# HISTORY OF WATER MANAGEMENT AT THE SENEY NATIONAL WILDLIFE REFUGE

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY
CONRAD ALAN FJETLAND

1973

ABSTRACT

HISTORY OF WATER MANAGEMENT AT THE
SENEY NATIONAL WILDLIFE REFUGE

By

Conrad Alan Fjetland

The history of water management on the Seney National Wildlife Refuge in northern Michigan was studied from the refuge's development in 1935 through 1969. Management prior to 1963 consisted of holding the pools at a stable level year around. Drawdowns for maintenance were frequently necessary and some biological drawdowns were tried, but managers in this period generally considered the pools with a history of stable water levels as the best pools on the refuge. In 1963 the approach to water management changed from one of stable water levels to one of fluctuating water levels. The general practice was to hold levels higher in the spring than at other periods of the year. Biological drawdowns were instituted as a normal management practice in 1963.

Census data from 1963 through 1969 were analyzed to determine how the water management practices in use affected waterfowl use. Analysis of the use by all waterfowl, Canada geese, mallards, black ducks, and ring-necked ducks was made. Pools were ranked by waterfowl preference and use on each pool was compared from one year to the next to determine where significant changes in use had taken place. Waterfowl use was related to water management through contingency tables. In two instances a dependency ($X^2 > 5.991$) was found between drawdowns and changes in waterfowl use. Canada goose use was found to be more likely to increase the same year as a drawdown and ring-necked duck use was found to be more likely to decrease the year following a drawdown. No dependence was found between mallard, black duck, and all waterfowl use and drawdowns. It is recommended that the biological drawdown be de-emphasized as a management tool at Seney Refuge because of its limited effectiveness. A relationship between fluctuating water levels and ring-necked duck habitat is discussed.

# HISTORY OF WATER MANAGEMENT AT THE SENEY NATIONAL WILDLIFE REFUGE

By

Conrad Alan Fjetland

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Resource Development

1973

G78904

## ACKNOWLEDGMENTS

Expressing thanks to all the people that have contributed to this paper is an impossible task. Over the years, many people have offered small bits of advice and criticism that, cumulatively, have played an important role in the paper's completion. A few have been major influences on this work, however, and I am indebted to them for their help.

Dr. C. R. Humphreys of Michigan State University inspired me to conduct research in the field of water management and got me started on this project. Manager John E. Wilbrecht of the Seney National Wildlife Refuge opened his files to me, provided invaluable guidance and technical assistance, and offered considerable constructive criticism as work on this thesis progressed. Dr. Lewis M. Cowardin of the Northern Prairie Wildlife Research Center was extremely helpful in suggesting the correct statistical approach to use. Dr. Harold H. Prince of Michigan State University reviewed the statistical analysis and offered suggestions as to the correct interpretation of the results.

I would like to thank Dr. C. R. Humphreys, Dr. Harold Prince, and Dr. Milton H. Steinmueller of Michigan State University for their critical reading of the manuscript and their comments.

Most of all, I want to thank my wife, Judy, for her patience and continued inspiration through the three long years it took to complete this thesis.

TABLE OF CONTENTS

LIST OF TABLES

| Table | | Page |
|---|---|---|

## LIST OF FIGURES

# INTRODUCTION

## Purpose of the Study

For many years, conservationists have been concerned over the continued decline in good waterfowl habitat. The tremendous growth of the human population has placed new demands on our environment. Land is needed to satisfy these demands: to grow the food needed; to furnish sites for development of urban areas; to supply recreational facilities for the growing hordes seeking ways to spend their leisure time.

High on the priority list of available sites for land development are the wetlands; the marshes, swamps, sloughs and floodplains that are relatively cheap to purchase and are generally unsuited for human use in their present condition. With each land "improvement," another piece of waterfowl habitat is lost forever. When all these losses are combined into one figure for the nation, the total is tremendous.

To offset these losses, projects such as the Waterfowl Production Area Program have been designed to preserve waterfowl habitat. These programs can hope to do little more than reduce future losses, however. To preserve our waterfowl resources, existing wetlands must be improved as well as preserved.

One of the most effective ways to improve a marsh is to develop and use a sound water management program. The proper use of water to improve habitat is no easy task, however. A marsh's ecology is a composite expression of the interaction of chemical and physical factors. Types of bottom soil, corresponding aquatic plant growth, water chemistry, and turbidity, all influence the character of a marsh and, hence, in some degree determine its value to waterfowl (Griffith, 1957).

All too often, these complex interactions are not considered before a water management program is developed for an area. Managers tend to adopt a program because it worked someplace else. Unfortunately, what works in Iowa may not work in Michigan. Further, what worked in Michigan ten or twenty years ago, may no longer be applicable.

The area of this study, the Seney National Wildlife Refuge, located in Michigan's Upper Penninsula, has been subjected to a wide variety of water management practices since its development in 1935. Over the years, a tremendous amount of data has been collected. Most of this information has remained unused in the refuge files.

The purpose of this study is to examine the history of water management on the Seney National Wildlife Refuge. A general review of each pool's history will be made. This will be followed by a detailed analysis of recent management, and the drawdown in particular, and how this management affects waterfowl use.

## Review of Literature on Water Management Practices

Many studies have been conducted over the years into the relationships between water level and marsh ecology. As biologists became aware of the possible benefits of fluctuating water levels in a marsh, numerous papers appeared discussing how water could be used to control undesirable plants, improve aquatic vegetation and affect waterfowl populations. These initial studies into water management were followed by in-depth research into the physical, chemical, and biological results of water level fluctuations and, in particular, the drawdown. This review of the literature is intended to highlight some of the more important papers on the subject of water management.

Prior to 1940 it was generally felt that stabilized water levels were essential in developing good waterfowl marshes. Bourn and Cottam (1939), McAtee (1939), Martin and Uhler (1939), and Anderson (1940) all discussed the adverse effects of fluctuating water levels. They all noted that stabilizing water levels was an important step in improving marsh conditions.

Through observations in the early 1940's such as that described by Hartman (1949), biologists began to realize that productivity on many marshes was dropping due to stabilized water levels and that these marshes could be improved by periodically draining them. Thus the biological drawdown was born.

Although the use of fluctuating water levels was practiced to improve waterfowl marshes in the 1940's, most authors approached the subject with caution and some still recommended stable water levels as the best management. Bellrose (1941) noted that lowering water levels in the summer exposes mudflats which produce more food per unit area. The moist soil plants produced on the mud flats attract larger numbers of mallards and pintails. He cautioned, however, that fluctuating water levels increase turbidity and are detrimental to aquatic plants. He recommended stable water levels for diving ducks. Low and Bellrose (1944), working in the Illinois River Valley, found that the best producers in lakes with stable water levels were burreed (*Sparganium eurycarpum*), buttonbush (*Cephalanthus occidantalis*), and longleaf (*Potamogeton americanus*). In semistable lakes, wild rice (*Zizania aquatica*), pickerelweed (*Ponterderia cordata*), and Walters millet (*Echinochloa Walteri*) were the best producers and, in fluctuating lakes, Walters millet, Japanese millet (*Echinochloa frumentacea*) and wild millet (*E. crusgalli*) were the best producers. In comparing these differences with a preferential duck food list compiled by Bellrose and Anderson (1943) it is found that the best foods were produced on the lakes with fluctuating water levels. They noted that the moist-soil plants as a group were better seed yielders than the true aquatic plants and their seeds are more readily available to most ducks.

Penfound and Schneidau (1945) listed the drawdown as one of many management tools that could be used to improve marshes in southeastern Louisiana. Griffith (1948) discussed the use of drawdowns to produce moist-soil food plants and the use of lower levels in late summer to make aquatic plant foods more readily available. He warned, however, that too low levels would allow the bottom to freeze and destroy the following year's food plants. Other authors were not so convinced of the value of fluctuating water levels and still recommended stable levels as the best management practice (Zimmerman, 1943; Moyle and Hotchkiss, 1945).

Other uses for water level fluctuations were found in the 1940's besides the improvement of aquatic and moist-soil plants for waterfowl. Ward (1942) noted that <u>Phragmites communis</u> could be controlled by flooding with as little as six inches of water. Uhler (1944) also discussed the use of changing water levels for control of several species of undesirable plants. Wiebe and Hess (1944), Wiebe (1946), and Hall, Penfound, and

Hess (1946) described how water management could be used to control malaria mosquitoes on Tennessee Valley Impoundments and at the same time improve wildlife habitat.

By 1950 the drawdown was widely accepted as a management technique and many papers appeared in the next two decades discussing virtually every aspect of water level manipulation. The mid-summer drawdown to increase seed production of moist-soil plants is widely used and has been described by many authors (Martin, 1953; Steenis, et al., 1954; Nelson, 1954; Uhler, 1956; McClain, 1957; MacNamara, 1957; and Keith, 1961).

While the drawdown was demonstrated to have useful applications in many areas, there remained instances where the results of dewatering were not beneficial. Singleton (1951) observed that valuable food plants on the east Texas Gulf Coast could be increased by maintaining constant water levels. Griffith (1957) noted that dewatering of humic soils followed by reflooding has resulted in phenomenal abundance of algae, defeating the initial objective of stimulating increased growth of desirable vegetation. Jensen (1964) found that if dewatering was not accomplished until late summer, the exposed bottom represented an extensive feeding area lost to the ecosystem. Beard (1969) found that an overwinter drawdown in Wisconsin resulted in a significant reduction in the distribution, relative abundance, and acreage of aquatic vegetation. Hammer (1970) studied the drawdown of two pools on the Lacreek National Wildlife Refuge in South Dakota and found that submergent aquatics, breeding pairs, and brood production were all lower on the pools following dewatering and that several years were required for significant recovery to take place.

Further investigations into the relationship of water to vegetation revealed that cattail (*Typha* spp.) will die out during periods of high water submerging the shoots by four feet over the winter (McDonald, 1955; Martin, *et al*., 1957). Robel (1962) found that a three inch rise of the water on the Great Salt Lake increased sago pondweed (*Potamogeton pectinatus*) 32% in those areas that had been less than sixteen inches in depth and decreased it 35% in deeper areas.

An in-depth study of changes in vegetation resulting from drawdown was conducted by Harris and Marshall (1963) on the Agassiz National Wildlife Refuge. They found that in the first season of drawdown the more an area combined early season drawdown, rich soil types, slow rates of mud flat drainage, and small amounts of stranded algae, the greater was the development of emergent aquatics. In the second year of drawdown, most areas developed greater amounts of upland and shoreline weeds and fewer emergents. On areas exposed before August

of
th
ex
of
of
(S
we
fi
ye
er

in
as
in
a
as
ot
no
no
th
ve
of
re
In
(P
la

of the first year, there was a loss of emergent cover in the second year, while the reverse was true on areas exposed later in the first year. After the second year of drawdown the soil dried more completely and by the end of five years of drawdown, nearly solid stands of willow (*Salix* spp.) developed. They also noted that sago pondweed made outstanding growth and seed production in the first year of reflooding. They recommended a one or two year drawdown every five to ten years to maintain emergent marshes at Agassiz.

Kadlec (1962) and Harter (1966) conducted studies into the chemical changes in the water and soil that are associated with a drawdown. Kadlec found a definite increase in plant nutrients during a drawdown. He noted a marked increase in soil nitrates during the drawdown as a result of aerobic nitrification. The response of other nutrients was less definite, but increases were noted and plant growth inproved. Kadlec found that the most favorable increase in fertility was obtained when the organic portion of the soil remained moist or even very wet during the drawdown. Harter found that flooding of soil changes the soil environment from oxidizing to reducing conditions within five days after flooding. Inundation of rice (*Oryza sativa* var *Zenith*) and smartweed (*Polygonium* spp.) caused a decreased uptake of calcium, magnesium, manganese and potassium and an increased uptake of phosphorus by both plants. Harter concluded that, since the nutrition of smartweed is so near that of rice, smartweed's inability to grow under waterlogged conditions is probably physiological. Drainage or ridges of soil above the water level were considered necessary to make smartweed proliferate naturally in a marsh.

Cook and Powers (1958) noted that high concentrations of iron in the marsh may inhibit plant growth and that iron may be regulated by oxidation through drainage followed by judicious applications of lime to raise the pH above 7.5.

Several authors have commented on the direct effect on waterfowl of water level manipulations. Brumsted (1954) noted that low water in late summer jeopardizes broods and has a selective effect on late-nesting species. Johnsgard (1955) observed that the net result of all the ecologic changes resulting from water fluctuation is a decrease in the variety of fauna and flora, with a concurrent increase in the number of individuals of a few of the more adaptable species. Wolf (1955) found that the result of water fluctuations behind dams, often quite drastic, was the development of less desirable habitats, discouraging some waterfowl from nesting. However, he found no difference in brood survival between areas of falling, stable, and fluctuating water levels. Weller and Spatcher (1965) noted that ma

we

Be

Ma

wh

co

Hi

di

bo

An

be

ma

mi

th

ma

mi

of

ma

We

in

of

pr

us

of

maximum bird numbers and diversity were reached when a well-interspersed cover-water ratio of 50:50 occurred. Bednarik (1963a) found that too high water levels in the Magee Marsh in Ohio concentrated duck nests on dikes where they were subject to high rates of predation, while complete drawdown resulted in a loss of pair habitat. His basic approach was to manipulate water levels in each diked marsh unit to expose the higher elevations of marsh bottom, creating a greater amount of nesting habitat. Anderson and Glover (1967) observed that areas flooded before spring migration produced nearly three times as many ducklings per acre as areas flooded after spring migration but before the nesting season. They concluded that waterfowl production and use may be increased on managed areas by flood-irrigation before the spring migration.

Much of the current thinking on the management of wetlands for waterfowl has been compiled into a field manual for wetland managers entitled "Techniques for Wetland Management" by Linde (1969). Linde's manual includes a section on drawdowns that discusses the use of drawdowns for food patch establishment, mud-flat food production, and muskrat control. He discusses the proper use of drawdowns and what the limitations of this method of marsh management are.

atur

mana

ecol

tool

a c

appl

effe

area

show

env

of

one

95,

of

qua

mil

off

Dec

was

Swa

As can be seen from this survey of the literature, the use of water level manipulations as a wildlife management tool results in many complex changes in the ecology of a marsh. The drawdown in a good management tool and has widespread applicability; however, it is not a cure-all for every marsh's problems. The same technique applied in two different areas can have a beneficial effect on one area and a detrimental effect on the other area. Thus, the management plan for a waterfowl area should be based on the objectives of the area, local environmental conditions, past histories, and analysis of practices employed, both on that area and on similar ones.

## Study Area

The Seney National Wildlife Refuge comprises 95,455 acres in Schoolcraft County, Michigan, southwest of Seney and west of Germfask (Figure 1). Refuge headquarters is located five miles south of Seney and one mile west of Michigan Highway 77. The refuge was officially established by Executive Order No. 7246 dated December 10, 1935, although initial construction work was begun in the summer of 1935 (Gillett, 1965).

The refuge is located within the Great Manistique Swamp, an area described by Halladay (1965) as:

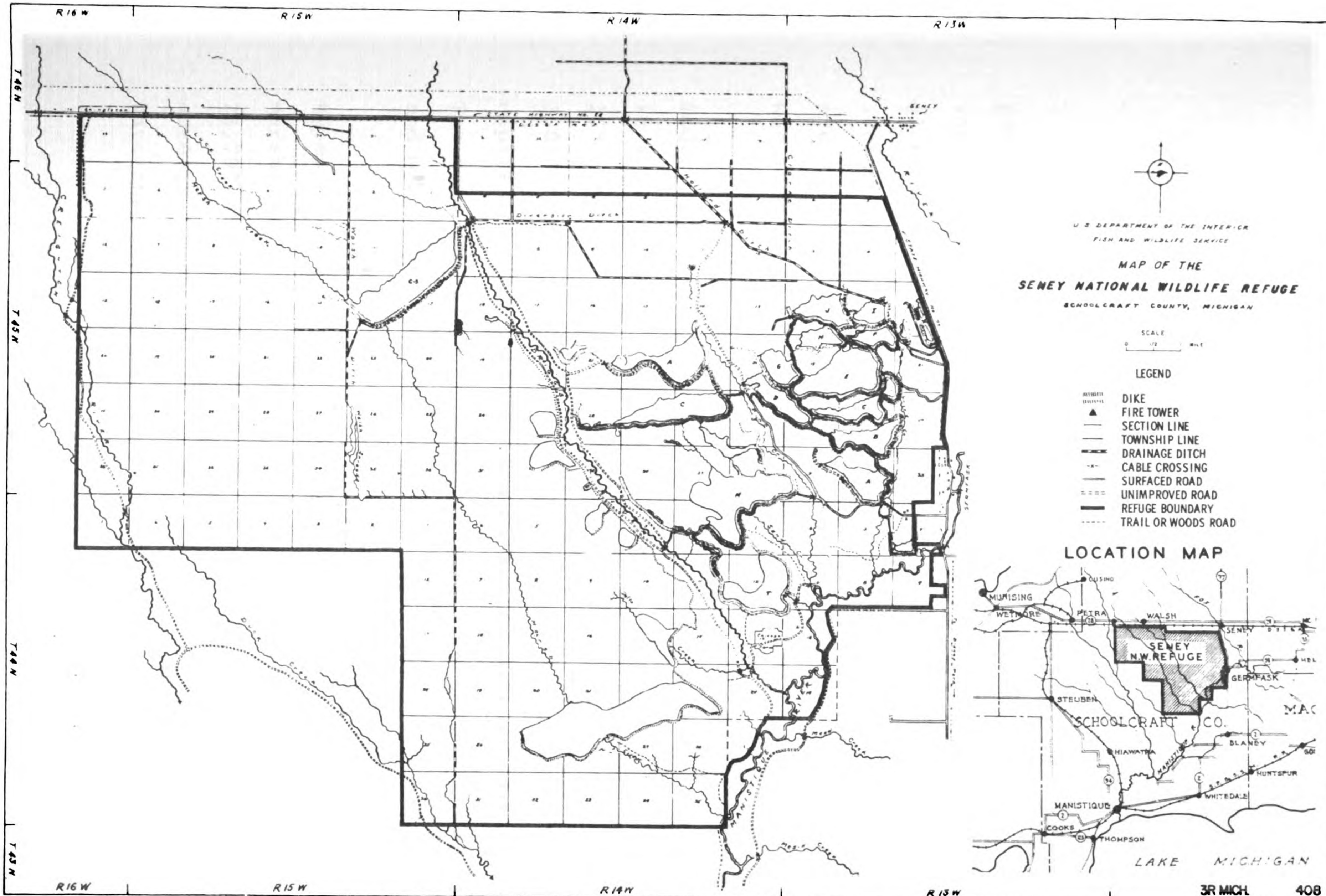


Figure 1.--Map of the Seney National Wildlife Refuge.

> . . . characterized by vast expanses of lowlands, consisting of a black spruce bog condition interspersed with patches of sedge glade and strips of high ground which support white and red pine. . . . The soil and subsoil throughout this region is pure, medium sand. Only a few inches of the surface layer have weathered and contain organic matter. Accumulations of peat and muck have formed throughout most of the bog and wet areas.

As the last of the glacial ice melted, the sandplain base of the area was formed by glacial outwash. The area was then flooded by a high water phase of the glacial Great Lakes between 9,500 and 10,000 years ago (Heinselman, 1965). The sand knolls or ridges of the area appear to be extinct dunes formed as the sandplain was first drained (Berquist, 1936).

Seney has a cool continental climate, somewhat moderated by the Great Lakes. The mean annual temperature is about 40° F.; mean July, 65° F.; and mean January, 15° F. Maximum and minimum temperatures recorded are 100° F. and -31° F. respectively. Average annual precipitation is 32.58". Snowfall averages 116 in. annually. The frost-free season is short, averaging about 73 days; and mid-summer frosts are not uncommon.

The refuge is composed of five broad habitat types, of which 430 acres are cropland; 10,240 acres, marsh; 7,243 acres, open water; 50,632 acres, swamp; and 26,797 acres, upland (timber and brush). Of the total acreage of the refuge, 23,513 acres are considered as waterfowl habitat (Table 1).

TABLE 1.--Habitat types and acres available as waterfowl habitat on Seney National Wildlife Refuge.

| Habitat Type | Total Acres | Waterfowl Habitat Acres |
|---|---|---|
| Cropland | 430 | 430 |
| Marsh | 10,240 | 4,960 |
| Water | 7,243 | 7,243 |
| Timberland | 22,957 | 1,920 |
| Swamp | 50,632 | 8,960 |
| Brush | 3,840 | -- |
| Administrative Land | 113 | -- |
| Total | 95,455 | 23,513 |

The land within the refuge boundaries has an interesting history. The last two decades of the 19th century saw most of the pine forests of the eastern Upper Peninsula cut. Some white pine (*Pinus strobus*, scientific names of plants in accordance with Fernald, 1950) was cut within the refuge boundary, although only small, isolated groves were found on the higher ground within the bogs and marshes (Halladay, 1965). Far more damaging to the land than the logging were the numerous fires near the turn of the century. Many of these fires were set to get rid of the waste left over from the timber removal. The result was a loss of the humus and other nutrients in the shallow layers of topsoil. In many areas the sandy subsoil was exposed and even now, seventy years later, the land remains open, or is covered by scattered aspen (*Populus* spp.). In other areas, jack pine (*Pinus Banksiana*) has sprung up in dense stands where the white pine forests once stood.

Following the removal of the forests, developers advertised the land as fertile farming country. Demonstration farms were set up and heavily fertilized to convince prospective buyers that the soil was actually very productive (Sypulski, 1941). It was during this period (1910-1920) that many drainage ditches were constructed in an attempt to lower the water table.

People bought the land and tried to farm it. They soon found, however, that the promoters' story of the land was much better than the land itself. The combination of poor soils, high water table, and short growing season was too much to overcome and many of the farmers were soon bankrupt. The farms were then abandoned and became tax delinquent, or were sold as hunting grounds.

By 1933, the Michigan Department of Conservation decided that the area was best suited for waterfowl and recommended that a federal refuge be established. As previously noted, this was done in 1935. The land came from three major sources: 2,736.5 acres was unreserved public domain; 7,069 acres was obtained from other federal agencies; and 85,648.8 acres were purchased, either from the State of Michigan or from private owners, at a cost of $177,340--an average cost of $2.07 per acre.

Seney Refuge serves both as a breeding area and as a resting and feeding stop for migrating waterfowl. Common breeding ducks are the mallard (*Anas platyrhynchos*, scientific names of birds in accordance with the American Ornithologists' Union Check-list, 1957), black duck (*Anas rubripes*), and ring-necked duck (*Aythya collaris*). The blue-winged teal (*Anas discors*), wood duck (*Aix sponas*), common goldeneye (*Bucephala clangula*), hooded merganser (*Hophodytes cucullatus*), and common merganser (*Mergus merganser*) also frequently nest on the refuge.

Of particular interest at Seney Refuge is the established flock of breeding giant Canada geese (Branta canadensis maxima). This flock was established in 1936 when 332 pinioned birds were released into two large goose pens (Johnson, 1947). The flock numbers about 1,500 birds at present. It has been closely managed over the years and many of the water management practices used on the refuge have been intended primarily for the Canada goose.

## General Hydrology and Limnology of Seney Refuge

The natural drainage pattern in the vicinity of the refuge is in a south-woutheasterly direction into the Manistique River which flows southwesterly. The gradient is six to twelve feet per mile (Heinselman, 1965).

The natural drainage was altered considerably in the early 1900's by the construction of numerous drainage ditches in the area in connection with the attempts at land development. The first of these ditches was the Clark Ditch, constructed in 1910. This ditch is about 3.5 miles long, with 1.1 miles within the refuge boundary. In 1911, the 8.7 mile Holland Ditch was dug, with 4.2 miles of this ditch on the refuge. The 23.1 mile Walsh Ditch was dug in 1915. Fifteen miles of this ditch are on the refuge.

The refuge pools were impounded by dikes built generally in an east-west direction across the natural drainage. Water flows by gravity from one pool to the next as it makes its way to the Manistique River. No pumping is necessary.

The refuge pool system is divided into three units. Unit one includes all those pools east of Pine Creek. Unit two contains the pools between Pine Creek and the Driggs River; and unit three includes those pools west of the Driggs River. There are 21 major pools on the refuge: 14 in Unit I; 4 in Unit II, and 3 in Unit III. In addition, there are several small impoundments created in Unit III by a series of spur dikes along the Riverside Dike. These are prefixed by an "s" in the flow chart (Figure 2). The flow chart indicates the principal water courses through the refuge. Unit I offers the most choices to the water manager, for the flow to D-1, F-1, G-1, H-1, I-1, or the Lower Goose Pen can be shut off without disrupting the flow through the remainder of the pools in the unit. In Unit II, only T-2 can be isolated without shutting water off to the entire unit. In Unit III, the flow cannot be effectively cut off from any of the pools.

No gauging stations are maintained on the north end of the refuge to accurately document water inflow data. Water supplies can be inferred, however, from outflow data; and some information on outflow data is available. The United States Geological Survey maintains guaging stations on the Manistique River near Germfask and Blaney Park. Outflow data can be approximated by


Holland Ditch
Clark's Ditch

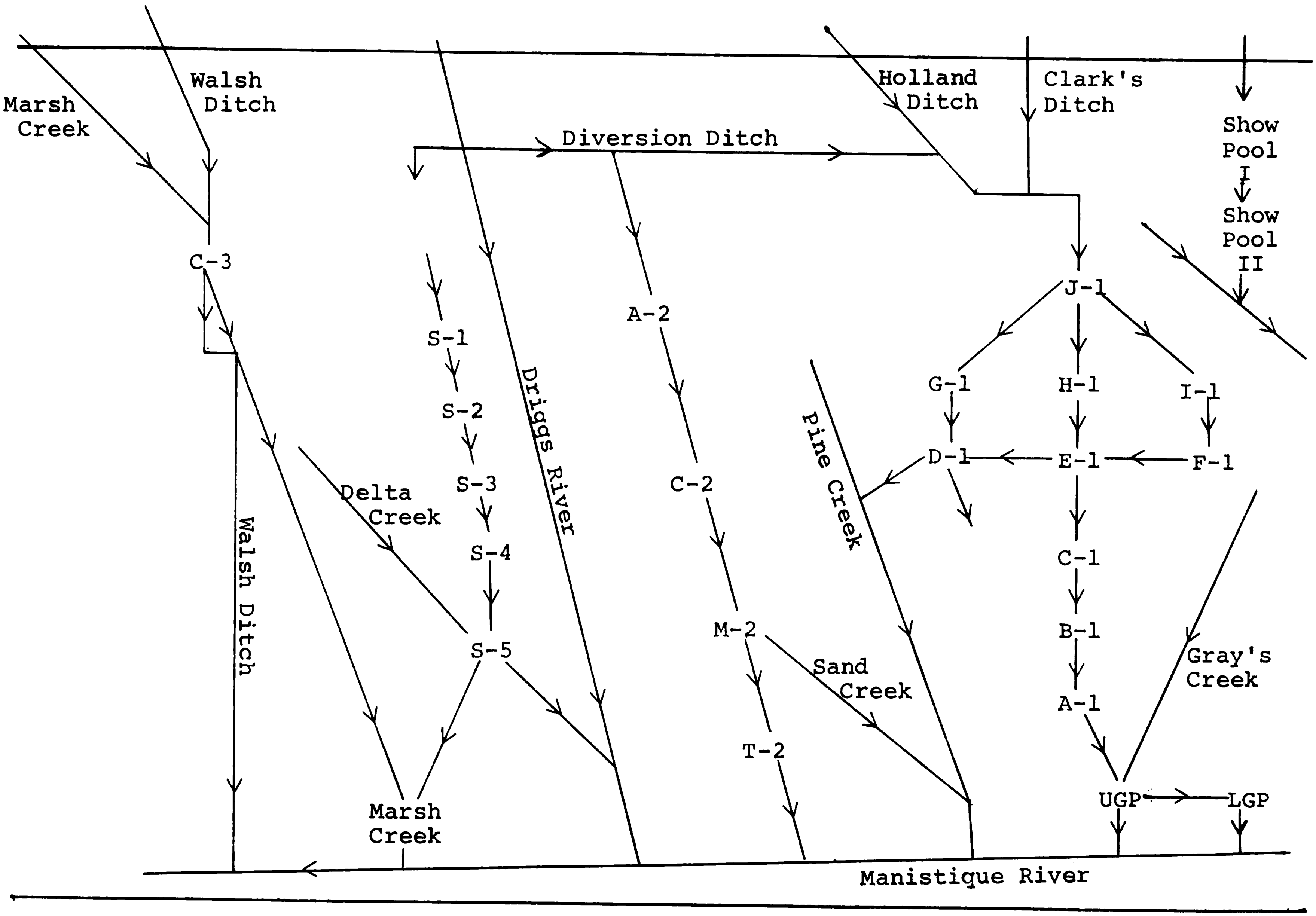


Figure 2.--Flow chart of the Seney Refuge Water System.

subtracting the Germfask station reading from the Blaney Park reading. Table 2 presents the mean discharge for each month based on seven years' readings (1962-1968). Maximum and minimum discharges for each month during the seven years are also given.

There are three tributaries to the Manistique River between these two stations which do not flow from the refuge but which are included in Table 2. These are Mead Creek, Mezik Creek, and Duck Creek. Partial-record stations have been recently established on these tributaries to determine their contribution. In addition, Holland Creek discharges from the refuge, but above the Germfask gauging station. Partial readings from this creek, as well as the other three, are presented in Table 3.

There are three main sources of water into Units I and II: Clark Ditch, Holland Ditch, and Diversion Ditch. Diversion Ditch was constructed in 1938 so that water could be diverted from the Driggs River into Units I and II when there was an insufficient supply from the normal sources. Normally, no water is channeled into it from the Driggs River.

Diversion Ditch has three water-control structures. A reinforced concrete control structure is located underneath the Driggs River Road bridge just east of the Driggs River and is used to control water entering the

TABLE 2.--Seney National Wildlife Refuge outflow data, 1962-1968, based on the difference between the USGS gauging stations on the Manistique River at Blaney Park and Germfask, Michigan.

| Month | Discharge in CFS | | |
|---|---|---|---|
| | Mean | Maximum | Minimum |
| January | 277 | 912 | 70 |
| February | 233 | 633 | 85 |
| March | 394 | 2,080 | 90 |
| April | 1,272 | 2,770 | 309 |
| May | 597 | 1,630 | 173 |
| June | 306 | 959 | 111 |
| July | 160 | 884 | 48 |
| August | 120 | 504 | 72 |
| September | 190 | 729 | 53 |
| October | 317 | 882 | 69 |
| November | 394 | 1,410 | 76 |
| December | 481 | 1,487 | 50 |

TABLE 3.--Partial-record discharge measurements made on tributaries to the Manistique River.

| | Discharge in CFS | | | | |
|---|---|---|---|---|---|
| | Holland Creek | Mead Creek | Mezik Creek | | Duck Creek |
| 8/15/67 | 1.71 | 1.18 | 3.35 | 9/8/67 | 1.13 |
| 11/2/67 | 7.18* | 38.2* | 15.5* | | 30.0* |
| 11/29/67 | 3.05 | 18.8 | 4.76 | 11/28/67 | 24.0 |
| 1/17/68 | 4.76 | 8.91 | 3.29 | | 4.92 |
| 5/14/68 | 3.33 | 20.2 | 6.00 | | 16.0 |
| 7/25/68 | 2.31 | 9.06 | 3.65 | | 6.56 |
| 11/7/68 | 5.67 | 20.4 | 6.52 | | 25.9 |

*Not base flow

ditch from the river. About 1 1/2 miles east of the river the ditch splits and feeds both Units I and II. Each branch of the Diversion Ditch is controlled by a concrete control structure.

One structure was constructed on the Holland Ditch just below where the Diversion Ditch intercepts. This structure, known as the Holland Ditch Diversion Structure consists of a control weir across the channel and a weir adjacent to the channel to allow a portion of excess flood waters to go into Unit II. This structure has long since been silted in, however, and is no longer functional.

Thus, all water from the Holland and Clark Ditches now flows into Unit I. Woolhiser (1942) has estimated that the discharge of Holland Ditch will vary from 15 to 500 CFS and that Clark Ditch will discharge about 25% of the volume of the Holland Ditch. Both ditches are unstable and subject to flashy runoff.

Even when no water flows from the Driggs River into Diversion Ditch, the ditch is capable of delivering up to 200 CFS from its 3000 acres of watershed (Woolhiser, 1942). The portion of this water that enters the ditch above the Unit I-Unit II split can be routed into either unit, while the rest enters Holland Ditch and Unit I.

When the pool system was first constructed, Holland Ditch was silted in below the Holland Ditch

Control Structure and the water spread out into the marshes. At that time it was estimated that 60% reached G-1 Pool and 40% reached J-1 Pool. This problem was corrected in 1946, however, and now most water flowing into Unit I enters J-1 Pool for distribution.

Water flowage in Unit III is much simpler. Water enters C-3 Pool from Walsh Ditch and Marsh Creek. It can either be discharged back into Walsh Ditch from C-3 Pool or allowed to flow through the marshes along Riverside Dike and eventually into Delta Creek or Marsh Creek Pools.

The refuge pools are shallow, depths seldom exceeding three feet except in the borrow ditches, and as a result, the pools respond quickly to changing conditions, such as temperature. The water is stained brown to varying degrees, probably due to the extensive growth of speckled alder (*Alnus rugosa*) in the area, and the presence of flooded timber in many of the pools (Linde and Morehouse, 1966; Cook and Power, 1958). In addition turbulence is often present from the effect of wind on the fine bottom materials in the shallow water. Secchi dish readings range from 2.0 to 9.5 feet as recorded by Lagler (1956).

The pH range of the refuge pools is from 7.2 to 9.7, as determined in August, 1942, by Lagler (1956) and in August, 1957, by Happ (1957). Dr. I. Barry Tarsis (personal communication) found slightly more acid conditions in June, 1964 (Range 6.0-7.4) as would be expected earlier in the growing season.

Dissolved oxygen in summer is normally near saturation. Occasionally, anaerobic conditions occur under the ice during the winter, as evidenced by infrequent winterkill of fish. The methyl orange alkalinity ranges from 27 to 75 PPM (Lagler, 1956) indicating waters of intermediate hardness characterized by normal growth of plants but not high productivity.

# HISTORY OF WATER MANAGEMENT

## Pool Histories Prior to 1963

The early history of each of the pools on the refuge is contained in several reports in the refuge files. This section contains a compilation of important events occurring prior to the year 1963. Notable sources of information were the Annual Water Plans, written each year since 1945; the Long Range Water Management Plan (Smith, 1958); and the Aquatic Plant Inventory, 1951 (Smith, 1952). Table 4 summarizes the drawdowns documented prior to 1963.

A-1 Pool was initially flooded in April, 1937, but was lowered later that same month to repair the spillbox. It was reflooded in September, 1937, and was fairly stable until 1945, when it was lowered 2 feet to protect badly eroded dikes. The level was brought back to normal in March, 1946, and the pool level was fairly stable until 1959. The pool was drained in 1959 for a pool bottom planting experiment and again in 1960 for a biological drawdown. An observation in the 1960 Water Management Plan is that the pool was used more by waterfowl in drawdown condition than before drawdown, though

TABLE 4.--Summary of drawdowns and other water level manipulations documented prior to the year 1963.

| Pool | 1936 | 1937 | 1938 | 1939 | 1940 | 1941 | 1942 | 1943 | 1944 | 1945 | 1946 | 1947 | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-1 | | IF | | | | | | | | PD | | | | | | | | | | | | | | DD | DD | | |
| B-1 | | IF | | | | | | | | | | | | PD | | DD | | PD | | | | | | | PD | LR | |
| C-1 | | IF | | | | | | | | | | | | | | | | | | | | | | | | | |
| D-1 | | IF | | DD | | | | | | | | | | | | | | | | | | DD | | | | | |
| E-1 | | IF | | | | | | | | | | | | | | | DD | | DD | | | | | | | | |
| F-1 | IF | | | | | | | | | | | | | | | | | | PD | PD | | | | | | | DD |
| G-1 | | IF | PD | PD | PD | | PD | | | | PD | PD | PD | | | | | | | | | | PD | | | | |
| H-1 | | IF | | | | | PD | DD | | PD | PD | | | | | | | DD | DD | | | | | | | | |
| I-1 | | IF | | | | | | | | | | | | | | | | | | DD | | | | | | | |
| J-1 | | IF | | | | | | | | | | | | | | | | | | DD | | | | | | | |
| UGP | | IF | | DD | DD | | | | | | | | | | | | | DD | | | | | | | | | |
| LGP | | IF | DD | | | DD | | | | | | | | | | | | | | | | DD | | | | | |
| USP | | IF | | | | | | | | | | | | | | | | | | DD | | | | | | | |
| LSP | | IF | | | | | | | | | | | | | | | | | | DD | | | | | | | DD |
| A-2 | | | | IF | | | | | | | | | DD | DD | | | | | | | | | | | | | |
| C-2 | | | | IF | | | | | | | | | PD | PD | | | | | PD | | | | | | | | |
| M-2 | | | | | | IF | PD | | | | | | | | | | | | | | PD | | PD | | | | |
| T-2 | | | | | | IF | PD | | | | | DD | | | | | | | | | | | | DD | DD | DD | DD |
| C-3 | | | | | | | IF | | | | | | PD | | DD | DD | | | | | | | | | | | |

IF = Initial Flooding; PD = Partial Drawdown; DD = Drawdown; LR = Level Raised.

not as much as the first year (1959) it was drained. A-1 Pool contains 259 surface acres of water when at crest level.

B-1 Pool was initially flooded in April, 1937, and levels remained fairly stable through 1948. In May, 1949, the pool was lowered 18 inches to create millet planting sites; normal levels were restored in March, 1950. The pool was completely drained from April, 1951, through March, 1952, for construction of a new B-A spillway. Construction of the C-B spillway in 1953 necessitated a partial drawdown in the summer of 1953. Levels were fairly stable from 1954 through 1959. In August, 1960, the pool was lowered a foot to spray cattail with herbicide, with no effects on aquatics observed. The pool was carried a foot above normal in September and October, 1961, in an attempt to drown cattail, but the efforts failed. B-1 Pool contains 243 surface acres when at crest level.

C-1 Pool was initially flooded in April, 1937. This pool is the only one on the refuge that has never been drawn down since its construction. Construction of new spillways was made possible by the use of coffer dams. The purpose of holding the levels stable during construction in 1953 and 1954 was to protect beds of wild rice that were established in the pool. C-1 Pool contains 302 surface acres when full.

D-1 Pool was initially flooded in April, 1937, but had to be lowered that same month for dike repair. Reflooded in April, 1938, the pool remained fairly stable until 1957. In that summer the pool was lowered as much as possible for construction of a new outlet to the beaver marshes below the dike. D-1 Pool is 197 acres in extent when full.

E-1 Pool was first flooded in April, 1937, and remained in a fairly stable and full condition through 1951. In the spring of 1952 the pool was drained for construction of the E-C spillway. Water levels were restored later that year and the pool remained full through 1953. In 1954 the pool was again drained for construction of the F-E and E-D spillways. This time the pool was low for most of the year. Reflooded in 1955, the pool was since remained fairly full and stable. E-1 Pool is the largest in Unit I containing 490 surface acres when full.

F-1 Pool was the first pool completed on the refuge, initial flooding taking place in September, 1936. Levels remained stable until 1954, when a brief drawdown was necessary for construction of the F-E spillway. Then in 1955, levels were dropped somewhat to facilitate construction of the I-F spillway. Neither of these two partial drawdowns is reported to have had adverse effects on the pool's aquatic plants. Levels were stable from 1956 through 1961. In November, 1962, the pool was drawn down for maintenance and construction. It was reflooded in March, 1963. The late fall drawdown in 1962 provided optimum conditions for geese, with 3,000 remaining on the exposed pool bottom until December 10, 1962. F-1 Pool contains 258 surface acres when at crest level.

G-1 Pool was initially flooded in April, 1937, but lowered again the same month for construction of a new concrete spillway. It remained drained until the fall of 1940 when levels were brought up to normal. It was necessary to lower the pool again in May, 1942, to prevent dike erosion and allow dike plantings to be made. Refilled in June, 1942, the pool remained full until 1946. In that year, the Holland Ditch was repaired and water no longer flowed directly to G-1 Pool. As a result, the pool almost dried up in late summer. The same thing happened in late summer in 1947 and 1948. In October, 1948, a supply ditch from J-1 to G-1 was completed and the water supply problem was solved. Normal levels were restored and the pool remained full until June, 1958. A partial drawdown was made that summer for biological purposes. This drawdown produced excellent growth of needle rush (<u>Elcocharis</u>, sp.) on areas where mineral soils were present, but little or nothing on sandy exposures. G-1 Pool contains 202 surface acres of water when full.

H-1 Pool was initially flooded in April, 1937, and remained full until October, 1942. At that time the pool was partially drained for construction of a new spillway. The pool was reflooded in the spring of 1943 but drained during September and October of the same year to burn the marsh. Low levels were again maintained in 1945 and 1946 for bottom fertilization and burning projects. Normal levels were again restored in 1947 and the pool remained full through 1952. In 1953 and again in 1954 the pool was drained to try and burn the large cattail marsh in the west part of the pool. Normal levels were restored in 1955 and the pool remained full through 1962. H-1 Pool contains 111 surface acres when at crest level.

I-1 Pool was initially flooded in April, 1937, and was not drained until 1955. In May of that year it was necessary to draw down the pool for construction of J-I and I-F spillways. Normal levels were restored in the spring of 1956 and the pool remained fairly full and stable through 1962. I-1 Pool contains 129 surface acres when full.

J-1 Pool also has a history of stable water levels. Initially flooded in April, 1937, the pool remained fairly full until 1955. In the summer of that year it was necessary to briefly drain the pool for construction of the J-I spillway. Normal levels were quickly restored and the pool remained full through 1962. J-1 Pool is 214 surface acres in extent when full.

The Upper Goose Pen Pool is a small, deep water pool that is used primarily as a supply for the Lower Goose Pen Pool. Records are rather sketchy on this pool because of its limited importance. It was initially flooded in 1937 and has been drawn down in 1939, 1940, and 1953 for spillway construction or repair. The pool contains 27 surface acres when full.

The Lower Goose Pen Pool was originally flooded in 1937 and was used to establish the Canada goose flock on the refuge. The pool was drawn down in 1938 for spillway construction and again in 1941 for island construction and repair. From 1942 through 1956 the pool remained full and stable. It was drained in the summer of 1957 as a biological drawdown and to permit land clearance around its edges. Normal levels were restored in 1958 and the pool remained steady through 1962. Sixty islands were constructed in this pool for the captive goose flock and they produce many geese in the pool. In addition, the close proximity of Sub-headquarters and Smith farm fields makes this pool a favorite loafing and watering area for fall geese. The Lower Goose Pen Pool contains 93 acres of surface water when at crest level.

The Show Pools are actually two small pools but are generally treated as a single habitat unit. They were initially flooded in 1937 and remained fairly full and stable through 1953. In 1954 the lower pool was drained briefly while repairs were made to correct a washout. The following year both pools were drawn down in the summer for a short period while new spillways were installed. Normal water levels prevailed from 1956 through 1961. In November, 1962, the lower pool was drawn down for maintenance. These pools are located along the highway and are open for fishing during the summer. In addition, there is a picnic area located on the shores of the pools. As a result, there is much disturbance to waterfowl attempting to use the pools. The combined acreage of the Show Pools when at crest level is 57 acres.

A-2 Pool was initially flooded in September, 1939. It remained fairly stable through June, 1948. At that time the pool was drained for replacement of the spillway and repair of eroded spots in the dike. The pool was not reflooded until April, 1950. Levels remained near normal from 1950 through 1962. A-2 Pool contains 282 surface acres when at crest level.

C-2 Pool was initially flooded in September, 1939, and remained fairly full and stable through 1947. From June, 1948, through April, 1950, the pool was partially drained to keep water away from the construction of the A-2 - C-2 spillway. Normal levels were restored in April, 1950. From July through November, 1954, the pool was partially drawn down in an attempt to attract large numbers of ducks and geese. Results were only partly successful as large areas of exposed bottom failed to produce any vegetation. From 1955 through 1962 the pool remained full and stable. C-2 Pool contains 501 surface acres when at crest level.

M-2 Pool was initially flooded in April, 1941, but was held at a low level through 1942 while the open spillway was completed. Normal levels were established in 1943 and the pool remained fairly full and stable through 1955. In 1956 a biological drawdown was attempted but the results were disappointing. The sandy bottom produced very little vegetation. Another biological drawdown was attempted in 1958 but poorer results were obtained than the first one. Normal levels were restored in April, 1959. M-2 Pool is the largest pool on the refuge with the exception of the Riverside Dike system and contains 863 surface acres when at crest level.

T-2 Pool was initially flooded in April, 1941, but held at a low level until 1943 to allow dike repair work to be completed. The pool was held full and stable from 1943 through 1946. In 1947 it was drained completely to facilitate pool bottom fertilization and plant cultivation experiments. Normal levels were restored in 1948 and the pool remained full through 1958. The pool was drained in midsummer, 1959, to expose the bottom for a planting experiment. Then in 1960, 1961, and 1962 the pool was subjected to a series of biological drawdowns to provide loafing sites for fall geese using the nearby Chicago Farm. During these three years, the pool was filled only during the months of April, May, and June for goose nesting; the rest of the time it was in drawdown. When at crest level, T-2 Pool contains 410 surface acres of water.

C-3 Pool was initially flooded in September, 1942, and remained full and stable through 1947. Insufficient water supplies resulted in a partial drawdown in the late summer of 1948. Normal water levels were restored in 1949 but the pool was drained in October, 1950, for spillway construction purposes. Normal water levels were restored in October, 1951. However, the new approved level in 1951 was set one foot lower than the approved level prior to the construction. The pool remained full and stable from 1952 through 1962. C-3 Pool is a large pool, containing 702 surface acres when at crest level.

Marsh Creek Pool and Delta Creek Pool are part of the vast Riverside Dike system that was built in the 1950's. Structures for these pools were completed in 1960, although considerable water had been impounded prior to the completion of the structures. These pools are very remote and water is difficult to manage on them. As a result, they have never really become stabilized. Marsh Creek Pool contains 950 surface acres of water. The size of Delta Creek Pool has not been calculated, but it is on the order of 150 acres.

## General Management Practices 1935-1962

Opinions as to the value of water level fluctuations and drawdowns varied considerably on the Seney Refuge prior to 1963. It can be generally stated, however, that stable water levels were the normal practice while fluctuations were of an experimental nature.

The necessity of drawing pools down for maintenance and construction work in the early years was one of the principle reasons that managers changed their minds as to the value of water level manipulations. If a pool produced good results when drained, it was often decided to try a similar approach the following year. Then, if the results were less favorable, a re-evaluation of the management program was in order.

For example, the 1946 Water Management Plan favored stabilized water levels during the nesting season and a drop of not more than six inches during the midsummer months. This type of management was considered consistent with natural lakes in the area. A drop in levels of a foot or eighteen inches was considered extreme (Johnson, 1946). Three years later, the same manager (Johnson, 1949) came out in favor of water level fluctuations, citing increases in waterfowl usage on

G-1 and H-1 Pools during years of low water as his reason.

In 1950 a new manager arrived and came out in strong favor of water level fluctuations. The 1950 Water Management Plan states, ". . . there should be but little ground for controversy in the question of fluctuating vs stable water levels; low water levels vs high water levels. All are necessary in a well-balanced management program" (Henry, 1950). Two years later Manager Henry (1952) revised some of his ideas on water management as it is applicable to the Seney Refuge. He noted that the pools with a history of stable water levels were producing the best vegetation. He recommended the use of stable water levels for 1952.

A comprehensive aquatic plant inventory was conducted in 1951 and the results of this survey formed a basis of water management on the refuge for several years. Smith (1952), who conducted the survey, had the following observations regarding water management:

1. Natural successional tendencies are constantly changing the aquatic habitat. These tendencies are striving from the wet to the more-dry or mesic type of habitat. Therefore, moderate changes in water levels will be required from time to time to achieve or maintain desired habitat conditions. This does not imply complete drawdown.

2. The effects of water level changes will be proportionate to the amount of rise or drop and to the duration of the net change.

3. A protracted drop in levels will retard or destroy submergent, and in some cases, floating-leaf vegetation species, and at the same time encourage growth of emergent vegetation.

4. The reverse will result from an effective rise in water levels.

5. In either case, some sacrifice will result. Even though encouragement of one group of aquatics is obtained through water level manipulation, one must remember that the undesirable species will be given the same stimulus as the desirable types. Carefully planned objectives weighing sacrifice against benefits derived should determine the degree, duration, and need of the fluctuation.

The next several years saw a general management practice of stable levels. Frequent interruptions took place, however, as construction of new spillways in Unit I was conducted. Some experimentation was conducted on Unit II pools in an attempt to improve their usefulness but the results were generally disappointing. By 1958 (Henry, 1958) it was concluded that the problems in Unit II were not entirely a matter of age as had been previously thought. The pools were noted to have greater proportions of sand and their large size made for deeper water over most of the pool surface. As a result, vegetation was poorer and the pools were less attractive to waterfowl.

Smith (1958) considered the value of water level fluctuations in the refuge's Long-Range Water Management Plan. He noted that past biological drawdowns had been used to provide goose food on exposed mudflats. While recognizing increases in waterfowl use on exposed mudflats, he questioned whether these temporary gains were worth subjecting submergent aquatics to destruction or long-term setbacks. He noted that in flooded impoundments, the best waterfowl usage occurs on those pools that are oldest, are probably the most fertile, and have a history of stable water conditions. Submergent aquatics such as wild celery (*Vallisneria americana*), bushy pondweed (*Naias flexilis*), and members of the potomogeton group were thought to be the prime attractions in the fall. Smith felt that this type of waterfowl food could best be produced under stable water level conditions.

Wilson observed in the 1960 Water Management Plan that past drawdowns had definitely set back natural succession of aquatics to more desirable species. He noted that pools which had extensive drawdowns or sterile soil bottoms showed an almost complete lack of use by waterfowl. There were only two exceptions to the trend of waterfowl use to the better pools. First, goose nesting has been just as good on the poor pools as on the stable pools although broods soon moved out to the stable pools after hatching. Second, there is a temporary extensive use by waterfowl, particularly geese and puddle ducks, of pools while completely drawn down and in a stage of dominantly sprouting vegetation on the pool bottom.

Wilson made similar comments in the 1962 Water Management Plan.

Thus, as late as 1962, the general management policy was one of stable water levels. Drawdowns were experimented with for biological purposes and were still frequently required for maintenance or construction, but they had not been accepted as a standard management technique. It was felt that the temporary benefits derived from a drawdown were more than offset in losses in future years.

## Water Management 1963-1969

Beginning in 1963 the general concept of water management changed at Seney Refuge from one of stable water levels to one of fluctuating water levels. In general, the new policy was to raise pool levels rapidly to nesting levels in March and to lower the pools following the nesting season to summer levels. The summer levels were set several inches to two feet lower, depending on the pool. The purpose of this type of management was to hasten spring break-up, thereby reducing over-the-ice mammalian predation, and to make aquatic plants more available in the summer (Sherwood, 1965). In addition, the lower summer levels exposed mud flats and sand bars, providing additional feeding and loafing areas.

The effect of this practice has been to make a drawdown merely a severe degree of a normal water level fluctuation. It is important, then, that the term drawdown be carefully defined to separate this management practice from normal water level fluctuations. For the purposes of this paper the term "drawdown" will be used to indicate the complete dewatering of a pool, except for borrow ditches and stream channels. In between the complete drawdown and the normal water level fluctuations is a rather grey area of "partial drawdowns." A partial drawdown has been described as one where some water remains on the area through the summer waterfowl brood period (Linde, 1969). To quantify this, for a pool to have been considered as partially drawn down, it will have had to have been more than 50% drained, but less than completely drained. At Seney, this often happens when a pool's spillway is opened completely, but because of bottom topography, not all of the pool drains. Table 5 indicates the complete and partial drawdowns for the years 1963-1969, using these criteria as guidelines.

Table 5 provides at a glance a broad picture of the drawdown history of the pools during the study years. It does not, however, give any details regarding the length of the drawdown or the season in which it was conducted. These factors can be as important as the

TABLE 5.--Drawdown histories of refuge pools 1963-1969.

| Pool | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|
| A-1 | DD* | | | | | | |
| B-1 | | | | | | PD* | |
| C-1 | | | | | | | |
| D-1 | PD | | | PD | PD | PD | PD |
| E-1 | | | | | | | |
| F-1 | | | | | | | |
| G-1 | | | | | DD | | |
| H-1 | | | | | DD | | |
| I-1 | DD | DD | DD | | | | |
| J-1 | | | | | | | DD |
| Show | | | | | | | |
| LGP | | | DD | DD | | DD | DD |
| UGP | | | DD | | | DD | |
| A-2 | | | | | | DD | |
| C-2 | | | | | | | DD |
| M-2 | | | | | | | DD |
| T-2 | DD | | | | | | |
| C-3 | | | | | | | |

*DD = Drawdown
PD = Partial Drawdown

drawdown itself. The following narrative descriptions describe the events surrounding each pool's drawdowns.

A-1 pool was drawn down in March, 1963, to facilitate the construction of a new spillway. The pool remained drained until October when about a foot of water was put in the pool to make a lush stand of smartweed (*Polygonium* sp.) available to migrant waterfowl. The pool was again lowered in December for the winter. Since 1963, A-1 pool has remained flooded.

B-1 pool was drawn down in August, 1968, to patch the existing spillway. The drawdown was only partial as the east half of the pool is lower and would not drain through the spillway located at the west end of the pool. The pool remained in partial drawdown throughout the fall and into the winter.

D-1 pool has been in partial drawdown several times during the years 1963-1969; from October, 1963, through March, 1964; from January, 1966, through February, 1966; from July, 1966, through March, 1967; from July, 1967, through March, 1968; from July, 1968, through September, 1968; and from July, 1969, through September, 1969. All drawdowns were partial because the existing water control structures make it impossible to drain the southeast corner of the pool. In recent years, D-1 pool has been used largely as a grazing site by allowing vegetation to become established on exposed mudflats each summer.

G-1 pool was drawn down in 1967 during October and November for aeration of the pool bottom. H-1 pool was also drained in 1967 from June through the end of the year. This was also a biological drawdown.

I-1 pool was drawn down from November, 1963, through March, 1964, for habitat improvement work. The pool was drained briefly in July, 1964, and again from November, 1964, through March, 1965, for refinements to the newly constructed islands in the pool. It was again lowered briefly during the summer of 1965 for erosion control work on the newly constructed goose nesting islands.

J-1 pool was lowered for about two weeks in August, 1969, to repair a leak in the J-to-I spillway. J-1's general management has been different from most of the other pools during this period because water levels are not fluctuated extensively in J-1 pool. Rather, they are continually maintained at spring levels. Since J-1 pool is the first pool in the Unit I chain, it is desired to have a reservoir of water held there in case extremely dry summer conditions make adequate supplies for the other pools unreliable. In addition, the J-to-H and J-to-G spillways are constructed without deep bays, and if J-1 were lowered, the supplies to these pools would be cut off. As a result, J-1 has remained at a fairly constant level, with the exception of the 1969 drawdown.

The Lower Goose Pen was drawn down in August and September, 1965, for island construction work and shoreline removal of a dense stand of tag alder (*Alnus rugosa*). The pool was again lowered during August and September, 1966, for additional habitat improvement work. In both 1968 and 1969, the Lower Goose Pen was drawn down during August and September to allow the planting of 9 acres of the pool bottom adjacent to the Subheadquarters farm field to rye.

The Upper Goose Pen was drained briefly during the summer of 1965 to repaint and patch leaks in the radial-gate water control structure. This pool was drained during July, October, and November of 1968 to aerate the bottom. The Upper Goose Pen is subject to frequent and severe fluctuations in water levels due to its small size, bottom topography, and large radial-gate water control structure, necessary to handle the entire Unit I outflow. In addition, the pool cannot be kept drained because the water must be quite high to flow into the Lower Goose Pen. Thus, drawdowns are subject to interruptions, as is the case in 1968.

A-2 pool was drained in June, 1968, and remained in drawdown for the rest of the year. The drawdown was biological, with bottom aeration and as experimental planting of Japanese millet as the prime objectives.

C-2 pool was drawn down in July, 1969, to permit the repair of deteriorating stop-log channels in the water control structure. The pool was allowed to return slowly to fall levels during September.

With C-2 drained during the summer of 1969 and the flow of water through Unit II cut off, M-2 Pool went dry by mid-August and remained drawn down for several days. Some water was restored to the pool by the end of August.

T-2 pool was drawn down in 1963 for the entire year in an effort to promote the establishment of emergent vegetation. Nineteen sixty-three was the fourth consecutive year that this pool was drained to try to improve habitat conditions.

The rest of the pools, C-1, E-1, F-1, the Show Pools, and C-3, were not in either a drawdown or a partial drawdown state during the years 1963-1969.

# ANALYSIS OF MANAGEMENT PRACTICES
# 1963-1969

## Approach

The usual approach in an analysis of a water level manipulation program is to determine changes in water chemistry, aquatic vegetation, and bottom composition and relate these factors to waterfowl. Major papers on the subject of water level manipulations, such as Kadlec's (1962) and Harris and Marshall's (1963), have been in-depth studies of the physical and vegetative characteristics of a marsh. The results of these studies were then used to conclude what practices were beneficial to waterfowl.

In this study, it was decided to analyze waterfowl use directly and relate changing patterns in waterfowl use to management practices employed. By using this approach, the middle step of inferring waterfowl benefits from physical characteristics has been eliminated. In other words, the question is not, "What do we think the ducks prefer?" but rather, "What do the ducks prefer?".

This type of an analysis is possible because waterfowl census data for 18 of the pools has been recorded by pool since 1963. (Marsh Creek and Delta Creek Pools are not censused and the two Show Pools are lumped together.) Prior to 1963, only data for total birds censused is available in the refuge files. For comparison, six censuses have been selected for each of the years 1963-1969. These censuses were taken during the first and third weeks of September and each week of October. Their dates are indicated in Table 6.

In this study it is possible to analyze fall use only. Censuses are not conducted during the summer months and for only a limited period in the spring. The second and fourth weeks of September could not be included as censuses were not conducted during one or more of the years during these weeks. The important month for fall migration is October, when all the species being considered peak. This month is well covered in the study.

Four species of waterfowl were selected for analysis: The Canada goose, mallard, black duck, and ring-necked duck. In addition, all waterfowl censused were lumped together by pool for each census and a fifth analysis was conducted for total waterfowl usage. No other species occur in great enough numbers to permit a meaningful analysis.

The determination of waterfowl usage has been conducted in two phases. In the first phase, the pools were ranked to determine general waterfowl preference for each pool in each year. Ranking was accomplished with

TABLE 6.--Dates of waterfowl censuses from 1963 to 1969 that were used to compute coefficient of usage figures and paired difference tests.

| Year | Census | | | | | |
|---|---|---|---|---|---|---|
| | First | Second | Third | Fourth | Fifth | Sixth |
| 1963 | Sept. 4 | Sept. 19 | Oct. 3 | Oct. 8 and 9 | Oct. 18 | Oct. 31 |
| 1964 | Sept. 4 | Sept. 22 | Oct. 5 | Oct. 14 | Oct. 23 | Nov. 2 |
| 1965 | Sept. 2 | Sept. 23 | Oct. 7 | Oct. 14 | Oct. 22 | Oct. 29 |
| 1966 | Sept. 1 | Sept. 22 | Oct. 6 | Oct. 13 | Oct. 20 | Oct. 27 |
| 1967 | Sept. 1 | Sept. 22 | Oct. 3 | Oct. 12 | Oct. 20 | Oct. 31 |
| 1968 | Sept. 6 | Sept. 19 and 20 | Oct. 4 | Oct. 11 | Oct. 17 | Oct. 31 |
| 1969 | Sept. 3 | Sept. 18 | Oct. 2 | Oct. 9 | Oct. 17 | Oct. 29 |

a coefficient of usage which was derived as follows:

$$\text{Coefficient of Usage} = \frac{\text{Sum of 6 Censuses for Year for Pool}}{\text{Size of Pool (Acres)}}$$

As an example, 379 mallards were counted on H-1 pool in 1968 during the six censuses. This total was divided by 111, the size of H-1 pool in acres. The result is a coefficient of usage of 3.41 birds per acre.

In all cases, the crest level size of the pool was used, regardless of the level of the pool at the time of the census. The area influenced by water level manipulations is being considered, whether or not it is completely flooded all the time.

An adjustment was necessary on the October 18, 1963, census as the census taker was not able to census A-2, C-2, or T-2 pools because of darkness. This adjustment was made by determining the proportional use of that date for the other 15 pools and applying this proportion to the use of A-2, C-2, and T-2 for the other five dates. Using the formula

$$\frac{\text{Total for 15 pools on 10-18-63}}{\begin{array}{c}\text{Total for 15 pools}\\ \text{on other 5 dates}\end{array}} = \frac{\begin{array}{c}\text{Total for A-2, C-2, or T-2}\\ \text{on 10-18-63}\end{array}}{\begin{array}{c}\text{Total for A-2, C-2, or T-2}\\ \text{on other 5 dates}\end{array}}$$

the use of these pools was calculated, and the results inserted on the census form. This was the only case where any adjustment to the census data was necessary.

The calculated coefficients of usage were used to make Tables 7 through 11 which show the decreasing order of preference of pools by all waterfowl, Canada geese, mallards, black ducks, and ring-necked ducks.

By ranking the pools general waterfowl preference was determined, but it was not possible to determine significant changes in preference. For example, from 1967 to 1968 the Lower Goose Pen remained ranked number one for the Canada goose, but the coefficient of usage changed from 42.26 to 12.06. Does this represent a significant change or not?

The second phase of the analysis is concerned with determining where significant changes in preference have taken place. This phase was conducted by using a paired-t test with observations paired by census number. A two-tailed test with 5 d.f. and a critical value of $t = 2.571$ was employed.

Since one year's census data was compared to the next, changes in total birds available could make it appear that significant changes in use were taking place, when in fact, increases were an expression of more birds migrating through the area. To remove this factor all census data was placed on a percentage basis by dividing the number of the particular species of waterfowl being considered on each pool by the total number of that species counted on all pools. The statistical question asked was, "Did the

TABLE 7.--Comparison of pools by rank for all waterfowl for the years 1963-1969. Figures in parentheses are the derived coefficients of usage.

| Rank | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|
| 1. | I-1 (29.64) | J-1 (22.47) | LGP (13.15) | LGP (70.34) | LGP (56.04) | J-1 (34.09) | LGP (15.78) |
| 2. | J-1 (25.34) | LGP (15.76) | H-1 (11.79) | J-1 (32.96) | UGP (38.92) | I-1 (28.45) | F-1 (12.34) |
| 3. | F-1 (18.51) | Show (15.38) | F-1 (11.67) | I-1 (11.70) | J-1 (34.43) | H-1 (19.36) | Show ( 8.19) |
| 4. | LGP (10.67) | F-1 (13.84) | C-1 (10.97) | Show ( 9.44) | I-1 (20.78) | F-1 (13.41) | C-3 ( 7.86) |
| 5. | C-1 ( 8.70) | C-1 (13.33) | E-1 (10.51) | H-1 ( 8.71) | C-1 (17.30) | E-1 (16.80) | E-1 ( 5.71) |
| 6. | E-1 ( 8.52) | H-1 ( 8.58) | I-1 (10.23) | F-1 ( 6.93) | F-1 (15.28) | LGP (14.67) | I-1 ( 4.94) |
| 7. | H-1 ( 8.40) | C-1 ( 7.55) | B-1 ( 8.70) | B01 ( 6.89) | A-2 (11.96) | C-1 ( 9.18) | A-2 ( 4.84) |
| 8. | B-1 ( 7.55) | B-1 ( 6.91) | A-1 ( 7.89) | E-1 ( 6.78) | H-1 (10.29) | G-1 ( 8.00) | D-1 ( 4.66) |
| 9. | C-3 ( 4.73) | C-3 ( 5.10) | Show ( 7.58) | C-1 ( 6.51) | D-1 ( 9.18) | B-1 ( 6.80) | C-1 ( 4.37) |
| 10. | A-1 ( 3.54) | A-1 ( 4.88) | UGP ( 6.30) | C-3 ( 6.04) | Show ( 8.77) | D-1 ( 6.22) | H-1 ( 3.61) |
| 11. | Show ( 3.51) | G-1 ( 4.59) | T-2 ( 4.85) | D-1 ( 4.23) | A-1 ( 8.33) | M-2 ( 4.56) | J-1 ( 2.98) |
| 12. | M-2 ( 2.42) | A-2 ( 3.76) | C-3 ( 2.86) | A-2 ( 3.11) | C-3 ( 6.30) | C-3 ( 4.14) | C-2 ( 2.86) |
| 13. | D-1 ( 2.29) | I-1 ( 3.75) | J-1 ( 2.36) | A-1 ( 2.84) | C-1 ( 6.01) | Show ( 3.98) | C-1 ( 2.41) |
| 14. | A-2 ( 1.88) | C-2 ( 2.98) | C-2 ( 2.28) | M-2 ( 2.41) | B-1 ( 5.03) | A-2 ( 3.52) | M-2 ( 2.29) |
| 15. | C-2 ( 1.88) | UGP ( 2.00) | D-1 ( 2.10) | C-2 ( 2.23) | E-1 ( 4.38) | C-2 ( 3.14) | B-1 ( 2.14) |
| 16. | UGP ( 1.74) | M-2 ( 1.68) | A-2 ( 1.88) | G-1 ( 2.19) | M-2 ( 4.01) | A-1 ( 2.46) | T-2 ( 1.77) |
| 17. | G-1 ( .90) | T-2 ( 1.28) | G-1 ( 1.13) | UGP ( .26) | C-2 ( 2.73) | T-2 ( 2.41) | A-1 ( 1.75) |
| 18. | T-2 ( .44) | D-1 ( .96) | M-2 ( 1.02) | T-2 ( .18) | T-2 ( 1.52) | UGP ( .81) | UGP ( .00) |

TABLE 8.--Comparison of pools by rank for the Canada Goose for the years 1963-1969. Figures in parentheses are the derived coefficients of usage.

| Rank | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|
| 1. | LGP (8.82) | LGP (12.01) | H-1 (8.96) | LGP (65.61) | LGP (42.26) | LGP (12.06 | LGP (15.04) |
| 2. | F-1 (8.20) | E-1 (11.41) | LGP (8.49) | H-1 ( 5.47) | H-1 ( 8.04) | F-1 ( 8.70) | F-1 ( 6.62) |
| 3. | E-1 (7.33) | H-1 ( 6.16) | E-1 (8.38) | E-1 ( 4.87) | D-1 ( 7.26) | H-1 ( 6.85) | E-1 ( 3.33) |
| 4. | B-1 (5.66) | F-1 ( 5.10) | F-1 (5.68) | F-1 ( 3.94) | F-1 ( 7.22) | E-1 ( 5.48) | D-1 ( 2.58) |
| 5. | I-1 (5.16) | C-3 ( 3.47) | C-1 (4.61) | C-3 ( 3.32) | C-3 ( 2.47) | B-1 ( 4.75) | I-1 ( 2.34) |
| 6. | H-1 (3.65) | B-1 ( 3.24) | T-2 (4.09) | I-1 ( 3.07) | I-1 ( 1.96) | C-1 ( 3.39) | Show ( 2.21) |
| 7. | A-1 (3.22) | C-1 ( 1.96) | I-1 (2.45) | B-1 ( 2.17) | E-1 ( 1.96) | Show ( 2.32) | C-2 ( 1.82) |
| 8. | C-3 (3.22) | A-1 ( 1.90) | B-1 (1.49) | M-2 ( 2.15) | G-1 ( 1.86) | G-1 ( 2.21) | H-1 ( 1.77) |
| 9. | C-1 (3.09) | I-1 ( 1.81) | A-1 (1.47) | D-1 ( 1.98) | M-2 ( 1.53) | A-2 ( 2.00) | M-2 ( 1.57) |
| 10. | D-1 (2.11) | G-1 ( 1.44) | J-1 (1.15) | C-1 ( 1.77) | B-1 ( 1.48) | T-2 ( 1.86) | C-3 ( 1.40) |
| 11. | J-1 (1.91) | Show ( 1.16) | C-3 ( .80) | Show ( 1.65) | A-1 ( 1.46) | I-1 ( 1.56) | T-2 ( 1.23) |
| 12. | M-2 (1.37) | A-2 ( .98) | D-1 ( .60) | J-1 ( 1.04) | Show ( 1.42) | D-1 ( 1.42) | C-1 ( 1.12) |
| 13. | A-2 (1.03) | C-2 ( .91) | C-2 ( .57) | A-1 ( .69) | T-2 ( 1.19) | C-3 ( 1.24) | A-2 ( 1.10) |
| 14. | UGP ( .92) | T-2 ( .84) | A-2 ( .56) | A-2 ( .51) | C-1 ( 1.16) | M-2 ( 1.02) | B-2 ( 1.01) |
| 15. | C-2 ( .41) | J-1 ( .74) | Show ( .53) | G-1 ( .50) | J-1 ( .44) | UGP ( .81) | G-1 ( .53) |
| 16. | C-1 ( .27) | M-2 ( .51) | C-1 ( .27) | C-2 ( .39) | A-2 ( .38) | J-1 ( .77) | J-1 ( .31) |
| 17. | T-2 ( .25) | D-1 ( .46) | M-2 ( .24) | T-2 ( .13) | C-2 ( .22) | C-2 ( .33) | A-1 ( .20) |
| 18. | Show ( .18) | UGP ( .00) | UGP ( .00) | UGP ( .00) | UGP ( .00) | A-1 ( .26) | UGP ( .00) |

TABLE 9.--Comparison of pools by rank for the mallard for the years 1963-1969. Figures in parentheses are the derived coefficients of usage.

| Rank | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|
| 1. | H-1 (3.65) | Show (2.23) | I-1 (1.67) | LGP (2.47) | LGP (9.82) | H-1 (3.41) | Show (1.35) |
| 2. | Show (2.46) | LGP (1.52) | LGP (1.45) | I-1 (2.21) | Show (1.37) | C-1 (1.47) | C-3 (1.02) |
| 3. | F-1 (2.16) | F-1 (1.18) | Show (1.28) | H-1 (1.06) | F-1 (1.32) | F-1 (1.36) | F-1 ( .79) |
| 4. | C-1 (1.00) | J-1 ( .89) | F-1 (1.18) | D-1 ( .95) | C-3 ( .91) | G-1 (1.32) | I-1 ( .72) |
| 5. | LGP ( .87) | G-1 ( .65) | C-1 ( .83) | Show ( .82) | I-1 ( .85) | LGP (1.08) | D-1 ( .59) |
| 6. | B-1 ( .79) | C-1 ( .65) | H-1 ( .44) | C-1 ( .82) | B-1 ( .72) | J-1 ( .73) | A-2 ( .50) |
| 7. | J-1 ( .71) | B-1 ( .59) | A-1 ( .44) | F-1 ( .62) | C-2 ( .72) | C-2 ( .72) | C-1 ( .48) |
| 8. | C-3 ( .69) | A-1 ( .58) | B-1 ( .34) | C-3 ( .62) | H-1 ( .68) | D-1 ( .70) | G-1 ( .35) |
| 9. | E-1 ( .44) | H-1 ( .53) | D-1 ( .25) | G-1 ( .57) | J-1 ( .57) | Show ( .68) | J-1 ( .27) |
| 10. | C-2 ( .34) | C-3 ( .34) | J-1 ( .24) | B-1 ( .53) | D-1 ( .55) | A-2 ( .66) | C-2 ( .26) |
| 11. | I-1 ( .31) | C-2 ( .32) | E-1 ( .23) | J-1 ( .36) | C-1 ( .47) | B-1 ( .53) | B-1 ( .22) |
| 12. | A-2 ( .30) | E-1 ( .27) | C-2 ( .16) | C-2 ( .34) | G-1 ( .44) | E-1 ( .46) | LGP ( .20) |
| 13. | M-2 ( .30) | M-2 ( .24) | T-2 ( .11) | A-1 ( .29) | A-2 ( .44) | I-1 ( .36) | H-1 ( .18) |
| 14. | A-1 ( .14) | I-1 ( .17) | M-2 ( .10) | E-1 ( .25) | A-1 ( .42) | C-3 ( .27) | E-1 ( .18) |
| 15. | G-1 ( .11) | UGP ( .15) | C-3 ( .07) | A-2 ( .17) | E-1 ( .38) | A-1 ( .22) | A-1 ( .15) |
| 16. | T-2 ( .09) | A-2 ( .15) | G-1 ( .06) | M-2 ( .06) | M-2 ( .21) | M-2 ( .18) | T-2 ( .07) |
| 17. | D-1 ( .07) | D-1 ( .07) | A-2 ( .06) | T-2 ( .02) | T-2 ( .06) | T-2 ( .12) | M-2 ( .07) |
| 18. | UGP ( .04) | T-2 ( .06) | UGP ( .00) | UGP ( .00) | UGP ( .00) | UGP ( .00) | UGP ( .00) |

TABLE 10.-- Comparison of pools by rank for the black duck for the years 1963-1969. Figures in parentheses are the derived coefficients of usage.

| Rank | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|
| 1. | F-1 (2.20) | H-1 (1.38) | I-1 (2.16) | I-1 (1.67) | LGP (3.30) | H-1 (4.47) | C-1 (1.13) |
| 2. | J-1 ( .95) | J-1 (1.37) | LGP (2.04) | LGP (1.29) | I-1 (1.51) | G-1 (2.08) | C-3 ( .98) |
| 3. | C-1 ( .91) | C-1 (1.23) | C-1 (1.42) | H-1 (1.22) | C-1 (1.14) | C-1 (1.58) | G-1 ( .81) |
| 4. | LGP ( .88) | LGP (1.18) | Show (1.16) | D-1 ( .88) | B-1 ( .89) | I-1 (1.02) | A-2 ( .78) |
| 5. | H-1 ( .80) | B-1 (1.16) | F-1 (1.05) | B-1 ( .86) | F-1 ( .88) | F-1 (1.01) | F-1 ( .71) |
| 6. | I-1 ( .67) | F-1 (1.12) | H-1 (1.04) | C-3 ( .67) | A-1 ( .78) | C-2 ( .99) | D-1 ( .65) |
| 7. | Show ( .61) | Show (1.09) | A-1 ( .61) | C-1 ( .56) | H-1 ( .64) | B-1 ( .88) | A-1 ( .53) |
| 8. | B-1 ( .48) | G-1 ( .87) | B-1 ( .49) | A-1 ( .44) | C-2 ( .42) | LGP ( .84) | C-2 ( .43) |
| 9. | M-2 ( .43) | I-1 ( .62) | J-1 ( .41) | G-1 ( .39) | C-3 ( .42) | J-1 ( .84) | H-1 ( .41) |
| 10. | C-3 ( .40) | A-1 ( .45) | C-2 ( .35) | J-1 ( .38) | D-1 ( .40) | D-1 ( .65) | Show ( .40) |
| 11. | C-2 ( .21) | M-2 ( .32) | D-1 ( .31) | F-1 ( .38) | J-1 ( .38) | A-2 ( .61) | LGP ( .35) |
| 12. | A-2 ( .20) | E-1 ( .28) | T-2 ( .26) | Show ( .33) | A-2 ( .38) | A-1 ( .45) | I-1 ( .29) |
| 13. | E-1 ( .15) | C-3 ( .26) | E-1 ( .24) | C-2 ( .28) | G-1 ( .36) | C-3 ( .40) | J-1 ( .29) |
| 14. | A-1 ( .14) | D-1 ( .23) | G-1 ( .17) | A-2 ( .21) | M-2 ( .29) | M-2 ( .27) | B-1 ( .26) |
| 15. | T-2 ( .11) | A-2 ( .23) | M-2 ( .15) | E-1 ( .16) | Show ( .28) | E-1 ( .15) | T-2 ( .23) |
| 16. | D-1 ( .10) | C-2 ( .18) | A-2 ( .14) | M-2 ( .07) | UGP ( .15) | Show ( .14) | M-2 ( .15) |
| 17. | G-1 ( .10) | UGP ( .15) | C-3 ( .14) | T-2 ( .01) | T-2 ( .13) | T-2 ( .11) | E-1 ( .14) |
| 18. | UGP ( .07) | T-2 ( .02) | UGP ( .00) | UGP ( .00) | E-1 ( .13) | UGP ( .00) | UGP ( .00) |

TABLE 11.--Comparison of pools by rank for the ring-necked duck for the years 1963-1969. Figures in parentheses are the derived coefficients of usage.

| Rank | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
|---|---|---|---|---|---|---|---|
| 1. | I-1 (21.26) | J-1 (15.01) | B-1 ( 6.01) | J-1 (30.37) | UGP (38.56) | J-1 (30.70) | C-3 ( 3.69) |
| 2. | J-1 (18.50) | Show ( 6.63) | UGP ( 5.67) | Show ( 5.21) | J-1 (32.71) | I-1 (23.99) | I-1 ( 1.47) |
| 3. | C-1 ( 2.99) | F-1 ( 3.66) | A-1 ( 5.14) | B-1 ( 2.96) | I-1 (14.11) | E-1 ( 8.25) | E-1 ( 1.41) |
| 4. | F-1 ( 1.63) | C-1 ( 2.84) | Show ( 3.51) | C-1 ( 2.73) | C-1 (13.64) | D-1 ( 3.15) | C-1 ( 1.27) |
| 5. | H-1 ( .54) | A-2 ( 1.98) | C-1 ( 3.30) | A-2 ( 2.04) | A-2 (10.39) | M-2 ( 2.88) | J-1 ( 1.12) |
| 6. | E-1 ( .48) | B-1 ( 1.48) | I-1 ( 1.97) | I-1 ( 1.93) | A-1 ( 4.45) | C-1 ( 2.33) | A-2 ( 1.10) |
| 7. | B-1 ( .46) | A-1 ( 1.17) | C-3 ( 1.70) | A-1 ( 1.21) | Show ( 3.32) | C-3 ( 1.87) | Show ( .63) |
| 8. | C-3 ( .21) | C-2 ( 1.00) | E-1 ( 1.42) | E-1 ( .73) | G-1 ( 2.39) | G-1 ( 1.46) | A-1 ( .55) |
| 9. | G-1 ( .03) | E-1 ( .93) | F-1 ( 1.16) | C-2 ( .63) | C-3 ( 2.20) | A-1 ( 1.18) | B-1 ( .51) |
| 10. | M-2 ( .03) | UGP ( .92) | H-1 ( 1.10) | C-2 ( .58) | E-1 ( 1.78) | F-1 ( 1.14) | G-1 ( .30) |
| 11. | UGP ( .00) | I-1 ( .78) | C-2 ( .89) | F-1 ( .31) | M-2 ( 1.78) | Show ( .79) | F-1 ( .20) |
| 12. | Show ( .00) | G-1 ( .63) | A-2 ( .79) | H-1 ( .18) | B-1 ( 1.74) | C-2 ( .60) | C-2 ( .10) |
| 13. | LGP ( .00) | M-2 ( .37) | C-1 ( .56) | G-1 ( .15) | F-1 ( 1.18) | B-1 ( .41) | M-2 ( .10) |
| 14. | D-1 ( .00) | C-3 ( .14) | M-2 ( .50) | M-2 ( .09) | C-2 ( .71) | H-1 ( .27) | D-1 ( .02) |
| 15. | A-1 ( .00) | D-1 ( .10) | J-1 ( .26) | UGP ( .00) | LGP ( .00) | T-2 ( .14) | UGP ( .00) |
| 16. | A-2 ( .00) | LGP ( .03) | D-1 ( .15) | LGP ( .00) | H-1 ( .00) | UGP ( .00) | LGP ( .00) |
| 17. | T-2 ( .00) | H-1 ( .02) | T-2 ( .13) | D-1 ( .00) | D-1 ( .00) | LGP ( .00) | H-1 ( .00) |
| 18. | C-2 ( .00) | T-2 ( .01) | LGP ( .00) | T-2 ( .00) | T-2 ( .00) | A-2 ( .00) | T-2 ( .00) |

proportion of total refuge use occurring on a pool change from one year to the next?".

With waterfowl use data expressed as a percentage it was probable that the data were poisson distributed and had to be transformed before running the test. Steel and Torrie (1960) indicate that where some of the values are under ten and especially when zeros are present, $\sqrt{x + 1/2}$ is recommended as the appropriate transformation. Accordingly, all data were transformed by this factor before running the paired-t test.

Following transformation, the data were paired off by year and census number: 1964-1963, 1965-1964, etc. Tables 12 through 16 present the observed values of t for each pool for each of the indicated species. Significant values are underlined.

In the second phase of the analysis, the size of the pool was not considered. Rather, each pool is considered to be a separate habitat unit that is being manipulated in relation to the others. By removing the acreage factor, any bias resulting from a more complete census of the smaller pools was removed. Doing this, however, could have had just the opposite effect by putting too much weight on the larger pools. Without the acreage factor, sheer numbers on a large pool might have outweighed a change on a small pool. The difference in pool size is not that great, however, and the census data often show

TABLE 12.--Observed values of t from the paired-difference test for all waterfowl for the years 1963-1969. Underlined figures indicate a significant change from the previous year in waterfowl usage has taken place.

| Pool | 1964-1963 | 1965-1964 | 1966-1965 | 1967-1966 | 1968-1967 | 1969-1968 |
|---|---|---|---|---|---|---|
| A-1 | .4203 | 2.6093 | -2.1614 | 1.7494 | -1.6618 | - .1411 |
| B-1 | .2383 | .0657 | - .1403 | -1.4218 | 2.6728 | -4.4126 |
| C-1 | - .1611 | 1.3840 | -1.3249 | .9049 | -1.3804 | .0461 |
| D-1 | - .7009 | .9295 | 1.0107 | 2.4220 | -1.4604 | .5661 |
| E-1 | 4.0015 | -1.1170 | -1.8307 | -2.6292 | 2.1216 | - .4321 |
| F-1 | -1.1565 | - .0348 | -4.7286 | 1.4687 | 1.5267 | .6010 |
| G-1 | 5.4990 | -3.1336 | 1.3436 | 1.6517 | .2371 | -2.2608 |
| H-1 | .2009 | .3149 | - .6885 | - .5939 | 2.0013 | -3.1082 |
| I-1 | -2.3649 | 3.1645 | - .4312 | .2242 | .0835 | 1.6807 |
| J-1 | - .6740 | -1.9036 | 2.4586 | -1.8769 | .5543 | -1.4076 |
| Show | 4.9574 | -1.2125 | 1.0794 | -1.2577 | 1.8093 | 2.5342 |
| LGP | .1671 | .6081 | 4.3847 | -1.6184 | -3.0716 | 1.1337 |
| UGP | 0 | 2.2368 | -2.2368 | 1.3027 | 1.3027 | 0 |
| A-2 | .6610 | 1.0731 | - .3573 | 3.6095 | - .8112 | 2.3986 |
| C-2 | 1.0826 | .4912 | -1.3077 | -1.4347 | .7950 | 1.5902 |
| M-2 | - .2770 | - .3269 | .6815 | .3355 | .1935 | - .1323 |
| T-2 | .0855 | 1.5882 | -2.2627 | 2.1864 | .1399 | .6733 |
| C-3 | .5301 | -2.5000 | 2.0173 | - .2310 | -1.4332 | 3.0547 |

TABLE 13.--Observed values of t from the paired-difference test for the Canada goose for the years 1963-1969. Underlined figures indicate a significant change from the previous year in Canada Goose usage has taken place.

| Pool | 1964-1963 | 1965-1964 | 1966-1965 | 1967-1966 | 1968-1967 | 1969-1968 |
|---|---|---|---|---|---|---|
| A-1 | - .4003 | - .1519 | -1.7775 | .8512 | -3.7749 | .5424 |
| B-1 | - .5264 | -1.8494 | .7764 | - .7597 | 4.8811 | -5.0565 |
| C-1 | .3026 | 1.4575 | -1.4749 | -1.6450 | 3.9867 | -4.4752 |
| D-1 | - .9822 | .5443 | 4.1205 | 2.8464 | -3.8141 | .7674 |
| E-1 | 2.3826 | -1.7817 | -2.1966 | -3.7546 | 4.5586 | -1.8111 |
| F-1 | - .9988 | 1.3712 | -5.1458 | 1.0747 | 4.2106 | - .1804 |
| G-1 | 3.1439 | -1.4995 | 1.2727 | 1.7890 | 1.4576 | -2.2578 |
| H-1 | 1.2623 | 1.3960 | -2.6441 | 1.7319 | .2041 | -3.3739 |
| I-1 | -1.4361 | .9666 | - .4094 | -1.8655 | .1938 | 1.6677 |
| J-1 | -2.0249 | 1.5128 | .9570 | -1.5814 | 1.2413 | -1.1949 |
| Show | 2.2368 | -2.2368 | 1.5670 | - .1393 | .3146 | .8836 |
| LGP | - .3166 | .6886 | 3.6959 | -1.3490 | -2.5059 | 1.3157 |
| UGP | -1.0012 | 0 | 0 | 0 | 1.0012 | -1.0012 |
| A-2 | 1.2792 | -1.4000 | -1.8497 | .4021 | 3.4328 | -1.5734 |
| C-2 | 1.8168 | .3383 | -1.5337 | -1.9803 | .9995 | 5.4692 |
| M-2 | - .5324 | 2.0247 | 1.7196 | .1433 | - .5261 | .6262 |
| T-2 | .0746 | .8028 | -1.2810 | 2.0918 | .1971 | .0243 |
| C-3 | .4110 | -3.8421 | 3.2518 | - .3978 | -1.0111 | 1.3983 |

TABLE 14.--Observed values of t from the paired-difference test for the mallard for the years 1963-1969. Underlined figures indicate a significant change from the previous year in mallard usage has taken place.

| Pool | 1964-1963 | 1965-1964 | 1966-1965 | 1967-1966 | 1968-1967 | 1969-1968 |
|---|---|---|---|---|---|---|
| A-1 | 2.7681 | .5870 | -1.4372 | - .4199 | - .7409 | 1.0957 |
| B-1 | .3654 | - .4437 | - .2248 | - .5704 | .3607 | - .4628 |
| C-1 | -1.0500 | 3.4322 | -2.2513 | -3.0276 | 5.5108 | -1.6469 |
| D-1 | - .5424 | 1.0000 | 1.7699 | - .1465 | 1.9906 | - .0735 |
| E-1 | - .2984 | - .1809 | - .3153 | .2544 | 1.5443 | - .5774 |
| F-1 | -1.2851 | 1.6585 | -4.9598 | 1.6362 | .2839 | .2817 |
| G-1 | 2.2467 | 2.2837 | 1.4046 | - .5574 | 1.8642 | -1.9734 |
| H-1 | - .8204 | .4589 | 1.0472 | -2.0053 | 2.7773 | -5.2607 |
| I-1 | - .9105 | 5.2943 | .5088 | -2.1528 | -1.3691 | .5132 |
| J-1 | .6628 | -3.3484 | .9504 | 1.8198 | - .2772 | .1051 |
| Show | 1.8556 | -1.2382 | -1.1285 | - .0352 | .7612 | 2.7616 |
| LGP | 1.6605 | .3284 | .0150 | 1.3994 | -1.9341 | 1.3035 |
| UGP | 0 | -1.0021 | 0 | 0 | 0 | 0 |
| A-2 | .2654 | -1.3703 | .9363 | 1.0980 | .7803 | .7570 |
| C-2 | 1.2183 | -1.0817 | 1.1407 | 1.1676 | .0852 | -3.6229 |
| M-2 | - .0645 | -1.1050 | -1.6702 | 1.6327 | - .0895 | 1.5936 |
| T-2 | .3845 | .4256 | -1.2965 | .6293 | 1.4332 | .0724 |
| C-3 | .3507 | -3.0360 | 4.0897 | .4121 | -3.2283 | 3.1148 |

TABLE 15.--Observed values of t from the paired-difference test for the black duck for the years 1963-1969. Underlined figures indicate a significant change from the previous year in black duck usage has taken place.

| Pool | 1964-1963 | 1965-1964 | 1966-1965 | 1967-1966 | 1968-1967 | 1969-1968 |
|---|---|---|---|---|---|---|
| A-1 | 1.1481 | .7498 | .4646 | 1.3142 | -2.2185 | 1.0178 |
| B-1 | 1.1506 | **-3.8458** | **2.6385** | - .6272 | - .3385 | -2.3049 |
| C-1 | .7818 | 1.9289 | **-4.3519** | 1.8364 | - .5458 | .1008 |
| D-1 | 2.0207 | .2481 | 1.8686 | -2.3189 | 1.0182 | .4664 |
| E-1 | 1.5708 | - .0367 | -1.0813 | -1.1798 | .6157 | .9950 |
| F-1 | -1.9561 | - .5806 | -1.3864 | 2.0138 | -2.3095 | .9197 |
| G-1 | 2.4422 | -1.9793 | 1.1106 | .1579 | 2.0697 | -1.2022 |
| H-1 | .7772 | - .7800 | 1.0348 | **-2.5929** | **3.0365** | **-4.2001** |
| I-1 | - .7770 | **3.2103** | - .8615 | .0075 | -2.1397 | -1.5880 |
| J-1 | 1.8294 | **-5.2188** | 1.0475 | -1.0891 | .6272 | - .7211 |
| Show | 1.3167 | .1714 | - .9461 | - .8697 | - .5424 | **2.9413** |
| LGP | .0442 | .6246 | - .4144 | .7474 | **-2.8261** | - .5703 |
| UGP | 0 | -1.0012 | 0 | 1.0012 | -1.0012 | 0 |
| A-2 | .1793 | - .9739 | .7303 | 1.5816 | - .3256 | 1.9312 |
| C-2 | - .3091 | 1.5086 | .3597 | - .3321 | 2.0908 | -1.7772 |
| M-2 | - .5317 | -1.3013 | -1.9402 | **2.5778** | - .9491 | .5338 |
| T-2 | -1.9264 | **3.8215** | **-2.9680** | 1.1478 | .2136 | .8517 |
| C-3 | - .7403 | - .8980 | **19.2478** | **-5.7884** | -1.9320 | **3.6551** |

TABLE 16.--Observed values of t from the paired-difference test for the ring-necked duck for the years 1963-1969. Underlined figures indicate a significant change from the previous year in ring-neck duck usage has taken place.

| Pool | 1964-1963 | 1965-1964 | 1966-1965 | 1967-1966 | 1968-1967 | 1969-1968 |
|---|---|---|---|---|---|---|
| A-1 | 1.8539 | <u>3.2477</u> | -1.5589 | <u>3.2873</u> | - .9888 | - .3292 |
| B-1 | 2.3042 | .4723 | - .4139 | - .9011 | -2.1233 | 1.6148 |
| C-1 | .9470 | - .5678 | .2249 | 1.1267 | - .9299 | .2371 |
| D-1 | 1.0012 | 0 | -1.0012 | 0 | 2.0975 | -2.0975 |
| E-1 | 1.2301 | .6676 | -2.1829 | .2691 | .7010 | .1520 |
| F-1 | 2.2503 | -2.4837 | -1.2753 | .8412 | .6532 | - .7190 |
| G-1 | .7929 | 1.2302 | -1.1483 | 1.2530 | - .8358 | .2273 |
| H-1 | -1.5688 | 1.5371 | -1.9165 | -1.0012 | 1.0000 | -1.0000 |
| I-1 | -2.1702 | 2.4243 | .4105 | .2164 | .7400 | -1.8597 |
| J-1 | -1.5927 | -1.5099 | <u>2.8272</u> | -2.5456 | .4323 | - .4414 |
| Show | 2.1730 | - .7629 | .8992 | -1.3083 | - .9302 | 1.4429 |
| LGP | 0 | 0 | 0 | 0 | 0 | 0 |
| UGP | 1.5266 | 1.9247 | <u>-2.8709</u> | 1.3761 | -1.3761 | 0 |
| A-2 | .7290 | -1.2271 | 1.7190 | 1.7530 | -2.4292 | 1.4822 |
| C-2 | 1.1818 | .7098 | -1.4711 | - .4429 | -1.5211 | - .2209 |
| M-2 | 1.0000 | .9521 | -1.0751 | .7115 | 1.2905 | - .6038 |
| T-2 | 1.0747 | 2.4198 | -2.0541 | 0 | 1.3743 | -1.3743 |
| C-3 | .4921 | 2.1381 | - .2618 | <u>2.9135</u> | - .5141 | 1.1778 |

more use on the smaller pools than on the larger ones. The results do not indicate that changes in use on small pools were overlooked.

As in the first phase of the analysis, it was necessary to calculate a use figure for A-2, C-2, and T-2 pools on the October 18, 1963, census. For each of the species being considered, the fifth censuses of these pools for 1964-1969 were averaged and this figure inserted into the October 18, 1963, census. It should be noted that no significant change in any species was recorded for any of these pools in 1964.

In this study the paired-t test was conducted on successive years only. In other words, changes were tested from one year to the next as 1967 versus 1966, or 1969 versus 1968. There were many other possibilities, such as examining a pool for changes over two, three, or more years. The number of possibilities were tremendous, however, and beyond the scope of this paper.

## Factors Affecting the Reliability of the Analysis

Waterfowl use of an area is influenced by many factors that can change considerably the total number of birds present at any given time. Any analysis of waterfowl use should consider these factors. Further, the collection of census data and analysis of this data has introduced additional variables which tend to limit the reliability that can be placed on the results of the analysis. Before considering the results of the statistical analysis, therefore, a discussion of these factors is necessary to properly evaluate their net effect on the results.

These factors can be grouped into four general categories for purposes of discussion: (1) factors affecting the accurate collection of data, (2) factors introduced by the waterfowl, (3) limitations in the statistical method used in this analysis, and (4) external influences which alter a bird's normal behavior. The first category is concerned with how standard the censuses are and how consistent the data are from one census to the next, all other things being equal.

Criteria for conducting the census are promulgated in the refuge's Wildlife Inventory Plan. Although this plan was not completed until January, 1968, the procedures set forth in it have been in use since the beginning of this study, 1963. This plan establishes the census route, time of day to conduct the census, how observers are to run the route, and conditions under which the census is to be conducted. The plan stresses the importance of following closely these criteria to assure maximum continuity in the data from year to year.

The census route (Figure 3) has been established to assure that the same areas are censused each time. In

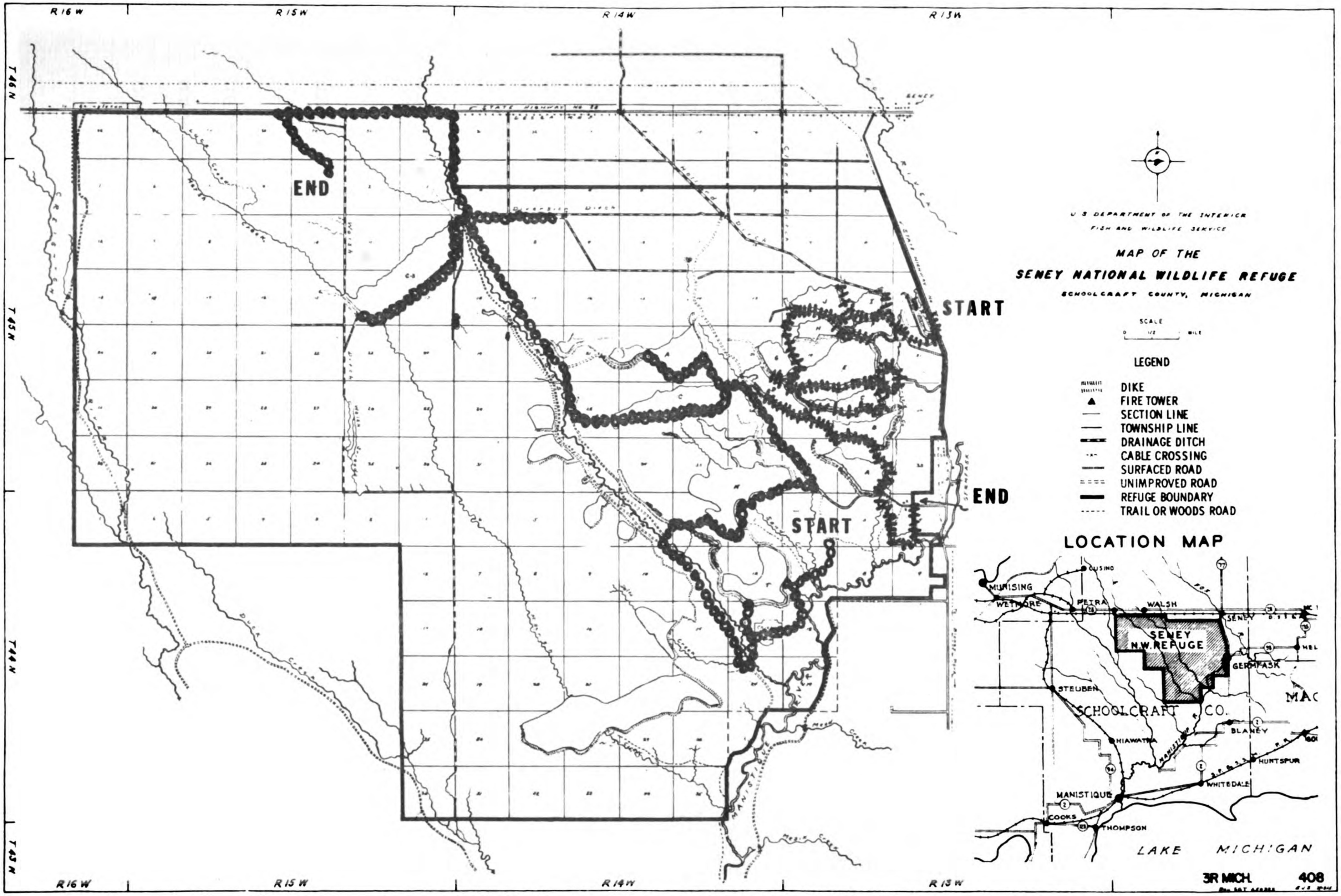


Figure 3.--Census routes used to collect waterfowl use data.

general, this route has been followed closely. One problem associated with the route is that not all the pools are censused completely. This is particularly true of A-2 and T-2 pools. Further M-2 pool, because of its large size, deep bays, and numerous stumps and islands, is not covered completely. In general, the larger pools receive less completely coverage than the smaller pools. This is not true in all cases, however, as the configuration of the pool, census route, and obstructions to a good view along the route are important factors. E-1 pool, for example, is one of the largest pools, but because of its long narrow shape and the fact that the census route covers both sides and the ends of the pool, E-1 is well covered. These factors, while important to the general ranking of a pool, remain constant from one year to the next and do not greatly affect the detection of significant changes in use within the area being covered.

More important than the route itself is the time of day that each pool is censused. The Wildlife Inventory Plan recognizes that the route is very long and that it should be run by two observers, one doing Unit I and the other doing Units II and III. This procedure has not been followed very closely, however, due to varying amounts of available personnel. At times, only one observer was used, resulting in a census on Unit II pools in the afternoon and C-3 pool in Unit III very late in the day. At other times two observers are used, but the second only censuses C-3 pool, usually around mid-day or early afternoon. On some occasions three observers were available and all the pools were censused in the morning. The result has been that Unit II pools have been censused either in the morning or in the afternoon and C-3 pool has been censused at almost any time of the day. The time of census has been much more consistent for the Unit I pools where the Show Pools are done in early morning and the route is finished at the Lower Goose Pen around noon.

This discrepancy in the timing of the censuses is an important factor. Of the forty-two censuses used in the analysis, twenty-nine were conducted by two observers, nine by one observer, and four by three observers. Since the use of a pool can vary tremendously at different periods of the day, the analysis of Unit I is considered more reliable than that of Units II and III.

Another factor involved in the accurate collection of data is the number of observers involved. In the forty-two censuses used to calculate changes in use, sixteen observers took part in the collection of the data. Differences exist between observers in estimating the size of large flocks, making proper identification of birds at great distances and under poor light conditions, and general thoroughness in the conduct of the census. These differences tend to reduce the accuracy of comparing one census to another.

Observers also differ in some instances as to what unit some birds should be counted in, particularly at the Lower Goose Pen. Some observers may have put birds close to the water in the pools while others counted them in Smith or Subheadquarters farm fields. This invisible line as to where the pool ends and the field begins makes analysis of good data at the Lower Goose Pen more difficult.

Weather can also be an important factor. The Wildlife Inventory Plan notes that clear, calm mornings should be selected whenever possible and that rainy, foggy, or windy days are to be avoided. These guidelines have been followed as closely as possible, but Seney's often unpleasant weather made it necessary to occasionally deviate from the desired conditions. Weather on the third census in 1965, for example, was windy with light showers. The third census in 1966 was clear and warm. It was also rainy on the fifth census in 1967, and sunny and warm on the fifth census in 1968.

Variations in weather conditions can affect the results of this study in two ways. First, unfavorable weather makes reliable observations more difficult as visibility decreases. Second, the birds themselves react differently under stormy conditions than they do under clear conditions. Analysis of the results on a proportional use basis tends to minimize these factors, however, because all pools are affected by the adverse conditions. Thus, even though the total number counted may drop considerably, this drop will be reflected in each of the pools censused.

The second general category of error considers those factors introduced by the birds themselves. Examples are variations in the dates of migration, variations in the total population available for manipulation, and variations in the type of use made of each pool.

This study was set up to cover the fall migration period and all species included in the analysis reach their peak fall numbers during the month of October. The week is not always the same from year to year for a given species, however, and the length of time that a high population is present also varies. In addition, the total number that stop at Seney can vary considerably from year to year. Ring-necked ducks offer the best example of this (Table 17). They have peaked twice in the first week of October, once in the second week, and four times in the third week. The number present in the peak week is often far different from the other weeks in October. Further, the peak number varies considerably from year to

TABLE 17.--Total number of ring-necked ducks counted on each census, 1963-1969.

| Year | Census | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1963 | 236 | 753 | 2909 | 1657 | 1686 | 2011 |
| 1964 | 162 | 772 | 2937 | 2693 | 588 | 1123 |
| 1965 | 169 | 979 | 1869 | 3068 | 1790 | 177 |
| 1966 | 356 | 560 | 824 | 1997 | 3732 | 3310 |
| 1967 | 277 | 775 | 1756 | 8209 | 11077 | 1675 |
| 1968 | 229 | 223 | 2807 | 7645 | 8951 | 462 |
| 1969 | 190 | 273 | 308 | 927 | 2927 | 157 |

year, 1967 and 1968 being very high years, and 1963, 1964, and 1969 being low years.

Canada geese, on the other hand, have been much more consistent (Table 18), usually at a high level all four weeks of October, with no drastic changes from one week to the next, or from one year to the next. Mallards and black ducks do not make large fall movements into the refuge and are thus not as greatly affected by changing migration patterns. The largest total compiled for mallards was 1,107 on October 20, 1967, and 806 for black ducks on October 31, 1967.

Variations in the total population present and the dates of peak numbers can have several effects on the results of the analysis. The analysis was conducted on a percentage basis to remove the effects of changes in total birds present. With relatively small changes in relation to the total counted, this method is quite effective in eliminating the total birds present factor. When changes in total numbers become large in relation to the total, however, other factors enter the picture that reduce the effectiveness of the percentage method. The fall ring-necked duck population, for example, is composed of two groups of birds. The first group is the nesting population comprised of about 200 birds in the fall. The second group is the migrating birds using the refuge and comprised of two or three very large flocks (1,000-3,000

TABLE 18.--Total number of Canada geese counted on each census, 1963-1969.

| Year | Census 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1963 | 861 | 1227 | 2440 | 3775 | 3982 | 3864 |
| 1964 | 526 | 1012 | 4548 | 5300 | 3803 | 4846 |
| 1965 | 610 | 1384 | 4104 | 3931 | 4108 | 2928 |
| 1966 | 1083 | 1041 | 4129 | 4110 | 4574 | 4778 |
| 1967 | 1105 | 1639 | 3083 | 5095 | 3664 | 3600 |
| 1968 | 949 | 2165 | 6386 | 6313 | 6007 | 4409 |
| 1969 | 779 | 1147 | 4032 | 4964 | 3989 | 4422 |

birds) plus a scattering of smaller numbers. These two groups behave quite differently and often use different parts of the refuge. The result is that when no migrants to speak of are around, the pools used most by the resident birds show high percentage use. When 3,000 or more migrants descend as one flock on a different pool, however, the local birds' use is completely overshadowed. Further, these large flocks don't come the same week every year, and some years they don't come at all. So, a pool's percentage use can change drastically from one week to the next and from one year to the next, depending on the movement of the large groups of migrant ring-necked ducks.

With this in mind, the statistical analysis for ring-necked ducks is expected to be less reliable than that for the other species. To a lesser extent, the all-waterfowl analysis will also be affected, because when large flocks of ring-necks are present, they comprise a significant portion of the refuge's waterfowl (70% on October 20, 1967).

The type of use being made of each pool by the waterfowl and what they happen to be doing at the time the pool is censused are also important areas of consideration. Not all pools serve the same purpose: some are feeding areas, some are loafing areas, some are staging areas, and some are combinations of these. The census only lasts for from fifteen minutes to one hour for any one pool and this is not enough time to observe whether or not the birds are temporarily absent. There are 168 hours in a week and a half-hour sample cannot be expected to give a complete picture of an area's use.

A-1 pool, for example, is usually censused around noon and seldom shows high use by geese. When this pool is visited just as the last light fades, however, as many as 3,000 geese are present. A-1 pool serves as a night-time loafing area for geese that are feeding in other areas during the day. Thus the daytime censuses miss the primary function of this pool with respect to Canada geese.

The statistical method used in this paper is not concerned with the type of use a pool is receiving, however, but rather simply whether or not whatever use that is occurring is changing. Later, in the discussion of the results the differences in use will be more completely considered.

A further limitation in the reliability of the analysis lies in the statistical method itself. The analysis for significant changes was conducted as a two-tailed test at the .05 level of probability with 5 d.f. and a critical value of $t = 2.571$. Since 540 paired-t tests were conducted, it can be expected that the results will give about twenty-seven erroneous significant differences by chance (5 for each 100 tests at the .05

level of probability). Tables 12 through 16 indicate that in seventy-one cases significant changes took place. Because of the erroneous results by chance, however, only about forty-four of these results can be considered actually significant. It is, of course, impossible to determine when looking at any one result whether it is really significant or whether it is one of the chance errors. Thus, analysis of any one significant change is seriously hampered and should not be attempted.

The number of erroneous results by chance can be reduced by reducing the size of the rejection region. If the data is considered as a two-tailed test at the .01 level of probability with 5 d.f. and a critical value of $t = 4.032$, twenty of the results would be significant. At this level of probability, the results can be expected to give 5 erroneous significant differences by chance. While the probability of making this type of an error has decreased, the probability of accepting the null hypothesis when it is false has increased. In other words, a greater chance exists that some truly significant changes would be overlooked. In view of this, the data will be analyzed at the .05 level of probability and due consideration will be given to the erroneous significant differences.

The fourth general category of error is concerned with external influences in the study area which can temporarily alter a bird's normal behavior. To be considered here are such factors as farming, baiting, wild rice planting, disturbance before a census, and hunting.

The analysis of waterfowl use for each pool was based on those birds present in the pools at the time of the census. Those birds using other parts of the refuge, such as the farm fields, were not considered. For the ducks this number was insignificant and would have no effect on the results. For the geese, however, considerable use is made of the refuge's farm fields. Table 19 shows the total number of geese counted on the six censuses on each field for each year. There is a considerable amount of shifting, not only from one field to another, but also in total use of the fields as the geese readily adapted to changing crop manipulations and successes. The changes in farm crop use by the geese can have two effects on the pool census data for those pools most closely associated with the fields. First, a pool might appear artificially low in use because most of the birds have been drawn off to a field. Second, a pool might appear artificially high in use because large numbers of geese using a neighboring field use the pool for loafing and drinking.

The pools which appear to be affected the greatest by the farm units are the Lower Goose Pen and A-1 pool by Subheadquarters and Smith farm fields, M-2 and T-2 pools

TABLE 19.--Geese using refuge farm units from 1963 through 1969 (figures are the total number of geese counted during the six census periods of each year).

| Farm Unit | Year | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
| Sub-headquarters | -- | 2635 | 1292 | 255 | 1000 | 3755 | 993 |
| Smith | -- | 5 | 580 | 609 | -- | 200 | 320 |
| Chicago | -- | 1135 | 1196 | 134 | 97 | 1500 | 3264 |
| Diversion | 615 | 1100 | 346 | 956 | 1483 | 3612 | 3434 |
| Walsh | -- | -- | 540 | 433 | 854 | 2830 | 264 |
| Conlon | -- | -- | -- | -- | -- | 425 | 300 |
| Total | 615 | 4875 | 3954 | 2387 | 3434 | 12,322 | 8575 |

by Chicago Farm, and C-3 pool by Diversion and Walsh farm units. When analyzing goose data on these pools, farming practices will have to be considered.

Baiting for waterfowl banding operations was conducted up to approximately October 10 at Seney during the study years. This encompasses the first three census periods of the study. The intensity of the banding operation varied slightly over the six year period, but the areas where baiting and trapping were done remained about the same. If trapping was confined to just one or two pools, and if the effort expended in these areas was great in relation to the numbers of birds present, a very definite change in normal use patterns could be introduced. However, trapping was spread out throughout Units I and II with at times as many as eleven pools baited at the same time. With the banding spread out, most birds drawn to the trap sites were from the immediate area. Baiting as it is conducted at Seney does not greatly affect the distribution of waterfowl by pool, although their location within a given pool may temporarily shift.

In September, 1968, a total of 800 pounds of wild rice (Zizania aquatica) was planted in pools A-1, E-1, F-1, J-1, and the Show Pools. Had these planting been successful, they could have exerted a definite influence on the 1969 pattern of use. These plantings were largely unsuccessful, however, and no unusual use was noted in the planted areas. There is a well established wild rice bed in C-1 pool where the last planting was done in 1955. On September 16, 1968, John Wilbrecht noted 400 black and mallard ducks in the four acre bed (personal communication). Since this bed was established at least eight years before the study began, it is not considered a temporary artificial influence, but rather, a natural part of the pool that would respond along with the pool to water management practices.

The only other significant aquatic planting made during the years 1963-1969 was that of 195 pounds of Japanese millet planted in A-2, Upper Goose Pen, B-1, and F-1 pools. The planting was done by this author to determine the effectiveness of mudflat planting at Seney Refuge. The main study area was A-2 pool, where 140 pounds were planted in five 1-acre plots. Thirty-five pounds were planted in the Upper Goose Pen and 10 pounds each in B-1 and F-1 pools (Fjetland, 1968). The millet in A-2 pool and the Upper Goose Pen grew well whereas that in B-1 and F-1 pools germinated poorly and the few plants that had started to grow had largely disappeared by the end of August. Canada geese were frequently seen grazing on the A-2 plot and evidence of use of the Upper Goose Pen site was found, although no geese were seen there. Geese continued to use the A-2 plot into the fall when the censuses in this study were made. Normally, 20 to 50 geese were observed on the site and on October 20, 94 geese were observed. With this much use noted, it is probable that the census data of A-2 pool was affected by the planting (a significant increase in goose use was recorded in A-2 pool in 1968) and the experiment will be considered in the analysis. The plantings in B-1, F-1, and the Upper Goose Pen pools had no effect on the fall censuses.

Disturbance is another factor that can temporarily alter waterfowl's normal behavior and affect the reliability of the census data. The primary problem here is when someone passes through part of the census area prior to the person conducting the census. The resulting movement of the birds disturbs normal use patterns. Generally, this problem is not very significant as efforts were made to keep any disturbance at a minimum. On some occasions during the first three census periods some disturbance took place when duck traps were checked. Occasionally, a user of the refuge's auto tour would disturb the waterfowl during the first census period. (The tour closed on September 15.) Other activities, such as road maintenance, were kept at a minimum on days that censuses were conducted. The way that the census route is set up also helps as the area nearest headquarters was covered early in the morning.

From observations made in 1968, 1969, and 1970, it appeared that ring-necked ducks were most adversely affected by disturbance. The mere appearance of a vehicle would cause thousands of ring-necks to leave a pool entirely and in some cases, to leave the refuge. Most other species tended to move about within the pool in which they were located.

Another form of disturbance is hunting. In 1963, 1964, and 1965 the area around the refuge was open to goose hunting beginning October 1 of each year. The goose season was closed adjacent to the refuge in 1966 to protect the local flock of Canada geese and remained closed through the 1969 season. The area most directly affected by the closure was the Lower Goose Pen Subheadquarters area where hunting took place along the fence. With the closure, it is expected that an increase in use in this area would take place. Goose use on the rest of the refuge was also affected to a lesser extent as movement patterns off the refuge changed with the closure. The closure will be considered in analyzing significant changes in Canada goose use.

While many variables in the census data have been pointed out in the previous pages, these variables are not considered to have invalidated the analysis. Further, they were not listed so that they could be used as excuses to explain significant changes that do not fit a general pattern of one kind or another. They were merely stated to show that an analysis of this type is a complex investigation where many factors have to be considered. It should be noted that many of these factors do not apply to all species, all pools, or all censuses. Further, they do not all act in the same direction. For example, waterfowl banding activities would tend to be offset by the disturbance created. Large fluctuations in use data as a result of the variables will tend to eliminate significant changes as the standard deviation becomes large. Thus there will be less significant changes than if there were no variables present. With an understanding of these variable factors and their significance with respect to the data, the results presented later in this paper can be more completely understood.

## Results

Evaluation of the significant changes in waterfowl use will be compared to the water management histories in two ways. First, waterfowl use the same year as a drawdown will be compared to years when there was no drawdown. Second, waterfowl use in the year following a drawdown will be compared to the no-drawdown situation. The instance of no drawdown exists when a pool has not been drawn down either that year or the year previously.

Drawdown histories of the pools were summarized in Table 5. Changes in waterfowl use from the previous year were calculated for each of the species for the years 1964-1969 (Tables 12 through 16). During those years there were 19 instances of complete or partial drawdown, giving nineteen possibilities for each species that a significant change in use could have taken place the same year as a drawdown. During those same years, there were eleven possibilities that a change in use could have taken place the year following a drawdown. In those cases where a pool was drawn down several years in a row, only the year following the last drawdown is considered in the year-following category. For example, I-1 Pool was drawn down in 1963, 1964, and 1965 (Table 5). Calculations for changes in use in 1964 and 1965 are in the same-year category and calculations in 1966 are in the year-following category. For 1967 and subsequent years on I-1 Pool, the calculations fall into the no-drawdown category.

For each of the species, there were 108 calculations for a change in use made (18 pools times 6 years). Since 19 of these occurred the same year as a drawdown and 11 the year following a drawdown, 78 occurred when there was no drawdown. Table 20 presents a breakdown of all the calculations shown in Tables 12 through 16 as to what type of changes occurred within each of the three

TABLE 20.--Breakdown of increases, decreases, and no changes in waterfowl use in relation to water management.

| Species | Same Year as Drawdown | | | Year Following Drawdown | | | No Drawdown | | |
|---|---|---|---|---|---|---|---|---|---|
| | Type of Change | | | Type of Change | | | Type of Change | | |
| | Increase | No Change | Decrease | Increase | No Change | Decrease | Increase | No Change | Decrease |
| All Waterfowl | 3 | 15 | 1 | 0 | 10 | 1 | 6 | 68 | 4 |
| Canada Goose | 6 | 12 | 1 | 0 | 10 | 1 | 5 | 66 | 7 |
| Mallard | 1 | 17 | 1 | 2 | 9 | 0 | 5 | 67 | 6 |
| Black Duck | 1 | 16 | 2 | 1 | 10 | 0 | 6 | 66 | 6 |
| Ring-necked Duck | 0 | 19 | 0 | 0 | 10 | 1 | 4 | 74 | 0 |

water management categories. To determine whether the data provide sufficient evidence to indicate a dependence between the type of changes taking place and drawdowns, contingency tables were set up for each species comparing the same year as a drawdown to no drawdown and the year following a drawdown to no drawdown (Mendenhall, 1967). Chi-square was calculated for each of the 10 contingency tables at 2 d.f. at the .05 level of probability with a critical value of $X^2 = 5.991$. The calculated values of $X^2$ are presented in Table 21.

In two cases a value of $X^2 > 5.991$ was obtained, rejecting the null hypothesis of independence of water management and changes in waterfowl use. The first of these cases is the Canada goose the same year as a drawdown compared to no drawdown. An examination of the data in Table 20 shows a relatively large number of significant increases in goose use the same year as a drawdown which suggests that pools are more likely to receive a significant increase in goose use the same year as a drawdown as compared to when there is no drawdown.

The second case where dependence is indicated is in the ring-necked duck the year following drawdown as compared to no drawdown. An examination of the data in Table 20 shows that only one significant decrease in ring-necked duck use occurred and that this took place the year following a drawdown. This suggests that a

TABLE 21.--Calculated values of Chi-square to test the independence of changes in waterfowl use from drawdowns.

| Species | Same Year as Drawdown vs No Drawdown | Year Following Drawdown vs No Drawdown |
|---|---|---|
| All Waterfowl | $X^2 = 1.12$ | $X^2 = 1.11$ |
| Canada Goose | 9.37 | 0.72 |
| Mallard | 0.20 | 2.35 |
| Black Duck | 0.26 | 0.84 |
| Ring-necked Duck | 1.05 | 9.59 |

significant decrease in ring-necked duck use is not very likely to occur, but when it does, it is more likely to take place the year following a drawdown than when there is no drawdown. As pointed out in the previous section, the many factors affecting the reliability of the ring-necked duck census data tend to obscure the significance of changing patterns of use.

In all other cases, low values of Chi-square were obtained, failing to reject the null hypothesis that changes in use by waterfowl in general, by mallards, by black ducks, by Canada geese the year following a drawdown, and by ring-necked ducks the same year as a drawdown, are independent of drawdowns. Changes in use in these cases do occur, but the evidence does not indicate that they are dependent on drawdowns.

In addition to determining the value of drawdowns, it is possible to calculate the relative value to waterfowl of each of the pools. Table 22 shows the general ranking of each pool for each waterfowl category. This table was developed by averaging the rankings for each of the seven years as presented in Tables 7 through 11. By breaking the rankings into three equal categories of usefulness, the relative preference by the various species of waterfowl for each of the pools can be easily stated. If a pool ranks in the top six positions it is considered

TABLE 22.--General ranking of the pools according to waterfowl preference for the seven year period 1963-1969.

| Rank | All Waterfowl | Canada Goose | Mallard | Black Duck | Ring-necked Duck |
|---|---|---|---|---|---|
| 1. | LGP | LGP | Show | C-1 | J-1 |
| 2. | F-1 | F-1 | F-1 | LGP | C-1 |
| 3. | J-1 | H-1 | LGP | H-1 | I-1 |
| 4. | I-1 | E-1 | H-1 | I-1 | Show |
| 5. | H-1 | I-1 | C-1 | F-1 | E-1 |
| 6. | C-1 | B-1 | I-1 | B-1 | B-1 |
| 7. | E-1 | C-3 | J-1 | J-1 | A-1 |
| 8. | Show | C-1 | B-1 | A-1 | C-3 |
| 9. | B-1 | D-1 | C-3 | G-1 | A-2 |
| 10. | C-3 | Show | G-1 | C-3 | F-1 |
| 11. | A-2 | A-1 | C-2 | Show | UGP |
| 12. | D-1 | M-2 | D-1 | D-1 | G-1 |
| 13. | A-1 | G-1 | A-1 | C-2 | M-2 |
| 14. | G-1 | A-2 | E-1 | A-2 | C-2 |
| 15. | UGP | T-2 | A-2 | M-2 | H-1 |
| 16. | M-2 | J-1 | M-2 | E-1 | D-1 |
| 17. | C-2 | C-2 | T-2 | T-2 | LGP |
| 18. | T-2 | UGP | UGP | UGP | T-2 |

"good." A ranking of 7-12 is "average," and a ranking of 13-18 is "poor."

For example, the Lower Goose Pen and H-1 Pool are good pools for Canada geese, mallards, and black ducks, and poor for ring-necked ducks. F-1 Pool is good for the same three species, and average for ring-necks. E-1 is good for geese and ring-necks, and poor for mallards and black ducks. J-1 is poor for geese, average for mallards and black ducks, and good for ring-necks. C-1 is average for geese and good for the three species of ducks. T-2 Pool is poor for everything, and I-1 rates good in all the categories. From these examples, it can be seen that each pool has a pattern of its own. Because it is good for geese, it does not follow that it will be good, average, or poor for any of the duck species. Being a good ring-necked duck pool does not necessarily mean that the pool is poor for other species, nor does it mean that the pool will be good for the other species. The only generalization that can be made is that in most cases mallards and black ducks rank about the same within a given pool.

An understanding of the individual capabilities of each of the pools is an important tool to developing the most effective type of management plan for the refuge. A single plan that attempts to manage all pools similarly is too general. A better plan would be to consider each pool individually, state what its apparent capabilities are, and to manage it accordingly. Radical changes in management should be kept to a minimum on the better pools. Room for experimentation is available on the pools that rank poor for most species.

## Conclusions and Discussion

Based on the findings of this study, it is concluded that the use of drawdowns on the Seney National Wildlife Refuge has had no appreciable effect on fall duck use. This finding is in agreement with other recent studies conducted on northern marshes. Linde (1969), in discussing impoundments in northern Wisconsin, noted that the amount of food produced by drawdown on northern marshes is sometimes negligible. He observed that in one area production of moist-soil food plants was practically nil and that a more profitable approach could have been made by increasing the pondweeds. Harris and Marshall (1963), in studies conducted on the Agassiz National Wilflife Refuge in northern Minnesota, cautioned that too-frequent drawdowns or annual heavy replacement of water in a pool during runoff, may actually lead to a decline in fertility. They recommended that the use of drawdown be limited to specific purposes with proper control and study until the present knowledge of the consequences of a drawdown is enlarged. Kadlec (1962) noted that, in sandy soils, too frequent or too severe drainage may be harmful.

While ducks failed to respond to drawdowns, there is evidence that drawdowns can be used to increase Canada Goose use of a pool during the fall. Geese respond positively to a drawdown pool and its exposed mud flats, but such an operation cannot be continued indefinitely on an annual basis (Bednarik, 1963b; Linde, 1969). An example of this occurred in D-1 Pool, which was partially drawn down in 1966, 1967, 1968, and 1969. Goose use increased significantly on D-1 in 1966 and again in 1967. However, in 1968, use of D-1 Pool by geese decreased significantly. In 1969, there was no significant change.

As a result of these findings, it is recommended that the drawdown should not be over-emphasized as a management tool at Seney National Wildlife Refuge. It is often necessary to draw a pool down for water control structure maintenance, other necessary repair work, farming, etc. so there seems to be little need for draining a pool simply because it hasn't been done for a long time. This is particularly true on some of the better pools, such as C-1 and F-1. If, in a given year, there are no pools drained for other reasons, it would be desirable to lower one or two to expose mudflats for Canada geese. A check of the records shows that this does not happen very frequently. Since the refuge was established, only the years 1944, 1958, 1961, and 1968 have passed without the need to lower a pool for some purpose other than a biological drawdown. Thus, it would appear that in most years, fall goose management should depend on the refuge's maintenance needs and other management programs, such as the lowering of the Lower Goose Pen for farming, rather than on the biological drawdown.

These recommendations are based on fall use only. Sufficient data does not presently exist to properly analyze spring and summer use. If such data is obtained and it shows that the use of drawdowns is beneficial during these periods, then management should be adjusted accordingly. The results of this study have not shown that biological drawdowns are harmful. They have merely pointed out that the benefits are small and can usually be achieved by other means.

Management of water on the Seney National Wildlife Refuge has been more complex than drawdowns vs stable water levels in recent years. Since 1963, pool levels in general have been fluctuated to maximize goose production. By raising water levels in the spring, the refuge has not only reduced goose nest predation by breaking up ice earlier, but has also eased the pressure on the water flowage system by providing for storage of large amounts of spring runoff. While this type of management provides definite benefits, it also has detrimental results.

Although muskrats (*Ondatra zibethica*) can tolerate water level manipulations within considerable limits (Errington, 1948) the timing of the fluctuations at Seney has been detrimental to the muskrat population. Zimmerman (1943) notes that rising levels in the spring can cause heavy losses of young muskrats and lowering the levels exposes the entrances to dens, allowing predator minks access. He recommends high levels throughout the winter for better muskrat management. Steenis, *et al*. (1954) recommend a spring drawdown for muskrats. Bellrose and Low (1943) and Brumsted (1954) noted that fluctuation of water levels is a primary factor limiting muskrat production. Friend, *et al*. (1964) found greater weight loss in muskrats occurring in areas of low winter water levels than in areas with normal water levels. They considered the use of winter drainage a possible tool in managing muskrat populations where trapping is not feasible. Bellrose and Brown (1941) stated that the optimum depth of water for muskrat lodge construction ranges between 12 and 18 inches, with 6 inches about the minimum and 24 inches approaching the maximum. Oldtimers in the Seney area have commented that muskrats were much more abundant on the refuge in the 1930's and 1940's than they are today. What few muskrats there are on the refuge now, appear to live mostly in bank dens. Yet, just east of the refuge, in the Fox River marshes, muskrats and their lodges are still common.

The openings that muskrats make in emergent marshes improve those marshes for waterfowl. Cartwright (1946), working on Big Brass Marsh in Manitoba, found that the resident population of canvasbacks, red-heads, and ruddy ducks, which nest around the clearings in the marsh, increased steadily following the clearing of hundreds of acres of the marsh by muskrats. At the Seney National Wildlife Refuge, the principal diving duck nesting in emergent vegetation is the ring-necked duck. Sarvis (1971) recently completed a study on the ring-necked duck at Seney and found that the preferred nesting habitat of the ring-necked duck is in cattail-sedge and sedge marshes near a small area of open water. Of the 36 nests he found, 29 were located less than 10 feet from an area of open water. Sarvis further found that most of the nests were located in isolated backwater areas where water levels were not affected by pool fluctuations in a 1:1 manner. Water levels in these areas fluctuated very little as a result of the refuge's water control practices (Sarvis, personal communication).

Whether or not the suspension of fluctuating water levels in the pools would result in an increase in muskrats and a corresponding increase in ring-necked duck production is not known, but it seems worth a try. Thus it is recommended that the practice of fluctuating water levels be suspended on two or three pools for a few years. A study of these pools should be conducted to determine if the gains in ring-necked duck production would more than offset any losses in goose production. The results of this study would then form a basis for future management with fluctuating water levels.

## SUMMARY

The use of water level manipulations as a wildlife management tool has been a widely accepted practice for many years. The many papers written on the effects of water level manipulations indicate that, while the results of such practices are generally favorable, there are situations where this technique cannot be used effectively. In the sandy soils in the northern Great Lakes Region, where this study was conducted, several authors have indicated that the beneficial results of drawdowns were minimal, and at times the practice could be harmful. This study was initiated to evaluate the long history of water level manipulations on the Seney National Wildlife Refuge and to determine whether or not waterfowl were significantly influenced by these manipulations.

The study area, Seney National Wildlife Refuge, is a 95,455 acre refuge located in Michigan's Upper Peninsula. Within the refuge, there are twenty-one man-made pools, totaling over 7,000 acres of surface water. These pools vary in size from less than 100 acres to nearly 1,000. Construction began in 1936 and all but two of the pools were first flooded by the early 1940's. The other two were flooded in the late 1950's. These

last two pools are in remote areas and little biological information is available for them.

Water management methods prior to 1963 consisted of holding the pools at a stable level year around. Some experimentation was done with biological drawdowns and it was frequently necessary to drain a pool for maintenance work or for other purposes. As a result, the pools present a wide variety of histories, from stable for many years to severe fluctuations. The refuge managers of this period generally concluded that the pools having a history of stable water levels were the best pools on the refuge. They recognized an immediate and often spectacular response by geese and ducks to exposed mudflats, but felt that these benefits were offset in the long run by the set-backs to aquatic plant development in the pools that had been drained. They also recognized pool-bottom fertility as an important factor in making a pool attractive to waterfowl and noted that the relatively sterile, sandy conditions of the Unit II pools made them less attractive than the Unit I pools.

In 1963, the approach to water management changed from one of stable levels to one of fluctuating water levels. The general practice was to hold low levels through the winter, raise them in the spring, hold high levels through the nesting season, and drop down to lower levels for the summer. There were several reasons for this change in management: First, by raising levels rapidly in the spring, break-up of pool ice could be accomplished up to two weeks earlier. This reduced over-the-ice mammalian predation on goose nests. Second, lower levels in the summer exposed mudflats and created feeding and loafing areas. Third, lower levels in the winter provided additional storage space for spring run-off and eased the threat of flood conditions.

Coinciding with the change in water management in 1963, there was a change in the refuge wildlife inventory procedures. Beginning with that year geese and ducks were counted and recorded by pool. This pool-by-pool census data in the refuge files made possible a statistical analysis of waterfowl usage of the refuge during fall migration. There was sufficient census information to analyze usage of all waterfowl; Canada geese, mallards, black ducks, and ring-necked ducks. The analysis was conducted in two steps. First, a coefficient of usage was determined for each of the species on each pool during the years 1963-1969. These coefficients were used to establish a ranking of the pools by waterfowl preference. Second, census data from one year was compared to the next, using the paired-t test, to determine where significant changes in use had taken place.

To determine how the significant changes in use that occurred related to water management, contingency tables were set up for each species comparing the types of changes in use the same year as a drawdown to a no-drawdown situation and also comparing changes in use the year following a drawdown to a no-drawdown situation. In two cases a dependency ($X^2 > 5.991$) was found between drawdowns and changes in waterfowl use. In the first case, the data showed that pools are more likely to receive a significant increase in goose use the same year as a drawdown than when there is no drawdown. In the second case, the data indicated that significant decreases in ring-necked duck use are not likely to occur, but when they do, they are more likely to take place the year following a drawdown than when there is no drawdown. For mallards, black ducks, all waterfowl, Canada geese the year following a drawdown, and ring-necked ducks the same year as a drawdown, the data failed to rule out the independence of water management and changes in waterfowl use.

Based on the findings of this study, it was concluded that the use of drawdowns has had no beneficial effects for ducks in the fall. There was evidence, however, that drawdowns could be used to increase Canada goose use of a pool the same fall that the pool was drawn down. As a result of these findings, it was recommended that the drawdown should not be over-emphasized as a management tool at the Seney National Wildlife Refuge. This recommendation is further supported by the observations of early managers that benefits gained when a pool was drained were offset in the long run by setbacks in the pool's aquatic plants. Since it is frequently necessary to drain a pool for maintenance or other needs, it was recommended that provision of mudflats for fall geese should depend on these programs rather than on the biological drawdown.

In addition to the drawdown, the refuge's practice of fluctuating water levels was discussed. It was pointed out that fluctuating water levels may be the major factor involved in the decline of the refuge's muskrat population. This, in turn, reduces the available nesting habitat for ring-necked ducks. It was recommended that the practice of fluctuating water levels be suspended on two or three pools for a few years to determine if the gains in ring-necked duck production would more than offset losses incurred by not using fluctuating water levels.

BIBLIOGRAPHY

## BIBLIOGRAPHY

American Ornithologists' Union. 1957. Checklist of North American Birds. Lord Baltimore Press, Inc., Baltimore. 691 pp.

Anderson, D. R. and F. A. Glover. 1967. Effects of water manipulation on waterfowl production and habitat. Trans. N. Am. Wildl. Conf. 32:292-300.

Anderson, H. G. 1940. Studies preliminary to a waterfowl habitat restoration program along the Illinois River. Trans. N. Am. Wildl. Conf. 5:369:373.

Beard, T. D. 1969. Impact of an overwinter drawdown on the aquatic vegetation in Murphy Flowage, Wisconsin. Wis. Dept. of Nat. Res. Res. Rept. No. 43. 16 pp.

Bednarik, K. E. 1963a. Water levels and waterfowl production in Lake Erie marshes. Game Research in Ohio. 2:176-184.

_________. 1963b. Marsh management techniques, 1960. Game Research in Ohio. 2:132-144.

Bellrose, F. C., Jr. 1941. Duck food plants of the Illinois River Valley. Ill. Nat. Hist. Surv. Bull. 21(8):237-280.

Bellrose, F. C., Jr. and H. G. Anderson. 1943. Preferential rating of duck food plants. Ill. Nat. Hist. Surv. Bull. 22(5):417-430.

Bellrose, F. C., Jr. and L. G. Brown. 1941. The effect of fluctuating water levels on the muskrat population on the Illinois River Valley. J. Wildl. Mgmt. 5:206-212.

Bellrose, F. C., Jr. and J. B. Low. 1943. The influence of flood and low water levels on the survival of muskrats. J. Mammal. 24:143-188.

Berquist, S. G. 1936. The Pleistocene history of the Tahquamenon and Manistique drainage region of the Northern Peninsula of Michigan. Geological Survey Division, Mich. Dept. Cons. Publ. 40. Geol. Ser. 34:17-137.

Bourn, W. S. and C. Cottam. 1939. The effect of lowering water levels on marsh wildlife. Trans. N. Am. Wildl. Conf. 4:343-350.

Brumsted, H. B. 1954. Some causes and effects of water level fluctuations in artificial marshes in New York State. Ph.D. thesis, Cornell University. 235 pp.

Cartwright, B. W. 1946. Muskrats, duck production, and marsh management. Trans. N. Am. Wildl. Conf. 11:454-457.

Cook, A. H. and C. F. Powers. 1958. Early biochemical changes in the soils and water of artifically created marshes in New York. N. Y. Fish and Game J. 5(1):9-65.

Errington, P. L. 1948. Environmental control for increasing muskrat production. Trans. N. Am. Wildl. Conf. 13:596-609.

Fernald, Merritt L. 1950. Gray's Manual of Botany. American Book Company. 1632 pp.

Fjetland, Conrad A. 1968. Experimental planting of Japanese millet. Unpublished manuscript. Seney Refuge Files.

Friend, M., G. E. Cummings, and J. S. Morse. 1964. Effect of changes in winter water levels on muskrat weights and harvest at the Montezuma National Wildlife Refuge. N. Y. Fish and Game J. 11(2):125-131.

Gillett, Francis C. 1965. Historical data for Seney National Wildlife Refuge. Unpublished memo. Seney Refuge Files.

Griffith, R. E. 1948. Improving waterfowl habitat. Trans. N. Am. Wildl. Conf. 13:609-618.

________. 1957. Management of waterfowl habitat on the National Wildlife Refuges. Trans. N. Am. Wildl. Conf. 22:215-220.

Hall, T. F., W. T. Penfound, and A. D. Hess. 1946. Water level relationships of plants in the Tennessee Valley with particular reference to malaria control. J. Tenn. Acad. Sci. 21:18-59.

Halladay, Orlynn J. 1965. History and development of Seney National Wildlife Refuge. Unpublished manuscript. Seney Refuge Files.

Hammer, D. A. ~~1970. Biological technician's report~~, 1970. Unpublished manuscript. Lacreek Refuge Files.

Happ, G. M. 1957. Seney National Wildlife Refuge student assistant final report. Unpublished manuscript. Seney Refuge Files.

Harris, Stanley W. and W. H. Marshall. 1963. Ecology of water-level manipulations on a northern marsh. Ecology. 44(2):331-343.

Harter, R. D. 1966. The effect of water levels on soil chemistry and plant growth of the Magee Marsh Wildlife Area. Ohio Game Monographs. No. 2. 36 pp.

Hartman, G. F. 1949. Management of central Wisconsin flowages. Wis. Conserv. Bull. 14(4):19-22.

Heinselman, M. L. 1965. String bogs and other patterned organic terrain near Seney, Upper Michigan. Ecology. 46(1 and 2):185-188.

Henry, C. J. 1950. Water management plan, 1950. Unpublished manuscript. Seney Refuge Files. 5 pp.

________. 1952. Water management plan, 1952. Unpublished manuscript. Seney Refuge Files. 5 pp.

________. 1958. Water management plan, 1958. Unpublished manuscript. Seney Refuge Files. 9 pp.

Jensen, A. C. 1964. Wildlife ecology of a heavily-used aquatic area. N. Y. Fish and Game J. 11(2): 132-147.

Johnsgard, P. A. 1955. The relation of water level and vegetative change to avain populations, particularly waterfowl. M. S. thesis. State Coll. Wash. 166 pp.

Johnson, C. S. 1946. Water management plan, 1946. Unpublished manuscript. Seney Refuge Files. 3 pp.

________. 1947. Canada goose management, Seney National Wildlife Refuge. J. Wildl. Mgt. 11(1):21-24.

________. 1949. Water management plan, 1949. Unpublished manuscript. Seney Refuge Files. 3 pp.

Kadlec, J. A. 1962. Effects of a drawdown on a waterfowl impoundment. Ecology. 43(2):267-281.

Keith, L. B. 1961. A study of waterfowl ecology on small impoundments in Southeastern Alberta. Wildl. Monographs. No. 6. 88 pp.

Lagler, Karl F. 1956. The pike, <u>Esox lucius</u> linnaeus, in relation to waterfowl on the Seney National Wildlife Refuge, Michigan. J. Wildl Mgmt. 20(2):114-124.

Linde, Arlyn F. 1969. Techniques for Wetland Management. Res. Rept. 45. Dept. of Nat. Res. Madison, Wis. 156 pp.

Linde, Arlyn F. and Max Morehouse. 1966. To feed wildlife . . . fertilize game foods? Wis. Conserv. Bull. 31(6):16-17.

Low, J. B. and F. C. Bellrose, Jr. 1944. The seed and vegetation yield of waterfowl food plants in the Illinois River Valley. J. Wildl. Mgmt. 8:7-22.

MacNamara, L. G. 1957. Potentials of small waterfowl areas. Trans. N. Am. Wildl. Conf. 22:92-96.

Martin, A. C. 1953. Improving duck marshes by weed control. U. S. Fish and Wildl. Circ. 19. 49 pp.

Martin, A. C., R. C. Erickson, and J. H. Steenis. 1957. Improving duck marshes by weed control. U. S. Fish and Wildl. Serv. Circ. 19 (Revised). 60 pp.

Martin, A. C. and F. M. Uhler. 1939. Food of game ducks in the United States and Canada. Tech. Bull. 634. USDA. 87 pp.

McAtee, W. L. 1939. Wildfowl Food Plants. Collegiate Press, Inc. Ames, Iowa. 141 pp.

McClain, P. D. 1957. Production of waterfowl foods on impoundments and marshes with low quality soils. Proc. N. E. Sec. Wildl. Soc., et al. Mimeo. 1-12 pp.

McDonald, M. E. 1955. Cause and effects of a die-off of emergent vegetation. J. Wildl. Mgmt. 19:24-35.

Mendenhall, W. 1967. Introduction to Probability and Statistics. Wadsworth Book Company. 393 pp.

Moyle, J. B. and N. Hotchkiss. 1945. The aquatic and marsh vegetation of Minnesota and its value to waterfowl. Minn. Dept. of Cons. Tech. Bull. 3.

Nelson, N. F. 1954. Factors in the development and restoration of waterfowl habitat at Ogden Bay Refuge, Weber County, Utah. Utah State Dept. of Fish and Game Publ. 6. 87 pp.

Penfound, W. T. and J. D. Schneidau. 1945. The relation of land reclamation to aquatic wildlife resources in Southeastern Louisiana. Trans. N. Am Wildl. Conf. 10:308-318.

Robel, R. J. 1962. Changes in submerged vegetation following a change in water level. J. Wildl. Mgmt. 26(2):221-224.

Sarvis, J. E. 1971. The breeding biology and ecology of the ring-necked duck in Northern Michigan. M. S. thesis. Utah State University. 70 pp.

Sherwood, G. A. 1965. Annual water program, 1965. Unpublished manuscript. Seney Refuge Files. 12 pp.

Singleton, J. R. 1951. Production and utilization of waterfowl food plants on the East Texas Gulf Coast. J. Wildl. Mgmt. 15(1):46-56.

Smith, E. J. 1952. Aquatic plant inventory, 1951. Unpublished manuscript. Seney Refuge Files. 59 pp.

________. 1958. Long range water management plan. Unpublished manuscript. Seney Refuge Files. 31 pp.

Steenis, J. H., N. C. Wilder, H. P. Cofer, and R. A. Beck. 1954. The marshes of Delaware, their improvement and preservation. Pittman-Robertson Publ. No. 2. Delaware Board of Game and Fish Commissioners. 42 pp.

Sypulski, John L. 1941. The Seney National Wildlife Refuge. N. Y. State Ranger School Alumni News. 1941.

Uhler, F. M. 1956. New habitats for waterfowl. Trans. N. Am . Wildl. Conf. 21:453-469.

________. 1944. Control of undesirable plants in waterfowl habitats. Trans. N. Am. Wildl. Conf. 9: 295-303.

Ward, E. 1942. Phragmites management. Trans. N. Am. Wildl. Conf. 7:294-298.

Weller, M. W. and C. S. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Spec. Rep. No. 43. Agric. and Home Econ. Exp. Sta. Iowa State Univ., Ames. 31 pp.

Wiebe, A. H. 1946. Improving conditions for migratory waterfoul on TVA impoundments. J. Wildl. Mgmt. 10:4-8.

Wiebe, A. H. and A. D. Hess. 1944. Mutual interests of wildlife conservation and malaria control on impounded waters. J. Wildl. Mgmt. 8:275-283.

Wilson, J. J. 1960. Annual water program, 1960. Unpublished manuscript. Seney Refuge Files. 8 pp.

________. 1962. Annual water program, 1962. Unpublished manuscript. Seney Refuge Files. 9 pp.

Wolf, K. 1955. Some effects of fluctuating and falling water levels on waterfowl production. J. Wildl. Mgmt. 19(1):13-23.

Woolhiser, Roye. 1942. Guide manual for controlling waters in the Seney National Wildlife Refuge. Typed. Seney Refuge Files. 9 pp.

Zimmerman, F. R. 1943. Water levels in relation to furbearers and waterfowl in Central Wisconsin. Wis. Conserv. Bull. 8(1):23-26.