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FACTORS INFLUENCING PREDATION ASSOCIATED WITH VISITS TO ARTIFICIAL GOOSE NESTS

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Abstract.—Artificial goose nests were used to determine what factors might increase predation after visits to nests of Cackling Canada Geese (*Branta canadensis minima*). We tested whether leaving the nest uncovered, marking the nest location with a flag, or placing the nest on an island or peninsula would increase the rate of predation. Predators destroyed significantly more of the nests with eggs exposed to view (61%) than of the nests with eggs covered with goose down (35%) ($P < 0.05$). However, the rate of predation was only slightly higher among nests located on peninsulas than on islands and equal proportions of flagged and unflagged nests were destroyed. We also determined that investigators attracted predators to the study area and caused an increase in predation at uncovered nests immediately after the visit. Covering the eggs with down essentially negated the effect of attracting predators when visiting the nest.

Among the 46 nests destroyed, 78% were destroyed by birds and 22% by mammals. Results of our study suggested that visibility of exposed eggs rather than nest markers provided important cues to avian predators and that islands probably provided some refuge from mammalian predators. Investigators can take steps to minimize their impact on nesting success and should incorporate a measure of that impact in their studies.

FACTORES QUE INFLUYEN EN LA DEPREDACIÓN, ASOCIADOS CON VISITAS A NIDOS ARTIFICIALES DE GANSOS

Resumen.—Se examinaron nidos artificiales de Gansos del Canada (*Branta canadensis minima*) para determinar los factores que podrian aumentar la depredación luego de las visitas. Se experimentó con nidos artificiales localizados en islas o penínsulas y con otros que fueron cubiertos o dejados al descubierto o su localización indicada con una pequeña bandera. Los depredadores destruyeron la mayoria de los nidos dejados al descubierto (61%) y tan solo afectaron el 35% de los nidos que fueron cubiertos con plumón de ganso. Sin embargo, la taza de depredación fue tan solo un poco más alta en nidos localizados en penínsulas que en islas, y de igual magnitud en nidos que fueron o no fueron marcados con banderas. Se determinó que los investigadores atraen depredadores al área de estudio y causan por consiguiente aumento en la depredación inmediatamente después de las visitas, particularmente en nidos que fueron dejados al descubierto. El cubrir los nidos con plumón de ganso, minimiza el efecto de atraer los depredadores.

De los 46 nidos destruidos, 78% fueron afectados por otras avea y el 22% por mamíferos. Los resultados sugieren que la exposición de un nido a la visibilidad por parte de depredadores provee a estos de pistas más concretas que las que le puedan proveer marcadores, y que las islas ofrecen cierta protección a la depredación por parte de mamíferos. Los investigadores deben tomar en consideración el impacto de sus visitas en sus investigaciones y tomar medidas para minimizar su efecto.

Dramatic declines in populations of the Cackling Canada Goose (*Branta canadensis minima*) and three other species of geese nesting in subarctic Alaska (Raveling 1984) have recently compelled researchers to determine the factors that affect their productivity. Because investigator visits to the nests of these species may increase predation, biases may result when estimating nesting success for the population (see Nichols et al. 1984 for review of impacts of investigators). Several studies that estimate the effects of visitation on nesting success have found no effect (Gottfried and Thompson 1978, Livezey 1980, Willis 1973), whereas others found nesting success significantly decreased (Bart 1977, Gillett et al. 1975, Lenington 1979, Ollason and Dunnet 1980, Robert and Ralph 1975, Strang 1980).

The intent of this study was to determine what factors might increase predation after visits to the nests of Cackling Canada Geese and what steps investigators might take to minimize their impact on nesting success. We hypothesized (1) that covering the eggs with down, as geese do when they leave the nest (Mickelson 1975), would reduce the rate of predation; (2) that marking the location of nests with flags would increase the risk of predation; (3) that the presence of the investigator would attract predators to the nest and predation would be increased (cf. Strang 1980); and (4) that visits to nests on islands would cause less of an increase in predation than visits to nests on peninsulas because of the relative inaccessibility of islands to foxes, one of the principal predators of geese and their eggs (Mickelson 1975). We tested these four hypotheses by analyzing predation rates of simulated goose nests subjected to various experimental treatments.

STUDY AREA AND METHODS

Field experiments.—Between 15 Jun. and 4 Jul. 1985, we monitored the fate of 96 artificial goose nests on 12 plots within nesting areas used by Cackling Canada Geese on the Yukon-Kuskokwim Delta, Alaska. The plots were in coastal tundra habitat between 3.2 km north and 11.5 km south of Old Chevak (61°26'N, 165°27'W) and were distributed among drainages of rivers that emptied into Hazen Bay, Angyoyaravak Bay, and Kokechik Bay. Mickelson (1975) provides a detailed description of habitats used by geese within this region.

Canada Goose eggs were simulated by domestic chicken eggs, which were smaller but similar in shape and color. The eggs were placed in nest bowls that had been used in previous years by geese. On each of the 12 plots, three eggs were placed in each of eight nest bowls, which were at least 30 m from other natural or experimental goose nests. The location of half of the experimental nests was marked by placing a pink, 10 cm × 12 cm flag on a 1 m wire, 5 m north of the nest bowl. Flagged and unflagged nests were at least 400 m apart to reduce the possibility that the flags would attract predators to the unmarked nests. Within each group of flagged and unflagged nests, two were nest bowls located on islands within ponds and two were on peninsulas. We covered half of these nests with goose down that had been collected during past years; in the remaining half of the nests the eggs remained exposed to view.

We varied the time intervals at which we visited nests in order to calculate the effect that visitation had on predation rates (see Bart 1977). Four of the twelve experimental areas were randomly assigned to each of three time intervals between initial placement of eggs and subsequent visit: (1) 3–6 h, (2) 21–33 h, and (3) 38–70 h. A nest was considered depredated when any eggs had been destroyed or removed.

The number of potential predators was recorded by scanning the area when the nests were initially set out and at the time they were rechecked. Potential predators were Glaucous Gulls (*Larus hyperboreus*), Long-tailed Jaegers (*Stercorarius longicaudus*), Parasitic Jaegers (*S. parasiticus*), arctic foxes (*Alopex lagopus*), red foxes (*Vulpes vulpes*) and American minks (*Mustela vison*).

At each depredated nest investigators attempted to identify the type of predator. Predation was attributed to mammals if no traces of eggshells were found around the nest, if shell fragments had tooth marks, or if tracks, fox fur, or scat were found near the nest. Predation was attributed to birds if egg fragments or punctured eggshells remained in or near the nest (Eisenhauer 1976; Ely and Raveling 1984; M. M. Vacca, pers. obs.).

Statistical analyses.—We used a series of three-way tests of independence (Sokal and Rohlf 1981) to determine the influence on predation rates of various combinations of the four experimental factors (exposure time, covering the eggs with down, marking the nests with flags, and location of the nest on an island or peninsula). The statistically significant combinations were then partitioned using two-way tests of independence (Sokal and Rohlf 1981) to determine which individual factors significantly influenced predation rates. Finally, 95% confidence intervals were calculated using one-tailed t-tests to determine the magnitude of the differences in predation rates among nests within paired treatments (covered vs. uncovered, flagged vs. unflagged, and island vs. peninsula). We were able to consider groups of nests on each of the 12 plots to be independent samples because of the balanced design of the experiment. Differences in the proportions of nests destroyed by avian and mammalian predators were tested for the various experimental treatments using Chi-square analysis (Sokal and Rohlf 1981).

To determine if the investigator attracted predators to the nest we calculated visitor impact according to Bart (1977). First we calculated the percent actual mortality (m_a) and the average length of time (t_i) of exposure to predators for clutches in nests subjected to each of the three time regimes (3–6 h, 21–33 h, 38–70 h). Using these figures we derived an average hourly rate (r) of mortality for the clutches that were exposed for 3–6 h (during which any impacts of visitation would have been concentrated) as follows: $(1 - r)^t = (1 - m_a)$. For each of the two longer time intervals we then computed what the expected mortality (m_e) would have been if this initial rate of mortality had remained constant, i.e., if all mortality observed during the 3–6 h period had been due to natural causes and there had been no visitor impact: $m_e = [1 - (1 - r)^t]$. Comparisons of these predicted values with the observed mortality rates were then made to determine if investigators had attracted predators to the nests and caused an increase in predation immediately following their visits to the nests. Significantly lower observed rates of mortality than predicted would imply that visitor impact had occurred.

TABLE 1. Design and results of experiments showing the influence of various factors on the rate of predation of artificial goose nests. The number of nests destroyed is shown in relation to the time they were exposed to predators, whether or not they were marked with flags or covered with down, and whether they were located on islands or peninsulas.

	Flagged				Unflagged				
	Covered		Uncovered		Covered		Uncovered		
Time exposed ($\bar{x}$)	Is.	Pen.	Is.	Pen.	Is.	Pen.	Is.	Pen.	Totals
3–6 h (4.2)									
Destroyed	1	0	0	1	0	0	2	2	6
Not destroyed	3	4	4	3	4	4	2	2	26
21–33 h (24.9)									
Destroyed	2	3	2	3	0	1	3	2	16
Not destroyed	2	1	2	1	4	3	1	2	16
38–70 h (51.7)									
Destroyed	2	2	3	4	3	3	4	3	24
Not destroyed	2	2	1	0	1	1	0	1	8

RESULTS

Effects of experimental treatments.—Predation was recorded at 48% of the 96 artificial goose nests we monitored; among these there were no instances of partial predation. The rate of predation varied greatly among the combinations of experimental treatments to which the nests were exposed (Table 1).

As expected, the rate of predation increased substantially with the amount of time the nests were exposed before being rechecked. Only 19% of the nests exposed for 3–6 h were destroyed whereas 50% and 75% of those exposed for 21–33 h and 38–70 h, respectively, were destroyed (Table 2). Eggs in nests which we left uncovered experienced almost twice the mortality as those in nests which we covered with down. The rate of predation was only slightly higher among nests located on peninsulas than among those on islands. Equal proportions of flagged and unflagged nests were destroyed by predators (Table 2).

Statistical tests for independence among these factors (time exposed, covering with down, flagging, and location on island or peninsula) revealed that there were no significant interactions in their influence on the proportion of nests destroyed. Among the six possible three-way tests of independence, only the three combinations that included exposure time as a factor were statistically significant (Table 3). When these combinations were further partitioned into two-way tests, we found that exposure time ($P < 0.01$) and covering the nest with down ($P < 0.05$) were the only two factors that significantly influenced predation rates (Table 3).

Because we found no significant interactions among the experimental factors, we were able to calculate confidence intervals for the effect of each factor on the rate of predation among the 12 experimental areas.

TABLE 2. Percent of artificial goose nests destroyed by predators under various experimental treatments.

Experimental treatment	n	Percent destroyed
Time exposed		
3–6 h	32	19
21–33 h	32	50
38–70 h	32	75
Covering with down		
Covered	48	35
Uncovered	48	60
Location of nest		
On island	48	46
On peninsula	48	50
Marking with flag		
Flagged	48	48
Unflagged	48	48

Under conditions similar to those in this study, goose nests not covered with down after a visit would be expected to suffer a rate of predation 12–38% (95% C.I.) higher than that of nests whose eggs were covered. Differences in depredation of nests marked with flags and nests not marked could be expected to vary from 17% lower to 17% higher (95% C.I.) and the loss of nests located on islands could range from 14% lower to 6% higher (95% C.I.) than loss of nests on peninsulas.

We also tested if rates of depredation by avian and mammalian predators were influenced differently by the various experimental treatments. Among the 46 nests destroyed, 78% were depredated by birds and 22% by mammals. Mammalian predators destroyed approximately equal numbers of uncovered and covered nests (six and four, respectively; corrected $\chi^2 = 0.50$, df $= 1$, $P > 0.10$). Avian predators, however, destroyed many more uncovered nests than covered nests (23 vs. 13), a difference that bordered on statistical significance (corrected $\chi^2 = 2.81$, df $= 1$, $P < 0.10$). Approximately equal numbers on islands and peninsulas (19 and 17, respectively) were destroyed by birds (corrected $\chi^2 = 0.139$, df $= 1$, $P > 0.5$). Nests on peninsulas, however, were more vulnerable to mammalian predators than nests on islands (seven vs. three destroyed, respectively), although this outcome was not statistically significant (corrected $\chi^2 = 1.70$, 1 df, $P > 0.10$). Both avian and mammalian predators destroyed an equal number of flagged and unflagged nests (18 each and five each, respectively).

Visitor impact.—Comparison of percent mortality among clutches in nests exposed to predators for varying lengths of time allowed us to test whether the investigator caused an initial increase in the rate of predation by attracting predators to the nest site. Because covering the eggs with

TABLE 3. Statistical independence among various factors that were tested for their influence on predation of artificial goose nests.

Factors[a] tested in treatments	df	G value	Significance of treatments[b]
Three-way tests[c]			
Time × covering × destroyed	7	30.118	**
Time × flagging × destroyed	7	25.210	**
Time × location × destroyed	7	22.176	**
Covering × flagging × destroyed	4	7.680	NS
Covering × location × destroyed	4	6.340	NS
Flagging × location × destroyed	4	0.836	NS
Two-way tests			
Time × destroyed	2	21.680	**
Covering × destroyed	1	6.074	*
Location × destroyed	1	0.166	NS
Flagging × destroyed	1	0.000	NS

[a] Time exposed to predators; covered with down or not; flagged or not flagged; located on island or peninsula; destroyed or not destroyed by predators.
[b] ** = $P < 0.01$, * = $P < 0.05$, NS = not significant.
[c] All three-factor interactions were not significant.

down significantly decreased the predation rate, we tested the groups of uncovered nests and covered nests separately for visitor impact.

Among clutches in uncovered nests, those in the 16 exposed for the shortest period of time (3–6 h) suffered 31.8% mortality. If this rate had remained constant, then the mortality for clutches in uncovered nests exposed for longer periods would have been 89.2% for those exposed an average of 24.9 h and 99.0% for those exposed an average of 51.7 h. Since these predicted values are much higher than the mortality rates observed during the study (Table 4), it is clear that the investigator's presence at the nests attracted predators and resulted in a higher rate of predation immediately after the visit than during subsequent hours of exposure.

This trend did not hold for nests that were covered with down. Among the 16 covered nests that were exposed for the shortest time, 6.3% were depredated. If this initial rate had remained constant, then predicted rates of mortality would have been 31.8% for those exposed for an average of 24.9 h and 54.8% for those exposed for an average of 51.7 h. Since these predicted rates are similar to and actually lower than the rates observed (Table 4), covering the eggs with down essentially negated the effect of attracting predators when initially visiting the nest.

Observations of predators.—Glaucous Gulls were the most common predator ($\bar{x}$ = 12.5, SD = 37.4) counted during 32 scans of the experimental plots, followed by Parasitic Jaegers ($\bar{x}$ = 0.81, SD = 1.84) and Long-tailed Jaegers ($\bar{x}$ = 0.19, SD = 0.74). No minks or foxes were recorded although a food cache of an arctic fox was found near one of the plots. The only direct observations of predation in this study were

TABLE 4. Test of visitor impact through comparison of observed and predicted mortality rates[a] for clutches in artificial goose nests left uncovered or covered with down. For uncovered nests, higher predicted rates than observed imply that visitor impact did occur, causing the rate of predation to increase immediately after the investigator left the nest and then to decline to natural levels afterward.

Treatment		Cumulative mortality during two intervals of exposure: 24.9 h[b]	51.7 h[c]
Uncovered nests	Predicted[d]	89.2%	99.0%
	Observed	62.5%	87.5%
Covered nests	Predicted[e]	31.8%	54.8%
	Observed	37.5%	62.5%

[a] Predicted cumulative mortality was calculated under the assumption that there was no visitor impact and that the observed hourly rates of predation for covered and uncovered nests visited after the shortest interval (3–6 h, $\bar{x}$ = 4.2 h, SD = 1.1, n = 32) should have remained constant throughout the longer intervals (cf. Bart 1977).

[b] Average time of exposure for nests visited after 21–33 h (n = 32, SD = 3.4).

[c] Average time of exposure for nests visited after 38–70 h (n = 32, SD = 10.5).

[d] Cumulative predicted mortality if initial predation rate observed for clutches in uncovered nests had remained constant (31.3% over 4.2 h = 8.5%/h).

[e] Cumulative predicted mortality if initial predation rate observed for clutches in covered nests had remained constant (6.3% over 4.2 h = 1.5%/h).

two instances in which Parasitic Jaegers were observed preying on eggs in artificial nests.

DISCUSSION

Results of this study support the hypothesis that visits by investigators to goose nests will, under certain conditions, have a measurable impact on predation. Predators were attracted to the study areas by investigators; however, only the artificial goose nests with eggs left exposed suffered a significant increase in predation rates. These nests suffered almost twice the rate of predation as nests in which the eggs were left covered with goose down, a difference attributable primarily to the higher rate of destruction of uncovered nests by avian predators. Our results confirm contentions of earlier studies on the Yukon-Kuskokwim Delta that jaegers and gulls followed people searching for waterfowl nests and sometimes took exposed eggs (Strang 1980) and that most losses of Cackling Canada Goose eggs resulted from such scavenging (Mickelson 1975). Other studies that tested the effect of leaving waterfowl nests exposed found that visibility of the eggs strongly influenced the rate of avian predation. Götmark and Åhlund (1984) found that after two hours 43% of their uncovered artificial Common Eider (*Somateria mollissima*) nests were destroyed by avian predators while the covered nests remained undisturbed. Dwernychuk and Boag (1972) found that the amount of vegetation concealing eggs from view was a major factor in the rate of destruction of artificial duck nests by avian predators.

Contrary to our expectations, marking the location of artificial goose nests with highly visible flags did not significantly increase predation. We hypothesized that flagging the nest would increase predation rates because avian predators commonly rely on visual cues to locate nests (Gottfried and Thompson 1978, Lenington 1979, Lill 1974, Strang 1980). Picozzi (1975) found that well-concealed artificial Red Grouse (*Lagopus lagopus*) nests suffered higher rates of predation by Crows (*Corvus corone*) when their locations were marked with short canes, and Reynolds (1985) observed that Sandhill Cranes (*Grus canadensis*) were attracted to stakes marking the location of shorebird nests. Both of these studies, however, dealt with prey species that normally rely on cryptic nests for defense against avian predators. In contrast, a Cackling Canada Goose nest is highly visible to avian predators, even when covered with down. Once incubation has begun geese are normally highly attentive to their nests, leaving them only for short periods (Mickelson 1975). Under undisturbed conditions, hens cover their eggs with nest material before departing, the gander guards the nest in the hen's absence, and attending geese usually defend their eggs from an attacking gull or jaeger (Mickelson 1975). Nests with exposed eggs would indicate that a defending adult is not nearby, either because it is during the egg-laying period when geese are less attentive or because the hen has been flushed from the nest. Therefore, exposed eggs rather than nest markers would be a better indication to a gull or jaeger of a potential food source.

Mammalian predators were not a major predator in our study, destroying only 10 of 96 artificial nests. Among these an equal number were flagged and unflagged nests, and approximately equal numbers were covered and uncovered nests, suggesting that mammals are not using static visual cues to locate nests, but instead may be following human scent, or are attracted by the investigator. Both Snelling (1968) and Willis (1973) believed that mammalian predators found nests by following human scent or were attracted to the area by flushing birds or other human activity. We also observed that nests on peninsulas were more vulnerable to mammalian predation than nests on islands, indicating that islands may provide refugia from mammalian predators.

Our results emphasize that in studies of nesting success it is important to know what predators are common in the study area and what cues they are likely to use to locate nests. In studies where gulls and jaegers are prevalent, investigators may be able to eliminate the impact of their visits to nests by covering the eggs with down before they leave. However, because patterns of predation may vary with density of nests or other factors, each study should include some measure of the impact of visitation.

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