Urban Ecosystems, 5: 119–129, 2001

The behavioral response of basking Northern water (*Nerodia sipedon*) and Eastern garter (*Thamnophis sirtalis*) snakes to pedestrians in a New Jersey park

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Abstract. Considerable attention has been devoted to the effects of people on birds and mammals, usually in wilderness or semiwilderness, but relatively little has been directed at reptiles in heavily populated areas. This paper examines the role of investigators and pedestrians on Northern water (*Nerodia sipedon*) and Eastern garter (*Thamnophis sirtalis*) snakes basking along a canal in New Jersey. The protocol involved 1–3 investigators approaching snakes that were basking between a path and the Raritan Canal. Investigators walked along the path until they were perpendicular to the snake, observed them for 60 seconds, and then approached them directly. Nearly 40% of the variability in distance to first respond for water snakes ($N = 135$) was accounted for by distance the snake was from the path, number of observers, and number of people currently using the trail, while 27% of the variability in time to respond was accounted for by number of observers, distance to path and water, and air temperature. There was no significant model for garter snakes ($N = 33$). Nearly 30% of water snakes, but only 5% of garter snakes, responded during the approach of an observer, and another 32% of water and 45% of garter snakes responded within the first minute of stopping on the trail nearest to them. Water snakes responded when the observer was farther away from them than did garter snakes. As the number of pedestrians on the path increased, water snakes responded when people were farther from them, but there were no differences for garter snakes in response distance. These data indicate differences in response, with water snakes responding sooner than garter snakes. Few garter snakes responded when they were over 150 cm from the path, while a quarter of the water snakes responded when they were from 200 to 300 cm from the path, suggesting that paths should be at least 400 cm from water, providing safe basking sites for water snakes. Further, the data indicate that walking past snakes without stopping results in less disturbance than stopping to watch them.

Keywords: human disturbance, walking paths, reptiles, snakes, basking, urban wildlife, urban park, state park

Introduction

The adverse effects of humans on wildlife have been investigated for many years. The impacts are numerous, and include both direct and indirect, and intentional and unintentional effects. Unintended but direct disturbance by people in close proximity can adversely affect a wide range of activities, including breeding, feeding, migrating, and roosting (Knight and Temple, 1995; Burger and Gochfeld, 1994). Birds have been well-studied, particularly those breeding in colonies (Carney and Sydeman, 1999), and those migrating in large concentrations (Burger, 1986, 1991; Pfister *et al.*, 1992; Roberts and Evans, 1993). There are some studies of the effects of human disturbance on mammals (Blane and Jaakson, 1994).

A great deal of attention has been devoted to the effect of human disturbance to wildlife in wilderness and semiwilderness areas (Knight and Gutzwiller, 1995), but there is relatively little research in urban and suburban areas. However, many species of wildlife inhabit environments where the human dimension plays a key role (Rees, 1997). Such urban studies mainly deal with birds or mammals, often in nature reserves or parks, particularly on the effects of fragmentation on bird communities (Dowd, 1992; Jokimaki and Suhonen, 1993), of pedestrians on forest-nesting birds (Fernandez-Juricic, 2000), and of cars on foraging birds (Keller, 1991). There have been few studies of the effects of humans on other vertebrates, such as fish (but see Hawkins *et al*., 1999) or reptiles, largely because of their solitary or secretive nature and the difficulty of observation. Road mortality in turtles has also been examined (Haxton, 2000), although death leaves little opportunity for learning or changes in behavioral responses.

In this paper I examine the behavior of Northern water (*Nerodia sipedon*) and Eastern garter (*Thamnophis sirtalis*) snakes that were basking along a canal in New Jersey to the approach of people. Of particular interest was whether there were species differences in response, whether snakes were more influenced by the number of people generally walking along the canal or to the number of people in a group, and whether the location of the snakes relative to the path and the canal influenced their response. My overall objective was to determine if differences in behavior of people influenced the responses of the snakes. I predicted that the snakes would respond more quickly if there were more people in a group because they would form a greater (louder, more ground vibrations) stimulus.

Water snakes spend a great deal of time in the water, forage in the water, and return to the water for protection from predators (King, 1986, 1993), while garter snakes are mainly terrestrial, although they swim and forage on frogs and fish (Logier, 1965). I have observed both species copulating on land. The Raritan Canal, where the study was conducted, is an old barge canal that follows the Raritan River, and is now a state park.

Examining the behavioral responses of wildlife to pedestrians is a method of determining tolerance, habituation, and possible adverse effects on behavior (Cooke, 1980; Burger and Gochfeld, 1991; Roberts and Evans, 1993; Prior and Weatherhead, 1994; Parent and Weatherhead, 2000). Whitaker and Shine (1999) examined the response of free-ranging brownsnakes (*Pseudonaja textillis*) and found that retreat was the most likely response; snakes moved toward the observer during only 12 of 455 encounters. Their study was of radio-tagged snakes which had an opportunity for habituation. Shine *et al*. (2000) examined the behavioral responses of free-ranging garter snakes to people walking by and to being "pecked" by a human finger; they found that body temperature, sex, and microhabitat affected response. Female massasauga rattlesnakes (*Sistrurus catenatus catenatus*) responded to increased human disturbance by becoming less visible to observers, while there was no difference for non-gravid females or males (Parent and Weatherhead, 2000).

While information on the effects of pedestrians on snakes is of interest in terms of their behavioral responses, it can also inform management, particularly the placement of future trails, control of the number of pedestrians, and the behavior of pedestrians along trails. The effects of pedestrians and others on wildlife should be incorporated into management decisions as another relevant factor that may impact habitat quality (Fernandez-Juricic, 2000). In some situations, buffer zones have been established to protect foraging and loafing birds (Rodgers, 1995; Rodgers and Smith, 1997), but the technique has not been widely used with other groups of vertebrates. Whatever the solution, science is key to making both management and policy decisions (Lyons, 1997).

Methods

Observations were made from 14 May through 3 October 2001 while walking on the tow path (converted to a walking/bike path) along the Raritan Canal, which parallels the Raritan River from New Brunswick south to Blackwells Mills, New Jersey. The tow path is now part of the New Jersey state park system, and is used extensively by walkers, bikers, naturalists, and joggers. No motorized vehicles are allowed on the path. The path that parallels the canal is used more frequently on weekends than during the week (Burger, unpubl. data). The canal and tow path are part of the Delaware and Raritan Canal State Park, one of central New Jersey's most popular recreational corridors. Consecutive sections of the canal were walked to eliminate the possibility of sampling the same snakes. Water snakes do not move great distances, and sampling different parts of the canal ensured that I was not sampling the same snakes. Mills *et al*. (1995) found that a related species of water snakes remained within about 250 m of their initial trap location.

The overall protocol was to walk at a constant speed along the canal (repeatedly timed in trial walks) looking for snakes. When a snake was spotted, the observer(s) noted the distance between the observer and the snake when it first responded by making a slight mark on the dirt trail. If it did not respond before the observer on the path was nearest the snake, the observer stopped and waited for 60 seconds (recording the time the snake responded, if it did). If it did not respond in 60 seconds, the observer walked off the path, toward the snake until it did respond. After the snake responded, all measurements were taken using a tape measure.

Information recorded included: date, time of day, number of observers (1–3), air temperature, water temperature, cloud cover, canopy cover over the initial location of the snake, substrate type (branches, bushes, rock, dirt, leaves, log, tree stump), distance from the water and from the path, distance of the observer when the snake first responded, time to respond (0 if the snake responded before the closest approach, and time to respond thereafter), and total number of pedestrians encountered on the trail in each 3 hr period (indicative of overall exposure to pedestrians that day). While some snakes that saw us first made a rapid departure, we undoubtedly missed some snakes that remained still and were hidden from view. Some snakes ($N = 6$ water snakes) that made a rapid departure were not examined because we could not determine their exact initial location. It was usually possible to determine where the snake was before it moved on the basis of the rustling sounds of the dry leaves. Habitat selection for basking is discussed elsewhere (Burger *et al*., ms).

Regression procedures were used to determine if observer group size, number of pedestrians on the path, distance to the path or water, percent of snake that was visible, or air temperature contributed to differences in response distance and time to respond (PROC GLM, SAS, 1999). The procedure adds the variable that contributes the most to explaining the variance ($R^2 =$ percent of the variance in y explained by x), then adds the next variable that increases the R^2 the most, continuing until all significant variables are added. Thus variables that vary co-linearly are entered only if they add independently to explaining the variation. The procedure also allows for interaction variables (number of observers x distance). The program notes if the data do not fit the assumptions. Wilcoxon X^2 tests were used to determine whether there were differences among variables as a function of species or other categories (SAS, 1999, version 8).

Results

There were differences between water snakes ($N = 135$) and garter snakes ($N = 33$) in the timing of their responses to pedestrians. A higher percentage of water snakes, compared to garter snakes, responded before observers were close to them on the trail ($X^2 = 14.6$, $P < 0.006$, figure 1). Some snakes (40% of the water snakes, 50% of the garter snakes) did not respond within 60 seconds of the observer stopping on the path in front of them.

There were significant models explaining variation in the distance to respond, and the time of response, for water snakes, but not for garter snakes (Table 1). Nearly 40% of the variability in distance to first respond for water snakes ($N = 135$) was accounted for by distance the snake was from the path, number of observers, and number of pedestrians currently using the trail, while 27% of the variability in time to respond was accounted for by number of observers, distance to path and water, and air temperature. While total number of pedestrians on the trail contributed significantly to variations in distance response for water snakes (but not for garter snakes, $N = 33$), the number of dogs, walkers, and bikers did not enter as a separate factor in the models. However, the number of joggers did enter for the time to respond for water snakes ($F = 5.75$, $P < 0.02$); snakes moved sooner when joggers went by compared to others. None of the interactions (e.g., observers X distance from path) contributed significantly to explaining variations in snake behavior.

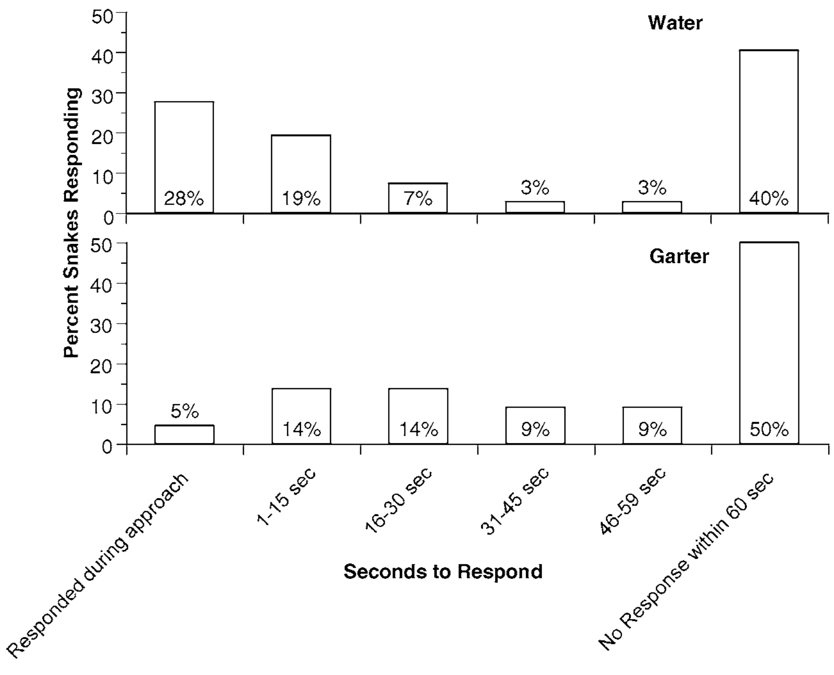

Figure 1. Behavioral response of water ($N = 135$) and garter snakes ($N = 33$) basking along the Raritan canal to an approaching pedestrian. Snakes could respond during the approach, or while the observer waited for 60 seconds on the path, while closest to the snake.

Table 1. Regression models explaining variation in behavioral responses of water and garter snakes. Given are the models explaining the most variation in the distance to first respond and the time to respond. NS = the variable is not significant

	Northern water snakes		Garter snakes	
	Distance to respond	Time to respond	Distance to respond	Time to respond
Model				
F	11.12	4.65	0.57	0.41
p	0.0001	0.0004	0.7491	0.8628
r^2	0.39	0.26	0.12	0.14
Factors entering (F, p)				
Number of observers	7.03 (0.009)	7.51 (0.008)	0.07 (NS)	0.56 (NS)
Number of people on trail	4.18 (0.04)	2.55 (NS)	0.09 (NS)	0.08 (NS)
Distance to path	25.58 (0.0001)	8.19 (0.005)	1.79 (NS)	0.12 (NS)
Distance to water	0.47 (NS)	4.44 (0.04)	0.41 (NS)	0.60 (NS)
Percent visible	0.24 (NS)	0.85 (NS)	0.17 (NS)	0.78 (NS)
Air temperature	0.02 (NS)	3.92 (0.05)	1.57 (NS)	0.51 (NS)

Water snakes responded when the observers were farther away than did garter snakes ($X^2 = 25.1$, d.f. = 9, $P < 0.003$, figure 2). Only 5% of the water snakes responded when the observer was 400 cm away. There were species differences in the percent responding as a function of the number of observers ($X^2 = 13.3$, d.f. = 6, $P < 0.03$). A higher percentage

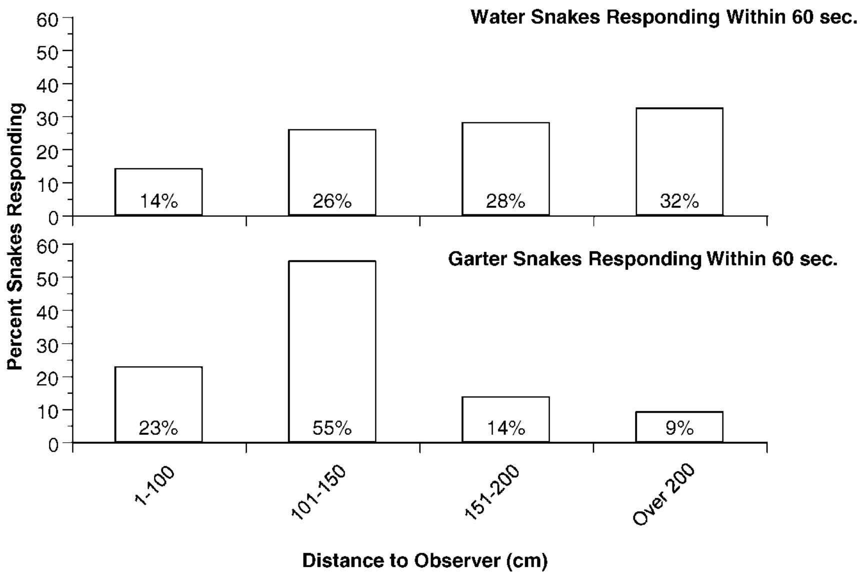

Figure 2. Distance the observer was from water snakes ($N = 81$) and garter snakes ($N = 17$) when the snake responded to the experimenter within 60 seconds.

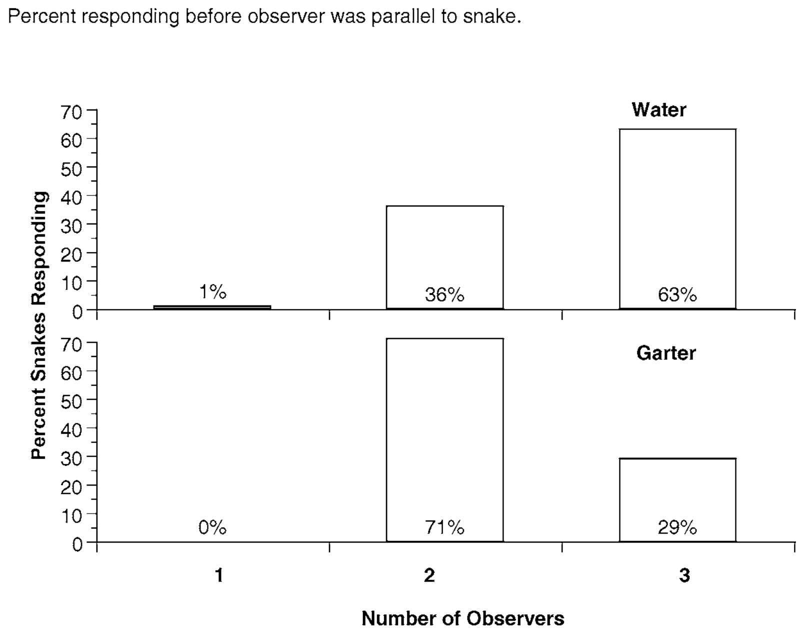

Figure 3. Percentage of water ($N = 135$) and garter snakes ($N = 33$) that responded as a function of the number of observers in the experimental group.

of water snakes responded when there were more observers; a higher percentage of garter snakes responded when there were two pedestrians compared to three observers (figure 3). It was the distance between the observer and the snake that was important for water snakes, since the percent responding was the same with all distances from the path (figure 4). However, for garter snakes, a higher percent responded as a function of distance from the path (figure 4).

Snakes were generally more responsive when there were more pedestrians on the path. The distance the observers were from water snakes when they responded was significantly related to the number of pedestrians on the path overall ($X^2 = 79.7$, d.f. $= 39$, $P < 0.0001$), however, this was not the case with garter snakes (figure 5). When there were over 15 pedestrians on the trail, however, both species tended to wait until pedestrians were closer before responding (figure 5). This may be because snakes that were wary had already moved before the observers arrived.

Discussion

Predation is an important factor influencing behavior of animals (Lima and Dill, 1990). Deciding whether to flee from a predator, and when to flee is an optimization problem. Any animal should not flee if there is no danger, if the predator has not detected it, or if it can still escape if it acts a little later. But animals should flee when the costs (being

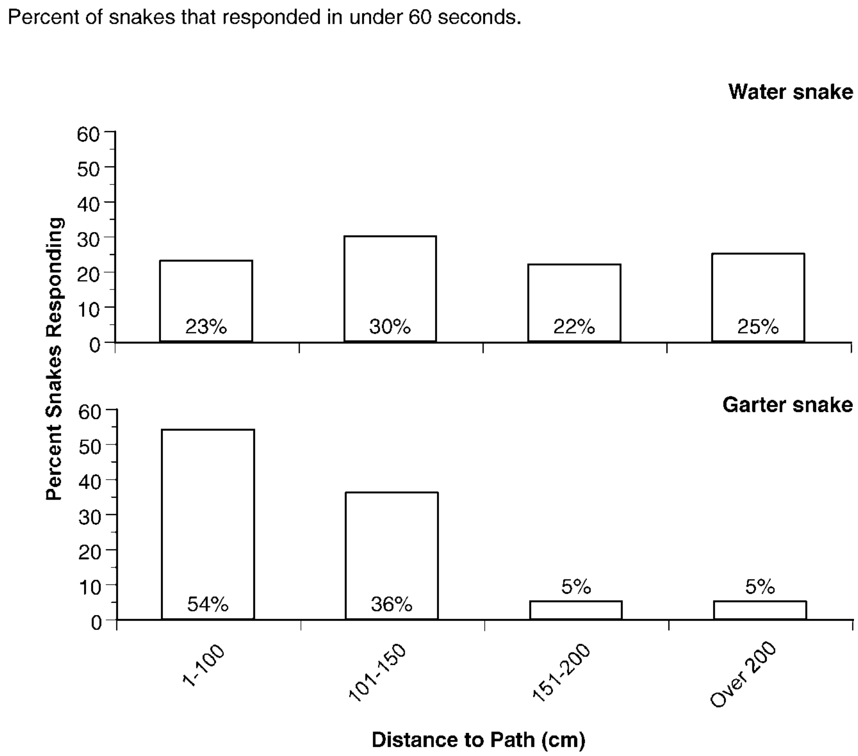

Figure 4. Percentage of water ($N = 81$) and garter ($N = 17$) snakes that responded to the approach of the experimenters (within 60 seconds) as a function of distance the snake was from the path along the Raritan canal.

injured or eaten) outweigh the benefits of remaining still (energy savings or keeping basking location). The benefits of flight are escape from predators (Weatherhead and Robertson, 1992), while fleeing interrupts other activities, such as foraging, looking for mates or other resources, or basking (Ydenberg and Dill, 1986). Where animals are continuously exposed to potential predators without ill effects, habituation should occur. Reptiles, such as lizards, can habituate to the continuous presence of predators (Downes, 2001). However, Parent and Weatherhead (2000) found that snakes continued to respond to people as if they were predators in disturbed areas, regardless of the level of disturbance. If the water snakes were habituated, I expected them to remain during a tangential approach, but they did not. In water snakes, wound frequencies (indicative of predation attempts) were highest in species with the most diurnal basking (Mushinsky and Miller, 1993), suggesting that this is a critical time for snakes.

When an encounter situation occurs between a snake and a pedestrian, either the snake or the pedestrian detects the approach first. The snake can either remain still and monitor the pedestrian or depart immediately. The pedestrian can either move by, stop, or approach the snake. The snake can then continue to monitor the pedestrian, or depart. In this series of experiments, the snakes all departed either during the tangential approach on the path, or

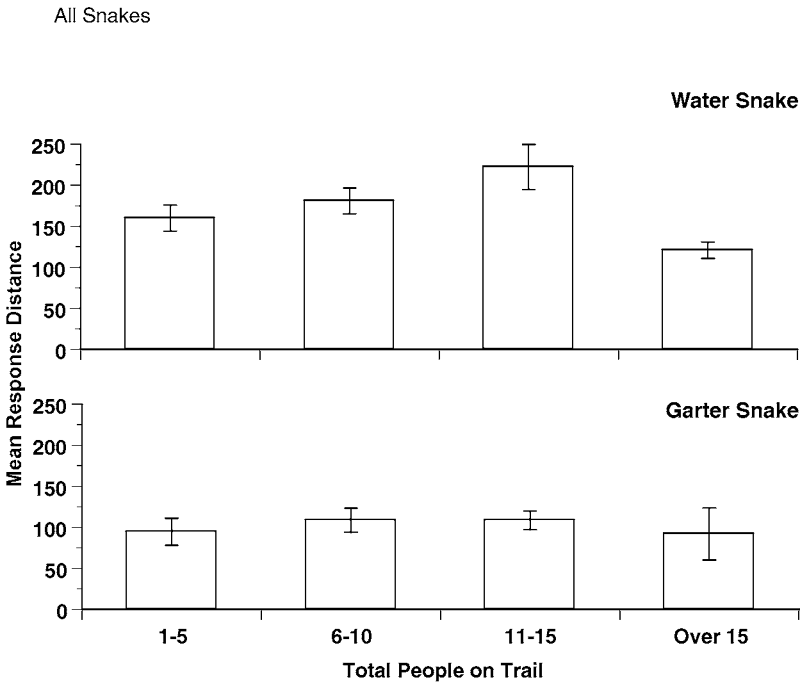

Figure 5. Mean response distance of water ($N = 135$) and garter snakes ($N = 33$) as a function of the total number of people on the path during three-hour observation periods. Response distance equals the distance between the snake and the experimenter when the snake first responded.

during the direct approach. Experimenters never got closer than 0.75 m of a water snake or 0.5 m of a garter snake before they departed rapidly, and never were able to touch them. It would have been possible to catch some with a rapid approach, or with a hook, but we did not attempt this. This is in contrast to brownsnakes (*Pseudonaja textillis*) (Whitaker and Shine, 1999) that allowed observers to touch them. Retreat was the most likely response for brownsnakes; they moved toward the observer in only 12 of 455 encounters (Whitaker and Shine, 1999).

In the present study individual snakes were approached only once as we normally walked different areas along the canal during each sampling period. About half of the brownsnakes studied retreated immediately when approached, and the rest remained stationary when the observer came as close as 0.5 m (Whitaker and Shine, 1999), while in this study all snakes retreated when the observer walked as close as 0.5 m. Thus, the brownsnakes were either more habituated, or less wary than either the garter or water snakes in this study. Since the brownsnake study was based on 40 radio-tagged snakes, each snake was approached many times and habituation undoubtedly occurred.

In this study we attempted to duplicate normal human activity along the path. Normally pedestrians do not approach the snakes, and indeed, most do not even see the snakes. Over 95% ($N = 357$) of the pedestrians we observed passing snakes in the course of our studies did not stop, look at them, or approach them. In urban and suburban environments, people (and their dogs) are often the most important predators; snakes are poached, collected, moved, or harassed. We observed pedestrians collecting snakes to take home to show their children, poaching them for trade purposes, and allowing their dogs to chase them for sport. During this study, we saw eleven people catch snakes and seven removed them from the study site.

While disturbing a basking snake once or twice may not pose a problem for the snake, continuous disturbance may be detrimental because it reduces total basking time. There were limited basking sites along the canal that were fully exposed to the sun because of the canopy cover over the canal bank and because of the general absence of logs or debris in the middle of the canal (where there was full sun penetration). The number of basking sites on logs at the edge of the canal was also limited because the park personnel periodically removed the logs where snakes were observed basking. While they could bask on the banks, these sites were less exposed to the sun.

The negative effects of less basking time require further investigation. Parent and Weatherhead (2000) examined the behavioral responses of eastern massasauga rattlesnakes and found no differences in condition, growth rates, and litter size of snakes with increasing exposure to human disturbance. However, they did not examine weight or condition of the litter, which might have varied since females in disturbed sites spent less time basking in the sun. Further, they used a rating for disturbance, and did not examine the behavior of individual snakes with respect to their rated exposure to human disturbance.

Conclusions from this study include: (1) there were species differences in responses of snakes, (2) water snakes were more responsive than garter snakes, (3) most snakes remained stationery when a person walked directly past without stopping or approaching, (4) all snakes examined retreated during a direct approach before the observer was within 0.5 m, (5) the distance from the path affected snake behavior, and (6) both the number of observers (experimenters in a group) and total number of pedestrians on a path affected snake behavior. Thus, if maintaining healthy conditions for basking snakes is a priority of managers of an urban park or refuge, then paths should be at least 400 cm from the water so that snakes have sufficient places to bask without being disturbed by passing pedestrians. I suggest this distance because only 5% of the water snakes responded when the observer was 400 cm away. Secondly, pedestrians should be cautioned to continue moving past basking snakes rather than approaching them, which disrupts basking. The data also indicate, however, that if there is sufficient distance between the water and paths, snakes are not disrupted by pedestrians walking, jogging, biking, or walking dogs.

Acknowledgments

I thank H. Jensen, M. Fitzgerald, C. Jeitner, S. Shukla and M. Gochfeld for helpful comments during this research, the New Jersey Department of Environmental Protection (Endangered and NonGame Program), and the Department of Parks for permits to conduct this research and the D&R Canal for permission to work with snakes along the canal and for providing maps and other information. This research was partly funded by NIEHS (ESO 5022) and the Consortium for Risk Evaluation with Stakeholder Participation (DOE, DE-FG 26-00NT

40938). The results, conclusions and interpretations reported herein are the sole responsibility of the author, and should not in any way be interpreted as representing the views of the funding agencies.

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