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A Short History of Pitfall Trapping in America, with a Review of Methods Currently Used for Small Mammals

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ABSTRACT

We review the history of pitfall trapping for small mammals in America, describe and classify currently used pitfall techniques, comment on the method we have developed for combining pitfall and snap traps in transects, and describe circumstances in which each of the currently used pitfall alternatives should be the method of choice in studies of small mammals.

Key Words: Pitfall, pitfall techniques, small mammals

INTRODUCTION

Pitfalls are steep-sided cavities in the ground used to trap animals. Antlions use pitfalls to capture small arthropods. Early human-beings dug pitfalls to trap mammals for meat and hides. In this century zoologists have rediscovered the pitfall as a device for capturing a variety of animals, including gastropods, arthropods, amphibians, reptiles, and mammals. Now there is growing interest in pitfalls as a means of capturing small mammals, particularly the smaller shrews so notoriously difficult to catch in conventional snap traps or live traps. Pitfalls are being used with increasing frequency to supplement conventional traps to secure data for shrews. Consequently, there is a rapidly growing literature describing pitfalls used alone and in combination with drift fences to trap small mammals, and another group of papers comparing capture rates of various kinds of pitfalls with a variety of traps, mostly Museum Special snap traps and Sherman live traps. Disparate elements in pitfall procedure have come together in the Proceedings of the International Colloquium on the Biology of the Soricidae in a pair of papers describing pitfall trapping concepts differing widely in scale and style. In the Proceedings, Kirkland and Sheppard (in press) advocated a standard pitfall array 25 m in diameter, whereas Handley and Varn (in press) touted a compact array only 2.5 m in diameter.

Our objectives in this paper are to present an historical overview of the development of pitfall trapping in America, to describe important improvements of the current pitfall trapping techniques, and to define circumstances in which one or any other of these alternatives should be the technique of choice in studies of small mammals. To assess the efficiency of some of the current models we compare the results of other pitfall configurations with our own results obtained with a compact array of pitfalls (Kalko and Handley, 1993). We have not included some often used European types, such as cones, because they seem to have no bearing on the development of pitfalls used in America. Nor have we included interesting specialty devices such as false floors and various sorts of inserts, since they have not found general application. We have looked for pitfall trapping techniques in the literature which we consider as important developments and do not intend this survey to be exhaustive or all-inclusive.

RESULTS

Early use of pitfall traps to sample small mammals

The idea of using pitfalls to capture shrews and other small mammals seems to have evolved in the 1930's. In an inventory of small mammals at Pancake Bay, Ontario, in 1935, Clarke (1938) used materials from a handy dump, "...discarded 50 pound shortening pails, a few miscellaneous buckets, and a tub" partly filled with water as pitfalls. In all he had only 569 pitfall nights, but he learned much from his experience and realized that he had discovered a very useful new trapping technique. He regarded the selectivity of his pitfalls in capturing small shrews and jumping mice as "very striking".

Llewellyn (1942) credited C. P. Patton with finding rodents and a least weasel *(Mustela nivalis)* in "posthole traps" near Blacksburg, Virginia, in 1936. Actually, Handley had discovered the row of 25 or 30 postholes which stood empty for several weeks awaiting their posts. In the meantime they caught rodents and the weasel which Handley collected and gave to Patton.

Subsequently, Handley dug several posthole pitfalls in a nearby swampy area, hoping to capture shrews. However, it was soon apparent that this kind of trapping was too labor-intensive to be practical, so Handley replaced the postholes with 3.8 liter cans. The experiment was abandoned because, unsuspected by Handley, the cans and postholes he used were too few to have a reasonable chance of capturing shrews. Prince (1941) may have been the first to employ cans in large numbers as pitfalls as we do today. In 1938 and 1939 in Ontario he used 6.5 liter galvanized tin sap buckets partly filled with water as a means of capturing many pygmy shrews (*Sorex hoyi*).

The use of drift fences with pitfalls

Like the pitfall, the ancient concept of the drift fence had to be rediscovered by zoologists as a means of enhancing trap success. Drift fences obstruct and disrupt the normal movement patterns of animals, causing them to "drift" along the fence until they can resume their normal courses. Used with pitfalls, the drift fence directs animals into pitfalls placed beside or at the ends of the fence. Early applications of drift fences did not include pitfalls and did not involve mammals. In 1938, Handley used funnel-entrance traps beside a chicken-wire drift fence across a narrow *Calamus* marsh through pasture to capture Virginia rails and sora for banding. Imler (1945), another early proponent of the drift fence idea, used fences to facilitate capture of bull snakes. Eventually Howard and Brock (1961) used drift fences with pitfalls to enhance the capture of rodents. Now drift fences are commonly used to link pitfalls together into arrays consisting of several, sometimes dozens, of pitfalls beside fences of various lengths and in a variety of configurations.

Pitfalls in transects

Usually pitfalls have been organized in grids, often in combination with live traps. Sometimes they have been placed in short lines sampling choice trapping sites. DeMott and Lindsey (1975) mentioned incorporation of pitfalls into 1000 m transects by Handley and students in the Gunnison Basin in the Colorado Rockies in July and August 1971. Individual 0.95 liter (1 quart) oil cans, without drift fences, were set at 5-10 m intervals in transects of 100 pitfalls each in five subalpine habitats for a total of 13,190 pitfall nights. The capture of shrews totaled 291 individuals and included five pygmy shrews (*Sorex hoyi*). In addition to this, in 1971 and 1975, in shorter transects of about 50 pitfalls each at a lower elevation in sagebrush, Handley and George Lowman caught 5 Merriam's shrews (*Sorex merriami*) and 18 dwarf shrews (*Sorex nanus*). These three species, as well as the occurrence of other long-tailed shrews in such large numbers, were previously unknown in the Gunnison Basin in spite of many years of snap trapping and live trapping in the same area by investigators based at the Rocky Mountain Biological Laboratory, near Crested Butte, Colorado.

Catalog of pitfall trapping concepts in current use

Many and diverse pitfall trapping concepts have been introduced in the past half century. Analysis of the literature reveals that there are a few common denominators. Smaller or larger pitfalls, liquid filled or dry; with drift fences of various lengths or without drift fences; fences in a triad or not; fences with a central gap or not; and pitfalls in grids, transects, or standing alone yield different results. The efficiency and utility of pitfalls depend on the kinds of traps used and their configuration. In current use these factors have been combined into two basic pitfall trapping concepts, differing in whether the pitfalls are combined with drift fences or not. Variation within these types is largely a matter of scale (Fig. 1).

Type 1A: Very large pitfalls without fences. Commonly these are 19 liter (5 gallon) cans, but sometimes smaller or larger cans are used, usually arranged in grids. The pitfalls of Clarke (1938), the first serious pitfall trapper, were of this type. Clarke used 50 pound cans and a tub, all partly filled with liquid, together with small snap traps, to inventory small mammals in Ontario. His pitfalls caught large numbers of masked shrews (23% of the pitfall captures), meadow jumping mice (25%), and woodland jumping mice (21%), as well as individuals of 11 other species of mammals in smaller numbers. In spite of their large size, his pitfalls caught few *Peromyscus* (only 2% of total captures) and few larger mammals. His small snap traps caught masked shrews and deer mice well (respectively 14% and 33% of snap trap captures) but jumping mice poorly.

Type 1B: Very small pitfalls without fences. These always are arranged in transects. Hudson and Solf (1958) were early proponents of this concept. They used 1.4 liter, 10 cm diameter water-charged pitfalls without fences for removal trapping in Washington. Their pitfalls caught long-tailed shrews and juvenile *Peromyscus* and voles reasonably well, but other mammals poorly.

In northern Ontario, Innes and Bendell (1988) used very shallow (12 cm depth) alcohol-charged pitfalls without drift fences in comparison with Victor snap traps and Longworth live traps. The small snap traps made the best showing, with 16.5 mammals per 100 trap nights. The shallow pitfalls were the poorest, with only 8.1 mammals per 100 trap nights. The pitfalls caught the only pygmy shrews, but caught no jumping mice and only a few deer mice and red-backed voles. The small snap traps caught the most deer mice, voles, and jumping mice. They even bettered the pitfalls in shrew captures, 10.6 to 7.7 per 100 traps.

In a statewide study of distribution of the southeastern shrew (*Sorex longirostris*) in Virginia (Pagels and Handley 1989), Pagels used 16 ounce (approximately 1/2 liter) beer cans, only 6.2 cm in diameter, in transects along highways. In 24 months

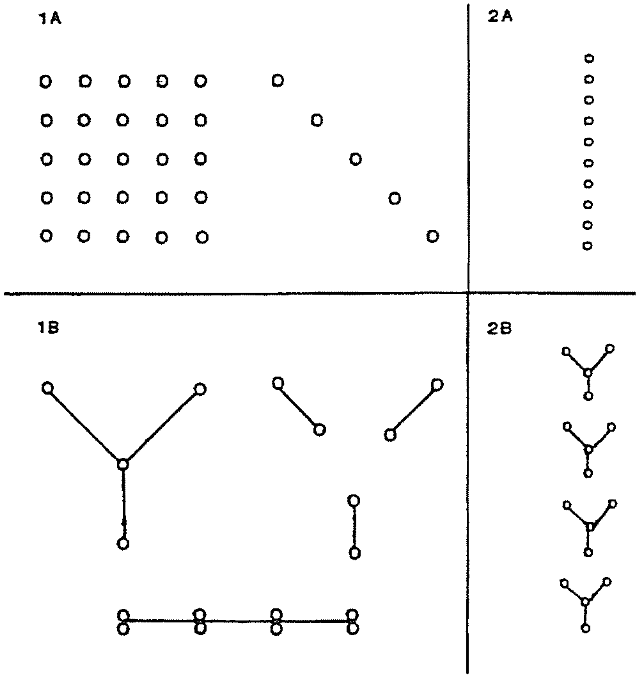

FIGURE 1. Diagrams of various configurations of pitfalls. 1A.-Without drift fences: Large pitfalls in a grid and large pitfalls in a transect. 2A.-Without drift fence: Small pitfalls in a transect. 1B.-With drift fences: Large pitfalls in a triad, with closed center; large pitfalls in a triad, with open center; and large pitfalls along a continuous fence. 2B.-With drift fences; Small pitfalls in triads in a transect.

these little cans, charged with liquid but without fences, caught 6 species of shrews, including 73 southeastern shrews at 33 of 107 localities within this shrew's potential range in Virginia. Granted that 55 of the localities were in the mountains where the southeastern shrew seems to be irregularly distributed, and although the small cans served their purpose, still the take was less than would have been expected in larger pitfalls.

Mitchell et al. (in press) compared capture rates of 3.8 liter pitfalls with drift fences and isolated 1/2 liter pitfalls in swamp forest in southeastern Virginia. The larger pitfalls caught 11 species; the small pitfalls only four. However, the capture rates of small shrews were similar with the two trapping methods--0.68/100 trap nights in large pitfalls; 0.40/100 trap nights in small isolated pitfalls.

The most practical way to use type 1B pitfalls is in transects. They are too small to be used effectively in isolation or in grids. They would be more effective in transects if upgraded to 11 cm, 2 liter plastic bottles in place of 6.5 cm, 1/2 liter beer cans. One the virtues of the 1/2 liter can is that it can be so quickly and easily implanted with a foot-operated bulb planter. However, not much would be lost in speed and ease using a 12 cm posthole digger to implant the 2 liter pitfall.

Type 2A: Very large arrays of moderate to large size pitfalls with drift fences arranged in triads, with or without a central gap. Briese and Smith (1974) were the first to use drift fences on a grand scale. They compared captures of small mammals for about a year in a live trap grid and in very large (39 liter) dry pitfalls beside a continuous drift fence around a 3.6 ha old field in South Carolina. With such large pitfalls they might have sampled the whole fauna up to the size of squirrels and opossums. In fact, the pitfalls captured twelve species and the live traps only eight. Superiority of the pitfalls in capturing insectivores and the harvest mouse (*Reithrodontomys humulis*) was overwhelming, respectively 398 to 8 and 93 to 7 for the year. Because the pitfalls were dry, adult cotton rats (*Sigmodon hispidus*), cotton mice (*Peromyscus gossypinus*), and house mice (*Mus musculus*) could leap or scramble out. Thus, the pitfalls sampled the insectivores and harvest mice and a younger segment of the population of some rodents better than the live traps did.

Bury and Corn (1987) experimented with drift fences of various lengths and concluded that the minimum effective length is between 2.5 m and 5 m. An 11 m gap in the center of each of their triads of pitfalls with 2.5 m drift fences rendered them as ineffective as triads of pitfalls without fences in comparison with triads of pitfalls with 5 m fences and a 6 m central gap. Short fences converging in the center as Williams and Braun's (1983) and Kalko and Handley's (in press) did are more effective.

Pagels et al. (1992) used 19 liter pitfalls in 20 m triads (5 m drift fences with a 10 m central gap) for comparing the small mammal faunas of forests and clear cuts. Their capture rate in a year of sampling was 17/100 trap mights. Small shrews accounted for 28.3% and jumping mice for 16% of total captures.

The 25 m diameter triad array without a central gap proposed by Kirkland and Sheppard (in press) as a standard for pitfall trapping evolved from the experiments of Bury and Corn (1987). It is designed to sample shrews and voles in large numbers. If the model is faithfully copied as Kirkland and Sheppard advised, capture data should be interchangeable among projects.

Type 2B: Compact arrays of small pitfalls with drift fences configured in a triad, without a central gap, arranged in transects. Trapping in California, Williams and Braun (1983) used a pitfall array with a triad of 1.2 m, 10 cm high drift fences, converging at a single central 7.6 liter pitfall. This small array caught long-tailed shrews and jumping mice well, but other mice and voles poorly.

Handley and Varn (in press) described the successful use of compact pitfall arrays in transects in South Carolina to capture the long-tailed shrew *Sorex longirostris* in swamp settings. Handley and Varn's array consisted of a triad of 1.2 m drift fences, 30 cm high, converging at a central 3.8 liter pitfall. A pair of 2 liter pitfalls were situated on either side, near the end of each drift fence. The array thus consisted of seven pitfalls in a triad with a diameter of about 2.5 m. The pitfalls were partly filled with preservative.

We have extended the Handley-Varn concept by combining transects of compact pitfall arrays with equivalent transects of Museum Special snap traps to sample the entire small mammal fauna (Kalko and Handley in press). Although the literature has many examples of comparisons of pitfall captures with captures of other types of traps (e.g., Clarke 1938; Briese and Smith 1974; Williams and Braun 1983; Innes and Bendell 1988; Mitchell et al. in press) our paper is the only one that describes the combination of transects of snap traps and pitfall arrays with comparable sampling characteristics. That is, the results of transects of pitfall arrays and snap traps demonstrate such close equivalence that we venture to combine capture results of the two trapping methods in a single analysis to estimate species diversity and relative abundance of the small mammal fauna as a whole. Other methods do not assess all the species of the fauna or do not assess relative abundance equally well for all species.

We think that our model has ideal dimensions to give a balanced picture of diversity and relative abundance of the small mammal fauna as a whole because each trapping method balances out the inequities of the other. In the configuration we used, the pitfall arrays capture long-tailed shrews and jumping mice and few if any mice, voles or short-tailed shrews. The snap trap transects capture mice, voles, and short-tailed shrews, but few long-tailed shrews and jumping mice. Larger pitfalls, longer drift fences, or closer spacing of arrays are likely to oversample shrews or add more species, thus making the comparison with snap trap transects more difficult.

Further comments on the compact pitfall array

The experiments of Williams and Braun (1983) in California with pitfall arrays similar to ours, suggest that comparable size and configuration of the array lead to universally similar results. In their pitfalls 72% of captures was a long-tailed shrew (*Sorex trowbridgii*) and 12% was a jumping mouse (*Zapus princeps*). In our pitfalls 80% of captures was the long-tailed shrew *Sorex cinereus* and 10% was jumping mice (*Zapus hudsonius* and *Napeozapus insignis*). Deer mice (*Peromyscus maniculatus*) made up only 7% of Williams and Brauns' captures; 0% of ours. In Williams and Brauns' snap traps, jumping mice and shrews together made up 4% of captures (6% in ours) and deer mice 96% (60% in ours).

In comparison with the much larger pitfall arrays of Bury and Corn (1987), with 30 m of drift fence face (length of fence x 6), our compact arrays with only 7.2 m of fence face caught available species more quickly (71% in the first seven days versus 40% in ten days) but caught proportionately fewer individuals, 219 versus 924. Reduced to equivalent fence face, our pitfalls had about 2% capture success; Bury and Corn's about 3%. We trapped with the handicap of a severe drought which undoubtedly limited our success. In our opinion, the 6 m gap in the center of Bury and Corn's arrays greatly reduced their capture success. We routinely found a majority of specimens in the central pitfall in our arrays.

To summarize, the compact arrays of pitfalls have proven to be efficient for capturing small mammals. They are quickly and easily set, cause so little disturbance to habitat that start-up time is negligible, and, in combination with comparable transects of snap traps, sample the whole small mammal fauna. Two or 3 persons can set a 100 pitfall transect of 14 arrays in 6 - 8 hours. Setting a transect of 100 snap traps as described in Kalko and Handley (in press), requires 1 - 3 hours with 1 or 2 persons, depending on habitat.

Therefore, larger pitfall arrays are not necessary for a detailed assessment of a small mammal fauna. Larger arrays clearly have the advantage of sampling a much larger area and a larger variety of species than compact arrays but this makes it more difficult to compare the results of the pitfalls and other trapping methods. Larger arrays also have the disadvantage of being costly in time and labor to set, and they cause environmental disturbance to the extent that they are not fully functional until several days after setting.

The ideal sampling technique intermingles a pair of snap trap and compact pitfall transects for two nights. The information gained with the compact pitfall arrays, used in combination with snap traps, makes them the method of choice when the objective of trapping is both qualitative and quantitative assessment of the whole small mammal fauna. After two nights, when the snap traps are removed, the pitfalls may be operated for at least another week, preferably longer, because they continue to yield useful information with little additional expenditure of time and effort for maintenance and specimen removal.

CONCLUSIONS

Each of the four pitfall methods in current use serves a special purpose. Thus, choice of method should depend on the objective of trapping.

Objective 1: Inventory of species of the whole small mammal fauna of an area.

Choice: Type 1A. Very large pitfalls without fences, used in a grid or a transect.

Comments: Excellent for inventory of species diversity of small mammals. Because some species are more prone to capture by pitfalls than others, capture data are not useful in studies of relative abundance of the whole small mammal fauna. Digging in large pitfalls can be difficult. The large pitfalls require large amounts of preservatives if not monitored frequently. There is some danger of injury to larger mammals accidentally stepping into the pitfalls.

Objective 2: Inventory and assessment of distribution of species of shrews.

Choice: Type 1B. Very small pitfalls without fences, used in transects along roads.

Comments: Samples only small shrews, but excellent for determining presence or absence of various species in a large area. Exceptionally quick and easy to set.

Objective 3: Analysis of shrew and vole faunas of an area.

Choice: Type 2A. Very large arrays of moderate size pitfalls with drift fences arranged in triads.

Comments: Samples part of the small mammal fauna very well (long-tailed shrews, short-tailed shrews, and voles), giving information on diversity of species and relative abundance for that fraction of the fauna. Because of difference in scale, it is difficult, if not impossible, to combine capture results with results of other trapping methods such as snap traps or live traps. Costly in labor and time to set up. Disturbance to habitat delays startup time. Difficult to site in some habitats. Because of size, configuration in grids or transects may be difficult.

Objective 4: Analysis of the whole small mammal fauna of an area, considering both diversity and relative abundance of species.

Choice: Type 2B. Compact arrays of small pitfalls with drift fences configured in triads, arranged in a transect, intermingled with an equivalent transect of snap traps.

Comments: Analyzes the whole small mammal fauna, yielding information on both diversity and relative abundance of species. Requires two trapping methods operated parallel to each other, but the expense of time required for set-up is modest. This sampling method is not limited by habitat type.

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