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USE OF THREE SOUTHERN MICHIGAN LAKES BY
WATERBIRDS DURING SPRING MIGRATION

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USE OF THREE SOUTHERN MICHIGAN LAKES BY WATERBIRDS DURING SPRING MIGRATION

By

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ABSTRACT

USE OF THREE SOUTHERN MICHIGAN LAKES BY WATERBIRDS DURING SPRING MIGRATION

By

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Daily counts of migrant waterbirds were conducted on three southern Michigan lakes during spring 1978 and 1979. Numbers and locations of waterbirds were recorded by species on lake outline maps. Water depth, aquatic macrophytes, and benthos were sampled along transects on the lakes. Levels of the habitat variables were compared with distributions of waterbirds, by species, using stepwise multiple regression. Comparisons of the spatial distributions of four Aythya spp. were made using a niche overlap measure. Avian species composition and extent of use varied between lakes. Although the distributions of mallard (Anas platyrhynchos), canvasback, (Aythya valisneria), redhead (A. americana), scaup (A. affinis, A. marila), ring-necked duck (A. collaris), red-breasted merganser (Mergus serrator), and American coot (Fulica americana) were described to varying degrees by subsets of the habitat variables, the distribution of bufflehead (Bucephala albeola) was not. Niche overlap among the Aythya spp. was greatest early in the season. Canvasback and ring-necked duck distributions overlapped least. Scaup and redhead distributions overlapped most. Species dominance

interactions and differences in foraging strategy are hypothesized as the mechanisms that separate the Aythya spp. during spring migration.

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INTRODUCTION

Hydraulic dredging is being tested as a lake restoration technique on Lake Lansing, Michigan. Much of the littoral zone will be dredged to a depth of 3-4 m. Studies on the impact of dredging are being conducted on physical, chemical, and biotic components of the lake. The predredging status of macrobenthos, phytoplankton and aquatic macrophytes have been evaluated by Siami (1979) and Wilson (1980).

Because few waterbirds use Lake Lansing as a breeding area, significant numbers of birds can be observed on the lake only during spring and fall. Although some birds probably use the lake only because it provides refuge from hunting during autumn, during spring they may use any locally available habitats without being disturbed by hunters. Most springtime activity occurs during the month of April. Congeneric species are often found together on lakes at this time. Lists of migrant species are available for some Michigan areas (e.g., Lerg 1975, and McWhirter and Beaver 1977) but associations of species on lakes are not well understood. Studies relating spatial organization, behavior, and habitat preferences are needed to provide additional information about species interactions.

Information from other areas may provide some suggestions as to how migrant waterfowl might respond to, and behave while on, Michigan lakes. For example, Thornburg (1973) and Sangster (1977) presented evidence that different waterfowl species respond to different macrohabitats (lakes or riverine pools) during migration. Also, Alexander and Hair (1979) reported species dominance relationships among the Aythya spp. on wintering areas.

The purposes of this study were to evaluate pre-dredging use of Lake Lansing and two other nearby lakes by waterbirds, to determine habitat preferences by the waterbirds, and to investigate niche overlap relationships among the Aythya spp. during spring.

DESCRIPTION OF THE STUDY AREA

The study area includes three shallow, waterwater lakes in south-central Michigan (Figure 1). All three lakes have substantial numbers of houses, cottages, or apartment buildings along their shores. Lake Lansing is a natural basin, 182 hectares in size. It occupies portions of sections 2, 3, 10, and 11 of T 4 N, R 1 W, Meridian Township, Ingham County. Although the lake has a maximum depth of 11.3 meters (Humphrys and Green 1962), approximately 77% of it is contained in the zone that lies shallower than the 3 meter depth contour (Mich. Cons. Dept. 1939).

At least 38 species of aquatic macrophytes occur in Lake Lansing (Wilson 1980). During midsummer the most conspicuous species is the macro-alga known as muskgrass (Chara globularis Thuill.). Common vascular hydrophytes (nomenclature following Scott and Wasser 1979) are naiad (Najas flexilis Willd.), waterstar mudplantain (Heteranthera dubia Jacq.), American wild celery (Vallisneria americana Michx.), common hornwort (Ceratophyllum demersum L.), cattail (Typha sp. L.), and bulrush (Scirpus sp. L.).

Lake O'Hills is a 12 hectare impoundment that was created for recreational and aesthetic purposes in conjunction with a housing project. It was created in 1972 and is located in sections 9 and 10 of T 4 N, R 1 W, Meridian

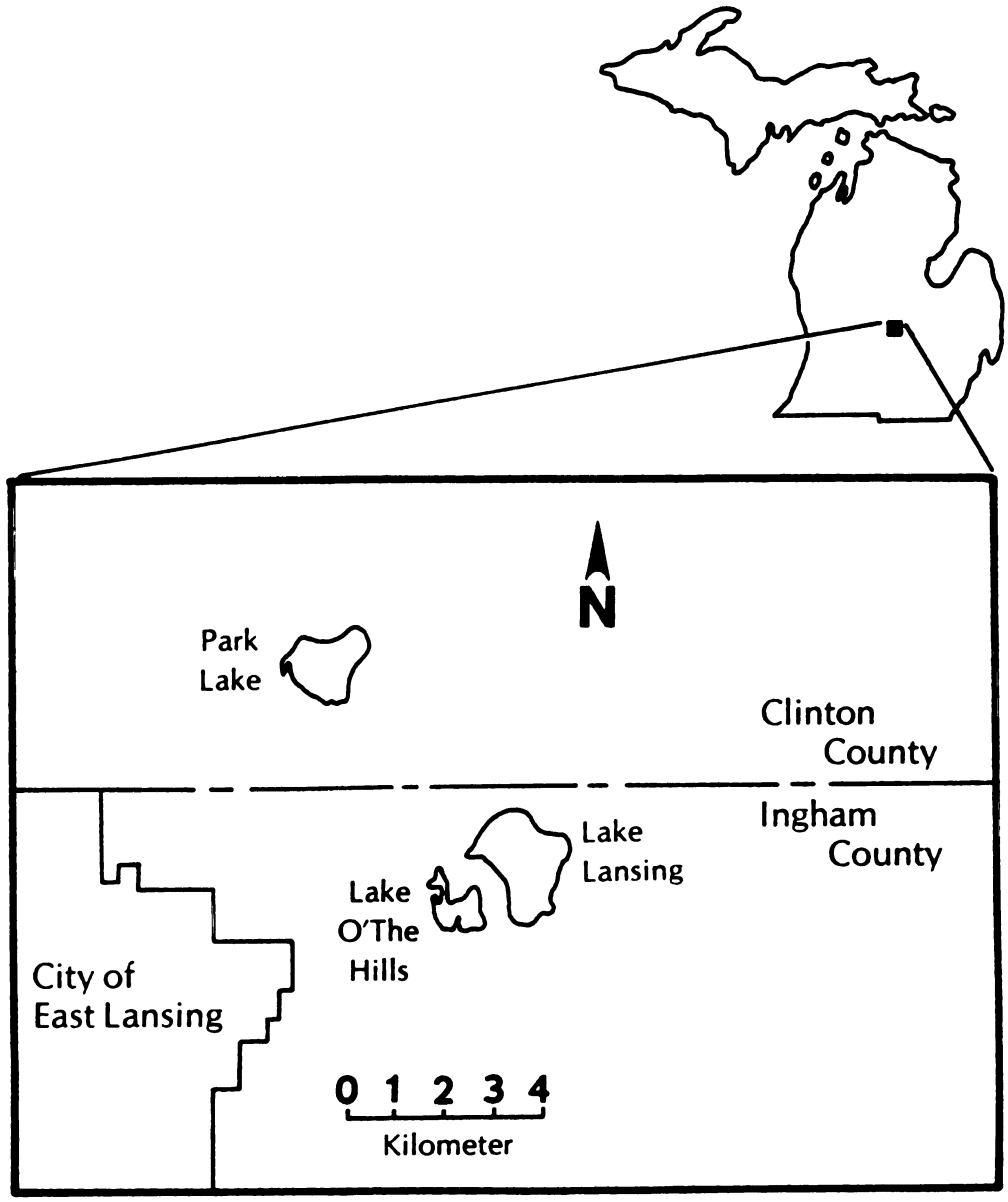

Figure 1. Location and relative sizes of the lakes on which waterbird studies were conducted.

Township, Ingham County. The approximate maximum depth of Lake O'Hills is 3 meters. Most of the lake is included in the 2-3 meter depth zone.

Muskgrass and naiads are the most common macrophytes in Lake O'Hills. Other species present in the lake are largeleaf pondweed (Potamogeton amplifolius Tuckerm.), curlyleaf pondweed (Potamogeton crispus L.), and fennel-leaf pondweed (Potamogeton pectinatus L.). Patches of cattail make up the small amount of shoreline cover.

Park Lake is a natural basin located in sections 28 and 29 of T 5 N, R 1 W, Bath Township, Clinton County. It has a surface area of 73 hectares and a maximum depth of 8.2 meters (Humphrys and Green 1962). Approximately 92% of the lake is shallower than three meters (Mich. Cons. Dept. 1939).

Muskgrass is the most conspicuous macrophyte on Park Lake. Common vascular hydrophytes include largeleaf pond-weed, fennelleaf pondweed, naiad, white waterlily (Nymphaea sp. L), cowlily (Nuphar sp. Sm.), watermilfoil and water-star mudplantain. Shoreline cover includes bulrush, cat-tail, and swamp loosestrife (Decodon verticillatus L.).

METHODS AND MATERIALS

Complete counts of waterfowl were made each morning at Park Lake, Lake Lansing, and Lake O'Hills beginning on the first day that Park Lake was ice free. The counts were conducted throughout spring until no more than twenty waterbirds were observed on Park Lake. During 1978 the starting time for the censuses varied from 0700 EST to 1100 EST. During 1979 all censuses were conducted beginning between 0700 EST and 0745 EST. A 10-60X variable power spotting scope aided field observations. During the censuses numbers by species and locations of waterbirds were recorded on field maps. Precise locations of birds were recorded by triangulation using aerial photographs to identify landmarks. Locations of flocks including more than 20 individuals were determined in a similar manner except that limits of the distribution of the flock were determined in addition to the flock center. The numbers of individuals engaged in feeding, resting, and courtship activities were also recorded during 24 of 32 mornings in 1979.

Grid systems were constructed on acetate outline maps of each of the lakes such that each square in the grid represented 0.25 ha (50 m X 50 m) of lake surface. The acetate maps were superimposed over each daily field map

and the number of birds, by species was recorded for each square in the grid. In instances where flocks occupied more than one square the number of birds in the flock was distributed evenly (to the nearest whole bird) over each occupied square. One bird from one daily count was considered to represent one waterbird use-day.

Daily species distributions were summed over the season, then all species were summed for each grid. The result was a distribution of total waterbird use-days for each 50 m X 50 m square area on the lakes for the season. Finally isopleths of bird use-days were generated by enclosing grids that contained more than a specified number of use-days. The isopleths for each year were compared and by occular estimation use-area boundaries were drawn where minima of bird use surrounded a maximum or where a minimum divided two maxima.

Chi-square goodness-of-fit was used to test the distributions of common waterbird species on the lakes. Expected values for the test statistic were calculated by multiplying the total number of use-days for the species by the proportion of the lake surface that was included in the use-area. Only those species for which the yearly total amounted to fifty or more use-days were tested. Each lake-year combination was tested separately.

Directional niche overlap probabilities were calcuated for the purpose of examining spatial interrelationships

among the Aythya spp. on Park Lake using the four use-areas as separate resources. At least six niche overlap indices have been proposed. The most recent and readily applicable are the Petraitis (1979) and Hurlbert (1978) techniques. Petraitis' technique was chosen over Hurlbert's for two reasons. First, it is directional, (that is, it allows examination of overlap by each species onto the other species) and second, it calculates a unique value for every distribution of the two species of interest. Although the Hurlbert technique is more easily understood and it can be calculated to include areas where only one of the species occurs, it calculates the same overlap for two distributions (Hulbert and Keith 1978, Petraitis 1979). Petraitis' overlap value (Φ) is a more abstract way of describing species overlap. It is the probability that the two species utilize the resources (in this case areas) equally. Petraitis' overlap is calculated from the equation: $\Phi = r^E$ where Φ is species overlap, r is the number of resource levels (in this case areas), and E is defined by the equation $E = \Sigma(p_{1j} \log_r p_{2j}) - \Sigma(p_{1j} \log_r p_{1j})$ where p_{ij} for this study is the proportion of individuals of species i that are observed in area j.

Species overlaps were calculated using totals that were obtained by summing species use, by area, over four day periods. Summing over four day periods makes general seasonal relationships apparent while masking daily fluctuations.

After use-areas had been determined transects were chosen for the collection of vegetational, depth and benthos data. Transects were chosen so as to include heavily used areas, areas that received moderate use, and low use areas (Figure A-1 through A-3). Park Lake and Lake O'Hills were sampled most intensively because they were most extensively used by waterbirds. Data were collected during June and July 1979. Water depth was measured to the nearest one-tenth meter at intervals of 10 meters from shore using a weighted sounding line. A $0.25m^2$ weighted wooden frame containing 25 equal $0.01m^2$ squares was used to determine percent occurrence of aquatic macrophytes. The frame was lowered into the water and the number of occupied $0.01m^2$ squares was recorded for each taxon. Percent occurrence was calculated as the ratio of the number of occupied squares to 25 (the total number of squares). Vegetational data were collected from a canoe in shallow water and by swimming in deeper water. Benthos samples were collected using a 15.2 cm X 15.2 cm ponar grab. Four or five samples were collected on each transect depending on transect length. A sample was taken at each end and one each at one-third and two-thirds the length of the transect in most cases. If a fifth sample was collected it was taken at the mid-point of the transect. Samples were transported to the laboratory where they were examined within twenty-four hours after collection. The samples were screened through

a number 30 U.S. standard seive (595 microns) and placed in a flat porcelain lined pan for examination. A liberal amount of sucrose solution (2 liters water/1 kg sucrose) was applied and the samples were stirred vigorously to dislodge invertebrates from the detritus matrix. Benthos from each sample were counted by taxon and preserved together in 90 percent ethanol. Later the alcohol was decanted off and the invertebrates were placed in an aluminum boat, oven dried at 60°C for 24 hours, and weighed to the nearest milligram on an electronic balance.

Multiple regression analysis relating waterbird species to environmental variables was done on the CDC 6500 computer at Michigan State University using procedures outlined by Kim and Kohout (1975) in the McGraw-Hill manual for version 6.0 of the Statistical Package for the Social Sciences.

RESULTS

The 1978 spring migration lasted from 7 April until 30 April (22 days). Totals of 1385, 456, and 6770 waterbird use-days representing 17, 9, and 20 species, respectively, were observed on Lake Lansing, Lake O'Hills, and Park Lake (Table 1). Spring migration was much more protracted in 1979. The 39 day census period began on 23 March and ended on May 1. Totals of 8599, 1783, and 22612 use-days representing 23, 14, and 24 species were observed on Lake Lansing, Lake O'Hills, and Park Lake during the 1979 season. Compared with 1978 this represents 6.2, 3.9, and 3.3 times as many use-days.

Seasonal waterbird abundances varied by lake (Table 1). American coot (Fulica americana Gme.) was the most common species on Lake Lansing. Scaup (Aythya affinis Eyton and A. marila L.) and mallard (Anas platyrhynchos L.) were the most common species on Lake O'Hills. The Aythya spp. were most common on Park Lake. Densities (use-days/hectare) of waterbirds were greatest on Park Lake and least on Lake Lansing (Table 2).

Social Activity

Waterbirds were observed feeding, resting, and engaged in courtship behavior during the 1979 morning counts. Less

Table 1. The number of water bird use-days, by species, as determined from daily ground censuses, for Lake Lansing, Lake O'Hills and Park Lake during the periods 7-30 April, 1978 and 24 March through 1 May, 1979.

Species	Lake Lansing (183 ha)		Lake O'Hills (12 ha)		Park Lake (73 ha)	
	1978	1979	1978	1979	1978	1979
Gavia immer Brun.	16	46			3	15
Podiceps auritus L.	2	162	1		14	104
Podiceps nigricollis L.						7
Podilymbus podiceps L.	59	55	1	5	57	63
Branta canadensis L.	1	32	24	92	28	70
Aix sponsa L.		4			2	22
Anas americana Gme.	8	16			31	24
Anas strepera L.		4			5	
Anas crecca L.						2
Anas platyrhynchos L.	65	195	228	514	50	192
Anas rubripes Brew.	5	8		1	1	23
Anas acuta L.						5
Anas discors L.	1	4		1	34	14
Anas clypeata L.		2		1		9
Aythya valisneria Wil.	21	23	2	7	790	2172
Aythya americana Eyt.	28	35		4	238	1268
Aythya collaris Don.		14	52	33	220	1167
Aythya affinis Eyt., A. marila L.	254	276	133	925	3586	12576
Bucephala albeola L.	41	78	12	137	309	265
Bucephala clangula L.		9		4	26	81
Mergus cucullatus L.		5				
Mergus serrator L.	170	908			4	8
Mergus merganser L.		4				3

Table 1. (cont'd.)

Species	Lake Lansing (183 ha) 1978	1979	Lake O'Hills (12 ha) 1978	1979	Park Lake (73 ha) 1978	1979
Oxyura jamaicensis Gme.	8	64		5	67	104
Fulica americana Gme.	651	6634	3	54	1264	4374
Larus argentatus Pont., L. delawarensis Ord.	49	23			23	2
Larus philadelphia Ord.	6					
Total	1385	8599	456	1783	6770	22612

Table 2. Total waterbird density (numbers/hectare), by year, for Lake Lansing, Lake O'Hills, and Park Lake.

Lake	1978	1978
Lake Lansing	7	47
Lake O'Hills	38	148
Park Lake	93	309

than 10% of the individuals of all species, except bufflehead, (Bucephala albeola L.) exhibited courtship behavior. Forty-eight percent of the bufflehead were engaged in courtship. Between one-third and two-thirds of all waterbirds were feeding during the censuses (Table 3). Chi-square tests indicate that a significantly ($P<0.05$) greater percentage of red-breasted merganser (Mergus serrator) were observed feeding compared with other species. American coot had the next highest feeding percentage. Approximately 50% of the redhead (Aythya americana), canvasback (A. valisneria), scaup, and bufflehead observed were feeding. Ringneck duck (A. collaris) and mallard fed the least.

Waterfowl use Within Lakes

Lake Lansing

Approximately 7.5 times as much of Lake Lansing was used in 1979 ('used' here meaning 10 or more use-days/0.25 ha grid) as compared to 1978 (Figure 2). Use did not exceed 115 bird days in a grid during either year. Six use-areas were outlined in Lake Lansing based on the isograms.

Chi-square goodness-of-fit tests indicated that all species, except pied-billed grebe (Podilymbus podiceps) during 1978, and horned grebe (Podiceps auritus) during 1979, were distributed unevenly over the use-areas on Lake Lansing during both years.

Area 1 (Figure 2) includes approximately 17 hectares in the northwest portion of the lake. It was used most

Table 3. Percentage of waterbirds observed feeding, by species, during morning ground counts.

Species	Total Number Observed	Percent Feeding
Red-breasted merganser	458	79 b[a]
American coot	7171	62 c
Canvasback	1120	52 d
Bufflehead	132	50 d
Scaup spp.	6313	48 de
Redhead	569	47 de
Mallard	102	36 e
Ring-necked duck	726	35 e

[a]Percentages followed by the same letter are not different ($p < .05$).

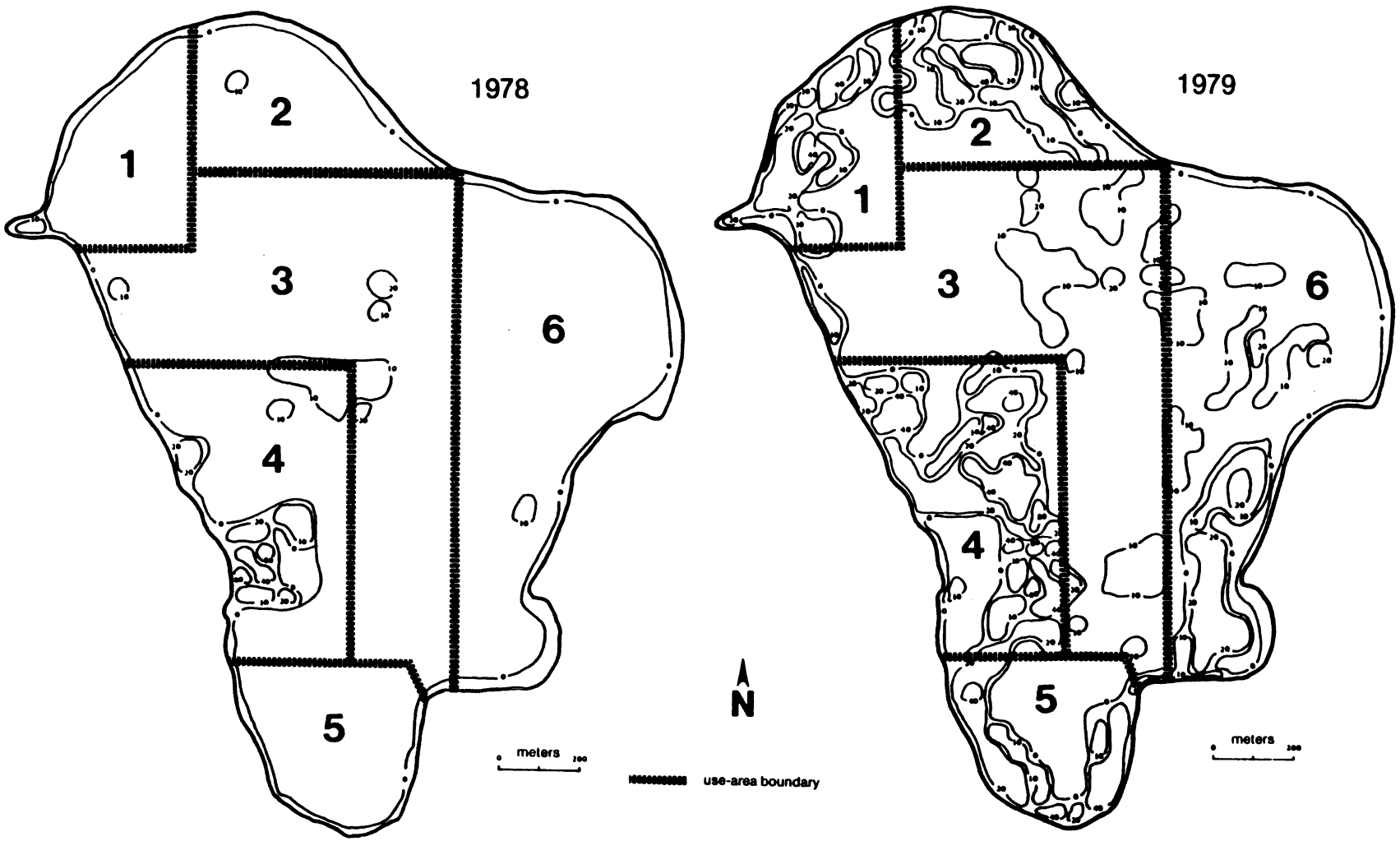

Figure 2. Distribution of waterbird use over Lake Lansing during the spring migration of 1978 and 1979. Use-areas based on a composite of use during both years are identified.

by mallard. Area 2 (20 hectares in the north-central portion of the lake) was relatively unused during the 1978 season. During 1979 it accomodated fairly large numbers of ruddy duck, Oxyura jamaicensis) American coot, and common loon (Gavia immer). Area 3 is a 66 ha area in the central portion of the lake that received little use by waterfowl. Area 4 is 28 ha in extent. It was used by pied-billed grebe, scaup, bufflehead and American coot. Use-area 5 is a 19 ha area that was used by pied-billed grebe. Area 6 has a surface area of 33 ha. It was used by common loon, horned grebe, pied-billed grebe and red-breasted merganser.

The distributions of scaup, red-breasted merganser, and American coot over use areas on Lake Lansing were significantly different ($P<0.01$) between years.

Lake O'Hills

Approximately 3 times as much of Lake O'Hills was used by waterbirds during the 1979 season as was used during 1978 (Figure 3). Use did not exceed 85 bird-days on any grid during either year. Based on the isograms five use-areas were delineated in the lake. Chi-square goodness-of-fit tests indicated ($P<0.05$) that, except for mallard in 1978, waterbirds were distributed unevenly over Lake O'Hills.

Area 1 (Figure 3) occupies 1.5 ha. It received light use during 1978 but was used by mallard in 1979. Area 2 is a 3 ha area that was used by ring-necked duck, scaup, and bufflehead. Area 3 is a 1.5 ha area that received little use.

Figure 3. Distribution of waterbird use over Lake O'Hills during the spring migrations of 1978 and 1979. Use-areas based on a composite of use during both years are identified.

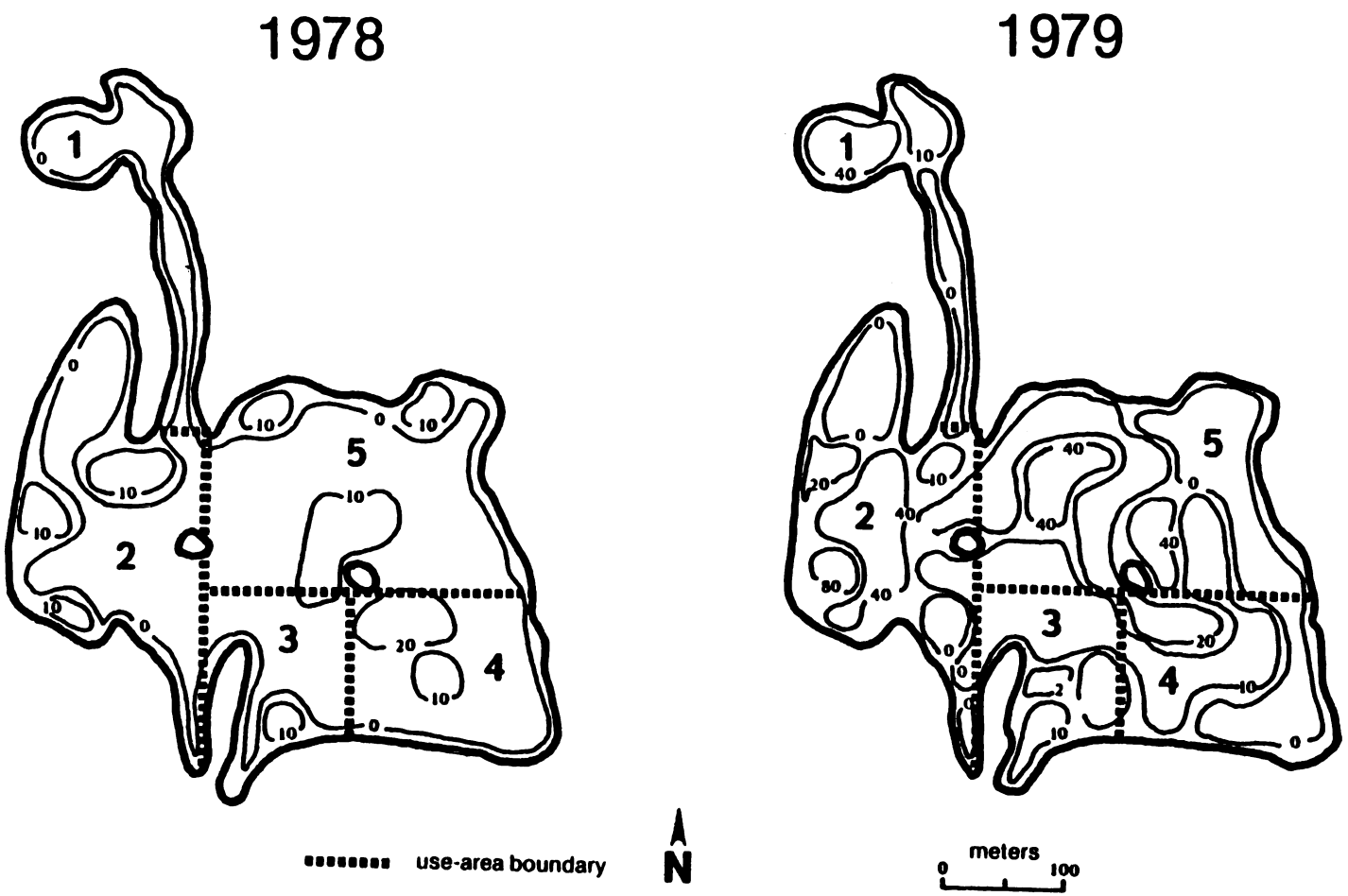

Figure 3.

Area 4 has a surface area of 2.2 ha. It was used by mallard, Canada goose (Branta canadensis), scaup, and bufflehead. Area 5 includes 3.9 ha. It too, was used by Canada goose, mallard, scaup, and bufflehead.

Chi-square analyses indicated that the distributions of mallard and scaup over Lake O'Hills varied significantly ($P<0.01$) between years.

Park Lake

Although 3.3 times as many waterbird use-days were counted on Park Lake during 1979 as compared to 1978, only 1.5 times as much of the lake surface was used. Four use-areas were identified on Park Lake based on isograms of bird use (Figure 4).

Chi-square goodness-of-fit indicated that during 1978 pied-billed grebe use was distributed evenly over the use areas. Other species had uneven distributions.

Area 1 (Figure 4) includes 13 ha of Park Lake. It was used by redhead, scaup, bufflehead, and American coot. Area 2 is a 22 ha area that was used by canvasback, redhead, scaup, and American coot. Area 3 was used by horned grebe, pied-billed grebe, the Aythya spp., and ruddy duck. It has a surface area of 33 ha. Area 4 is a 5 ha area that was used by American coot.

Chi-square analyses indicated that the distributions of pied-billed grebe, canvasback, redhead, ring-necked duck,

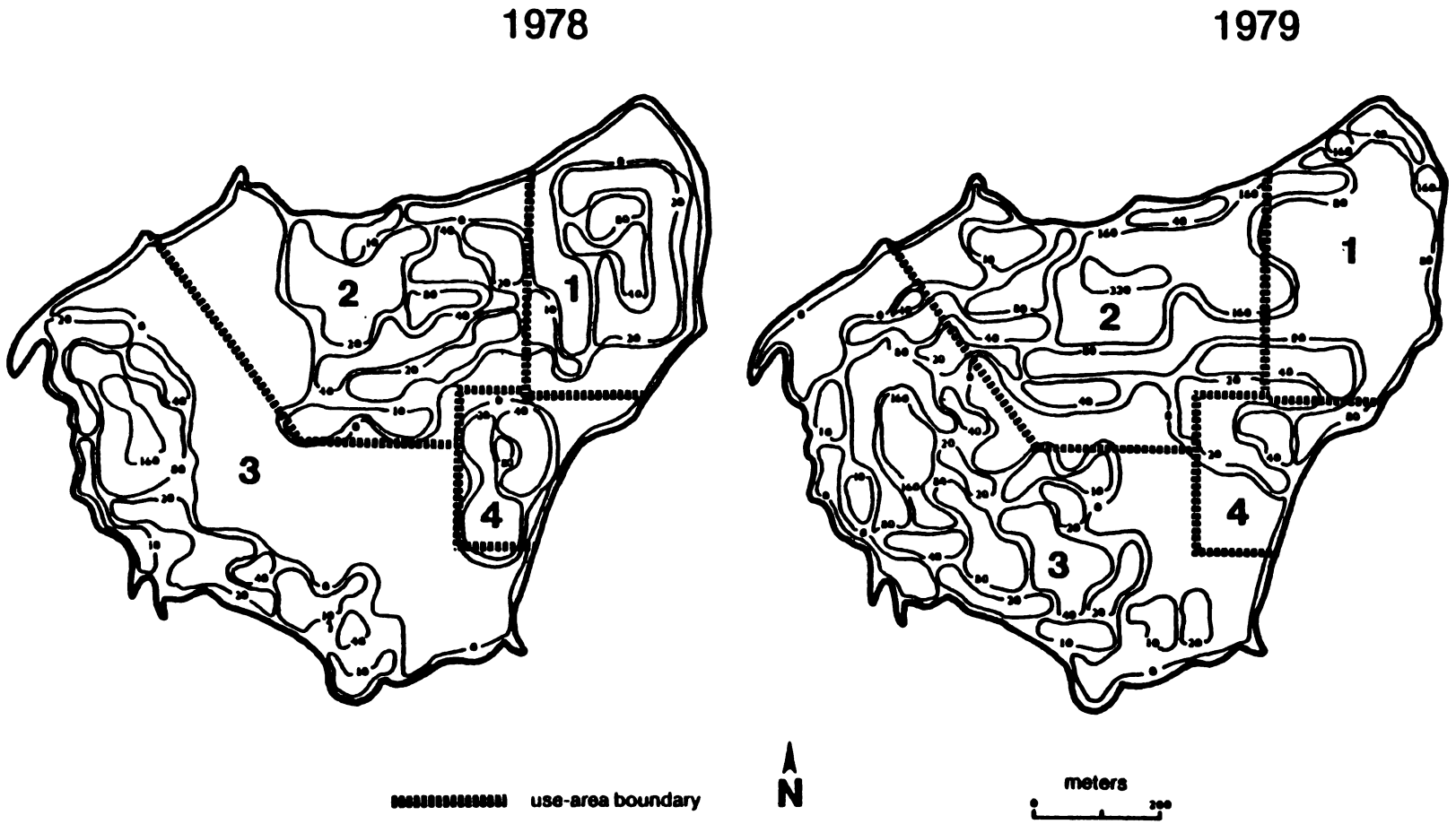

Figure 4. Distributions of waterbird use over Park Lake during the spring migrations of 1978 and 1979. Use-areas based on a composite of use during both years are identified.

scaup, bufflehead, ruddy duck and American coot varied significantly ($P<0.01$) between years.

Species Relationships Among the Aythya spp.

During 1978 the four Aythya species were observed together on Park Lake during eleven mornings. Although niche overlaps were calculated for the periods 15-18 April and 19-22 April, overlaps involving redhead could not be calculated for the latter period. Overlaps were higher during 15-18 April than during 19-22 April (Table 4). Canvasback overlapped less than other species, particularly during the 19-22 April period. Redhead overlapped to a similar degree with all other species. Scaups and redhead overlapped most.

Overlap values were calculated for 5 four day periods from 29 March until 19 April in 1979 (Figure 5). Overlaps were highest early in the season. In ten of fifteen cases, canvasback overlapped equally with or to a greater extent onto other species. Overlaps involving canvasback were smaller than overlaps among the other species. Redheads overlapped less or equally onto other species in twelve of the fifteen cases. They overlapped most with scaup. Ring-necked duck overlapped variably with redhead and scaup. They overlapped least with canvasback. Scaup overlaps were variable.

Table 4. Directional niche overlaps of the Aythya spp. on Park Lake calculated for 2 four day periods in 1978.

Species		4/15-4/18		4/19-4/22	
A	B	A on B	B on A	A on B	B on A
Canvasback	Redhead	.85	.82		
Canvasback	Ring-necked duck	.93	.94	.50	.32
Canvasback	Scaup	.87	.88	.53	.47
Redhead	Ring-necked duck	.82	.82		
Redhead	Scaup	.81	.79		
Scaup	Ring-necked duck	.99	.89	.99	.88

Figure 5. Niche overlaps and population levels of the Aythya spp. on Park Lake during spring 1979. Overlaps were calculated by summing species use by area, over four day periods.

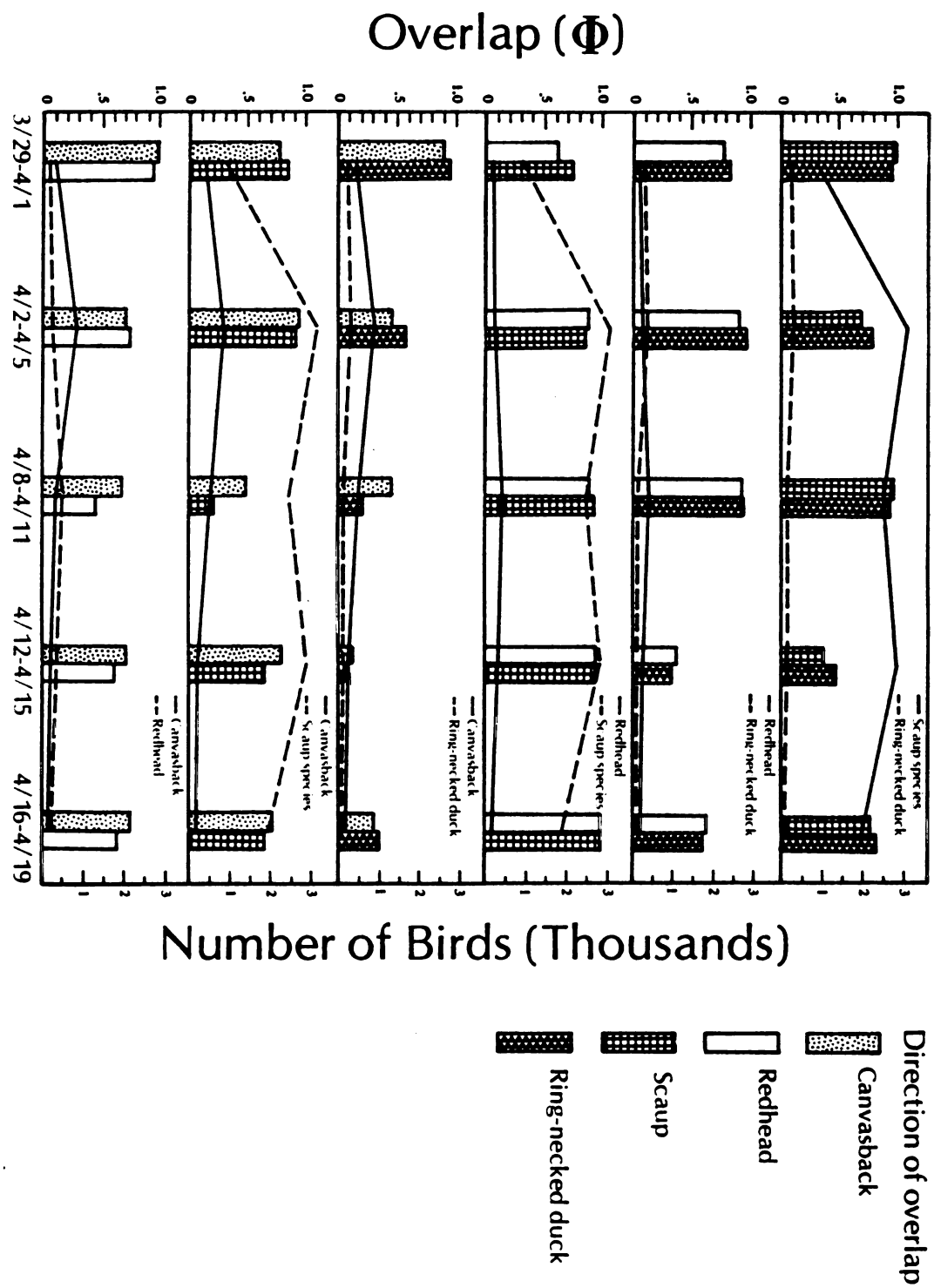
Overlap (Φ)
Number of Birds (Thousands)
Date
3/29-4/1
4/2-4/5
4/8-4/11
4/12-4/15
4/16-4/19
Direction of overlap
Canvasback
Redhead
Scaup
Ring-necked duck

Figure 5.

Lake Communities

Aquatic macrophytes

Thirteen species of aquatic macrophytes were found in Lake Lansing (Table 5). Muskgrass was the most common. Flatstem pondweed (Potamogeton zosteriformis Fern.) was the most important vascular hydrophyte. It was found in water 1.5-2.0 m deep (Table 6). The other pondweeds occurred infrequently. Non-vegetated substrate was found in over 39% of the samples.

The two most important vascular hydrophytes in Lake O'Hills are naiad and fennelleaf pondweed (Table 5). Naiad was found at depths greater than 1.5m (Table 6). Fennelleaf pondweed was restricted to depths of 1.5-2.0m. Plants in Lake O'Hills were not covered by calcium encrustations. They appeared brighter and more crisp than plants in the other lakes.

Muskgrass was found in over 57% of the Park Lake samples (Table 5). Bare substrate occurred less than 17% of the time. Fennelleaf pondweed, largeleaf pondweed, and water star mudplantain were the most important vascular hydrophytes in Park Lake. Fennelleaf pondweed and large leaf pondweed occurred at depths of 1.0-1.5m (Table 6). Waterstar mudplantain was found in water 2.0m deep. Naiad was found on all transects and at all depths. Waterlily occurred across the western portion of the lake. It was found in water less than 1.5m deep.

Table 5. Percent occurrence, by species, of aquatic macrophytes on the three study lakes.

Species	Lake Lansing (n=255)	Lake O'Hills (n=115)	Park Lake (n=420)
Chara sp.	39.6	41.8	57.1
Potamageton zosteriformis	6.8		
P. pectinatus	Tr[a]	5.6	4.8
P. amplifolius		0.9	4.3
P. crispus	0.6	Tr	
P. robbinsii (Oakes)	Tr		
P. richardsonii (Benn.)	Tr		
Najas sp.	6.4	33.6	3.5
Elodea canadensis (Michx.)	0.8		1.5
Vallisneria americana	0.1		Tr
Scirpus sp.	Tr		Tr
Heteranthera dubia	2.1		4.4
Ceratophyllum demersum	3.6		0.6
Nymphaea sp.			3.0
Nuphar sp.			1.9
Myriophyllum sp.	1.6		2.8
Non-vegetated substrate	39.4	22.0	20.2

[a]Trace amounts are less than 0.1 percent.

Table 6. Distribution, by depth, of the common aquatic macrophyte species that were present on the three study lakes.

Depth	Lake Lansing	Lake O'Hills	Park Lake
0.5 m	Chara sp. (sparse)	Chara sp. (sparse)	Chara sp. Najas sp. Nymphaea odorata Nuphar sp.
1.0 m	Chara sp. Elodea canadensis Vallisneria americana	Chara sp.	Chara sp. P. Pectinatus Potamogeton amplifolius N. odorata
1.5 m.	Chara sp. Potamogeton zosteriformis Najas sp. Potamogeton crispus	Chara sp. Najas sp. P. pectinatus	Chara sp. P. pectinatus P. amplifolius Najas sp.
2.0 m	Chara sp. P. zosteriformis Najas sp. P. crispus	Chara sp. Najas sp. P. pectinatus	Chara sp. H. dubia Myriophyllum sp.
> 2.0m	Najas sp. C. demersum H. dubia Myriophyllum sp.	Chara sp. Najas sp.	Najas sp. Myriophyllum sp.

Benthos

Midge larvae (Chironomidae) were the most numerous and widely distributed benthic invertebrates in Lake Lansing (Table 7). Scuds (Amphipoda) and mayfly nymphs (Ephemeroptera) were next in importance. Both taxa were present in approximately the same densities and frequencies. Numbers and frequencies of phantom midge larvae (Chaoboridae) and biting midge larvae (Ceratopogonidae) in Lake Lansing samples were also similar. Biting midge larvae occurred in samples taken from sandy substrate along the eastern shore of the lake (transects 6-A and 7) whereas phantom midge larvae were found in all areas except the northwest portion of the lake (transect 2). Water mites (Hydracarina) were found on all transects with a 28% frequency of occurrence.

Midge larvae were found in every sample that was taken from Lake O'Hills (Table 7). Mayfly nymphs and scuds were widely distributed at low densities. They were found in samples taken from all transects. Snails (Gastropoda), horse and deer fly larvae (Tabanidae) and fingernail clams (Sphaeriidae) were also evenly distributed at low densities.

Park Lake contained a greater number of benthos taxa compared with the other lakes (Table 7). Although mayfly nymphs were the most numerous and widely distributed, numbers from two samples accounted for over 50% of the total. Midge larvae were found in nearly 98% of the samples and were about as numerous as mayfly nymphs.

Table 7. Frequency of occurrence and mean density (numbers/m^2) of benthos taxa found in samples taken on the three study lakes.

Benthos taxon	Lake Lansing (n=36)		Lake O'Hills (n=19)		Park Lake (n=42)	
	Frequency	Mean Density	Frequency	Mean Density	Frequency	Mean Density
Amphipoda	38.9	175±140	42.1	73±73	64.3	158±226
Ephemeroptera	44.4	167±154	36.8	125±125	76.2	1012±2005
Odonata						
Anisoptera					23.8	159±208
Zygoptera					9.5	97±41
Trichoptera	13.9	60±24			73.8	125±121
Coleoptera					9.5	151±143
Diptera						
Chironomidae	100.0	320±269	100.0	1003±883	97.6	727±860
Ceratopogonidae	27.8	73±46	15.8	142±99		
Chaoboridae	25.0	91±55			14.3	129±98
Tabanidae			15.8	130±112		
Gastropoda			31.6	73±34	9.5	75±21
Pelecypoda						
Sphaeriidae			26.3	69±56	21.4	100±108
Hydracarina	27.8	65±30			38.1	75±66

Relationships Between Waterbird Use and Habitat Variables

The relationships of selected habitat variables with numbers of waterbird species use-days (number of use-days/ $0.25km^2$) by location within a lake during 1979 were analyzed using stepwise multiple regression. Waterbird species were included in the regression analysis if they occurred in at least 10 of the 0.25 km^2 areas in which benthos data were collected (i.e., if benthos sample size was greater than or equal to 10 for the waterbird species).

The multiple regression analysis of Lake Lansing data compared amounts of use, at specific locations, by red-breasted merganser and American coot with water depth; densities of muskgrass, curlyleaf pondweed, flatstem pondweed, naiad, watermilfoil and waterstar mudplantain; numbers of scuds, mayfly nymphs, and midge larvae; and total dry biomass of invertebrates. Water depth explained a significant ($P<0.1$) amount of the variation in the distribution of red-breasted merganser. The relationship was negative ($r = -0.43$). Waterstar mudplantain density explained a significant amount of the the variation in American coot distribution.

The multiple regression analysis of Lake O'Hills data compared amounts of use, by location, for mallard, ring-necked duck, scaup, and bufflehead with water depth; densities of muskgrass, fennelleaf pondweed, and naiad; numbers of mayfly nymphs and midge larvae; and total dry

biomass of invertebrates. Mayfly nymph numbers were correlated with locations of mallard ($P<0.1$). The densities of muskgrass, naiad, and fennelleaf pondweed were associated with locations of scaup ($r^2 = 0.70$). Water depth was related with locations of ring-necked duck ($P<0.1$). The relationship was negative ($r = -053$). No variables were related to locations of bufflehead.

The multiple regression analysis of Park Lake data compared amounts of use by canvasback, redhead, ring-necked duck, scaup, and American coot with water depth; the densities of muskgrass, largeleaf pondweed, fennelleaf pondweed, naiad, waterweed, watermilfoil, waterstar mudplantain, waterlily, and cowlily; numbers of scuds, mayfly nymphs, caddisfly nymphs (Trichoptera) and midge larvae; and total dry biomass of invertebrates. Densities of largeleaf pondweed and watermilfoil were related ($P<0.10$) with locations of canvasback (Table 8). Numbers of midge larvae, density of muskgrass, and water depth were associated with the distribution of redheads. Ring-necked duck use was related with densities of cowlily and watermilfoil, while locations of scaup related with numbers of midge larvae and density of waterweed. The densities of muskgrass, waterweed, waterstar mudplantain and total dry biomass of invertebrates were associated with use by American coot.

Table 8. Results of stepwise multiple regression analysis (P<.1) relating waterbird abundance with selected environmental variables for Park Lake.

Species	Environmental Variables	Multiple regression (r^2) Partial	Total
Canvasback	Potamogeton amplifolius	.081*	
	Myriophyllum sp.	.153*	
			.234
Redhead	Chironomidae	.223**	
	Chara vulgaris	.093**	
	Depth	.084*	
			.400
Ring-necked duck	Nuphar sp.	.152*	
	Myriophyllum sp.	.084*	
			.236
Scaup spp.	Chironomidae	.179**	
	Elodea canadensis	.067*	
			.246
American coot	A. canadensis	.128*	
	Heteranthera dubia	.102**	
	Invertebrate dry weight	.058*	
	C. vulgaris	.098**	
			.386

*Significant at P<.10
**Significant at P<.05

DISCUSSION

Cold weather early in the 1979 season delayed migration. Greater daily numbers of waterbirds on the lakes over an extended period of time resulted in an increase in bird use compared to 1978. A greater number of species was also observed in 1979.

The area of lake surface that was used on both Lake Lansing and Lake O'Hills during 1979 as compared to 1978 increased proportionally with number of waterbird use-days. Additional use of Park Lake resulted in increased densities of birds since the amount of surface area that was used was not proportional to the increase in use-days.

Although relative abundance of common species on individual lakes remained constant from 1978 to 1979, waterbird communities varied by lake. Lake Lansing was used by American coot and piscivorous species such as common loon, horned grebe, pied-billed grebe, and red-breasted merganser. Lake O'Hills was used by Canada geese, mallard, ring-necked duck, scaup, and bufflehead. Park Lake was used by pochards, bufflehead, and American coot.

Although distributions of common waterbird species differed by year, niche overlaps among the Aythya spp. on Park Lake were similar during both years. Overlaps were greatest

early in the seasons. Observations indicate that this may be because early spring migrants required several days to acclimate to the lake environment. During this period individuals of many species were found together in one large group. After 2-3 days the large aggregation broke up as smaller groups left and occupied other portions of the lake. Thereafter newly arriving migrants joined established groups across much of the lake.

The aquatic macrophyte and benthos communities of the three lakes are different. Lake Lansing contains more pondweed species but has a less diverse benthos than Park Lake. Lake O'Hills has the least diverse flora. It has a benthos diversity similar to Lake Lansing. Park Lake contains the overall most diverse biota. It has nearly as rich a macrophyte community as Lake Lansing and it contains the richest benthos composition. It also contains the least amount of non-vegetated substrate.

Mallard use was related to mayfly nymph numbers on Lake O'Hills. Mallard were nesting during April. Hens require large amounts of protein during laying. Mayfly nymphs might have provided an available supply of protein on Lake O'Hills.

The negative correlation between red-breasted merganser distributions and depth could possibly be related to merganser foraging strategy on Lake Lansing. Perhaps their

primary food items were more abundant or more available in shallow areas (one meter) than in deeper areas.

When considered in conjunction with niche overlap relationships, the correlations of use by the Aythya spp. with habitat variables on Park Lake provide additional information about the interactions of the species. Canvasback use was not described by habitat variables that described redhead and scaup use. This suggests that canvasbacks use areas that are different from the areas that redhead and scaup use. The distribution of canvasback overlapped only moderately with the distributions of redhead and scaup. This supports the hypothesis that canvasback use different areas. Alexander and Hair (1979) found that canvasbacks defended foraging sites and were dominant over other Aythya spp. Siegfried (1976) mentioned that he had observed aggressive encounters between canvasback and redhead. Perhaps canvasback aggressively exclude redhead and scaup from use-areas. Distributions of canvasback and ring-necked duck were correlated with a common habitat variable (water-milfoil density). The distributions of the two species overlapped little. This indicates that canvasback and ring-necked duck use similar areas but are not found together. Alexander and Hair (1979) observed that canvasback were most frequently involved in aggressive encounters with ring-necked duck. Distributions of redhead and scaup on Park Lake were both correlated with numbers of midge larvae.

Distributions of the two species overlapped extensively. Siegfried (1976) described a similar relationship between canvasback and scaup. He suggested that since canvasbacks feed primarily on plant material while scaup feed on free swimming invertebrates, it follows that food habits differences must separate the species. Such a relationship could also separate scaup and redhead because, like canvasback, redhead feed more on plant material than do scaup (Bellrose 1976). Ring-necked duck use was correlated with a different set of habitat variables than described redhead and scaup use. Niche overlaps of ring-necks with scaup and redheads were variable. This indicates that ring-necked duck are seldom found in the same areas with redhead and scaup because they use different resources. Alexander and Hair (1979) found that ring-necked duck were aggressive and dominated redhead and scaup. Perhaps ring-necked duck aggressively exclude redhead and scaup from use-areas.

American coot distributions were related to waterstar mudplantain density on both Lake Lansing and Park Lake. Pirnie (1935) also described a relationship between coot use and mudplantain on Lake Lansing. He indicated that coot feed heavily upon this plant.

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APPENDIX

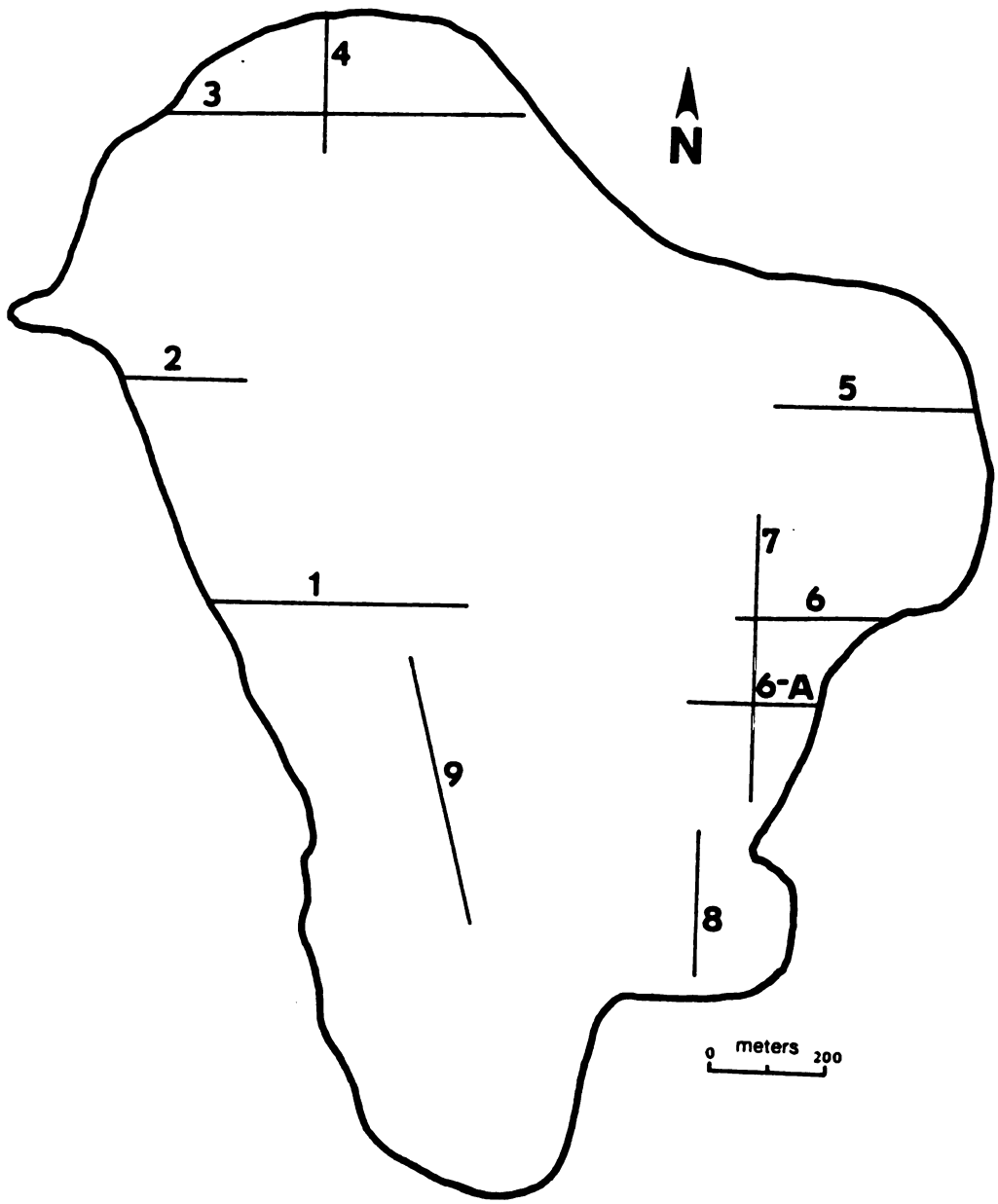

Figure A-1. Location of transects on Lake Lansing.

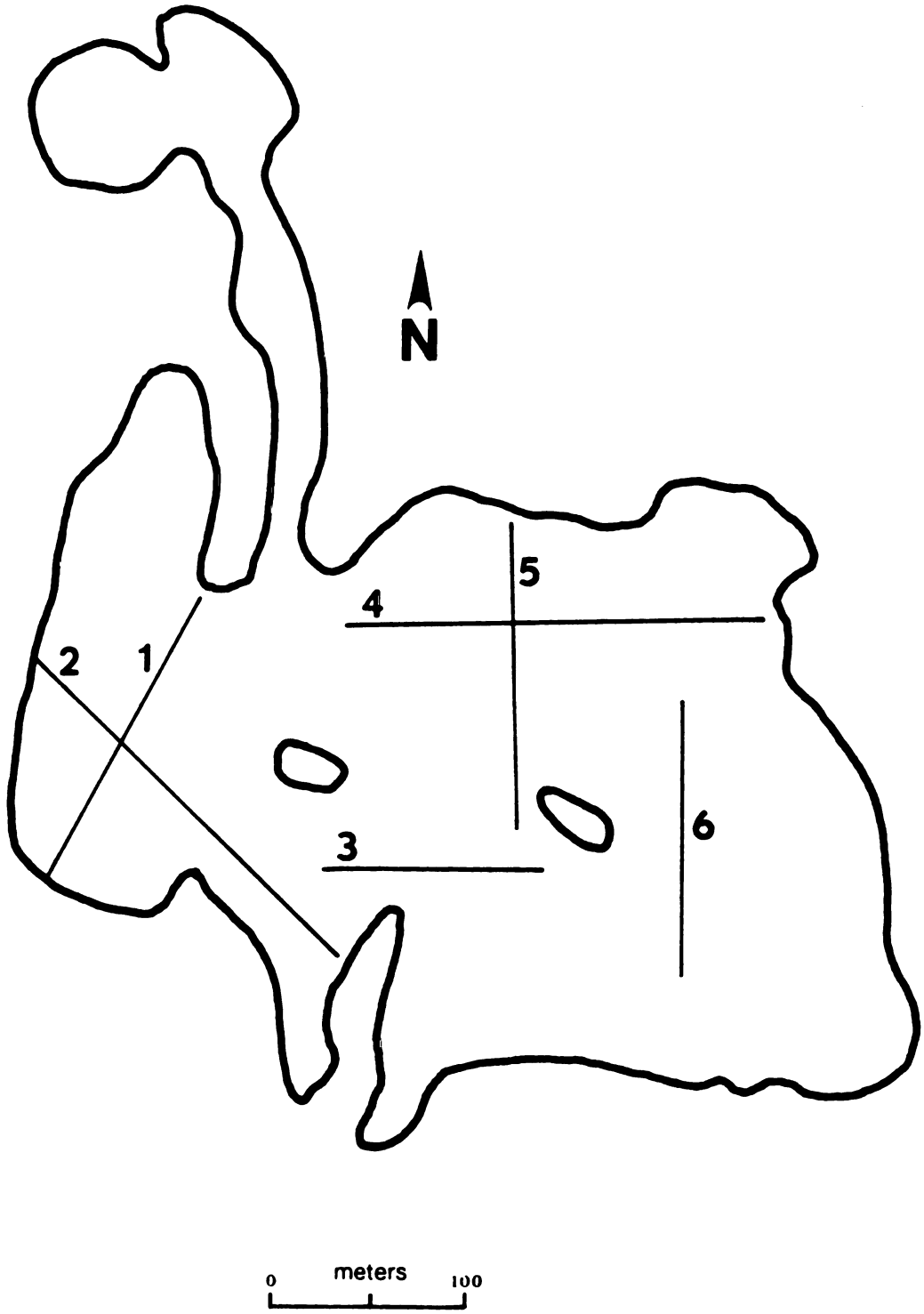

Figure A-2. Location of transects on Lake O'Hills.

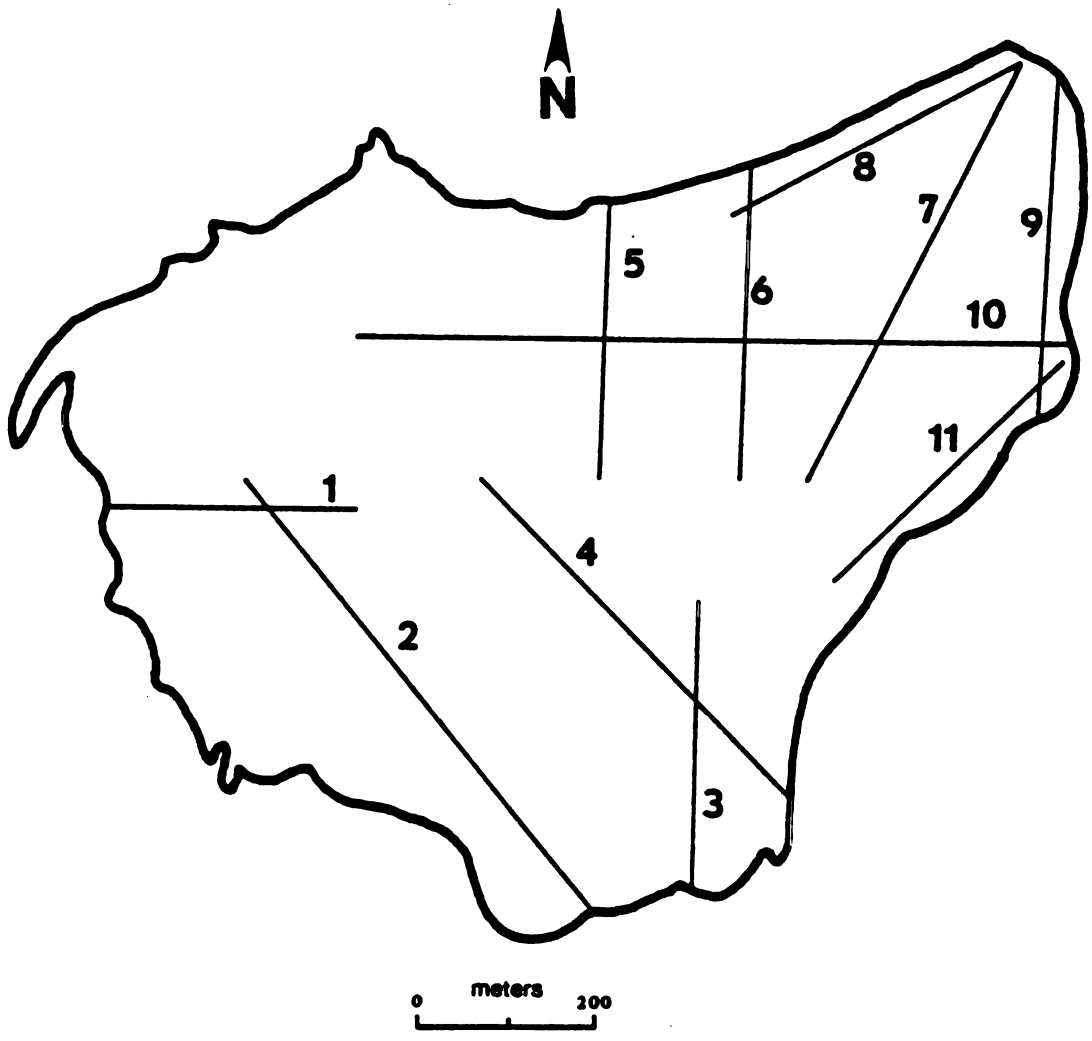

Figure A-3. Location of transects on Park Lake.