Tools and Technology

Effects of Trap Type on Small Mammal Richness, Diversity, and Mortality

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ABSTRACT When evaluating richness and diversity of small mammal communities, it is important to consider the impact that trap efficacy may have on these indices. The objectives of our study were to determine species-specific trap efficacy relative to Sherman traps and pitfall traps, assess the impact of trap efficacy on measures of species richness and diversity, and compare mortality rates between trap types and whether pitfall covers reduce trap mortality. In the summers of 2009 and 2010, we trapped throughout Wisconsin, USA, in 5 vegetation communities. We used 180 transects (190 m long) of 20 Sherman live traps spaced every 10 m and 10 pitfall traps spaced every 20 m for 4 consecutive nights. We trapped 3,261 small mammals of 23 species in 34,235 combined trap-nights. Pitfall traps were more effective at capturing shrews and voles, whereas Sherman traps captured more mice (*Peromyscus* spp.) and squirrels. Irrespective of vegetation community, both trap types together captured significantly higher species richness and diversity than either trap type captured independently. Covers significantly reduced mortality of *Peromyscus* spp., but not for voles or shrews, and covers reduced overall captures of voles. Our results indicate that Sherman and pitfall traps capture different portions of the small mammal community and, regardless of the vegetation community, should be used in combination when assessing species richness and diversity. © 2014 The Wildlife Society.

KEY WORDS pitfall traps, richness, Shannon–Wiener diversity index, Sherman live trap, small mammals, trap mortality, Wisconsin.

In ecological studies of small mammals, trapping is often used to capture species in an area. Indices of richness and diversity are calculated from these captures and used to describe the structure of small mammal communities (e.g. Caro 2001, Sullivan and Sullivan 2001, Constantine et al. 2004). Underlying assumptions of these metrics are that individuals captured during trapping reflect accurately the number of species and relative abundance of animals that occur in an area. In order to meet these assumptions, a number of trap types are often used (Beachman and Krebs 1980, Kalko and Handley 1993). Traditionally, snap traps were used extensively to capture small mammals and numerous studies have compared snap traps to pitfall traps or live traps such as Sherman traps or Longworth traps (Wiener and Smith 1972, Hansson and Hoffmeyer 1973, Beachman and Krebs 1980, Kalko and Handley 1993, Woodman et al. 1996). Although effective, snap-trapping removes animals from the population and therefore cannot be used in mark–recapture studies or studies that require live animals. Furthermore, removal trapping may have ethical

ramifications, especially when rare or sensitive species are captured (Farnsworth and Rosovsky 1993). Consequently, use of snap traps in ecological studies has declined and live traps such as Sherman traps or pitfall traps have replaced them.

A number of studies comparing Sherman traps and pitfall traps have demonstrated species-specific trap biases and indicated that pitfall traps are a valuable addition to trapping protocols (Williams and Braun 1983, Nicolas and Colyn 2006, Umetsu et al. 2006, Dizney et al. 2008); nevertheless, it is often unclear as to the extent that adding pitfall traps to a trapping protocol will affect richness and diversity calculations. Moreover, most studies that compared Sherman traps to pitfall traps sampled in one vegetation community or system, limiting their inference to other communities or systems. If trap type affects metrics of small mammal community structure irrespective of vegetation community, then results from studies using only one trap type may be biased. Given the prolific use of metrics such as richness and diversity for describing small mammal communities, the need to understand the effects of trap type on these metrics and abundance within a variety of systems is important.

In addition to understanding trap efficacy and how it affects community metrics, mortality rates can vary with trap type. Traps with high mortality rates can be counterproductive in studies that require live animals or affect populations of conservation concern. In particular, pitfall traps often have

extremely high mortality rates, especially for shrews and during wet weather (Briese and Smith 1974, Bury and Corn 1987, Anthony et al. 2005). To decrease mortality in pitfalls, covers have been employed to reduce moisture accumulation on rainy nights (Bury and Corn 1987, Dizney et al. 2008). However, there have been few published studies addressing the effectiveness of rain covers at decreasing mortality or whether they alter capture rates. In Australia, shade covers reduced captures of both herpetofauna and mammals (Hobbs and James 1999). If rain covers produce similar results, they may also reduce captures in pitfall traps.

Although there are many trap types available to sample small mammals, including tracking plates (Boonstra et al. 1992), hair snares (Dickman 1986), and camera traps (De Bondi et al. 2010), Sherman traps and pitfall traps are among the mostly widely used and we focus on them for the purpose of this study. We trapped small mammals in 5 vegetation communities across a large geographical extent using a combination of Sherman and pitfall traps to 1) compare the efficacy of Sherman traps and pitfall traps at capturing small mammal species and population demographics; 2) evaluate how trap type affects community metrics of richness and diversity across several vegetation communities; 3) compare relative mortality rates for both Sherman traps and pitfall traps; and 4) determine whether the use of pitfall trap covers reduces pitfall mortality or captures. We hypothesized that Sherman traps and pitfall traps would capture different small mammal species, leading to differences in community metrics. We also hypothesized that mortality rates would be higher in pitfall traps and that rain covers would reduce mortality.

STUDY AREA

We conducted the study throughout Wisconsin, USA (Fig. 1). Mean summer temperatures statewide ranged from 16° C in the north to 23° C in the south and mean winter temperatures ranged from -17° C in the north to -8° C in the south; annual precipitation varied from 81 cm in the north to 71 cm in central and southern Wisconsin (Wisconsin State Climatology Office 2010). As a result of glaciation, Wisconsin had little topographic relief, with elevations ranging from 177 m to 595 m. Abiotic factors and differential climatic conditions created 2 major floristic divisions in Wisconsin, with boreal flora in the north and prairie flora in the south (Curtis 1959). We focused on natural areas, and using a stratified approach we selected 23 study areas distributed relatively evenly across the state. At each study area, we selected 6–9 sites harboring native vegetation communities (on average, sites were 8.74 km apart; range = 0.09–30.51 km), for 180 total sites sampled in 2009 ($n = 83$) or 2010 ($n = 97$). Vegetation communities varied by area and, for the purpose of this study, we grouped sites into 5 general vegetation communities: barrens ($n = 28$), dry forests ($n = 40$), dry prairies ($n = 24$), forested wetlands ($n = 49$), and wet prairies–wetlands ($n = 39$). State Natural Areas (http://dnr.wi.gov/topic/Lands/naturalareas/) were used extensively, with property ownership including state, county, federal, reservation, and private.

METHODS

Small Mammal Surveys

From June to August 2009 and 2010, we trapped small mammals (<250 g) using 190-m transects with a Sherman
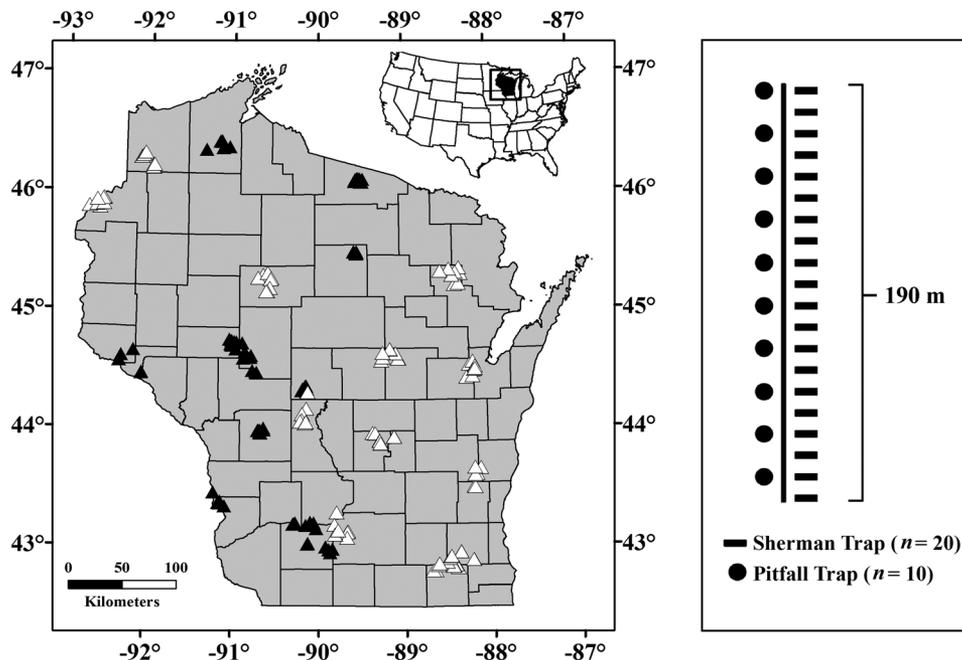
Figure 1. Left panel: Locations of small mammal trapping transects for 2009 (closed triangles) and 2010 (open triangles) in Wisconsin, USA. Right panel: Diagram depicting transect layout. Traps were placed within 1 m of the each transect.

live trap (7.6 cm × 8.9 cm × 23.9 cm; H.B. Sherman, Inc., Tallahassee, FL) at 10-m intervals ($n = 20$/transect) and a pitfall trap (38 cm deep, 20-cm diam, 10-L, floral cooler buckets; Syndicate Sales, Inc., Kokomo, IN) at 20-m intervals ($n = 10$/transect; Fig. 1). We used transects rather than grids to maximize species richness (Read et al. 1988, Pearson and Ruggiero 2003). When possible, we oriented transects in a cardinal direction; however, because of the irregular shape and small size of many vegetation communities, we often placed transects to fit in order to keep transects within one distinct vegetation community. Because of time and labor constraints, we installed pitfall traps at every other station. When possible, we positioned traps within a 1-m radius of the flag and along natural runways such as fallen trees or rocks. Extremely rocky soil and shallow bedrock precluded digging of pitfall traps in 6 dry prairie transects. We baited Sherman and pitfall traps with peanut butter spread approximately 4 mm thick between sheets of paper towel and cut into 2.5 cm × 2.5 cm squares. One square was used in each trap and bait was replaced as needed. We trapped for 4 consecutive nights and checked traps approximately 1–4 hours after sunrise and 4 hours before to 1 hour after sunset. Following identification of high mortality rates in pitfall traps during rainy nights in 2009, we placed black corrugated plastic covers (30 cm × 30 cm) approximately 15 cm above every other pitfall trap ($n = 5$/transect) using 2 wooden dowels in 2010.

We identified captured animals to species, determined sex, and weighed and marked each individual with a slight ear notch using scissors. Subsequent ear biopsies and genetic techniques were used to verify identification of *Peromyscus* spp. (Stephens et al. 2014). A different combination of ear notches was used each day and these, along with weight and sex, were used to identify recaptured individuals. To identify recaptured shrews, we trimmed the terminal caudal hairs. In 2010, we also recorded the presence or absence of precipitation during the trapping interval. We prepared incidental deaths and voucher specimens as study skins, skeletons, and tissues and deposited them in the UW—Stevens Point Museum of Natural History, Stevens Point, WI; National Museum of Natural History, Washington, D.C.; Natural History Museum of Utah, Salt Lake City, UT; University of Alaska Museum, Fairbanks, AK; and Harvard Museum of Comparative Zoology, Cambridge, MA. Our trapping protocol was approved by the University of Wisconsin Stevens Point—Stevens Point Animal Care and Use Committee (protocol no. 201004.14) and followed guidelines outlined by the American Society of Mammalogists (Sikes et al. 2011).

Data Analysis

Because peanut butter is odoriferous and more bait at a station could potentially attract animals to a trap station, before beginning analyses we assessed whether a baited pitfall trap, paired with a Sherman trap, was influencing the capture rates in Sherman traps. Pitfall traps were never used independently, thus it was not possible to test whether baited Sherman traps affected capture rates of pitfall traps. For 7 commonly captured species we used a paired-sample t-test to compare the number of individuals captured in Sherman traps without a paired pitfall trap to Sherman traps paired with a pitfall trap within a transect. Results of this test indicated that trap pairing significantly increased captures of white-footed mice (*Peromyscus leucopus*) in Sherman traps by approximately 12% ($t = 2.330$, df = 119, $P = 0.021$), but did not significantly affect captures of northern short-tailed shrews (*Blarina brevicauda*; $t = -1.888$, df = 33, $P = 0.068$, meadow vole (*Microtus pennsylvanicus*; $t = 1.412$, df = 55, $P = 0.163$), southern red-backed voles (*Myodes gapperi*), ($t = -1.117$, df = 48, $P = 0.269$), woodland deer mice (*P. maniculatus gracilis*; $t = -1.786$, df = 23, $P = 0.087$), thirteen-lined ground squirrels (*Ictidomys tridecemlineatus*; $t = 0.879$, df = 21, $P = 0.389$), or eastern chipmunks (*Tamias striatus*; $t = -0.138$, df = 27, $P = 0.892$). These results indicate that trap pairing only minimally affected capture rates in Sherman traps and we chose to proceed with further analysis. Transects were used as the unit of replication for community analyses and captures were pooled across transects for all other analyses.

For the 12 species with ≥ 30 individuals, we used a chi-square goodness-of-fit test to compare the distribution of captures among traps according to trap availability. Expected chi-square values were based on number of trap-nights, approximately a 2:1 ratio of Sherman traps to pitfall traps when adjusted for tripped or disabled traps where: trap-nights = (traps × no. of trap checks) − (sprung Sherman traps or disabled pitfall traps × 0.5; Nelson and Clark 1973, Beauvais and Buskirk 1999). One trap-night was subtracted for missing or destroyed traps. Because prior exposure to traps is known to change individual capture rates (Getz 1961), we only used first-time captures in these analyses, reducing the number of captures used in analyses and making them more conservative in their ability to detect differences. Pitfall traps are considered a passive trap, capturing animals by haphazard encounter, rather than an animal purposefully entering. However, there has been little documented evidence to support this hypothesis. If pitfall traps are passive, then greater ambient light should decrease captures by making the traps more visible. For species with ≥ 4 captures in each trap type during morning and evening checks, we assessed whether nocturnal and diurnal capture distributions were similar using a chi-square test of independence. When this test was significant, we also used a chi-square goodness-of-fit test to determine whether distributions in trap types were different. Pitfall traps are known to capture smaller animals (Umetsu et al. 2006); thus, for 7 species with ≥ 12 individuals in each trap type, we used a Mann–Whitney U-test to assess whether Sherman live traps and pitfall traps captured animals of similar weights. We used weight within a species as a surrogate for age. Weights of animals trapped in 2009 were not used because weights were infrequently recorded if animals had died in a trap. Additionally, for these same species we used a chi-square test of independence to determine whether both trap types were capturing similar sex ratios. *Sorex cinereus* and *B. brevicauda*

were excluded from analysis because sexing these species proved difficult in the field.

For transects containing both trap types (6 transects removed from dry prairies; $n = 174$), we calculated the richness (total no. of species) and diversity using the Shannon–Wiener diversity index ($H = -\Sigma p_i \log_e p_i$, where p_i = relative abundance of the ith species) for Sherman live traps, pitfall traps, and a combination of both traps using first-time captures (Shannon and Weaver 1949). These values were compared within each of the 5 vegetation communities using a 1-way repeated-measures analysis of variance (ANOVA) with Greenhouse–Geisser correction for unequal variance and Bonferroni *post hoc* tests. Based on histograms, some data sets were only marginally normally distributed; however, ANOVAs are reasonably robust to slight deviations in normality (O'Brien and Kaiser 1985).

Mortality is likely to increase when traps are wet; and using all captures from 2010 and pair-wise chi-square tests, we compared mortality rates of groups of similar genera and locomotion: quadrupedal insectivores represented by shrews (*B. brevicauda* and *Sorex* spp.), quadrupedal rodents represented by arvicoline rodents (*M. pennsylvanicus*, prairie vole [*Microtus ochrogaster*], *M. gapperi*, and southern bog lemming [*Synaptomys cooperi*]); and scansorial rodents (*Peromyscus* spp.) captured in covered pitfall traps, uncovered pitfall traps, and Sherman live traps on both rainy and non-rainy nights. Finally, we used a chi-square goodness-of-fit test to analyze whether using pitfall trap covers changed the number of captures within the aforementioned groups and

meadow jumping mice (*Zapus hudsonius*). All statistical analyses were performed in PSAW Statistics version 18 (IBM SPSS Statistics, Chicago, IL). Statistical significance was assessed at $\alpha = 0.05$.

RESULTS

Trap Efficacy
We captured 1,264 individuals of 19 species in 2009 and 1,997 individuals of 22 species in 2010, totaling 3,261 individuals of 23 species of small mammals (Table 1). Sherman live traps captured 1,924 individuals of 22 species in 22,599 trap-nights (8.5% trap success) and pitfall traps accounted for 1,337 individuals of 17 species in 11,636 trap-nights (11.5% trap success). Sherman traps captured 6 unique species (all >50 g), and pitfall traps had 1 unique capture (Table 1). Pitfall traps were more effective at capturing 8 of 12 species that had >30 captures. At the extremes, pitfall traps were nearly 40 times more likely to capture pygmy shrews (*S. hoyi*) than were Sherman traps, whereas *I. tridecemlineatus* and *T. striatus* were 18 and 7 times more likely, respectfully, to be captured in Sherman traps (Table 1).

Among 4 species that had significantly higher capture rates in pitfall traps overall, capture distributions of *B. brevicauda* and *M. gapperi* in pitfall traps and Sherman traps were significantly different for diurnal and nocturnal trap checks (Table 2). After adjusting for trap-nights, there were no differences in capture rates between trap types for diurnal

Table 1. Number of individual small mammals captured in Wisconsin, USA, natural vegetation communities during the summers of 2009 and 2010 and associated catch per 100 trap-nights (CPU), adjusted for tripped or disabled traps. Differences in probability of capture are the multiplicative increase in capture in one trap type versus another (Sherman trap advantage is set in bold-faced type, pitfall trap advantage is not). All differences in probability were significant at $P < 0.05$ as indicated by chi-square goodness-of-fit test.

Species	No. of individuals captured		Sherman live trap		Pitfall trap		Differences in probability of capture
	2009	2010	Captures	CPU	Captures	CPU	
Peromyscus leucopus	**436**	**757**	**1,004**	**4.443**	**189**	**1.624**	**2.7**
Myodes gapperi	91	359	262	1.159	188	1.616	1.4
Sorex cinereus	179	267	28	0.124	418	3.592	29.0
Microtus pennsylvanicus	167	173	166	0.735	174	1.495	2.0
Blarina brevicauda	167	59	96	0.425	130	1.117	2.6
Peromyscus maniculatus gracilis[a]	**26**	**96**	**104**	**0.460**	**18**	**0.155**	**3.0**
Zapus hudsonius	32	53	24	0.106	61	0.524	4.9
Sorex arcticus	31	50	11	0.049	70	0.602	12.3
Ictidomys tridecemlineatus	**47**	**25**	**70**	**0.310**	**2**	**0.017**	**18.0**
Tamias striatus	**12**	**49**	**57**	**0.252**	**4**	**0.034**	**7.3**
Sorex hoyi	13	30	2	0.009	41	0.352	39.8
Synaptomys cooperi	11	28	7	0.031	32	0.275	8.9
Glaucomys volans	8	18	26	0.115	0	0.000	
Peromyscus maniculatus bairdii[a]	20	5	24	0.106	1	0.009	
Microtus ochrogaster	15	1	15	0.066	1	0.009	
Mustela ermine	2	14	16	0.071	0	0.000	
Condylura cristata	3	4	1	0.004	6	0.052	
Tamiasciurus hudsonicus	2	4	6	0.027	0	0.000	
Glaucomys sabrinus	2	0	2	0.009	0	0.000	
Sorex palustris	0	2	1	0.004	1	0.009	
Mustela frenata	0	1	1	0.004	0	0.000	
Reithrodontomys megalotis	0	1	0	0.000	1	0.009	
Sylvilagus floridanus	0	1	1	0.004	0	0.000	

[a] The woodland form of the deer mouse (*Peromyscus maniculatus gracilis*) and the prairie form (*P.m. bairdii*) are listed as separate taxa because of marked difference in morphological characteristics and habitat preferences.

Table 2. Number of individuals of small mammal species with ≥4 captures in each trap type during nocturnal and diurnal checks in Wisconsin, USA, during the summers of 2009 and 2010.

Species	Nocturnal captures		Diurnal captures		Chi-square test	
	Sherman	Pitfall	Sherman	Pitfall	Chi-square	P
Blarina brevicauda	87	126	9	4	4.04	0.044
Microtus pennsylvanicus	128	148	38	26	3.51	0.060
Myodes gapperi	206	176	56	12	19.17	<0.001
Sorex cinereus	22	376	6	42	3.54	0.060

captures of *B. brevicauda* ($\chi^2 = 0.06$, df = 1, $P = 0.806$) and *M. pennsylvanicus* ($\chi^2 = 1.25$, df = 1, $P = 0.263$), whereas *M. gapperi* was captured 2.3 times more often in Sherman traps during diurnal checks ($\chi^2 = 0.81$, df = 1, $P = 0.004$). *Sorex cinereus* was still captured more often in pitfall traps during diurnal checks ($\chi^2 = 43.41$, df = 1, $P < 0.001$).

Of 7 species analyzed, only *M. gapperi* and *P. leucopus* had significantly different mean weights between trap types (Table 3). Sherman traps caught larger *P. leucopus* than pitfall traps by 2.5 g, whereas pitfall traps caught larger *M. gapperi* by 1.4 g (Table 3). Of 5 species for which we compared sex ratios between trap types, only *M. pennsylvanicus* ($\chi^2 = 6.49$, df = 1, $P < 0.011$) and *P. leucopus* ($\chi^2 = 4.59$, df = 1, $P < 0.032$) had significantly different sex ratios. For *M. pennsylvanicus*, Sherman traps captured 55.1% females and 44.9% males, whereas pitfall traps captured 35.8% females and 64.2% males. For *P. leucopus*, Sherman traps captured 44.7% females and 55.3% males, whereas pitfall traps captured 54.8% females and 45.2% males.

Community Composition

We observed significantly different richness and Shannon–Wiener diversity values among Sherman traps, pitfall traps, and both trap types combined for all 5 vegetation communities (Fig. 2). For all vegetation communities, the richness from both trap types combined was significantly higher than values derived from either Sherman traps or pitfall traps separately (Fig. 2). On average, richness calculated from a combination of pitfall and Sherman traps increased by 63% and 47% from using only Sherman traps or pitfall traps, respectively (Fig. 2).

For barrens, dry prairies, forested wetlands, and wet prairies–wetlands, the diversity values from both trap types combined were significantly higher than values derived from Sherman live or pitfall traps individually (Fig. 3). In these communities, with the exception of forested wetlands,

diversity values for Sherman traps and pitfall traps were not significantly different from each other (Fig. 3). In forested wetlands, pitfall traps had significantly higher diversity values than Sherman traps (Fig. 3). In dry forests, combined trap diversity values were not significantly different from those of pitfall traps, but both were significantly higher than those from using Sherman traps independently (Fig. 3). On average, Shannon–Wiener diversity values calculated from a combination of pitfall traps and Sherman traps was 72% and 32% greater than using only Sherman traps or pitfall traps, respectively (Fig. 3).

Mortality

In 2010, 27% of 17,101 combined trap-nights had a rain event; on rainy checks, we observed higher mortality for arvicoline rodents and *Peromyscus* spp. in both covered and uncovered pitfall traps, but not Sherman traps (Fig. 4). Adding covers to pitfall traps did not significantly lower arvicoline mortality on rainy or non-rain checks, but did significantly lower mortality for *Peromyscus* spp. in both instances (Fig. 4). On checks without rain, mortality of arvicoline rodents was lower in Sherman traps than both covered and uncovered pitfall traps and mortality of *Peromyscus* spp. was lower in Sherman traps than uncovered pitfall traps but Sherman trap mortality was not significantly different from that in covered pitfall traps (Fig. 4). Shrew mortality was *independent* of trap type and rain events (Fig. 4). The addition of covers to pitfall traps significantly lowered captures of arvicoline rodents by 29.7% ($\chi^2 = 9.074$, df = 1, $P = 0.003$), but not *Peromyscus* spp. ($\chi^2 = 1.38$, df = 1, $P = 0.240$), shrews ($\chi^2 = 0.994$, df = 1, $P = 0.319$), and *Z. hudsonius* ($\chi^2 = 0.231$, df = 1, $P = 0.631$).

DISCUSSION

One common goal of small mammal community studies is to accurately determine the number of species and their relative

Table 3. Mean weight of small mammal species captured in Sherman traps and pitfall traps in Wisconsin (USA) natural vegetation communities during the summers of 2009 and 2010. An asterisk (*) indicates species with a significant difference in weight ($P \leq 0.05$, Mann–Whitney *U*-test).

| Species	Sherman			Pitfall			Mann–Whitney test	
	n	$\bar{x}$	SD	*n*	$\bar{x}$	SD	U	P
Blarina brevicauda	21	18.16	2.79	36	18.63	3.30	342.0	0.549
Microtus pennsylvanicus	77	27.5	11.05	95	30.71	12.51	3,111.0	0.092
*Myodes gapperi**	208	18.43	5.33	148	19.81	6.30	13,509.0	0.049
*Peromyscus leucopus**	620	21.13	5.51	133	18.64	6.74	40,332.0	<0.001
Peromyscus maniculatus gracilis	80	17.78	4.12	96	17.31	3.98	628.0	0.906
Sorex cinereus	16	3.78	0.55	200	3.91	2.00	1,540.5	0.803
Zapus hudsonius	14	16.29	2.67	39	16.39	3.57	263.5	0.847
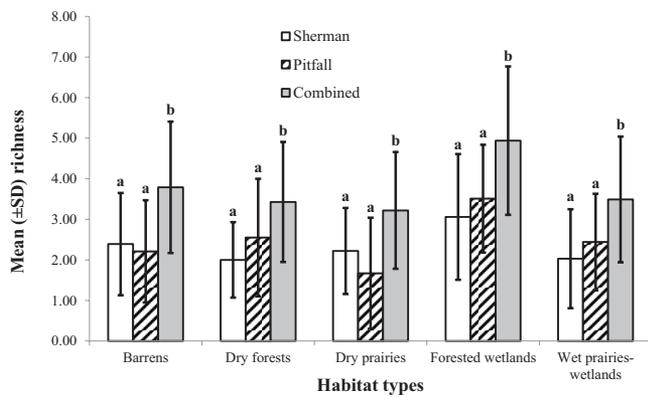
Figure 2. Mean transect (±SD) species richness of small mammals captured by Sherman traps, pitfall traps, and a combination of both trap types in 5 Wisconsin (USA) vegetation communities. Data from 2009 and 2010 were pooled for analysis. Within each vegetation community, trap types sharing a common letter were not significantly different ($P \leq 0.05$) as indicated by Bonferroni-corrected *post hoc* tests. The one way repeated measures analysis of variance for richness of small mammal captures among 3 trap types (Sherman traps, pitfall traps, and a combination of both trap types) was significant for all habitats: barrens ($F_{1.56,42.13} = 22.14, P < 0.001$), dry forests ($F_{1.31,51.26} = 24.66, P < 0.001$), dry prairies ($F_{1.32,22.48} = 16.56, P < 0.001$), forested wetlands ($F_{1.50,71.75} = 51.90, P < 0.001$), and wet prairie–wetlands ($F_{1.67,63.59} = 33.02, P < 0.001$).

abundance in an area. Parallel to other studies, we found that Sherman traps and pitfall traps differentially captured species, which led to different estimates of richness and diversity irrespective of vegetative community. Furthermore, Sherman traps had lower mortality rates than did pitfall traps. We expected that pitfall covers would reduce mortality during rain events; yet, we found that covers did little to lesson mortality and additional measures may be necessary for pitfall traps to act as effective live traps.
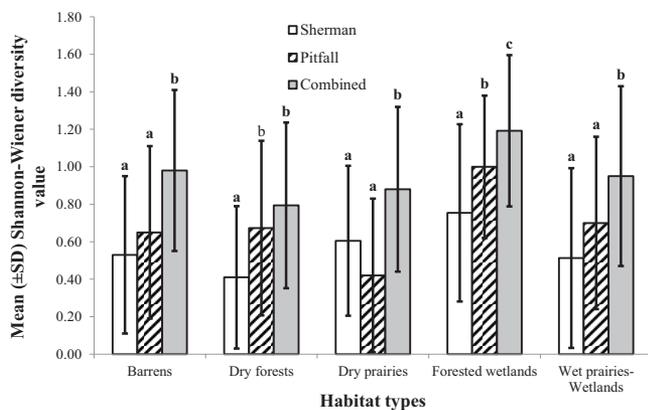
Figure 3. Mean transect (±SD) Shannon–Wiener diversity index values of small mammals captured by Sherman traps, pitfall traps, and a combination of both trap types in 5 Wisconsin (USA) vegetation communities. Data from 2009 and 2010 were pooled for analysis. Within each vegetation community, trap types sharing a common letter were not significantly different ($P \leq 0.05$) as indicated by Bonferroni-corrected *post hoc* tests. The one way repeated measures analysis of variance for Shannon–Wiener diversity of small mammal captures among 3 trap types (Sherman traps, pitfall traps, and a combination of both trap types) was significant for all habitats: barrens ($F_{1.43,38.51} = 14.79, P < 0.001$), dry forests ($F_{1.40,54.75} = 13.03, P < 0.001$), dry prairies ($F_{1.43,24.39} = 14.19, P < 0.001$), forested wetlands ($F_{1.23,58.79} = 30.85, P < 0.001$), and wet prairies–wetlands ($F_{1.44,54.88} = 19.72, P < 0.001$).
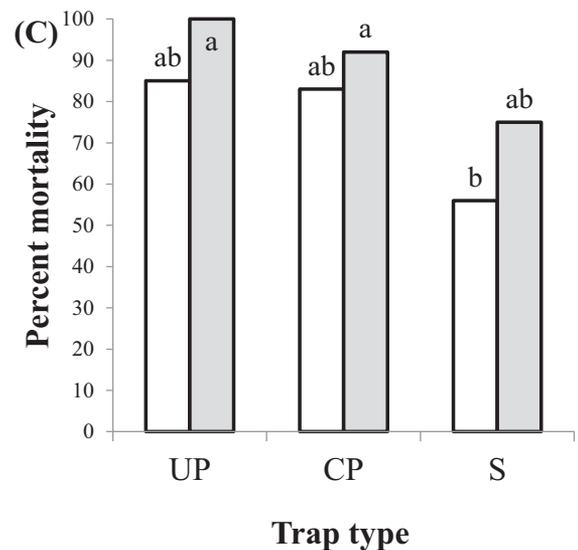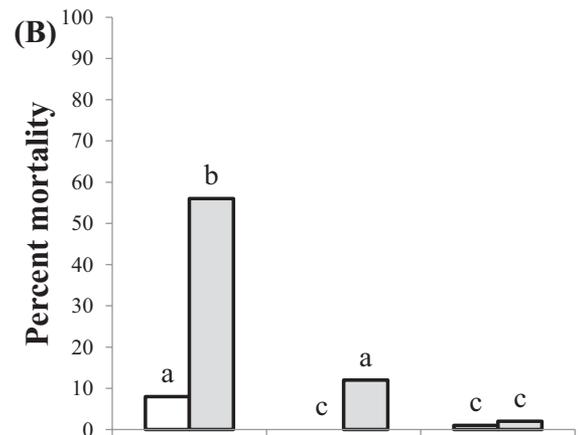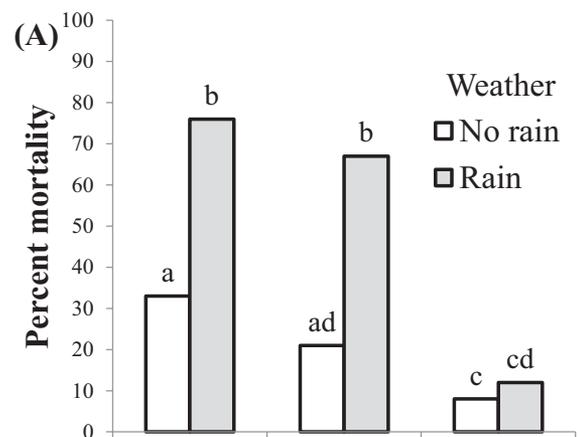
Figure 4. Arvicoline rodents (A), *Peromyscus* spp. (B), and shrew (C) mortality for uncovered pitfall traps (UP), covered pitfall traps (CP), and Sherman traps (S) after periods with and without rain from animals captured during 2009 and 2010 in Wisconsin, USA. Trap types sharing a common letter were not significantly different ($P \leq 0.05$) as indicated by a chi-square test of independence.

Trap Efficacy

We found marked differences in species captured between Sherman traps and pitfall traps. Sherman traps captured

more *Peromyscus* spp. and squirrels; whereas, pitfall traps captured more arvicoline rodents, shrews, and *Z. hudsonius*. These results are consistent with other studies, which found that Sherman traps capture larger animals that are more adept at climbing and saltation, whereas pitfall traps capture younger and smaller animals that are less cursorially or scansorially adapted (Williams and Braun 1983, Bury and Corn 1987, Handley and Kalko 1993, Dizney et al. 2008). However, jumping mice, although adept at saltatorial locomotion, were captured almost 5 times more often in pitfall traps than in Sherman live traps. This difference has been noted in other studies (Williams and Braun 1983, Kalko and Handley 1993, Evrard 1998); however, Anthony et al. (2005) found no capture tendencies of jumping mice toward pitfall traps. Discrepancies among studies are likely a function of pitfall depth, with deeper pitfalls or drowning pitfall traps capable of capturing larger animals (Buckner 1955, Ribeiro et al. 2011). Capture ratios differed for 4 species between nocturnal and diurnal checks. Nocturnal captures of *B. brevicauda*, *M. pennsylvanicus*, and *M. gapperi* were more likely in pitfall traps than Sherman traps, but for diurnal captures we observed no significant trap bias for *B. brevicauda* and *M. pennsylvanicus*, and more captures of *M. gapperi* in Sherman traps. Although many species captured in pitfall traps have relatively poor vision (George et al. 1986, Boonstra et al. 1993), illumination by ambient light may decrease the capture rate in pitfall traps. This further supports the hypothesis that pitfall traps are passive, and capture species by happenstance encounter (Williams and Braun 1983). Baiting pitfall traps is likely still important for drawing animals in (Sealander and James 1958); nonetheless, further research is needed to determine exactly how much baiting increases the probability of capture for these species in pitfall traps.

Although many studies have documented captures in pitfall traps biased toward smaller or younger animals (Briese and Smith 1974, Beachman and Krebs 1980; Nicolas and Colyn 2006, Umetsu et al. 2006), in our study *P. leucopus* was the only species that showed this tendency, whereas pitfall traps actually caught significantly larger *M. gapperi*. All other species showed no significant difference in capture weights between trap types. This may be a function of the relatively deep and narrow dimensions of our pitfall traps that kept most animals from jumping out. *P. leucopus* are known to jump blindly when disturbed (Brown 1964), and this, along with their adept scansorial ability (Williams and Braun 1983), may have allowed larger individuals to escape capture. The difference in sex ratios of *M. pennsylvanicus* and *P. leucopus* between the 2 trap types was unexpected. Differences in sex ratios of *M. pennsylvanicus* may have been a function of trap density. Male meadow voles disperse farther than females (Blair 1940, Baird and Birney 1982), predisposing them to a greater chance of capture in pitfall traps. Male *P. leucopus* also disperse farther than females (Krohne et al. 1984); however, differences in sex ratios may be explained by the capture of pregnant females. Although we did not explicitly keep track of pregnant animals, many pregnant *Peromyscus* spp. may have been unable to escape from pitfall traps. Most of our trapping was conducted during the breeding season; this may have caused a slight shift in sex ratios toward more females in pitfall traps.

Community Composition

Many studies have established species-specific trap biases among trap types and that these biases must be considered when conducting species-specific and community trapping (Williams and Braun 1983, Kalko and Handley 1993, Dizney et al. 2008). Nevertheless, understanding the extent to which these biases affect overall community metrics and comparisons among studies is important. Often, small mammal community composition is quantified using values of species richness or indices of diversity (e.g. Caro 2001, Sullivan and Sullivan 2001, Constantine et al. 2004). Our study highlights the importance of using more than one trap type when sampling small mammals at the community level, regardless of the vegetation community sampled. We found that in all 5 vegetation communities, richness values calculated from Sherman traps and pitfall traps independently were similar, but using both in combination gave a significantly larger value. We also found that diversity calculated from Sherman traps and pitfall traps independently was similar for 3 vegetation communities, but was significantly greater when using these traps in concert. Consequently, using only one trap type to sample a small-mammal community may yield different results when comparing small mammal communities among vegetation communities or studies (i.e., significant differences in estimates of richness and diversity may be detected simply as an artifact of trap efficacy). It is well-documented that pitfall traps capture more shrews; however, we found that pitfall traps also captured more voles and jumping mice. Often pitfall traps are not used in small mammal community studies, are used at extremely low densities, or are used in herpetofaunal studies and mammal communities are assessed *post hoc*. It is likely that studies of small mammal community ecology that sample in vegetation communities similar to the types we trapped in and that do not use pitfall traps, are missing or underrepresenting a significant portion of the community that are rarely captured in Sherman traps. Subsequently, this may lead to conclusions that are incomplete at best and possibly erroneous.

We deployed pitfall traps at half the density of Sherman traps, yet were still able to detect significant differences when calculating these community metrics. The ability of pitfall traps to capture more than one animal during a trap check may be one reason that pitfall traps are viewed as more efficient than Sherman traps (Williams and Braun 1983). This is important when considering the extra effort of setting pitfall traps, which can be substantial in areas with heavy or rocky soil; and when this effort is coupled with limitations in time and labor, it may ultimately limit equal trap effort between these 2 trap types. Understanding species-specific trap bias and how it relates to calculations of community composition can be used to determine the optimal trap ratio.

Mortality

Animals are often more likely to be captured on nights with rain (Gentry et al. 1966, Bury and Corn 1987, Umetsu et al. 2006), yet for mark–recapture studies, consideration of increased capture rates must be tempered by the realization that mortality also increases from hypothermia or drowning during rainy nights (Strombgren 2006). We found that shrew mortality was universally high, regardless of trap type or whether a rain event occurred. This mortality is likely a consequence of their high metabolic requirements (Morrison et al. 1957), and may be reduced by increasing food availability and increase frequency of trap checks (Buckner 1955, Hawes 1977, Strombgren 2006, Do et al. 2013). We found no difference in mortality rates between rainy and non-rainy nights for Sherman trap captures of either arvicoline rodents or *Peromyscus* spp., indicating that this type of trap may be especially useful in mark–recapture studies. For uncovered pitfall traps, we observed an increase in mortality on rainy nights by 43% for arvicoline rodents and 48% for *Peromyscus* spp. Pitfall trap covers were not effective at significantly reducing arvicoline rodent mortality on rainy nights, but covers did significantly reduce mortality of *Peromyscus* spp. by 44%. Covers also significantly reduced *Peromyscus* spp. mortality on trap checks without rain by 8%. Discrepancy in cover efficacy among groups was likely caused by differences in life-history traits and ability to thermoregulate, where *Peromyscus* spp. are better able to cope with unfavorable conditions (Morrison and Ryser 1959). Condensation or small amounts of precipitation often caused complete saturation of the pelage in arvicoline rodents and frequently caused death. For these instances, placing a sponge, leaf litter, or nesting material in the bottom of pitfall traps may help animals stay dry and further increase the utility of pitfall traps in mark–recapture studies. Flooding, especially in wet areas, was also a serious problem and having an absorbent material in the bottom of the pitfall trap would be insufficient to prevent drowning (Strombgren 2006). Placing Styrofoam, or other buoyant material, in the pitfall trap may act as a "life raft" and help reduce mortality when flooding occurs (D. Bautz, Wisconsin Department of Natural Resources, personal communication). It is important to note that covered pitfall traps were not effective at significantly reducing mortality of species most commonly captured in pitfall traps. Moreover, we found that the addition of pitfall trap covers reduced captures of arvicoline rodents by nearly 30%. If pitfall traps are mainly passive in nature, and depend on the animal blundering into the trap, the covers themselves or the shadows cast therefrom may alert animals to the presence of the trap and deter them from venturing close enough for capture. Shillito (1963) found that when short-tailed voles (*Microtus agrestis*) were exposed to new objects, these objects were approached slowly and carefully inspected. Investigation of covers could allow arvicoline rodents to detect pitfall traps and evade capture. Many arvicoline rodents, such as meadow voles, occur in open grasslands where the addition of novel objects would be more conspicuous (Grant 1971). Additionally, shadows cast from greater ambient and lunar light, within these vegetation communities, may make traps easier to detect. Our pitfall covers were made from black plastic; the use of a more camouflaged material may help eliminate this bias if visual cues are deterring vole captures in traps with covers.

MANAGEMENT RECOMMENDATIONS

Sherman and pitfall traps complement each other in the species that they capture and our results suggest that more than one trap type must be used to sample effectively small mammal community assemblages, regardless of the vegetation community that is being trapped. Furthermore, it may not be necessary to have an equal number of Sherman live and pitfall traps to increase richness and diversity index measures. The use of transects of Sherman traps, with interspersed 10-L pitfall traps, may be a way to optimize captures yet reduce the labor involved with installation of pitfalls. For some species, Sherman live and pitfall traps captured different sex ratios and mean body mass. This should be taken into consideration when choosing a trap to study the demographics of a population. Pitfall covers were effective at reducing mortality of some species during rain events, but not for species most commonly captured in pitfall traps. Pitfall covers may also reduce captures of arvicoline rodents. More research is needed to fully assess the utility of pitfall covers.

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