Feeding Ecology and Nesting Success of Forster's Terns on Lake Osakis, Minnesota

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ABSTRACT

A colony of Forster's Terns (*Sterna forsteri*) nesting on Lake Osakis, Minnesota, was studied in 1992 (132 pairs) and 1993 (158 pairs). Objectives were to: 1) identify the major prey species of the terns, 2) determine whether food availability was limiting, 3) measure reproductive success, and 4) identify the types of disturbances to the colony. Average foraging distance and group sizes were measured by weekly shoreline surveys. Prey identification, size, and feeding rates were measured using half-hour observation blocks, during morning, afternoon, and evening time periods. Average foraging distance from the colony site varied from 1.4 to 3.5 km. The average foraging group size was 2.8 in 1992 and 2.1 in 1993. Courtship feeding rates ranged from 0.53 to 1.32 fish per hour. As chicks aged, feedings rates decreased, and the size of the prey increased significantly. The main prey species were yellow perch, shiners, sunfish, and northern pike. Reproductive success was 0 for 1992 and between 0.126 and 0.323 for 1993. The main disturbances to the colony were boats, Great Blue Herons, a mink, and possibly a Great Horned Owl. Predation pressure rather than food availability appeared to be limiting reproductive success at the Lake Osakis colony. Recommendations include annual monitoring of major regional nesting sites to provide long-term population trends, protection of these sites, and distribution of educational materials to the public, particularly in areas that support a large sport-fishing community and with large, piscivorous, waterbird colonies.

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INTRODUCTION

Forster's Terns *(Sterna forsteri)* are a close relative of Common Terns *(Sterna hirundo)* that have adapted to nesting overwater in salt or freshwater marshes, typically on floating beds of dead cattail *(Typhus spp.)*, or on top of muskrat houses *(Ondatra zibethicus)* (Bergman et al. 1970, McNicholl 1982). Their distribution ranges from California, across most of the prairie pothole regions, including southern Canada with pockets in the Great Lakes region and the southern Atlantic states (Fig. 1). Most birds overwinter in the Gulf of Mexico (Coffin and Pfannmuller 1988).

In Minnesota their range lies mostly in the west to west-central regions (Coffin and Pfannmuller 1988), with 24 historical colony nesting sites (Fig. 1). Within the state, the terns typically nest in wetland types 4 and 5, as classified by Cowardin et al. (1979): wetlands with extensive bed of emergent vegetation and large bodies of open water for foraging (Louis 1989, Cuthbert 1993). As of 1986, slightly fewer than 1,000 breeding pairs nested in Minnesota (Cuthbert 1993). This was believed to be a serious decline in the number of breeding pairs compared to 40 or 50 years ago (Coffin and Pfannmuller 1988). In 1984 Forster's Terns were listed as a "species of special concern" in the state of Minnesota (Coffin and Pfannmuller 1988).

Most of the published literature on the food habits of Forster's Terns simply identifies the bird as being mainly piscivorous, while occasionally taking insects on the wing (Roberts 1932, Bergman et al. 1970, McNicholl 1971). Only Robert's (1932) observations are from within Minnesota. A few studies have also identified the particular type of fish; Roberts (1932) reported two sunfish *(Lepomis spp.)*, and Zuvanich (1963) saw a fathead minnow (*Pimephales* spp.) and a carp (Cyprinus Carpio) near a nest. McNicholl (1971) also cites general observations on their food habits and gives many single reports of the type of fish or insect consumed. Salt and Willard (1971) discuss the foraging behavior within a salt-marsh Forster's Tern colony and report the size range of fish taken (from 1 to 10 cm), but not the types of prey. They found seasonal variation in the mean size of the fish taken (from 146 g in April & May to 65.2 g in June & August).

Very few reports exist on the proximity of the feeding areas to a colony. The most recent report is by Mossman (1989) who states that foraging is often "close" to the colony, but may occur at locations up to 10 km away. Salt and Willard (1971) report the possible effects of increased wave action influencing foraging site selection due to the decreased

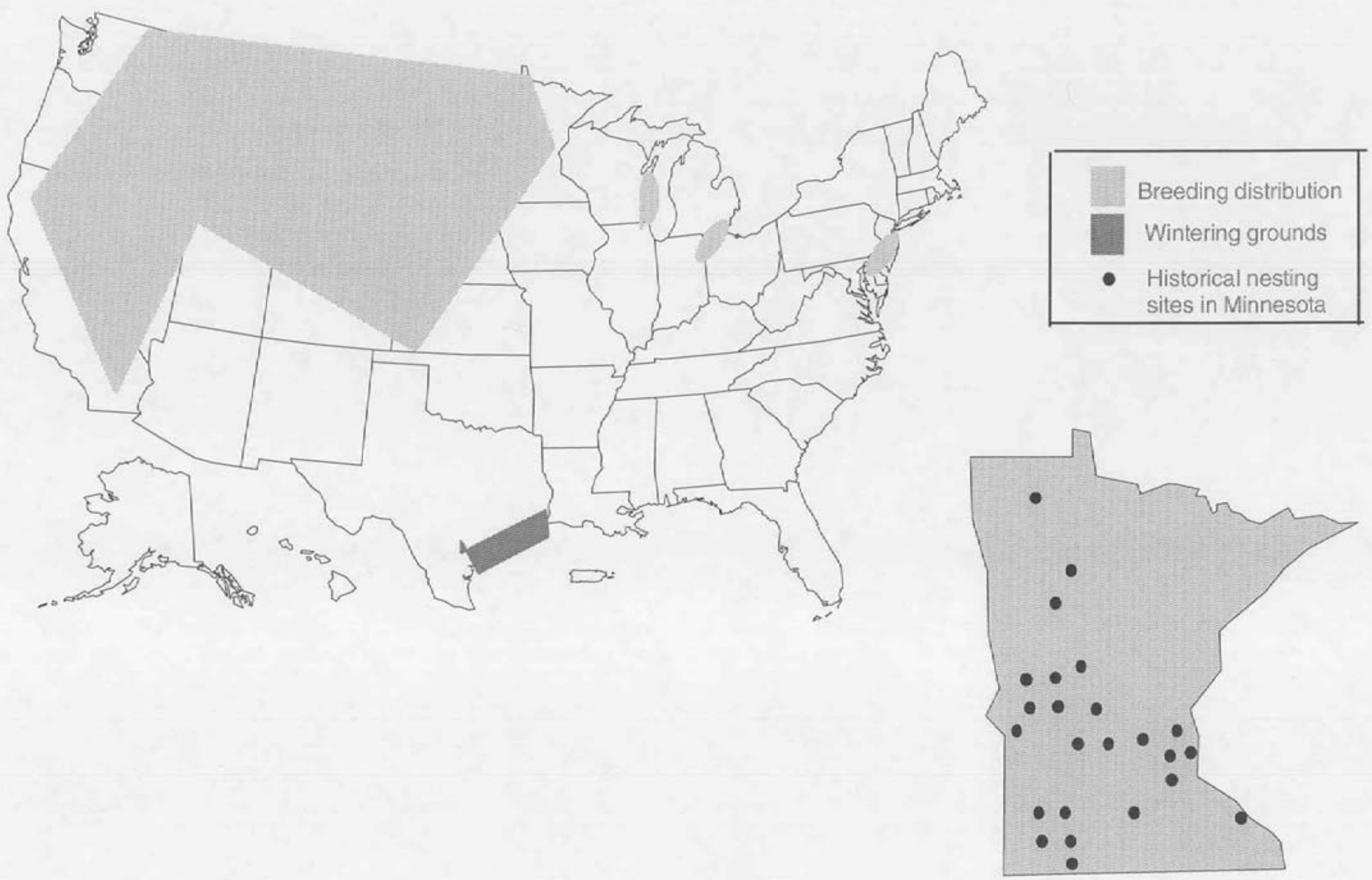

Figure 1. U.S. distribution of the Forster's Tern and historical nesting sites within Minnesota.

visibility of the prey. Data obtained on the proximity of foraging in colonial waterbirds often is site specific and will vary widely, even within a particular location, because prey are often very clumped and unpredictable (Erwin 1978).

Burger (1981) discussed the vulnerability of colonial nesting larid species to disturbances, particularly to human disturbance. She indicates that it can lead to lower reproductive success and even abandonment of the ternery. Although, Bernstein (1990) mentions that Forster's Terns tolerated the activities of an estimated 100 anglers per day on a Wisconsin lake, the effect of such disturbances on the reproductive success of the terns was not measured. Other types of potential disturbances include the typical predators of tern colonies, Great Horned Owl *(Bubo virginianus)*, Great Blue Heron *(Ardea herodias)*, Black-crowned Night Heron *(Nycticorax nicticorax)* and mink *(mustela vison)*.

This report discusses the outcome of a two-year study at an important historical nesting site in Minnesota, the Two-mile Bar colony on Lake Osakis (Coffin and Pfannmuller 1988). Lake Osakis contains one of the largest Forster's Tern colonies in Minnesota; in 1981 and 1983 an estimated 1,000 pairs nested there. The purpose of this study was to look at the feeding and nesting ecology of this species on Lake Osakis. The specific objectives were to identify their prey base and to determine whether food availability appeared to be limiting, to identify the types of disturbances to the colony, and to measure their overall reproductive success.

STUDY AREA

Lake Osakis is a 2,537 hectare lake located in Todd and Douglas Counties. The lake contains 34 kilometers of shoreline, and has extensive emergent beds located primarily along the southwest shore (Fig. 2). A second major emergent bed is located on the opposite shore of the lake. For both years of the study the terns nested within cattail beds on the tip of Two-Mile Bar, on the southwest shore. This site is also a historical nesting grounds for Western Grebes *(Aechmophorus occidentalis)* (Coffin and Pfannmuller 1988), and in 1993

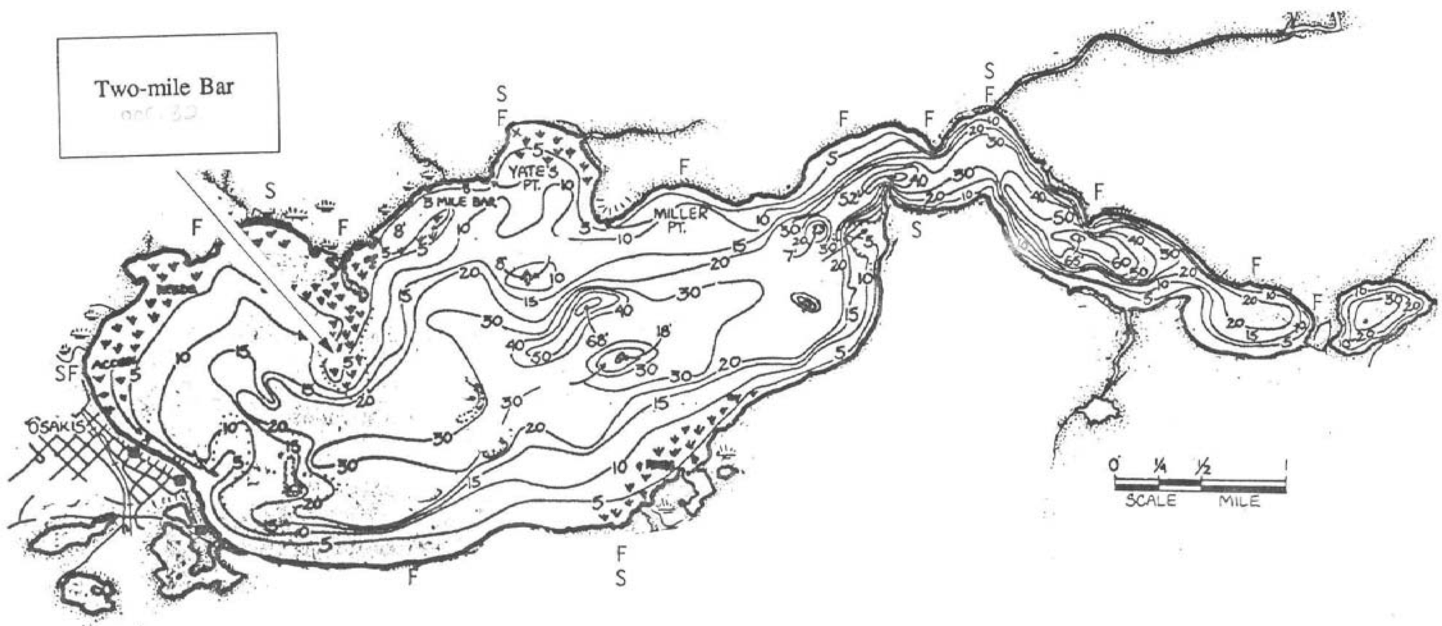

Figure 2. The study site, Lake Osakis, is located in Todd and Douglas counties. Two-mile Bar colony is on the southwest shore of the lake.

F-Foraging survey access points.
S-Seining sites.

approximately 400 western grebe nests were there interspersed among the tern nests. In 1992 Western Grebes nested further south in Pederson Bay rather than within these beds (G. Nuechterlein pers. comm.).

MAJOR OBJECTIVES AND METHODS

Objective 1: To identify the main feeding areas of Forster's Terns on Lake Osakis, Minnesota.

Methods:

(a) Foraging surveys were conducted during fair weather (e.g. not raining), during peak colony activity periods, at approximately weekly intervals by car. Thirteen observation sites, distributed at access points around the lake (Fig. 2) were established to look for foraging terns. At each site I would scan for foraging birds, wait 1-2 minutes and scan again. Terns were sighted using binoculars or a spotting scope and an effort was made not to count foraging birds more than once. Terns were assumed to be foraging if they were hovering or flying with their bill pointed downward (Salt and Willard 1971). Four foraging surveys were conducted in 1992 and eleven surveys in 1993. Only one colony of Forster's Terns was established on the lake for both 1992 and 1993, so it was assumed that any tern sighted foraging on the lake was from the Two-mile Bar colony. For each sighting the number of terns and the distance from the colony was recorded.

I used the Mann-Whitney Sum Ranks test to examine whether a difference in foraging distance and foraging group size existed between years and to also compare courtship to chick feedings in distances and group sizes within 1993.

Objective 2: To examine seasonal fluctuations in the availability of major prey species.

Methods:

(a) Seining sites were established in areas accessible by car, where Forster's Terns were seen foraging. I completed 3 seining surveys in 1992 and 4 seining surveys in 1993. The sites were identical from year to year, except that I reduced the number of sites sampled by 2 in 1993.

Objective 3: To determine the feeding rates and prey taken by Forster's Terns during two critical periods: feeding of mates prior to and during egg formation and feeding of chicks at various stages of development.

Methods:

(a) To prevent disturbances to the colony, a kayak was used to provide a silent approach to the area. I conducted behavioral observations using a floating muskrat house blind (Nuechterlein 1975). The mobile blind allowed me to approach courting or nesting birds to within several meters. The blind was anchored approximately 75 meters away from the colony. I then slowly approached the colony in the blind. The Forster's Terns showed no fear of the blind and would frequently land on top of it to engage in courtship displays.

(b) Prey brought to mates or chicks were identified and the approximate size (relative to bill length) was estimated using binoculars, 35mm camera, or video camera. Prior to the first field season, I practiced estimating fish sizes by conducting trial runs, using fish held in a tweezers on which was marked the average size of a tern bill (3.75 cm, Palmer 1962). In this way I also obtained percent error on size estimations. When possible, prey were identified to species (family for minnows and sunfish). For prey the identification summaries, I included only prey items that were viewed well, so that the unknown category would be exclusive of the other species listed.

(c) Feeding rates to mates and chicks were determined using 30-minute focal-bird sampling techniques (Altmann 1974) within the colony. The close proximity of nests allowed 3-4 pairs to be followed simultaneously. I divided the day into three 5-hour periods (5:30-10:30, 10:30-3:30, 3:30-8:30) and attempted to distribute observations equally among them (weather and other uncontrollable events permitting). The time period for observing each marked family was alternated, so in a 3-day period every family was watched in each time period.

I also obtained courtship feeding rates from randomly chosen, unmarked pairs. Prior to conducting an observation I would note whether the pair had eggs (was incubating). Because these were random observations of unmarked birds I had no way of knowing their nesting stage, and in the analysis observations for courtship feeding rates were divided into pairs with eggs and without eggs. Because Forster's Terns often begin incubation with the first egg, some pairs may still have been in the process of laying.

To minimize disturbances to the colony I measured chick feeding rates (as opposed to chick weights) and the size, and species of the prey offered to chicks. At hatching, the colony size had decreased enough to allow me to follow all tern pairs with chicks, so chick data includes nearly all broods hatched during the study period.

(d) Feeding data were collected from half-hour sampling periods. Rates are expressed on an hourly basis. To detect whether a difference in feeding rates occurred during the day, I compared each observation period (morning, afternoon, and evening), with and without eggs, using Kruskal-Wallis One-Way Anovas. Within each observation period, I compared courtship feeding rates with eggs to those without eggs, using the MannWhitney Ranks Sum Test.

I compared chick feeding rates with chick age (weeks 1, 2 and 3) using Wilcoxon Rank Sums; for the fish size with chick age I used Duncan's multiple range test and Kruskal-Wallis One-Way Anova.

(e) To examine size selection of yellow perch in 1993, I compared size of yellow perch from the seines to that of the prey being offered in both courtship and chicks feedings. Size frequencies of yellow perch in courtship feedings were compared to data from a seining bout conducted on June 3 using MannWhitney Ranks Sum Test.

Similarly, size frequencies of yellow perch in chick feedings were compared to data from two seining surveys, conducted on June 20th and July 1st. Using a proportions test (with Yates correction), I also compared the proportion of yellow perch seined to the proportion of yellow perch offered to chicks, at weekly intervals for the month of July.

Objective 4: To determine colony size, hatching dates, nesting success, and major sources of natural and human disturbances to the colony.

Methods:

(a) In 1992 I determined the colony size by one overall colony check, using a visual estimate from the blind during mid-incubation stage. In 1993 I conducted four (approximately every two weeks, starting in June) overall visual estimates of the whole colony. I measured nest success as the number of young hatched per adult pair and reproductive success as the number of chicks fledged per adult pair (158 adult pairs for 1993). To determine the nesting chronology for each year, I counted the number of pairs at each nesting stage in a given 10-day period obtained from my data sheets.

(b) A colony disturbance was defined as 15 or more birds in the air giving alarm calls. I recorded the time of day and duration of all colony disturbances occurring while conducting observations in the colony. When possible, the source of the disturbance was identified.

RESULTS

Objective 1: Foraging areas

In 1992, Forster's Terns on Lake Osakis foraged an average distance of 1.4 + 0.2 km (n=69) from the colony site. In 1993 the terns traveled significantly (U=5667, p=0.001) farther (x=3.6 ± 0.2, n=325) to forage than in 1992 (Fig. 3). The distance traveled ranged from 0.5 to 11.0 km. No difference existed, in 1993, for the foraging distance (U=7984, p=0.333) or group size (U=996, p=0.094) between the courtship feeding period and chick feeding period. They appeared to utilize most of the available shoreline, but foraged more in vegetated areas. I saw no difference (U=2217, p=0.851) in foraging group size between the two years, in 1992 the average group size was 2.88 ± 0.70 (n=24) whereas in 1993 the group size was 2.1 ± 0.19 (n=156) (Fig. 4). The group size ranged from 1 to 20 during the established foraging surveys. In general, terns would plunge dive in shallow waters within 5 to 20 m from shore. I would frequently observe foraging terns cruising up and down the shoreline flying and hovering about 8 meters high above the water. On four occasions, (while kayaking across the lake), I observed Forster's Terns surface-skimming in group sizes ranging from 4 to 40. They appeared to be feeding on emerging cadisflies (Tricoptera).

Objective 2: Prey availability

Tables 1 and 2 list the species and numbers of fish captured by seining in 1992 and 1993. No yellow perch were caught while seining in 1992, whereas yellow perch comprised of 40% to 87% of the fish in

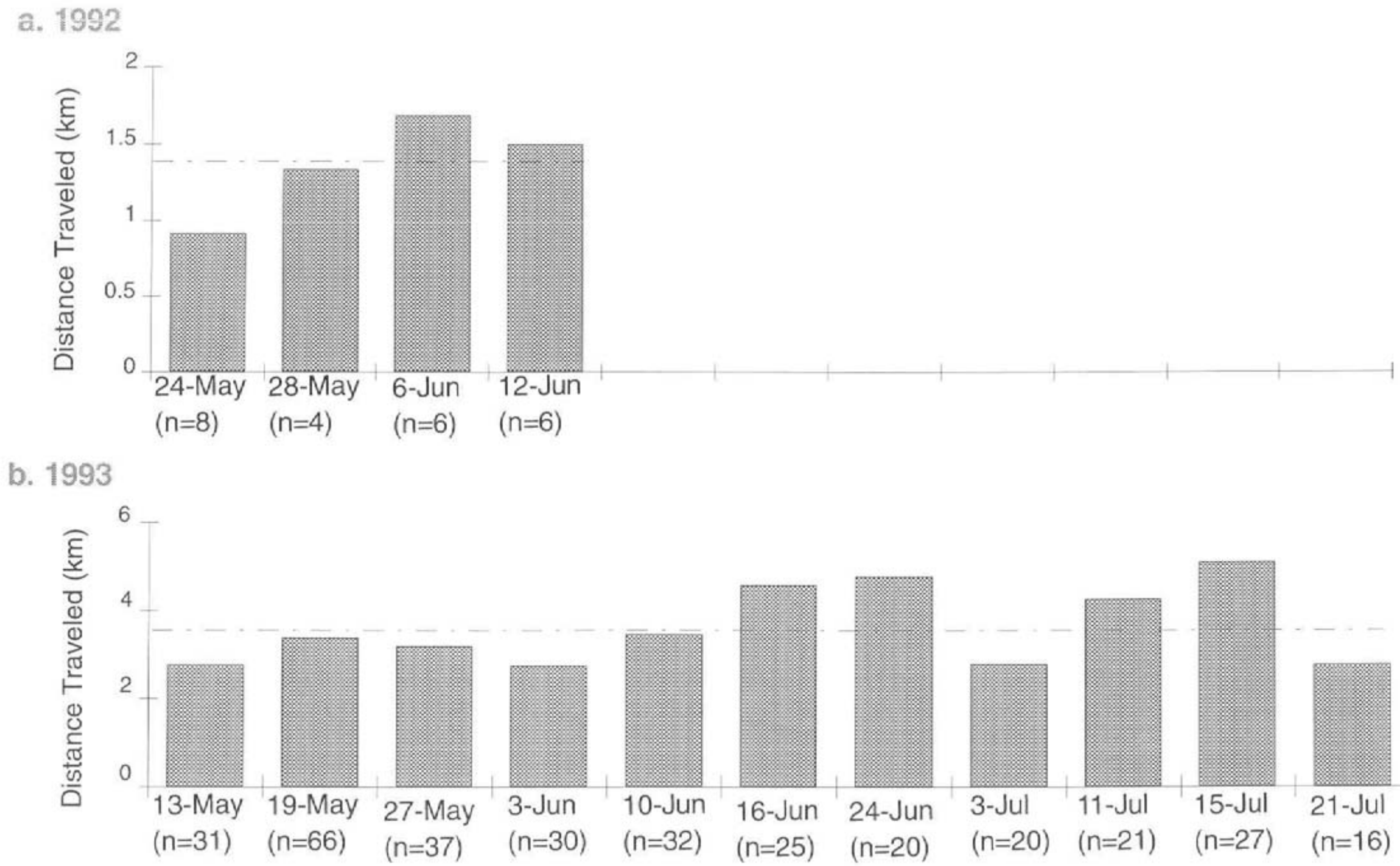

Figure 3. Average foraging distance (km) for the Two-mile Bar colony site for 1992 (a) and 1993 (b).

Foraging distances were recorded at weekly intervals during the period of colony activity. The 1992 colony failed on 15 June. Dashed line signifies overall average. There was a significant difference (T=5667, p=0.001) in the mean distance traveled between the two years.

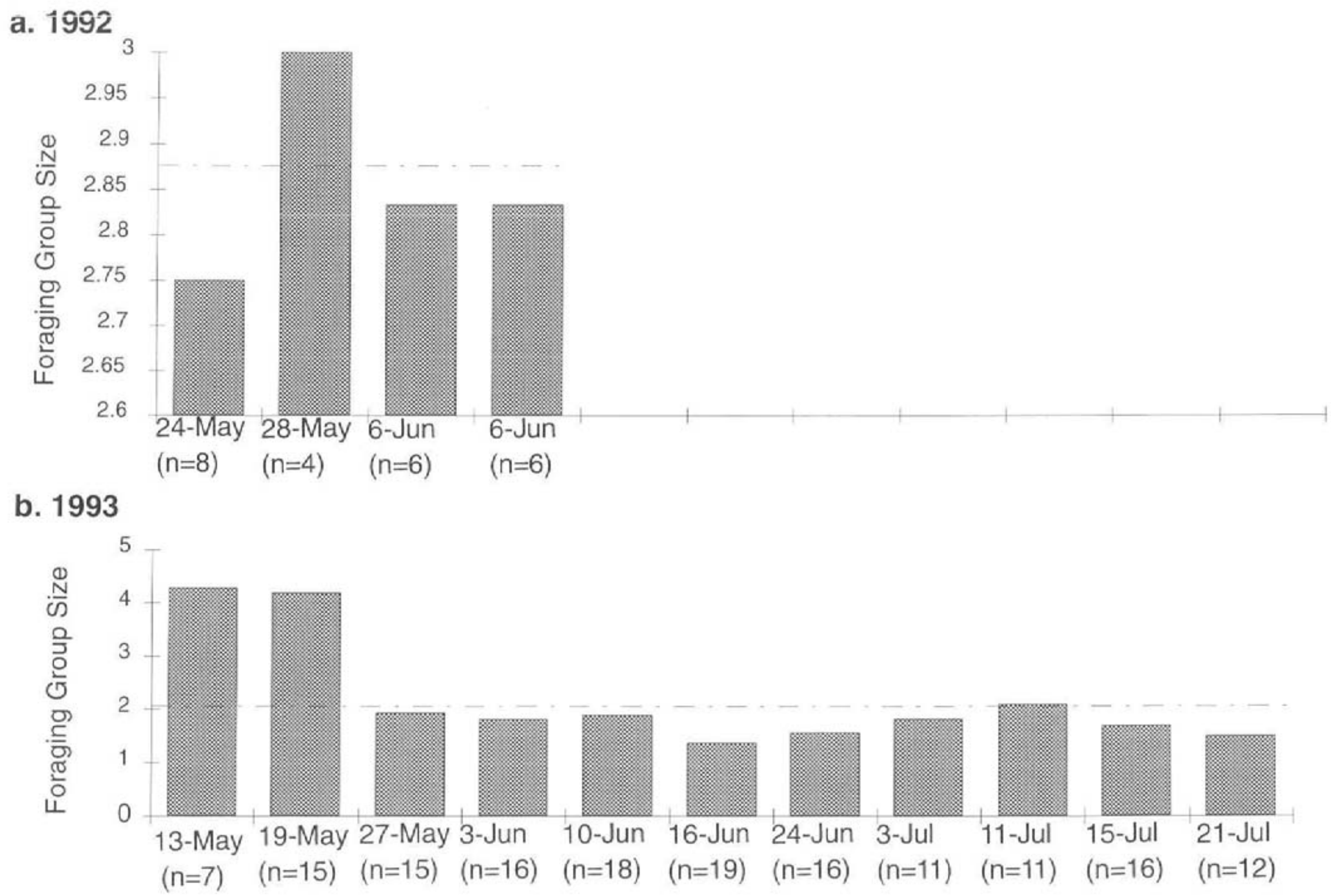

Figure 4. Average weekly foraging group size for 1992(a) and 1993 (b), recorded at weekly intervals.

No significant difference (T=2217, p=0.851) was found between the two years.

Table 1. Summary of seining data for 1992.

Date	Species	# of each species	# sites sampled
6/5	spottail shiners bluegill sunfish *(Lepomis macorchirus)* smallmouth bass *(Micropterus dolomieui)*	15 1 1	6
6/12	spottail shiner bluegill sunfish	60 2	6

Table 2. Summary of seining data for 1993.

Date	Species	# of each species	# sites sampled
6/3	yellow perch	40	1
	spottail shiner		
		36	
6/20	yellow perch	25	1
	northern pike	3	
7/1	yellow perch	45	3
	spottail shiner	3	
	killifish	3	
	bluegill sunfish	6	
	northern pike	1	
	johnny darter	1	
	(Etheostoma nigrum)		
7/10	yellow perch	128	4
	spottail shiner	37	
	stickleback	17	
	blackchin shiner	3	
	(Notropis heterodon)	4	
	bluegill sunfish		
/7/16	yellow perch	828	4
	spottail shiner	209	
	blackchin shiner	12	
	fathead minnow	7	
	killifish	2	
	walleye	1	
7/22	yellow perch	171	4
	spottail shiner	50	
	stickleback	2	
	(Gasterosteidae)	6	
	fathead minnow	1	
	walleye	4	
	largemouth bass		

seine samples obtained in 1993. Thus, yellow perch appeared to be the most abundant fish available for the terns in 1993. Fewer seines were conducted in 1992 because of the colony abandonment in June (see below).

Objective 3: Feeding rates

Courtship

In 1992, courtship feeding rates prior to egg laying, ranged from 0.53 fish per hour to 0.80 fish per hour (Fig. 5a). I observed an overall decline in feeding rates when the eggs were present, but this decline was statistically significant ($U=3532$, $p=0.039$) only for the evening time period.

The 1993 courtship feeding rates were slightly higher ranging from 0.99 to 1.32 fish per hour (Fig. 5b). Again, I saw an overall decline for those pairs with eggs. This decline in feeding rates was significant for the afternoon ($U=4540$, $p=0.008$) and evening ($U=2055$, $p=0.034$) time periods.

Average prey size for courtship feedings were similar for both years, $x=5.86 \pm 0.623$ cm for 1992 and $x=5.08 + 0.277$ cm for 1993 (Fig. 6).

I observed no differences in courtship feeding rates between the three main observation periods, morning, afternoon and evening. This was tested for pairs with and without eggs in both 1992 (with eggs $H = 2.67$, $df = 2$, $p = 0.263$, without eggs $H = 5.36$, $df = 2$, $p = 0.07$) and 1993 (with eggs $H = 1.067$, $df = 2$, $p = 0.301$; without eggs $H = 2.400$, $df = 2$, $p = 0.586$).

The main species of fish identified in courtship feedings, in 1992, were sunfish (Centrarchids), shiners *(Notropis spp.)*, yellow perch *(Perca flavescens)* and northern *pike (Esox masquinongy)* (Fig. 7a). In 1993 the primary species of fish brought in were yellow perch and shiners (mostly *Notropis hudsonius)* (Fig. 7b). I observed only one

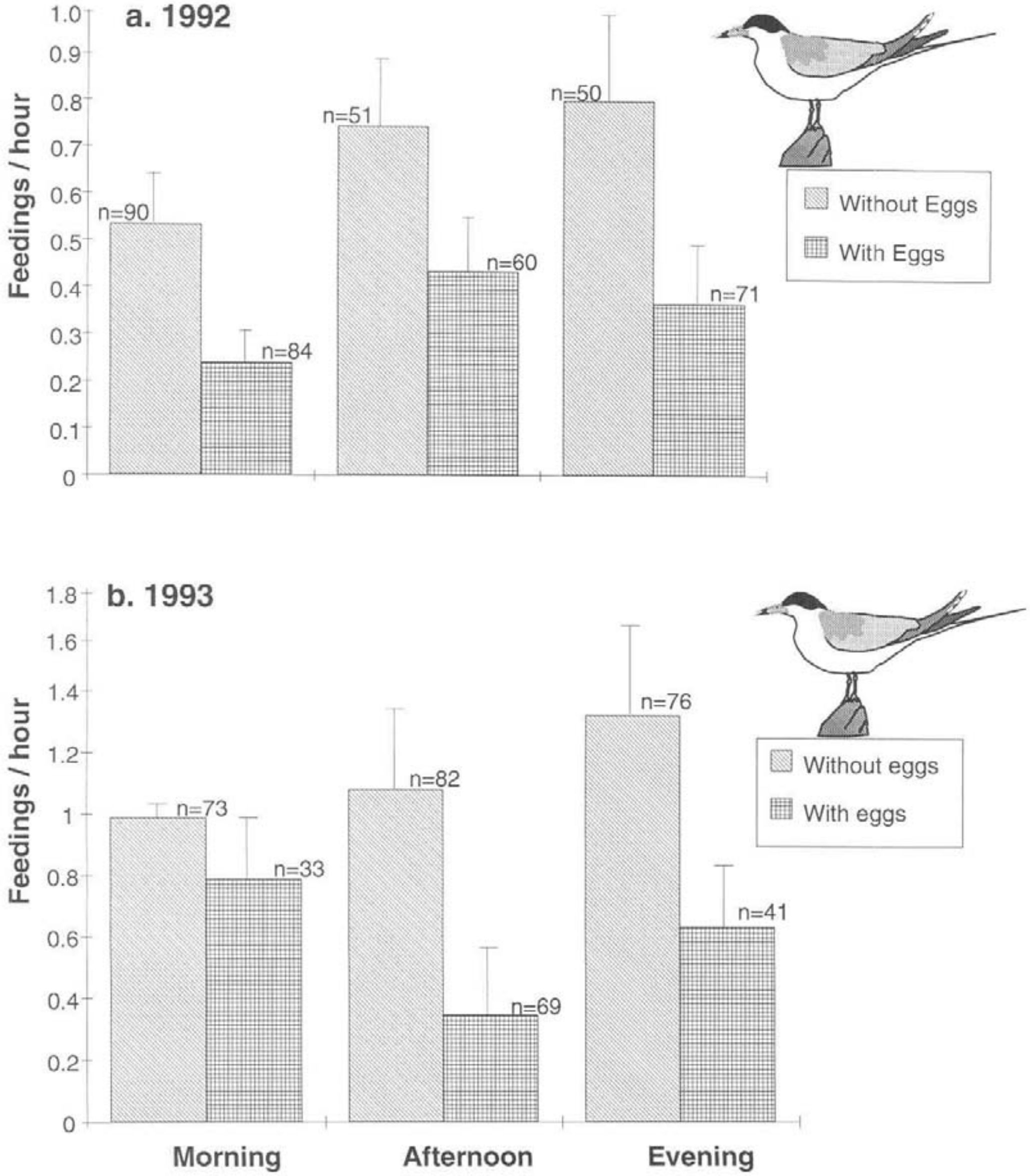

Figure 5. Courtship feeding rates (+/- 2SE) for 1992 (a) and 1993 (b).

The decline in feeding rates for pairs with eggs was significant ($p<0.05$) for afternoons in 1992, and afternoons and evenings in 1993.

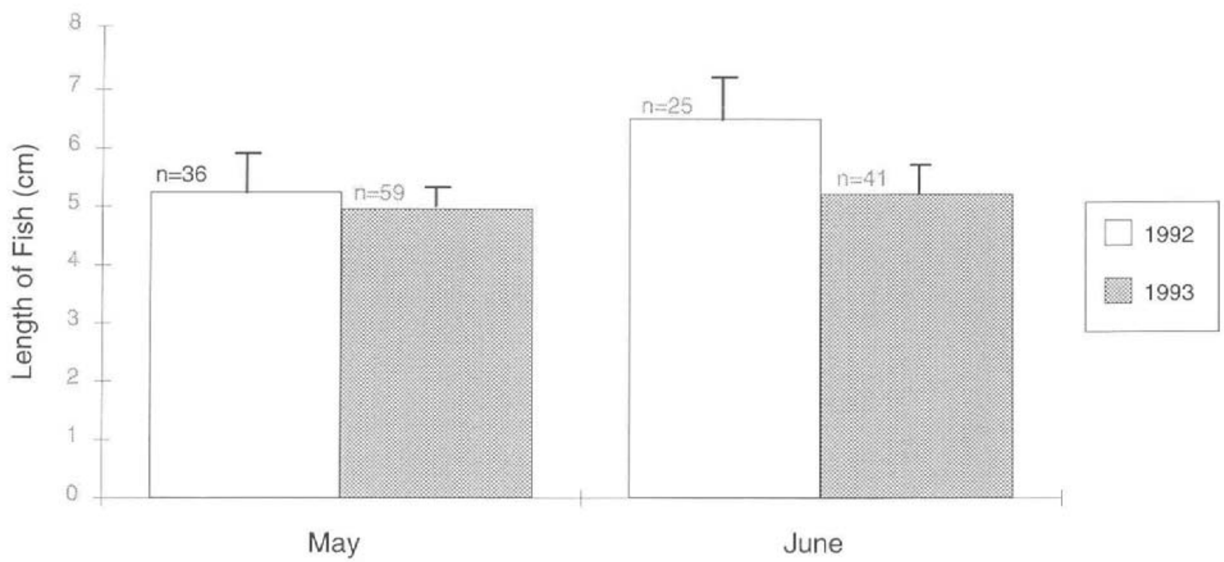

Figure 6. Average fish size (+/- SE) of courtship feedings for 1992 and 1993.

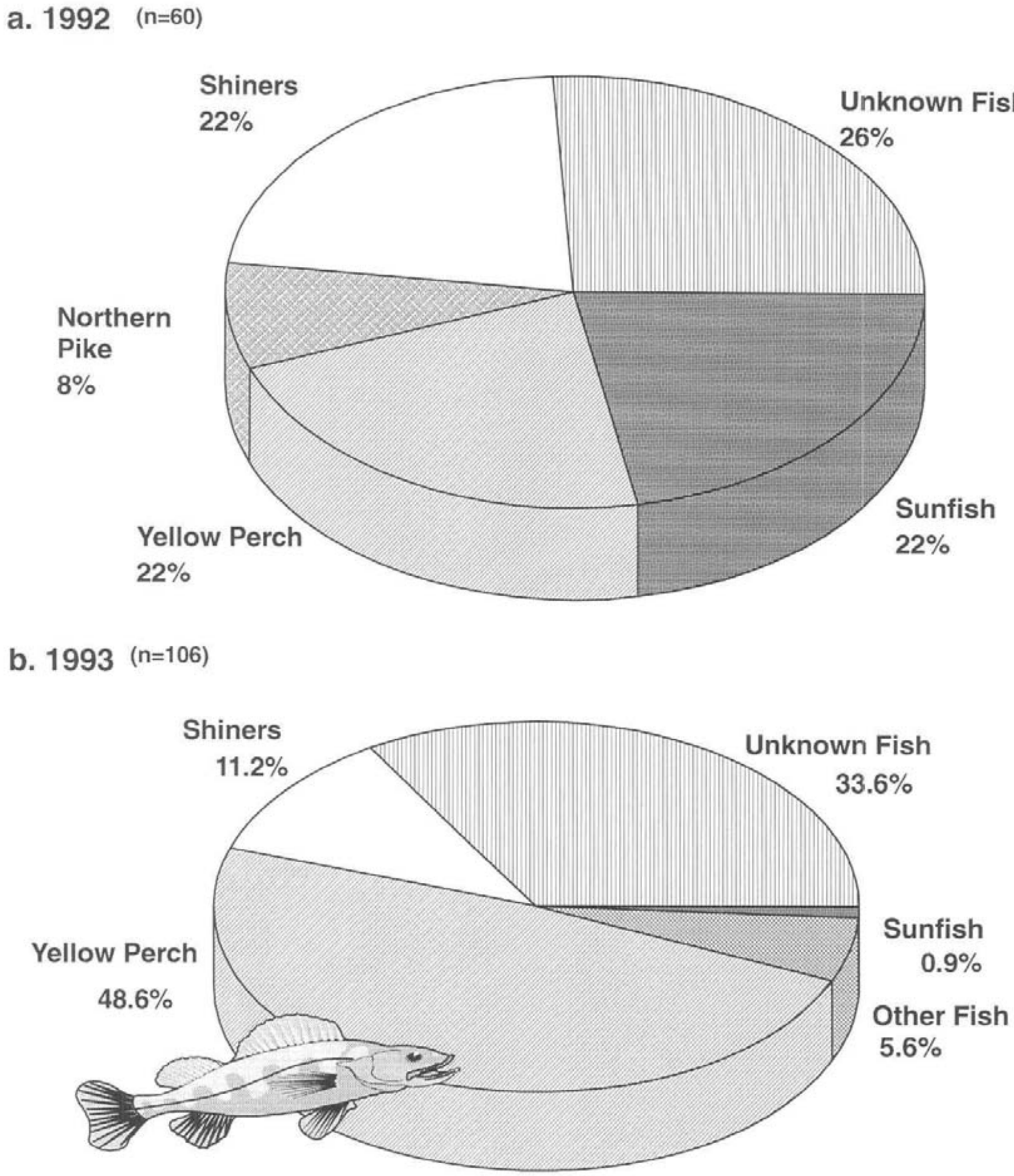

Figure 7. Species of fish observed in courtship feedings in 1992 (a) and 1993 (b).

The "other" fish category includes, 3 banded killifish (*Fundulus diaphanus*), 3 stickleback (Gasterosteidae), and 1 mudminnow (*Umbra limi*). All of the fish identified to species in the shiners category were spottail shiners.

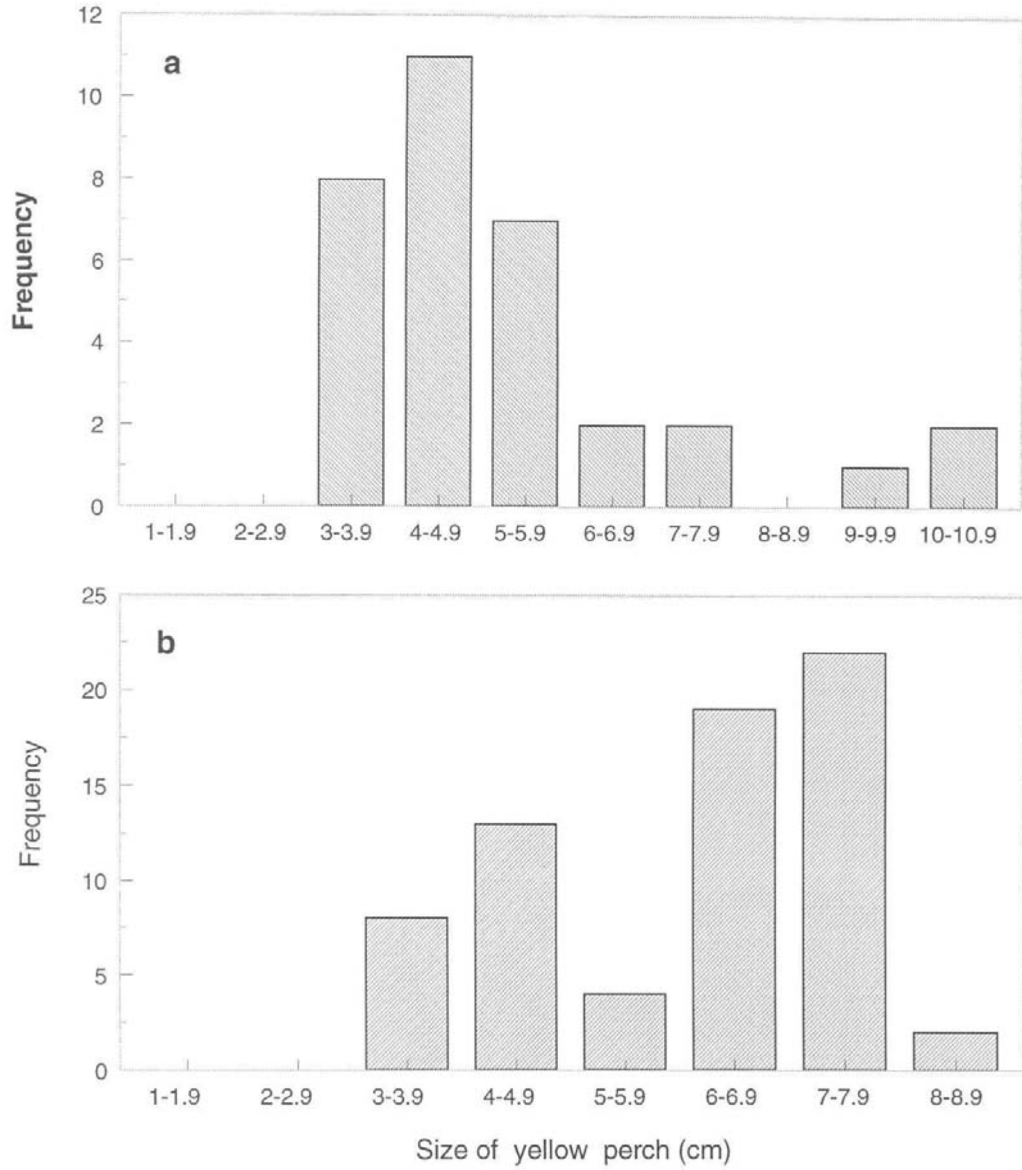

Figure 8. Size frequencies of yellow perch in courtship feedings (a) and seines (b).

Data for the seine are from 1 June 1993. The yellow perch size frequencies for courtship feedings are from +/- a week from 1 June 1993. There was no difference (U=998 P=0.296) between the two groups.

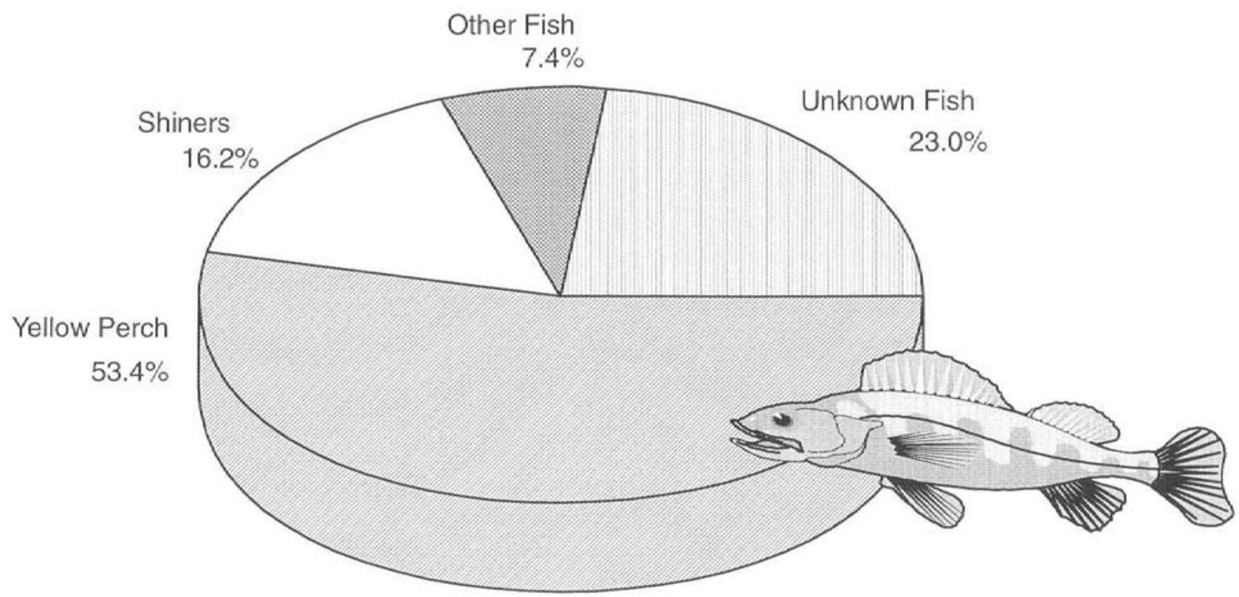

Figure 9. Species of fish offered to chicks (n=148).

The "other" category includes 1 northern pike, 8 sticklebacks, 1 fathead minnow and 1 johnny darter (*Etheostoma nigrum*).

insect, a June bug (Phyllophaga), being offered in a courtship feeding in 1992.

In 1993, yellow perch were the most abundant species seined (Table 2) and the most frequently observed species offered in courtship feedings. I found no significant difference ($U=998$, $P=0.296$) between the yellow perch size frequencies observed in courtship compared to the size of yellow perch seined (Fig. 8).

Chicks

The types of fish offered to chicks in 1993 (no chicks were hatched in 1992) were similar to those offered in courtship (Fig. 9). I observed one insect being offered to a chick, a dragonfly (Anisoptera), but it was rejected by the chick.The rate at which. chicks were fed decreased (CHISQ = 9.72, df = 2, $p < 0.05$) as the chicks got older (Fig. 10). Chicks were fed between 1.38 to 2.20 fish per hour.

The size of the prey brought in significantly increased (df = 144, $p < 0.05$) as the chicks aged (Fig. 11a). This was found to be true of yellow perch prey size as well ($F = 5.65$, df = 2, $p < 0.05$) (Fig. 11b). I found no significant difference ($U = 2133$, $p = 0.11$) between the size frequency of the yellow perch seined compared to the yellow perch size frequency offered to chicks (Fig. 12). For 3 out of the 4 weeks of July, terns captured a significantly greater proportion of yellow perch than was expected (week 1: $z = 2.87$, $p = 0.004$; week 2: $z = 2.88$, $p = 0.004$; week 3: $z = 2.29$, $p = 0.022$; week 4: $z = 0.281$, $p = 0.779$) (Fig. 13).

Objective 4: Nest success

In 1992, I estimated that 132 pairs of Forster's Terns nested at Lake Osakis. Nest initiation within the colony in 1992 was relatively synchronous (Fig. 14). This colony was abandoned during mid-incubation, and I observed very little renesting.

In 1993 I estimated that 189 nests were initiated. Due to the intermittent severe weather in 1993 many nests were lost (approximately 140) consequently, many terns renested throughout the early part of the season (through mid-June). The maximum number of pairs of terns nesting at Osakis at any given time was 158 (counted on 6/18). For 1993, 45 nests hatched 105 chicks (for hatching dates, see Table 3). Approximately 33 chicks were lost to weather and or exposure. One section had twelve chicks which disappeared overnight, which is indicative of Great Horned Owl predation (Nisbet 1975, Nisbet and Welton 1984). At the end of July, a mink entered into the colony (for further description see below) and dispersed the chicks, so I was unable to calculate an absolute nesting and fledging success. Instead I used a range, the minimum being those chicks that I know fledged, assuming that chicks under two weeks of age did not survive (however, see Burness and Morris 1993). The maximum includes chicks two weeks old and younger. Of the 98 chicks, a minimum of 20 chicks and a maximum of 51 chicks fledged. The reproductive success for 1993 was 0.126 to 0.323. The colony was less synchronous in their breeding cycle than what I observed in 1992 and individual sections appeared to be more synchronous than the colony as a whole (see Table 3).

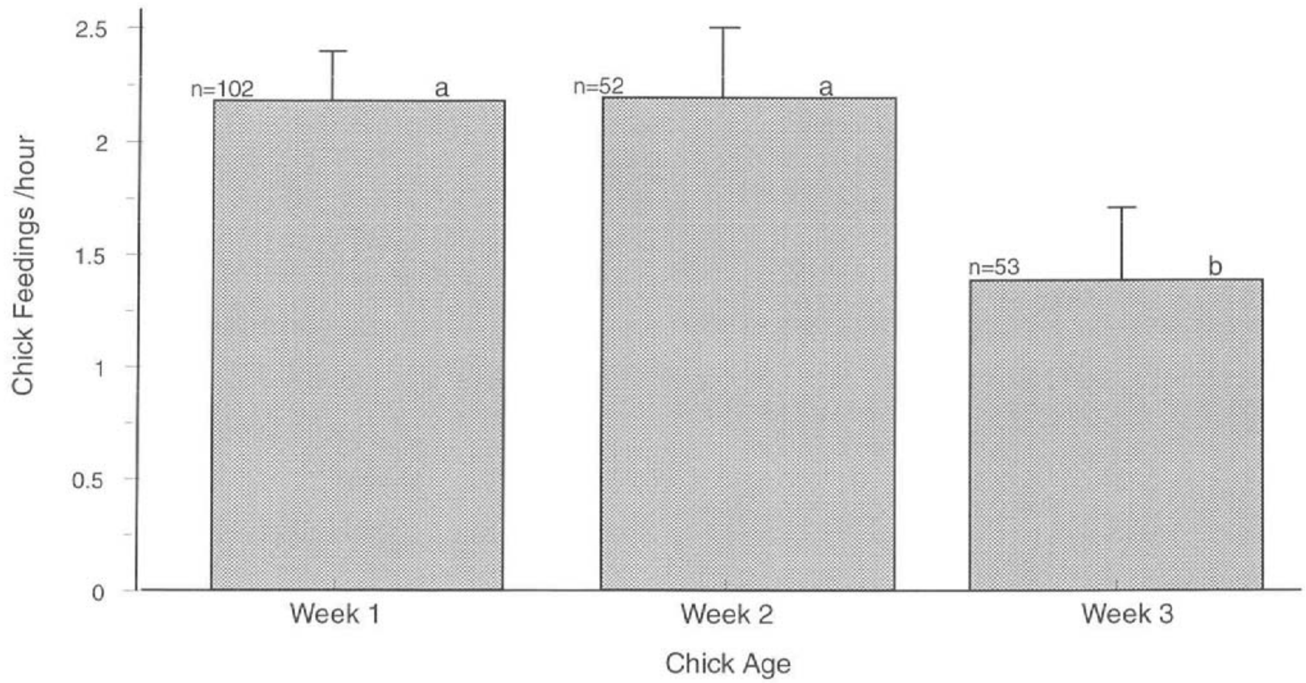

Figure 10. Mean chick feeding rates (+/- 2 SE).

The data from week 1 are from 18 families, and weeks 2 and 3 are from 15 families. Mean feeding rates with different letters are significantly different (CHISQ=9.72, df=2, p=0.008).

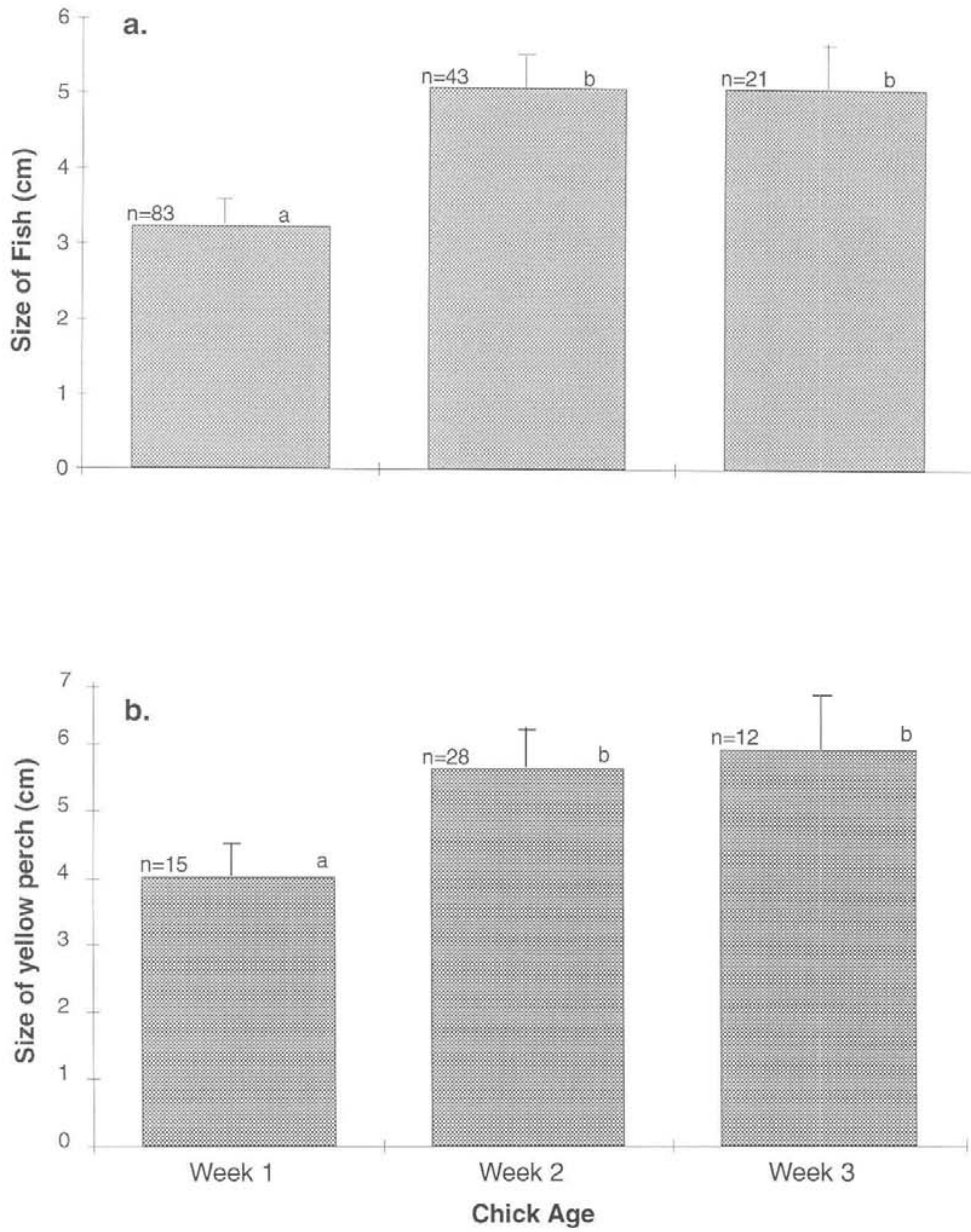

Figure 11. Sizes of (a) all fish and (b) yellow perch brought to chicks at 1,2, and 3 weeks of age.

Ages with different letters are significantly different ($p<0.05$) in size.

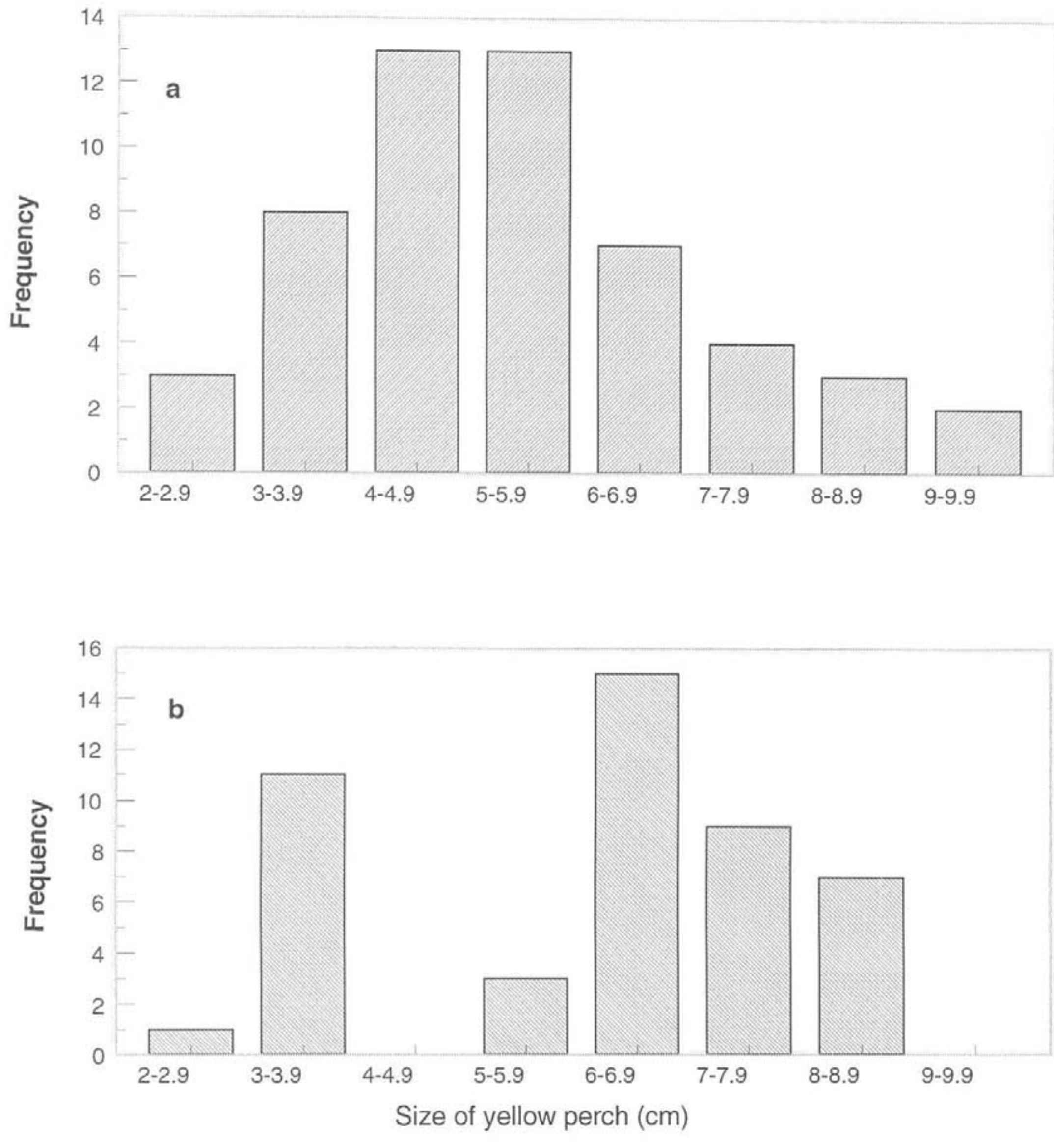

Figure 12. Size frequencies of yellow perch from chick feedings (a) and seines (b).

Seine data are from two seining bouts, one on 20 June and one from 1 July 1993. Chick data are from the month of July 1993. No significant (U=2133, P=0.109) was found between the two groups.

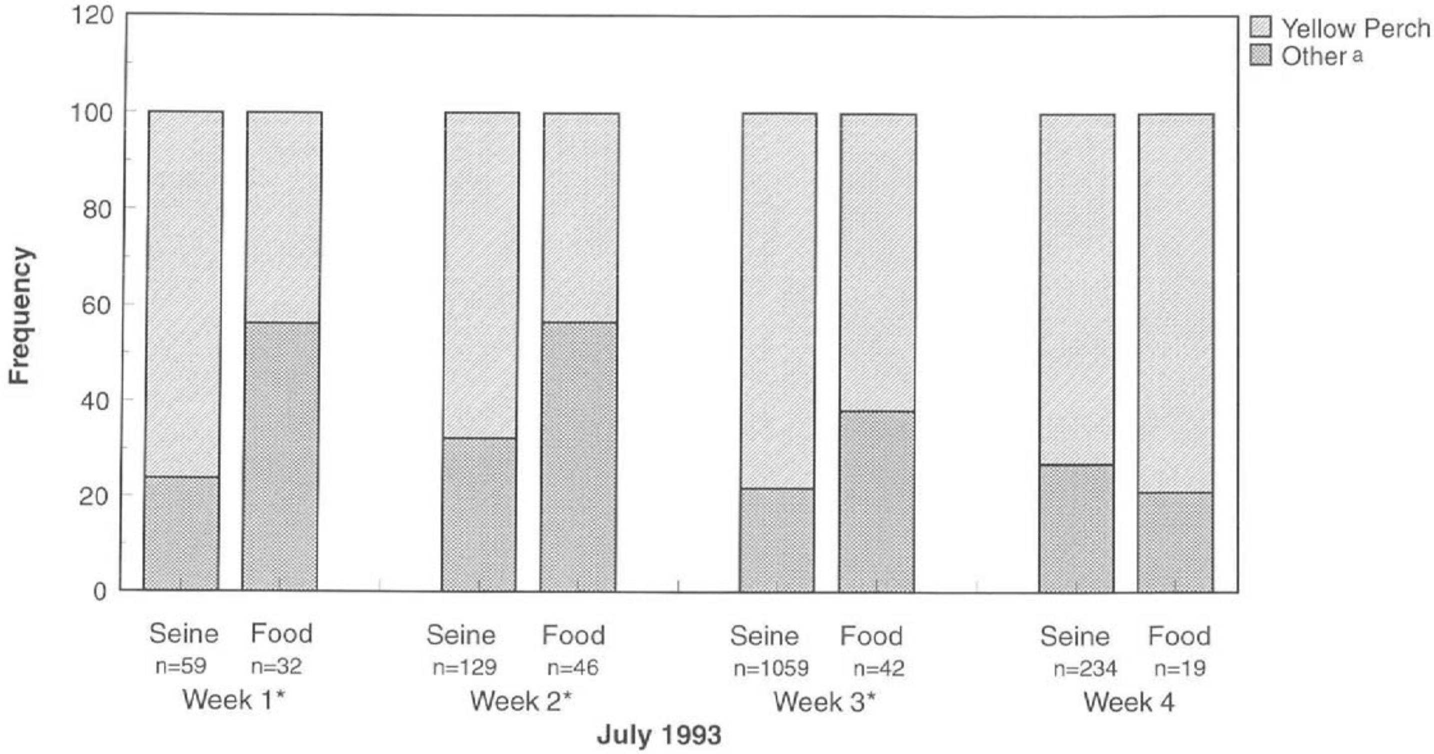

Figure 13. A comparison of prey seined versus the prey captured by Forster's Terns.

[a] For a list of "other " fish species see Fig. 8 and Table 3. * significantly different ($p<0.05$) proportions within each week.

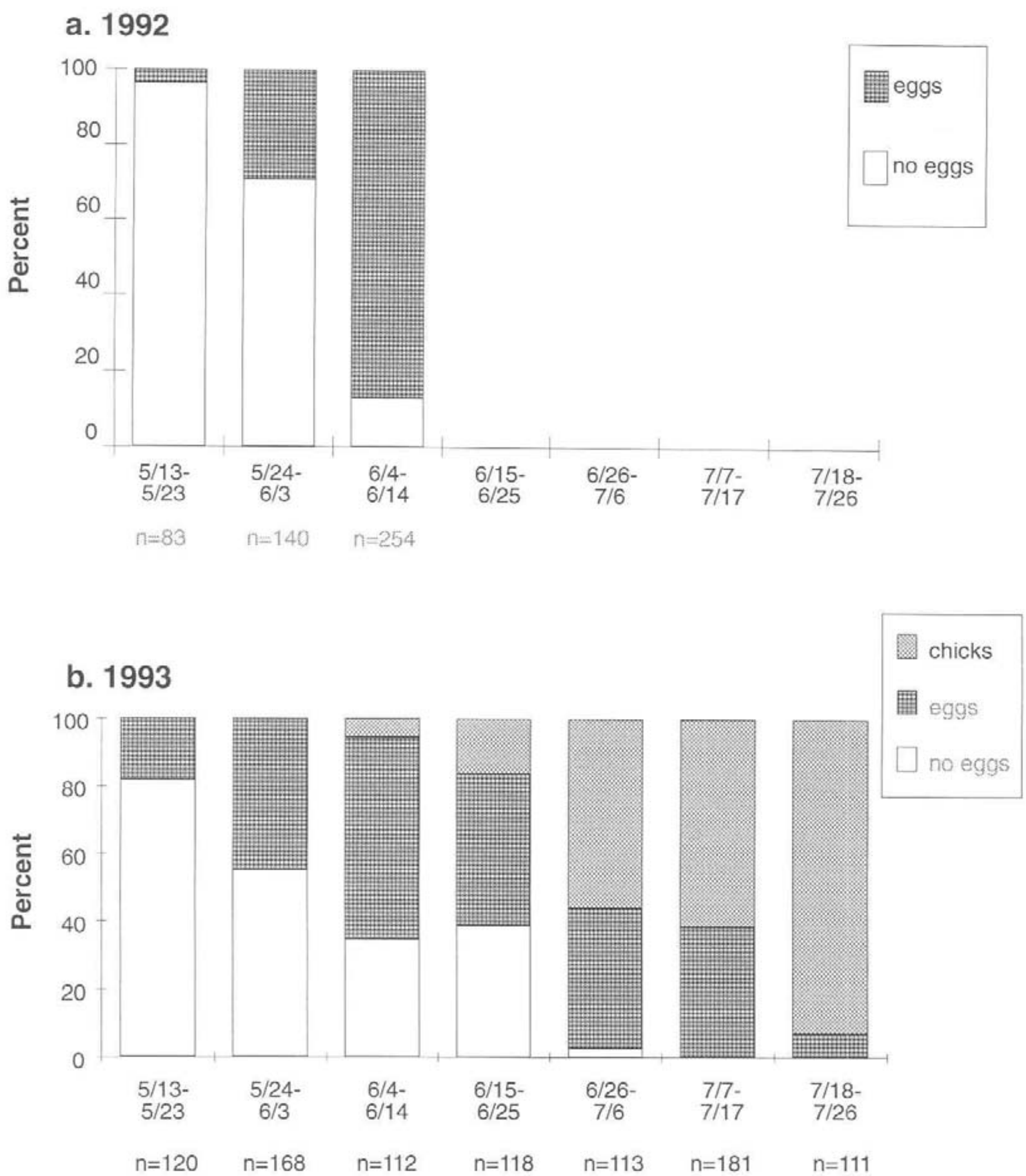

Figure 14. Lake Osakis nesting chronology for 1992 (a) and 1993 (b).

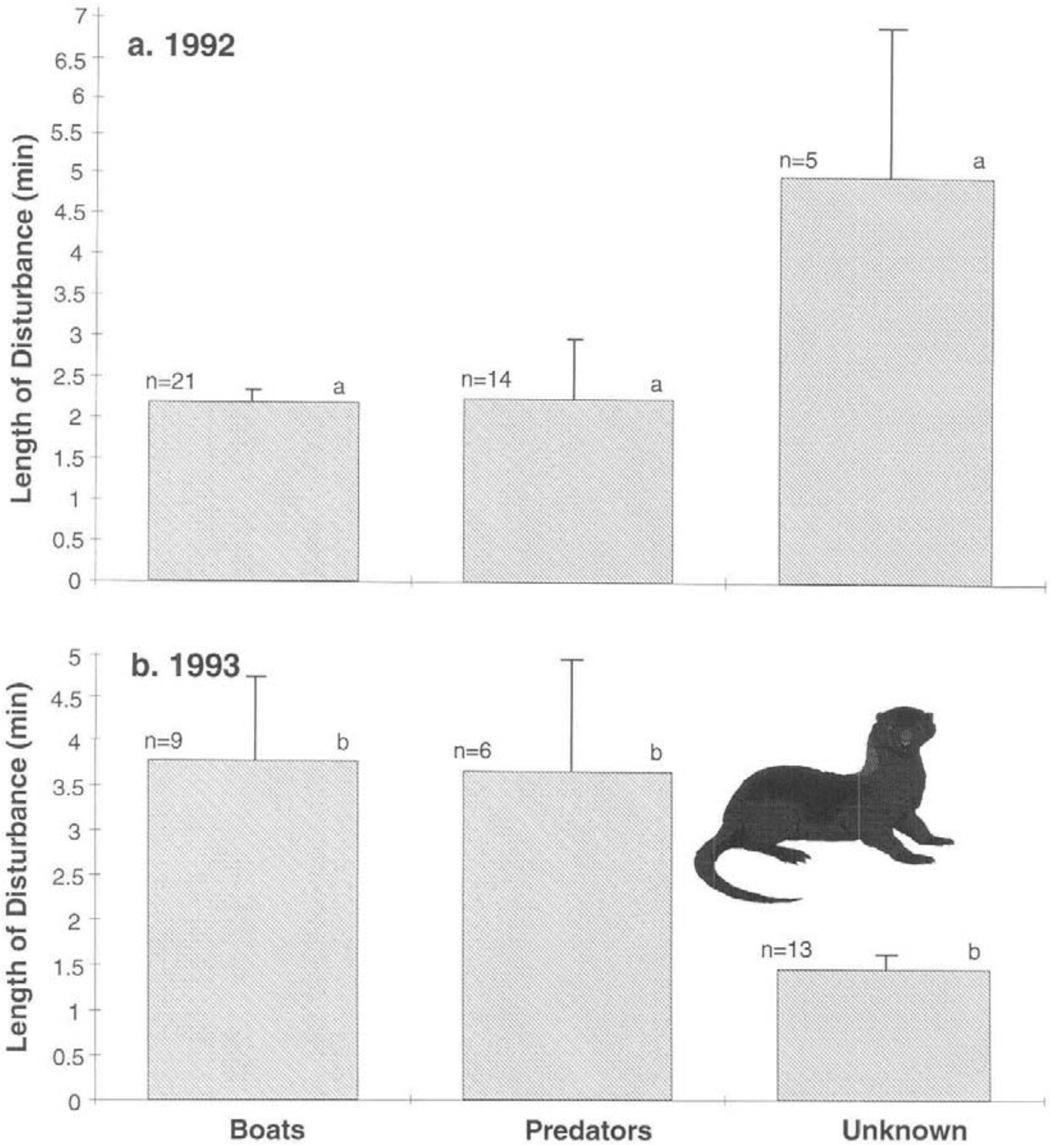

Figure 15. Cause and length (+/- SE) of disturbances in 1992 (a) and 1993 (b).

A disturbance was defined as 15 or more terns in the air. Different letters signify that disturbances lengths are significantly different ($p<0.05$). There was no difference in the lengths of disturbances between years ($U=970$, $p=0.963$).

Table 3. Hatching dates and fledging success for chicks of the Two-mile Bar colony in 1993.

Section	Hatching Date	Number of chicks hatched	Number of chicks fledged	Cause of Death
	7/20	2	0	weather
	7/18	2	0	weather
	7/21	1	0	weather
3c	7/4	3	0	predator/owl?[d]
	7/4	3	0	predator/owl?
	7/5	2	0	predator/owl?
	7/5	2	0	predator/owl?
	7/4	2	0	predator/owl?
3d	7/3	2	2	
	7/4	2	2	
3e	7/15	4	(4)	
	7/17	3	(3)	
	7/18	2	(2)	
	7/19	3	(3)	
	7/18	1	(1)	
	7/18	2	(2)	
	7/19	2	(2)	
	7/20	1	(1)	
	7/20	1	(1)	
4	7/10	?2	1	

a - The numbers in parentheses are chicks that I could not confirm whether they fledged or not, due To a mink entering the colony on July 27th (see text for more detail).

b - This category included chicks that I saw dead in the nest and missing nests (the substrate was gone). Whether could often not be distinguished from exposure.

c - This chick was pecked at by a neighbor during very windy conditions and did not survive.

d - All of section 3c's chicks disappeared over night, which is indicative of Great Horned Owl predation Nisbet and Welton 1984).

Table 4. Reproductive success (# fledged/breeding pair) for Forster's Terns compared to previous studies.

Author	This Study	McNicholl (1982)	Louis (1989)	Trick (1982)
Location	Osakis, MN (1 colony, 2 years)	Delta Marsh Manitoba (1 colony, 2 years)	MN (3 sites, 2 years)	Green Bay, WI (2+ colonies, 4 years)
Reproductive Success	1992: 0[a] 1993: 0.14 – 0.31[b]	1968: 0 1969: 0.07	1985: 0.46, 0, 0.16 1986: 0, 0.13, ?	1978: 0.36 1979: 0.36 1980: 0.46 1981: 0.64

a - In 1992 the entire colony abandoned the site (see text).

b - A range is given for the Osakis colony in 1993 due to a mink entering the colony towards the end of the breeding season, the higher value includes chicks two weeks and under and the lower value is the minimum reproductive success (see text and table 5).

Sources of Disturbance

The major types of disturbances to the Two-mile Bar colony were boats and predators.

Boats

In 1992 more boats entered into the colony than did predators (21 vs 14), and they caused birds to remain in the air for a similar length of time (Fig. 15a). Probably due to the adverse weather in 1993, fewer boats (n=9) entered into the colony, but they created, on average, a disturbance that was twice as long as those observed in 1992 (Fig. 15b). However, variation in 1993 was substantial, and I found no statistical difference in the lengths of disturbances between the two years ($U = 970$, $p = 0.963$) .

Due to the configuration of the colony in 1993, I recorded a much higher occurrence of "unknown" disturbances. This was due to the configuration of the colony. In 1992, the colony was mostly concentrated on one large mat of cattails, whereas in 1993 the colony was dispersed into many sections. When the terns were concentrated into one area, the whole colony would often be involved in a disturbance. With the colony divided into sections, often only those closest to the disturbance would react. On all occasions except for one, boats entering into the colony were simply fishing, and if the terns started mobbing the boat or if the boat operators saw the blind (n = 4), they would generally leave the area. The one exception was a man with two children that purposely buzzed the colony 3 times with his boat, presumably to see all the terns in the air.

Predators

Predators that were actually *observed in* the colony included Black-crowned Night Herons, Great Blue Herons, and a mink. Generally when a Great Blue Heron (n = 13) or Black Crowned Night Heron (n = 1) entered the colony, some or all of the colony would initiate mobbing behavior, which was effective in driving out the predator. In 1992, mobbing appeared to be more coordinated, and frequently the whole colony would respond. In 1993, when the mink entered into the colony, the size of the colony had decreased substantially to about 40 nesting pairs. All of the adults were involved in the mobbing, which appeared to have little effect on the mink's behavior. The mink remained in the colony for 8 hours or more, first entering into the colony at 10:00 am. The mobbing behavior fluctuated throughout the day, depending on whether the terns could see the mink. When the mink initially entered into the colony, mobbing was very strong. All of the chicks fled, and none were observed taken by the mink due to the vegetation, but presumably some of the younger chicks were eaten. One chick was later seen to have sustained a wing injury. Most of the older chicks fled into a stand of common reed *(Phramites communis).* Later in the day (while the mink was still present in the colony) a boat came into the area and fished beside the common reed stand, consequently getting mobbed by the already stressed adults. Essentially, the terns were in the air intermittently for the entire day.

Another predator observed flying over the area, in 1993, was a Great Horned Owl (pers. comm. Don Enger). In 1992, the entire Two-Mile Bar colony was abandoned in mid-June, when approximately 90% of the colony was on eggs, possibly because of nocturnal Great Horned Owl activities. Decapitation of prey is indicative of Great Horned Owl predation (Austin 1948). In 1991, Nuechterlein and Buitron (pers. comm.) found decapitated Forster's Terns on top of their muskrat house blind. In 1992, I found a decapitated Red-necked Grebe in the colony *(Podicpes grisegena*) and in 1993 I regularly found decapitated Western Grebes (n=6) and an Eared Grebe (*Podiceps nigricollis*). I did not find any evidence of dead Forster's Terns in 1992 or 1993.

Other minor disruptions (not qualifying for my definition of a disturbance) included carp spawning, muskrats building platforms and white pelicans approaching too close to nests.

DISCUSSION

Objective 1: *Foraging areas*

Forster's Terns appear to be most similar to Common Terns (*Sterna hirundo) in* their foraging habits. They feed close to shore, adjacent to or at intermediate distances from the colony, and primarily in smaller group sizes (Erwin 1978). Foraging birds appeared to maintain a "private air space" (Salt and Willard 1971) around themselves. When one bird invaded another's proximity, territorial vocalizations were used or a chase would ensue. McNicholl (1980) suggested that Forster's Terns foraging at regular sites may occasionally maintain feeding territories. I also observed individual terns regularly feeding at certain open areas of the lake, but they did not appear to maintain permanent feeding territories.

The significant difference in traveling distances between years is probably related to the variations in prey availability and the unpredictability of prey schools from year to year. Since no significant difference was found within 1993 it appears that the presence of chicks did not affect the distance adults traveled.

Erwin (1978) related the distance traveled to colony size for terns. The size difference between the two study years is minimal and although the colony was more fragmented in 1993, this should not affect foraging distances traveled.

Objective 2: Prey availability

Estimating the availability of food is a problem for most seabird studies (Erwin 1977, Monaghan et al. 1992) and any sampling data will inherently have biases. I found no significant differences in the size of yellow perch between courtship, chick or seining data, which appears to indicate that the seines were selecting for some of the targeted prey of Forster's Terns on Lake Osakis.

Other researchers have used inferences of food availability and foraging distances from the colony, by measuring incubation shift frequencies (Ashmole and Ashmole 1967, Nelson 1970). At the Two-mile Bar colony shift frequencies for 1992 were 0.67 ± 0.09 per hour and for 1993 1.13 ± 0.15 switches per hour. These data, along with the feeding rate data, suggest that finding prey on Lake Osakis, was not a limiting factor for either year.

Objective 3: Feeding .rates

Tern courtship behavior can be divided into three main stages: 1) mate assessment - during which a male may offer fish to several females; 2) temporary-liaison - a male feeds one female; 3) established pairs - the female stays mostly on the pair's territory in the nesting colony while the male regularly brings her food (Nisbet 1973).

The significance of courtship feeding has been debated extensively over the years (Royama 1966, Wiggins and Morris 1986). Three main functions have been proposed, pair-bond maintenance (Lack, 1940), food provision for the female (Royama 1966), and an expression of dominance (Smith 1980).

For Common Terns, Nisbet (1973b) has shown that the rate of courtship feeding, during the established pair stage, is correlated with the size of the eggs that a female can lay, as well as hatchability and fledging success. These results appear to support the food provision function, allowing a female to build up her reserves and devote her energy towards making larger eggs. Theoretically a male can have a direct affect on his potential reproductive success by feeding his mate.

Forster's Tern courtship feeding during the established pair stage appears to provide females with an important source (and quite possibly the only) of food. Because of their vulnerability to weather (see below and McNicholl, 1982), Forster's Terns are constantly faced with the possibility of having to renest. Courtship feedings potentially provide an efficient way to expedite the renesting process. Although, more work needs to be done, I observed intense food-begging behavior by females and higher rates of courtship feedings in several marked renesting birds. In Common Terns, a slight resurgence of female food begging behavior and courtship feedings was seen upon the initiation of a second clutch. However, the feeding rates were much lower than initial courtship feeding rates (Wiggins et al. 1984). Cullen and Ashmole (1963) found that in renesting Black Noddies *(Aknous tenuirostris)*, the timing of courtship feedings occurred for a time period similar to that needed for egg replacement.

Courtship feeding rates for Forster's Terns are similar to those of the Common Tern. However, researchers have used different methods, and some caution should be used in comparing rates (Nisbet 1973, Nisbet 1977, Morris 1986, Wiggins and Morris 1987). Morris (1986) reported between 0.65 and 0.85 feedings per pair per hour prior to egg laying, with feedings declining after the laying of the second egg (from 0.4, at 2-3 eggs, down to 0.15 at 72 hrs after the clutch was completed). Over a two-year period Nisbet (1977) reported higher feeding rates of 1.57 and 1.34 measured prior to and during the egg laying period. A decline in courtship feeding rates, for pairs with eggs, was also observed for Forster's Terns at the Two-mile Bar colony. However, this anticipated change in rates was harder to detect in the data, with randomly chosen individuals. But, with the high rate of nest loss, using randomly selected pairs was a reliable method to use, so I was assured that feeding rates were guaranteed.

Both Nisbet (1977) and Morris (1986) observed changes in courtship feeding rates between their two years of study. This suggests that the rate may reflect the food availability for that year. Nisbet (1977) stated that the difference in availability of one species of fish (silversides, *Menidia menidia)* affected the amount of feedings received by females from one year to the next. Similarly, the lower courtship feeding rates observed for the Osakis colony in 1992, may be a reflection of the decline in the availability of yellow perch.

Morris (1986) compared the courtship feeding rates between morning, afternoon and evening time periods and found a significant decrease in the afternoon time period (11:30-15:30) for both years of his study. He did not offer an explanation for this occurrence, but I suspect it might be related to higher mid-afternoon temperatures. Both of the years of my study were unusually cool summers, and I did not observe an afternoon decline. It would be .interesting to compare these data to those of a more typical (i.e. hotter) Minnesota summer.

Direct comparison of prey items of Forster's Terns and Common Terns is difficult, since most published studies of the Common Terns have been in an oceanic habitat. I am not aware of any published research on prey selection in Forster's Terns, with the exception of the individual observations cited earlier (see Introduction) and those of Salt and Willard (1971), who discuss size only. The size range of the prey items brought to females and chicks at Osakis were similar to that of Salt and Willard (1971) (1 to 10 cm), but I did occasionally see fish up to 12 cm (which were swallowed with some difficulty).

Cuthbert (1954) reported that in Black Terns *(Childonias niger),* minnows (cyprinidae) comprised of a small percentage (13%) of the diet fed to chicks. Although Black Terns typically nest interspecifically with Forster's Terns (Bergman et al. 1970), Black Terns are primarily insectivorous, not piscivorous so their feeding habits are very different (see Cuthbert 1954).

At Lake Osakis, the prey base for Forster's Terns shifted from 1992 to 1993. Sunfish comprised of 22% of the total species offered in courtship feedings during 1992, but less than 1% of the diet in 1993. The seining data do not offer much evidence of a decline in sunfish. However, the species may be less desirable as prey because of their shape. When available, yellow perch may be preferred by Forster's Terns. I had the opportunity to watch a flock of terns follow and successfully prey upon a school of yellow perch nearby the colony. Yellow perch have young that school during daylight hours, in shallow waters around vegetation (Becker 1983), traits which make them easy prey for the terns. My seining data indicates that perch fry were much less abundant at Lake Osakis in 1992 than in 1993 and may have suffered a major year-class failure. Two previous seinings showed that in 1986 yellow perch comprised of 88.60 of the 12 species caught in seines and in 1990 75.60 of the 16 species caught (Lake Osakis seining data, Department of Natural Resources, Glenwood, Minnesota). No data is available for 1992 or 1993.

At Lake Osakis the most highly desired game fish are walleye *(Stizostedion vitreum)*, northern pike, and largemouth bass *(Micropterus salmoides)*. Yellow perch are not considered a highly desired game fish, although some locals enjoy fishing for them (pers. comm., Don Enger). It was encouraging to note the minor role that highly desired game fish played in the terns' diet, because many local fishermen dislike Western Grebes and other fish eating species for fear of them "eating all their fish."

Most tern studies record the feeding rates (number of feedings per hour) of chicks relative to their weight rather than age (e.g. Trick 1982, Palmer 1941, Hawksley 1954, Dunn 1979). However, Dunn mentioned that chick feedings rates for Black Terns decreased as the chicks got older. Her sample was from one 5, one 15 and two 19 day old chicks. Cuthbert (1954) reported that the feeding rates for :Black Tern chicks generally increased through day 8, but that it dropped dramatically at the juvenile (flying) stage. Wiggins and Morris (1987) reported that Common Tern feeding rates (male and female rates combined) averaged 0.56 feedings per hour for the first week and 0.58 feedings per hour for the second week. This rate is almost half of what I measured for Forster's Terns during the first and second weeks. This could be related to coastal environment or to the food availability for that :year. Erwin (1977) reported higher feeding rates (1.23 prey/ young/ hour) for Common Tern chicks.

Prey size data at Lake Osakis suggest an increase in fish size offered by the adults as the chicks aged. Wiggins and Morris (1987) found that the length of the fish brought in by the male parent was correlated with chick age. Presumably, once chicks are big enough to eat larger prey, it is more efficient for parents to bring back larger fish. Efficiency of prey size however, also relates to foraging distance (Taylor 1979). Erwin (1977) states that the flexibility in foraging ranges and habitat use for the Common Tern, allows the parents to bring in a wide variety of prey size for their young. If they are foraging close to the colony bringing in smaller prey can still remain energetically efficient.

The decrease in chick feeding rates between the second and third weeks, appears to reflect an actual decrease in prey volume since no differences were found in fish size between the second and third weeks of age. Cuthbert (1954) reported similar data for Black Tern juveniles.

Objective 4: Nest success

The reproductive success of Forster's Terns at Lake Osakis for 1992 (0 young fledged per adult pair) and 1993 (0.13-0.32) was clearly lower than is desirable for maintaining stable population sizes. Assuming an estimated 1,000 pairs still breed in Minnesota (Cuthbert 1993), the Two-mile Bar colony in 1992 and 1993 contained approximately 300 of Minnesota breeding population. In 1985 Lake Osakis comprised of approximately 25% (198 pairs) of the breeding population, but reproductive success (number of fledglings per breeding pair) for Lake Osakis was not reported (Louis 1989).

Trick (1982) estimated that Forster's Terns nesting in Green Bay needed 0.74 to 1.1 young per breeding pair in order to maintain the population, but reported average reproductive success of 0.37 for the six years of his study. DiCastanzo (1980) calculated a similar recruitment estimate of 1.1 young per breeding pair per year required to sustain Common Tern populations.

Morris and Hunter (1976) report that prolonged reproductive failure can result in Common Terns eventually abandoning a site. In 1981 and 1983, approximately 1,000 pairs of Forster's Terns nested at Two-mile Bar, whereas in 1985 and for the two years of this study under 200 pairs attempted nesting. This decline in breeding pairs at Osakis can be interpreted as either: (1) a very serious decline in the overall breeding population over the last decade, or (2) a decrease in the proportion of Forster's Terns selecting the Two-mile Bar site, because of predation and other pressures (see Erwin 1977). Regular monitoring of alternate colony sites is needed to distinguish between these two possibilities.

Aside from weather, the primary factors affecting reproductive success at Lake Osakis appeared to be the presence of Great Horned Owls and a mink. Predation events in Common Tern colonies have been well documented (Table 5). Austin (1948) reported that Great Horned Owls can be very destructive in Common Tern colonies; in a 2 month period 311 adults were killed. In some colonies, Common Terns conduct nightly desertions when Great Horned Owls, are present, which causes prolonged incubation, reduced hatchability and a decrease in the survival of young (Marshall 1971, Nisbet 1975, Nisbet and Welton 1981).

Possibly, the abandonment of the Two-mile Bar colony in 1992 was the result of nightly activities of a Great Horned Owl and the inabilities of Forster's Terns to coordinate nightly desertions as previously observed in the Common Tern. All of the reports of nightly desertions of Common Terns have been made from non-fluctuating, dry-land colony habitats. No comparisons have been made on the effects of Great Horned Owl predation on Common Terns in their two different types of reported nesting habitats (Burger and Lesser 1979) .

Abandonment of a larid colony due to predation activities during the nesting season has been observed by Southern and Southern (1979), who reported an entire (2,000-3,000 pairs) Laughing Gull (Larus atricillia) colony abandoning due to the presence of a raccoon. Cuthbert (1993) did not specifically mention the Two-mile Bar colony, but reports predation by Great Horned Owls, Black-crowned Night Herons and mink as being the main causes of chick mortality for Forster's Terns in Minnesota. In a study on Black Skimmers Burger (1982) reported that if a colony was unsuccessful due to a predator (as opposed to weather) that they were less likely to return and use the colony the following breeding season.

McNicholl (1975) has suggested that certain larid species nesting in somewhat unstable habitats, like Forster's Terns, often have high group adherence, but low site tenacity. The overnight abandonment of the Two-mile Bar colony in 1992 appears to support his supposition. Assuming Forster's Terns are similar to Black Skimmers (Burger 1982) in their reactions to predation, the same group of individuals would not be expected to nest at a site that has had no reproductive success from a predation event(s) the previous year. Somewhat surprisingly, after abandoning the site in 1992, Forster's Terns nested at Two-mile Bar again in 1993.

Table 5. Predation at tern colonies. For gulls see: Burger (1974), Southern & Southern (1977), Kruuk (1972), Emlen et al. (1966).

Author	**Species**	**Predator**	**Prey's Reaction**	**Effect on Colony**
Austin (1948)	Common Tern	Rat	None ?	Loss of eggs & young
Burness & Morris (1993)	Common Tern	Mink	"Dreads"	Exposure of chicks & eggs. Increases pre-hatching & post-hatching mortality.
Hunter & Morris (1976)	Common Tern	Black Crowned Night Heron (BCHN)	Abandon up to 3 hrs.. Left when BCNH arrived in the form of a panic. No mobbing.	Loss of eggs & chicks.
Nisbet (1975)	Common and Roseate Terns	Great Horned Owl	Nightly desertion	Reduced hatching & extended incubation. Higher predation earlier in the season. Took chicks that were in poor condition.
Nisbet and Welton (1981)	Common Tern	1. Great Horned Owl 2. BCHN	1. Nightly desertion (leave in form of a panic). 2. None already deserted from owl.	1. Death of adult and chicks. 2. Loss of chicks and eggs.

When the terns arrived in the spring of 1993, over 200 pairs of Western Grebes were already initiating nests at Two-mile Bar. Forster's Terns often nest interspecifically with Western Grebes (Nuechterlein 1981), and possibly the presence of the grebes encouraged the arriving terns to stay. The presence of 400 grebes would presumably decrease the risk of predation to nesting adult terns. The reoccurring evidence of decapitated grebes (rather than terns) in 1993 seems to support this scenario. Another possibility, is that the group of Forster's Terns nesting at Osakis in 1993 were not the same individuals that nested there in 1992.

Burness and Morris (1993) had several incidents, in a Common Tern colony, of mink entering at night. They never observed a mink enter into the colony during the daytime and reported that tern reactions from mink disturbances differed from Great Horned Owl; the Common Terns did not desert the colony in the presence of a mink.

The variation in the effectiveness of mobbing is probably related to the type of predator in the colony. Presumably, the purpose of mobbing behavior aids in evicting potential threats to the eggs and young. Lemmetyinen (1971) has noted that predators are more easily evicted if the terrain is open, with no vegetation. Great Blue Herons are large and conspicuous, and respond to tern mobbing behavior even in dense vegetation. Mink on the other hand, are low to the ground, can easily conceal themselves in the vegetation. The densely vegetated nesting habitat of Forster's Terns may restrict the effectiveness of mobbing on low-lying intruder, such as a mink. I also noticed a behavioral difference in mobbing by terns when directed at herons versus the mink. For Great Blue Herons terns would swoop very close to the head, making the heron duck. For the mink, the terns gave alarm calls, but remained at a stationary height (not swooping).

Although most boats entering into the colony at Osakis created a disturbance, I think their presence generally did not adversely affect the terns' reproductive success. I saw neither eggs or chicks being lost as a direct result of a boat in the colony, and boats generally did not remain in the colony long enough to keep the terns off their nests for damaging lengths of time. Potentially, chicks could be disturbed enough to scatter, and this may be a concern when they are young enough to require a high amount of parental attendance (e.g. brooding).

Although, I have no way to quantify this, in 1993 the terns seemed more tolerant of boats entering into the colony. On at least two occasions boats were in the center of the colony and the terns did not react to their presence (in a mobbing like behavior).

At the Two-mile Bar colony, Forster's Tern chicks did not roam from their nests nearly as much as had been previously reported (Bent 1963, McNicholl 1971). This may be related to the lack of investigator interference, which is generally a concern in most seabird colony studies (Duffy 1979). On the three occasions when families moved, two lost their nesting substrate during a storm, and one family probably moved due to their close proximity to two other nests. Most families stayed on or very near their initial nesting site until their chicks started to fly.

CONCLUSIONS AND RECOMMENDATIONS

This study clearly supports previous observations that Forster's Terns are primarily piscivorous (Roberts 1932, Bergman et al 1970, McNicholl 1971). Although the species of fish taken are probably relatively site specific, they provide a baseline for use in future studies. At this important breeding location food availability did :not appear to have a major effect on reproductive success. The major limiting factors on reproductive success of this species at Lake Osakis appeared to be a) predators and b) nest destruction by wave action.

On a long-term basis, I think predation on young (and potential predation on adults), is the most important factor depressing reproductive success at Lake Osakis. Whether predator control is an option depends upon the resources available and the status of this species in Minnesota. It is unknown how many Great Horned Owl or mink are in the area. If more than several animals are involved, predator removal would not be effective on a long-term basis.

Even in bad years this species is clearly capable of renesting, given enough time in the breeding season. Even with the severe weather of 1993 nests hatched and fledged chicks. I found that the most damaging scenario was the combination of rain and high wind; rain weights down the mats of cattail, allowing the waves to disperse them more easily. Over the 1993 field season, the water levels rose approximately 5-6 cm (personal observation), yet there were suitable cattail mats still available for nests. The lack of nesting substrate early in the spring during some years might be more related to whether the wind causes the ice to shear off emergent stems at breakup rather than to spring water levels (see Louis 1989). Conceivably a break could be built to prevent the serious wave action on the nests perhaps in combination with nesting platforms. However, I would not recommend nesting platforms at Two-mile Bar because:

(1) there appeared to be plenty of substrate and (2) nesting platforms make adults and nests more vulnerable to predators (Louis 1989) .

If Lake Osakis is any indication of the average success that this species is experiencing overall (see Trick 1982, Cuthbert 1993), the Minnesota Department of Natural Resources may want to consider upgrading the status of Forster's Terns to threatened. However, the population fluctuations we are observing over the past ten years could be related to this species lack of site tenacity (McNicholl 1975) and knowledge of state boundaries. Forster's Terns may be the least thoroughly censused colonial bird in the state due to its nesting habitat (Guertin and Pfannmuller 1985). The most important management actions that could be taken would be to:

(1) maintain important historical nesting grounds, in both Minnesota *and* surrounding states and

(2) regularly monitor populations at these sites, which will provide data on long term population trends.

Providing educational materials on the food habits and status of Forster's Terns and other nongame waterbirds such as Western Grebes is also important, particularly for people living in areas nearby important colonies. Knowledge of these birds and the potential income they could bring in by attracting bird watchers will perhaps lessen the negative image that large waterbird colonies have on lakes that support a large sport-fishing community.

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