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A Comparison of Herpetofaunal Sampling Effectiveness of Pitfall, Single-ended, and Double-ended Funnel Traps Used with Drift Fences

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ABSTRACT. – **We assessed the relative effectiveness of pitfalls, single-ended, and double-ended funnel traps at 12 replicate sites in sand pine scrub using drift fence arrays. Pitfalls captured fewer species but yielded more individuals of many species and higher average species richness than funnel traps. Pitfalls and funnel traps exhibited differential capture bias probably due to differences in behavior or morphology. More surface-active lizards, frogs, and small semifossorial herpetofaunal species were captured in pitfalls whereas captures of large snake species were restricted to funnel traps. Double-ended funnel traps captured twice as many large snakes as single-ended funnel traps. All three trap types yielded similar estimates of relative abundance of lizards and frogs but not snakes. Estimates of relative abundance of large snakes were higher for double-ended funnel traps than pitfalls or single-ended funnel traps. Pitfall and funnel traps yield complementary results, and choice of type(s) depends on target species and sampling goals.**

Drift fences with pitfall and single-ended (1E) or double-ended (2E) funnel traps are an effective sampling method of herpetofaunal communities. Applications include inventory, estimation of species relative abundance, long-term monitoring, determination of activity cycles, intercommunity comparisons, and other experimental purposes. However, as for all sampling techniques, there are potential biases from selective sampling. Small, surface-active species are more easily captured by pitfall or funnel traps than are large snakes and turtles (Campbell and Christman, 1982; Enge and Marion, 1986). Tree frogs (Jones, 1986; Dodd, 1991) or other arboreal species are less likely to be captured on the ground by either trap type (Gibbons and Semlitsch, 1982). Species possessing climbing or jumping abilities are more likely to escape or trespass drift fences than are terrestrial herpetofauna (Franz et al., unpubl. data; Dodd, 1991; Corn, 1994). Home range size, daily and seasonal movement patterns, and microhabitat fidelity also influence capture effectiveness (Gibbons and Semlitsch, 1982; Bury and Corn, 1987; Corn and Bury, 1990).

Differences in relative effectiveness of trap types or the arrangement of arrays can also bias herpetofaunal sampling. Funnel traps are more effective than pitfalls in capturing snakes (Campbell and Christman, 1982; Gibbons and Semlitsch, 1982; Vogt and Hine, 1982; Bury and Corn, 1987). Pitfall trapping may be enhanced by the use of drift fences, especially for reptiles (Corn and Bury, 1990), and especially snake captures (Bury and Raphael 1983; Raphael, 1988). Fence length, numbers, height, and arrangement can affect results (Campbell and Christman, 1982; Vogt and Hine, 1982; Jones, 1986; Bury and Corn, 1987; Corn and Bury, 1990).

No single trapping system captures all species in proportions representative of their actual abundance, rendering estimates of population or relative abundance and diversity among habitats difficult (Corn, 1994). Although several studies discuss advantages and disadvantages of different capture techniques, the effectiveness of different trap types in yielding similar estimates of species richness and relative abundance of herpetofauna has not been examined thoroughly. Here, we compare the relative effectiveness of pitfall, 1E, and 2E funnel traps used with drift fences for sampling herpetofauna of the sand pine scrub of central Florida. We hypothesize that there are differences in relative effectiveness of sampling taxonomic categories, species richness, numbers of individuals, or relative abundance among the three trap types. These results could have useful implications for the selection of trap type(s) in relation to target species or sampling objectives, as well as in the interpretation of capture data using these techniques.

Materials and Methods

Study Area.—The study was conducted in sand pine scrub in the Ocala National Forest, Marion County, Florida. Sand pine scrub is a sclerophyllous, shrub-dominated ecosystem nearly restricted to Florida. In its natural state, peninsular scrub is subject to high intensity, low frequency wildlife. Post-fire recovery is rapid, with pre-disturbance dominant plants regaining site dominance within a few years (Abrahamson, 1984a, b; Givens et al., 1984). In the mature forest, the canopy is limited to a single tree species, sand pine (*Pinus clausa*). The shrub stratum is dominated by myrtle oak (*Quercus myrtifolia*), sand live oak (*Q. geminata*), Chapman's oak (*Q. chapmanii*), fetterbush (*Lyonia ferruginea*), and two palmetto species (*Serenoa repens* and *Sabal etonia*). Soils supporting sand pine scrub are excessively drained aeolian or marine sands (Kalisz and Stone, 1984). This area receives approximately 130 cm of rainfall annually, with over half falling between June and September. Average temperatures range from 20–32 C between April and October and 11–23 C between November and March (Aydelott et al., 1975).

Methods.—We established a single trapping array in each of 12 randomly selected sites in the Ocala National Forest. Nine sites were 5- to 7-year-old open-scrub sites recently disturbed by catastrophic burning or clearcutting and followed by high- or low-intensity site preparation methods; and three were mature (≥55 year-old) sand pine forest sites. General site selection criteria were (1) similar elevation, topographic, and soil characteristics; (2) stand area ≥8.5 ha; and (3) ≥0.9 km from any known water source (temporary or permanent) or other habitat type. Arrays were located at least 25 m from roads or stand edges (except for two drift fences of one array).

Trapping arrays (Fig. 1) used material equivalent to two standard Campbell and Christman (1982) arrays, but consisted of eight 7.6-m lengths of erect, 0.5-m-high galvanized metal flashing arranged in an "L" pattern with a 7.6-m space between each length. All arrays were oriented with one arm (four drift fences) running north-south and the other east-west. Drift fences were buried 4–6 cm into the ground for support. Two black 18.9-L plastic paint buckets with 1.25-cm holes drilled into the bottom for drainage were sunk flush to the ground at both ends of each fence (N = 16 per site). Sticks were jammed into the drill holes to prevent animal escape. A sponge was placed into each bucket and dampened at each visit to reduce probability of desiccation. Funnel traps consisted of aluminum window screen (76 cm wide) rolled into a cylinder and stapled, with a screen wire funnel inserted into one (1E) or both (2E) ends pointing inward (Campbell and Christman, 1982). Funnel openings were approximately 3–5 cm in diameter. One 1E and one 2E funnel trap were randomly placed along either side of and adjacent to each fence (N = 8 per site each). Buckets were shaded by squares of Masonite pegboard slanted over the opening.

Trapping arrays were opened and closed simultaneously for alternating two-week periods from August 1991 through September 1992. We checked open traps every 2 to 3 d. Animals were marked for identification by toe (lizards and frogs) or scale (snakes) clipping and released at the point of capture. Pitfall traps were closed by fitting pegboard squares over the buckets and covering them with sand for a tighter seal. Funnel traps were closed by stuffing sponges into funnel openings.

We excluded recaptures from the data set for this analysis. Odd-numbered buckets were eliminated from the data set in order to create a balanced design (N = 8 pitfalls, 1E, and 2E funnel traps, respectively, per site). Trap success was calculated based on array-nights, defined as captures per trapping array per 24 h. We calculated numbers of individuals trapped, numbers of commonly trapped taxonomic groups and species, relative abundance, species richness, and Shannon's divesity indices (Brower and Zar, 1977) for each trap type based on 12 sites.

Results

We captured 484 reptiles (16 species) and amphibians (four species) in 2340 array-nights for an average of 0.21 individuals per array-night. Mean captures per array were higher for pitfalls (28.83 ± 4.39) than for 1E (6.67 ± 1.02) or 2E (4.83 ± 1.21) funnel traps. Pitfalls trapped 71.5% of individuals, while 1E and 2E funnel traps captured 16.5% and 12.0%, respectively.

Pitfall captures yielded higher mean species richness (6.33 ± 0.43) than 1E (3.83 ± 0.47) or 2E (2.92 ± 0.40) funnel traps. However, 1E and 2E funnel traps captured 14 and 15 species, respectively, while pitfalls captured only 11 species over the 14-month period. Combined, all funnel traps captured 18 of the 20 species trapped during the study period, while an equivalent number of pitfalls captured only 12.

Differences in numbers of species and individuals trapped, as well as evenness yielded different diversity indices among trap types. Mean species diversity calculated from pitfall captures was double (0.674 ± 0.03) that from 1E (0.486 ± 0.06) or 2E (0.382 ± 0.06) funnel traps.

By the fifth trapping period (December 1991), 95% of all species captured during the study had been recorded for all traps combined (Fig.

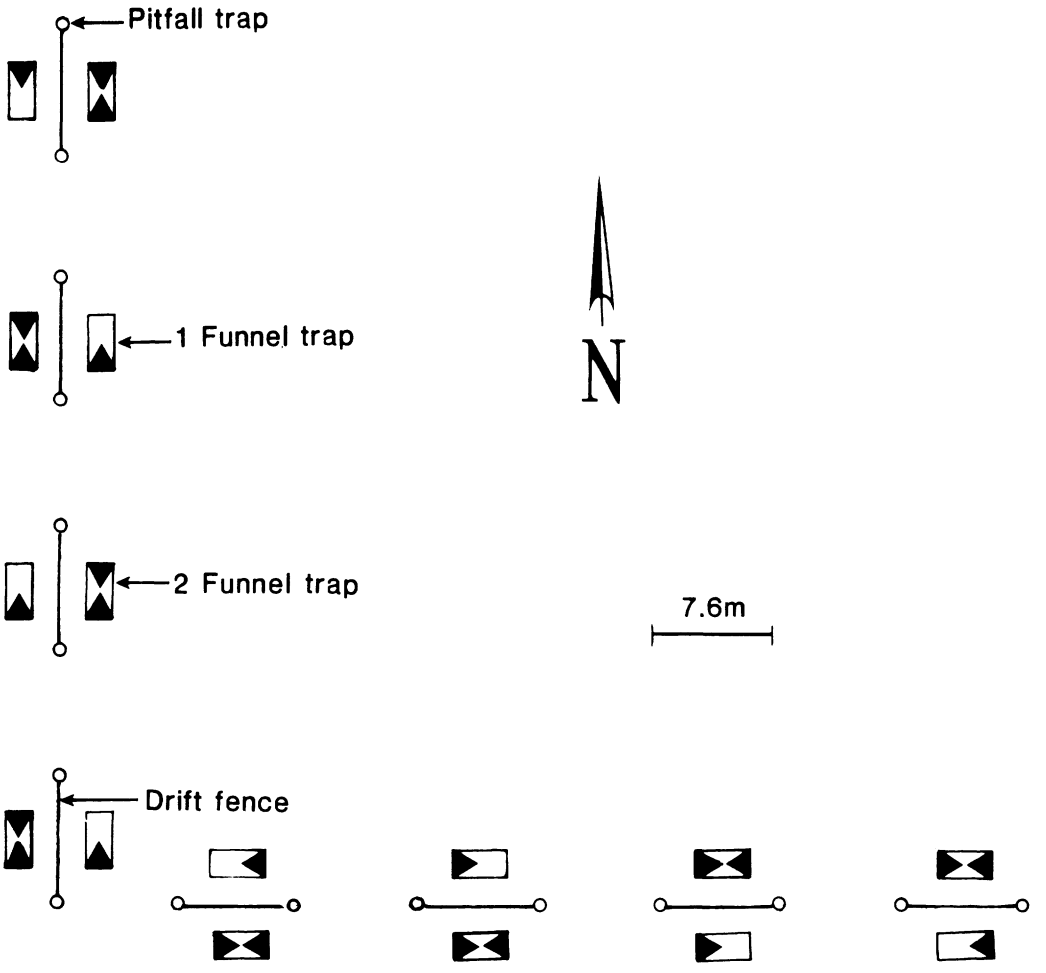

FIG. 1. Array design used to compare trapping effectiveness among pitfalls (B), single-ended (1E), and double-ended (2E) funnel traps (N = 12 arrays; one per site) in sand pine scrub. One 1E and one 2E funnel trap was randomly placed along either side of each drift fence. For ANOVA, only odd-numbered (every other) pitfalls were included in the data set (such that N = 8 each for pitfalls, 1E, and 2E funnel traps per array).

2). Even after 15 trapping periods, however, no single trap type had captured more than 75% of the study total. Pitfalls and 2E funnel traps had trapped over 90% of their species total by the fifth trapping period, whereas 1E funnel traps had not captured over 90% of their totals until trapping period 10. Lower overall captures in winter, however, may have slowed the addition of species per trapping period.

Trap type efficiency varied among taxonomic categories (Table 1). Pitfalls captured more terrestrial frogs and lizards than 1E or 2E funnel traps. Excluding the small (mean SVL = 137.6 mm), semifossorial *Tantilla relicta*, only 20 snakes of 8 species (all ≥285 mm mean SVL) were trapped during the study. All were trapped in 1E or 2E funnel traps. Double-ended funnel traps captured twice as many large snakes as 1E funnel traps. Nearly 94% of *T. relicta* were trapped in pitfalls. Only two species, the semifossorial *Eumeces egregius* (N = 61) and *T. relicta* (N = 31), were trapped commonly in pitfalls but virtually never in funnels.

Despite differences in numbers of individuals trapped, the relative capture proportions of frogs (mean range 19.0–24.2%) and lizards (mean range 60.9–69.7%) did not notably differ among trap types. Estimates of relative abundance of snakes were greater for 2E (mean 19.6%) than 1E (mean 8.4%) funnel traps ($P = 0.0161$). Snakes were not captured by pitfalls except for *T. relicta*, which was rarely captured in funnel traps.

Capture efficiency by a given trap type was not consistent among species within taxonomic categories (Table 1). Among frogs, higher numbers of *Scaphiopus holbrooki* and *Gastrophryne carolinensis* were captured in pitfalls, whereas *Bufo terrestris* captures were similar among trap types.

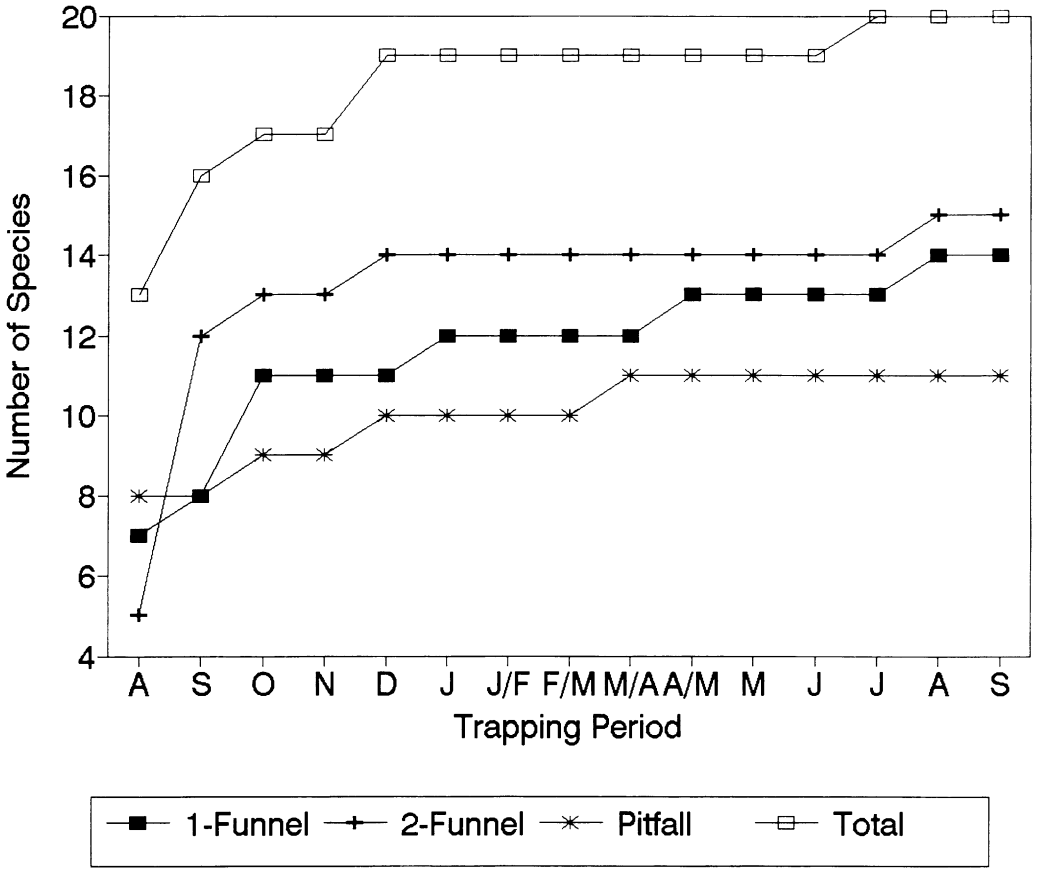

FIG. 2. Cumulative number of herpetofaunal species captured in all traps, pitfalls, single-ended, and double-ended funnel traps in 12 arrays (one per site) per trapping period (13 nights), in sand pine scrub, August 1991–September 1992.

Among lizards, all *E. egregius* and higher numbers of *Cnemidophorus sexlineatus, Eumeces inexpectatus,* and *Sceloporus woodi* were captured in pitfalls than either type of funnel trap. There was no difference in capture success for *Anolis carolinensis* or *Scincella lateralis* among trap types.

DISCUSSION

Differences in capture efficiency and bias of pitfalls and funnel traps in sand pine scrub are substantial but seem to be complementary. Pitfalls captured higher numbers of lizards and frogs than funnel traps but no large snakes. Bury and Corn (1987) reported similar findings. However, trap type efficiency may vary among habitats and regionally. Campbell and Christman (1982) noted that funnel traps were almost as effective as pitfalls at sites having saturated soil. Clawson and Baskett (1982) reported high capture success of snakes, lizards and frogs using single- and double-ended funnel traps in Missouri. Vogt and Hine (1982) reported higher success by funnel than pitfall traps in capturing lizards, in Wisconsin including *C. sexlineatus.*

Pitfalls yielded higher average species richness but fewer species overall than either funnel trap type, primarily because of the lack of snake captures. Our results support the suggestion by others (Bury and Raphael, 1983; Corn, *in press*) that differences in capture success among species as well as selective effectiveness among trap types limit the validity of diversity indices based on capture data.

Pitfalls and funnels each exhibited trap bias against some taxonomic groups and species, probably because of differences in behavior, size, and morphology. Our results were similar to others (Campbell and Christman, 1982; Gibbons and Semlitsch, 1982; Vogt and Hine, 1982; Bury and Corn, 1987) inasmuch as funnel traps were responsible for the capture of all large snake species. However, they were ineffective in capturing two small semifossorial species including *T. relicta,* and *E. egregius.* Similar capture success of *B. terrestris, A. carolinensis, E. inexpectatus,* and *S. lateralis* by pitfalls or either funnel trap variant suggests differences in these species behavior or climbing ability compared with

TABLE 1. Overall percent and mean number (±SE) of taxonomic groups and individuals of commonly trapped species captured per array (N = 12) in pitfalls, single-ended, and double-ended funnel traps with drift fences from August 1991–September 1992 in sand pine scrub.

		1-Funnel		2-Funnel		Pitfall	
Taxonomic category	N	Total study (%)	Mean per array	Total study (%)	Mean per array	Total study (%)	Mean per array
Lizards	335	16.5	4.42	12.0	3.08	71.5	20.42
			0.69		1.03		3.98
Sceloporus woodi	141	14.2	1.67	7.8	0.92	78.0	9.17
			0.59		0.58		2.76
Eumeces egregius	61	0.0	0.00	0.0	0.00	100.0	5.08
			0.00		0.00		1.11
Cnemidophorus sexlineatus	57	14.0	0.67	14.0	0.67	72.0	3.42
			0.22		0.41		1.10
Anolis carolinensis	38	44.7	1.41	28.9	0.91	26.4	0.83
			0.47		0.50		0.24
Eumeces inexpectatus	28	21.4	0.50	17.9	0.42	60.7	1.42
			0.36		0.26		0.6
Scincella lateralis	10	20.0	0.17	20.0	0.17	60.0	0.50
			0.11		0.17		0.26
Frogs	96	17.7	1.42	7.3	0.58	75.0	6.00
			0.66		0.29		1.73
Bufo terrestris	26	30.8	0.67	19.2	0.42	50.0	1.08
			0.22		0.26		0.42
Scaphiopus holbrooki	41	19.5	0.67	4.9	0.17	75.6	2.58
			0.50		0.11		0.80
Gastrophryne carolinensis	28	3.6	0.08	0.0	0.00	96.4	2.25
			0.08		0.00		1.24
Snakes (excluding *T. relicta*)	20	35.0	0.58	65.0	1.08	0.0	0.00
			0.19		0.29		0.00
Tantilla relicta	31	6.5	0.17	0.0	0.00	93.5	2.42
			0.17		0.00		0.48

other frogs or lizards. Also, we observed several species in our study sites, including *Crotalus adamanteus*, adult *Gopherus polyphemus*, *Rhineura floridana*, and *Hyla femoralis*, which were never trapped by any trap type probably because of rarity, size, or secretive fossorial or arboreal habits, respectively.

Results of our study have implications for the selection of trap types in relation to sampling objectives, at least in sand pine scrub. We concur with Corn (1994) in recommending simultaneous use of both pitfalls and 2E funnel traps with drift fences for more complete estimates of species richness. Funnel traps are necessary for capturing large snakes, and 2E funnels appear to be more effective than 1E funnel traps. Pitfalls also sample small, semifossorial species. For the capture of large numbers of individuals of many species of terrestrial frogs, pitfalls are most effective. Estimates of relative abundance of lizards and frogs may be similar among the three trap types.

Although all trap types captured similar numbers of species, we still were capturing new species one year after trapping began. This, along with the fact that some species known to be within study sites were never trapped, suggests that (a) long-term sampling is necessary, and (b) additional use of other techniques such as time-constrained searches and road-cruising (Campbell and Christman, 1982; Corn, 1994) would enhance sampling results.

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