EFFECTS OF EGG TYPE ON DEPREDATION OF ARTIFICIAL GROUND NESTS

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ABSTRACT.—We examined depredation of artificial ground nests containing three egg types (brown chicken, white chicken, or Northern Bobwhite [*Colinus virginianus*]) in relation to plot age (clearcut vs uncut) and time period (trials 1–5) at the Barrens Grouse Habitat Management Area, Centre County, Pennsylvania, from May–July 1993. One hundred thirteen (38%) of the total nests were disturbed. Fewer nests were disturbed in clearcut (32%) than in uncut plots (43%) ($P \leq 0.05$). Clearcut plots had higher densities of brushy vegetation near ground level which better concealed nests and reduced foraging efficiency of predators. Rates of nest disturbance varied with time period ($P \leq 0.005$); in general, rates were greater in trials 1–3 than in trials 4–5, partially because of gypsy moth (*Lymantria dispar*) defoliation during trials 1–3. Nest fate also differed significantly ($P \leq 0.001$) with egg type. Rates of disturbance were lower with nests containing brown chicken eggs (24%) compared to nests containing white chicken eggs (46%) or Northern Bobwhite (43%) eggs. Nests with brown chicken eggs were better camoflaged and, hence, less likely to be disturbed. Based on our findings, we recommend that brown chicken eggs be used as an alternative to Japanese Quail (*Coturnix coturnix japonica*) eggs when simulating nests of Ruffed Grouse (*Bonasa umbellus*) or Wild Turkey (*Meleagris gallopavo*) in artificial ground nest studies. *Received 28 Feb. 1995, accepted 1 June 1995.*

The effects of egg size (e.g., Reistma et al. 1990) and egg color (e.g., Westmoreland and Best 1986, Yahner and DeLong 1992) have been examined in experimental studies designed to infer predation rates on nests of bird species with relatively small eggs. In addition, the effects of egg size on predation rates by American Crows (*Corvus brachyrhnchos*) have been investigated in meadows using large chicken eggs, small chicken eggs, and white painted Japanese Quail (*Coturnix coturnix japonica*) eggs (Montevecchi 1976). Relatively large eggs, including brown chicken, Japanese Quail, and Northern Bobwhite (*Colinus virginianus*) eggs also have been used in a variety of artificial nest studies as a means of determining rates of predation on nests simulating those of larger birds such as gallinaceous birds (e.g., Boag et al. 1984, Yahner and Wright 1985). However, no studies to our knowledge have examined differences in rates of nest disturbance on artificial ground nests in forested habitats using large eggs that differ in both size and color. This information is important in the experimental design of artificial nest studies intended to obtain estimates of predation on natural ground nests in various landscapes (e.g., Storaas 1988, Willebrand and Marcström 1988). Our objective was to compare rates of depredation among artificial ground nests containing

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three egg types that vary in both size and color and placed in forested plots of two age classes.

Study area and methods.—We conducted this study at the 1166-ha Barrens Grouse Habitat Management Area (HMA), State Game Lands 176, Centre County, Pennsylvania, the site of four previous studies of depredation of artificial ground nests (Yahner and Wright 1985, Yahner et al. 1989, 1993; Yahner and Mahan 1996). The Barrens Grouse HMA has been managed via forest clearcutting since 1976 by the Pennsylvania Game Commission to create habitat for Ruffed Grouse (*Bonasa umbellus*) (Yahner 1991, 1992). It contains an uncut (reference) and a cut (treated) sector of similar size. The treated sector is subdivided into 50% and 75% cut areas, corresponding to the amount of forest clearcutting and contained 136 contiguous, 4-ha blocks (e.g., see Yahner 1993, Yahner et al. 1993); 76 and 60 blocks are in the 50% and 75% areas, respectively. Each block is subdivided into four 1-ha (100 × 100 m) plots arranged in a checkerboard pattern (plots A–D). Our study was focused in the 75% area; in this area, plot A (western plot) in each block was clearcut during winter 1975–1976, and plot B (northern plot) was cut during winter 1980–1981, plot C (eastern plot) was cut in winters 1985–1986 or 1986–1987, and plot D (southern plot) was uncut.

Overstory trees (>7.5 cm dbh and >1.5 m tall) in plot D of the 75% area were about 70 years old and consisted primarily of quaking aspen (*Populus tremuloides*), bigtooth aspen (*P. grandidentata*), oak (*Quercus* spp.), and pitch pine (*Pinus rigida*). Common understory trees (2.5–7.7 cm dbh) and shrubs (<2.5 cm dbh) in all plots of the 75% area were aspen, dwarf chinkapin oak (*Q. prinoides*), scrub oak (*Q. ilicifolia*), and blueberry (*Vaccinium* spp.) (Yahner 1993).

Gallinaceous birds nesting at ground level at the Barrens Grouse HMA were Ruffed Grouse and Wild Turkey (*Meleagris gallopavo*) (Yahner et al. 1989, Yahner 1993). Potential predators on ground nests were American Crow, Blue Jay (*Cyanocitta cristata*), Virginia opossum (*Didelphis virginianus*), eastern chipmunk (*Tamias striatus*), gray squirrel (*Sciurus carolinensis*), red squirrel (*Tamiasciurus hudsonicus*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), black bear (*Ursus americanus*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and weasel (*Mustela* spp.) (Therres 1982, Yahner et al. 1993).

We placed artificial ground nests during five time periods from late May to late July 1993 in the 75% area (Table 1). Each nest consisted of three fresh eggs put in a slight depression in leaf litter adjacent to a log, overstory tree, or stump (Yahner and Wright 1985, Yahner et al. 1993). Each nest contained one egg type: brown chicken, white chicken, or Northern Bobwhite. Based on a sample of 10 eggs/type, mean length and

TABLE 1

FATE OF 299 ARTIFICIAL GROUND NESTS IN RELATION TO AGE OF PLOT, TIME PERIOD, AND EGG TYPE AT THE BARRENS GROUSE HABITAT MANAGEMENT STUDY AREA, CENTRE COUNTY, PENNSYLVANIA, 1993

| Variable | Level | Nest fate | | | |
| | | Undisturbed | | Disturbed | |
		N	%	N	%
Age of plot	Clearcut	101	68	48	32
	Uncut	85	57	65	43
Time period	Trial 1	37	62	23	38
	Trial 2	35	58	25	42
	Trial 3	26	43	34	57
	Trial 4	46	77	14	23
	Trial 5	42	71	17	29
Egg type	Brown chicken	76	76	24	24
	White chicken	53	54	46	46
	Northern Bobwhite	57	57	43	43
Total		186	62	113	38

width of brown chicken eggs were 52 × 40 mm, white chicken eggs were 56 × 42 mm, and bobwhite eggs were 30 × 24 mm. Brown chicken eggs are light brown to buffy in color; white chicken and bobwhite eggs were dull or creamy white (Harrison 1975). Ruffed Grouse eggs were 39 × 30 mm (buffy), and Eastern Wild Turkey eggs are 63 × 45 mm (pale buff or buffy white) (Harrison 1975).

A trial was six days in length, with eight days between trials (methodology follows that of Yahner and Scott 1988). During each trial, 15 clearcut plots (plot C) and 15 uncut plots (plot D) were selected randomly. Two nests were placed in each plot; nests were separated by 30–35 m and placed 5 m from the edge of the plot. When placing nests, we wore rubber gloves and boots to minimize human scent at nests (Nol and Brooks 1982). This experimental design gave 60 nests/trial equally divided between the two plot ages and among the three egg types (total = 300 nests; one of the 300 nests was omitted from analysis due to incorrect placement).

We checked nests six days after placement between sunrise and 12:00 h (DST) to determine the fate (undisturbed, disturbed by avian predator, disturbed by unknown predator) of each nest (Yahner and Wright 1985). A disturbed nest was characterized by ≥ one broken or missing egg on day 6 of a given trial. Appearance and mode of disturbance of the eggs were used to identify predators as avian (e.g., peck hole in egg) or un-

known (Rearden 1951, Boag et al. 1984, Yahner and Wright 1985). In addition, eggs and eggshells were removed on day 6 of each trial.

We examined the dependency of nest fate (undisturbed vs disturbed) on plot age (clearcut vs uncut), time period (trials 1–5), egg type (brown chicken, white chicken, or Northern Bobwhite), using a four-way test-of-independence (Dixon 1990). Likelihood ratios (G^2) were used to test for interactions of nest fate with the three other variables, using log-linear models (Sokal and Rohlf 1981, Dixon 1990). Likelihood ratios are appropriate when analyzing attribute variables in multi-way contingency tables. If nest fate were significantly dependent on a given variable, we used *a posteriori* G-tests for goodness-of-fit about the cell (level) of interest (Sokal and Rohlf 1981). Because corvids are major predators on artificial nests at the Barrens Grouse HMA (e.g., Yahner and Wright 1985, but see Yahner et al. 1993), the frequency of nests disturbed by avian predators was compared among the three egg types using a G-test for goodness-of-fit.

<center>RESULTS</center>

One-hundred thirteen (38%) of 299 artificial ground nests were disturbed during the five trials (Table 1). Regardless of egg type, nest fate was associated with age of plot ($G = 4.7$, df $= 1$, $P < 0.05$). Fewer nests (all egg types combined) were disturbed in clearcut plots (N $= 48$, 32%) than in uncut plots (N $= 65$, 43%). Nest fate also was associated with time period ($G = 18.0$, df $= 4$, $P < 0.005$). The frequency of total disturbed nests in trial 3 (N $= 34$, 57%) was significantly higher than expected ($G = 6.3$, df $= 1$, $P < 0.025$), whereas frequency of total disturbed nests in trial 4 (N $= 14$, 23%) was significantly lower than expected ($G = 4.7$, df $= 1$, $P < 0.05$). In general, the percentage of disturbed nests/trial was greater in trials 1–3 (38–57%) compared to that in trials 4–5 (23–29%).

Nest fate varied with the three egg types ($G = 14.0$, df $= 1$, $P < 0.001$) (Table 1). The frequency of disturbed nests with brown chicken eggs (N $= 24$, 24%) was considerably lower than expected ($G = 8.2$, df $= 1$, $P < 0.005$), but the frequencies of disturbed nests with white chicken (N $= 46$, 46%) or Northern Bobwhite eggs (N $= 43$, 43%) were not different from expected ($Gs \le 2.7$, df $= 1$, $P > 0.10$). Moreover, there was a significant interaction among nest fate, egg type, and time period ($G = 17.9$, df $= 8$, $P < 0.05$). In particular, fewer nests with brown chicken eggs were disturbed in trial 1 (N $= 2$, 2%) than expected ($G = 6.0$, df $= 1$, $P < 0.05$), and more nests with Northern Bobwhite eggs were disturbed in trial 3 (N $= 16$, 14%) than expected ($G = 7.9$, df $= 1$, $P < 0.005$).

Thirty-six (32%) of the 113 disturbed nests were preyed upon by avian predators, principally Blue Jays and American Crows. The frequency of nests lost to avian predators differed among the three egg types (G = 11.9, df = 2, P < 0.001). Of the total nests disturbed by birds, eight (22%) were those containing brown chicken eggs, 22 (61%) had white chicken eggs, and six (17%) had Northern Bobwhite eggs. Avian predators destroyed more nests with white chicken eggs than expected (G = 11.6, df = 1, P < 0.001) and less with Northern Bobwhite eggs than expected (G = 5.1, df = 1, P < 0.05).

Discussion.—Our finding that rates of disturbance of artificial ground nests were lower in clearcut plots than in uncut plots concurs with results obtained in other studies of artificial nests at the Barrens Grouse HMA (e.g., Yahner and Wright 1985, Yahner and Cypher 1987, Yahner and Scott 1988). Clearcut plots were characterized by higher densities of brushy vegetation near ground level, which presumably better concealed artificial nests and reduced foraging of nest predators such as crows (Picozzi 1975) and raccoons (Bowman and Harris 1980). Moreover, uncut plots contained overstory trees that served as perch sites for avian nest predators (Yahner et al. 1989).

Most studies of artificial nests at the Barrens Grouse HMA have not documented significant differences in rates of nest disturbance over time (e.g., Yahner et al. 1989, 1993). However, as in the present study, Yahner and Wright (1985) found reduced rates of nest disturbance later in the breeding season, possibly because family groups of crows move to communal roosting sites and agricultural feeding sites (Cross 1946). Another possible explanation for greater nest disturbance in earlier trials of our study may be related to gypsy moth (*Lymantria dispar*) defoliation. Although we did not quantify the extent of defoliation caused by gypsy moth larvae, it was greatest during trial 3, which preceded the pupal stage of the life cycle and corresponded to the period of most extensive defoliation on the study area in spring and summer 1993 (Yahner and Mahan 1996). Extensive defoliation by gypsy moths has been shown to increase rates of artificial nest predation (Thurber et al. 1994).

Nests with brown chicken eggs in our study were better camouflaged and, hence, less likely to be disturbed by predators than other egg types, particularly by avian predators that rely on vision when foraging. A 24% disturbance of nests with brown chicken eggs was comparable to the rate found in a previous study at the Barrens Grouse HMA (Yahner et al. 1993). Our rate of disturbance of nests with Northern Bobwhite eggs (38%) was higher than that reported with an artificial nest study in Virginia using Northern Bobwhite eggs (20%) (Leimgruber et al. 1994).

In contrast to nests with brown chicken eggs, nests with more visually

conspicuous egg types, i.e., white chicken and Northern Bobwhite, were lost at a comparable rate despite appreciable differences in size between the two types. These results concur with those of Montevecchi (1976), who found similar rates of predation by American Crows on white eggs of three sizes placed in meadows. Perhaps because corvids are common nest predators at the Barrens Grouse HMA (Yahner and Wright 1985, Yahner and Scott 1988), color rather than egg size was the major factor influencing nest disturbance in our study. Although nests with Northern Bobwhite eggs were preyed upon as expected, conceivably many of the nests with missing Northern Bobwhite eggs at the end of trials could have been those in which eggs easily were carried away by large avian nest predators such as the American Crow (see Montevecchi 1976). For instance, of the 39 nests with no eggs present at the end of a given trial, the majority (N = 30, 77%) were those with eggs of Northern Bobwhite.

Some concern has been raised about size of eggs used in artificial nest studies (e.g., Boag et al. 1984, Reitsma et al. 1990, Roper 1992). Eggs of Japanese Quail used in artificial nest studies, for example, are considerably larger than those of songbirds, e.g., warblers, thereby potentially reducing rates of nest disturbance by smaller-sized mammalian predators that are less efficient at handling a larger egg (e.g., red squirrels and eastern chipmunks (Boag et al. 1984, Reistma et al. 1990). Thus, eggs used in our study, which were intended to simulate egg size of larger birds (e.g., Ruffed Grouse, Wild Turkey), probably were too large for handling by smaller predators.

Various investigators have often used either brown chicken eggs (e.g., Andren and Angelstam 1988, DeGraaf and Anglestam 1993, Yahner et al. 1993) or Japanese Quail eggs (Boag et al. 1984, Ratti and Reese 1988) as part of the experimental design of artificial nest studies in forested habitats. Based on our findings, we recommend brown chicken eggs as a suitable alternative to Japanese Quail eggs, both in terms of size and color, when simulating nests of Ruffed Grouse and Wild Turkeys in artificial ground nest studies.

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