2868

Unveiling Escape and Capture Rates of Aquatic Snakes and Salamanders (*Siren* spp. and *Amphiuma means*) in Commercial Funnel Traps

John D. Willson, Christopher T. Winne, and Luke A. Fedewa[a]
University of Georgia, Savannah River Ecology Laboratory
PO Drawer E, Aiken, South Carolina 29802 USA
E-mail (JDW): willson@srel.edu

ABSTRACT

Aquatic funnel trapping with commercially available minnow traps has proven effective for sampling several aquatic snake species. However, the efficacy of this technique for sampling snakes has received little controlled evaluation. We investigated the ability of aquatic snakes to escape from three funnel trap varieties (cylindrical steel, cylindrical plastic, and rectangular collapsible nylon mesh). We found that when intentionally released into traps, the majority (74%) of snakes escaped within 24 hours. Snakes escaped most frequently from collapsible traps, and of the species tested, *Seminatrix pygaea* escaped most frequently. We found significant differences in capture rates among trap types for *S. pygaea*, *Farancia abacura* (both captured most in plastic traps), and *Nerodia fasciata* (captured most in steel traps). Additionally, as we captured many large aquatic salamanders (*Siren* spp. and *Amphiuma means*), we also report trapping efficacies of the funnel traps for these amphibians.

INTRODUCTION

Although numerous herpetological field sampling techniques have been developed, many are ineffective for studying snakes. For many snake species, low abundance, prolonged periods of inactivity, and highly secretive lifestyles make sampling difficult, such that biologists must often resort to opportunistic captures to obtain adequate sample sizes (Parker and Plummer 1987, Sun et al. 2001). Systematic techniques that have been successfully employed in snake studies include terrestrial pitfall or funnel trapping (often in conjunction with drift-fences; Fitch 1951, Gibbons and Semlitsch 1981, Enge 1997), visual encounter surveys (Rodda 1993, Sun et al. 2001), driving roads (Fitch 1987), and the use of artificial cover objects (Grant et al. 1992). However, these techniques are of limited utility for sampling aquatic habitats or thoroughly aquatic species [but see Enge (1997) and Willson and Dorcas (2004) for discussions of aquatic drift fences].

Funnel trapping with commercially available minnow or crayfish traps has proven effective for sampling reptiles and amphibians in aquatic habitats (Keck 1994, Siegel et al. 1995a and 1995b, Johnson and Barichivich 2004, Willson and Dorcas 2004). This technique has been used to capture a variety of aquatic snake species and may be one of the only ways to effectively target highly aquatic species such as mud and rainbow snakes (*Farancia* spp.), black swamp snakes (*Seminatrix pygaea*), and crayfish snakes (*Regina* spp.; Gibbons and Semlitsch 1991). Additionally, trapping can reduce capture bias inherent in sampling methods based on opportunistic captures (Heyer et al. 1994, Keck 1994).

Despite the utility of aquatic funnel trapping for sampling aquatic snakes, this method is under-utilized, both in ecological field studies and in biodiversity surveys. In fact, many published comparisons of herpetological sampling techniques have not included aquatic funnel trapping (e.g., Campbell and Christman 1982, Fitch 1987 and 1992). Of the few aquatic snake trapping studies that have been conducted, most were funnel trap designs for specific situations (e.g., Casazza et al. 2000). Other studies used aquatic trapping as a primary method for capturing snakes but included little discussion of trap efficacy, methodology, or potential biases (e.g., Shine 1986, Green et al. 1994 and 1999, Seigel et al. 1995a and 1995b). In contrast, aquatic trapping of amphibians has received much more attention, resulting in sophisticated, quantitative sampling schemes suitable for many applications (e.g., Calef 1973, Fronzuto and Verrell 2000, Buech and Egeland 2002, Willson and Dorcas 2003 and 2004). We investigated the efficacy of three commercially available funnel trap varieties for capturing aquatic snakes and subsequently released snakes into traps to examine the ability of snakes to escape. We also include trapping data for large aquatic salamanders (*Siren* spp. and *A. means*) as little is known about sampling these secretive and little-studied amphibians (but see Johnson and Barichivich 2004).

METHODS AND MATERIALS

Fieldwork was conducted in three wetlands (Ellenton Bay, Risher Pond sloughs, and Pen Branch Delta) on the U.S. Department of Energy's Savannah River Site (Aiken and Barnwell Counties, South Carolina, U.S.A), between 5 May and 2 July 2003. Ellenton Bay is a 10-hectare isolated Carolina bay-type wetland. Ellenton Bay is devoid of fish, crayfish, and large aquatic salamanders (*Siren* spp. and *A. means*) but harbors a diverse assemblage of amphibian and reptile species (Davis and Janecek 1997). Risher Pond sloughs are a series of heavily vegetated temporary wetlands that are often flooded by nearby streams during wet years. Due to their intermittent connection with permanent water sources, we caught fish, crayfish, *Siren* spp., and *A. means* within Risher Pond sloughs. Pen Branch Delta is a riverine wetland located at the mouth of Pen Branch creek as it flows into the Savannah River. Pen Branch Delta has many crayfish and fish species, and water is present throughout all months of the year. During the study period, each wetland was trapped for a series of 15 (Ellenton Bay and Pen Branch) or 20 (Risher Sloughs) consecutive nights.

Three aquatic funnel trap types, frequently marketed to capture minnows and crayfish, were used for trap efficacy comparisons and snake retention experiments (Table 1). These were cylindrical galvanized steel traps (model G-40; Cuba Specialty Manufacturing Company, Fillmore, New York), cylindrical plastic traps (model 700; N.A.S Incorporated, Marblehead, Ohio), and rectangular collapsible traps (model RN10; Memphis Net and Twine Co. Inc., Memphis, Tennessee). All traps were used as purchased from the manufacturer (e.g., funnel openings were not widened; Keck 1994). Steel and plastic traps were equally durable, but we often needed to repair broken zippers or torn nylon mesh of collapsible traps.

Because snakes are known to select microhabitats and may not be evenly dispersed throughout the environment (Herbrard and Mushinsky 1978, Weatherhead and Charland 1985, Reinert 1993, Sun et al. 2001) we did not want to randomly or systematically place traps throughout the habitat. Instead we initially selected and flagged 90 trap locations within each wetland, often choosing microhabitats along natural

Table 1. Characteristics of three types of commercially available minnow traps used to capture aquatic snakes, *A. means*, and *Siren* spp. in aquatic habitats in South Carolina.

Style	Material	Shape	Length (cm)	Width (cm)	Funnel extension (cm)	Funnel opening diameter (cm)	Mesh size (cm)	Price (U.S.)
steel	galvanized steel	cylindrical	42	19 diameter	11	2.5	0.6	$8.96
plastic	plastic	cylindrical	43	16 diameter	11	2.5	0.4	$7.25
collapsible	nylon mesh	rectangular	38	24 x 24	5 - 10	6.0	0.4	$10.99

barriers (i.e., fallen logs, funneled grasses, etc.), to increase trap capture rates (Fitch 1951, Keck 1994). Thirty traps of each type were then randomly assigned to the flagged locations. Traps were set in shallow water with approximately 3 - 5 cm of the trap remaining above water level to ensure trapped animals had access to air. Traps were not intentionally baited, although incidental captures of fish and amphibians often resulted in natural baiting of traps (Keck 1994).

Traps were checked daily for snakes and all contents were subsequently removed. Each captured snake was returned to the laboratory, where species, sex, snout-vent-length, and mass were recorded. Each snake was then branded (Clark 1971) with a unique code to ensure that we did not conduct multiple release tests on recaptured snakes. The following day, snakes were released into traps through the funnel openings within the capture locality (separate from the 90 traps used to evaluate capture efficiency) to observe 24-hour trap retention. Animals were systematically assigned to release trap types so that all three trap types were equally represented in the resultant analyses. After 24 hours, the release traps were rechecked and the presence or absence of the released snake was recorded. *Siren* spp. and *A. means* captures were also recorded but releases were not conducted for these species.

RESULTS

Fifty nights of aquatic trapping (N=4500 trap nights) yielded 93 snakes of six species. The most frequently captured species was the black swamp snake (*Seminatrix pygaea*, N = 49), which comprised more than half of total snake captures. Mud snakes (*Farancia abacura*, N = 18) and southern banded watersnakes (*Nerodia fasciata*, N = 16) were also frequently captured. Glossy crayfish snakes (*Regina rigida*, N = 6), cottonmouths (*Agkistrodon piscivorus*, N = 3), and rainbow snakes (*F. erytrogramma* N = 1) were seldom captured.

We tested for differences in escape and capture frequencies among trap types using the G-test for goodness of fit for more than two classes (Sokal and Rohlf 1995). When deliberately released into traps, very few snakes (26% of snakes that did not die in traps) were retained for 24 hours (Fig. 1). Of the four most commonly captured species, *S. pygaea* exhibited the lowest retention frequency (12% of those that did not die in traps; see below), followed by *F. abacura* (34% retained). *Nerodia fasciata* was retained more frequently when compared to other species (67% retained). Overall, there was a strong but nonsignificant trend for snakes to escape from collapsible traps at a higher rate than either plastic or steel traps (all snakes combined, 72 releases; $G = 5.35$; $p = 0.069$). When examined by species, there were no significant differences in retention frequency among trap types for *F. abacura* ($G = 1.38$; $p = 0.5$), *R. rigida* ($G = 2.78$; $p = 0.25$) or *S. pygaea* ($G = 1.88$; $p = 0.39$). In contrast, *N. fasciata* was never retained in collapsible traps, but was always retained in plastic or steel traps ($G = 6.59$; $p = 0.037$). Three *S. pygaea* became entangled in the mesh of steel release traps and either drowned or were killed by carnivorous aquatic insects before the traps were checked.

Capture frequencies among trap types were significantly different (all snake captures; $G = 21.08$; $p < 0.001$) and were significantly different for all commonly captured species when examined individually [*F. abacura* ($G= 6.35$; $p = 0.041$), *N. fasciata* ($G = 11.24$; $p = 0.004$), *S. pygaea* ($G = 21.77$; $p < 0.001$)]. Plastic and steel minnow traps captured more individuals than collapsible traps, with plastic traps capturing most *S. pygaea* and *F. abacura*, and steel traps capturing most *N. fasciata* (Fig. 2). Interestingly, siren (*S. intermedia* and *S. lacertina*) captures ($n = 228$) were also biased toward plastic and steel traps ($G = 93.1$; $p < 0.001$). Although there were more *A. means* ($n = 14$) captures in collapsible traps, there was no detectable difference between trap types ($G = 2.98$; $p = 0.226$). Five *S. pygaea* (10% of captures) captured in steel traps died after becoming entangled in the mesh.

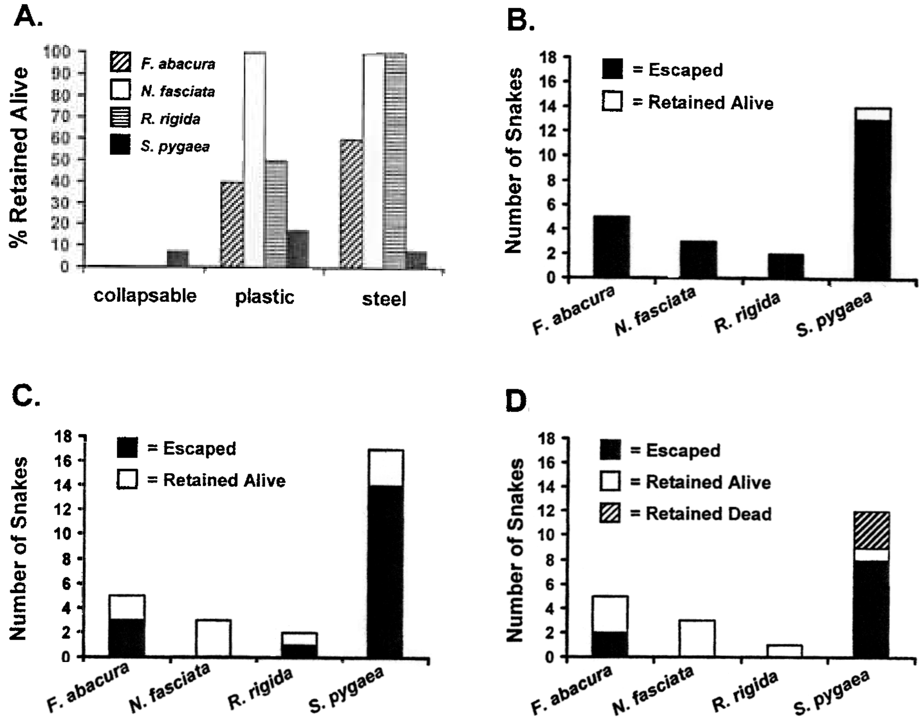

Figure Retention of aquatic snakes released into funnel traps after 24 hours. A) Percentage of snakes of each species retained in traps of each type. Numbers of snakes escaped, retained alive, or retained dead (i.e., died while tangled in mesh) in B) collapsible, C) plastic, and D) steel funnel traps, 24 hours after release into traps. Retention was significantly different among trap types for *N. fasciata* ($G = 6.59$; $p = 0.037$). Other trends were not statistically significant.

DISCUSSION

We found that that the majority (74%) of snakes released into aquatic traps escaped within 24 hours of release. This suggests that capture frequencies are underestimates and overall capture rates could be greatly improved by checking traps more frequently or modifying traps to make escape more difficult (e.g., lengthening the funnels; Keck 1994). Of the species studied, *S. pygaea* escaped most frequently, likely due to its small size. *Farancia abacura* escaped more frequently than *N. fasciata*, possibly due to its slimmer build, narrow head, or natural exploratory behaviors associated with burrowing in mud or aquatic debris. Escape rates were highest in collapsible traps (only one snake was retained after 24 hours), possibly resulting from the larger entrance holes or shorter funnel extensions. Both plastic and steel traps had higher retention rates (33 and 44% respectively).

High escape frequencies may partially explain our low trap capture rates (0.02 snakes per trap night overall). Additionally, a severe drought in the year preceding this study (2002) may have caused local population declines of aquatic snakes and further depressed capture rates as seen by Seigel et al. (1995) at Ellenton Bay following a severe drought in the late 1980's. However, our capture of large numbers of highly secretive aquatic snakes (*Farancia* spp., *S. pygaea*, and *R. rigida*), which are particularly difficult to sample using conventional methods (e.g., visual encounter surveys, terrestrial

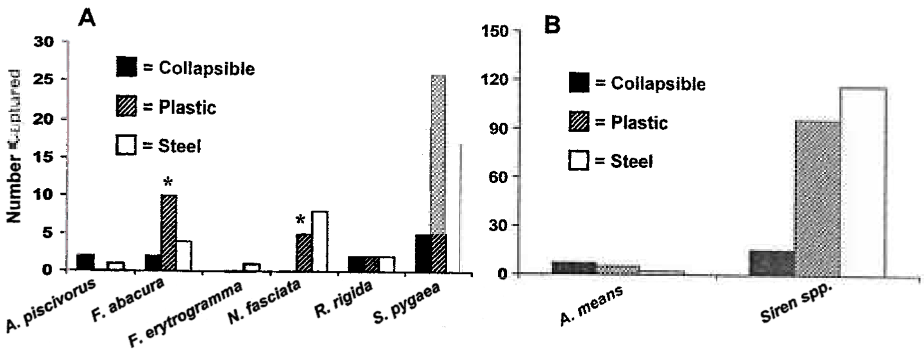

Figure 2. Captures of A) aquatic snakes and B) large aquatic salamanders (*Siren* spp. and *A. means*) in three types of commercial funnel traps over a 58-day trapping period on the Savannah River Site, Aiken Co., South Carolina. Significant differences in captures among trap types within a species are noted with an asterisk (*). Overall snake captures (N = 93) were significantly different among trap types ($G = 21.08$; $p < 0.0001$).

sampling; Gibbons and Semlitsch 1991), confirms the utility of aquatic trapping for sampling these species. Indeed, our capture rates for plastic and steel traps were substantially higher than the overall average at certain locations (e.g., 0.06 snakes per trap night for plastic traps at Ellenton Bay). Aquatic funnel trapping also proved to be a reliable method for sampling large fully aquatic salamanders (*Siren intermedia*, *S. lacertina*, and *Amphiuma means*), with 228 *Siren* spp. and 14 *A. means* captured over a 35-day period. Because Ellenton Bay did not contain *Siren* spp. or *A. means* we were essentially only trapping for these species for 35 of the 50 days.

We found substantial and statistically significant differences in snake capture frequencies among the three funnel trap varieties. Generally, plastic and steel traps captured more snakes and sirens than collapsible mesh traps. When examined by species, *F. abacura* and *S. pygaea*, were most frequently captured in plastic traps, while *N. fasciata* and *Siren* spp. were most frequently captured in steel traps. Although the exact cause for these differences is unknown, the results of our release study suggest that the difference may lie at least partially in higher snake escape rates from collapsible traps. Interestingly, the only two species captured most in collapsible traps were *A. piscivorus* and *A. means*. These are both large, heavy-bodied species that were probably only able to enter the wider entrance holes of collapsible traps.

Although funnel trapping is an effective means for capturing highly secretive aquatic snakes and salamanders, many snakes can readily escape from commercial funnel traps, greatly reducing potential capture rates. We found that collapsible-mesh funnel traps, although easy to transport and apparently effective for trapping amphibians (Willson and Dorcas 2004), were relatively ineffective for snake trapping. Plastic and steel traps both captured large numbers of snakes, were less expensive, and needed fewer repairs than collapsible traps. Use of steel traps, however, often resulted in undue mortality of small snakes (10% of *S. pygaea* captures). Thus, we recommend plastic traps for sampling small snake species (e.g., *S. pygaea*) and steel traps for larger species such as watersnakes (*Nerodia* sp.) and encourage the development of novel methods for reducing escape rates.

ACKNOWLEDGEMENTS

We thank Ben Lawrence and Cameron Young for assistance checking traps, and Michael E. Dorcas, J. Whitfield Gibbons, Robert N. Reed, and John H. Roe, for providing useful comments on the manuscript. Manuscript preparation was aided by the Environmental Remediation Sciences Division of the Office of Biological and Environmental Research, U.S. Department of Energy through Financial Assistance Award No. DE-FC09-96SR18546 to the University of Georgia Research Foundation.

LITERATURE CITED

Buech, R. R. and L. M. Egeland. 2002. Efficacy of three funnel traps for capturing amphibian larvae in seasonal forest ponds. Herpetological Review 33:182-185.

Calef, G. W. 1973. Natural mortality of tadpoles in a population of *Rana aurora*. Ecology 54:741-758.

Campbell, H. W. and S. P. Christman. 1982. Field techniques for herpetofaunal community analysis, p. 192-200. *In*: N. J. Scott, Jr. (ed.), Herpetological Communities: A Symposium for the Society for the Study of Amphibians and Reptiles and the Herpetologists' League, August 1977. Wildlife Research Report 13. United States Department of the Interior, Fish and Wildlife Service, Washington, D.C.

Casazza, M. L., G. D. Wyle, and C. J. Gregory. 2000. A funnel trap modification for surface collection of aquatic amphibians and reptiles. Herpetological Review 31:91-92.

Clark, D. R., Jr. 1971. Branding as a marking technique for amphibians and reptiles. Copeia, 1971: 148-151.

Davis, C. E. and L. J. Janecek. 1997. DOE Research Set-Aside Areas of the Savannah River Site. National Environmental Research Park Program, Department of Energy, Savannah River Ecology Laboratory. SRO-NERP25. Pp. 1.1-1.9.

Enge, K. M. 1997. A standardized protocol for drift-fence surveys. Quincy, Florida, Florida Game and Fresh Water Fish Commission: 68.

Fitch. H. S. 1951. A simplified type of funnel trap for reptiles. Herpetologica 7:77-80.

Fitch. H. S. 1987. Collecting and life-history techniques, p. 143-164. *In*: R. A. Seigel, J. T. Collins, and S. S. Novak (eds.), Snakes: Ecology and Evolutionary Biology,. McGraw-Hill, Inc., NY.

Fitch. H. S. 1992. Methods of sampling snake populations and their relative success. Herpetological Review 23:17-19.

Fronzuto, J. and P. Verrell. 2000. Sampling aquatic salamanders: tests of the efficiency of two funnel traps. Journal of Herpetology 34:146-147.

Gibbons, J. W. and R. D. Semlitsch. 1981. Terrestrial drift fences with pitfall traps: an effective technique for quantitative sampling of animal populations. Brimleyana 7:1-16.

Gibbons, J. W. and R. D. Semlitsch. 1991. Guide to the Reptiles and Amphibians of the Savannah River Site. University of Georgia Press, Athens, GA.

Grant, B. W., A. D. Tucker, J. E. Lovich, A. T. Mills, P. M. Dixon, and J. W. Gibbons. 1992. The use of coverboards in estimating patterns of reptile and amphibian abundance, p. 379-403. *In*: R. Siegel, and N. Scott (eds.), Wildlife 2001. Elsevier Science Publ., Inc., London, UK.

Greene, B. D., J. R. Dixon, J. M. Mueller, M. J. Whiting, and O. W. Thornton, Jr. 1994. Feeding ecology of the Concho water snake, *Nerodia harteri paucimaculata*. Journal of Herpetology 28:165-172.

Greene, B. D., J. R. Dixon, and M. J. Whiting. 1999. Reproductive ecology of the Concho water snake, *Nerodia harteri paucimaculata*. Copeia 1999:701-709.

Herbrard, J. J. and H. R. Mushinsky. 1978. Habitat use by five sympatric water snakes in a Louisiana swamp. Herpetologica 34:306-311.

Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster (eds.). 1994. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington D.C.

Johnson, S. A. and W. J. Barichivich. 2004. A simple technique for trapping *Siren lacertina*, *Amphiuma means*, and other aquatic vertebrates. Journal of Freshwater Ecology 19:263-269.

Keck, M. B. 1994. A new technique for sampling semi-aquatic snake populations. Herpetological Natural History 2:101-103.

Parker, W. S. and M. V. Plummer. 1987. Population Ecology, p. 253-301. *In*: R. A. Seigel, J. T. Collins and S. S. Novak, (eds.), Snakes: Ecology and Evolutionary Biology. McGraw-Hill, Inc., NY.

Reinert, H. K. 1993. Habitat selection in snakes, p. 201-240. *In*: R. A. Seigel and J. T. Collins (eds.), Snakes: Ecology and Behavior. McGraw-Hill, Inc., NY.

Rodda, G. H. 1993. Where's Waldo (and the snakes)? Herpetological Review 24:44-45.

Seigel, R. A., J. W. Gibbons, and T. K. Lynch. 1995a. Temporal changes in reptile populations: effects of a severe drought on aquatic snakes. Herpetologica 51:424-434.

Siegel, R. A., R. K. Loraine, and J. W. Gibbons. 1995b. Reproductive cycles and temporal variation in fecundity in the black swamp snake *Seminatrix pygaea*. American Midland Naturalist 134:371-377.

Shine R. 1986. Ecology of a low-energy specialist: food habits and reproductive biology of the Arafura filesnake (Acrochordidae). Copeia 1986:424-437.

Sokal, R. R. and F. J. Rohlf. 1995. Biometry. 3rd edn. W. H. Freeman and Company, NY.

Sun, L., R. Shine, Z. Debi, and T. Zhengren. 2001. Biotic and abiotic influences on activity patterns of insular pit-vipers (*Gloydius shedaoensis*, Viperidae) from north-eastern China. Biological Conservation 97:387-389.

Weatherhead, P. J. and M. B. Charland. 1985. Habitat selection in an Ontario population of the snake, *Elaphe obsoleta*. Journal of Herpetology 19:12-19.

Willson, J. D. and M. E. Dorcas. 2003. Quantitative sampling of stream salamanders: a comparison of dipnetting and funnel trapping techniques. Herpetological Review 34:138-140.

Willson, J. D. and M. E. Dorcas. 2004. A comparison of aquatic drift fences with traditional funnel trapping as a quantitative method for sampling amphibians. Herpetological Review 35:148-150.