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FORAGING FLIGHT LINE PATTERNS BY ISLAND-NESTING WADING BIRDS BEFORE AND AFTER AN OIL SPILL

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Abstract.--In 1989, we made 51 h of observations of foraging flights by wading birds nesting on Isle of Meadows, a small dredge-spoil island located in the Arthur Kill, New York City. The next year, several major oil spills in this estuary caused widespread environmental and ecological damage, including changes in the types of foraging habitats used by local wading bird populations. In 1998, we made 40 h of foraging flight observations at this same colony. We also made 10 roadside censuses, nine censuses by boat, and one aerial census in 1998 in order to locate major feeding sites for birds nesting on Isle of Meadows.

Beginning in the mid-1980s and as recently as 1997, three separate islands in the Arthur Kill were colony sites for wading birds; however, Isle of Meadows contained the only active nests in 1998. For Glossy Ibises, we found significant differences between 1989 and 1998 in the direction of foraging flight lines; however, for three piscivorous wading bird species, flight line patterns in both years were very similar. We also document the locations of several wading bird feeding areas in New Jersey and on Staten Island.

Key Words.--egrets, foraging, habitat, herons, ibises, oil spills, pollution

INTRODUCTION

For more than 30 years, accidental discharges from oil tankers, pipelines, and other sources have caused widespread damage to the world's oceans, bays, and estuaries (Burger, 1997). From microscopic algae to the largest vertebrates, all trophic levels in the aquatic ecosystem are in some way affected by an oil spill (Cooper and Cristini, 1994; Brzorad and Burger, 1994; Maccarone and Brzorad, 1994; Schwartz, 1985; Baker, 1976). For example, water birds may come into contact with oil while swimming, by ingesting oiled food, placing nests in contaminated areas, or using oiled nesting materials. Once exposed, these birds may suffer increased mortality; systemic damage resulting from contact with even weathered oil; decreased reproductive success because of egg inviability, and starvation of offspring because of low food availability (King and Lefever, 1979; Macko and King, 1980; Hoffman and Albers, 1984). The short-term effects of oil spills on ecosystems are well documented (Walsh, 1968; Chasse, 1978; Piatt *et al.* 1990; Burger, 1994). In addition, the growing number of long-term studies of oil spills describe a slow process of recovery that may require many years (Conan, 1982; Boesch and Rabalais, 1984; Baker, 1993; Piatt, 1993; Garrity *et al.*, 1994).

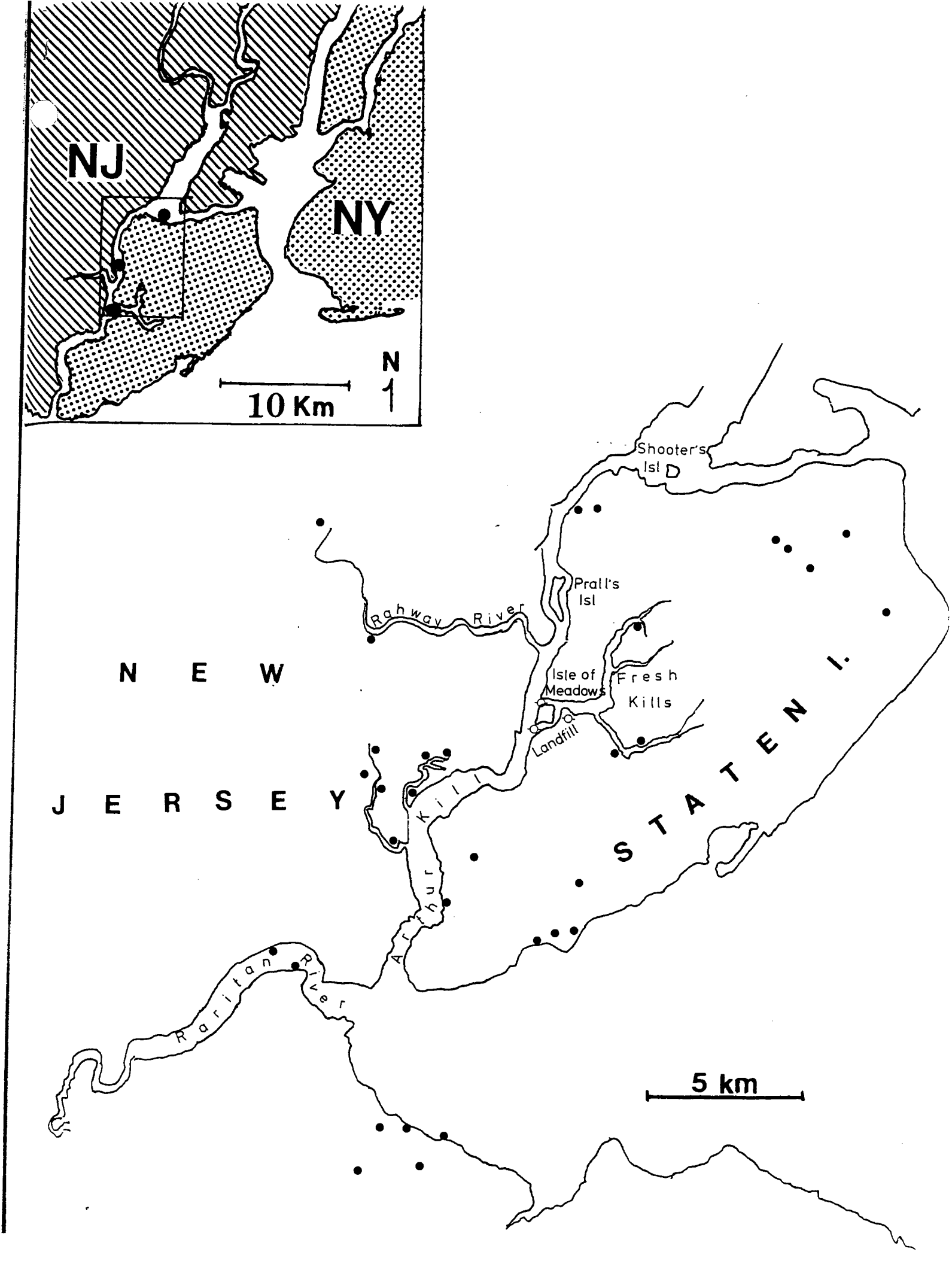
On 1 January 1990, an underwater pipeline burst, releasing > 2,000,000 L of No. 2 oil into the Arthur Kill. Several other discharges later that winter and spring brought the total amount of oil to c. 5,000,000 L. The widespread short-term effects of these spills have been described in Burger (1994). More recently, we have begun to investigate the long-term effects of the 1990 oil spills on wading bird foraging ecology. In 1997, we repeated several earlier studies to

determine the extent to which wading birds had returned to foraging sites that were used extensively before the oil spills (Maccarone and Brzorad, in review). Here we examine flight line patterns by birds breeding on Isle of Meadows. This is one of three small islands in the Arthur Kill, and currently the only island with an active wading bird colony. We compare the frequency and major compass directions of wading bird foraging flights in 1989 and 1998. In addition, we conducted censuses by automobile, boat, and airplane in order to identify several foraging sites used by wading birds from the Isle of Meadows colony. Previous studies at wading bird breeding colonies have used foraging flights to successfully locate feeding sites (Custer and Osborn, 1978; Maccarone and Parsons, 1986; Smith 1995). Because we have baseline data from before the oil spills, the present study provides an opportunity to examine the long-term effects of a catastrophic event on wading bird ecology and behavior.

STUDY AREA AND METHODS

Isle of Meadows is the southernmost of the three small islands in the Kill van Kull-Arthur Kill waterway that separates New York City from New Jersey (Fig. 1). This area is one of the most highly industrialized and heavily polluted waterways in the United States. In the mid-1980s, breeding colonies of long-legged wading birds became established on Prall's and Shooter's Islands (Maccarone and Parsons 1986). In 1987, a colony was also formed at Isle of Meadows (Parsons, 1991). The total nesting population (TNP) among the three colonies has fluctuated almost since these colonies were founded. The

Figure 1. (Inset) Locations of the three islands in the Arthur Kill waterway. (Main map) Study area, showing Isle of Meadows, the locations from which foraging flight observations were made (open circles), and locations visited during roadside censuses in New Jersey and on Staten Island (closed circles).


NJ
NY
N
10 Km
Shooter's Isl
Prall's Isl
Rahway River
N E W
J E R S E Y
Isle of Meadows
Fresh Kills
Landfill
Arthur Kill
STATEN I.
Raritan River
5 km

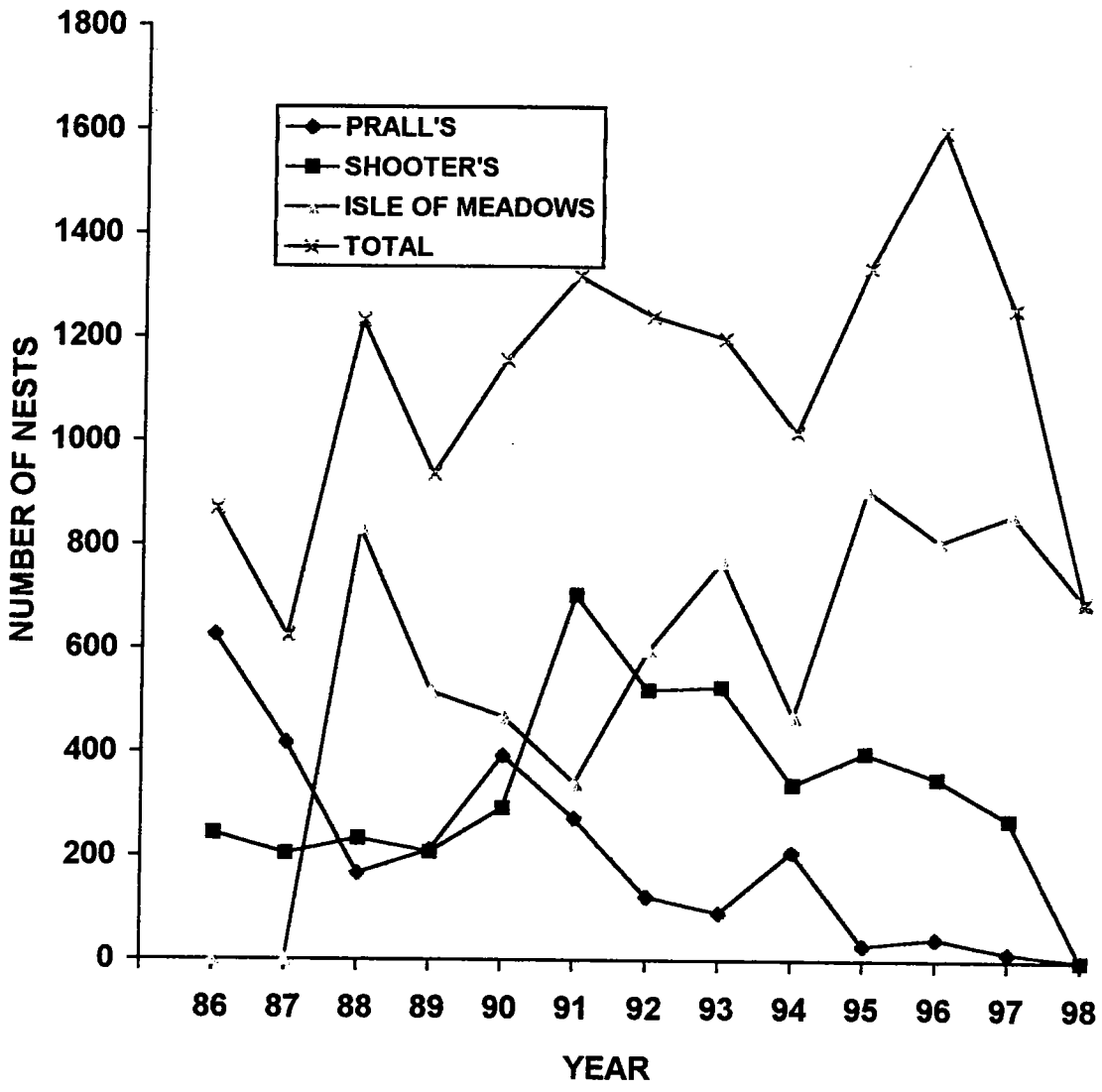
fluctuations in TNP became more pronounced during the late 1990s, in part because of drastic changes in the number of nests located on the different islands from one year to the next (Fig. 2). In particular, Isle of Meadows experienced changes in both TNP and species composition (Table 1). By 1998, Cattle Egrets (*Bubulcus ibis*) had virtually abandoned the island, and Glossy Ibises (*Plegadis falcinellus*) and Great Egrets (*Casmerodius albus*) had increased dramatically.

In 1989, we established three observation points, located north, south, and east of this island. These points were used to observe wading bird flights in part to document the location of major feeding areas. A similar flight line study at Prall's and Shooter's Islands in 1985 helped to determine the locations of major feeding areas for birds from these two colonies (Maccarone and Parsons, 1986). In both studies, we made the assumption that all flights were related to foraging. Observations were made from a small boat anchored just offshore the north and south points, and from a location along Route 440, a north-south highway located east of the island (Fig. 1). The sprawling Fresh Kills Landfill separated Isle of Meadows from this observation point, but lack of access to the landfill prevented us from moving closer to the island.

In 1989, we made 51, 1-h observations, randomized with regard to time of day (07'30-18'00), tide level (slack to flood), and location (N, E, or S). We recorded flight lines for 18 h from both the north and south, and 15 h from the east. For each flight, we recorded the species, number of individuals, time, compass bearing (to the nearest 10°), and direction (towards or away from the colony). The same three points were used to record flight lines in 1998. We recorded the same

Figure 2. Numbers of wading bird nests on three islands in the Arthur Kill waterway. Nests were present but not counted on Isle of Meadows in 1987. Data provided by New York City Audubon Society.

NUMBER OF TOTAL NESTS IN ARTHUR KILL WADING BIRD COLONIES



categories of information as in 1989. The 40, 1-h observations were again randomized, with15 h made from both the north and south, and 10 h from the east.

Comparisons of flights in 1989 and 1998 were analyzed three ways: (1) total flights along broad compass directions (N, S, and E) for each species; (2) flights made along 20° compass bearings for each species, and (3) number of flights each hour. We first created an index of flight line frequency to compensate for the different numbers of nests for each species in 1989 and 1998. For each hour in both years, we calculated values for this index by using the following formula:

$$\text{Index} = [(\text{N. Flying Birds}/\text{N. Hours})/(\text{N. Nests})] \times 100$$

After we completed flight line observations in 1998, the compass directions of all foraging flights were projected onto maps. We then used major compass directions taken by wading birds to establish a roadside census in New Jersey and another on Staten Island. The New Jersey census consisted of 16 sites (8 freshwater, 8 estuarine) along a 37-km route in Union and Middlesex Counties. The Staten Island (Richmond County) census route also consisted of 16 sites (10 freshwater, 6 estuarine) along a 70-km route (Fig. 1). Censuses were conducted in early June at different tide levels and times of day. For each census, we recorded the number and species of wading birds observed at each site. Each census required approximately 2 h to complete, but this varied with vehicular traffic patterns and the number of birds that we observed. On 3 June, we conducted a 1-h aerial census that included sites in New Jersey and on Staten Island. We could not accurately determine from the air whether each site was freshwater or estuarine, and so habitat comparisons cannot be made. Neither the

roadside censuses nor the aerial census were made in previous years and so comparisons cannot be made.

In similar surveys that we performed in this area in 1997, we noticed few birds foraging in the Rahway River north of Isle of Meadows. We therefore focused our activities in 1998 in areas south of that colony. Because many flight lines carried birds down (south) or across (west) the Arthur Kill, we made two 16-km censuses by boat along that waterway in 1998. We started at Isle of Meadows, then went south along the west shoreline until the southern tip of Staten Island. We then crossed over to the east shoreline and went back north until Isle of Meadows. We did not take these censuses in previous years and so cannot compare the use of this feeding site between years.

In 1988, we made 32 censuses along the Rahway River, from its mouth at the Arthur Kill to the point where it crossed under a railroad bridge. In 1998, we made seven such censuses. In both years, censuses were made at falling and rising tides. We compare the number of wading birds observed foraging along the Rahway River in both years. To compensate for the different number of nests each year, we created an index of habitat use. This index was computed using the following formula:

$$\text{Index} = [(\text{N. Foraging Birds}/\text{N. Censuses})/(\text{N. Nests})] \times 100$$

Our statistical analyses compare foraging flight line directions and foraging habitat use in 1989 and 1998 for each species. We used X^2 analysis to compare: (1) the numbers of flying birds using three broad compass directions (N, S, and E), and (2) the numbers of flying birds using narrower 20° compass bearings. We

also used X^2 analysis in 1998 to measure preference for freshwater and estuarine foraging habitats. We used two-tailed Mann-Whitney U-tests to compare: (1) flight line frequency indices for N, S, and E directions, and (2) usage indices for the Rahway River.

RESULTS

Total Foraging Flights

During 51 h of observations in 1989, we recorded a total of 1495 flights among four major wading bird species: Black-Crowned Night-Herons (*Nycticorax nycticorax*), Glossy Ibises, Great Egrets, and Snowy Egrets (*Egretta thula*). In 1998, those same four species made a total of 1827 flights in 40 h. When the number of nests in both years is factored in, indices of flight line frequency between years were similar for BNHEs (1.16 vs. 1.40) and SNEGs (6.21 vs. 7.64). Indices for GLIBs (13.47 vs. 9.40) and GREGs (28.21 vs. 10.55) were significantly lower in 1998 (Mann-Whitney, $P < 0.05$). Although Cattle Egrets were a major species in 1989 (62 nests, or 12% of TNP), they virtually disappeared from the Isle of Meadows colony by 1998 (9 nests, or 2%). Therefore, our comparison will include only the other four species.

North-, South-, and Eastbound Flight Line Frequencies

We compared the frequencies of north, south, and east flight lines in 1989 and 1998, and found significant changes for each species in only one of three broad directions. All species except GREGs showed a proportionate increase in north-

bound flights; GREGs were alone in having an increase in east-bound flights. No species differed between years in the number of south-bound flights (Table 2).

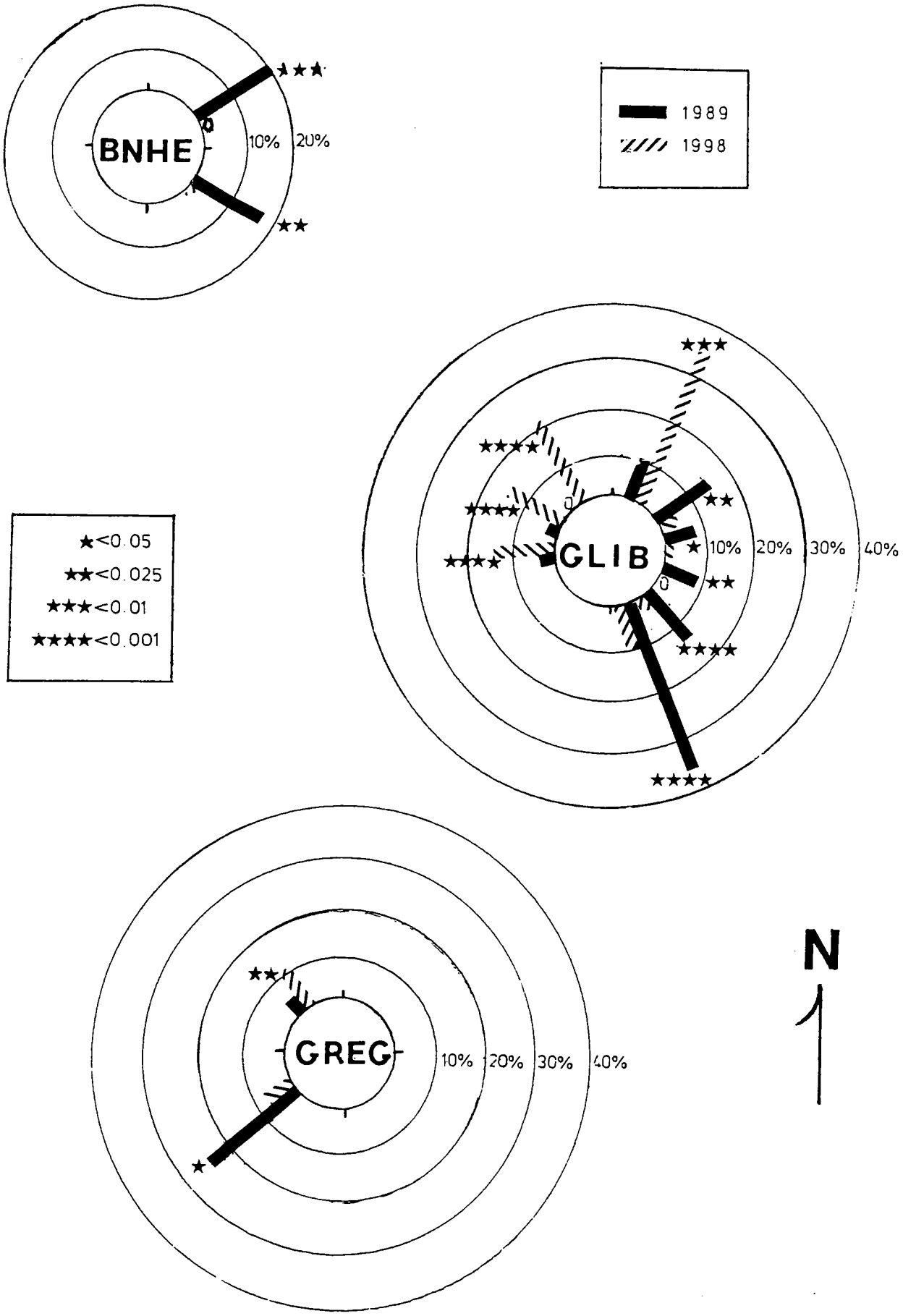
Major Compass Bearings Used for Flight Lines

After we compared flight line frequencies along broad directions, we then compared frequencies along narrower 20° arcs. A total of 18 such 20° arcs exist in a circle. Based on X^2 analyses of the number of flights in each 20° arc in 1989 and 1998, species differed in the number of arcs that showed significant changes between years (Fig. 3). GLIBs had the greatest total change in major flight line directions, with 9 of 18 bearings (50%) showing significant differences. BNHEs and GREGs each had two significant changes (11%), and SNEGs had none (all $P < 0.05$). In addition to the different number of arcs for each species that changed between years, there was no discernible pattern in the changes. Not a single 20° arc that changed between years involved more than two species. Two arcs involved two species, and the other eight arcs involved only one species.

Foraging Habitats Used by Wading Birds

When compared with the number of birds breeding on Isle of Meadows in 1998, few birds were observed during roadside censuses. On Staten Island, we found 17.0 ± 7.7 birds/census and 1.1 ± 0.6 birds/site (mean, standard deviation). The difference between the most and least abundant of the four major species was only 1.0 bird/census. In New Jersey, we found 8.6 ± 5.2 birds/census and 0.6 ± 0.7 birds/site. Great Egrets and Snowy Egrets were the only common species.

Figure 3. Comparison of major compass bearings for wading bird foraging flights at Isle of Meadows in 1989 and 1998. Species codes are shown in the center of circles, which represent the colony. Concentric circles indicate 10% increments in flight line frequency. Bars are drawn only for 20° bearings that are significantly different between years, based on X^2 analysis. Snowy Egrets had no 20° bearings that differed between years.


BNHE
10%
20%
1989
1998
★<0.05
★★<0.025
★★★<0.01
★★★★<0.001
GLIB
10%
20%
30%
40%
GREG
10%
20%
30%
40%
N

The number of birds observed in freshwater and estuarine habitats was compared with the relative occurrence of these sites in the roadside censuses. Black-Crowned Night-Herons showed a preference for freshwater habitats ($X^2 = 5.23$, $df = 1$, $P < 0.05$) and Great Egrets a preference for estuarine sites ($X^2 = 5.07$, $df = 1$, $P < 0.05$). Neither Glossy Ibises nor Snowy Egrets showed a preference for either habitat type (X^2s, dfs = 1, Ps> 0.05). In the only aerial census, we observed a total of 62 birds: 35 Great Egrets, 15 Snowy Egrets, 11 Glossy Ibises, and one Great Blue Heron (*Ardea herodias*).

The use of the Rahway River had declined drastically between 1988 and 1990, the year of the oil spills (Maccarone and Brzorad, 1995), and was still low in 1997 (Maccarone and Brzorad, in review). For three of the four major species, we observed significantly fewer birds foraging along the Rahway River in 1998 than ten years earlier (Table 3). Only GREGs did not differ between years. During two 16-km censuses along the Arthur Kill, we observed 8 birds on one census and 10 birds on the other, for a mean of 0.6 birds/km of shoreline.

DISCUSSION

Wading birds at the Isle of Meadows colony made foraging flights at about the same rate in 1998 as in 1989. In addition, our analysis of major compass directions for foraging flights suggests that the vast majority of flights in 1998 probably carried birds to the same feeding locations as 10 years ago. The three major piscivorous species showed little or no significant change in flight line directions eight years after the oil spills. In fact, these species had returned to pre-

spill reproductive success only two to three years after the spills (Parsons, 1996). Glossy Ibises were the notable exception in one-half of their major compass bearings had changed between 1989 and 1998. Ibises were the only species that showed major changes between years. It is possible that changes between years in flight line directions and probably foraging sites was a response to changes in the invertebrate prey availability. Long-term studies of oil spills in estuaries have found that some invertebrate populations may require seven to as much as 15 years to recover fully (Burger, 1997). These changes may also reflect increased competition for feed that could result from the almost threefold increase in the number of Ibises nesting on Isle of Meadows since 1989. Although the oil spills eight years ago caused immediate ecosystem-wide damage and possible long-term consequences (Burger, 1994), overall flight line patterns at this colony are extremely similar to those before the spills.

Of the three islands, Isle of Meadows was the furthest from the broken pipeline. This may have lessened the immediate impact or else accelerated the recovery of the nearby estuary. Isle of Meadows also experienced the least human disturbance after the oil spills. Human disturbance may have accounted in part for the decline and eventual complete abandonment first of Prall's Island, and this year of Shooter's Island, as well. However, despite the apparent stability at Isle of Meadows, the TNP is the lowest since 1987, the second year of colonization. The low number of nests in 1998 comes at a time when wading birds have begun to colonize other nearby islands (P. Kerlinger, pers. comm.). For dredge-spoil islands, such as the three Arthur Kill islands, colony "life

expectancy" may be relatively short-lived, in part because of changes in vegetation (Landin and Souts, 1977). As far back as the late 1980s, we had begun to notice some damage to the Gray Birch (*Betula populifolia*) that was the most common tree species for nest placement. Thus, it is possible that the decline in the nesting population was a normal event.

Despite our efforts to locate important feeding sites based on flight line analysis, the most productive of the 10 roadside censuses in New Jersey and on Staten Island (25 total birds) represented < 2% of the total nesting population on Isle of Meadows. Similarly, the 62 birds that we observed from the airplane represented < 5% of the total nesting population on Isle of Meadows. Finally, our nine censuses by boat along the Rahway River and Arthur Kill also found relatively few birds. Because we had not previously investigated the foraging habitats used by wading birds at this colony, we only have comparative data for the Rahway River. These data suggest the continued avoidance of the lower Rahway River, a pattern that we first documented in 1990, the year of the spills (Maccarone and Brzorad, 1995). The absence of large numbers of wading birds in this large, nearby estuary cannot easily be explained if the Arthur Kill ecosystem has in fact improved in the eight years since the oil spills. Similarly, other estuarine locations that we visited were not important feeding areas in 1998. Although we have not located major feeding sites, we are doubtful that local estuaries contain the same abundance of food, especially invertebrates, as before the oil spills.

ACKNOWLEDGMENTS

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Table 1. Number of active nests and percentage of TNP on Isle of Meadows in 1989 and 1998.

	Year			
	1989		1998	
Species	Number	Percentage	Number	Percentage
BNHE	258	51	278	42
CAEG	62	12	9	2
GLIB	78	15	211	32
GREG	18	4	73	11
SNEG	90	18	87	13
Total	506	100	660	100

Source: New York City Audubon Society

Table 2. Comparisons of indices[1] of flight line frequencies by four species of wading birds along three broad directions at Isle of Meadows. Each cell gives values for a two-tailed Mann-Whitney U-test, N_1 and N_2, and significance level. All significant differences were increases between years.

Direction	BNHE	GLIB	GREG	SNEG
North	U = 68	U = 60	U = 144	U = 24
	18, 15	18, 15	18, 15	18, 15
	P < 0.02	P < 0.01	N. S.	P < 0.01
South	U = 83	U = 151	U = 152	U = 70
	18, 15	18, 15	18, 15	18, 15
	N. S.	N. S.	N. S.	N. S.
East	U = 81	U = 74	U = 30	U = 66.5
	15, 10	15, 10	15, 10	15, 10
	N. S.	N. S.	P < 0.02	N. S.

[1]Index = [(N. flying birds/hour)/(N. Nests)] X 100

Table 3. Index[1] of wading bird activity in the Rahway River in 1988 and 1998. Based on 32 censuses in 1988 and seven in 1998. Censuses were made at falling and rising tides and were 3 km in length.

	Species			
Year	BNHE	GLIB	GREG	SNEG
1988	0.08	3.75	2.42	4.66
1998	0.01	1 15	2.15	2.30
Difference[2]	$P < 0.05$	$P < 0.02$	N. S.	$P < 0.05$

[1]Index = [(N. Foraging Birds/N Censuses)/(N. Nests)] X 100
[2]Based on two-tailed Mann-Whitney U-tests ($N_1 = 32$, $N_2 = 7$)