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Comparative Studies of Small Mammal Populations with Transects of Snap Traps and Pitfall Arrays in Southwest Virginia

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ABSTRACT

In a long-term project at Mountain Lake in southwest Virginia we are studying ecological preferences and population variations in small mammals. Using snap traps in transects we have accumulated large amounts of data on rodents but little on shrews. To enhance the capture success of shrews and to compare various techniques for capturing small mammals, we experimented with compact arrays of pitfall traps set parallel to our standard snap trap transects. Snap traps caught masked shrews in small numbers, voles in moderate numbers, and white-footed and deer mice in great numbers. Pitfalls on the other hand caught white-footed and deer mice in very small numbers, jumping mice in moderate numbers, and masked shrews in great numbers. We concluded from our results that the two trapping methods are complementary, and we combined snap trap and pitfall captures in a single analysis. To put the results of our pitfall trapping in perspective, we also summarize capture data on small mammals from the continuing long-term snap trap study and from a short-term pitfall study. We describe species-specific habitat preferences among the long-tailed shrews we sampled and consider the influence site moisture may have on habitat choice by various shrews.

Key Words: pitfall, snap trap, small mammals, shrew, Virginia, ecology

INTRODUCTION

The Mountain Lake small mammal project, designed to determine ecological preferences and long-term population variations in small mammals, has been in progress since 1962. Using standard transects of snap traps, the study has accumulated a large amount of data on rodents, but relatively little on shrews.

A common plight of studies that use conventional traps such as snap traps to sample populations of small mammals is the difficulty of capturing small shrews (e.g., *Sorex* and *Cryptotis*). Data on distribution and abundance of these shrews usually are not comparable with data for large shrews (*Blarina*) and rodents. Pitfalls provide a solution to this trapping dilemma, but the extent of equivalence of capture data from pitfalls and snap traps is an unresolved problem.

In view of the growing literature on various pitfall types and techniques and another group of papers comparing capture rates of pitfalls with a variety of other traps, Kirkland and Sheppard (in press) recommended standardizing pitfall trapping techniques so that results of diverse studies will be comparable. They suggested a large array, about 25 m in diameter, as a standard. At the same time Handley and Varn (in press) proposed much smaller pitfalls in compact arrays, about 2.5 m in diameter, to be used in a transect. We assume that small pitfall arrays arranged in transects might be more similar in sampling characteristics to transects of snap traps than larger pitfall arrays are. In contrast to other types of pitfalls, the small pitfall arrays also are easier to set and cause less disturbance to the environment.

In order to determine the efficacy of the small pitfall arrays, we set four transects of arrays of the miniature pitfalls parallel to four snap trap transects from the long-term project at Mountain Lake. Our main objective was to measure the capture success of small mammals (especially long-tailed shrews) based on pitfall trapping, for comparison with the capture success of small mammals (especially rodents and short-tailed shrews) as determined by snap trapping. For further comparisons we also include a summary of the long-term study at Mountain Lake and the results of a preliminary pitfall study in 1987 in the same area. In addition to species richness and abundance of small mammals obtained by various trapping methods, we discuss the distribution and habitat preferences of various species, with emphasis on shrews. In a companion paper we compare the compact pitfall array with other types of pitfalls in current use (Handley and Kalko, in press).

METHODS

Study site, projects, and observation periods

In this paper, we present data from three related projects, all done in the vicinity of Mountain Lake (37°21'N, 80°32'W), Giles County, Virginia. The first project is a continuing long-term study of distribution, population dynamics, and ecology of small mammals using transects of snap traps. This study has been underway since 1962. We give some details of the 1991 snap trapping and the first summary of a 15-year segment (1976-1991) in which small mammals were sampled with a standardized routine. Throughout this paper "long-term study" refers to the 1976-1991 segment. Reporting a second project of the fall of 1991 (4 September - 17 October), we compare capture rates of snap trap transects used in the long-term study with capture rates of pitfall arrays set parallel to them. Finally, from our third project, we show the results of a short-term study with pitfalls at the Mountain Lake Biological Station done by Handley in the fall of 1987 (28 August - 25 September) which gave us data on the effect of rainfall on capture success, lacking in our 1991 data base. Our definition of "small mammal fauna" in this paper includes shrews, mice, voles, and jumping mice. Although we occasionally caught chipmunks (*Tamias striatus*), flying squirrels (*Glaucomys volans*), and packrats (*Neotoma floridana*) in snap traps, we did not include them in the results presented here. We sampled these species with larger traps in a separate project.

Weather conditions

In the fall of 1987, climatic conditions at Mountain Lake were about average for that season. There was rain on 11 of the 29 days of pitfall operation. In contrast, the fall of 1991 was unusually dry. Drought conditions prevailed. Some streams dried up and soil was dry and often powdery. Rainfall in August, September, and October totaled only 44.7 mm (August, 25.9 mm; September, 11.7 mm; October, 7.1 mm). In this three month period the greatest precipitation in 24 hours was only 13.2 mm on 4 August 1991. Average rainfall for these months for the 15-year period, 1972-1987, was 308 mm (104.1 mm, 98.2 mm, 105.7 mm) (G. Parker, pers. comm.). Temperature was near normal in the fall of 1991. Maxima and minima averaged

23°C and 13°C in August, 20°C and 11°C in September, and 16°C and 3°C in October.

Habitats sampled

1) Snap trap transects (1976-1991). Sampling included all of the major habitat types in the area: A) Cliff and Talus. B) Forest. C) Stream and Bog. D) Meadow. Six snap trap transects were set in each of the four habitats, thus 24 transects in all.

Transects were sited in all of the major topographic units of the area, including three high ridges (Big Mountain, Salt Pond Mountain, and Butt Mountain), all cresting above 1200 m; and four drainages (Big Stony Creek, Little Stony Creek, Sinking Creek, and John's Creek), exiting from the area as low as 900 m. Transects varied in elevation from 945 to 1250 m.

Transects also sampled variations in each of the major habitat types. Thus, habitats represented in the Cliff and Talus habitat included cliffs with little breakdown and shallow talus or massive breakdown and deep talus, moist cool cliffs and warm dry cliffs, talus aprons, and talus streams. The Forest habitat type included coniferous and deciduous forests, moist and dry forests, and rocky and deep soil forests, with much or little herbaceous ground cover. The Stream and Bog habitat type included sphagnum bogs with hemlock and with spruce, sedge bogs with alder and with St. Johnswort, and banks of streams through rhododendron thickets, through meadow, and through forest. The Meadow habitat type included meadows in the form of old fields in various stages of regrowth, with patches of grass and sedge, or goldenrod and ironweed, moist and dry meadows, and a narrow linear meadow along a utility line.

2) Pitfall transects (1991). Four pitfall transects were set parallel to snap trap transects, each of them representing one of the four major habitat types:

A) Cliff and Talus. Castle (Wind) Rock Ledge, 7.1 km NNE Mountain Lake, 1250 m. Transect through damp talus at the foot of a ledge in birch-red maple forest on a relatively cool northwest-facing slope.

B) Forest. Twin Springs Trail, 2.6 km NNE Mountain Lake, 1165 m. Transect along trail through flat, rocky, dry, oak-hickory forest with numerous rotting logs but little herbaceous ground cover. Three of the pitfall sites were flooded in rain.

C) Stream and Bog. Ashley Bogs (Little Meadows), 4.4 km NW Mountain Lake, 945 m. Transect included a wet sedge-alder-*Osmunda* bog, with mud and standing water, adjacent to steep slopes with dry oak-hickory forest; and a dry (seasonally damp) sedge-*Hypericum*-alder bog with adjacent flat ground white pine forest. All pitfall sites were flooded in rain.

D) Meadow. Ashley Meadows (Little Meadows), 4.5 km NW Mountain Lake, 940 m. Transect segments in openings in valley floor white pine forest: damp meadow at old house site, damp swale with sedge and *Hypericum* between lawn and forest, and large dry sedge-*Hypericum* meadow. Half of the sites were flooded in rain.

3) Pitfall trapping at forest ponds (1987). The pitfalls were installed around two forest ponds, Horton and Sylvatica, at the Mountain Lake Biological Station. None of these flooded.

Configuration of transects

1) Snap trap transects (1976-1991). In most years of the study 24 transects were used. Each transect contained 100 (rarely fewer) Museum Special snap traps,

spaced at intervals of about 10 (occasionally 5) meters (measured by pacing), and baited with rolled oats. The average transect was a little less than 1000 meters long. In the fall of 1991 only 23 snap trap transects were set, as one long used study area was lost to development in 1987.

2) Pitfall transects (1991). Our pitfalls were 2 liter plastic soft drink bottles with their tops cut off (20 cm deep and 11 cm in diameter) and 3.8 liter (1 gal.) containers approximately 17 cm deep and 15 cm in diameter. The containers were sunk into the ground with lips flush with the surface to form pitfalls. Each pitfall was sheltered from rain, falling leaves, sun, and moonlight by a square of vinyl siding 30 x 30 cm. In damp ground we compensated for fluctuating water tables by pegging down the pitfalls. One long, hooked peg on either side of a pitfall effectively held it in place. We filled the pitfalls to about half their depth with 10% formalin to preserve specimens.

We formed the pitfalls into arrays of seven pitfalls each in a 3-leaf clover pattern (120° between arms), with a 3.8 liter container at the center and 2 liter bottles on either side, near the distal end of each arm (drift fence). The drift fences, pieces of vinyl siding 1.2 m long by 30 cm high, converged at the central pitfall. An array of seven pitfalls fits into a triangle a little less than 2.5 m from corner to corner. For more details see Handley and Varn (in press).

We set four pitfall transects parallel to four snap trap transects. Each 1000 m transect contained 14 compact pitfall arrays (totaling 98 pitfalls) at intervals of about 75 m, and 100 Museum Special snap traps at intervals of about 10 m. Theoretically, snap traps might have caught something that otherwise could have gotten into a pitfall or vice versa. However, we assume that with the pitfall arrays 75 meters apart, only every seventh snap trap was near a pitfall array, so impact of one trapping method on the other must have been slight.

3) Pitfalls at forest ponds (1987). In the fall of 1987 Handley experimented briefly with 16 pitfalls that had been installed by Adrian Massey for a study of salamanders at the Mountain Lake Biological Station. The pitfalls were 3.8 liter cans on either side of aluminum drift fences that partly surrounded two small forest ponds. The pitfalls had roofs and, as far as possible, they were kept dry.

Sampling routine and trap nights

1) Snap trap transects (1976-1991). Throughout the study the same transects have been sampled usually biannually, in a night-day-night routine (n-d-n = 2 trap nights).

2) Pitfall transects (1991). Immediately after installation we checked the pitfall transects with the same n-d-n routine described above. After the snap trap transects were removed, we continued to check the pitfall arrays periodically during a sampling period of four weeks. We could not record the captures of the first n-d-n of the Cliff and Talus pitfall transect. In place of these missing data we have included the captures of the first week of the Cliff and Talus habitat. Comparing the results of the n-d-n captures with the results after 1 week for the other pitfall transects, we doubt the extra nights had much if any effect on species composition in the Cliff and Talus habitat. Also, the overstatement of number of individuals is probably below 40% as most of the other pitfall arrays caught around 60% of the total number of specimens for the one week sampling period in the first n-d-n period.

3) Pitfalls at forest ponds (1987). The pitfalls were checked twice daily for 29 days.

RESULTS

Comparison of captures of small mammals in parallel transects of pitfall arrays and snap traps

Pitfalls and snap traps combined sampled a total of 12 species of small mammals (Tables 1 and 2). This represents the entire small mammal fauna of the area. The number of species caught was similar in the two trapping methods (eight species in snap traps, nine in pitfalls), but the species composition differed (Table 1). Five species were caught by both trapping methods: masked shrew (*Sorex cinereus*), big-tailed shrew (*Sorex dispar*), smoky shrew (*Sorex fumeus*), short-tailed shrew (*Blarina brevicauda*), and meadow vole (*Microtus pennsylvanicus*); four only in the pitfalls: pygmy shrew (*Sorex hoyi*), lemming vole (*Synaptomys cooperi*), meadow jumping mouse (*Zapus hudsonius*), and woodland jumping mouse (*Napaeozapus insignis*); and three only in the snap traps: white-footed mouse (*Peromyscus leucopus*), deer mouse (*Peromyscus maniculatus*), and red-backed vole (*Clethrionomys gapperi*).

Species richness varied with habitat. The Cliff and Talus habitat showed the greatest richness with a total of nine species, followed by the Stream and Bog habitat with eight species, the Meadow habitat with six species, and the Forest habitat with only five species.

The number of species caught within habitats depended on the trapping method. In Cliff and Talus three of the total of nine species were caught only by snap traps, two only by pitfall arrays, and four by both methods. In Stream and Bog three of eight species were caught only by snap traps, three by pitfall arrays, and two by both methods. In Meadow two of six species were caught by snap traps alone, three by pitfall arrays, and one by both methods. Finally, in Forest four of five species were caught by snap trapping alone and one by both methods.

Capture success (number of specimens caught) was higher in the snap trap transects than in the pitfall arrays, 107 versus 77 (Table 1). However, 59 of the snap trapped mammals were white-footed mouse and deer mouse, which we rarely caught in our pitfalls. Without *Peromyscus*, the capture results favor the pitfalls, 77 to 48.

The capture success of the two trapping methods varied with species (Table 2). *Peromyscus*, which made up 55% of the total snap trap captures, were not caught in pitfalls in the n-d-n schedule. In contrast, long-tailed shrews, which made up only 13% of total captures from snap trap transects totaled 82% of pitfall captures. Short-tailed shrews were sampled in higher numbers in snap traps (13% of total captures) than in pitfall arrays (6% of total captures). Jumping mice, 8% of pitfall captures, were not caught in snap traps. Voles, constituting 19% of snap trap captures, accounted for only 4% of pitfall captures.

The capture success of the two methods differed in the various habitats (Table 1). In Stream and Bog the transect of pitfall arrays caught more mammals (25) than the snap trap transect (19). In Cliff and Talus the number of specimens was almost the same (27 in pitfalls to 26 in snap traps) and in Meadow the two methods were equally productive (19 each). In the Forest, because of *Peromyscus*, the snap trap transect caught many more mammals (43) than the pitfall arrays (6).

TABLE 1. Comparison of two night catches in paired snap trap (ST) and pitfall (PF) transects near Mountain Lake, Virginia, September 1991.

	Cliff & Talus		Stream & Bog		Forest		Meadow		Totals	
	ST	*PF	ST	PF	ST	PF	ST	PF	Snap traps	Pitfalls
Sorex cinereus	2	17		18	3	6		16	5	57
Sorex dispar	3	1							3	1
Sorex fumeus	4	4	2						6 13%	4 82%
Sorex hoyi		1								1
Blarina brevicauda	5	3	3	1	2		4	1	14 13%	5 6%
Peromyscus leucopus	6		3		27		6		42	
Peromyscus maniculatus	4		3		10				17 55%	
Clethrionomys gapperi	2				1				3	
Microtus pennsylvanicus			8	1			9		17 19%	1
Synaptomys cooperi				2						2 4%
Zapus hudsonius				3				1		4
Napaeozapus insignis		1						1		2 8%
Total specimens	26	27	19	25	43	6	19	19	107	77
Total species	7	6	5	5	5	1	3	4	8	9

*Seven night catch

TABLE 2. Comparison of frequency (percent of total catch) of five groups of small mammals in catches of paired pitfall and snap trap transects. Data from Table 1.

Species	Total species	Pitfalls	Snap traps	Combined pitfalls & snap traps
Sorex				
long-tailed shrews	4	82%	13%	42%
Blarina				
short-tailed shrews	1	6%	13%	10%
Peromyscus				
white-footed & deer mice	2	0	55%	32%
ARVICOLINAE				
voles	3	4%	19%	13%
ZAPOPIDAE				
jumping mice	2	8%	0	3%
Total species	12	9	8	12
Total catch		77	107	184

Abundance and distribution of long-tailed shrews as measured with snap trap transects in a 15-year study

In the long-term study, captures of long-tailed shrews *(Sorex)* totaled 297 specimens in 34,763 trap nights (Table 3). The masked shrew was the most frequently captured, 52% of total captures of *Sorex*. The smoky shrew comprised 38% and the big-tailed shrew was only 10% of total captures. The average capture rate for the masked shrew in the 15-year sample was 0.44 shrews per 100 trap nights.

Abundance of long-tailed shrews varied with habitat (Table 3). Snap trap transects in Cliff and Talus habitats caught the most shrews, with 36% of total captured long-tailed shrews. Stream and Bog habitats contributed 25% of captures, while Forest habitats produced 20%, and Meadow habitats only 19% of the *Sorex*.

The Cliff and Talus habitat also exhibited the greatest diversity of species (Table 3). Three species, masked, smoky, and big-tailed shrews, were represented in that habitat in substantial numbers. These same three species were also found in Stream and Bog, but the big-tailed shrew was caught there only once in 15 years. It was never found in Meadow or Forest habitat, which revealed only two species each.

Habitat preferences varied among the long-tailed shrews (Table 3). The masked shrew occurred in all habitats but was taken most often in Forest (32%) and Meadow (30%); less often in Stream and Bog (19%) and Cliff and Talus (19%). The smoky shrew also was trapped in all habitat types, but in smaller numbers than the masked shrew. In contrast to the masked shrew, most smoky shrews were trapped in Cliff and Talus (42%) and Stream and Bog (41%); only 11% were caught in Forest and 6% in Meadow. The big-tailed shrew was taken almost exclusively in Cliff and Talus (97%); only once in rocks on an alluvial plain in a Stream and Bog habitat.

TABLE 3. Habitat preferences of long-tailed shrews in a 15-year sampling period (1976-1991) in snap trap transects near Mountain Lake, Virginia. Number of specimens in each habitat type and percentage of species total in each habitat type. Total trap nights 34,763.

	Cliff & Talus	Stream & Bog	Forest	Meadow	Total specimens of each species
Sorex cinereus	29(19%)	29(19%)	48(32%)	47(30%)	153(52%)
Sorex dispar	30(97%)	1(3%)	0(0%)	0(0%)	31(10%)
Sorex fumeus	48(42%)	46(41%)	12(11%)	7(6%)	113(38%)
Total specimens of long-tailed shrews per habitat	107(36%)	76(25%)	60(20%)	54(19%)	297(100%)

Abundance and distribution of long-tailed shrews as measured bytransects of pitfall arrays in sampling periods of four weeks

Small mammals captured in four pitfall transects from which specimens were removed after 2 nights, after one week (1w), and after four weeks (4w) from first removal, totaled 219 specimens of 11 species (Table 4). Four species of long-tailed shrews made up 82% of total captures. Short-tailed shrews and rodents were caught infrequently and in small numbers. Compared with results of the long-term snap trap study (Table 3), the four transects of pitfall arrays reached 61% of total numbers of *Sorex* from the entire 15-year sampling of 24 snap trap transects. The capture rate of long-tailed shrews in pitfalls was 1.6% (captures divided by trap nights, 181/11,270), almost twice that for snap traps with 0.9% (297/34,763).

The masked shrew was the most commonly caught small mammal in the pitfall arrays. For that species, captures in four weeks of continuous pitfall trapping (170 specimens in 11,270 trap nights) exceeded the entire take from 15 years of snap trapping in 24 transects (153 specimens in 34,763 trap nights). The capture rate of this shrew was almost four times greater in pitfalls than in snap traps (1.5% versus 0.4%).

We caught only nine smoky shrews in the four pitfall transects in four weeks, fewer than we expected in view of the numbers (28) captured in the 23 snap trap transects of 1991 and in the 15-year study (113). In the 23 transects of snap traps set in 1991, total captures of smoky shrews slightly exceeded captures of masked shrews (28 vs. 25).

Our capture of only one big-tailed shrew in the month of pitfall trapping was in sharp contrast to the six taken in the 1991 snap trap transects and 31 taken in the 15 years of snap trapping. On the other hand, we caught a pygmy shrew (*Sorex hoyi*) in a pitfall, the first of this species ever taken in the Mountain Lake area.

The capture success of the pitfall arrays varied over time. For example, the take in the last three weeks of the project was greater than the take in the first week in the Cliff and Talus transect, but smaller in the last three weeks than in the first week in the other three transects (Table 4). In the Stream and Bog and Meadow transects

TABLE 4. Pitfall trapping near Mountain Lake, Virginia, September-October 1991. Numbers of small mammals caught in pitfalls in four habitats in the first week (1w) and in the second through fourth weeks (4w) of sampling. Specimens removed on the second morning (Table 2) are included in the first week's (1w) catch.

Taxon	Cliff & Talus			Stream & Bog			Forest			Meadow			Totals	
	1w	4w	total	1w	4w	total	1w	4w	total	1w	4w	total	specimens	percent
Sorex cinereus	17	28	45 (27%)	32	23	55 (32%)	14	6	20 (12%)	7	23	50 (29%)	170	77.0%
Sorex dispar	1		1										1	0.5%
Sorex fumeus	4	4	8		1	1							9	4.0%
Sorex hoyi	1		1										1	0.5%
All *Sorex*														[82.0%]
Blarina brevicauda	3	1	4	1	1	2				1		1	7	3.0%
Peromyscus leucopus							2	2	4				4	
Peromyscus maniculatus		1	1					2	2				3	
All *Peromyscus*														[3.0%]
Microtus pennsylvanicus				2		2					3	3	5	
Synaptomys cooperi				2	3	5				1		1	6	
All Microtines														[6.0%]
Zapus hudsonius				6	2	8				1	2	3	11	
Napaeozapus insignis	1		1							1		1	2	
All jumping mice														[6.0%]
Total specimens	27	34	61	43	30	73	16	10	26	31	28	59	219	
Total species	6	4	7	5	5	6	2	3	3	5	3	6	11	
Total pitfall nights	588	2450	3038	784	1862	2646	784	2352	3136	490	1960	2450	11,270	

we found a decline from the second to the seventh night but during the same period captures in the Forest increased.

Temporal variation in capture rate (Table 4) was dominated in the pitfalls by fluctuations in numbers of masked shrews. Overall the numbers of this shrew declined from 90 after the first week to 80 in the next three weeks. We caught enough masked shrews so that we can comment on its preferences of habitat. In the pitfall transects most masked shrews were caught in the Stream and Bog habitat (32%) and in Meadow (29%). Fewer were caught in the Cliff and Talus (27%), and only 12% in the Forest habitat.

Pitfall trapping at forest ponds (1987)

In the pitfalls set around forest ponds at the Mountain Lake Biological Station in 1987, 67 small mammals were captured in 446 trap nights: masked shrew 64, smoky shrew 1, least shrew (*Cryptotis parvus*) 1, and lemming vole 1. The number of masked shrews at the forest ponds, 14 per 100 pitfall nights, is astonishingly high. In contrast, masked shrews in snap trap transects at the same time averaged only 0.3 shrews per 100 trap nights. The capture of a least shrew is also notable as this individual is one of only ten that have been caught during the 1962-1991 period in the Mountain Lake area.

Capture of long-tailed shrews in the pitfalls around the ponds frequently coincided with rainfall (Fig.1). Most masked shrews, 46 (72%), were caught on rainy days; only 18 (28%) on dry days. Only six shrews were caught in the first nine days (7 of 9 days without rain), whereas 33 were caught in the next 9 days when it rained on eight of the days.

DISCUSSION

Comparison of snap trap and pitfall transects

Comparison of the results of our trapping with transects of the compact pitfall arrays set parallel to transects of Museum Special snap traps shows that these two methods of trapping small mammals are closely complementary. The combination of pitfall trapping and snap trapping sampled the whole small mammal fauna of the area. Although in total the two trapping methods had similar sampling characteristics (number of species, and number of individuals caught), each sampled a different part of the fauna. The samples from the two methods showed little overlap in species composition. The compact pitfall arrays were best for capturing masked and pygmy shrews, lemming vole, and jumping mice. Museum Special snap traps excelled in capturing big-tailed, smoky, and short-tailed shrews, white-footed and deer mice, and red-backed and meadow voles. Also, there was little overlap in the total number of specimens per species sampled by each method. Stated in more general terms, snap trapping in the Mountain Lake area caught masked shrews in small numbers, voles in moderate numbers, and *Peromyscus* in great numbers, while compact pitfall arrays caught masked shrews in great numbers, jumping mice in moderate numbers, and *Peromyscus* in low numbers (Table 1).

Our combination of trapping methods yielded results on species diversity, distribution, and relative abundance that cannot be achieved with either pitfalls or snap traps used alone. The trapping results indicate to us that the configuration of the pitfall arrays and snap trap transects used in this study achieve capture data that can be combined into a single data set to better estimate relative abundance of taxa in inventories of the whole small mammal fauna. In the combined captures in 1991 *Sorex* and *Peromyscus* made up about one-third each, voles made up about one-sixth, and *Blarina* and jumping mice together made up the final sixth (Table 2). We assume that other configurations of traps (e.g., variations in size of pitfalls, length of drift fence, and spacing of pitfalls and snap traps) might lead to different capture results, difficult to compare. Larger pitfall arrays for example might oversample shrews or mice and interfere substantially with the snap trap transects if they were used in combination.

For example, Pagels et al. (1992) used large pitfall arrays to compare the small mammal faunas of forests and clearcuts in central Virginia (Cumberland County). Their arrays were triads with 5 m arms, a 10 m central gap, and 19 liter (5 gallon) pitfalls. If these triads were equivalent to our snap trap/pitfall combination, we would expect that they sampled small mammals in proportions similar to our results. This is the case for mice; in their study, mice, including *Peromyscus*, accounted for about one-third of all small mammals. However, Pagels et al. obtained different results for the rest of the small mammals. Small shrews accounted for one quarter, *Blarina* and jumping mice for one quarter, and voles for the remaining fraction. As capture techniques and habitats sampled differ from our study, we cannot say whether the differences in proportions of species observed by Pagels et al. are due to trapping method only or to different faunal compositions.

Abundance of long-tailed shrews

Most investigators who have trapped in the habitat of the masked shrew have found it to be the most abundant species in their pitfalls (e.g., Clarke 1938; Innes and Bendell 1988). Our results corroborate this, as the masked shrew made up by far the largest fraction (77%) among the small mammals we caught in 1991 in pitfalls. In contrast, the most abundant small mammal in snap traps of the 15-year sample always has been a *Peromyscus* or a vole, while the masked shrew was only 2.2% of total captures (153 of 6998), and in 1991 snap traps it was only 3.6% (25 of 704).

Three other species of long-tailed shrews (smoky, big-tailed, and pygmy) were few in pitfalls, together totaling only 5% of small mammals caught in 1991. Again the 15-year snap trap sample presented a very different picture. The numbers of these three species together (145 individuals or 2.1% of all small mammals) were almost the same as numbers of the masked shrew.

We seldom caught smoky shrews in our pitfalls--only nine in 11,270 pitfall nights (0.08/100). Perhaps capture success was depressed because of the drought. However, snap traps in 1991 caught 28 smoky shrews--twice the annual mean (14.1) for the 15-year sample. The 28 shrews translate to a capture rate of 0.43/100--more than five times the capture rate of this shrew in the pitfalls.

The big-tailed shrew is even less frequently caught in pitfalls (Pagels 1987). It is clear from our data that snap traps capture big-tailed shrews better than the compact pitfall arrays. Only one big-tailed shrew was caught in pitfalls in 1991, while snap traps caught six. Snap traps caught 31 individuals or 10% of all long-tailed shrews in the 15-year sample. We suspect that the home range of the big-tailed shrew has a large vertical component, which makes the placement of traps difficult. Whereas our snap traps were set mainly under rocks and always as deep in talus as we could reach, the pitfalls could be set only on the surface. Under drought conditions, as in 1991, the big-tailed shrew probably spends most of the time in the cool, damp crevices under the rocks and seldom comes to the warm, dry surface. Thus, the greater success of snap traps for sampling this shrew seems to reflect our inability to place pitfalls where this species is most active. In cool, wet weather the results might be different.

The rarest of Mountain Lake shrews, the pygmy shrew, has never been taken in the project's 29 years of snap trapping. Our 1991 pitfalls caught one. Other studies also have shown that pygmy shrews are rarely caught in traps other than pitfalls (e.g., Clarke 1938, Ontario; DeMott and Lindsay 1975, Colorado; Kirkland, et al. 1987, Pennsylvania; Pagels 1987, Virginia; Prince 1941, Ontario).

These data indicate that pitfalls are superior for sampling masked and pygmy shrews; snap traps are better for sampling smoky and big-tailed shrews. We think that our compact pitfall arrays yield reasonable estimates of relative abundance of masked and pygmy shrews. Probably neither trapping method estimates the abundance of smoky or big-tailed shrews very well.

Habitat preferences of long-tailed shrews

Our snap trap data clearly segregated the common long-tailed shrews, masked shrew (52% of *Sorex*), and smoky shrew (38% of *Sorex*) by habitat preference. The masked shrew preferred Forest and Meadow by 62% (15-year data) to 80% (1991 data), while the smoky shrew favored Cliff and Talus and Stream and Bog by 83% (15-year data) to 100% (1991 data). Cliff and Talus and Stream and Bog were the most moist of the four habitats sampled. The other Mountain Lake *Sorex* were almost exclusively in Cliff and Talus. In fact, Cliff and Talus had the greatest species richness of *Sorex*. It is likely that moisture can explain the observed species richness in shrews, as moisture is regarded as one of the major determinants of soricid richness (e.g., Kirkland, 1991). We further assume that the masked shrew, which preferentially occurred in Forest and Meadow, might have greater tolerance of dryness than the other long-tailed shrews do.

In contrast to our snap trap results, Spencer and Pettus (1966) did not find segregation of common long-tailed shrews by habitat. They studied habitat preferences of five species of *Sorex* with pitfalls during four consecutive summers in Colorado and observed in three of the five species a year-to-year consistency in habitat choice. The masked shrew was always the most abundant species and it, together with the common vagrant shrew (*Sorex vagrans*), was caught most often in the wettest habitat, marsh, which differs from our findings. Perhaps differences in the distribution and availability of food lead to varying degrees of interspecific competition among the shrews, and might explain the observed pattern.

In our 1991 pitfall data for the masked shrew we observed an apparent shift in habitat preference, contradicting our snap trap data. We found high numbers of this species in Cliff and Talus, Stream and Bog, and Meadow habitats and low numbers in the Forest habitat. Based on our long-term snap trap results we would expect highest numbers in Forest and Meadow and lower numbers in Cliff and Talus and Stream and Bog. The Forest habitat in which we placed the pitfall transect was extremely dry in the fall of 1991, so it is likely that the observed shift in habitat preference of this species was a change in accessibility for capture (i.e., the shrews became more subterranean or emigrated to damper habitats), an artifact of the drought.

This assumption is supported by a study by Moore (1949) who used pitfalls along the Twin Springs Trail, the site of our forest transect, in August 1947. In 144 pitfall nights he caught 22 masked shrews. Moore observed that conditions along the trail in August 1947 varied from mesic to near hydric. Rain filled his pitfalls to a depth of as much as an inch almost daily. In contrast to Moore's capture rate of 15 shrews per 100 pitfalls our capture rate for masked shrews along Twin Springs Trail, under drought conditions, was only 0.6 shrews per hundred pitfalls. These results clearly demonstrate that not only trapping method but also climatic factors affect capture success. They also show how cautious one must be, especially in short-term projects, to evaluate capture techniques and climatic influence before assigning habitat preferences for species.

All our results indicate that moisture has a strong influence on habitat preference in shrews. Kirkland (1991) suggested as a possible reason that greater site moisture might lead to greater abundance and diversity of invertebrates suitable as prey for shrews. Kirkland (1991) further hypothesized that given sufficient moisture and thus adequate food resources, habitats support syntopic populations of shrews. He postulated that syntopic shrews ideally sort into size classes, each with a pair of species, one a common generalist and the other an uncommon specialist. In Kirkland's classification masked and pygmy shrews are small and smoky and big-tailed shrews are medium size. By Kirkland's hypothesis the common *Sorex* in the Mountain Lake fauna, masked and smoky shrews, represent different size classes and should be able to coexist without the habitat separation we observed in our long-term snap trap results. Even after considering site moisture our findings do not support Kirkland's hypothesis. One explanation could be that masked and smoky shrew differ in their requirements for moisture. Our results indicate that the masked shrew might have a greater tolerance of dryness.

Influence of moisture on capture rate of shrews

When we checked pitfalls on a daily basis in 1987, we found that almost three-quarters of the masked shrews were caught on rainy days. In this instance, captures correlated with rainfall rather than with chronology. Of course, we would expect a decrease in captures with the passage of time as individuals were removed from populations. However, the greatest number of captures occurred on the 24th day of sampling. Our results are in accordance with those of Doucet and Bider (1974) who observed that rainfall increased the nocturnal activity of the masked shrew. They observed that time of onset of rain also correlated with activity, and that temperature, clouds, and wind direction had a smaller bearing on activity.

The large number of masked shrews caught in 1987 at the ponds (Fig.1) may also have been influenced by the proximity of standing water, no more than 1-2 m from any of the pitfalls. Similarly, the relatively large numbers taken in 1991 pitfall transects (Table 4) in the bogs, which were partially flooded (2.1 shrews per 100 pitfalls); in the meadow, where half of the pitfalls were partially flooded (2.0 shrews per 100 pitfalls); and in Cliff and Talus, on a cool and damp north slope (1.5 shrews per 100 pitfalls) seem to correlate with soil moisture. In contrast, the dry forest transect had a capture rate for long-tailed shrews of only 0.6% and most of those shrews were caught in the three arrays in the transect that were partially flooded.

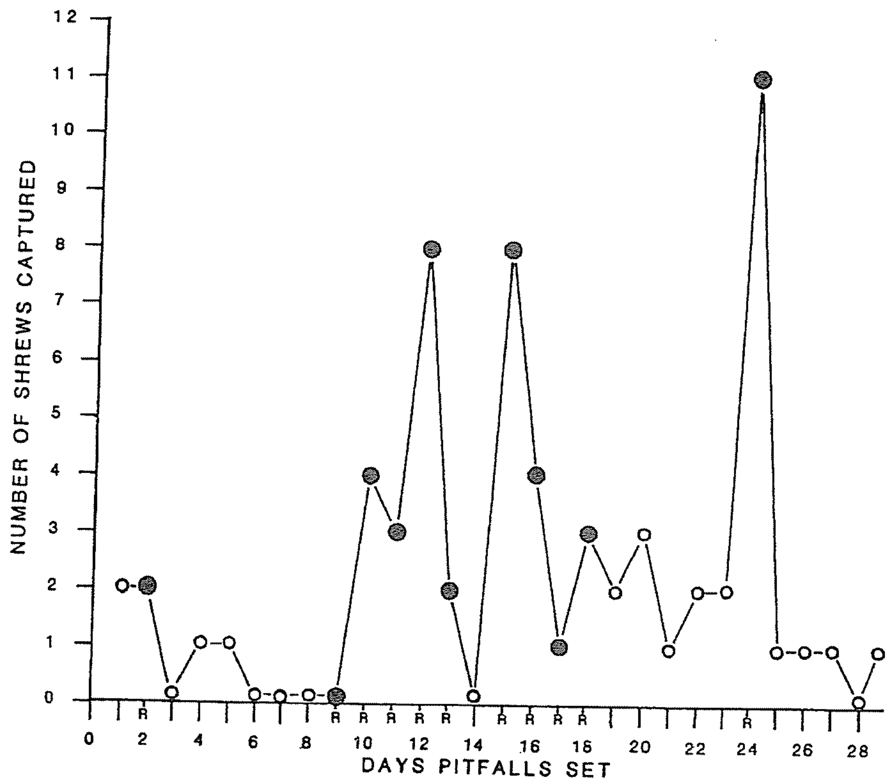

FIGURE 1. Captures of masked shrews (Sorex *cinereus*) in pitfalls around forest ponds at the Mountain Lake Biological Station, 28 August to 25 September 1987 (29 days). Days with rainfall marked with R and with black dot capture symbol.

CONCLUSIONS

Do captures of small mammals in compact pitfall arrays answer questions about distribution and abundance of these species sufficiently well to justify the extra effort of setting a pitfall transect? When dealing with the small mammal fauna as a whole, the answer is definitely yes. The pitfalls yield information on species richness, distribution, and on the abundance of long-tailed shrews and jumping mice that cannot be obtained with snap traps, while the snap traps produce much better data for mice, large shrews, and most voles. The trapping methods we used are complementary, and data from the two sources can be pooled for analysis. Our transects of compact pitfall arrays in combination with transects of snap traps are a solution to the long-standing problem of how to set transects using two trapping methods that are complementary and achieve comparable results.

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