EFFECTS OF HUMAN DISTURBANCE ON BREEDING OF DOUBLE-CRESTED CORMORANTS

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ABSTRACT.—In 1975 and 1976, studies of the Double-crested Cormorant were conducted in the St. Lawrence Estuary to assess the influence of investigators visiting colonies during the breeding season. Frequent visits caused nest abandonment, gull predation, and discouraged late-nesting birds from settling in disturbed experimental colonies. Late clutch commencement was more prevalent in the relatively undisturbed controls. Birds were less susceptible to disturbance in the second year of study, but for some reason other than habituation. *Received 10 March 1977, accepted 19 October 1977.*

INVESTIGATORS of reproductive success in colonial birds infrequently determine experimentally if successive visits to follow marked nests reduce the number of young finally fledged. Obviously if the data are biased they may lead to misleading conclusions when applied to a population model, a management decision, or an evaluation of toxic chemical concentrations. Here we report on an attempt to assess this bias in our studies of nesting success in the Double-crested Cormorant (*Phalacrocorax auritus*).

Human disturbance has been reported to increase predation by gulls and crows on eggs and young Double-crested Cormorants (Mendall 1936, Drent et al. 1964, Vermeer 1970, Lock and Ross 1973, Kury and Gochfeld 1975). Nestlings may also die of prolonged exposure to heat or cold (Mendall 1936). Controlled studies of human interference have been conducted on several species of gulls (Kadlec and Drury 1968, Hunt 1972, Robert and Ralph 1975, Gillett et al. 1975), all of which noted some adverse effects.

STUDY AREA AND METHODS

In 1975 and 1976 we conducted studies in the St. Lawrence Estuary on Ile Gros Pèlerin, near Rivière du Loup, Québec, and on Ile-aux-Pommes, 40 km downstream. Ile-aux-Pommes is a flat grassy island of 20 ha supporting about 300 nesting pairs of cormorants, 2,000 Common Eider (*Somateria mollissima*) nests, 3,800 Herring Gull (*Larus argentatus*) nests, and 600 Great Black-backed Gull (*L. marinus*) nests (Reed 1973). Both this island and Gros Pèlerin were uninhabited by people during our studies.

The topography of Gros Pèlerin is characterized by two rounded hills rising to 150 m and bordered in places by cliffs up to 50 m high. Much of this 22-ha island is forested by white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), and white birch (*Betula papyrifera*). About 1,600 nests of Double-crested Cormorants were counted in 1975, the majority in birch trees. Also nesting on the island were Black-crowned Night Herons (*Nycticorax nycticorax*) (380 nests), Great Blue Herons (*Ardea herodias*) (47 nests), Herring Gulls (530 nests), and Great Black-backed Gulls (fewer than 30 nests). Cantin (1974) estimated the following number of nests for other species in 1974: Common Eiders, 71; Razorbills (*Alca torda*), 80; and Black Guillemots (*Cepphus grylle*), 75.

In both years on Ile-aux-Pommes we studied only late nests in which laying began in late June or July. Earlier nesting occurred but conflicts with other studies on the island precluded visits by us in May and June. In July and August, visits of 45–60 min were made every 4–5 days to check marked nests. Pleasure boats were sometimes seen in the vicinity and each summer other visitors may have passed through our marked colonies.

On Gros Pèlerin we established an experimental and control colony for both the ground-nesting and

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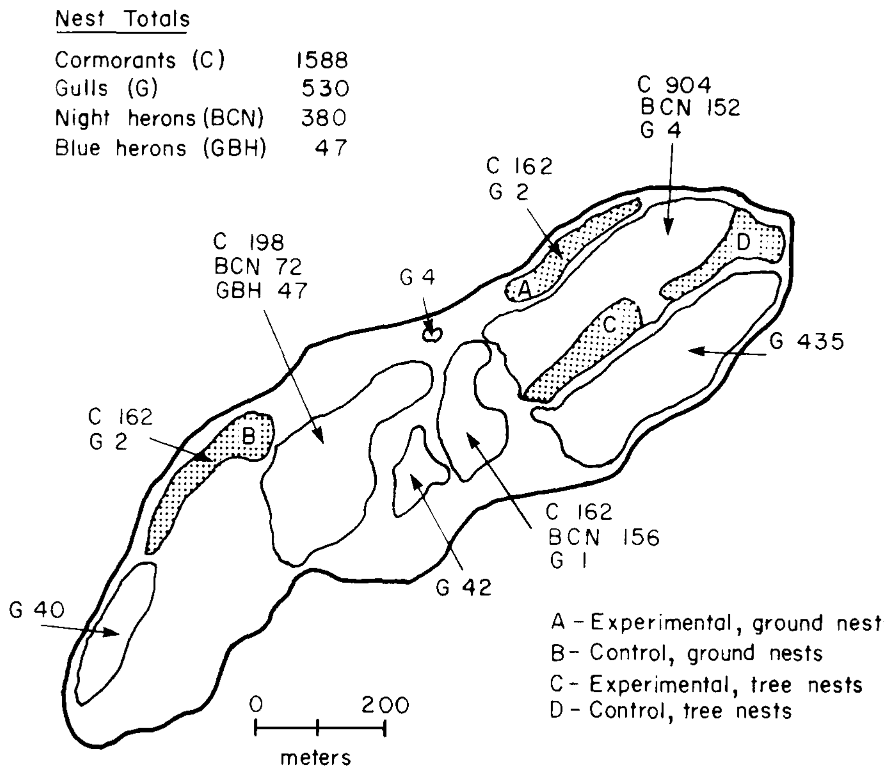

Fig. 1. Location of experimental and control colonies on Gros Pèlerin in 1975; locations reversed in 1976. Nest totals based on 1975 census and totals in 1976 were similar.

tree-nesting birds (Fig. 1). In 1976 we reversed the experimental and control to account for differences in environment, age structure of the colonies, and effects of habituation. The design of the experiment was to visit each control twice, once to record the clutch size of each nest and again to determine the number of fledglings. However, each year one control was also visited at the beginning of laying (noted later in tables). The treatments of the experimentals were our visits (14 to 20) to assess reproductive success. We tried to visit the experimental colonies every 3–4 days, weather permitting. Each visit to an experimental colony on the ground lasted from 45 min to 2 h. The tree nests were checked from an adjacent cliff and since eggs and young were not marked, visits to these experimentals and controls required only about 20 min. A visit to a control on the ground lasted about 30 min. Colonies were not visited during rain, and on sunny days we avoided colonies after mid-morning to minimize heat exposure among young. Some visits had to be made during cold, windy periods. As far as we know, no one else entered the colonies on Gros Pèlerin during the studies.

In 1976, to study predation during periods with and without disturbance, we set up a blind on a cliff overlooking the experimental colony of ground-nesting birds on Gros Pèlerin. One could enter the blind undetected by cormorants. The 40 min following our normal visit was considered the "disturbed" period, because early in the laying season some nests remained unattended for this length of time after we had passed through the colony. "Undisturbed" periods were those before a visit, or after the 40-min interval. Observations were made from late April to mid-June, when 104 young were in 61 visible nests. Hatching began on 26 May.

Standard t-tests were employed to test for differences between mean clutch size, brood size, and rates of predation. Because time intervals varied from day to day in the study of predation, a weighted variance was calculated for use in that t-test. Chi-square tests of independence were used to compare frequency distributions of clutch and brood sizes between colonies.

In this paper, an "active" nest is one in which laying occurred.

TABLE 1. Clutch comparison of cormorants nesting on the ground in experimental and control colonies on Gros Pèlerin, 29 May 1975 and 25 May 1976[a]

Number of eggs in nest	Percentage of clutches			
	1975[b]		1976[c]	
	Experimental	Control	Experimental	Control
0	4	7	5	4
1	6	6	5	9
2	20	15	14	17
3	40	43	44	45
4	28	28	31	24
5	2	1	1	1
Number of nests	107	118	65	82
Mean clutch size ± SD per nest with eggs[d]	2.99 ± 0.92 (n = 103)	3.03 ± 0.87 (n = 110)	3.11 ± 0.85 (n = 62)	2.92 ± 0.92 (n = 79)

[a] In 1975, experimental visited 8 times before 29 May and control visited once. In 1976, experimental visited 10 times before 25 May but the control had never been visited
[b,c] Frequency distribution of experimental and control similar, $\chi^2 = 1.7^{ns}$ with 4 df for 1975, and $\chi^2 = 1.1^{ns}$ with 3 df for 1976
[d] No significant differences between colonies or years, $P > 0.05$

RESULTS

Ile-aux-Pommes.—The number of nests increased from 247 in July 1975 to 307 in July 1976, including in both years many new nests constructed in June in sites not recently utilized by cormorants. On 8 July 1975, we marked 50 active nests in 3 subcolonies, the first of these comprising 14 new nests located around a bay on the west end of the island. All 33 eggs in these 14 nests were destroyed by gulls, 29 of the eggs disappearing within 60 min of our first visit. No re-laying occurred.

The other 2 subcolonies, adjacent to and east of the first, included 93 fledglings around 113 old nests, 45 with recent clutches. We marked 36 of the 45 new clutches, some of which were presumably second clutches. These 36 nests produced a mean of 0.75 fledged young.

Not all new nests in 1975 were doomed to failure. A fourth subcolony of 64 new

TABLE 2. Clutch comparison of cormorants nesting in trees in experimental and control colonies on Gros Pèlerin, 29 May 1975 and 25 May 1976[a]

Number of eggs in nest[d]	Percentage of clutches			
	1975[b]		1976[c]	
	Experimental	Control	Experimental	Control
0	5	10	2	4
1	4	7	4	4
2	8	6	14	12
3	21	26	23	21
4	12	6	17	22
5	3	4	2	1
6	2	0	0	0
Adult on nest[e]	45	41	38	36
Number of nests	75	110	52	109
Mean clutch size ± SD per visible nest with eggs[f]	3.11 ± 1.10 (n = 37)	2.83 ± 1.06 (n = 54)	3.00 ± 0.97 (n = 31)	3.08 ± 0.94 (n = 65)

[a] In 1975, experimental visited 7 times before 29 May and control not previously visited. In 1976, experimental visited 6 times before 25 May and control once in late April
[b,c] Frequency distribution of experimental and control similar, $\chi^2 = 5.2^{ns}$ with 6 df for 1975, and $\chi^2 = 0.8^{ns}$ with 4 df for 1976
[d] Each of the four colonies contained some nests (maximum of 9) in which some eggs had recently hatched. For the table, the young were considered as eggs and mean clutch size calculated accordingly
[e] Tenacious adults in late stage of incubation or covering small young were not forced to leave their nests
[f] No significant differences between colonies or years, $P > 0.05$

TABLE 3. Brood comparison of cormorants nesting on the ground in experimental and control colonies on Gros Pèlerin, 5 July 1975 and 28 June 1976[a]

Number of young in nest	Percentage of broods			
	1975[b]		1976[c]	
	Experimental[d]	Control[e]	Experimental	Control
0	70	43	9	12
1	14	10	16	9
2	7	13	35	20
3	8	12	33	24
4	0	4	5	6
Recent eggs and/or young <1 wk old[f]	1	18	2	29
Number of nests	95	100	55	89
Mean brood size ± SD among nests with young >2 wk old[g]	1.82 ± 0.86 (n = 28)	2.26 ± 0.97 (n = 39)	2.31 ± 0.85 (n = 49)	2.44 ± 0.87 (n = 52)
Young fledged per active nest	0.41		1.42	

[a] In 1975, experimental visited 18 times before 5 July and control visited once. In 1976, experimental visited 19 times before 28 June and control twice
[b,c] Frequency distribution significantly different in 1975 (χ^2 = 24.8, 4 df, $P < 0.005$) and in 1976 (χ^2 = 19.3, 5 df, $P < 0.005$)
[d] A group of 12 large young that had left their nests could not be separated into their respective broods and are omitted
[e] Three groups of large young (21 birds) outside their nests could not be separated into broods and are omitted
[f] Eggs found in nests with large young considered infertile and are omitted
[g] No significant differences between experimental and control in 1975 or 1976, $P > 0.05$

nests, located about 300 m east of the 14 new nests mentioned above, and visited 7 times, produced at least 1.19 young per active nest. In 1976, early nesting occurred in this subcolony, indicating successful establishment in the new nesting site.

On 9 July 1976, eggs were marked in 47 new nests of the year around the bay where we had marked 14 new nests in 1975. By our fifth visit in early August all eggs and the few small young had been destroyed by gulls. Thus in both years the new nests around the bay failed and we attribute this in part to the large number of gulls frequenting the bay. It is also possible that many birds constructing new nests in June were young inexperienced nesters. The fact that predation was not high in 1975 among the older nests can be explained partly by the presence of the nearly grown young who stayed in or near the colony during our visits.

Gros Pèlerin.—The effects of our presence on Gros Pèlerin were more subtle, with no heavy predation occurring during any one visit. In both years we began marking nests in late April and continued checking nests until fledging in mid-July. To determine if our presence in these experimental colonies had affected either mean clutch size or the frequency distribution of clutches, the controls were checked in late May (Tables 1 and 2). In neither year was there any significant difference in mean clutch size, frequency distribution of clutches, or proportion of empty nests between experimentals and controls of ground-nesting or tree-nesting birds. However, even if we had caused a high rate of nest abandonment in an experimental colony, it probably could not have been detected in this comparison, particularly for ground nests, because abandoned ground nests disappeared in a few days as neighboring cormorants took the nest material.

The controls were again checked in late June or early July to evaluate effects of disturbance on survival of young (Tables 3 and 4). In neither year was mean brood size significantly different between experimentals and controls, in either ground or tree nests. But in 1975 the experimental on the ground contained more empty nests (70% vs. 43%, χ^2 = 12.8, 1 df, $P < 0.005$) (Table 3), and among tree nests both the experimental and control manifested many empty nests (61% and 48% empty, Table 4). All empty tree nests were failures. A very small percentage of ground nests, both

TABLE 4. Brood comparison of cormorants nesting in trees in experimental and control colonies on Gros Pèlerin, 5 July 1975 and 5 July 1976[a]

Number of young in nest[d]	Percentage of broods 1975[b] Experimental	1975[b] Control	1976[c] Experimental	1976[c] Control
0	61	48	9	8
1	17	12	26	23
2	10	17	29	36
3	11	9	22	17
4	0	0	2	8
Recent eggs and/or young <1 wk old	1	14	12	8
Number of nests	83	101	68	75
Mean brood size ± SD among nests with young >2 wk old[e]	1.84 ± 0.86 (n = 31)	1.92 ± 0.75 (n = 38)	1.98 ± 0.84 (n = 54)	2.13 ± 0.92 (n = 63)
Young fledged per active nest	0.79		1.31	

[a] In 1975, experimental visited 15 times before 5 July and control previously visited once. In 1976, experimental visited 13 times before 5 July and the control once

[b,c] Frequency distribution significantly different in 1975 ($\chi^2 = 13.1$, 4 df, $P < 0.025$) but not in 1976 ($P > 0.05$)

[d] No young had flown from their nests by 5 July

[e] No significant differences between experimental and control in 1975 or 1976, $P > 0.05$

in the experimental and control, were empty because the young were outside their nests. In contrast, in 1976 fewer than 13% of nests were empty in any colony. As discussed later, birds were perhaps more susceptible to disturbance in 1975, and thus abandoned more nests.

In both years the controls on the ground contained a higher percentage of late nests with eggs or very small naked young (1975, 18% vs. 1%, $\chi^2 = 13.9$, 1 df, $P < 0.005$; 1976, 29% vs. 2%, $\chi^2 = 15.5$, 1 df, $P < 0.005$) (Table 3). For tree nests, the control had more late nests only in 1975 (14% vs. 1%, $\chi^2 = 8.2$, 1 df, $P < 0.005$) (Table 4).

If nest failure had been high in experimentals and birds moved to the undisturbed controls to renest, a simple explanation would exist for the late nests in the controls. However, nest failure was very high in the experimentals only in 1975, but the highest percentage of late nests occurred in a control in 1976 (Table 5). Thus the late clutches may have been laid by delayed nesters who chose to avoid the disturbed colonies.

Fledging success in the experimental colonies was higher in 1976 than in 1975 (1.3 to 1.4 young per active nest vs. 0.4 to 0.8, Tables 3 and 4). Only early nests contributed to fledging success in experimental colonies on Gros Pèlerin.

Data from the blind in 1976 indicated that human induced predation could not be invoked to entirely explain the high failure rate of disturbed nests in 1975. During

TABLE 5. Percentage of active nests that failed in experimental colonies and proportion of late nests in these experimental colonies and their corresponding control[a]

Year	Location	% active nests failing in experimental	% late nests on 28 June or 5 July: Experimental	% late nests on 28 June or 5 July: Control
1975	Ground	76	1	18
	Trees	58	1	14
1976	Ground	31	2	29
	Trees	32	12	8

[a] In 1975 vs. 1976, a higher percentage of ground nests failed ($\chi^2 = 23.8$, 1 df, $P < 0.005$) and a higher percentage of tree nests failed ($\chi^2 = 8.5$, 1 df, $P < 0.005$)

8 h 10 min observation of a ground colony in a disturbed state (14 observation periods), Herring Gulls removed 4 eggs (0.49/h). In 73 h observation without disturbance, predators removed 10 eggs (4 by Crows *Corvus brachyrhynchos*, 6 by Herring Gulls) (0.14/h, rates not significantly different, $P > 0.05$). Seven of these 10 eggs were taken in one observation period during a violent wind on 7 May, which allowed gulls and crows to hover over the cormorants, who readily left their nests. Since we were usually unable to reach the island during stormy periods, we believe that the rate of 0.14 eggs/h for the undisturbed periods is too low. No predation of young was noted from the blind, but the remains of two chicks were found in a gull colony.

Cormorants made no attempt to expel from the colony gulls or crows in the act of predation. During the undisturbed periods one or two gulls often roamed unmolested among the nests searching for bits of fish. One pair of gulls that nested in the colony seemed responsible for most of the egg predation, but these and other gulls were extremely aggressive toward crows that entered the colony. Thus we agree with several other authors who suggest that the presence of gulls who repel raiding crows can augment hatching success in colonial birds (Olsson 1951, Koskimies 1957, Reed 1973, Dwernychuk and Boag 1972).

Discussion

On Ile-aux-Pommes we caused the immediate failure of some subcolonies of late-nesting birds by facilitating gull predation. Predation was probably heavier on this island than on Gros Pèlerin because more inexperienced cormorants were nesting for the first time near a concentration of gulls at a date when eggs of other species were unavailable to gulls. The ratio of adult gulls to cormorants on Ile-aux-Pommes was about 15.3, compared with 0.3 on Gros Pèlerin, assuming gull numbers on Ile-aux-Pommes were similar to those reported by Reed (1973).

On Gros Pèlerin, in both years, cormorants nesting in the disturbed ground and tree colonies incubated normal clutches and reared as many young as early-nesting adults in the less disturbed controls. But in both years the control ground colonies contained more late nests than the experimentals, and in 1975 the control tree colony also had more late nests. Only in 1975 did an experimental colony manifest more empty nests than its control (ground nests), but in 1975 both the experimental and control tree colonies had many empty nests (61% and 48% in 1975 vs. 9% and 8% in 1976). These comparisons suggest a reduction in susceptibility to disturbance from 1975 to 1976, a change not attributable to habituation because experimentals and controls were reversed between years.

Other lines of evidence suggested that adults on Gros Pèlerin were particularly susceptible to disturbance in 1975. First, as already noted, nest failure was higher in 1975. This was partly due to a tendency to abandon nests. For example, before the end of May, 28% of all marked active nests on the ground were abandoned and torn apart by neighbors, whereas in 1976 the corresponding figure was only 4%. Loss of eggs and young also contributed to nest failure. In 1975 more marked eggs disappeared from ground nests than in 1976 (46% vs. 27%, $\chi^2 = 17.1$, 1 df, $P < 0.005$) and more young disappeared or died (61% vs. 38%, $\chi^2 = 9.1$, 1 df, $P < 0.005$). Second, it was evident that in 1975 adults were less protective of eggs and young and readily left their nests when we approached. In 1976 adults late in incubation or with small young were so aggressive that we had to force many off their nests to avoid being bitten, a problem that never arose in 1975. The same change in behavior was noted independently by Austin Reed (pers. comm.) among early-nesting cormorants on Ile-aux-Pommes. Considered together, these annual differences suggest that, for some reason, adults exhibited less nest tenacity in 1975 than in 1976.

Some aspects of our effort to evaluate reproductive success on Gros Pèlerin are biased. The data on clutch size of early nests should be correct if one accepts a strict definition based on only complete sets of eggs undiminished by predation or by early abandonment. Also the data on number of young fledged per successful early nest should be correct. But, since the experimentals contained few late nests, which may be less successful than early nests, reproductive performance of successful nests as a whole could be overestimated. If breeding success is expressed by number of laying attempts that were successful, or by young fledged per laying attempt, the data from experimental colonies will underestimate the success that would have occurred in the absence of the investigation.

Kury and Gochfeld (1975) have recommended that colonies managed for tourists should be visited late in the nesting cycle when young are half grown. We agree with this recommendation because nest abandonment is most likely to occur early in the season. Kury and Gochfeld also suggested that some disturbance early in the season would be desirable so as to induce loss of nests, subsequent re-laying, and thus the presence of late nests with eggs and young for viewing later in the season. We do not concur with the latter. On Gros Pèlerin our disturbance early in the season did not have this effect, the late nests being found mostly in the control sites.

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