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ARTIFICIAL POTHOLE AND LEVEL DITCH DEVELOPMENT AS A MEANS OF INCREASING WATERFOWL PRODUCTION

by

Charles H. Lacy

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Management

UTAH STATE UNIVERSITY
Logan, Utah

1959

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To Dr. Jessop B. Low, leader, Utah Cooperative Wildlife Research Unit, and Dr. Allen W. Stokes, associate professor of wildlife management, Utah State University, I am indebted for their guidance and encouragement.

Without the aid of these people this project could never have been concluded.

Charles H. Lacy

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INTRODUCTION

The glaciated prairie pothole country of the Midwest forms a vital segment of the most important waterfowl breeding habitat in North America. Here are hatched three-quarters of all the ducks raised in the United States. During a recent seven-year period the three-state area of Minnesota and the Dakotas produced an average of 4 to 5 million ducks annually (Janzen, 1947). This wetland region which once comprised 115,000 square miles in five states had shrunk to about 56,000 square miles by 1956 (Lynch, 1956). To maintain the present rate of waterfowl production in the face of continued destruction of habitat through drainage and other land use practices detrimental to breeding ducks will require that remaining wetlands, particularly those in public ownership, be developed as much as possible toward their maximum potential for waterfowl production.

In recent years the U. S. Fish and Wildlife Service has excavated several hundred experimental artificial potholes and level ditches on its refuges in the Dakotas and Minnesota. It was believed that these water areas would increase the number of ducks breeding on the refuge marshes by providing additional territorial sites. Before more funds are invested to expand this work it is important to determine the success of the existing development in meeting this objective.

This study, to evaluate the artificial pothole and level ditch development, was initiated in 1957 by the U. S. Fish and Wildlife Service

At Lower Souris National Wildlife Refuge in North Dakota. The project was carried out in collaboration with the Utah Cooperative Wildlife Research Unit and the Department of Wildlife Management, Utah State University.

Review of literature

Although several studies have been made to determine the value of artificial water areas for fur production, relatively few have dealt primarily with waterfowl. One of the first studies of artificial ponds for ducks was conducted by the North Dakota Agricultural Experiment Station (Saugstad, 1939).

Scott and Dever (1940) and Provost (1948) investigated marsh blasting as a means of opening up overgrown marshes.

In 1949 Cooch (1949) inventoried 357 artificial dugouts in Manitoba and compared their breeding duck populations with those of natural areas.

Brumsted and Hewitt (1952), and later Benson and Foley (1956), reported on investigations of small man-made marshes in New York State and concluded that these areas were valuable producers of waterfowl.

The large number of artificial ponds constructed on the Great Plains as watering places for livestock form important waterfowl nesting areas. In western South Dakota the relationship of grazing to duck use of stock ponds was studied by Bue, Blankenship and Marshall (1952). Smith (1952) summarized the results of a Montana Fish and Game Department project to study the relation of newly created stock reservoirs in eastern Montana to waterfowl production.

Mathiak and Linde (1956) evaluated the level ditch development work on Horicon Marsh in Wisconsin. Although the study emphasized aspects of fur production, it also recognized the value as duck nesting habitat.

The concept of territoriality, as it applies to waterfowl, was defined by Hochbaum (1944) and later modified by Sowls (1955), Dzubin (1955) and Smith (1955). Their work suggested that waterfowl breeding habitat might be improved by addition of specialized water areas designed mainly to fulfill the territorial requirements of breeding ducks. Hochbaum believed that where space for breeding pairs to spread apart and isolate themselves was limited, small satellite ponds could be created to increase the territorial shoreline.

Evans, Hawkins and Marshall (1952) concluded from their study of brood movements in the Minnedosa pothole country of Manitoba that habitat there could best be improved by increasing the number of available breeding territories. According to Evans and Black (1956), the factor limiting duck production on the Waubay area in South Dakota is lack of the space provided by small water areas (potholes) and which is necessary for the spring dispersal of breeding pairs.

The most recent work conducted on artificial potholes and level ditches is Hammond's (1958) evaluation of data collected during the past 20 years on wildlife refuges in the Dakotas, Minnesota and Nebraska.

Purpose

The following objectives were established to assess the value of artificial pothole and level ditch development as a technique for increasing waterfowl production on wildlife refuges:

1. To estimate waterfowl production resulting from the pothole and ditch development

2. To measure use of artificial potholes and level ditches by breeding, summering and migrant waterfowl
3. To determine the type of water area best suited for use in management, and
4. To determine supplementary management measures needed to maintain productivity

Field work was conducted during the 1957 and 1958 waterfowl breeding seasons.

STUDY AREAS

General

Because of the study facilities available, Lower Souris National Wildlife Refuge in north central North Dakota was chosen for the site of the present investigation (Figure 1).

The Souris marshes lie in the bed of what was once glacial Lake Souris, but which is now a low plain. Accounts of early explorers described the pristine marshes, which consisted of sloughs and oxbows of the Souris River, as teeming with water birds and other wildlife. Drained about 1900 for agricultural purposes, the area was later acquired by the U. S. Fish and Wildlife Service and established as a migratory waterfowl refuge. Restoration began in 1935 with the construction of a series of low earthen dams across the river valley. The waters of the resulting five shallow impoundments now reach from the international boundary southeast for about 35 miles upstream to the wooded sandhills. The Souris River, which furnishes water to the marshes, arises in the Moose Mountains of Canada. It meanders southeast into North Dakota, bends north, and flows back into Canada, forming a U-shaped pattern known locally as the "Souris Loop."

The present refuge includes 58,000 acres of land and water area subdivided into five major management units, each consisting of a dam, its reservoir, and adjacent upland. The dams and the respective units are numbered according to the distance of each dam in river miles

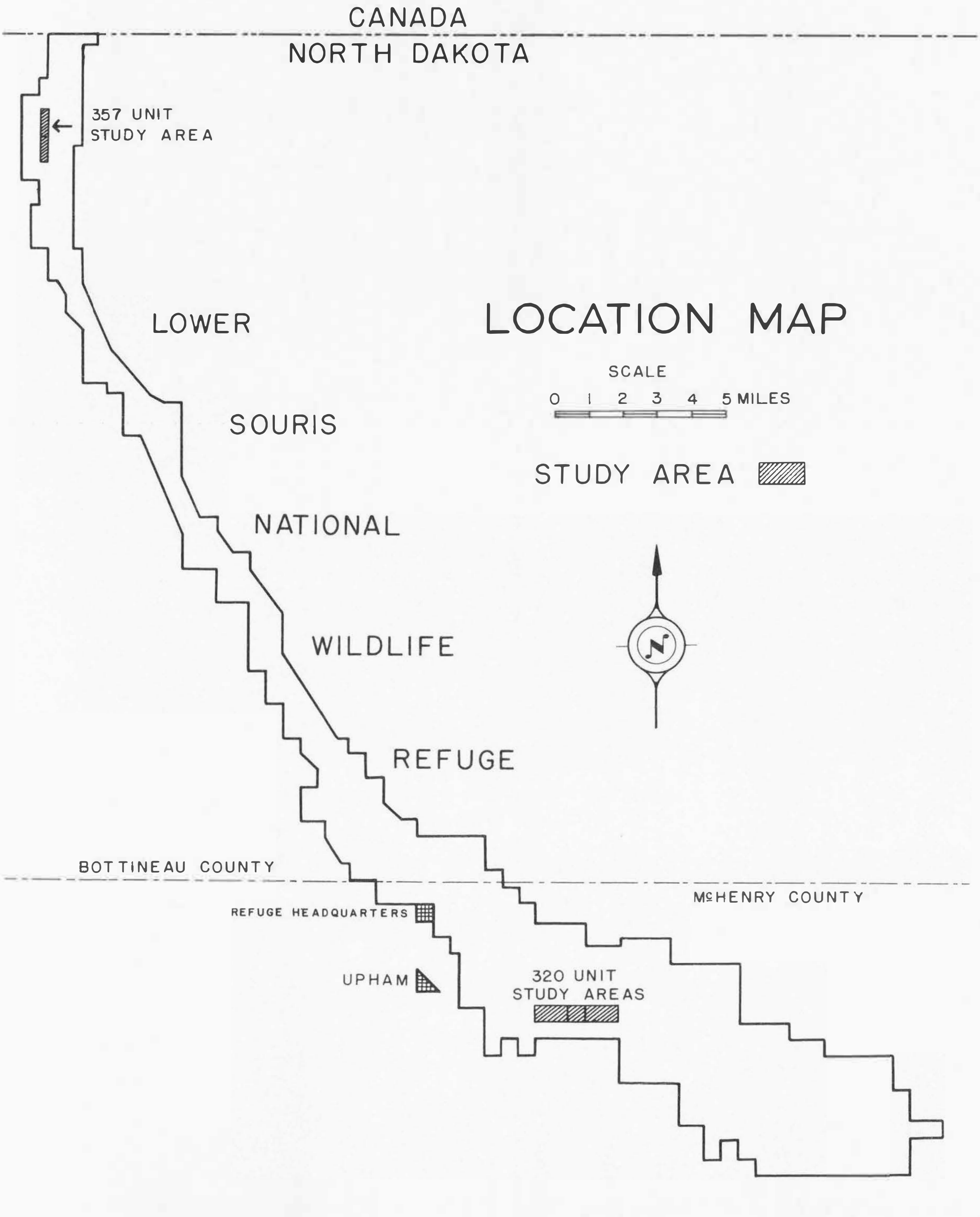

Figure 1. General map showing location of study areas

downstream from the Canadian boundary. Water control structures permit regulation of marsh levels.

Immediately north of the broken sandhill terrain the Souris valley is wide and nearly level with the surrounding plain. Farther northwest the valley becomes progressively narrower. In Unit 357 the nearby farmland is elevated nearly 100 feet above lake level. The numerous coulees dissect the moderate to steep slopes.

This region is part of the Drift Plain, a topographic feature of the Great Plains. Its stone-free Chernozem soils are quite fertile, with most of the land devoted to small grain (wheat, barley, and flax) farming. Much of the remainder is pasture or hay meadow. The native mixed-grass prairie (Weaver and Clements, 1938) persists in many places.

Hot summers and cold winters characterize the typically continental climate. The 55-year average minimum temperature at the Minot, North Dakota weather bureau station for January is -4° F., whereas the average July maximum is $+85^{\circ}$ F. Prevailing northwest winds are strongest during the spring. The average velocity is 10 miles per hour over the year. Precipitation averages 15.70 inches annually, most of which occurs during the 121-day growing season (U. S. Weather Bureau, 1952). From year to year the weather is quite variable. Deviations from average are common. The land has been subject to periodic, often severe, droughts. The period of the present study was warm and dry, a continuation of the drouthy weather pattern which began in 1955.

Eleven species of ducks, canada geese, and coot[1] commonly breed on

[1]See Appendix for scientific names of animals and plants mentioned.

the refuge marshes. A large variety of other bird and mannal species occur in the area in various numbers. Several are of importance to waterfowl.

The only avian predator of duck nests of consequence at Lower Souris is the crow. However, this bird is not sufficiently abundant to constitute a serious threat to duck production.

Skunks and raccoons, both abundant, take the greatest toll of nests, causing large losses in some years. Foxes and badgers are common. Moderate numbers of coyotes inhabit certain parts of the refuge.

The abundant muskrats, by cutting openings in the stands of marsh vegetation, improve interspersion of water and cover and thereby are considered beneficial to nesting waterfowl. Mink and weasel are common, but damage few duck nests.

Four areas, three in Unit 320 and one in Unit 357, were selected for study (Figure 1). Areas I, II, and III form an ecological unit distinct from Area IV.

Study Area I

Physiography.--The Unit 320 study areas are situated along the south edge of the 320 marsh (Figure 2). Area I is a large peninsula known as Swearson Point (Figure 3). The west portion is separated from open water by a dense strip of emergent vegetation 50 to 200 feet wide. A broader, shallow emergent marsh area borders the eastern half of the point.

Ulen loamy fine sand is the predominant soil type. Most of this tract is upland pasture surrounded by a relatively narrow strip of

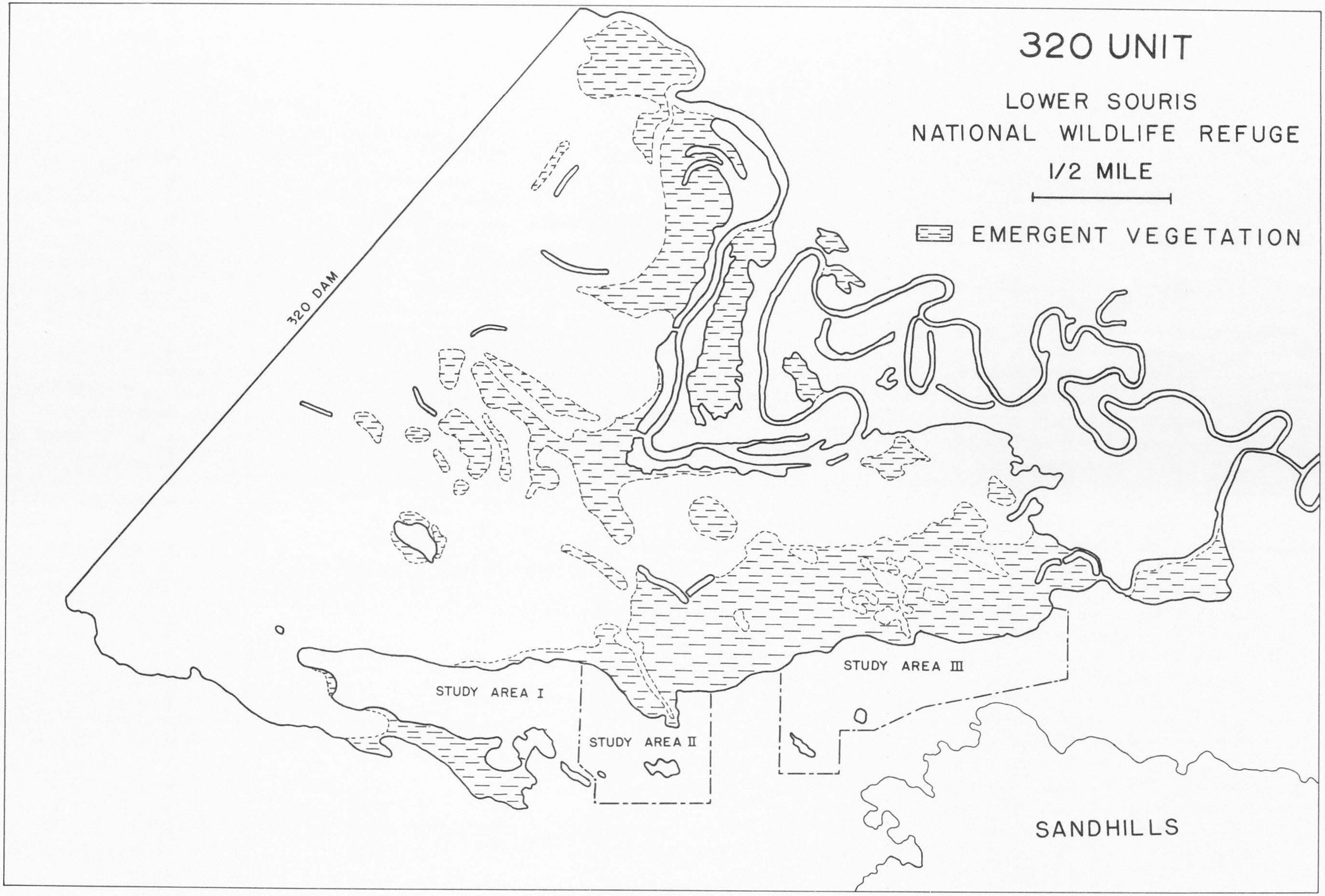

Figure 2. Location of study areas in 320 Unit

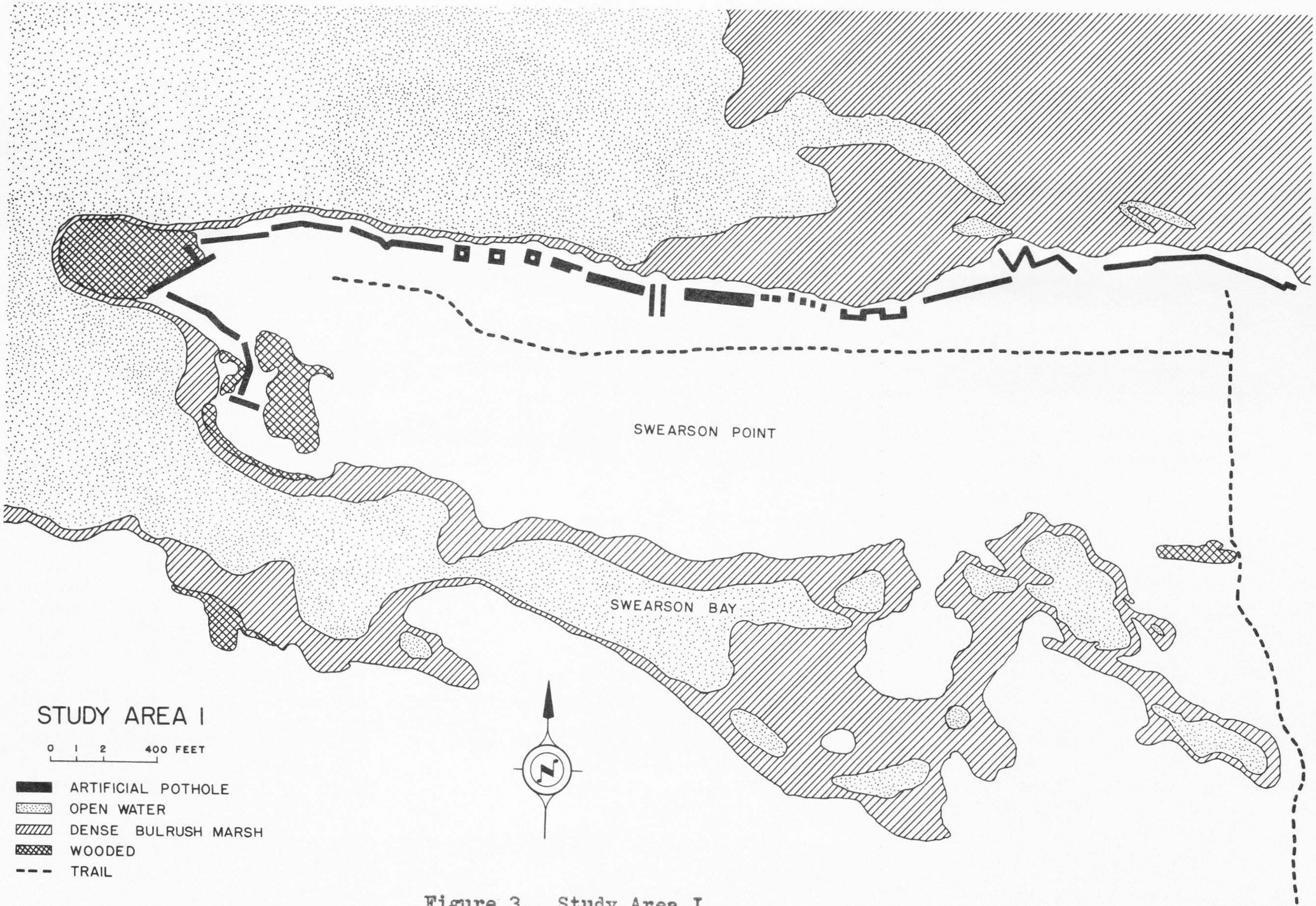

Figure 3. Study Area I

lowland. The topography is gentle.

Pondweeds and other aquatic plants are abundant in the bays and soughs of the marsh and through much of the open lake. Emergent vegetation is mostly softstem bulrush mixed with some cattail, river bulrush and reedgrass or phragmites. The common prairie grasses are needlegrass, smooth brome, wheatgrass, Canada wild rye, and prairie June grass. Much of the upland, which was once under cultivation, is covered by a mixture of grasses and sweet clover. Rose and wolfberry occur as scattered patches. The west end of the point is overgrown with willows. In general, high quality nesting cover is abundant. The entire area is grazed by livestock.

Artificial potholes and level ditches.--In this investigation I have used the term artificial pothole or dugout to designate a small man-made water area of less than one-half acre. The majority of the artificial ponds at Lower Souris are 0.05 acre or smaller. All are shallow, less than 5 feet deep, and were excavated in low-lying ground where water remains near the surface.

For study purposes I have termed as level ditches those water areas which are 10 to 20 feet wide and approximately 10 or more times as long. The distinction between artificial potholes and level ditches is itself artificial at best, since both are relative terms. Where a pond ceases to be a pothole and becomes a level ditch can be determined only by arbitrary means.

During the summer of 1956, 25 water areas were dredged along the marsh edge by dragline. The arrangement and configuration of the potholes and ditches are shown in Figure 3. The ditch spoil banks were not piled in continuous banks, as were those of the potholes, but were placed alternately on both sides of the excavations.

Lengths of these ponds range from 25 to more than 900 feet, while widths vary between 12 and 50 feet, with depths of 2 to 4 feet.[1] Water is supplied by seepage from the lake.

Study Area II

Physiography.--Study Area II is immediately east of Swearson Point. Except for an area of upland on the south and west sides, this 104-acre tract is quite low with numerous shallow cattail or bulrush-choked depressions (Figure 4). During wet years these small sloughs would hold 6 inches to 2 feet of water. Four semi-permanent sloughs lie in the study area. The largest is 4 acres, while the others are less than 0.25 acre in size. Low shoreline gradient coupled with heavy vegetation growth make the marsh edge irregular and indistinct.

Emergent vegetation is mainly softstem bulrush, but cattails are more plentiful here than farther west. River bulrush, hardstem bulrush, three-square and phragmites also are present. Pondweeds are abundant in the marsh openings. Prevalent lowland grasses are prairie cordgrass, whitetop, wild barley, smooth brome, bluegrass, and wheatgrass. Sedges and spikerushes are common. Willows grow in several locations. Vegetation of the uplands is like that of Swearson Point. The upland soil type is Ulen loamy fine sand. Tanberg fine sandy loam occupies lower elevations. All of the land is within a grazing unit.

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[1]See Appendix for other specifications.

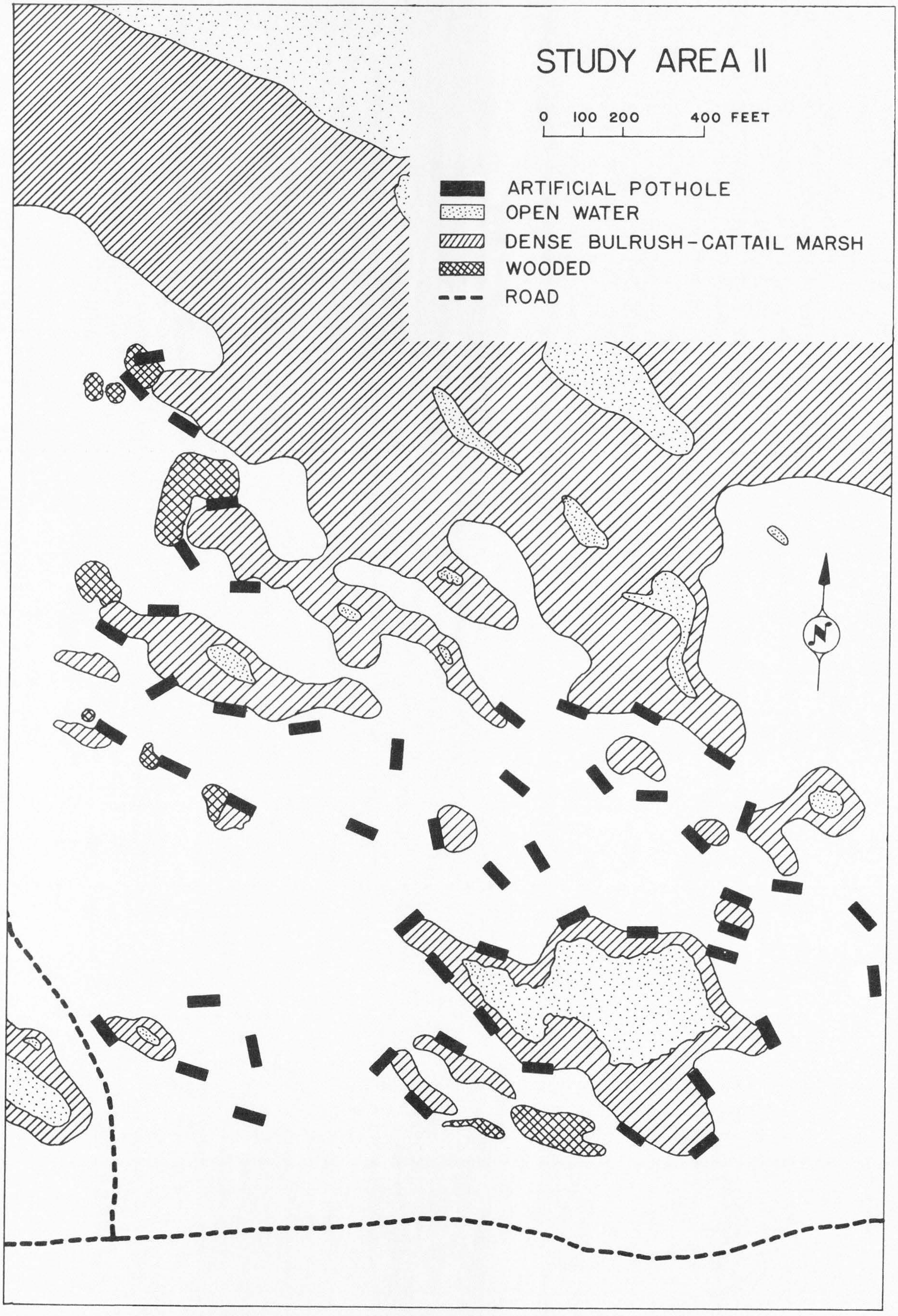

Figure 4. Study Area II

Artificial potholes.--Fifty-three potholes were constructed during the early summer of 1956 by dragline. These dugouts were placed at the marsh and slough edges. The spoil was piled in a continuous bank at the edge of each pothole. Lengths vary between 50 and 100 feet and widths from 15 to 30 feet. Water is derived probably from a combination of run-off, ground water, and marsh seepage sources.

Study Area III

Physiography.--Separated from Area II to the west by one-quarter section of grassland, Study Area III lies just north of the sandhills (Figures 5 and 6). Though slightly lower in elevation, the general topography is much like that of Area II. Soil types are identical.

A nearly pure cattail stand forms the emergent vegetation of the marsh. Pondweed beds are sparsely distributed near the shoreline but are abundant farther north. Much of the upland vegetation is sweet clover. Terrestrial grass species are the same as those of the areas previously described. The low ground is dominated by Baltic rush, sedge, wild barley, and sow thistle. A considerable portion of this tract is of a wooded or brushy nature. Willows are the principal tree species. Quaking aspen, which covers the sandhills, forms several thickets on the study area.

Nesting cover, though abundant under natural conditions, was limited during the study. Much was cut as hay.

Artificial potholes.--Pond construction was carried out during autumn of 1957, when 69 water areas were created. Thirty-five were dug

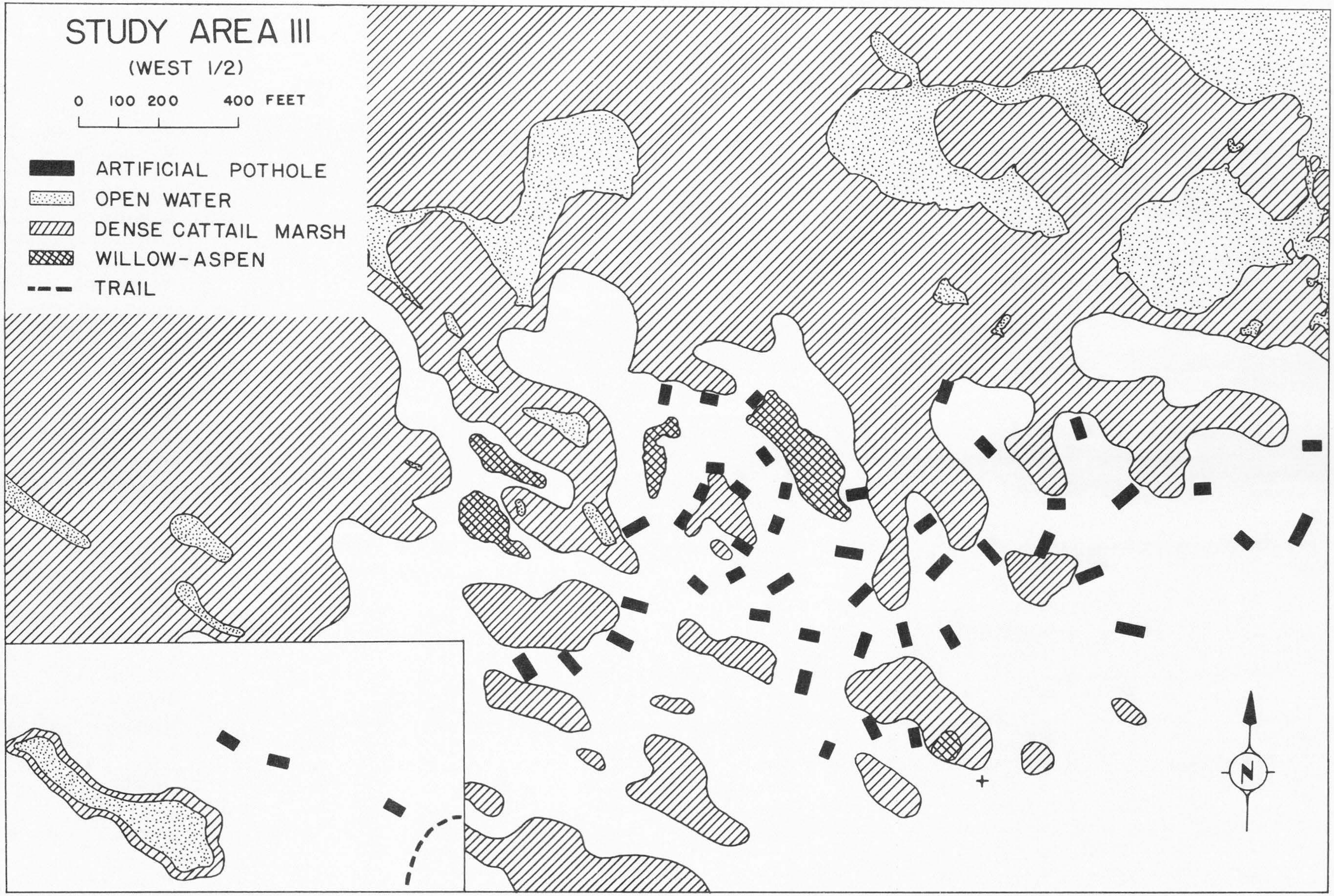

Figure 5. Study Area III (west 1/2)

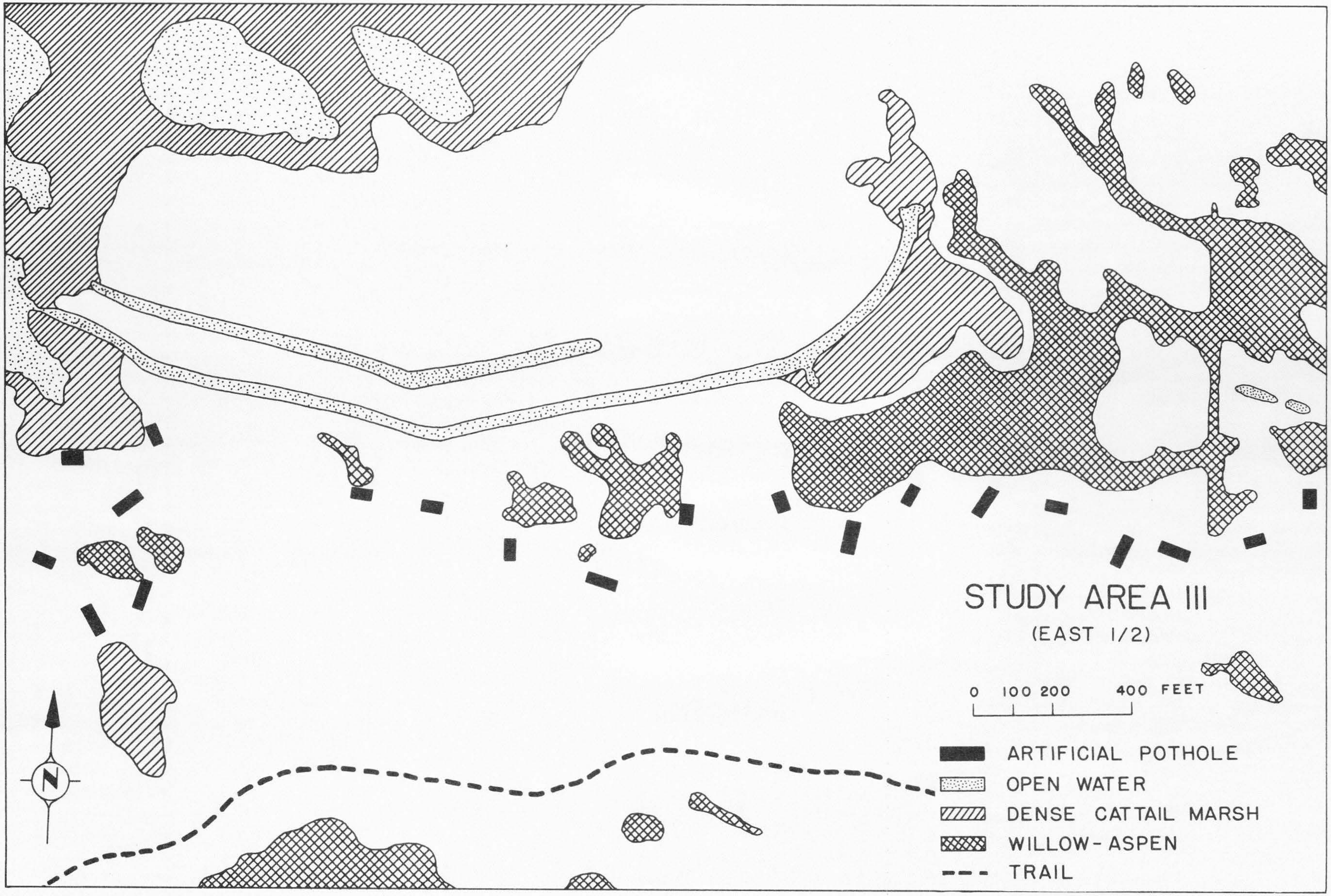

Figure 6. Study Area III (east 1/2)

with dragline and 34 with Caterpillar tractor-dozer. The potholes were placed near or adjacent to the marsh shoreline and at the edges of wet depressions. Where cattail-covered sloughs bordered pothole sites, the spoils were piled in the sloughs and pushed flat by the dozer. Others were merely placed at one side or end of the excavation and leveled. The spoils of 14 dragline-built potholes were left in piles. Runoff, ground water and seepage from the marsh provide water.

Study Area IV

Physiography.--Study Area IV is located in Unit 357 near the northern extremity of the refuge, approximately two miles south of the international boundary, and some 35 miles northwest of Area I. Here the old river bottom is covered by an open water reservoir about five miles long, one-half mile wide, and up to four feet deep. The study area forms a one-mile strip of shoreline on the west side of the lake (Figure 7). It is bordered on the south by a similar control area of equal length.

The bottomland soils are wet alluvial deposits of Lamoure clay. Barnes loam or sil loam occurs at middle elevations, while Buse soils are found higher up.

In some years the deeper water supports heavy stands of sago pondweed and other aquatic vegetation, though 1957-58 growth was poor. Emergent vegetation forms a narrow, dense band, 50 to 100 feet wide, of marsh fringe around the impoundment periphery. Several distinct vegetation zones extend successively back from shallow water onto dry land. Each can be distinguished by its dominant species: 1) softstem bulrush,

Figure 7. Study Area IV forms a one-mile strip of shoreline on the west side of an open water reservoir. May 1958

2) river bulrush, 3) sedge-prairie cordgrass, and 4) wolfberry-upland prairie grasses. Softstem occurs in nearly pure stands while river bulrush is mixed with lesser amounts of common cattail. Wheatgrass, needlegrass and smooth brome are the most common prairie grasses.

Much of the area which was once under cultivation has been allowed to revert to its natural state. Approximately two-thirds is grazed by livestock; the remainder is idle land.

Artificial potholes.--In November 1956, 34 artificial potholes were excavated by dragline at the marsh edge. These rectangular areas range in size from 15 x 40 x 2 feet to 25 x 60 x 2 feet, with the long axis of each parallel to the shoreline. All lie between the river bulrush and sedge-cordgrass zones of vegetation. The potholes are spaced at intervals of approximately 50 and 100 feet. Each spoil is piled in a continuous bank on the west, or uphill, side of the excavation. The lake provides the source of water for the potholes.

METHODS OF STUDY

Census of breeding pairs

Breeding pair inventories were conducted during both seasons of study to determine the number and species composition of waterfowl using the artificial potholes and level ditches for nesting. These counts were made weekly in four study areas and one control area in order to obtain quantitative data on waterfowl preference, if any, for various water area types, and to measure the peak nesting population of each species.

Breeding population data were gathered by the method described by Evans and Black (1956). Each pair, single hen or lone drake, was assumed to represent a nesting pair and was designated as an "indicated pair." Groups of drakes were likely birds which were either unmated or had abandoned their hens prior to molting, and were recorded as "gathered birds." Assemblages which consisted of several drakes displaying around a single hen were classified as "courting parties." The census which showed the highest number of indicated pairs of a species was considered the peak breeding population for that species. The total nesting population for all species represented the sum of the peak populations of each species. It was necessary to employ the sum of the species peaks to estimate the total population because all species did not nest simultaneously. In no case did a single count ever equal the entire duck nesting population. The censuses were begun at the time intolerance was first noted between mallard or pintail pairs.

Since the objective of the inventory was to enumerate those birds which showed positive attachment to the area for nesting, the actual census procedure used was of great importance. The most reliable censuses would be those made when maximum numbers of breeding pairs were on the water areas which they used as jumping-off places for laying flights to the nest, or when territorial occupancy was highest. At Delta, Sowls (1955) found that time to be during early morning hours.

All regular weekly inventories were made during the two hours following sunrise. Several additional counts were made each season at different times of the day for comparison purposes. Windy or stormy weather was avoided whenever possible. When wind velocity was greater than 10 to 12 miles per hour, ducks appeared restless and were often on the move, seeking sheltered places. Censuses attempted under such conditions and repeated on following calm days were found to be inaccurate, yielding figures which were generally low.

Study Areas I and II could be censused in two hours and were usually visited on the same day, while Areas III and IV were covered on separate days.

Duck counts were made on foot. A method of coverage to minimize duplication of ducks already counted was outlined for each study area and followed on every census. Since flushed ducks usually flew in the direction of the main marsh, the general plan was to begin at the water areas nearest the marsh and to work toward the more distant ponds. The landing places of flushed birds were noted so that no birds would be counted twice.

Each water area was assigned a code number and the ducks seen were recorded according to the area on which they were observed. The nature of the terrain necessitated modification of enumeration methods for the different study areas. In Area IV, to permit comparison of study and control area populations, and because of the proximity of the potholes to the shoreline, both the ducks sitting on the potholes and those in the marsh fringe were counted. Weekly inventories of Study Area I included only those ducks actually sitting on the potholes and ditches. "Beat-out" counts of the marsh would have been desirable, but were too time-consuming for the data gained. The entire shoreline (potholes, ditches and marsh) of Swearson Point was censused once annually at the time of the regular refuge breeding pair count. Both ducks on the artificial potholes and those on natural sloughs were recorded in Area II. Inventories of Area III, where the natural sloughs were farther from the artificial ponds, included only birds on the potholes.

Weekly breeding pair counts were made from late April until late June during both years of study.

Observations of breeding pairs

Early morning observations from vantage points in the Unit 320 study areas yielded information on the manner in which breeding ducks used the potholes and ditches, and on the reliability of the weekly inventories as measurements of the breeding population.

Estimation of production

The nesting study began in 1957 as a means of measuring production was discontinued when it became evident that predation and other extraneous factors were biasing results. The nests were located by means of a rope drag, with short lengths of chain attached, towed between two pickup trucks, by systematic searching, and by observation of nesting hens in flight to the nest. For estimates of production this method was found to be inferior to the brood studies later used.

Duck production of the study areas was estimated by applying hatching success, as observed from a brood count conducted by refuge personnel of the entire refuge, to the study area breeding pair populations. Hatching success is expressed as the percent of breeding pairs that nest successfully. It is determined each year by a single census, which alone is inadequate, and must be corrected to indicate those broods "not countable" (young which are flying or have not yet hatched) at the time of the census. This correction is made by means of a brood chronology census. The procedure employed is essentially as described by Murdy and Anderson (1955).

The criterion used in this study as a measure of production was the number of broods hatched per breeding pair. It was determined by dividing the number of broods hatched during the season by the number of breeding pairs present in the spring.

Summer and autumn waterfowl census

Frequent inspections of the study areas were made through the summer and fall to note use by broods, summering and migrant waterfowl.

Vegetation survey

During August of 1957 and 1958 surveys were made to check growth and species composition of vegetation in the artificial water areas and on spoil banks. Of primary concern were: 1) the rate of encroachment of emergent vegetation into the ponds, 2) the natural establishment of pondweeds and other waterfowl food plants, 3) the survival and growth of pondweeds transplanted into Study Area II potholes in 1956, and 4) the rate of vegetation establishment on spoil banks.

Aquatic and emergent vegetation data were recorded according to coverage of each species. For the vegetation of the spoils, records of species frequency of occurrence, dominant species, and total coverage by all species were sufficient to yield the information desired. Except for casual observations in Area I, these surveys were confined to Areas II, III, and IV.

Miscellaneous data

To facilitate recording of field data, large-scale field maps showing water area locations and other features of the study areas were traced from aerial photographs. Land and marsh acreages were measured by planimeter.

Several potholes in Area II were marked with numbered signs so that they could be identified with binoculars at distances during breeding pair behavior observations.

In 1958 water gauges made from wooden lath and calibrated in inches were installed in all study areas. Water levels were recorded weekly during the breeding season. General records of major fluctuations were kept in 1957 and during the remainder of the 1958 field season.

Length, width, and depth measurements made of all ditches and potholes permitted calculation of surface area and volume.

PRESENTATION OF DATA

Waterfowl populations at Lower Souris Refuge

Spring migration waterfowl population.--Spring migrants did not greatly utilize the ditch and pothole development. In April 1957 large numbers of mallards and pintails moved north through the Souris River valley. During the early stages of this migration many of the artificial ponds were dry. Those that held water were frozen. Later when the potholes and ditches were ice-free, many ducks continued to concentrate on the larger water bodies and on temporary field water. Few blue-winged teal, gadwalls, or shovelers appeared on the potholes immediately after arrival on the breeding grounds. Not until breeding pairs began to disperse for nesting did any numbers of ducks begin to use the artificial water areas, though occasional courting parties, pairs and single birds were seen earlier.

Breeding season waterfowl population.--The nesting population was determined from inventories made periodically during the breeding season. It was assumed that birds tallied on these counts represent ducks using the artificial potholes and level ditches for breeding and not those which are temporarily in the area and which later shift to some other portion of the refuge (or leave the region entirely) to nest. Data gathered on the behavior of ducks using the artificial water areas during the breeding season and presented in the section on duck utilization would suggest that these birds constitute the true nesting population of the study areas. The following population and nesting chronology data support this conclusion.

Indicated pairs of the various species began to appear on the artificial ponds at the time when the same species elsewhere on the refuge were starting nesting activities. Numbers of the blue-winged teal and gadwall, which together made up 70-80 percent of the study area population, increased rapidly to peak plateaus which remained relatively stable for periods of several weeks. Had the birds been north-bound migrants, a rapid decrease in density shortly after the peak was attained might have been expected, indicating a departure phase of migration. Peak numbers of indicated pairs were in fact recorded subsequent to the time when most transient birds would have departed.

Maximum breeding pair populations occurred during or just prior to the period when greatest numbers of nests were begun. This relationship is shown graphically for the blue-winged teal in Figure 8, and for the gadwall in Figure 9. The peak breeding population would logically occur when maximum numbers of breeding pairs were on their nesting home ranges, or a relatively short time before, during and just after the egg-laying period. The recorded population peaks for these two species agree generally with the peaks expected when nesting chronology is considered. Brood data, when compared with date from actual nests (Figure 9), present nesting peaks which are delayed to a degree depending on nesting success, but which still do not greatly alter the comparison made above.

Compared with 1957, breeding pairs increased on the study areas and

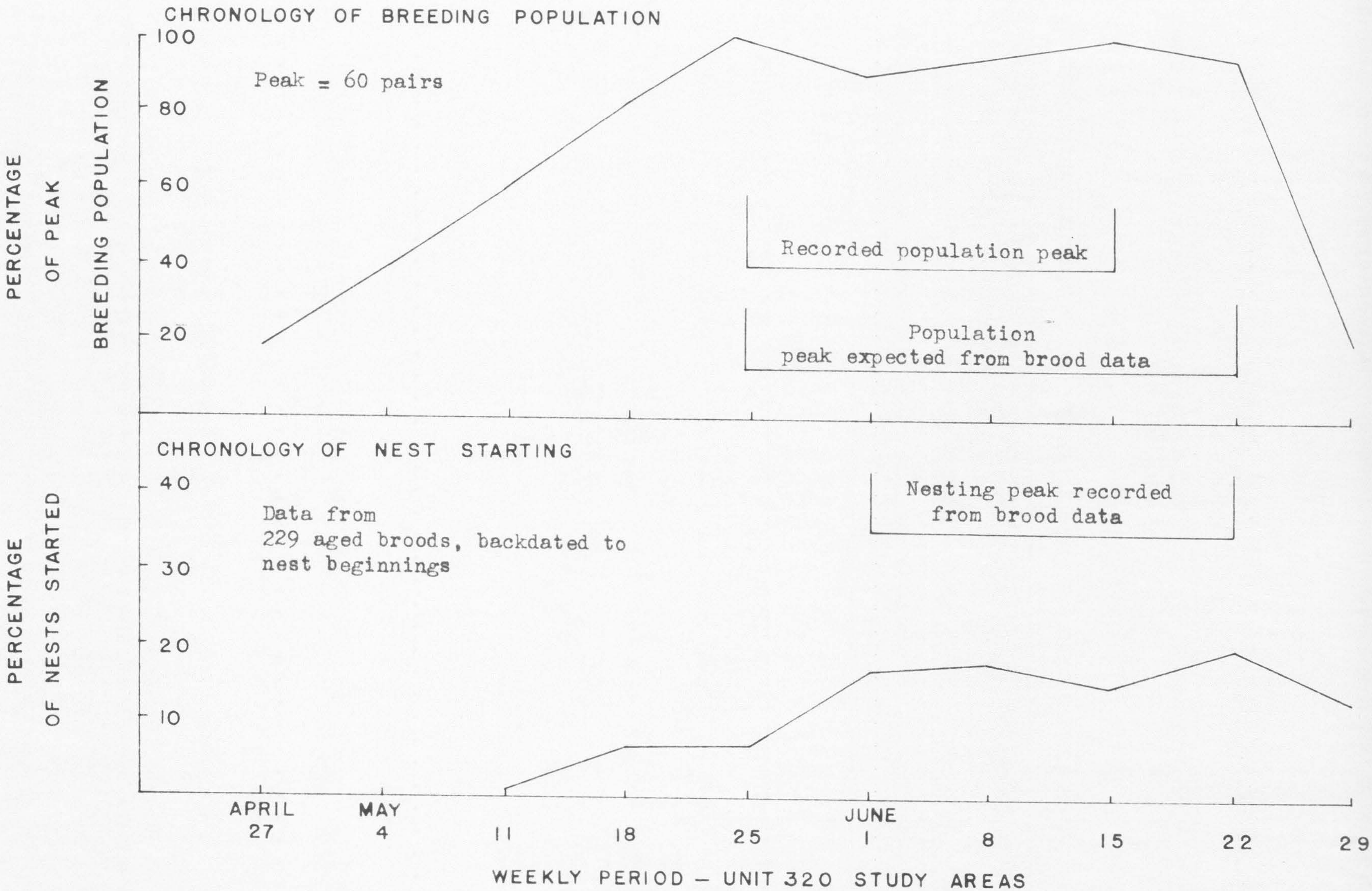

Figure 8. Breeding populations and next beginnings of the blue-winged teal, 1957

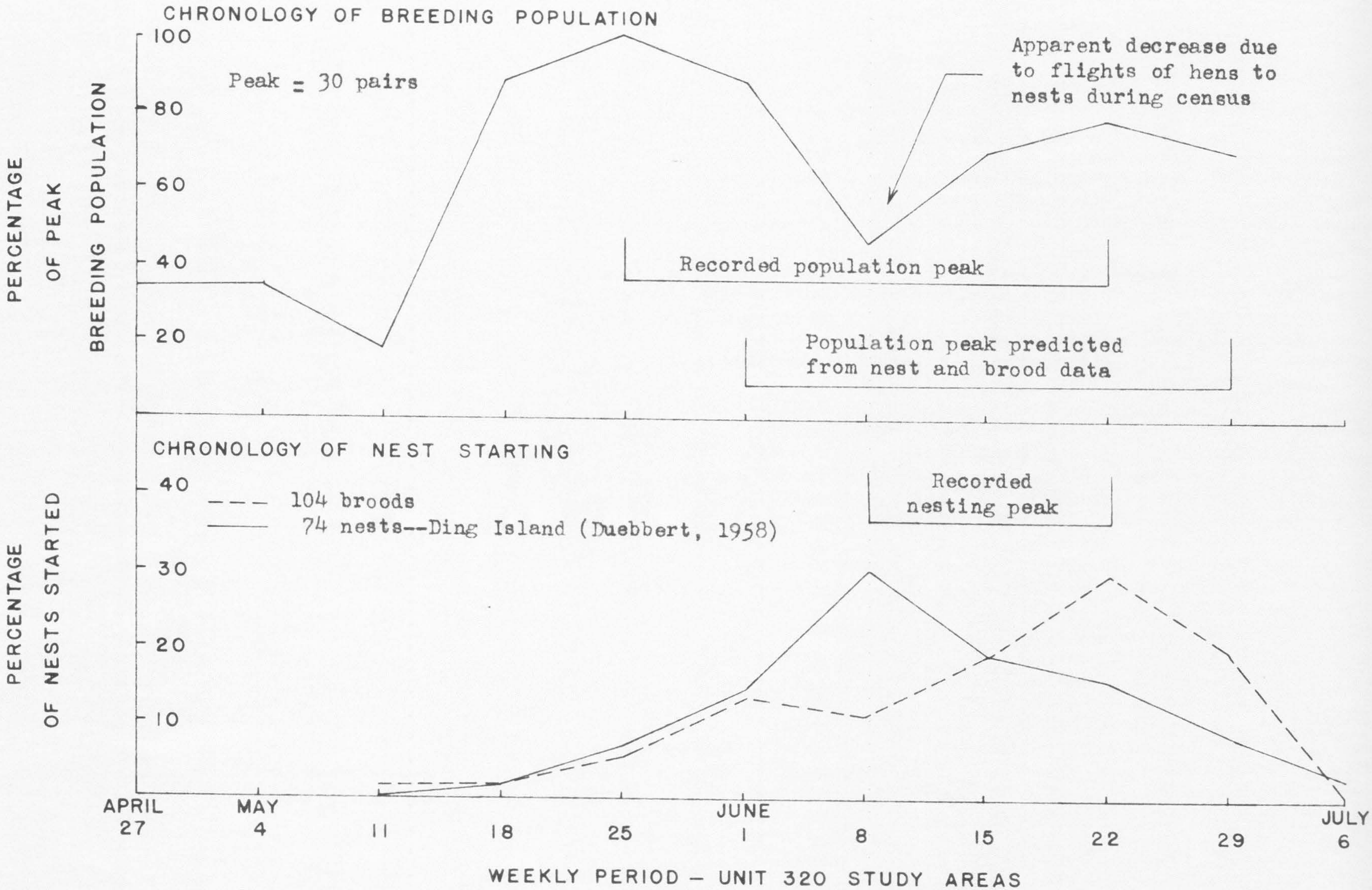

Figure 9. Breeding populations and nest beginnings of the gadwall, 1957

over the refuge as a whole in 1958 (Table 1). This upward trend could have been a reflection of either a true population increase resulting from high production and survival the previous year or of the dry weather cycle. Absence of other water areas may have caused more birds to nest on the refuge.

The rate of increase in Study Area I was greater than in the other study areas, and almost double the increase for the entire refuge (Table 2). The near desertion of Ding Island, one-half mile to the north of Area I, by nesting ducks in 1958 due to nest predation, might have been one of the causes. In 1957 more than 200 gadwall and mallard pairs nested there. These ducks probably nested on the mainland (including Area I), in 1958. No explanation can be given to account for the large increase in blue-winged teal, however.

Figure for Area I include only ducks counted on the potholes and level ditches. Forty-two breeding pairs utilized these water areas for nesting in 1957 and 87 in 1958, for an average of 65 pairs (Table 1). Thus, it might be speculated that the ditch and pothole development created habitat capable of supporting over a two-year period, in conjunction with the nearby marsh, some 65 breeding pairs. The number of these birds whose presence may be attributed to the artificial water areas can only be surmised.

To determine more conclusively the value of the development in Area I, the combined population of the artificial ponds and adjacent marsh edge was compared with that of another area to the south. This shoreline strip which borders Swearson Bay was the only area in the

Table 1. Waterfowl breeding pair populations on study areas, Lower Souris Refuge, 1957-58

	Indicated pairs of waterfowl								
Study area	I		II		III	IV		Control	
Species Year:	1957	1958	1957	1958	1958	1957	1958	1957	1958
Mallard	2	7	5	6	7	7	10	4	7
Pintail	1	1	4	4	0	3	2	3	2
Blue-winged teal	19	38	41	51	47	21	22	13	12
Shoveler	3	6	5	7	5	4	5	1	2
Gadwall	14	27	16	22	23	7	12	6	8
Baldpate	1	3	1	3	1	4	4	2	2
Green-winged teal	0	0	0	1	0	1	1	0	0
Total dabblers	40	82	72	94	83	47	56	29	33
Lesser scaup	2	5	2	4	1	1	2	0	1
Redhead	0	0	1	3	0	1	1	1	1
Canvasback	0	0	0	0	0	2	1	0	2
Total divers	2	5	3	7	1	4	4	1	4
Total	42	87	75	101	84	51	60	30	37

Table 2. Changes in the waterfowl breeding population of three study areas at Lower Souris Refuge during the period 1957-58

Year	Indicated pairs, by study area				Entire refuge
	I	II	IV	Total	
1957	42	75	51	168	5907
1958	87	101	60	248	8402
Percent increase	107.1	34.7	17.6	47.6	57.7

vicinity similar to Area I, for which census records were available for at least one year prior to the ditch and pothole construction. Table 3 compares the population of the two areas. In 1956 Swearson Bay held more breeding pairs than did the Area I shoreline, possibly because of better interspersion of land and water. In 1957, the year after the study area was developed, both populations decreased, rising again in 1958. However, numbers of breeding pairs using the Area I shoreline decreased 22 percent less in 1957, and increased 101 percent more in 1958 than did the breeding pairs using Swearson Bay. If these differences were due to the artificial ponds, then there would be a net increase of 22 percent, or 6 indicated pairs per mile of shoreline in 1957, and of 101 percent, or 29 pairs per mile of shoreline in 1958. This increase for the entire Area I shoreline of 1.5 miles would be 9 pairs in 1957 and 44 pairs in 1958, or an average of 26 pairs for the two-year period. These calculations are for dabbling ducks which made up about 95 percent of the nesting pairs; to include diving ducks would not change the average by more than one pair.

The validity of such a comparison of the two areas, based upon only one annual census of each, might be questioned. In 1957 the annual Area I shoreline census made on the same day as the census of Swearson Bay was not the highest count of the study area shoreline, and therefore did not represent the peak population. Other weekly counts of only the artificial ponds, as shown in the weekly breeding pair population tables in the Appendix, yielded higher figures. Since the duck population of Swearson Bay on those days is not known, the other inventories of Area I could not be used in a comparison. Also, the possibility exists that, since

Table 3. Dabbling duck breeding densities on developed and undeveloped shoreline setments in Unit 320, 1956-58

Item	1956 (Control)	1957	1958	1957-58 Average
Indicated pairs per mile of shoreline				
Swearson Bay (undeveloped)	47	22	53	38
Study Area I[a]	29	20	62	41
Comparison with year 1956				
Swearson Bay	1.00	0.47	1.13	0.80
Study Area I	1.00	0.69	2.14	1.41
Indicated pairs per mile expected for study area shoreline, without development	29	14	33	24
Net increase due to pothole and ditch development (indicated pairs per mile	0	6	29	18

[a]Developed in 1956 after population figures for that year were taken.

during both years Swearson Bay was censused later in the day than was Area I, the figure for the former may include a time-of-day bias. Pairs nesting in other areas, even along the north shore of the point, may have been feeding or loafing in Swearson Bay at the time of the census. Finally, on the bias of past shoreline populations of similar areas, the dabbling duck population of Swearson Bay should not have been as great as recorded. The natural shorelines of both areas were overgrown with emergent vegetation and did not represent what would generally be considered good dabbling duck breeding habitat. The true population increase resulting from the artificial ponds would be somewhere between the peak indicated pair populations recorded for the potholes and ditches and the increase determined by comparing Area I with Swearson Bay. For these reasons population and production data for Area I are less reliable than data for the other areas.

Study Area II figures represent both ducks on the artificial water areas and on natural sloughs (Table 1). These data can be interpreted better on an area rather than linear basis (Table 4). If no potholes had been excavated, only ducks from the natural sloughs and marsh edge would have nested on Area II. All but one of these sloughs were so filled with cattail and bulrush that probably few ducks would have used them. Based on figures for similar areas in South Dakota (Evans and Black, 1956) the maximum number of ducks which would have used the 5 natural sloughs for nesting would likely not have exceeded 8 breeding pairs in 1957 and 12 in 1958. Probably fewer would have used the overgrown marsh edge. The breeding pairs which remain after these figures are deducted from the

Table 4. Breeding populations of Study Areas II and III per unit of land and water

Areas	Total breeding population		Number of pairs per artificial pond		Number of pairs per wet acre of artificial pond		Number of pairs per square mile	
	1957	1958	1957	1958	1957	1958	1957	1958
Study Area II:								
Total pairs	75	101					461	621
Pairs attracted by potholes	59	77	1.09	1.50	32.1	44.0	363	498
Study Area III:								
Pairs attracted by potholes		84		1.22		51.0		207

Area II population show that 59 pairs were attracted by the 53 potholes in 1957, and 77 in 1958, or approximately 1 to 1.5 pairs per pond (Table 4).

Included in the 104 acres of Area II are the artificial potholes, natural sloughs and the shoreline, but not the interior, of the marsh (Table 5). This area should include most of the essential requirements of the breeding population of the study area. The number of ducks per square mile, determined by multiplying the Area II population by 6.15, ranged from about 450 to over 600 breeding pairs (Table 4).

Area III was censused only during 1958, when 84 indicated pairs were observed on the 69 artificial potholes (Table 1). Most, or all, of the ducks counted likely represented birds whose presence as nesting pairs could be attributed to the artificial potholes, since natural sloughs were rather distant to complicate population estimates. The cattail marsh north of the pothole area formerly held few nesting pairs. Table 4 compares Area III with Area II. The number of pairs per artificial pothole is lower for the smaller ponds of Area III than for those of Area II. The breeding duck densities of about 200 to 600 pairs per square mile for the two areas compare favorably with the most productive breeding ranges on the continent.

As in Area I, the artificial potholes in Area IV lie along the marsh edge. However, the breeding population of 51 indicated pairs in 1957, and 60 in 1958 includes ducks seen on the potholes and also those on the adjacent shoreline (Table 1). Table 6 compares Area IV with a control area in which there are no potholes. Unfortunately no counts which separated Area IV from the control area prior to artificial pond

Table 5. Relative acreages of water area and shoreline length of four study areas, Lower Souris Refuge, 1957

Areas	Study area				
	I	II	III	IV	Total
Total acreage of study area		104	260		364
Number of artificial ponds with water	25	53	69	34	181
Wet acres:					
Artificial ponds	2.69	1.83	1.65	0.91	7.08
Natural sloughs		5.0			5.0
Total	2.69	6.83	1.65	0.91	12.08
Length of shoreline in miles	1.5			1.0	

Table 6. Number of breeding pairs per mile of shoreline, per artificial pond, and per wet acre on Study Area IV and control area

Area	Dabling ducks - indicated pairs								
	Per mile of shoreline			Per artificial pond			Per wet acre		
	1957	1958	Mean	1957	1958	Mean	1957	1958	Mean
Developed Study Area IV	47	56	52						
Undeveloped Control area	29	33	31						
Difference due to development	18	23	21	0.53	0.68	0.61	1.80	2.53	2.25

construction are available. If the populations of the two areas are assumed to have formerly been similar (the tracts are identical habitat types) then the number of ducks attracted to the potholes would be equal to the difference between the two populations, or 18 pairs in 1957 and and 23 in 1958. Diving ducks are not included in Table 6. While scaup, redhead, and canvasback pairs were seen along the marsh fringe, none were observed on the potholes. There is no evidence that these birds used the artificial ponds in Area IV for nesting.

Examination of refuge census records for the years 1953-56 disclosed a history of low breeding duck populations for the 11.25 mile segment of shoreline of which the Unit 357 study and control areas are a part. Counts made during the 1953-56 period showed an average of only 8.4 pairs per mile of lake edge.

In Area IV, where the breeding population chronology differed from that of the other study areas, the periods of highest populations, or plateaus, were of slightly shorter duration. Possibly some pairs which had apparently settled to nest found certain breeding requirements to be lacking and moved elsewhere. High waves which occasionally battered the shoreline, especially during the windy spring of 1958, may have adversely affected its attractiveness to nesting ducks.

Species composition of breeding ducks on the study areas was similar to that of the rest of the refuge (Table 7). The most notable difference was in the number of diving ducks. No ruddy ducks or canvasbacks were observed on the artificial ponds. Two redheads were seen on artificial potholes for the first time in 1958. All other diving duck use was by lesser scaup. As emergent vegetation growth increases, the sites for

Table 7. Species composition of breeding pairs at Lower Souris Refuge, 1958

Species	Percent of total indicated pairs study area					Entire refuge
	I	II	III	IV	Total	
Mallard	8.1	5.9	8.3	16.7	9.0	21.0
Pintail	2.4	4.0	0	3.3	2.1	6.7
Blue-winged teal	43.7	50.5	55.9	36.6	47.7	37.5
Shoveler	6.9	6.9	6.0	8.3	6.9	5.1
Gadwall	31.0	21.8	27.4	20.0	25.3	22.3
Baldpate	3.4	3.0	1.2	6.7	3.3	1.7
Green-winged teal	0	1.0	0	1.7	0.6	0.2
Total dabblers	94.3	93.1	98.8	93.3	94.9	88.8
Lesser scaup	5.7	4.0	1.2	3.3	3.6	2.3
Redhead	0	2.9	0	1.7	1.2	4.5
Canvasback	0	0	0	1.7	0.3	2.1
Total divers	5.7	6.9	1.2	6.7	5.1	11.2
Total	100.0	100.0	100.0	100.0	100.0	100.0

floating nests become available, use by diving ducks will probably become greater.

Most common on the study areas were blue-winged teal, gadwall, mallard, and shoveler, in that order. Blue-winged teal made up a slightly greater portion of the species composition of the study areas than of the remainder of the refuge, while mallards and pintails comprised a smaller segment of the population. This would suggest that the teal responded most to the development. Mallards and pintails seemed to prefer other habitat. Area IV, with its comparatively higher proportion of mallards was either preferred by this species or was less suitable for the other ducks.

One pair of Canada geese used the largest artificial pond in Area I during the 1958 breeding season. A nest, possibly of the same pair, was located in the marsh fringe just outside the water area.

Summer waterfowl population.--As the breeding season advanced, drakes began to gather in flocks in preparation for the molt. In 1958 small bands of pre-molting drakes often were seen on artificial water areas (usually the larger ones) in Areas I and II. Most of these drakes were mallards, though blue-winged teal and gadwalls were present too.

A flightless mallard drake which was captured on a small artificial pond provided the only evidence of use by molting adults.

Though occupied at times by broods, the artificial potholes and level ditches were too small for extensive brood use. Those water areas nearest the marsh were most frequently utilized.

Autumn migration waterfowl population.--Limited numbers of flying adults or young, mainly blue-winged teal, used the artificial ponds during August, September, and October. These fall populations were considerably smaller and of less significance than the breeding populations. The largest number of ducks seen in any one of the several visits to Area IV in August was 25 birds. Far greater concentrations could be found in other parts of the marsh. As the artificial ponds age, however, such use will likely increase. A level ditch several years old at Des Lacs Refuge, west of Lower Souris, held approximately 800 mallards during September 1957.

Waterfowl populations at other refuges

At Lower Souris, waterfowl breeding population densities varied considerably between the four different study areas. Records for similar development work at other midwestern refuges also varied. The following data, portions of which are presented in greater detail by Hammond (1958), relate to breeding duck populations.

Tamarac National Wildlife Refuge--west central Minnesota.--Since 1940 more than 12 miles of level ditches have been dug in peat soils, primarily in marsh areas overgrown with emergent vegetation. Widths varied from 6 to 30 feet. Portions of the ditch edges have become overgrown with brush. Part of the shoreline is wooded. Use of these water areas by breeding ducks has been slight, with populations of 2.6 to 3.3 pairs of ringnecks, blue-winged teal, mallards, and wood ducks per mile of ditch. Ringnecks preferred the wider ditches. Greatest numbers of pairs were seen in areas of timberless shoreline with at least 15 to 40 acres of dryland nesting sites per mile of ditch.

Mud Lake National Wildlife Refuge--north western Minnesota.--Nesting ducks made little use of 15-year-old ditches through peat soils. In 1957, populations averaged four breeding pairs per mile of ditch.

Sand Lake National Wildlife Refuge--north eastern South Dakota.--Approximately 1¼ miles of level ditch were dug in 1955 and 1956 in two different habitat types. The north ditch was located in a marsh which had a bottom of muck and was overgrown with phragmites. Food there was scarce. The 1957 breeding population of this area was recorded at one pair per mile of ditch, while the south ditch, which lay in sandy soil along an upland edge where food was in fair to moderate supply, harbored 12 pairs per mile.

From 1954 to 1956, 142 artificial potholes were excavated. A group of 97 ponds constructed in a lowland pasture bordered by phragmites marsh, and which were 15 x 30 x 5 feet in size, held only 0.07 pairs per water area in 1957. The other 45 larger potholes located near the south ditch held 0.22 pairs per water area. Vegetation in the ponds resembled that of Lower Souris potholes.

Lacreek National Wildlife Refuge--south central South Dakota.--Artificial pothole development work was conducted from 1952 to 1956. About 53 potholes were dug in and around the north margin of a marsh bay surrounded by grassy upland. Food in the marsh, which was overgrown with hardstem bulrush, was plentiful. In 1957 the ponds attracted 0.53 breeding pairs per water area, in addition to the number which would have been expected to use the area without development. An additional 25 potholes constructed in a wet meadow along the south edge of the same marsh attracted 1.2 breeding pairs per pothole. The 1958 breeding populations of both areas were slightly higher.

Waterfowl utilization

Although occasional migrants, broods and flightless adults were observed on artificial potholes and ditches, breeding pairs made by far the greatest use of the development. Data on breeding pair utilization were gathered by observations made specifically for that purpose in the Unit 320 study areas and from breeding pair censuses, with additional observations made incidental to other work in the study areas.

Breeding pairs started to move onto the artificial potholes and level ditches at the time roughly corresponding to the break-up of gregariousness, or the prenesting phase of the breeding cycle. These birds roosted on the large marsh nearby and flew to the artificial ponds early in the morning, usually before dawn. There they would remain for several hours before returning again to the marsh to spend the remainder of the day feeding and loafing.

The time spent daily by each pair on the potholes and ditches was shortest early in the season, just after the pairs began to use the artificial ponds. Occupancy was then highest during the two to three hours following dawn, or until about 8:00 a.m., when pairs began to depart again for the marsh. Midday and evening occupancy were low throughout the breeding season.

Hens, often accompanied by their drakes, walked or flew from the artificial ponds to investigate nesting cover in "search" of potential nest sites. This activity in the blue-winged teal, gadwall, shoveler and mallard occurred relatively early in the morning. Gadwall and mallard pairs could be seen in nesting cover at dawn, while blue-winged teal and shovelers were somewhat later.

The onset of laying marked the beginning of longer pothole occupancy by breeding pairs. As during the prelaying period, the artificial pond served as a jumping-off place for the hen on her way to the nest to lay. Her drake usually waited on the same water area for her return. After the hen returned to the pond the pair loafed and fed there (when food was available) for a time, later flying to the marsh.

Since laying generally was prolonged later into the morning than was nest cover scouting, the length of time that the pair or drake remained on the artificial water area was longer during the laying period than earlier. As the season progressed pairs stayed later on the potholes and ditches, though peak occupancy continued to be during early morning hours. No great change was noted between midday and evening utilization. There was little movement to the ponds after sunset. The four-acre natural slough in Area II, however, was utilized throughout the day for feeding and loafing. In the morning it served also as a waiting area. There, populations showed two daily peaks: one in the morning and the other in the evening. This would suggest that breeding ducks did not use the artificial ponds primarily for feeding.

Through early incubation, and until nearly hatching time in some species, the drake continued to wait on the artificial water area for the hen. The attachment of the hen to the ponds persisted after she was abandoned by her drake.

Morning activity of the breeding pair was not restricted to a single water area. Though the daily laying flights of most hens observed regularly originated from the same water areas, a pair might use several potholes and nearby natural sloughs in a single morning. Flights back and forth between the ponds and the marsh were frequent in Areas I and IV.

The waiting area of the drake was generally the closest pothole to the nest. Of the 67 nests found in Areas I and II in 1957, laying flights to 35 were seen to originate from the nearest pothole or ditch.

Intolerance of the gadwall to the presence of other gadwall pairs became greater as the season advanced from a time when the first pairs were beginning to visit nesting cover to the period when most hens were laying. Soon after the first numbers of gadwalls arrived on the artificial potholes they could be seen in pairs or in groups of two to three pairs. Later, as intolerance increased, these pairs tended to disperse more uniformly over the habitat, so that no pothole held more than one pair of gadwalls per water area, but here also the number of pairs per occupied water area decreased while the total population increased. Seldom during the laying period was a gadwall pair observed to successfully alight and remain on an artificial pothole that was already occupied by another pair of gadwalls. When a pair attempted to land on an occupied pothole a three-bird chase, in which the drake of the "resident" pair would evict the intruders, usually ensued. Though both the breeding population and the number of potholes occupied increased substantially during the second season of study, the number of pairs per occupied pothole did not change. For the larger level ditches, however, the number of pairs per ditch was greater in 1958 than in 1957.

Blue-winged teal and mallards also were prevented in many instances from landing and remaining on potholes by the aggressive action of pairs already present. Though blue-winged teal drakes vigorously defended their waiting areas (Figure 10), they were not so successful as gadwalls or mallards in expelling transgressing pairs. Occasional groups of two to three pairs of teal could be seen through the breeding season, though in such aggregations there was much social friction, with each pair usually at an opposite corner of the water area. The number of pairs per occupied pothole, the number of potholes occupied and the total breeding population of the blue-winged teal increased in 1958.

The various activities of ducks during the nesting season greatly influenced the accuracy of breeding pair inventories. The peak gadwall population, for example, was recorded just before large numbers of pairs began to visit nesting cover. The nest cover inspections, which occurred while censuses were being conducted, caused a reduction in the number of pairs observed on the water areas. Counts of other species were similarly affected. During the laying period counts were likewise lowered for gadwalls and other species which might be at the nest while pair counts were being conducted. Blue-winged teal and shovelers usually did not go to lay until after the counts were completed. As incubation advanced census figures declined rapidly and breeding pair inventories were discontinued.

Factors affecting utilization

In this study attempts were made to analyze the effects of several factors which might influence use of artificial ponds by breeding ducks.

Figure 10. Blue-winged teal drakes vigorously defending their waiting areas

Only pond size, spacing and spoil bank height (either pushed flat or left standing) could be isolated in a sufficient number of water areas for analysis. Such information is important if future habitat development projects are to be designed to produce a maximum number of ducks per dollar invested.

In order to obtain information on comparative duck use of individual ponds it was necessary to devise a method of ranking the water areas according to the amount of duck use each received. This was accomplished by means of what I have termed the "relative use rating." During the weekly breeding pair inventories records were kept of the number of indicated duck pairs seen on each water area. The total number of indicated pairs observed on a pond during the seven censuses conducted between May 5 and June 22, 1958, constituted the relative use rating for that pond.

Water area size.--Earlier studies have shown that, in general, the smaller the water area, the greater the duck use per acre it will receive. In South Dakota, Evans and Black (1956) divided 391 natural potholes into 7 size classes, the largest of 12 or more acres, and calculated the number of breeding pairs for each class. They found that the smallest, 0 to 0.09 acre, held over 4 times as many ducks per acre of water area as the next larger size. The remaining 5 classes, in ascending order of size, showed progressively smaller reductions in duck use per wet acre. Stoudt (1956) obtained similar results in a study in the parkland pothole country of Saskatchewan. In neither study, however, were water areas smaller than 0.09 acre sub-classified.

In this investigation data from the few artificial ponds larger than

0.05 acre were inclusive, but suggested a trend similar to that observed by Evans and Black. Differing results were obtained, however, from data representing 448 observations of artificial potholes 0.05 acre and smaller.

Sixty-four artificial potholes in Areas II and III were divided into the following 4 size classes according to area in square feet:

Class 1 = 500 sq. feet, 12 potholes
Class 2 = 1000 sq. feet, 21 potholes
Class 3 = 1500 sq. feet, 17 potholes
Class 4 = 2000 sq. feet, 14 potholes

An analysis of variance test (Ostle, 1954) made with the relative use ratings of the 64 potholes of 4 size classes showed the linear regression of duck use on water area size to be significant at the 99.5 percent level, as shown graphically in Figure 11.

The means of relative use ratings for each size class, in order of increasing size, were 2.33, 4.48, 7.29, and 9.14. When the Class 1 relative use rating was set equal to 1.00, and the other three means adjusted accordingly so that their relation to the Class 1 mean would remain unchanged, then the following association of duck use with area size became evident:

Size class	1	2	3	4
Duck use	1.00	1.92	3.13	3.92

Changes in duck use paralleled changes in pond size; that is, duck use per acre of water area was approximately the same for water areas of 500 to 2000 square feet (0.046 acre). The water area size beyond which duck use per acre would begin to decline is unknown, but would likely be between 0.04 and 0.1 acre (4356 square feet).

Though use per acre was approximately the same regardless of water area size, within limits, costs of construction were not. Up to a certain

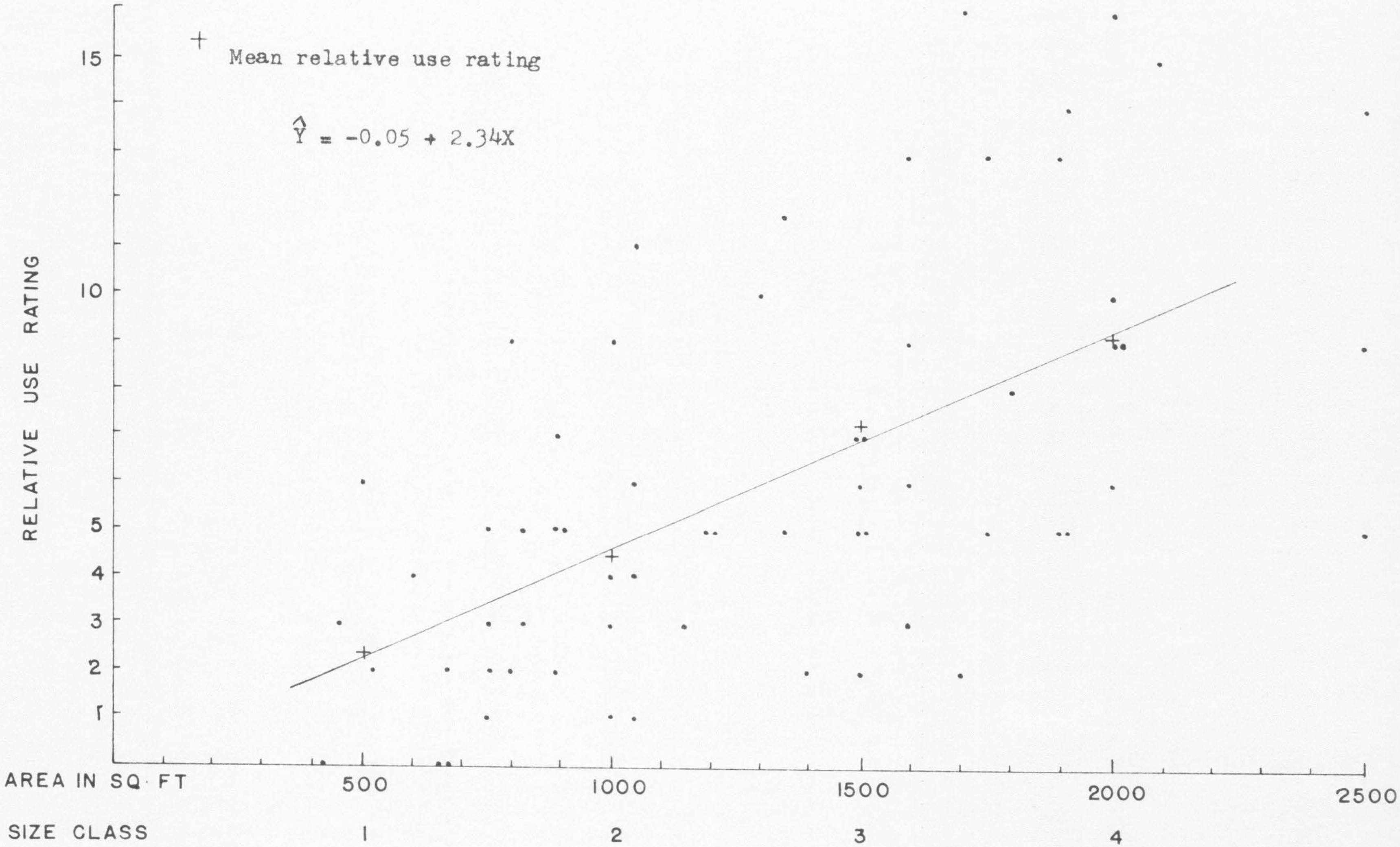

Figure 11. Scatter diagram showing relation of duck use to water area size.

pond size it would be more economical to build a small number of large potholes than to excavate a large number of small ponds, at the same spacing, to produce the same number of ducks. The latter would require that equipment be transported farther and more often. Further study will be necessary to determine relative costs of different sizes of artificial ponds.

For similar reasons level ditches were not as productive per dollar invested as artificial potholes. For example, in 1958 a 900-foot level ditch on Swearson Point was used by an estimated 7 breeding pairs. The same use might have resulted if 7 potholes, each 100 feet long, had been constructed instead, at a saving of 100 feet of ditch length.

<u>Water area spacing</u>.--To determine if duck use per pothole would decrease as potholes were placed closer and closer together, 35 artificial ponds of size Class 2 were divided into 3 classes of spacing: 50, 100, and 150 feet. An analysis of variance test performed with the relative use ratings of these ponds showed that there was a difference between the three mean use ratings significant at the 75 percent level. The mean ratings, with the mean for the 50-foot spacing class adjusted to unity as a base for comparison, showed the following relationships:

Spacing	50 ft.	100 ft.	150 ft.
Duck use	1.00	1.44	1.59

Though artificial ponds may, according to the above data, be made to produce about 1.6 times as many ducks under 150-foot spacing as under 50-foot spacing, the cost of excavation per pothole also increases due to the threefold increase in the distance the earth-moving equipment must be transported.

Another point to consider is that, as the spacing is reduced by a given rate, the number of ponds that can be accommodated in a certain tract will increase at a different, greater rate. For example, only 9 potholes 25 x 75 feet in size can be placed in a square 106-acre plot if spaced 150 feet apart. At 100-foot spacing, 15 potholes of the same size could be fit into the same tract, while if spaced 50 feet apart, 45 potholes could be accommodated. If spacing were reduced to much less than 50 feet, however, a rather large proportion of the available nesting cover would be under the bottoms of the spoil banks.

Spoil bank height.--It was believed that by leveling the spoil piles waterfowl use could be increased and pothole life prolonged. To determine if there was a difference between duck use of potholes with leveled spoils and those with high-piled spoils a "Student's T-Test" (Ostle, 1954) was applied to the relative use ratings of 16 artificial ponds in Area III. The results showed a difference, significant at the 800 percent level. The averages were 6.0 for the 9 ponds with leveled spoils and 3.3 for the 7 with high-piled spoils. The true difference might have been less than shown by the means, however, and should be subjected to further study involving a larger number of ponds. Whether leveling of spoil banks would be economically justified is questionable at this time, since it does add considerably to the cost of the ponds. Pothole life is little affected.

Evidence from other studies indicates that additional factors may be important. At Delta, Manitoba, Sowls (1955) observed that certain sections of roadside ditch were consistently better producers of ducks than other sections of the same size. This difference he attributed to the nature of the ditch banks; where heavily overgrown with rank vegetation Sowls found no pintails, and comparatively few mallards, shovelers, and gadwalls. Only blue-winged teal showed no preference for ditch sections with open banks. Tall vegetation bordering the water probably contributed to non-use of certain ditches at Sand Lake and Tamarac Refuges also.

Stoudt (1956) found that natural potholes in wooded areas held fewer breeding ducks than those in open country. Similar results were described earlier for level ditches at Tamarac Refuge.

Other factors which are not properties of the water areas themselves will be mentioned later.

Waterfowl production

Brood mobility made duck production arising from the artificial potholes and level ditches difficult to assess. Few broods utilized the artificial ponds; most traveled to the marshes soon after hatching, and remained there until capable of flight. Because of this movement of broods away from the study areas, and because nesting studies were not reliable measurements of nesting success at Lower Souris, production was estimated by applying hatching success rates of entire refuge management units to the pothole and ditch breeding pair populations.

The estimated hatching success in Unit 320 was 50 percent in 1957 (Hammond, 1957) and 25 percent in 1958, while in Unit 357, hatching success was 57 and 37 percent for the same period (Table 8). Though the breeding populations of 3 of the study areas were considerably higher in 1958 than in 1957, the reduction in nesting success prevented a proportional increase in production. The estimated number of broods hatched by the

Table 8. Calculated total duck production of study areas, 1957-58

Areas	Hatching success (percent)		Number of breeding pairs		Number of broods hatched		Number of broods per square mile		Number of broods per mile of shoreline	
	1957	1958	1957	1958	1957	1958	1957	1958	1957	1958
Unit 320	50	25								
Study Area I			42	87	21	22			14	15
Study Area II			75	101	38	25	234	154		
Study Area III				84		21		52		
Unit 357	57	17								
Study Area IV			51	60	29	10			29	10
Control Area			30	37	17	6			17	6

ducks believed to be attracted by the pothole and ditch development in 1957 ranged from less than 2 broods per wet acre to slightly more than 16 (Table 9). Production the following year continued within this range. Had 1958 nesting success remained at the level of the previous year, production could have reached 25.5 broods per wet acre (Area III). The increase in duck production caused by the pothole and ditch development varied between 29 and 80 percent in Areas I, II, and IV.

Hatching success, which has varied considerably between any two years at Lower Souris, would over a period of many years average close to 50 percent. The year 1958 was one of the poorest years on record. Hatching success rates for most areas of central United States are similar to those of Lower Souris. Kalmbach (1939) found hatching success in an analysis of 22 field studies which included observations on 7600 nests, to be 60 percent. Hence, a more realistic, but conservative prediction of the expected long-term annual production of the potholes and ditches might be that based on a rate of 50 percent.

Utilization by other animal species

Though coot were common on much of the refuge marsh, few were observed on the artificial water areas. The development has probably added little to coot habitat. Perhaps after the ponds have aged and have more emergent vegetation coot use will increase.

American bitterns were frequently seen in the artificial potholes where frogs, small fish and insects and other invertebrates provided abundant food.

Killdeer and other shorebirds utilized the exposed bottoms of the

Table 9. Calculated total duck production attributed to artificial potholes and level ditches, 1957-58

Areas	Number[a] of breeding pairs		Number of broods hatched		Number of broods per water area		Number of broods per wet acre[b]		Percent production increase due to development		
	1957	1958	1957	1958	1957	1958	1957	1958	1957	1958	Mean
Unit 320											
Study Area I	9	44	5	11	0.18	0.75	1.86	4.04	29	50	40
Study Area II	59	77	30	19	0.56	0.36	16.10	10.50	79	76	78
Study Area III		84		21		0.31		12.70			
Unit 357											
Study Area IV	18	23	10	4	0.30	0.12	11.28	4.30	34	40	37

[a]Pairs attracted by artificial ponds. Does not include pairs which would have used the study areas prior to development.

[b]Number of broods produced per acre of ditch and pothole water area.

nearly dry potholes and ditches in later summer.

The artificial potholes of Area II served as watering areas for mourning doves in August 1956, shortly after construction. Little use was observed in 1957 after vegetation had begun to grow on spoil banks and at pond margins.

Sharp-tailed grouse, Hungarian partridge, and ring-necked pheasants utilized the potholes and ditches during both seasons of study. The rank vegetation on many of the spoil banks likely produced a considerable volume of food for these species. Cock pheasants used the spoils for crowing spots in the spring.

The artificial ponds appeared to be of considerable value as habitat for fur bearers such as mink and raccoon. Tracks of both were usually abundant at the damp edges of the ponds. Use by these species would be expected to increase as animal life becomes more abundant in the water areas. Signs of frequent digging by mammals were observed on many spoil banks. The spoils would provide dry den sites in areas which would otherwise be too damp. Muskrats were occasionally seen.

The tracks of white-tailed deer showed frequent use of the potholes as watering holes.

Most ponds held frogs in 1958. Tadpoles were numerous.

The artificial water areas nearest the marsh, which at times were subject to overflow, held large numbers of small unidentified fish during 1958.

By the spring following construction, aquatic insects were abundant in the artificial ponds. Most conspicuous were the back swimmers, diving beetles, and water boatmen.

Pothole and ditch longevity

In order to determine the value of the pothole and ditch development for duck production it is necessary to have some measure of the longevity or duration of productivity of the water areas. The process of ecological succession by which lakes become marshes, and eventually dry land, depends to a large degree upon climate (Odum, 1953). The immediate factors which affect the artificial ponds are encroachment of emergent vegetation into the water areas and sedimentation. The former, which depends upon initial depth and fertility of the pond, can be controlled by application of herbicides.

During the winter and spring following excavation, wind erosion of the high, sandy spoil banks caused accumulation of approximately an inch of soil material in the artificial water areas. Added to this, in Area I, was a similar amount of dust blown from the dry lake bed (Unit 320 was drained in the winter of 1956-57). Partial coverage of the spoils by growth of vegetation greatly reduced subsequent erosion. Leveling of spoils did not materially affect sedimentation.

Muck accumulation in island borrow pits which were 40 inches deep when excavated in 1935 averaged 20 inches (50 percent) in 1958, 23 years later. A similar rate of sedimentation might be expected for the artificial potholes and level ditches.

Because the artificial ponds were excavated in areas of firm sod where plant roots held the soil particles together, sloughing or cave-in of the banks has been slight. The banks of roadside and dike borrow pits in such areas have remained relatively stable for periods exceeding 20 years.

On the basis of sedimentation rates of similar "old" roadside, dike and island borrow pits, I would estimate the minimum productive life of artificial water areas with minimum measurement of 15 feet wide and 3 to 4 feet deep to be approximately 30 years under management. Wider and deeper ponds would remain productive longer. Actual longevity, of course, will depend upon future climatic conditions. A series of wet years, by keeping the ponds bank-full of water, would retard the establishment and spread of emergent vegetation. After the ponds have become shallow, slight changes in water levels may mean the difference between high breeding pair occupancy and none at all.

Vegetation

Effects of vegetation on productivity of the artificial water areas can be either beneficial or detrimental. Plant growth on the spoil banks, by checking erosion, prolongs pothole life, while emergent vegetation which spreads inward from the pond borders has the opposite effect. Without management the water surface could in time become so filled with vegetation that duck use would cease. Submerged aquatic vegetation such as pondweeds provide quality duck food with little of the undesirable effects of emergent growth.

Spoil banks.--The rate at which vegetation became established on the spoil banks was governed in part by the water area site, the depth to which organic topsoil was buried beneath sandy mineral substrate, and land use. Spoils of shallow ponds constructed in low areas where the organic material penetrated deep, and which thus consisted almost entirely of organic matter, were more rapidly vegetated than those of similar ponds in areas of shallow topsoil. Sod clumps protruding from the low spoils of shallow potholes usually contained plant parts, permitting rapid vegetative reproduction. In contrast to the deep ponds, the shallower water areas had low spoils; consequently the fertile topsoil was less deeply buried, and vegetative growth more rapid. Grazing of part of Area IV by livestock affected both species composition and density of spoil vegetation. In the grazed portion, where vegetation density was about 70 percent that of the nearby ungrazed area, Canada thistle was the most abundant species, occurring in nearly pure stands on some spoils.

Eleven to 12 species of plants dominated the spoil banks of Areas II and IV (Table 10). In Area II vegetation spread rapidly. By August 1958, two years after excavation, the spoil banks were 70 percent covered with vegetation. The number of plant species present increased from 40 to 50. Emergents such as cattail, river bulrush and softstem bulrush persisted on some spoils for two years. Flixweed, which was scarce in 1957 became established in heavy stands on some spoils in 1958. Other species which were present on at least 50 percent of the spoil banks, but which were not abundant on any were Canada thistle, sow thistle, marsh elder, germander, smartweed, and dock. Most of the plants which colonized the spoils were pioneer species characteristic of early successional stages.

In Area IV the number of species increased from 12 in 1957, when silverscale, smartweed, and river bulrush were the most common plants, to 40 in 1958. Notable in the latter year was the reduction of silverscale from one of the most abundant plants to a state of relative scarcity, and the appearance of wild barley.

Baltic rush and wild barley formed the dominant spoil vegetation in

Table 10. Dominant plants of spoil banks

Plant species	Percent frequency of occurrence	
	1957	1958
Study Area II		
Wild barley	82	78
Wheatgrass	70	85
Silverweed	70	74
Rough cinquefoil	63	63
Prairie cordgrass	67	78
Ragweed	59	74
Sweet clover	59	85
Water hoarhound	52	56
Willow	19	22
Flixweed	0	56
Average coverage[a]	52	69
Study Area IV		
Sweet clover		100
Canada thistle		97
Wild barley		76
Smartweed		70
Average coverage		51

[a]Average percent of spoil surface covered by vegetation.

Area III one year after excavation.

At Lower Souris, the rapid natural establishment of vegetation made seeding of the spoil banks unnecessary.

Water areas--emergent aquatic vegetation.--The greatest problem likely to confront those responsible for maintenance of pothole and ditch productivity is the prevention of encroachment of undesirable emergent aquatic plants, principally cattails, river bulrush, softstem bulrush, hardstem bulrush, and three-square into the water areas. These plants became established by a combination of several circumstances. Immediately after excavation the artificial water areas were devoid of vegetation except for occasional plants which had fallen into the ponds during the construction process. Such plants in many instances took root the following spring and developed into colonies. At the same time other emergents advanced by runners or rootstalks from the pond edges. Later, during the dry summers of 1957 and 1958 water levels receded, exposing bare mud banks. Conditions were then ideal for germination of seedlings, many of which survived and grew.

Table 11 shows emergent vegetation present in the artificial ponds. In general, emergents which invaded the water areas in 1957 continued to spread in 1958, while some appeared in new areas during the latter year. In two growing seasons common cattail had, in one extreme case, spread from a natural slough into an adjacent artificial pothole, covering nearly the entire pond surface (Figures 12, 13, and 14). This reduced duck use in 1958 (in that pond) to 36 percent of the 1957 level. Few other potholes, however, were more than 25 percent covered by common cattail (Figures 15, 16, 17, and 18). In future development work growth of

Table 11. Emergent vegetation of artificial potholes

Plant species	1957		1958	
	Frequency[a]	Coverage[b]	Frequency	Coverage
Study Area II				
Common cattail	82	11	94	12
Spikerush	59	2	41	2
Softstem bulrush	53	16	79	12
Water plantain	53	tr[c]	59	2
Hardstem bulrush	29	7	29	7
River bulrush	24	12	24	19
Three square	21	11	35	11
Arrowhead	18	tr	12	tr
Smartweed	15	tr	9	tr
Sedge	12	11	21	3
Whitetop	12	5	15	11
Prairie cordgrass	12	tr	12	tr
Sloughgrass	9	tr	12	tr
Water hemlock	3	tr	18	tr
Phragmites	0	0	6	3
Study Area III				
Narrow-leaved cattail			85	9
Common cattail			15	tr
Smartweed			13	tr
Sedge			3	tr
Arrowhead			3	tr
Study Area IV				
River bulrush	97	4	97	11
Softstem bulrush	24	tr	85	3
Wild millet	9	tr	0	0
Arrowhead	9	tr	91	3
Prairie cordgrass	6	tr	6	tr
Sloughgrass	3	tr	28	tr
Bur-reed	0	0	36	tr
Water hemlock	0	0	19	tr
Spikerush	0	0	6	tr

[a]Frequency of occurrence expressed as a percent.

[b]Average percent of bottom covered by a species. Determined from only those potholes in which that species was present.

[c]Less than 5 percent.

Figure 12. Pond constructed in June 1956. By May 26, 1957, about 11 months after excavation, some cattail growth was evident.

Figure 13. The same pond as above, 23 months after construction. Cattails now covered much of the pond surface, May 20, 1958.

Figure 14. By late June 1958, cattails had extended completely across the pond shown on the preceding page. Little use could be expected in 1959.

Figure 15. Artificial pothole in Area III during the spring following construction. Cattail marsh shows in background. May 24, 1958.

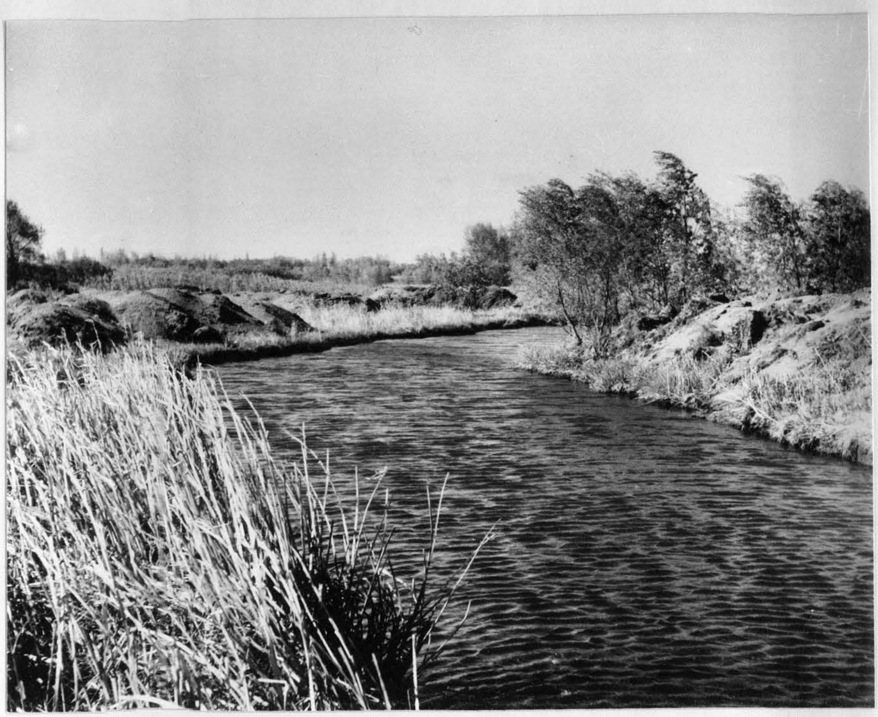

Figure 16. Level ditch about 10 months after construction. May 26, 1957

Figure 17. One year after top photograph was taken, no spread of emergents into the water area could be detected. May 24, 1958

Figure 18. There was little encroachment of emergent vegetation into the artificial potholes of Area IV during the first 19 months after excavation. May 1958

this species can either be controlled by herbicides or prevented by excavating potholes deep enough so that water depth will never be less than 3 to 4 feet. A strain of narrow-leaved cattail which appeared to be Typha glauca, or possibly Typha angustifolia (Hotchkiss and Dozier, 1949), and which grows in deeper water will be more difficult to prevent and may require control by herbicides. It was confined in 1958 to artificial ponds in Study Area III, but was present over much of the Unit 320 marsh, and possibly in all of the other units also. This cattail grows in water up to 4 feet deep, according to McDonald (1951) and, in 1958, apparently germinated in at least one foot of clear water.

The bulrushes pose a similar problem. River bulrush and softstem bulrush have spread the most rapidly.

Approximately half of the artificial ponds in Areas II and III will likely need herbicidal treatment every second year, while those of Areas I and IV could be treated less often.

Water areas--submerged aquatic vegetation.--During the summer of 1956 pondweeds were artificially introduced into certain artificial potholes in Areas I and II. The next year pondweeds were planted in 20 artificial potholes in Area III. In the season following planting there was only a slight difference in pondweed abundance between treated and untreated potholes. Pondweeds were growing and spreading in 39 of the 40 Area III ponds checked (Table 12). The small initial gain in pondweed growth obtained by transplanting pondweeds would not justify the expense of such work.

Pondweeds were established naturally during the first year after

Table 12. Aquatic vegetation of artificial potholes

Plant species	1957 Frequency[a]	1957 Coverage[b]	1958 Frequency	1958 Coverage
Study Area II				
Sago pondweed	62	24	88	22
Small pondweed	53	15	35	26
Clasping-leaf pondweed	12	9	3	tr[c]
Bladderwort	12	2	21	tr
Horned pondweed	9	8	41	10
Water milfoil	9	2	9	tr
Waterweed	0	0	3	tr
Muskgrass	0	0	3	tr
Total pondweeds	79	30	91	36
Study Area III				
Total pondweeds			97	5
Muskgrass			13	tr
Bladderwort			30	tr
Study Area IV				
Small pondweed			60	32
Water milfoil			65	tr
Clasping-leaf pondweed			63	tr
Horned pondweed			50	tr
Star duckweed			28	tr
Sago pondweed			25	tr

[a]Frequency of occurrence expressed as a percent.

[b]Average percent of bottom covered by a species. Determined from only those potholes in which that species was present.

[c]Less than 5 percent.

excavation in Areas I, II, and III. By 1958 some ponds held extensive beds of sago, small pondweed, and horned pondweed. No pondweeds were found in Area IV ponds until 1958.

Though luxuriant stands of aquatic vegetation provide duck food and probably increase duck use, they are not absolutely necessary as evidenced by the high duck pupulations on the artificial ponds in the early spring of 1957 when little food was available there. Probably far more important are the abundance and quality of food in the marsh.

Water areas--green algae.--Shortly after excavation, and in the spring following, green algae (Chlorophyceae) was observed in several of the artificial ponds. *Rhizoclonium* spp. was most abundant and was mixed at times with lesser amounts of *Spirogyra* spp. By mid-summer some ponds were entirely covered by dense "mats" of algae. The most important effect of this plant is likely the reduction of light available to submerged aquatic vegetation. Whether it actually inhibits duck use of the artificial water areas is problematic.

Cost analysis

Artificial ponds have been constructed by blasting with dynamite, by dragline and by dozer. Blasting as a marsh management technique was explored in an earlier study by Provost (1948) in Iowa. He found blasted holes to be of greater value in emergent vegetation in deep water than in shallow water. Best results were obtained if blasting was done over a substrate of hardpan. In a Wisconsin study (Mathiak and Linde, 1956) the original intention was to compare dynamite with dragline as a means of level ditch construction. However, blasting soon proved so expensive that it was discontinued. The cost of dynamite and labor was more than twice the total costs of excavating the same length of ditch with drag-line. In addition, dynamite was found to produce a generally inferior type of ditch. The large quantity of loosened muck along the edges of the ditch made the banks unstable and highly susceptible to wind and wave erosion. Sedimentation was more rapid than in the dredged ditch.

Dragline and dozer were the means employed for pond excavation at Lower Souris. The Unit 357 potholes were constructed under contract by a commercial dragline with a one-cubic-yard bucket at a cost of $0.123 per cubic yard of earth excavated, or at a total cost of $315 for the 2,482 cubic yards of earth moved.

Artificial water areas in Unit 320 were dug by a 3/4 yard refuge-owned dragline and by a Caterpillar tractor with a 12-foot dozer blade. Cost estimates for the Unit 320 work are based on the $0.123 per cubic yard rate, but actual costs are probably somewhat less. Operational costs of the refuge dragline and dozer were similar. The costs per cubic yard of earth moved by each would also be quite close, probably in the neighborhood of $0.10 per yard.

The costs of ducks produced by the four study areas are based on the production of breeding pairs attracted by the artificial water areas (Table 13). The production was calculated using 1957-58 hatching success rates. Actual costs of 1957 and 1958 production by study area were not estimated since predictions of future or long-term production based upon them would likely be misleading. Instead, only relative costs for the different areas were calculated, with Area II as a basis for comparison.

Table 13. Comparative cost of duck production for four study areas with production of Area II used as a basis of comparison

Item	Study area I	Study area II	Study area III	Study area IV
Total initial cost[a]	$1640	$870	$1050	$315
Number of water areas	25	53	69	34
Average cost of each water area	$ 65.60	$ 16.40	$ 15.23	$ 9.25
Comparative cost per brood produced				
1957	11.31	1.00		1.09
1958	3.26	1.00	1.09	1.72

[a]Calculated on the basis of a rate of $0.123 per cubic yard of earth excavated.

The smaller potholes (Area II, III, and IV) held the greatest number of ducks per dollar invested and were more economical than level ditches or the largest potholes.

As reflected by the relative costs of duck production, population densities of breeding pairs per unit of water area were highest in Areas II and III. Based on two years of study, at least one pair of breeding ducks per pothole can be expected for artificial ponds of the type constructed in these areas, though under optimum conditions populations of 1.5 pairs might be reached. The potholes in Areas II and III averaged about 1050 square feet in area and cost about $15.00 to build if 3 feet deep, and $20.00 if 4 feet deep. A rough approximation of the actual cost of ducks produced by such ponds might be made if it is assumed that the previously observed occupancy rate will continue through the anticipated productive life of a pothole, or about 30 years. The total expected production of that period, at 50 percent hatching success, would be 15 broods. The cost per brood produced would then be about $1.00 to $1.33, depending upon the depth of the water area, and the cost per duckling, about $0.17 to $0.25 assuming an average of 6 ducklings per brood. In terms of volume of earth moved, a brood might be produced for each 8 to 11 cubic yards of earth excavated. The differential in maintenance costs of deep and shallow ponds would tend to equalize the costs given above; potholes 4 feet in depth should require little maintenance. To attempt at this time to further refine any prediction of duck costs would be hazardous.

DISCUSSION

Use of the artificial ponds constructed at Lower Souris and at other midwestern refuges was largely limited to breeding waterfowl. The ponds alone did not attract high populations of nesting ducks. The great variation in use of similar ponds in different areas shows that other factors, in addition to the ponds themselves, are important in determining the number of waterfowl that utilize the potholes and ditches.

Areas where food or nesting cover is limited support few nesting ducks. For example, at Sand Lake Refuge a level ditch in a phragmites marsh where food and nesting cover were scarce supported one-twelfth the breeding population (per mile of ditch) of another ditch located in an upland area with adequate nesting cover, and near a marsh where food was available in moderate quantity. Level ditches at Tamarac Refuge held greatest numbers of breeding pairs where dryland nesting cover was most abundant. Heavy growth of timber and brush lowered nesting populations. The peat and muck bottoms of the marshes, and the type of vegetation growth which resulted, probably contributed to the generally low overall use of the ditch and pothole developments at these refuges. More desirable plant species, and usually larger numbers of nesting ducks, occur where mineral soils exist (Hammond, 1958).

Areas which support relatively large numbers of species of high mobility, such as the mallard, may not be suitable for less mobile birds like the blue-winged teal. Smith (1955) found at Ogden Bay Refuge in

Utah, that if the various breeding requirments (loaf spot, nest cover, and feeding area) were too widely separated, only the mobile species would cocupy the area. It is therefore important that the artificial water areas, nesting cover, feeding areas, and brood marsh all be in an area small enough to lie within the nesting home ranges of the most sedentary species.

From this study it would appear that the primary function of the artificial potholes and level ditches is to meet the territorial requirements of breeding pairs. The ponds are most valuable as supplements to already existing habitat. Only where lack of space for the dispersal and isolation of breeding pairs is the breeding requirement which is most limited, and which hence limits nesting populations, is ditch and pothole development economically justified. If food or nesting cover is not available, little improvement will likely result from such work.

Value as a management technique for habitat development

In the future the reduction of natural waterfowl breeding habitat is likely to continue. As waterfowl become less abundant the monetary value of each duck to the American public will increase. Methods of habitat improvement that are now economically prohibitive may in 10 or 20 years be considered feasible.

Artificial potholes and level ditches form a valuable supplement to habitat already in public ownership when the costs of ducks which they raise are compared to costs of ducks produced as the results of artificial progagation or outright purchase of habitat from private interests.

Artificial propagation of mallards has cost the state of Wisconsin

$2.00 for each duck liberated (Hunt, et al., 1958). Not only was the expense deemed prohibitive, but captive-reared ducks were considered poorer as game than wild birds.

Federal acquisition of natural waterfowl habitat in the prairie pothole country has been suggested as a means of habitat preservation. It was recommended (Hawkins, 1957) that the tracts to be purchased be those in danger of destruction, and which annually produce at least 100 young ducks per square mile. Hawkins (1957) estimated that the cost of ducks raised on such acquired areas would be approximately $0.34 per duckling if the purchase price of $35.00 per acre were amortized over a period of 50 years. Costs of ducks produced by artificial potholes and level ditches placed in proper habitat are not expected to exceed the above figure.

Level ditches are inferior to artificial potholes as means of improving waterfowl breeding habitat. The potholes can produce ducks at less expense. For this reason ditches should probably not be considered unless they can be made to perform a multiple function. In some areas ditch construction can be justified for muskrat management alone (Mathiak and Linde, 1956). The potential production which can be expected from an artificial pothole approximately 1050 square feet in area has been estimated at 15 broods or 90 ducklings, at a cost of $1.00 to $1.33 per brood, or $0.17 to $0.25 per duckling, depending on pond depth. Future maintenance expenses will tend to equalize these costs, while fur values will lower them.

Breeding populations which have resulted from construction of artificial potholes compare favorably with those of the most productive prairie pothole country of the United States and Canada. Breeding pair densities in the latter areas do not greatly exceed 200 pairs per square mile, while on artificial pothole study areas at Lower Souris and Lacreek refuges, populations of 400 to 600 pairs per square mile were recorded.

In certain areas other methods of habitat development such as chemical or mechanical control of emergent vegetation or manipulation of marsh water levels may serve the same function as artificial ponds at less cost.

Recommendations

It has been demonstrated in this study that artificial potholes are more economical as supplements to waterfowl breeding habitat than are level ditches, and should be the preferred choice when habitat is to be manipulated solely for the purpose of increasing duck populations. Ditches are most valuable when they can be made to serve additional functions such as muskrat management, or where, like roadside, dike, or island borrow pits, they are the by-products of other construction.

For maximum waterfowl use with reasonable longevity, level ditches should be at least 15 to 20 feet wide, with depths of at least 4 feet. Banks should be steep to prevent establishment and spread of emergent vegetation. Frequent bends in the ditches would minimize wave erosion and also increase breeding pair occupancy by providing for visual isolation of one pair from another, thereby increasing the number of defended sites. Placing short spoil banks alternately on each side of the excavation would add to this effect.

In order to produce the greatest number of ducks per dollar invested, artificial potholes should be at least 20 to 25 feet wide and 40 to 75 feet long. Surface area should not be greater than 2000 square feet or less than 500 square feet. Sizes larger or smaller than this are likely to be less effective. The rectangular shape is preferred from the point of economy of construction. Depths of at least 4 feet would be desirable for permanency. Costs of future maintenance, which would consist primarily of chemical control of emergent vegetation, will increase as depths decrease. Shallow ponds less than 3 feet deep might require herbicidal treatment as often as every second year. Where narrow-leaved cattails are absent, the deeper ponds may remain free of emergents for many years. Chemical control of emergent vegetation is still largely in the experimental stage. As new and more effective herbicides are developed, the cost of application will likely be reduced. To determine whether emergents can be most economically controlled by chemical or mechanical (increasing initial depth) means will require continued study. Present data are inconclusive, but suggest that mechanical control might be cheaper than treatment with herbicides now available.

Grazing by livestock, if not heavy enough to be detrimental to duck nesting, would aid in control of emergent vegetation.

Excavation of ponds in areas of firmly bound sod will minimize sloughing of banks and thus prolong effective life of the development.

At least two banks of the artificial potholes should be steep in order to provide open loafing spots and to keep the banks free of emergent vegetation. The other one or two banks could be sloped to make food available to dabbling ducks, though this may not be necessary. To maintain a high level of use by breeding pairs it is not necessary that food be plentiful in the artificial water areas. At Lower Souris most pairs fed in the nearby marsh or on natural sloughs. Such areas must be available anyway for use by broods; if brood rearing waters are lacking other nesting habitat will produce few ducks.

Spoil banks probably need not be leveled. Little increase in pond longevity or duck use could be conclusively attributed to this work. It would likely be offset by the added cost of leveling the spoils.

Control of pond water levels by a series of narrow, connecting ditches might prove valuable for control of vegetation through water level manipulation. Continued circulation of fresh water through the artificial water areas would likely reduce algae accumulation. If water levels are allowed to recede during the summer, exposing the bare damp bottoms, cattails may become established by seedling germination and create a management problem. Erosion of banks may also increase. According to Provost (1948), alternate flooding and drying reduces bank stability by increasing fragmentation of the soil.

Distribution of artificial ponds should be correlated with the mobility of the species for which the ponds are constructed. For the sedentary blue-winged teal, highest occupancy per dollar invested was attained when the artificial ponds were spaced about 100 feet apart.

Artificial water areas are probably most efficient when placed in a "block" pattern similar to Areas II and III, which extend back some distance from the larger marsh, but still within the daily traveling range of breeding pairs. A wider distribution of the defense sites would result from such a pattern than from a linear arrangement of ponds adjacent to the shoreline. Another result would be more efficient utilization of nesting cover, with greater dispersion of nests and lowered predation rates.

The potholes and ditches should be in lowland areas where ground water lies near enough to the soil surface to maintain adequate water levels.

Excessive nest predation on spoil banks greatly reduces the potential of pothole and ditch development in marsh interiors.

There must be a suitable large shallow water area within the daily traveling range of breeding pairs. This marsh should provide all of the daily requirements except those of nesting cover and isolation from other pairs. Top quality nesting cover in unlimited quantity close to the ponds is essential, as are brood rearing waters.

Lowland areas subjected to frequent uncontrolled flooding should generally be avoided. At Lower Souris, whitetop-cordgrass meadows which were at times flooded provided otherwise adequate sites for artificial ponds. In areas such as this a combination dike and level ditch could be built around a group of artificial ponds to hold out high water. This method was employed in 1958 at Lower Souris.

Grassland areas, because of the open nature of the banks of ponds constructed there make preferred sites.

Fertile mineral soils provide the greatest return of the investment. In the Midwest sandy loams have shown satisfactory results (Hammond, 1958).

Concentrations of breeding ducks into greater than natural densities will probably increase losses to nest predation. Some form of predator control should be established. Earlier trapping seasons on refuges in northern areas would permit harvest of mink and raccoons from the artificial water areas prior to freeze-up, and would also help to defer the cost of the development work. For skunks and raccoons, the two most serious predators of duck nests in the region, control by poison eggs, may be the most effective.

The above discussion, which applies mainly to Lower Souris Refuge might not be entirely valid for areas where ecological conditions differ.

Aspects of dabbling duck management have been the primary concern of the investigation. Where diving duck habitat is to be improved techniques will likely differ.

SUMMARY

1. A study was conducted during 1957-58 to evaluate an experimental artificial pothole and level ditching project at Lower Souris National Wildlife Refuge in North Dakota.

2. Populations of nesting waterfowl were measured by censuses made weekly during the breeding season on 181 artificial potholes and level ditches in four study areas. Behavioral observations of breeding pairs provided a check on census reliability and furnished added data on pond utilization. Other counts conducted during the summer and fall measured use by broods, summering and migrant ducks. Production was determined from brood studies. Surveys were made of vegetation in the ponds and on the spoil banks.

3. Increases in breeding populations attributed to the pothole and ditch development ranged from 6 to 29 pairs per mile of shoreline for potholes and ditches located along the lake edge. Potholes distributed in low-lying tracts extending back from the marsh attracted more than one pair per water area, or nearly 500 pairs per square mile.

4. Duck populations on similar developments at other midwestern refuges showed wide variation, indicating that other properties of the habitat besides the ponds themselves strongly influenced duck use and resulting production.

5. Use of the artificial ponds was largely limited to breeding pairs. The water areas served the ducks as jumping-off places for

investigations of nesting cover and for laying flights to the nest. They were defended and used as waiting areas by the mated drakes. Most activity occurred early in the morning, when breeding pairs flew to the ponds after spending the night on the larger adjacent marsh. Later in the day they returned to the marsh. Pothole and ditch occupancy was greatest during early morning hours and lowest in late evening.

6. Duck use per acre of water area was approximately the same for potholes of from 500 to 2000 square feet in size.

7. The primary function of the artificial ponds was to meet the territorial requirements of breeding waterfowl.

8. The pothole and ditch development was believed responsible for an increase in production ranging from 29 to 80 percent of the previous level. From 2 to 16 broods per wet acre were hatched by ducks attracted by the development. Future production at Lower Souris was predicted on the basis of a hatching success rate of 50 percent.

9. The minimum productive life of the development under management was estimated to be about 30 years.

10. Rapid establishment of vegetation on spoil banks made seeding to prevent erosion unnecessary at Lower Souris.

11. The greatest management problem is the control of undesirable emergent aquatic vegetation which tends to fill the artificial ponds.

12. Planting of pondweeds to hasten establishment was found to be impractical and unnecessary at Lower Souris Refuge.

13. Artificial potholes were more economical producers of ducks than were level ditches. Ponds ranging from 500 to 2000 square feet in size

and spaced about 100 feet apart were most satisfactory. Spoil banks probably do not need to be leveled.

14. Costs of ducks produced by artificial potholes and level ditches placed in suitable habitat did not, when amortized over a period of 30 years, exceed $0.25 per duckling.

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APPENDIX

Table 14. Physical date relating to artificial potholes and level ditches, Lower Souris Refuge

	Study area				
	I	II	III	IV	Total
Number of water areas	25	53	69	34	181
Dragline	25	53	35	34	147
Dozer			34		34
Total surface area in square feet	117,145	79,776	71,736	39,625	308,282
Dragline			32,133		
Dozer			39,603		
Average surface area in square feet	4,686	1,054	1,039	1,165	1,714
Dragline			918		
Dozer			1,165		
Total volume of earth excavated in cubic yards	13,344	7,038	8,544	2,482	31,408
Dragline			4,473		
Dozer			4,071		
Average volume of earth excavated in cubic yards	534	133	124	73	174
Dragline			128		
Dozer			120		

Table 15. Waterfowl species nesting at Lower Souris Refuge listed in descending order of abundance

Common name[a]	Scientific name
Blue-winged teal	Anas discors
Gadwall	Anas strepera
Mallard	Anas platyrhynchos
Pintail	Anas acuta
Redhead	Aythya americana
Shoveler	Spatula clypeata
Lesser scaup	Aythya affinis
Canvasback	Aythya valisneria
American widgeon (Baldpate)	Mareca americana
Ruddy duck	Oxyura jamaicensis
Canada goose	Branta canadensis
Green-winged teal	Anas carolinensis
Wood duck	Aix sponsa
Hooded merganser	Lophodytes cucullatus

[a]Nomenclature according to the A. O. U. Checklist, Fifth Ed., 1957.

Table 16. Common and scientific names of animals mentioned

Common name	Scientific name
Birds[a]	
American bittern	*Botaurus lentiginosus*
Coot	*Fulica americana*
Common crow	*Corvus brachyrhynchos*
Hungarian partridge	*Perdix perdix*
Killdeer	*Charadrius vociferus*
Mourning dove	*Zenaidura macroura*
Ring-necked pheasant	*Phasianus colchicus*
Sharp-tailed grouse	*Pediocetes phasianellus*
Mammals[b]	
Badger	*Taxidea taxus*
Coyote	*Canis latrans*
Fox	*Vulpes fulva*
Mink	*Mustela vison*
Muskrat	*Ondatra zibethica*
Raccoon	*Procyon lotor*
Striped skunk	*Mephitis mephitis*
Long-tailed weasel	*Mustela frenata*
White-tailed deer	*Odocoileus virginianus*
Others	
Frogs	*Family Ranidae*
Back swimmers	*Family Notonectidae*
Diving beetles	*Family Dytiscidae*
Water boatmen	*Family Corixidae*

[a]Nomenclature according to the A. O. U. Checklist, Fifth Ed., 1957.

[b]Palmer (1954).

Table 17. Common and scientific names of plants mentioned[a]

Common name	Scientific name
Arrowhead	Sagittaria spp.
Baltic rush	Juncus balticus
Bladderwort	Utricularia vulgaris
Bluegrass	Poa spp.
Bulrush	Scirpus spp.
Canada thistle	Cirsium arvense
Canada wild rye	Elymus canadensis
Cattail	Typha spp.
Clasping-leaf pondweed	Potamogeton richardsonii
Common cattail	Typha latifolia
Dock	Rumex spp.
Flixweed	Descuriania sophia
Germander	Teucrium occidentale
Hardstem bulrush	Scirpus acutus
Horned pondweed	Zannichellia palustris
Marsh elder	Iva xanthifolia
Muskgrass	Chara spp.
Needlegrass	Stipa spp.
Phragmites, Reedgrass	Phragmites communis
Pondweed	Potamogeton spp.
Prairie cordgrass	Spartina pectinata
Prairie Junegrass	Koeleria cristata
Quaking aspen	Populus tremuloides
Ragweed	Ambrosia spp.
River bulrush	Scirpus fluviatilus
Rose	Rosa spp.
Rough cinquefoil	Potentilla norvegica
Sago pondweed	Potamogeton pectinatus
Sedge	Carex spp.
Silverscale	Atriplex argentea
Silverweed	Potentilla anserina
Sloughgrass	Beckmannia syzigachne
Smartweed	Polygonum spp.
Smooth brome	Bromus inermis
Small pondweed	Potamogeton pusillus

Common name	Scientific name
Softstem bulrush	*Scirpus validus*
Sow thistle	*Sonchus arvensis*
Spikerush	*Eleocharis palustris*
Star duckweed	*Lemna trisulca*
Sweet clover	*Melilotus spp.*
Three square	*Scirpus americanus*
Water hemlock	*Cicuta maculata*
Water hoarhound	*Lycopus americanus*
Water milfoil	*Myriophyllum exalbescens*
Water plantain	*Alisma spp.*
Waterweed	*Elodea occidentalis*
Wheatgrass	*Agropyron spp.*
Whitetop	*Scolochloa festucacea*
Wild barley	*Hordeum jubatum*
Wild millet	*Echinochloa crus-galli*
Willow	*Salix spp.*
Wolfberry	*Symphoricarpos occidentalis*

[a]Nomenclature from Stevens (1950) and Fassett (1957).

Table 18. 1957 weekly waterfowl breeding pair populations, Study Area I

Species	Number of breeding pairs											
	4/27[a]	5/4	5/11	5/18	5/25	6/1	6/8	6/15	6/22	6/29	7/14	Peak number
Mallard	0	2	2[b]	1	1	1	2	2	0	1	1	2
Pintail	0	0	1	0	0	0	0	0	1	0	0	1
Blue-winged teal	0	11	7	14	16	7	12	18	19	18	9	19
Shoveler	0	1	1	3	0	1	0	2	0	0	0	3
Gadwall	1	2	0	13	14	7	4	8	7	10	10	14
Baldpate	0	0	0	0	0	0	0	1	0	0	0	1
Scaup	0	0	0	0	1	1	0	2	0	0	1	2
Total	1	16	11	31	32	17	18	33	27	29	21	42

[a]Represents count made during the weekly period ending April 27.

[b]Peak count is underlined for each species. Figures show indicated pairs.

Table 19. Weekly waterfowl breeding pair populations--Study Area I

Species	Number of breeding pairs									
	4/27[a]	5/4	5/11	5/18	5/25	6/1	6/8	6/15	6/22	Peak number
Mallard	1	4	7[b]	3	4	5	6	2	1	7
Pintail	0	0	0	0	0	0	1	0	0	1
Blue-winged teal	0	0	12	31	26	31	38	36	23	38
Shoveler	0	0	0	2	2	5	6	4	2	6
Gadwall	0	0	2	17	18	27	21	21	20	27
Baldpate	0	0	1	0	2	1	3	0	1	3
Scaup	0	0	0	1	3	2	5	4	3	5
Total	1	4	22	54	55	71	80	67	50	87

[a]Represents count made during the weekly period ending April 27.

[b]Peak count is underlined for each species. Figures show indicated pairs.

Table 20. Weekly waterfowl breeding pair population, 1957 - Study Area II

Species	Number of breeding pairs											
	4/27[a]	5/4	5/11	5/18	5/25	6/1	6/8	6/15	6/22	6/29	7/14	Peak number
Mallard	3	3	4	3	5[b]	2	5	2	2	4	0	5
Pintail	1	1	1	2	2	4	0	0	1	0	0	4
Blue-winged teal	10	10	25	30	37	41	39	35	32	24	1	41
Shoveler	3	1	2	5	3	3	2	4	4	2	0	5
Gadwall	8	7	5	10	12	16	8	10	13	7	1	16
Baldpate	0	0	1	1	1	0	0	0	0	0	1	1
Scaup	0	0	1	0	2	1	0	0	2	1	0	2
Redhead	3	0	0	0	1	0	1	0	1	1	0	1
Total	28	22	39	51	59	67	55	51	55	39	3	75

[a]Represents count made during the weekly period ending April 27.

[b]Peak count is underlined for each species. Figures show indicated pairs.

Table 21. Weekly waterfowl breeding pair populations, 1958 - Study Area II

Species	Number of breeding pairs									
	4/27[a]	5/4	5/11	5/18	5/25	6/1	6/8	6/15	6/22	Peak number
Mallard	4	1	2	3	3	6[b]	3	1	2	6
Pintail	0	1	0	3	0	3	4	3	1	4
Blue-winged teal	0	0	18	39	43	51	45	35	24	51
Shoveler	2	1	2	7	5	5	7	5	5	7
Gadwall	2	0	19	15	19	20	21	22	13	22
Baldpate	0	0	1	1	1	2	1	3	2	3
Green-winged teal	0	0	0	1	0	1	0	1	1	1
Scaup	0	0	0	0	0	2	0	4	2	4
Redhead	0	0	0	0	0	0	3	1	0	3
Total	8	3	42	70	72	90	84	75	50	101

[a] Represents count made during the weekly period ending April 27.

[b] Peak count is underlined for each species. Figures show indicated pairs.

Table 22. Weekly waterfowl breeding pair populations, 1958 - Study Area III

Species	Number of breeding pairs									
	4/27[a]	5/4	5/11	5/18	5/25	6/1	6/8	6/15	6/22	Peak number
Mallard	4	2	7	3	1	1	3	1	0	7
Pintail	0	0	0	0	0	0	0	0	0	0
Blue-winged teal	0	0	9	42	35	47	24	35	28	47
Shoveler	0	0	0	0	1	0	5	4	3	5
Gadwall	0	0	0	8	20	23	22	18	10	23
Baldpate	0	0	0	0	0	0	1	1	1	1
Scaup	0	0	0	0	1	0	0	0	0	1
Total	4	2	16	53	58	71	55	59	42	84

[a]Represents count made during the weekly period ending April 27.

[b]Peak count is underlined for each species. Figures show indicated pairs.

Table 23. Weekly waterfowl breeding pair populations, 1957 - Study Area IV

Species	Number of breeding pairs						
	5/18[a]	5/25	6/1	6/8	6/15	6/22	Peak number
Mallard	7[b]	2	4	1	Not censused	2	7
Pintail	3	2	1	0		0	3
Blue-winged teal	6	21	21	11		9	21
Shoveler	0	0	4	1		2	4
Gadwall	2	2	7	7		5	7
Baldpate	0	3	2	3		4	4
Green-winged teal	0	1	0	1		0	1
Scaup	0	1	0	0		0	1
Redhead	0	1	0	0		0	1
Canvasback	0	2	0	0		0	2
Total	18	35	39	24		22	51

[a]Represents count made during the weekly period ending May 18.

[b]Peak count is underlined for each species. Figures show indicated pairs.

Table 24. Weekly waterfowl breeding pair populations - Study Area IV

Species	Number of breeding pairs								
	4/27[a]	5/4	5/11	5/18	5/25	6/1	6/8	6/15	Peak number
Mallard	10[b]	6	3	4	7	3	4	5	10
Pintail	2	0	0	0	2	2	0	0	2
Blue-winged teal	0	7	10	22	21	15	7	5	22
Shoveler		-migration-		5	5	3	0	0	5
Gadwall	2	2	4	4	10	12	10	4	12
Baldpate	0	0	0	0	4	0	0	0	4
Green-winged teal	0	0	0	0	1	0	0	0	1
Scaup	0	0	0	0	1	0	0	2	2
Redhead	0	0	0	0	0	0	1	1	1
Canvasback	0	0	0	0	1	0	1	0	1
Total	14	15	17	35	52	35	23	17	60

[a]Represents count made during the weekly period ending April 27.

[b]Peak count is underlined for each species. Figures show indicated pairs.

Table 25. Weekly waterfowl breeding pair populations, 1957 - control area

Species	Number of breeding pairs				
	4/18[a]	5/25	6/1	6/8	Peak number
Mallard	4[b]	0	3	1	4
Pintail	3	1	1	0	3
Blue-winged teal	5	8	13	8	13
Shoveler	1	1	0	0	1
Gadwall	0	0	6	3	6
Baldpate	0	0	2	0	2
Green-winged teal	0	0	0	0	0
Scaup	0	0	0	0	0
Redhead	0	0	1	0	1
Canvasback	0	0	0	0	0
Total	13	10	26	12	30

[a]Represents count made during the weekly period ending May 18.

[b]Peak count is underlined for each species. Figures show indicated pairs.

Table 26. Weekly waterfowl breeding pair populations, 1958 - control area

Species	Number of breeding pairs								
	4/27[a]	5/4	5/11	5/18	5/25	6/1	6/8	6/15	Peak number
Mallard	7[b]	4	4	1	7	3	0	2	7
Pintail	1	0	0	0	1	2	1	1	2
Blue-winged teal	0	4	8	12	10	7	9	4	12
Shoveler	- migration -			1	2	0	0	0	2
Gadwall	0	0	0	8	8	8	4	7	8
Baldpate	2	0	0	0	0	0	0	0	2
Green-winged teal	0	0	0	0	0	0	0	0	0
Scaup	0	0	0	0	1	1	0	0	1
Redhead	0	0	0	1	0	0	0	0	1
Canvasback	0	0	0	0	2	0	0	0	2
Total	10	8	12	23	31	21	14	14	37

[a]Represents count made during the weekly period ending April 27.

[b]Peak count is underlined for each species. Figures show indicated pairs.