STATUS AND BREEDING SUCCESS OF COMMON TERNS IN MINNESOTA

A THESIS

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL

OF THE UNIVERSITY OF MINNESOTA

BY

JOAN ELIZABETH MCKEARNAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF SCIENCE

OCTOBER 1986

ABSTRACT

Recent concern about the population size of Common Terns (Sterna hirundo) in the Great Lakes region led to a two-year study on the status and breeding success of Common Terns in Minnesota. All known colonies were censused in 1984; breeding success was monitored at the Duluth sites in 1983 and at all sites in 1984. Colony sizes ranged from 27-489 pairs and approximately 860 pairs of terns nested in Minnesota in 1984; the current breeding population is estimated to be a third the size of the Common Tern population in Minnesota in the 1930's. Breeding success was estimated at 0.15 fledglings/pair; 6% of the eggs laid survived to fledging. Factors that contributed to nest failure included: storm damage, use of suboptimal nesting habitat, predation, nest site competition with gulls and human disturbance. A computer model was used to simulate growth of the Minnesota population and it predicted extinction of all colonies within 25 years if terns continue to fledge young at the rate recorded, and if no immigration occurs from outside Minnesota. Future management efforts should include population monitoring, improvement and protection of tern breeding habitat, exclusion of breeding Ring-billed Gulls from tern nesting sites, and monitoring of contaminant levels in lakes adjacent to nesting areas.

ACKNOWLEDGEMENTS

Many people assisted me with fieldwork; these include Kriste Ericsson, Kenneth Sargent, Lynelle Hansen, and Calvin Harth. I am particularly grateful to Donna Laing who helped with numerous aspects of the project. Terry Wiens collected data at the Lake of the Woods colony when I was not present; I also greatly appreciate the moral support and advice he offered during this study. I thank Thomas Davis for help with technical aspects early in the project and I also thank the many people who provided information about colonies, including Janet Green, Jacob Miller, Lee Pfannmuller and Hildegard Reiser. I am grateful to my dissertation committee members, John Carlson, Donald Christian and Ronald Regal, for their comments on earlier drafts of this thesis. I am especially indebted to my adviser, Francesca Cuthbert, for her advice and the considerable time she devoted to the study. The research was funded from grants from the Minnesota Department of Natural Resources Nongame Wildlife Program, College of Letters and Sciences of the University of Minnesota-Duluth, and Sigma Xi, the Scientific Research Society.

TABLE OF CONTENTS

LIST OF TABLES

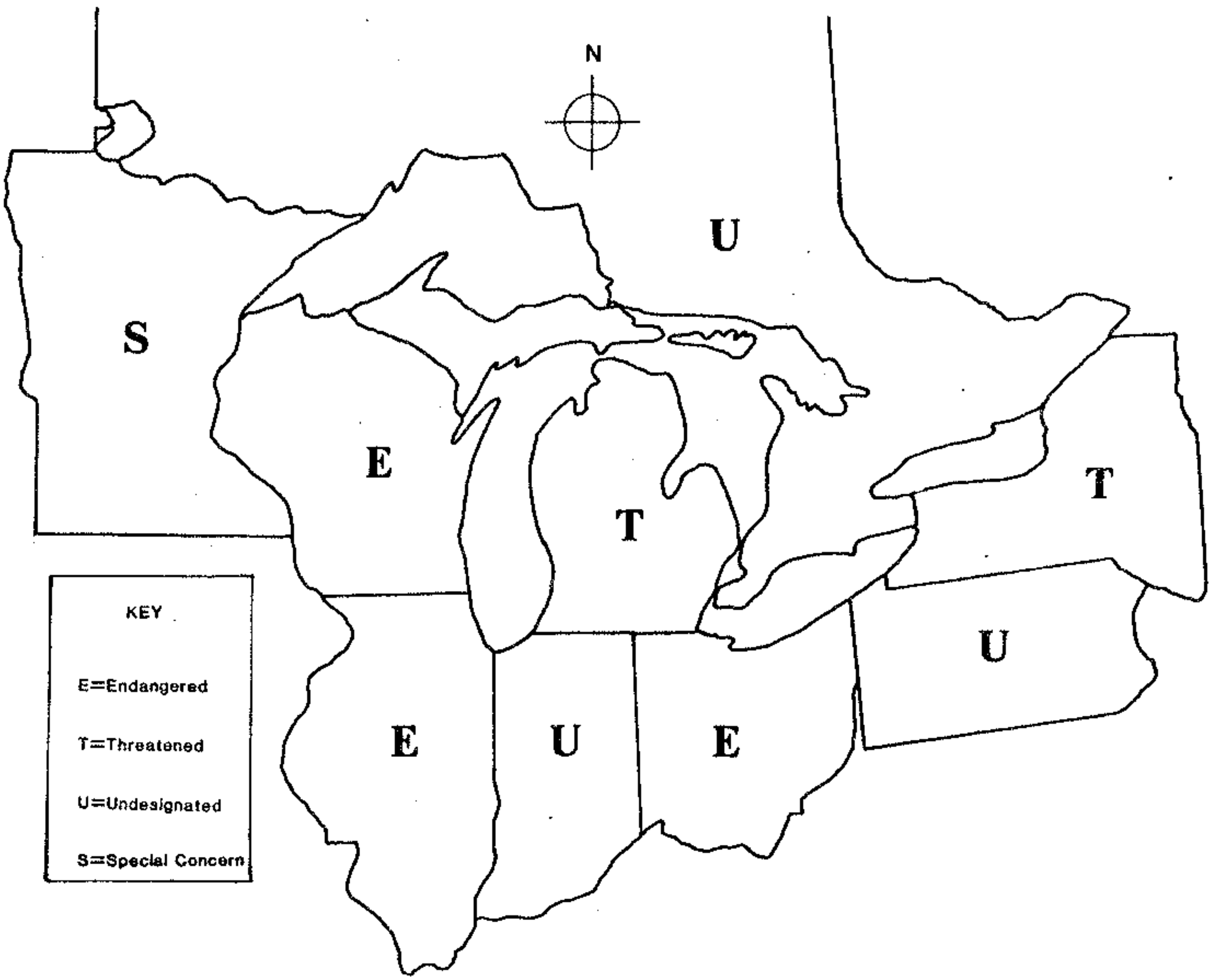
LIST OF FIGURES

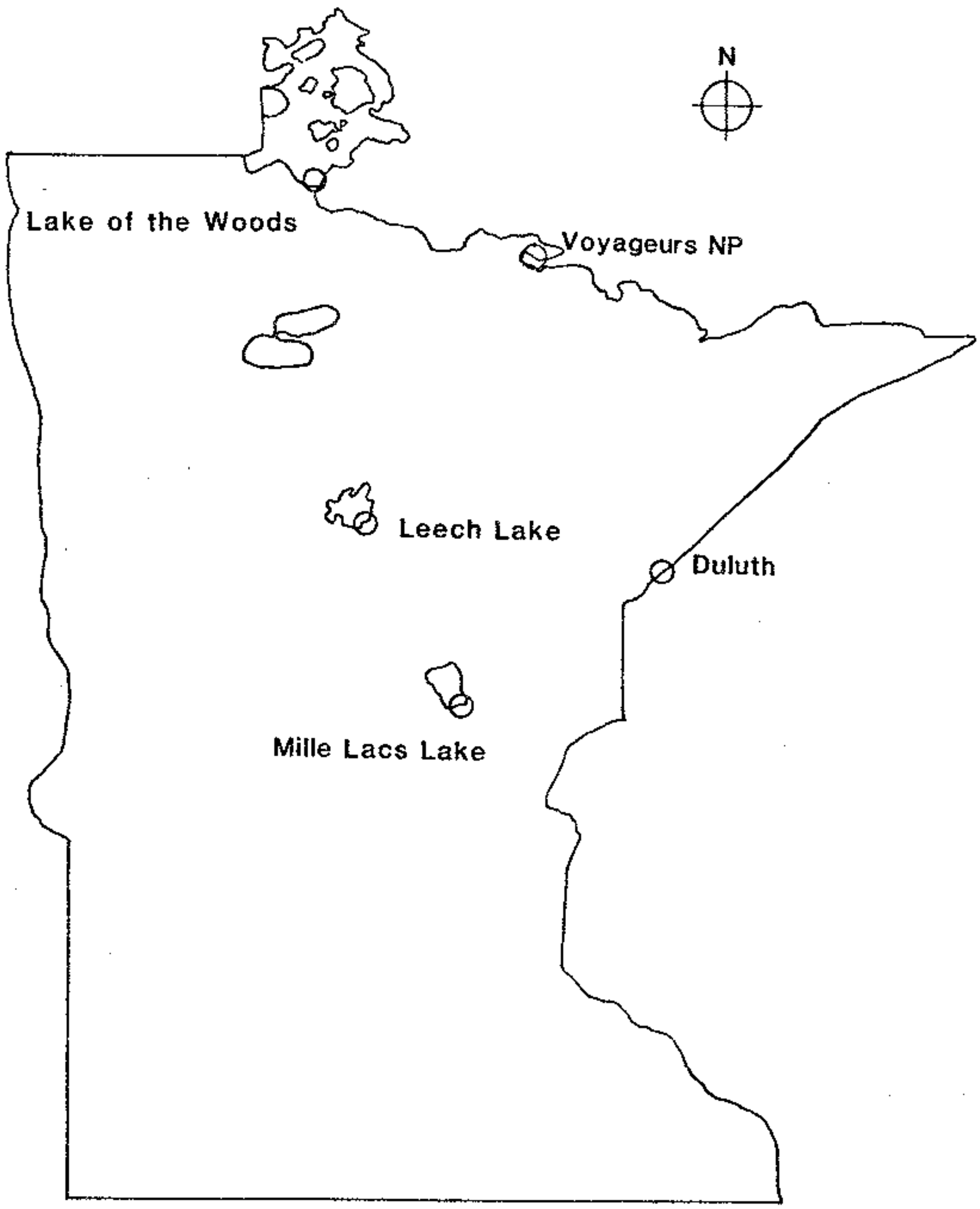
INTRODUCTION

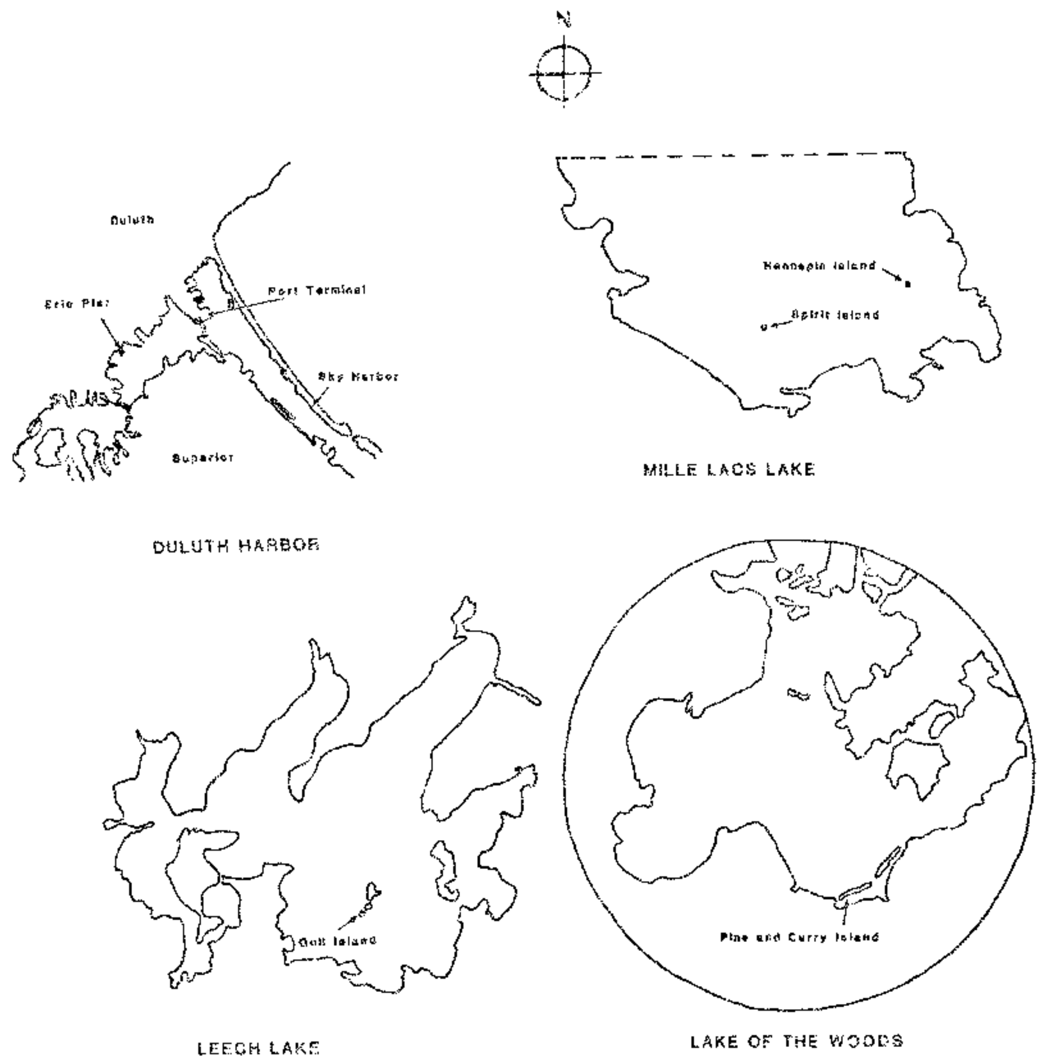
Population numbers of several species of the avian family Laridae have varied greatly in North America in the last century. During the late 19th and early 20th centuries many gulls and terns were subjected to human persecution (Nisbet 1973, Southern 1980, Kress et al. 1983); adults and eggs were collected for food, and feathers were used in the millinery trade. As a result of these activities, many gulls and terns were extirpated from large portions of their range (Erwin 1984). Legislation passed in the early 20th century facilitated a period of recovery for these birds (Southern 1980). High reproductive potential, relatively long life spans, and the ability to relocate when disturbed were important life history traits that helped larids recover from dangerously low levels (Kress et al. 1983). Some gull species have recovered to previous numbers and are expanding their range (Southern 1980). Terns, however, never fully recovered. Many populations increased in size but did not reach the numbers believed to exist in the 19th century (Nisbet 1973, Courtney and Blokpoel 1983).

From the 1940's to the mid-1970's Common Tern (Sterna hirundo) populations in North America declined as a result of habitat loss and expansion of gull populations (Nisbet 1973). Population trends have varied from state to state since the mid-1970's, but there is concern over regional declines in the Great Lakes region (Kress et al. 1983, Shugart and Scharf 1983). A November 1983 survey (Cuthbert et al. 1984) of wildlife departments of states bordering the Great Lakes revealed that three states (Wisconsin, Illinois and Ohio) list the Common Tern as "Endangered" while two states (New York and Michigan) assigned this species to the "Threatened" category (Fig.1). The status of the Common Tern was undesignated in Indiana, Ontario, and Pennsylvania. In Minnesota, the Common Tern appears on the "Special Concern" list. At the inception of this study biologists for the Minnesota Nongame Wildlife Program suspected that the Minnesota population had declined but information was insufficient to warrant placing the species on the endangered or threatened list. The purpose of this study was to evaluate the status and breeding success of Common Terns in Minnesota.

Four primary Common Tern breeding areas have been identified in Minnesota (Figs. 2 and 3) (Henderson and Mattson 1979). A fifth colony of approximately 20 pairs was located at Kabetogama Lake in Voyageurs National Park, St. Louis County (H. Reiser pers.comm.). Its existence has been known since 1974 by local birders, but was not reported to the Minnesota Department of Natural Resources until 1985. During the past several years the Minnesota Ornithologists' Union (MOU files) has compiled census estimates provided by


N
U
S
E
T
T
U
E
U
E
KEY
E=Endangered
T=Threatened
U=Undesignated
S=Special Concern


N
Lake of the Woods
Voyageurs NP
Leech Lake
Duluth
Mille Lacs Lake


N
Duluth
Erie Pier
Port Terminal
Sky Harbor
Superior
DULUTH HARBOR
Hennepin Island
Spirit Island
MILLE LACS LAKE
Gull Island
LEECH LAKE
Pine and Curry Island
LAKE OF THE WOODS

amateur ornithologists but no other information is available for Common Terns in Minnesota. In this study I asked the following questions: (1) how many pairs of terns are nesting in Minnesota, (2) what is the breeding success of terns at each colony, (3) what factors influence success at each colony, and (4) what is the predicted population growth of Common Terns in Minnesota?

STUDY AREAS

In 1983 I limited my study to the Duluth Harbor colonies, but in 1984 these efforts were expanded to include all known breeding sites in Minnesota. The Duluth Harbor in St. Louis County had two primary colonies, the Port Terminal and Sky Harbor Airport. A third site, the 40th Avenue West Dredge Disposal Site, was used by terns during both years, but because the birds were probably renesters from the other two sites, data collected at this colony site were not included in my study.

DULUTH HARBOR

Port Terminal- The Port Terminal (46°45'N,92°06'W) is an industrial development used primarily for shipping activity. The terns nested in several subcolonies. One large group nested on a sandy triangular area bounded by two roads. Vegetation was mostly white sweet clover (*Melilotus alba*) and was dense in most places except for a bare circular depression of approximately 30m in diameter. Another large group of birds used a flat, fine gravel section bordered by a road on one side and a Ring-billed Gull (*Larus delawarensis*) colony on the other. The vegetation was mostly sandbar willow (*Salix interior*) and dwarf horsetail (*Equisetum scirpoides*) and varied in density between years. This area also had large deposits of snow and dirt that had been removed from the Duluth city streets during the previous winter. These snowpiles decreased in size during the summer and usually were completely melted by June or July.Other nesting occurred along the Soo Line railroad tracks, a parking lot and behind the gull colony. About 5000 pairs of Ring-billed Gulls and approximately 10-20 pairs of Herring Gulls (Larus argentatus) nested adjacent to the terns.

Sky Harbor- The Sky Harbor site (46°43'N,92°03'W) is on the bayside of the runway at Sky Harbor Airport on Minnesota Point. The airport is small with relatively little traffic. The nests were located on a small sandspit with low vegetation, primarily poison ivy (Rhus radicans) and tansy (Tanacetum vulgare). Human disturbance is low because people are restricted from the runway.

MILLE LACS LAKE

Two colonies were located in Mille Lacs Lake, Mille Lacs County. Hennepin and Spirit Islands comprise the Mille Lacs Islands National Wildlife Refuge.

Hennepin Island- Hennepin Island (46°10'N,93°32'W) is a 0.13 ha island of glacial boulders, stone, and gravel. The terns nested on the low-lying southern tip on gravel and stone. In 1984, 180 pairs of Ring-billed Gulls nested on the larger boulders in a discrete colony. There was no vegetation in the tern colony.

Spirit Island- Spirit Island (46° 09'N,93° 39'W) is a little smaller than Hennepin (0.10 ha) and consists only of large boulders. All nests were 2-4 m above the water level and the island was not vegetated. The tern nests were in small groups of 4-10 nests interspersed among the 170 gull nests.

LEECH LAKE

There is only one colony on Leech Lake, Cass County. Gull Island is the smallest island (0.16 ha) of a three-island archipelago.

Gull Island- Gull Island (47°07'N,94° 21'W) consists of large rocks that form an assymetrical horseshoe filled in by sand. Terns nested on the beach while approximately 280 pairs of Ring-billed Gulls and one pair of Herring Gulls nested on the rocks. In 1984 about 20 pairs of terns nested in a single patch of vegetation, but most tern nests were placed on bare sand.

LAKE OF THE WOODS

There are several records of incidental nesting at Lake of the Woods, Lake of the Woods County (Hirsch 1982), but the traditional and major breeding site is on Pine and Curry Island, a state Scientific and Natural Area.

Pine and Curry Island- Pine and Curry Island (48° 51'N,94° 46'W) is a 7 km long sandy island. In 1984, 98% of the terns nested on the southwest tip of the island. This was a beach habitat with sparse to relatively dense vegetation, mostly beach pea (*Lathyrus japonicus*), tail wormwood (*Artemesia caudata*), and sandbar willow. No gulls nested nearby, although many Ring-billed, Herring and Franklin's Gulls (*Larus pipixcan*) were observed loafing on Morris Point, 150 meters away (T. Wiens). The beach was posted against human trespass.

METHODS

CENSUS TECHNIQUES

The number of breeding pairs at each colony was determined by a direct nest count conducted when the majority of birds were in the late incubation stage. Only nests with eggs were counted and each nest was marked to avoid recounting.

BREEDING SUCCESS

Hatching success was defined as the percent of eggs laid that hatched and chick survival as the percent of hatched chicks that survived to fledging. I calculated the total productivity of a colony in two ways: 1) reproductive success as the number of young fledged/breeding pair and 2) fledging success as the proportion of total eggs laid that survived to fledging. To measure the breeding success of the terns at a colony, I needed to determine the survival of a chick. Nests were individually marked with numbered wooden stakes or adjacent rocks were numbered with a water-resistant marker. During each visit, I recorded nest contents (number of eggs and chicks, dead or alive) and banded chicks with US Fish and Wildlife Service aluminum leg bands. Eggs were monitored until they hatched, disappeared or were found abandoned, inviable, or broken. Chicks were monitored until they died, disappeared or fledged. Though tern chicks do not start to fly until they are approximately 21 days old, they may leave the nest when they are several days old and can be difficult to locate as they get older. Nisbet and Drury (1972) and Langham (1972) found the main chick mortality occurred before 7-10 days; I considered chicks to be fledged at 15 days after hatching.

Another approach to monitoring older chicks is to confine them to enclosures until they fledge (Nisbet and Drury 1972, Erwin and Custer 1982). I built enclosures in the larger colonies (Port Terminal, Leech Lake and Lake of the Woods) in 1984. The Mille Lacs and Sky Harbor colonies were small enough to search the whole site for chicks.

Enclosures were made with 25-cm-high chicken wire (2.5 cm mesh) supported by 1 m long wooden stakes. The enclosures were a maximum of 6 m in diameter and no closer than 25 cm to the edge nests to insure enough landing space for the adults. In enclosures with little or no vegetation, shade was provided with rocks and driftwood. Only a sample of nests were enclosed at each colony: 13 nests at the Port Terminal (2 enclosures); 28 at Leech Lake (2 enclosures) and 23 at Lake of the Woods (3 enclosures).

I visited Duluth Harbor on alternate days in 1983 and all colonies every 5-7 days in 1984 when weather conditions were favorable. Time spent in the colony was limited to 20 mins except when enclosures were erected and during a census, but no more than 20 minutes were spent in each section or subcolony.

FACTORS INFLUENCING BREEDING SUCCESS

During each visit, I looked for and recorded signs of agents or factors that may have influenced success (i.e. tracks of predators). In 1983, all dead chicks were collected and frozen. A gross internal and bacteriological evaluation was performed by the University of Minnesota Veterinary Diagnostic Laboratory, St. Paul Campus in December 1983.

POPULATION PROJECTIONS

To predict population trends of the Common Tern colonies, I used a computer model written by Walter Conley of New Mexico State University. Because no information exists on the population structure of Minnesota terns, I searched the literature for information on the demography on other Common Tern populations. The model assumes that no immigration into or emigration from the population occurs, so I needed to know the age composition of the total population (breeders and non-breeders), annual survival of immature and breeding birds, and the percent of the age class that was presumed to be breeding.

Austin and Austin (1956) provided an age composition of the breeding population of Common Terns on Cape Cod. Using survival data from this paper I was able to extrapolate the age composition for the total population. Three papers contained data on survival of fledglings to age 4, when most birds reach maturity, and annual adult mortality (Austin and Austin 1956, Nisbet 1978, and DiCostanzo 1980). From the survival of fledglings to age 4, I calculated an annual survival of immature birds. Austin and Austin (1956) reported an annual adult survival averaging 75% and survival of fledglings to age 4 was 20%. More recently, Nisbet (1978) found annual adult survival to average 87% and 10% fledgling survival to age 4 in the declining population of Massachusetts. DiCostanzo (1980) estimated 92% annual adult survival and 14.3% survival of fledglings to four years of age for the stable colony of Great Gull Island near Long Island, New York. Population parameters for the computer simulation are given in Table 1.

Young and inexperienced breeders produce smaller clutches and have lower hatching success than older birds (Hays 1978). Using the figures that Hays (1978) reported for breeders at age 3-7 years, I adjusted the natality for each age class so that natality for the younger birds was lower than older birds at proportions similar to what Hays (1978) had found.

I assumed that the four primary breeding areas were subpopulations of the Minnesota population and constructed a population projection for each subpopulation using the hatching success for each breeding area as the natality

TABLE 1. Model parameters for each subpopulation

Age class	Age Composition total	Age Composition breeding	percent breeding	Survival(px) Aus*	Survival(px) DiC#	Survival(px) Nis+
0-1	39.3%	0.0%	0.0%	@	@	@
1-2	12.8	0.9	2.5	.585	.523	.464
2-3	10.9	2.8	9.3	.585	.523	.464
3-4	9.2	19.0	74.5	.585	.523	.464
4-5	7.8	21.5	100.0	.750	.920	.870
5-6	5.8	16.1	100.0	.807	.920	.870
6-7	4.7	13.0	100.0	.737	.920	.870
7-8	3.5	9.7	100.0	.727	.920	.870
8-9	2.5	7.0	100.0	.676	.920	.870
9-10	1.7	4.7	100.0	.647	.920	.870
10-11	1.1	3.1	100.0	.778	.920	.870
11-12	.9	2.4	100.0	.000	.000	.000

* Austin and Austin (1956)

DiCostanzo (1980)

+ Nisbet (1978)

@ mx values and first year px values are different for each subpopulation and are pooled for the Minnesota population.

(mx) and chick survival as survival of birds of age 0 to age 1. I also combined the data of all of Minnesota's colonies and ran a projection for the whole population. Projections were computed three times using each of the survival data from Austin and Austin (1956), Nisbet (1978), and DiCostanzo (1980).

RESULTS

MINNESOTA POPULATION ESTIMATES

The total number of breeding pairs in Duluth in 1983 was 171 with 85% of the pairs nesting at the Port Terminal (Table 2). The total breeding population for Minnesota in 1984 was estimated to be 861 pairs. Leech Lake was the largest colony with 489 pairs representing over half the Minnesota population. The population at the Port Terminal declined between the two years, but remained stable at Sky Harbor; the total decrease in Duluth was 31 pairs. The Hennepin and Spirit island colonies were similar in size (47 and 46 pairs respectively) and 139 pairs nested on Pine and Curry Island.

BREEDING SUCCESS

Hatching success, chick survival, and overall breeding success for all colonies are presented in Tables 3,4, and 5, respectively.

At the Port Terminal, hatching success was similar between 1983 and 1984, but chick survival appeared worse in 1984 than in 1983. No chicks survived in the enclosures in 1984, but 13 fledglings from outside the enclosures were observed in the colony. I calculated a minimum success using this fledglings and found 4% fledging success and

TABLE 2. Number of breeding Common Terns in Minnesota

Colony site	Year	No. of Pairs
Port Terminal	1983	146
	1984	113*
Sky Harbor	1983	25
	1984	27
Mille Lacs Lake		
Hennepin Island	1984	47
Spirit Island	1984	46
Leech Lake		
Gull Island	1984	489#
Lake of the Woods		
Pine and Curry Island	1984	139
TOTAL MINNESOTA	1984	861

* census conducted by T.E. Davis

census conducted by J. Miller

TABLE 3. Hatching Success in Minnesota

Colony site	Year	No. Eggs sampled	Percent hatched
Port Terminal	1983	392	21%
	1984	34	29
Sky Harbor	1983	56	7
	1984	77	75
Hennepin Island	1984	124	11
Spirit Island	1984	115	9
Leech Lake	1984	68	31
Lake of the Woods	1984	66	39
TOTAL MINNESOTA	1984	482	29

TABLE 4. Chick Survival in Minnesota

Colony Site	Year	No. Chicks Hatched	% Fledged
Port Terminal	1983	81	23%
	1984	10	0
Sky Harbor	1983	4	50
	1984	58	10
Hennepin Island	1984	14	21
Spirit Island	1984	10	20
Leech Lake	1984	43	57
Lake of the Woods	1984	26	15
TOTAL MINNESOTA	1984	139	19

Table 5. Overall breeding success in Minnesota

Colony Site	Year	Success: Fledging	Success: Reproductive
Port Terminal	1983	5%	0.13
	1984	0(4)*	0.00(0.12)*
Sky Harbor	1983	4	0.08
	1984	8	0.22
Hennepin Island	1984	3	0.06
Spirit Island	1984	2	0.06
Leech Lake	1984	18	0.43
Lake of the Woods	1984	6	0.17
TOTAL MINNESOTA	1984	6	0.15

* minimum success for fledglings observed outside enclosures

0.12 reproductive success; this result is similar to success reported from the previous two years at this site (Cuthbert et al. 1984).

Sky Harbor experienced two very different years. Hatching success in 1983 was low, but chick survival was relatively high. In 1984, the hatching rate was high but there was a low survival of chicks. Although, fledging success doubled among years, it was still below 10% and adults produced less than 0.25 chicks per pair.

Hatching success, chick survival and breeding success were very similar at the Mille Lacs colonies. Breeding successes for these colonies were the lowest for all colonies. Leech Lake had the highest breeding success with the highest chick survival and third highest hatching rate. Though, Lake of the Woods had a high hatching rate, chick survival was low, resulting in poor breeding success.

Mean clutch size was calculated for all colonies (Table 6). The highest and lowest mean clutch size are found at Sky Harbor for 1983 and 1984, respectively. An analysis of variance, using Tukey's honestly significant difference method for multiple comparisons (Sokal and Rohlf 1981) demonstrates a significant difference between the two years at Sky Harbor ($n = 52$, $p < .05$), Sky Harbor and Port Terminal in 1983 ($n = 171$, $p < .05$), Sky Harbor in 1983 and Lake of the Woods in 1984 ($n = 77$, $p < .05$), and Lake of the

Woods and Leech Lake ($n = 189$, $p < .05$). A positive correlation between mean clutch size and hatching success proved to be significant, also ($r = .710$, $n = 8$, $p < .05$).

A two-way contingency analysis (Sokal and Rohlf 1981) revealed that hatching rates varied among colonies ($X2 = 125.96$, $df = 5$, $p < .001$) and years in Duluth ($X2 = 80.03$, $df = 1$, $p < .001$). Chick survival was also significantly different among colonies ($X2 = 24.86$, $df = 5$, $p < .001$) and years in Duluth ($X2 = 7.17$, $df = 1$, $p < .01$). Breeding success was variable among colonies ($X2 = 27.01$. $df = 5$, $p < .001$) but not among years ($X2 = .10$, $df = 1$, $.90 < p < .50$).

For all of Minnesota, an estimated 29% of the eggs laid survived to hatching and 19% of the chicks hatched survived to fledging. Fledging success was 6% and reproductive success was 0.15 chicks/pair.

FACTORS INFLUENCING BREEDING SUCCESS

Reasons for failure of eggs to hatch and chicks to fledge are summarized in Tables 7 and 8. The majority of eggs (89%) that failed to hatch in 1984 had disappeared. Inviable eggs composed a small proportion of the unhatched eggs. Fifty-six per cent of the unfledged chicks had disappeared in 1984 and 51% in 1983.

I found several factors that contributed to reproductive failure. These included: climatic factors, sub-

TABLE 6. Mean clutch size of Common Terns in Minnesota

Colony site	Year	Avg. no. eggs/nest
Port Terminal	1983	2.68
	1984	2.57
Sky Harbor	1983	2.24
	1984	2.85
Hennepin Island	1984	2.64
Spirit Island	1984	2.50
Leech Lake	1984	2.46
Lake of the Woods	1984	2.79
TOTAL MINNESOTA	1984	2.65

TABLE 7. Fates of unhatched eggs

Colony Site	Year	Disappeared	Broken	Deserted	Inviable
Port Terminal	1983	70%	6%	23%	1%
	1984	83	17	0	0
Sky Harbor	1983	53	17	22	8
	1984	90	5	0	5
Hennepin Island	1984	100	0	0	0
Spirit Island	1984	80	6	9	5
Leech Lake	1984	90	4	4	2
Lake of the Woods	1984	88	7	0	5
TOTAL MINNESOTA	1984	89	5	3	3

TABLE 8. Fates of unfledged chicks

Colony Site	Year	Disappeared	Found Dead
Port Terminal	1983	53%	47%
	1984	54	46
Sky Harbor	1983	0	100
	1984	38	62
Hennepin Island	1984	80	20
Spirit Island	1984	100	0
Leech Lake	1984	50	50
Lake of the Woods	1984	75	25
TOTAL MINNESOTA	1984	56	44

optimal habitat, predation, nest site competition with gulls, and human disturbance.

Climatic factors-- Storm driven waves caused flooding in two of the colonies. At least 10 nests were washed away on the lowest portion of Hennepin Island. Higher-than-normal water levels at Lake of the Woods combined with high winds destroyed many nests close to shore on at least four occasions; all nine nests in two enclosures were destroyed.

Suboptimal habitat-- Many terns that utilized the Port Terminal nested on poor quality habitat. In 1983, approximately 30 tern pairs nested on snow piles. As the snow disappeared, nests fell apart and chicks drowned in puddles of melted snow or died of hypothermia. In 1984, the snow piles thawed before the start of incubation and the willow grew rapidly, forcing many terns to abandon these patches of dense vegetation that were about 1 m in height.

Terns also used poor quality habitat on Spirit Island. The birds nested in depressions on the boulders and often no nesting material was used. In some cases, the boulders were inclined and the eggs rolled out of the cup. Chicks could easily fall off the boulders and become trapped in the crevices.

Predation-- Mammalian and avian predators were known to be present at two colonies. Red fox (Vulpes vulpes) predation was probably the predominant cause of chick death at Pine and Curry Island in 1984. Few chicks survived past five days after hatching and fox tracks were discovered during each visit after peak of hatching. At the Port Terminal, tracks of striped skunks (*Mephitis mephitis*) and domestic dogs (*Canis familiaris*) were found on the colony site. Visitors sometimes allowed their dogs to wander through the colony.

Owl predation was evident at the Port Terminal in 1983. Dismembered tern chick carcasses were found on several occasions and one owl pellet was discovered in the colony. A Great Horned Owl (*Bubo virginianus*) roosted on Hearding Island, approximately 1 km away. At Lake of the Woods, Common Ravens (*Corvus corax*) were observed entering the colony on numerous occasions, but no actual predation was documented (T. Wiens, pers. comm).

Nest site competition with gulls-- Competition with Ring-billed Gulls for nesting habitat was most evident at the Port Terminal. The rapidly expanding gull population continued to take more territory each year. In many sections these areas were where terns had nested in previous years (T.E. Davis, pers. comm.). This problem has not been observed at the other sites because no one has noted where terns have nested in relation to gulls in the past.

Human disturbance-- Human disturbance occurred with greatest frequency at the Port Terminal. Many nests were deserted following the 1983 visit of a Navy destroyer and the 1984 Fourth of July celebration which attracted many tourists. Cars were parked all over the Port Terminal and at least 3 eggs were crushed after the first incident. Prior to the 1983 census, several nests were covered with sand by construction workers. Other types of human activity that contributed to disturbance included sport fishing, an Air-stream Trailer convention, shipping activities and work crews on the railroad tracks.

Human disturbance occurred with considerably lower frequency at the other sites. is considerably less. Sky Harbor is protected by the runway; Hennepin, Spirit, and Gull Islands are uninviting and difficult to reach and Pine and Curry Island is posted. Despite these barriers, people do occasionally visit the colonies, as was evident from my discovery of a beer can on Spirit Island.

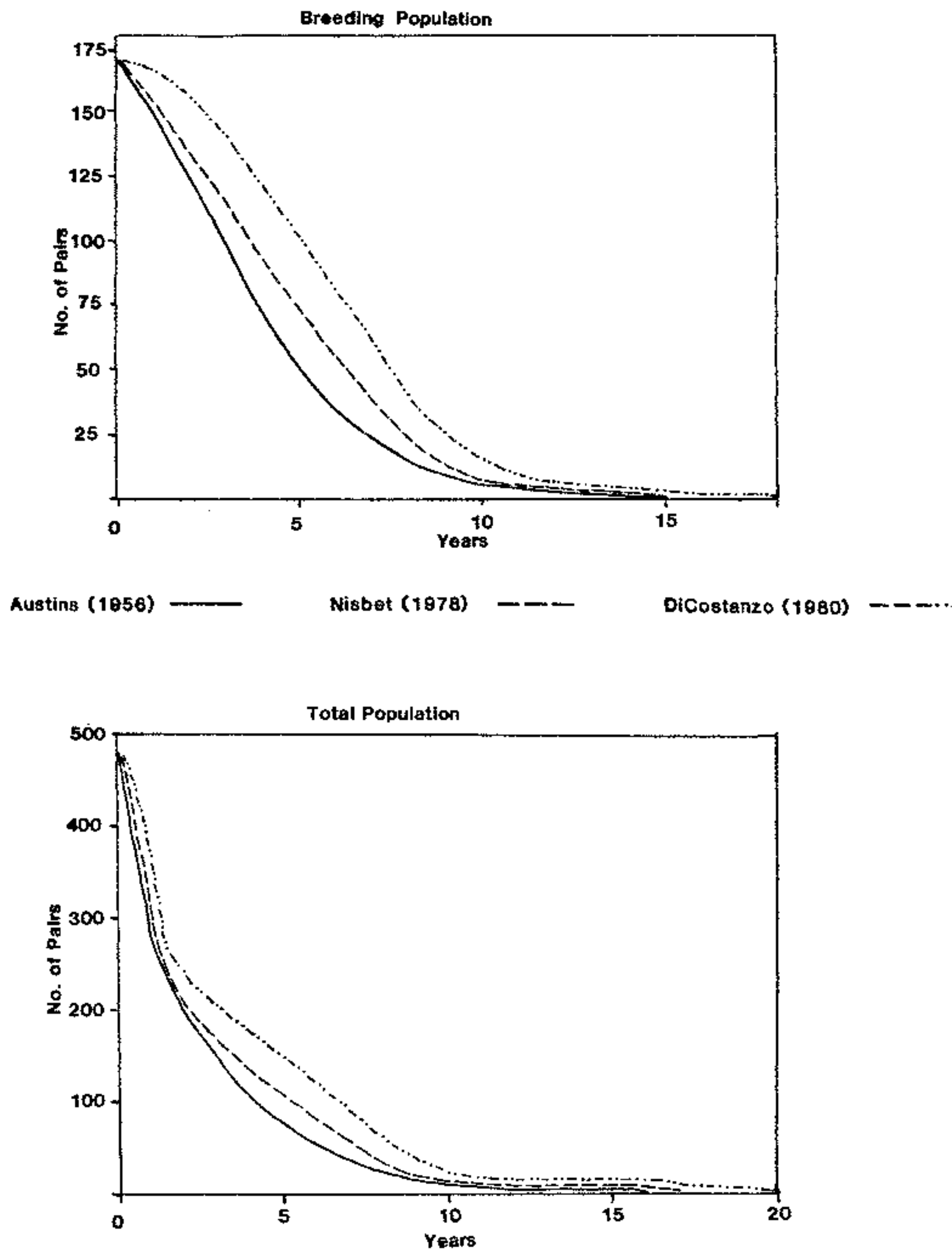
Autopsies-- The post-mortem analysis of the 13 carcasses collected in 1983 failed to establish cause of death for any chicks. No bacteria was isolated, but a few abnormalities were discovered. Seven chicks had unusual livers, either pale or abnormal in size. Chicks with pale livers and two additional chicks with pale internal organs may have suffered blood loss before death or there may have been a suppressed formation of hemoglobin or red blood cells. These observations suggest that the chicks either sustained an injury which caused death or that anemia is a common problem in chicks produced in the Duluth Harbor.

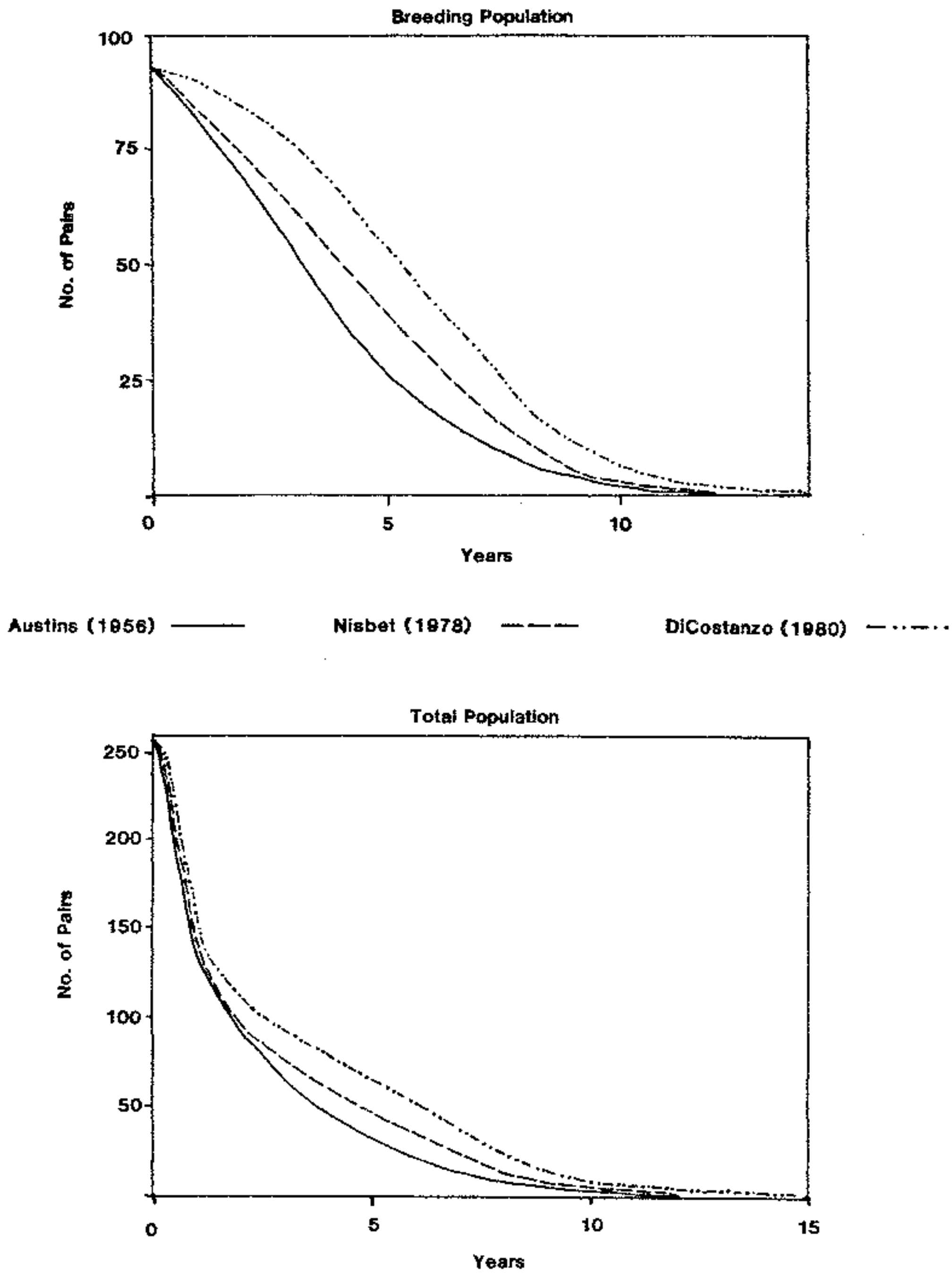
POPULATION PROJECTIONS

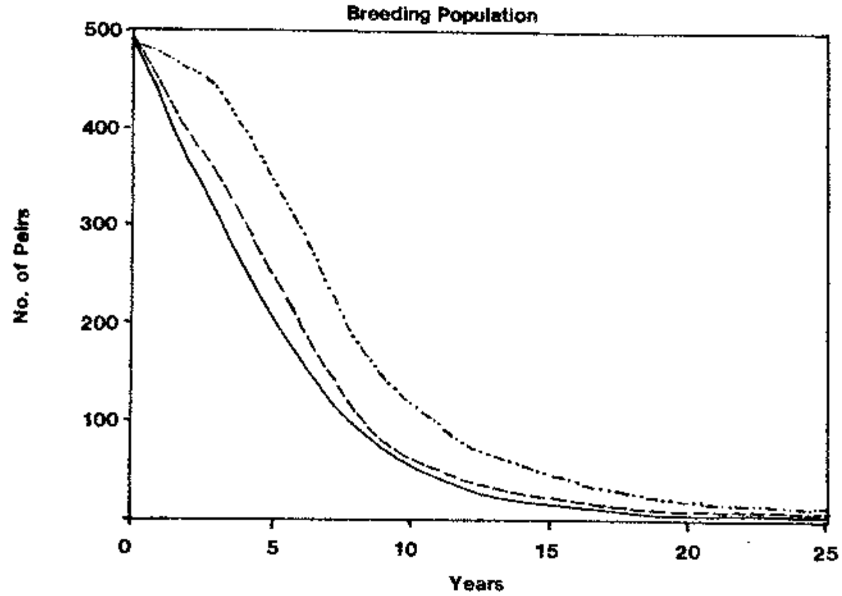
Projections for the four major subpopulations and the Minnesota population are presented in Figures 4-8. Projections for both the breeding and total populations of each breeding area are included.

The most notable aspect of the projections are that all subpopulations and the Minnesota population are declining for all three survival data. This decline is so rapid that only one subpopulation, Leech Lake, survives to year 25. All subpopulations were reduced to half their initial size by year 6. The rate of loss varied between 20-40% a year.

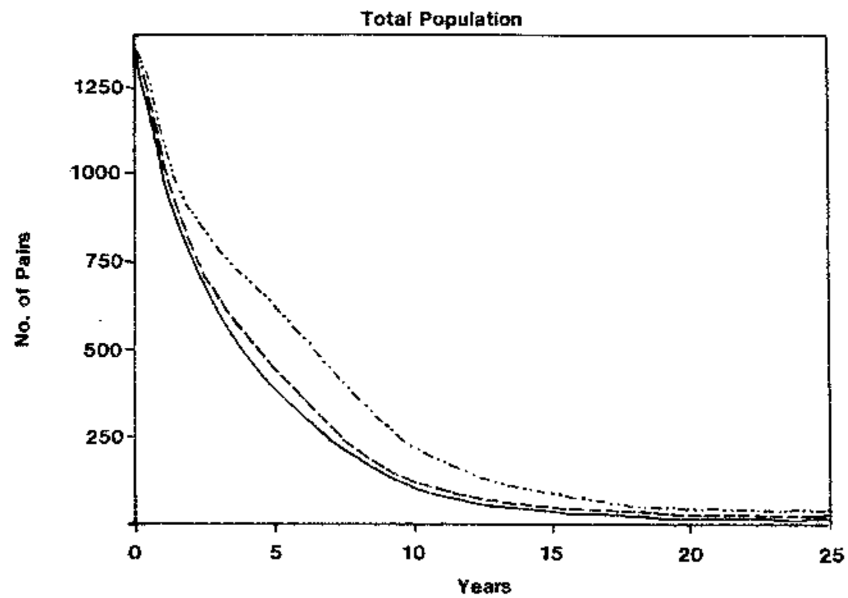
The Mille Lacs subpopulation becomes extinct in 11-14 years the shortest amount of time for all colonies. Duluth and Lake of the Woods had similar projection, expiring in 15-20 years.According to the model the entire population of Common Terns will go extinct in Minnesota in 20-25 years if reproductive success remains at 0.15 fledglings/pair/year and if all assumptions of the model are met.

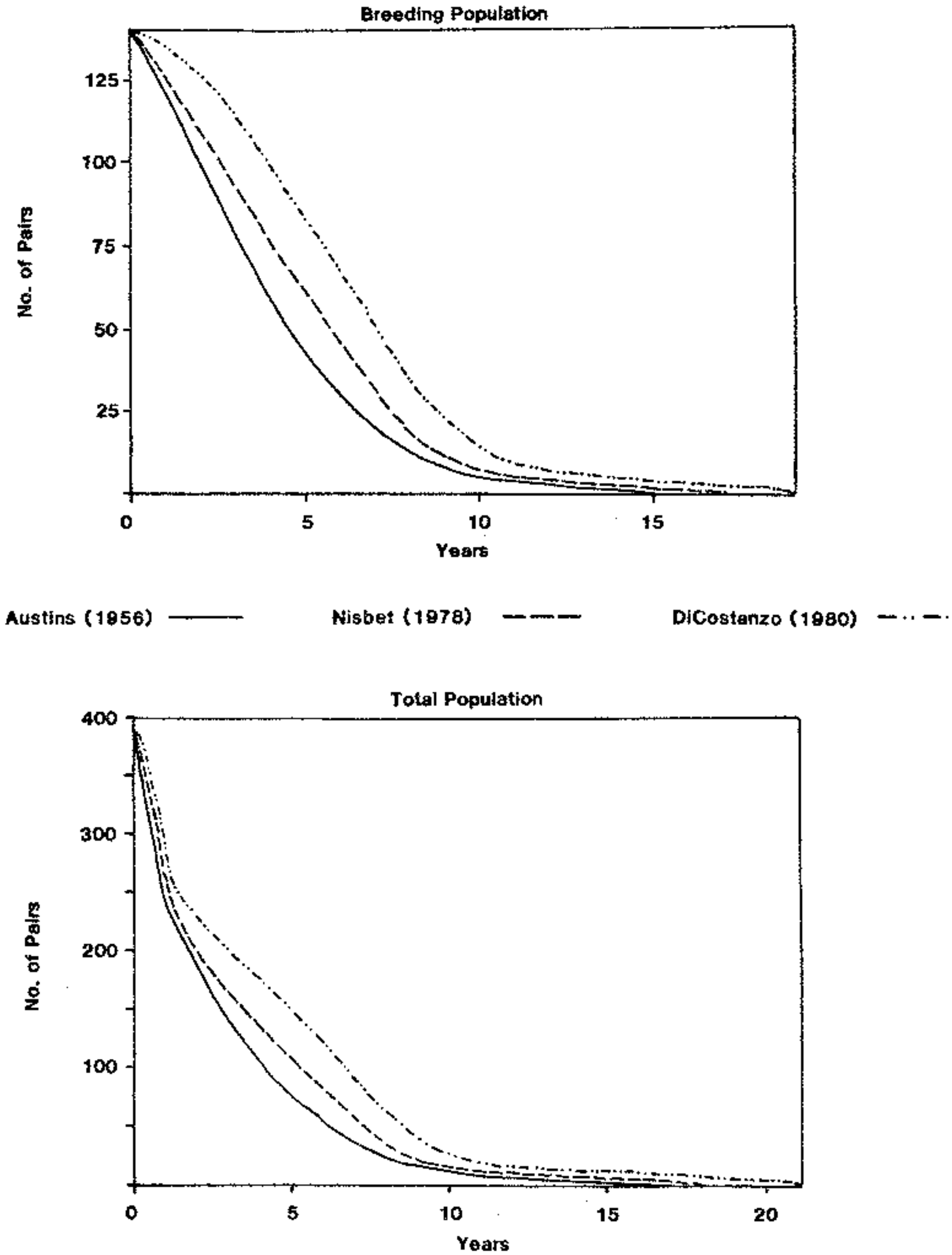

Breeding Population
No. of Pairs
175
150
125
100
75
50
25
0
5
10
15
Years
Austins (1956)
Nisbet (1978)
DiCostanzo (1980)
Total Population
No. of Pairs
500
400
300
200
100
0
5
10
15
20
Years

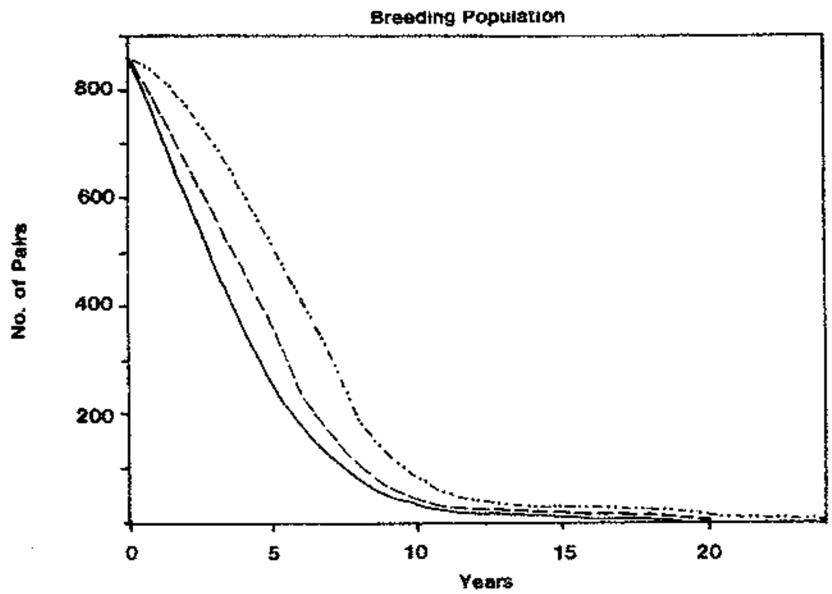

Breeding Population
No. of Pairs
100
75
50
25
0
5
10
Years
Austins (1956)
Nisbet (1978)
DiCostanzo (1980)
Total Population
No. of Pairs
250
200
150
100
50
0
5
10
15
Years



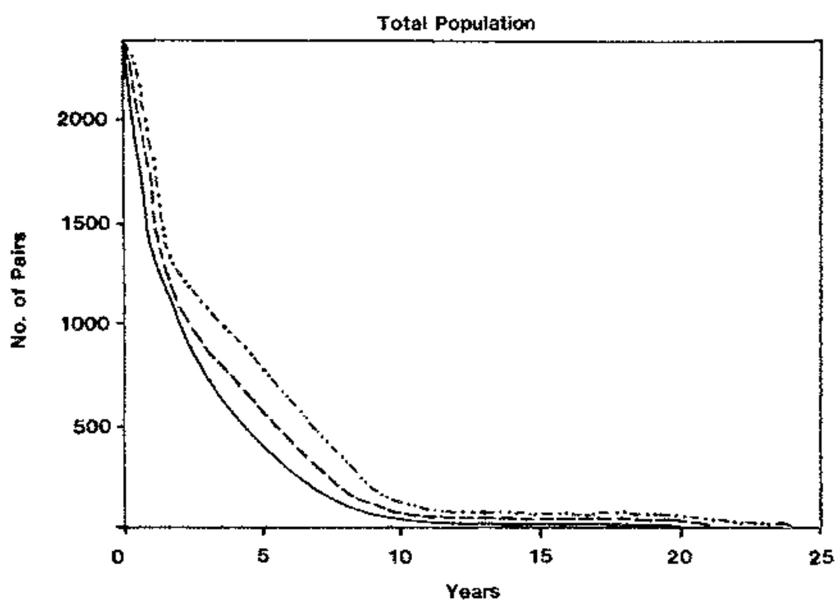
Austins (1956) ——— Nisbet (1978) — — — DiCostanzo (1980) — · · — · ·




Breeding Population
No. of Pairs
125
100
75
50
25
0
5
10
15
Years
Austins (1956)
Nisbet (1978)
DiCostanzo (1980)
Total Population
400
300
200
100
0
5
10
15
20
Years



Austins (1956) ——— Nisbet (1978) — — — DiCostanzo (1980) —·· — —



DISCUSSION

MINNESOTA POPULATION ESTIMATE

The census conducted in 1984 was the first attempt to obtain a complete population estimate for Common Terns in Minnesota. This effort was unique in that it included all known breeding sites and was conducted during a single breeding season while terns were approximately in the same stage of the breeding cycle. Previous censuses were made at different stages in the terns' breeding chronology and usually were not direct nest counts. Despite these inconsistencies, comparisons indicate that tern population numbers were greater in the past than in 1984 (Table 9) For example, in 1981, 227 Common Tern pairs were counted at the Port Terminal (Cuthbert et al. 1984). In 1963, more than 60 adults were observed at the Sky Harbor site (unpubl. data, MOU files). At Hennepin and Spirit Islands, approximately 580 pairs were counted in 1930 (Roberts 1936). At Gull Island over 1000 pairs were estimated in 1933 (Roberts 1936) and in the late 1960's (unpubl. data, MOU files). Another 100 pair were estimated on Pine and Curry Island in 1932 (unpubl. data, MOU files). Based on these records, I estimated that approximately 2600 pairs nested in Minnesota during the 1930's; three times the number of terns present in 1984.

In recent years, the population trends appear to be

TABLE 9. Historical colony sizes of Common Terns in Minnesota*

Year	Port Terminal	Sky Harbor	Hennepin Island	Spirit Island	Gull Island	Lake of the Woods
1915	-	-	100	150	-	-
1930	-	-	500	80	-	-
1932	-	-	-	-	-	1000
1933	-	-	100	12	1000	-
1963	-	30	100	-	-	-
1968	-	-	-	-	1000	-
1973	12	-	25	-	-	-
1978	148	7	51	20	410	-
1981	227	-	-	-	-	-
1982	190	-	-	-	150	125

* all data gathered from MOU files and Roberts (1936)

- no data collected this year

different among colonies. The Port Terminal colony has decreased to half the size reported at its peak in 1981. Census reports were not available for the past five years at Sky Harbor, but no more than 15 pairs have been observed since 1963. Nest counts at the Mille Lacs colonies in the past few years were performed in late May-early June and probably underestimated the number of terns that had just begun to lay eggs. Fewer than 50 pair have been estimated to nest on these islands in the past four years (unpubl. data, MOU files).

The Leech Lake colony decreased in size during the late 1970's but is now increasing. The present size is similar to that estimated in the mid-70's-- around 500 pairs (unpubl. data, MOU files). At Lake of the Woods, the population has remained stable in the last three years on Pine and Curry Island (T. Wiens, pers. comm.) Colony size at other sites in Lake of the Woods have not been well-documented except for a 1981 census when 288 pairs were counted in the Minnesota portion of Lake of the Woods (Hirsch 1982).

BREEDING SUCCESS

There is a considerable degree of variability in Common Tern breeding success at different sites throughout its breeding range (Table 10). Other investigators (Langham 1972, Nisbet and Drury 1972, Lemmetyinen 1973, Morris et al. 1976, Burger and Lesser 1979, and Shugart and Scharf

TABLE 10. A comparison of breeding success estimates

Study	Location	Fledgling Age (days)[1]	Hatching Success	Chick Survival	Fleding Success	Reproductive Success
Langham (1972)	England	16[2]	--	59-88%	--	--
Nisbet and Drury (1972)	Massachusetts	22[2]		--	0-71%	0.00-2.09
Lemmetyinen (1973)	Finland	14	68-87%	47-68%	--	0.99-1.66
Morris et al. (1976)	Lakes Erie and Ontario	*[2]	28-81%	0-45%	0-36%	0.00-0.95
Burger and Lesser(1979)	New Jersey	*[2]	--	--	--	0.00-0.96
Shugart and Scharf(1983)	Lakes Huron and Michigan	*[3]	--	--	7%	--

1 number of days after hatching that chicks were considered fledged
2 enclosures used to monitor chicks
3 eggs were counted at peak of incubation and chicks were counted after most chicks had hatched
* not specified

1983) found reproductive success to range from 0.00-1.46 fledglings per breeding pair; fledging success ranged from 0-70% survival of eggs to fledging. Hatching rates varied between 28-81% (Morris et al. 1976) and chick survival ranged from 0-88% (Langham 1972, Lemmetyinen 1973, Morris et al. 1976).

Productivity of all colonies in Minnesota was far below the expected 30% fledging success used by Shugart and Scharf (1983) or the 1.1 reproductive success derived by DiCostanzo (1980) and Nisbet (1972) as the criteria for good success. Excluding any migration to and from the population, during my study,terns did not produce enough young to maintain the colony.

I suspect that I underestimated the breeding success of terns at Leech Lake. Because nests were too dense at the center and the fence would come too close to the nests, both the enclosures on Gull Island were erected on the periphery of the colony. One enclosure was built next to the beach shore and the other on the opposite side of the colony, surrounded by gull nests on three sides. No chicks survived in the enclosure adjacent to the gulls and there was 32% fledging success in the enclosure near shore. Most nests on Gull Island were not surrounded by gulls and success appeared good outside the enclosure. If the colony size is increasing , as the census data indicate, then the success I reported may be an underestimate and the colony may be producing enough young to maintain itself.

FACTORS INFLUENCING BREEDING SUCCESS

Comparisons with other studies show that disappearance of eggs was also the most common fate of unhatched eggs. In a study done by Morris et al.(1976) in the lower Great Lakes, 33% of the eggs disappeared, with desertion (15%)the second most common cause of egg failure (Morris et al. 1976). Lemmetyinen (1973) estimated that 58% of the eggs in his study were lost to predators. The proportion of eggs that disappeared in 1984 was considerably higher than that reported by Lemmetyinen, Morris et al. and for this study in 1983. Because my visits in 1984 were conducted only once a week, many deserted or inviable eggs could have disappeared before my weekly visit causing me to categorize them incorrectly. Therefore, the proportion of eggs that disappeared during my study may have been overestimated.

Lemmetyinen (1973) reported that 60-70% of the unfledged chicks were taken by predators. This is higher than the percentage of chicks that disappeared in Minnesota. Chick disappearance was less common than egg disappearance in this study.

A major problem in studies of reproductive success is how to account for the large number of disappearances. Predation is usually given as the most likely cause , especially if flooding can be eliminated as a possibility.

It is difficult to assess the impact of a predator, but it is possible to estimate the number of eggs and chicks taken by predators by constant observation of a colony or an area in a colony or by using time-lapsed photography to record the presence and activities of predators.

Gulls can be major predators in tern nesting adjacent to gull colonies (Palmer 1941, Hatch 1970, Burger and Lesser 1979). Ring-billed gulls were seen in or near the enclosures at Leech Lake and at the Port Terminal gull fledglings were often found in the tern colony. The islands at Mille Lacs were at least 1-2 weeks behind in their breeding chronology and I suspect that the proximity of gulls to terns at these sites may induce enough stress on the terns to delay their breeding activities.

Although I found no direct evidence of gull predation at any of the Minnesota sites, the large number of missing eggs and chicks suggests heavy predation by several predators. Roberts (1936) recorded hatching success at the Mille Lacs islands to be approximately 80% prior to gulls nesting at these sites. It is possible that the decrease in hatching success was caused by gull predation. The amount of gull predation at sites outside of Minnesota varies among locations. For example, Morris et al. (1976) and Courtney and Blokpoel (1980) observed no Ring-billed Gull predation at the lower Great Lakes sites. Hatch (1970) reported heavy chick predation (0.48-1.2 chicks/ pair/ season) by Herring

Gulls and Great Black-Backed Gulls (Larus marinus) in Maine, but no egg predation. Burger and Lesser (1979) have observed gulls with tern eggs on a few occasions in New Jersey. Although gulls are essentially diurnal, Ring-billed Gulls have been observed feeding on fish at night in an artificially-illuminated harbor (Leck 1971). The gulls at the Port Terminal appear to be active at night, however, it would seem difficult for gulls to prey on eggs or chicks when both adults are at the nest. It is most likely that if gull predation does occur at a colony, it is most likely to occur when the terns are disturbed, either by humans or nocturnal predators.

The availability of food could affect the productivity of a colony. One of the major methods of examining this variable is to study the growth of the chicks by weighing chicks at different stages of development. This was not done in this study because I wanted to minimize investigator disturbance. Instead I weighed the dead chicks that were collected for analysis in 1983 and compared these weights to those of chicks of the same age from other studies. Five of the seven chicks whose age at death was known had weights equal to or higher than weights reported by Langham (1972) and LeCroy and Collins (1972). I also observed feeding behavior at several nests at the Port Terminal in 1983. There were many occasions when a foraging adult was back with food within 10 mins of departure from the nest. I do not believe that availability of food was a problem for terns at the Port Terminal. My conclusions concur with other investigators who found that availability of food was a greater problem for terns in oceanic environments than for terns in freshwater environments (Lemmetyinen 1973).

Many factors influenced success at the Minnesota Common Tern colonies and, while single factors can rarely be correlated with breeding success (Morris et al. 1976), I believe that one of the major problems that confronts terns in Minnesota is the scarcity of quality breeding habitat that is not subjected to human disturbance or predation. According to Palmer (1941), terns have three prerequisites for an optimal breeding site: 1) isolation by natural barriers to eliminate predators, 2) a constant supply of food nearby, and 3) topographical conditions that allow the majority of birds to see and hear their neighbors from their nest. In Minnesota, few sites are available that satisfy all three prerequisites and therefore terns nest in suboptimal habitat. Terns depend on large bodies of water for a constant food supply, but some sites on these large lakes have succumbed to encroaching vegetation (Davis and Niemi 1979), and others (i.e. Pine and Curry Island) are accessible to predators.

Nest site competition may be the biggest factor in the decline of Common Terns in the Great Lakes. The decline in Common Tern numbers coincides with a large increase in numbers of Ring-billed Gulls at tern sites (Blokpoel et al. 1978). Shugart and Scharf (1983) thought that the increase in Ring-billed Gulls that occurred between 1962 and 1976 at sites in Lakes Michigan and Huron did not result in actual takeovers of active tern sites. However, combined with the high water levels, the greater number of gulls nesting in their study area may have reduced the amount of nesting area that was previously available to terns in 1962. Although there is evidence that Ring-billed Gulls can take over tern breeding sites, there is only indirect evidence that declines in Common Tern numbers can be explained by loss of nesting area to Ring-billed Gulls (Shugart and Scharf 1983). Blokpoel et al. (1978) take a stronger position: unless the increase in Ring- billed Gull numbers is halted (naturally or by human control) the Common Tern may well be a rare nester in the Great Lakes.

Although Roberts (1936)observed 25-30 Ring-billed Gulls loafing on Spirit Island in 1933, this species was not known to nest in Minnesota until the 1960's (unpubl. data, MOU files). During the 1970's there was a rapid increase in population size, but recent census data suggest that the population growth has slowed (Table 11). To examine competition for nesting habitat more closely, it will be necessary to document exact locations at the colony site where the terns and gulls are nesting over a period of several

TABLE 11. Number of pairs of Ring-billed Gulls adjacent to tern colonies

Year	Port Terminal	Hennepin	Spirit	Gull Island
1963	0	100	0	0
1970	0	--	50+	0
1971	--	--	--	6
1974	2	50	--	--
1976	--	87	131	82
1977	239	89	85	92
1978	979	190	164	58
1979	1477	187	184	--
1980	2839	100+	250	--
1981	3747	193	208	200+
1982	--	196	181	200+
1983	--	100	250	291
1984	>5000	180	170	285

-- no data collected this year

* all data gathered from MOU files

years. Comparisons of annual changes may demonstrate a gull takeover of tern nesting territory.

Management efforts in the next few years should focus on investigating the quality of nesting habitat for terns and nest site competition with the gulls. New studies could include discovering the source of egg and chick disappearance, the contribution of Ring-billed Gulls to tern reproductive failure, and movements of birds between sites in and outside of Minnesota. Providing new habitat for the terns that would exclude gull and human activity could be the best solution to the low breeding success of Common Terns in Minnesota.

Another aspect that merits continued investigation is the effect of chemical contaminants on reproductive success. Numerous studies have correlated contaminants with eggshell thinning, congenital anomalies, behavioral abnormalities, and embryonic death in piscivorous birds (Hays and Risebrough 1972, Gilman et al. 1977, Fox et al. 1978, King et al. 1978). A 1977 study by Niemi et al. (in press) found four organochlorines (PCB, HCB, DDE, DDT) in tern eggs and chicks at the Port Terminal. Continued monitoring of contaminants in the Great Lakes region should also be a management objective.

Population Projections

The population projections have several important limitations. Models cannot take into account all significant population variables and interactions. This model is for a closed population and does not allow for emigration or immigration. The data entered into the computer model was from one or two years and it is possible that success varies from year to year. These projections are idealized and should not be construed as accurate predictions of population sizes. However, because it is possible to demonstrate trends and compare the subpopulations the model is still a valuable tool.

The model shows that if productivity in Minnesota continues at the 1984 level, the Common Tern population in Minnesota will continue to decline. Also, the subpopulation most in danger of extirpation are the birds using the Mille Lacs sites. These colonies were the smallest and had the lowest success. Leech Lake, with the largest subpopulation and highest success would survive the longest. Management plans may want to focus on the colonies which are more in jeopardy of extirpation than those that are more stable.

What is needed to improve the accuracy of the model is to increase the accuracy of the population parameters in the model. Breeding success from several years would provide more accurate information, but it is difficult to say how many years would be adequate. An investigator could collect several years' data and calculate an `average' year or find the range of breeding success and use those figures to determine the trend. The population simulation written by Conley has a stochastic natality option which an `average' mx could be entered and annual natality would vary randomly among years.

Once the accuracy is increased then it is possible to estimate net migration. Any significant deviations from actual numbers of the projections would indicate that birds are leaving or entering the population. For example, in Duluth the projections show that between 149-166 pairs should have nested in 1984. Disregarding that the estimate of 149 is within reasonable error for the actual 140 pairs found in Duluth, according to the model, 9-26 pairs emigrated from the subpopulation.

The general trend of the population projections was not influenced by the different survival data from Austin and Austin (1956), Nisbet (1978) and DiCostanzo (1980), but the rate of decline did differ. Projections using DiCostanzo's (1980) data gave the longest survival and projections using Austin and Austin (1956) data gave the shortest, usually 2-5 years before DiCostanzo. DiCostanzo had the highest adult survival and the second highest fledging survival. Nisbet's adult and fledging survival was respectively 5 and 4% lower than DiCostanzo's and though Austin and Austins' adult survival was considerably lower than both Nisbet's and DiCostanzo's, their fledging survival was 6-10% higher.

Despite the limitation of the model, the basic pattern remains the same: all projections show a serious decline in the number of terns in the next 25 years. The model confirms the 1.1 young/ pair/ year criteria for a stable population. The terns in Minnesota must increase reproductive success considerably in order to become a stable population.

LITERATURE CITED

Austin, O.L. and O.L. Austin,Jr. 1956. Some demographic aspects of the Cape Cod population of Common Terns (Sterna hirundo). Bird-banding 27:55-66.

Blokpoel, H., P.M. Catling, and G.T. Haymes. 1978. Relationship between nest sites of Common Terns and vegetation on the Eastern Headland, Toronto Outer Harbor. Can. J. Zool. 56:2057-2061.

Burger, J. and F. Lesser. 1979. Breeding behavior and success in salt marsh Common Tern colonies. Bird-banding 50:322-337.

Courtney, P.A. and H. Blokpoel. 1980. Behavior of Common Terns nesting near Ring-billed Gulls. Can. Field Naturalist 94(3):336-338.

Cuthbert, F.J., J.E. McKearnan, and T.E. Davis. 1984. Status of Common Terns nesting in the Duluth Port Terminal 1982-83. Loon 56:20-24.

Davis, T.E. and G.J. Niemi. 1979. Larid breeding in the western tip of Lake Superior. Loon 52:3-14.

DiCostanzo, J. 1980. Population dynamics of a Common Tern colony. J. Field Ornithol. 51:229-243.

Erwin, R.M. 1984. Monitoring colonial waterbird populations in the Northeast: historical and future perspectives. Trans. of the 1984 Northeast Fish and Wildlife Assoc. Conference 41:97-109.

Erwin, R.M. and T.W. Custer. 1982. Estimating reproductive success in colonial waterbirds: an evaluation. Col. Waterbirds 5:49-56.

Fox, G.A., A.P. Gilman, D.B. Peakall, and F.W. Anderka. 1978. Behavioral abnormalities of nesting Lake Ontario Herring Gulls. J. Wildl. Manage. 42(3):477-483.

Gilman, A.P., G.A. Fox, D.B. Peakall, S.M Teeple, T.R. Carroll and G.T. Haymes. 1977. Reproductive parameters and contaminant levels of Great Lakes herring gulls. J. Wildl. Manage. 41(3):458-468.

Hatch, J.J. 1970. Predation and piracy by gulls at a ternery in Maine. Auk 87:244-254.

Hays, H. 1978. Timing and breeding success in three- to seven-year-old Common Terns. Ibis 120:127-128.

Hays, H. and R.W. Risebrough. 1972. Pollutant concentrations in abnormal young terns from Long Island Sound. Auk 89:19-35.

Henderson, C.L. and J. Mattson. 1978. Minnesota colonial waterbirds nesting site inventory. Minn. Dept. of Natural Resources, St. Paul.

Hirsch, K. 1982. New colonies in Lake of the Woods. Loon 54:37-39.

King, K.A., E.F. Flickinger, and H.H. Hildebrand. 1978. Shell thinning and pesticide residues in Texas aquatic birds, 1970. Pesticides Monitoring Journal 12:16-21.

Kress, S.W., E.H. Weinstein, and I.C.T. Nisbet. 1983. The status of tern populations in the northeastern United States and adjacent Canada. Col. Waterbirds 6:84-106.

Langham, N. 1972. Chick survival in terns (Sterna spp.) with particular reference to the Common Tern. J. Anim. Ecol. 41:385-395.

Leck, C.F. 1971. Nocturnal habits of Ring-billed Gulls (Larus delawarensis) at Thimble Shoal, Virginia. Chesapeake Science 12:175.

LeCroy, M. and C.T. Collins. 1972. Growth and survival of Roseate and Common Tern chicks. Auk 89:595-611.

Lemmetyinen,R. 1973. Breeding success in Sterna paradisaea Pontopp. and S. hirundo L. in southern Finland. Ann. Zool. Fennici 10:526-535.

Minnesota Ornithologist' Union (MOU) files, unpubl. data

Morris, R.D., R.A.Hunter, and J.F. McElman. 1976. Factors affecting reproductive success of common tern (Sterna hirundo) colonies in the lower Great Lakes during the summer of 1972. Can. J. Zool. 54:1850-1862.

Niemi, G.J., T.E. Davis, G.D. Veith and B. Vieux. 1986. Organochlorine chemical residue in herring gulls, ring-billed gulls and common terns of western Lake Superior. Archives of Environmental Contaminants and Toxicology: in press.

Nisbet, I.C.T. 1973. Terns in Massachusetts: present numbers and historical changes. Bird-banding 44:27-55.

Nisbet,I.C.T. 1978. Population models for Common Terns in Massachusetts. Bird-banding 49:50-58.

----- and W.H. Drury. 1972. Measuring breeding success in Common and Roseate Terns. Bird-banding 43:97-106.

Palmer, R.S. 1941. A behavior study of the Common Tern. Proc. Boston Soc. Nat. History 42:1-119.

Roberts, T.S. 1936. The Birds of Minnesota. 2nd revised ed. 2 vols. Minneapolis:University of Minnesota Press.

Shugart,G.W. and W.C. Scharf. 1983. Common Terns in the northern Great Lakes: current status and population trends. J. Field Ornithol. 54(2): 160-169.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry 2nd ed. W.H. Freeman and Co. New York

Southern, W.E. 1980. Comparative distribution and orientation of North American gulls. pp. 449-498. In J. Burger, B.L.Olla and H.E. Winn (eds.) Behavior of Marine Animals, Vol. 4, Plenum Press, New York.