for our other focal genera. We revisit this assumption in the Discussion. Camera-trap deployment occurred in October and December 2022 and February 2023. We left cameras at each site for 61–191 days and set them to high sensitivity to record 3 images for every detection event, with a 5-second delay between detection events. We used CamPark model T10 cameras (Shenshen, China; https://www.campark.net/), with a focal distance of 10 cm and greater, and Covert Scouting Cameras model MP30 (Russellville, KY; https://www.feradyne.com/), with a +3 close-focus lens stack affixed in front of the camera lens using reusable poster putty.

We visited each camera every 3 weeks to download images, replenish baits and lures for Least Weasels, and replace batteries if needed. Based on the photo-quality of many of our detections and the cryptic nature of many of these species, we felt most confident identifying mammals to genus rather than species, except for Least Weasels. For the same genera photographed multiple times, we determined an independent detection event as photographs taken greater than 1 hour apart (Weerakoon et al. 2014). We grouped small mammals into 3 separate taxonomic guilds types for comparison: mice (genera *Peromyscus*, *Mus*, and *Zapus*), voles (*Microtus* and *Clethrionomys*), and shrews (*Blarina* and *Sorex*). However, we found that almost all of the mice were *Peromyscus* (>99%), the great majority of voles were *Microtus* (91%), and most shrews were *Blarina* (75%). Images of poor quality where species genera could not be determined were deleted from analysis.

We determined the effectiveness of each camera-trap design by comparing the number of detections and time to first detection by small-mammal type using the R program v. 4.4.3 (R Core Team 2024). Our data on number of detections were not normally distributed; thus, we used Tukey's-based nonparametric pairwise comparison tests to assess detection rates between camera-trap designs by small-mammal type (α = 0.05) using the 'nparcomp' package v. 3.0 in R (Konietschke et al. 2019; see also the supplemental spreadsheet data [Captures] on detection results showing number of detections ['captures'] for each mammal type at each location ['Site'] by camera trap design, available online at https://osf.io/hs3zg). We used the 'nparcomp' package to compute nonparametric multiple contrast tests and simultaneous confidence intervals for relative treatment effects by implementing rank-based methods for multiple comparisons (Konietschke et al. 2015).

To determine time to first detection, we followed a similar analysis to Ebel and White (2024) and used log-rank tests to compare survivorship curves for each camera trap design by small mammal type (α = 0.05) using the 'survival' v. 3.8-3 and 'survminer'v. 0.5.0 packages in R (Kassambara et al. 2024, Therneau 2024). The 'survminer' package analyzes time-to-event data to produce survival curves based on the Kaplan–Meier non-parametric method. We adapted its use to determine time to first detection rather than time until death (see supplemental spreadsheet data [Detection] on time to first detection showing the number of days ['time'] until first detection event ['status': '1' detected and '0' not detected] for each mammal type by camera trap design at each location [individual row], available online at https://osf.io/ztdb2). Unfortunately, we lost temporal data for our Hawk Mountain site and could not determine time to first detection. R code for our analysis of the supplemental material referenced above is available online at https://osf.io/x4ewp.

Results

Our cameras were set out for a total of 3375 trap days (24-hr periods) across all locations, and we recorded a total of 1253 independent small-mammal detection events (Table 1, Fig. 3). We detected no Least Weasels during our study. We recorded fewer total small-mammal detections with open camera traps (n = 229)

Table 1. Summary of the total number of small-mammal detections (det.; n = 15 camera-trap locations) and median number of days to first detection (n = 14 camera-trap locations) for each small mammal type (i.e., mice, shrew, vole) as recorded by each camera-trap design (i.e., open, box, bucket).

	Small-mammal type							
	Mice		Shrews		Voles		All small mammals	
Camera-trap design	Total det.	Median days to first det.	Total det.	Median days to first det.	Total det.	Median days to first det.	Total det.	Median days to first det.
Open	229	1	0	NA	0	NA	229	1
Bucket	333	21	23	80	43	24	399	21
Box	537	23	17	42	71	30	625	28
All	1099	21	40	46	114	30	1253	24

compared to box (n = 625) and bucket (n = 399) camera traps (P < 0.01) and found no significant difference in the total number of small-mammal detections between boxes and buckets (P = 0.60) (Table 1, Fig. 4). Box camera traps detected significantly more mice (n = 537) compared to open camera traps (n = 229; P = 0.02), while the number of mice detected with bucket camera traps (n = 333) did not differ significantly from box (P = 0.30) or open camera traps (P = 0.27) (Table 1, Fig. 4). Overall, box camera traps detected the greatest number of mice and voles (n = 71), while bucket camera traps detected a greater number of shrews (n = 23), though these differences were not significant ($P \geq 0.65$; Fig. 4).

We found that open camera traps detected mice faster (1 median day to first detection) than box (23 median days to first detection) and bucket camera traps (21 median days to first detection) (P < 0.01); however, no voles or shrews were detected with open camera traps (Table 1; Figs. 4, 5). The time to first detection did not significantly differ between box and bucket camera traps for mice (P = 0.40), shrews (P = 0.99), or voles (P = 0.80) (Table 1, Fig. 5).

Discussion

We detected no Least Weasels during our study and rejected our hypothesis that there were no differences in the effectiveness of small-mammal (mouse, vole, and shrew) detections between camera-trap designs. Both box and bucket camera traps

Figure 3. Camera-trap photographs of small terrestrial mammals detected using open, box, and bucket camera-trap designs across 15 locations in Pennsylvania.

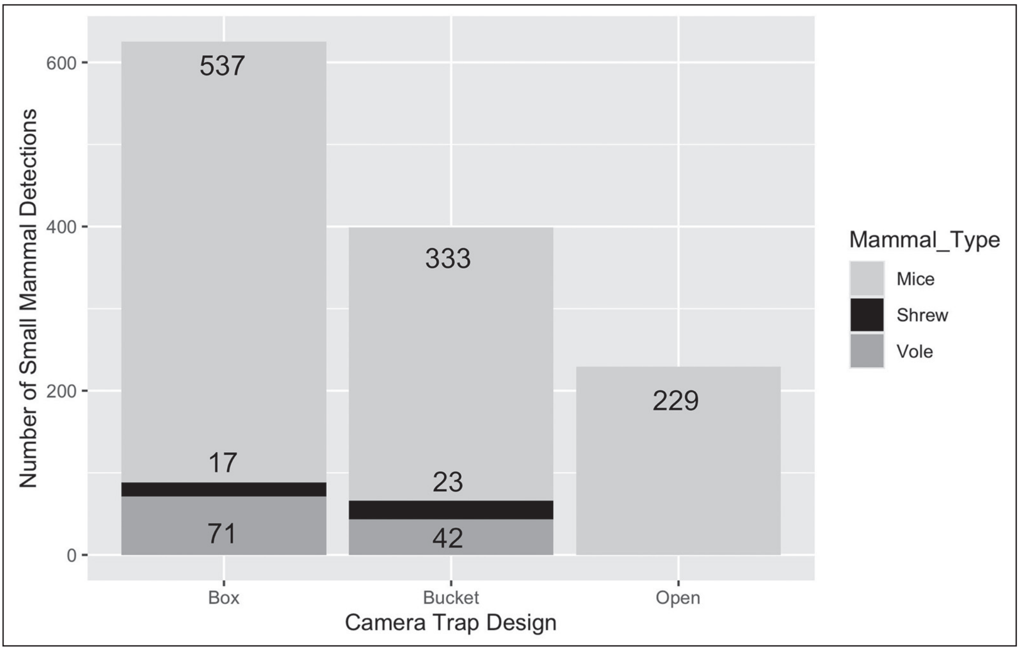

Figure 4. Number of small-mammal detections by camera-trap design stacked by small-mammal type. Open camera traps detected significantly fewer small mammals than box and bucket traps ($P < 0.01$), and box traps detected significantly more mice than open traps ($P = 0.02$). We found no significant difference in small-mammal detections between box and bucket camera-trap designs ($P \geq 0.27$). Open camera traps did not detect any voles or shrews.

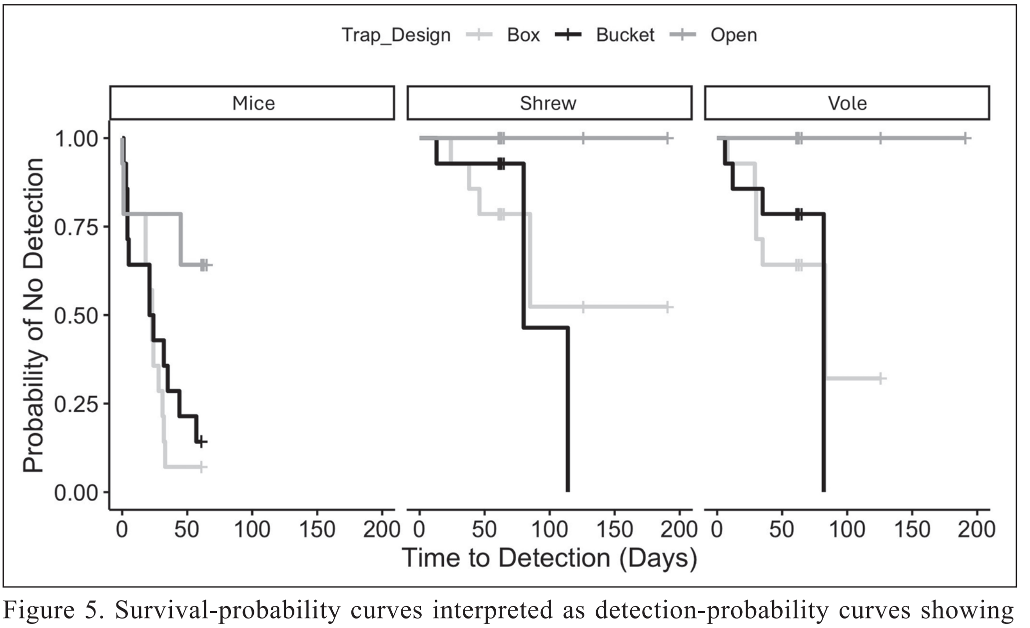

Figure 5. Survival-probability curves interpreted as detection-probability curves showing time to first detection for each small-mammal type by camera-trap design. Open camera traps did not detect voles or shrews.

detected significantly more small mammals overall than open camera traps. No voles or shrews were detected with open traps, and box traps detected significantly more mice compared to open traps (Table 1, Fig. 4). The number of mice detected by bucket traps did not significantly differ from box or open traps. Although open traps detected mice faster compared to box and bucket traps, they did not detect any voles or shrews, and time to first detection did not differ between box and bucket traps for mice, voles or shrews (Table 1, Fig. 5).

Overall, box and bucket traps were similar in their effectiveness at detecting small terrestrial mammals, while open traps were the least effective. Littlewood et al. (2021) found that utilizing a baited tunnel and close-focus lens was effective at capturing quality photos. Similarly, in a study comparing 3 camera-trap methods in northwestern California (i.e., open-facing ground, open-facing tree, and tube or box-like trap), McCluskey (2024) found that the "tube" camera-trap design—modelled after the "selfie trap" developed by Gracanin et al. (2022)—detected the greatest number of small-mammal species. McCluskey (2024) also found that the time to first detection for each species was similar across camera-trap designs and varied from 0.43 to 7.00 days, though most small-mammal species were detected within the preliminary 4-day survey effort. This amount of time to first detection was much shorter than ours, possibly due to McCluskey (2024) baiting specifically for small mammals (e.g., mice and voles). Overall, time to first detection in our study varied greatly with respect to trap design and small-mammal type, as our open camera traps detected mice very quickly. This difference may be due to the wider field of view of the open camera traps, allowing them to detect the more arboreal *Peromyscus* mice above ground more readily than the semi-fossorial shrews and voles.

Environmental factors such as habitat type, resource availability, canopy cover, precipitation, and season can influence small-mammal abundance, species activity, and detection probability when using cameras (Jolly et al. 2024, Littlewood et al. 2021, McCluskey 2024). For example, Mölle et al. (2021) and Soininen et al. (2015) found that box camera-trap designs more effectively detected small mammals in the subnivean environment during the winter. Additionally, Littlewood et al. (2021) demonstrated that habitat type may influence the detection probability of small mammals due to food availability. Thus, studies have used bait to attract small mammals to camera traps to increase detection rates and improve photo quality (Meek and Vernes 2015). For example, Gracanin et al. (2022) placed a bait holder in front of the camera within their selfie camera trap, which facilitated the documentation of facial images of small mammals. The use of bait in this way can provide higher-resolution and more-focused images that improve confidence in species identification, particularly between similar species (Gracanin et al. 2022, Porter and Dueser 2024). Though we did not use baits or lures for mice, voles, or shrews, such attractants can cause these animals to stay in the camera trap longer, possibly improving the likelihood of capturing quality photos to aid with species identification. In their modified bucket trap, Porter and Dueser (2024) used cracked corn, sunflower seeds, and peanut butter, while McCleery et al. (2014) used black oil sunflower seed and chicken scratch. Fink and Jackowski (2025) used box traps baited with a combination of bird seed and dried mealworm to successfully detect small mammals. We assumed none of the lures or attractants used in this study impacted detection rates for mice, voles or shrews as we used none of the above-mentioned food baits. Instead, we used lures and attractants for Least Weasels, of which we had no detections. To improve detection of weasels, both Ebel and White (2024) and Bergeson et al. (2025) recommended that baits and lures be used in combination, such as salmon oil with either red meat or raw chicken. Camera traps can also be designed to prevent the removal of the bait by non-target animals, such as *Procyon lotor* (L.) (Northern Raccoon); an example is the bucket design with internal barriers, known as "walls of despair", surrounding the bait holder to deter non-target species (Dueser et al. 2025, Porter and Dueser 2024). However, such an approach may not prove effective for larger non-target animals such as bears, which could flip and destroy the entire bucket.

Though we did not quantify photo quality, we observed, anecdotally, that photo quality from the box and bucket traps were better than that of open traps (Fig. 3), likely due to the reduced distance between the small mammal and the camera. Furthermore, open traps appeared prone to false triggers (when the cameras took images without an animal present) due to shifting shadows and vegetation within the field of view. One method to increase the likelihood of capturing fast-moving targets and decrease blurry images is to program cameras to take videos. In a comparison of paired cameras—one set to video and the other to photographs—Villette et al. (2016) determined that video was more effective over photographs when detecting small mammals such as rodents. Also, the additional angles provided by videos can assist with species identification (Porter and Dueser 2024). However, the use of videos can make data processing more time consuming.

Recently, the use of the adapted-hunt drift fence technique (AHDriFT) in conjunction with a bucket camera-trap design has been used to improve photo detections of small terrestrial mammals (Appendix 1). An AHDriFT system consists of a form of drift fence used to funnel small and medium-sized animals toward a bucket camera trap (Amber et al. 2021, Martin et al. 2017, White et al. 2023). Amber et al. (2021) evaluated the effectiveness of AHDriFT as an alternative to traditional camera trapping. Not only were the arrays durable in extreme environmental conditions, but also the high photo quality allowed for the identification of all vertebrates to the species level. The authors recommended using AHDriFT to determine terrestrial vertebrate biodiversity and to simultaneously target multiple species (Amber et al. 2021). White et al. (2023) compared the effectiveness of AHDriFT systems to Sherman traps for surveying small-mammal communities and found that analysis from AHDriFT photos revealed a greater species richness, species evenness, and Shannon's diversity values. White et al. (2023) also identified multiple secretive species of *Peromyscus*, *Microtus*, *Sorex*, and *Blarina* using an AHDriFT system. A limitation of the AHDriFT system is the high up-front equipment cost and effort to build this design in the field. However, long-term benefits suggest more efficient and effective small-mammal detections (Amber et al. 2021, White et al. 2023).

Our results suggest that both box and bucket camera traps were effective for small-mammal photo detections, and we recommend their use for future research determining the richness and diversity of small-mammal communities. We also recommend using bait to decrease time to first detection and employing novel designs, such as the "walls of despair", to avoid unwanted photos of non-target animals (Dueser et al. 2025, Porter and Dueser 2024). Also, using video combined with still images may assist in better identification of small mammals (Porter and Dueser 2024, Villette et al. 2016).

Based on the results of Amber et al. (2021) and White et al. (2023), the use of AHDriFT systems can increase detections of small mammals. The traditional AHDriFT system used a bucket camera-trap design (Amber et al. 2021, Martin et al. 2017, White et al. 2023); we suggest using box cameras with AHDriFT systems when studying small mammals. From our experience in the field, box camera traps were easier to set up and captured better profile pictures of small mammals for potentially easier identification (Fig. 3). Also, we found that our bucket traps were more visible in the field (attracting unwanted attention) and were more easily knocked over by animals and people (unless securely fastened by additional cables and anchors), and bucket lids were more difficult to remove in cold weather. However, box traps were heavier to carry than the buckets. A possible adjustment to the box camera trap is to use a plastic design, rather than metal, to make it more lightweight and manageable in the field. We recommend that future efforts compare the effectiveness of bucket and box designs in combination with the AHDriFT system for photo-detecting small terrestrial mammals.

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Appendix 1. The adapted-hunt drift fence technique (AHDriFT) is used in combination with the bucket camera-trap design to improve photo-detection of small terrestrial mammals. This technique was modeled after White et al. (2023).