NORTHWEST NATURALIST
Friday Sep 19 2008 02:31 PM
Allen Press • DTPro System

nwnt 89-03-04 Mp_171
File # 04em

NORTHWESTERN NATURALIST 89:171–180 WINTER 2008

EFFICACY OF THREE TYPES OF LIVE TRAPS USED FOR SURVEYING SMALL MAMMALS IN THE PACIFIC NORTHWEST

LAURIE DIZNEY, PHILIP D JONES, AND LUIS A RUEDAS
Department of Biology, Portland State University, Portland, OR 97201

ABSTRACT—Capture rates of 3 trap types were compared at 5 sites in and around Portland, Oregon, USA: Sherman traps, custom-made steel-mesh traps, and pitfall traps. Simpson and Shannon diversity indices were calculated for various combinations of trap types and compared for differences. Sherman and mesh traps also were evaluated for mortality rates before and after the use of a rain shield during the rainy winter months. Of the 5 species of small mammals caught in all 3 types of traps, pitfalls were the most effective trap, followed by Sherman traps, with mesh traps a very distant third. Sherman traps significantly outperformed mesh traps overall when compared for larger species that were not contained by pitfall traps. Different combinations of trap types yielded significantly different Simpson and Shannon diversity indices, with pitfalls having the highest measures for small mammals, and a combination of Sherman and pitfall traps having the highest measures when considering both larger and smaller mammals. Use of rain shields with Sherman and mesh traps did not affect mortality rates. However, mortality was affected by trap type, with significantly higher death rates in mesh than Sherman traps.

Key words: capture rate, live trap, mesh trap, pitfall trap, rain shield, Sherman trap, small mammals, trap mortality, trap success

A critical, but often overlooked, aspect of sampling small mammals within a community is the choice of trap to be used. Most population studies assume that there exists equal catchability among individuals being sampled. This assumption has, however, been shown to be invalid at least some of the time (Young and others 1952; Weiner and Smith 1972; Slade and others 1993; Anthony and others 2005; Belant 2007). Failure to address these differences in trapability may result in significant biases in estimates (Manly 1970; Carothers 1973; Burnham and Overton 1978). Many seemingly innocuous variables can affect trapping success, including: trap type, configuration of the trapping array, bait preference (Smith and others 1975; McComb and others 1991), local weather (Doucet and Bider 1974), and season and phase of the moon (Mengak and Guynn 1987). In addition, trap efficacy for a given species may differ in different localities (Williams and Braun 1983). No single trap type will capture individual members of a local ecological community of all species, sexes, and age classes with equal probability (Smith and others 1975). Therefore, a combination of trap types should be used to gain as broad a representation of the local small mammal fauna as possible (Getz 1961; Smith and others 1971; Weiner and Smith 1972; Szaro and others 1988).

To date, no study known to us has compared these 3 trap types for sampling small mammals at the same time and location. Furthermore, small mammals are often at risk for hypothermia, which can eventually lead to the death of many captives in live traps, in turn biasing the results of mark-release-recapture studies (Rosenberg and Anthony 1993). To examine trap related biases in sampling mammals in the Pacific Northwest, the present study combined the use of 3 types of live traps: folding Sherman, custom mesh, and pitfall. The objectives of this study were to determine if there were differences in capture rates and diversity analysis among small mammal species using various combinations of 3 kinds of live traps, and if the use of a rain shield during the rainy season increased the survival rate of individuals caught in the Sherman and mesh traps.

METHODS

Study Sites

Five sites were sampled in and around the Portland, Oregon, USA, metropolitan area:

Forest Park (5048692.5 N, 484267.53 E, UTM Zone 10, WGS-84), Multnomah Co.; Tryon Creek State Park (5031184.0 N, 474109.6 E, UTM Zone 10, WGS-84), Multnomah Co.; Powell Butte Park (5036804.5 N, 461386.22 E, UTM Zone 10, WGS-84), Multnomah Co.; Oxbow Regional Park (5037392.5 N, 445064.88 E, UTM Zone 10, WGS-84), Multnomah Co.; and Tualatin River National Wildlife Refuge (TRNWR; 5026923.0 N, 486732.9 E, UTM Zone 10, WGS-84), Washington Co. These sites were selected for their differing sizes, habitats and levels of human disturbance, and potential differences in biodiversity. Forest Park, at a relatively flat 184 m above sea level (masl), consisted of a mix of Douglas-fir (*Pseudotsuga menziesii*), Western Hemlock (*Tsuga heterophylla*), Western Redcedar (*Thuja plicata*), Bigleaf Maple (*Acer macrophyllum*), and Red Alder (*Alnus rubra*). Sword Fern (*Polystichum munitum*), Vine Maple (*Acer circinatum*), and Oregon Grape (*Berberis aquifolium*) dominated the understory, with a moderate level of English Ivy (*Hedera helix*). Several hiking or biking trails crossed the trapping web, making Forest Park the only study site to have daily human and domestic dog intrusions. Tryon Creek State Park, 105 masl, had essentially the same composition of vegetation as Forest Park, but with a much greater invasion of English Ivy, as well as Stinging Nettle (*Urtica dioica*), in the understory. The center of the trapping array was atop a mesa, so that at least part of each trap line sloped downwards, half of them quite steeply. Two small creeks surrounded the trapping site. Powell Butte Park was the most anthropogenically altered of the sites. It had a relatively open canopy made up of Douglas-fir, Bigleaf Maple, and Red Alder. The site was dominated by Stinging Nettle, such that for about half of the year the understory was dense, and the other 6 mo it was quite open. Of all the parks, Powell Butte had the smallest amount of bryophytes, coarse woody debris (CWD: snags, stumps, and downed logs), large shrubs, and tree cover. The Tualatin River National Wildlife Refuge (TRNWR; 33 masl), on the banks of the Tualatin River, was virtually level and dominated by Hawthorn (*Crataegus monogyna*) and Himalayan Blackberry (*Rubus discolor*). The area is interspersed with wetlands, so that during winter and spring of wet years, parts of the trapping web were covered in water. The trapping site at Oxbow Regional Park on the Sandy River (36 masl) was within a remnant patch of old growth forest. Large Douglas-fir, Western Hemlock, and Western Redcedar dominated the area and provided about 90% canopy cover. Bryophytes, mosses, and large amounts of CWD covered the ground and there was a healthy secondary story including Vine Maple, Salmonberry (*Rubus spectabilis*), Hazelnut (*Corylus cornuta*), and Thimbleberry (*Rubus parviflorus*).

Sampling

For these analyses, specimens were sampled from October 2002 through May 2004. Trapping was performed using a 200-m dia trapping web (Wilson and Anderson 1985; Parmenter and others 1998; Parmenter and others 2003). The web design included 144 trap stations on 12 spokes with 12 trap stations on each 100-m spoke, 1 trap station in the center of the web, and 30° separation between spokes. The first 4 stations of each line were spaced 5 m apart while the remaining 8 were set at 10-m intervals. The center of the web was also considered a trap station and included 2 Sherman and 2 mesh traps at 90° angles to each other. Each of the stations included an aluminum folding Sherman trap (7.6 cm × 8.9 cm × 22.9 cm) and a custom-built mesh trap (7.6 cm × 8.9 cm × 22.9 cm) modeled after those of O'Farrell and others (1994). The mesh traps were constructed of galvanized steel mesh with a galvanized teeter-totter treadle and gravity drop down door. Due to park regulations, concern for the habitat, and dictates of the web design, pitfall traps were positioned only at stations 4, 7, and 12 of each line. Pitfall traps were made using a 19-L bucket (0.30 m dia, 0.36 m height) buried flush to the rim, with a fitted bucket lid (for rain and predator cover) suspended above, leaving an approximately 8 cm gap for access by small animals (Williams and Braun 1983).

Sherman and mesh traps were baited with a mixture of peanut butter and rolled oats. Pitfall traps were not baited. Polyfiber nesting material was added to Sherman and mesh traps when warranted by the weather. Traps were set out for 4 consecutive nights at a site, with collection occurring at dawn the following day. After collection on the last morning, all Sherman and mesh traps were removed. To avoid extraneous captures, pitfall traps were closed

TABLE 1. The number of individuals within each species captured in each trap type. [a] Signifies the number of each trap type used per trapping array (trap effort). Trap efficacies are shown within parentheses and are calculated as such: number of individuals/trap effort × 1000.

	Total Captures	Sherman 29200[a]	Mesh 29200[a]	Pitfall 7200[a]
P. maniculatus	1743	1367 (46.8)	134 (4.6)	242 (33.6)
S. trowbridgii	440	160 (5.5)	3 (0.1)	277 (38.5)
S. vagrans	124	70 (2.4)	3 (0.1)	51 (7.1)
M. oregoni	91	57 (2.0)	7 (0.2)	27 (3.8)
N. gibbsii	30	19 (0.7)	0 (0.0)	11 (1.5)
S. townsendii	6	0 (0.0.0)	0 (0.0)	6 (0.8)
S. bendirii	6	0 (0.0.0)	0 (0.0)	6 (0.8)
Z. trinotatus	2	0 (0)	0 (0.0)	2 (0.3)
T. townsendii	218	174 (6.0)	44 (1.5)	na
G. sabrinus	35	28 (1.0)	7 (0.2)	na
T. douglasii	9	6 (0.2)	3 (0.1)	na
M. erminea	6	4 (0.1)	2 (0.1)	na
Totals	2710	1885 (64.6)	203 (7.0)	622 (86.4)

with the lid while not in use. Each park was trapped 10 times over the course of this study, approximately every 8 wk. Total effort was 65,600 trap nights (29,200 each for Sherman and mesh traps and 7200 for pitfall traps).

This research was conducted under the auspices of federal and state permits, and complied with the American Society of Mammalogists' guidelines for animal care and use (Gannon and others 2007). Captured animals were transferred from traps into clear, sealable plastic bags for transport to the center of the web for processing. Standard precautionary methods were implemented (Mills and others 1995). Each animal was identified to species and evaluated for gender, reproductive status, mass, relative age, and any other notable characteristics. Euthanasia was performed, when applicable, using a chloroform chamber (Mills and others 1995). Specimens that were not euthanized were ear tagged and released at the point of capture (Parmenter and others 1998).

For the rainy season from October 2003 through May 2004, mesh and Sherman traps were placed within a clear 1 mil (2.54×10^{-5} m) plastic bag with only the trap opening exposed, in an effort to reduce trap mortality due to rain and cold. During the previous rainy season (October 2002 to May 2003), no such protective measures were taken. To compare mortality before and after placement of the rain shield, only 5 species caught in Sherman traps and 2 species caught in mesh traps had minimally enough captures in all 4 categories (alive, dead, with rain shield, without rain shield) for analysis.

Data Analysis

To account for unequal trap effort due to fewer pitfalls than Sherman and mesh traps per trapping web, trap efficacy was calculated by dividing captures per trap type for each species by the total trap nights per trap type, and then multiplying by 1000. For instance, the trap efficacy for 1743 Deer Mice (*Peromyscus maniculatus*) captured in Sherman traps would be 1743 ÷ 29,200 × 1000. Trap efficacies were also calculated for total captures (all species combined). Statistical comparisons were made using a Chi-square goodness-of-fit test for binomial distribution with acceptance of the null hypothesis (equal trapability) at 0.05 for each species alone, and 0.01 (Bonferroni correction) when species were totaled (Miller 1991). If equal trapability applied, then the total number of observed captures of each species should have been equally divided between the 3 trap types according to trap effort. In other words, Sherman and mesh traps would have captured an equal number of small mammals and pitfall traps would have captured approximately 25% of that number. Three separate Chi-square analyses were undertaken with the trap efficacy data. The 1st compared the trapability of all 3 types of trap for the 5 species small enough or immobile enough to be contained by the pitfalls (Table 1; first 5 species). But the mesh traps performed poorly and were largely responsible for the huge Chi-square values, so the 2nd analysis compared the trapability between just Sherman traps and pitfall traps for the same 5 species. The 3rd Chi-square analysis compared the 4 species that were too large to be contained in pitfall traps in an analysis of trapability between Sherman and mesh traps only (bottom 4 species of Table 1). Three species, *Sorex bendirii* (Marsh Shrew), *Scapanus townsendii* (Townsend's Mole), and *Zapus trinotatus* (Pacific Jumping Mouse) were omitted from all Chi-square analyses due to their low capture numbers and because they were caught in pitfall traps only. They were, however, included in the diversity analyses (see below). When comparing just 2 trap types, Yate's Correction for Continuity was applied to the Chi-square analysis (Zar 1999).

Simpson and Shannon diversity indices were calculated for various trap combinations using software from Brower and others (1998), and then compared with a *t*-statistic (Brower and others 1998) with significance set at 0.05 to assess differences in diversity measurements resulting from trap type. While both Shannon's Index (H') and Simpson's Index (D_S) consider species richness and evenness, D_S is a measure of the inverse of dominance of a community, and H' is a measure of uncertainty (Brower and others 1998), providing somewhat different diversity measures of a community.

Three separate mortality analyses were also performed using Chi-square contingency tables with Yates's Correction for Continuity, or Fishers Exact Test for Count Data when 1 or more expected frequencies were less than 5 (Crawley 2002). The 1st analysis compared species singly and in total to assess whether there was a significant change in mortality from application of the rain shield. The 2nd and 3rd analyses compared Sherman and mesh traps to each other, both with and without a rain shield, to evaluate the differences in mortality that might occur due to trap type. All of the above analyses, unless otherwise noted, were performed in R, a free statistical software package available on the web (R Development Core Team 2006).

RESULTS

Captures

A total of 2710 individuals from 12 species were captured during the 20 mo of this study (Table 1). *Peromyscus maniculatus* was the most prevalent species captured (64.3% of total captures), followed by *Sorex trowbridgii* (Trowbridge's Shrew; 16.2%), *Tamias townsendii* (Townsend's Chipmunk; 8.0%), *Sorex vagrans* (Vagrant Shrew; 4.6%), *Microtus oregoni* (Creeping Vole; 3.4%), *Glaucomys sabrinus* (Northern Flying Squirrel; 1.3%), *Neurotrichus gibbsii* (Pacific Shrew-mole; 1.1%), *Tamiasciurus douglasii* (Douglas's Squirrel; 0.3%), *Mustela erminea* (Short-tailed Weasel; 0.2%), *Scapanus townsendii* (0.2%), *Sorex bendirii* (0.2%), and *Zapus trinotatus* (0.07%).

Trap Efficacy

At first glance, Sherman traps appear to have far out-performed mesh and pitfall traps (Table 1). However, when weighted for trap effort, pitfalls captured more individuals overall, as well as more individuals in 4 of the 5 species (Fig. 1). After mesh traps were omitted from the analysis due to their exceedingly poor capture rate (Table 2, top section), pitfall traps significantly outperformed Sherman traps overall, as well as within 4 of the 5 species considered; only *P. maniculatus* were caught significantly more frequently by Sherman traps than by pitfall traps among the species that were containable by pitfalls.

When comparing trap efficacy between Sherman and mesh traps for the 4 larger species (Table 2; bottom section), mesh traps caught fewer individuals overall, as well as significantly fewer *T. townsendii* and *G. sabrinus*. Mesh traps also captured fewer *T. douglasii* and *M. erminea* than Sherman traps, though the differences were not significant, most likely due to the small sample sizes.

Different combinations of trap types resulted in different species accumulations and numbers of individuals captured, which in turn affected diversity measures (Table 3). Mesh traps performed so poorly that a combination of Sherman and pitfall traps versus a combination of Sherman, pitfall, and mesh traps resulted in no significant difference in either Simpson or Shannon diversity. Therefore, mesh traps were omitted from the diversity analyses. When considering all sizes of species captured (Table 3, top section), use of Sherman and pitfall traps together resulted in 3 more species captured, as well as highly significant differences in both diversity indices than when Sherman traps were used alone. Because there is a limit to the size of a mammal that can be contained by a pitfall, perhaps a more meaningful comparison is one that considers just those species that are

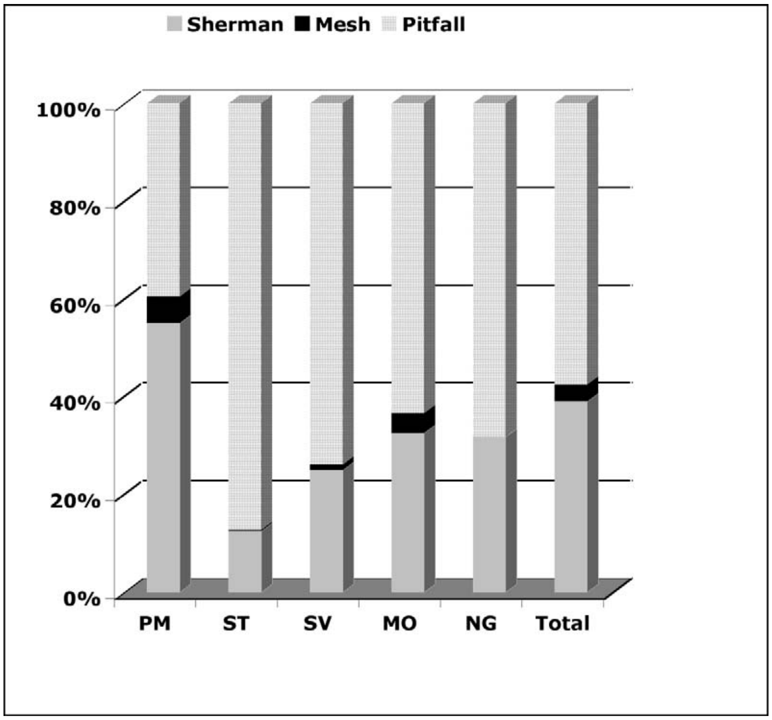

FIGURE 1. Trap efficacy for Sherman, custom mesh and pitfall traps. The bars show the contribution of each trap type, after adjustment for trap effort, to the total number of captures within a given species and among all 5 species. PM = *Peromyscus maniculatus,* ST = *Sorex trowbridgii,* SV = *Sorex vagrans,* MO = *Microtus oregoni,* and NG = *Neurotrichus gibbsii.*

at least theoretically trappable by a pitfall. For this study, those species are *P. maniculatus, S. trowbrigii, S. vagrans, M. oregoni, N. gibbsii, S. townsendii, S. bendirii,* and *Z. trinotatus.* Captures from pitfall traps alone resulted in the highest levels of diversity followed by Sherman and pitfall traps combined, and lastly Sherman traps alone. All pairwise comparisons of either index revealed highly significant differences in diversity measures obtained by different traps or trap combinations. Pitfall traps alone resulted in higher values than either Sherman traps alone or Sherman and pitfall traps combined; and Sherman and pitfall traps combined had higher diversities than Sherman traps alone.

Trap Mortality

Overall, the effects of the rain shield upon mortality were not significant regardless of species or trap type (Table 4; top section). The mortality of 2 species, *S. vagrans* in Sherman traps and *T. townsendii* in mesh traps actually increased with placement of the rain shield, though the results were not significant.

In comparing mortality between Sherman and mesh traps, trap type appears to be a factor in mortality (Table 4, bottom section). When no rain shield was in use, mortality was significantly less in Sherman traps both for all species combined and for *P. maniculatus,* the only species for which there were enough captures for separate analysis. When a rain shield was applied, mortality also was lower for *P. maniculatus* and for all species combined in Sherman traps than in mesh traps, though not significantly.

DISCUSSION

Trap Efficacy

Significant differences in the success rate of the 3 trap types used for capturing small mammals were found in this study. While some investigations have shown live traps constructed from open mesh to be superior to enclosed

TABLE 2. Trap Efficacy using Chi-square Goodness-of-Fit analyses. The top section compares 3 trap types among 5 species of small mammals, the 2nd section compares the trapability of the same 5 species in just Sherman and pitfall traps, and the bottom section compares trapability between Sherman and mesh traps for 4 species too large to be contained by pitfall traps. Obs = Observed; Exp = Expected.

	Sherman Obs-Exp	Mesh Obs-Exp	Pitfall Obs-Exp	X^2	*p*
P. maniculatus	591.4	−641.6	50.3	994.8	<0.001
S. trowbridgii	−35.8	−192.8	228.6	1,276.1	<0.001
S. vagrans	14.8	−52.2	37.4	156.2	<0.001
M. oregoni	9.5	−33.5	17.0	63.3	<0.001
N. gibbsii	5.4	−13.4	7.7	33.8	<0.001
Total	592.5	−933.5	341.0	1,566.9	<0.001
P. maniculatus	76.3		−76.3	22.5	0.001
S. trowbridgii	190.6		190.6	521.3	<0.001
S. vagrans	−27.1		27.1	36.9	<0.001
M. oregoni	−10.1		10.4	7.4	0.006
N. gibbsii	−5.1		5.1	4.5	0.034
Total	−156.8		156.8	67.5	<0.001
N. townsendii	65	−65		76.3	<0.001
G. sabrinus	10.5	−9.5		11.4	<0.001
T. douglasii	1.5	−1.5		0.44	0.510
M. erminea	1	−1		1.67	0.200
Totals	76.5	−79.5		89.6	<0.001

Sherman traps (Holdenreid 1954, O'Farrell and others 1994), and Sherman traps more successful than pitfall traps (Dowler and others 1985), others have found pitfall traps superior to other live traps (Boonstra and Krebs 1978; Beacham and Krebs 1980; Williams and Braun 1983). The analyses herein suggest that, overall, pitfall traps were superior to both Sherman and mesh taps across the 5 species of small mammals that were caught in all 3 trap types. In addition, pitfall traps caught 4 of the 5 species (*S. trowbridgii*, *S. vagrans*, *M. oregonii*, and *N. gibbsii*) significantly more often based on trap effort than Sherman traps did. Although the 5th species (*P. maniculatus*) was caught more often in Sherman traps than in mesh or pitfall traps, pitfalls still had a high trap efficacy for this species.

For larger species that are not contained by a pitfall trap, Sherman traps significantly outperformed mesh traps for all species combined, and for the capture of 2 of the species (*T. townsendii* and *G. sabrinus*) when analyzed separately. There was no difference in trap efficacy in the other 2 species (*T. douglasii* and *M. erminea*), although their low capture numbers in mesh traps prevents meaningful comparisons.

A number of factors may have had an influence on our results. The custom-made mesh traps may have been inferior to Sherman traps due to problems in construction and stability (Holdenreid 1954; O'Farrell and others 1994). Because of the flexible nature of wire cloth, the mesh traps were easily deformed during transport, leading to doors aligning improperly which possibly allowed the escape of captured individuals. In addition, the treadle arms holding the doors open were inconsistent in the amount of pressure required to trigger the door to shut. Small species, such as shrews and small mice, may not have been of sufficient mass to activate the treadle in all of the mesh traps. Adding weight to these arguments is the fact that the mesh traps performed better, though still less well than expected, on larger species, such as *T. townsendii, G. sabrinus, T. douglasii,* and *M. erminea.* Sherman traps also have the capability of being set up with incorrect trigger pressures as well as the treadle sticking due to bait or excreta underneath it, but this problem was at least partially overcome in our study by weekly cleaning of the traps.

Because an animal unwittingly falls into a pitfall while moving about, complications due to trap type preferences or fear of entering a trap are removed with the use of pitfall traps. Bait preferences have been shown to create differing trap efficacies (Rickart and others 1991, O'Farrell and others 1994). Pitfall traps do not need to be baited to entice an animal to enter,

TABLE 3. Diversity measures resulting from different combinations of trap types and comparisons of the diversities obtained (*t*). Small species are those contained by pitfall traps: *P. maniculatus*, *S. trowbridgii*, *S. vagrans*, *M. oregoni*, *N. gibbsii*, *T. townsendii*, *S. bendirii* and *Z. trinotatus*. D_S is Simpson's Index of Diversity and H′ is Shannon's Index of Diversity.

	Inds/spp	D_S	H′	t (D_S)	p	t (H′)	p
Diversity : all							
Sherman + pitfall	2507/12	0.5480	0.5186				
				5.40	<0.001	4.47	<0.001
Sherman	1885/9	0.4559	0.4476				
Diversity : small mammals							
Sherman + pitfall	2295/8	0.4681	0.4060				
Sherman	1673/5	0.3204	0.2989				
Pitfall	622/8	0.6422	0.5421				
Sherman + pitfall vs. Sherman				8.24	<0.001	7.31	<0.001
Sherman + pitfall vs. pitfall				11.18	<0.001	7.39	<0.001
Sherman vs. pitfall				17.86	<0.001	12.50	<0.001

alleviating this problem as well. Indeed, our pitfall traps performed exceptionally well in capturing insectivores, which may not have been attracted to the bait in the Sherman and mesh traps. By eliminating the potential biases introduced by trap and bait preferences, pitfalls may offer a more thorough survey of the small mammal community. Additionally, single capture traps, such as Sherman and mesh traps, can confound population density and presence-absence studies due to the fact that once a trap is occupied no other animal can use it. The same is not true for pitfall traps, where any number of small mammals can be captured. The problem of predators removing prey from an open pitfall does, however, remain. We tried to minimize the problem by covering the pitfall with a lid suspended above, leaving an approximately 8 cm opening. This potentially hid the prey species from some predators, and also alerted us to the fact that a capture may have been taken if the lid was removed.

There were no instances in our study wherein a small species of mammal was captured only in a Sherman or mesh trap and not in a pitfall trap, although of note, 3 rare species (*S. townsendii* [*n* = 6], *S. bendirii* [*n* = 6], and *Z. trinotatus* [*n* = 2]) were caught only in pitfall traps. Not surprisingly, then, pitfall traps alone had the highest levels of diversity. This is not only due to the extra 3 species captured only in pitfall traps, but also to differences in the number of *P. maniculatus* captured. Sherman traps caught many more *P. maniculatus* than pitfall traps, resulting in a lower evenness factor, which in turn lowered both Simpson and Shannon diversity indices for Sherman traps. This is particularly evident when comparing small mammal captures in pitfall traps versus Sherman and pitfall traps combined. Intuitively, it would seem that Sherman and pitfall traps used together should capture a more diverse fauna than pitfall traps used alone, particularly because the same number of species was captured in both combinations. Yet because of the number of *P. maniculatus* captured in Sherman traps, pitfall traps ended up with a significantly higher diversity indices due to the evenness component.

Pitfall traps however, can only capture small mammals or those whose mobility does not permit jumping. Our pitfall traps caught primarily insectivores (5 species) and small ro-

TABLE 4. Mortality analysis using Pearson's Chi-square Goodness-of-Fit test with Yates's Correction for Continuity to determine the effectiveness of a rain shield and differences in mortality by trap type and the presence or absence of a shield. [a] Includes captures from species whose totals were too small to analyze separately. [b] Indicates an odds ratio from Fisher's Exact Test which was used instead of Chi-square in cases where count data equaled <5.

	Dead Captures (% of total captures)			
	No shield	Shield	X^2	*p*
Sherman				
P. maniculatus	23 (6.8)	60 (7.3)	0.03	0.86
S. trowbridgii	9 (64.3)	35 (58.3)	0.01	0.91
N. townsendii	8 (13.1)	5 (13.5)	[b]1.03	1
S. vagrans	4 (40.0)	20 (58.8)	[b]2.10	0.47
M. oregoni	2 (40.0)	7 (16.3)	[b]0.30	0.23
Total[a]	46 (10.6)	131 (13.0)	1.32	0.25
Mesh				
P. maniculatus	15 (27.3)	8 (15.1)	2.45	0.12
N. townsendii	2 (16.7)	2 (33.4)	[b]2.30	0.57
Total[b]	19 (27.1)	12 (18.2)	0.89	0.34
No shield	Sherman	Mesh		
P. maniculatus	23 (6.8)	15 (27.3)	20.21	$\ll$0.001
Total[a]	46 (10.6)	19 (27.1)	12.27	0.0004
Shield				
P. maniculatus	60 (7.3)	8 (15.1)	3.13	0.08
Total[a]	131 (13.2)	12 (18.2)	1.05	0.31

dents (3 species). Other studies have also found pitfall traps to be superior to Sherman traps (Umetsu and others 2006), especially for capturing insectivores (McComb and others 1991). The only larger species we caught in pitfall traps was *S. townsendii*, which can neither jump nor climb. However, Sherman traps were required for capturing larger, more mobile species. O'Farrell and others (1994) found mesh traps outperformed Sherman traps for 5 of 6 species in several different habitat types; however, those authors did not sample forest habitats of the Pacific Northwest. The differences in results between that study and our study actually support their findings that there likely are strong differences in trapability among species, habitats, and regions that must be taken into account when designing studies.

Trap Mortality

The low number of captures for most species in our study makes it difficult to draw robust conclusions about trap mortality. Only 5 species had enough captures to analyze the use of a rain shield in conjunction with Sherman traps, and, arguably, only 2 species had enough captures for analysis using mesh traps. Of these species, only *Microtus oregoni* captured in Sherman traps seemed to benefit, though not significantly, from the use of a rain shield.

The concept of a rain shield for protection of small mammals captured in live traps in excessively wet climes appears intuitively to be a good one; however, our particular type of shield had some problems. In our design, the use of plastic bags did not prevent rainwater from occasionally pooling in the bottom of the rain shield. This caused the floor of the trap to be wet and almost certainly added to the stress of the captured animal. There also may have been an inadvertent increase in moisture containment within the trap due to decreased air circulation. Indeed, the rather large, though statistically insignificant, increase in mortality of *S. vagrans* in Sherman traps and *T. townsendii* in mesh traps with the use of a rain shield seemed to be due to the added moisture. Some studies have used polyvinylchloride tubing of appropriate length and diameter to contain the traps, or cardboard milk cartons. These weather shields appear to have been somewhat successful in preventing weather induced mortalities (J. L. Dunnum, pers. comm.). Further testing and modification of our sampling design, as well as possible modifications of our rain shield design when used with Sherman and mesh traps may improve the survival rate of captured individuals.

Conclusion

Our research suggests that the species of interest should dictate the traps used. For small mammals, and particularly insectivores, pitfall traps alone appear to offer the best trapability, and can be purchased for a fraction of the cost of Sherman traps. No additional species were captured by the addition of Sherman traps, though additional individuals were caught. For chipmunks and larger mammals, larger traps are obviously needed, and our data show Sherman traps to be superior to mesh traps. If all small mammals are to be included in the study, then a combination of pitfall and Sherman traps captures more species, more individuals, and results in significantly greater diversity indices than Sherman traps alone. Pitfall traps should therefore be considered a vital addition to field studies in order to more completely survey small mammal communities.

ACKNOWLEDGMENTS

We thank the Oregon Department of Fish and Wildlife, Oregon Parks and Recreation Department, Metro Regional Parks and Greenspaces Department, Portland Parks and Recreation Department, and Tualatin River National Wildlife Refuge for access to research sites. Gratitude to B Edmunds, L Patrick, L Garrett, M Cambell, and too many others to list, including students in the Portland State University (PSU) Biology Department's Mammalogy classes over the years of the study, who helped with field data collection and site preparation. We acknowledge PSU for supplying equipment, funds, and facilities. This study was partially funded by PSU, Mazamas Climbing Club, and American Society of Mammalogists (ASM).

LITERATURE CITED

ANTHONY MN, RIBIC CA, BAUTZ, GARLAND,T JR. 2005. Comparative effectiveness of Longworth and Sherman live traps. Wildlife Society Bulletin 33:355–359.

BEACHAM TD, KREBS CJ. 1980. Pitfall versus live-trap enumeration of fluctuating populations of *Microtus townsendii.* Journal of Mammalogy 61:486–499.

BELANT JL, WINDELS SK. 2007. Efficacy of a multi-capture live trap for small mammals. Ohio Journal of Science 107:16–18.

BOONSTRA R, KREBS CJ. 1978. Pitfall trapping of *Microtus townsendii.* Journal of Mammalogy 59:136–148.

BROWER JE, ZAR JH, VON ENDE CN. 1998. Ecological Quantatative Analysis Software to Accompany Field and Laboratory Methods for General Ecology. Boston, MA: WCB/McGraw-Hill. 237p.

BURNHAM KP, OVERTON WS. 1978. Estimation of the size of a closed population when capture probabilities vary among animals. Biometrika 65:625–633.

CAROTHERS AD. 1973. The effects of unequal catchability on Jolly-Seber estimates. Biometrics 29:79–100.

CRAWLEY MJ. 2002. Statistical Computing: An Introduction to Data Analysis Using S-Plus. West Sussex, UK :John Wiley & Sons, Ltd. 761 p.

DOUCET GJ, BIDER JR. 1974. The effect of weather on the masked shrew. Journal of Mammalogy 55: 348–363.

DOWLER RC, KATZ HM, KATZ, AH. 1985. Comparison of live trapping methods for surveying small mammal populations. Northeastern Environmental Science 4:165–171.

GANNON WL, SIKES RS, Animal Care and Use Committee of the American Society of Mammalogists. 2007. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 88:809–823.

GETZ LL. 1961. Responses of small mammals to live traps and weather conditions. American Midland Naturalist 66:160–170.

HOLDENREID R. 1954. A new live catch rodent trap and comparison with 2 other traps. Journal of Mammalogy 35:267–268.

MANLY BFJ. 1970. A simulation study of animal population estimation using the capture-recapture method. Journal of Applied Ecology 7:13–39.

MCCOMB WC, ANTHONY RG, MCGARIGAL K. 1991. Different vulnerability of small mammals and amphibians to two trap types and two trap baits in Pacific Northwest [USA] forests. Northwest Science 65: 109–115.

MENGAK MT, GUYNN DG JR. 1987. Pitfalls and snap traps for sampling small mammals and herpetofauna. The American Midland Naturalist 118: 284–288.

MILLER RG JR. 1991. Simultaneous statistical inference. New York, NY: Springer-Verlag. 299 p.

MILLS JN, YATES TL, CHILDS JE, PARMENTER RR, KSIAZEK TG, ROLLIN PE, PETERS CJ. 1995. Guidelines for working with rodents potentially infected with Hantavirus. Journal of Mammalogy 76:716–722.

O'FARRELL MJ, CLARK WA, EMMERSON FH, JUAREZ SM, KAY FR, O'FARRELL TM, GOODLET TY. 1994. Use of a mesh live trap for small mammals: Are results from Sherman live traps deceptive? Journal of Mammalogy 75:692–699.

PARMENTER CA, YATES TL, PARMENTER RR, MILLS JN, CHILDS JE, VAMPELL ML, DUNNUM JL, MILNER J. 1998. Small mammal survival and trapability in mark-recapture monitoring programs for Hantavirus. Journal of Wildlife Diseases 34:1–12.

PARMENTER RR, YATES TL, ANDERSON DR, BURNHAM KP, DUNNUM JL, FRANKLIN AB, FRIGGENS MT, LUBOW BC, MILLER M, OLSON GS, PARMENTER CA, POLLARD J, REXSTAD E, SHENK TM, STANLEY TR, WHITE GC. 2003. Small mammal density estimation: A field comparison of grid vs. web. Ecological Monographs 73:1–26.

R DEVELOPMENT CORE TEAM. 2006. R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

RICKART EA, HEANEY LR, UTZURRUM CB. 1991. Distribution and ecology of small mammals along an elevational transect in Southeastern Luzon, Philippines. Journal of Mammalogy 72:458–469.

ROSENBERG DK, ANTHONY RG. 1993. Differences in trapping mortality rates of northern flying squirrels. Canadian Journal of Zoology 71:660–663.

SLADE NA, EIFLER MA, GRUENHAGEN NM, DAVELOS AL. 1993. Differential effectiveness of standard and long Sherman live traps in capturing small mammals. Journal of Mammalogy 74:156–161.

SMITH GC, KAUFMAN DW, JONES RM, GENTRY JB, SMITH MH. 1971. The relative effectiveness of two types of snap traps. Acta Theriologica 16:284–288.

SMITH MH, GARDNER RH, GENTRY JB, KAUFMAN DW, O'FARRELL MH. 1975. Density estimation of small mammal populations. In: Golley FB, Petrusewicz K, Ryszkowski R, editors. Small mammals: their productivity and population dynamics. Cambridge, UK: Cambridge University Press. p. 25–53.

SZARO RC, SIMONS LH, BELFIT SC. 1988. Comparative effectiveness of pitfalls and live-traps in measuring small mammal community structure. In: Szaro RC, Severson KE, Patton DR, technical coordinators. Management of amphibians, reptiles, and small mammals in North America. Proceedings of the symposium July 19–21, 1988; Flagstaff, AZ: United States Department of Agriculture Forest Service General Technical Report RM-166: 282–288.

UMETSU F, NAXARA L, PARDINI R. 2006. Evaluating the efficiency of pitfall traps for sampling small mammals in the neotropics. Journal of Mammalogy 87:757–765.

WEINER JG, SMITH MH. 1972. Relative efficiencies of four small mammal traps. Journal of Mammalogy 53:868–873.

WILLIAMS DF, BRAUN SE. 1983. Comparison of pitfall and conventional traps for sampling small mammal populations. Journal of Wildlife Management 47:841–845.

WILSON KR, ANDERSON DR. 1985. Evaluation of a density estimator based on a trapping web and distance sampling theory. Ecology 66:1185–1194.

YOUNG H, NESS J, EMLEN JT JR. 1952. Heterogeneity of trap response in a population of house mice. Journal of Wildlife Management 16:169–180.

ZAR JH. 1999. Biostatistical Analysis. Upper Saddle River, NJ: Prentice-Hall, Inc. 663 p.

Submitted 23 April 2008, accepted 16 June 2008. Corresponding Editor: Paul Cryan.