PRELIMINARY ASSESSMENT OF TERN REPRODUCTION IN RELATION TO ENVIRONMENTAL CONTAMINANTS ON THE MISSISSIPPI RIVER

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Requisition number 35805: Final Report

INTRODUCTION

In this paper we report the concentrations of PCB's and other chlorinated hydrocarbons in the eggs of the black tern (Chlidonias niger) and Forster's tern (Sterna forsteri) from the upper Mississippi River in Minnesota. We also report on the reproductive success of these species.

This study had four initial objectives: 1) to survey areas of the Mississippi River with extensive emergent aquatic vegetation in search of black tern and Forster's tern breeding colonies, 2) to determine levels of certain chlorinated hydrocarbons in samples of eggs of the black tern, 3) to determine, insofar as possible, hatching success in the colonies encountered, 4) to compare the thickness index of collected eggshells with that of shells collected before 1947.

METHODS AND MATERIALS

DESCRIPTION OF THE STUDY AREA

The study area, in general, was the Mississippi River in Minnesota, from the head of Lake Pepin (river mile 791) to the Iowa border (river mile 674). Areas with extensive stands of emergent aquatic vegetation were surveyed by boat, on foot, and in vehicles. Other areas of likely habitat were also surveyed. Two of these areas were not directly connected to the Mississippi River, but were close in proximity. All other areas were backwaters.

COLONY LOCATION

To determine colony locations areas of likely habitat were surveyed with the use of spotting scopes and binoculars. By observing the flights of black terns or Forster's terns the observer was eventually lead to areas of heavy tern activity. Close scrutiny of these areas usually revealed the presence of a breeding colony. A boat and/or

wading was employed to inspect the entire colony area. When located, nests were flagged and numbered.

EGG COLLECTION

Eggs were collected only from clutches containing two or more eggs. Only one egg was collected from each nest sampled. Clutch size and other pertinent information (nest and egg condition, number and age of any young present, pipping or addled eggs etc.) were recorded each time the nest was checked. Eggs were individually wrapped in aluminum foil, labelled, and transported to the laboratory. Due to the sensitive status of Forster's terns in this area, no plans were made to collect their eggs. However, observation of the Forster's tern colony revealed that the nests were abandoned prior to hatching. When we determined that a nest was indeed abandoned, we were then able to collect eggs from it. No viable Forster's tern eggs were collected.

HATCHING SUCCESS

Black tern and Forster's tern chicks are semi-precocial. They are capable of moving off the nest a short distance within a few days of hatching. When approached, the very young chicks will leave the nest to hide among nearby vegetation, thereby being well concealed and difficult to locate. In order to observe hatching success, we attempted to limit the area in which young terns could hide by placing a fence around selected nests prior to hatching. A fence made out of 1" poultry wire, two feet high and four feet across, was anchored around the nest. Some vegetation was always included within the fence to serve as cover for the chicks.

SAMPLE PREPARATION

All instruments were thoroughly cleaned and rinsed with pesticide grade methylene chloride and hexane. After measurement for weight,

size, and volume, eggs were opened and the contents placed into a glass dish. Egg contents were then examined. All black tern eggs were less than three days old and showed very little embryo development. Forster's tern eggs were 2 to 3 weeks old, due to the fact that we could not collect them earlier, but had to wait until nest abandonment. Egg contents were homogenized, placed into a glass jar, sealed with foil, and frozen at -21°C until analysis.

CONTAMINANT ANALYSIS

Egg contents were weighed and blended with 60 grams of pre-extracted sodium sulfate. This was placed into a Soxhlet apparatus and extracted for 12 hours. After extraction, lipid content was determined by evaporation. Lipids were re-dissolved in hexane and chromatographed on a column with 15 grams of Florisil to remove the lipids. The Florisil was activated at 675°C for three hours, then deactivated with 0.25% water prior to use. Three eluates were collected: 60 ml of hexane, 50 ml of 30% methylene chloride in hexane, and 60 ml of 50% methylene chloride in hexane. Eluates were concentrated to 10 ml or less in a flash evaporator.

Identification of compounds was performed on a Varian model 3700 gas chromatograph equipped with a Ni^{63} electron capture detector and a DB-5 fused-silica column of 30 m length with a 0.25 mm inside diameter. Compounds were quantified on a Varian model 4270 integrator by comparison to standard pesticide mixtures. Carrier gas was helium at a flow rate of 2 ml/minute. Make-up gas was 10% methane 90% argon at a flow rate of 30 ml/minute. A temperature program ran from an initial temperature of 75°C to a final temperature of 250°C at the rate of 4°C per minute. The detector operated at 300°C.

RESULTS AND DISCUSSION

COLONY LOCATIONS

Five different colonies were located. The northernmost colony was a Forster's tern colony. It was the only Forster's tern colony located in this study and was located in the Weaver Bottoms area just south of Half Moon Lake (Figure 1). A black tern colony was also located in the Weaver area, south of the Whitewater River and west of Highway 61, approximately due west of the main channel at river mile 743 (Figure 1). Other black tern colonies were found at the following locations: the Winona Pools, off Straight Slough, 2 miles south of the main channel at river mile 734.5 (Figure 2); Boller's Lake, approximately 3 miles SW of Lock and Dam 5A, just off Highway 61 (Figure 3); Lawrence Lake, $\frac{1}{2}$ mile west of the main channel at river mile 691.5 (Figure 4). An additional black tern colony was suspected, but not confirmed, at Blue Lake near LaCrosse, WI, at the SE corner of the intersection of Highways 16 and 61. All black tern colonies were located in thick stands of emergent aquatic vegetation, and with the exception of the Winona Pools colony, the nests were wet and floating. Forster's tern nests were similar to black tern nests but were built approximately one foot above the surface of the water on a very small, low island.

NEST COUNTS, CLUTCH SIZE AND HATCHING SUCCESS

Nest counts, mean clutch size, and hatching success are given in Table 1. Mean clutch size for black terns was 2.52 eggs/nest in 1984. This is similar to the mean clutch sizes reported by other investigators (Table 2). Mean clutch size for Forster's terns was 2.00 eggs/nest. This mean is slightly lower than that reported by other studies. (Table 2). Hatching success for black terns was 14 chicks/78 eggs

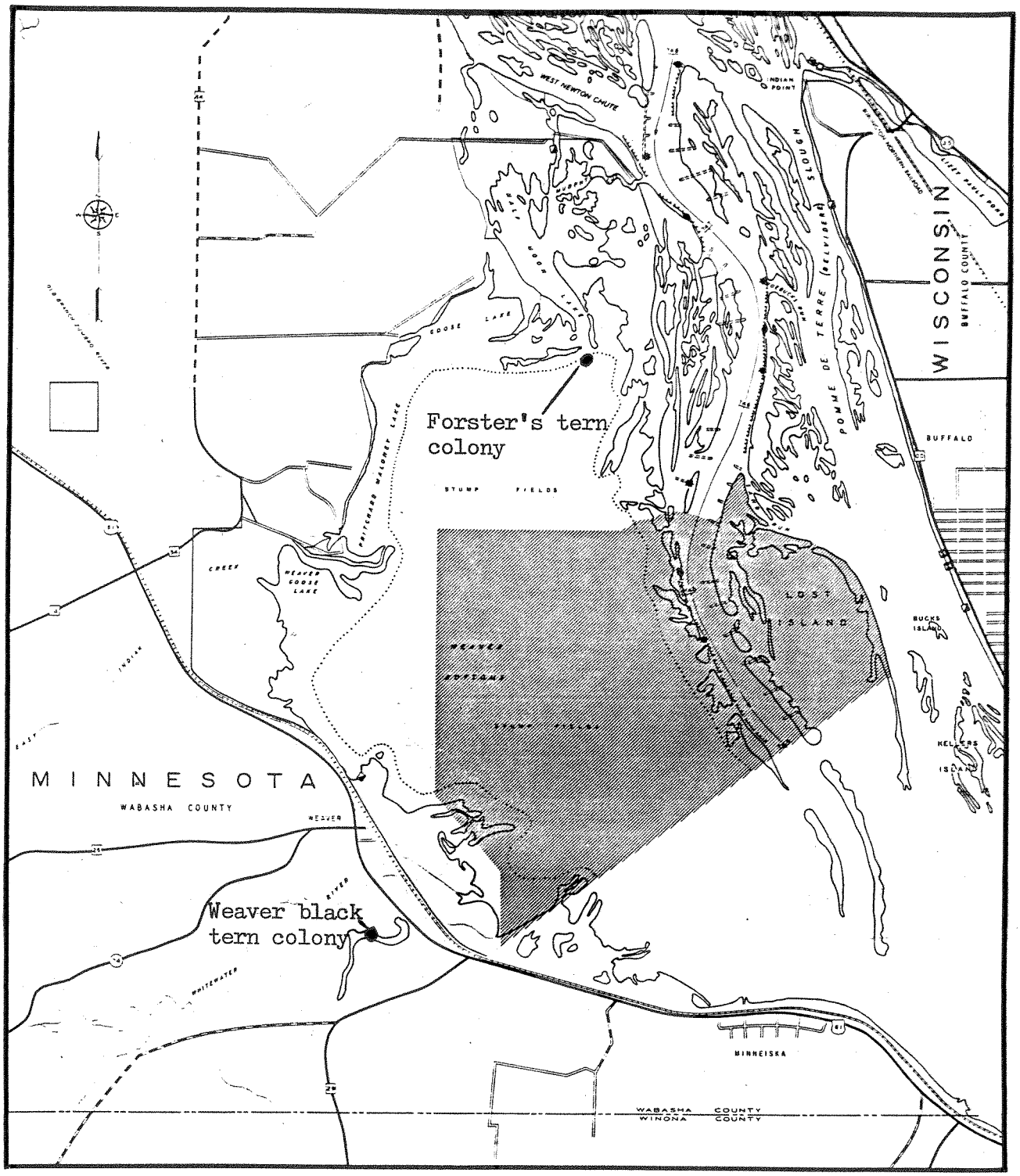

Figure 1. Locations of the Weaver black tern colony and the Forster's tern colony located in 1984

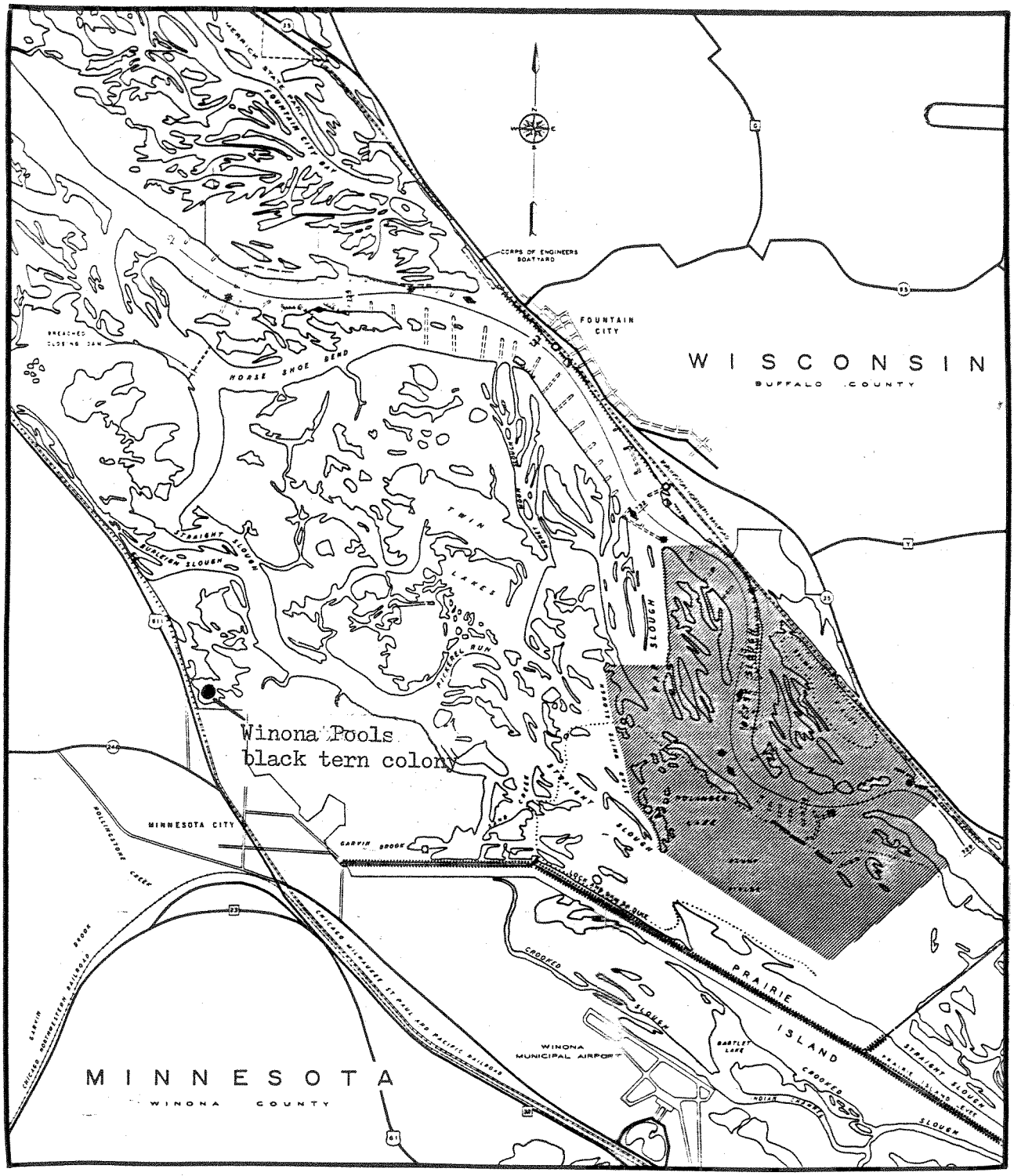

Figure 2. Location of the Winona Pools black tern colony.

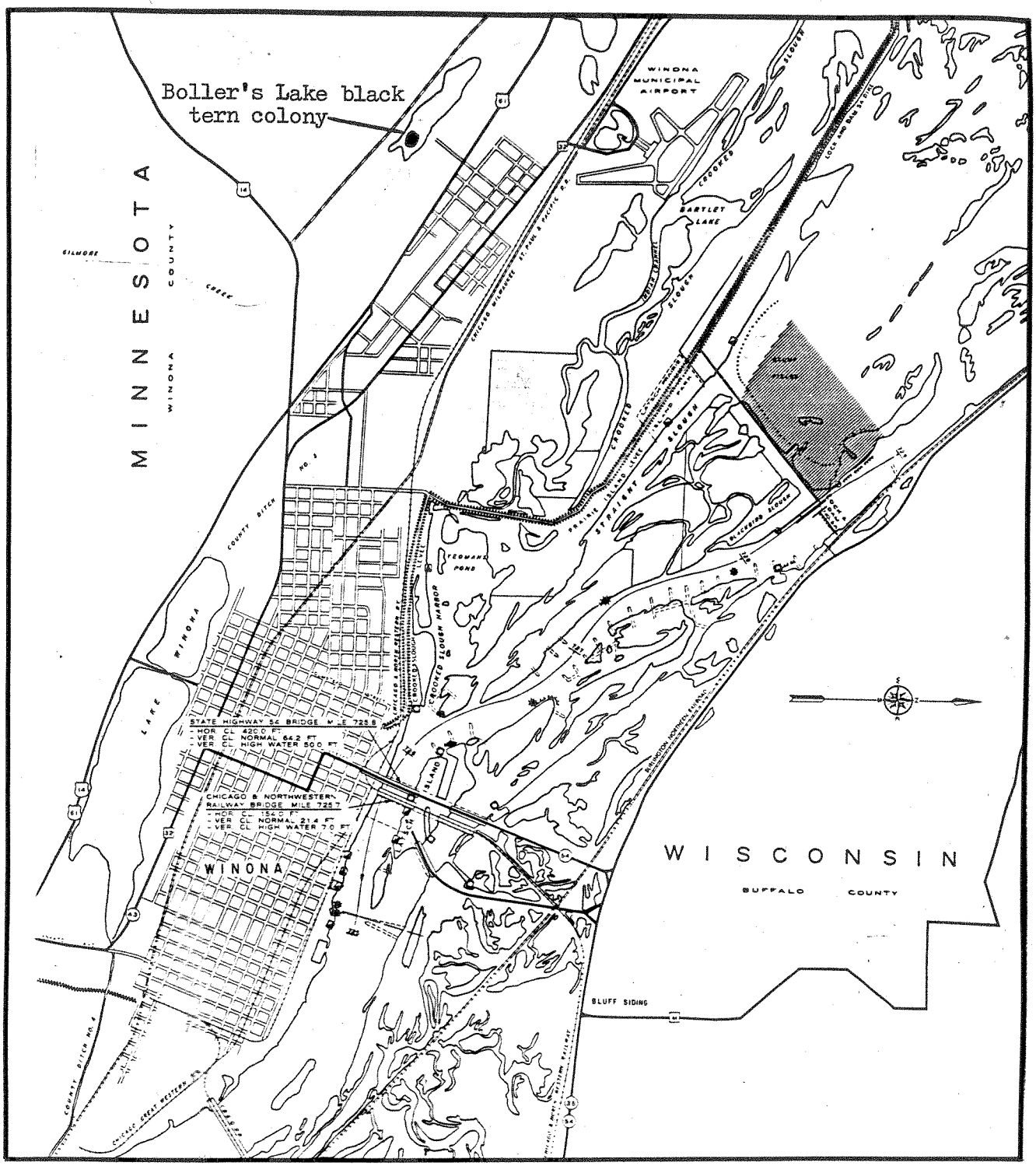

Figure 3. Location of the Boller's Lake black tern colony.

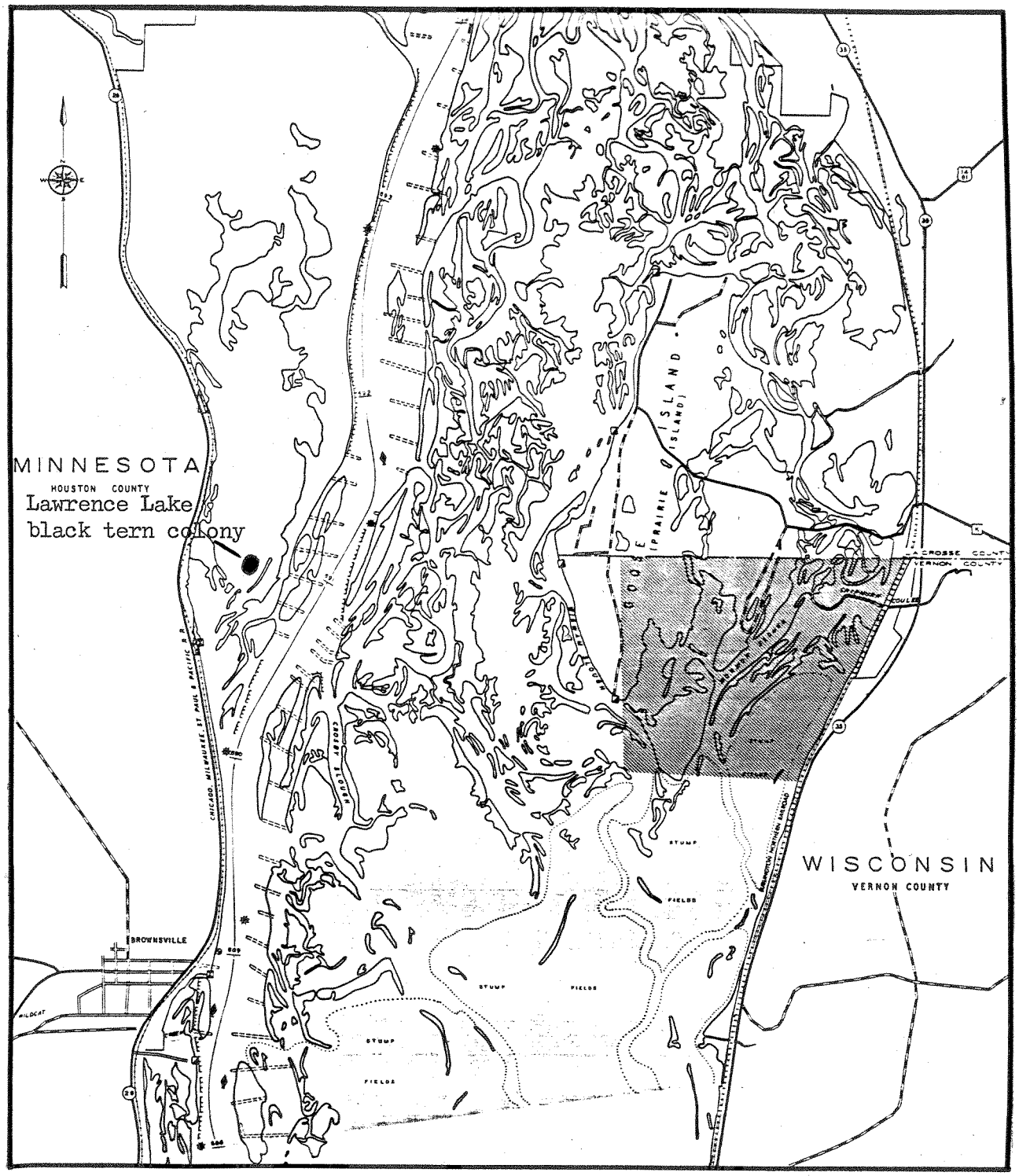

Figure 4. Location of the Lawrence Lake black tern colony.

Table 1. Colony size, mean clutch size, and hatching success for black terns and Forster's terns in 1984 from the Mississippi River in Minnesota.

Colony	number of nests	number of eggs	mean clutch	hatching[a] success	number eggs disappeared
Black terns					
Weaver	12	27	2.25	7/27 26%	20
Winona Pools	5	15	3.00	0/15 0%	15
Boller's Lake	11	29	2.64	6/29 21%	23
Lawrence Lake	3	7	2.33	1/7 14%	6
TOTAL	31	78	2.52	14/78 18%	64
Forster's tern	3	6	2.00	1/6 17%	5

a) hatching succes = no. of chicks/ no, of eggs per cent.

Table 2. Mean clutch sizes reported by other investigators for black terns and Forster's terns.

Study and Year	Mean clutch size	
	Forster's terns	Black terns
Thompson, 1977	2.7	
Bergman et al., 1970	2.5	2.6
Platt, 1979		2.67
Platt, 1980		2.14
Cuthbert, 1954		2.25

(18%) in 1984. Hatching success for Forster's terns in 1984 was 1 chick/ 6 eggs (17%). By comparison, Fox (1976) found a hatching rate of 61% in common terns.

Fencing nests proved to be only partially successful. The 1" poultry wire was too large to hold black tern chicks. On one occasion a chick was observed actually crawling through the mesh. Smaller mesh is needed for this technique to yield better results. By carefully searching through the vegetation surrounding each nest it was possible to locate the chicks that had left the nest and escaped through the fence. Chicks found inside a fence, or close to a nest but outside a fence, were counted as hatched from that nest. There was only a slight difference in mean clutch size and hatching success between fenced and unfenced nests.

The reproductive success of the birds in this study was quite low. Undoubtedly, the fledging rate for the terns in this study was even lower than the hatching rate. It is known for certain that the Forster's terns did not successfully fledge any young; the one chick that did hatch was lost in less than two days from hatching. Several factors contributed to the low reproduction rate.

The Winona Pools black tern colony was abandoned completely. This colony did not display the usual nest building habits. The nests in this colony were built approximately one foot off the surface of the water. This was unlike the other colonies that had wet and floating nests. It is unclear whether this variation in nesting habit contributed to the colony abandonment.

In 1984 the weather had an effect on reproductive success. Unusually heavy rains in June resulted in high water during the critical

nesting period. Nests were observed to be lost due to high, rising water and increased current through some of the colonies. Two of three Forster's tern nests were washed out. When water levels rose almost two feet, the nests became inundated, causing the nest to break apart. The eggs, consequently, were found floating and cold. These nests were abandoned and no attempt at renesting was observed. However, one Forster's tern nest did hatch one chick. In this case, the fence placed around the nest was of benefit. The fence helped prevent the break up of the nest and did not allow the nest to be washed away by the current flowing through the colony.

Two of the three black tern nests at Lawrence Lake were similarly lost to high water and current. Five of seven eggs were thus lost. One of the remaining two eggs hatched; the fate of the other egg is uncertain.

The Weaver and Boller's Lake colonies suffered egg loss also. Twenty of 27 eggs at Weaver and 23 of 29 eggs at Boller's Lake did not produce chicks. Those eggs that did not hatch disappeared previous to hatching. Much of this loss was observed after heavy storm activity.

Predation may also account for some of the egg loss. Though no direct predation was observed, indirect evidence of predation was present. One Forster's tern egg was found about 10 feet off the nest and had been cracked open by some means. A water snake (Natrix sipedon) was observed in the Winona Pools colony, and other snakes could have been present in the other colonies as well. Crows (Corvus brachyrhynchos) were seen in the vicinity of all the colonies, and great horned owls (Bubo virginianus) are abundant in the area. Other predators may have been present and may account for some of the egg loss.

Observer interference is always a possibility in any nesting study.

However, the terns in this study always readily returned to the nest once the observer had moved away. Similarly, the fences placed around nests did not appear to cause a disturbance. Adults returned to the fenced nests soon after the observer moved from the nest.

No one reason can be stated unequivocally to be the cause for the low reproductive rate displayed by the terns in this study. Further study is needed to determine more specifically the reproductive rate of these species and the reasons for that rate.

CONTAMINANTS ANALYSIS

Geometric means (ppb, wet weight) and ranges of PCB's (as Arochlor 1260) and selected organochlorine insecticides in black tern and Forster's tern eggs are found in Table 3.

PCB's had the highest mean concentration of any of the contaminants encountered in this study in both black terns and Forster's terns. Black terns and Forster's terns had geometric mean levels of 92 ppb and 280 ppb, respectively. These levels are much lower than levels reported for black terns in other areas of the midwest.(Table 4). Note that Table 4 presents data in arithmetic means and this report uses geometric means. The levels of PCB's in terns were also lower than levels found in other species (great blue herons (Ardea herodias) and great egrets (Casmerodius albus)) from the upper Mississippi River (Nosek and Faber, 1984). PCB's had the highest mean concentrations of any of the contaminants detected for terns in this study, as well as for black terns in Green Bay (Faber and Hickey, 1973) and for great blue herons and great egrets from the upper Mississippi River (Nosek and Faber, 1984).

p,p' DDE had the second highest mean concentration of the contaminants encountered in this study in both black terns and Forster's terns. Black terns and Forster's terns had geometric mean levels of

Table 3. Geometric means, ppb wet weight, (± standard error) and ranges of organochlorines in black tern eggs (N=12) and Forster's tern eggs (N=3) from the Mississippi River in Minnesota.

Compound	Black terns geo. mean	Black terns range	Forster's terns geo. mean	Forster's terns range
PCB's	92 ± 1.2	37-320	280 ± 1.3	200-480
p,p' DDE	48 ± 1.2	25-220	140 ± 1.4	83-260
p,p' DDT	12 ± 1.2	2.8-34	15 ± 3.9	ND[a] - 71
p,p' DDD	15 ± 1.2	6.8-67	14 ± 3.7	ND-62
Dieldrin	3.1 ± 1.3	1.0-29	2.6 ± 1.7	0.97-6.4
HE & oxy[b]	3.1 ± 1.3	0.89-16	4.3 ± 1.3	3.0-7.7
trans-nonachlor	2.9 ± 1.4	0.18-11	26 ± 1.4	13-42
alpha chlordane	1.8 ± 1.2	0.74-4.6	12 ± 1.6	6.0-31
HCH	0.26 ± 1.1	ND -1.6		ND

a) ND = none detected at a detection limit of approximately 0.03 ppb.
b) Heptachlor epoxide and oxychlordane

Table 4. Mean concentrations of organochlorines in black terns as reported by other investigators.

Compound	Year	mean ppb wet weight	Reference
PCB's	1980	686	Mossman, 1981[a)]
	1970	8660	Faber and Hickey, 1973
p,p' DDE	1980	720	Mossman, 1980
	1970	4890	Faber and Hickey, 1973
Dieldrin	1980	16	Mossman, 1981
	1970	250	Faber and Hickey, 1973
Heptachlor epoxide	1980	14	Mossman, 1981
DDT and TDE	1970	290	Faber and Hickey, 1973
BHC	1970	20	Faber and Hickey, 1973

a) Mossman, 1981. personal communication

48 ppb and 140 ppb, respectively. Again, similar to PCB's, these levels are much less than those reported for terns in other studies,(Table 4), and for other species from the Mississippi River. p,p' DDE was also found to have the second highest mean concentration of contaminants detected in black terns from Green Bay (Faber and Hickey, 1973) and great blue herons and great egrets from the Mississippi River (Nosek and Faber, 1984).

Other members of the DDT family of compounds and metabolites were also detected in this study. p,p' DDT and p,p' DDD were detected (Table 5). p,p' DDD and o,p' DDT were not separated on this column and their levels are reported as a sum, with p,p' DDD comprising almost all of the total.

Dieldrin was found in all the eggs analyzed from both black terns and Forster's terns. Dieldrin was the only compound for which the black terns had a higher geometric mean concentration than the Forster's tern. For all other compounds in this study the Forster's terns had higher concentrations than the black terns.

Alpha chlordane, oxychlordane, and trans-nonachlor are related compounds. They are components of the commercial mix for chlordane or are metabolites of chlordane. In this study, oxychlordane is reported with heptachlor epoxide, since these two compounds were not separated on the column used. Their level is a sum. Heptachlor epoxide is a metabolite of heptachlor. The levels of all these compounds are low when compared to data available for other species of birds from the Mississippi River (Nosek and Faber, 1984).

HCH (also known as BHC) in this report is given as the sum of four isomers of HCH. Alpha HCH, beta HCH, delta HCH, and gamma HCH are

Table 5. Parts per billion (ppb, wet weight) of selected contaminants in eggs from black terns and Forster's terns from the Mississippi River in Minnesota, 1984.

Sample	PCB's A1260	p,p'DDE	p,p'DDT	p,p'DDD	Dieldrin	HE & oxy[a]	trans-nonachlor	HCH	alpha chlordane
Black terns									
03	63	45	13	8.5	2.4	1.1	3.4	ND[b]	2.9
04	180	220	2.8	16	6.6	5.9	11	0.36	0.95
05	260	88	29	46	1.6	5.6	8.7	1.6	4.3
06	320	89	34	32	5.5	3.6	11	0.43	4.1
09	37	32	6.7	7.1	3.6	2.4	2.1	ND	2.2
10	99	26	16	67	2.1	5.2	5.2	0.48	3.1
13	58	34	12	9.9	2.7	2.2	0.18	0.15	0.74
14	78	25	7.8	6.9	1.2	0.89	1.3	ND	0.81
15	170	31	16	12	1.0	1.2	0.95	ND	1.1
16	43	41	19	18	1.8	3.6	4.9	0.14	0.78
17	41	65	7.2	6.8	29	16	3.7	0.50	4.6
18	78	30	15	13	5.5	4.4	2.8	0.08	1.5
Forster's terns									
01	480	260	ND	ND	0.97	7.7	31	ND	31
02	240	83	51	42	6.4	3.0	13	ND	8.6
04	200	120	71	62	2.7	3.5	42	ND	6.0

a) Heptachlor epoxide and oxychlordane
b) ND = none detected at a detection limit of 0.03 ppb.

included. These are components of the commercial mix lindane. HCH was found in 8 of 12 black tern eggs and was not detected in any of the Forster's tern eggs. The presence of HCH in terns suggests that they are exposed to lindane while on their wintering grounds, and carry the HCH burden with them when migrating to their breeding grounds. HCH was found in black terns but not Forster's terns in this study. This could imply that the two species utilize different wintering grounds.

For all compounds in this study the terns contained levels that were much lower than those found by other investigators for the same species. For all compounds in this study, with the exception of dieldrin, the Forster's terns had higher levels of contamination than did the black terns.

The method used for contaminants analysis allowed for the detection of mirex and endrin. Neither of these two compounds were present at detectable levels in black terns or Forster's terns

The level of contamination among black terns is generally lower than that found in other bird species (great blue herons and great egrets) reported for the upper Mississippi River (Nosek and Faber, 1984). And yet we cannot conclude that these species are not affected by the low levels of contamination observed. We know very little about the effects of any of these contaminants on terns. The possibility that they adversely affect nesting behavior remains, since reproduction was so poor in this study.

EGGSHELL THICKNESS INDEX

Eggshell thickness was analyzed by use of the eggshell thickness index defined by Ratcliffe (1970) as follows:

$$\frac{\text{shell weight (g)}}{\text{length (cm) X width (cm)}} \quad \text{X } 10$$

The mean eggshell thickness index for black terns was 0.71 ± 0.01 in 1984. This was not statistically significantly different compared to a pre-1947 mean of 0.69 (Faber and Hickey,1973). The mean thickness index for Forster's terns in 1984 was 0.87.

DDE is often correlated to decreases in eggshell thickness index. Linear regression analysis was used to determine if the level of DDE in the egg was correlated with the calculated eggshell thickness index. In this study no statistically significant correlation was found for either black terns or Forster's terns. Eggshell thinning does not appear to be a significant factor, at least in the black terns that we studied.

SUMMARY

In this study 120 miles of the Mississippi River in Minnesota were surveyed. A total of 31 black tern nests and three Forster's tern nests were located.

Hatching success for black terns in this study was 14 chicks out of 78 eggs (18%). Hatching success for Forster's terns was 1 chick out of 6 eggs (17%). Those eggs that did not hatch were lost from the nests. These hatching rates are very low. This study does not give a definitive answer to why the rate is so low, although weather accounted for loss of at least 4 nests.

The terns in this study had lower levels of contamination when compared to terns from other areas. PCB's had the highest mean concentration of all contaminants detected in black terns (92 ppb) and Forster's terns (280 ppb). This has been the case in terns from other areas and in different species of birds from the upper Mississippi River. In this study, p,p' DDE had the second highest mean concentration of all contaminants detected (48 ppb in black terns and 140 ppb in Forster's terns). All other compounds detected in black terns and Forster's terns in this

study were well below the mean levels of PCB's and DDE.

Black terns did not show a decrease in mean eggshell thickness index as compared to pre-1947 means. Eggshell thinning does not appear to be a problem among black terns in the upper Mississippi River.

Tern reproduction on the upper Mississippi River in Minnesota is very low. Further, more comprehensive, study is needed to determine the reasons for such low reproduction.

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