A STUDY OF WATERFOWL ECOLOGY AT PONDS BLASTED IN MANITOBA'S DELTA MARSH

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

RONALD H. HOFFMAN

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ABSTRACT

A STUDY OF WATERFOWL ECOLOGY AT PONDS BLASTED
IN MANITOBA'S DELTA MARSH

by Ronald H. Hoffman

Forty-one ponds were blasted with ammonium nitrate in a prairie marsh. During 33 weeks of field work (fall of 1964 through 1966) quantitative measurements were made of pond morphometry, soils, waters, macrophytes, invertebrates, and waterfowl use.

Changes in morphometry indicated a minimum life of 30 years for the 5 x 26 x 52-foot ponds. High water loss contributed to increased salinization of pond soils and waters. A few large storms added more water to the ponds than the same amount falling in many small showers. Ponds within 300 feet of the bays received seepage water. The macrophyte, *Potomogeton pectinatus*, and the invertebrates, *Daphnia* and Tendipedidae, dominated the aquatic community. Plants common to the surrounding meadow invaded the pond shoulders. During the first two years, the quality and quantity of macrophytes and invertebrates increased in the ponds.

The waterfowl species composition of the ponds was characterized by few diving ducks and a large percentage

of blue-winged teal (Anas discors). Use by ducks followed a pattern of highest abundance early in the morning during spring. Duck selection of certain ponds was not significantly influenced by measured variations in pond age, food, cover, water levels, or bay-to-pond distance. The pattern of pond location in relation to other features in the marsh seemed to influence waterfowl distribution at the ponds.

Duck nests were concentrated along the bays before pond construction. After blasting the ponds in a uniform pattern, duck nests were more evenly distributed. Both pond proximity and vegetation seemed to affect nest density. Severe nest predation resulted from predators being attracted to the ponds.

The 25 ponds appeared to increase the carrying capacity by 35 breeding pairs. Waterfowl abundance and available habitat probably modified the degree of response. Actual production was far less than expected from the breeding population because of severe nest predation. The ponds chiefly functioned as isolation areas for breeding pairs, so other production requirements must be offered in nearby areas.

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By

Ronald H. Hoffman

A THESIS

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TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

History of Subject

A major concern of North American conservationists is the loss of waterfowl habitat. Recurring droughts and expanded drainage programs have reduced our wetlands (Sayler, 1962). In addition, the quality of many wetlands is threatened by the increasing demands of our society (Jahn and Hunt, 1964).

Steps are being taken to ameliorate this threat to waterfowl habitat. Vast programs of wetland acquisition, leasing, and development are being tried. Presently acquisition and leasing are stressed. However, as the price of land increases, wetland development will receive additional attention (Uhler, 1956).

Pond construction, one form of wetland development, has been based on the findings of various workers. Leopold (1933:131) described game as a product of edge. Hochbaum (1944), Sowls (1955:53), Evans and Black (1956), McKinney (1965), and others have suggested territorialism as limiting the carrying capacity for breeding pairs of some local areas. Studies of natural potholes by Evans *et al*. (1952), Evans and Black (1956), and Glover (1956) have showed an increase in breeding ducks after additional precipitation made more water areas available.

A variety of methods have been used to construct waterfowl ponds. Pirnie (1935:292) mentions broods using small open water areas resulting from peat fires. Mechanical methods include--draglines (Mathiak and Linde, 1956; Lacy, 1959; Hammond, 1964; Mathiak, 1964), bulldozers (Mathiak, 1964), and backhoes (Mathiak, 1964). Scott and Dever (1940), Provost (1948), Mendall (1949), and Mathiak (1964) used dynamite to blast small ponds. Recently, ammonium nitrate has been used instead of dynamite (Mathisen et al., 1964; Mathisen, 1964 and 1965).

Most of these studies have been concerned with methods of construction and not with waterfowl use. For example, of 25 papers I reviewed on blasting, only six dealt with biological studies. Provost (1948) concluded that dynamited ponds in an Iowa sedge marsh were attractive to migrant blue-winged teal, but had dubious value as an inducement to nest. In Maine, Mendall (1949) reported black ducks increased from four to 14 pairs after dynamiting ponds. Lacy (1959) and Hammond (1964) found about one pair of ducks per pond in North Dakota. Workers in Minnesota (Mathisen, 1964 and 1965) and Wisconsin (Mathiak, 1964) report duck use of ammonium nitrate blasted ponds in areas having little use previous to blasting.

Currently ammonium nitrate-blasted ponds are being emphasized. Several marsh development plans include large appropriations for blasting (Westerberg, 1965; Byrant, 1965). In addition, exhibitions of blasting are creating widespread public interest.

Nature of the Study

This study was initiated to gain a clearer understanding of blasting as a habitat development technique. My objectives were to examine waterfowl use of ammonium nitrate-blasted ponds and to compare use with food and cover differences.

The study was a cooperative two-year project of the Delta Waterfowl Research Station and Michigan State University. The Delta Marsh, its previous and current waterfowl studies, financial support, and the station's laboratory facilities provided an excellent opportunity to carry out the field work. Planning and writing the manuscript were conducted at the University.

Study Area

Along Lake Manitoba's south shore lies the Delta Marsh (Fig. 1). Extending as far as five miles inland it borders the Lake for nearly 24 miles. The Delta Marsh has been separated into three parts; West Marsh, East Marsh, and Lake Francis Marshes. This study was undertaken in the East Marsh which extends from the towns of St. Ambroise on the East to Delta on the West; a distance of 11 miles.

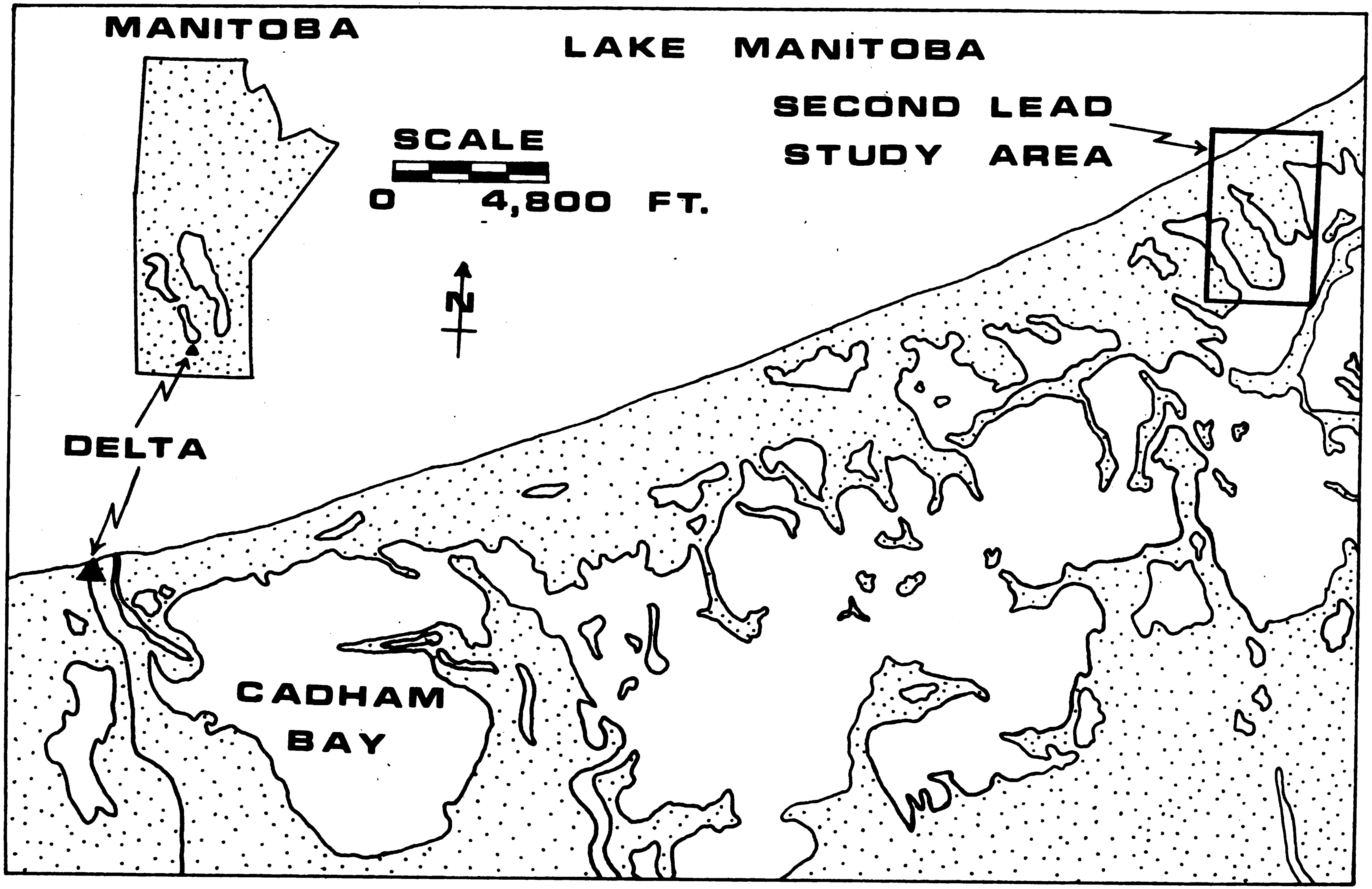

Figure 1.--Map showing the location of the Delta Marsh and a portion of the East Marsh, including the Second Lead study area, 1966, Delta, Manitoba.

Today Lake Manitoba is but a small remnant of glacial Lake Agassiz. Formed by the retreating Wisconsin glacier, this ancient lake's lacustrine sediments cover Devonian limestones (Ellis, 1938; Johnston, 1934). The Delta Marsh lies upon a onetime lakebed, called the First Prairie Steppe (Ellis, 1938).

During recent times ice and wind have formed a series of sandy ridges along Lake Manitoba's south shore. In addition, the ancient Assiniboine River and several smaller streams, especially the Portage River, have deposited their loads of alluvium in a meandering pattern of natural levees. The result which one sees today is a land mass with a complex of shallow bays, sloughs, and ponds less than six feet deep.

Delta has a humid continental climate with cool summers. Winnipeg (60 miles southeast) records a mean annual temperature of 45.3 degrees Fahrenheit and 20.1 inches mean annual precipitation (Dominion Government Department of Transport).

As Hochbaum (1944:6) has pointed out, the Delta Marsh has a history of fluctuating water levels. During periods of drought as much as half of the marsh may become dry, but during wet years most of it has been under water.

Starting at the lakeshore and moving southward one encounters a series of vegetative types; a narrow strip of ridge forest, a belt of phragmites encompassing most of the marsh, next come haylands, and finally grainfields of the Portage Plains (Hochbaum, 1944; and Löve and Löve, 1954). Although the marsh is covered chiefly by phragmites, many water areas are bordered by bulrushes; and the intermittently flooded areas usually are whitetop meadows. The East Marsh thus conforms to Reid's (1961:13) definition of a marsh as "a broad wet area on which abundant grasses and sedges grow."

Most of this study was conducted on a 78-acre peninsula seven miles east of Delta, (T.14 N, R.6 WPM, sec. 25); an area often referred to as the Second Lead. A sandy road enters the area from the North. Here ponds S-1 thru S-28 were blasted (Fig. 2) and shall be referred to as an experimental nest study area. The intrazonal soil (Finch et al., 1957) had a profile of a thin humus layer covering strata that ranged from a texture of sandy loam to clay loam.

A whitetop meadow covered 60 percent of the study area. The ground water table was near the surface only in bulrush and mixed emergent vegetation cover types (Fig. 3).

A 20-acre nesting check area was located to the east of First Bay (Fig. 2). During the spring the check area was separated from the rest of the marsh by flooded shallows. The soil and vegetation of the check area resembled those of the Second Lead study area.

Ponds were blasted in several other locations. Ponds T-1 thru T-8 were blasted three miles east of Delta, B-1 1-1/2 miles east of Delta, and R-1 thru R-4 1-1/2 miles

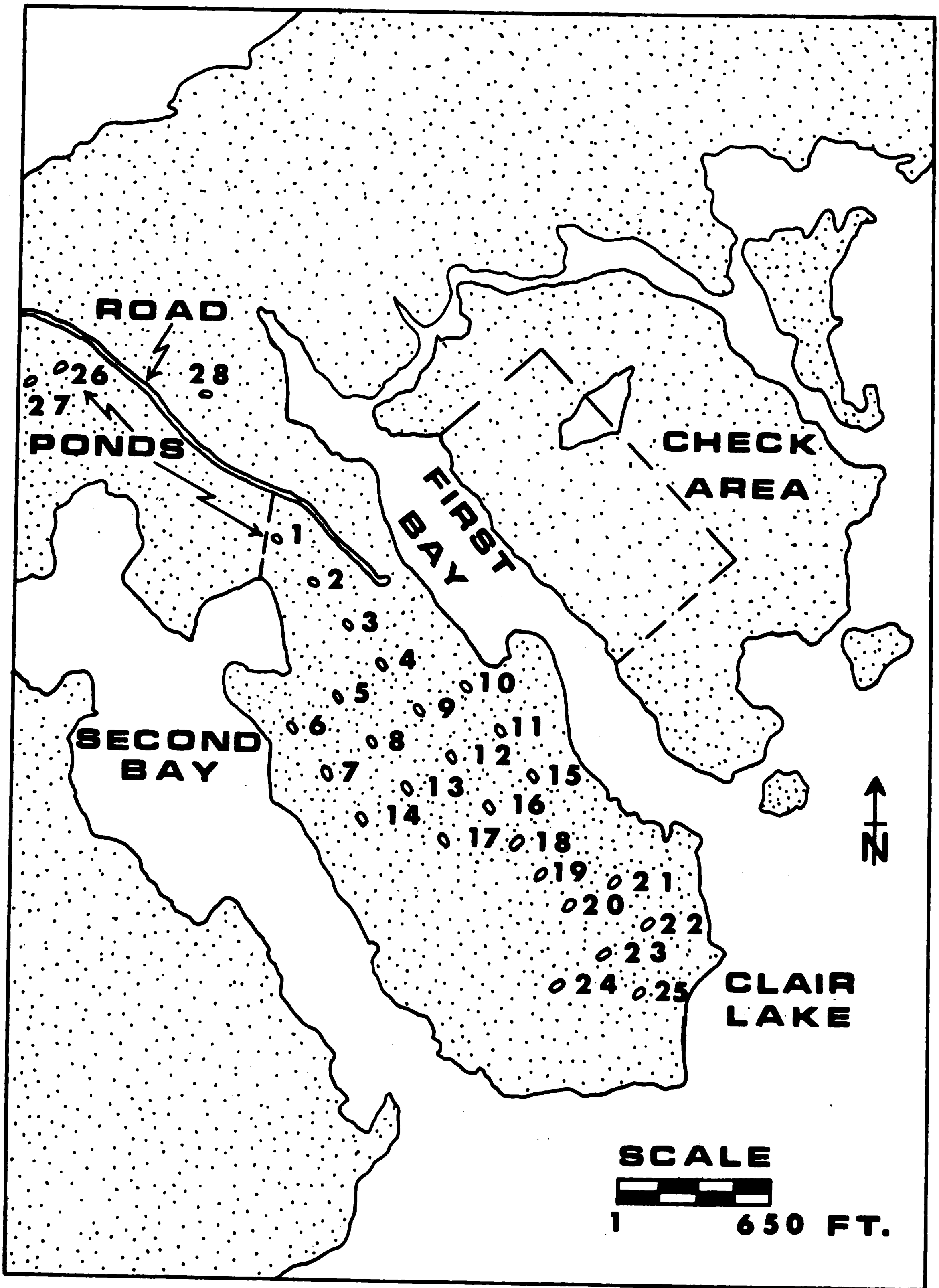

Figure 2.--Map of Second Lead study area showing pond locations, 1966, Delta, Manitoba.

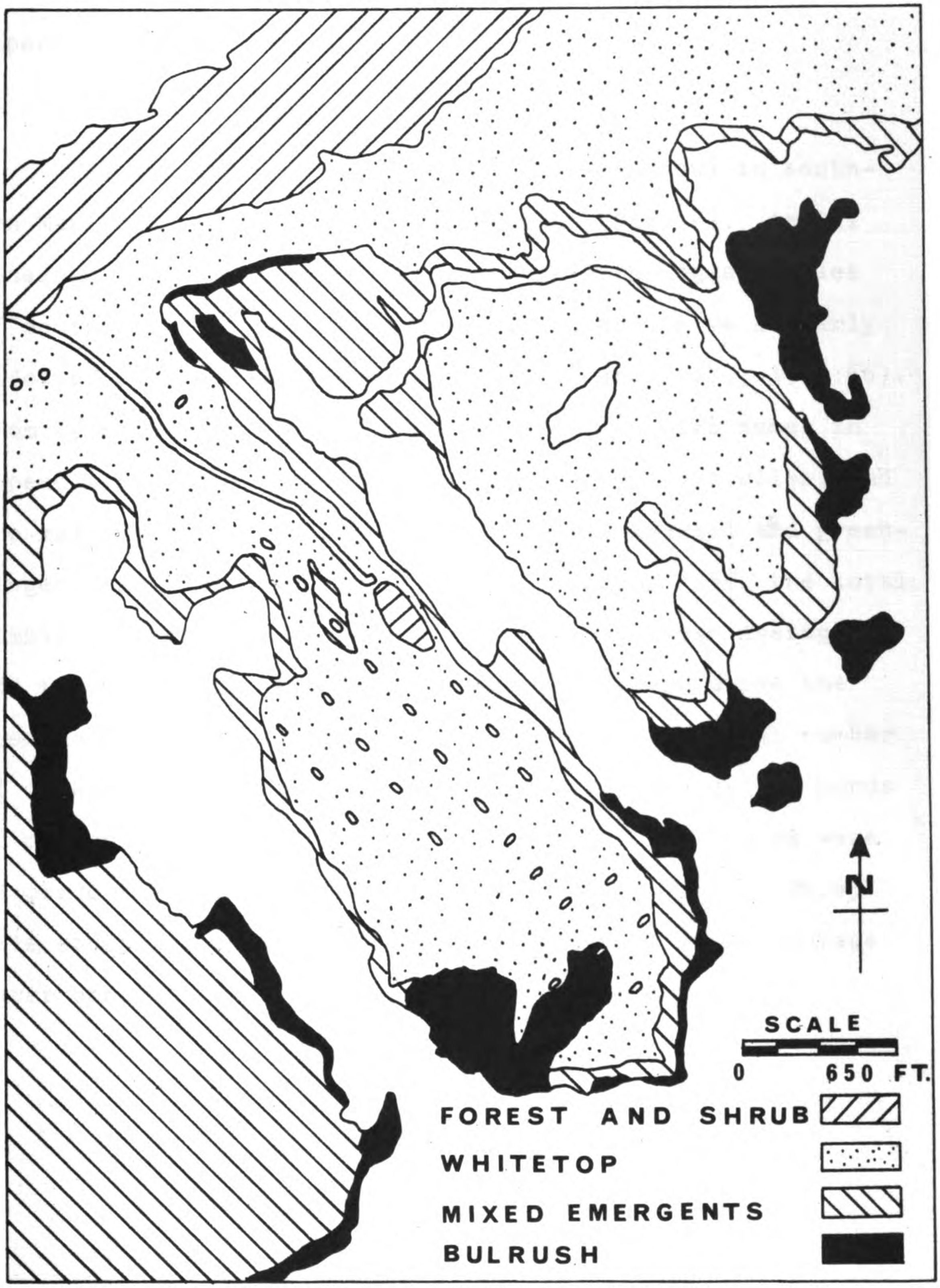

Figure 3.--Map of study area showing distribution of four primary cover types, 1966, Delta, Manitoba.

south of Delta. (Additional information is given in Appendix A).

Waterfowl Population Levels

The abundance of water areas and waterfowl in southern Manitoba has fluctuated in the past (Fig. 4). Aerial censuses during May, covering nearly 39,000 square miles of southern Manitoba (Delta Marsh included), give a yearly index of pond and duck abundance (Smith and Droll, 1966:66). From 1956 through 1966, the pintail, (scientific names in Appendix B), blue-winged teal, lesser scaup, shoveller, and the mallard have fluctuated more than the gadwall and green-winged teal (Smith and Droll, 1966). During 1965, the total number of ducks was 27 percent below the 12-year average, and the number of natural ponds was 23 percent above the average (Smith and Droll, 1965). In 1966, the total number of ducks was 20 percent below the 13-year average and ponds 36 percent above (Smith and Droll, 1966). Blue-wings were 60 percent below the long-term average (op. cit.). Thus, this study was undertaken during a period of above-average water conditions and below-average duck abundance.

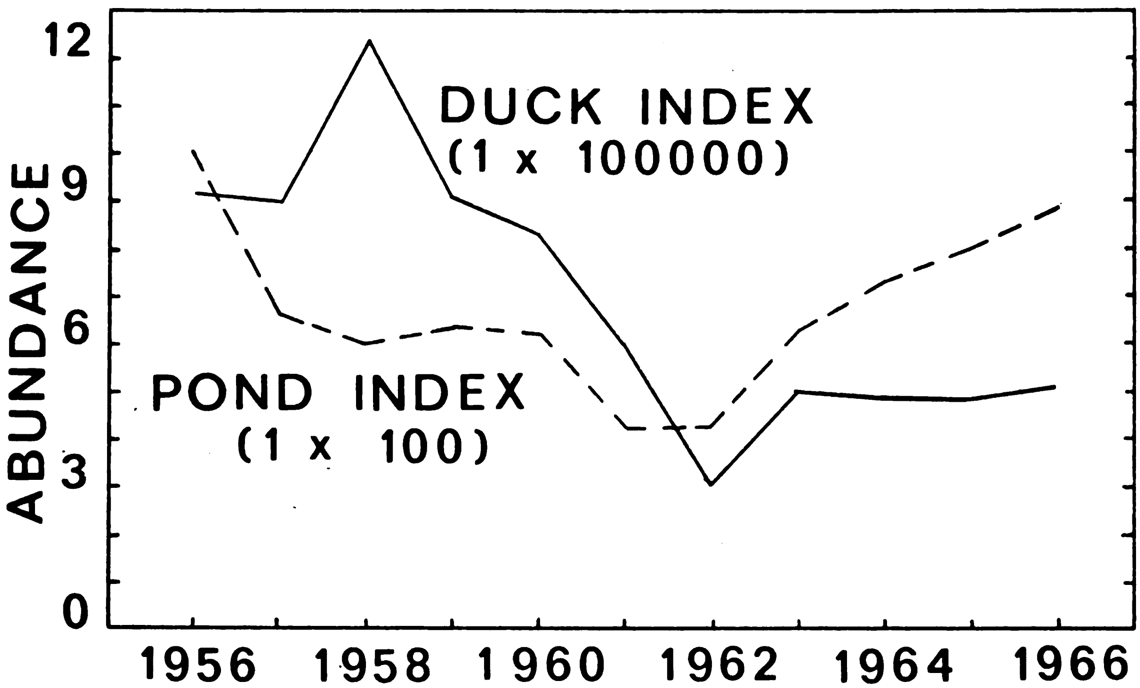

Figure 4.--The yearly abundance of ponds and breeding waterfowl in southern Manitoba (Smith and Droll, 1966).

METHODS

Pond Construction

All of the study ponds were blasted with Amex, a commercial mixture of ammonium nitrate and fuel oil. For the remainder of this paper they will be referred to as, "the ponds."

Pond construction followed the procedures and safety recommendations of Mathisen *et al*. (1964), Mathiak (1965), Radtke and Byelich (n.d.), and Spencer Chemical Co. (1963). Three holes, 16 feet apart and three to four feet deep, were dug in a straight line. Each end of a length of detonating cord (about 20 feet) was attached to a half stick of 50 percent ditching dynamite and then placed in the center of a 50-lb. bag of Amex. One bag was lowered into each hole and packed with dirt. Thus each bag of Amex was connected by detonating cord. Then one blasting cap, either fuse-type or electrical, was attached to the detonating cord. The material was then ready for detonation.

Ponds S-1 through S-17 were blasted in August 1964 and ponds S-18 through S-25 in August 1965. Ponds S-1 through S-17 were called 1-year ponds in 1965 and 2-year ponds in 1966. Ponds S-18 through S-25 were considered 1-year ponds in 1966.

Abiotic Measurements

Ponds S-1 through S-25 were measured for width, length and depth. A line was stretched between two permanent markers across the longitudinal axis of the ponds. By lowering a ruler at 2-foot intervals along this line, pond depth was measured to the nearest inch. During 1965 and 1966 morphometrical measurements were made in July of 2-year ponds and in August of 1-year ponds. Weekly water-level records were kept for two ponds in 1965, six ponds in 1966, and for First Bay during both years.

Water tests were made of First Bay, Second Bay, and of randomly selected ponds. A Hach colorimeter (Hach, 5th ed.) was used to test for nitrite, nitrate, ammonium, ortho and meta phosphate, turbidity, and calcium during August 1966. In August of 1965 and 1966, specific conductance was measured with a Radiometer conductivity meter and pH with a Beckman model N meter. The limit of visibility in pond waters was measured with a Secchi disk (Welch, 1958:159-160) every month during the summer.

Aquatic soil samples were collected from 10 randomly selected ponds during August 1966. The samples were air-dried and then stored in plastic bags until January. The Soil Testing Laboratory at Michigan State University analyzed the samples for various nutrients and pH with the Spurway technique (Spurway and Lowton, 1949); and for percent organic matter with the Walkely-Black method (Jackson, 1960:219-221)

Sampling of Vegetation

Aquatic Vegetation

Pond plants are described in terms of percent frequency and weight. All plants growing within the excavations were considered aquatic, even though water levels declined drastically during the summer. Frequency refers to presence in a sampling unit (Brown, 1954:24).

The aquatic vegetation in eight 1-year and eight 2-year ponds was sampled during July and again in August. Two 6- x 24-inch plots were randomly located in each pond, one in the middle and one near the edge. All plants in these plots were collected with an Ekman dredge, placed in plastic bags, and returned to the laboratory where they were sorted to species, air-dried, and then weighed on a trip-balance scale to the nearest 0.1 gram. Frequency was based on these plots in 1965; but in 1966, the frequency sampling unit included the entire excavations of ponds S-1 through S-25.

Terrestrial Vegetation

Meadow and pond "shoulder" vegetation is described in terms of percent frequency, percent coverage, and stem length. Pond "shoulder" or edge arbitrarily included a 6-foot wide area surrounding the excavation. Coverage was defined as "the amount of ground covered by an individual species" (Brown, 1954:42). Length refers to the above-ground stem projection and in most cases was equivalent to plant height.

Terrestrial vegetation was measured with the line-intercept method (Canfield, 1941) using 2-foot plots. Forty-eight randomly located plots were sampled during July and again in August on the shoulders of eight 1-year and eight 2-year ponds. Twenty plots were randomly selected from a 950-foot line bisecting the Second Lead meadow near ponds S-10 and S-7. Twenty plots were similarly chosen from a 700-foot line in the check nesting area. Meadow vegetation was sampled only during July.

Plant identification was based on Gleason (1952), Scoggan (1957), Fassett (1960), and comparisons with identified specimens in the Delta Waterfowl Research Station herbarium.

Sampling of Invertebrates

Invertebrates were sampled with a tow net and an Ekman dredge. A 34-mesh per inch net with a 9 1/2-inch diameter was pulled for a distance of 6.9 feet (approx. 200 liters) through the waters of four 1-year and four 2-year randomly selected ponds. A bottom sample was collected from the edge and middle of the same ponds with a 1/4 square-foot Ekman dredge. Dredge contents were strained through a 30-mesh per inch screen and the residue placed in quart jars along with a few milliters of undiluted formalin.

Permanent sampling sites were randomly located in the ponds. Net tows were always taken between the same two markers, whereas a particular bottom site was never sampled more than once. Net tows were taken May 12, and then every two weeks from June through August of 1966. Bottom samples were collected every two weeks from July 13 through August 11 of 1965 and June through August 10 of 1966.

In the laboratory, invertebrates were analyzed according to the procedure described by Welch (1948:303-306). Animals were sorted from the remaining detritus in a white porcelain pan, volumetric measurements made with a graduated centrifuge tube, and then separated into taxonomic groups. If a sample contained less than an estimated 500 individuals, direct counts were made. If the sample contained more than an estimated 500 individuals, volumetric measurements were made of the taxa and the number of individuals estimated from the volume. Pennak (1953), Usinger (1963), and personnel of the Delta Waterfowl Research Station aided identification. Once processed, all samples were placed in labeled vials with a preservative.

Waterfowl Investigations

Each week ducks were counted on the study area. The counts were made during the periods of May 4 through August 31 in 1965 and April 23 through August 25, 1966. The usual procedure was to count ducks on the bays first (which seldom flew) and then to systematically check each pond from which ducks almost always flushed. This minimized duplication of counts. The censuses were made between 8:00 and 10:00 A.M. The species, sex, number, and location of all ducks seen were recorded on field forms.

Each week, personnel of the Delta Marsh Development Committee made low-altitude aerial duck censuses of the marsh. By flying 60 miles an hour over half-mile east-west transects, two observers were able to give complete coverage. Counts began on June 9 in 1965 and on May 10 in 1966 and continued through the study period. All counts were completed before 11:00 A.M. Except for green-winged teal and blue-winged teal which were grouped into "teal," ducks were recorded by species, or when identification was uncertain, as "undetermined."

A 15-foot observation tower was erected on the study area. This concealment made it possible to watch several ponds from one location. Records were kept of the time undisturbed ducks spent on top of the pond shoulders, at the water's edge, in the water, or feeding. In addition, general behavior associated with pond use was noted.

Various techniques were used to investigate the effects of pond construction on duck nesting. The Second Lead area was burned in August 1964 and again in 1966. The check area was also burned only in 1966. After burning, the number of old duck nests and their locations were recorded for the periods before and after pond construction.

A chain, with tin cans attached, was dragged between two vehicles in a systematic search for active nests (Sowls, 1950). The study areas were dragged twice during 1966, May 27-30 and June 20-21. Some nests were discovered incidental to other investigations. All nests were marked by placing consecutively numbered lath 5-paces south of the nest. Species were determined by identification of flushed hens, egg size and shape, and nest down (Broley, 1950). Weekly checks of the nests revealed clutch size and nesting success. "Hair catchers" (single wire with barbs) were placed near each nest to help determine predators visiting those nests destroyed. The condition of eggshells and the nest were used to ascertain nesting success or the cause of nest loss (Kalmback, 1937; Sowls, 1948; Rearden, 1951).

FINDINGS AND ANALYSES

Changes in Pond Morphometry

Morphometrical measurements were taken to determine the rate of siltation in newly created ponds. One month after blasting, the ponds averaged five feet deep, 25.6 feet wide, and 52.3 feet long. During the next two years the steep-sided shoulders eroded into the ponds (Figure 5). After two years the mean pond length had increased 4.3 feet, width increased 0.7 foot, and depth had decreased four inches. Most of the dimensions overlap at the 95 percent confidence interval (Table 1). The ponds increased in length more than in width because most of the spoil was thrown parallel to the longitudinal axis of the ponds.

The rates of siltation can be affected by soil type, pond shape, water level, vegetation, muskrats, etc. (Provost, 1948, and others). At Delta, muskrats seem to have the greatest potential for increasing siltation. Muskrats did not use any of the ponds measured, but elsewhere their use substantially decreased depth (Figure 6). High muskrat use could drastically reduce the duration of the ponds.

From my findings it is difficult to predict accurately the life expectancy of the ponds. Provost (1948:

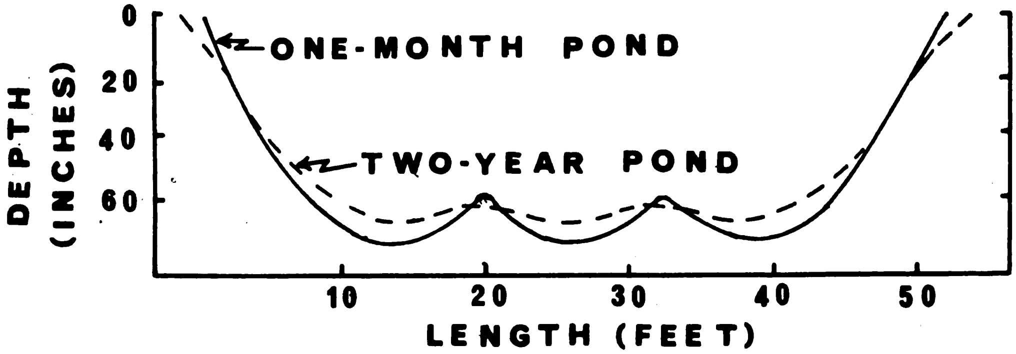

Figure 5.--Changes in pond morphometry after two years. Spacing of ammonium nitrate charges caused the two mounds in the pond bottom, 1966, Delta, Manitoba.

A. Typical 1-year pond in early May.

B. Typical 2-year pond in late August.

C. Pond siltation increased by muskrats.

D. Three blue-winged teal and one shoveller at a pond.

Figure 6.--Photographs of the ponds, 1966, Delta, Manitoba.

TABLE 1.--Results of pond morphometrical measurements. Confidence limits are at the 95 percent level, 1966, Delta, Manitoba.

Pond Age (Months)	1	11	23
Number of Samples	8	14	14
Length (feet)	52.6 ± 1.4	54.6 ± 2.0	56.6 ± 1.3
Width (feet)	25.6 ± 1.7	26.6 ± 1.8	26.3 ± 1.5
Distance from Edge		Depth (inches)	
2 ft. interval	16 ± 2	16 ± 2	21 ± 2
4 " "	35 ± 3	31 ± 3	33 ± 2
6 " "	50 ± 2	43 ± 3	45 ± 2
8 " "	60 ± 3	51 ± 3	52 ± 2
10 " "	68 ± 2	61 ± 5	60 ± 3
12 " "	74 ± 1	69 ± 4	65 ± 3
14 " "	75 ± 4	71 ± 3	69 ± 4
16 " "	71 ± 3	69 ± 3	66 ± 3
18 " "	65 ± 7	64 ± 5	62 ± 3
20 " "	58 ± 3	60 ± 5	61 ± 4
22 " "	67 ± 3	61 ± 6	62 ± 4
24 " "	72 ± 3	66 ± 5	65 ± 4
26 " "	73 ± 5	67 ± 4	67 ± 3
Mean	60.3	56.1	56.0
% Mean Loss	--	7.0	7.3

364) found that the average depth of ponds dynamited in peat decreased 35 percent during the first five years with a decelerating rate of siltation in later years. The average depth of ponds at Delta decreased 7.0 percent after one year and showed no substantial decrease the following year (Table 1). Strohmeyer (1963) studying Provost's ponds 16 years later also found a deceleration in the rate of siltation and believed that they might persist for "25 to 30 years or more." Since the Delta ponds had a lower initial rate of siltation, they may well last 30 years.

Construction Costs

The average pond in this study cost $20.00. Of this amount ammonium nitrate accounted for $13.00, other materials $4.00, and labor $3.00. If the ponds persist for 30 years the prorated construction cost would range between $0.60 and $0.70 per pond per year.

Water-level Fluctuations

In contrast to bays, ponds usually receive most of their water from precipitation (Hochbaum, 1944; Evans et al., (1952). From June 16 through August 25, Delta had 3.63 inches of rain in 1965 and 4.25 inches in 1966. During the same periods pond S-3 lost 27 inches of water in 1965 and 52 inches in 1966. First Bay lost only four to five inches both years. In 1965, there was less total rainfall, but more storms with rain of a half-inch or more than in 1966 (Figure 7). Therefore, it appears that many small rain showers supplied less water to the ponds than the same amount falling in fewer, but more severe storms.

Although the ponds obtained most of their water from precipitation, bay-pond distance also influenced water levels (Figure 8). Ponds within 300 feet of the bays received seepage inversely proportional to their distance from the bays. Beyond 300 feet the bays contributed little seepage water to the ponds.

Soils and Waters of Study Area

Soil samples were collected to give an index of chemical composition of the ponds. The Spurway technique does not indicate the availability of nutrients. Furthermore, Kadlec (1960:50) justly criticized air drying of aquatic soil samples. Therefore, results of soil analysis (Table 2) are offered chiefly as an index to the general level of nutrients.

Soil tests showed little difference in the chemical composition of 1- and 2-year ponds (Table 2). The 95 percent confidence limits of chloride, magnesium, nitrogen, and pH did not overlap, but their differences are not considered biologically significant to this study.

Tests of bay and pond waters showed differences in mean turbidity, pH, specific conductance, and calcium content (Table 3). Turbidity was higher in the bays than in

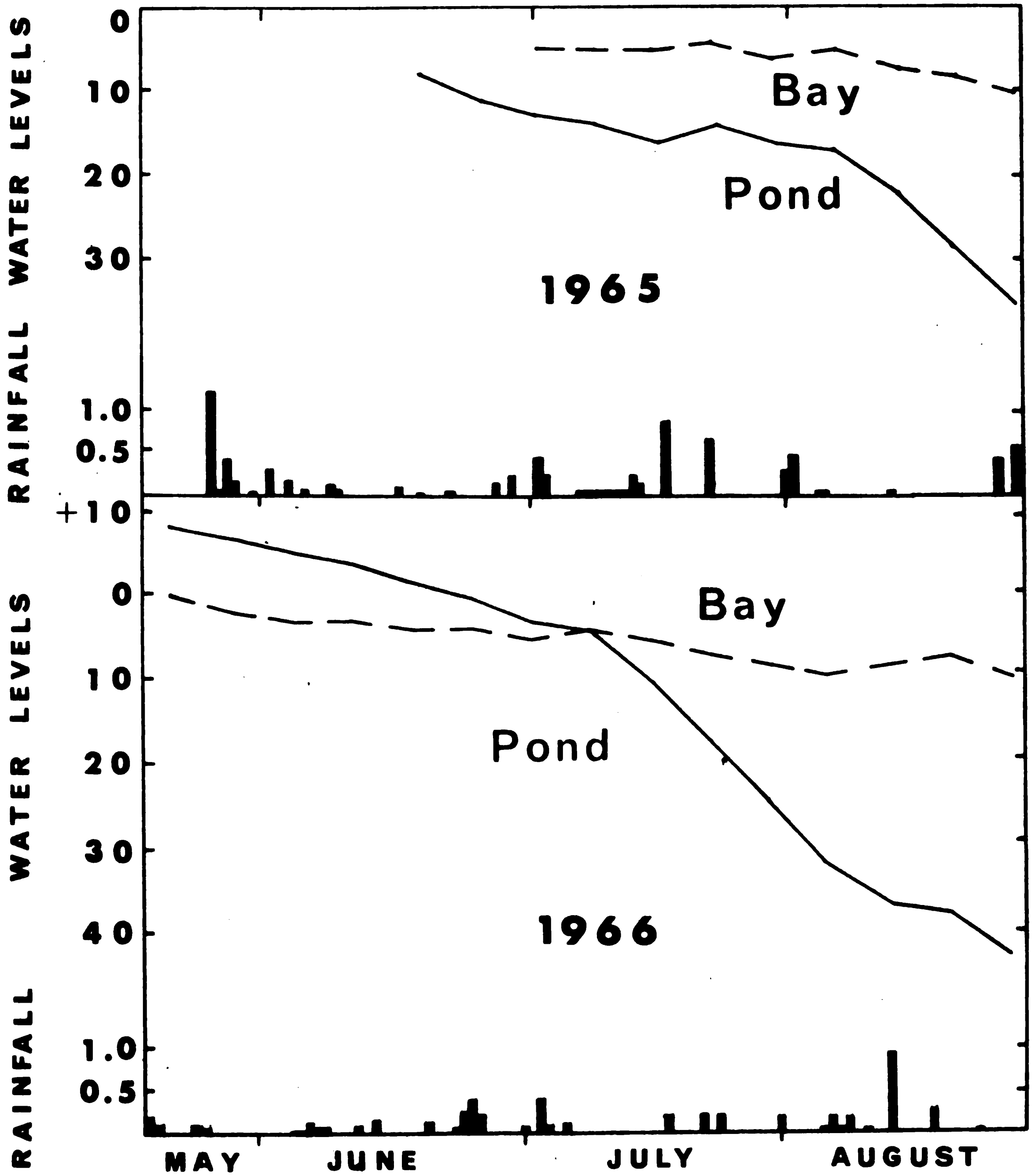

Figure 7.--Relationship of rainfall to water-level fluctuations of First Bay and pond S-3. Data expressed in inches. Rainfall measurements recorded by the staff of the Delta Waterfowl Research Station, Delta, Manitoba.

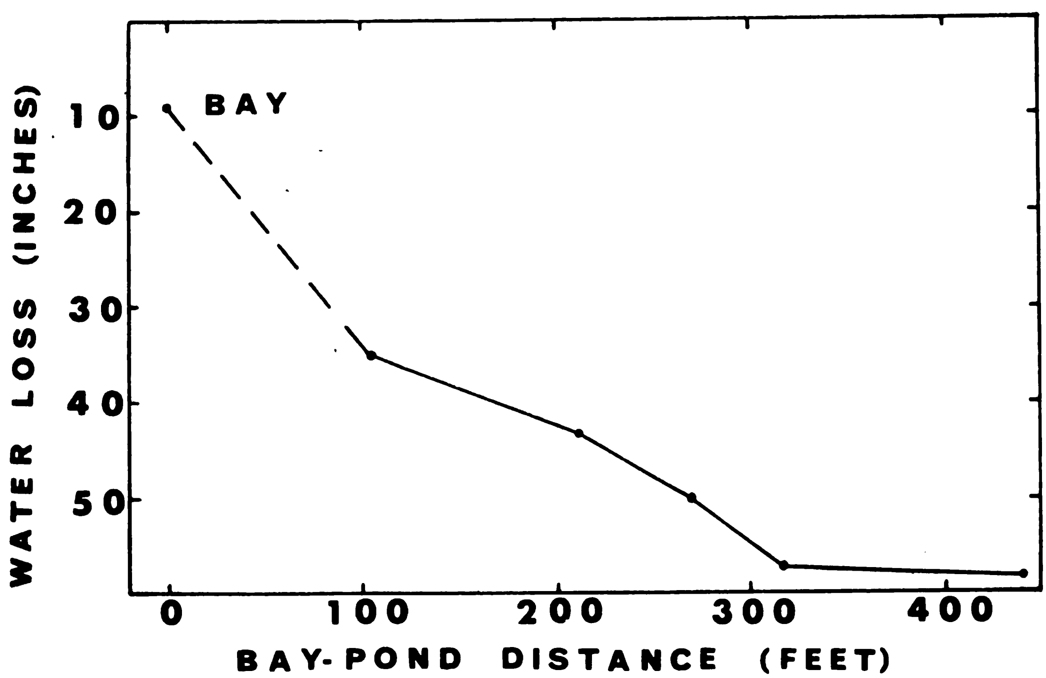

Figure 8.--The effect of bay-to-pond distance on pond-water loss, August 25, 1966, Delta, Manitoba.

TABLE 2.--Results of pond soil analyses, 1966, Delta, Manitoba. Confidence limits are at the 95 percent level.

	1-Year Ponds	2-Year Ponds
	Number of Samples 4	Number of Samples 6
% Organic matter	11.8 ± 7.2	7.4 ± 2.9
pH	8.0 ± 0.0	8.2 ± 0.0
Nitrogen (ppm)	4 ± 3	15 ± 6
Sulphate (ppm)	1100 ± 1500	800 ± 500
Sodium (ppm)	1050 ± 350	980 ± 440
Calcium (ppm)	560 ± 70	620 ± 30
Chloride (ppm)	260 ± 130	90 ± 10
Potassium (ppm)	101 ± 16	76 ± 30
Magnesium (ppm)	17 ± 0	18 ± 0
Manganese (ppm)	4 ± 3	5 ± 0
Phosphorus (ppm)	2 ± 0	1 ± 0
Iron (ppm)	tr	tr

TABLE 3.--Results of August pond and bay water analyses, Delta, Manitoba. Confidence limits are at the 95 percent level.

	Ponds				Bays	
Year Sample Size	1-Month 1965 3	1-Year 1965 13	1-Year 1966 8	2-Year 1966 8	1965 1	1966 2
Secchi disk (in.)	---	---	42 ± 5	32 ± 4	---	---
Turbidity (JTU)*	---	---	21 ± 21	20 ± 0	---	68 ± 21
pH	7.9 ± 0.0	8.8 ± 0.1	8.6 ± 0.0	9.1 ± 0.0	8.4 ± -	8.3 ± 0.1
Ammonium (ppm)	---	---	1.0 ± 0.0	0.8 ± 0.0	---	0.8 ± 0.0
Nitrate (ppm)	---	---	2.7 ± 0.0	2.1 ± 0.0	---	2.3 ± 0.0
Nitrite (ppm)	---	---	0.00	0.00	---	0.00
Conductivity (mmhos)	9.4 ± 0.3	4.4 ± 0.9	3.2 ± 0.0	3.2 ± 0.2	2.9 ± -	1.6 ± 0.0
Calicum (ppm)	---	---	115 ± 23	121 ± 17	---	56 ± 0
Phosphate, Ortho (ppm)	---	---	0.1 ± 0.0	1.7 ± 0.0**	---	0.2 ± 0.1
Phosphate, Meta (ppm)	---	---	0.2 ± 0.0	3.5 ± 0.0**	---	1.6 ± 0.3

*Jackson Turbidity Units.
**Questionable accuracy.

the ponds, while pH, calcium, and specific conductance were lower in the bays.

Wave action and water levels may explain the major differences noted between bay and pond waters. Because of their small size, the ponds received less wave action; and therefore were less turbid.

The drastic reduction in pond water levels (Figure 7) during the summer and reflooding the following spring not only may have concentrated, but also increased the dissolved nutrients. Cook and Powers (1956) noted an inverse relationship between total alkalinity and water levels and suggested that evaporation may have been responsible. Kadlec (1960:51) believed that drying reduced the colloidal fraction of sediments, releasing adsorbed ions which resulted in an increase of dissolved nutrients upon reflooding. Reid (1961:181) and others have stated the interrelationship involving water loss, the carbon dioxide-carbonate system, calcium, and hydrogen ion concentration.

Testing showed differences in 1- and 2-year pond waters (Table 3). Phosphate concentrations and pH were higher in the 2-year ponds, while specific conductance, nitrate, ammonium, and visibility (Secchi disk) decreased. Phosphate readings in the 2-year ponds are of questionable accuracy because such high concentrations are seldom encountered. Except for May 1966, a Secchi disk could be seen at the bottom of the ponds. Only May disk readings are shown (Table 3).

The influence of water loss on dissolved nutrients (discussed above) may also be applicable to the comparison of 1-year and 2-year ponds. Welch (1952:372-373) described situations where decreasing water volumes were accompanied by changes in pH and conductivity. He (*op. cit.*) suggested that precipitation of calcium and magnesium carbonate reduced electrolytes and increased pH. The cycle of repeated drying and reflooding could compound this effect.

Pond soils and waters were saline. The differences observed were similar to those often encountered, so are not considered atypical of the region. After two years of study, it is not clear if an "alkali problem," similar to that described by Keith (1958:88), will develop. If salinization does increase with pond aging, pond vegetation could be drastically altered in the future.

Vegetation

Meadow Community

Differences between 1965 and 1966 meadow vegetation (Table 4) probably were due to burning in August of 1964. *Chenopodium rubrum*, *Erigeron*-*Solidago*-*Aster* group, and *Ranunculus sceleratus* especially were more abundant in 1965. Burning did not seem to affect the frequency or cover of *Scolochloa festucacea* or *Atriplex patula*. Burning did reduce leaf litter cover, but the meadow still fits the "Scolochloetum" described by Löve and Löve (1954).

TABLE 4.--Plant species composition of meadow and pond shoulders, expressed in percentage frequency and coverage, 1966, Delta, Manitoba.

Area	Meadow		1-yr. Ponds				2-yr. Ponds		Meadow	
Year	1965		1965		1966		1966		1966	
Number of plots	20		48		48		48		20	
	Freq	Cover	Freq	Cover	Freq	Cover	Freq	Cover	Freq	Cover
Leaf litter	100	26.1	4	0.2	35	1.6	80	15.4	100	48.5
Scolochloa festucacea	90	2.2	38	1.7	42	0.6	75	0.9	100	1.8
Atriplex patula	50	3.3	10	4.2	38	4.7	46	11.2	45	7.6
Chenopodium rubrum	50	7.5	23	3.5	13	3.1	4	0.6	5	1.6
Erigeron, *Solidago*, & *Aster* spp.	35	1.9	4	0.4	6	0.6	2	0.1	5	0.2
Ranunculus sceleratus	30	0.5	0	0	0	0	0	0	0	0
Sonchus arvenses	10	1.5	0	0	17	2.6	21	2.8	10	0.5
Rumex maritmus	5	0.4	6	0.6	0	0	0	0	0	0
Scirpus paludosus	0	0	2	0	0	0	8	0.8	0	0
Other	5	0	2	0	4	0.2	0	0	0	0
Total plant coverage		17.3		10.5		11.8		16.4		11.7

Edge Vegetation

Pond shoulders varied from areas of little spoil deposition to areas where soil was piled in mounds 2-foot high. This variability in substrate undoubtedly affected plant colonization. The following discussion includes sample areas of varying depths of spoil.

Eight plant species were commonly recorded on the pond shoulders. *Scolochloa festucacea*, *Atriplex patula*, *Chenopodium rubrum*, and *Sonchus arvenses* had the highest percent frequency and coverage (Table 4). When stem length is considered *Scolochloa festucacea*, rose two to three times taller than *Atriplex patula*, *Chenopodium rubrum*, and *Sonchus arvenses* (Table 5).

One-year pond shoulder vegetation differed from that of 2-year ponds (Table 4). *Scolochloa festucacea* frequency and *Atriplex patula* cover increased with pond age, while *Chenopodium rubrum* decreased. *Scirpus paludosus* appeared after two years, and leaf litter substantially increased in both frequency and cover.

Provost (1948:372) believed that plants invaded dynamited potholes from two sources, "undisturbed marsh" and from plants which established themselves "in the excavations." The latter group "met the invaders from the marsh usually at the waterline under the banks" (*op. cit.*). After the first year invasion by *Chenopodium rubrum* and other marsh plants, the pond shoulders resembled

TABLE 5.--Average stem length* of meadow and pond-shoulder vegetation, Delta, Manitoba.

Species	Meadow 1965	Meadow 1966	1-Yr. Pond 1966	2-Yr. Pond 1966
Scolochloa festucacea	29	31	22	35
Atriplex patula	2	3	9	6
Chenopodium rubrum	4	12	9	12
Erigeron, _Solidago_, & _Aster_ spp.	6	8	11	2
Ranunculus sceleratus	2	--	--	--
Sonchus arvenses	6	13	11	8
Rumex maritmus	12	--	--	--
Scirpus paludosus	--	--	--	12
Other	--	--	45	--

*Length in inches.

the surrounding meadow. However, after only two years of study, it is not clear whether the vegetation on the shoulders will become part of the Scolochloa community or if it will become a separate community.

The appearance of Scirpus paludosus on the shoulders of 2-year ponds may indicate a separate shoulder community. Coupland (1950) noted that S. paludosus can tolerate high concentrations of salts and grows around bare central areas. If pond salinization increases with age (p. 29) the pond shoulders would resemble Coupland's (1950) conditions and thus favor a separate shoulder community.

Aquatic Macrophytes

Plants quickly appeared in the ponds. Zannichellia palustris and Potomogeton pectinatus were among the most widespread (high frequency) species and comprised over 90 percent of the total weight (Table 6). Fourteen additional species, some of which had a high frequency, were found in the ponds. On the basis of frequency and weight, Zannichellia palustris and Potomogeton pectinatus dominated the plant community of the ponds.

Reported studies offer possible explanations for sources of plants in newly denuded areas. Shull (1914: 337), Penfound (1953:569), and others noted that submerged seeds will germinate after many years of dormancy and thus are an important origin of pioneering plants. Birds have been known to transport aquatic plants either by adherence

TABLE 6.--Aquatic plant species composition at 1- and 2-year ponds, expressed in frequency and percentage of total weight (grams), Delta, Manitoba.*

Species	1-Year Ponds				2-Year Ponds	
	1965		1966		1966	
	Frequency	Weight	Frequency	Weight	Frequency	Weight
Zannichellia palustris	100	68%	81	2%	76	5%
Potomogeton pectinatus	75	31	56	88	94	92
Scirpus validus	38	t**	56	8	32	
Ranunculus sceleratus	12	t	50		35	t
Chara sp.	12	t	19		15	
Utricularia vulgaris	12	t	6	1	6	
Scolochloa festucacea			94		74	1
Typha latifolia			25		6	
Myriophyllum exalbescens			19		32	2
Phragmites communis			13		3	
Scirpus paludosus			6		71	
Rumex maritmus					9	
Scirpus acutus					9	
Lemna minor					3	
Sencecio congestus					3	
Hippuris vulgaris					3	
Total percentage		99		99		100
Total weight (grams)		63.8		9.3		175.4

*Frequency based on 16 plots in 1965 and 25 entire ponds in 1966 during July and August. Weight based on 16 plots in 1965 and 32 plots in 1966 during July and August.

**t = less than 0.5% weight.

of various plant parts to their bodies or passage through the digestive tract (Arber, 1920:301; Schlichting, 1958). Undoubtedly wind is also responsible for short-range dispersal of plants. Certainly differences in 1- and 2-year pond flora were affected by the available sources of vegetative parts and seeds, and by the means of dispersal of each species. Probably most of the pond macrophytes were carried by ducks or came from dormant seeds already present in the soil.

Several pond species flowered and a few produced seeds. *Ranunculus sceleratus*, *Myriophyllum exalbescens*, *Scolochloa festucacea*, and *Sencecio congestus* flowered, but I found no fruits or seeds. Practically every clump of *Potomogeton pectinatus* formed fruit, but few if any mature seeds. *Scirpus validus*, *S. acutus*, and *S. paludosus* produced seeds. Other species (Table 6) did not flower or produce fruits. It appears that once introduced to the ponds, only the *Scirpus spp*. reproduced by sexual means; and the other species seem to have increased by vegetative means only.

Data from all aquatic plots and sampling dates were pooled into two groups, 1- and 2-year ponds. The 1965 total macrophyte weight of 1-year ponds was nearly seven times the 1966 1-year pond weight (Table 6). This difference may have been due to yearly variations in growth and dissimilar growing sites (1-year ponds were S-1 through S-17 in 1965 and S-18 through S-25 in 1966, Figure 2). The higher frequencies noted in 1966 1-year ponds as compared to 1965 ones, were mainly due to a change in the frequency sampling unit. After two years, the ponds contained five more species and three times the weight of the 1-year ponds. In spite of the high degree of variability during the early stage of pond succession, the trend was towards increasing number of plant species and quantity with pond age.

Future changes in the aquatic plant community are difficult to predict. Bird (1930:412) states that succession in aspen parkland lakes progresses from various species of Potomogeton to a stage of Scirpus, Typha, and Carex. Natural pond vegetation in the Delta Marsh (Löve and Löve, 1954) indicates that a sere of Utricularia, Myriophyllum, and Hippuris will follow the Potomogeton stage. The same investigators (op. cit.) found Lemna spp. common, but it was absent in the ponds even though the ponds seemingly offered a possible habitat.

Invertebrates of 1- and 2-Year Ponds

The quantity of invertebrates in the ponds was sparse in comparison with that of the marsh. Collias and Collias (1963), making total counts, found as many as 1,000 Daphnia per liter in a small bay near Delta. Using a macroplankton net, the highest I ever found was an average of 18 per liter.

A Chi-square two-sample case test (Siegel, 1956: 104-111) showed a statistically significant difference ($p < 0.001$) in the proportion of invertebrate biomass in

1- and 2-year ponds (Figure 9). Older ponds contained a greater biomass of invertebrates during most of the summer. They were more abundant in 1-year ponds only during late June and early July, when zooplankton and nekton reached a peak.

In contrast to biomass, the total number of invertebrates during the summer was similar in the two groups of ponds, although their seasonal abundance differed (Table 7, and 8). In general, invertebrates in 2-year ponds reached a peak earlier in the summer. This was especially true of benthic organisms. The 1-year ponds had a slightly higher total number of invertebrates during the summer.

A qualitative comparison of the two pond groups offers an explanation to the contrasting biomass and total number estimates of invertebrate abundance. In net tows Daphnia composed 97 percent of the 1-year pond invertebrates, while five taxonomic groups--Daphnia, Lymneae, Chaoborus, Physidae, and Coroxidae--comprised the same percent in 2-year ponds. Similarly, in bottom samples only three taxa (Tendipedidae, Daphnia, and Oligachaeta) comprised 95 percent of the younger ponds samples, while 95 percent of the 2-year pond samples consisted of seven taxa (Tendipedidae, Lymneae, Daphnia, Oligochaeta, Spongillidae, Physidae, and Hydrophilidae). Lymneae and Physidae, snails, made up a large portion of the 2-year sample biomass.

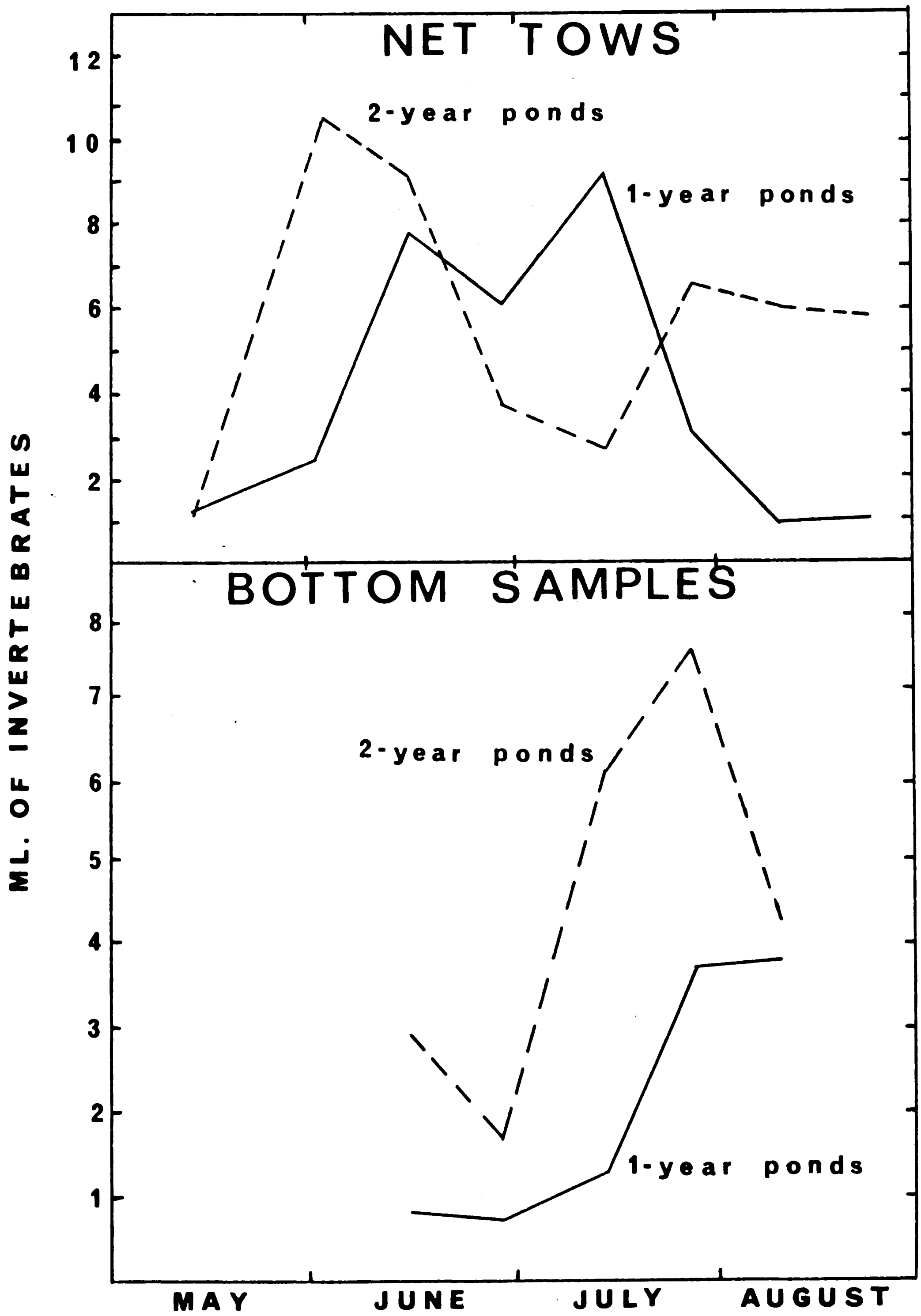

Figure 9.--Comparison of 1- and 2-year pond invertebrate biomass, 1966, Delta, Manitoba. Expressed as volume per 200-liter net tows and per one-square-foot bottom samples.

TABLE 7.--Comparison of 1- and 2-year pond bottom samples for invertebrates, 1966, Delta, Manitoba. Expressed in numbers per square foot.

	June			July		August		Per-
	1	15	30	13	27	10	Total	cent
Tendipedidae								
1-yr. 1965	--	--	--	117	256	169	542	62.4
1-yr. 1966	3	68	200	161	238	50	720	40.1
2-yr. 1966	138	151	150	94	61	74	668	43.4
Daphnia spp.								
1-yr. 1965	--	--	--	41	34	23	98	11.3
1-yr. 1966	20	158	212	140	106	21	657	36.6
2-yr. 1966	29	102	16	41	22	9	219	14.2
Oligochaeta								
1-yr. 1965	--	--	--				0	0
1-yr. 1966	5	14	31	56	122	102	330	18.4
2-yr. 1966	28	111	13	5	13	1	171	11.2
Lymneae spp.								
1-yr. 1965	--	--	--				0	0
1-yr. 1966				1	4	3	8	0.3
2-yr. 1966			8	84	96	52	240	15.6
Physidae								
1-yr. 1965	--	--	--	4	17	25	46	5.3
1-yr. 1966							0	0
2-yr. 1966	1	3	1		22	15	42	2.7
Spongillidae								
1-yr. 1965	--	--	--	5	30	4	39	4.5
1-yr. 1966					6	10	16	0.9
2-yr. 1966	4	16	15	9	14	14	72	4.7
Hydrophilidae								
1-yr. 1965	--	--	--	14	5	1	20	2.3
1-yr. 1966		1		3	15	4	23	1.2
2-yr. 1966				7	4	21	32	2.1
Other								
1-yr. 1965	--	--	--	15	41	68	124	14.1
1-yr. 1966	2	3	2	5	15	17	44	2.5
2-yr. 1966	4	8	8	10	34	31	95	6.2
Total								
1-yr. 1965	--	--	--	196	383	290	869	100.0
1-yr. 1966	30	244	445	366	506	207	1798	100.0
2-yr. 1966	204	391	211	250	266	217	1539	100.0

TABLE 8.--Comparison of 1- and 2-year pond net tows for invertebrates, 1966, Delta, Manitoba. Expressed in numbers per 200 liters.

	May 12	June 1	June 14	June 28	July 13	July 26	August 9	August 23	Total	Per-cent
Daphnia spp.										
1-year	38	630	1242	716	1916	280	98	121	5041	97.0
2-year	10	1243	1319	395	50	246	133	11	3407	81.0
Hydrochnidae										
1-year		8	1	1	1	1	1	50	63	1.2
2-year		26	5	2	2	4	2		41	1.0
Chaoborus spp.										
1-year				2	1	16	1	8	28	0.5
2-year	12	8	20	42	33	22	84	61	282	6.8
Coroxidae										
1-year				1	4	9	4	3	21	0.4
2-year					1	37	25	2	65	1.5
Lymnaea spp.										
1-year					3	3	1	1	8	0.2
2-year				20	26	38	6	40	130	3.1
Coenagrioidae										
1-year					1			1	2	tr
2-year	1			1	1	22	12	2	39	0.9
Physidae										
1-year									0	0
2-year				1	13	83	11	36	144	3.4
Other										
1-year		5	8	1	5	2	3	1	25	0.5
2-year	2	2	4	2	8	13	13	11	55	1.5
Total										
1-year	38	643	1251	720	1931	311	108	185	5188	99.8
2-year	25	1279	1348	463	134	465	286	163	4163	99.2

In both groups of ponds, *Daphnia* and Tendipedidae, respectively, were the most numerous zooplankton and benthic organisms. A Chi-square two-sample case test (Siegel, 1956) showed a statistically significant difference ($p < 0.001$) in the numerical proportion of *Daphnia* and Tendipedidae in the two groups of ponds (Tables 7 and 8). Both of them were more abundant in the 2-year ponds early in the summer. However only the total number of Tendipedidae was similar in both ages of pond while *Daphnia* were more abundant in 1-year ponds. Thus, during the summer, increased diversity of invertebrates in 2-year ponds was accompanied by an increase in biomass, but not in the total number of organisms.

The means of dispersal of each taxa probably affected their abundance in the ponds. Various animals have been found transporting viable aquatic organisms (Maquire, 1959). Water birds have been known to transport snails (Malone, 1965) and crustacean eggs (Proctor, 1964). Pennak (1953: 15) believed wind could carry plankton and benthos. Flying insects easily could have reached the ponds.

Upon reaching the ponds, environmental requirements and biotic interactions affect each organism's survival. These limiting factors are more easily recognized at the species level than at the taxa levels used in this study, so only broad generalizations are indicated.

Daphnia, Tendipedidae, and Oligocheata were the most common invertebrates in 1-year ponds. In general, they are primary consumers feeding on organic matter, algae, and macrophytes (Dineen, 1953; Pennak, 1953). Their "life form" (Odum, 1959:295) can be classified as plankton and benthos. Since the 1-year ponds did contain organic matter (Table 2), vegetation, and few predators; Daphnia and Oligochaeta were more numerous in them. The early season low number of Tendipedidae and Oligochaeta was probably because few individuals had dispersed to the younger ponds.

The most common invertebrates of the 2-year ponds not only included the three taxa of the 1-year ponds, but in addition Lymnaea, Physidae, Chaoborus, Coroxidae, Spongillidae, and Hydrophilidae. Chaoborus is a plankton predator while the others are primary consumers (Dineen, 1953; Pennak, 1953). Periphyton, a new "life form" (Odum, 1959), was added to the list of common invertebrates with the inclusion of Lymnaea, Physidae, and Spongillidae. Chaoborus probably reduced Daphnia, but this reduction in numbers was replaced with the addition of periphyton. Although there was little measurable increase in organic matter (Table 2), the macrophytes did increase (Table 6) with pond aging. Undoubtedly, producer and consumer organisms found in the 2-year ponds increased the available microhabitats and niches which resulted in a greater diversity and biomass of invertebrates.

Waterfowl Populations

Ducks were counted for four main reasons: (1) to compare pond species composition with that of the marsh, (2) to compare pond seasonal abundance with that of the marsh, (3) to determine the size and distribution of the breeding population, and (4) to investigate the factors of pond age, food, cover, water levels, and bay-to-pond distance on duck distribution at the ponds.

Species Composition

The Wilcoxon matched-pairs signed-ranks test (Siegel, 1956:75-83) was used to compare the duck species at the ponds with those of the East Marsh and the bays surrounding the study area. The weekly percent composition of each species in each area was compared with the same species in other areas. The comparison was limited to the months of May and June because few ducks used the ponds at other times.

Several sources of bias may have been introduced by comparing the species composition of the three areas. Counts of the East Marsh were taken from the air while those of the bays and ponds were taken from the ground. Smith (1958:56) found that if 50 percent of a species were seen from the air, its species composition would be similar to that recorded on the ground. Probably additional bias was introduced because different observers made the aerial and ground counts. Neither of these factors was considered a large source of error for comparing species compositions.

This statistical method of comparison contains certain limitations. Because of above mentioned bias, a comparison of duck density would be meaningless. Therefore the percent composition of each species was compared. The percentage of the total population that each species comprised was an average proportion; and should not be confused with density.

The duck species composition of the Second Lead bays (Figure 11) was compared with that of the East Marsh (Figure 10, Table 9). Mallards, gadwalls, shovellers, redheads, and ruddy ducks were found in relatively the same proportion in both areas. The Second Lead bays contained a higher percentage of pintails and teal while baldpates, canvasbacks, and scaup comprised a smaller proportion. Evidently the Second Lead bays had a more restricted species composition than the surrounding marsh.

The duck species composition at the ponds (Figure 13) was compared to that of the East Marsh and the Second Lead bays (Table 9). Only the percentage composition of gadwalls and shovellers were similar in the three areas. Teal made up a larger percentage of the pond composition than they did in the marsh or bays, even though the bays contained higher percentages of teal than the East Marsh. Mallards, pintails, baldpates, canvasbacks, redheads, scaup, and

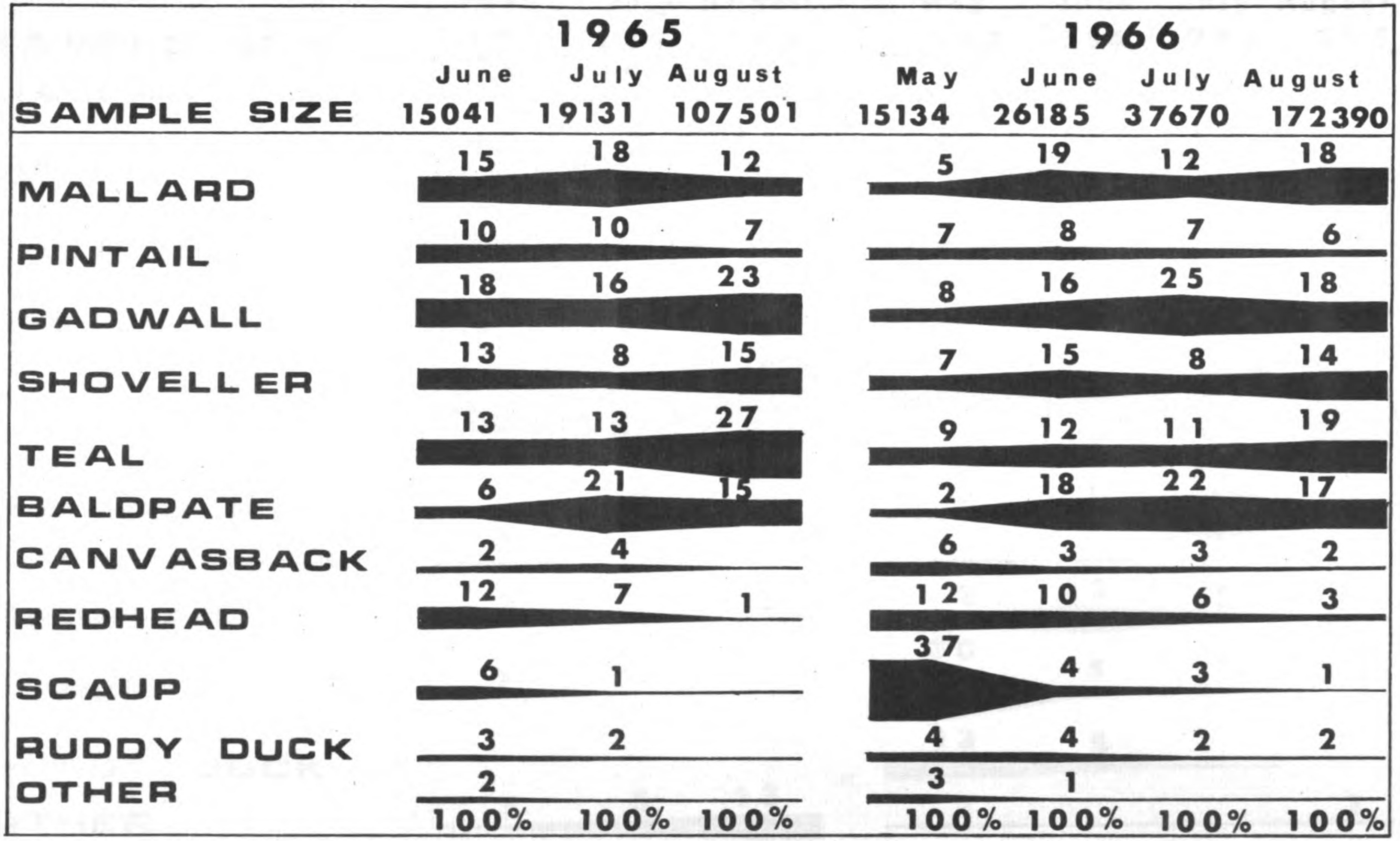

Figure 10.--Species composition of ducks in the East Marsh. Based on weekly counts by the Delta Marsh Development Committee, Delta, Manitoba.

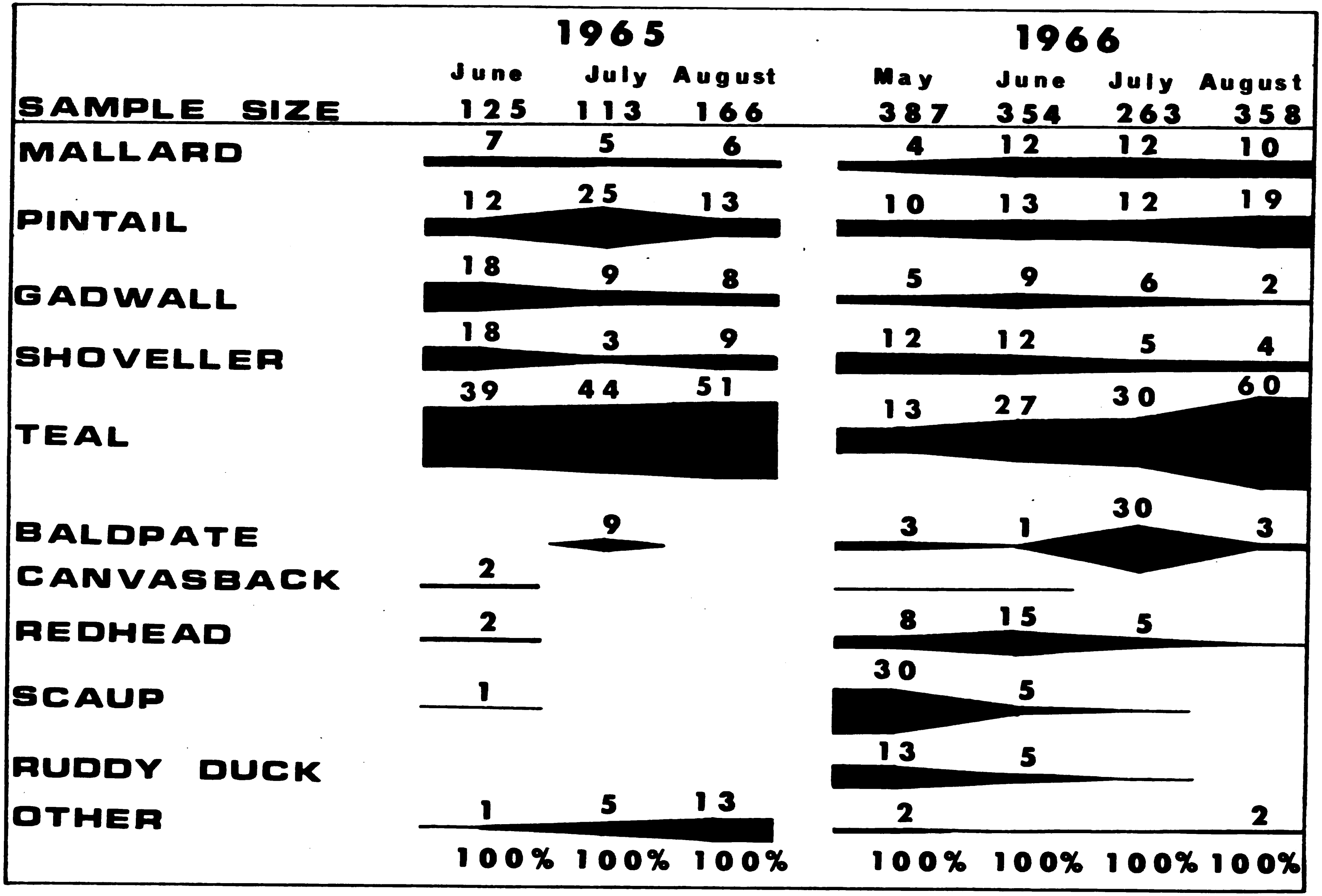

Figure 11.--Species composition of ducks at the study area bays. Based on weekly counts, Delta, Manitoba.

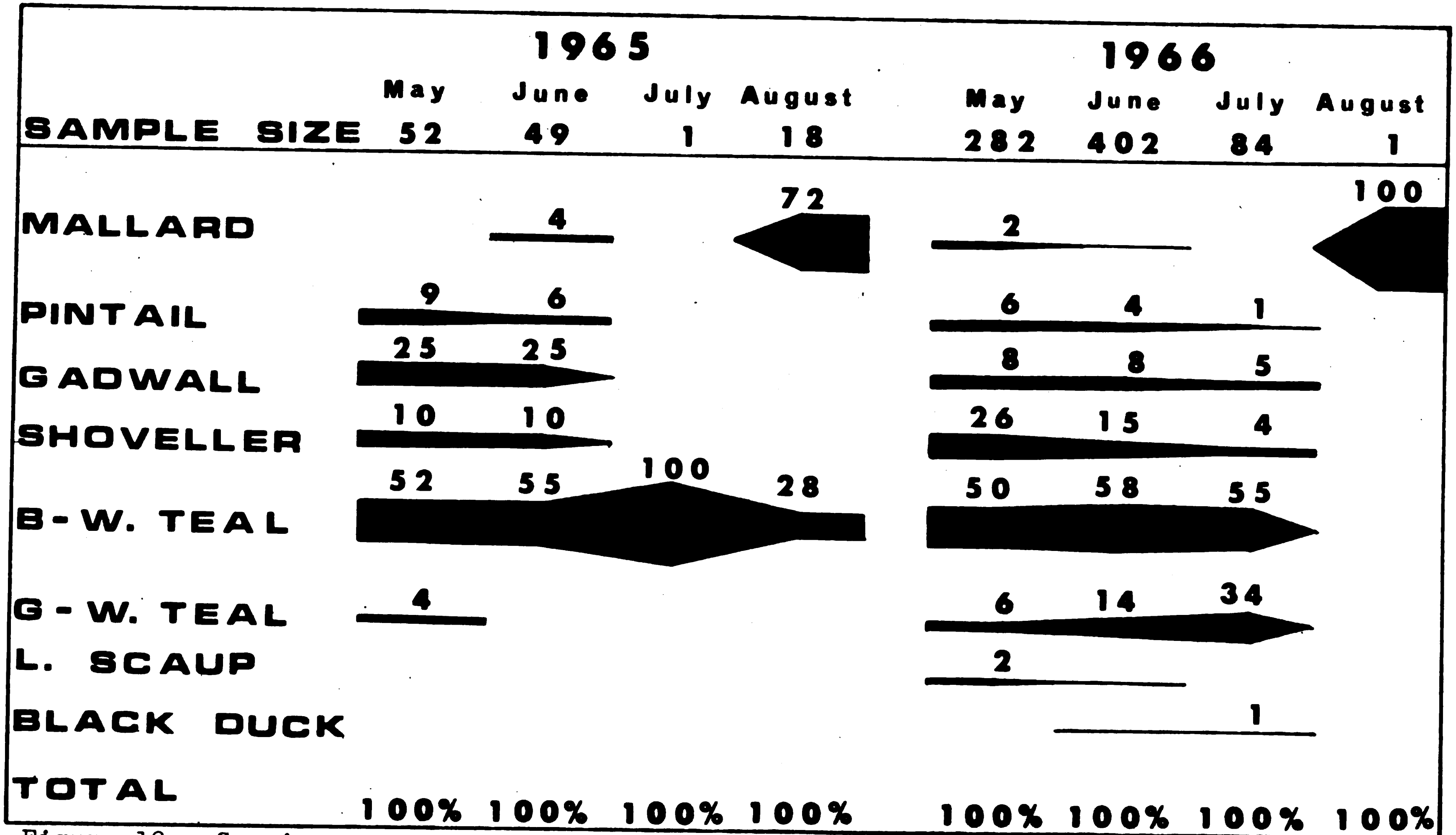

Figure 12.--Species composition of ducks at the ponds. Based on weekly counts, Delta, Manitoba.

TABLE 9.--Comparison of the species compositions of the East Marsh, the study area bays, and 27 blasted ponds. (The Wilcoxon matched-pairs test was used to compare the weekly percent composition of each species during June 1965 and May through June 1966.)

Comparison of: Species	Bays to East Marsh	Ponds to East Marsh	Ponds to Bays
Mallard	0*	---	-
Pintail	+	--	---
Gadwall	0	0	0
Shoveller	0	0	0
Teal	+++	+++	+++
Baldpate	--	---	---
Canvasback	-	---	---
Redhead	0	---	---
Scaup	-	---	---
Ruddy Duck	0	---	---

*Level of significance:

99 percent +++ higher percent, --- lower percent
98 percent ++ higher percent, -- lower percent
95 percent + higher percent, - lower percent
Less than 95 percent 0.

ruddy ducks were either completely absent in the ponds or found in lower proportions than at the surrounding areas. This suggests that of the 11 species most commonly found in the area, only two, shoveller and gadwall, used the ponds as much as would have been expected and that teal used them more than was expected.

The differences between species compositions at the ponds and the surrounding areas could be due to specific habitat preferences, to overcrowding, or a combination of the two. There can be little doubt that some species prefer certain habitats because of structural adaptations, physiological responses, and specific behavior (Odum, 1959: 27). In addition, the number of individuals of a species is affected by the carrying capacity of a particular time and place, and the extent to which a specific population fills that capacity (Odum, 1959:183).

In case of the low pond use by diving ducks, it appears that they respond mostly to their habitat preferences. Evans and Black (1956:36) found that diving ducks usually remained on larger waters than dabbling ducks. Most diving ducks patter along the surface when rising from the water, and thus require longer "take-offs." Although the 50-foot ponds offered ample distance for take-off, the small size probably limited diving duck use.

In contrast to divers, dabbling ducks (as a group) showed no clear preferences for any of the three areas.

In Iowa, Provost (1948) noted larger numbers of blue-winged teal, smaller numbers of mallards and shovellers, a few wood ducks and green-winged teal, and no gadwalls or baldpates using blasted ponds; even though all frequented the marsh. Hochbaum (1944:78), Smith (1958:33), and Drewien (1966) found specific habitat preferences among dabbler ducks while Keith (1961:46-47) reported that they frequented ponds and lakes to nearly the same extent. Similarly, my findings showed that dabbling ducks as a group, did not prefer any one of the three areas compared, although individual species differences did exist. Therefore, each species must be examined separately.

Some species of dabbling ducks may have been affected more by overcrowding than by habitat preference. Evans and Black (1956:38) postulated that the most abundant breeding ducks dispersed into small, less-desirable wetlands as their population density increased. However, gadwall seem to have less dispersal urge than other dabbling ducks (Gates, 1962; Drewien, 1966).

The yearly abundance of each species in the marsh and ponds offers a partial explanation to the differences in species composition of the three areas. In the East Marsh during June, all species of dabbling duck increased in 1966 over 1965, while only shovellers and teal increased in the ponds (Table 10). This may indicate that teal and shovellers may have been close to the carrying capacity of

TABLE 10.--Comparison of June 1965 and 1966 dabbler duck numbers in the East Marsh and at 17 artificial ponds, Delta, Manitoba.

Species	East Marsh[1]			Ponds		
	1965	1966	% Change	1965	1966	% Change
Mallard	2,225	4,840	+118	2	0	-
Pintail	1,515	2,030	+34	3	2	-
Gadwall	2,655	4,220	+58	12	10	-17
Shoveller	1,930	3,920	+103	5	34	+580
Teal	2,015	3,025	+50	27	144	+433
Baldpate	825	2,125	+158	0	0	-
Total	11,165	20,160	+80%	49	190	+380%

[1]Data from Delta Marsh Development Committee.

the adjacent area and therefore increased their use of the newly created ponds. In contrast, other dabbling duck species showed no increase at the ponds because their populations possibly were below the carrying capacity of the local area.

Mallard and pintail use of the ponds probably was "low" because these early nesters had completed much of their breeding activities before the ponds were free of ice. Mallards return to Delta in early April (Hochbaum, 1944) yet the ponds were frozen until mid-April.

Current information--including this study--does not provide a positive answer to the observed differences in dabbler duck species composition. Circumstantial evidence indicates that both habitat preferences and overcrowding in the study area may have resulted in a pond species composition dominated by teal.

Seasonal Abundance

Ice probably restricted early season duck use of the ponds. In general, spring break-up of the bays occurred several days to over a week earlier than in the ponds. In 1965 on May 6 (the first census) the ponds were free of ice and ducks were present. In 1966, the ponds were first clear of ice by April 22, but were frozen again from April 28 to May 2. The first ducks were seen at the ponds May 4 even though they had been using the surrounding bays for several weeks.

From early May until mid-June, pond utilization followed the trends of waterfowl abundance in the marsh (Figure 13). Dillion (1955) described a similar Delta Marsh trend as a decrease from a prebreeding high to a breeding low. Sowls (1955:13) believed that during early spring, Delta's population was comprised of transient and resident ducks.

In contrast to the marsh, duck abundance at the ponds sharply increased in late June (Figure 13). This is a period when many ducks move into the marsh to moult and pass their flightless period (Hochbaum, 1944:119). Some ducks using the ponds were still paired while others were gatherings of postbreeding drakes. Paired ducks most likely were renesters.

The ponds received little use after mid-July even though ducks increased in the surrounding areas (Figure 13). Only two newly-hatched broods and a few adults were seen on the ponds during this period. Mathisen _et al_. (1964) also reported little brood-use of blasted ponds. Broods apparently prefer larger water areas which offer better escape from possible predators (Evans and Black, 1956:40). Once ducks are able to fly they prefer large open potholes (Evans _et al_., 1952:41). Flightless ducks were never seen on the ponds, but they did frequent the surrounding bays. Hochbaum (1944:122) similarly never encountered flightless ducks at natural potholes in the Delta Marsh.

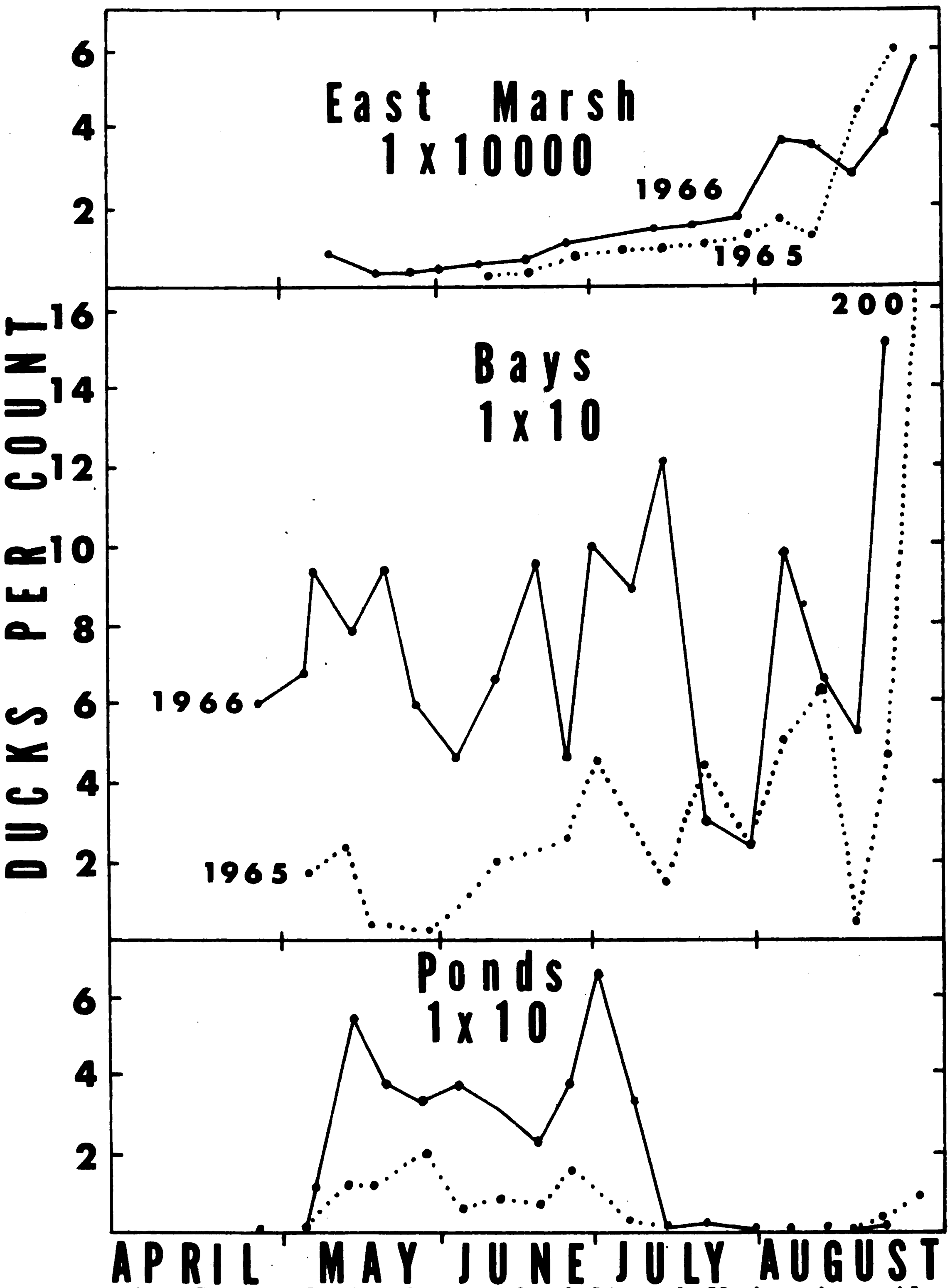

Figure 13.--Seasonal abundance of adult and flying juvenile ducks at the East Marsh, study area bays, and 17 ponds. East Marsh data from the Delta Marsh Development Committee, Delta, Manitoba.

Ducks utilized the ponds during the time of year commonly associated with spring migration, breeding, and postbreeding activities (Figure 13). The population composition of the most common species (Table 11), blue-winged teal, reflects these activities. From April to mid-June breeding pairs comprised the bulk of the blue-wings present, indicating little use for migration purposes. After mid-June breeding pairs decreased and non-breeders, mostly gatherings of postbreeding drakes, increased in abundance. The population composition of species other than blue-wings showed the same general pattern.

Breeding Population

The breeding duck population was determined by a method described by Evans and Black (1956:54). Ducks were recorded as lone pairs, single males, single females, groups of pairs, groups of males, one male with a pair, and unidentified. Lone pairs, lone drakes, and lone hens were assumed to represent nesting pairs. It also was assumed that half of the nesting pairs seen on the First and Second Bays were in the study area, while all breeders seen on the Clair Lake transect were included (Figure 2). The peak number of breeding pairs for each species was taken as the breeding population for that species. For example, 12 pairs of blue-winged teal, the peak number, were seen on May 26 (Table 11), so the breeding population

TABLE 11.--The blue-winged teal population composition for 25 artificial ponds, 1966, Delta, Manitoba.

Date	Breeding Ducks			Nonbreeding Groups				Total Ducks	Breeding Pairs
	Pair	Lone Male	Lone Female	Male w/Pair	Pairs	Males	Undi.		
5/6	1	0	0	0	0	0	0	2	1
5/13	8	0	0	0	5	0	0	26	8
5/19	7	2	0	1	0	0	0	19	9
5/26	8	4	0	1	1	2	0	27	12*
6/2	6	2	0	1	4	4	0	29	8
6/9	4	7	0	2	0	4	0	25	11
6/16	5	5	0	0	0	0	0	15	10
6/23	6	4	0	1	8	4	0	39	10
6/30	6	3	0	0	4	39	5	67	9
7/7	2	1	1	0	0	7	20	33	4

*Indicated breeding pair population of 25 blasted ponds for 1966.

of teal was estimated at 12 pairs for the ponds. The breeding population of all species was the sum of the individual peak numbers of breeders for each species, regardless of the peak date (Table 12).

In 1966, the Second Lead area contained a calculated 64 breeding pairs (Table 12). Only parts of the bays were censused in 1965 so no calculation was made of the whole Second Lead area. On the average, an artificial pond had 0.8 pairs in 1965 and 1.4 pairs in 1966. For every mile of edge there were 15 pairs along the bays and 27 pairs along the ponds in 1965, while in 1966 there were 16 pairs per mile of bay edge and 51 pairs per mile of pond edge.

<u>Factors Affecting Pond Selection</u>

The weekly duck-count total ranged from only one duck on pond S-24 to 74 on S-3. Of the ducks seen on pond S-3, 25 were a flock of drakes! Flocks of this size were encountered only a few times, so it was not possible to determine from the total number of ducks if certain ponds were being favored.

By grouping the ponds into 1- and 2-year classes, it was possible to minimize the bias of flocking to particular ponds. Arrangement of the data in this manner fulfilled the assumptions of the Student t-test (Li, 1957). A comparison of the two age groups showed no statistically significant difference ($p > 0.20$) in total duck use (Table 13).

TABLE 12.--Second Lead breeding pair population based on weekly counts, Delta, Manitoba.

Species	Peak Date	Ponds	Flooded Areas	Bays*	Total
		1965	17 Ponds		
Pintail	5/12	0	0	3	3
G-W. Teal	5/12	1	0	1	2
Shoveller	5/28	2	0	0	2
Gadwall	5/28	3	0	0	3
Mallard	6/9	1	0	2	3
Canvasback	6/16	0	0	1	1
Redhead	6/16	0	0	1	1
B-W. Teal	6/23	6	0	2	8
Total		13	0	10	23
		1966	25 Ponds		
Baldpate	5/5	0	0	2	2
Mallard	5/6	1	0	4	5
Pintail	5/6	2	1	3	6
Shoveller	5/13	11	2	1	14
Gadwall	5/13	4	0	2	6
G-W. Teal	5/13	3	0	0	3
L. Scaup	5/19	2	1	2	5
Canvasback	5/19	0	0	1	1
B.-W. Teal	5/26	12	3	3	18
Redhead	6/2	0	0	3	3
Ruddy Duck	6/9	0	0	1	1
Total		35	7	22	64

*Only a portion of the bays censused in 1965.

TABLE 13.--Comparison of duck use at 1- and 2-year ponds, 1966, Delta, Manitoba.

Pond Age*	Total Ducks		Breeding Pairs	
	1-year	2-year	1-year	2-year
B-W. Teal	86	99	4	4.0
G-W. Teal	33	21	1	1.0
Shoveller	15	35	3	4.0
Gadwall	10	12	0	2.0
Pintail	6	4	1	0.5
Mallard	3	1	0	0.5
Lesser Scaup	0	4	0	1.0
Black Duck	2	0	0	0
Total	155**	176**	9	12.0

*Based on eight 1-year ponds and a weighted sample of 17 2-year ponds.

**No statistically significant difference (Student t-test $p > 0.20$).

Even though duck use was similar at the two age classes of pond, two species did seem to indicate a preference (Table 13). Shovellers appeared to select 2-year ponds and green-winged teal the 1-year class. It is not clear whether such a difference did exist because of the small sample size.

It is of particular interest that ducks used both age groups of pond with nearly equal intensity. Certainly macrophytes and invertebrates increased qualitatively and quantitatively (Table 14). Based on Welch's (1952:379) description of pond-age classes, the ponds passed from a young stage (little or no vegetation) to an adolescent stage of invading plants. Apparently, changes in early stages of succession did not significantly affect waterfowl use of the ponds.

A Chi-square one-sample test (Seigel, 1956) was used to ascertain if breeding pairs were uniformly distributed on the ponds. Flocking did not bias the distribution because only lone males, lone females, or lone pairs were considered as breeding pairs. The total number of breeding pairs seen on each pond served as an index of breeding duck use. The pair index ranged from one on pond S-24 to 15 on S-8, with a mean of 7.2 for ponds S-1 through S-25. A statistically significant difference ($p < 0.001$) indicated that breeding pairs were not uniformly distributed.

TABLE 14.--Summary of a comparison of 1- and 2-year ponds, 1966, Delta, Manitoba. (Changes in quality and quantity of macrophytes and invertebrates did not affect waterfowl use.)

	1-year Ponds	2-year Ponds
Pond Morphometry		
mean depth	5 feet	similar
mean width	26 feet	similar
mean length	55 feet	similar
Soil and Water Chemistry	saline	similar
Macrophytes		
aquatic		
quality	Potomogeton + 10 species	P. +15 species
quantity (mean)	0.6 grams/sq.ft.	11.0 grams/sq.ft.
edge		
quality	Scolochloa +4 species	S. +5 species
quantity (cover)	11.8%	16.4%
Invertebrates		
quality		
plankton	Daphnia	D. +5 taxa
benthos	Tendipedidae +2 taxa	T. +6 taxa
quantity		
mean number		
plankton	325/100 liters	262/100 liters
benthos	149/sq.ft.	128/sq.ft.
mean biomass		
plankton	0.5 ml/100 liters*	0.7 ml/100 liters*
benthos	1.0 ml/sq.ft.*	2.2 ml/sq.ft.*
Waterfowl		
quality	B-W Teal +6 species	Same
quantity (total)	155**	176**

*Statistically significant difference in seasonal abundance in the same row.
**No statistically significant difference in the same row.

Breeding pair distribution can be affected by a variety of environmental factors. Studies by Furniss (1938) and Rogers (1964) have demonstrated that water levels influence breeding pair use. Girard (1941, Mendall (1949), and Keith (1961:77-78) believed that food was important. However, Ignatoski (1966) and Evans and Black (1956:38) found that breeding ducks did not seem to be attracted by food. Cover has been reported to affect pair use (Saugstad, 1939; Smith, 1953; Smith, 1958). In contrast, Evans and Black (1956:38) and Keith 1961:77) found variations in cover had little effect on breeding-duck usage. These are not the only factors affecting pair distribution on a local area, but they are the ones commonly supposed to affect such use. Water levels, bay-to-pond distance, food, and cover were examined in this study.

The combined effect of increased food and cover was previously examined when total duck use at 1- and 2-year ponds was compared (Table 13). This did not specifically compare breeding pair use; but since there was no statistically significant difference in total use, it seemed inadvisable to compare statistically one type of use, that by pairs. Both the quality and quantity of food and cover increased in the older ponds (Table 14), yet this change does not appear to have significantly affected waterfowl use.

The available biomass of invertebrates in individual ponds was compared with breeding pair use (Figure 14). A Spearman rank correlation test (Siegel, 1956) showed no statistically significant association ($r_s = 0.154 \quad p > 0.05$) between breeding pair use and the invertebrate biomass of the ponds.

Invertebrates were not the only food source in the ponds during the spring. Sago pondweed occurred in most of the ponds, but was more abundant in the 2-year group (Table 6). Rhizomes were present, but no tubers were found in the ponds. Since duck use at the 1- and 2-year ponds was similar and since little plant material was available in the spring, it is doubtful that aquatic vegetation played a major role in affecting pair use of the ponds.

A Chi-square 2 x 2 contingency test (Siegel, 1956) was used to discover if the distance from the ponds to the bays influenced pair distribution. During May and June the number of pairs using the ponds nearest the bays was compared with those further away (Table 15). No statistically significant difference ($p > 0.35$) indicated that bay-to-pond distance had little affect on pair use.

These results can be applied also to the influence of pond water levels on duck use, because water levels were inversely proportional to bay-to-pond distance (Figure 8). At the end of June the water levels of three ponds nearest the bays had lost an average of 11 inches and two ponds

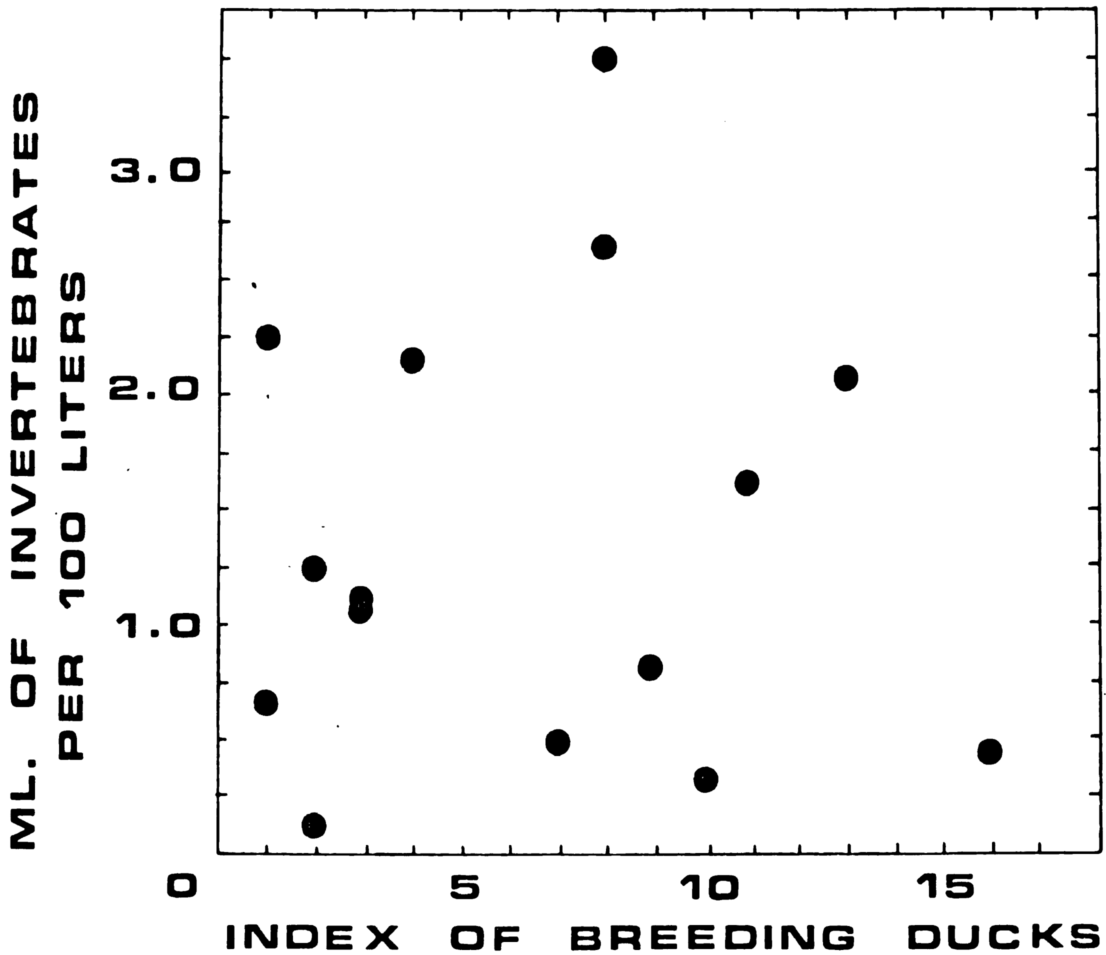

Figure 14.--Graph showing poor association between breeding duck use and invertebrate biomass at the ponds, Delta, Manitoba. Each value is the mean of two net tow samples for invertebrates and the total of four counts of breeding pairs of ducks during May 13 through June 30, 1966.

TABLE 15.--Comparison of pond locations and breeding pair use, Delta, Manitoba, 1966.

	Bay-Pond Distance		Central Location*	
	<325 Ft.	>325 Ft.	End Ponds	Center Ponds
May	41	42	27	66
June	52	46	35	53
Total	93**	88**	62***	119***

*See Figure 2 End Ponds S-1 through S-4, S-6, and S-19 through S-25 and center ponds S-7 through S-18.

**Chi-square $p > 0.35 < 0.40$.

***Chi-square $p > 0.05 < 0.10$.

further away averaged 22 inches below the edge of the ponds. This difference in water levels did not cause a statistically significant difference in waterfowl use of the two pond groups.

Breeding ducks did use certain ponds more than others, but pond age (food and cover), invertebrate abundance, water levels, and distances from bay to pond (as encountered and measured in this study) did not cause this selection. Admittedly these factors, either singly or combined may affect pair use in other situations.

Ponds S-7, S-8, S-13 and S-18 had the highest breeding pair use, and ponds S-2, S-23, and S-24 had the lowest. Most of the high-use ponds were centrally located while the low-use ponds were at either end of the pond chain (Table 15, Chi-square $p > 0.05 < 0.10$). This would suggest that pairs reacted more to the ponds as a complex, as opposed, to a factor or factors within a particular pond.

Man and wildfowl view their environment differently. Because of this difference it is hard to understand why ducks use certain ponds more than others if it was not due to some environmental factor within the ponds. Therefore the following explanation based on duck response to the macrohabitat (in contrast to microhabitat--that with a pond) is speculation on my part.

Not all of the needs of breeding waterfowl were satisfied in the ponds. Observations indicated that the ponds served mainly as isolation and loafing areas. Ducks spent only a short time per pond visit and did little feeding (Table 16). Hochbaum (1955), Sowls (1955), and others found that loafing, feeding, nest site, graveling areas, etc. may be widely separated. Thus, breeding ducks made frequent trips to other areas of the marsh because the ponds were only part of their home range.

Movement from one area of the home range to another may explain the distribution of the breeding pairs. Hochbaum (1955) states:

> These ducks of the Delta Marsh use their environment in an orderly fashion; there is a pattern to their travels. . . ., the marsh itself is a pattern of aerial lanes as well marked by the flights of waterfowl as the roads on a highway map.

Furthermore, Peter Ward (*in litt.*) states:

> There is a well developed east to west flight line that passes just north of the mid-point of your pothole complex. While not as easily seen now, it was very obvious during the high water period, 1955-57.

I do not know if the increased flight activity above the most-used ponds was due to the ponds themselves or to the presence of a "flight path."

If a "flight path" did exist over the centrally located ponds in 1966, ducks would most likely use the ponds in an inverse proportion to the distance from ponds to "flight path." Perhaps ponds S-7, S-8, S-13, and S-18 received the highest use because they were under the "flight path," and the end ponds had fewer breeding ducks because they were farther away. Only circumstantial

TABLE 16.--Time ducks spent per pond-visit, feeding, and loafing while at the ponds, May-June 1965 and 1966, Delta, Manitoba.

Time Spent:	On a Pond[1]				Spoil	Water Edge	On Water	Total	Feeding	
Species	n	$\bar{x}$	$s_{\bar{x}}$	n					n	%
Mallard	15	15.7	2.5	--	--	--	--	--	--	--
Pintail	24	18.9	6.8	8	100%	0%	0%	100%	7	0
Gadwall	34	27.0	5.2	8	94	2	4	100	5	5
Shoveller	48	13.7	2.1	11	91	0	9	100	8	3
B-W. Teal	108	12.9	1.7	42	68	18	14	100	32	4
G-W. Teal	3	9.9	--	--	--	--	--	--	--	--
Redhead	8	12.3	3.1	--	--	--	--	--	--	--
L. Scaup	17	12.3	2.6	--	--	--	--	--	--	--
Total	275	15.6	1.3	59	86%	7%	7%	100%	52	3%

[1] n = sample size.

$\bar{x}$ = mean number of minutes.

$s_{\bar{x}}$ = standard error.

evidence of this study supports such a theory. Certainly it is a topic which deserves future consideration.

Duck Behavior at the Ponds

Observations were made from a tower overlooking the ponds for two principal reasons: (1) to determine if duck use was higher at any particular time of day, and (2) to ascertain the average time spent at the ponds, feeding, loafing, etc.

Diurnal Activity Pattern

Observations were made of the number of ducks using the ponds at all times of day to determine if a diurnal activity pattern existed during the spring. Based on 16 different periods (total of 31 hours of observation in 1966) the pattern appeared to be one of highest use early in the morning (from sunrise to two hours after sunrise) and then declining utilization for the remainder of the day (Figure 15).

Time Spent at Ponds

Ducks constantly moved from one pond to another and to surrounding areas. On the average, a duck spent 15 to 16 minutes per pond visit (Table 16). Gadwalls spent the longest time per visit--27 minutes, and green-winged teal the shortest--9 minutes. Based on 87 observations, ducks undisturbed by man moved 64 percent of the time from one pond to another and 36 percent of the flights were to

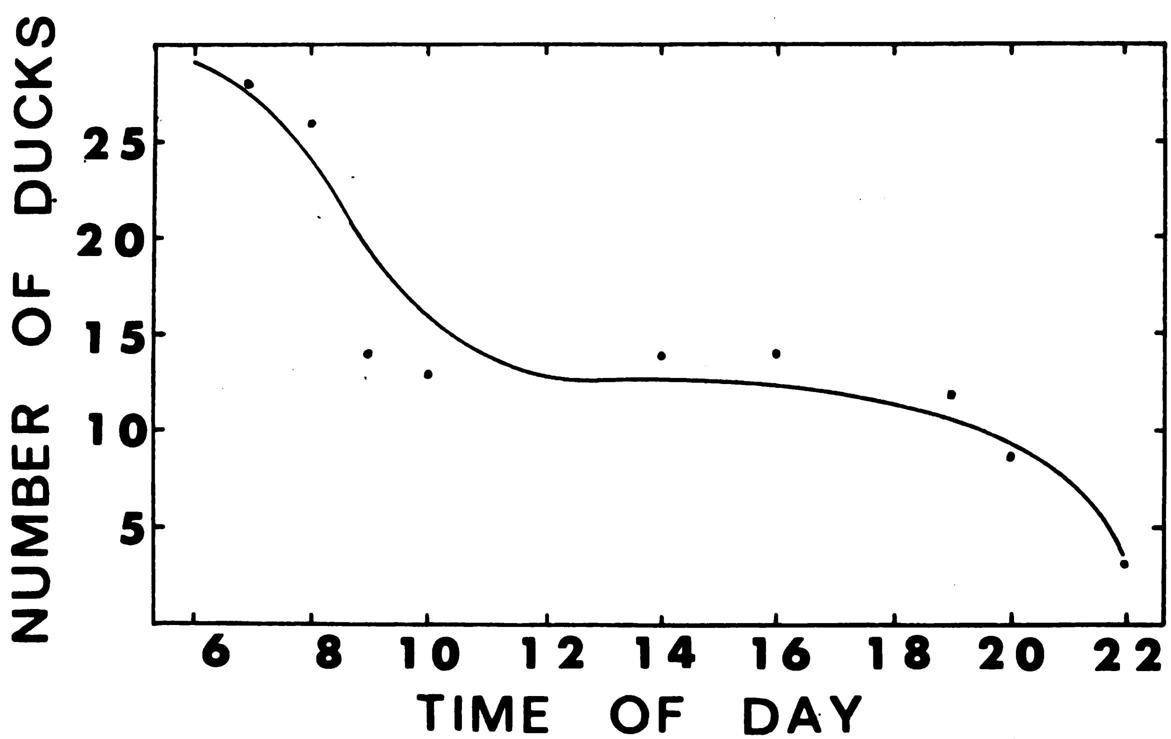

Figure 15.--Diurnal duck activity pattern at the ponds during the spring. The curve smoothed by eye is based on 31 hours of observation in 16 days during 1965 and 1966, Delta, Manitoba.

adjacent bays. Similarly, Evans and Black (1956:44) found that pairs seldom remained on one pothole for any length of time.

The diurnal activity pattern and the constant movement of the birds affected the accuracy of censuses. Most of the censuses were taken between 8:00 A.M. and 10:00 A.M. so neither the maximum nor the minimum number of ducks was present on the ponds for that particular day. Also because the ducks were constantly moving from place to place, it was not possible to predict consistently the number of ducks using a particular pond at a certain time of the day.

During May and June, ducks spent most of their time while at the ponds on top of the shoulders, instead of at the water's edge or in the water (Table 16). This was especially true when the tops of the spoil banks were bare of vegetation and thus offered a loafing place with a good elevated view of the surrounding area. Provost (1948) also believed that ducks were attracted by the naked shoulders of blasted ponds. Ducks spent less than 10 percent of their time in the water and less than half of that time feeding (Table 16). Either these ponds were not used as feeding areas or food was so abundant that little time was needed to meet their food requirements.

Nesting

Ponds and Nest Locations

Old nests were located before and after pond construction to determine if the ponds affected the distance from nests to the bays. Before the ponds were blasted, 73 percent of the nests were within 400 feet of the bays while only 44 percent were within the same distance after pond construction (Table 17).

Hens often used the ponds as jumping-off places enroute to their nests. During 31 hours of observation in 1966, hens were seen on 45 occasions leaving the ponds for nearby nests. The jumping-off ponds were not always those closest to the hen's nest, but most were within 200 feet.

Ponds and Nest Density

In 1966, a 78-acre experimental area containing 25 artificial ponds and a 21-acre check area without ponds (Figure 2) were searched for duck nests to evaluate the effect of artificial ponds on nest density. Blue-winged teal nests composed 42 percent of the 108 nests found in the two areas (Table 18). Shoveller and pintail nests were the next most common. The check area contained 2.1 nests per acre. The experimental area only had 0.3 nests per acre where there were 5.1 acres per pond, and 1.4 nests per acre where there were 2.2 acres per pond.

TABLE 17.--Comparison of the distance from duck nests to the bays before and after pond construction, 1964 and 1966, Delta, Manitoba.

Bay-Pond Distance (feet)	Cumulative Percent	
	Before	After
0-100	6	0
101-200	26	9
201-300	46	14
301-400	72	44
401-500	80	84
501-600	100	100
Number of Nests	99	49

TABLE 18.--Comparison of duck nest densities at an experimental area with artificial ponds and at a check area without ponds, 1966, Delta, Manitoba.

	Check	Experimental	
Number of Ponds	0	8	17
Blue-winged Teal	18	3	25
Shoveller	6	2	9
Pintail	10	0	5
Mallard	4	3	1
Gadwall	1	1	1
Redhead	2	0	0
Lesser Scaup	0	0	1
Unknown*	4	5	7
Total	45	14	49
Acres	21	41	37
Acres/pond	--	5.1	2.2
Nests/acre	2.1	0.3	1.4

*Old nests found chiefly after an August burning of cover.

Other studies have shown that vegetation and proximity to water may affect nest location. Williams and Marshall (1938), Bue *et al*. (1952), Sowls (1955:67), Evans and Black (1956:49), Glover (1956), Keith (1961:55), and others have stressed the importance of cover to nest densities. Some investigators (Bennett, 1938:106; Steel *et al*., 1956) stressed proximity of water. When nesting cover was nearby, Evans *et al*. (1952:40-41) and Evans and Black (1956:48) found little relationship between nest location and potholes used by breeding ducks.

Quantitative sampling of the experimental and check area vegetation revealed differences in their flora, yet both could be classified as whitetop meadows. In the check area the percent cover was--leaf litter 93.4 percent, *Scolochloa festucacea* 0.8 percent, *Sonchus arvenses* 14.8 percent, and *Cirsuim sp*. 7.4 percent. In comparison with the experimental area (Table 4), leaf litter, *S. arvenses*, and *Cirsium sp*. were more abundant in the check area. The frequency and average height of plants in the two areas were similar. Since plants had not begun to grow when most ducks were selecting their nest sites, the higher percent cover of leaf litter at the check area was the most obvious difference during the spring.

Mathiak and Linde (1956) reported a higher concentration of nests in an area with level ditches than areas without ditches. Provost (1948) found that blasted ponds induced few ducks to nest. At the experimental area, as the number of ponds per acre increased, so did the number of nests. At a nearby area without artificial ponds there were more nests than at the experimental area, suggesting that creating ponds in itself does not always influence nest density. Although as Dzubin (1955) has pointed out, the nest site must have some relationship to the water areas used by pairs, it does not necessarily have to be close to the water. The lower density at the experimental area was probably due to the differences in vegetative cover in the two areas.

Fates of Nests

A larger percent of the nests were unsuccessful in the experimental area, where 80 percent of the nests were known to be destroyed while only 60 percent were lost in the check area (Table 19). Sowls (1948:130) found that 35 percent of the nests hatched in the area he studied at the Delta Marsh. Mathiak and Linde (1956) reported very high nest loss near level ditches in Wisconsin.

Predators were the chief cause of nest loss (Table 19). The striped skunk (*Mephitis mephitis*), Franklin ground squirrel (*Citellus franklinii*), and the raccoon (*Procyon lotor*) destroyed most of the unsuccessful nests.

Several factors may have contributed to higher predation in the experimental area. Early in the spring the check area was separated from the adjacent dry marsh by a flooded shallow zone. Although the check area was not

TABLE 19.--Comparison of nest fates at experimental and check areas, 1966, Delta, Manitoba.

	Number		Percent	
	Check	Exp.	Check	Exp.
Successful	24	4	32	6
Incomplete Data*	6	9	8	14
Unsuccessful	44	50	60	80
Skunk	15	20	20	32
Squirrel	13	9	18	14
Raccoon	4	5	5	8
Deserted	2	5	3	8
Human	0	2	0	3
Unknown	10	9	14	14
Total	74**	63		

*Nests chiefly found after August burning.

**Also includes nests found in general vicinity of check area, so the total is larger than the 45 nests in Table 18.

free of skunks, it did not lose as many nests to skunks as did the experimental area (Table 19). A road leading to the experimental area, plus the fact that more man-hours were spent around the ponds may have attracted the larger predators. Kalmback (1938) and Keith (1961:78) found more nests destroyed in dense vegetation than in sparse cover. Because a large number of leopard frogs (*Rana pipiens*) and Dakota toads (*Bufo hemiophrys*) were found around the ponds, skunks may have been attracted to the ponds and consequently covered areas they normally would not have searched for nests. All of these factors--flooding, the road, activity by humans, differences in cover, and the ponds--may have resulted in higher predation at the experimental area.

Displaced Eggs and Eggshells

Duck eggs and eggshells were found at many of the ponds. On August 11, 1965, eight ponds were checked and four contained either whole eggs or eggshells. Three eggs, one each of blue-winged teal, shoveller, and gadwall were located in or near the ponds. Also six eggshells cracked by predators were found.

On June 21, 1966 I saw a female redhead fly away from her nest with a cracked egg containing a partially developed embryo. Examination of the nest revealed that a tractor had run over it, cracking at least three eggs.

Sowls (1955) was able to induce a shoveller hen to make 81 trips from nest to pond each time carrying a shell. Probably nesting hens carried most of the cracked eggs to the ponds.

More eggs and eggshells were found near the ponds than in other areas of the marsh. However, they only may have been easier to locate at the ponds. Bennett (1938:36), Hochbaum (1944:88), Sowls (1955:82), and Glover (1956) have also noticed displaced eggs. Mathiak and Linde (1956) found eggshells in level ditches. The role which this phenomenon plays in the breeding biology of ducks is unknown and deserves further study.

Duck Production

Duck production is commonly based on direct counts of broods near the flying age. However, broods in the experimental area did not use the ponds, but rather dispersed to surrounding bays. Therefore my production estimates of pond production are based on (1) nesting data and (2) the breeding population.

From Nesting Data

Production estimates can be made from nesting studies if human disturbance does not affect nest predation and if all nests are found. When proper care has been taken, human disturbance does not increase nest predation (Hammond and Foward, 1956; Keith, 1961:70). Not all of the nests were found during the spring. A partial search of the experimental area after fall burning revealed eight formerly missed nests. Bennett (1938:122), Glover (1956), and Steel et al. (1956) concluded they found about 70 percent of the nests present (approx. same percent I found in the spring).

If the above assumptions are correct, the actual production at the experimental area was far less than its potential. Forty-eight nests were found during the spring and if this represented 70 percent of the nests, then the experimental area contained an estimated 69 nests. Since only 6 percent of the nests were successful, only 34 eggs would have hatched (average of 8.2 eggs per nest) compared with the 32 known to have hatched.

Keith (1961:69) summarized six nesting studies conducted on the Canadian prairies, and found that 39 percent of the dabbler duck nests were successful. Under average nest-loss conditions described by Keith (1961), a potential of 220 eggs might have hatched from 27 successful nests in the experimental area--far exceeding the known hatch.

Nests do not give a clear evaluation of pond production. Although nests probably did offer an accurate estimate of production at the study area, my estimates may have included pairs that never used the ponds. An area without ponds was compared with the experimental area, but an additional variable--cover--complicated analysis. Therefore the following is a forecast of production based on pair counts.

From Breeding Population

Production can be based on the breeding population when the percentage of hens producing broods and the average brood size at flight age are known. Abnormally few hens produced broods in the study area (Table 19) so calculations were based on other prairie studies reporting the percentage of hens successful. Brood data also was taken from these reported studies. The following estimate should be recognized as a hypothetical production--an average expected for prairie conditions--and not an observed production because only pair data came from my study.

The ponds theoretically could have produced 113 flying ducks in 1966 (Table 20) and the entire experimental area (including all water areas), approximately 200 ducks. Brood mortality and inaccuracy of this estimate could account for the difference between the theoretical estimate of 220 eggs hatching and the 200 flying ducks produced.

The usefulness of predicting production from the breeding population depends on the accuracy of three factors: (1) pair counts, (2) percentage of the hens successful, and (3) brood size.

Pair counts are evaluated below in the discussion.

The percentage of successful hens and the average brood size vary between areas and years. Such variations were minimized by selecting data from ten different studies (Table 20).

TABLE 20.--Potential duck production of 25 ponds, 1966, Delta, Manitoba.

No. of Pairs* at 25 Ponds		Approximate Percent Hens Successful	Average Class III Brood Size	Production Ducks
B-W. Teal	12	50[1-9]	7.8[1,4,9]	46
Shoveller	11	44[1-4]	6.2[1,4]	32
Gadwall	4	41[1-4]	6.0[1,4]	11
G-W. Teal	3	86[4]	5.0[4]	13
Pintail	2	57[1,2,4]	4.6[1,4]	5
L. Scaup	2	33[2]	4.9[10]	3
Mallard	1	41[1-9]	6.0[1-4,9]	3
Total	32			113

*From Table 12.

[1]Bue et al. (1952), S. Dakota.

[2]Keith, (1961), SE Alberta.

[3]Evans and Black, (1956), S. Dakota.

[4]Evans et al. (1952), S. Manitoba.

[5]Dzubin, (1956), S. Manitoba.

[6]Leitch, (1956), SW Saskatchewan.

[7]Reeves et al. (1956), SW Saskatchewan.

[8]Sterling, (1956), S. Saskatchewan.

[9]Stoudt and Yeager, (1956), SW Saskatchewan.

[10]Dillion, (1955), Delta, Manitoba.

Two factors affect brood sizes: (1) initial nests have larger clutch sizes than renests, and (2) ducks near flight age often form aggregations (Keith, 1961:71). The high rate of predation in the study area could have decreased clutch size. Unfortunately, no procedure is presently available to evaluate these factors (Jahn and Hunt, 1964:45).

This method admittedly has many short-comings, but it does give an indication of expected production. Many areas of the marsh other than the ponds were used to produce each flying duck. Therefore pond production depends also on these areas. However, this potential easily might have been realized if predators had destroyed only an average or normal number of nests.

DISCUSSION

An evaluation of breeding duck use of the ponds depends on two factors: (1) the accuracy with which the breeding population is estimated and (2) a knowledge of factors limiting duck production.

Census Method

Breeding population estimates usually are based on pair counts. Computed breeding densities may vary from the actual population because of the following sources of error:

1. Error may result from some pair bonds breaking before the peak in breeding numbers. McKinney (1965) has shown that both species and individual variations affect the stage in the breeding cycle when the male breaks contact with the hen. Usually mallards, pintails, and gadwalls have weaker pair bonds than shovellers and blue-wings (Sowls, 1955:96).

   Mallards and pintails probably were underestimated because many of the hens were already nesting before the earliest censuses. Since the ponds were frozen during this early period, censuses of them would not be affected as greatly as counts of pairs using the bays.

2. Some pairs may move into the area after the peak in breeding numbers. If "late pairs" were renesters, probably they would have been counted earlier (Sowls, 1955:138). If the "late breeders" are nesting for the first time, the breeding population might be underestimated. Because of the large nest losses in the area (Table 19), it can be assumed most of the late breeders were renesters and did not represent new pairs.

3. Low (1947) pointed out that lone drakes should be used cautiously as indicating a breeding pair; but Bennett (1938:123), Dzubin (1955), Glover (1956), and Smith (1958) have shown that lone drakes at waiting sites usually do indicate nesting pairs.

4. Undoubtedly two drakes accompanying a hen represent a breeding pair. However, no clear evidence supports this hypothesis, so they were not included as breeding pairs.

5. There is considerable turn-over in ducks using an area during a day (Table 16, Evans and Black, 1956:44). Also ducks have specific differences in their mobility (Dzubin, 1955). Censuses were taken as quickly as possible once a week to

minimize the influence of this factor. It was assumed that the number of ducks moving onto the area was equal to those moving off.

6. The mid-morning counts probably were conservative because duck use of the ponds was highest early in the morning (Figure 14).

7. The intensity of sampling can affect the accuracy of an estimate. More censuses might have shown higher use, but greater intrusion also might have affected duck use. Weekly censuses were considered a compromise between an adequate sample and duck tolerance to repeated disturbance by investigators.

Most of these sources of error tend toward a low estimate of the population. Therefore I believe that this estimate is conservative but fairly close to the actual breeding population of the study area.

Factors Limiting Duck Production

Wetland improvement is aimed at attracting waterfowl. Blasting ponds is no exception. An effective program of habitat manipulations demands a knowledge of limiting factors. Likewise attempts to increase waterfowl production should be aimed at conditions which most directly affect the carrying capacity of a breeding area.

Hochbaum (1944) and others have suggested that during a brief period in the spring, the carrying capacity of an area may be limited by drake intolerance to other pairs of the same species. Dzubin (1955) used the words "amoeboid" and "moving territory" to describe the defended portion of a pair's home range. Some species such as shovellers are more territorialistic (McKinney, 1965) than the gadwall and certain other species (Hammond and Mann, 1965; Gates, 1962). McKinney (1965) concluded that "chasing" tended to disperse pairs and that it could significantly effect breeding densities.

Based on these and other studies it is often assumed that creating potholes in the breeding range of ducks will allow more pairs to use an area and thereby incread duckling production. However, many suitable ponds lack ducks, and unless a reservoir of nonbreeding birds exists because of insufficient water areas, creating new ponds may just dilute the existing breeding populations.

Lack of water may limit the number of breeding ducks in local areas. For a long time drought and extensive drainage programs have continued to reduce breeding habitat. Studies by Evans et al. (1952), Evans and Black (1956), Glover (1956) and data from Smith and Droll (1966, Figure 5 prior to 1963) show a close correlation between duck abundance and available water areas.

With the return of water, ducks are expected to increase. Since 1963, an increase in total water areas in southern Manitoba has not been accompanied by an increase in ducks (Figure 5). Apparently scarcity of water areas was not the only factor limiting duck abundance in Manitoba's prairies in recent years. Consequently, widespread pond construction might not have resulted in a greater production of ducks.

The number of ducks attracted to any area may vary from year to year. Factors limiting duck abundance are constantly changing. Under one set of conditions a population's tolerances may be entirely different from those under another set of conditions. Thus, there are as many variations of duck use as there are combinations of factors limiting duck production. This is especially true for highly mobile populations like waterfowl. They are opportunists, inevitability responding to nearly ideal conditions and avoiding less favorable areas. This causes shifts that are unexplainable from data collected at small areas.

Long-term information on duck abundance or production is lacking for my study area. However, I believe it safe to assume that trends in waterfowl abundance at the study area generally followed those of southern Manitoba. If so, then the lack of water areas probably did not limit breeding populations during my study.

Nevertheless I believe that blasting ponds did increase the local carrying capacity for breeding pairs. I base this conclusion on four points: (1) pond use was highest during the breeding season, (2) the ponds contained more pairs per mile of edge than the bays, (3) the number of pairs at the ponds increased in 1966 from 1965 while the Bay's population was similar during both years, and (4) reported studies of breeding pair behavior. Mendall (1949:62), Hochbaum (1944), Evans and Black (1956:45), and Lacy (1959:76) also believed that small water areas functioned chiefly for breeding pairs.

In 1966, the carrying capacity of the study area was increased to accommodate 35 additional breeding pairs (Table 12). This does not mean that these 35 pairs would have failed to nest without the ponds. Certainly the constant movement between the marsh and ponds (Table 16) indicates that the ponds were only part of the complex used by ducks. Nevertheless, an opportunity was available for other pairs to fill the vacuum left by the 35 pairs attracted to the ponds. Figure 5 indicates that this vacuum was not filled in 1966, so attracting ducks to the ponds in 1966 probably diluted the population rather than increasing it.

If new ponds increased the carrying capacity by 35 additional breeding pairs, then presumably production should have increased. An additional 113 ducks (Table 20) theoretically should have been produced, in part, by the ponds (under an average rate of predation) if water areas had been limiting production. However, this potential was not achieved because predators destroyed most of the nests near the ponds, and water did not appear to limit duck abundance.

In general, species which have strong territorialistic behavior and whose population density had reached the carrying capacity of the area should have benefited most from the ponds. Probably other species benefited less depending on their density and tolerance to other species.

MANAGEMENT

Objectives are basic to selection of management techniques. Blasting small water areas for waterfowl may achieve four major aims: (1) increase the carrying capacity for breeding pairs, (2) attract ducks for protection, (3) attract ducks for recreation, and (4) stimulate public interest in waterfowl management.

The relationship between pond construction and increases in the carrying capacity was appraised in the discussion.

It may be possible to increase duck production by attracting pairs away from areas of low nesting success. Although vegetative cover also affects nest site selection, the site must bear some relationship to the water area used by pairs (Dzubin, 1955). Pond construction adjacent to good nesting cover may concentrate nests and thus facilitate control of predators, flooding, fire, and human disturbance.

It is also possible to attract ducks to areas of low nesting success. Nests located near the test ponds were far less successful than those in areas without ponds. Undoubtedly, predators also are attracted to the ponds.

An effective predator control program may be justified under such conditions.

Ponds must be constructed sufficiently close to brood areas so newly hatched ducklings can safely traverse the distance. Evans et al. (1952) believed that broods could safely travel up to two miles overland. However, the possible hazards of such a long trip would be reduced by inducing hens to nest closer to brood areas.

Aside from attracting ducks to increase production, pond construction simply may be justified by duck use. The addition of small water areas may increase the attractiveness of many refuges. Furthermore, artificial ponds offer excellent opportunities for bird watching, photography, hunting, and other forms of recreation.

There can be little doubt that pond construction, and blasting in particular, stimulates public interest. Many other useful techniques of wildlife management fail to attract attention. Blasting ponds is visual proof of effort expended and thereby, in itself, may vindicate its use because of the positive attitude created with the public. However, such a philosophy produces few additional ducks.

The use of ammonium nitrate to create pond ponds has distinct advantages and disadvantages in comparison with other means of construction (Mathisen et al., 1964: Mathiak, 1964 and 1965; Radtke and Byelich, n.d.). Each project proposal should consider cost, safety, pond size and shape, accessibility, available equipment and personnel, etc. before selecting the appropriate method.

Pond cost in terms of flying ducks produced appears to be relatively cheap. For example, if the prorated construction cost of a pond is $0.70 per year (p. 22) and if 113 flying ducks theoretically could have been produced, in part, on 25 ponds; then a flying duck would have cost $0.15 in 1966. At best this is a crude estimate which covers only construction costs. Such a cost is economically feasible if the lack of ponds limits duck production. However, production is often limited by several factors so the actual production may be far less than forecast, as it was in this study. Under such conditions, pond cost can not be justified by duck production.

Findings of this study indicate that during the first few years after construction, food and cover in the ponds does not affect pair use. Certainly there is no need to plant aquatics where they pioneer quickly.

Constructing ponds, by itself, does not guarantee more ducks. Creating ponds may increase ducks when and where a lack of water is limiting local production or when pairs are attracted to areas of higher nesting success. Recreation and stimulation of public interest help to offset occasions when blasting ponds fail to increase duck production.

In a final analysis, wise management of a resource necessitates a broad base. A wide variety of wildlife management tools are available; no one of which by itself will increase waterfowl. One tool, habitat improvement, can be accomplished by several techniques. Some of the characteristics and limitations of blasted ponds are offered in this paper as a guide for placing pond construction in perspective with the total spectrum of waterfowl management.

SUMMARY

1. Pond construction has long been suggested as a means of improving waterfowl habitat. Ammonium nitrate now is being used as an economical means means of blasting ponds. Because few studies have dealt with biological evaluation of such habitat improvement, this study was initiated to help fill this gap in understanding. Thirty-three weeks were spent in the field from the fall of 1964 through 1966.
2. Twenty-five ponds, 17 blasted in 1964 and eight in 1965, were studied intensively while less intensive work was conducted on 16 other ponds. Located in Manitoba's Delta Marsh, the primary study area consisted of a 78-acre whitetop meadow surrounded on three sides by bays. The study period was characterized by above-average water conditions and below-average duck abundance in southern Manitoba.
3. Three 50-pound bags of ammonium nitrate placed 16 feet apart blasted a hole 5 x 26 x 52 feet. Two years after construction pond depth decreased

7 percent. The ponds may persist for 30 years. If so, a pond would have a prorated yearly cost of between \$0.60 and \$0.70.

4. The ponds received most of their water from precipitation. A few large storms added more water to the ponds than the same amount falling in many small showers. Within 300 feet of the bays, the ponds received seepage water at an inverse proportion to their distance from the bays.
5. Due to large water loss, soil and water nutrients increased, resulting in saline conditions in the ponds.
6. Plants common in the surrounding whitetop meadow were first to pioneer onto the ponds shoulders. Scholochloa festucacea, Atriplex patula, Chenopodium rubrum, and Sonchus arvense had the highest frequency and cover. Scirpus paludosus seemed to be favored by increased salinization that accompanied pond aging.
7. Potomogeton pectinatus and Zannichellia palustris began growing in the ponds soon after blasting. During the first two years, the ponds were dominated by these two species, but Utricularia, Myriophyllum, and Hippuris may increase.
8. A significantly larger invertebrate biomass occurred in the 2-year ponds than in 1-year ponds. Daphnia and Tendipedidae, the most numerous invertebrates,

each had a significantly different seasonal abundance in the two pond age classes. In general, the quality and quantity of invertebrates increased with pond age.

9. The number of ducks in the East Marsh increased as the season advanced from spring to fall. However, ducks used the pond most during the spring and early summer, very little during mid-summer, and to a limited amount in late summer.
10. Few diving ducks used the ponds even though they frequented the marsh. Dabbler duck species used the ponds to varying degrees, depending on their habitat preferences and abundance. Blue-winged teal dominated the species composition.
11. Ducks used the ponds in a diurnal activity pattern of highest use early in the morning and declining use as the time of day advanced.
12. Ducks spent an average of 15 minutes per pond visit. Most of their time was spent loafing and little time feeding.
13. In 1966, an estimated 64 breeding pairs used the Second Lead area, of which 35 pairs were at 25 ponds. In 1965 and 1966, respectively, the bays had 15 and 16 pairs per mile of shoreline, and the ponds 27 and 51 pairs. Blasting ponds increased the carrying capacity of the Second Lead area for 35 additional breeding pairs.

14. Breeding ducks used certain ponds more than others. Their selection was not significantly affected by the measured variations in pond food, cover, water levels, or bay-to-pond distance. Therefore it was concluded that ducks responded more to the ponds as a whole, rather than to some factor(s) within particular ponds.
15. Displaced eggs and eggshells were found near many of the ponds. The possible role which this phenomenon plays in the breeding biology of ducks is unknown.
16. Nesting hens used the potholes as jumping-off places enroute to their nests. Since the ponds were evenly distributed, nests also were distributed more evenly after pond construction than before.
17. In an area with artificial ponds the number of nests increased as the number of ponds increased, but there were more nests in another similar area without ponds. Apparently hens located their nests in response to pond proximity but differences in vegetative cover prevented a clear examination.
18. Predators destroyed a high percentage of the nests around the ponds. Only 6 percent of the nests were known to be successful in the experimental area as compared to 32 percent in the check areas.

19. A theoretical production of 113 flying ducks was calculated for 25 ponds. Since pairs and broods used many areas other than the ponds, and since the breeding population did not seem to be limited by water areas, this estimate is a theoretical potential and not an observed production.

20. Based on the theoretical estimate of production and the prorated cost of pond construction, a flying duck would have cost $0.15 in 1966.

21. Blasting ponds potentially fulfills three objectives; to increasing the carrying capacity for breeding pairs, to attracting ducks for recreation and protection, and to stimulate public interest. Whether one or all of these aims are accomplished depends on individual situations.

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APPENDIX A

Ponds mentioned in the text were blasted in the following locations.

Ponds	Location
S-1 thru S-28	T.14 N, R.6 WPM., sec. 25
T-1 thru T-8	T.14 N, R.6 WPM., sec. 20, S. 1/2
B-1	T.14 N, R.6 WPM., sec. 18, NW, 1/4
R-1 thru R-4	T.14 N, R.7 WPM., sec. 12, SW, 1/4

APPENDIX B

COMMON AND SCIENTIFIC NAMES OF DUCKS MENTIONED IN THE TEXT

The scientific names of ducks were taken from the American Ornithologists' Union Check-list (1957).

Mallard	*Anas platyrhynchos*
Black Duck	*Anas rubripes*
Gadwall	*Anas strepera*
Pintail	*Anas acuta*
Blue-winged Teal	*Anas discors*
Green-winged Teal	*Anas carolinensis*
Shoveller	*Spatula clypeata*
Baldpate	*Mareca americana*
Canvasback	*Aythya valisineria*
Redhead	*Aythya americana*
Scaup (Lesser Scaup)	*Aythya affinis*
Ruddy Duck	*Oxyura jamaicensis*

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