Use of artificial nests to investigate predation on freshwater turtle nests

Michael N. Marchand, John A. Litvaitis, Thomas J. Maier, and Richard M. DeGraaf

Abstract Habitat fragmentation has raised concerns that populations of generalist predators have increased and are affecting a diverse group of prey. Previous research has included the use of artificial nests to investigate the role of predation on birds that nest on or near the ground. Because predation also is a major factor limiting populations of freshwater turtles, we examined the potential of using artificial nests in identifying factors that limit recruitment. We buried eggs of northern bobwhites (*Colinus virginianus*) to simulate turtle nests and placed remotely triggered cameras at a sample of nests to identify predators. Twenty-two percent of all nests were either depredated or disturbed within 7 days of placement. The proportion of nests depredated decreased with increasing distance from the edge of ponds. Predation was greater on nests within 50 m of pond edges than nests farther from pond edges. Clumped nests were depredated at a greater rate than scattered nests. Remotely triggered cameras at nests indicated that raccoons (*Procyon lotor*) were the most frequent nest predators. Some potential biases associated with the use of artificial nests in avian studies (e.g., lack of parental care) might not apply to the application of artificial nests in studies of turtle demography. We conclude that artificial nests might be useful to investigate factors that limit populations of freshwater turtles.

Key words artificial nest, fragmentation, New Hampshire, nest predation, reptile, turtle

Habitat loss and fragmentation have known consequences for a number of vertebrate taxa, including birds (Wilcove 1985, Yahner 1988, Robinson et al. 1995), mammals (Henderson et al. 1985, Barbour and Litvaitis 1993, Keith et al. 1993), and amphibians (Vos and Stumpel 1995, Gibbs 1998, Knutson et al. 1999). Among these consequences are potential increases in populations of generalist predators that benefit from human-altered habitats (Wilcove 1985, Robinson and Wilcove 1994, Oehler and Litvaitis 1996). Such predators (e.g., raccoon [*Procyon lotor*], striped skunk [*Mephitis mephitis*], and fox [*Urocyon cinereoargenteus* and *Vulpes vulpes*]) might severely reduce the abundance of prey restricted to remnant patches of habitat. These small patches of habitat might concentrate prey and be easily penetrated by predators, elevating both foraging efficiency and predator abundance (Andrén and Angelstam 1988, Brown and Litvaitis 1995, Schneider 2001). Increased predator abundance might be a major proximate factor causing the regional declines of some prey species (Oehler and Litvaitis 1996).

The consequences of habitat fragmentation on reptiles have received little attention (exceptions include Dodd 1990, Parker and Whiteman 1993, Gibbons et al. 2000, Kjoss and Litvaitis 2001). In comparison to a number of mammals and birds, reptiles could be especially vulnerable to fragmentation due to limited dispersal capabilities, delayed sexual maturity, and relatively low fecundity (Congdon et al. 1993). Also, because juvenile reptiles

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often are difficult to observe, a reduction in recruitment might go undetected until the abundance of adults began to diminish. Although high adult survivorship is crucial in maintaining stable populations of turtles, all life stages must be considered for successful conservation of turtle populations (Brooks et al. 1991, Congdon et al. 1993). Predation (especially by mammals) often is the leading cause of turtle egg mortality (Congdon et al. 1983), and rates of predation can approach 100% (Congdon et al. 1987). For example, nest survival and turtle recruitment increased following a removal of raccoons in Iowa (Christiansen and Gallaway 1984). Also, turtle nests near edge habitats might suffer increased rates of predation, potentially resulting from an abundance of predators attracted to habitat edges (Temple 1987).

Because of the difficulty in locating natural turtle nests, artificial nests might be useful in investigating the role of predation on turtle populations. Artificial nests have been used extensively to investigate patterns of predation on avian populations (e.g., see the review by Major and Kendal 1996) and might provide insight into factors limiting recruitment in turtle populations. We used artificial nests to address the following questions: 1) Does nest distribution (i.e., near vs. far from a pond; scattered vs. clumped) affect vulnerability to predation? and 2) What species are the major potential predators of turtle nests?

Study area

We used 18 ponds (0.3–4.3 ha) within a 900-km^2 portion of Strafford and Rockingham counties, New Hampshire, for nest experiments. Landscapes surrounding ponds consisted of a mosaic of forests, agricultural areas, fields, and developed areas. New Hampshire is largely forested (ca 85%; Sundquist and Stevens 1999), but the southern portion of the state has undergone rapid development and increases in human populations (Vogelmann 1995). New Hampshire was the fastest-growing state in the Northeast between 1990 and 1998 (7% population increase), and increases in human populations and forest fragmentation are predicted to continue (Sundquist and Stevens 1999).

Dominant overstory species included American beech (*Fagus grandifolia*), maples (*Acer* spp.), oaks (*Quercus* spp.), eastern white pine (*Pinus strobus*), and eastern hemlock (*Tsuga canadensis*). Semi-aquatic and aquatic turtles in the region included painted (*Chrysemys picta*), snapping (*Chelydra serpentina*), musk (*Sternotherus odoratus*), spotted (*Clemmys guttata*), wood (*Clemmys insculpta*), and Blanding's turtles (*Emydoidea blandingii*) (Taylor 1993). The last 3 species are currently considered rare in New Hampshire (Kanter et al. 2001). The painted turtle was the most abundant species occurring within the study area (M. N. Marchand and J. A. Litvaitis, unpublished data). Potential nest predators in our study area included raccoon, striped skunk, red and gray fox, coyote (*Canis latrans*), opossum (*Didelphis virginiana*), fisher (*Martes pennanti*), mink (*Mustela vison*), and eastern chipmunk (*Tamias striatus*).

Methods

Rates of predation and influence of nest distribution

We created 20 artificial turtle nests in areas surrounding each of 18 ponds in both scattered (n = 10) and clumped (n = 10) designs (360 nests total). Areas in which we placed nests consisted of mostly small clearings in the forest canopy, dirt trails within forested areas, roadside banks, fields, and lawns. Two scattered nests were constructed each at distances of 0, 50, 100, 150, and 200 m from pond edges in the most suitable nesting habitat available between 30 May and 24 June 2000. We constructed clumped nests (10 nests within an area <0.2 ha) within 50 m of the edge of each pond between 29 June and 21 July 2000. Both nest exposure periods were within the nesting season of painted turtles (late May through July; Ernst et al. 1994).

For each nest, we excavated a hole approximately 10 cm deep with a trowel and placed 3 commercially obtained northern bobwhite (*Colinus virginianus*) eggs (Strickland Game Bird Farm Inc., Pooler, Ga.) in the hole and covered them with soil. Nesting female turtles often release bladder water while digging out a nest (Ernst et al. 1994), and we attempted to mimic this by utilizing water from a tank that held several captive female painted turtles. We sprayed this water onto the eggs in the nest and also on the surface of the completed nest. To minimize human scent left at nests, we wore rubber boots and gloves, and placed equipment on a plastic drop sheet while creating artificial nests (Whelan et al. 1994). We recorded the location of each nest with a handheld GPS unit and placed plastic flagging within 3 m to enable our quick relocation of the nest.

Within each nest distribution type, we created all nests at a pond on the same day and recorded nest fate after 7 days of exposure. Each nest was recorded as depredated (≥1 egg was consumed), disturbed, or survived. Disturbed nests sometimes resulted in exposed eggs, increasing their vulnerability to predation, desiccation, or drowning from precipitation accumulating in the nest. Therefore, we combined disturbed and depredated nest data for all analyses. We used a 7-day sampling period because real turtle nests often suffer the greatest predation during the first several days after nest excavation (Tinkle et al. 1981, Congdon et al. 1983, Christens and Bider 1987; but see Snow 1982). Similarly, most artificial nests were depredated in the first 7 days of a 21-day sampling period (Hamilton et al. 2002).

Predator identification

We placed remotely triggered cameras on a sample (≥3 per pond) of both scattered ($n=52$) and clumped nests ($n=36$). We set cameras to record the time and date on the photographs. Cameras were triggered by a non-mercury tilt switch activated when the nest was disturbed (Maier et al. 2002). Due to potential for theft at some locations, we did not place cameras at all ponds. Therefore, the number of cameras differed among individual ponds and artificial nest types.

Data analysis

We used a test for linear trend to determine whether there were differences in the proportion of scattered nests depredated at 5 distances from pond edges (Zar 1999: 565). Because all clumped nests were within 50 m of pond edges, we grouped scattered nests as those near (0 and 50 m) and far (100, 150, 200 m) from pond edges and used a 2 × 2 contingency table with a 2-tailed Fisher exact test to determine whether rates of predation differed among grouped distances. Given that grouped distances differed for scattered nest patterns, we truncated our scattered data at 50 m and compared nests of similar distances (≤50 m) for the 2 nest types. We used a Wilcoxon signed-rank test to compare the percentage of nests depredated at each pond among scattered- and clumped-nest distributions. Additionally, we examined the potential effect of camera presence on rates of predation. We tested scattered nests within 50 m of pond edges for a camera effect with a 2-tailed Fisher exact test. For clumped-nest trials, the presence of a camera potentially could have impacted all other nests within the same clump. Therefore, we compared rates of predation for clumps having 2–3 cameras present ($n=14$) with clumps having no cameras present ($n=4$). Because of the large divergence in sample sizes, we simply compared rates of predation between groups. Significance levels for all tests were $P<0.05$.

Results

Rates of predation and influence of nest distribution

Twenty-two percent of all nests ($n=78$ of 360) were either depredated or disturbed. Prior to truncating our scattered-nest data to those ≤50 m from a pond edge, predation on scattered artificial nests (8%, range = 0–20%) was less than that on clumped nests (36%, range = 0–100%; $Z=2.519$, $P=0.012$). The proportion of scattered nests preyed upon decreased with increasing distance from pond edges (linear trend: $\chi^2=8.713$, $P=0.003$, Figure 1). Scattered nests near to (≤50 m) had a greater percentage depredated than those far from (≥100 m) pond edges (15% vs. 3%; Fisher exact test, $P=0.003$). Nineteen percent ($n=36$) of scattered nests at the pond edge were depredated, 11% ($n=36$) at 50 m, and only 3% ($n=36$) of nests 100, 150, and 200 m from a pond were depredated. After truncating scattered-nest data at 50 m, clumped nests were depredated at a greater rate than scattered nests ($Z=2.049$, $P=0.04$).

Predator identification

Raccoons were the most frequently detected predator (14 nests at 5 pond sites). We also photographed fishers (4 nests at 3 sites) and a gray fox

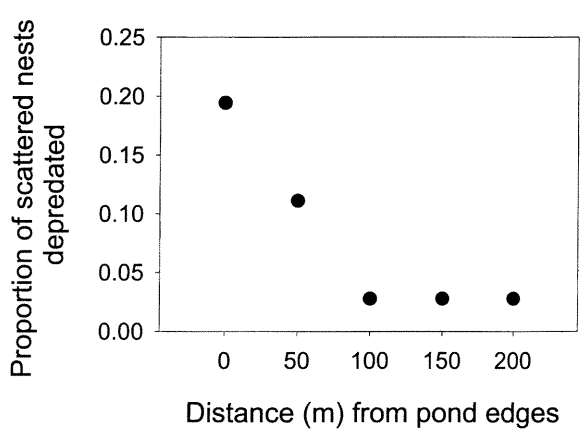

Figure 1. Proportion of scattered artificial turtle nests depredated decreased with increasing distance from the edge of ponds in southeastern New Hampshire, 30 May–1 July 2000.

Figure 2. Gray fox (*Urocyon cinereoargenteus*) excavating artificial turtle nest at 0150 hours on 4 June 2000 in southeastern New Hampshire.

(1 nest at 1 site; Figure 2) preying on nests. Red squirrels (*Tamiasciurus hudsonicus*) were photographed disturbing 2 nests (at different sites), but these nests were not depredated. Other species photographed that did not prey on nests included white-tailed deer (*Odocoileus virginianus*, $n=1$), American crows (*Corvus brachyrhynchos*, $n=2$), gray squirrel (*Sciurus carolinensis*, $n=1$), and a mouse (*Peromyscus* sp., $n=1$). Two species of nest predator were photographed at individual nests on 2 occasions (raccoon and fisher; gray fox and raccoon). Additionally, several cameras photographed pairs of raccoons at individual nests. Among nests with cameras, the average number of nights until predation was similar among scattered nests (3.3 nights, SD = 1.8, $n=7$) and clumped nests (3.6 nights, SD = 1.9, $n=10$).

Predation of scattered nests was more frequent within 50 m of a pond when a camera was present (30%, $n=27$) than at nests without cameras (7%, $n=45$; Fisher exact test, $P=0.015$). Clumps with a camera present (32%±37 SD, range = 0–100%) were not depredated at a greater rate than clumps without cameras (48%±43 SD, range = 0–100%). Predation of scattered nests with a camera present was greater for nests near water than for nests far from water (Fisher exact test, $P=0.025$), supporting the observed distance effect.

Discussion

Use of artificial nest experiments to examine nest predation of turtle populations has received little attention. In an early application of artificial nests, Patterson (1971) buried chicken eggs in clear boxes and exposed them to zoo canids in order to examine the role of turtle bladder water. At a wildlife refuge in New Jersey, predators readily excavated dummy nests containing snapping turtle eggs, dove eggs, chicken eggs, and ping-pong balls (Wilhoft et al. 1979). Recently, Hamilton et al. (2002) utilized artificial nests to investigate the effects of deer feeders, habitat, and sensory cues on rates of turtle nest predation. Numerous biases associated with the application of artificial nests to study avian predation have been noted (Major and Kendal 1996, Wilson et al. 1998, King et al. 1999). Some potential biases (e.g., lack of parental care at artificial nests, egg size, and color differences) might not be as important in the use of artificial nests for turtles, whereas others might be unique to turtles. For example, scent trails left by female turtles while traveling from water to nest sites might aid predators in locating nest sites; however, predation can occur without visual or olfactory cues associated with nesting turtles (Wilhoft et al. 1979).

Predation rates reported for natural turtle nests (e.g., Congdon et al. 1983, 63%; Burke et al. 1998, 84.2%) often are greater than the average predation rate for our artificial nests. However, rates of predation in our study (all nests = 22%, clumped nests = 36%) were similar to those reported for a group of painted turtle nests in Michigan (Tinkle et al. 1981, 21%). Predation rates among our ponds varied from 0–100% for clumped-nest distributions. Similarly, large annual variations in rates of predation have been reported for real turtle nests. For example, the average predation rate of a snapping turtle population was 70% over an 8-year period, and rates varied from 30–100% (Congdon et al. 1987). Although studies examining rates of predation for real turtle nests often monitored nests for the entire incubation period, most predation occurred within the first several days following nest construction (Tinkle et al. 1981, Congdon et al. 1983, Christens and Bider 1987). For example, 88% of artificial turtle nests were destroyed by predators during a 21-day exposure period, with the largest percentage of nests depredated within the first 7 days (Hamilton et al. 2002).

Wilson et al. (1998) warned against the use of artificial avian nests as a measure of actual predation rates, but suggested this approach might be useful in revealing patterns of predation. In our assessment of artificial nests to examine factors affecting predation of turtle nests, we provide several examples of how artificial nests could be used.

Our results indicated that rates of freshwater turtle nest predation might decrease with increased distance from water. Predation on painted turtle nests was greater at locations near ponds (Legler 1954, Christens and Bider 1987), but other investigators did not detect a distance effect for predation rates on other turtle species (Congdon et al. 1987, Robinson and Bider 1988, Burke et al. 1998). However, any increase in nest success associated with greater distance from water might not correspond to increased recruitment. Hatchling turtles, as well as adult females, traveling a long distance from nest sites to ponds could incur greater mortality than those individuals traveling only a short distance to water. The distance that adult females travel to nest sites might vary among individuals, species, and availability of nesting habitat. Freshwater turtles in South Carolina traveled up to 275 m to nest; however, 90% of nest and upland hibernation sites were within 73 m of the wetland perimeter, and 44% of sites were within 30.5 m of the wetland perimeter (Burke and Gibbons 1995).

Our results also indicated that clumped nests might suffer greater rates of predation compared to scattered-nest distributions. Because individual nests were closer together when clumped, a predator might have had an increased chance of finding a second nest once the first nest was located. Additionally, predators could have spent time searching in areas where a greater reward was available. For example, clumped nests might suffer greater predation as a result of "area-concentrated searches" conducted by predators (Andersson and Wiklund 1978). Predation of snapping turtle nests was greater when nests were clustered (≤1 m to nearest nest) than when nests were separated (Robinson and Bider 1988). Similarly, nests of diamondback terrapins (*Malaclemys terrapin*) located within 1 m of other nests suffered greater rates of predation (Burger 1977). However, Burke et al. (1998) investigated the effect of nest density on predation rates of turtle nests in South Carolina and found no relationship. If predators search areas where they have previously located nests, clumped nests might be encountered more often than scattered nests. In our study, we conducted clumped-nest trials after the scattered-nest trials were completed at each pond site. If predators learned where nests were located, they likely had a greater chance of locating a second nest placed in the same location. However, it was unlikely that predators learned between nest trials because predation rates on scattered nests were extremely low (0–20%).

Remotely triggered cameras were effective at identifying nest predators. Raccoons were the most frequent nest predators at our artificial nests, consistent with observations of real turtle nests (e.g., Christiansen and Gallaway 1984, Christens and Bider 1987). To our knowledge, fishers previously had not been reported to depredate turtle nests (artificial or natural) at other sites. However, fishers frequently have been photographed depredating artificial avian nests in New Hampshire (DeGraaf 1995, Sloan et al. 1998). In our trials with scattered nests, those with cameras had greater predation rates than nests without cameras; however, this trend was not consistent with clumped-nest trials. It is possible that the increased time we spent at clumped-nest locations resulted in a concentrated odor, regardless of whether cameras were present. However, our cameras were not placed randomly at nest sites, making results statistically invalid. Cameras are commonly used in field studies to identify predators and investigate predator behavior (Cutler and Swann 1999). However, the effect of camera systems on predation rates must be investigated further if results from similar studies are to be interpreted accurately.

In addition to factors addressed in this paper, artificial nests could be used to investigate other factors influencing rates of predation. For example, vegetative cover at the nest might affect predator detection. Nests of snapping turtles located under moderate amounts of vegetation had greater survival (60%) than those found under little (35%) or no vegetation (11%) (Robinson and Bider 1988). In an ongoing study, we are sampling habitat features at several spatial scales (*sensu* Brown and Litvaitis 1995) to determine whether land-use patterns alter vulnerability to predation.

Our nests mimicked those of painted turtles; however, the patterns of nest predation we detected are relevant to other species of turtles, including those considered less abundant. With the declines of a number of turtle species and an increase in habitat loss and fragmentation, it is necessary to understand whether and how recruitment of turtles is being altered. Attempts at managing habitats, such as creating artificial nesting areas to enhance recruitment (e.g., Kiviat et al. 2000), might prove unsuccessful if predation patterns are not considered. Our application of artificial nests suggested this might be a useful tool in comprehensive investigations of turtle demography.

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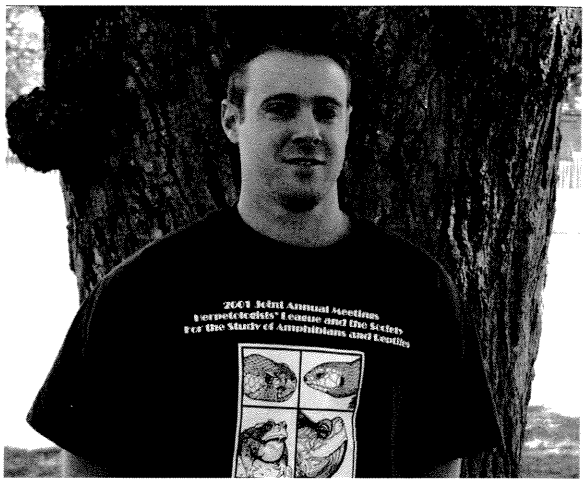

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