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Great Blue Herons as Environmental Indicators: Importance of Feeding Site Location

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United States
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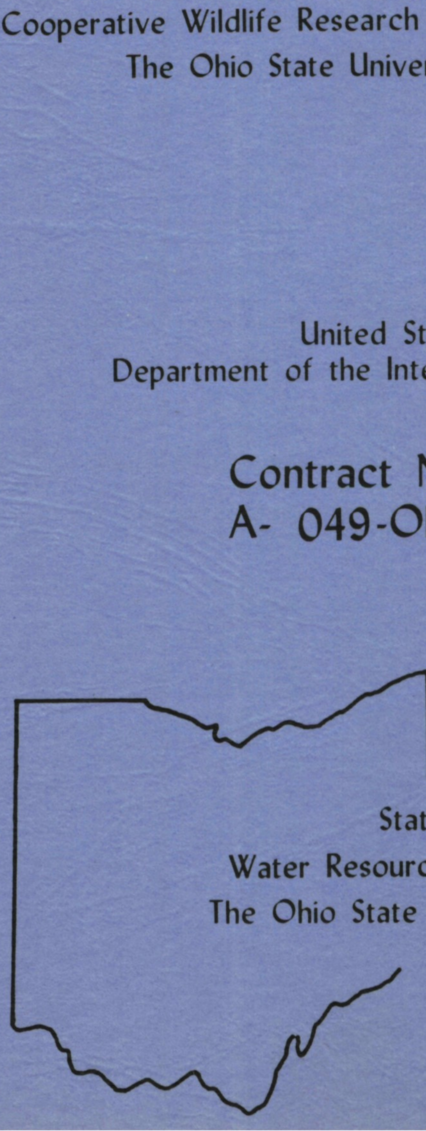

State of Ohio
Water Resources Center
The Ohio State University

GREAT BLUE HERONS AS ENVIRONMENTAL INDICATORS:

Aspects of Foraging Ecology

by

Gerald A. Grau 1/ and Robert W. Parris 2/
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The Ohio State University

June 1980

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INTRODUCTION

The success of wildlife species is generally related to the quality of the environment. In recent years, several wildlife species have provided biological assays for contaminant materials found in the environment. To be useful as an indicator of environmental quality, a species must be easily available, sufficiently large for tissue sampling, long lived, and show a relatively high contamination of the toxic material in question (Moore 1966). Herons possess many attributes which make them desirable as environmental indicators. Herons are long lived and at a high trophic level on the aquatic food chain. Thus, they are subject to bioaccumulation and biomagnification of toxic materials (Presst 1966, Harriss 1971, Hoffman 1974, and Fimreite 1974). Toxic substances, depending on type and concentration, have caused aberrant behavior, reproductive failure, and mortality in herons (Stickel 1975). Herons are opportunists, feeding on a variety of organisms including fish, crustaceans, insects, amphibians, reptiles, and small mammals (Martin et al. 1961). Any habitat alteration by chemical contaminants, such as heavy metals, pesticides, and polychlorinated biphenyls, which reduce the reproduction and survival of these organisms will ultimately lead to an alteration or reduction in heron food supply and possible a reduction in heron density. Thus, information on contaminant residues in heron tissues, heron reproductive success, and heron population abundance can yield information on the state of the environment in which heron's feed. Herons nest in colonies which provide a convenient place for collecting data on population and reproductive status and for collecting birds for tissue sampling.

Although population success can indicate the quality of the environment, detailed information on feeding ecology is needed to locate the source of the contamination. Hoffman (1974) found significantly different mercury levels in Great Blue Heron (Andea herodias) tissue samples taken from two colonies about 32 km apart. This difference in tissue concentration was attributed to different feeding locations, but the feeding sites for birds from these two heronries were not determined. The social organization of foraging Great Blue Heron appears to vary greatly. Foraging Great Blue Herons have been reported to be both territorial and nonterritorial depending on a number of factors (Dennis 1971, Krebs, 1974, Brandman 1976, and Bayer 1978). Territorial herons generally have been thought to be foraging on a more evenly distributed food source than have the nonterritorial herons, and sample a more specific part of the environment than nonterritorial herons. There is little information showing any relation of feeding location to nest site location within the heronry, but in some cases, individuals from closely associated nests are more likely to leave the heronry together than individuals from different part of the colony (Krebs 1974, DesGranges 1978). These individuals are assumed to feed within the same vicinity. This type of feeding behavior could stratify a heronry, and make intepretation of sampling data more difficult. For example one part of a Lake Erie heron colony may feed near Cleveland while the other parts feed near Toledo. Thus, the point of collection in the heronry would determine the residue levels found in the tissues. Hoffman (1974:34) noted a trend for higher mercury levels in adult Great Blue Heron tissues during the post-hatching period of the reproductive cycle. This trend could easily result from either an increase in environmental mercury during the breeding season or an increase in food consumption needed to provide the energy required for successfully raising the young birds.

The objectives of this study were to determine the amount of seasonal and yearly variation in feeding site location and the amount of overlap in feeding site location for herons from the various colonies in the southwestern Lake Erie region. We also wanted to determine the effect of behavior, such as territoriality at the feeding site or stratification of the breeding colony, on the feeding site location. This study also documents the feeding intensity during the various phases of the reproductive cycle for correlation with the trend for increased tissue mercury levels noted by Hoffman (1974).

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METHODS AND MATERIALS

Feeding ecology and behavior observations were conducted from Feburary through August 1977 and from March through August 1978 on marshes in the southwestern Lake Erie region. In 1975 and 1976, the large mainland heronry (Elm heronry) split into four smaller colonies all located in close proximity to one another on Sandusky Bay. Thus, this study included the West Sister Island heronry and all the mainland heronries located on Sandusky Bay.

Breeding population sizes, for the Great Blue Heron colonies studied, were estimated by nest counts from the ground late in the breeding season. Since the mainland heronies were relatively new or small, the number of nests was closely related to population size. However, nest counts in the large and older West Sister Island heronry may have overestimated the heron population by up to 10% (Edford 1976:75).

Heron feeding sites were determined by observing flight lines to and from the colony, habitat searches, and telemetry. Flight line (or vanishing point) is a technique consisting of recording the directions of arriving and departing birds from a given area. The data yield information on the bird's destination or departure point. The vanishing point technique has been used extensively with homing pigeons (Mathews 1968) and with colonial nesting birds (Kahl 1964, Ogden 1977, and Verbeek 1977). During this study, flight lines consisted of recording the directions, in 20 degree intervals, of herons entering or leaving the colony. The flight lines generally were observed from a high point close to the colony to obtain maximum visibility for measuring directions of departing and arriving herons. Flight line counts were taken either weekly or monthly depending on the colony and usually at specific times for each colony. Counts from at least two areas adjacent to the colony were needed to observe all possible flight directions from the majority of colonies. Flight line counts were combined for yearly and seasonal comparisons of heron flight line use for each colony. These flight line counts were used to determine the major feeding sites of herons from each colony as well as seasonal and yearly changes in feeding site use. Habitat searching for foraging herons was coupled with the flight line counts to document actual heron feeding sites. The flight directions of herons from these feeding sites also were observed to determine if herons from more than one colony foraged at that site.

Radio transmitters were attached to 18 adult Great Blue Herons and these birds were tracked to document foraging areas, movement behavior during the breeding and post breeding seasons, and initial dispersion after breeding. Adult Great Blue Herons were captured with a rocket net set at bait sites (Parris 1977). Three type of receivers (AVM LA-11 and LA-12, and Wildlife Materials Falcon-5) were used during the study. Three element yagi antenaes were used for locating radio-equipped herons. Radio-equipped herons were located from the ground and with occasional use of aircraft during the breeding season. Aircraft were used to locate herons during the initial dispersion following the breeding season. Solar or battery (90 day power life) powered transmitters, both types weighed between 50 and 75 grams, on frequencies between 164.450 MHz and 164.725 MHz were attached to the herons dorsal surface with harnesses that looped around the wings. Daily movements were determined from locational fixes taken every 20 or 30 min. On days when movement behavior was not monitored, generally one to five locational fixes were taken.

Various factors affecting heron use of feeding sites were measured. Foraging area sizes were determined by measuring the total area of all known feeding sites for herons from each colony of 1972 U.S. Geological Survey maps and 1977 N.O.A.A. maps of the southwestern Lake Erie region. Periodic census were made at a diked marsh, undiked marsh and shoreline habitat from late March through August 1978 to compare heron use of these habitats and to demonstrate changes in the number of feeding herons due to the breeding cycle. To document and characterize the heron breeding stages, the number of nests, number of occupied nests, number of adults at the nest, adult posture at the nest, and the number of nest material gathering trips were recorded weekly during the 1978 breeding season at the Hickory Isle heronry. Wave height in the shoreline habitat was measured to determine the effect of wave height on the number of feeding herons. Weekly samples of water depth, turbidity, and fish abundance were taken in the diked marsh for comparison with surveys of feeding herons.

Observations on foraging and loafing behavior of herons were made at feeding sites in the diked wetland habitat. All foraging herons studied were in shallow water areas lacking emergent vegetation, loafing herons were studied on these and adjacent areas. Foraging and loafing herons were observed with a 15X spotting scope and all observations were made during daylight hours. Observations were taken in ten minute intervals and any observation terminated before ten minutes was not analyzed. During the ten minute observation period, various feeding, locomotion, and comfort behavior patterns were counted or timed. Prey captured during the observations were identified and the length of the of the prey was estimated in comparison to the heron's bill length (1/2 beak, 1 beak or 1 1/2 beak). Fish were sampled with a 50 foot bag seine and a 120 foot variable mesh gill net at heron feeding sites to compare availability with their presence in the heron diet.

The prey intake rate was determined by estimating the length of the prey item in comparison to the length of the heron's bill and converting the estimated length to weight by the use of a length weight table (Carlander 1953) for the species as shown by other studies (Recher and Recher 1968, Krebs 1974, and Cook 1978a). The average weight of all known species for each specific size interval was used to estimate weights of undentified prey in each interval. Crayfish, the only major non-pisces prey, weight was obtained from the results of a previous heron diet study in southwestern Lake Erie (Hoffman 1974). Arthropod prey other than crayfish were not included in the determination of the prey intake rate. Loafing herons were not observed to take prey other than arthropod prey, not including crayfish, during the study.

RESULTS AND DISCUSSION

HERONRY LOCATION, POPULATION SIZE, AND FORAGING SITES

West Sister Island heronry - West Sister Island, a 39.4 ha island in southwestern Lake Erie, is located 14 km from the Ohio shore and approximately 32 km from the closest mainland heronry (Fig. 1). The island is approximately 29 km from the closest Canadian shore and 24 km from the closest Michigan shore. The northern 2/3 of the island is a mature hackberry (*Celtis occidentalis*) forest and the southern 1/3 of the island is covered by hackberry, sumac (*Rhus* spp) and poison ivy (*Rhus radicans*) shrubs. The southern shore of the island is a gravel beach and the rest of the shoreline consists of rocky cliffs. Great Blue Herons have been known to nest on the island since the 1930's (St. Clair, personal communication), but estimates of the size of the breeding population varied from 100 (Campbell 1968) to thousands (Core 1948). Since herons have nested on the island for at least a few decades, the reluctance of many observers to count the nests may indicate that the island contained a large breeding population for quite some time.

Nests counts were made late in the breeding season and included both Great Egret (*Casmerodium albus*) and Great Blue nests, since they could not be differentiated. Estimates of the number of nests for each species (Table 1) were based on the ratio of Great Blue Herons to Great Egrets seen entering and leaving the heronry during flight line observations. Although our estimate was lower than Scharf's (1978) estimate of 1600 heron nests, West Sister Island contained the largest breeding population of Great Blue Herons in the region (Table 2).

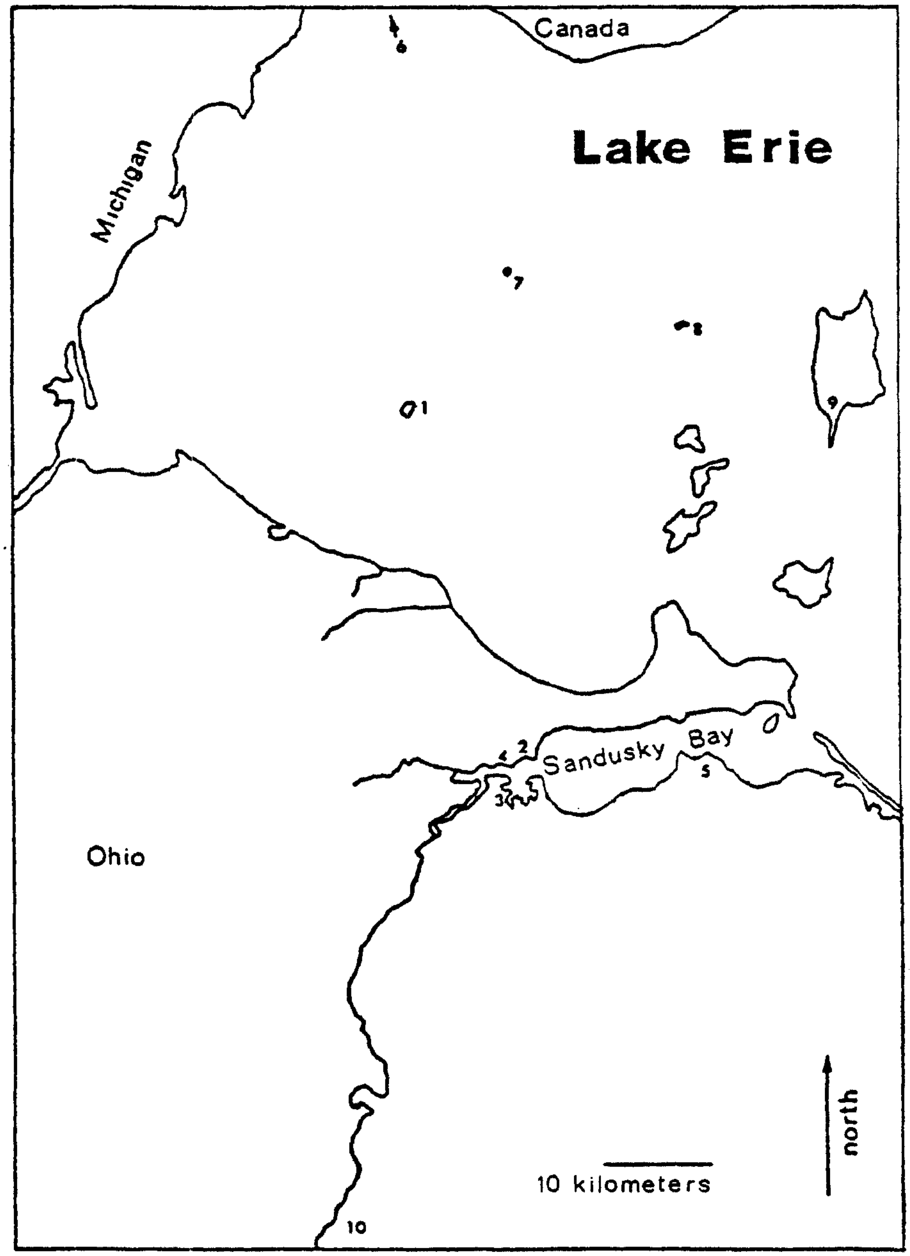


Figure 1. Great Blue Heron colony locations (1978) in the southwestern Lake Erie region. 1) West Sister Island, 2) Mackey, 3) Hickory Isle, 4) Lane, 5) Moxley, 6) Detroit River, 7) Middle Sister Island, 8) East Sister Island, 9) Pelee Island, and 10) Sandusky River

TABLE 1. Nest counts or estimates of colonial breeding waterbirds on West Sister Island during 1977 and 1978.

Species	Number of Pairs or Nests	
	1977	1978
Great Blue Heron (*Ardea herodias*)	1,158 1/	1,167 1/
Great Egret (*Casmerodius albus*)	100 1/	100 1/
Black Crowned Night Heron (*Nycticorax nycticorax*)	600-1,000 2/	600-1,000 2/
Herring Gull (*Larus argentatus*)	184	299
Cattle Egret (*Bubulcus ibis*)	5 2/	20 2/
Little Blue Heron (*Florida caerulea*)	0	1 3/
Louisiana Heron (*Hydranassa tricolor*)	0	1 3/

1/ Estimate based on a count of nests

2/ Visual estimate

3/ Pair seen but nests not found

TABLE 2. Great Blue Heron population sizes of colonies located in the southwestern Lake Erie region.

Colony Name	Year	# Nests	Source
West Sister Island	1977	1,158	present study
	1978	1,167	present study
Mackey	1977	647	present study
	1978	904	present study
Hickory Isle	1977	127	present study
	1978	99	present study
Lane	1977	175	present study
	1978	0	present study
Moxley	1977	87	present study
	1978	131	present study
Detroit River	1977	11	Scharf (1978)
Middle Sister Island	1977	31	Blokpoel and McKeating (1978)
	1978	20	Wesloh (personal communication)
East Sister Island	1977	40-50	Blokpoel and McKeating (1978)
	1978	low	present study
Pelee Island	1977	low	Putnam (1978)
Sandusky River	1977	low	Kleen (1977)

Because of the island's topography and vegetation, flight line counts had to be taken from two different areas to view all possible flight directions. Although herons left the island in many directions, the majority of heron movement in 1977 and 1978 was contained within just a few flight lines. The five major flight directions to and from the island comprised 93% and 96% of the total heron movement in 1977 and 1978 respectively. These major flight directions were all in the direction of the Ohio coast, between Toledo and the Portage River, the closest and largest shallow water areas in relation to the colony (Fig. 2). The flight line patterns were similar between years and had a high degree of correlation (Spearman's Rank Correlation, $P < .01$) (Fig. 3). The seasonal flight line patterns for both years, also were highly correlated (Spearman's Rank Correlation, both years, $P < .01$) (Fig. 3). This lack of significant yearly or seasonal variation in flight line use indicates a relatively constant use of feeding areas by the herons.

Searches of suitable habitat showed that the West Sister Island herons foraged at 14 sites (Table 3 and Fig. 2). As suggested by the flight line data, the major feeding areas were in Ohio marshes bordering Lake Erie. Six major marshes comprise approximately 4,501 ha of wetland habitat on the Ohio shore. Herons from West Sister Island also foraged on the Toussaint River and at the mouth of the Portage River. These foraging herons did not go past the Toussaint River on the Ohio mainland, but they did follow the Lake Erie shore to the mouth of the Portage River. Herons from this heronry also foraged in marshes bordering Lake Erie in Michigan, but these areas contained few foraging herons and little of the flight line movement was directed towards the Michigan coast. Recent maps, 1977 N.O.A.A., indicate much of

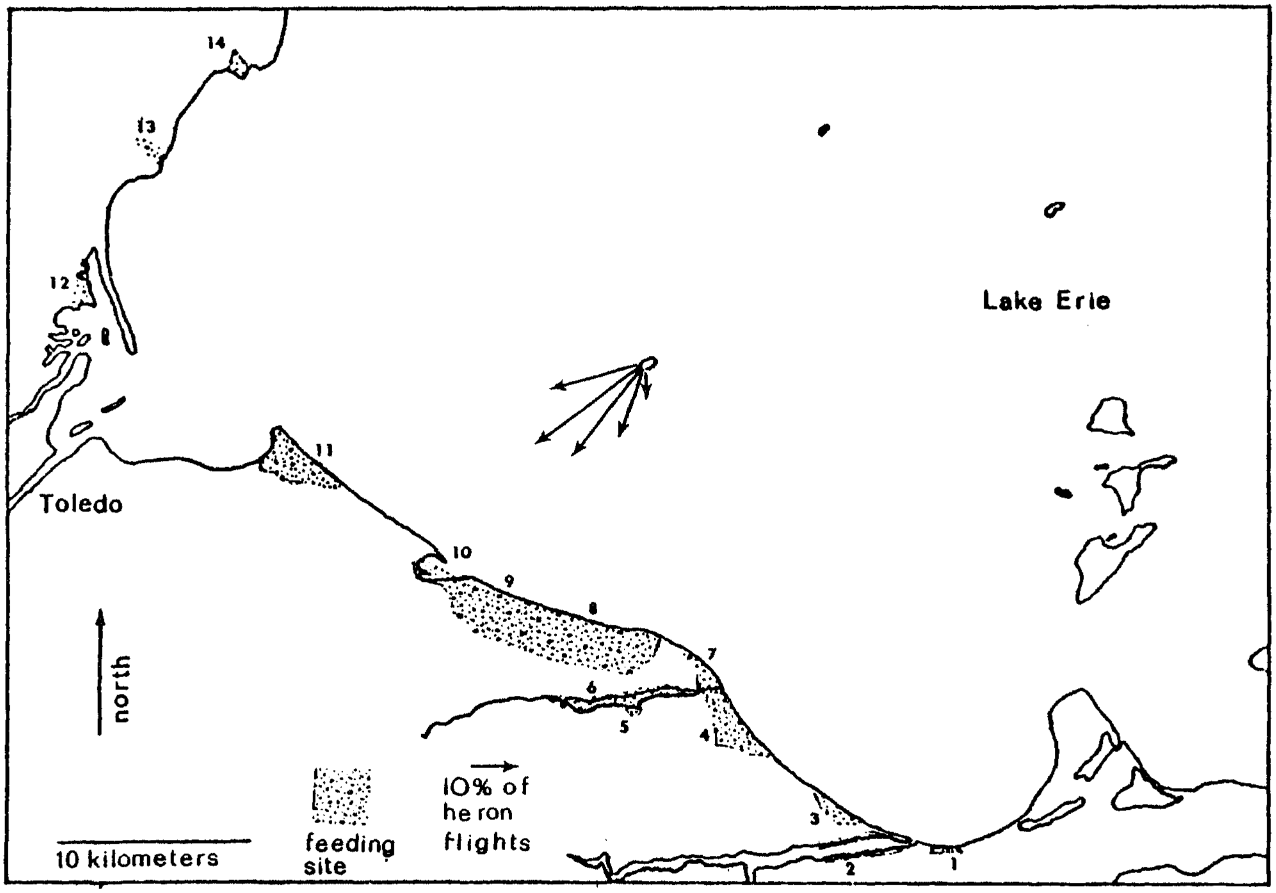


Figure 2. Feeding sites and the major flight directions (1977 and 1978 flight directions combined) of Great Blue Herons from the West Sister Island colony. Vectors radiating out from the colony center indicate percentage of heron movement from the colony and not distance traveled. Feeding sites: 1) Port Clinton Beach, 2) Portage River (mouth), 3) Darby Marsh, 4) Toussaint Marsh, 5 and 6) Toussaint River and Wildlife Area, 7) Nevar Marsh, 8) Crane Creek Marsh, 9) Ottawa National Wildlife Refuge, 10) Metzger Marsh, 11) Cedar Point Marsh, 12) Erie Game Area, 13) Misc. Wetland #1, and 14) Misc. Wetland #2.

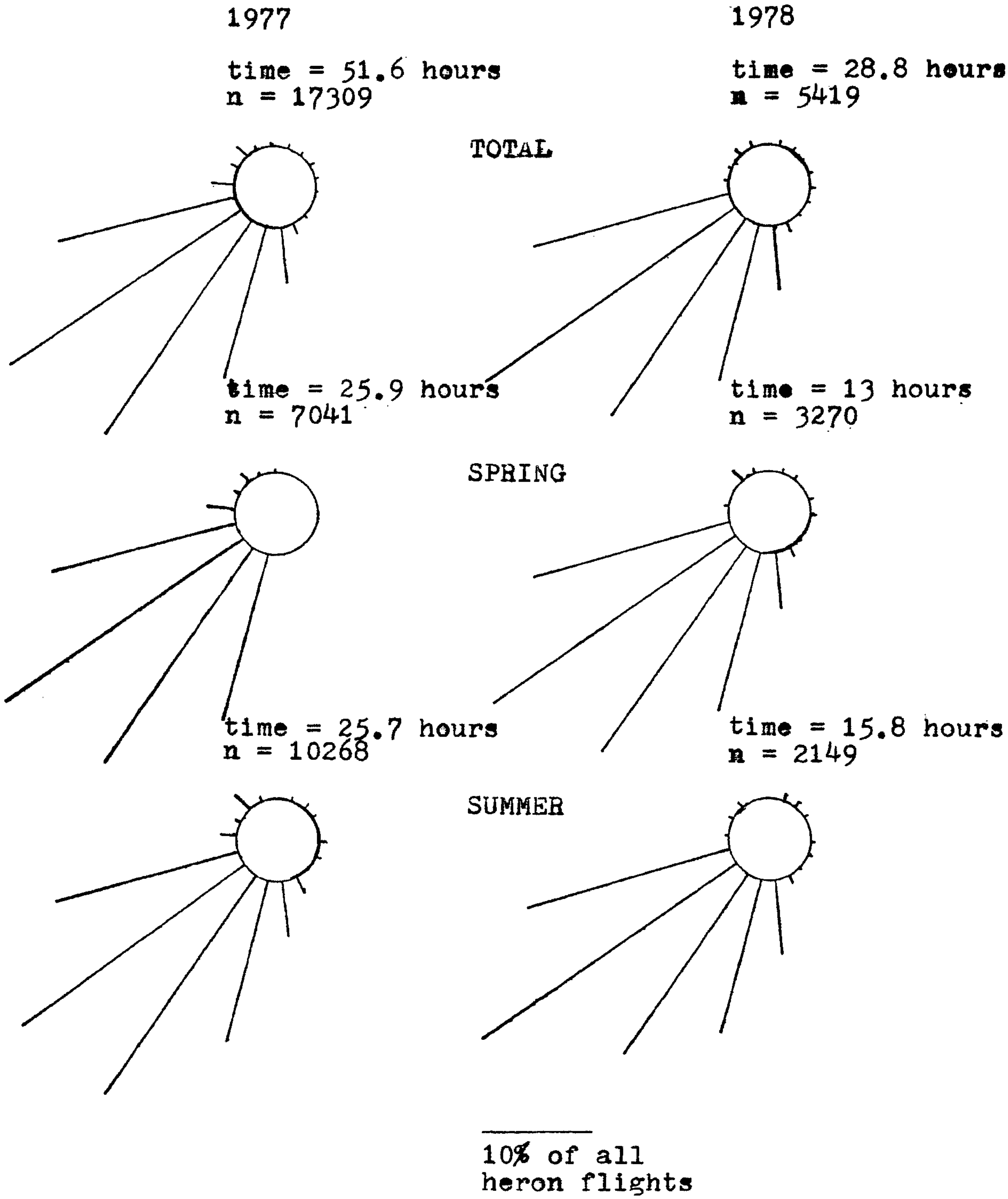


Figure 3. Yearly and seasonal use of flight directions by herons from the West Sister Island colony. Vector length represents percentage of herons using that flight direction and not distance traveled. The time spent observing heron flights and the number of herons observed are given.

TABLE 3. Foraging area size, distance from colony, and use by herons from West Sister Island. Locations of the foraging sites are shown on Fig. 2.

Foraging Site	Size (ha)	Distance from Colony (km)	Largest number of herons observed during the breeding season	
			1977	1978
Port Clinton Beach 1/	12	29	9	3
Portage River (mouth) 1/	70	26	7 2/	16 2/
Darby Marsh 1/	283	26	80	54
Toussaint Marsh	659	19	87	122
Toussaint River and Toussaint Wild. Area	146	18-19	94 2/	58 2/
Nevar Marsh	423	16	90 2/	56 2/
Crane Creek Marsh	1,214	14	134 2/	361 2/
Ottawa National Wildlife Refuge	840	14	177 2/	288 2/
Metzger Marsh	455	16	7	24
Cedar Point Marsh	910	19	321	209
Erie Game Area	172	29	12 2/	21 2/
Misc. Wetland #1	42	26	6 2/	p 3/
Misc. Wetland #2	74	26	14 2/	p 3/

1/ foraging site also used by mainland nesting herons
2/ estimate based on partial count of herons at site
3/ herons present but not counted

this wetland in Michigan was being filled. Herons from West Sister Island foraged in a total of 5,300 ha of wetland habitat. The distances of these foraging sites from the colony ranged from 14 to 29 km with the majority of birds flying towards foraging sites 14 to 19 km away. Some, but only a few, herons from this heronry could have been traveling up to 40 km to feeding sites on the Canadian coast.

Two West Sister Island herons were captured and fitted with radio transmitters late in June 1978. These herons tended to feed in the area they were caught (area #9, Fig. 2) and in surrounding wetlands (area #8, Fig. 2). Daily locations of these two herons indicated that their feeding sites were approximately 14 to 16 km from the colony (Table 4).

Sandusky Bay heronries - The four heronries, Mackey, Lane, Hickory Isle, and Moxley, we studied were located in the Sandusky Bay marshes and were from 1 to 16 km apart (Fig. 1). These heronries were formed when the Elm heronry (1527 nests in 1974) split up in 1975 and 1976 (Edford 1976, Grau and Bittner 1978). Five other Great Blue Heron colonies were located in southwestern Lake Erie however all contain less than 50 nests each (Table 2 and Fig. 1). Thus, approximately 95% of the Great Blue Herons breeding in the southwestern Lake Erie region were included in this study.

The Mackey heronry was located in a small woodlot owned by the Winous Point Shooting Club and was approximately 1 km from the Lane heronry, 5 km from the Hickory Isle heronry, and 16 km from the Moxley heronry. The woodlot, approximately 1 km from the Elm heronry, was bordered by diked marsh except

TABLE 4. Feeding site distance for radio-equipped herons from the West Sister Island and Sandusky Bay colonies.

Distance from Colony (Km)	% of daily feeding site locations	
	Mackey Colony (N = 287)	West Sister Island Colony (N = 13)
0-2	56.2	0
2-4	33.4	0
4-6	9.4	0
6-8	1.0	0
8-10	0	0
10-12	0	0
12-14	0	0
14-16	0	100.0
16-18	0	0

to the north where it was bordered by agricultural land. Great Blue Herons first nested there in 1976 (Grau and Bittner 1978) when 97 nests were constructed. The Mackey heronry increased to 647 nests in 1977 and to 904 nests in 1978. This colony was the largest mainland heronry in 1977 and 1978. The average number of nests per tree ranged from 4.4 to 6.9 in 1976, 1977, and 1978. The nest tree condition was recorded only during the 1977 season when 78% of the nest trees were dead.

The Hickory Isle colony was located on a small island in undiked marshland owned by the Winous Point Shooting Club on the south shore of Muddy Creek Bay, the western end of Sandusky Bay. This colony grew from 3 nests in 1975 (Grau and Bittner 1978) to 127 nests in 1977 and decreased to 99 nests in 1978. All nest trees were dead and the majority of nest trees contained only one or two nests.

In 1975, 134 nesting pairs established the Lane heronry (Edford 1976) in a small woodlot owned by the Winous Point Shooting Club on the north shore of Muddy Creek Bay. The woodlot is surrounded by marsh except to the southwest where it was bordered by the bay. The number of occupied nests decreased from 685 in 1976 (Grau and Bittner 1978) to an estimated 175 in 1977. No herons nested in this heronry in 1978 although herons occasionally were seen perched in nest trees.

The Moxley heronry was located in a small woodlot on a private marsh bordering the south shore of Sandusky Bay. This heronry was the eastern most mainland heronry and was the furthest away from the other mainland heronries. The colony size increased from 3 nests in 1975 (Grau and Bittner 1978) to 87 nests in 1977 and 131 nests in 1978.

All mainland colonies had similar flight line patterns in that the majority of heron movements were contained within just a few flight directions. The majority of movement from these colonies in 1977 and 1978 was contained within Sandusky Bay and Muddy Creek Bay (Fig 4 and 5).

Because of the Mackey colony's size and surrounding woodlots, flight line counts had to be made from four locations surrounding the colony to observe all possible flight directions. The major directions of heron flight from this colony in 1977 and 1978 were to the large marshes surrounding the colony at Muddy Creek Bay and to a lesser extent to the Portage River (Fig. 4). Many of the herons were observed to land and feed in these areas during the flight line counts. The flight line patterns in 1977 and 1978 as well as the seasonal flight line patterns for each year were highly correlated (Spearman's Rank Correlation, $P < .01$ each), indicating little yearly or seasonal variation (Fig. 6).

Flight line observations were taken from two locations to observe all possible flight directions from the Lane colony which was active only in 1977. The major movement of herons from this colony was to the west even though abundant shallow water areas were present just east of the colony (Fig. 5). This relative lack of movement to the east could be due to the large number of herons from the Mackey heronry feeding in the area between the two colonies. For example, all six herons captured and radio-tagged in the marsh just east of the Lane heronry in 1977 were from the Mackey colony. The Lane colony's seasonal flight lines were highly correlated (Spearman's Rank Correlation, $P < .01$) (Fig. 7) indicating little seasonal variation.

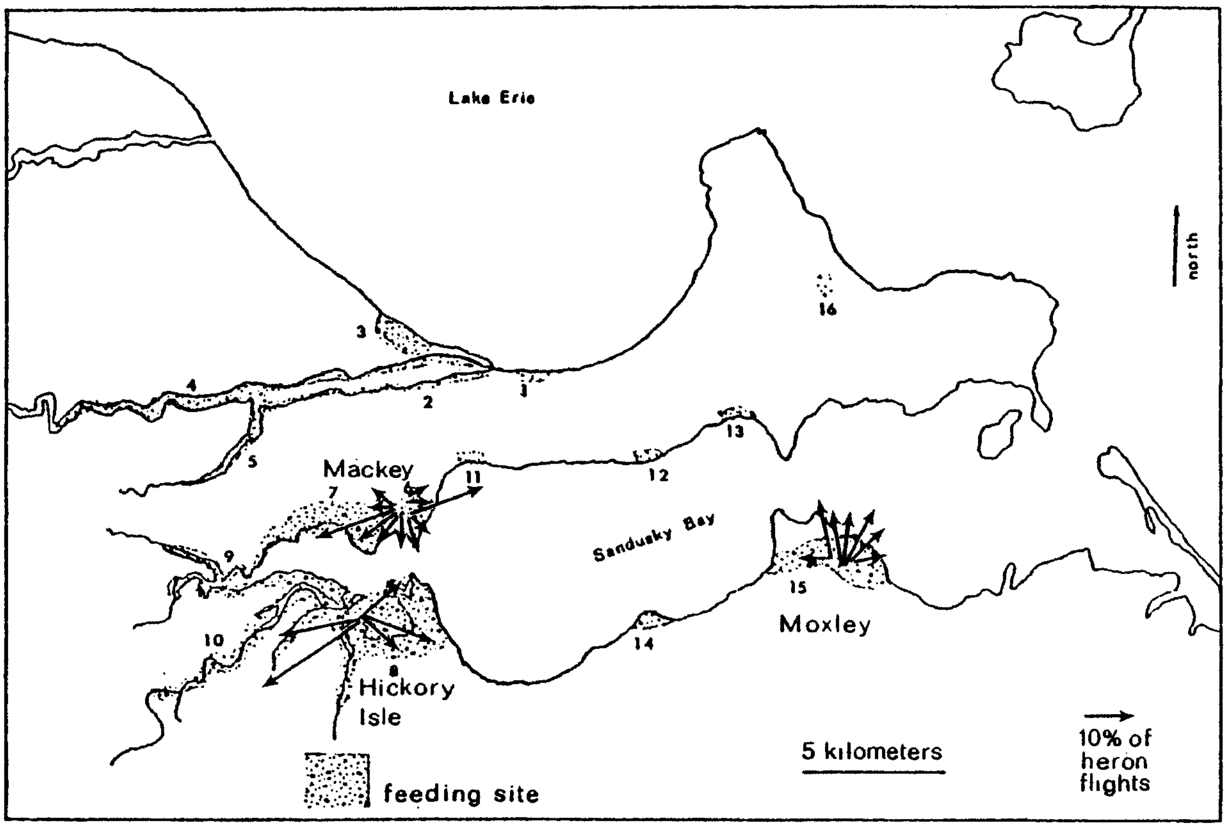


Figure 4. Feeding sites and the major flight directions (1977 and 1978 flight directions combined) of Great Blue Herons from the Mackey, Moxley, and Hickory Isle colonies. Vectors radiating out from colony centeres indicate percentage of heron movement from that colony and not distance traveled. Feeding sites: 1) Port Clinton Beach, 2) Porage River (mouth), 3) Darby Marsh, 4) Portage River, 5) Little Portage River, 6) Winous Point North Marsh, 7) Winous Point West Marsh, 8) Winous Point South Marsh, 9) Muddy Creek, 10) Sandusky River, 11) Misc. Wetland #1, 12) Misc. Wetland #2, 13) Misc. Wetland #3, 14) Willow Point Marsh, 15) Moxley Marsh, and 16) East Harbor State Park.

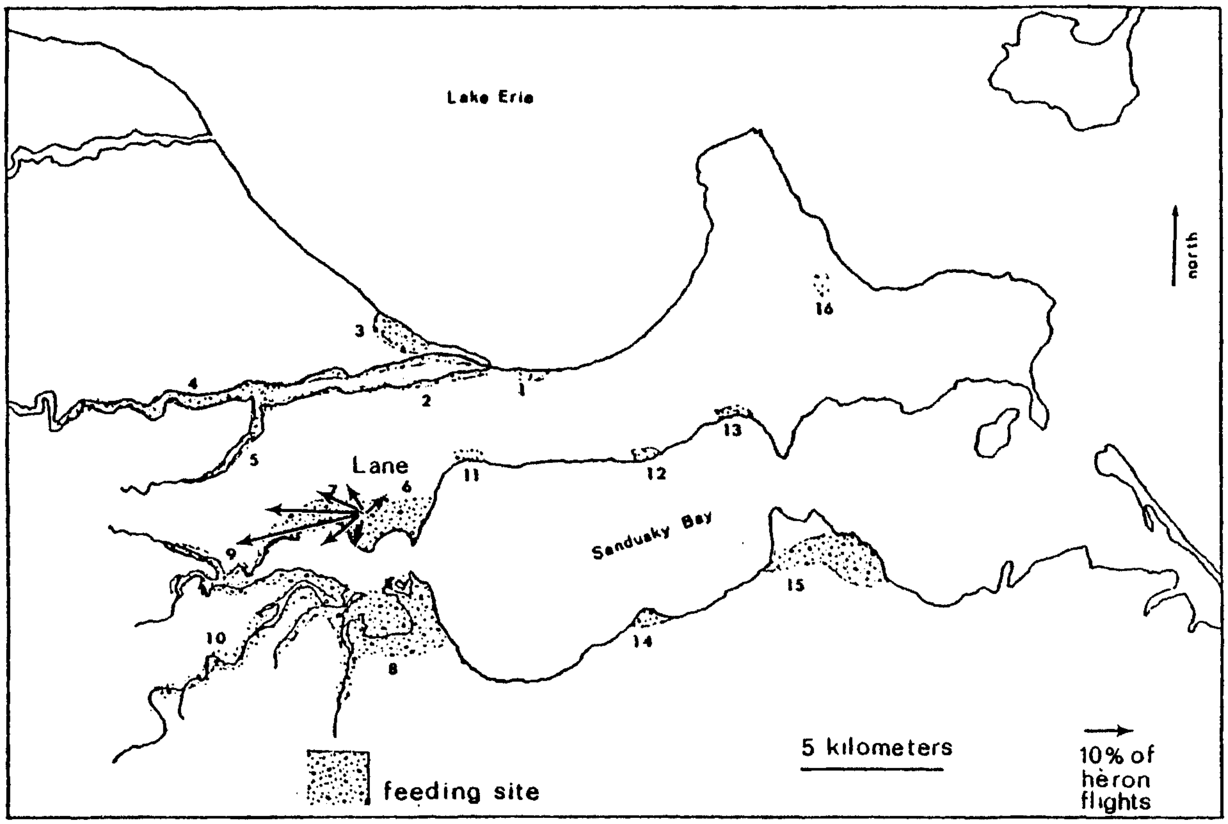


Figure 5. Feeding sites of mainland nesting herons and the major flight directions (1977) of Great Blue Herons from the Lane heronry. Vectors radiating out from the colony center indicate percentage of heron movement from that colony and not distance traveled. Feeding sites: 1) Port Clinton Beach, 2) Portage River (mouth), 3) Darby Marsh, 4) Portage River, 5) Little Portage River, 6) Winous Point North Marsh, 7) Winous Point West Marsh, 8) Winous Point South Marsh, 9) Muddy Creek, 10) Sandusky River, 11) Misc. Wetland #1, 12) Misc. Wetland #2, 13) Misc. Wetland #3, 14) Willow Point Marsh, 15) Moxley Marsh, and 16) East Harbor State Park.

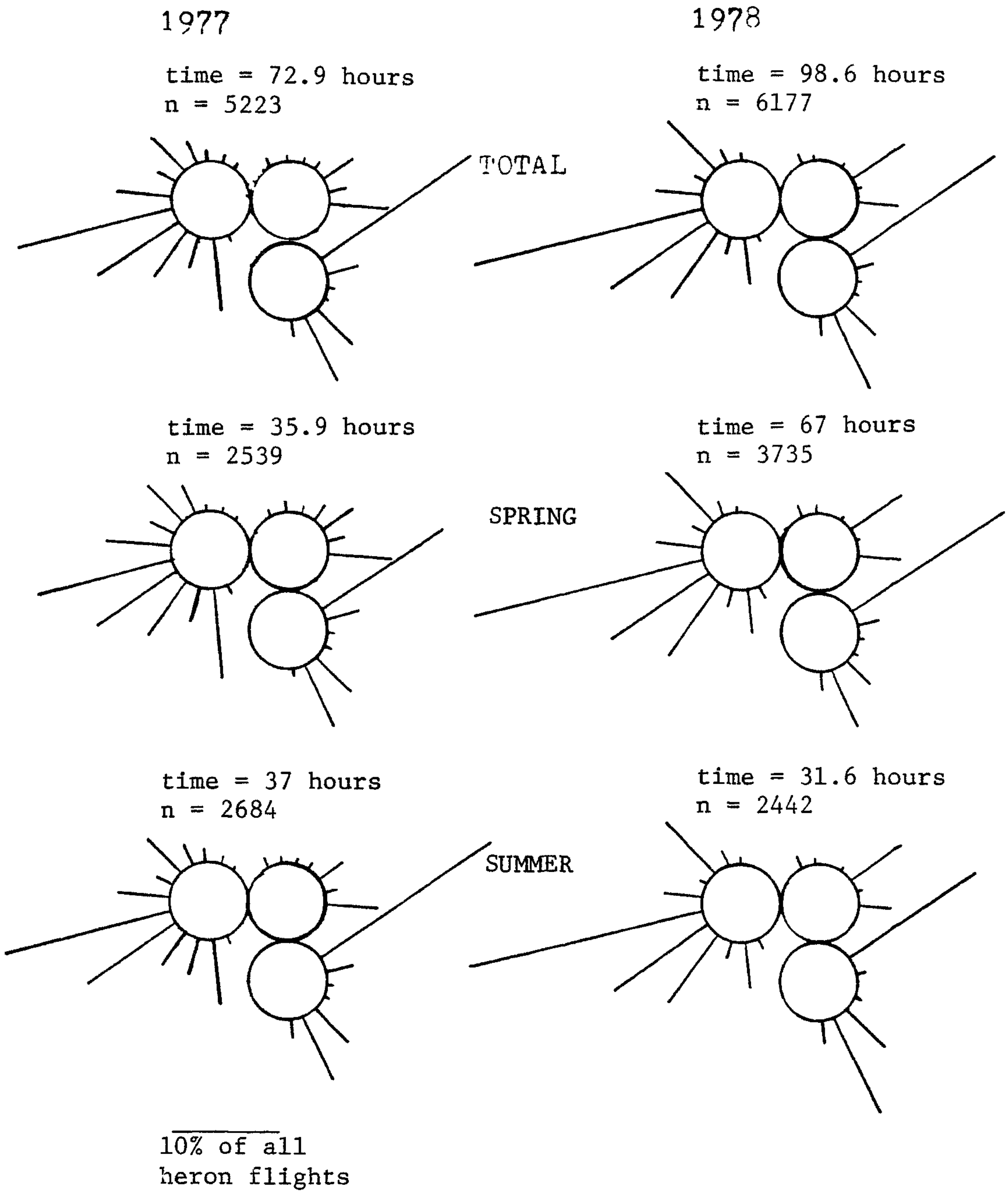
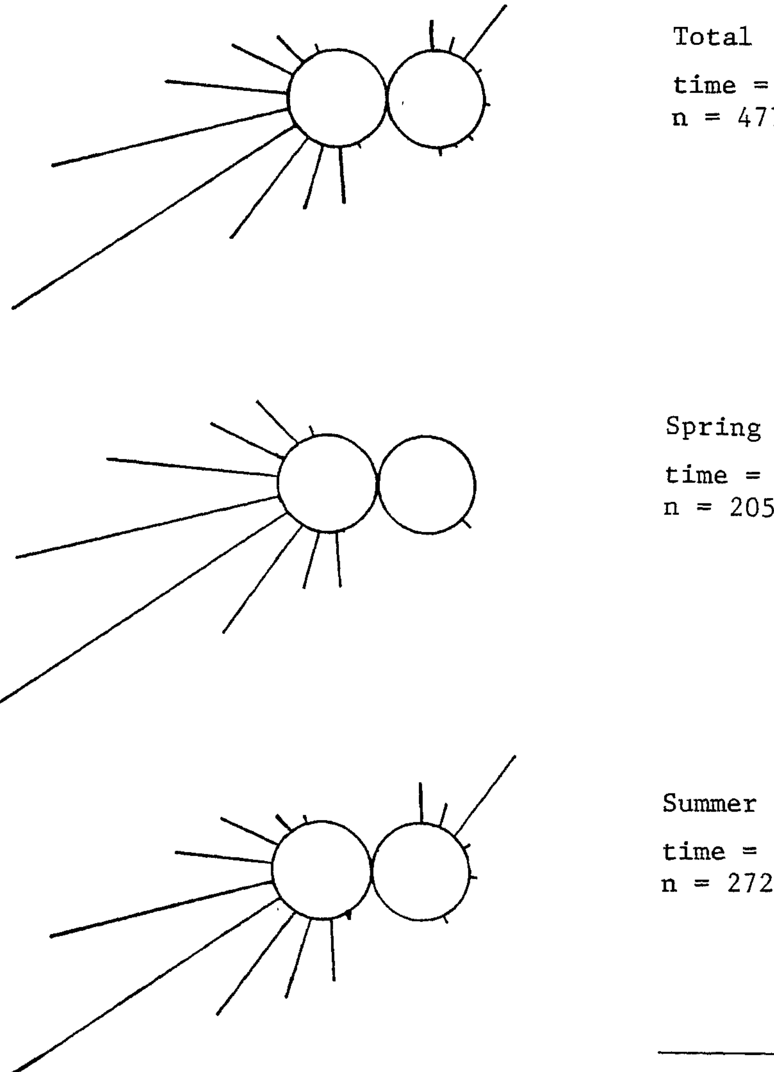


Figure 6. Yearly and seasonal flight lines for herons from the Mackey heronry. Vector lenght represents percentage of herons using that flight direction and does not represent distance traveled. The time spent observing the heron flights and the number of herons observed are given. The three circles represent the observation points around the colony.



Total

time = 19 hours
n = 477

Spring

time = 8 hours
n = 205

Summer

time = 11 hours
n = 272

10% of all
heron flights

<u>Figure 7.</u> Seasonal flight lines for herons from the Lane heronry. Vector length represents percentage of herons using that flight direction and does not represent distance traveled. The time spent observing the heron flights and the number of herons observed are given. The two circles represent the observation points around the colony.

The Hickory Isle colony's major flight lines for both years were in the directions of the large undiked marshes bordering the colony to the east and the west (Fig. 4). Similar to Lane colony, Hickory Isle colony's major flight line directions were not towards the shallow water areas close to Mackey colony. Yearly flight line use as well as seasonal use were highly correlated (Spearman's Rank Correlation, $P < .05$ and $P < .01$, respectively) (Fig. 8).

Flight line observations were taken only in July 1977 and 1978 for the Moxley colony. Two locations were used to observe all possible flight directions from the colony. Heron flight direction from this colony was a broad front of movement towards the marshes immediately surrounding the colony to the northeast, north, and west (Fig. 4). Most of the herons leaving the colony were observed landing in these nearby feeding areas. A yearly comparison of flight lines showed a high degree of correlation between the relative amount of heron movement in the flight lines for 1977 and 1978 (Spearman's Rank Correlation, $P < .01$) (Fig. 9).

Herons from the Sandusky Bay colonies tended to feed in the shallow water areas surrounding their respective colonies, but there was considerable overlap in the feeding sites of herons from these colonies. The major feeding sites of mainland nesting herons, as suggested by flight line patterns, were the large wetland areas of Sandusky Bay and Muddy Creek Bay (Table 5 and Fig. 4). The Portage River northwest of the colonies was also used as a feeding site. The feeding site distances from the colonies ranged from adjacent to the colony to 10 km away, however, most of the herons used feeding sites up to 5 km away. Although not a common occurrence, a few herons from the Mackey colony were

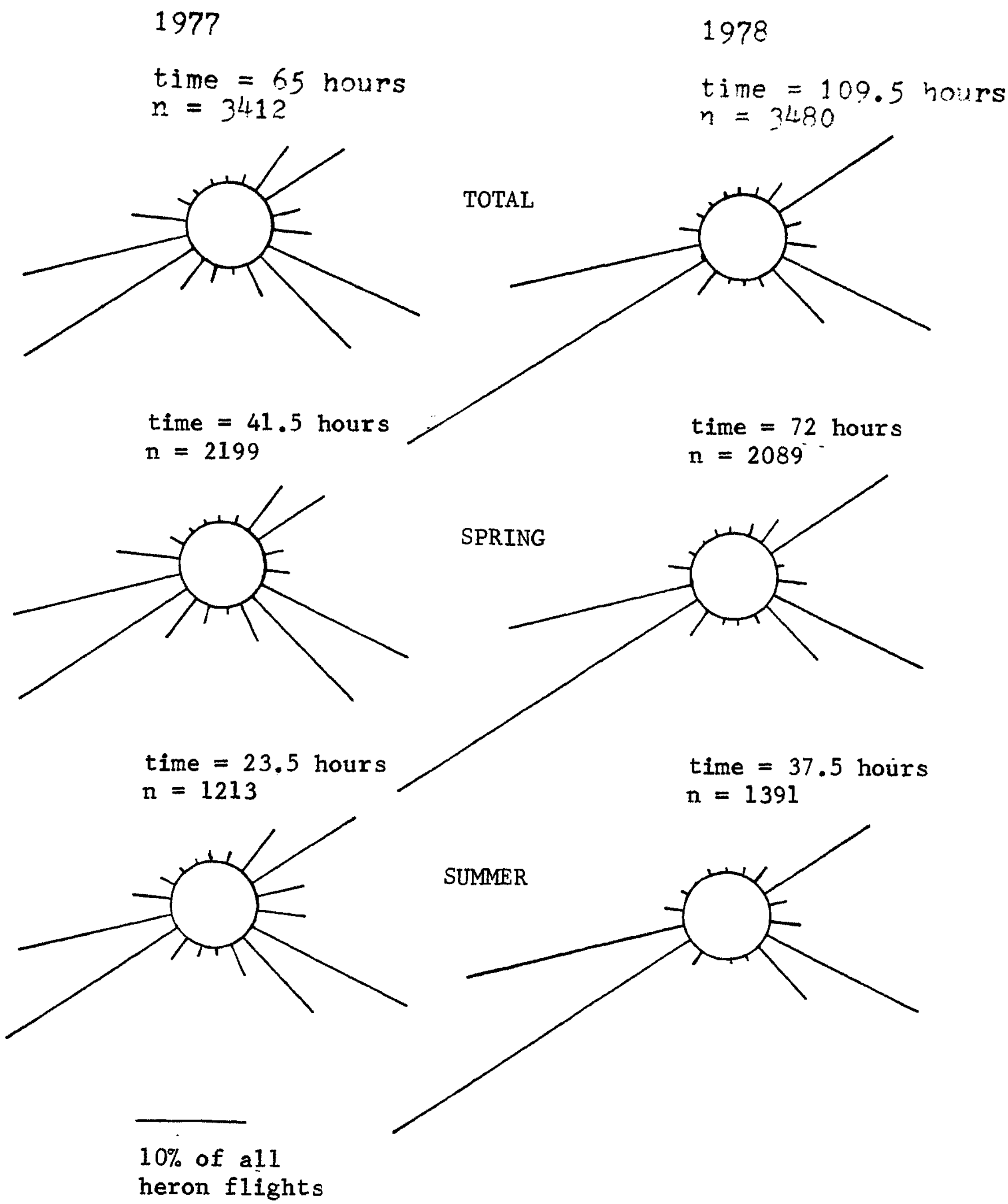


Figure 8. Yearly and seasonal flight lines for herons from the Hickory Isle heronry. Vector length represents percentage of herons using that flight direction and does not represent distance traveled. The time spent observing the heron flights and the number of herons observed are given.

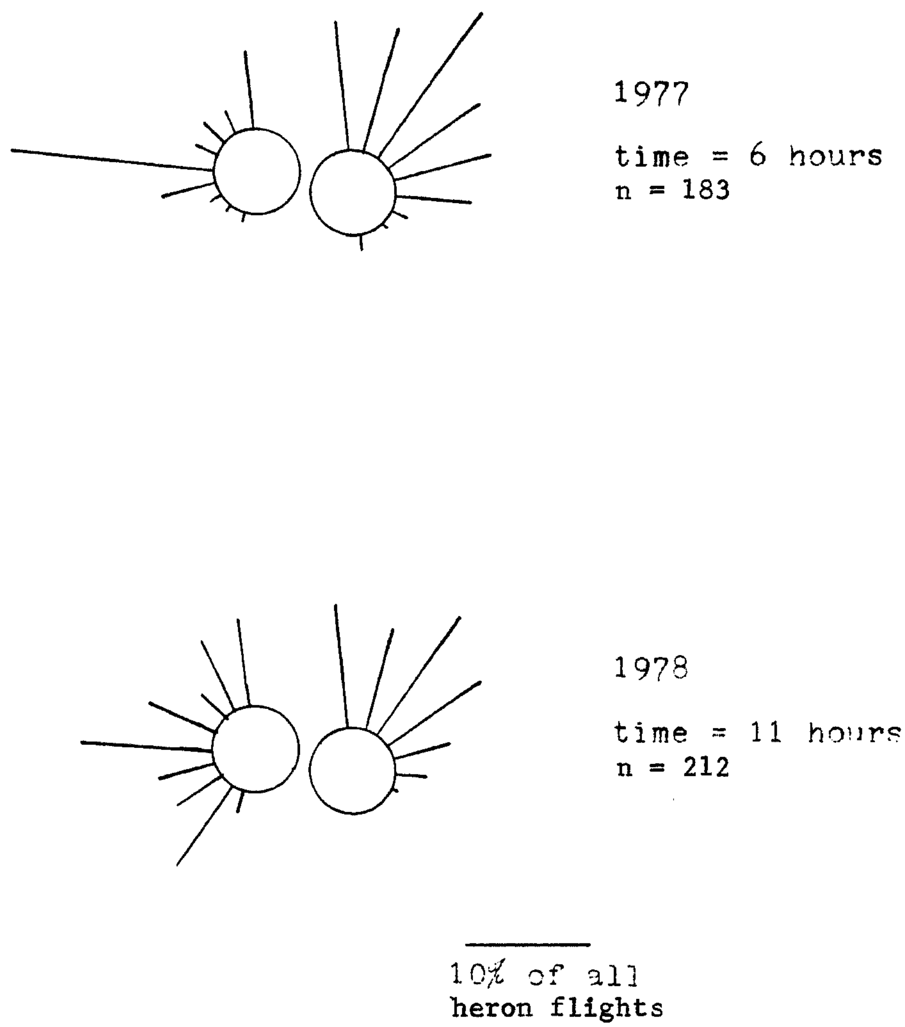


Figure 9. Yearly flight lines for herons from the Moxley heronry. Vector length represents percentage of herons using that flight direction and does not represent distance traveled. The time spent observing the heron flights and the number of herons observed are given. The two circles represent observation points around the colony.

TABLE 5. Foraging area size, distance from the closest Sandusky Bay colony, and use by Sandusky Bay herons. Location of the foraging sites are shown in Figure 4 and 5.

Foraging Site	Size (ha)	Distance from closest colony (Km)	Largest Number of herons observed during the breeding season	
			1977	1978
Port Clinton Beach 1/	12	6	9	3
Portage River (mouth) 1/	70	6	7 2/	16 2/
Darby Marsh 1/	283	6	80	54
Portage River	223	3	p 3/	p 3/
Little Portage River	183	5	36 2/	32 2/
Winous Point North Marsh 4/	390	0	274	334
Winous Point West Marsh 4/	497	0	252 2/	472
Winous Point South Marsh 4/	1,419	0	211	435
Muddy Creek 4/	183	3	61	71
Sandusky River	181	2	62	51
Misc. Wetland #1	107	3	16 2/	6
Misc. Wetland #2	22	6	7	5
Misc. Wetland #3	44	5	9	4
Willow Point Marsh	114	6	30	18
Moxley Marsh 4/	529	0	81 2/	123 2/
East Harbor State Park	23	10	7	5

1/ foraging site also used by island nesting herons
2/ estimate based on partial count of herons at site
3/ herons present but not counted
4/ and associated wetlands

observed flying to the large marsh bordering the Moxley colony a distance of approximately 16 km. The total shallow water foraging area used by Sandusky Bay nesting herons was 4,280 ha.

The sixteen Sandusky Bay nesting herons captured and fitted with radio transmitters in 1977 and 1978 were all from the Mackey colony. The feeding locations of these radio-equipped herons were similar to the feeding locations found with the flight line and habitat searching techniques (feeding areas # 4,5,6,7,8,9,10, and 12, Fig. 4). The majority of daily locations of these radio-equipped herons were within 5 km of the colony, and the furthest location was approximately 8 km from the colony (Table 4).

Miscellaneous feeding sites - Several habitats, such as drainage ditches, streams, farm ponds and shoreline not associate with wetland habitat, were not included in calculating the total area used by foraging herons. Although Great Blue Herons from the Sandusky Bay and West Sister Island colonies were observed feeding in all of these habitats, these areas were not thought to be major foraging sites. Drainage ditches along roadways and irrigation ditches were used as foraging sites but sustained use of these areas was not considered significant because of the temporary nature of the water supply in these ditches . There are 180+ farm ponds (U.S. Geological Survey Maps, 1972) in the southwestern Lake Erie region but a number of characteristics, such as steep side construction, close proximity to residences, and recreational activities (Stockdale 1976), make most of them undesirable as heron feeding sites. Streams and shoreline not associated with wetland probably provided more potential foraging sites than the other two habitats but their overall contribution to the heron foraging area was not considered significant. The majority of herons found at streams were located at backwater areas and places where the bank vegetation was sparse and open. Streams were not considered significant foraging areas because most of the small streams in the area were heavily wooded and the canopy partly or completely enclosed the stream. Shoreline not associated with wetlands was not considered to significantly contribute to heron foraging areas because many of these areas were near residential areas or were used for human recreational activity.

Feeding site patterns - Although differences existed in foraging site use by herons from different colonies, certain major feeding site patterns were apparent. Herons from all the colonies foraged in shallow water habitats including diked marsh, undiked marsh, and rivers with no use of terrestrial habitats as major foraging sites. All colonies in the areas had flight line patterns with the majority of heron movement contained within a few major flight lines leading to large feeding areas. Heron flight lines also were highly correlated yearly and seasonally suggesting relatively constant use of feeding sites by the herons breeding in each colony. Although distances traveled to obtain food varied between colonies, herons from all the colonies tended to feed in shallow water areas closest to the colony as shown for Herring Gulls (Drury and Nisbet 1969). Differences in distance traveled by island and mainland nesting herons was due to the location of the colony site in relation to feeding sites. The shallow water foraging areas were approximately 14 to 29 km from the island colony and within 10 km of the Sandusky Bay colonies. The amounts of shallow water habitat used as foraging areas by island and mainland nesting herons also were similar. Island nesting herons, roughly 2300 breeding adults, used approximately 5,300 ha of shallow water habitat and the mainland nesting herons, roughly 2200 breeding adults, used approximately 4,280 ha of shallow water habitat. Custer and Osborn (1977), Werschkul et al. (1977) and Buckley (in Prep.) also found the number of breeding herons in an area to be correlated with the amount of shallow water habitat nearby. The Sandusky Bay herons' and island nesting herons' feeding areas overlapped on only 5% to the total foraging area. Thus the differences in mercury levels in these two heron populations (Hoffman 1974) could be attributed to a separation of feeding areas during the breeding season. The smaller colonies on Sandusky Bay tended to avoid using feeding sites adjacent to the large colony but there was prevalent overlap at other feeding sites by herons in these colonies. Thus, the amount of overlap in feeding sties by herons from different colonies is likely related to the distances between the colonies, the location of foraging areas, and possibly the origin of the colonies, since the Sandusky Bay heronries were established when the original heronry broke up.

BEHAVIOR

Heronry Stratification - Two colonial waterbird studies (Krebs 1974 and Davis 1973) have shown that birds nesting close together or in one section of a colony often feed in the same general area. The Hickory Isle heronry was chosen to examine the relationship between a heron's nest location within a heronry and its respective feeding site because all herons were easily observed in this relatively small and open colony. During the 1978 flight line observations, nest location within the heronry as well as flight direction was recorded. Due to the nature of the woodlot, the colony was easily divided into three sections (Fig. 10). In 1978, there were 31 nests in section A, 57 nests in section B, and 11 nests in section C. If stratification of the heronry did not occur, the flight line pattern of each heronry section would be expected to mimic the flight line pattern of the whole colony and the other sections. There was a significant difference ($X^2 = 1,714.74$, d.f. = 36 $P < .005$) in the flight line patterns of the different sections of the heronry (Fig. 11). Herons from section A used eastern flight directions mainly, herons from section B used western flight directions most frequently, and herons from section C used southwestern and western flight directions almost exclusively. Although the flight line data tend to suggest stratification of the heronry, this stratification was not absolute because all of the major flight lines were used by herons from each section.

The role of flocking in association with heronry stratification also was examined during this study. Krebs (1974) found stratification within a heronry due to herons leaving the colony in flocks. During our flight line observations, the number of herons leaving the colony in flocks also was recorded. A flock was defined as two or more herons leaving the heronry within 300 meters of each other and flying in the same direction. All the colonies had birds leaving in flocks. One obvious pattern was that flocking was positively correlated with the size of the heronry (Table 6). Flocks from Hickory Isle heronry were separated into two categories. Homogeneous flocks were composed of herons from the same nest section, and heterogeneous flocks were composed of herons from different nest sections. As shown by Krebs (1974), herons flocked

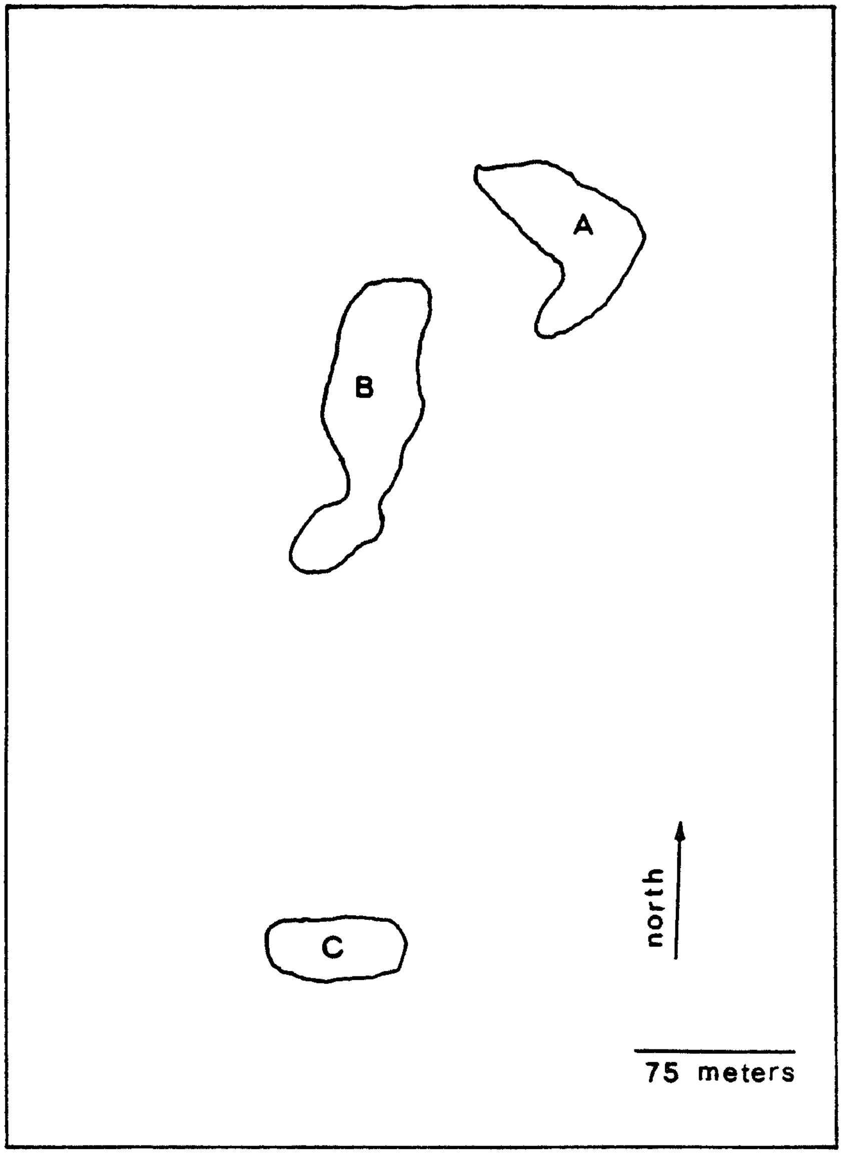


Figure 10. The spatial arrangement of the three nest sections (A, B, and C) of the Hickory Isle heronry during 1978.

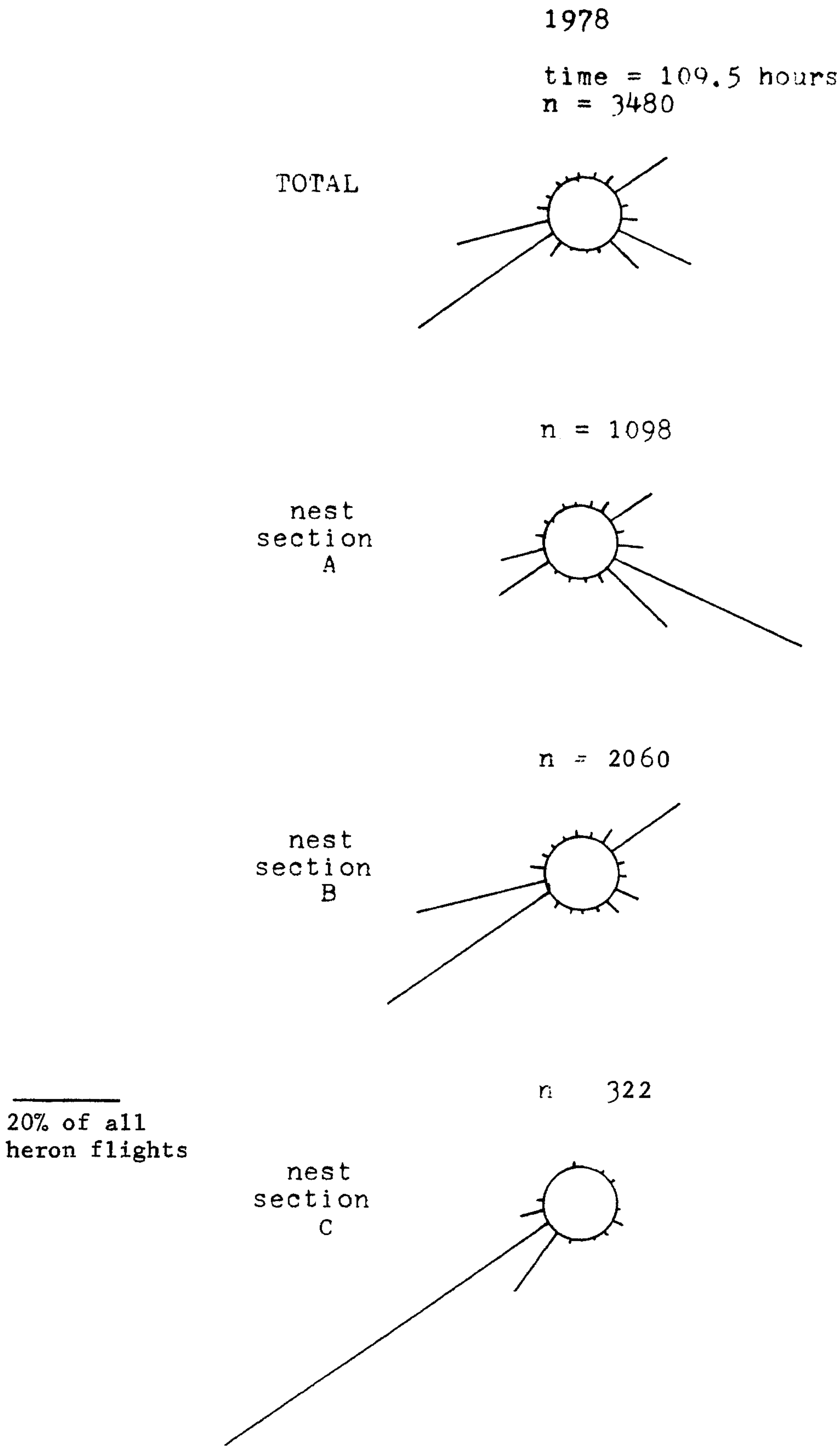


Figure 11. Yearly flight lines for herons from the three sections (A, B, and C) of the Hickory Isle heronry during 1978. Vector length represents percentage of herons using that flight direction and does not represent distance traveled.

TABLE 6. Percentage of herons leaving the colony in flocks for the West Sister Island and Sandusky Bay colonies during 1977 and 1978.

Colony	Year	Population Size 1/ (Pairs)	% of herons departing in flocks from the colony 1/
Moxley	1977	87	10.2
Hickory Isle	1978	99	11.4
Hickory Isle	1977	127	15.1
Moxley	1978	131	9.7
Lane	1977	175	24.5
Mackey	1977	647	24.5
Mackey	1978	904	31.2
West Sister Island	1977	1,158	49.7
West Sister Island	1978	1,167	45.7

1/ Spearman's Rank Correlation, $P < .01$

significantly more with herons from the same nest section than with herons from another section of the heronry (Table 7). Thus, herons leaving the colony in flocks tend to be with birds from neighboring nests. Krebs (1974) hypothesized that colony stratification and flocking with nearest neighbors allowed for a transfer of information on choice feeding sites. Although we made no attempt to follow flocks to the feeding site, we observed individuals from some flocks land at the same site and feed together while individuals in other flocks left the flock and fed at widely separate locations. The feeding sites in this study were relatively stable without large changes in water levels or location. Under these conditins, we found no evidence to inidicate that flocking served an information transfer function, and consider the flocks to best fit Etkin's (1964) definition of aggregations.

Foraging Great Blue Herons exhibited a range of sociality from the occurrence of single birds to large groups depending on habitat, geographic area, and time of the breeding cycle. In the southwestern Lake Erie region, both individuals and groups occur at the foraging site, but groups appear to be the norm for both loafing and foraging herons. For this study, group size was the number of herons within 50 m of the heron under observation for ten min. Although group sizes were generally small, loafing herons were observed in groups up to approximately 100 individuals and foraging herons were observed in groups up to approximately 200 indivuduals.

A number of wading bird studies (Grubb 1976, Krebs 1974, and Kushlan 1978) have shown group size to be related to foraging success. In this study, herons foraging in groups had a significantly greater prey intake rate

TABLE 7. Flock composition with respect to nest sections (A, B, and C) within the Hickory Isle heronry during 1978.

	Number of Flocks					
	homogeneous flocks			heterogneous flocks		
	AA	BB	CC	AB	BC	AC
Observed	32	106	13	25	8	1
Expected	11	81	2	60	23	9

X = 145.62, d.f. = 5, P < .001

than herons foraging alone (Wilcoxin Test, $P < .001$) (Table 8). Previous studies have suggested that the relation between foraging success and flock size was due either to some type of communal or coordinated behavior by the individuals in the group that enhanced foraging success (Grubb 1976 and Kushlan 1978) or to prey abundance in prime feeding habitats (Krebs 1974 and Willard 1977). The extremely large groups observed during this study were the result of the wetland management practices which decreased water levels and concentrated prey in certain areas similar to Kushlan's (1976) pond with fluctuating water levels. However, the smaller groups and single herons observed during my timed observations were in the same marsh units. The number of steps taken by single foraging herons during a ten min observation period ($\overline{X}$ = 65.5, S.D. = 43.6, N = 54) was not significantly different from the number of steps taken by herons foraging in groups ($\overline{X}$ = 64.1, S.D. = 39.5, N = 287). Herons in groups exhibited no easily observable but unusual behavior as compared to single foraging herons, suggesting that behavior was not responsible for increased foraging success in groups. As Krebs (1974) found for Great Blue Herons in British Columbia, our flocks appeared to be aggregations in prime feeding areas but more information is needed on prey distribution.

Individual heron feeding sites - Individual heron feeding sites were determined by monitoring the movements of eighteen radio-equipped Great Blue Herons. The individual's location was identified to marsh unit rather than the exact position in the marsh due to the limited capabilities of the telemetry equipment. Marsh units ranged in size from 75 to 500 ha, and were separated by dikes (or had been at one time) or were local names for areas of a particularly large wetland. Because marsh units varied in size, certain aspects of the movement

TABLE 8. Prey intake rate (gm per ten min) of Great Blue Herons under various conditions.

	Prey Intake Rate		
	$\overline{X}$	S.D.	N
Age			
Adult	11.4	20.2	341
Young	5.9	11.2	92
Group Size			
1	5.0	17.2	54
> 1	12.5	20.8	287
Month			
April	8.2	17.4	11
May	10.8	22.3	83
June	15.6	17.2	29
July	12.5	18.6	76
August	10.5	18.8	142

behavior and individual feeding sites of radio-tagged herons were difficult to ascertain and evaluate numerically, but major feeding patterns were evident from the data.

During the breeding season, all radio-tagged herons foraged in two or more marsh units (Table 9). While some of the herons tended to feed in neighboring and associated marsh units, others used marsh units up to 9 km apart. The herons also foraged in several locations within a marsh unit. For example, one radio-tagged heron was observed foraging in two different areas, a pool and a channel, and to loaf in a large tree on one marsh unit. Individual herons did not forage in just one habitat type, but could be found in diked wetlands, undiked wetlands, and rivers. No obvious pattern of marsh unit use was exhibited by the herons over the breeding season. The telemetry data for heron #10 during the 1978 field season exhibits the typical feeding site use pattern during the breeding season (Table 10 and Fig. 12).

Some yearly variation in the foraging location of individuals occurs although the major foraging sites for each colony did not change. In 1978, one heron from the 1977 field season returned and was located in the colony it nested in the previous year. Unfortunately, this heron's transmitter functioned erratically in 1978, but the bird was located on several feeding sites over the 1978 season. Only two of these sites were marsh units used for foraging the previous year. A few herons color marked as nestlings in the Sandusky Bay colonies were observed in the West Sister Island colony in later years. One adult, radio-tagged in 1977, was not located in the southwestern Lake Eire region during the 1978 breeding season. However, after the 1978

TABLE 9. Number of marsh units used by radio-equipped herons during the breeding season and the distance of the marsh units from the colony.

Heron Number	Capture Date	Field Season	Last Date Located in Colony	# of marsh units utilized	distance from the colony (Km)
Mackey Heronry					
1	6/9	1977	7/3	6	.8-4.7
2	6/15	1977	7/7	5	1.0-2.7
3	6/19	1977	7/10	5	1.1-5.8
4	6.23	1977	7/6	4	1.0-1.9
4 1/	-	1978	6/20	6	1.0-6.1
5	6/24	1977	6/30	2	1.0-1.6
6	6/25	1977	7/4	3	.8-1.6
7 1/	7/2	1977	7/6	2	1.0-1.6
8	7/8	1977	-	-	-
9 1/	3/29	1978	6/23	5	1.0-4.2
10	4/21	1978	7/8	12	.8-4.7
11 1/	4/27	1978	4/28	2	.8-1.0
12 2/	5/11	1978	6/1	6	.8-5.5
13	5/30	1978	7/20	9	.8-4.2
14	6/7	1978	7/4	8	.8-6.1
15	6/13	1978	7/13	8	.8-6.9
16 2/	6/24	1978	7/9	4	.8-1.6
West Sister Island Heronry					
17	6/27	1978	7/1	5	14.3-15.8
18	6/29	1978	7/8	4	14.5-15.6

1/ solar powered transmitter functioned erratically

2/ battery powered transmitter believed to have discharged early

TABLE 10. Locations of heron # 10 during the 1978 breeding season. The location symbols refer to the sites, shown in Figure 12.

Date	Amount Time (h) Monitored	Locations
4/21	x 1/	1B, Colony
4/22	x	Colony
•		
4/24	x	1A
4/25	x	1A
•		
•		
5/24	x	Colony, 1A
5/25	x	1E, Colony
5/26	x	le, Colony
5/27	13.25	1E, Colony, 1A, lm
5/28	12.67	1E, Colony, 1B
5/29	x	Colony, 1A, 1E
5/30	x	Colony, 1A
5/31	x	Colony
6/1	11.00	1E, Colony, 1A, 1f
6/2	13.50	Colony, 1k
6/3	1.50	1E, 1H
6/4	22.33	1H, Colony 1A, 1B, 1E
6/5	x	Colony, 1E
6/6	13.50	Colony, 1E, 1A
6/7	1.50	Colony
6/8	21.83	Colony, 1K, 1E
6/9	x	1A, Colony
6/10	1.50	Colony
6/11	22.33	Colony, 1K, 1B
6/12	x	Colony
6/13	12.92	Colony, 1B
6/14	x	Colony, 1B
6/15	x	1k, Colony
6/16	x	Colony
6/17	x	-
6/18	x	lm, Colony
6/19	0 .50	Colony
6/20	22.33	lm, Colony
6/21	x	1k
6/22	1.00	1L
6/23	22.00	Colony, 1k
6/24	22.00	1m
6/25	22.00	1h, Colony, 1m
6/26	x	1m
6/27	x	Colony
6/28	x	1h
6/29	x	Colony
6/30	x	Colony
7/1	x	Colony
7/2	x	1B
7/3	12.16	Colony, 1i, 1L
7/4	11.75	1f, Colony, 1h
7/5	x	1h
7/6	x	1f
7/7	x	Colony
7/8	x	Colony

1/ one to five radio locations obtained, but heron not continuously monitored

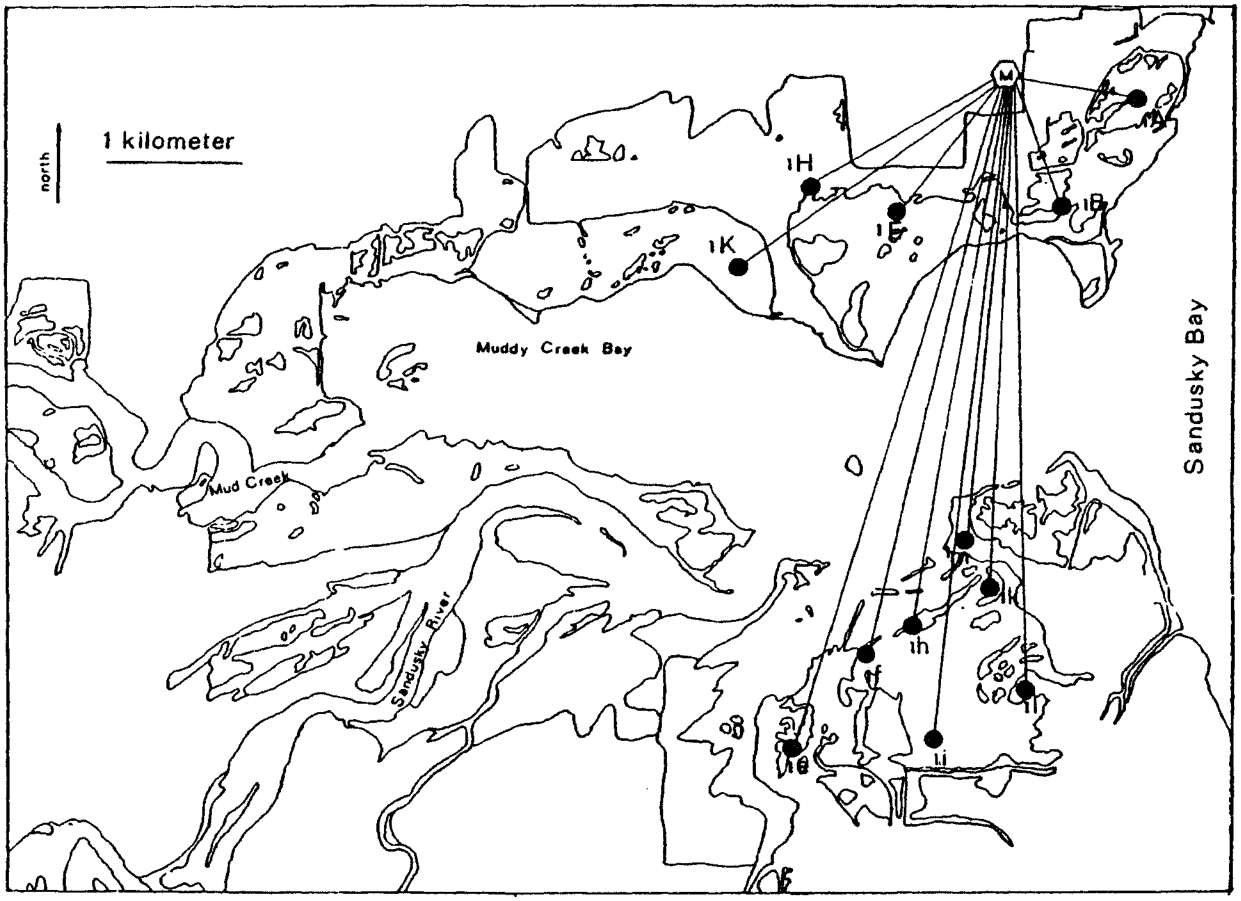


Figure 12. Feeding sites of radio-equipped heron #10 during the 1978 season.

breeding season, a radio signal corresponding to this heron's transmitter was detected at Lum Michigan approximately 182 km north of the study area. This heron may have nested north of the Lake Erie region in 1978. The failure by Guttman et al. (In Press) to detect genetic differences between herons in the West Sister Island and Mackey colonies also indicates some lack of loyalty to the heronry and surrounding feeding areas.

Daily movements - For daily movement information, radio-tagged herons were tracked for periods of 20 to 25 hours. The total distance traveled during these tracking periods varied greatly between mainland and island nesting herons, because of the farther distance of the feeding sites from the colony for the island nesting herons. In a 20 to 25 hour tracking period, mainland nesting herons traveled an average of 9 km and island nesting herons traveled an average of 83 km (Table 11). Sixty four trips from the colony to the feeding areas and back to the colony were recorded. The herons visited only one marsh unit in 85.9% of these trips, two marsh units in 10.9% of the trips, and three units in 3.1% of the trips. Mainland nesting herons visited an average of 2.1 marsh units per traking period and island nesting herons averaged 3.0 marsh units (Table 11).

The radio-tagged herons were located during the night as well as the day to determine differences in activity. For both night and daylight observations, there was a seasonal trend for the herons to spend less time in the colony as the season progressed (Table 12). However, herons tend to be at the colony more frequently at night than during the day. There was almost an absence of movement between the colony and feeding areas at night as compared

TABLE 11. Distance traveled and number of marsh units visited by radio-tagged herons during 20 to 25 hour tracking periods.

	Distance Traveled (km)			# of Marsh Units Visited		
	$\overline{X}$	(S.D.)	Range	$\overline{X}$	(S.D.)	Range
Breeding Season						
West Sister Island 1/ N = 2	82.8	(20.9)	61.8-103.7	3.0	(1.0)	2-4
Mainland N = 22	9.2	(4.2)	3.5-16.7	2.1	(.8)	1-4
Post-Breeding Season						
Mainland N = 3	2.9	(.8)	2.3-4.2	2.3	(.5)	2-3

1/ West Sister Island herons were only tracked at the feeding site and when not located at the feeding site were presumed to be at the heronry.

TABLE 12. Time in the colony and number of moves between colony and marsh by radio-tagged herons during daylight and at night.

Month	Daylight			Night		
	Time monitored (hours)	% time in Colony	# moves per hour	Time monitored (hours)	% time in Colony	# moves per hour
April	9.5	63.0	.42	.5	100.0	0
May	46.9	47.1	.32	4.9	50.0	0
June	398.8	37.2	.27	162.2	59.0	.10
July	191.4	18.9	.22	44.6	10.9	.04

to daylight hours. The low rate of movement during the night and the tendency to spend more time in the heronry at this time indicate that night foraging was not as frequent or as significant as daylight foraging.

Aggressive interactions - Aggressive interactions at the foraging site usually resulted from violations of individual distance when one heron strayed too close to another foraging heron or when one heron approached a heron handling prey. The aggressive interaction consisted of a display, similar to that described by Cook (1978b) for the Grey Heron (*Ardea cineria*), or a display coupled with a chase. If the intruding heron did not leave the immediate area after a display, the displaying heron lunged and gave chase. Chases occurred after 86% of the 35 displays observed during the timed foraging observations. Occasionally, an intruding heron also performed the aggessive display and both herons then displayed while approaching each other. Usually, one eventually flew or walked away, but when neither backed down, they approached to within one meter of each other, and jumped upwards and towards each other to bringing the wings and feet into striking position. Pecking did not occur in this situation. One or both of the combatants left the area after this type of encounter.

The activity of the closely spaced herons determined whether or not aggressive interactions occurred. Loafing herons did not have aggressive interactions even though the herons were close together. Nine percent of the timed foraging observations contained aggressive interactions, and as group size increased, so did the number of interactions (Table 13). Krebs (1974) also

TABLE 13. Aggresive interaction rates for herons foraging in various size groups.

Group Size	# of Aggressive Interactions 1/	Aggresive Interaction Rate (per minute) 1/
1	0	0
2-3	5	.005
4-5	10	.011
6-7	5	.009
>7	15	.048

1/ Spearman's Rank Correlation, $P < .05$

found an increase in aggressive interactions with an increase in group size. The effect of activity on "individual distance" has been shown for other species, for example gazelle (Walther 1977).

The Great Blue Herons in the southwestern Lake Erie region did not show evidence of being territorial at the feeding site. Territories are generally recognized by a change in the individual's behavior (example, aggressiveness to conspecifics) when it crosses the fixed boundary it has established. Thus, the boundaries do not move as the individual moves within the territory. "Individual distance" refers to a specific distance from the individual (Hediger 1968) and as the individual moves the individual distance also moves with it. The aggression shown at the feeding site was apparently released by violations of individual distance rather than crossing fixed boundaries established by the herons. The herons also used a number of feeding sites each day instead of feeding repeatedly within recognized boundaries as reported by Bayer (1978). Thus, territorial behavior was not evident on the foraging sites we studied and the individuals fed (or sampled the environment) at widely spaced locations.

Post-breeding behavior - After the breeding season, some radio-equipped Great Blue Herons dispersed from the area while others lingered in the feeding areas. Although a few herons over-wintered in the Lake Erie marshes, radio-equipped herons remained in the area only up to 93+ days after breeding (Table 14). Herons that stayed in the feeding areas tended to feed in the same marsh units they used during the breeding season plus other marsh units

TABLE 14. Great Blue Heron utilization of feeding sites in southwestern Lake Erie during the breeding and post-breeding seasons.

Herons #	No. marsh units utilized		Overlap	Days in Lake Erie Area,
	breeding season	post-breeding season	No. of units	Post-breeding
1	6	3	2	9
2	5	4	2	18
3	5	3	1	12
4	5	3	0	93+
4 1/	6	-	-	-
5	2	3	2	14+ 3/
6	3	3	2	10
7 1/	2	5	1	87±7
8	-	3	-	-
9 1/	5	-	-	-
10	12	6	4	58±11
11 1/	2	5	0	-
12 2/	6	-	-	-
13	9	6	5	46±11
14	8	1	1	4
15	8	5	3	53±11
16 2/	4	1	1	2
17	5	2	0	42±12
18	4	3	1	12

1/ Solar powered radio-transmitter functioned erratically
2/ Battery powered radio-transmitter believed to have discharged
3/ Heron was recaptured and transmitter removed 14 days post-breeding

not previously used (Table 14). These herons generally did not use the colony during this time, and the distance of their daily movements decreased (Table 11). However, the birds still foraged in approximately 2 marsh units per day.

Four radio-tagged herons were located after the breeding season outside the breeding area. All of these locations were in a southwesterly direction from the breeding area indicating the adults' initial orientation in post-breeding wanderings was towards the Mississippi drainage system (Fig. 13). The four locations all in the same general direction could indicate a narrow migration corridor to wintering areas, but more information is needed on this topic.

HERON ABUNDANCE AT FEEDING SITES

The number of foraging herons at a foraging site is not static and many variables influence the utilization of a given area on a seasonal or daily basis. Little scientific literature on daily use is available. An attempt was made to observe and record the more common factors that influence the number of herons foraging at an area during observations on feeding behavior.

Breeding stage - Various activities, such as pair bond formation and maintenance, nest site construction, repair, and defense, and care of the young, require a large amount of time at the nest site. The energy demands of the growing nestlings on the other hand require increased foraging activities by the parents. Thus, herons spend more time at the nest site during the early and mid stages of breeding and forage more during the late breeding

Figure 13. Locations of radio-equipped herons from the island and mainland colonies outside of the breeding area during the post-breeding season.

stages (Bayer 1978 and Brandman 1976). We recorded heron activities at the nest during the breeding season and how this behavior was related to the number of herons at the foraging sites. In 1978, thirteen select nests in the Hickory Isle heronry were observed for information on the number of parents present at the nest, the posture of the parent at the nest, and the number or nest material gathering trips made. In addition, the total number of nests in the colony and the number of nests occupied by adults or young, were recorded throughout the season. Five distinct phases, courtship, incubation-initial brooding, brooding-late breeding, fledging, and initial post-breeding, can be seen in Great Blue Heron reproductive behavior. These phases are often overlapping within the colony due to incomplete breeding synchronization between pairs in the colony.

The courtship stage began in mid March and ended in mid April. Because of ice in Muddy Creek Bay preventing access to the heronry, we were unable to observe early and mid courtship behavior. During late courtship, the number of nests within the colony increased and the highest rate of nest material gathering trips was observed (Fig. 14 and 15). Nest material gathering trips were those where one partner leaves the nest flies a short distance from the colony, picks up a twig, flies back to the nest site, and then usually gives the twig to its partner. These trips strengthen the pair bond (Mock 1976) as well as provide material for nest construction and repair. Material gathering trips are generally to an area close to the colony and frequently within the colony. At this breeding stage, both parents spend a large amount of time at the nest (Fig. 15). The most common posture of the parent at the nest was standing (Fig. 15).

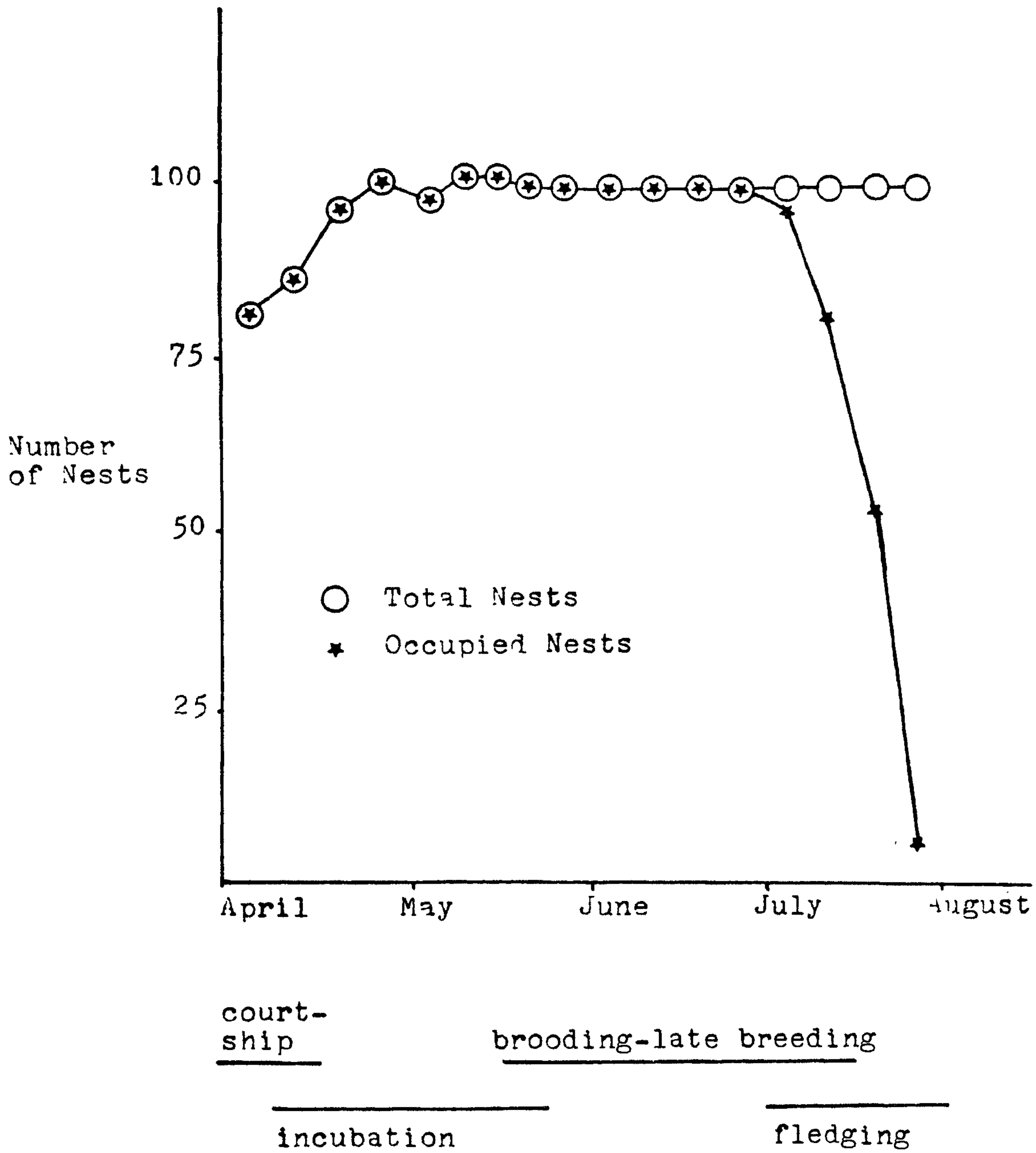


Figure 14. Number of nests and number of occupied nests in relation to four breeding stages in the Hickory Isle heronry during 1978.

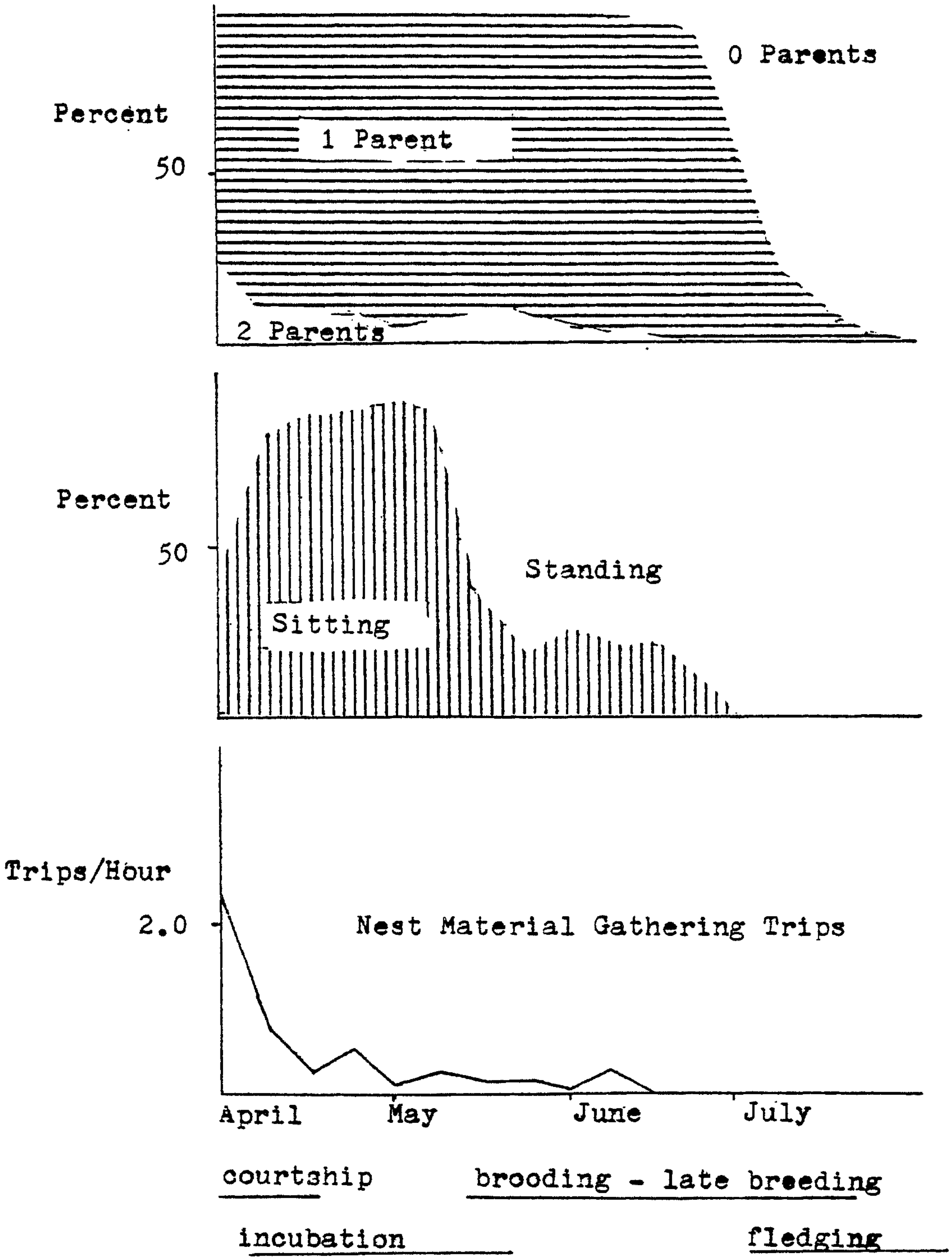


Figure 15. The amount of time the parents attended their nest, their posture while at the nest, and the frequency of nest material gathering trips per nest for the Hickory Isle colony based on weekly observations of thirteen nests from the first week of April to the last week of July 1978,

The incubation-initial brooding stage started in early April and ended in mid to late May. The number of nests in the colony was stabilized at this time and all nests were occupied (Fig. 14). Nest material gathering trips were reduced from the courtship stage rate (Fig. 15). Fewer nests had both parents present and sitting, the most common adult posture at the nest, was associated with incubation of eggs or brooding of small young (Fig. 15).

During the brooding-late breeding stage from mid May to mid July, the colony size was stable (Fig. 14). Nest material gathering trips were present at the beginning but absent by the end of this stage (Fig. 15). Both parents were rarely observed together at the nest, and incubation or brooding was not frequent (Fig. 15). At this time, nestlings were quite readily seen and heard by observers on the ground. Some nests no longer had at least one parent in constant attendance at the nest (Fig. 15).

The fledging stage during the month of July was characterized by the rapid decline of occupied nests in the colony (Fig. 14). At this stage, most nests no longer had a parent in constant attendance and the adults did not sit while at the nest (Fig. 15). Young of the year were observed at the foraging site starting the first week of July 1978.

The last stage was the post-breeding stage. This stage started in mid July and ended at the end of summer. The colony was empty by the first week of August although young and adult herons were occasionally seen roosting in the colony. This stage was characterized by some young and adult herons leaving the breeding area.

The different breeding stages of Great Blue Herons were reflected in the number of herons present at the feeding site. Three different foraging habitats, diked marsh, undiked marsh, and shoreline, were censused periodically for herons throughout the 1978 field season. Although there were daily variations, the number of adults on the foraging sites was low during courtship and incubation, increased through the late breeding stage and peaked at the fledging stage when the young were also at the site (Table 15). During the post-breeding stage there was a decrease in the number of herons present at the foraging site due to initial dispersion of many of the young and adult herons.

Prey intake by adults increased from April through June when the nestlings were making their greatest demand for food and then declined through July and August as the nestlings fledged and became independent (Table 8). Because of the large variability in prey intake, these differences were not statistically significant (Kruskal-Wallis Test, P = .15). The variation is attributed to the lack of knowledge on the nesting stage of adults observed on the foraging site.

Habitat type and wetland management - Although some researchers (Bent 1926, Martin et al. 1961 and Palmer 1962) report Great Blue Herons feeding in terrestrial habitats, we did not find terrestrial foraging herons in the southwestern Lake Erie region. Many different shallow water habitats in the southwestern Lake Erie region were used as foraging sites by Great Blue Herons, but this study focused on only three of these habitats.

TABLE 15. Number of herons present at three different shallow water habitats by month over the 1978 season.

Month	N	Number of Herons					
		Diked Marsh		Undiked Marsh		Shoreline	
		$\overline{X}$	(S.D.)	$\overline{X}$	(S.D.)	$\overline{X}$	(S.D.)
March	2	1.5	(.5)	0	(0)	0	(0)
April	13	7.2	(3.2)	1.4	(1.1)	2.6	(2.1)
May	15	23.4	(15.6)	2.5	(2.3)	3.5	(4.1)
June	12	38.3	(20.2)	3.3	(1.1)	5.3	(3.1)
July	14	57.9	(21.7)	4.9	(3.7)	18.0	(15.4)
August	10	23.4	(9.8)	3.1	(.9)	9.6	(5.1)

The three habitats studied in 1978 included diked marsh, undiked marsh, and shoreline. All three of these sites were approximately 1 km from the largest mainland colony. The diked marsh was 237 ha in size and its prime management was a drawdown in mid to late May to decrease water levels and expose mudflats to promote emergent aquatic plant germination, growth, and development. The undiked marsh was 30 ha in size and its water level was affected only by the bay's fluctuations. The shoreline habitat was 74 ha in size and was located along a dike. Although diked marsh had the greatest heron use no significant difference in heron use per ha was found (Table 16).

Because the diked marsh with water level control tended to have more heron use and occasionally contained larger flocks during water level drawdown, several parameters in the 237 ha diked marsh were measured weekly from May to August. Water depth was measured along a transect across the marsh, turbidity samples were taken, and the fish in two fish traps were counted. Turbidity fluctuated widely due to runoff from the agricultural watershed and wind conditions and was not correlated to the seasonal increase in feeding herons (Fig. 16). The mean of all the weekly turbidity samples was 21.3 J.T.U. (S.D. 12.6) which was similar to the turbidity readings found for Great Egret feeding sites in two marine habitats of 22.3 J.T.U. and 28.2 J.T.U. (Custer and Osborn 1978). Water levels decreased and mudflat areas increased due to pumping and evapo-transpiration from May to mid June and by evapo-transpiration from from May to the end of June and then a decrease through August (Fig. 16). Although weekly sampling with a trap was not considered reliable (Hanson 1944), patterns were evident from the data. The

TABLE 16. Heron abundance on three shallow water habitats (diked marsh, undiked marsh and shoreline) during the 1978 season.

Month	N	herons per ha					
		Diked Marsh		Undiked Marsh		Shoreline	
		$\overline{X}$	(S.D.)	$\overline{X}$	(S.D)	$\overline{X}$	(S.D.)
March	2	.05	(.02)	.0	(0)	.0	(0)
April	13	.20	(.07)	.30	(.25)	.22	(.17)
May	15	.57	(.40)	.52	(.47)	.30	(.37)
June	12	.99	(.52)	.67	(.22)	.44	(.27)
July	14	1.48	(.57)	1.01	(.77)	1.48	(1.28)
August	10	.59	(.25)	.64	(.20)	.79	(.42)
Total	66	.77	(.62)	.62	(.52)	.62	(.82)

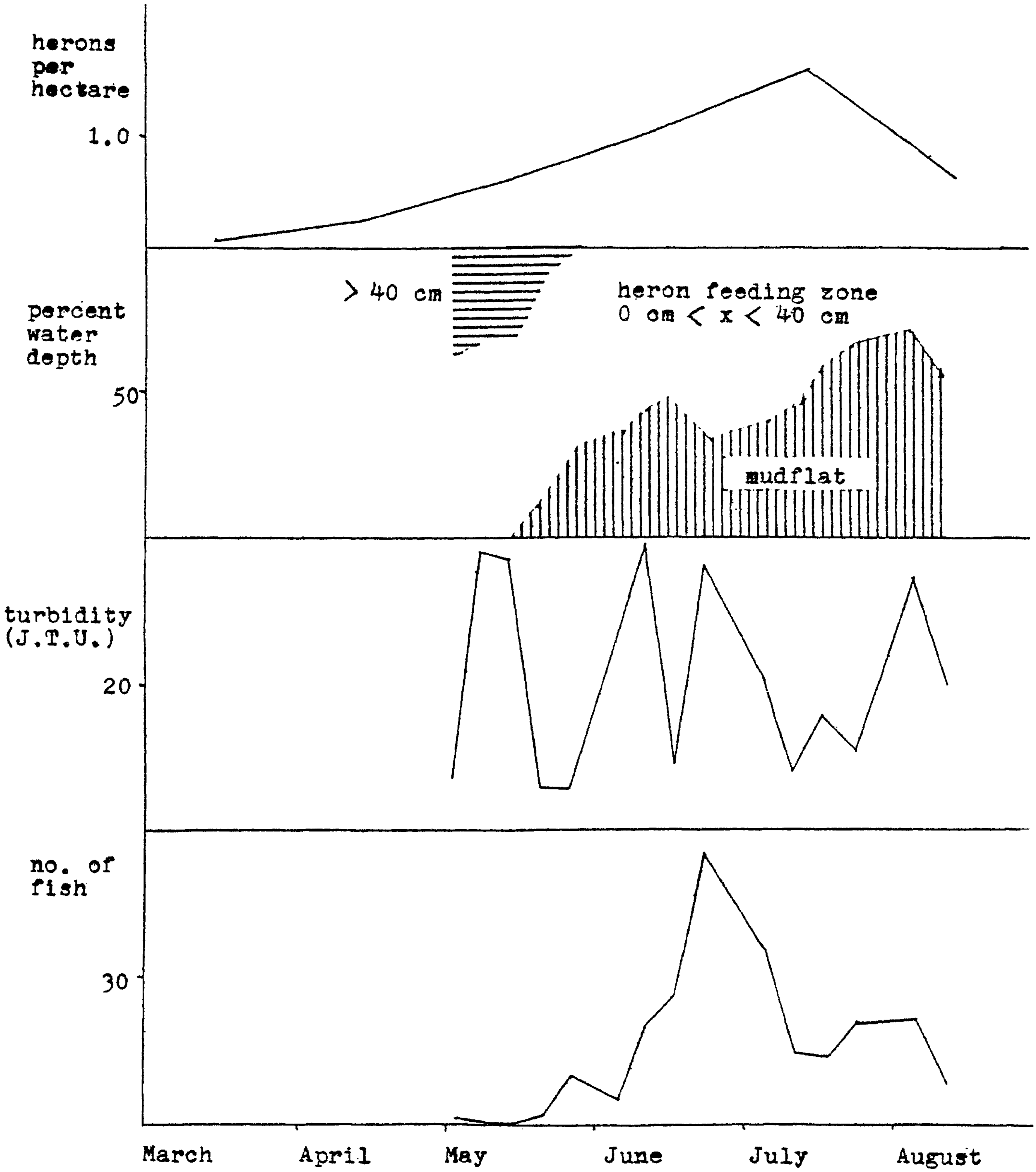


Figure 16. Monthly heron use, weekly water depth, turbidity, and number of fish trapped from a managed, diked marsh during 1978.

peak of fish abundance occurring in June was due to decreasing water levels which concentrated the prey and also to recruitment in the population when young fish reached a size of 5 cm and were able to be caught in the traps. Fish abundance peaked in late June and early July and coincided with the time of increased food needs by the developing herons. Brandman (1976) and Owen (1960) also found this correlation in timing of heron breeding.

Studies by Lack (1954), Custer and Osborn (1977), and Fascola and Barbiere (1978) have shown that heron colony size was related to the amount of shallow water foraging habitat available to these birds. Our counts and estimates of herons at major foraging sites in the southwestern Lake Erie region were rough due to the nature of the feeding sites and their inaccessability, but these counts indicate, with a few exceptions, the larger the area the greater the number of herons observed feeding there (Tables 3 and 5).

The number of herons feeding at bay and lake shoreline in 1977 varied widely and appeared to be related to wave height. Thus, when counts of herons foraging in shoreline habitat were made in 1978, wave height was also measured. The dikes and emergent vegetation generally prevented the development of extreme wave conditions on the marsh habitats. Significantly more herons were at the foraging site when waves were under 10 cm in height than when wave conditions were over 10 cm (Table 17). This pattern occurred for most of the months the observations were made. Although waves over 10 cm did not directly affect the herons, their foraging success apparently was reduced.

It is obvious to anyone who walks or uses a boat in heron foraging habitat that herons flush and leave the area when approached, and they will flush at an even greater distance if the person approaches unexpectedly. Herons on only one small foraging area were believed to be affected by human disturbance. The Port Clinton beach was used by a few herons in the early part of both seasons but during the late breeding season in June and July, when human recreational activity at the beach reached high levels, no herons were observed foraging there. One common feature of all major heron foraging areas, both public and privately owned, was the lack of human disturbance due to terrain or the property owners prevention of human access.

TABLE 17. Number of herons present at a shoreline habitat under different wave conditions.

	Number of Herons						
	Wave < 10 cm			Wave > 10 cm			
Month	$\overline{X}$	(S.D.)	N	$\overline{X}$	(S.D.)	N	P (T-test)
March	0	(0)	2	-	-	0	-
April	3.8	(1.5)	9	0	(0)	4	.005
May	7.0	(3.6)	7	.5	(1.0)	8	.005
June	6.0	(3.0)	10	2.0	(1.0)	2	.05
July	21.7	(15.4)	11	4.3	(2.6)	3	.05
August	10.4	(4.7)	9	2.0	(0)	1	-

SUMMARY

This study was conducted from Febuary to August 1977 and from March to August 1978 in the southwestern Lake Erie region to determine the major feeding locations of Great Blue Herons from the colonies in the area. Factors affecting heronry stratification, individual heron feeding sites, heron movement behavior, aggressive behavior at the feeding site, and the abundance of herons at a feeding site also were studied. Ten Great Blue Heron colonies were located in the southwestern Lake Erie region. This study dealt with the larger heronries in the area, the West Sister Island colony and the Sandusky Bay colonies (Mackey, Lane, Hickory Isle and Moxley) which comprised 95% of the Great Blue Herons population breeding in this region.

The major feeding areas of Great Blue Herons from the West Sister Island heronry and the Sandusky Bay heronries were documented by observations of heron flight directions to and from colonies and feeding areas, and radio-telemetry. Flight directions from all the colonies were similar in that the majority of heron flights were contained within just a few flight directions. The flight line patterns for the colonies were relatively constant over the season and between years, indicating an over all fixed use of feeding areas. The Sandusky Bay colonies, approximately 2200 breeding adults, were in close proximity (within 16 km) to one another. Although the feeding sties for these colonies overlap, herons from the smaller colonies tended not to use the marshes around the larger colony. Herons from each section of a heronry tended to use different flight directions to the feeding areas and the members of flocks leaving the heronry tended to be from the same

section. However, the flock members did not always feed in the same area. The West Sister Island colony, approximately 2300 breeding adults, was located 14 km from the mainland and was 32 km from the closest Sandusky Bay colony. The Sandusky Bay Herons foraged within 10 km of the colonies in 4,280 ha of wetland, and the island nesting herons foraged 14 to 29 km from the colony in 5,300 ha of wetland. Feeding sites for the West Sister Island and Sandusky Bay herons overlapped only on 5% of the wetland area. Although distances traveled to obtain food varied between the two nesting populations, the herons from each colony used the closest foraging areas to their respective colony.

Herons from the same part of a colony tend to use the same flight lines to the feeding sites, but individual herons use a number of different feeding sites with no distinct set pattern. Herons are very aggressive on the feeding site but do not appear to be territorial. Average distance traveled daily by Great Blue Herons was 83 km for West Sister Island birds and 9 km for Mackey birds. Herons made from 1 to 3 foraging trips from the colony a day and used approximately two separate feeding areas each day. During daylight herons tended to change locations more often and spend less time at the colony than during the night.

As the breeding season progressed, the adults spent more time at the feeding site and their prey intake increased. Habitat type, size of the feeding area, wetland management, wave height, and human disturbance affected the use of feeding sites by Great Blue Herons. The herons did not leave the southwestern Lake Erie region in a coordinated manner at the end of the breeding season. Thus, the amount of time on these feeding sites varied greatly for these birds.

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