THE IMPACTS OF PREDATION ON WILD TURKEYS

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Abstract: Concerns that greater predator populations and accelerating habitat fragmentation may exacerbate impacts of predation on wild turkey (*Meleagris spp.*) populations prompted our examination of the literature on this subject. We found several major themes throughout this search. Variability in nest and renest initiation may account for low production in some populations and may be confused with effects of nest predation. For most wild turkey populations, nesting success was low, with predation responsible for the loss of most unsuccessful nests. Raccoons (*Procyon lotor*) were the most commonly reported nest predator. Poult survival was low, with predation the major cause of mortality. Predation also was the major cause of mortality among yearling and adult wild turkey hens and yearling gobblers. Hunting was the major cause of mortality for adult gobblers. Predator control was successful in increasing wild turkey productivity in short-term specific instances where a small cadre of identified nest and poult predators was targeted, but numerous factors impact the success of control programs. Control of wild turkey predators is cost ineffective as a broad management strategy and is not accepted by the public.

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The wild turkey has made a remarkable comeback in North America from what many considered the road to extinction. Due to restoration efforts by state game agencies and many other entities, wild turkeys now number over 5.4 million (Tapley et al. 2001). Viable populations exist in every state, except Alaska, and in Mexico and several Canadian provinces. The ocellated turkey (*M. ocellata*) exists in viable populations in Mexico, Guatemala, and Belize.

In most areas, wild turkey numbers are stable or continue to increase, but some local-level populations are declining. These declines have prompted concern among biologists and the public that predation may cause these declines. Anecdotal reports of the devastating effects of predation on wild turkeys abound, and include everything from nest destruction to decimation of adults by a variety of predators. In the past, recommendations to lessen predation rates have been generally indirect and habitat based rather than centering on direct predator control. Recently, however, concerns have been raised among the biological community that changing habitats and increasing predator populations may call for more direct methods.

With development and expansion of urban areas and other changing land uses, habitat fragmentation is increasing (Flather et al. 1989). Areas of high-quality wild turkey habitat are lost resulting in smaller segments left for foraging, nesting, and brood rearing. With the declining fur market, populations of mammalian predators are increasing (Sargeant et al. 1993, Woolf and Hubert 1998) and regulatory protection and curtailed use of certain pesticides has allowed a similar increase in many avian predators (Sauer et al. 2004).

Therefore, our objectives were to (1) examine the literature on effects of predation on wild turkeys at each stage of the life cycle, (2) determine if predators are limiting turkey populations, and if so, (3) evaluate

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if predator management is an effective tool to increase turkey populations.

RESULTS

Nesting

Nest Initiation

To fully understand effects that predation has during the nesting phase of the wild turkey's life cycle, it is necessary to examine the dynamics and variability of nest initiation. High production may confound detection of predation losses, and low production may appear to be related to high predation rates when it may simply result from a low rate of nest initiation.

Different turkey populations exhibit wide ranges of nest initiation rates, often with varying rates for adult and yearling hens. Roberts et al. (1995) for eastern hens (*M. g. silvestris*) in New York, found higher nesting rates for adult hens than for yearlings. In Alabama, Hillestad (1973) noted that of 5 hens radio-tracked in 1968, only one was known to nest. However, on the same site in 1969, nest initiation was 100% (5 of 5) for adults and 60% (3 of 5) for yearlings. On a different Alabama site, Everett et al. (1980) found an initial nesting rate of 88% (29 of 33) for adult hens, whereas 85% (11 of 13) of the yearlings attempted to nest. Lower rates were reported in Mississippi, where overall initial nest initiation rates during 1984–1995 averaged 72% (Miller et al. 1998*b*).

Nesting rates may differ among subspecies. Typically, the eastern subspecies shows high nest initiation rates, even for yearlings. In Wisconsin, Paisley et al. (1998) found nesting rates for adults to range from 95% to 100% compared to 67% to 100% for yearlings. Even where they have been translocated from Iowa and Missouri to South Dakota, nest initiation rates remain high for eastern turkeys, ranging from 81 to 94% (Lehman et al. 2001, Leif 2001).

Nest initiation rates for the Merriam's subspecies (*M. g. merriami*) are often reported as low, especially for yearlings. Wakeling (1991), in Arizona, found a high of 62% nest initiation for adults in 1988 and a low of 33% in 1989. Similar results were reported for a South Dakota population where Wertz and Flake (1988) found an average adult nesting rate of 42% during 1984–1985 and no nest initiation by yearlings, while Flake and Day (1996) found nesting rates of 77% (36 of 47) and 17% (1 of 6) for adult and yearling hens, respectively. However, in the central Black Hills of South Dakota, Rumble and Hodorff (1993) reported a nest initiation rate of 97% for adults and 73% for yearlings. An Oregon population of Merriam's turkeys exhibited similarly high nest initiation for adults (100%), but a much lesser rate for yearlings (31%) (Lutz and Crawford 1987). Rumble et al. (2003) suggested a correlation between adult and yearling nesting rates for Merriam's turkeys in which yearling nesting rates are low or nonexistent until adult nesting rates exceed 60%.

Two studies of the Rio Grande subspecies (*M. g. intermedia*) reproductive behavior show an interesting contrast. The first, in ancestral Rio Grande turkey range on the Edwards Plateau in central Texas, recorded nesting behavior for only 38 of 53 hens for a nest initiation rate of 72% (Reagan and Morgan 1980). The second study, on a translocated Rio Grande turkey population in Oregon, showed a much greater nest initiation rate of 99% (67 of 68) for adults and 94% (31 of 33) for yearlings (Keegan and Crawford 1993). This may suggest that habitat quality may be more important than subspecies or other factors in influencing nest initiation.

In a south Florida study, the Osceola subspecies (*M. g. osceola*) exhibited a relatively low rate of nest initiation, with nests discovered for only 59% (202 of 345) of monitored hens (Williams and Austin 1988). Greater nest initiation rates were seen for ocellated turkeys in Guatemala, where 89% (8 of 9) instrumented hens attempted to nest (Gonzalez et al. 1996). For the Gould's turkey (*M. g. mexicana*), Schemnitz et al. (1990) reported that 1 of 2 radio-transmittered hens attempted to nest.

Renest Initiation

An important factor in the overall examination of nesting, renesting can contribute significantly to the overall productivity of a population. The rates at which hens attempt to renest after loss of a clutch or brood, also may be an indicator of population viability.

In an Oregon Rio Grande population, Keegan and Crawford (1993) found renesting to be very important to overall nesting success. Renesting rates for adult and yearling hens that lost clutches were 74% (39 of 53) and 25% (4 of 16), respectively. Total renesting accounted for 30% (43 of 141) of all nests, 19% (12 of 63) of successful nests, and 17% (98 of 568) of poults hatched during the study period. Renesting after brood loss accounted for 30% (13 of 43) of all renesting attempts and 33% (4 of 13) of all successful renesting attempts. None of the 16 yearling hens that lost broods renested.

Renesting may be of varied importance in other populations. For the Osceola subspecies, Williams and Austin (1988) found a relatively low renest initiation rate of only 28% (26 of 93). Similar results were found for eastern wild turkeys in Alabama, where only 22% (3 of 13) adults and 0.0% (0 of 4) yearlings attempted to renest (Everett et al. 1980) and in Mississippi (Miller et al. 1998*b*) where renest initiation rates averaged only 34%. However, in Wisconsin, Paisley et al. (1998) found renesting to average 55% for that eastern population and also found that 13% of adult hens attempted a third nest, but no yearlings did so. For 27 eastern hens in South Dakota that lost their first nest, 26% (7 of 27) attempted to renest (Leif 2001). Renesting was an important reproductive parameter for eastern and Rio Grande turkeys in northeastern South Dakota, ranging from 50 to 100% during 3 years of study (Lehman et al. 2001). Renesting may be important for the ocellated turkey in Guatemala, because Gonzalez et al. (1996) found a renesting rate of 40% (2 of 5). Renesting was much more common in Mer-

riam's turkeys in South Dakota (Rumble and Hodorff 1993) than in Arizona (Wakeling et al. 1998).

When combined with variable first nest initiation rates, the considerable variability of renest initiation serves to illustrate the complexity of attempting to analyze the factors influencing wild turkey productivity, particularly when nest success is added to the mix.

Nesting Success

Even when wild turkey hens initiate nests, the successful hatching of eggs is far from certain. Nests are lost from a variety of causes, including human disturbance, flooding, inclement weather, fire, and predation. Nest success may be the primary factor affecting annual population change. Roberts et al. (1995) considered the variability of annual nesting success to be the most important factor in determining annual population fluctuation in New York.

There appears to be little difference in nesting success due to the hen age. Keegan and Crawford (1999) found nesting success for a Rio Grande population in Oregon to range from 50 to 70% among years, but found no difference between adults and yearlings. Roberts et al. (1995) also reported no difference in nesting success due to age of the hen in New York. Adult hens, though, may fare better in some areas, as they are more likely than yearlings to choose nesting sites in core habitat as opposed to edges (Thogmartin 1999). In the Arkansas Ozarks, Badyaev et al. (1996) found smaller breeding season (spring) home ranges for adult hens than for yearlings, possibly causing differences in vulnerability to predation between adult and yearling hens.

Wild turkey research has consistently documented relatively low nesting success. In Alabama, Speake (1980) found that over 44% of 119 eastern wild turkey nests were lost to predation. Vander Haegan et al. (1988), in Massachusetts, found even lower nesting success, with over 55% of wild turkey nests failing to produce young. Of the nests lost (21 of 38), 12 were lost to predation (7 to egg predation and 5 to predation of the hen). On the Waterhorn Unit of the Francis Marion National Forest in South Carolina, from 1982–1984 radiomarked adult hens produced a total of 27 nests. Only 11 (55%) of these were successful, 7 (26%) were abandoned due to human disturbance, 6 (30%) were destroyed by predators, 2 (10%) were flooded, and 1(5%) was abandoned for unknown reasons (Still and Baumann 1990).

Western subspecies also show relatively low nesting success. Flake and Day (1996), for a Merriam's turkey population in South Dakota, found a nesting success rate of 44% (17 of 39), with predation accounting for the failure of 19 of 22 unsuccessful nests. In northern Texas, Hohensee and Wallace (2001) found that 6 of 19 Rio Grande turkey nests were successful, with nest depredation by mammals accounting for 53% of the nest loss. Ransom et al. (1987) found that of 10 nests by Rio Grande hens monitored in south Texas, all were destroyed by nest predators.

Nest studies in which artificial nests are made using chicken or domestic turkey eggs typically show high rates of predation. In Alabama, Davis (1959) found that of 107 artificial nests, only 16 remained undisturbed. In one set of 78 artificial nests in Texas, 77 were destroyed by predators (Baker 1979).

In a declining population of eastern wild turkeys in the Ouachita Mountains in Arkansas, Thogmartin (1998) found that 87% of wild turkey nests failed, primarily due to predation. Lowery et al. (2001) states that predation is thought to be a more important factor in nest success than weather conditions. Certainly, predation is the most consistently reported cause of nest failure for adults and yearling hens and by subspecies.

Nest Predators

The raccoon is the primary nest predator over most of the wild turkey's range (Davis 1959, Speake 1980, Ransom et al. 1987, Williams and Austin 1988). In an early poisoned egg study, Davis (1959) found that almost one-third of 107 artificial nests were destroyed by raccoons.

Raccoons have demonstrated learned behavior associated with predation of wild turkey nests. In a test of their ability to learn, Johnson (1970) provided chicken eggs to captive raccoons. Those raccoons captured from areas with good turkey populations immediately ate the eggs, whereas raccoons from areas with no turkeys did not open the eggs and did not seem to know that they contained food. Raccoons may increase their home range size during turkey nesting season, possibly in search of nests. Priest et al. (1995) observed an increase in home range and a shift from bottomland hardwoods to upland pine areas for raccoons during the spring in Mississippi. At the same time, most of the wild turkey hens on this area also left their winter range in the bottomland areas and initiated nests in the upland pine habitat (Seiss 1989).

Other significant mammalian nest predators include the opossum (*Didelphis virginiana),* spotted and striped skunks (*Spilogale putorius* and *Mephitis mephitis*), gray foxes *(Urocyon cinereoargenteus*), red foxes (*Vulpes vulpes*), and coyotes (*Canis latrans*) (Davis 1959, Baker 1979, Williams et al. 1980, Williams and Austin 1988, Paisley et al. 1998, Hohensee and Wallace 2001). Feral or free-ranging dogs (*Canis familiaris*) also may be significant nest predators (Speake 1980).

The most significant avian nest predator is the crow (*Corvus* spp.), and they are widely reported as responsible for wild turkey nest predation (Davis 1959, Speake 1980, Williams et al. 1980, Vander Haegan et al. 1988, Rumble and Hodorff 1993). In Montana, nest predation is also attributed to ravens (*Corvus corax*) and black-billed magpies (*Pica pica*) (Thompson 1993).

A variety of other species have been reported to prey on turkey nests, but usually not at significant levels. However, in Texas, Reagan and Morgan (1980) attributed nearly 50% of the nest predation they ob-

served to snakes, including rat snakes *(Elaphe obosoleta*) and bull snakes (*Pituophis melanoleucus*). In this same study, a rock squirrel (*Spermophilus variegatus*) was observed destroying a nest.

Other species that are popularly suspected as nest predators include the feral hog (*Sus scrofa*) and the armadillo (*Dasypus novemcinctus*), but most evidence suggests that they are not significant turkey nest predators. Feral hogs have occasionally been implicated for wild turkey nest disturbance (Davis 1959, Hohensee and Wallace 2001), but even at high population levels they normally do little damage (Williams et al. 1980). Kennamer and Lunceford (1973), using artificial nests, observed some nest disturbance by armadillos, but no evidence that they ate any eggs. In Florida, Williams et al. (1980) also found no evidence of egg predation by armadillos.

Poult Predation

Mortality

Low poult survival is very well documented for the eastern subspecies of wild turkeys, with most losses occurring during the first 2 weeks after hatching. Overall poult mortality is usually reported to range from 60 to 80% (Glidden and Austin 1975, Everett et al. 1980, Speake 1980, Speake et al. 1985, Vangilder et al. 1987, Vander Haegan et al. 1988, Hubbard et al. 1999*a*). Even greater rates have been reported, however. In south Georgia and north Florida, Peoples et al. (1995), found a 6-year average poult mortality >90%, with 96% of the total mortality occurring within 14 days of hatching.

Less information is available for other wild turkey subspecies, but low poult survival rates are documented in 2 studies on Merriam's turkeys. In South Dakota, Flake and Day (1996) found a mortality rate of 57% during the first 2 weeks post-hatch, but no further poult loss was documented through mid-August. In Wyoming, Hengel (1990) found a poult mortality rate of 64%. Reported Gould's turkey poult mortality of about 60% is consistent with the other subspecies, with all or most mortality occurring during the first 2 weeks after hatching (Schemnitz et al. 1990). Little research has been conducted on poult mortality among ocellated turkeys, but Gonzalez et al. (1996) observed a very high mortality rate of 87%, with only 4 of 31 poults surviving the summer.

Cause for poult mortality is difficult to determine because poults at their most vulnerable age are small and hard to observe. However, predation is obviously an important factor. Speake et al. (1985) determined the cause of death for 49% of poults that died during their study. Among the group of poults where cause of death could be determined, predation accounted for 82% of losses. Mammal, avian, and reptile predators accounted for 42, 16, and 7% of losses, respectively. Unknown predators caused 17% of the losses. An even greater predation rate of 88% of poult losses was reported by Peoples et al. (1995).

Predators

Mammalian predators may be particularly efficient at finding poults. In Alabama, Speake et al. (1985) found that free-ranging dogs and raccoons accounted for 57 and 24% of the identifiable mammalian predation, respectively. Gray foxes and bobcats (*Lynx rufus*) accounted for the rest of the mammal predation. Mammals accounted for about 93% of the poult predation in an Iowa population, with red foxes, weasels (*Mustela* spp.), mink (*Mustela vison*), and coyotes identified and listed in declining order of importance (Hubbard et al. 1999*a*). In Florida and south Georgia, Peoples et al. (1995) attributed 71% of total poult predation to mammals, primarily raccoons, bobcats, and gray foxes.

Some avian predators also are implicated regularly in poult losses. In Alabama, broad-winged hawks (*Buteo platypterus*) and red-tailed hawks (*Buteo jamaicensis*) accounted for 92% of the identifiable avian predation. The remaining avian predation was attributed to an eastern screech-owl (*Otus asio*) (Speake et al. 1985). In an Iowa study, red-tailed hawks were the only avian predator documented to take poults. Cooper's hawks (*Accipiter cooperii*), great horned owls (*Bubo virginianus*), and barred owls (*Strix varia*) also were present on the study area but were never observed attacking or killing poults (Hubbard et al. 1999*a*). Peoples et al. (1995) documented poult losses from red-tailed hawks, Cooper's hawks, and barred owls, but found red-shouldered hawks (*Buteo lineatus*) responsible for the greatest avian predation. In South Dakota, Merriam's turkey poults in the southern Black Hills were attacked by golden eagles (*Aquila chrysaetos*) and goshawks (*Accipiter gentilis*) (Lehman 2003, Lehman and Thompson 2004).

Reptiles are seldom documented as poult predators, but Speake et. al. (1985) reported poult losses from gray rat snakes. Alligators (*Alligator mississippiensis*) and corn snakes (*Elaphe guttata*) also have been documented to take poults (Peoples et al. 1995).

Yearling-Adult Predation

Hen Mortality

Most research shows no difference in mortality rates between yearling and adult hens (Miller et al. 1995, Roberts et al. 1995, Vangilder 1996, Wright et al. 1996) but some studies have determined lesser survival for yearlings than adult hens (Vander Haegan et al 1988, Miller et al. 1998*a,* Hubbard et al. 1999*b*).

Overall, annual eastern wild turkey hen survival averages from 50 to 65% (Vander Haegan et al. 1988, Roberts et al. 1995, Vangilder 1996, Hubbard et al. 1999*b*). Little difference is reported in survival of Merriam's turkey hens (Wertz and Flake 1988) and Rio Grande turkey hens (Hohensee and Wallace 2001). Arizona Merriam's turkey yearling hens had lower survival rates than adult hens during the winter which may be attributed to inexperience, but higher survival rates during the summer that may be influenced by the fact that yearling hens were not accompanied by

broods (Wakeling 1991). According to Gonzalez et al. (1996), ocellated turkey hens have survival rates of 60%.

Mortality may be attributed to many causes, but predation is well documented as the main cause of death. For eastern wild turkey hens in Massachusetts, Vander Haegan et al. (1988) determined predation to be the cause of 75% (12 of 16) documented deaths. Hubbard et al. (1999*b*), in Iowa, found predators to be the cause of death for 79% (42 of 53) of the hens that died in that study. Roberts et al. (1995) and Wright et al. (1996) determined that predators caused 74% and 71%, respectively, of documented hen deaths. For Rio Grande hens in Oregon, Keegan and Crawford (1999) attributed 73% of known mortality to predators.

Hens are most at risk during the nesting season and the greatest percentage of hen mortality occurs during that period (Kurzejeski et al. 1987, Vander Haegan et al. 1988, Miller et al. 1995, Roberts et al. 1995, Miller et al. 1998*a*).

Hen Predators

Mammals are by far the most common predators of wild turkey hens (Miller et al. 1995, Roberts et al. 1995, Chamberlain et al. 1996, Hubbard et al. 1999*b,* Hennen and Lutz 2001). Among mammals, canids, especially coyotes, but also including red and gray foxes and domestic dogs, are often listed as predators of hens (Everett et al. 1980, Speake 1980, Palmer et al. 1993*a,* Wright et al. 1996). However, the most commonly reported predator of turkey hens is the bobcat (Everett et al. 1980, Speake 1980, Vander Haegan et al. 1988, Still and Baumann 1990, Vangilder 1996). Other mammalian predators include the raccoon (Palmer et al. 1993*a,* Roberts et al. 1995, Miller et al. 1998*a,* Hennen and Lutz 2001) and according to Hennen and Lutz (2001) the badger (*Taxidea taxus*).

The great horned owl is the only avian predator of wild turkey hens regularly reported (Palmer et al. 1993*a,* Roberts et al. 1995, Wright et al. 1996, Hubbard et al. 1999*b,* Hennen and Lutz 2001) and is even recorded as the major predator in a Mississippi study (Miller et al. 1998*a*). The golden eagle is listed as an occasional hen predator (Speake 1980) and a northern goshawk may have been responsible for the death of a hen in New York (Roberts et al. 1995). Golden eagles were witnessed to have attacked Merriam's turkeys several times in the Black Hills; however, only one kill on an adult female was confirmed (Lehman and Thompson 2004; C. Lehman, National Wild Turkey Federation, unpublished data).

Gobbler Mortality

Gobblers are generally reported to be less vulnerable to predation than hens, and yearling gobblers are reported to be more susceptible to predators than adults (Everett et al. 1980, Speake 1980). Two factors are probably responsible for these differences: healthy gobblers seldom or never spend the night on the ground as do nesting or brood-rearing hens, and adult gobblers are so large as to make them difficult prey for all but the largest and most capable predators. However, adult gobblers are more vulnerable to human-caused mortality than are yearlings (Paisley et al. 1996, Wright and Vangilder 2001). Other factors also affect predation on gobblers. Paisley et al. (1996), found predation on gobblers to be greatest in the breeding season in Iowa. Possibly, gobblers become focused on breeding activities and may lose some degree of caution. The approach of predators also may be obscured by the fanned tail while gobblers strut during their mating display.

Gobbler Predators

As previously mentioned, gobblers, especially adults, are large enough to make them difficult prey for many predators. Bobcats, however, are quite capable of killing gobblers and are the most commonly reported gobbler predator (Everett et al. 1980, Speake 1980, Vangilder 1996, Wright and Vangilder 2001). Great horned owls are regularly reported to prey on gobblers (Vangilder 1996, Wright and Vangilder 2001). Coyotes are often implicated as gobbler predators, and predation has been documented (Paisley et al. 1996, Vangilder 1996), but some gobbler kills attributed to coyotes are probably from coyotes scavenging kills made by other predators (Wright and Vangilder 2001). Other predators reported to take gobblers include the golden eagle and the gray fox (Speake 1980).

Mitigating Predation

Predator Control

It is clear from the studies on wild turkeys that except for adult gobblers, predation is the major source of mortality for wild turkeys at every stage of their life. The major predators are well documented, and while the raptors are completely protected by law, most of the mammalian predators can be either hunted or trapped. In simple terms, a method by which to increase turkey numbers or prevent declining populations is to implement predator control.

From a nationwide survey on the public's attitudes toward predator control among a random sample of United States households, most respondents would support predator control to enhance avian recruitment, but only in specific circumstances (Messmer et al. 1999). Respondents supported control of specific mammalian predators when control was recommended to reverse declines of desirable avian species, but did not support predator control as a landscape-level management strategy applied without appropriate focus. Control of raptors was not supported under any circumstances described in the survey.

Nesting success and poult production can be improved following intensive predator control. Speake (1980) found a 5-year average of 3.5 poults/hen on an Alabama study area under intensive predator removal. An adjacent area with no control averaged only 1.1 poults/hen over the same period. Beasom (1974*a*), after intensive predator control efforts in a south Texas

area, found that turkeys and white-tailed deer (*Odocoileus virginianus*) exhibited large increases in reproductive success and potential increases in density. In this study, control was most effective when carried out just prior to and during the breeding season. Control efforts had more impact during dry years when there was little vegetative cover. In years of good rainfall, the differences between treated on untreated areas were less evident.

Intensive predator control is expensive and time consuming. In Alabama, Speake (1980) calculated a total cost of $3,270 at 1975 prices for predator control on the 2,024 ha study area, and this figure does not include cost of traps or trapping labor. Beasom (1974*b*), to achieve mammalian predator control on a 2,185 ha south Texas study area, used a variety of methods for 5 months per year for 2 years. This intensive effort used 135 M-44 cyanide sets, 250 man-hours of hunting, 8,000 strychnine baits, and 27,446 steel trap days (1 trap for 1 day = 1 trap day) and removed 183 coyotes, 117 bobcats, 34 raccoons and 48 striped skunks, as well as other, less significant predators. Effort was made in this study to avoid killing or capturing non-target species, but deer, turkeys, songbirds, and several raptor species were captured or killed, as well as the targeted predators.

Speake (1980) noted that even with no predator control, the turkey population either maintained or increased abundance. He concluded that intensive predator control is expensive and seldom justified, but that trapping should be encouraged and that control of feral or free-ranging dogs is probably desirable. Even when predators are successfully removed, intensive predator control efforts are likely to have only short-term benefits. Beasom (1974*a*) noted that predators repopulated a south Texas study area each year when removal efforts ceased.

In addition to calculations on expense and labor involved in predator control, there are other considerations. Coyote populations were lowered on a Texas study site, but with a 9-month lag time, and only after intense and expensive effort. Mesopredator populations, including bobcat, badger and gray fox, increased on the treatment areas (Henke and Bryant 1999). Rodent density and black-tailed jackrabbit (*Lepus californicus*) density increased as well.

Weather

Other abiotic factors may confound efforts to mitigate the effects of predation on turkeys. In Mississippi, Palmer et al. (1993*b*) found predation on incubating hens and nests to be related directly to the last rainfall event. They hypothesized that rainfall increases efficiency of nest predators by increasing the detection of scent from nesting hens. Lowrey et al. (2001) suggested that although predation may be a more important factor in nesting success than weather, relationships between the 2 factors are important to hen survival and productivity. Roberts and Porter (1998) found daily nest survival was negatively correlated with increased rainfall. High predator populations during dry springs may actually have less impact on nesting turkeys than lesser predator populations under wet conditions.

Habitat Management

Management and manipulation of the juxtaposition and interspersion of habitats may reduce the efficiency and impacts of predation on wild turkeys. As opposed to short-term effects from predator control (Beasom 1974*b,* Speake 1980, Henke and Bryant 1999), habitat management may have longer-term effects in increasing turkey population abundance or preventing declines.

According to Roberts and Porter (1996), nest success is one of the most important parameters affecting annual wild turkey population change. For the hen, one of the most crucial factors influencing the success of her nest is her choice of nesting sites. In Mississippi, Seiss et al. (1990) found that hens selected nest sites in forest stands <4-years-old. Additionally, nests in forested areas were more successful than nests in non-forested areas, possibly due to greater predator populations in non-forested habitat. Similarly, Thogmartin (1999) found that hens in Arkansas generally nested in large patches of pine and avoided patches containing oak, apparently preferring the thicker, grassy understory found in the pine stands.

Traditionally, land managers have encouraged creating or promoting the amount of ''edge'' or transition zones between different habitat types. Diversity and interspersion of habitat types has become commonplace because this arrangement of plant foods and cover types may provide the optimum habitat for a wide variety of wildlife. Seiss et al. (1990) found that successful wild turkey nests in forested areas were generally located <10 m from more than 1 man-made edge and speculated that proximity of edges may have provided hens with travel lanes to and from the nest. These travel lanes may provide the hen with better access to resources such as food and water, limit time off the nest, and reduce scent trails from the nest. However, spatial arrangement and interspersion of habitat types affects the efficiency of many turkey predators, especially during the nesting season. Fragmentation of habitat and increase in edge favors many predators of ground nesting birds. Thogmartin (1999) states that the 2 most common nest predators in the Ouachita Mountains in Arkansas are black rat snakes and raccoons, both of which favor forest edges for hunting (Durner and Gates 1993, Pedlar et al. 1997). Management activities that promote increased edge may enhance efficiency of these nest predators.

Certain factors mitigate effectiveness of nest predators. Baker (1979) found significant differences in nest predation rates due to effects of different grazing regimes and due to differences in plant communities where the nest occurs. Typically, nests with greater cover suffered lower rates of predation. In some areas, proximity to deer feeders may increase predation rates. Cooper and Ginnet (2000), in an artificial nest study

in Texas, found higher nest predation rates at sites near feeders than at nest sites farther away.

Habitat type and spatial arrangement also affect predation on turkeys beyond the nesting season. After assessing 80 mortalities of radiomarked turkeys over a 5-year period, Thogmartin and Schaeffer (2000) found that mortality occurred nearly twice as often in edge as in core habitat, especially during summer and fall when vegetation density was greatest. Interestingly, canid predation was most pronounced within edge habitat where 7 of 8 kills occurred. Bobcat predation was nearly equally distributed between edge and core habitats. There were species differences in predation by season, as bobcat predation occurred in winter and spring, whereas canid predation occurred throughout all seasons equally.

DISCUSSION

For all wild turkeys except adult gobblers, predation is the major cause of mortality. This is well documented for all habitats, all subspecies, and at all stages of life. For most wild turkey populations, predation is not a regulating factor. Most populations continue to grow and in many places wild turkeys are expanding their range (Tapley et al. 2000). However, some local and regional populations are declining (Thogmartin 1998, Miller et al. 1998*b*), and in these declining populations, high rates of predation and low productivity are common threads. For the land manager attempting to reverse these declines, there are two options: reduce the number of predators or increase the productivity of the hens.

In the absence of other factors, variations in nest initiation rates alone may account for great differences in the productivity of different populations. Where nest initiation rates are low, or nonexistent as in the case of yearlings in some populations, population growth may be slow or limited even without the effects of other factors such as predation. When low rates of nest initiation are combined with the effects of predation or inclement weather, the combined effects on population growth are more severe. In such instances predation may be additive; however, little information exists on the effects of predation on populations with lowered reproductive potential. Typically, wild turkeys are thought to be under a compensatory biological system, and predation has little effect in annual survival.

Reducing predator numbers on a broad scale is expensive, time-consuming, and is not universally supported by the public as a management tool. The benefits are often confined to a brief time period during and immediately after control efforts. However, for certain local wild turkey populations, there may be a benefit to short-term, intensive predator control where this control is designed to allow population recovery and targets a specific predator species or guild. This targeted, ''surgical'' approach is acceptable to the public as a method to enhance avian recruitment (Messmer et al. 1999). Stochastic modeling on the effects of intensive coyote removal on pronghorn (*Antilocapra americana*) populations in Oregon showed relatively long-term pronghorn population stability (to about 10 years after initiating control) after only 3 years of intensive coyote control (Phillips and White 2003). In this case, coyotes had been identified as the species responsible for regulating that population. It is possible that some turkey populations may show a similar response to predator control. Great care must be taken to remove only the predators impacting turkey abundance, because removal of some predators may result in increased abundance of other predators that may prey on turkeys.

Habitat management that addresses habitat deficiencies or factors that promote predator efficiency is much more likely to provide long-term increases in wild turkey population abundance than is predator control. Urban development, land management decisions that influence recreational use, and silvicultural treatment of public and private lands are creating habitat fragmentation that may improve habitat suitability for predators. Techniques that reduce fragmentation, providing larger, more homogeneous blocks of nesting habitat increase nesting success (Seiss et al. 1990, Thogmartin 1999). Large block forest management may reduce efficiency of many nest predators. Grazing regimes that allow time for vegetative cover to mature, especially in larger pastures, increase nest and brood success (Baker 1979). Improving habitat quality for turkeys by large-scale methods such as prescribed fire and thinning of over-stocked stands may promote the growth of seed producing grasses and legumes, which are desirable for seed and insect production. There is evidence that increasing the hen's nutritional plane increases productivity, perhaps increasing nest and renest initiation rates, with the potential for correspondingly greater poult production (Pattee and Beasom 1979). More research is underway on this topic (W. Kuvlesky, Texas A&M University, Kingsville, personal communication) with the potential to add nutritional considerations to management objectives.

Turkeys have evolved with a host of predators. The literature indicates that predation has not been a regulating factor for most turkey populations, nor has predator control been shown to have long-term benefits. Predator control may be justified in site-specific instances. Widespread use of predator control to benefit turkey abundance is probably not a prudent expenditure of management dollars.

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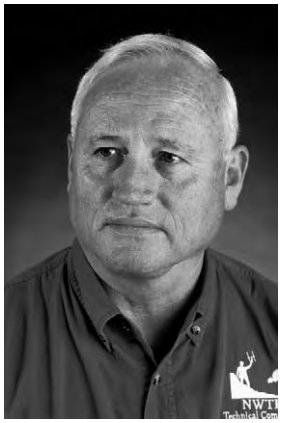

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