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WATERBIRD RESPONSES TO HABITAT CHANGES ON AN OPEN WATER SYSTEM IN CENTRAL MICHIGAN

By

Patrick James Rusz

A DISSERTATION

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ABSTRACT

WATERBIRD RESPONSES TO HABITAT CHANGES
ON AN OPEN WATER SYSTEM IN CENTRAL MICHIGAN

By

Patrick James Rusz

Waterbird use of a newly-created 350 ha industrial cooling pond in central Michigan was examined over a 6-year period, 1979-1984. Numbers, distributions, and activities of waterbirds were recorded. Water depth, aquatic macrophytes, and benthos were sampled, and data on the fish community were obtained from secondary sources. A chi-square test was used to determine if distributions of waterbirds and macrophytes coincided.

The water level was lowered by about 1.3 m for the entire year in 1980, and again in fall of 1983. The cooling pond was gradually drained in fall of 1984. There was only 1 macrophyte species present, and the distribution of plants was similar each year. The benthic community was poorly developed throughout this study. The reduced water level in 1980 resulted in a much greater density of plant material near the surface than in any other year. Small fish were most numerous in 1979, 1982, and 1983.

Waterbird use, especially by American wigeon, redhead, and American coot, was much greater in 1980 than in any other year. Common loon and horned grebe had more use-days

in 1979, double-crested cormorant and red-breasted merganser were most abundant in 1982, and common merganser use was greatest in 1983. Canada goose use was high in all 3 years in which the water level was reduced, and greatest during the progressive drawdown in 1984. The number of species seen declined each year, but the mean weekly species diversity index was highest in 1980.

Coincidence of birds and vegetation was particularly evident for American wigeon, redhead, and American coot in 1980, and these species were most numerous where plant growth was most extensive. Plant-eating and piscivorous species did not use the cooling pond intensively except in years when the levels of plants and small fish exceeded that found in most open water systems. Canada goose use seemed influenced by the amount of dry ground loafing sites.

ACKNOWLEDGEMENTS

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I am indebted to Harold Prince, my research advisor, for his guidance and editing of the manuscript. I thank Jonathan Haufler, Donald Beaver, and Leighton Leighty for serving on my research committee. Stanley Zarnoch and Carl Ramm provided valuable advice on data analysis. I am particularly grateful to Richard Rusz for his help in collecting and synthesizing the field data.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (cont'd):

LIST OF TABLES (cont'd):

LIST OF FIGURES

INTRODUCTION

While freshwater wetlands are diminishing at an alarming rate (Shaw and Fredine 1956, Whitesell 1970) open water systems such as lakes, recreational impoundments, and industrial ponds for cooling or wastewater treatment are increasing in number (Street 1982, Uhler 1956). The morphometry, water chemistry, and plant and animal communities of open waters differ markedly from those of wetlands. Open water systems are typically deep, lack substantial emergent vegetation, and are often subject to considerable wave action. Diversity of waterbird microhabitats within most open water systems seems low in comparison with wetlands (Weller and Fredrickson 1974).

Despite their seemingly low diversity of microhabitats, many open water systems are used by significant numbers of a wide variety of waterbirds during specific times (Prince et al. 1984, Reeves 1980, Thornburg 1973, Bellrose 1976). However, there is a dearth of information on the nature of waterbird use of open waters because such habitats are usually not managed for waterbird use by industries or governmental agencies. There are a few detailed descriptions of waterbird use of certain open waters such as wastewater treatment lagoons (Willson 1975, Dornbush and Anderson 1964, Medema 1980), and there have been several recent attempts to correlate waterbird use with selected habitat variables on open waters. White and James (1978) and Hobaugh and Teer (1981) used multivariate methods to characterize waterfowl use of open water systems in Texas, but the former study was primarily focused on the marshy fringes of lakes rather than the lake proper. Reeves (1980) used multiple regression analysis to compare levels of certain habitat variables with distributions of waterbirds (by species) on 3 lakes in central Michigan. Blomberg (1982) used regression analysis to determine habitat characteristics which influenced duck use of gravel pits in Colorado.

Such correlation studies have led to management recommendations by the respective authors, but verification of waterbird responses to habitat manipulations on open waters is virtually absent. An exception is the study of Street (1982) who reported increased waterfowl use of a gravel pit in England after construction of sheltered, shore-based loafing sites, introduction of a variety of vegetational species, and addition of organic matter to stimulate production of invertebrates.

The complexity of interrelated factors which might influence habitat selection in open water systems makes it difficult to determine specific cause-effect relationships. Habitat manipulations usually affect many variables such as the density, relative abundance, diversity, availability, and species composition of both benthic and surface dwelling plants and animals. Hence, measured responses of birds can seldom be directly linked to changes in a single parameter or even set of parameters. Costs and other considerations make strict replications or use of control areas nearly impossible in studies of large open water systems. In addition, year-to-year differences in migration chronology and/or population numbers due to weather or conditions on the breeding or wintering grounds may further confound interpretation of results of field studies involving migrating birds. Thus, there is need for long term field studies in open water systems in which such problems are minimized.

The primary purpose of this study was to determine, over a 6-year period, the species assemblages, and levels and types of waterbird use associated with a newly-created open water system lacking the complexity of habitat components usually found in naturally-formed open waters. The water depth in this system was manipulated during my study, so an adjacent open water system was also studied during the same period to facilitate interpretation of results from the primary study area. Implicit in my research is the hypothesis that open water systems are used by discrete waterbird communities which can be predicted on the basis of relatively few proximate factors.

For purposes of this report, the term "waterbird(s)" refers to all avian species, except herring gull and ring-billed gull, which used the off-shore areas of the open water systems I studied. Herring gull and ring-billed gull were the most frequently observed species on the primary study area, and a large breeding colony of ring-billed gull was present there each year of my study. These 2 species are excluded from my study since the data on their use of the study area are presented by Rusz (1985). Various species of small, non-swimming shorebirds were also present on the shores of the open water systems I studied, but are not referred to in this report. Scientific names of bird species included in this study are in Appendix A.

DESCRIPTIONS OF STUDY AREAS

Location And General Setting

The open water systems I studied are a 350 ha industrial cooling pond and a 150 ha wastewater treatment pond located in central Michigan near major migration corridors (Bellrose 1976) and concentration areas of Canada geese and both dabbling and diving ducks. The cooling pond, which served as the primary study area, and the wastewater treatment pond are in an industrial complex on the southern edge of the City of Midland (Figure 1). The industrial complex includes Consumers Power Company's Midland Energy Center and Dow Chemical Company facilities. Land use near the complex is industrial and commercial on the north, residential and light commercial on the west, and rural residential and agricultural on the south and east.

Cooling Pond

The cooling pond was constructed to serve Consumers Power Company's Midland Energy Center and associated nuclear power plant. Soil was excavated to the level of a lowland drained by a small creek. Soil in most of the lowland was left undisturbed (Figure 2), however additional earth was excavated to provide a deeper supplemental water

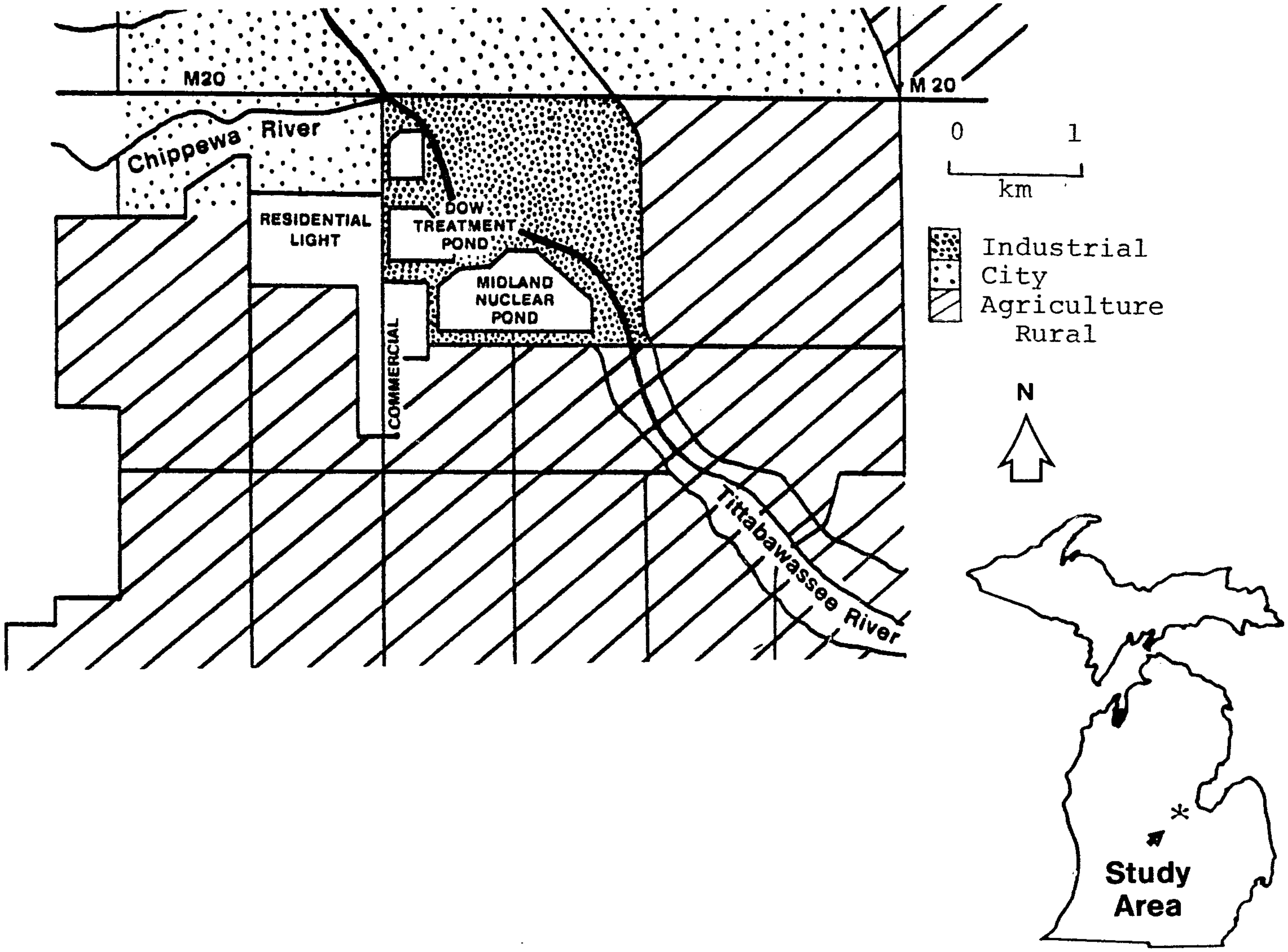
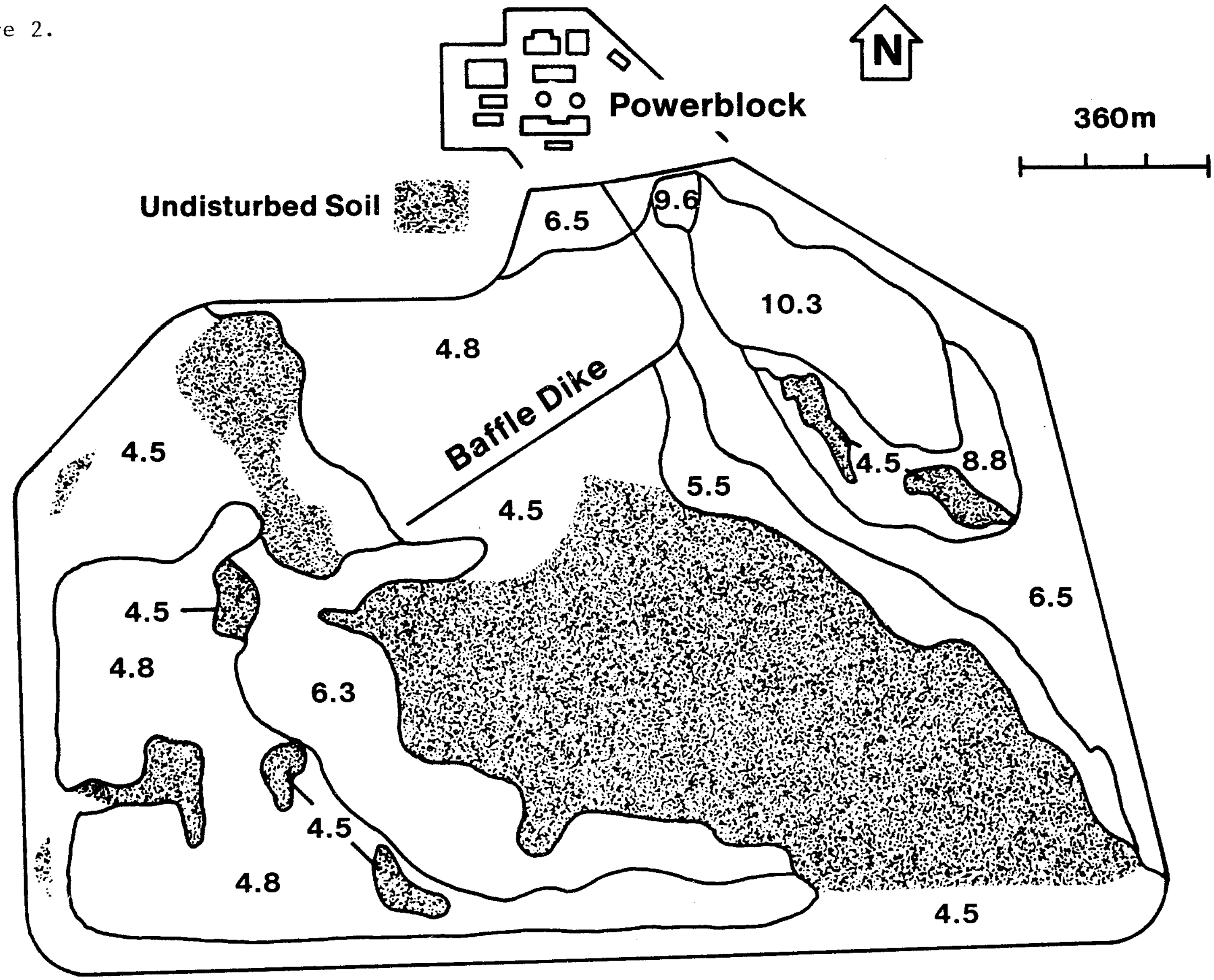


Figure 1. Location of the study area in central Michigan.

Figure 2. Areas of different depths (in meters) and general locations of soil undisturbed during excavation of the cooling pond. Within the areas delineated, 90 percent of measured depths differed by less than 0.3 m. Depths were 1.3 m lower in 1980 and from late July to December of 1983. A progressive drawdown of the cooling pond occurred in fall of 1984.

Figure 2.



Powerblock
N
360m
Undisturbed Soil
6.5
9.6
10.3
4.8
Baffle Dike
4.5
4.5
5.5
4.5
8.8
4.5
6.5
4.8
6.3
4.5
4.8
4.5

7

storage area in the northeast part of the cooling pond and material for the perimeter and baffle dikes. The baffle dike was designed to direct water currents in the cooling pond. All dikes are rip-rapped with large stones and wide enough to allow travel by motor vehicles.

The cooling pond was completed in 1977 and filled to capacity by early 1978 with water from the Tittabawassee River, a major tributary of Lake Huron. Its mean depth (at capacity) is about 5 m, with a maximum depth of about 11 m (Figure 2). The Midland Energy Center was not in operation during my study; hence the temperature regime and water circulation in the cooling pond was comparable to that of many Michigan lakes of similar size and depth.

During my study, the bottom type in the unexcavated areas of the cooling pond was mostly a thin (10-15 cm in depth) organic deposit (original floodplain topsoil) underlain by clay. There were also a few narrow strips (located along the old creek bed) of sand and silt underlain by clay; however these covered less than 2 ha of the cooling pond bottom. Elsewhere, the bottom type was clay.

The cooling pond had virtually no emergent vegetation, but there were extensive beds of submergent macrophytes, primarily water milfoil (Myriophyllum spicatum). A wide variety of fish species entered the cooling pond as it was filled. Dense populations of yellow perch (Perca flavescens), rock bass (Ambloplites rupestris), black crappie (Pomoxis nigromaculatus), gizzard shad (Dorosoma cepedianum), and various minnows were present during my study (Lawler, Matusky & Skelly Engineers, Inc. 1980, Consumers Power Company unpublished data). The benthic community was poorly developed.

The water level of the cooling pond was lowered by about 1.3 m for the entire year in 1980, and again for August through December of 1983. This was done to facilitate dike repairs and other construction. In fall of 1984, all water was drained from the cooling pond. The drawdown commenced on 1 October and was essentially completed (except for isolated areas) by 21 December. Water levels within-years and before the drawdowns in 1983 and 1984 were stable.

No hunting or other recreational use of the cooling pond was allowed during the study. Consequently, waterbirds were disturbed only on infrequent occasions by construction on the perimeter dikes and by regular patrols of security guards. Waterbirds using the perimeter dikes for loafing returned to the same areas quickly after being disturbed by the security patrols.

Dow Tertiary Treatment Pond

The Dow tertiary treatment pond is owned and operated by Dow Chemical Company. During my study, the treatment pond had virtually no submergent macrophytes, but had small clumps of cattail (*Typha* sp.) and other emergent vegetation along part of its shoreline. Chironomidae (midges) emerged from the treatment pond in large numbers periodically in summer and early fall. On several occasions during my study, such "hatches" were dense enough to attract up to 2,000 tree swallows (Irodoprocne bicolor) and 50 night hawks (Chordeiles minor) which hawked flying insects over the treatment pond. There was no significant fish population in the treatment pond.

The Dow tertiary treatment pond remained partly open throughout most of the winter in each year of my study. Water levels were 0.5-1.0 m higher in spring than in summer and fall each year, except in 1981 when the water during summer remained at the higher spring level. In summer and fall of other years, a narrow sandbar was visible extending about 50 m from the north shore of the treatment pond.

METHODS AND MATERIALS

Waterbird Observations

Field studies on both open water systems were conducted during at least one 24-hour period each week for 5 consecutive years, 1979-1983, when the cooling pond was not covered by ice. Field work in 1979 did not begin until 3 to 4 weeks after spring ice-out, and after portions of the migrating populations of some waterbird species had already passed through central Michigan. In the other 4 years, field work began within 4 days after spring ice-out. Data were collected in a maximum of two 24-hour periods each week during peak times of waterbird migrations. Numbers, distributions, and activities of waterbirds were usually recorded during 6 times in each 24-hour period (dawn, 0700-1000 hours, 1000-1300 hours, 1300-1600 hours, 1600-1900 hours, and sunset).

A 15x-60x zoom spotting scope mounted on the window of a vehicle and 10 X 50 mm binoculars were used to make complete counts of waterbirds by species. To assess waterbird activity, each bird was observed for at least one 15-second interval during each of the 3-hour time blocks. Activities were categorized as: feeding, social, alert, comfort movements (e.g., preening), or locomotor (swimming or walking).

Distributions of waterbirds by species on the cooling pond were mapped by triangulation according to a grid, with each grid square representing 0.5 ha. Birds which appeared to move from one grid square to another during mapping were assigned to the grid square in which they were first seen. Numbered posts corresponding to grid coordinates were established on the perimeter dikes to facilitate mapping. For waterbirds on the Dow tertiary treatment pond, only general locations were recorded.

In fall of 1984, field studies were conducted on 2 days prior to drawdown, and daily thereafter (1 October to 21 December). Only numbers of birds (by species) were recorded during one 2-hour period each day. Observations were usually made in morning or late afternoon.

Measurement Of Habitat Variables

Lawler, Matusky & Skelly Engineers, Inc. (1980) used color aerial photographs supplemented by SONAR and samples taken with an Eckman dredge to map the distribution of macrophytes in the cooling pond in 1979. My subsequent observations and SONAR and grab samples indicated the distribution of macrophytes in the cooling pond was essentially the same each year of my study. Hence, detailed analysis of plant distributions was conducted in only 1 year, 1981. The percent of surface covered by macrophytes was determined for each 0.5 ha grid square primarily by analysis of false color infrared aerial photographs (1 cm = 21.5 m) taken in July 1981. A dot pattern was superimposed and the percentage of the total dots (1024 per grid cell) which overlay visible vegetation was recorded. Field checks indicated that macrophytes within about 1 m of the water surface when the photographs were taken were detected, and all areas with submersed vegetation had material within 1 m of the surface. Therefore, use of the false color infrared aerial photographs appeared to be an accurate method of determining the distribution of macrophytes and the extensiveness of plant coverage within each grid square. The validity of the method was further verified in fall of 1984 when it was possible to walk on the cooling pond bottom following draining and directly observe the distribution of all macrophytes.

The relative density of plants in the cooling pond was visually estimated and photographed in late summer of each year of my study. There were no visually obvious differences in the density of macrophytes at or near the surface among years in 1979, 1981, 1982, and 1983. An obviously higher density of macrophytes in 1980 was documented by photographs, and quantitative estimates of actual plant density were made in late summer of 1983. The estimates were made by shearing and collecting all plant material (throughout the water column) within 1 m of the surface in 9 randomly selected 1 m diameter plots within the plant beds. The plant material was oven dried at 60°C for 24-48 hours and weighed.

Benthic invertebrate samples were collected using a 15.2 cm X 15.2 cm ponar grab in 40 randomly selected grid squares of the cooling pond. Samples were examined within 24 hours after collection. The samples were screened through a number 30 U.S. standard seive (595 microns) and a sucrose solution was used to separate invertebrates from other material in the samples.

Water depths in each grid square were measured in 1981 using a weighted sounding line and an electronic depth finder. A total of 1,220 depth measurements were made. Additional continuous recordings with the depth finder indicated very little variation in depth within grid squares in the cooling pond.

Lack of access prevented direct measurement of habitat variables in the Dow tertiary treatment pond. Only the relative water depth at various times (as indicated by water marks on shoreline objects) was regularly recorded.

Data Analysis

Waterbird count data were converted to use-days by multiplying the mean number of birds per count and the number of days between consecutive 24-hour observation periods in which a particular species was seen. Evening counts were weighted by the approximate number of night hours per 24-hour sampling period. Use-days were estimated to facilitate comparisons of the level of use among species with differing migration chronology and among years with differing numbers of observation periods. For analysis and reporting, data were grouped by season as follows: spring, ice-out (>75 percent open water) to 15 June; summer, 16 June to 14 September; fall, 15 September to ice-in (<50 percent open water).

Diversity indices for each week's sampling period in 1979-1983 for the cooling pond were calculated by the Shannon-Wiener formula (Wilson and Bossert 1971):

$$H_s = -\sum_{i=1}^{s} p_i \log_e p_i$$

where H_s is the diversity index, s is the number of species in a group, and p_i is the proportion of all birds in the i^{th} group. In the calculation of diversity indices and in all statistical analyses, actual count data, not estimated use-days, were used.

I performed one-way analyses of variance to determine if differences in the mean weekly diversity indices among seasons and among years were statistically significant. Bartlett's test of heterogeneity of variances and the Kolmogorov-Smirnov test of non-normality were significant for the untransformed data, so the subsequent ANOVA and *a priori* contrasts were made using transformed data (log x + 1).

A chi-square goodness-of-fit test was used to determine if the observed number of grid squares occupied by both plants and birds on the cooling pond was significantly different from the expected number based on the proportion of the total grid squares which contained plants. The same test was used to determine if the observed number of grid squares with birds but without plants was significantly different from the expected value. Waterbird distribution data for 17 species on the cooling pond in each of 5 years (1979-1983) were subjected to this chi-square test.

Further analysis of distribution data for 3 species of birds for which exceptionally high use and coincidence with plants was recorded in 1980 was performed. Vegetated grid squares in the cooling pond were considered to be in 4 locations. Locations 1, 2, and 3 consisted of contiguous 0.5 ha grid squares with at least 10 percent of each grid square in the location covered by macrophytes. Location 4 consisted of the remaining vegetated grid squares (actually not in a single location) on the cooling pond. I adopted the null hypothesis that the numbers of birds of each species seen in a particular location would be proportional to the total area of that location. Only birds which occupied vegetated grid squares were considered in the analysis. A chi-square test was used to determine the validity of the null hypothesis, and an *a posterior* test employing the Bonferroni *z* statistic was used to identify significant components of the chi-square analysis. Neu et al. (1974) suggested this 2-step method for evaluating preference or avoidance by animals of specific habitats.

RESULTS

Habitat Conditions In The Cooling Pond

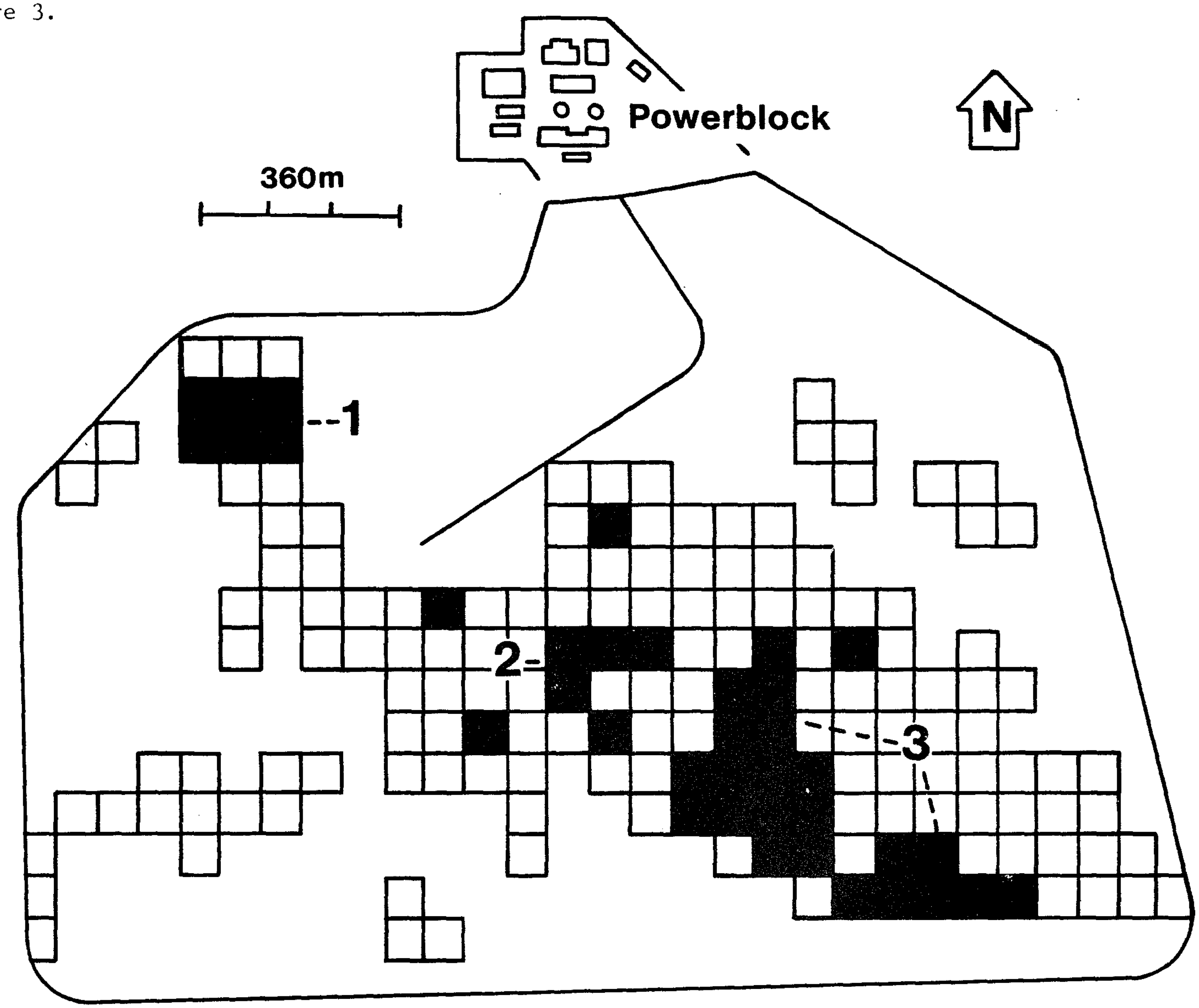
Vegetation

Two species of macrophytes were present the first year (1979) after the cooling pond was filled. The predominant species was spiked water milfoil (*Myriophyllum spicatum*). A small bed (<0.2 ha) of floatingleaf pondweed (*Potamogeton natans*) was found in the northwest part of the cooling pond. From early summer of 1980 through 1984, only spiked water milfoil was found.

Visual observations and SONAR and grab samples indicated the macrophytes grew only where the soil (cooling pond bottom) was undisturbed during construction (Figure 2). Colonization of these areas of inundated organic soil was extensive. Because of this bottom type - plant relationship, the distribution of macrophytes was similar each year. Analysis of the false color infrared aerial photographs taken in 1981 revealed that about 40 percent of the grid squares had some detectable macrophytes within about 1 m of the surface (Figure 3). The percentage of each grid square covered by macrophytes ranged from 1 to 90 percent. There were 3 locations (Figure 3) with contiguous grid squares in which vegetation covered at least 10 percent of each grid

Figure 3. Locations of vegetated grid squares in the cooling pond. Darkened grid squares indicate at least 10 percent of the grid square was covered by macrophytes. Numerals (1-3) indicate locations where there were contiguous grid squares in which vegetation covered at least 10 percent of each grid square.

Figure 3.



square. About 39 percent of location 1, 17 percent of location 2, and 29 percent of location 3 were covered by macrophytes. The average percent coverage by plants of the remaining vegetated grid squares was about 4 percent.

The density of plant materials near the surface was much greater in 1980 than in any other year (Table 1). In late summer and fall of 1980, the spiked water milfoil formed extensive mats on the surface (Figure 4). Until late October, these mats were so dense that waterbirds (including great blue heron) could stand on them, and the plant material supported a 1 m^2 wooden frame made of 2.5 cm square strips. The frame was placed in 125 randomly selected locations within plant beds in early September, and in each location vegetation covered 100 percent of the frame's interior. Primarily as a result of post-growing season senescence, the macrophyte density gradually decreased visibly in November. Macrophytes were deposited by waves in piles up to 0.5 m deep and 4 m wide along the east shore in late November, but the plant density throughout the vegetated areas remained many times higher than in any other year.

The density of plants in 1980 was associated with a lowered water level throughout the year (Table 1). The water level was lowered to a similar level in late July of 1983 (after much of the growing season was over), but the plant density did not noticeably increase and appeared similar to that in 1979, 1981, and 1982. The mean dry weight of plant material within 1 m of the surface was 12.9 g/m^3 (n=9,

Table 1. Relative water depths and plant densities in the cooling pond during 1979-1983 by season and year. Water depths and plant densities varied in fall of 1984 as water was drained from the cooling pond.

Year	Season	Water Depth	Plant Density
	Spring	High[1]	Low
1979	Summer	High	Low
	Fall	High	Low
	Spring	Low[2]	Moderate[3]
1980	Summer	Low	High[4]
	Fall	Low	High
	Spring	High	Low
1981	Summer	High	Low
	Fall	High	Low
	Spring	High	Low
1982	Summer	High	Low
	Fall	High	Low
	Spring	High	Low
1983	Summer	High	Low
	Fall	Low	Low[5]

[1] Mean depth 5.4 m.
[2] Mean depth 4.1 m.
[3] Intermediate between low and high densities in late spring; lower during most of spring waterbird migration.
[4] Very dense mats of plant material at surface (see Figure 4).
[5] Mean dry weight of plant material within 1 m of surface was 12.9 g/m^3 ($n = 9$, $SD = 3.1$) in late summer of 1983.

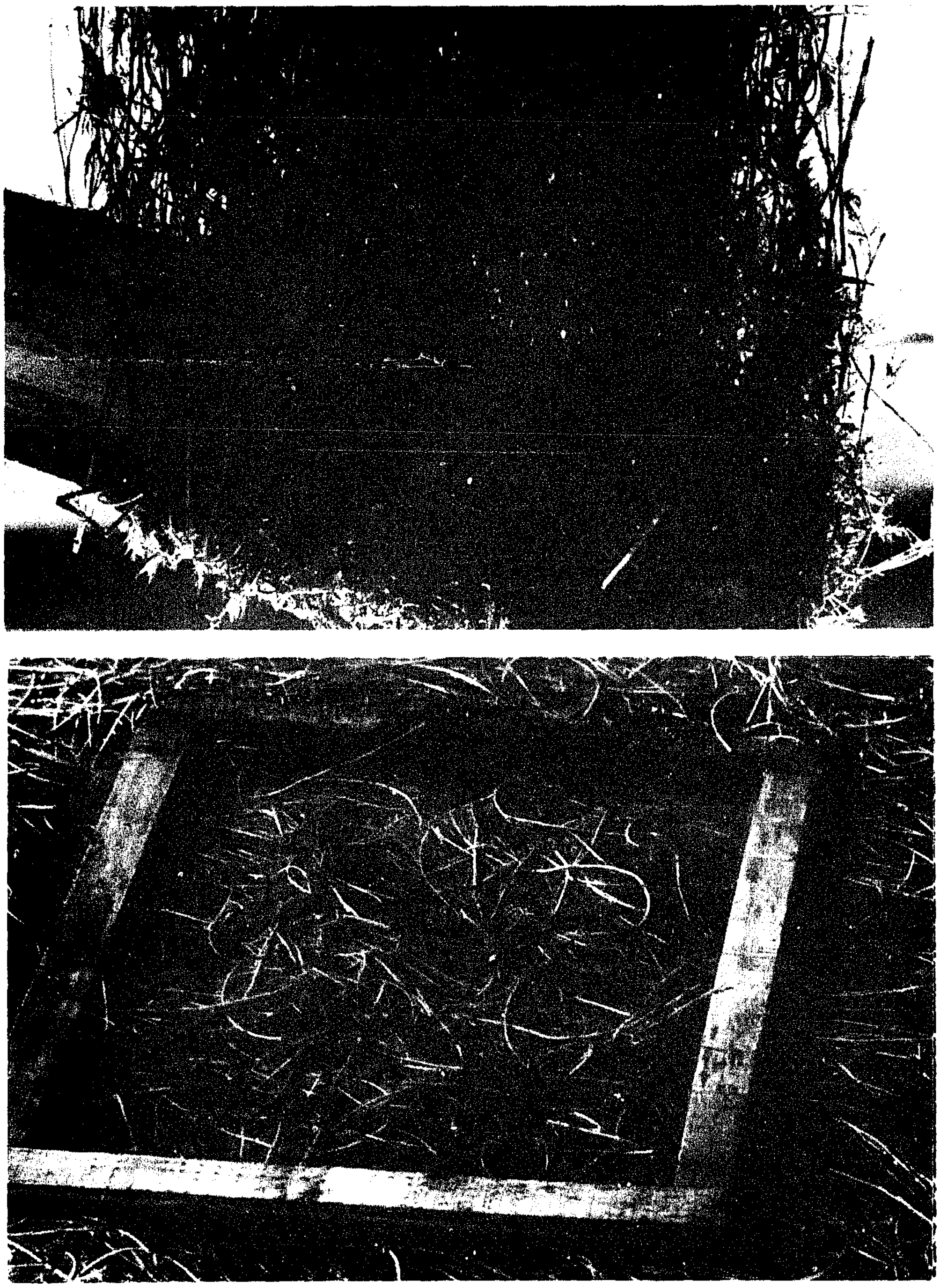


Figure 4. Dense growth of macrophytes on the cooling pond in early fall of 1980. The upper photo shows macrophytes draping boat oar; the lower photo shows 1 m^2 wooden frame supported by macrophytes growing to water surface.

SD=3.1) in late August of 1983. Thereafter, the plant density appeared to decrease steadily during the fall. Thus, the mean sample dry weight of 12.9 g/m^3 was indicative of the maximum amount of plant material near the surface available to migrating waterbirds in fall of 1983.

The distribution and density of plant material in late summer of 1984 appeared similar to that in 1979, 1981, 1982, and 1983. However, from 20 September to 27 September (prior to drawdown) macrophytes were cut and removed from the upper 1.5 m of about 75 percent of the cooling pond surface. Approximately 250 m^3 of plant material (non-dried) was removed (about one-third of the estimated total amount). Plants were cut in 2 of the 3 locations (locations 1 and 2) where macrophytes were most extensive, and in most grid squares north of location 3 (Figure 3).

The water level in 1984 was lowered by about 15 cm each day from 1 October to 18 October, and by about 20 cm each day from 19 October to 1 November. Thereafter, water was mostly confined to isolated depressions and the deep area in the northeast part of the cooling pond (Figure 2). From about 10 October to 29 October, the density of plant materials at the surface increased steadily (as stem length exceeded water depth) until there was essentially no standing water in the plant beds on 29 October. Dense mats of macrophytes were present in water less than 30 cm deep from 22 October to 28 October in the unharvested southeast part of the cooling pond.

Benthos

Sampling with an Eckman dredge in 40 randomly selected grid squares in late May and June of 1981 revealed a very sparse and poorly developed benthic community. Only 9 of 85 samples had invertebrates. The most specimens captured in any sample was 6 chironomid (midge) larvae. The other 8 samples which contained invertebrates had 4 or less chironomid larvae. Two samples had a few snail and clam shell fragments, and 1 sample had a single mayfly (*Hexagenia* sp.) larvae. Each of the samples which contained chironomid larvae were from within the macrophyte beds and also contained organic material from the unexcavated area of the cooling pond bottom. Hence, it was concluded that chironomid larvae were sparse and generally confined to the macrophyte beds and organic bottom type. Examination of numerous rocks (rip-rap) along the shore both in 1981 and in 1984 after much of the pond was drained, revealed only a few mayflies (Heptageniidae) and sow bugs (Isopoda). After most of the cooling pond was drained in early December of 1984, a sparse population of large clams (density <10 per ha) was visible. Because of the low numbers of specimens in my samples and previous (1979) samples of Lawler, Matusky & Skelly Engineers, Inc. (1980), no further sampling of benthos was conducted.

Fish

No systematic attempt to periodically sample fish populations in the cooling pond was made. However, electrofishing and occasional netting by Lawler, Matusky & Skelly Engineers, Inc. (1980 and unpublished data), more intensive netting by Consumers Power Company (unpublished data) in fall of 1984, my field observations, and the history of colonization of the cooling pond by fish all suggest the fish community was numerous and diverse during my study.

Fish entered the cooling pond via intake pipes during filling in spring (7 April to 4 May) and fall (8 November to late December) of 1978. Screens prevented entry of most fish larger than 15 cm in length; hence, mostly minnows and young of other species entered the cooling pond (Mr. P. Bradley Latvaitis, Environmental Department, Consumers Power Company, personal communication). In 1979, extremely large and dense schools of minnows (Cyprinidae) could be seen from shore, and electrofishing provided further evidence of the abundance of minnows (Mr. Latvaitis, personal communication). In 1980 and 1981, my observations and occasional netting by Lawler, Matusky & Skelly Engineers, Inc. indicated that yellow perch (*Perca flavescens*) and rock bass (*Ambloplites rupestris*) more than 10 cm in length were extremely abundant.

In 1982 and 1983, extremely dense and extensive schools of small (less than 4 cm in length) gizzard shad (*Dorosoma cepedianum*) were visible near the cooling pond's surface on numerous occasions. These schools were so dense that it was possible to scoop them from the water with hand-held nets. Gizzard shad often spawn in sloughs, ponds, lakes, and large rivers (Becker 1976), so the gizzard shad I observed and captured could have originated from either spawning in the cooling pond or entry through the intake pipes in late 1980. Water from the Tittabawassee River, which has very heavy fall runs of gizzard shad, was added to the cooling pond in late November and December of 1980 to bring its level back to normal after drawdown.

From 14 September to 19 December of 1984, Consumers Power Company conducted an intensive trap netting program to transfer game fish from the cooling pond to the Tittabawassee River prior to completion of the drawdown. Results of the trap netting indicated gizzard shad and carp (Cyprinis carpio) had the highest standing crops (biomass) among species in the cooling pond. It was estimated that at least 16 metric tons of gizzard shad and a similar biomass of carp were in the cooling pond in fall of 1984. Among fishes less than 12 cm in length, black crappie (Pomoxis nigromaculatus) was most numerous, followed (in order of numerical abundance) by gizzard shad, various sunfishes (Centrarchidae), and yellow perch (Mr. Latvaitis, personal communication). Small minnows, which electrofishing results and observations indicated were extremely abundant in 1979, were not numerous in fall of 1984.

Waterbird Use, 1979-1983

The total number of waterbird use-days on the cooling pond ranged from a high of about 147,000 in 1980 to a low of approximately 20,700 in 1982 (Figure 5). The number of use-days recorded in 1980 was much higher than the combined total of 117,700 use-days for the other 4 years for which yearly use was estimated, and was 178 percent higher than the 5-year average for the cooling pond.

Use-days estimated for the Dow tertiary treatment pond (Figure 5) ranged from a high of about 29,400 in 1979 to a low of about 7,800 in 1983. The 1979 total was 72 percent higher than the 5-year average; the 1980 total of 18,200 was only 6.7 percent higher than the 5-year average for the Dow tertiary treatment pond.

All of the 17 most abundant species using the cooling pond exhibited year-to-year differences in amount of use (Table 2). Peak use by 12 of the 17 species occurred in 1980. The largest absolute yearly differences in use were recorded for American wigeon, redhead, American coot, and scaup which were all abundant that year. Two species--common loon and horned grebe--had more use-days recorded in 1979 than in any other year. Double-crested cormorant and red-breasted merganser were most abundant in 1982, but the difference between the 1982 and 1983 totals for red-breasted merganser was only about 14 percent. Use by common merganser was greatest in 1983.

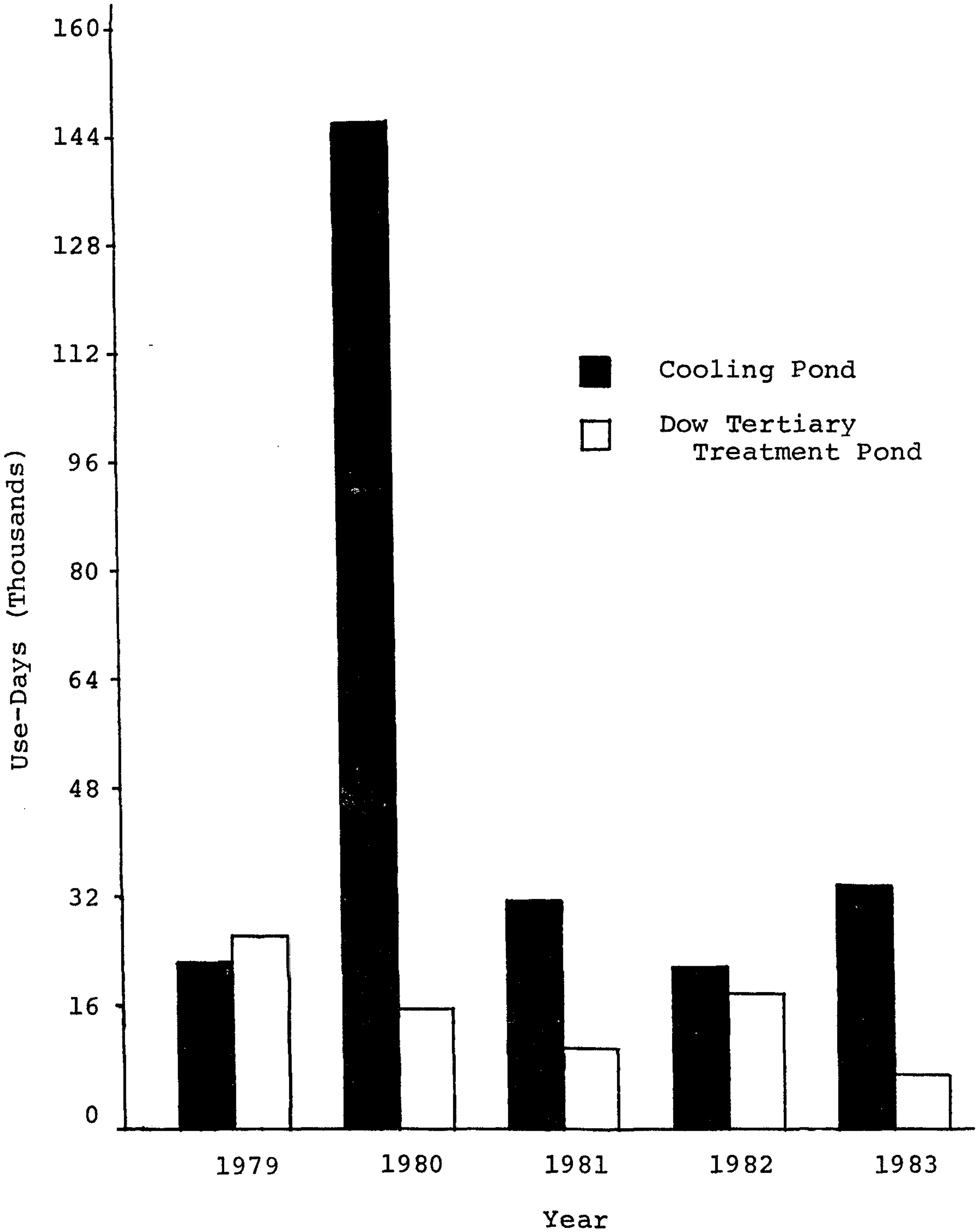


Figure 5. Relative estimated total waterbird use-days on the cooling pond and Dow tertiary treatment pond by year.

Table 2. Estimated use-days by year for the 17 most abundant waterbird species on the cooling pond. Estimates are to the nearest 10 use-days. The highest number of use-days recorded in a year for each species is underlined.

Species	Year				
	1979	1980	1981	1982	1983
Horned grebe	1,160	530	500	330	140
Pied-billed grebe	110	960	80	50	10
Common loon	830	340	320	190	60
Double-crested cormorant	20	150	370	970	100
Common merganser	40	3,050	1,500	1,030	8,110
Red-breasted merganser	2,540	2,380	2,810	9,240	8,130
Mallard	2,660	14,360	5,000	2,720	7,070
Gadwall	60	1,170	30	10	10
American wigeon	150	17,360	330	10	10
Redhead	500	25,470	1,440	60	240
Canvasback	50	2,990	310	90	40
Scaup	2,910	19,020	4,750	1,130	970
Ring-necked duck	100	2,360	40	10	20
American goldeneye	1,160	3,000	1,950	370	120
Bufflehead	980	1,050	90	220	10
Canada goose	6,580	13,060	7,980	3,940	11,890
American coot	4,820	38,260	5,380	100	40

Among the 17 most abundant species on the cooling pond, common loon, horned grebe, double-crested cormorant, scaup, common merganser, and red-breasted merganser had more use-days recorded in spring than in summer or fall (Table 3). Mallard use was greatest in summer, and use by Canada goose, American wigeon, redhead, American goldeneye, and American coot was greatest in fall. There were only slight seasonal differences in use by pied-billed grebe and gadwall, and between spring and fall use by ring-necked duck, canvasback, and bufflehead.

High use was recorded for each of the 17 most abundant species on the cooling pond in particular season-year combinations. Common loon and horned grebe had 25 percent and 37 percent, respectively, of their total 5-year use-days recorded in spring of 1979 (Table 3). Pied-billed grebe, Canada goose, gadwall, American wigeon, redhead, canvasback, American goldeneye, and American coot had 20 to 77 percent of their total use-days recorded in fall of 1980. Ring-necked duck, scaup, and American goldeneye had 23 to 51 percent of use in spring of 1980 (Table 3), and 32 percent of all mallard use was recorded in summer of 1980. The highest use by double-crested cormorant and red-breasted merganser was in spring of 1982, while 48 percent of common merganser use occurred in spring of 1983.

High use recorded in particular season-year combinations was the result of both more birds (larger flock sizes) and longer duration of use. An exception was the high use recorded for scaup in spring of 1980 which resulted from

Table 3. Estimated use-days by season, summed for 5 years (1979-1983), for the 17 most abundant waterbird species on the cooling pond. Estimates are to the nearest 10 use-days. The highest number of use-days by season is underlined for each species.

Species	Season: Spring	Season: Summer	Season: Fall	Period Of Highest Use	Percent Of Total In Highest-Use Period
Horned grebe	1,910	30	620	Spring 1979	37
Pied-billed grebe	230	210	670	Fall 1980	48
Common loon	1,090	370	280	Spring 1979	25
Double-crested cormorant	1,210	280	120	Spring 1982	42
Common merganser	9,550	0	4,180	Spring 1983	48
Red-breasted merganser	21,560	10	3,530	Spring 1982	36
Mallard	8,510	16,650	6,650	Summer 1980	32
Gadwall	160	440	670	Fall 1980	52
American wigeon	370	3,680	13,790	Fall 1980	77
Redhead	4,880	4,990	17,840	Fall 1980	63
Canvasback	1,640	10	1,840	Fall 1980	50
Scaup	22,280	20	6,480	Spring 1980	51
Ring-necked duck	1,280	100	1,150	Spring 1980	47
American goldeneye	1,650	0	4,950	Spr,Fall 1980 (tie)	23
Bufflehead	1,160	70	1,120	Fall 1979	27
Canada goose	8,540	6,460	28,450	Fall 1980	20
American coot	8,380	6,590	33,640	Fall 1980	59

increased flock sizes only. Up to 991 scaup used the cooling pond for about 2 weeks (6 April to 19 April) in that season. Intense, but brief, scaup use also occurred in fall of 1980 when a relatively large number (peak of 662 on 19 October) of scaup was seen on the cooling pond, but only for a few days.

Among the 13 most abundant species on the Dow tertiary treatment pond, substantial year-to-year differences in use-days were recorded for mallard, American wigeon, blue-winged teal, redhead, scaup, ring-necked ducks, Canada goose, and American coot (Table 4). However, both the absolute and relative year-to-year differences were generally much smaller than those recorded for the most abundant species on the cooling pond. In addition, the years of peak abundance were not the same as for the corresponding species on the cooling pond, and 1979 was the year of the greatest total number of use-days.

As on the cooling pond, there were major differences between years in the relative abundance of species on the Dow tertiary treatment pond, but scaup was the most abundant species each year. The general chronology of waterbird use of the Dow tertiary treatment pond was also similar each year of my study. Waterbird use in spring was essentially limited to brief use by large (>100) numbers of scaup and American goldeneye in April. Those two species contributed 85 percent of the 5-year total of use-days recorded in spring (Table 5). From late April to mid-June, total

Table 4. Estimated use-days by year for the 13 most abundant waterbird species on the Dow tertiary treatment pond. Estimates are to the nearest 10 use-days. The highest number of use-days recorded in a year for each species is underlined.

Species	Year				
	1979	1980	1981	1982	1983
Mallard	5,070[a]	1,680	290	2,740	1,660
Black duck	150	90	195	150	180
American wigeon	1,030	130	10	350	10
Blue-winged teal	5,870	1,730	460	1,920	320
Northern shoveler	20	20	20	30	10
Redhead	2,520	2,320	630	2,040	590
Scaup	9,340	8,860	7,380	6,130	3,390
Ring-necked duck	250	40	50	50	10
American goldeneye	1,610	1,490	2,900	2,950	1,020
Bufflehead	190	740	370	550	130
Ruddy duck	320	590	150	140	90
Canada goose	1,210	300	30	30	410
American coot	1,390	140	10	10	10

[a] Higher estimated use-days for mallard in 1979 is likely due in part to more complete censusing of broods in summer. In 1979, several censuses were made from the Dow tertiary treatment pond's dikes. In the other years, censusing of broods was done from less advantageous locations.

Table 5. Estimated use-days by season, summed for 5 years (1979-1983), for the 13 most abundant waterbird species on the Dow tertiary treatment pond. Estimates are to the nearest 10 use-days. The highest number of use-days by season is underlined for each species.

Species	Season: Spring	Season: Summer	Season: Fall	Period Of Highest Use	Percent Of Total In Highest-Use Period
Mallard	560	8,560	2,320	Summer 1979	35
Black duck	100	10	660	Fall 1981	25
American wigeon	20	260	1,230	Fall 1979	59
Blue-winged teal	330	8,210	1,850	Summer 1979	49
Northern shoveler	40	20	30	Spring 1982	28
Redhead	170	850	7,070	Fall 1980	26
Scaup	8,810	10	26,290	Fall 1979	27
Ring-necked duck	20	10	370	Fall 1979	64
American goldeneye	2,180	0	7,800	Fall 1981	29
Bufflehead	620	0	3,070	Fall 1982	14
Ruddy duck	140	10	1,180	Fall 1980	34
Canada goose	150	930	900	Summer 1979	41
American coot	140	10	1,410	Fall 1979	90

waterbird use was negligible (<400 use-days) each year.

The 5-year total summer use was about 1.4x that of spring on the Dow tertiary treatment pond. Nearly 90 percent of the summer use was by mallard and blue-winged teal, and an additional 5 percent was by Canada goose. Substantial summer use by mallard and blue-winged teal, including from 5 to 20 broods, occurred each year except 1981 and 1983.

Total fall use was greater than in the other seasons. The 5-year total for fall was nearly 3x that of summer and about 4x that of spring (Table 5). Nine of the 13 most abundant species on the Dow tertiary treatment pond had their highest number of use-days recorded in fall. Ninety percent of the total use of the Dow tertiary treatment pond by American coot occurred in fall of 1979, and 59 percent of American wigeon use and 64 percent of ring-necked duck use also occurred in fall of 1979 (Table 5).

Eleven species of waterbirds were seen on the cooling pond each year from 1979 to 1983, but were not abundant in any year (Table 6). An additional 13 species were seen in at least one year, but not in all 5 years. Year-to-year differences in use were pronounced for several of these species. Use by wood duck, blue-winged teal, and pintail was greater in 1980 than in the other 4 years, use by common tern and green heron was greatest in 1979, use by snow goose, Bonaparte's gull, and ruddy duck was greater in 1980, and whistling swan use was higher in 1983.

Table 6. Estimated use-days for waterbird species observed on the cooling pond in at least 1 year but not in all 5 years, and/or for which a low number (5-year total <650) use-days were recorded. Numbers in parentheses are total observations; dashes indicate species not seen in that year.

Species	Year 1979		1980		1981		1982		1983	
Western grebe	1	(1)	--		--		--		--	
Eared grebe	2	(9)	--		--		--		--	
Black tern	12	(21)	--		--		--		--	
White pelican	1	(4)	--		--		--		--	
Common egret	1	(2)	--		--		--		--	
Wood duck	1	(1)	457	(281)	--		--		--	
Red-necked grebe	14	(11)	1	(2)	5	(4)	--		--	
Green-winged teal	2	(4)	24	(58)	2	(6)	--		--	
Oldsquaw	32	(11)	6	(16)	1	(1)	--		2	(2)
Common tern	555	(226)	61	(29)	22	(24)	2	(7)	--	
Northern shoveler	10	(28)	9	(12)	1	(5)	2	(4)	--	
Snow goose	3	(9)	1	(3)	370	(214)	8	(16)	--	
Black-crowned night heron	10	(28)	7	(8)	7	(12)	1	(1)	--	
Bonaparte's gull	1	(2)	10	(29)	116	(73)	23	(37)	5	(68)
Caspian tern	53	(49)	197	(127)	87	(63)	116	(97)	165	(105)
Hooded merganser	5	(8)	6	(14)	4	(6)	1	(2)	6	(24)
Black duck	11	(24)	76	(68)	89	(88)	53	(38)	66	(55)
Blue-winged teal	64	(30)	143	(75)	42	(57)	3	(5)	2	(4)
Pintail	3	(8)	252	(143)	6	(16)	3	(17)	2	(5)
White-winged scoter	2	(4)	32	(12)	1	(1)	4	(12)	1	(2)
Ruddy duck	61	(48)	88	(92)	125	(199)	13	(57)	3	(27)
Whistling swan	14	(23)	37	(16)	70	(157)	11	(18)	170	(138)
Great blue heron	11	(9)	45	(48)	1	(4)	27	(19)	23	(13)
Green heron	192	(156)	139	(80)	17	(37)	3	(8)	16	(8)

Five species were present in low numbers on the Dow tertiary treatment pond each year, and an additional 16 species were observed in at least 1 year, but not in all 5 years (Table 7). With exception of common tern, species found on both the cooling pond and the Dow tertiary treatment pond in low numbers had their peak use in different years. Among these species, year-to-year differences in use of the Dow tertiary treatment pond were largest for gadwall, common tern, and canvasback (Table 7).

Forty-one and 34 species of waterbirds were observed on the cooling pond and Dow tertiary treatment pond, respectively, from 1979-1983 (Appendix A). Although the species which occupied the Dow tertiary treatment pond, except Wilson's phalarope, over the course of a year were also observed on the cooling pond, the species compositions of the 2 open water systems were often different in particular 24-hour observation periods. Species seen on the cooling pond only were Western grebe, eared grebe, common loon, black tern, white pelican, whistling swan, common egret, and green heron. Ten species--horned grebe, common loon, double-crested cormorant, common merganser, hooded merganser, gadwall, pintail, white-winged scoter, great blue heron, and green heron--were observed on the cooling pond in all 5 years, but in 4 or fewer years on the Dow tertiary treatment pond. In contrast, only northern shoveler and Wilson's phalarope were seen in more years on the Dow tertiary treatment pond than on the cooling pond.

Table 7. Estimated use-days for waterbird species observed on the Dow tertiary treatment pond in at least 1 year but not in all 5 years, and/or for which a low number (5-year total <130) use-days were recorded. Numbers in parentheses are total observations; dashes indicate species not seen in that year.

Species	Year 1979	1980	1981	1982	1983
Snow goose	16 (13)	--	--	--	--
Black-crowned night heron	1 (2)	--	--	--	--
Red-necked grebe	--	--	--	1 (1)	2 (5)
Double-crested cormorant	--	--	--	6 (9)	1 (1)
Pied-billed grebe	--	1 (2)	1 (1)	--	--
Pintail	17 (24)	1 (4)	--	--	--
Wood duck	--	1 (2)	2 (8)	--	--
Hooded merganser	--	1 (3)	--	7 (20)	--
Great blue heron	1 (1)	--	1 (2)	--	--
Horned grebe	2 (5)	1 (2)	--	1 (1)	--
Gadwall	147 (148)	5 (35)	--	4 (15)	--
Oldsquaw	3 (12)	1 (2)	2 (8)	--	--
White-winged scoter	1 (3)	1 (2)	1 (2)	--	--
Common tern	142 (69)	3 (22)	--	1 (1)	1 (2)
Green-winged teal	55 (66)	2 (13)	1 (2)	7 (30)	--
Common merganser	--	4 (10)	1 (2)	1 (2)	2 (5)
Bonaparte's gull	1 (1)	19 (46)	2 (9)	4 (16)	6 (31)
Caspian tern	9 (13)	6 (24)	1 (3)	8 (13)	1 (2)
Red-breasted merganser	3 (6)	1 (4)	1 (1)	3 (10)	1 (2)
Canvasback	7 (30)	1 (4)	75 (60)	16 (34)	2 (9)
Wilson's phalarope	3 (17)	1 (1)	3 (14)	22 (100)	2 (8)

Sixteen species were observed on both open water systems in all 5 years. They were: Bonaparte's gull, Caspian tern, red-breasted merganser, mallard, black duck, American wigeon, blue-winged teal, redhead, canvasback, scaup, ring-necked duck, American goldeneye, bufflehead, ruddy duck, Canada goose, and American coot. However, the only species relatively abundant on both open water systems were mallard, American wigeon, redhead, scaup, American goldeneye, bufflehead, Canada goose, and American coot. These same 8 species and Caspian tern and common tern were the only species for which movements of individual birds or flocks between the 2 systems within a 24-hour observation period were recorded. Such movements were infrequent and involved few birds, except in the case of fall-migrating American goldeneye which often used the cooling pond as a night roost after spending most of the day on the Dow tertiary treatment pond. Most birds of all other species appeared to select 1 of the 2 open water systems and remain there as long as they stayed in the immediate area.

The number of species seen on the cooling pond declined steadily each year from a high of 41 in 1979 to 29 in 1983 (Figure 6). An overall declining trend in the number of species seen also occurred on the Dow tertiary treatment pond, but the pattern was not as consistent. There were 28 species seen on the Dow tertiary treatment pond in 1979, 29 in 1980, 25 in 1982, and 22 in 1983 (Figure 6).

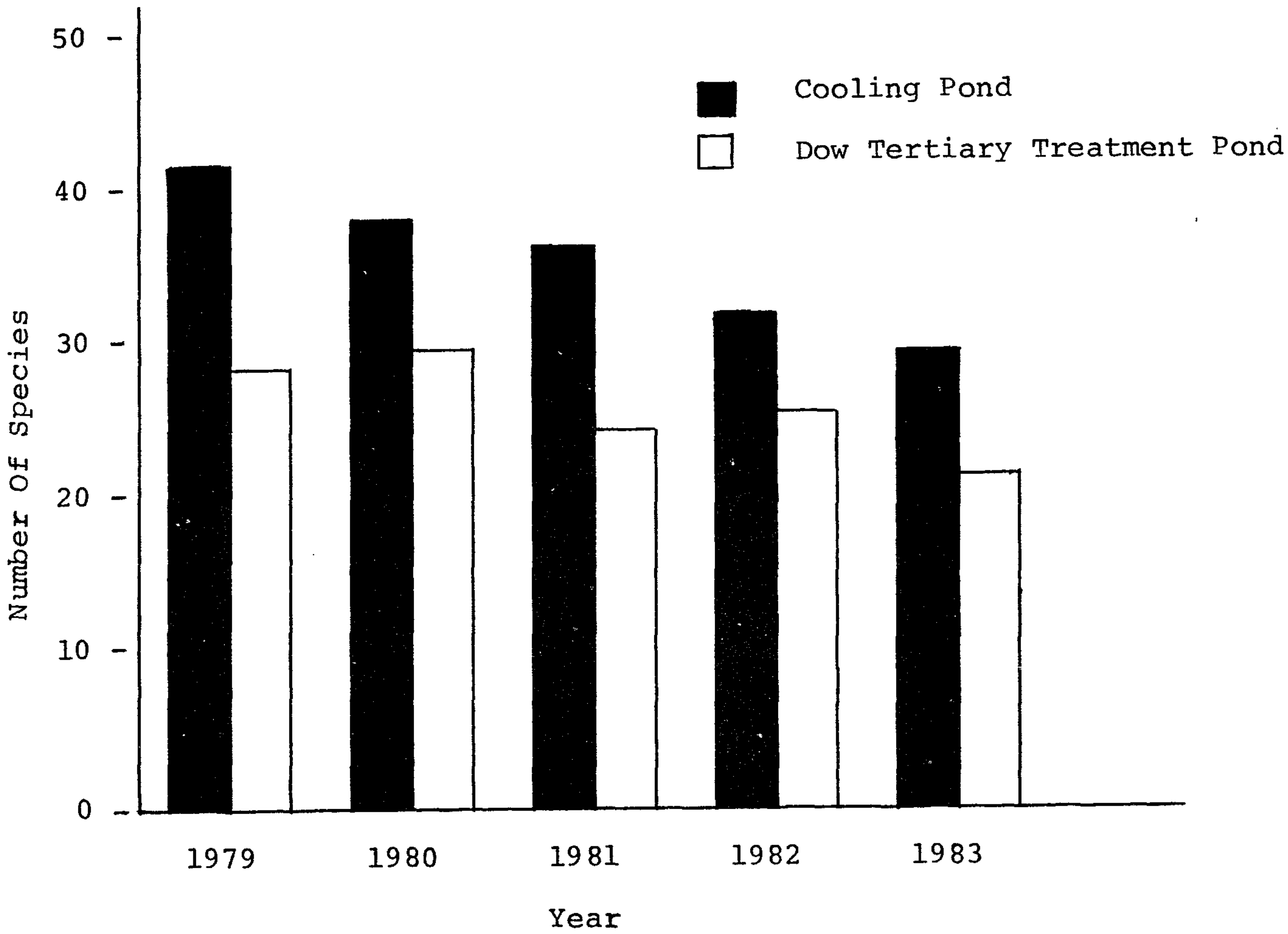


Figure 6. Number of species observed on the cooling pond and Dow tertiary treatment pond by year.

Five species--Western grebe, eared grebe, black tern, white pelican, and common egret--were seen on the cooling pond in 1979, but not in subsequent years (Table 6). Wood duck was present in 1979 and 1980, but not observed in the next 3 years. Red-necked grebe and green-winged teal were not seen in 1982 or 1983 (Table 6). Four additional species--common tern, northern shoveler, snow goose, and black-crowned night heron--were not seen in 1983 after having been observed in the 4 previous years. Oldsquaw was seen on the cooling pond each year except 1982. This general pattern of species appearing to stop using the cooling pond after previous use was not observed for the Dow tertiary treatment pond (Table 7). Only 6 of 16 species seen in 1 year but not in all 5 years on the Dow tertiary treatment pond exhibited this use pattern.

The mean weekly species diversity index for the cooling pond was significantly higher in 1980 than in the other 4 years for which year-around data were recorded (Table 8). Mean weekly diversity in each season was higher than for the respective seasons in the other 4 years. Bartlett's test (Snedecor and Cochran 1967) indicated the variances in mean weekly species diversity were lower in 1980 than in the other years in each season. Inspection of the data used to calculate the diversity indices revealed that the higher diversity and lower sample variances in 1980 were due to better numerical balance among species occupying the cooling pond and more persistent use by several species

Table 8. Mean 24-hour species diversity indices ($\bar{x}$) and standard deviations (SD) by season and year for waterbirds on the cooling pond. Numbers in parentheses are total 24-hour observation periods in a season or year.

Year	Spring $\bar{x}$		Spring SD	Summer $\bar{x}$		Summer SD	Fall $\bar{x}$		Fall SD	Year Total $\bar{x}$		Year Total SD
1979	1.23^{a}	(9)	0.31	0.68^{a}	(13)	0.25	1.21^{ab}	(12)	0.41	1.01^{a}	(34)	0.42
1980	1.68^{b}	(12)	0.24	1.43^{b}	(12)	0.18	1.47^{a}	(10)	0.29	1.53^{b}	(34)	0.25
1981	1.19^{a}	(11)	0.45	0.72^{a}	(12)	0.22	1.11^{abc}	(12)	0.41	0.81^{a}	(38)	0.42
1982	1.17^{a}	(13)	0.31	0.46^{a}	(13)	0.27	0.85^{bc}	(12)	0.41	0.81^{a}	(38)	0.43
1983	1.17^{a}	(14)	0.48	0.53^{a}	(12)	0.28	0.69^{bc}	(10)	0.64	0.79^{a}	(36)	0.55

$^{a-c}$ Column means with unlike superscripts differ ($P<0.05$) by Scheffe's test (Snedecor and Cochran 1967).

including redhead, American wigeon, American coot, mallard, and Canada goose. In the other years, the depressing effect on species diversity of differing migration chronology among species was greater in spring and fall.

Waterbird Activities

There were significant year-to-year differences in the percentages of birds observed feeding for 12 of the 17 most abundant species on the cooling pond (Table 9). Years of greatest percentages observed feeding coincided with the years of highest use-days for 6 of those species.

The percentages of Canada geese, mallards, gadwall, American wigeon, redhead, and American coot seen feeding were significantly greater in 1980, the year of highest use by these species on the cooling pond, than in any other year. The highest percentages of birds seen feeding in a particular year were 67 percent for American coot, 60 percent for gadwall, and 55 percent for American wigeon (all in 1980). In contrast, double-crested cormorant, common merganser, red-breasted merganser, canvasback, scaup, ring-necked duck, American goldeneye, and bufflehead had relatively low percentages of birds feeding in their high-use years on the cooling pond (Tables 2 and 9).

Significantly higher percentages of birds feeding were recorded for horned grebe in 1979 and 1983, for common loon in 1980, for red-breasted merganser and scaup in 1979, and for double-crested cormorant in 1983 than in the other years. There were no significant differences among years

Table 9. Percentages of birds of the 17 most abundant waterbird species on the cooling pond observed feeding. Numbers in parentheses are total 15-second observations of individuals of a species.

Species	Year 1979		1980		1981		1982		1983	
Horned grebe	50.7^{a}	(675)	17.9^{b}	(408)	8.8^{c}	(250)	27.0^{b}	(241)	42.4^{a}	(66)
Pied-billed grebe	4.5^{a}	(199)	23.7^{b}	(448)	14.3^{b}	(84)	31.3^{b}	(16)	11.1^{b}	(36)
Common loon	28.9^{a}	(5,739)	34.7^{b}	(2,520)	29.4^{a}	(1,844)	23.9^{a}	(3,340)	23.5^{a}	(925)
Double-crested cormorant	12.7^{a}	(165)	6.9^{a}	(1,540)	9.5^{a}	(1,264)	6.3^{a}	(554)	30.0^{b}	(100)
Common merganser	6.4^{a}	(78)	7.8^{a}	(1,092)	1.6^{a}	(367)	4.8^{a}	(1,031)	5.2^{a}	(3,386)
Red-breasted merganser	37.4^{a}	(944)	22.3^{b}	(1,340)	25.4^{b}	(1,495)	8.6^{c}	(6,712)	5.4^{d}	(3,310)
Mallard	6.8^{a}	(2,478)	25.0^{b}	(5,013)	0.9^{c}	(982)	0.3^{c}	(703)	8.8^{a}	(1,756)
Gadwall	0.0^{a}	(37)	59.8^{b}	(570)	11.1^{a}	(18)	0.0	(3)	0.0^{a}	(16)
American wigeon	23.6^{a}	(165)	54.6^{b}	(7,888)	0.0^{a}	(104)	0.0	(5)	0.0	(2)
Redhead	9.0^{a}	(378)	25.3^{b}	(13,687)	15.3^{a}	(894)	0.0^{a}	(33)	16.5^{a}	(236)
Canvasback	6.9^{a}	(29)	4.2^{a}	(1,488)	0.9^{a}	(340)	0.0^{a}	(26)	1.9^{a}	(212)
Scaup	9.3^{a}	(589)	4.4^{b}	(8,855)	1.5^{c}	(2,445)	0.4^{c}	(1,021)	0.0^{c}	(489)
Ring-necked duck	0.0^{a}	(39)	5.8^{a}	(1,320)	0.0^{a}	(32)	0.0^{a}	(12)	0.0^{a}	(65)
American goldeneye	2.8^{a}	(249)	1.9^{a}	(213)	0.0^{a}	(15)	3.8^{a}	(26)	0.8^{a}	(125)
Bufflehead	5.6^{a}	(594)	6.1^{a}	(446)	8.7^{a}	(69)	4.4^{a}	(158)	10.0^{a}	(30)
Canada goose	7.0^{a}	(2,566)	27.7^{b}	(6,644)	2.8^{c}	(3,136)	8.3^{a}	(1,477)	5.1^{a}	(3,890)
American coot	47.0^{a}	(2,450)	67.0^{b}	(17,497)	40.3^{c}	(4,010)	6.3^{d}	(80)	17.5^{d}	(57)

[a-d] Row percentages with unlike superscripts are significantly different ($P<0.05$) based on binomial distribution. Percentages without superscripts indicate sample size <10.

in the percentages of canvasbacks, ring-necked ducks, American goldeneyes, buffleheads, and common mergansers seen feeding.

<u>Relationships Between Waterbird Distributions And Habitat Variables</u>

Chi-square goodness-of-fit comparisons indicated that the observed number of waterbird occupied grid squares with and without macrophytes differed significantly from the expected number based on proportion of occurrence for 30 of 85 species-year combinations tested for the cooling pond (Table 10). American coot, American wigeon, redhead, scaup, ring-necked duck, pied-billed grebe, canvasback, mallard, gadwall, and Canada goose occupied significantly more grid squares with vegetation than expected in 1980, and the coincidence of birds with vegetation was more evident for those species in 1980 than in the other years (Table 10).

Redhead occupied significantly more vegetated grid squares than expected in 4 years (1979, 1980, 1981, and 1983). American coot, American wigeon, and pied-billed grebe occupied more vegetated grid squares in 3 years (1979, 1980, and 1981). Scaup and canvasback were similarly associated with vegetation in 1979 and 1980, and ring-necked duck (in 1980 and 1981), American goldeneye (1979 and 1982), common loon (1981), and double-crested cormorant (1982) also occupied more vegetated grid squares than expected (Table 10). Species which occupied significantly

Table 10. Number of grid squares (N=440) occupied by both birds and vegetation (C) and total grid squares occupied by birds (n) of the 17 most abundant species on the cooling pond. Species-year combinations are ranked based on the difference in the number of grid squares occupied by birds with and without vegetation. Higher ranks generally indicate better coincidence of birds and vegetation, but small sample sizes for certain species-year combinations prohibit some comparisons.

Rank	Species	Year	C	n
1	American coot	1980	118**	165
2	American wigeon	1980	88**	108
3	Redhead	1980	123**	181
4	Scaup	1980	88**	139
5	Ring-necked duck	1980	35**	37
6	Pied-billed grebe	1980	40**	47
7	Common loon	1981	55**	83
8	Canvasback	1980	31**	40
9	Redhead	1979	27**	34
10	Mallard	1980	109**	203
11	American wigeon	1981	24**	33
12	Redhead	1983	27**	40
13	Redhead	1981	57**	44
	Gadwall	1980	17**	21
15	Pied-billed grebe	1979	24**	37
	American coot	1979	45**	78
	Ring-necked duck	1981	11**	11
18	Pied-billed grebe	1981	24**	38
	American coot	1981	63**	116
	American goldeneye	1979	16**	22
21	Canvasback	1979	10**	11
22	American wigeon	1979	15*	23
23	Double-crested cormorant	1982	21*	36
24	Scaup	1979	26*	47
	American goldeneye	1982	11*	17
26	Horned grebe	1980	19	34
	Ring-necked duck	1979	7	10
28	Gadwall	1979	5	7
	Double-crested cormorant	1983	7	11
30	American wigeon	1983	3	4
	Common merganser	1979	2	2
	Common loon	1979	102**	202
33	Gadwall	1982	1	1
	Ring-necked duck	1982	4	7
	Pied-billed grebe	1983	7	13
36	American coot	1983	4	8

Table 10 (cont'd):

Rank		Year	C	n
	Pied-billed grebe	1982	5	10
38	Gadwall	1981	6	13
	Scaup	1981	61	123
	Ring-necked duck	1983	3	7
	American goldeneye	1983	6	13
42	Canvasback	1983	5	12
	Double-crested cormorant	1980	2	6
44	Common merganser	1981	12	27
	Gadwall	1983	2	7
	Double-crested cormorant	1979	2	7
	Canvasback	1982	4	11
48	Canada goose	1980	98*	200
	American goldeneye	1981	4	12
50	American wigeon	1982	0	5
	American goldeneye	1980	61	127
	Bufflehead	1983	3	11
	Bufflehead	1981	14	33
	Scaup	1983	24	53
	Common loon	1983	17	39
56	Double-crested cormorant	1981	6	18
	Canvasback	1981	11	28
58	Redhead	1982	3	13
	Bufflehead	1979	38	83
60	Bufflehead	1980	13	35
61	American coot	1982	5	20
62	Canada goose	1983	28	67
63	Scaup	1982	20	52
	Bufflehead	1982	15	42
65	Common loon	1980	22	58
66	Red-breasted merganser	1980	37	90
67	Common merganser	1980	31	80
	Horned grebe	1983	8	34
	Mallard	1979	47	112
	Mallard	1981	53	124
71	Canada goose	1979	57	133
72	Mallard	1983	24	69
73	Canada goose	1981	34	90
74	Horned grebe	1981	37	97
	Common loon	1982	49	121
76	Canada goose	1982	29	85
77	Red-breasted merganser	1979	83	194
	Horned grebe	1979	77	182
79	Mallard	1982	27	84
80	Horned grebe	1982	19**	83
81	Red-breasted merganser	1983	48	143

Table 10 (cont'd):

Rank	Species	Year	C	n
82	Red-breasted merganser	1981	48	143
83	Common merganser	1982	19**	101
84	Common merganser	1983	68*	201
85	Red-breasted merganser	1982	67**	231

* Chi-square test significant, $P<0.05$.
** Chi-square test significant, $P<0.01$.

more grid squares without vegetation than expected were horned grebe (in 1982), red-breasted merganser (1982), and common merganser (1982 and 1983). In 1982 and 1983, relatively large numbers of horned grebes, red-breasted mergansers, and common mergansers were observed in the deeper water area in the northeast part of the cooling pond (Figure 2).

Coincidence of birds and vegetation was particularly evident for American coot, American wigeon, and redhead in 1980 (Table 10), and the abundance and incidence of feeding by those species were also much higher in 1980 than in any other year. Chi-square analyses of the distributions of American coot, American wigeon, and redhead in 1980 indicated that birds of those species were not evenly distributed among the vegetated grid squares. Each of the 3 species seemed to prefer locations (Figure 3) of the cooling pond where macrophytes were most extensive (Table 11). More American wigeon occupied all 3 locations where there were contiguous grid squares with at least 10 percent of each grid square covered by macrophytes than expected based on proportion of occurrence (availability of habitat). American coot appeared to prefer only locations 2 and 3 (both in the southeast part of the cooling pond), and redhead were more numerous than expected in locations 1 and 3. The relative difference between observed and expected numbers of birds of all 3 species in 1980 was greatest for location 3, the largest of the 3 locations

Table 11. Occurrence of birds of 3 species in 4 vegetated locations in the cooling pond in 1980. Total areas (in ha) of locations are: 1 - 3.0, 2 - 2.5, 3 - 11.0, 4 - 68.5. Locations 1, 2, and 3 consisted of contiguous 0.5 ha grid squares with at least 10 percent of each grid square covered by macrophytes. Location 4 consisted of the remaining vegetated grid squares in the cooling pond (see (Figure 3).

Location	Proportion[a] Of Total Area	Species	Number Of Birds Observed	Number Of Birds Expected	Proportion Observed In Each Location (Pi)	Family Of 99% Confidence Intervals On Pi[b]
		American wigeon	866	432	0.070**	$0.063 \leq Pi \leq 0.077$
1	0.035	Redhead	1,365	693	0.069**	$0.064 \leq Pi \leq 0.074$
		American coot	20	924	0.001**	Can not Compute[c]
		American wigeon	580	358	0.047**	$0.041 \leq Pi \leq 0.053$
2	0.029	Redhead	251	574	0.013**	$0.010 \leq Pi \leq 0.016$
		American coot	1,333	766	0.050**	$0.046 \leq Pi \leq 0.054$
		American wigeon	7,024	1,605	0.569**	$0.556 \leq Pi \leq 0.582$
3	0.130	Redhead	12,584	2,572	0.636**	$0.626 \leq Pi \leq 0.646$
		American coot	17,314	3,431	0.656**	$0.647 \leq Pi \leq 0.665$
		American wigeon	3,877	9,952	0.314**	$0.302 \leq Pi \leq 0.326$
4	0.806	Redhead	5,587	15,948	0.282**	$0.272 \leq Pi \leq 0.292$
		American coot	7,732	21,278	0.293**	$0.284 \leq Pi \leq 0.302$

[a] Represents expected proportion of birds if birds occurred in each location in exact proportion to availability; compared to confidence interval on Pi.
[b] Based on Bonferroni z statistics (Neu et al 1974).
[c] Calculations exceeded capability of calculator because of low Pi value.
** Observed values significantly different ($P<0.01$) from expected values.

with contiguous grid squares with at least 10 percent of each grid square covered by macrophytes (Table 11).

Waterbird Response To Fall Drawdown In 1984

Twenty-five species of waterbirds were observed on the cooling pond in fall of 1984 (Table 12). The total estimated use-days of 25,530 was considerably higher than that in fall of any year except 1980.

There were 17,910 use-days recorded for Canada goose, 70 percent of the fall 1984 total and twice that recorded in fall of 1980 (when the previously highest amount of Canada goose use of the cooling pond occurred) (Table 3). Use by Canada goose occurred throughout the period from 15 September to 10 December, with a peak number of 485 seen on 28 October. Over 400 geese were seen on 12 dates, and 300-400 Canada geese were observed on an additional 13 dates from 19 October to 10 December.

In contrast, more than 25 redheads were seen only during a 16-day period (14 October to 29 October). Fifty-six percent of the total redhead use occurred during only 6 days (23 October to 28 October) when the density of inundated plant material on the cooling pond was greatest. After 28 October, there was essentially no water in the areas with macrophytes. Other species which exhibited a similar use chronology were gadwall, American wigeon, and American coot. Eighty-five percent of gadwall use, 96 percent of use by American wigeon, and 95 percent of American coot use

Table 12. Estimated use-days, by species, in fall of 6 years (1979-1984) for waterbirds on the cooling pond. Dashes indicate species not seen that fall.

Species	Fall Use-Days By Year					
	1979	1980	1981	1982	1983	1984
Horned grebe	220	180	180	16	16	9
Pied-billed grebe	100	530	3	40	3	1
Common loon	110	60	90	24	1	2
Bonaparte's gull	--	1	--	--	1	19
Caspian tern	--	1	--	--	--	--
Double-crested cormorant	2	16	24	80	2	5
Common merganser	50	1,140	1,320	220	1,460	1,660
Red-breasted merganser	210	640	1,770	250	660	590
Hooded merganser	4	5	4	1	2	--
Mallard	1,090	2,860	630	1,820	250	1,240
Black duck	10	60	90	50	70	30
Gadwall	10	650	3	2	--	260
American wigeon	70	13,700	30	1	1	330
Green-winged teal	1	20	--	--	--	8
Blue-winged teal	--	7	--	--	--	5
Northern shoveler	10	6	--	--	--	--
Pintail	3	250	--	1	--	--
Wood duck	--	1	--	--	--	--
Redhead	220	17,090	190	10	50	1,860
Canvasback	50	1,740	4	30	17	30
Scaup	1,730	4,440	150	160	3	580
Ring-necked duck	90	1,060	--	3	4	20
American goldeneye	1,160	1,500	1,930	360	40	12
Bufflehead	630	460	20	12	2	12

Table 12 (cont'd):

Species	Fall Use-Days By Year					
	1979	1980	1981	1982	1983	1984
Oldsquaw	30	6	1	--	1	--
White-winged scoter	2	30	4	1	1	--
Ruddy duck	50	60	14	3	2	--
Snow goose	3	1	370	8	--	350
Canada goose	4,300	8,740	5,870	2,890	6,650	17,910
Whistling swan	12	30	70	--	--	50
Great blue heron	1	20	--	16	20	140
Green heron	1	1	--	--	--	2
Black crowned night heron	--	1	--	--	--	--
American coot	4,800	28,780	5	15	40	350
Totals	14,970	84,090	12,770	6,010	9,300	25,530

occurred from 21 October to 29 October.

Common mergansers used the cooling pond primarily during 5 November to 19 November, while virtually all red-breasted merganser use occurred from 25 October to 4 November. Up to 156 common mergansers and 88 red-breasted mergansers were seen foraging on small fish in isolated areas formed as drawdown progressed.

Use by mallard was more sporadic than that of the other species which used the cooling pond in fall of 1984. The peak numbers of mallards seen were 263 on 28 November and 141 on 19 November. No well-defined chronology of use by mallard was evident in fall of 1984, with fewer than 15 mallards present on 54 dates during the 91-day sampling period.

Eighty-five percent of the fall 1984 scaup use occurred from 10 October to 19 October. Snow goose use of the cooling pond was primarily during 8 November to 12 November.

Canada goose, mallard, common merganser, red-breasted merganser, and snow goose were observed in numerous areas in the cooling pond in fall of 1984. Canada goose, mallard, and snow goose were most often seen loafing on dry ground exposed as the drawdown progressed. Common merganser and red-breasted merganser were most often seen in the deeper northeast part of the cooling pond. All redhead, gadwall, American wigeon, and American coot observed were in location 3 (Figure 3) where macrophytes were not harvested prior to drawdown. (Macrophytes were harvested in locations 1 and 2 and in all grid squares northwest of location 3.) All scaup were seen in or nearby location 3.

DISCUSSION

Differences in use between years by a number of waterbird species were much greater on the cooling pond than on the Dow tertiary treatment pond. Use of the cooling pond by horned grebe and common loon was particularly high in 1979. Pied-billed grebe, mallard, gadwall, American wigeon, redhead, canvasback, scaup, and American coot were much more abundant in 1980 than in any other year of my study. Use of the cooling pond by Canada goose was high in both 1980 and 1983, and during fall of 1984. Double-crested cormorants were most numerous in 1982, and red-breasted merganser use was high in 1982 and 1983. Use by common merganser was highest in 1983. Years of high abundance on the cooling pond by these species did not correspond with years of high abundance for the same species on the Dow tertiary treatment pond. This suggests that while differences in migration chronology and/or population numbers may have contributed some of the between-years variation in waterbird use of the cooling pond, the differences were largely attributable to changes in habitat.

My results suggest that lowering the water level of the cooling pond was not directly associated with increased numbers of waterbirds with exception of Canada goose. High use by Canada goose was recorded in fall of 1980, 1983, and 1984 when water levels were reduced. Macrophyte density was abnormally high in summer and fall of 1980, but not in 1983, and only for a few days in part of the cooling pond in fall of 1984. However, use by Canada goose was only 24 percent less in fall of 1983 than in 1980, and much higher in fall of 1984. Chi-square analysis of Canada goose distribution data indicated a bird-plant association in 1980, but not in 1983. The percentage of Canada geese seen feeding was high in 1980, but low in 1983 and fall of 1984 when most Canada geese on the cooling pond fed in croplands outside the study area. In 1980 and 1983, Canada geese were frequently seen on the baffle dike and shore areas exposed after drawdown. Therefore, I speculate that the water level drawdowns in 1980, 1983, and 1984 resulted in high Canada goose use in part because more suitable dry ground loafing area was available. Street (1982) stated that waterbirds roosting on a lake, especially in windy conditions, must expend valuable energy in order to "keep station" on the water, and that in rough weather they much prefer to rest on land. Bellrose (1976) and other authors have suggested that Canada geese favor large open areas to provide "a feeling of security." Hence, the dry ground away from the dikes in fall of 1984 may have provided the Canada geese with less energy demanding and more secure loafing sites than provided by the perimeter and baffle dikes and open water in the other years.

My results strongly suggest that the high use of the cooling pond in 1980 by pied-billed grebe, mallard, gadwall, American wigeon, redhead, and American coot was a direct response to a high density of macrophytes near the surface. Although the water level during the growing season caused the high density of macrophytes, water level was apparently not directly associated with high use of the cooling pond by these species. Use by these species was low in fall of 1983 when the water level was the same as in fall of 1980, but the macrophyte density near the surface was low.

The general chronology of use, distributions, and activity data for pied-billed grebe, mallard, gadwall, American wigeon, redhead, and American coot further support the conclusion that macrophyte density strongly influenced use of the cooling pond by these species. Chi-square analysis indicated bird-plant associations for each of these species in 1980, and the percentages of birds of each species seen feeding were significantly higher in 1980 than in any other year. Mallards used the cooling pond primarily in summer of 1980, while pied-billed grebe, gadwall, American wigeon, redhead, and American coot were most abundant in fall. Macrophyte density was high in both summer and fall of 1980, but not in spring.

Seeds, tubers, and rootstocks are generally the most important plant parts to North American migrating waterbirds (Bellrose 1976, Anderson 1959). Martin and Uhler (1939) suggested that seeds are the most important parts of *Myriophyllum* eaten by waterfowl. They further stated:

> *Myriophyllum spicatum* is the most useful form of watermilfoil in western and northern parts of the United States, there being more than 225 records of its consumption by ducks, but the quantities of seen eaten average rather small. (Martin and Uhler 1939:91)

On the cooling pond, most of the available plant material near the surface was leaves and stems, and my observations of feeding birds, and of remaining plant parts in the macrophyte beds, indicated that both leaves and stems were eaten extensively by waterbirds in summer and fall of 1980. Literature on the feeding habits of pied-billed grebe, mallard, gadwall, American wigeon, redhead, and American coot provides further evidence that density of such plant material near the surface can be an important factor influencing use of open water systems by these species.

Pied-billed grebe is the only species of grebe which often consumes vegetation (Bent 1923). Leaves and stems of submerged aquatic plants are used extensively by mallards in brackish marshes of Chesapeake Bay (Stewart 1962) and numerous other areas (Quay and Critcher 1965, Bellrose 1976, Saunders and Saunders 1981. Unlike most dabbling ducks, which feed primarily on the seeds, gadwall and American wigeon seem to prefer the stems and leafy parts of macrophytes (Bellrose 1976:216,206). Redheads feed more extensively on aquatic plants and less on animal life than other diving ducks, and often feed by tipping up or submersing their heads like dabblers in habitats (such as the cooling pond in 1980) in which they do not need to dive for food (Bellrose 1976:324). American coot also frequently feed on aquatic plants (Pirnie 1935).

Although the number of use-days by canvasback and scaup were high on the cooling pond in 1980 when the density of macrophytes was high, and chi-square analysis of distribution data suggested a bird-plant association, some aspects of my results are not consistent with a hypothesis that macrophyte density directly influenced use of the cooling pond by these 2 species. There was no significant difference between years in the percentage of canvasbacks observed feeding. Only about 4 percent of canvasbacks were seen feeding in 1980, a much lower percentage than recorded for pied-billed grebe (24 percent), mallard (25 percent), gadwall (60 percent), American wigeon (55 percent), redhead (25 percent), Canada goose (28 percent), and American coot (67 percent) in that year. Similarly, only 4 percent of scaup were seen feeding in 1980, a significantly lower percentage than the 9 percent of scaup observed feeding on the cooling pond in 1979 when the macrophyte density was low. In all years of my study, diving scaup were assumed to be attempting to feed, but no scaup returned to the surface with visible food in their bills, as was often observed for redhead and American coot. In addition, most of the scaup use in 1980 occurred in spring before the macrophytes reached high densities. Use of the cooling pond in the fall when macrophytes were dense was by a large number of scaup for only a few days. If availability and density of macrophytes were important to scaup, higher use by this species should have occurred in fall rather than in spring of 1980.

Canvasbacks feed extensively on small clams, snails, and other animals on some of their more important staging and wintering areas such as Keokuk Pool, Mississippi River (Thompson 1973) and Chesapeake Bay (Perry 1974), and available literature suggests that scaup are more inclined to feed on animal matter than plants (Bellrose 1976: 354, Cottam 1939). Several studies of scaup food habits have revealed that benthic invertebrates, especially clams and snails, are very important in scaup diets in staging and wintering areas (Cronan 1957, Rogers and Korschgen 1966, Yocom and Keller 1961, Anderson 1959, Thompson 1973). Benthic invertebrates were virtually absent in the cooling pond during my study.

Scaup also feed on free-swimming invertebrates, at least on the breeding grounds (Siegried 1976, Rogers and Korschgen 1966, Bartonek and Hickey 1969, Munro 1941). Although free-swimming invertebrates were not observed or captured in repeated near-surface grab sampling with a

Kemmerer water bottle, the water milfoil beds could have supported populations of free-swimming and/or clinging invertebrates, especially in summer and fall of 1980. However, if scaup (or canvasbacks) were exploiting such a food resource on the cooling pond in 1980, diving (feeding) should have been observed more frequently than my results indicated. Siegfried (1974) found that lesser scaup on the Delta Marsh in Manitoba prior to nesting fed 98 percent of the time by diving, and the average daily percentages of birds observed feeding were 35.1 for mated females, 16.6 for mated males, and 18.0 for unmated males. My observations of scaup on the Dow tertiary treatment pond, which contained substantial numbers of small invertebrates (midges) in summer and fall, also indicated high (20-50 percent) percentages of scaup seen feeding.

Hence, despite the coincidence of the distributions of canvasback and scaup and macrophytes in 1980, these species may not have been directly exploiting plants or associated food resources. I speculate that the dense macrophytes (possibly in combination with numbers of other waterbirds on the cooling pond in fall) was a proximate cue which prompted initial selection of the cooling pond by migrating canvasbacks and scaup, but suitable food could not be found (at least in the case of scaup). This resulted in infrequent feeding bouts and the brevity of use of the cooling pond by large numbers of canvasback and scaup in fall of 1980.

Differences among years in use of the cooling pond by many waterbird species seem directly related to abundance of small fishes. Field observations and results of test netting indicated that fish less than 10 cm in length were most numerous in 1979 and again in 1982 and 1983 following intake of water, and presumably small fish, in 1978 and late 1980. Waterbird species whose years of peak abundance coincided with that of small fishes in the cooling pond included: horned grebe, common loon, double-crested cormorant, common merganser, and red-breasted merganser. Each of these species is piscivorous (Bent 1923, Peterson 1965, Bellrose 1976). Five additional species--Western grebe, eared grebe, black tern, white pelican, and common egret--were seen only in 1979, and their absence in subsequent years accounts in large part for the decline in the number of species seen on the cooling pond during 1979-1983. Although these and several other piscivorous species seen on the cooling pond were not abundant in any of the years of my study, the between-years differences in use by horned grebe, common loon, double-crested cormorant, red-breasted merganser, and common merganser appear too large to be accounted for by differences in migration chronology and/or population numbers.

Use of the cooling pond by horned grebe and common loon was greatest in 1979 and high percentages of feeding activity were recorded for both species that year. Use occurred over several weeks in spring and fall, and 5 loons used the cooling pond throughout much of the summer in 1979. Summer use of central Michigan waters by common loons is very unusual.

Double-crested cormorants and red-breasted mergansers were more frequently observed in 1982, while both red-breasted mergansers and common mergansers were abundant on the cooling pond in 1983. The lateness of the start of field studies in spring of 1979 may account, in part, for the low number of common merganser use-days that year. The percentages of double-crested cormorants, red-breasted mergansers, and common mergansers observed feeding was low in their years of peak abundance. However, the infrequent observations of feeding may have reflected increased foraging efficiency in those years. During times when red-breasted mergansers and common mergansers were most numerous on the cooling pond in 1982 and 1983, individual birds appeared to capture small fish regularly in only a few attempts (dives).

The relatively low use of the cooling pond by piscivorous waterbirds in 1980 and 1981 may reflect changes which occurred in the fish community's size-class structure. Changes in prey vulnerability due to differences in the amount of available escape cover (macrophytes) also could have contributed to low use of the cooling pond by fish-eating waterbirds in 1980. Common loon was the only piscivorous species for which chi-square analysis of distribution data revealed a significant bird-plant association (in 1979 and 1981). Waterbird species which occupied significantly fewer grid squares with vegetation than expected based on proportion of occurrence were all piscivorous. They were horned grebe (in 1982), and red-breasted merganser and common merganser (in 1982 and 1983). This suggests that fish-eating birds may not have been able to forage efficiently in the macrophyte beds, or most small fishes in spring and fall occupied non-vegetated, deeper areas of the cooling pond.

As a result of high and persistent use of the cooling pond by pied-billed grebe, mallard, gadwall, American wigeon, redhead, Canada goose, and American coot, the mean weekly species diversity was considerably higher in 1980, when macrophyte density was high, than in the other years. This suggests that on open water systems, amount of food can dramatically influence waterbird species diversity, even if the taxonomic and structural diversity of food resources remains constant. I speculate that waterbird species forage with varying efficiency on particular resources such as plants, and when resource level increases more species can achieve net caloric and/or protein gains by exploiting that resource.

On the cooling pond, waterbird use (except by Canada goose) seemed largely influenced by the total amount of available food. Although plants and fish were present each year of my study, plant-eating and piscivorous waterbird species did not use the cooling pond intensively except in years and at specific times when levels of these 2 types of food resources exceeded that found in most open water systems. Similarly, the Dow tertiary treatment pond was not attractive to waterfowl until mid-summer each year, a time when midges, Cladocera, and other invertebrates begin to proliferate in waste stabilization ponds (Swanson 1977). Park Lake, a central Michigan lake which annually attracts large numbers of spring migrating scaup (Reeves 1980), contains an unusually high density and biomass of large snails (*Viviparus* sp.) (Rusz and Prince 1985, unpublished data). Other important Midwestern scaup staging areas also have dense benthic invertebrate populations (Thompson 1973). Blomberg (1982) found that density of submersed macrophytes was an important variable influencing use of Colorado gravel pits by waterfowl, and important redhead and American wigeon wintering areas in Mexico all have high densities of submersed macrophytes (Saunders and Saunders 1981).

Except in 1980, use of the cooling pond by plant/invertebrate-eating waterbird species was negligible in comparison with the total migrating populations which pass through central Michigan (Bellrose 1976), and much less than that recorded for important waterfowl habitats in the Midwest. However, throughout this study, use of the cooling pond by fish-eating species, particularly when considered on a density (e.g., birds per ha) basis, was high in comparison with other habitats for which data are available.

The most important waterfowl habitats near the cooling pond are the Shiawassee River State Game Area, the Shiawassee National Wildlife Refuge, and several large coastal marshes. These areas harbor many times more dabbling ducks and geese than the cooling pond in both spring and fall, but appear to attract mergansers for shorter periods than the cooling pond, and are used by fewer redhead and American wigeon than were observed on the cooling pond in 1980 (Mich. Dept. Natural Resources, unpublished data summarized in Prince et al. 1984).

Most Midwestern open water systems which attract large numbers of waterbirds are used primarily as roosts by dabbling ducks and Canada geese which feed in nearby agricultural fields. Lake Sangchris, a 871 ha cooling impoundment associated with a power plant in central Illinois, harbors total waterfowl numbers many times greater than those recorded on the cooling pond (Sanderson and Anderson 1981). However, most of the waterfowl use was by mallards and numbers of redhead and American wigeon on Lake Sangchris were comparable to those on the cooling pond in 1980. Numbers of mergansers were less than those recorded on the cooling pond throughout this study, despite a diverse fish community in Lake Sangchris (Tranquil et al. 1981).

Counts of up to 40,000 waterfowl were made on two 344 ha lagoons in the Muskegon County Wastewater Management System in 1976 and 1977 (Medema 1980). This open water system is located about 90 km west of the study area, and is surrounded by croplands which provide waste grain to puddle ducks and Canada geese. While most of the use is by mallards, there were 7,700 American wigeon use-days recorded in 1976 and 16,109 use-days for that species in 1977. There were about 1,000 redhead use-days in 1977 and less than that in 1976. Use of the lagoons by mergansers was negligible, probably because there are no fish in the lagoons.

Park Lake had higher use by redhead and American coot in spring of 1979 than did the cooling pond in spring of 1980. A total of 1,300 redhead use-days and 4,400 American coot use-days were recorded on Park Lake in spring of 1979 (Reeves 1980). However, use of Park Lake by American wigeon and mergansers in spring was negligible. Hunting and other disturbances preclude significant waterfowl use of Park Lake in fall.

Most use of Midwestern waters by mergansers, common loon, horned grebe, and double-crested cormorant is apparently confined to the Great Lakes and connecting waters (Bellrose 1976), and data are available for only a few locales. Reed (1971) studied a 36 km^2 area of Lake Erie near Monroe, Michigan and recorded nearly 55,000 use-days by common mergansers from 6 October to 17 December 1970.

My results imply that the waterbird communities of Midwestern open water systems can be described and predicted, assuming birds are not disturbed by human activity, on the basis of the total amounts of 4 types of food resources: submersed plants, free-swimming invertebrates, benthos, and fish. Open waters with large amounts of plant material can be expected to attract considerable numbers of pied-billed grebe, mallard, gadwall, American wigeon, redhead, American coot, and perhaps canvasback and Canada goose. Those with high densities of free-swimming invertebrates are likely to be used primarily by scaup, American goldeneye, mallard, blue-winged teal, and perhaps redhead. Open waters with dense fish populations will attract horned grebe, common loon, red-breasted mergansers, and common mergansers, if the water transparency permits efficient detection and pursuit of prey by these piscivorous species. Eriksson (1984) found that black-throated loon (*Gavia arctica*) and red-breasted merganser do not necessarily frequent Swedish lakes with the highest densities of fish, but rather select those in which transparency in combination with fish density results in the highest availability of prey. Open water systems with high biomass of large benthic invertebrates will be used by scaup and perhaps canvasback.

The numbers of birds of each species using a particular open water system will likely be a function of both the density of available food and the surface area of the system. Exceptions would be those systems used by mallards and Canada geese primarily as roosts. In such waters, bird numbers would likely be influenced by the amount of waste grain or other food outside the system. Use by Canada goose could also be influenced by the amount of loafing sites. The most diverse waterbird communities should occur on those open water systems which have high amounts of all 4 types of food resources.

Water level management is probably the only economical way to increase the availability of food in open water systems. Drawdowns can be used to increase the density of macrophytes as was demonstrated in the cooling pond in 1980. Drawdown should be done prior to the growing season to ensure a vegetation response. If this is not possible, the availability of plant material near the surface could be increased by lowering the water level to some fraction of macrophyte stem length, as occurred on the cooling pond during the 1984 fall drawdown. Drawdown might also be used to maintain a high organic base in wastewater systems so as to provide conditions favorable for production of midges, Cladocera, and other prolific aquatic organisms.

More research needs to be done to determine the levels of food necessary to attract large numbers of waterbirds in open water systems. The density of plants in the cooling pond in 1980, the density of invertebrates in some waste stabilization ponds, and the biomass of benthic invertebrates in Park Lake, Keokuk Pool (Mississippi River), and other open waters meet the requirements of important waterbird species. Such food levels appear comparable to the food levels found in natural marshes. Studies of food levels and waterbird use in adjacent open water systems and natural marshes could yield useful information. If the levels of food in open water systems must be similar to that of natural marshes in order to attract large numbers of waterbirds, systems with such food levels are probably scarce and warrant management and/or protection of habitat components. Knowledge of threshold food levels required to cause significant waterbird responses would also be a prerequisite to determining the feasibility of management proposals aimed at increasing waterbird use of particular open water systems.

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APPENDIX

Table A1. Common and scientific names of waterbird species observed on the cooling pond and Dow tertiary treatment pond during 1979-1983. Numerals indicate number of years in which a species was seen. Letters indicate relative abundance: VA = very abundant ($\geq$1,000 use-days on cooling pond, $\geq$200 use-days on Dow tertiary treatment pond each year); A = abundant ($\geq$1,000 use-days ($\geq$200 for Dow tertiary treatment pond) in at least 1 but not in all 5 years); C = common ($\geq$650 use-days for 5-year total, $\geq$130 use-days on Dow tertiary treatment pond, but not meeting criterion for abundant); U = uncommon ($<$650 use-days, $<$130 on Dow tertiary treatment pond for 5-year total).

Common Name	Scientific Name	Cooling Pond	Dow Tertiary Treatment Pond
Western grebe	*Aechmophorous occidentalis*	1U	
Red-necked grebe	*Podiceps grisegena*	3U	2U
Horned grebe	*P. auritus*	5A	3U
Eared grebe	*Colymbus podiceps*	1U	
Pied-billed grebe	*Podilymbus podiceps*	5C	2U
Common loon	*Gavia immer*	5C	
Bonaparte's gull	*Larus philadelphia*	5U	5U
Common tern	*Sterna hirundo*	4U	4U
Caspian tern	*S. caspia*	5U	5U
Black tern	*Chlidonias niger*	1U	
Double-crested cormorant	*Phalacrocorax auritus*	5C	2U
White pelican	*Pelecanus erythrorhynchos*	1U	
Common merganser	*Mergus merganser*	5A	4U
Red-breasted merganser	*M. serrator*	5VA	5U
Hooded merganser	*Lophodytes cucullatus*	5U	2U
Mallard	*Anas platythynchos*	5VA	5VA
Black duck	*A. rubripes*	5U	5U
Gadwall	*A. strepera*	5A	3U

Table A1 (cont'd):

Common Name	Scientific Name	Cooling Pond	Dow Tertiary Treatment Pond
American wigeon	A. penelope	5A	5A
Green-winged teal	A. crecca	3U	4U
Blue-winged teal	A. discors	5U	5VA
Northern shoveler	A. clypeata	4U	5U
Pintail	A. acuta	5U	2U
Wood duck	Aix sponsa	2U	2U
Redhead	Aythya americana	5A	5VA
Canvasback	A. valisneria	5A	5U
Scaup	A. marila, A. affinis	5A	5VA
Ring-necked duck	A. collaris	5A	5U
American goldeneye	Bucephala clangula	5A	5VA
Bufflehead	B. albeola	5A	5A
Oldsquaw	Clangula hyemalis	4U	3U
White-winged scoter	Melanitta fusca	5U	3U
Ruddy duck	Oxyura jamaicensis	5U	5C
Snow goose	Anser caerulescens	4U	1U
Canada goose	Branta canadensis	5VA	5A
Whistling swan	Cygnus columbianus	5U	
Great blue heron	Ardea herodias	5U	2U
Common egret	Casmerodius albus	1U	
Green heron	Butorides virescens	5U	
Black-crowned night heron	Nycticorax nycticorax	4U	1U
American coot	Fulica americana	5A	5A
Wilson's phlalrope	Steganopus tricolor		5U