REPRODUCTIVE SUCCESS AND NEST ATTENTIVENESS OF COMMON TERNS AT PINE AND CURRY ISLAND, MINNESOTA IN 1993

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ABSTRACT

The breeding status of Common Terns on Pine and Curry Island at Lake of the Woods, Minnesota in 1993 was determined by conducting a census, monitoring reproductive success, and observing nest attentiveness and disturbances. The census was conducted by counting all nests when it was believed that the greatest number of adults would be incubating. A sample of 23 nests inside two wire enclosures were monitored for reproductive success. Nest attentiveness was measured by observing 1-4 nests from blinds during 36 4-hr diurnal observation periods between 26 May-28 July. The number of subcolony or whole colony disturbances was also recorded during these 4-hr observation periods. Eight nocturnal observations were conducted to ascertain if disturbances occur at night.

We counted 153 active nests on 21 June. Forty-one percent of the eggs laid in the enclosures survived to fledging and 1.04 chicks fledged per nest. These estimates indicate that reproductive success was higher than the observed success for the last few years and were only slightly below the success needed to maintain the colony. The predominant causes of fledging success were dying or missing chicks. The entire colony or parts of the colony were disturbed an average 2.1 times per hour and terns were off their nests 1.7 minutes per hour on average. The source of disturbances was unidentified 93.8% of the time; identified sources of disturbance were predominantly corvids, Canada Geese, or gulls. A Great Horned Owl caused desertion of nests for most of the colony on at least four occasions before the owl was removed on 28 June. After the owl was removed, some terns still deserted their nests at night, but another owl was not believed to be the cause. Terns with full clutches incubated eggs 97.1% of the time on average and the non-incubating mate was present 9.9% of the time.

Management recommendations include continued discouragement of gulls, removal of mammalian and owl predators, and prevention of human disturbance. Monitoring of reproductive success and censuses should be used to determine success of management recommendations.

INTRODUCTION

In the past few years, reproductive success of Common Terns at Pine and Curry Island at Lake of the Woods has been poor (Table 1). In 1992, no chicks were observed to survive past a few days after hatching. In the early part of the season, little egg predation had been observed but later in the season, many chicks had died during hatching. Nesting attempts were observed as late as 29 July. The final check of the season on 13 August revealed that most nests were abandoned and the unprotected eggs were being depredated by crows (Maxson and Haws 1992).

The causes contributing to reproductive failure were unclear and it was apparent that any successful management strategy for this important colony in Minnesota required a more intensive study of the colony in 1993. This report presents the results of this study which focused on several aspects of the terns' breeding activities. The study consisted of two major parts: 1) colony census and quantification of reproductive success, and 2) observations of disturbances to the colony and documentation of individual nest attentiveness. This report concludes with management recommendations which should aid in the future success of this species at Lake of the Woods.

METHODS

Study Site

The focus of the study was on the large colony of Common Terns nesting on a separated portion of Pine and Curry Island that has been designated Tern Island by Department of Natural Resources employees (Fig. 1). Tern Island was once the southwest tip of Pine and Curry Island but since 1985 has been separated as a result of erosion. Tern Island is approximately 300 m by 50 m with a northeast to southwest orientation. The major portion of Lake of the Woods lies to the northwest and Four Mile Bay to the southeast.

The amount and distribution of vegetation on the island varies from year to year. In 1993, vegetation occupied approximately one-third of the northeast end of the island and almost half of the southwest end. About 50 m in the middle of the island was sparsely vegetated. A sandspit on the northeast tip was also sparsely vegetated. The vegetation was comprised of mostly sand cherry (*Prunus pumila*), beach pea (*Lathyrus maritmus*), and willow (*Salix* spp.).

Other parts of Pine and Curry Island were checked occasionally throughout the summer for nesting Common Terns. However, no behavioral observations were conducted at these sites.

Census and Reproductive Success

Census -- We attempted to count all nests in the colony on seven occasions between 1-21 June. We methodically searched the island and individually marked all observed nests with a numbered stake to avoid double-counting and to facilitate subsequent censuses. During these counts, the number of eggs in each nest and signs of factors affecting success (broken eggs, predator tracks, etc.) were recorded. The final census was conducted on 21 June which was considered to be the peak of incubation, the stage when the most pairs in the colony are incubating. This stage is assumed to be just before the first chicks hatch in the colony (Nisbet 1973).

Reproductive success -- We used enclosures to monitor reproductive success for a sample of 23 nests because of the large size of the island and the difficulties involved in pursuing chicks in such a large area. Two enclosures were erected on opposite sides of the colony where nest densities were high. Enclosures were constructed of 2.5-cm (1-in) hexagonal mesh fencing ("chicken wire"). The fencing was supported by dowels and stood approximately 30 cm tall with approximately 5-10 cm buried into the sand.

Nests were monitored on alternate days, weather permitting, from 21 June until 1 August. New nests were marked and contents of all nests within enclosures were recorded. Chicks were banded with aluminum U.S. Fish and Wildlife Service (USFWS) numbered leg bands to aid in monitoring them after they left their nest. Dead chicks were collected and frozen for post-mortem analysis by the USFWS National Wildlife Health Research Center in Madison, WI. Chicks were monitored for 15 days after hatching or until they left the enclosure or died. Although chicks typically do not fledge until 21 days after hatching, the 15-day criterion was used as the fledge time because previous studies indicated that most chicks surviving to 15 days had a good chance of fledging (Langham 1972, LeCroy and Collins 1972). McKearnan and Cuthbert (1989) also used this criterion at Lake of the Woods in 1984 making comparisons with 1993 reproductive success easier.

Observations on disturbance and nest attentiveness

Disturbance observations -- During the early stages of the breeding season the colony was observed from a boat anchored approximately 50 m from shore. Four 4-hr observations were conducted between 13 May-22 May, two from the lakeside and two from the bayside. Data collected included weather information (temperature, wind speed and direction, and percent cloud cover), the number of disturbances (terns flying up in groups or individuals engaged in interspecific aggression), length of disturbances, level of disturbance (1-2 birds, subcolony or entire colony), and the source of disturbances.

On 11 May, a permanent blind was constructed of pine planks and natural-colored canvas for observation within the colony. The blind was located approximately one-third of the island's length from the northeastern tip. This location allowed a view of the sparsely-vegetated middle section of the island and parts of the more heavily-vegetated northeastern part of the island. On several occasions, a portable blind was used to observe nests not visible from the permanent blind. After 26 May, all 4-hr observation periods were conducted from either blinds. Data collected were similar to that collected from the boats except that the maximum and minimum temperature since the previous observation could be recorded because a max-min thermometer was installed in the blind.

The colony was divided into three major subcolonies: 1) birds nesting in the middle sparsely-vegetated section (sandy subcolony), 2) birds nesting east of the sandy section (east subcolony), and, 3) birds nesting west of the sandy section (west subcolony). Approximately 28-30 pairs nested on the northeast tip. These nests were too far away to be observed from the blind. Disturbances at the subcolony level were recorded as occurring to one or more of the three major subcolonies. Disturbances at the single nest level were obtained only for those individual nests being observed for nest attentiveness. However, any interspecific aggressions observed by chance and the species involved were recorded.

Diurnal observations were conducted, weather permitting, approximately every 2-3 days from 26 May until late incubation when observations were conducted almost every day. From 3-10 July no observations were conducted but they were resumed during 11 -29 July. A total of 36 diurnal observations were made. Observations were conducted during four time periods: 1) early AM (0530-0930 [all times in CDT]), 2) late AM (0930-1330), 3) early PM (1330-1730), and 4) late PM (1730-2115, terminated early before the sun set). Observations rotated among these four time periods, so that they were evenly distributed among different times of day. The season was divided into four different breeding stages to determine if differences in disturbances occurred among different stages during the colony's breeding phenology. The pre-incubation stage was 26 May-1 June (before eggs were laid). The incubation stage was between 2-28 June (before eggs hatched) (eggs hatched later than expected). The brooding stage was that period (29 June-24 July) between hatching and when the first chicks fledged. Post-brooding stage was that period after 24 July when many chicks were fledging.

Eight nocturnal observations were conducted between 5 June- 29 July to determine what disturbances occurred at night. These observations started just before sunset (2115) and were terminated after sunrise (0530). Visual observations could be made until about 2230-2300, except on moonlit nights when shadows could be discerned after 2300. After that, observations were made based on vocalizations of birds during the night until visual observations could be resumed after 0400 the following morning.

Occasionally, dusk observations were conducted from the boat between 2100-2230. These were used to observe parts of the colony not visible from the blind and in hopes of observing a predator entering the colony. Four observations were made between 6-15 June and a fifth on 25 July.

Nest attentiveness observations -- Observations on nest attentiveness were made concurrently with observations for disturbances. One to four nests were selected for a 2-hr observation period based on visibility from the blind and breeding status (full clutches were preferred). Data collected included: amount of time eggs or young were incubated or brooded by an adult (termed the attendant), amount of time the second adult (termed the mate) was within 1 m of the nest, number of times adults exchanged attendant duties, and the number of times adults delivered food to the nest.

Observations were made for nests with eggs, nests with young, and broods no longer associated with nests. Twenty-four nests with eggs were observed twice and 18 observed only once for a total of 66 observations. Ten nests with chicks were observed once. Twenty-eight broods not associated with nest were observed but it is not known how many times an unnested brood was observed because of their mobility.

Statistical analysis

Hatching success was defined as the proportion of eggs hatched of eggs laid. Chick survival was the proportion of chicks fledged of chicks hatched. Fledging success was defined as the proportion of eggs that survived to fledging and breeding success as the number of chicks fledged per nest. Chi-square tests of independence were conducted on hatching success, chick survival, and fledging success to detect differences between the enclosures.

The total number and length of disturbances was calculated for each subcolony by adding the number and length of entire colony disturbances to the number and length recorded for each subcolony for each observation period. The mean number and length of disturbances per hour were calculated and tested for normality using the Kolmogorov D-statistic. Neither of the variables were normal so Kruskal-Wallis tests were performed to test for differences in the number and length of disturbances among subcolonies, among time periods for each subcolony, and among the different breeding stages for each subcolony.

Attendant presence was calculated as the percentage of time that one adult was over the eggs or young and mate presence was calculated as the percentage of time that the mate was within 1 m. Attendant exchange and food delivery rates were calculated as the number of exchanges or number of food items delivered per hour, respectively. These variables were tested for normality with Kolmogorov D-statistic and in all cases the data were not normal. The Mann-Whitney test was performed to detect differences between all four nest attentiveness behaviors between nests with partial clutches and those with full clutches. The Kruskal-Wallis test were used to test for differences among nests with eggs, broods in the nest, and broods out of nest. The Kruskal-Wallis test was also used to test for differences among time periods for all nest behaviors.

The level of significance of 0.05 was used for all tests. Tests were performed on PC-SAS version 6.07.

RESULTS AND DISCUSSION

Census and Reproductive success

Census -- By 21 June, 230 nests had been marked (Table 2). Of these, at least 153 were active. Eighteen previously marked nests that had been counted the previous census but were not located on 21 June were considered "Not found". Thirteen nests marked during earlier censuses and not recounted for more than one census were considered "Unknowns". Either of these categories could occur because stakes were removed or buried in the sand or nests were well hidden by vegetation. Unknown nests were likely to be inactive because it was more likely that nests without eggs or abandoned nests would repeatedly escape our notice than would well-tended nests with eggs. A conservative population estimate of the Tern Island colony would be 153 pairs in 1993. The average clutch size on 21 June was 2.37 eggs/nest with 80 3-egg clutches, 49 2-egg clutches, and 24 1-egg clutches.

The colony size was the smallest since 1989 but falls within the range of the last fourteen years (Table 1). Colony size since annual records were kept appear to fluctuate widely with the number of nests between 25-485; no consistent trend is apparent.

Terns also nested at two other sites on Pine and Curry Island. One nest with 2 chicks and one egg was discovered at the Middle Curry Sanctuary on 17 July but was not found again during two subsequent searches. Four nests with eggs were found at Oak Point on 2 July but these nests were also unsuccessful.

Reproductive success -- Reproductive success early in the season is best represented by data from the 21 June census (Table 2). Twenty nests had been abandoned and two nests had displaced eggs. Twenty-four nests had either missing eggs or eggs pecked by birds and were considered depredated. The west subcolony had the most nests, but also suffered the highest rate of desertion and depredation. This might have been a result of the presence of loafing gulls along the shoreline near the west subcolony and three nesting attempts by Ring-billed Gulls in the subcolony. The east subcolony had the next highest rate of desertion and depredation. Both of these subcolonies had higher nest densities than the sandy subcolony which might have attracted predators.

No mammalian tracks were observed on the island. Most egg predation was probably committed by avian predators; several eggs were apparently pierced by a bird's beak. Possible avian predators include crows, ravens, gulls, Ruddy Turnstones, and blackbirds (Burger and Gochfeld 1991). Missing eggs could also have been taken by small mammals or snakes but we have no evidence to support or discount that possibility. No incidents of predation were observed.

Reproductive success in the enclosures was relatively good compared to previous years. Hatching success was lower at the east than west enclosure (81% versus 91%, but not significantly different, $\chi^2 = 1.17, P > 0.25$), but chick survival was higher at the east enclosure (57% versus 41%, also not significant, $\chi^2 = 1.21, P > 0.25$, Table 3). Overall, 41% of the eggs laid survived to fledging, and 1.04 fledglings were produced per nest. Success was higher than was observed the last time enclosures were used on the island in 1984 when fledging success was 0.06 fledglings/egg and breeding success was 0.17 fledglings/nest (McKearnan and Cuthbert 1989). Breeding success was slightly below the 1.1 chicks per pair per year necessary to maintain the colony (Nisbet 1978, DiConstanzo 1980, Penning 1993).

This estimate may be conservative because it was discovered that chicks could escape the enclosure when they first became mobile. At this stage, chicks were still small enough to fit through the 2.5-cm mesh and one brood of three was found outside the enclosures. Five broods and a total of 11 chicks may have escaped the enclosures (Table 4). In all cases, the whole brood disappeared within a day or two of hatching and these nests were near the edge of the enclosure. Adults may have landed on the other side of the fence and encouraged chicks to go through the fence. Areas adjacent to the enclosures were searched for banded chicks, but none were found or observed from the blinds. The fates of these chicks are uncertain, but it is unlikely that a predator was able to take all chicks in a brood at once, thus we do not believe that the chicks were depredated from within the enclosure.

Chicks dying of unknown causes was the predominant reason for failure of eggs to survive to fledgling (Table 4). A total of 12 dead chicks were discovered in the enclosures and 11 were sent to the National Wildlife Health Research Center for post-mortem analysis. Bacterial and viral tests were unremarkable and the botulism test was negative. Pesticide exposure was also believed not to be involved (Appendix I). Some chicks' deaths may be a result of brood reduction and starvation as many of the chicks that died were the smallest in the brood (Langham 1972). Chick survival past 15 days of age in other studies has been observed to be higher than chick survival for younger chicks (Langham 1972, LeCroy and Collins 1972) , but in our study, the age of death for chicks was evenly distributed among ages (Table 5). Four chicks died past age 15 days, which lowers the reproductive success estimate. If these deaths were included in the overall reproductive success estimate, fledging success would be 34.5% and breeding success would be 0.87 fledglings per nest.

We also surveyed fledglings from the boat while circling the island on 27 July. Sixty-three chicks were counted, mostly along the shoreline. Many more, including 21 in the enclosures were probably located within the vegetation, but the count does indicate that reproductive success in 1993 was the highest in the past few years (Table 1).

Observations of disturbances and nest attentiveness

Diurnal disturbances -- Overall, terns were disturbed an average of 2.1 times/hr and were off their nests an average 1.7 mins/hr. Most disturbances were short-lived and birds returned to their nests in less than a minute. There was a significant difference among the three subcolonies in the number of times/hr terns were disturbed (Kruskal-Wallis test, $P = 0.02$), but differences for time terns were off the nest per hour was barely not significant (Kruskal-Wallis test, $P = 0.053$). Terns in the west subcolony were disturbed most, while those in the sandy subcolony were disturbed least (Table 6).

No differences were detected in number or length of disturbances among different time periods of the day (Kruskal-Wallis test, all Ps > 0.05). However, differences were detected among different breeding stages for each subcolony (Kruskal-Wallis test, all Ps < 0.001). Generally, the number and length of disturbances declined during the breeding season (Table 7).

Sources of disturbance -- The source of most disturbances could not be determined. Terns appeared to fly off nests for no reason. Occasionally, approaching boats might have been the cause, but on other occasions, boats the same distance from the island elicited no response. The source of whole or subcolony disturbance could be positively identified for 33 of 532 (6.2% of total) disturbances during diurnal observations. On all occasions the cause was avian (Table 8). American Crows, Common Ravens, Canada Geese, and Ring-billed Gulls comprised 81.8% of identified disturbances. A Northern Harrier was also observed being mobbed once but not during the observation period. Unauthorized humans were observed on Tern Island twice but neither instance occurred during observation periods.

Interspecific sources of disturbance to one or two nests were identified 132 times (Table 9). Blackbirds, gulls and Canada Geese were the major (83.3%) species involved in interspecific aggressions. Some species appear to be innocuous to terns, e.g. Purple Martin or Piping Plover, but terns chased them at least on one occasion. Aggression between terns was observed on numerous occasions.

Nocturnal disturbances -- Nocturnal observations revealed that a Great Horned Owl was a major cause of disturbance to terns on Tern Island. Although the owl was only observed on 17 June, the third nocturnal observation, it was believed to be the cause of nocturnal desertions for at least several nights before it was removed on 28 June. During the four nocturnal observations prior to owl removal, terns were observed abandoning nests between 2130-2230. On these occasions, terns displayed typical nocturnal desertion behavior as described by Marshall (1942). Shortly after sunset, single birds or small groups would rise off their nests and start circling the perimeter of the colony and flying over the middle sections. Some would settle back on their nests only to arise again a few moments later. Terns would continue circling with the flocks flying around the island getting larger and larger. Eventually when it was completely dark, terns apparently would leave to spend the night elsewhere. Occasionally throughout the night, vocalizations by Killdeer or Piping Plovers could be heard. Between 0345 and 0400 the next morning, tern vocalizations would start again and birds could be seen again flying around the perimeter. Between 0400 and 0430, most terns would return to their nests. Typically, they would land and take flight a few times before incubating.

Observations from the boat at dusk prior to owl removal did not always indicate a nocturnal desertion but it was difficult to see terns on nests in the colony. Some birds were observed circling on at least two dusk observations and some disturbances were observed but many birds returned back to their nests. All loafing terns and gulls left the island before complete darkness fell.

After removal of the owl, some, but not all, terns were still observed deserting nests for the night. Terns appeared "skittish" and left nests frequently during nightfall, but many returned. On the first night observation after the owl was removed, 2 July, many birds remained on nests until 2245 when they apparently were disturbed by a Great Blue Heron feeding along the shoreline. As the heron made its way from east to west along the southern shore, adults rose and start flying around. Some terns may have dive-bombed the heron as squawks were heard on occasion. Eventually most adults left their nests and chicks could be heard calling. Adults were heard flying around for most of the night until 0400 when they started returning to nests. This pattern was similar for the last three observations (8 July, 14 July, 29 July): a) many terns, but not all, deserted during the night; b) desertion was not usually shortly after dusk, but later in the evening, once as late as 0100; and, c) terns did not desert in large groups, but singly or in small groups in apparent response to some disturbance such as a Great Blue Heron. A beaver might also caused some disturbances. Before dawn on one occasion, many terns hovered over something along the shoreline in a very tight group and some birds dive-bombed the object. The area were terns had been hovering was checked after the observation period and several branches that had been chewed by a beaver were found. On one occasion a beaver was observed swimming from the north shoreline toward Morris Point.

Based on these observations, it is not known whether the owl was the sole source of disturbance early in the season and after its removal terns remained "skittish", reacting to herons and beavers abnormally; or if herons and beavers are a normal cause of colony disturbances in the absence of Great Horned Owls. Neither herons or beavers appeared to be a threat to the terns as neither appeared to enter the colony. If they are a normal cause of disturbance then it seems that it doesn't take much to disturb terns at night. It would be impossible for a manager to ensure that terns are not disturbed at night.

The effect a Great Horned Owl can have on a colony is two-fold: 1) the direct impact of predation, and 2) the indirect effect of exposure of eggs and chicks to cool temperatures during night desertion (Lamey 1984). After one nocturnal observation, a decapitated Herring Gull was found in the east subcolony. On another occasion, at least one, possibly two, sets of tern feathers were found suggesting owl depredation of adult terns. The owl was removed before chicks hatched, so there was no opportunity for chick predation, but other colonies in Minnesota have been known to suffer from owl predation on chicks (McKearnan and Cuthbert 1989). The indirect effect of night desertion on colony success may be more serious than the direct effect. The nocturnal desertions may have prolonged incubation by 3-7 days. The mean incubation period for eggs in enclosures was 28 days. Incubation for Common Terns is typically 20-23 days (Harrison 1984). Minimum temperatures were typically in the 40's-50's°F during June and July which would have delayed development if eggs were not incubated at night. In previous years, when few chicks survived past a few days, they may have died as a result of exposure during particularly cold nights. Why chicks were not similarly affected this year when night desertion continued after the owl was removed is unclear; perhaps adults with chicks were more tenacious in brooding than those with eggs, and were not those observed deserting. However, many chicks were heard calling during nocturnal observations after disturbances occurred in the colony.

We do not believe that another owl was in the vicinity because of the change in the terns' behavior with respect to night desertion that indicated a different source of disturbance. However, removal of the owl coincided with the first hatching of chicks, so the change in behavior may have been a result of the tern's stronger drive to stay near the nest and protect their chicks. This drive, however, may have been eventually overridden by a stronger drive to protect oneself. There is still much that remains to be understood concerning nocturnal disturbances.

Diurnal nest attentiveness -- Eggs were incubated, on average, 95.7% of the time during the day. Mates averaged 9.9% of the time within 1 m of the nest. Terns with partial clutches were significantly less attentive than those with full clutches (74.2% versus 97.1%, Mann-Whitney test, $P = 0.001$). There was a significant difference in all four nest attentiveness behaviors measured (time that attendant was incubating or brooding, time that mate was present, attendant exchange rate, and food delivery rate) among adults with eggs, adults with young in nest, and adults with young out of the nests (Kruskal-Wallis test, all Ps < 0.0001, Table 10). Attendants and mates were at the nest more frequently during incubation than after chicks hatched, and also more frequently when chicks were in the nest than when they were out of the nest. Conversely, after chicks hatched, the adults spent more time away from the nest, presumably foraging because more food was delivered to the nest. Adults exchanged attendant duties most when young had hatched but had not left the nest. Exchange rates were zero for broods out of the nest because adults were away from the nest so much that it was difficult to distinguish between adults. However, while one adult was brooding the other adult never attempted to intrude on this activity as they had during incubation.

The high rate of attentiveness during incubation would suggest that disturbances during the day are not sufficient to interfere with breeding success. Other studies have found that incubation attentiveness is typically between 95-99% (Courtney and Blokpoel 1980, Miller 1987). Rates of attendant exchange have been observed to be between 0.67-1.41 times/hr (Miller 1987) at Gull Island, Leech Lake, Minnesota and between 1.0-2.0 times/hr at colonies in Ontario (Courtney and Blokpoel 1980). These would indicate that diurnal nest attentiveness at Tern Island fell within the normal range of Common Terns. Courtney and Blokpoel (1980) found the mean percentage of time that both adults were present at the nest during incubation to be between 39.8-69.4%, well above the 9.9% measured at Tern Island. Perhaps food was more available in their study than in Lake of the Woods and adults could afford to spend more time near the nest.

CONCLUSIONS

The presence of Great Horned Owls may have a significant impact on Common Tern reproductive success, not only because of predation on chicks and adults, but also because of the indirect effect of night desertion and prolonged exposure of eggs and chicks to cool temperatures and possibly other predators. In 1993, incubation was 4-7 days longer than normal for Common Terns. At least one adult tern was depredated by a Great Horned Owl. If the owl had not been removed its effect on the colony might have been disastrous, with continued night desertion resulting in undue exposure of chicks and predation on chicks. The owl's effect may have continued past its removal by causing some "skittish" terns to abandon nests at night. However, there remains many unexplained factors regarding reproductive success. Eleven chicks in the enclosures died of unknown causes which did not appear to result from disease or exposure to pesticides. Overall, reproductive success of Common Terns on Pine and Curry's Tern Island in 1993 was relatively high compared to the past few years. Production was just below the rate necessary for maintenance of the colony.

MANAGEMENT RECOMMENDATIONS

1. Continue census - this would be the minimum requirement for monitoring the colony's success. We recommend that an annual census be conducted just prior to first hatching. At Lake of the Woods hatching typically occurs in the last few days of June or the first days in July. Records of this census should include date, contents of nests (number of eggs or young, broken or depredated eggs), location of nests on island, and number of active nests (nests with eggs or young). This information would assist in ascertaining population trends, what stage the colony was in when census was conducted, factors affecting reproductive success, the relationship of terns to geomorphological or vegetational changes, and possible effects gulls might have on nesting terns.

2a. Monitor reproductive success with enclosures - With relatively little effort, especially if monitoring of Piping Plovers continues, reproductive success could be monitored with weekly visits by erecting enclosures around a sample of nests. A modification to the enclosures is suggested, however, to prevent young chicks from escaping. Chicken wire could still be used but with a smaller mesh lining at the bottom of the fence. A product called Gutter Guard for house gutters would be suitable, inexpensive, and easy to work with because of its flexibility. Hardware cloth (2 x 2) with its finer mesh could be substituted for chicken wire but it is more expensive and more difficult to work with because of its stiffness.

2b. Estimate reproductive success by visiting colony a few times during the season. If weekly visits are not possible, then visiting colony two-four times during the season could provide a rough estimate of reproductive success. The first visit should be scheduled at the same time as the census. A second visit might be scheduled 2-3 weeks after the first visit to estimate hatching success. One or two visits could be scheduled when it is expected that most chicks are fledging (4-5 weeks after first visit). During these visits estimates of number of chicks and fledglings would provide an estimate of chick survival and fledging success. Nisbet and Drury (1972) suggest using enclosures with this schedule.

3. Continue prevention of gull breeding attempts as suggested in 1993 Piping Plover management report (Maxson and McKearnan 1993).

4. Continue mammalian predator control as suggested in 1993 Piping Plover management report (Maxson and McKearnan 1993).

5. Continue public education and distribution of brochures as suggested in 1993 Piping Plover management report (Maxson and McKearnan 1993).

6. Attempt to remove Great Horned Owls prior to the incubation stage of Common Terns. The best time to schedule removal would be late April or early May before terns arrive at the colony. At this time, owl fledglings are still dependent on their parents, so any removal would affect fledglings also . Removals at an earlier date could result in neighboring birds or non-territorial owls moving into the territories (T. Lamey, pers. comm.). If one owl is removed, attempts should be made to see if another owl is in the vicinity using taped crow or owl vocalizations to attract owls. However, use of tapes should be limited to those times when attempts are made to remove owls to prevent owls "learning" about tapes (T. Wiens, pers. comm.)

Other avenues of investigation

1. One method that could be used to identify sources of disturbance or predation without investigators observing from blinds would be the use of video cameras or time-lapsed photography. These methods might allow the documentation of predation, behavior among chicks, feeding rates, etc. without the presence of investigators. However, investigators would still need to set up the cameras and check the equipment, probably within the same day of setup. The method would still be time-intensive and expensive, but might offer some insights into factors affecting success.
2. Another aspect that could be investigated further is food availability. Fisheries data on fingerlings and minnows in Lake of the Woods might be helpful to see if any relationship exists between fish populations and tern success. Also, chick growth could be measured by weighing chicks that would be monitored on a regular basis.
3. Analysis of banding data also might indicate whether Lake of the Woods is a source population or a population sink. When colonies are checked late in the season, chicks could be banded

with USFWS bands. Data from banding returns might indicate intercolony movement and whether adults breeding in Minnesota are adults that were raised in Minnesota. A preliminary banding analysis performed by Burson (1990) was based on minimal returns. Banding data could be insightful if more chicks were banded each year, theoretically generating more returns.

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Table 1. Colony size and notes on reproductive success of Common Terns at Pine and Curry Island from 1979-1992.

Year	Number of active nests[1]	Notes on reproductive success[1]
1979	~ 50	
1980	~ 25	30+ nests destroyed
1981	44	
1982	~ 125	
1983	~ 125	
1984	139	estimated 0.17 fledged young/nest
1985	210	estimated 140 young
1986	485	high predation
1987	168	
1988	52	all depredated
1989	123	9 chicks observed on 8/13
1990	177	64 young fledged
1991	274	9 young fledged
1992	186	0 young fledged

[1] number of nests and notes provided by MNDNR, except for 1984 data were from McKearnan and Cuthbert (1989)

Figure 1. PINE AND CURRY ISLAND SNA

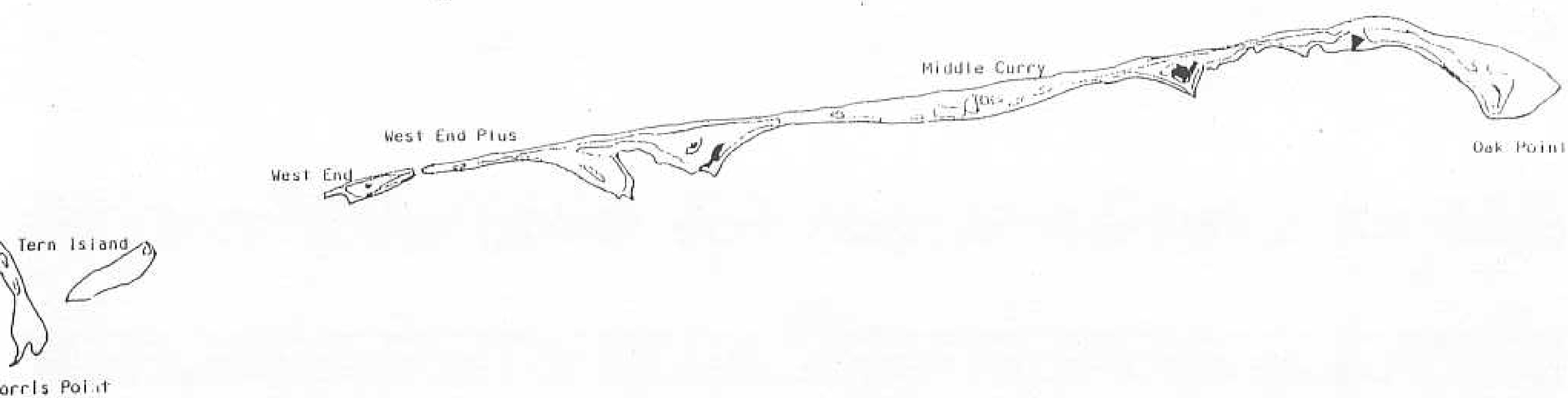

Table 2. Number and status of marked nests on 21 June, 1993 at different subcolonies within Tern Island. Numbers in parantheses are percentages of total number of nests in the subcolony .

Status	East	Sandy	West	Eastern tip	**Total**
Active	48 (62.3)	26(89.7)	51 (54.2)	28 (93.3)	153 (66.5)
Not found	10 (12.9)	2 (6.9)	5 (5.3)	1 (3.3)	18 (7.8)
Unknown	5 (6.5)	0 (0.0)	8 (8.5)	0 (0.0)	13 (5.7)
Abandoned	4 (5.2)	0 (0.0)	16 (17.0)	0 (0.0)	20 (8.7)
Displaced	2 (2.6)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.9)
Depredated	8 (0.3)	1 (3.4)	14 (14.9)	1 (3.3)	24 (10.4)
Total	77	29	94	30	230

Table 3. Hatching success, chick survival, fledging success, and breeding success of nests inside the enclosures.

	East	West	Total
Number of eggs laid	26	32	58
Number of nests	10	13	23
Mean clutch size	2.60	2.46	2.52
Number of eggs hatched	21	29	50
Hatching success (# eggs hatched/ egg laid)	0.81	0.91	0.86
Number of chicks fledged	12	12	24
Chick survival (#chicks fledged/ chick hatched)	0.57	0.41	0.48
Fledging success (# fledglings/egg)	0.46	0.38	0.41
Breeding success (fledglings/nest)	1.20	0.92	1.04

Table 4. Fate of eggs or chicks that did not survive to fledging in the enclosures.

Fate	East enclosure	West enclosure	Total
Egg missing	2 (14.3)	1 (5.0)	3 (8.8)
Egg broken	0 (0.0)	2 (10.0)	2 (5.9)
Egg abandoned	3 (21.4)	0 (0.0)	3 (8.8)
Chick disappeared[1]	4 (28.6)	7 (35.0)	11 (32.4)
Chick died - unknown causes	5 (35.7)	10 (50.0)	15 (44.1)
Total eggs failed	14 (100.0)	20 (100.0)	34 (100.0)

[1] chicks might have escaped enclosures.

Table 5. Age of chicks who died inside enclosures at death.

Age (days)	Number of chicks
2	2
4	2
7	2
8	2
9	1
10	1
11	1
14	1
15	1
17	1
19	1
20	1
21	1

Table 6. Mean number of disturbances and mean time off nests for terns in each subcolony.

Subcolony	Number disturbances/hr	Time off nest (mins/hr)
East	1.9	1.6
Sandy	1.6	1.4
West	2.6	2.1
Total	2.1	1.7

Table 7. Mean number of disturbances and mean time off nests for each stage in the breeding season for each subcolony.

Subcolony Breeding stage	Number disturbances/hr	Time off nest (mins/hr)
East		
Pre-incubation	3.6	3.2
Incubation	2.8	2.0
Brooding	1.2	1.3
Post- brooding	0.9	0.8
Sandy		
Pre-incubation	3.2	2.2
Incubation	1.9	1.4
Brooding	1.5	1.6
Post- brooding	0.7	0.7
West		
Pre-incubation	3.7	2.9
Incubation	4.1	2.9
Brooding	1.8	1.8
Post- brooding	1.0	0.9

Table 8. Known sources of whole or subcolony disturbances during diurnal observations.

Species	Number of times	Percent
American Crow	12	36.4
Canada Goose	6	18.1
Common Raven	5	15.2
Ring-billed Gull	4	12.1
Peregrine Falcon	2	6.1
Bonaparte's Gull	1	3.0
Herring Gull	1	3.0
Cooper's Hawk	1	3.0
Merlin	1	3.0
Total	33	99.9

Table 9. Known sources of single nest disturbances during diurnal observations.

Species	Number of times	Percent
Yellow-headed Blackbird	31	23.5
Ring-billed Gull	28	21.2
Franklin's Gull	24	18.2
Red-winged Blackbird	14	10.6
Canada Goose	13	9.8
Spotted Sandpiper	5	3.8
American Crow	4	3.0
Common Grackle	3	2.3
Killdeer	3	2.3
Piping Plover	3	2.3
Great Blue Heron	2	1.5
Herring Gull	1	0.8
Purple Martin	1	0.8
Total	132	100.0

Table 10. Mean nest attentiveness behaviors for nests with full clutches, nests with young, and broods not associated with nests.

Behavior	Full Clutch	Young in nest	Young out of nest
Time at nest or with young (%)	97.1	88.5	12.3
Time mate present (%)	9.9	7.6	0.0
Number of attendant exchanges/hr.	0.61	1.02	0.00
Number of food items delivered/hr.	0.26	1.76	4.33

APPENDIX I

U.S. FISH AND WILDLIFE SERVICE
NATIONAL WILDLIFE HEALTH RESEARCH CENTER
6006 Schroeder Road
Madison, Wisconsin 53711
608-271-4640 (FTS 364-5418)

DIAGNOSTIC SERVICES CASE REPORT

Case # 11756 Epizoo # ______ RHT RMW

Submitter:
Stephen Maxson
MN DNR
102 23rd St.
Bemidji, MN 51601

Specimen description/identification:
Common Terns.

Date Submitted: 08/25/93

Location: Lake of the Woods Co., MN.

General Diagnosis: Undetermined.

Comments: Bacterial cultures were unremarkable and botulism testing was negative. Brain cholinesterase activities of three of four birds increased substantially after incubation, but I do not believe pesticide exposure, at least to organophosphates or carbamates, was involved. Virology is pending; we will issue a supplementary report only if those results alter the diagnosis.

______ Preliminary Report (/ /) date   X Final Report (09/15/93) date

______ See attached necropsy records for individual specimen observations.

Note: Copies of this report have been sent to:
______ USFWS Regional Office (RO-)
Attention:
___ Migratory Bird Coordinator
___ F & W Enhancement: Endangered Species
___ F & W Enhancement: Environmental Contaminants Coordinator

Pathologist: J. Christian Franson, DVM

If you have questions regarding this case, contact Ronald M. Windingstad at 608-271-4640 (FTS 364-5418). Include above Case Number. Diagnostic findings may not be used for publication without the pathologist's knowledge and consent.