Urban Ecosyst (2007) 10:193–201
DOI 10.1007/s11252-007-0019-6

The behavioral response of emerging pine snakes (*Pituophis melanoleucus*) to people: implications for survival and protection

Joanna Burger

Published online: 7 March 2007

Abstract Considerable attention has been devoted to the effects of people on birds and mammals, usually in wilderness areas. In contrast, human disturbance of reptiles has largely been ignored. Many reptiles, such as snakes, are hard to conserve because they are difficult to locate and protect. The young are especially vulnerable to predators when they first hatch and must emerge from nest sites. In this paper, the response of pine snake (*Pituophis melanoleucus*) hatchlings to the presence and handling by people was observed in the laboratory and in the field. Pine snakes lay their eggs in underground burrows in open sandy pine barrens, and the hatchlings push their way to the surface to emerge. Hatchlings that were visually-disturbed or touched as they emerged returned immediately to their tunnels and nests, and required more time to re-emerge than did their siblings that were not visually-disturbed or touched during their initial disturbance. In nature, undisturbed pine snakes showed similar re-emergence times to those from the laboratory, and disturbed snakes required longer to re-emerge. These data suggest that in nature even the presence of people in nesting areas of pine snakes would lengthen the time the young are in burrows, exposing them to additional threats from predators. This suggests that parks or nature reserves with vulnerable snake populations should restrict human disturbance during the period when young snakes are emerging from their nests. Field observations indicate that a set-back distance of more than 12 m from known nesting areas is essential to protect emerging hatchlings.

Keywords Human disturbance · Reptiles · Snakes · Emergence · Urban wildlife · Park · Wildlife management area · Set-back distance

Introduction

The adverse effects of humans on wildlife have been investigated for many years. 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).

J. Burger (✉)
Division of Life Sciences, Rutgers University, 604 Allison Rd, Piscataway, NJ 08854-8082, USA
e-mail: burger@biology.rutgers.edu

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; Rodgers and Smith 1995; Rodgers 1997). There are some studies of the effects of human disturbance on mammals (Blane and Jaakson 1994). These studies have mainly dealt with wilderness regions (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).

Urban studies have also dealt mainly with birds or mammals, often in nature reserves or parks, particularly on the effects of fragmentation, pedestrians, and cars on bird communities (Keller 1991; Dowd 1992; Jokimaki and Suhonen 1993; Fernandez-Juricic 2000). There have been few studies of the effects of humans on other vertebrates, such as fish or reptiles, largely because of their solitary or secretive nature and the difficulty of observation. Burger et al. (2004) examined the effect of pedestrians on the behavioral responses of basking Northern water (*Nerodia sipedon*) and Eastern garter (*Thamnophis sirtalis*) snakes along a canal in New Jersey. Factors that affected their response to people walking along the canal were distance of the basking snake from the trail, number of people in the immediate group, and number of people who had used the path that day. Garter snakes responded less quickly, and less severely to approaching pedestrians than did water snakes. These experiments suggest that snakes are affected by the presence of people, even if they are not directly approached or handled.

Pine snakes nest in the New Jersey pine barrens, where the females dig long underground tunnels leading to nest cavities where they lay eight to nine eggs (Burger and Zappalorti 1986, 1988a, 1991, 1992). We found that females show a high nest site philopatry, making the nests vulnerable to poachers and predators that learn where these sites are (Burger and Zappalorti 1992). Upon hatching, the young burrow or push up through the sand to reach the surface (Burger and Gochfeld 1985). Although the young in a nest may emerge within an hour of each other, they may also require hours or days to all emerge. During this time the young remaining in the nest are vulnerable to predators because of the lingering odor of the hatched eggs. Pine snake hatchlings in the pine barrens are exposed to a variety of predators, including hawks, owls, foxes and other mammals, which they avoid by finding cover under pine boughs or other debris (Burger and Zappalorti 1988b). The ability to respond quickly might protect hatchlings from predators or people, particularly if they use visual or vibratory cues to withdraw before they are noticed. Poaching of pine snake eggs and hatchlings is a significant problem in the New Jersey pine barrens, and in some years, over 40% of the nests in our Pine Barrens study sites have been dug up by people (Burger et al. 1992). Since the New Jersey pine barrens is so close to New York, Philadelphia, and a very urban New Jersey, it serves as a recreational haven for a wide range of people, including naturalists, photographers, snake poachers, and off-road vehicle enthusiasts who could inadvertently disrupt snake nests, exposing the young to predators.

In this paper, I examine the responses of pine snake (*P. melanoleucus*) hatchlings emerging from their underground burrows to the presence and handling by people in the laboratory. Experiments were conducted in the laboratory because of the difficulty and logistics of finding emerging hatchlings in the wild, and controlling for variables in exposure to people. I predicted that handling would be more disruptive than a visual disturbance, but that siblings that remained in the nest would be unaffected by the response of the disturbed snake. Emerging pine snakes were also observed opportunistically in the field. The present work is part of an on-going project to understand the ecology and nesting behavior of pine snakes in the New Jersey pine barrens (see references above).

Materials and methods

The experiments described in this paper were conducted in 1985–1988, but are reported now because of increased human disturbance in snake nesting habitats in the New Jersey pine barrens. Increasingly, people on off-road vehicles are invading the pine barrens, and are particularly drawn to the same open sandy areas that pine snakes use for nesting. This makes it likely that people will encounter emerging pine snake hatchlings; in some cases people may not even be aware of them.

Observations on natural pine snake emergences occurred opportunistically from 1985 until the present, when we could observe both researchers and naturalist/recreationists approach pine snake nests (both knowingly and unknowingly). The greatest human threat, however, is from poachers that aim to steal the young for economic gain or to add to their snake collections. These people approach emerging hatchlings, and catch them when possible.

For the experiment, Pine snake eggs were hatched in the laboratory as part of a conservation effort to increase reproduction; this species is listed as threatened in New Jersey. Under appropriate state and local permits, 62 pine snake clutches were taken from natural nests or from females brought into the laboratory to await oviposition (Burger 1991). Clutches were divided into groups of three eggs that were incubated together, each in a separate plastic shoebox (eggs were placed in moist sand and covered with sphagnum moss). All procedures were approved by the Rutgers University Animal Review Board and were monitored by the university veterinary staff.

When the first egg in a clutch showed signs of hatching (a small slit in the shell), the eggs were placed in an artificial nest in a 42×26×21 cm aquarium and maintained at a constant temperature (27–28°C) in a darkened room with a small red light to allow monitoring of behavior. Only one three-egg clutch was placed in each artificial nest. The artificial nests were created using a plastic freezer box (10×10 8 cm) placed against the side of the aquarium, with holes in each side for the snakes to leave the “nest” when they desired (Fig. 1). This allowed me to see the eggs and hatchlings when they were in the nest. The aquarium was filled with sand to within 5 cm of the top; the artificial nest was completely covered with sand. Each aquarium was fitted with a mirror attached to the back side, and angled so that I could see the top of the sand surface from below, but the snakes could not see me.

Observations were made continuously from 6 am until midnight, and at least every 15 min during the night (which required the help of a research assistant), from a distance of 60

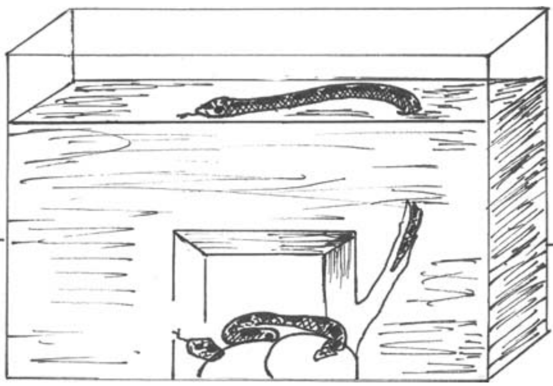

Fig. 1 Diagram of the experimental aquarium

cm. Observations were made on 468 hatchlings. Once a hatchling was three-quarters of the way out of its nest tunnel, it was subjected to the prescribed protocol. For undisturbed snakes (N=318), my arm remained drawn to my side, for disturbed snakes (N=74), I moved my hand to within 30 cm of the emerging snake and then withdrew it, for touched snakes (N=76), the emerging snake was touched lightly on the head and my hand was then removed. The control snakes did not see anything above the sand, and I recorded the snakes behavior, and the time between treatment and when the snake next emerged. In some cases, a hatchling retreated after a second emergence attempt (without any disturbance during this second time), and I recorded the time between the second and the third emergence.

The individuals within a clutch were randomly assigned to one of the three treatments. More hatchlings were undisturbed than were disturbed (visually or by handling). Only one hatchling from any nest was visually disturbed or touched. Siblings could be distinguished by color differences (hatchlings differed in the amount of black and white, on the vividness of the black and white pattern, and on the amount and distribution of black on the head), timing (some emerged before their siblings were completely hatched), or my observing them for the duration of the experiment. Once a hatchling was completely emerged and 10 cm from the emergence entrance, it was removed from the aquarium. The endpoint for these observations was the interval between treatment and when the hatchling next attempted emergence.

Different treatment groups were compared using a Kruskal Wallis non-parametric one way analysis of variance (ANOVA, generating a X^2 statistic, SAS 1995). The level for significance was designated as $P<0.05$.

Results

Once undisturbed snakes were half-way out of their emergence tunnels, 43% continued to emerge and to explore the aquarium (and they were subsequently removed). The other 57% looked around, and went back into their tunnel, but only 12% of those that returned to the nest went completely back into the nest. All of the visually-disturbed and touched snakes returned immediately to their nests, and did not remain partially in the emergence tunnel. Some of the disturbed snakes (both visually-disturbed [60%] and handled [88%]) returned to the nest a second time (and thus emerged a third time) even though they did not receive any disturbance after the initial exposure.

Once snakes retreated, the time between the first and the next emergence varied significantly by treatment (Fig. 2, Table 1). The behavior of undisturbed and disturbed snakes varied significantly by treatment (X^2=93, $P<0.001$). Disturbed snakes (both visually-disturbed and handled) required significantly more time to emerge for both the second time and the third time compared to undisturbed snakes (Fig. 1, Table 1). Disturbed snakes also waited less time before emerging from their burrows for the third time (Table 1).

Another response of either visually-disturbed or handled hatchlings was to dig side chambers from their nest once they returned to it (when disturbed). A higher percentage of touched snakes (80%) went into (or dug new) side burrows from the nest chamber than did visually-disturbed snakes (20%). Only 1% of the undisturbed snakes that returned to their nests went into side burrows or chambers.

Over the years I have observed some pine snakes emerging from natural nests when I have been at least 12 m away (and remained absolutely still). Of these, 12% (of 16 hatchlings) immediately returned to their burrows; the rest emerged and moved to

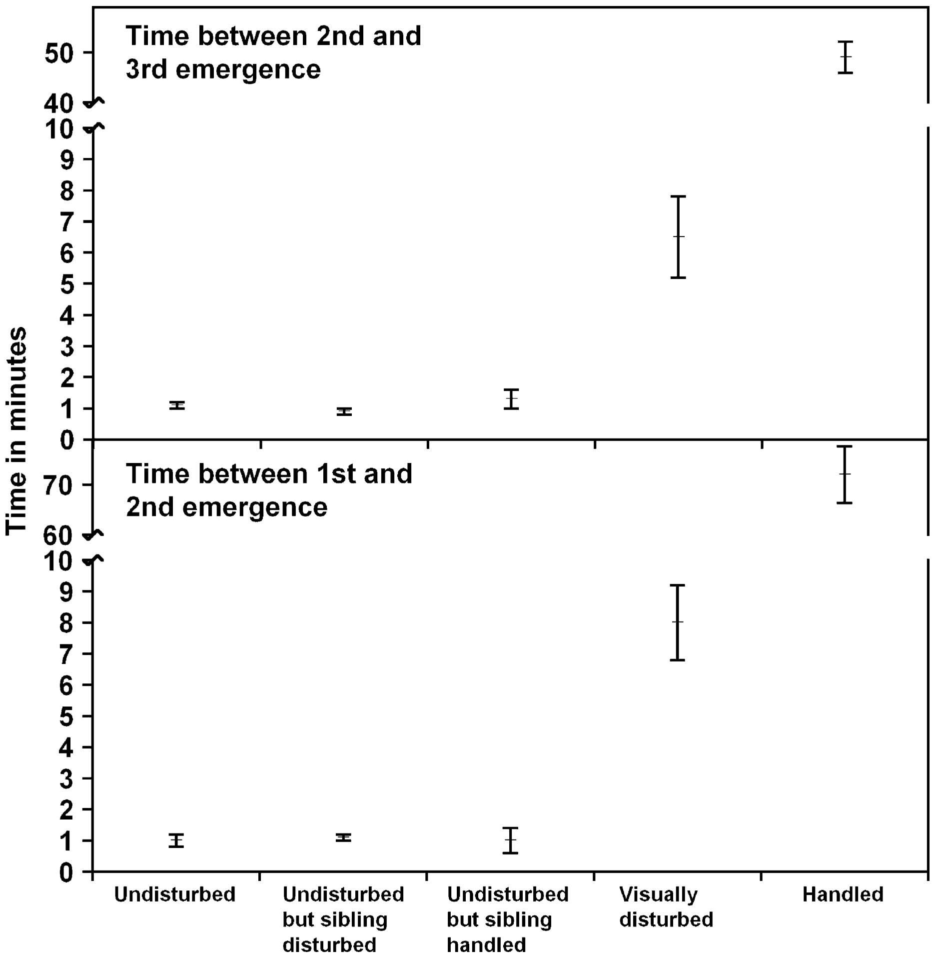

Fig. 2 Time (in min) for snakes to re-emerge if they retreated to their tunnel (or nest) after treatment (control, visually-disturbed, touched)

vegetation to hide (Table 2). Of hatchlings that I approached within 8 m before seeing them, 27% (of 82 hatchlings) returned to the nest once they emerged. Most merely backed up and emerged within a minute of their initial emergence attempt (81%). Of 62 hatchling that I did not see until I was 3 m away (because they blend in with the sand), all retreated immediately, and only 10% emerged within a minute of re-entering their burrows.

Once I had occasion to witness a recreational approach (I was hidden from view because I was making observations of emergence behavior). The two recreationists were walking slowly through the nesting area. Upon seeing emerging snakes, they moved quickly to the nest site, the emerging snakes (three had their heads up at the same time) retreated quickly when the recreationists were 9 m away. The recreationists did not dig up the hatchlings, although they moved a little sand before they gave up. The hatchlings did not emerge for at least 2 h after this disturbance.

Table 1 Response of pine snake hatchlings to being visually-disturbed or handles compared to those hatchling that were undisturbed

Treatment	Number in initial sample	Percent that emerged and stayed emerged	Time between 1st and 2nd emergence (min)	Time between 2nd and 3rd emergence (min)	$X^2(p)$
Undisturbed	168	43	1.0±0.2	1.1±0.1	1.87 (NS)
Undisturbed, but sibling visually disturbed	74	47	1.1±0.1	0.9±0.1	16.3 (<0.0001)
Undisturbed but sibling handled	76	41	1.0±0.4	1.3±0.3	23.6 (<0.0001)
Visually disturbed	74	0	8.0±1.2	6.5±1.3	26.7 (<0.0001)
Handled	76	0	72±5.6	49±3.1	23.6 (<0.0001)
X^2 (p)			80 (<0.0001)	87 (<0.0001)	

Shown is the time between emergence the first time and the second emergence, and between the second and the third emergence.

NS not significant

Discussion

Predation (including poaching) is an important factor influencing behavior of animals (Lima and Dill 1990). Deciding whether there is a danger from predators or people, whether to respond to a predator or person, and how to respond 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 soon. Animals should flee when the costs (being injured, eaten, or removed from the wild) outweigh the benefits of remaining still (energy savings). The benefits of flight (i.e. retreat to the nest for hatchlings) are escape from predators (Weatherhead and Robertson 1992), but retreating interrupts other activities, such as successful emergence, looking for a safe hiding place, or foraging (Ydenberg and Dill 1986; Burger et al. 2000). Where animals are continuously exposed to potential predators without ill effects, habituation may occur. Reptiles, such as lizards, can habituate to the continuous presence of predators (Downes 2001), although basking watersnakes showed

Table 2 Observations of the responses of pine snake hatchlings to my approach in the field in New Jersey

Response	12 m	8 m	3 m
Number of hatchlings	16	82	63
Number immediately retreating to nest	2	22	63
Percent emerging within 1 min after retreating to nest	50	81	10

Shown is the distance (in m) of observer from emerging hatchlings, and the number of snakes that immediately retreating to the nest.

only minimal habituation (Burger et al. 2004). Further, 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.

When an encounter situation occurs between a hatchling snake and a person, either the snake or the person detects the approach first. The snake can either remain still and monitor the person or depart immediately (either back into the nest or to the safety of low vegetation). The person can either move by, stop, or approach the hatchling. The snake can then continue to monitor the person, or depart. The results in this paper indicate that if a hatchling emerging from its nest burrow observes a person (either in the laboratory or the field), it immediately retreats. The amount it retreats, and the delay to the next emergence, depends upon the strength of the encounter. More hatchlings that were touched retreated into the nest and went into side tunnels than hatchlings that only saw a visual-disturbance. Similarly, the time to attempt emergence again was related to the strength of the disturbance. In contrast, undisturbed snakes that went back into their tunnels (in both the laboratory and the field) had very short inter-emergence intervals.

The pattern of responding to visual disturbances may be critical for survival of hatchlings in the wild. When hatchlings are just starting to emerge they are difficult to see because they blend with the sand. At this time they are fairly cryptic, and retreat is less obvious. However, when more than a few centimeters of their body has emerged, they become visible to predators because of their striking visual pattern and movement. It is at this time that the hatchling must decide on a course of action when faced with a predator (or poacher). Retreating to the nest, and digging side burrows, may lead to increased survival because it removes them from the surface, and predators that fly (hawks) normally give up. Mammalian predators that will dig (such as fox, raccoon, people) normally dig to the nest and take the snakes residing there. Any eggs or hatchlings in side-burrows will likely avoid predation because the act of digging up the nests obliterates the very small side tunnels. Predation and poaching account for significant losses in eggs, hatchlings and snakes when they are in subterranean burrows (either while nesting or hibernating, Burger et al. 1992). Retreating to side burrows is a reasonable strategy since we often encountered nests that had been poached or dug up by foxes or raccoons, and found either eggs or hatchlings in side burrows about 30% of the time. Since three to four females sometimes nest in the same burrow system, side chambers with eggs and hatchlings can be missed; even people who dig up snake nests fail to realize that there may be more clutches in side burrows. Hatchlings have an even better chance of avoiding predators or poachers by digging side tunnels because these tunnels are smaller than those dug by nesting females (thus they collapse easier during predation attempts), and they can be several feet long, in any direction from the nest.

Conclusions from this study include: (1) nearly all disturbed snakes (in the field and laboratory) retreated into their nest burrows when disturbed, (2) there were differences in re-emergence behavior of snakes depending upon whether they experienced no disturbance, a visual disturbance, or were touched, (3) hatchlings with the greatest degree of disturbance returned to their nests and many dug side tunnels away from the nest, and (4) these behaviors may increase survival when faced with either poachers or predators.

Finally, disturbance by people can have the effect of prolonging the time hatchlings are in the nest chamber. Since mammalian predators hunt by smell, and there is an added odor from the hatching eggs, prolonging the time in nests increases their vulnerability. Thus managers can increase snake productivity and recruitment by reducing human disturbance, allowing hatchling snakes to emerge quickly and disperse to hiding places. Disturbance during emergence is a general problem for reptiles such as lizards, turtles and snakes that lay their eggs underground or under logs or other debris. Once the eggs hatch, the hatchlings are more vulnerable than during the egg stage because of hatching odors. Managers might consider limiting human disturbance to vulnerable nesting habitats during the critical hatching and emergence phase. The field data in this paper suggest that a set-back distance of more than 12 m is necessary to protect emerging pine snakes.

Acknowledgments I thank M. Gochfeld, R. T. Zappalorti and E. DeVito for helpful comments during this research, the New Jersey Department of Environmental Protection (Endangered and NonGame Program) for appropriate permits, and the Tiko Fund for partial support.

References

Blane JM, Jaakson R (1994) The impact of ecotourism boats on the St. Lawrence beluga whales. Environ Conserv 21:267–269

Burger J (1986) The effect of human activity on shorebirds in two coastal bays in northeastern United States. Environ Conserv 13:123–130

Burger J (1991) Foraging behavior and the effect of human disturbance on the Piping Plover (*Charadrius melodus*). J Coast Res 7:39–52

Burger J, Gochfeld M (1985) Behavioral development: nest emergence of young pine snakes (*Pituophis melanoleucus*). J Comp Psychol 99:150–159

Burger J, Zappalorti RT (1986) Nest site selection by pine snakes, *Pituophis melanoleucus*, in the New Jersey pine barrens. Copeia 1986:116–121

Burger J, Zappalorti RT (1988a) Habitat use in free-ranging pine snakes *Pituophis melanoleucus* in the New Jersey pine barrens. Herpetologica 44:48–55

Burger J, Zappalorti RT (1988b). Effects of incubation temperature on pine snakes *Pituophis melanoleucus* in the New Jersey pine barrens. Herpetologica 44:48–55

Burger J, Zappalorti RT (1991) Nesting behavior of pine snakes *(Pituophis m. melanoleucus)* in the New Jersey pine barrens. J Herpetol 25:152–160

Burger J, Zappalorti RT (1992) Philopatry and nesting phenology of Pine Snakes *Pituophis melanoleucus* in the New Jersey pine barrens. Behav Ecol Sociobiol 30:331–336

Burger J, Jeitner C, Jensen H, Fitzgerals M, Carlucci S, Shukla S, Burke S, Ramos R, Gochfeld M (2004) The behavioral response of basking Northern water (*Nerodiasipedon*) and Eastern garter (*Thamnophis sirtalis*) snakes to pedestrians in a New Jersey park. Urban Ecosyst 7:17–27

Burger J, Zappalorti RT, Gochfeld M (2000) The defensive behaviors of pine snakes *(Pituophis Melanoleucus*) and black racers (*Coluber Constrictor*) to disturbance during hibernation. Herpetol Nat Hist 7:59–66

Burger J, Zappalorti RT, Dowdell J, Hill J, Georgiadis, T, Gochfeld M (1992) Subterranean predation on pine snakes *(Pituophus melanoleucus)*. J Herpetol 26:259–263

Carney KM, Sydeman WJ (1999) A review of human disturbance effects on nesting colonial waterbirds. Waterbirds 22:68–79

Dowd C (1992) Effect of development on bird species composition of two urban forested wetlands in Staten Island, New York. J Field Ornithol 63:455–461

Downes S (2001) Trading heat and food for safety: costs of predator avoidance in a lizard. Ecol 82:2870–2881

Fernandez-Juricic E (2000) Local and regional effects of pedestrians on forest birds in a fragmented landscape. Condor 102:247–255

Jokimaki J, Suhonen J (1993) Effects of urbanization on the breeding bird species richness in Finland: a biogeographical comparison. Ornis Fenn 70:71–77

Keller VE (1991) The effect of disturbance from roads on the distribution of feeding sites of geese (*Anser brachyrhynchus, A. anser*), wintering in north-east Scotland. Ardea 79:228–232

Knight BL, Gutzwiller KJ (eds) (1995) Wildlife and recreationists. Island, Washington DC

Knight RL, Temple SA (1995) Wildlife and recreationists: coexistence through management. In Knight RL, Gutzwiller KJ (eds) Wildlife and recreationists. Island, Washington DC, pp327–334

Lima SL, Dill LM (1990) Behavioral decisions made under the risk of predation: a review and prospectus. Can J Zool 68:618–640
Parent C, Weatherhead PJ (2000) Behavioral and life history responses of eastern massasauga rattlesnakes (*Sistrurus catenatus catenatus*) to human disturbance. Oecologia 125:170–178
Pfister C, Harrington BS, Lavine M (1992). The impact of human disturbance on shorebirds at a migration staging area. Biol Conserv 74:115–126
Rees WE (1997) Urban ecosystems: the human dimension. Urban Ecosyst 1:63–75
Roberts G, Evans PR (1993) Responses of foraging sanderlings to human approaches. Behaviour 126:28–43
Rodgers JE (1997) Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in Florida. Wildl Soc Bull 25:139–145
Rodgers JE, Smith HT (1995) Set-back distances to protect nesting bird colonies from human disturbance in Florida. Conserv Biol 9:89–99
Statistical Analysis System (SAS) (1995) SAS users' guide. Statistical Institute, Inc, Cary, NC
Weatherhead PJ, Robertson IC (1992). Thermal constraints on swimming performance and escape response of northern water snakes (*Nerodia sipedon*). Can J Zool 70:94–98
Ydenberg RC, Dill LM (1986). The economics of fleeing from predators. Adv Stud Behav 16:229–249