

String theory: reducing mortality of mammals in pitfall traps

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Abstract Pitfall traps are commonly used to sample reptiles and amphibians, but their use often results in high levels of mortality in small mammals. I tested a method intended to allow mammals to escape pitfall traps but retain captured amphibians and reptiles. I established 2 pitfall trap transects in each of 10 forested sites. Each transect contained 7 arrays of 4 pitfall traps each, with 28 traps/transect and 56 traps/site. I attached jute twine to the undersides of coverboards in one of the 2 transects at each site and suspended it into pitfall traps to provide escape routes for mammals; the other transect included pitfall traps without twine. Sampling occurred October 1999-June 2000, with some traps being closed during winter because snow made them inaccessible. Number of mammals retained in pitfall traps without escape strings differed significantly (234/3) from those with strings. Numbers (90/76) of amphibians captured in traps without strings did not differ significantly from those with strings. Reptile captures differed significantly (63/34) between traps without strings and those with strings. My results indicated that this method reduces mammal mortality in pitfall traps while preventing amphibians from escaping. However, reptiles may be capable of using strings to escape pitfall traps.

Key words coverboards, *Ensatina eschscholtzii*, mammal mortality, pitfall traps, small-mammal escape devices, SMED, *Sorex trowbridgii*

Pitfall traps are used commonly to sample amphibians, reptiles, and small mammals. This method, however, often results in high levels of mammal mortality. Mammal mortality in pitfall traps probably results from starvation (Pearson 1947). Researchers using pitfall traps to capture amphibians typically sample during periods of wet weather, when amphibians are active on the surface. In the western United States, wet periods are generally associated with cooler temperatures. Reptiles may be less active and captured less often in pitfall traps during cool, wet periods, but small mammals are still captured year-round. As endotherms, small mammals are more sensitive to cool, wet conditions than the ectothermic reptiles and amphibians. Kogut and Padley (1997) proposed that the best way to reduce mammal mortality in pitfall traps was to increase frequency of trap checks. While this may reduce mortality some-

what, mortality, particularly in shrews, still occurs even if traps are checked several times each day and night. Sarrazin and Bider (1973) reported 19% mortality in masked shrews (*Sorex cinereus*) when traps were checked hourly, during days and nights.

Researchers have attempted to keep small mammals alive in traps by providing food. Getz (1961) supplied rolled oats in live traps, checked the traps twice daily, and reported 88% mortality in *S. cinereus*. Manville (1949) baited live traps with sunflower seeds and oats, checked the traps 4-5 times daily, and reported 97% mortality in *S. cinereus*. In Michigan, Yunker et al. (1992) placed approximately 7 grams of red worms (*Eisenia foetida*) in pitfall traps, checked the traps twice daily, and reported 83% mortality in *S. cinereus*. To further reduce mortality in their traps, Yunker et al. (1992) changed the food type to whitefish and maintained 7 g in each pitfall. They reported 23% mortality with this food

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type and the same frequency of trap visits. These authors also reported disturbance of traps by raccoons (*Procyon lotor*) but did not speculate as to whether the raccoons were attracted to the white-fish or to trapped mammals.

Shelters and nesting materials have limited utility in keeping small mammals alive in pitfall traps. Drickamer and Paine (1992) placed cotton nesting material in traps and checked them once a day. They reported 8-36% mortality for 6 small-mammal species. Kogut and Padley (1997) constructed shelters of polystyrene and wood doweling that could float if traps filled with rainwater, and placed cotton batting in the shelters. During the sampling period most of the traps accumulated less than 5 mm of water and temperatures did not drop below 15° C. Eight individual small mammals captured in the shelters survived. However, the glue used in shelter construction softened, undermining the structural integrity of the shelters, and greater levels of rainfall may have rendered them unusable by captured animals. Also, shelters were tested in 18.9-l plastic buckets and were too large for use in the Number 10 steel cans that are commonly used to sample amphibians. Reducing the time interval between trap checks and providing food, nesting material, and shelter may, independently or in combination, reduce mammal mortality in pitfall traps. However, if small mammals are not the target, efforts should be made to allow them to escape from pitfall traps, thereby reducing the need to replace food in traps and keep nesting material and shelters dry.

While most methods used to reduce mammal mortality in traps have focused on keeping animals alive within the traps until released by the researcher, Aubry and Stringer (2000) developed a pitfall trap insert, called a small-mammal escape device (SMED), which was intended to allow mammals to escape traps but to retain captured amphibians. This device consisted of a dowel covered with fiberglass window screen. The dowel was anchored in the bottom of the pitfall trap and extended up out of the trap. In theory, small mammals would climb the dowel and jump away from the trap to escape. SMEDs successfully reduced mammal mortality in pitfall traps. The authors captured 7 individual small mammals in traps with SMEDs and 103 mammals in traps without SMEDs. However, they reported a significant difference in numbers of amphibians captured in traps with SMEDs (68) versus those without (205). The authors recommended increasing the number of traps or trapping nights to achieve an adequate sample size.

Institutional animal care and use committees (IACUC) scrutinize all methods relative to potential pain, suffering, and mortality of live, vertebrate animals, and may hesitate to approve use of pitfall traps in research projects unless an effort is made to reduce mammal mortality. Additionally, some peer-reviewed journals require inclusion of a statement regarding project adherence to animal welfare regulations with submission of manuscripts. In an effort to reduce mammal mortality in pitfall traps and meet IACUC guidelines, I developed a method intended to reduce mortality of small mammals in pitfall traps. My objective was to test a method to reduce mammal mortality in pitfall traps by allowing captured mammals to escape the traps. Inherent in this objective was a need to retain captured salamanders and reptiles in the traps.

Methods

I conducted this study on the Six Rivers National Forest in the Klamath Mountains of northwestern California (USA). The study area was within the Klamath River drainage in northern Humboldt and southern Del Norte counties, approximately 50 km inland from the Pacific Ocean. Vegetation in the area consisted of a mixed conifer-hardwood forest of Douglas-fir (*Pseudotsuga menziesii*) with an understory of tanoak (*Lithocarpus densiflorus*), bigleaf maple (*Acer macrophyllum*), and Pacific madrone (*Arbutus menziesii*). Elevation ranged from 700 to 1,750 m above sea level with moderate to steep slopes.

The study was designed to incorporate separate research on effects of silvicultural edges on amphibians. I randomly selected 10 paired clearcut-late seral forest sites from all possible sites with similar aspect, slope, and amount of substrate cover within the study area. Clearcuts at the sites ranged from 10 to 25 years of age. Within each paired site, I installed 2 150-m pitfall trap transects parallel to each other and perpendicular to the forest edge. Transects were located approximately 20 m apart and at least 75 m from roads, streams, or other features that might affect abundance of mammals, amphibians, or reptiles. Each transect extended from 75 m in the clearcut, through the edge, and to 75 m in the adjacent late seral forest. On each transect, I centered one trap station on the clearcut-late seral forest edge. In the clearcuts and late seral forests, trap stations were centered at 15, 30, and 75 m from the edge. Each transect contained 7 trap stations, or 14 stations/site. A trap sta-

tion consisted of a drift fence and 4 pitfall traps. I constructed drift fences with 5-m lengths of 46-cm-wide, fine-gauge, fiberglass window screen. The screen was stretched taut between and stapled to 2 wooden stakes, and additional stakes were positioned along the fence for support. I buried the lower 5 cm of each fence, and thus the drift fences served to direct animals toward pitfall traps. Two traps were located at each end of the fence. Traps were positioned directly adjacent to the fence, with 2 cans on the uphill side of the fence and 2 cans on the downhill side of the fence. Pitfall traps consisted of Number 10 steel cans with one open end, and each can was buried so that the open top was flush with the ground. I inserted a plastic collar in the top of each can to prevent captured animals from crawling out of the trap. Three to 4 drain holes in the bottoms of the traps reduced accumulation of water.

Each pitfall trap was covered with a 29 x 29 x 2-cm coverboard, positioned so that there was a slight gap between the board and the ground, allowing animals to crawl underneath. Coverboards served to attract animals to traps and to shelter captured animals. I attached escape strings to the undersides of all coverboards along one transect/site and suspended them into pitfall traps to provide escape routes for mammals (Figure 1). Escape strings consisted of 48-cm-long pieces of jute twine. Strings were stapled to the undersides of coverboards near the edge of each board and then again near the center, so that a mammal reaching the top of the string could climb along the underside of the coverboard, using the string, and reach the edge of the trap (Figure 1).

Sampling occurred October 1999-June 2000, with traps at some lower-elevation sites remaining open through winter and others being closed due to snow levels. Trapping effort ranged 854-3,318 array-nights, with the pitfall trap station functioning as the array, for the 10 sites. Mean trapping effort was 1,672 array-nights. I closed pitfall traps with plastic lids when they were not in use. I checked open traps once weekly, and captured animals were removed from traps and identified to species. All live animals were released at least 2 m away from the location of capture. For all animals captured in traps where strings had been installed, I recorded whether the string was intact. In traps with removed strings, I documented whether the strings had been chewed off and were lying in the traps or had

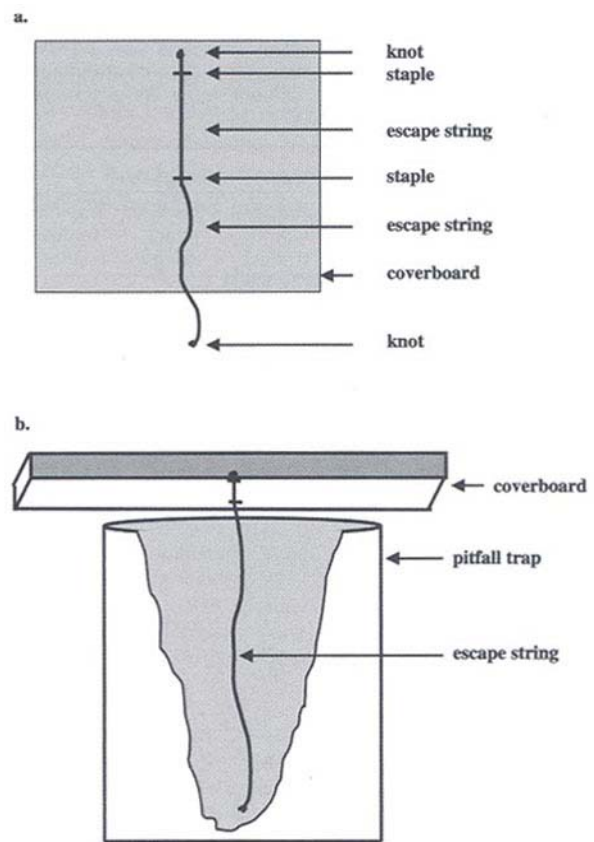


Figure 1. Schematic representations of (a) coverboard showing attachment of escape string and (b) cutaway view of pitfall trap showing placement of escape string within trap.

been carried away. I pooled small-mammal, amphibian, and reptile data separately for all 10 sites. I used 3 paired *t*-tests to determine whether differences existed in numbers of small mammals, amphibians, and reptiles captured in traps with escape strings versus those without. Animals captured in traps where escape strings had been chewed off, hereafter called removed strings, were not included in analyses.

I installed rain gauges at each site and checked them weekly during the sampling period (October-June). Automated temperature data recorders were established in 4 of 10 sites and recorded temperatures hourly for the duration of the study.

Results

Mean weekly rainfall for all 10 sites during the study was 4.4 cm (range 0-13.5). Temperature ranged from -1.51 to 38.8° C during the study. I caught 234 ($\bar{x}$ =23.4/site, SE=3.46, n =10) mammals

Table 1. Animal captures by species in pitfall traps without escape strings, in traps with intact strings, and in traps with removed strings. An asterisk indicates a significant difference ($P < 0.05$) in captures in traps without strings versus traps with intact strings.

Species	Captures		
	Traps without strings	Traps with intact strings	Traps with removed strings
Mammals			
<i>Sorex trowbridgii</i>	224	0	23
<i>Neurotrichus gibbsii</i>	6	0	1
<i>Microtus californicus</i>	2	0	2
<i>Peromyscus maniculatus</i>	2	1	1
<i>Scapanus latimanus</i>	0	2	0
Total Mammals*	234	3	27
Amphibians			
<i>Ensatina eschscholtzii</i>	77	70	4
<i>Plethodon elongatus</i>	11	4	1
<i>Rhyacotriton variegatus</i>	1	0	0
<i>Taricha granulosa</i>	2	0	0
<i>Bufo boreas</i>	0	2	2
Total Amphibians	90	76	7
Reptiles			
<i>Elgaria coerulea</i>	36	11	2
<i>Eumeces skiltonianus</i>	16	17	1
<i>Sceloporus occidentalis</i>	9	5	0
<i>Elgaria multicarinata</i>	1	1	0
<i>Thamnophis ordinoides</i>	1	0	0
Total Reptiles*	63	34	3

(Table 1), primarily Trowbridge's shrew (*Sorex trowbridgii*), in traps without escape strings, and 3 mammals ($\bar{x}=0.30/\text{site}$, $\text{SE}=0.21$, $n=10$) in traps with intact escape strings. This difference was significant ($t_1=6.7$, $P\leq0.001$). I caught 27 mammals in traps with removed strings. Of these, 6 strings had been chewed off, presumably by small mammals, and were lying in the bottoms of the traps, and 21 had been chewed off and carried away. In traps without escape strings, 226/234 mammals (97%) were dead. In traps with intact strings, all 3 mammals were dead. Mortality in traps with damaged or removed escape strings was 26/27 (96%).

I caught 90 amphibians ($\bar{x}=9.0/\text{site}$, $\text{SE}=1.57$, $n=10$, Table 1), primarily salamanders, in traps without escape strings, and 76 amphibians ($\bar{x}=7.6$, $\text{SE}=1.61$, $n=10$) in traps with intact escape strings. This difference was not significant ($t_1=0.9$, $P=0.40$). Seven amphibians were captured in traps with damaged or removed strings. Of these, 2 strings were chewed off and found in the traps, and the 5 others had been chewed off and carried away.

I caught 63 reptiles ($\bar{x}=6.3$, $\text{SE}=4.85$, $n=10$, Table 1) in traps without escape strings and 34 reptiles ($\bar{x}=3.4$, $\text{SE}=3.43$, $n=10$) in traps with intact escape strings. This difference was significant ($t_1=2.9$, $P=0.02$). I captured 3 reptiles in traps with damaged or removed strings, with one string having been chewed off and found in the trap and 2 strings having been chewed off and carried away.

Discussion

Escape strings successfully reduced mammal mortality in pitfall traps. Two anecdotal observations made during the sampling period provided additional insight into the utility and success of the escape strings. In the first instance, a trap in which an escape string had been chewed off and carried away contained a live *S. trowbridgii* that had been unable to escape. I attached a new string to the underside of the coverboard and replaced the coverboard on the trap. I moved 5 m away and watched. Within 3 minutes, the shrew emerged from beneath the coverboard and escaped. In the second instance, a live *S. trowbridgii* was captured in a trap in which no escape string had been installed. In the interest of determining how quickly the animal could escape, I attached a string to the underside of the coverboard and replaced the coverboard. The shrew escaped within 4 minutes. I could not determine how long the shrews had been in the traps, and with the coverboards in place I was unable to actually see the shrews use the escape strings. However, if the animals were capable of escaping the traps without using the strings, they probably would have done so prior to my arrival.

In addition to reducing mammal mortality in pitfall traps, this method eliminates the need to provide food, nesting material, and shelter for captured mammals, and reduces suffering experienced by trapped animals. Allowing small mammals to escape pitfall traps also reduces the likelihood of predation of amphibians and reptiles by small mammals retained simultaneously in pitfall traps. Finally, food supplied in pitfall traps, and the small mammals themselves, attract predators such as raccoons (Yunger et al. 1992) or bears (*Ursus americanus*, personal observation), which can depredate or scavenge captured animals and damage pitfall traps, coverboards, and drift fences. Allowing mammals to escape pitfall traps eliminates the need to provide food to captured mammals and thus reduces mortality and damage caused by larger predators.



One end of pitfall trap array showing coverboard placement, pitfall trap, and attachment of escape string to coverboard.

The primary shortcoming of this method is continually replacing escape strings. Mammals at some sites seemed to learn to remove the strings, presumably for nesting material, without falling into the traps. Jute twine is a suitable material for escape strings because it has a rough texture, which probably makes climbing easier for small mammals. During some preliminary laboratory testing of materials using white mice, I found that other materials, such as 2-cm strips of aluminum and fiberglass window screen and 1-cm nylon cord, were climbed easily by mice. However, some species of plethodontid salamanders are good climbers (Petranka 1998) and also might use these materials to escape traps. While jute twine may be used successfully to reduce mammal mortality in pitfall traps, there is still some mortality associated with mammals removing escape strings from coverboards and mammals subsequently falling into these traps and dying. In this study, 26 mammals died in traps where strings had been removed, accounting for 10.2% of the total mortality. In several instances, I found jute twine chewed and formed into the shape of nests in the bottoms of pitfall traps. These pieces of jute twine had presumably been removed from the coverboards of the traps in which they were found. A significant improvement on this method would be to find another material that is easily climbed by small mammals and difficult for amphibians and reptiles to climb, but is not taken by small mammals for nest material.

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