

EFFECT OF FLAGGING ON PREDATION OF ARTIFICIAL DUCK NESTS

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Abstract.—Nest markers are used commonly to identify and mark locations of nests. However, they also may attract predators and increase nest predation. We tested the effect of plastic flagging on predation of artificial duck nests, during two consecutive 14-d periods, along two 45-km segments of graveled road near Crandall, Manitoba, Canada. Estimates of daily mortality rates between flagged and unflagged nests did not differ, but the power of rejecting the null hypothesis was low. Daily mortality rates of nests were higher between day 0 and 8 than between day 8 and 14. A flag-by-interval interaction was significant, indicating that flagged nests had a higher mortality rate than unflagged nests between day 8 and 14. Differential nest-site vulnerability may affect predation soon after nest construction, whereas flagging may increasingly influence predation as nests age. We recommend that nests not be marked with flagging and that natural objects be used to aid in nest relocation.

EL EFECTO DE LAS CINTAS PLÁSTICAS EN LA DEPREDACIÓN DE NIDOS ARTIFICIALES DE ANÁTIDOS

Sinopsis.—Comúnmente se utilizan marcadores de nidos para identificar y marcar la localización de nidos. Sin embargo, ellos también pueden atraer depredadores y aumentar la depredación de los nidos. Probamos el efecto de las cintas plásticas en la depredación de nidos artificiales para anátidos durante dos períodos consecutivos de 14 días siguiendo dos veredas en piedrilla de 45 km cerca de Crandall, Manitoba, Canada. Estimados de tasas de mortalidad diaria de nidos fueron mayores entre los días 0 y 8 que entre los días 8 y 14. Una interacción de bandera por intervalo fué significativa, indicando que nidos marcados tenían una tasa de mortalidad mayor que nidos no marcados entre los días 8 y 14. Diferencias en la vulnerabilidad de las localidades de los nidos puede afectar la depredación justo después de que comience la construcción de los nidos, mientras que las marcas pueden influenciar el aumento en la depredación de los nidos con la edad del nido. Recomendamos que no se marquen los nidos con cintas plásticas y que se utilicen objetos naturales para asistir en relocalizar nidos.

Predation of nests affects waterfowl production in the prairie pothole region (Cowardin et al. 1985). Although waterfowl researchers strive to be non-intrusive (Gloutney et al. 1993, Klett et al. 1986), some research activities may attract predators to nests (Dwernychuk and Boag 1972, Picozzi 1975, Reynolds 1985) and increase nest predation. Studies of nesting success commonly use markers to aid in the relocation of nests (Duebert and Kantrud 1974, Dwernychuk and Boag 1972, Livezey 1980, Reynolds 1985). However, markers may increase predation on nests (Picozzi 1975, Reynolds 1985, Yahner and Wright 1985). No nest-marking experiments have been conducted in the prairie pothole region, where predator assemblages differ from previous studies.

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Because locating waterfowl nests is labor intensive (Cowardin et al. 1985, Duebbert and Kantrud 1974), investigators have used artificial nests to study factors influencing nesting success (Esler and Grand 1993, Hammond and Forward 1956, Salathé 1987, Vacca and Handel 1988). Predation on artificial nests may (Götmark et al. 1990) or may not (Martin 1987, Storaås 1988) be directly comparable to predation on natural nests, but provides a relative measure of predation on natural nests under similar conditions (Götmark et al. 1990). Researchers can use artificial nests to obtain a large sample size, develop hypotheses regarding natural nest predation, and conduct experiments (Leimgruber et al. 1994).

Results from nest-marking experiments have differed because of a small difference in treatments (Vacca and Handel 1988) or poor study design (Hammond and Forward 1956, Picozzi 1975). No studies have evaluated the effect of flagging on nests that are spaced over an extensive area, which may prevent pseudoreplication (Hulbert 1984) by ensuring that the probability of a nest being disturbed is independent of neighboring nests (i.e., nests are statistically independent replicates). If nests are statistically independent, then individual predators may not learn to associate flags with nests (i.e., develop a search image for flags), which would control for biological independence to evaluate the attractiveness of flags to nest predators without confounding a flagging effect with learning. Therefore, we used artificial nests to test the effect of plastic flagging, the material recommended for marking waterfowl nests (Klett et al. 1986), on predation of widely spaced artificial duck nests.

STUDY AREA AND METHODS

During two consecutive 14-d periods (Period 1 = 4–18 Jun. 1993, Period 2 = 18 Jun.–2 Jul. 1993), we conducted an artificial nest experiment in road rights-of-way along two 45-km segments (transects) of graveled road near Crandall, in southwestern Manitoba, Canada (50°09'N, 100°46'W). The experiment corresponded with the nest initiation period for dabbling ducks in this region (Greenwood et al. 1995). Rights-of-way vegetation was dominated by smooth brome (*Bromus inermis*), interspersed with sweet clover (*Melilotus* spp.), cheat-grass (*Bromus tectorum*), willows (*Salix* spp.), and small stands of quaking aspen (*Populus tremuloides*). Ducks commonly use rights-of-way for nesting (Cowardin et al. 1985, Greenwood et al. 1995, Sullivan and Dinsmore 1990). Flooded fields or wetlands were typically located <400 m from rights-of-way. Predator composition was typical for the prairie pothole region of Canada (Greenwood et al. 1995); potential nest predators included Black-billed Magpies (*Pica pica*), American Crow (*Corvus brachyrhynchos*), coyote (*Canis latrans*), American badger (*Taxidea taxus*), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and Franklin's ground squirrel (*Spermophilus franklinii*).

One hundred nests (50 flagged or unflagged/45-km segment) were constructed in <8 h during the first day of each period. Although the distribution of natural nests is likely to be clumped, artificial nest density

approximated a minimum estimate of natural duck nest density for this area in 1993 (150 nests of *Anas* spp. found in a 78-km² site, Devries et al. 1994). Because predation rates for natural nests may decrease slightly as the breeding season progresses (Greenwood et al. 1995), we used two 14-d periods to assess whether the timing of nest construction influenced predation. Nests were centered in rights-of-way between the edge of the road and the edge of fields and were placed in similar habitat 0.8 km apart except near houses, which were given a 0.4-km buffer. Nests were placed in different locations on the same transect between periods 1 and 2, with period-2 nests starting 0.4 km past the beginning of the period 1 nests. Nest depressions were dug into the ground by rotating the convex end of a 2-liter plastic beverage container in the soil to a depth of approximately 2.0 cm. Nest depressions were lined with a mixture of approximately 50% fresh and 50% dried brome that was collected >10 m from each nest location. Fresh unwashed eggs were collected from pen-raised, wild-caught (F₂ and F₃ generation) Mallards (*Anas platyrhynchos*) (Whistling Wings Inc., Hanover, Illinois) and were stored <1 wk prior to each period in straw-lined wooden boxes in a cool basement. Three eggs were placed in each nest and approximately 75% of the eggs were covered with brome to conceal them from avian predators (Sugden and Beyersbergen 1986). Nest construction usually required <3 min. Gloves and rubber boots were worn to reduce human scent while handling eggs and while constructing and visiting nests. All nests were marked with a 1.5-m dead leafless willow placed 2 m from nests. It was assumed there were no confounding effects of using willows as markers because they were natural, common in rights-of-way, and not contaminated with foreign odors. Different routes were walked on each visit to and from nests to avoid creating trails. Trampled vegetation within 1 m of the nest was lifted upon logging. Traffic along graveled roads was minimal.

Proportional differences between treatments (effect sizes) from nest marking experiments have ranged from 0.17 to >0.5 (Picozzi 1975, Yahner and Wright 1985). We anticipated a small effect size because we did not expect predators to develop a search image toward widely spaced nest markers. Therefore, the sample size recommendation ($n = 50$ nests) of Klett and Johnson (1982) was increased to 100 nests per treatment because we wanted to have statistical power ≥ 0.80 with an expected effect size ≥ 0.15 .

Flagging was assigned randomly to transect 2 during period 1, whereas transect 1 was not flagged, and vice versa for period 2. Nests were flagged by attaching a 2 × 25 cm piece of fluorescent orange plastic flagging (Forestry Suppliers Inc., Jackson, Mississippi) to the top of willows. If we had alternated between flagged and unflagged nests on the same transect, and many consecutive nests had been disturbed on a transect, the effect of flagging would have been confounded with the effect of dependency between nests; predators may have followed rights-of-way and disturbed consecutive nests regardless of the treatment at each nest. Consequently, we used a two-period crossover design to test predator response to flag-

ging while controlling for dependency between consecutive nests. Nest fates, were determined on day 8 (interval 1) and on day 14 (interval 2) between 1200–1800 h. A nest was considered disturbed if any eggs were missing or damaged.

The sequence of disturbed and intact nests on each transect was compared using a one-tailed one-sample runs test (Siegel 1956) to test for clumping from the lack of independence (i.e., randomness of nests disturbed along each transect within a period). A one-tailed test was chosen because, biologically, lack of randomness could only result from dependency between consecutively disturbed nests (i.e., clumping), not from a systematic pattern of nest disturbance. The one-sample runs test was also used to test for residual effects of the cross-over design (i.e., randomness of nests disturbed along each transect across periods) by comparing the number of consecutively disturbed and intact nests on each transect.

Mayfield daily nest mortality estimates (DME; Mayfield 1961) were calculated using nest exposure days, because nest exposure days during interval 1 (8 d) and 2 (6 d) differed. Nests disturbed during interval 1 and 2 were assumed to have been disturbed on days 4 and 11, respectively. It was also assumed that flagged and unflagged nests were disturbed similarly during each interval, because the visitation schedule was not random, and therefore, may have biased mortality estimates by assigning all disturbed nests to the same day. DME were compared with analysis of variance using exposure days as a weighting factor (Klett and Johnson 1982, Lokemoen et al. 1990) (PROC GLM, SAS Inst., Inc., 1988). Nests were excluded from the analysis because they could not be found ($n = 1$), were disturbed by haying ($n = 1$), or the flagging was missing ($n = 2$). A parsimonious model was selected by sequentially eliminating non-significant interaction terms and comparing mean squared error between models and by comparing the overall contribution of each term in the model using type III sum of squares. The fitted model tested for an overall difference between flagged and unflagged nest mortality rates, a difference in mortality rates between intervals, and a difference in the mean response of flagging constant across intervals (i.e., flag by interval interaction).

The power ($1 - \beta$) of analysis of variance tests (PROC GLM, SAS Inst., Inc. 1988) was calculated to determine the probability of making a type II error. Sample size and effect size estimates for power could not be directly calculated using analysis of variance because nests were pooled by categories (e.g., flagged nests disturbed during interval 1). Therefore, a likelihood ratio test (White and Garrott 1990) was constructed to determine sample size for power ≥ 0.80 using the effect size of this study (0.08) and to determine the effect size required for power ≥ 0.80 with the sample size of this study ($n = 98$).

RESULTS

Flagged and unflagged nests were disturbed randomly on transect 1 and 2 (transect 1 unflagged $z = 1.484$, $P = 0.069$; transect 1 flagged, $z =$

TABLE 1. Mayfield (1961) estimates of daily mortality rates (DME) and number of disturbed nests by interval for flagged and unflagged nests along 2 45-km road segments in south-western Manitoba in 1993.

Interval	DME (no. nests)			
	Flagged		Unflagged	
	Transect 1 (<i>n</i> = 48) ^a	Transect 2 (<i>n</i> = 50)	Transect 1 (<i>n</i> = 50)	Transect 2 (<i>n</i> = 48)
Day 0-8	0.046 (15) ^c	0.048 (16) ^b	0.059 (19) ^b	0.054 (17) ^c
Day 8-14	0.033 (8)	0.042 (11)	0.019 (4)	0.01 (2)

^a Total number of nests on a transect.

^b Period 1 (4-18 Jun. 1993).

^c Period 2 (18 Jun.-2 Jul. 1993).

0.305, $P = 0.367$; transect 2 unflagged, $z = 0.664$, $P = 0.255$; transect 2 flagged, $z = 0.242$, $P = 0.405$), meaning nests were independent (statistically and biologically) replicates. There were no residual effects of crossover between flagged and unflagged nests on transect 1 or 2 ($z = 1.186$, $P = 0.117$; $z = 0.067$, $P = 0.472$), suggesting nests disturbed on transects 1 or 2 during period 2 were independent of nests disturbed on the same transect during period 1. We found few instances of partial nest disturbance; only 4% of the eggs in 92 disturbed nests were left intact.

Overall, predators disturbed 50 flagged (DME = 0.030) and 42 unflagged (DME = 0.028) nests. DME did not vary ($F_{1,4} = 3.43$, $P = 0.138$; $1 - \beta = 0.3$) between flagged and unflagged nests, but were higher in interval 1 than in interval 2 ($F_{1,4} = 49.68$, $P = 0.002$; $1 - \beta = 1.0$; Table 1, Fig. 1). A flag-by-interval interaction was significant ($F_{1,4} = 19.83$; $P = 0.011$; $1 - \beta = 0.91$), indicating that flagged nests had a higher mortality rate than unflagged nests during the second interval (Table 1, Fig. 1). No differences were detected in the DME between flagged ($F_{1,2} = 0.74$, $P = 0.481$; $1 - \beta = 0.08$) or unflagged ($F_{1,2} = 0.07$, $P = 0.818$; $1 - \beta = 0.05$) nests in period 1 and period 2.

DISCUSSION

Overall, flagged and unflagged daily nest mortality rates were similar. However, flagged nests during the second interval were disturbed at a higher rate than unflagged nests. Nest mortality may not be constant across time and/or space, with nest mortality declining as nests age, and the vulnerability of nests to predation a function of nest location (Klett and Johnson 1982). Therefore, similar mortality between flagged and unflagged nests during the first interval may have been related to predators quickly finding nests at high-risk sites (Klett and Johnson 1982), with flagging effects negligible. As nests aged (i.e., interval 2), flags may have served as a visual stimulus that attracted predators.

Nest markers did not affect predation of artificial nests of Cackling Canada Geese (*Branta canadensis minima*) (Vacca and Handel 1988), but

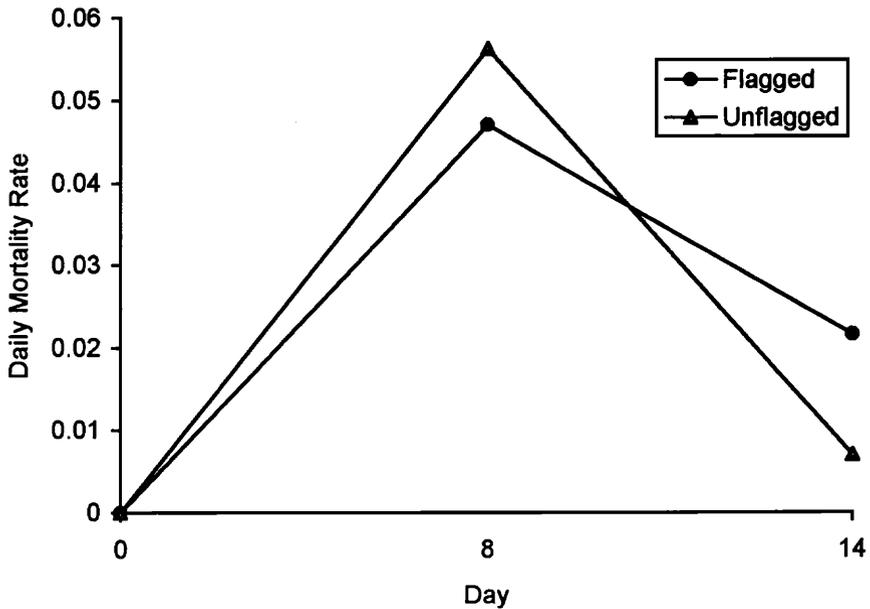


FIGURE 1. Mayfield (1961) estimates of daily mortality rates by day, pooled across 2 periods (4–18 June and 18 Jun.–2 Jul. 1993), for flagged and unflagged nests along 245-km road segments in Southwestern Manitoba in 1993.

did increase predation of artificial Red Grouse (*Lagopus lagopus*) (Picozzi 1975) nests, natural Red-necked Phalarope (*Phalaropus lobatus*) (Reynolds 1985) nests, natural Semipalmated Sandpipers (*Calidris pusilla*) (Reynolds 1985) nests, and artificial ground nests (Yahner and Wright 1985). Therefore, nest markers may, at times, affect nesting success. For example, some individual predators, when exposed repeatedly to nest markers, may learn to associate highly visible markers with nests (Picozzi 1975, Reynolds 1985, Yahner and Wright 1985). Because disturbed nests in this study were independent replicates spaced evenly along 45-km transects, individual predators were exposed to few nests and were unlikely to develop a search image for markers.

Hurlbert (1984) eloquently stated the importance of replication and independence in ecological studies. However, many studies using artificial nests have not tested for independence between nests (e.g., Esler and Grand 1993, Vacca and Handel 1988). We recommend that future studies use the 2-period cross-over design and test for independence between nests, but adopt a uniform (e.g., 7 d) visitation schedule. This would allow for analysis using likelihood ratio tests, a more appropriate and powerful test (e.g., White 1983), because each data record is used in the analysis and not pooled across categories.

Future studies should investigate the role of search images in nest predation in small habitat blocks, or decrease the spacing of nests to expose

individual predators to more nests over extensive areas. If predators develop a search image for markers, mortality rates of flagged nests may be higher than found in this study. Because nests may not be independent replicates if the spacing between nests is <400 m, plots or transects may need to be replicated. In our study area, artificial duck nests separated ≥ 400 m were independent replicates; however, artificial duck nests constructed in habitat configurations different than linear rights-of-way should also be evaluated for independence.

We believe our results suggest that flagging may effect predation of artificial nests under certain conditions. Our study found that flags may be a visual stimulus, which increases the predation of artificial nests without predators learning to associate flagging with nests (i.e., not developing a search image). We recommend not marking nests with flagging, instead natural objects should be used to aid in nest relocation.

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