Uetz, G. W., and J. D. Unzicker. 1976. Pitfall trapping in ecological studies of wandering spiders. J. Arachnol. 3:101-111.

PITFALL TRAPPING IN ECOLOGICAL STUDIES OF WANDERING SPIDERS

George W. Uetz

Department of Ecology, Ethology and Evolution
University of Illinois
Urbana 61801

John D. Unzicker

Section of Faunistic Surveys and Insect Identification
Illinois Natural History Survey
Urbana 61801

ABSTRACT

The use of pitfall trapping and quadrat sampling in ecological studies of spiders is discussed. Comparison of these methods in studies of species diversity shows pitfall trapping to give a closer estimate of the total number of species in a community. Limiting the method to studies of cursorial forms, like wandering spiders, may diminish sampling error due to differential species activity. Several conditions for limited use of pitfall trapping in ecological research are proposed. Improvements in trap dispersion and trap design are presented which may substantially reduce sampling errors. Descriptors: Pitfall trapping, ecological methods, wandering spiders.

INTRODUCTION

Wandering or cursorial spiders have been the subject of numerous ecological studies over the past few years. These spiders, recognized by many arachnologists as a distinct group among spiders, move actively over the ground, running down or pouncing on their prey rather than relying on the use of webs. Balogh and Loksa (1948) called this group a "syntrophium," due to the similarity of their predatory strategies and habitat choices. A term used in current ecological literature for such a group is "guild" (Root, 1967). Lycosidae, Clubionidae, Gnaphosidae, Hahniidae, Ctenidae and some members of the Agelenidae and Pisauridae make up the majority of this guild.

A major problem in ecological research on these spiders is the lack of accurate sampling techniques (see Duffey, 1972). Two basic methods have been used for sampling cursorial forms in the ground stratum: quadrat sampling and pitfall trapping. Both methods are subject to error due to a variety of factors, and require scrutiny.

In previous studies (unpubl.) we have used both methods, and have mixed feelings about their accuracy. Quadrat sampling should provide an absolute density measure, but is influenced by the activity of animals in the brief span of time when the sample is taken. Results are also influenced by the presence of the investigator, since many spiders escape capture by running away as s/he approaches. Pitfall trapping provides a contin-

Table 1.–Estimates of density of forest floor wandering spiders made by sight-count methods and quadrat sampling. See text for details (*Oak-maple-tulip forest, Delaware; †Oak-hickory forest, Illinois).

Species	Sight-Count no/m²	Quadrat no/m²
**Schizocosa crassipes*	16-20	1-3
**Castaneira longipalpus*	1-8	0
**Xysticus transversatus*	3-10	2-4
†*Xysticus elegans*	1-5	1-2
†*Schizocosa saltatrix*	11-19	2-3

uous sample, yet is undoubtedly influenced by activity levels and movements of the spiders. Before beginning an ecological study, we attempted to compare methods by invoking the wisdom of the literature as well as performing some preliminary field trials. Our findings have influenced our choice of methods, and we present them here.

COMPARISON OF PITFALL TRAPPING AND QUADRAT SAMPLING

In an earlier study (Uetz, in press) quadrat sampling was abandoned in favor of pitfall trapping after it was discovered that several numerous species were collected in disproportionately low numbers or missed entirely by the first method. Samples taken with a 0.25 m^2 frame (similar to one used by Turnbull, 1966) are compared with sight-counts of individuals (see Duffey 1962) in 1 meter square plots in Table 1. Paired data were taken at approximately the same time of day in the same area, yet show considerable differences in density for several species. Observation by a third party during quadrat sampling revealed that movement of spiders away from the investigator accounted for lower numbers taken by this method. The only solution to this problem is a quadrat sampler which can be operated from a distance, as developed by Mason and Blocker (1973). Unfortunately, such devices are unwieldy at very least, and can only be operated in open areas like pastures or old fields. Differences in sampling due to temporal stratification of species can be countered by taking quadrat samples at regular intervals over a 24 hour period.

We surveyed the literature for studies of a wide range of communities utilizing both quadrats and pitfalls and used the data to compare the effectiveness of each in sampling species composition. We were able to to find several with a full year's data from continuous pitfall trapping and weekly or biweekly quadrat sampling (with similar extraction techniques) (Duffey, 1962; Huhta, 1971; Muma and Muma, 1949; and our own unpublished data). Assuming that together these methods sample the total number of species in an area, we can evaluate the estimates made by each method alone. We compared the total number of species with the number collected by each method (Fig. 1). The pitfall trapping results correlate significantly (r=0.988), whereas the quadrat sampling results show a non-linear relationship with the total number of species. The quadrat technique adds very few species to a community list beyond those compiled by pitfall trapping alone. In fact, in almost all cases, there were a larger number of species *absent* from quadrat samples and *present* in pitfalls than vice versa. Moreover, quadrat sampling does not sample a constant fraction of species present, but takes a disproportionately larger fraction in more diverse communities. These data suggest that pitfall trapping gives a

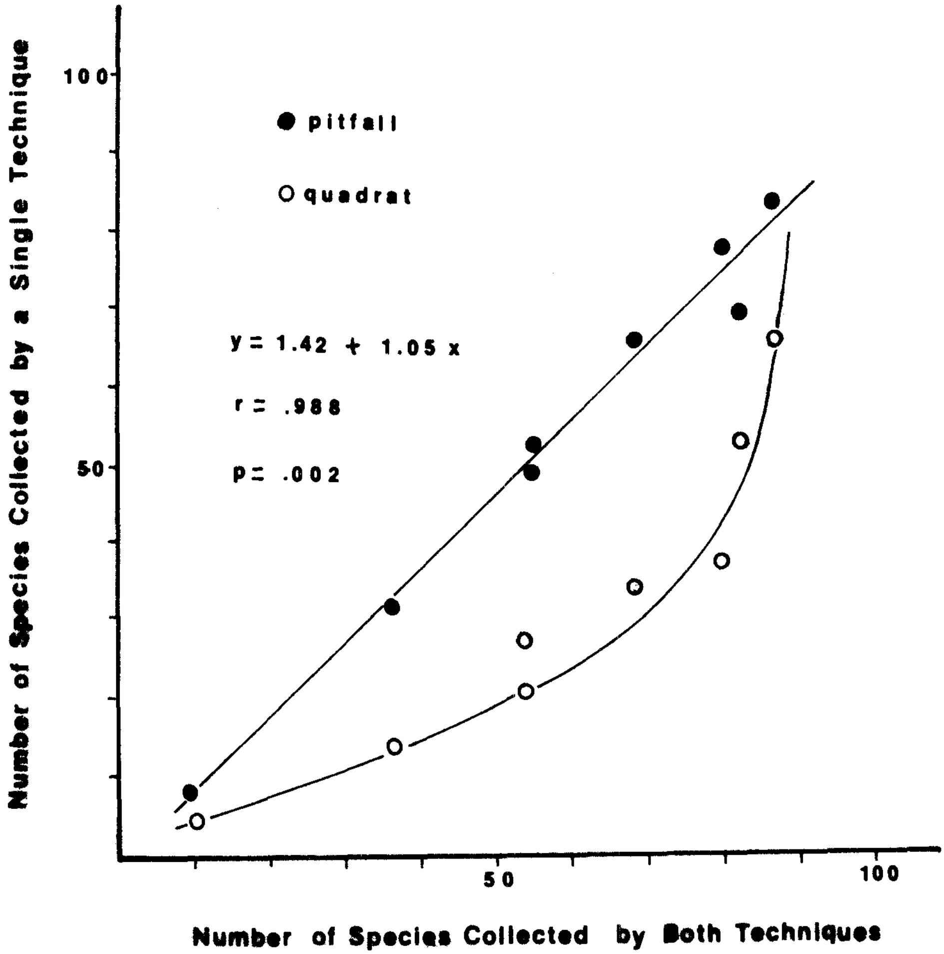
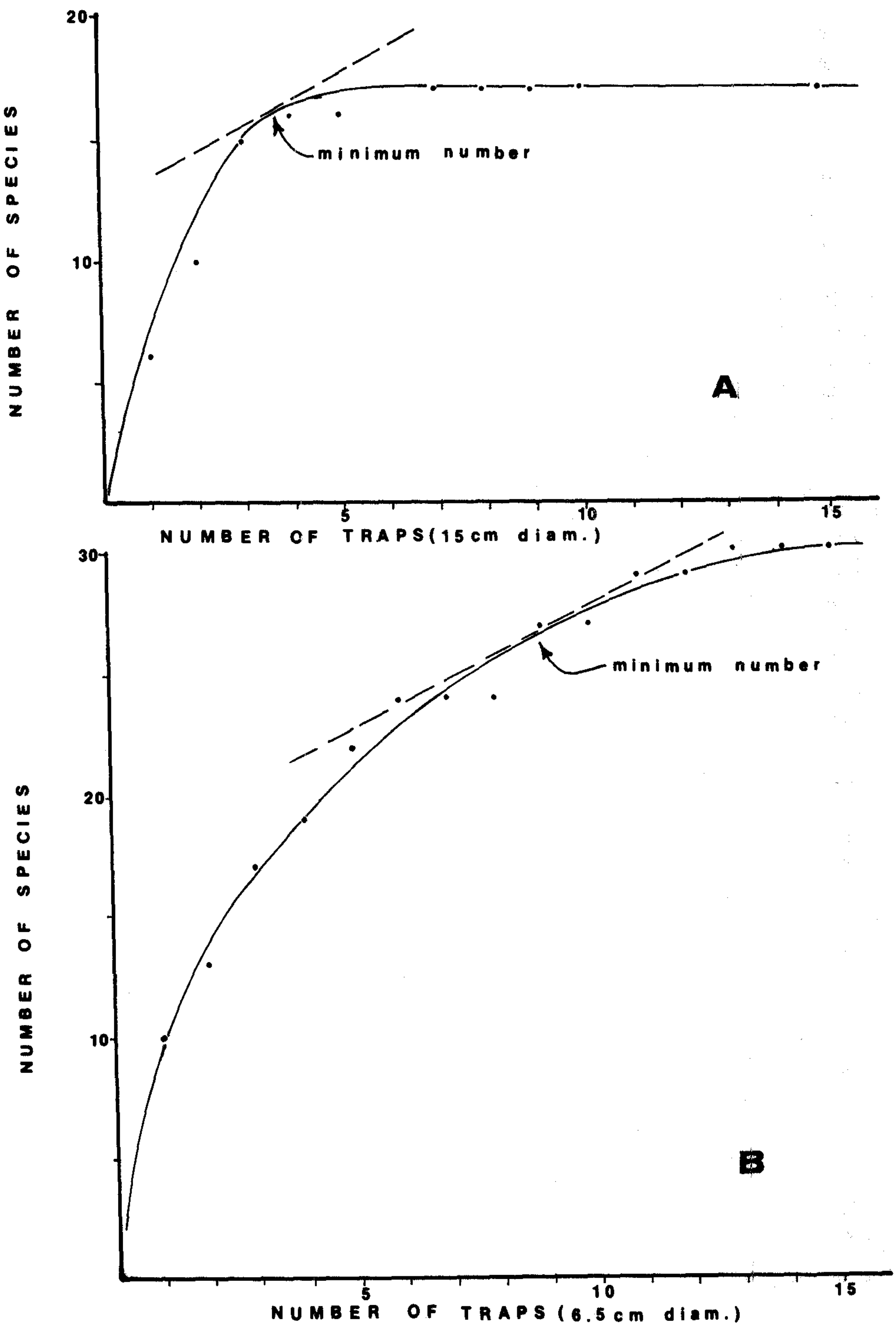


Fig. 1.–Comparison of the number of spider species collected by pitfall trapping and quadrat sampling with the number of species collected by both together. Taken from data in previously published studies (Duffey, 1962; Huhta, 1971; Muma and Muma, 1949) and our own unpublished data.

closer estimate of the total number of species in a community, and would be more useful in studies of species diversity.

Whether or not either method is acceptable for ecological research will depend on the degree of reliability with which it samples the relative abundance of species. Neither of the two methods compared is without bias in this regard, and it seems that a truly accurate means of assessing relative numbers is yet to be found. Quadrat sampling is an acceptable method for slow moving or nonmotile species in soil and litter, and provides accurate estimates of density for web-builders and some wandering spiders. Pitfall trapping is *only* suitable as a means of sampling cursorial forms, and appears to be the best available at present.


20
10
NUMBER OF SPECIES
minimum number
A
5
10
15
NUMBER OF TRAPS(15cm diam.)
30
20
10
NUMBER OF SPECIES
minimum number
B
5
10
15
NUMBER OF TRAPS (6.5cm diam.)

USE OF PITFALL TRAPPING IN ECOLOGICAL RESEARCH

Allred, et al. (1963), Barnes (1953), Barnes and Barnes (1954), Berry (1970), Dondale (1971), Fichter (1954), Heydeman (1961), Huhta (1971), Muma and Muma (1949), Peck (1966) and Tretzel (1954) utilized pitfall trapping as one of several methods to study species composition of wandering spiders and other cursorial arthropods, while Breymeyer (1966a), Fox and Dondale (1973), Muma (1973), Pearson and White (1964), Schmoller (1971), Van der Aart and de Wit (1971), Whitcomb, et al. (1963) and Williams (1959a) used only pitfall trapping. Williams (1959a, 1959b, 1962), Breymeyer (1966a, 1966b), and Dondale, et al. (1972) have used pitfall trapping to study diel activity periodicities in various cursorial arthropods.

Several authors have discussed pitfall trapping and its handicaps, and there is disagreement concerning the interpretation of data collected by this method. Greenslade (1964), Southwood (1966), and Turnbull (1973) have concluded that pitfall trapping is not a reliable means of sampling population density or species composition. They believe that differences in activity of some species, impedance of movement in some habitats and climate factors all influence results to the point of rendering them useless. However, Greenslade does mention the usefulness of this method in mark and recapture studies, and discusses ways in which community comparisons can be made from pitfall data.

Huhta (1971), Duffey (1962) and Kessler-Geschiere (1970) have demonstrated that pitfall and quadrat sampling can give widely varying measures of the dominance relation of species and sex ratios. All suggest that using these methods together increases their usefulness in ecological sampling. Vlijm and Kessler-Geschiere (1967) have described pitfall trap catches by a formula: $A=W \times X \times D$, where $A=$ number of active animals in an area; $W=$ a weather factor; $X=$ a habitat category; and $D=$ actual density. Comparison of communities, then, can be made more accurate by comparing samples taken under similar weather conditions (i.e., the same season). If the influence of the habitat factor can be taken into account or minimized, accuracy will be increased further (Greenslade, 1964).

Breymeyer (1966a) has studied the seasonal abundance of wandering spiders, and compared the faunas of the field layers of several communities. The data were expressed in terms of "penetration" (the relative density of active individuals per trap effort), a term derived from Heydemann (1961). This quantity is also referred to as "active density" (Uetz, unpublished data). Data from several studies presented with her paper provide a comparison of quadrat sampling and pitfall trapping, showing them to be similar in their ability to record variation in numbers over a season. Breymeyer has concluded that by limiting the use of pitfall trapping to cursorial forms, much of the influence of differential species activity is minimized, and community comparisons can be made with some degree of confidence.

Gist and Crossley (1973) developed a method for estimating density from pitfall trap catches in an enclosed area, based on removal trapping methods. Comparisons of this method and litter sieving from quadrat samples showed no significant difference between the two methods for estimating density.

Fig. 2.–A method for determining the number of pitfall traps necessary for an accurate sampling of the fauna in an area, based on species-area curves. Number of accumulated species is plotted against the numbers of traps in a sample, and a line with 0.05 slope is drawn tangent to the curve. Data are from two separate studies in forest litter spiders: A- in an Oak-Hickory forest in Illinois, using 15 cm diameter can traps, and B- in an Oak-Tulip-Maple forest in Delaware, using 6.5 cm diameter can traps.

We feel that pitfall trapping may be used, with caution, in ecological studies of cursorial spiders if the following conditions are met:

1. Analysis of data must be restricted to known cursorial forms of similar foraging strategies.

2. Collection should be made over a long period of time (i.e., the entire growing season).

3. Comparisons of communities should be made on the basis of samples taken in the same seasons, in the same general climatic regime.

4. Comparisons of communities must take into account the possiblity of impedance of movement by various habitat factors.

5. Pitfall trapping should be backed by a second method (i.e., quadrats, time-search, sight-count, etc.).

6. Efforts should be made to reduce known sources of error (i.e., trap placement, design, number of traps, attractant or repellant qualities of preservative, etc.).

We, like others, have reservations about the interpretation of results obtained by this method. However, we feel its use in studies relying on relative abundance, species diversity, habitat breadth, niche overlap and foraging activity of wandering spiders can be recommended, if the above conditions are met.

REDUCING ERROR IN STUDIES WITH PITFALL TRAPS

The sources of error in pitfall trapping mentioned in the literature can usually be placed in one of two categories: 1) error resulting from dispersion or placement of traps; or 2) error resulting from aspects of trap design. To conclude our discussion of the use of pitfall trapping, we would like to propose some ways to reduce error from both of these sources.

Problems have arisen in past studies when too many or too few traps were used, and where traps have been too close or too far apart. The particular sampling regime chosen should ultimately depend on the patchiness of the environment sampled; the size of the sample area, the size of the trap, and the type of information sought. Trap location is usually best determined by a stratified-random type method, which allows the investigator to place trap lines or sets in various patch types or at predetermined intervals along an environmental gradient. The upper limit on intertrap distance should be determined by the nature of the area being sampled, while the lower limit should be guided by the size of the spiders and the potential for depleting their population. Small traps (3-6 cm diameter) have been placed as close as 1 m (Duffey, 1962; Vlijm and Kessler-Geschiere, 1967), and as far apart as 10 m (Breymer, 1966). Larger traps have been placed much farther apart; 10 m (Uetz, unpublished data) - 20 m (Dondale, et al., 1972).

Choice of both trap size and trap number can be arrived at by use of the species-area curve common to plant ecology (see Oosting, 1956). The number of species accumulated in the sample is plotted against the numbers of sizes of samples. The minimum number or size can be determined by drawing a line of five percent rise per 10 percent sample (see Fig. 2) tangent to the curve. Another method for determining the number or size of trap to use is to plot standard error of the mean (numbers of organisms) or SE/x ratio against numbers or sizes of traps (see Fig. 3), and choose the minimum number or size of traps that will bring the standard error down to the significance level desired. A variation of this method is to solve the equation for standard error of the mean for various confidence limits as in Muma (in press).

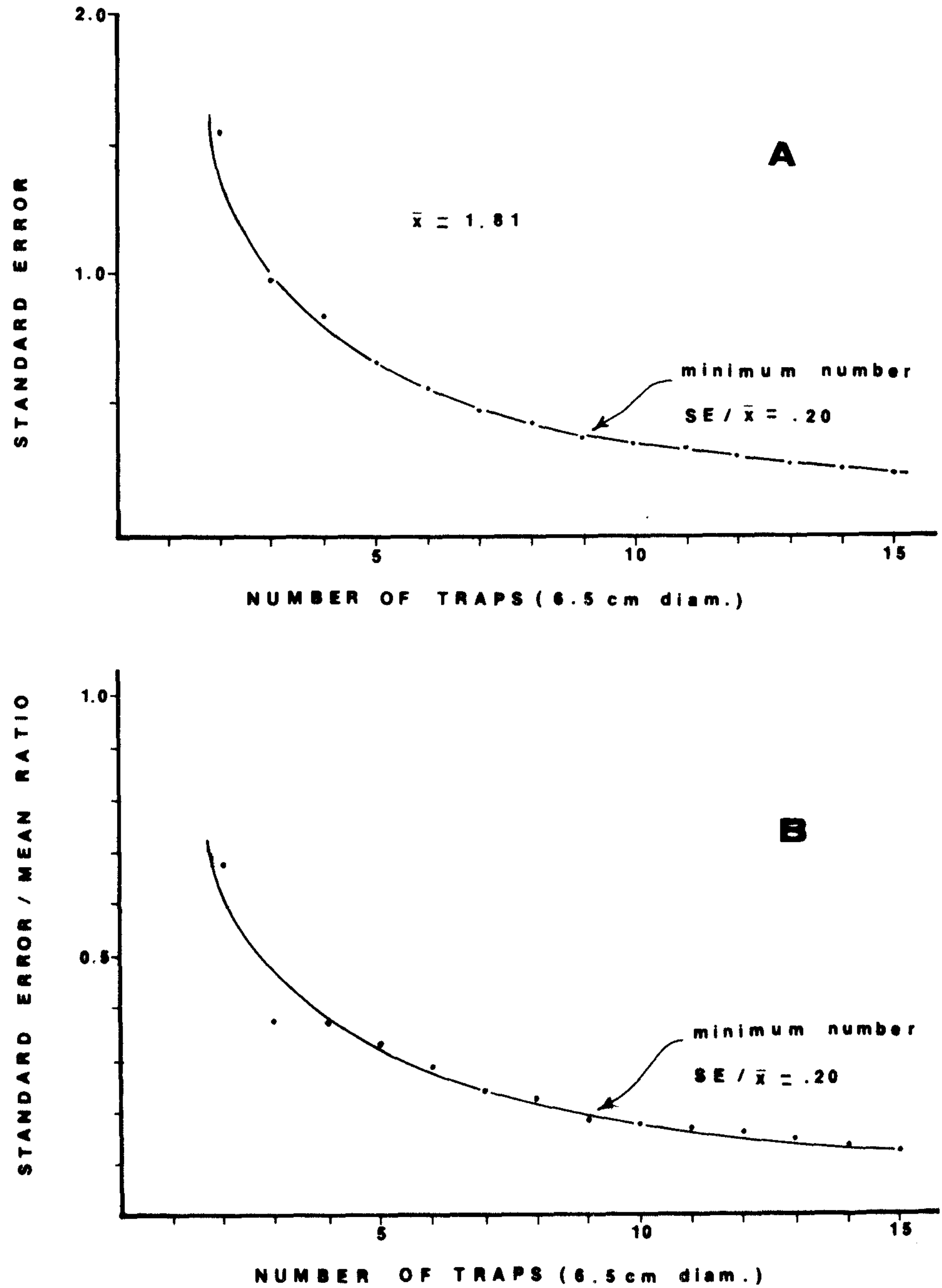


Fig. 3.—A method for determining the number of pitfall traps necessary for a statistically reliable estimate of spider numbers. A- Standard error of the mean (S.E.), and B- S. E. /$\bar{x}$ ratio are plotted against the numbers of pitfall traps in a sample. Data used are number/trap week of *Schizocosa crassipes* Walckenaer from a study in an Oak-Tulip-Maple forest in Delaware.

Aspects of the trap itself can contribute significantly to error in pitfall trapping studies (Greenslade, 1964; Duffey, 1972). There are probably as many kinds of pitfall traps as there are people that use them. An adequate sampling of these can be found in the literature already mentioned. In our present research, we use a trap that in our opinion is an improvement over previous designs. It was designed for the purpose of reducing error from common sources, and we present it here merely as an example of what might be done to improve accuracy.

Our pitfall trap design is a synthesis of ideas found in Fichter (1941), Muma (1970), Moulder and Reichle (1972), Holm and Edney (1973) and Palmieri and Rogers (1973). The trap (Fig. 4) consists of a metal can (15 cm diameter; 22 cm depth) with a 10 cm wide sloped metal collar coldered to the rim. Placed inside the can is a plastic funnel (same diameter as the can) with stem cut off. A plastic food storage jar (10 cm diameter; 7 cm depth) containing ethylene glycol preservative is used for capturing falling animals. The funnel fits snugly into the can and jar. Above the trap, a 20 cm × 20 cm piece of hardware cloth (1/2 inch mesh) mounted on wire supports serves as a roof and mannal excluder. Rainwater overflowing from the jar is drained out of the trap by holes punched in the bottom of the can.

The trap design has several advantages over other traps previously used.

1. The screen roof excludes leaves, debris, and raccoons without creating a microclimate over the trap.

2. The collar assures that the rim will always be flush with the surface of the soil despite erosion, expansion or contraction, thus eliminating an important source of error.

3. The can is readily obtainable (and usually free).

4. Drainage holes for excess water eliminate the possibility of flooding and the need for a roof.

5. The funnel is lowered to prevent escape, and has a large opening so that arthropods will fall directly into the preservative.

6. The collecting jar is interchangeable and lightweight. Numerous full jars can be carried in a backpack.

7. Handling or servicing time is *ca.* 1 minute per trap.

There is no truly accurate method for sampling wandering spiders. Quadrat sampling and pitfall trapping, the principal methods used to study this guild, both fall short of providing a reliable estimate of density. Because of the cursorial habits of this group, and the likelihood of temporal stratification of species, a continuous sampling method is desirable, and pitfall trapping is indicated. Comparison of the methods has shown pitfall trapping to provide a closer estimate of the number of species in a community. Reports in the literature suggest that limiting this method to cursorial forms may eliminate, to some degree, the effect of differences in activity among species on relative abundance estimates. In this paper, we have pointed out ways of reducing error in pitfall trap catches and have enumerated conditions under which results may be used. On the basis of our findings and those in the literature, we would suggest that pitfall trapping *can* be used, with caution, in ecological studies.

ACKNOWLEDGMENTS

The authors would like to thank Drs. Donald C. Lowrie, Daniel T. Jennings, Martin H. Muma, and Mr. George Kulesza and Andrew Penniman for reviewing the manuscript.

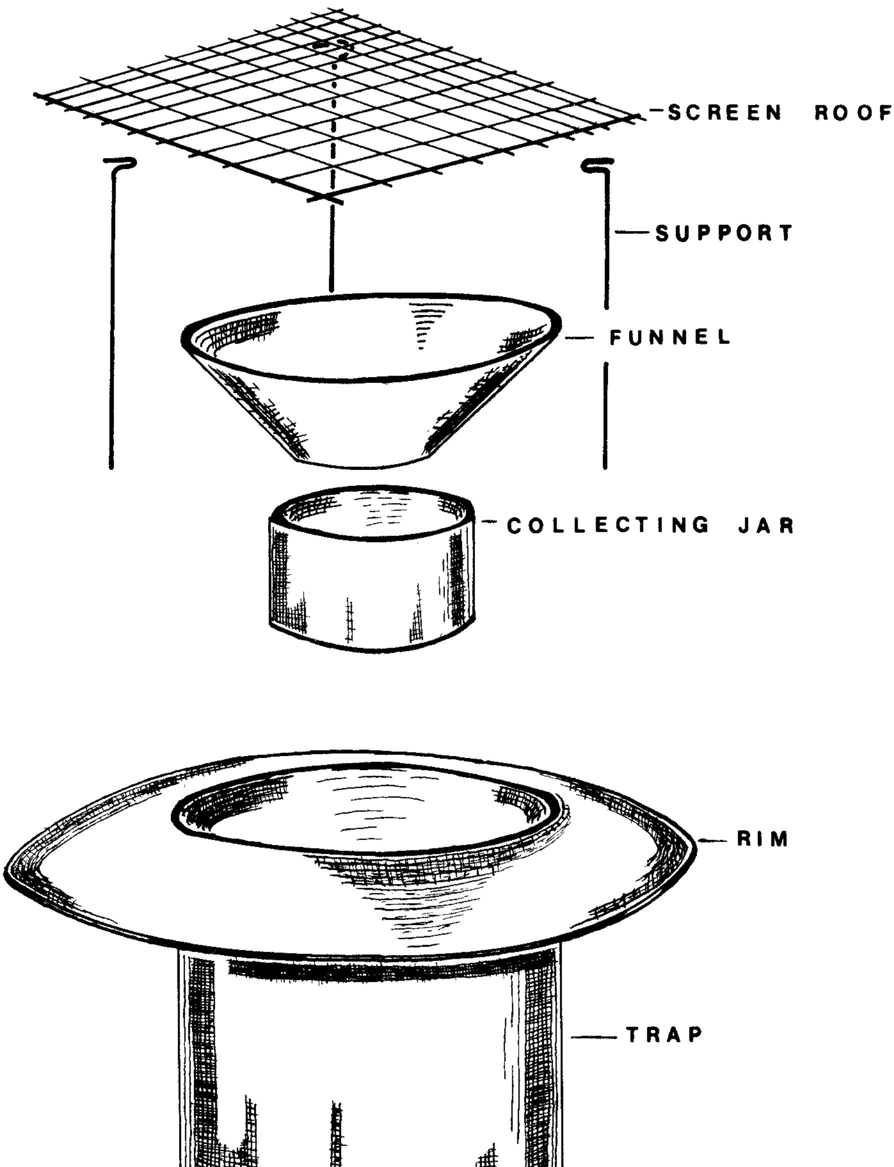


Fig. 4.–Design for an improved pitfall trap (see text for details).

LITERATURE CITED

Allred, D. M., D. E. Beck, and C. D. Jorgensen. 1963. Biotic communities of the Nevada Test Site. Brigham Young Univ. Sci. Bull., Biol. Ser., 2:1-52.

Balogh, J., and J. Loksa. 1948. Quantitative-biosoziologische Untersuchung der Arthropodenwelt ungarische Sandgebiete. Arch. biol. hung. 18:65-100.

Barnes, R. D. 1953. The ecological distribution of spiders in nonforested maritime communities at Beaufort, North Carolina. Ecol. Monogr. 23:315-337.

Barnes, B. M., and R. D. Barnes. 1954. The ecology of the spiders of maritime drift lines. Ecology 35(1):25-35.

Berry, J. W. 1970. Spiders of the North Carolina piedmont old field communities. J. Elisha Mitchell Sci. Soc. 86:97-105.

Breymeyer, A. 1966a. Relations between wandering spiders and other epigeic predatory arthropoda. Ekol. Polska. A. 14:27-71.

Breymeyer, A. 1966b. Diurnal cycles of the macrofauna in age-different biocoenoses. Acad. Pol. Sci. Bull. Ser. Sci. Biol. 14:211-213.

Dondale, C. D. 1971. Spiders of Heasman's Field, a mown meadow near Belleville, Ontario. Proc. Entomol. Soc. Ontario 101:62-69.

Dondale, C. D., J. H. Redner, and R. B. Semple. 1972. Diel activity periodicities in meadow arthropods. Canad. J. Zool. 50(8):1155-1163.

Duffey, E. 1962. A population study of spiders in limestone grassland. The field layer fauna. Oikos 13:15-34.

Duffey, E. 1972. Ecological survey and the arachnologist. Bull. British Arachnol. Soc. 2:69-82.

Fichter, E. 1941. Apparatus for comparison of soil surface arthropod populations. Ecology 22(3):338-339.

Fichter, E. 1954. An ecological study of invertebrates of grassland and deciduous shrub savanna in eastern Nebraska. Amer. Midl. Nat. 51(2):321-439.

Fox, C. J. S., and C. D. Dondale. 1973. Annotated list of spiders (Araneae) from hayfields and their margins in Nova Scotia. Canad. Entomol. 104(12):1911-1915.

Gist, C. S., and D. A. Crossley, Jr. 1973. A method for quantifying pitfall trapping. Environ. Entomol. 2(5):951-952.

Greenslade, P. J. M. 1964. Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). J. Animal. Ecol. 33:301-310.

Heydemann, B. 1961. Untersuchungen über die Activitäts-und Besiedlungs dichte bei epigäischen Spinnen. Verh. dtsch. Zool. Ges. Saarbruchen:538-556.

Holm, E., and E. B. Edney. 1973. Daily activity of Namib Desert arthropods in relation to climate. Ecology 54:45-56.

Huhta, V. 1971. Succession in the spider communities of the forest floor after clear-cutting and prescribed burning. Ann. Zool. Fennici 8:483-542.

Kessler-Geschiere, A. M. 1970. Sex-ratio in spiders inhabiting the field Bull. Mus. Hist. nat. 41 (suppl. 1):102-107.

Mason, C. E., and H. D. Blocker. 1973. A stabilized drop trap for unit-area sampling of insects in short vegetation. Environ. Entomol. 2:214-216.

Moulder, B. C., and D. E. Reichle. 1972. Significance of spider predation in the energy dynamics of forest-floor arthropod communities. Ecol. Monogr. 42:473-498.

Muma, M. H. 1970. An improved can trap. Notes Arachnol. Southwest. 1:16-18.

Muma, M. H. 1973. Comparison of ground surface spiders in four central Florida ecosystems. Florida Entomol. 56(3):173-196.

Muma, M. H., and K. E. Muma. 1949. Studies on a population of prairie spiders. Ecology 30(4):485-503.

Oosting, H. J. 1956. The study of Plant communities. W. H. Freeman and Co., San Francisco. 440 pp.

Palmieri, J. R., and T. J. Rogers. 1973. Beetles. Carolina Tips 36(9):33-34.

Pearson, R. G., and E. White. 1964. The phenology of some surface active arthropods of moorland country in north Wales. J. Animal. Ecol. 33:245-258.

Peck, W. B. 1966. The population composition of a spider community in west central Missouri. Amer. Midl. Nat. 76(1):151-168.

Root, R. B. 1967. The niche exploitation pattern of the Blue-gray gnatcatcher. Ecol. Monogr. 37:317-350.

Schmoller, R. 1971. Habitats and zoogeography of alpine tundra arachnida and carabidae (Coleoptera) in Colorado. Southwestern Nat. 15:319-329.

Southwood, T. R. E. 1966. Ecological methods with particular reference to the study of insect populations. Metheun & Co., London. 391 pp.

Tretzel, E. 1954. Reife-und Fortpflanzungszeit bei Spinnen. Zeitsch. Morph. Ökol. Tiere 42:634-691.

Turnbull, A. L. 1973. Ecology of the true spiders (Araneomorphae). Ann. Rev. Entomol. 18:305-348.

Van der Aart, P. J. M., and T. de Wit. 1971. A field study on interspecific competition between ants (Formicidae) and hunting spiders (Lycosidae, Ctenidae, Pisauridae, Clubionidae). Neth. J. Zool. 21(1):117-126.

Vlijm, L., and A. M. Kessler-Geschiere. 1967. The phenology and habitat of *Pardosa monticola*, *P. nigriceps* and *P. pullata* (Araneae, Lycosidae). J. Animal. Ecol. 36:31-56.

Whitcomb, W. H., H. Exline, and M. Hite. 1963. Comparison of spider populations of ground stratum in Arkansas pasture and adjacent cultivated field. Arkansas Acad. Sci. 17:1-6.

Williams, G. 1959a. The seasonal and diurnal activity of the fauna sampled by pitfall traps in different habitats. J. Animal Ecol. 28:1-13.

Williams, G. 1959b. Seasonal and diurnal activity of Carabidae, with particular reference to *Nebria*, *Notophilus* and *Feronia*. J. Animal Ecol. 28:309-330.

Williams, G. 1962. Seasonal and diurnal activity of harvestmen and spiders in contrasted habitats. J. Animal Ecol. 31:23-42.