

REPRODUCTIVE PERFORMANCE OF CASPIAN TERNS AT A NEW COLONY ON LAKE ONTARIO, 1979-1981

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In 1976, we found a group of 7 nests of the Caspian Tern (*Sterna caspia*) on the Eastern Headland, Toronto Outer Harbour, Toronto, Ontario (Blokpoel and Fetterolf 1978). There seems to be no information about reproductive performance of Caspian Terns at newly established colonies. Such information could be valuable in assessing whether such colonies will survive or disband. The objective of this study was therefore to determine reproductive performance at this new colony. In this paper we (1) report the reproductive performance of the terns during our 3-year study, (2) evaluate two different methods for monitoring reproduction, (3) assess the impact of investigator disturbance and of mammalian predation on reproduction, and (4) compare our findings with those of previous investigators.

METHODS

Study area.—The study was conducted during April–August 1979–1981 at the Eastern Headland, Toronto Outer Harbour. The Headland is a man-made peninsula which juts approximately 5.5 km into Lake Ontario in a southwestern direction from Toronto's waterfront (Fig. 1). The Caspian Terns nested in area B each year since 1976 (Fig. 1), shifting nesting sites slightly from year to year, but remaining in a relatively dry sandy area with sparse herbaceous vegetation. The sandy, open area was bounded on all sides by 1.5–6 m cottonwoods (*Populus deltoides*) and 0.5–4 m willows (*Salix* spp.). The terns usually nested on elevated (0.5–2.5 m) mounds and were always surrounded by densely packed nests of Ring-billed Gulls (*Larus delawarensis*). The terns nested in 2 groups in 1979 and 1981; in 1980 there was only 1 nesting group.

Procedures to assess reproductive performance.—In 1979, we documented hatching success (defined below) by entering the colony every 1–3 days throughout the nesting season in fair weather. To distinguish this assessment method from the one used in 1980 and 1981 (described below), we use the term "direct monitoring." Visits were made between 0800 and 1000. Eight visits during the first 60% of the egg-laying period averaged 35.6 min (SD = 9.43, range = 20–50 min). We marked nests using numbered sticks. Each egg was marked with a felt-tipped pen to indicate order of laying. We handled most eggs on each visit to determine if the egg was warm or cold, damaged, or pipping. Within 2 days of hatching we banded each chick with an aluminum band. Visits continued until there were no nests with eggs or chicks in the study area. During June and July we studied Ring-billed Gulls nesting near the terns. These visits usually lasted 20–30 min and occurred on days when Caspian Terns were not visited.

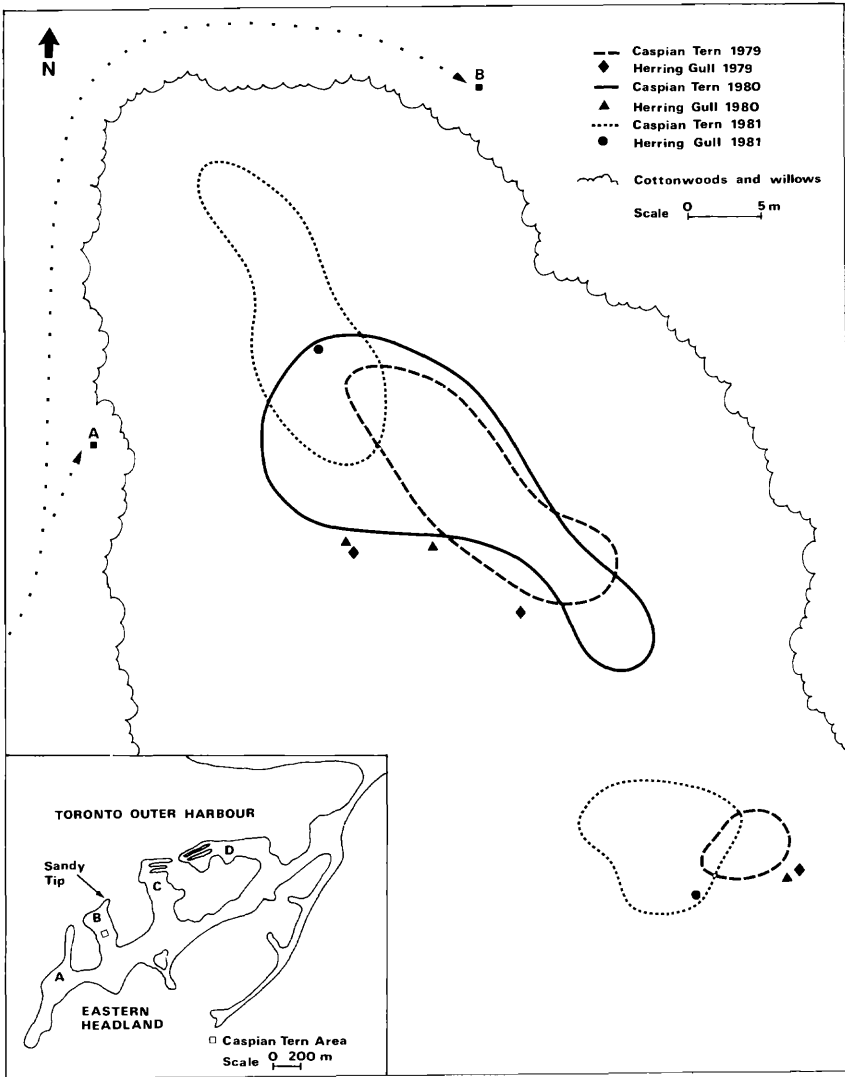


FIGURE 1. Map showing the Caspian Tern nesting location on the Eastern Headland, the sandy tip of area B, and a detailed map of the Caspian Tern nesting sites in 1979-1981. Herring Gull nest sites are shown for each year. Locations of the observation platforms (A, B) are also shown.

In 1980 and 1981, we checked nests every other day between 0900 and 1700 until the first eggs pipped. We marked nests with brightly colored numbered stakes and marked and handled eggs as in 1979. Whenever possible, we limited visits to 20 min in each subcolony (\bar{x} = 15.6, SD = 4.89, range = 5-26 min, n = 28). After pipping began, we

did not visit gull or tern nesting sites again until all terns with eggs and chicks had left the sandy area.

Once pipping of the first eggs began, we monitored each nest from a remote observation post to eliminate our activity in the colony as a possible cause of chick mortality. A ladder concealed amongst 3.5 m cottonwoods served as a platform for the observer (except late in 1980 and 1981, see below). Observation posts were 12–15 m from the nearest tern nest (Fig. 1). The area between the observer and the terns was occupied by Ring-billed Gulls. These gulls as well as the terns remained on their nests (territories) during observation periods.

During each observation period we (1) recorded the presence and activities of adults at each known nest site (incubation, brooding, standing-by), (2) mapped the location of new nests as determined by incubation behavior, (3) determined the number of eggs in nests which were initiated after direct monitoring ended, (4) counted the number of chicks in each brood, and (5) mapped or recorded the new location of broods which had moved from their nest sites. Accurate mapping was facilitated by topographical features and by a grid of numbered stakes placed in the nesting area during direct monitoring in 1980. We describe this procedure to assess reproductive performance as "remote monitoring." All 1980 observations were conducted daily whenever possible, whereas those in 1981 were made every 1–4 days. All remote monitoring was carried out between 0900 and 1200 by the senior author.

We recorded a new nest whenever a tern exhibited incubation behavior at a specific location for a full remote observation watch (usually 1 h) and at the same site on subsequent watches. We used brooding behavior to determine hatching in each nest. During incubation these terns sit so that the tips of the primary feathers cross to form an "x" above the tail. Brooding behavior was indicated when the tips of the primaries were lowered and became almost parallel to the anterior-posterior body axis. Each new nest location was easily confirmed after the terns abandoned the nesting areas because there was a concentration of pebbles and fish bones in and around the nest bowl.

Eggs were incubated immediately after the first egg was laid so observing the number of eggs in a nest from 12–40 m required a good telescope, patience, and a certain degree of luck. The interval between the laying of eggs in a nest is 2.3–2.7 days (Quinn 1980). To make sure that a clutch was completed, clutch size was not recorded until at least 6 days after a nesting attempt was first noted. Observations of clutch size were possible when terns changed incubation duties, left the nest to defecate, or stood off the nest in hot weather.

Families were distinguishable as spatially discrete units of adults attending chicks, i.e., adults and chicks from the same nest were closer to one another than to neighboring families. Considerable natural variation in the plumage color of chicks (Chanoit 1970, Shugart 1977), the variation in brood sizes, and the variation in the size of chicks among neighboring broods gave us 3 additional clues to determine family iden-

tity. Families were easily distinguished until chicks reached 4–6 weeks of age.

In late July 1980 and 1981, the terns moved from the nesting area to the sandy tip of area B (about 200 m away) (Fig. 1). By this time, 46 out of 56 (82%) of the families (1980) and 60 out of 71 (85%) of the families (1981) had chicks of 30 days of age or older, i.e., fledging age (see below). We visited every 1–2 days and observed the birds from a concealed location in vegetation. The terns stood along the open shoreline in distinct groups consisting of 1–2 adults and 1–3 chicks. Some families could still be individually identified on the basis of chick plumage color, brood size, and chick size, but without spatial cues previously provided by nest sites, many could not. We therefore instituted a system to determine fledging of chicks that were still less than 30 days of age. Caspian Tern chicks do not lose all their down until the age of about 30 days. Since we knew the number of pre-fledging-aged chicks with down prior to the long distance movement, we counted the number of downy chicks on each visit.

In 1980 we removed 49 Ring-billed Gull nests and contents around the edge of the tern colony on our last 2 visits during the direct monitoring period. In 1981, we removed Ring-billed Gull nests and contents at each tern nesting area (northernmost-30; southernmost-25) on our last 2 visits during the direct monitoring period. A few pairs of Herring Gulls (*L. argentatus*) also nested in the sandy area (Fig. 1). In 1981, a pair of Herring Gulls nested at the edge of each of the tern sub-colonies. Just after the terns started nesting, the northernmost pair was collected and the nest was removed. We removed no Herring Gulls in 1980. Collection of gulls and removal of gull nests was done under permits issued by the Canadian Wildlife Service.

Definition of terms.—Because some definitions used in previous assessments of reproductive performance of gulls and terns vary widely and because we use several terms unique to our study, we present the following definitions: (1) “hatching success” was the number of eggs hatched divided by the number of eggs laid, (2) “fledging success” was the number of chicks reaching 30 days of age (fledging) divided by the number of eggs hatched, and (3) “net reproductive output” was the number of chicks fledged divided by the number of eggs laid.

Definition of egg and chick fates are especially important in this study because we determined hatching of eggs and loss of chicks from a remote observation post. An egg that failed to hatch was one that was incubated for at least the length of a normal incubation period (27 days, Penland 1976) but from which no chick emerged successfully. We designated an egg as deserted when it was cold to the touch (direct monitoring) or not incubated by a tern (remote monitoring) before the completion of a normal incubation period. We counted an egg as disappeared when it was observed missing before the completion of a normal incubation period. An egg was termed “depredated” if destroyed or damaged between direct monitoring visits or remote monitoring observa-

tions. A chick that died on territory was one observed dead on the territory of a pair which had a decrease in brood size while no nearby broods had decreased. The dead chick had no obvious signs of predation by mammals or attacks by conspecifics. We recorded a chick as disappeared whenever a brood decreased in number, a neighboring brood did not increase in number, and the missing chick was not observed dead. A young tern was considered the victim of predation whenever a chick was observed dead or had disappeared during the observation period immediately following predation in the colony. Once a dead chick was observed near the nest with severe head wounds so we assumed the chick was killed by conspecifics.

Organization of the data.—We present data on reproductive performance for “initial nests” initiated before 15 June and “late nests” begun after that date (after Shugart et al. 1978). We present 3 groups of data for hatching success in 1980 and 1981: (1) initial nests observed using direct monitoring before pipping and remote monitoring after pipping, (2) initial nests observed using remote monitoring only, and (3) late nests observed using remote monitoring. This breakdown allows a comparison of initial nests monitored directly with those monitored remotely.

RESULTS

Nest starts.—Compared to 1979, there was no notable increase in nest starts in 1980 (Table 1). However, nesting attempts increased by 25% between 1980 and 1981. There was also a shift in the relative frequencies of initial and late nesters over the 3-year study. The proportion of late nesting attempts was lower in each of the last 2 years than in the first (1979 vs 1980, $\chi^2 = 7.61$, $P < .01$; 1979 vs 1981, $\chi^2 = 18.77$, $P < .001$). There was no significant difference in initial and late nest starts between the last 2 years ($\chi^2 = 1.58$, $P > .05$).

Clutch size.—Of the nests in which eggs hatched in 1980 and 1981 during remote monitoring, we failed to determine clutch sizes prior to hatching at 7 nests (18%). At each we counted the number of chicks and eggs within 6 days after the first egg hatched.

During remote monitoring, we did not observe clutch sizes in 7 (58%) nests started late in the last 2 years of the study because these nests were destroyed by predators shortly after they were initiated. The modal clutch size for late nests with known contents was 2 eggs. Given the laying interval between eggs of less than 3 days (Quinn 1980), we therefore assumed that nests where adults incubated for more than 3 days contained 2 eggs and those where adults incubated for fewer than 3 days contained 1 egg.

The frequency of 1-, 2-, and 3-egg clutches in initial nests varied significantly during the 3-year study ($\chi^2 = 9.65$, 3×3 contingency table, $df = 4$, $P < .05$). Mean clutch size for initial nests changed from 2.07 (SD = .82, $n = 41$) in 1979, to 2.24 (SD = .63, $n = 59$) in 1980, and 2.30 (SD = .72, $n = 81$) in 1981. The frequency of different clutch sizes for late nests did not vary during the study ($\chi^2 = 7.36$, 3×2 contingency

TABLE 1. Hatching success and egg fates at initial and late nests determined by direct or remote monitoring in 1979-1981. See text for details.

Year	Nest type	Method	No. nests	No. eggs laid (a)	No. eggs hatched (b)	Hatching success		No. eggs failed to hatch	No. eggs deserted	No. eggs disappeared	No. eggs depredated	No. eggs out of nest	No. eggs destroyed by worker
						(a/b x 100%)	100%						
1979	Initial	D ¹	41	88 ²	52	59	22 (25) ³	9 (11)	1 (1)	2 (2)	0 (0)	0 (0)	2 (2)
	Late	D	28	36	20	56	7 (19)	2 (6)	0 (0)	6 (17)	0 (0)	0 (0)	1 (3)
	Total		69	124	72	58	29 (23)	11 (9)	1 (1)	8 (7)	0 (0)	0 (0)	3 (2)
1980	Initial	D	43	100	87	87	7 (7)	6 (6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Initial	R	16	32	28	88	4 (12)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Late	R	13	24	8	33	2 (9)	0 (0)	0 (0)	13 (54)	1 (4)	0 (0)	0 (0)
Total		72	156	123	79	13 (8)	6 (4)	0 (0)	13 (8)	1 (1)	0 (0)	0 (0)	
1981	Initial	D	68	157	123	78	15 (10)	12 (8)	2 (1)	3 (2)	0 (0)	0 (0)	2 (1)
	Initial	R	13	29	25	86	2 (7)	2 (7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Late	R	9	18	6	33	2 (11)	0 (0)	0 (0)	10 (56)	0 (0)	0 (0)	0 (0)
Total		90	204	154	75	19 (9)	14 (7)	2 (1)	13 (7)	0 (0)	0 (0)	2 (1)	

¹ D = Direct, R = Remote. See text for details.² Excludes egg fates for three nest starts because egg fates were unknown.³ All figures in parentheses are percentages.

table, $df = 3$, $P > .05$). Mean clutch size for late nests was 1.50 (SD = .51, $n = 28$) in 1979, 1.85 (SD = .38, $n = 13$) in 1981, and 2.00 (SD = .50, $n = 9$) in 1981. Clutch size for 11 nests in 1977 was 2.00 (Haymes and Blokpoel 1978).

Egg fate.—Of 381 eggs laid during direct monitoring in 1979–1981, only 3 (0.8%) eggs disappeared from a nest that was being incubated (eggs warm) on the previous visit (Table 1). After incubation ceased, eggs that failed to hatch or eggs that were deserted were visible at nest sites for an average of 26.9 days (SD = 18.7, range = 2–64 days, $n = 45$). By 1 week after hatching, adults attending nests stood and resettled so frequently that the nest contents could be determined with certainty.

Using direct and remote monitoring, we observed 309 eggs in clutches which were incubated for at least 27 days in 1980 and 1981. Of these, 3 (1.0%) could not be accounted for when broods were first seen about 6 days after hatching began. In other words, there was an egg or chick missing from each of 3 nests. In these instances, we assumed the egg had hatched and that a chick had disappeared. We may therefore have slightly overestimated hatching success and underestimated fledging success. Nevertheless, we correctly estimated net reproductive output.

Hatching Success

Initial nests.—Both in 1980 and 1981, hatching success at initial nests was not significantly different during direct and remote monitoring (1980, $\chi^2 = .06$, $P > .05$; 1981, $\chi^2 = .51$, $P > .05$) (Table 1). We therefore combined those data for each year. Hatching success was lowest in 1979, increased greatly in the next year, and decreased slightly in 1981 (Table 1). The levels of hatching success in the last 2 years of the study were each significantly higher than in 1979 (1980— $\chi^2 = 21.18$, $P < .001$; 1981— $\chi^2 = 11.69$, $P < .001$), whereas levels of hatching success in the last 2 years did not differ significantly ($\chi^2 = 2.57$, $P > .05$).

To test whether the reduction in the duration of our visits from 1979 to 1980 and 1981 may have affected hatching success, we compared hatching success between years for initial nests that were directly monitored. Hatching success was significantly lower for directly monitored initial nests in 1979 than in 1980 ($\chi^2 = 17.50$, $P < .001$) and 1981 ($\chi^2 = 9.32$, $P < .005$). However, hatching success was not different between 1980 and 1981 ($\chi^2 = 2.51$, $P > .05$).

Late nests.—During the first year of the study, hatching success for late nests reached 56% and during each of the last 2 years was nonsignificantly lower at 33% (1979 vs 1980— $\chi^2 = 2.03$, $P > .05$; 1979 vs 1981— $\chi^2 = 1.57$, $P > .05$). A comparison of hatching success between initial and late nests in the first year of the study revealed no difference ($\chi^2 = .26$, $P > .05$). However, a similar comparison within each of the last 2 years indicated significantly higher hatching success for initial nests than late nests (1980— $\chi^2 = 31.99$, $P < .001$; 1981— $\chi^2 = 16.63$, $P < .001$).

Fledging Success

Initial nests.—We did not monitor fledging success in 1979 because most chicks disappeared from the nesting site within 2–10 days of hatching. We assume that several of those chicks died even though we only found 2 chicks dead or dying on the colony site. Chicks younger than 10 days are the most likely to die when the study site is directly monitored as it was in 1979 (see Shugart et al. 1978, Quinn 1980). Two band returns at locations away from the Headland demonstrate that at least 2 individuals fledged (57 chicks were banded in 1979).

Ninety percent of the chicks that hatched in initial nests in 1980 reached our fledging criterion of 30 days of age (Table 2). Fledging success for initial nests climbed to 98% in the next year and was significantly higher than in the previous year ($\chi^2 = 5.88, P < .05$).

Late nests.—Fledging success for late nests was 50% in each of the last 2 years of the study. This success rate was significantly lower than for initial nests in 1980 (Fisher's exact test, $P < .001$) and in 1981 (Fisher's exact test, $P < .001$).

Net Reproductive Output

Net reproductive output was not measured in 1979. In 1980, 79% of the eggs laid in initial nests produced chicks which fledged (Table 2). In 1981, net reproductive output was 78%. By contrast, only 17% of all eggs laid late in the season in both years produced chicks of fledging age. The differences in net reproductive output for initial and late nests within each year were significant (1980— $\chi^2 = 33.90, P < .001$; 1981— $\chi^2 = 28.09, P < .001$).

DISCUSSION

Assessment of our methods.—We believe that direct monitoring for 20 min or less every second day before pipping in combination with remote monitoring thereafter provided accurate data and eliminated any chick mortality which could have resulted from our presence in the tern colony. Remote observation of adult activity and new nest starts presented no problems for the observer because incubation behavior at a nest site was obvious. Remote observations of clutch size were, we believe, highly accurate with the possible exception of late nests which were destroyed by predators shortly after they were begun. The brood size gave a highly accurate indication of clutch size and disappearance of eggs or chicks was rare. When eggs failed to hatch, they were usually visible at nest sites for several weeks.

Determination of brood size using remote monitoring was easy until at least 14 days after hatching began in a nest because the family remained on the original nest site and chicks were easily counted. Families rarely moved more than 5 m from the nest scrape; such moves occurred

TABLE 2. Fledging success, net reproductive output, and chick fates at initial and late nests as determined by remote monitoring during 1980 and 1981.

Year	Nest type	No. eggs laid (a)	No. eggs hatched (b)	No. chicks fledged ² (c)	Fledging success (b/c × 100%)	Net reproductive output (c/a × 100%)	Chick fate		
							No. chicks dead on territory	No. chicks disappeared	No. chicks killed by conspecifics
1980	Initial	132	115	104	90	79	6	3	1 ¹
	Late	24	8	4	50	17	1	0	3 ¹
	Total	156	123	108	87	69	7	3	4
1981	Initial	186	148	145	98	78	2	1	0
	Late	18	6	3	50	17	0	0	3 ¹
	Total	204	154	148	96	73	2	1	3

¹ Only one dead chick was observed but other chicks disappeared immediately following predation (see text).² A chick was considered fledged when 30 days of age.

gradually over a period of several observation periods and usually not until the chicks were 21–28 days of age. Counts were more difficult for late broods that moved to the sandy tip of area B in 1980 and 1981. After families moved, some chicks of less than 30 days of age were missing on the first count of young terns. Thereafter, counts of downy chicks were the same or higher than the expected number of young of less than 30 days of age. (Counts were higher than expected probably due to retention of down past 30 days of age.) As a result, we believe these late season observations yielded accurate assessments of fledging.

We caution readers that use of our method for recording family histories requires hours of daily observation preferably with many hours of previous experience. Remote monitoring can only be used in certain areas. Our study area was highly suitable for remote monitoring of terns which are often very flighty at other colonies because (1) the nesting area was open sand with almost no vegetation obscuring nests, (2) the surrounding trees provided a concealed, high viewing point from which all nests could be observed, and (3) the surrounding Ring-billed Gulls seemed to have a calming effect on the terns. Careful daily mapping of families is also required (see also Holley 1981) and is greatly facilitated by a grid of numbered stakes such as the one used in this study.

There have been numerous past studies on other larids which have documented the negative impacts of human disturbance (Herring Gull, Hunt 1972; Western Gull, *L. occidentalis*, Robert and Ralph 1975, Hand 1980; Glaucous-winged Gull, *L. glaucescens*, Gillett et al. 1975; Heermann's Gull, *L. heermanni*, Anderson and Keith 1980; Sooty Tern, *S. fuscata*, Ashmole 1963). As far as we are aware, use of the remote observation method to assess reproductive performance in combination with no investigator visits to study areas during the post-hatching period has not been reported for gulls and terns (however, see Bunnell et al. 1981 for White Pelicans, *Pelecanus erythrorhynchos*). We believe this method is essential to accurately document fledging success because human disturbance can cause nonrandom chick mortality (Fetterolf in press). We can therefore never be sure whether investigator disturbance has affected fledging success unless we leave the birds alone during the post-hatching period.

Nest starts and clutch size.—The increase in nest starts between 1980 and 1981 may be explained by several factors including removal of gull nests, human disturbance (see Bergman 1953), and/or food supply (see Soikkeli 1973). We have insufficient data to comment on the last 2 factors and we believe that removal of the Herring Gulls near the northernmost tern sub-colony in 1981 probably resulted in the increase in Caspian Tern nest starts. Three pairs of terns nested in the Ring-billed Gull removal area in 1980 and 2 in 1981. Thus, Ring-billed Gull removal probably had a minimal effect on the number of tern nest starts. In contrast however, 21 tern nests were initiated within 5 m of the removed Herring Gull nest site in 1981. In the same year, a pair of Herring Gulls nested at the southern edge of the southern Caspian Tern sub-colony

(Fig. 1). While the Herring Gulls were using the site, the closest tern nested about 5.5 m from the gull nest. After the gulls had abandoned their territory following fledging of their offspring, 4 pairs of terns started nests within 5.5 m of the nest site.

The ratio of initial to late nest starts increased during the study, especially between 1979 and 1980. The terns probably began nesting on the Headland in 1976. Assuming that the colonizers were relatively young birds, we suggest that increasing age and experience of the nesters could have contributed to earlier nesting and larger clutches in subsequent years. Both earlier nesting and larger clutch size have been attributed to increased age and breeding experience in other larids (see Ryder 1980 for review). Perhaps the relatively high levels of investigator disturbance in 1979 delayed nesting and also contributed to smaller clutches in that year.

HATCHING SUCCESS

Comparisons between years.—Hatching success was higher in the last 2 years of the study than in the first. In 1977, hatching success at the Headland was 81.8% at 8 initial nests (Haymes and Blokpoel 1978). Although the duration of visits in 1977 was not documented, it probably was not more than 20 min per visit. Ascribing a nearly 50% increase in hatching success between 1979 and 1980 to increased age and experience of nesters is problematic especially in light of the high hatching success in 1977. Three results suggest that our disturbance caused some hatching failures in 1979. After decreasing the length of our visits in 1980, hatching success was higher in the last 2 years of the study than in the first year. Second, when we reduced the duration of our visits by nearly 60% during 1980 and 1981, the percentage of eggs that failed to hatch dropped by about two-thirds (Table 1). Also, during direct monitoring, 21 of 152 (14%) initial nests were deserted whereas during remote monitoring only 1 of 29 (3%) nests were deserted. In Ring-billed Gulls, investigator visits which continue after pipping begins can significantly reduce hatching success (Fetterolf 1983).

Human disturbance of Caspian Terns during incubation can lead to poorer hatching success due to cooling of eggs (Penland 1976), predation by gulls (Quinn 1980, Blokpoel 1981), or even desertion of the colony site (Väisänen 1973). Our activities apparently resulted in only 5 eggs (1%) being eaten by gulls. Mammalian predators, however, ate 29 out of 484 (6%) of all eggs and 29 out of 78 (37%) of the eggs in late nests.

Direct effects of mammalian predation.—Although the mammalian predators were not observed in the tern colonies, we have strong circumstantial evidence for their presence. In early August 1979, we found egg shells in the last 4 late nests which had yet to hatch eggs. In 1980 and 1981, at least 98% of all nesters and their young (the majority of fledging age) were present on the colony sites in late July. Within a

48-h period (between subsequent remote observations) in each year, the site was completely deserted.

In 1980 and 1981, tern nests with eggs and/or freshly-hatched chicks disappeared from the nesting area at the same time as the adults and mobile young. In both years, egg shells and 1 dead chick with wounds were found in the colonies. About every second night in 1980, a predator hunted in the wooded area 15–25 m west and northwest of the tern colony and killed and partially devoured at least 41 adult as well as fully grown young Ring-billed Gulls. In the same area, a predator also ate eggs and killed freshly hatched chicks of Black-crowned Night Herons (*Nycticorax nycticorax*) nesting 3–7 m high in trees. We believe the predator was a raccoon (*Procyon lotor*) because it climbed the trees to prey upon the herons and because the skin of each dead gull was neatly pulled from the body indicating considerable “manual” dexterity. This predator was active in the wooded area until the gulls deserted this area during mid July. Prior to the terns’ desertion of the nesting area there was no evidence of predation, e.g., gull corpses, in the open sandy area. In 1981, there was no indication of predator activity in the wooded area. A strong odor of skunk (*Mephitis mephitis*) in the tern nesting areas suggested that this species was responsible for the depredation.

Scharf et al. (1978) reported coyotes (*Canis latrans*) preying on nesting Caspian Terns, however we could find no other accounts of mammalian predation on these terns. We therefore consider such predation on the Headland to be unusual for the species. The gulls apparently provided a buffer against these terrestrial predators and terns with reduced hatching success nested late in the season when the density of gulls constantly declined as the gulls finished breeding and left the site. Where mammals are a threat and mammalian-free nesting locations are limiting, selection should thus favor early nesting amongst gulls by terns. On the Great Lakes and elsewhere, Caspian Terns often nest with gulls even at insular locations (Evans et al. 1970, Soikkeli 1973, Penland 1976, Martin 1978, Scharf et al. 1978, Quinn 1980).

Comparison with other studies.—Hatching success at the Headland in 1979 was lower than on Lake Michigan ($\chi^2 = 20.01$, $P < .001$) (Ludwig 1965) as well as on the Baltic Sea ($\chi^2 = 4.92$, $P < .05$) (Soikkeli 1973) and slightly higher but not statistically different from hatching success on Lake Huron ($\chi^2 = 3.05$, $P < .10$) (Quinn 1980) (Table 3). In 1980 and 1981, hatching success increased greatly in our study and surpassed hatching success in Soikkeli’s (1973) ($\chi^2 = 16.46$, $P < .001$) and Quinn’s (1980) ($\chi^2 = 17.56$, $P < .001$) studies but not Ludwig’s (1965) ($\chi^2 = .31$, $P > .05$) investigation. We suggest that reduced disturbance contributed to higher hatching success during the last 2 years of the study. Ludwig (1965) provided no information on his methodology so we cannot assess his impact, if any, on hatching success. Soikkeli (1973) visited his colonies less frequently than we did, but because he marked all nests in larger colonies, his periods of disturbance were probably more pro-

TABLE 3. Reproductive performance for Caspian Terns in previous studies.

Colony, lake or country	Year	No. nests	Hatching success (%)	Fledging success (%)	Net reproductive output (%)	Source
L. Mich. colonies	1963-1964	200	81	70 ¹	—	Ludwig (1965)
Medarklubb and Gadden, Finland	1970	141	68	91 ²	62	Soikkeli (1973)
Medarklubb and Gadden, Finland	1971	133	69	91	64	Soikkeli (1973)
Medarklubb and Gadden, Finland	1972	144	76	80	61	Soikkeli (1973)
Ile aux Galets, L. Mich.	1975	261	—	—	67 ³	Shugart et al. (1978)
Hat Island, L. Mich.	1976	592	—	—	60	Shugart et al. (1978)
Hat Island, L. Mich.	1977	241	—	—	55	Shugart et al. (1978)
Hat Island, L. Mich.	1978	124	—	—	46	Shugart et al. (1978)
Shoe Island, L. Mich.	1978	247	—	—	68	Shugart et al. (1978)
Hat Island, L. Mich. ⁴	1977	15	—	—	00 ⁵	Shugart et al. (1978)
Ile aux Galets, L. Mich. ⁴	1977	66	—	—	16	Shugart et al. (1978)
Shoe Island, L. Mich. ⁴	1977	51	—	—	60	Shugart et al. (1978)
High Island Shoal, L. Mich. ⁴	1977	42	—	—	70	Shugart et al. (1978)
South Limestone Isl., L. Huron	1978	159	66	64 ⁶	43	Quinn (1980)
South Limestone Isl., L. Huron	1979	106	74	43	32	Quinn (1980)

¹ Only an estimate, no data presented.

² Fledging success was the number of hatched eggs minus the number of dead chicks found.

³ Young reaching at least 28 days of age were considered fledged.

⁴ These data are for late nests. All other data in the table are for initial nests.

⁵ Shugart et al. (1978) gave no minimum age for fledging of young at late nests, but the oldest chicks could have been about 28 days of age.

⁶ Young reaching at least 30 days of age were considered fledged.

longed than our 20 min visits in 1980 and 1981. Quinn's (1980) visits averaged 64 min. Thus investigator disturbance may have affected hatching success in past studies of Caspian Terns especially considering the strong tendency for these birds to flee from the colony during egg-laying (Väisänen 1973, Penland 1976, Martin 1978).

FLEDGING SUCCESS AND NET REPRODUCTIVE OUTPUT

Comparison between years.—Abandonment of the nesting area by terns with chicks occurred much earlier in 1979 than in the last 2 years. Since there was no evidence of mammalian predation on or near the terns until August in 1979, investigator disturbance apparently precipitated early abandonment of the nesting area. In addition, it is likely that our presence in the colony caused chick mortalities. Penland (1976) concluded that his presence caused the killing of many young (30–40% of chicks aged 6–10 days) by neighboring adults because chicks ran from their natal territories in response to his activity. We also observed chicks running from their nest sites during our direct assessment procedures in 1979 (see also Quinn 1980).

Fledging success was higher at initial nests in 1981 than in 1980 because more chicks died on territories in 1980 (Table 2). All died in the nest bowl and were less than a week of age. These deaths may have resulted from poor brooding caused by the nocturnal presence of the predator. At other locations on the Headland we have found Common Tern (*Sterna hirundo*) nestlings dead from exposure and still in the nest bowl 10–15 m from freshly killed adult Common Terns.

Comparison with other studies.—Ludwig's (1965) "guesstimate" of fledging success on Lake Michigan in 1963–1964 was 20–28% lower than our findings for the Headland (Table 3). Initial nesters at the Headland raised higher proportions of their fledglings ($\chi^2 = 9.56$, $P < .01$) and had higher net reproductive output ($\chi^2 = 21.07$, $P < .001$) than terns in the 3-year study on the Baltic Sea (Soikkeli 1973). Fledging success ($\chi^2 = 114.09$, $P < .001$) and net reproductive output ($\chi^2 = 122.84$, $P < .001$) were also higher on the Headland than in the 2-year study on Lake Huron (Quinn 1980). Shugart et al. (1978) reported a significantly lower net reproductive output ($\chi^2 = 9.01$, $P < .001$) in a 4-year study at 4 colonies on Lake Michigan.

These large differences are not explicable in terms of age or experience of nesters at the Headland and other sites. Since the colony at the Headland is of very recent origin and the colonies studied elsewhere are old, established breeding colonies (Soikkeli 1973, Shugart 1977, Martin 1978), a higher proportion of older, experienced birds (which are usually more productive) probably nested at the latter sites.

Food was also probably not an important limiting factor at the Headland. Common Terns at the Headland in 1979 were not food-limited (Courtney and Blokpoel 1980). Soikkeli (1973) and Quinn (1980) implicated food as a limiting factor in their investigations, whereas Shugart et al. (1978) stated that food was not limiting in their study. Shugart et al. (1978) excluded losses of eggs and chicks caused by wash-outs of

nests and cannon-netting activities, yet net reproductive output averaged 18% lower in their colonies than on the Headland. In their study, Herring Gull predation of tern chicks was common in one year at one colony, but was not a problem in other years (Shugart et al. 1978). Only disease, poor parental care (e.g., improper brooding), or possibly investigator disturbance could explain the lower net reproductive output in their study. The authors do not mention disease or parental care but they entered the colonies frequently. We therefore suggest that the absence of investigator disturbance in our study may account for some of the difference in net reproductive output between the 2 investigations.

Our results implicate investigator disturbance as a factor which can bias reproductive performance in Caspian Terns. Caspian Terns may be so sensitive to disturbance that many questions cannot be addressed unless investigators virtually eliminate their own effects, e.g., by remote monitoring (as in this study), concealment in a tunnel to an observation blind (Shugart et al. 1981), video tape, or time lapse photography. Monitoring yearly changes in reproductive performance would be most effective and least likely to cause damage when visits are brief (preferably less than 20 min) and infrequent (every 6–7 days) during egg-laying and limited to 1 or 2 brief visits during post-hatching. Prior to hatching, fences could be erected around representative sample nests (see Quinn 1980). Post-hatching visits should be made when as many chicks as possible are large enough (>21 days of age) to successfully return to the natal territory without getting lost or killed by adult terns or gulls. In the Great Lakes area, there is an additional problem in that Caspian Terns do not nest in a highly synchronous manner (Blokpoel 1981). This means that even the best-timed post-hatching visit to a colony (i.e., when most chicks are at least 3 weeks old) may result in the deaths of younger chicks that cannot as yet defend themselves against gulls and terns.

SUMMARY

During 1979–1981, we monitored reproductive performance at a recently established, expanding colony of Caspian Terns on a peninsula near Toronto. During the 3-year period, clutch size and hatching success increased for early-nesting birds. Mammals, probably raccoons and skunks, preyed upon eggs and chicks late in the season, thus affecting mainly late nesters. In 1979, we visited the nesting site until all chicks had left the area. In 1980 and 1981, we monitored reproductive performance from a remote platform once first eggs pipped. Comparison with other studies indicated that terns at the Headland had markedly greater success than Caspian Terns elsewhere. We conclude that the greatly increased success of terns in our study resulted at least partly from the reduction of our activities in the colony.

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