WATERFOWL—WATER TEMPERATURE RELATIONS IN WINTER

by

Ronald A. Ryder

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ABSTRACT

A study was conducted in Larimer County, Colorado, 1967-70, to investigate the ability of waterfowl to winter north of the 0° C isotherm. Ground and aerial counts were made of selected duck and goose concentration areas where waterfowl maintained patches of open water. The number of birds using an area and the size of the area were estimated from aerial photographs. The area of open water per bird and ambient temperature appear to be directly related.

Ten 3-hour experiments were conducted with captive, wild Mallards in a controlled temperature, cold room to determine the effect of ducks on low water temperatures. Also, the metabolism of 13 Mallards was studied in the laboratory to compare heat loss from the feet and legs when exposed to 0° C water (test conditions) and when exposed to 0° C air temperatures (control). Ducks under test conditions produced significantly ($p<0.001$) more heat than ducks under control conditions. The test condition metabolism (kcal/kg/hr) represented an increase of 22.7 percent over the control metabolism.

Nocturnal behavior of Redhead ducks on a pond was observed during freezing weather. Activity was greater at night during freezing weather than during warmer weather. Duck defecation rates and chemical content of feces were determined from captive ducks.

INTRODUCTION

This study constituted a subproject of a major project entitled, "Annual Variation of the Surface-Water Temperature and Desirable Temperatures for Aquatic Life". The original research proposal was submitted in 1967 by Dr. Ronald A. Ryder, Professor of Wildlife Biology at Colorado State University. In September of 1967 B. C. Borden undertook the project as a thesis problem to fulfill requirements for a Master of Science degree in Wildlife Biology. He unfortunately was drafted after one field season. T. M. Pojar served as graduate research assistant from September 1968 to June 1969. Pojar's work has been summarized in a Master of Science thesis (1970) which is available on interlibrary loan and thus only a summary of his findings is included herein.

ACKNOWLEDGMENTS

The work upon which this publication is based was supported by funds provided by the United States Department of the Interior, Office of Water Resources Research, as authorized under the Water Resources Research Act of 1964, Public Law 88-379.

We would like to express our sincere appreciation to Fred A. Harrington, who piloted the aircraft during the 1968 and 1969 field season; the Colorado Game, Fish and Parks Division for allowing the use of their equipment and facilities; Robert Moreng of the Avian Science Department of Colorado State University for providing the ducks used in the 1969 laboratory phase of the study. We especially appreciate the assistance of John Fitch and Peter Hall of the Department of Physiology and Biophysics at Colorado State University, in setting up the metabolism measuring equipment and their thoughtful advice throughout the 1969 laboratory study.

NEED FOR THE STUDY

Grieb (1965) stated: "The basic requirements for ducks are similar to all animal species -- food, water and shelter. However, these items must be examined more specifically by season of the year since ducks move from one broad general habitat to another in their migration from breeding to winter habitat then back again". This statement also applies to geese.

Winter habitat is important to a total waterfowl management plan. Although a majority of the ducks and geese in the Central Flyway winter in warmer areas to the south of Colorado, a significant number prefer to remain on the more northerly wintering grounds. In these areas they are subjected to frequent winter storms and ice, but continue to remain and find conditions favorable for residence.

There is a tendency for some species of waterfowl to winter as far north as food and weather conditions permit (Buller 1964). This is the case in the South Platte River Valley of Northeastern Colorado, one of the more northern major wintering areas of the Central Flyway. Thousands of ducks and geese winter here each year. Normal winters usually result in an almost total freeze-up of wetlands. Even though feeding and resting habitat are apparently limited, large numbers of birds remain until spring migration.

What are the relationships of waterfowl and habitat with winter weather and below freezing water temperatures? How do ducks and geese cope with the adversities of winter in the more northerly wintering areas?

A preliminary search of the literature revealed little knowledge of the effects of waterfowl on water temperature. Generally, it was thought that large concentrations of ducks and geese can, by various means, keep some water ice-free on otherwise frozen wetlands (Grieb 1954 and Kinghorn 1949).

OBJECTIVES

1. To determine the effects of winter water temperatures and related weather factors on waterfowl use of selected reservoirs and streams in northern Colorado.

2. To determine the amount and causes of ice-free water on the selected reservoirs during heavy freeze.

3. To determine the effect of ducks on winter water temperatures.

STUDY AREA

Description of the Area

The study was conducted in eastern Larimer County in the vicinity of Fort Collins, Colorado. Larimer County is located in north-central Colorado and extends to the Wyoming - Colorado border. The study area was bordered in the west by the foothills of the Rocky Mountains and extended eastward twelve miles across the short-grass prairie to the Larimer-Weld County boundary line. From Fort Collins it extended south ten miles to Loveland, Colorado. All totaled, the area encompassed approximately 182 square miles of rolling prairie farmland interspersed with wetlands (Fig. 1).

Numerous wetland types are found in this area. Irrigation reservoirs and ponds are predominant and range in size from 1,640 surface acres to less than one acre. The Cache la Poudre River flows approximately eighteen miles northwest to southeast across the study area. Associated with the reservoirs are networks of canals and ditches. Also interspersed throughout the area are numerous sloughs and marshes of both permanent and semi-permanent nature.

Ducks and geese are found in northeastern Colorado in all seasons o the year. Each year during fall migration, thousands of ducks and geese visit the area. Many, including residents, remain to winter and feed on waste grain in nearby wheat, milo and corn fields as long as weather permits.

The mallard (*Anas platyrhyrchos*) is by far the most numerous duck during winter and is the predominant nester in spring. A resident flock of Great Basin Canada geese (*Branta canadensis moffitti*) and giant Canada geese (*B. c. maxima*), which were introduced in 1957 and now number approximately 1,100 (Grieb 1967), have enticed many migrant Canada geese to winter in the area.

Table 1 shows the maximum surface areas of the forty-four reservoirs, lakes and ponds selected for the study. Also included in the study was an 8.5 mile segment of the Cache la Poudre River extending from east of Fort Collins to the Larimer - Weld County boundary line (Fig. 1).

Table 1: Approximate maximum surface acres of water of wetlands used in the study.*

Wetland	Surface Acres	Wetland	Surface Acres
Boyd Lake	1640	North Poudre #6	443
Cobb Lake	760	Claymore Lake	78
Fossil Creek Res.	853	Hinkley Res.	83
North Poudre #2	275	Deines Res.	30
Heinricy Lake	30	Annex #8	175
Horshoe Lake	416	North Poudre #10	64
Water Supply #1	226	Dry Creek Res.	15
Houts #1	40	South Grey Res.	76
Houts #2	42	North Grey Res.	36
Douglas Lake	586	Hagen Pond	2
Timnath Res.	700	Mud Lake	6
Terry Lake	530	Duck Lake	8
Divide #8	407	Nelson Res.	11
Water Supply #3	211	Stewart Lake	6
Water Supply #4	76	Kitchel Res.	11
Curtis Lake	151	Baker Pond	5
Lindenmeier Lake	107	Fisher Pond	3
Boxelder #3	30	Winick Pond South	3
North Poudre #1	86	Winick Pond North	1
North Poudre #3	217	Elder Res.	18
North Poudre #4	119	College Lake	13
North Poudre #5	402	Herring Lake	13

* Not included -- 8.5 mile route along Cache la Poudre River between the Weld County Line and Fort Collins, Colorado

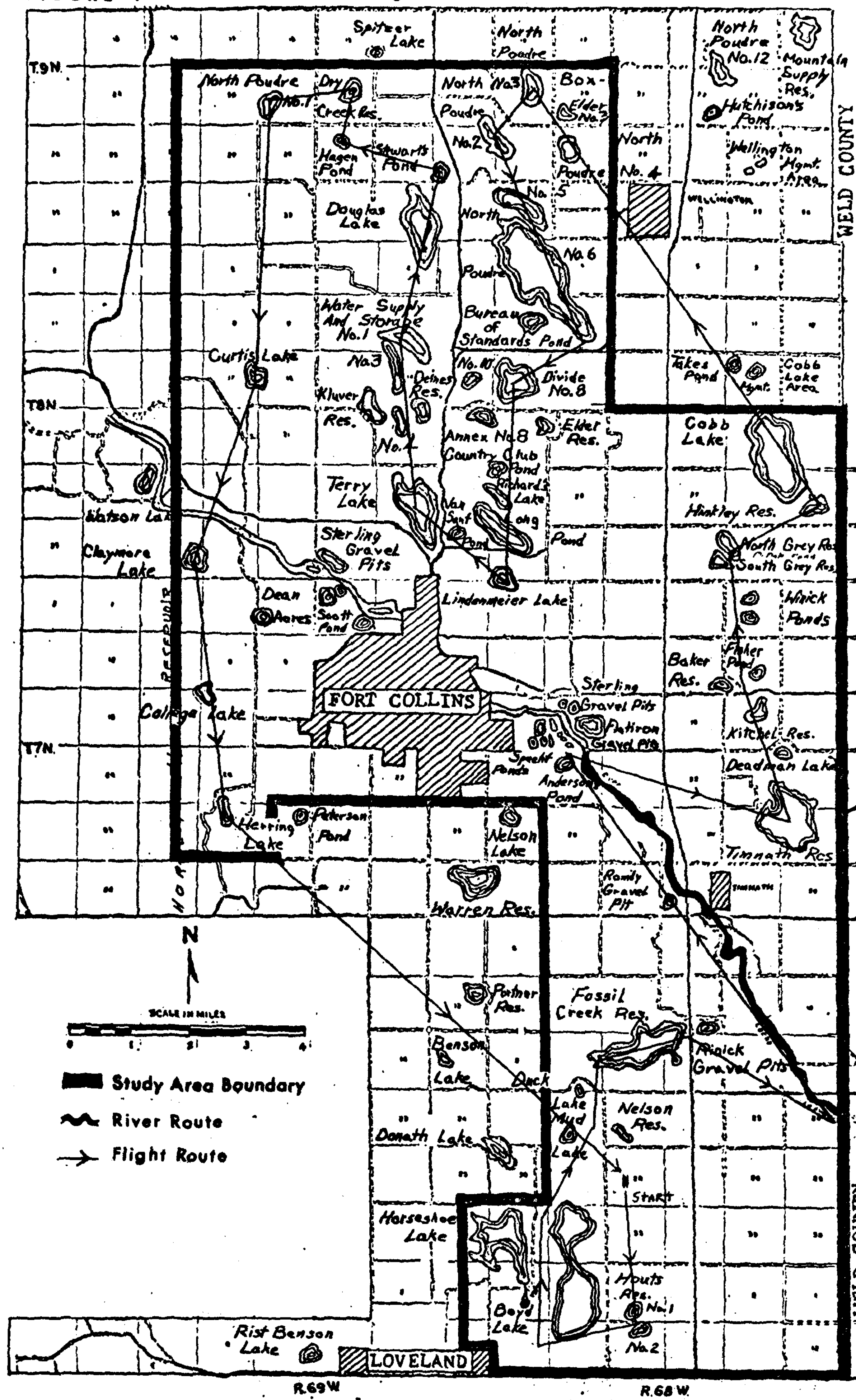
General Use of Wetlands

Irrigation is the most important domestic use of water in this area. Over 80 percent of the larger wetlands are owned by irrigation companies and many are leased to hunting clubs, boating clubs and private individuals for hunting and fishing. The Colorado Game, Fish and Parks Division has also leased several of the reservoirs and has purchased some marsh areas. With these wetlands the Division has created public hunting and fishing areas, state recreational areas and most important has set aside several large reservoirs as waterfowl sanctuaries.

Eastern Larimer County provides a diversity of waterfowl habitat. In spring and summer waterfowl may be found on most of the wetlands where disturbance is limited. Nesting ducks prefer marsh areas, ditches and canals, and small ponds with adequate vegetative cover. Most reservoirs are unsuitable for nesters due to maintenance of the shorelines and various other disturbances. However, resident Canada geese have responded well to nest structures built by the Colorado Game, Fish and Parks Division, and readily nest on the reservoirs using both the structures and the ground vegetation available.

In fall when hunting commences, most ducks and geese move to the larger reservoirs for protection. Usually by December 1 most wetlands are covered with ice and the only open water occurs in warm water seep-areas and in spots along the river and on the reservoirs. After the hunting season many birds move from the reservoirs into the riverbottom and other areas with some ice-free water.

FIGURE 1



EASTERN LARIMER COUNTY, COLORADO

METHODS AND MATERIALS

Waterfowl Counts and Estimates

Initially, waterfowl were counted from the ground with a 20X spotting scope, but this technique proved unsuitable. Not all areas of the larger reservoirs could be seen from the ground and often waterfowl had to be counted from great distances. General water conditions were difficult to determine. Bad road conditions in winter prohibited access to some of the more important areas and necessitated abandoning ground counts. Most ground counts were preliminary to the actual field period and were believed less important than the aerial counts. Limited ground counts were made when one aerial count was discontinued due to heavy winds.

Weekly aerial counts began in early January, following the duck hunting season, and were continued until ice thawed in early March. The flights began between 7:30 and 8:00 a.m., usually during mid-week, and were finished within an hour-and-a-half, weather permitting. Cessna 150 aircraft were used. Counts and estimates were made from an altitude of 500 to 600 feet and results recorded on a Uher portable tape recorder. Later, these data were transcribed on permanent record sheets. Fig. 1 indicates the flight route through the study area.

Ducks and geese were counted separately. However, species composition of each group was not believed important for the purposes of this study. In this area, Canada geese make up the entire wintering population of geese, with rare exceptions, and most of the ducks are mallards (Rutherford and Hayes 1968).

Waterfowl were normally well distributed on the river and total counts were possible. However, on the reservoirs estimates were usually required since the birds concentrate around and in small ice-free water areas. Estimating by groups of one hundred was the usual procedure.

During the first flight, photographs were taken of open water areas with a 4 x 5 Graflex camera. During subsequent flights several 35 mm photographs were taken of waterfowl concentrations in an attempt to check estimates made at the same time. These 35 mm slides were taken with a standard lens at one-thousandth of a second shutter speed from an altitude of between 550 and 600 feet.

Aerial counts and estimates, and photography proved to be very suitable for the purposes of this study. Large areas could be surveyed and observed in a short period that could not be included from the ground.

<u>Estimates of Ice-Free Water</u>

Estimates of the amount of ice-free water on each reservoir were obtained simultaneously with the aerial waterfowl counts. Intuitive estimates in acres to the nearest tenth were made immediately following counts, and were recorded on tape and transcribed later. Reference areas of known acreage were studied in order to improve the estimate. Estimates of large acreages were not involved, since the amount of ice-free water on a reservoir when it is frozen is usually quite small, two acres or less.

Ice-free waters on the reservoirs were classified into one of three categories according to the apparent causative agent: (1) water kept ice-free due to introduction of warmer water from outside sources; (2) water kept ice-free due to waterfowl use; and (3) unknown causes.

Diurnal Waterfowl Use of Reservoirs

In order to supplement other data, studies were initiated to determine the diurnal use of selected reservoirs by waterfowl. Attempts to do so in 1967 were limited and were further pursued during the second and third field period (see Pojar 1970).

Selected reservoirs were observed in early morning, at mid-morning, in early afternoon and for one hour until sunset. Ducks and geese were counted with a 20 x spotting scope and movements to and from the area were recorded. Prevailing weather conditions and the distribution of ducks and geese on the reservoirs were noted.

Duck - Water Temperature Experiments

Experiments to determine the effect of ducks on low water temperatures were begun in late January 1968 and continued for five weeks. Two experiments per week were conducted with captive adult male mallards. A 10' x 20' controlled temperature cold room, owned by the Colorado Game, Fish and Parks Division, was used for the experiments.

There were three experimental groups of ducks all tested in the same water depth of four inches: (1) water surface area of 1.5 square feet, thermostat set at 36° F and two ducks; (2) surface area 2.7 square feet, thermostat 36° F and three ducks; and (3) surface area 1.5 square feet, thermostat 32° F and two ducks.

To allow equalization of water and air temperatures, two aquaria, an experimental and a control, were placed in the cold room and filled with four inches of well water approximately twenty hours before each experiment.

Three hours before each experiment the water in both containers was briefly stirred to prevent any temperature stratification.

Preliminary water temperatures were taken from both containers prior to the experiments. The ducks were then placed in the experimental aquaria, their wings secured with rubber bands, and a net over the container. The ducks were selected at random from the nine captives.

Each experiment was conducted for three hours. Every half-hour the air temperature and six water temperature observations were taken from both the experimental and control aquaria using 0.1^{o} F precision rod thermometers. Water temperature readings were averaged for each aquarium.

For the experimental aquarium, two observations of the temperature increase were calculated for each half-hour interval: (1) the observed water temperature of the experimental aquarium minus its water temperatures at the start of the experiment; and (2) the first calculation plus or minus the difference between the observed water temperature of the control aquarium and its water temperature at the start of the experiment. It was assumed that there were corresponding decreases and increases in the water temperature of both the experimental and control containers.

After three hours the ducks were removed, the water was stirred and a 200 ml sample of water was taken to determine the amount of feces deposited per duck per hour. From this sample two 20 ml subsamples were dried and weighed to the nearest tenth of a milligram. Corrections were made for the dissolved solids in the well water used.

Defecation Rates

Six ducks were selected at random from the nine adult male mallards available to determine their hourly rate of defecation. Two observations per duck were made, except for one that was accidentally released before the second observation. Individual ducks were isolated in a small cage with a catch tray for one hour approximately five hours after feeding. The bird was then removed, the droppings were counted and collected for later drying and weighing to the nearest hundredth of a gram.

The ducks were weighed immediately after capture and prior to release. (Table 2). They were fed approximately three parts Gooch's Best Turkey Feed, an all-purpose diet, and one part whole corn.

Excessive disturbance of the penned ducks late in this phase of the study limited the number of reliable observations obtained. Therefore, further study was conducted the second and third field seasons (*cf*. Pojar 1970).

Table 2. Banding information and weights of the captive ducks used in the water temperature experiments.

Species	Age	Sex	Band Number	Weight At Capture (grams) 1-19-68	Weight At Release (grams) 3-12-68
Mallard *	Adult	Male	717-16176	935	985
Mallard	Adult	Male	717-16177	995	**
Mallard *	Adult	Male	717-16178	1030	1240
Mallard *	Adult	Male	717-16179	975	**
Mallard *	Adult	Male	717-16180	990	950
Mallard	Adult	Male	717-16181	895	**
Mallard *	Adult	Male	717-16182	1025	1060
Mallard	Adult	Male	717-16183	1015	***
Mallard	Adult	Male	717-16184	1000	1110

* Used to determine defecation rate.
** Released prior to 3-12-68.
*** Died prior to 3-12-68.

Temperature of Ice-Free Water

Temperatures of ice-free water in natural lakes and reservoirs were not obtained during the first field period. Ground observations were extremely difficult to obtain due to the isolation of open water on the reservoir and prohibited access to some of the more important areas. A Stoll-Hardy HL - 14 Radiometer was employed in an attempt to determine water temperatures from an airplane. The radiometer is useful in determining the temperature of distance objects that radiate as "black bodies". This instrument, however, needed repair and could not be used during the first field period.

Weather Data

Weather data for November through March, 1967-68 and for the past eleven winters were collected from the Colorado State University Weather Station. These data included daily observations and monthly means for maximum, minimum and mean air temperatures, range of air temperatures, relative humidity and wind velocity. Daily observations and monthly sums were collected for the amount of precipitation, snow depth and sky conditions.

RESULTS AND DISCUSSION

Larimer County Weather

Table 3 shows monthly averages and sums of weather data for winters 1956-57 through 1967-68. These data are by no means adequate for determining norms or trends in the winter weather of eastern Larimer County. However, by comparing individual winters and the 1967-68 winter with past data, some general conclusions can be made.

Fig. 2 is a bargraph representation of mean monthly air temperatures for the past twelve winters and includes total snowfall for each winter. The 1961-62 winter appears to have been the coldest, whereas, the winters of 1960-61 and 1966-67 were the mildest. The twelve-year low air temperature (-32° F) was recorded on January 10, 1962. The 1962-64 Colorado yearbook (1965) lists an all-time low of -41° F in 1951. Air temeratures of less than -10° F were rare, with the exception of the 1961-62 winter. Mean January air temperatures were lowest of the winter months during five of the twelve winters, December during three, February during one, March during one and both January and February during two winters. Mean January air temperatures were all below 32° F, except for 1965, during the past twelve years. Nine of the December months and six of the February months were below 32° F.

Based on the data in Table 3 and illustrated in Fig. 2, the winter of 1967-68 appears to have been average if not slightly above. December was the coldest month followed by progressive increases in mean, monthly air temperatures from January to March. Total snowfall (47.3 inches) was the highest of the twelve years. The average annual snowfall for Larimer County is 43.4 inches (Anonymous 1965). Snowfall must be considered due to its effect on feeding waterfowl and the ability of snow to insulate lake ice and perpetuate freeze (Ruttner 1952).

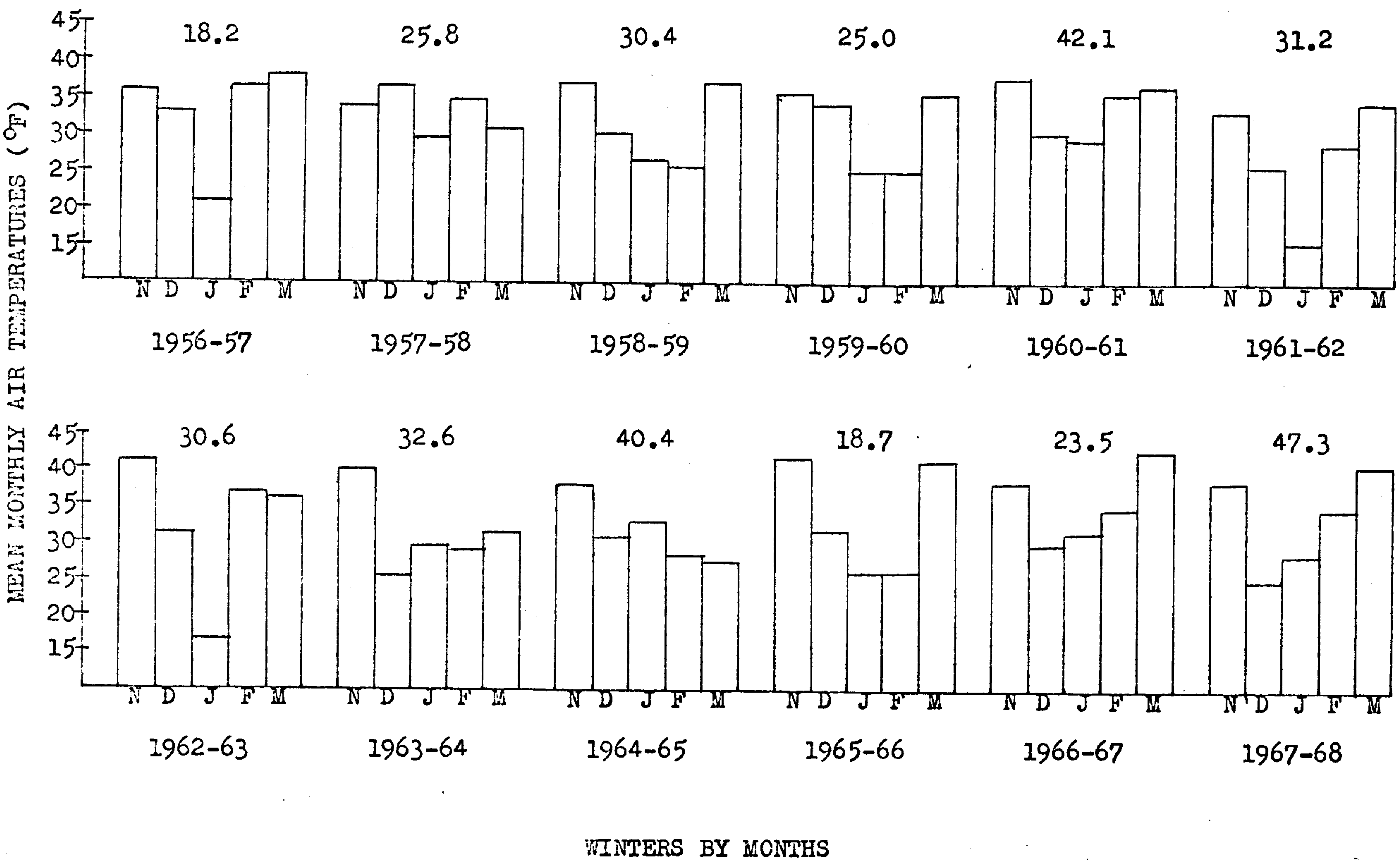
Table 3a: Monthly averages and sums of weather data for winter months November through March, 1956 to 1968.

(Winters) Month & Year	Average Air Temperature (°F) Daily Max.	Daily Min.	Daily Mean	(inches) Total Snowfall	(mph) Average Wind Velocity	Sky Condition (No. of Days) Clear	P. Cloudy	Cloudy
Nov. 56	50.1	21.9	36.0	8.6	6.6	7	14	9
Dec. 56	48.3	19.3	33.8	2.8	5.3	13	12	6
Jan. 57	35.1	6.9	21.0	4.4	4.9	7	13	11
Feb. 57	50.7	22.8	36.8	0.0	5.9	7	12	9
Mar. 57	51.1	24.4	37.7	2.4	7.2	8	10	13
Nov. 57	45.5	22.5	34.0	0.5	5.7	8	12	10
Dec. 57	52.6	21.2	36.9	0.0	8.1	11	16	4
Jan. 58	45.7	13.8	29.7	4.8	6.5	13	13	5
Feb. 58	47.6	22.1	34.9	5.3	6.5	4	7	17
Mar. 58	41.2	21.1	31.2	15.2	5.3	3	6	22
Nov. 58	52.7	22.1	37.4	7.7	5.6	8	10	12
Dec. 58	43.8	17.5	30.6	1.6	5.0	6	11	14
Jan. 59	39.3	14.8	27.0	5.2	5.1	5	16	10
Feb. 59	36.3	15.7	26.0	4.9	5.0	8	7	13
Mar. 59	50.0	25.4	37.7	11.0	7.9	5	9	17
Nov. 59	51.0	20.4	35.7	1.0	7.3	7	14	9
Dec. 59	48.6	19.7	34.2	0.0	5.4	9	16	6
Jan. 60	38.5	12.0	25.2	5.9	5.0	5	12	14
Feb. 60	35.6	14.4	25.0	10.9	6.1	2	9	18
Mar. 60	49.1	22.1	35.6	7.2	7.1	3	9	19
Nov. 60	51.9	23.3	37.6	2.8	5.7	7	14	9
Dec. 60	42.9	17.6	30.2	4.7	6.0	13	8	10
Jan. 61	45.9	12.5	29.2	3.2	4.7	14	11	6
Feb. 61	48.9	21.9	35.4	8.0	6.1	7	11	10
Mar. 61	47.6	25.5	36.6	23.4	5.8	3	15	13
Nov. 61	46.3	21.4	33.8	7.6	-	-	-	-
Dec. 61	38.1	14.1	26.1	3.1	-	-	-	-
Jan. 62	31.2	0.1	15.6	4.3	-	10	11	10
Feb. 62	39.9	17.9	28.9	10.4	-	3	10	15
Mar. 62	46.9	21.7	34.3	5.8	-	7	10	14

Table 3b: Monthly averages and sums of weather data continued.

(Winters)	Average Air Temperatures (°F)			(inches)	(mph)	Sky Condition (No. of Days)		
Month & Year	Daily Max.	Daily Min.	Daily Mean	Total Snowfall	Average Wind Velocity	Clear	P. Cloudy	Cloudy
Nov. 62	55.0	26.8	40.9	4.0	9.2	9	14	7
Dec. 62	46.6	16.7	31.6	0.8	9.5	12	12	7
Jan. 63	32.1	1.9	17.0	12.8	12.2	7	14	10
Feb. 63	50.4	23.0	36.7	6.4	14.5	4	17	7
Mar. 63	49.5	22.7	36.1	6.6	13.2	14	6	11
Nov. 63	54.8	25.0	39.9	0.0	4.4	9	13	8
Dec. 63	39.7	11.5	25.6	9.9	4.4	9	14	8
Jan. 64	42.2	16.3	29.3	3.7	7.4	13	12	6
Feb. 64	40.8	15.7	28.2	5.3	8.5	8	13	8
Mar. 64	44.6	19.1	31.9	13.7	6.7	6	12	13
Nov. 64	51.3	24.4	37.8	4.3	5.5	8	13	9
Dec. 64	42.8	18.6	30.7	0.9	6.1	10	10	11
Jan. 65	47.0	19.6	33.3	8.2	6.8	9	7	15
Feb. 65	41.0	14.9	27.9	10.8	5.6	9	8	11
Mar. 65	39.5	14.3	26.9	16.2	5.7	8	10	13
Nov. 65	56.2	28.3	42.2	0.0	5.8	7	15	8
Dec. 65	45.4	17.9	31.7	6.4	4.3	5	18	8
Jan. 66	39.6	12.0	25.8	2.4	4.4	6	15	10
Feb. 66	38.7	12.9	25.8	9.9	3.6	6	12	10
Mar. 66	58.1	25.3	41.7	0.0	6.3	10	11	10
Nov. 66	50.4	25.0	37.7	0.0	4.1	4	17	9
Dec. 66	42.8	16.7	29.7	3.0	4.6	8	13	10
Jan. 67	45.3	18.3	31.8	10.6	6.4	3	19	9
Feb. 67	48.3	21.0	34.7	6.4	7.5	8	16	4
Mar. 67	57.5	28.3	42.9	6.5	7.0	6	13	12
Nov. 67	52.2	23.1	37.7	12.5	4.4	13	8	9
Dec. 67	35.7	13.6	24.7	16.1	5.0	5	11	15
Jan. 68	41.9	13.7	27.8	0.7	4.2	10	14	7
Feb. 68	46.6	22.4	34.5	9.7	4.8	7	10	12
Mar. 68	55.5	26.0	40.8	8.3	5.4	10	11	10

Figure 2: Comparison of mean air temperatures for months November through March of winters 1956-57 through 1967-68. Total snowfall for each winter above bargraphs.

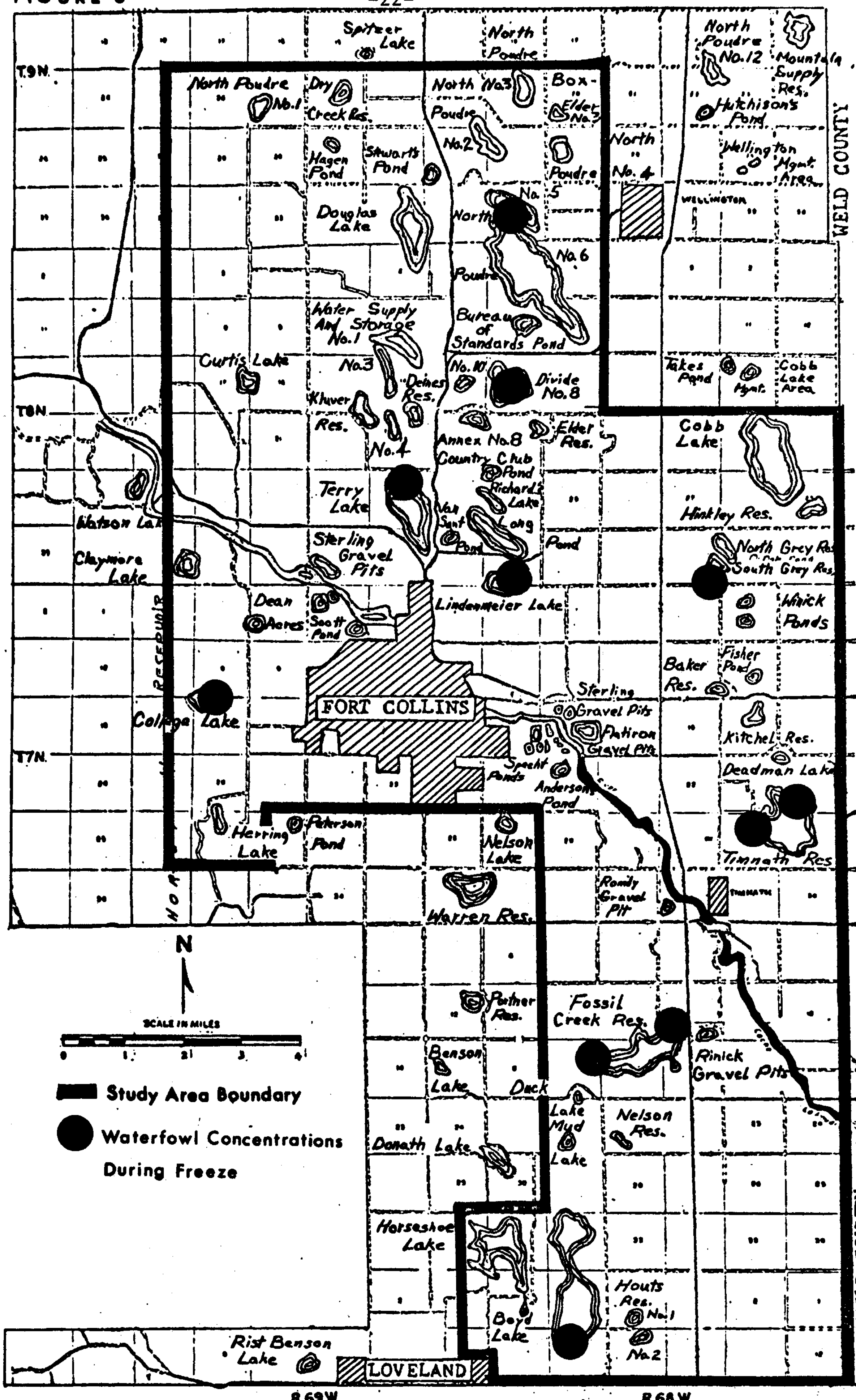


Waterfowl - Use of Wetlands in Winter

Field counts and observations were begun after January 1, 1968, to avoid any "forced" distribution of waterfowl due to hunting pressure. Goose hunting continued until January 15. This, however, was not a significant factor since most of the study was closed to goose hunting. Hunting on the remainder of the area was limited, particularly late in the season. Waterfowl concentrated on the larger reservoirs for protection during hunting season. Immediately afterwards, there was considerable movement of ducks from these areas to warm-water seep-areas and streams with open water (Hopper 1968).

Table 4 shows the average duck-and goose-use of the wetlands during freezeup. Heavy freeze occurred during the second week of December and persisted until the fourth week of February. During aerial censuses, January 11 through March 6, twelve major waterfowl concentration areas, including the Cache la Poudre River, were noted (Fig. 3). In these areas the birds congregated around and in the available open water.

FIGURE 3



EASTERN LARIMER COUNTY, COLORADO

Table 4: Average duck-and goose-use of wetlands during the freeze period, 1967-68.

Wetland	Average Duck Use	Average Goose Use	Wetland	Average Duck Use	Average Goose Use
Boyd Lake	164	27	North Poudre 6	45	52
Cobb Lake	0	0	Claymore Lake	0	0
Fossil Creek Res.	518	850	Hinkley Res.	1	0
North Poudre 2	0	63	Deines Res.	0	0
Heinricy Lake	2	0	Annex 8	0	16
Horshoe Lake	0	23	North Poudre 10	0	0
Water Supply 1	0	0	Dry Creek Res.	0	6
Houts 1	0	0	South Grey Res.	429	50
Houts 2	0	0	North Grey Res.	8	2
Douglas Lake	5	6	Hagen Pond	11	11
Timnath Res.	472	292	Mud Lake	0	0
Terry Lake	197	407	Duck Lake	0	0
Divide 8	629	602	Nelson Res.	0	0
Water Supply 3	36	0	Stewart Lake	3	0
Water Supply 4	36	0	Kitchel Res.	0	0
Curtis Lake	0	0	Baker Pond	0	0
Lindenmeier Lake	126	291	Fisher Pond	4	0
Boxelder 3	4	0	Winick P. South	0	0
North Poudre 1	0	0	Winick P. North	0	0
North Poudre 3	0	14	Elder Res.	16	21
North Poudre 4	0	0	College Lake	97	363
North Poudre 5	129	358	Herring Lake	0	0
(Poudre River)**					

* Approximate freeze period of wetlands for winter of 1967-68 -- second week of December through fourth week of February.

** Cache la Poudre River -- 8.5 mile long count route.

Grieb and Boeker (1954) stated that there is a steady influx of ducks into eastern Colorado beginning in September, usually reaching a peak in December and tapering off until late February or early March. However, aerial census during the winter of 1967-68 revealed that the number of ducks steadily increased from early January onward. An exception was a short period in mid-February when duck numbers decreased due to the onset of more severe weather and colder temperatures (Fig. 4). Apparently, the birds did not leave the area, but moved into the riverbottoms and smaller wetlands for protection from the weather. During this period an increase in duck-use of the river was noted (Fig. 5). After the severe weather subsided there was a rapid increase in duck-use of the reservoirs and a decrease in use of the river. During the final flight on March 6, 1968, 7, 977 ducks were estimated to be present on the study wetlands.

A preliminary count of most of the wetlands in late November prior to freeze revealed over 6,000 ducks. Immediately after freezeup, the number dropped to less than 1,000. Apparently, there was a peak in late November or early December as Grieb and Boeker (1954) indicated in earlier years, but the ensuing decrease lasted less than a month. Steady increases from January to March were most likely a build up of spring migrants.

Goose numbers generally decreased from late January through February (Fig. 4). The largest number (8,207) were seen in the area on January 20, when large numbers were observed flying north along the foothills and many were sighted standing on frozen, otherwise unused reservoirs in the northern segment of the study area. Grieb and Boeker (1954) stated that peak flights of geese occurred in January. After January 20 the number of geese on the reservoir dropped drastically from an estimated 8,207 to 1,561 on January 31.

Hopper (1968) stated that in Colorado, geese utilize reservoirs throughout the winter and remain on them during severe weather. Evidence of this is shown in Fig. 4. Adverse weather during mid-February increased goose-use of the reservoirs that Borden studied. During late February, goose numbers once again dropped sharply. Presumably this decrease left only residents in the area while migrants moved north. Geese were rarely seen on the river.

Some difficulty was experienced in censusing geese using the reservoirs because of their feeding habits. Obviously, there was some conflict between feeding times and count times. However, during aerial census, notes were made of geese feeding in fields and elsewhere.

Figure 4: Comparison of total ducks and geese using the study area for eight complete aerial count dates, Jan. 11 through Mar. 6, 1968.

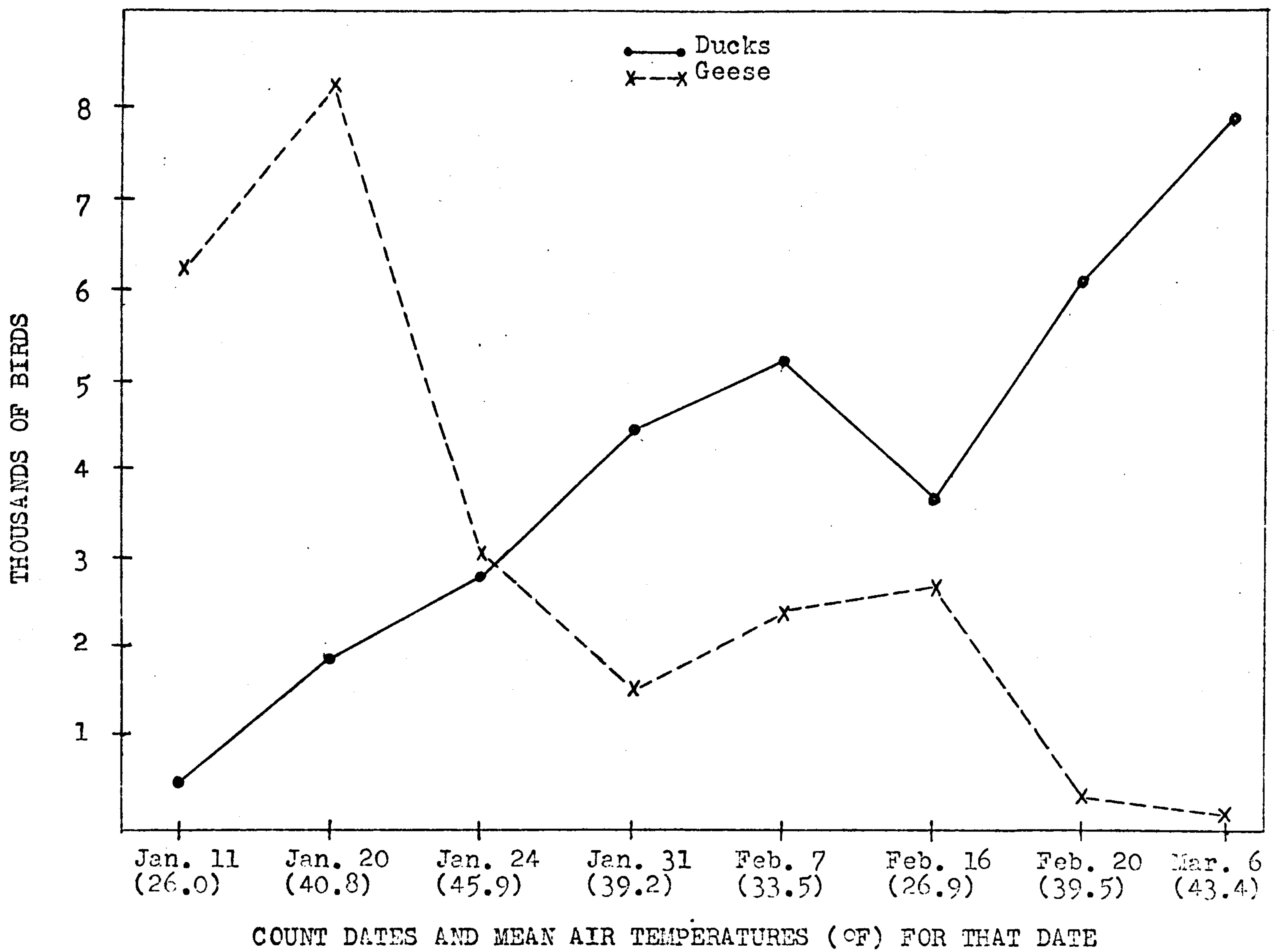
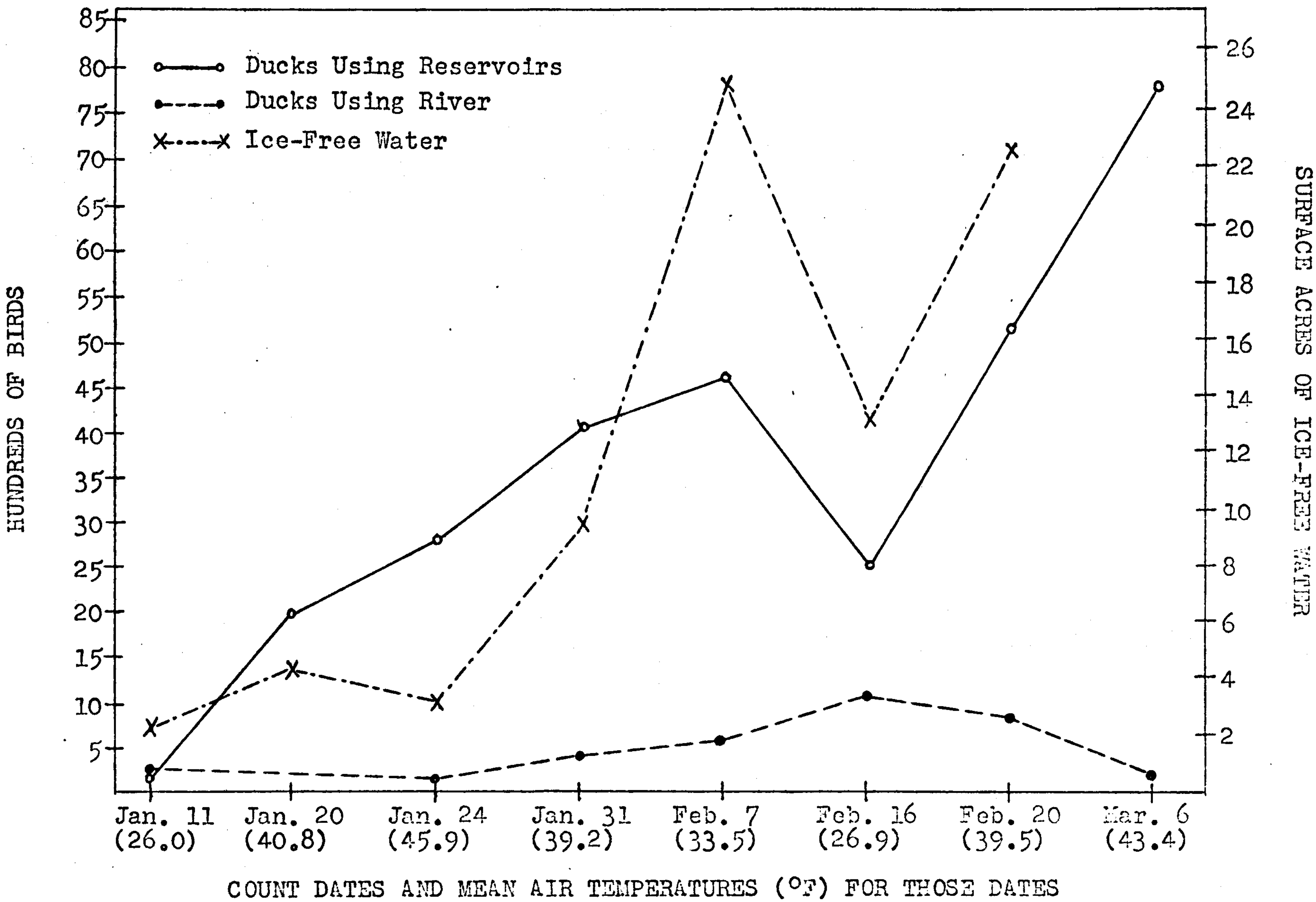


Table 5. Comparison of total ducks and geese present on the study area and weather data for each aerial count date.

Count Date	Total Waterfowl On Reservoirs		Ducks On River	Air Temperatures (of)			Snow Cover On Ground	(mph) Average Wind Velocity	Sky Condition
	Ducks	Geese		Max.	Min.	Mean			
1-11-68	262	6208	328	37.2	14.8	26.0	Moderate	7.4	P. Cloudy
1-20-68	1955	8207	*	54.1	27.5	40.8	Light	4.2	Clear
1-24-68	2790	3035	77	60.7	31.0	45.9	Trace	3.2	P. Cloudy
1-31-68	4057	1561	356	52.0	26.4	39.2	None	8.6	Cloudy
2-07-68	4659	2379	573	52.2	14.8	33.5	None	3.2	P. Cloudy
2-16-68	2526	2665	1093	36.5	17.2	26.9	Heavy	5.4	Cloudy
2-20-68	5256	326	782	53.0	26.0	39.5	Moderate	3.9	Cloudy
3-06-68	7775	169	202	62.0	24.8	43.4	Trace	4.0	P. Cloudy

* No count was made on the river for this date due to heavy winds during the flight.

Figure 5: Comparative use of reservoirs and the Cache La Poudre River by ducks and surface acres of ice-free water on the reservoirs for eight complete aerial count dates, Jan. 11 through Mar. 6, 1968.



DAILY WEATHER DATA FOR WINTER OF 1967-68

Table 6a: November 1967

Date	Air Temperature (° F) Max.	Min.	Mean	(inches) Snowfall	Wind Miles Past 65 Ft. Tower (7 a.m. to 7 a.m.)	Sky Condition
1	66.7	32.8	49.8	-	182	Cloudy
2	57.9	22.0	40.0	6.2	102	Cloudy
3	26.1	7.8	17.0	T	66	P. Cloudy
4	28.4	14.1	21.3	-	82	Cloudy
5	38.8	9.4	24.1	-	59	Clear
6	45.3	13.0	29.2	-	63	Clear
7	54.9	17.5	26.2	-	75	Clear
8	59.8	23.7	41.8	-	69	Clear
9	61.3	26.8	44.1	-	81	Clear
10	58.0	35.0	46.5	-	155	Clear
11	71.0	30.8	50.9	-	122	P. Cloudy
12	55.3	35.9	45.6	-	75	Cloudy
13	68.0	32.2	50.1	-	110	Cloudy
14	60.8	35.0	47.8	-	66	Cloudy
15	70.9	28.6	49.8	-	91	Clear
16	68.9	34.7	51.8	-	135	P. Cloudy
17	60.0	25.2	42.6	-	83	P. Cloudy
18	48.0	21.3	34.7	-	55	P. Cloudy
19	65.2	26.0	45.6	-	112	Clear
20	59.2	25.2	42.2	-	155	Clear
21	51.7	24.0	37.9	6.3	117	Cloudy
22	29.0	19.2	24.1	T	89	P. Cloudy
23	41.7	24.1	32.9	-	107	Clear
24	50.5	18.1	34.3	-	191	P. Cloudy
25	46.7	24.7	35.7	-	161	Cloudy
26	38.9	22.0	30.5	-	140	Clear
27	37.0	12.3	24.7	-	48	Clear
28	40.9	14.1	27.5	-	59	P. Cloudy
29	48.3	18.8	33.6	-	65	Clear
30	55.8	18.2	37.0	-	273	Cloudy
$\overline{X}$	52.2	23.1	37.7	12.5	106	

Table 6b: December 1967.

Date	Air Temperature (° F) Max.	Min.	Mean	(inches) Snowfall	Wind Miles Past 65 Ft. Tower (7 a.m. to 7 a.m.)	Sky Condition
1	46.3	24.3	35.3	-	152	Cloudy
2	38.0	5.0	21.5	-	59	Clear
3	50.6	15.0	32.8	-	73	Clear
4	51.0	26.7	38.9	-	76	P. Cloudy
5	51.6	17.7	34.7	-	129	Clear
6	42.3	22.1	32.2	-	188	Clear
7	39.4	15.4	27.6	-	60	P. Cloudy
8	36.2	23.5	29.9	-	272	Cloudy
9	36.4	22.1	29.3	T	116	P. Cloudy
10	47.5	14.7	31.1	-	105	Cloudy
11	56.7	22.9	39.8	-	324	P. Cloudy
12	38.6	13.0	25.8	1.4	77	Cloudy
13	14.6	9.1	11.9	5.1	106	Cloudy
14	18.3	7.2	12.8	2.0	70	Cloudy
15	19.0	5.0	12.0	T	65	Cloudy
16	31.7	8.3	20.0	-	131	Cloudy
17	33.5	19.4	26.5	.2	89	Cloudy
18	31.9	6.5	19.2	-	74	P. Cloudy
19	37.0	11.0	24.0	-	68	P. Cloudy
20	24.0	10.8	17.4	2.3	100	Cloudy
21	22.0	-9.0	6.5	T	129	Clear
22	31.8	5.4	18.6	-	88	P. Cloudy
23	55.4	14.3	34.9	-	134	P. Cloudy
24	52.0	32.8	42.4	-	215	P. Cloudy
25	36.6	26.0	31.3	.4	109	Cloudy
26	35.0	24.1	29.6	2.5	137	Cloudy
27	24.2	-2.5	10.9	.2	103	P. Cloudy
28	37.0	18.4	27.7	T	156	Cloudy
29	31.1	10.4	20.8	1.0	81	Cloudy
30	21.6	6.7	14.2	1.0	144	Cloudy
31	16.8	-6.0	5.4	T	72	P. Cloudy
$\overline{X}$	35.7	13.6	24.7	16.1	119	

Table 6c: January 1968

Date	Air Temperature (° F) Max.	Min.	Mean	(inches) Snowfall	Wind Miles Past 65 Ft. Tower (7 a.m. to 7 a.m.)	Sky Condition
1	34.0	5.4	19.7	-	80	P. Cloudy
2	16.3	-4.0	6.2	.3	100	P. Cloudy
3	36.0	-7.0	14.5	-	130	Clear
4	33.0	0.6	19.5	-	117	Clear
5	41.0	18.4	29.7	-	160	P. Cloudy
6	21.0	-5.9	7.6	.4	82	Clear
7	32.5	-6.3	13.1	-	55	Clear
8	38.7	4.2	21.5	-	82	P. Cloudy
9	30.3	18.6	24.5	-	60	P. Cloudy
10	34.2	6.2	20.2	-	68	P. Cloudy
11	37.2	14.8	26.0	-	177	P. Cloudy
12	27.6	4.0	15.8	-	68	Clear
13	40.0	2.5	21.3	-	63	P. Cloudy
14	49.4	18.7	34.1	-	47	Cloudy
15	46.1	14.1	30.1	-	48	Clear
16	53.0	16.3	34.7	-	77	Cloudy
17	46.8	26.7	36.8	-	165	P. Cloudy
18	35.7	15.7	25.7	-	71	Clear
19	52.9	18.5	35.7	-	76	P. Cloudy
20	54.1	27.5	40.8	-	100	Clear
21	53.0	22.4	37.7	-	113	Clear
22	44.2	32.2	38.2	-	82	P. Cloudy
23	42.1	24.0	33.1	-	99	Cloudy
24	60.7	31.0	45.9	-	76	P. Cloudy
25	56.5	31.0	43.8	-	102	Cloudy
26	39.0	28.8	33.9	-	136	Cloudy
27	34.9	28.1	31.5	-	67	Cloudy
28	53.1	28.0	40.6	-	231	P. Cloudy
29	46.6	24.0	35.3	-	90	Clear
30	56.2	18.0	37.1	-	195	P. Cloudy
31	52.0	26.4	39.2	-	206	Cloudy
$\overline{X}$	41.9	13.7	27.8	.7	102	

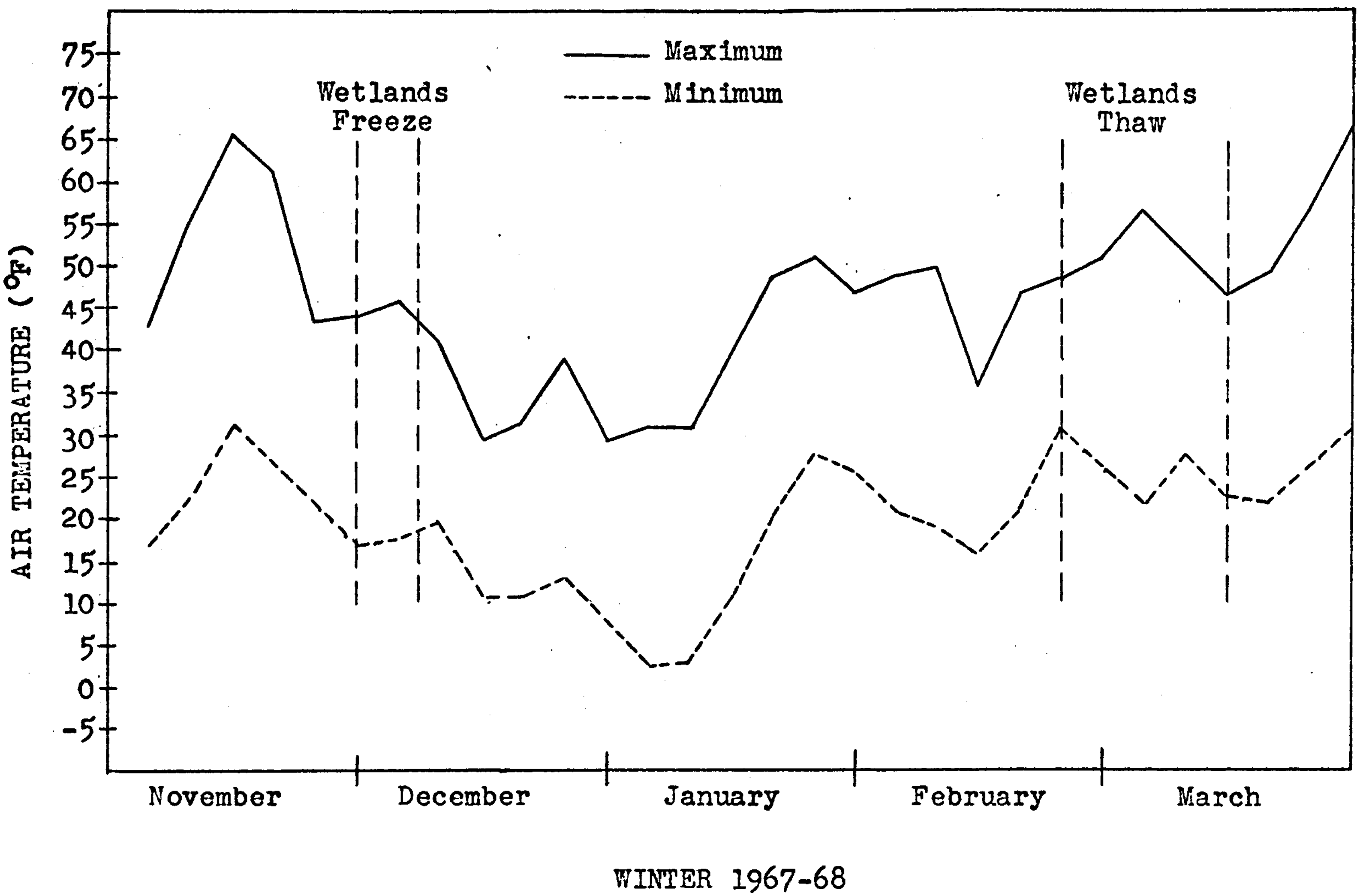
Table 6d: February 1968.

Date	Air Temperature (° F) Max.	Min.	Mean	(inches) Snowfall	Wind Miles Past 65 Ft. Tower (7 a.m. to 7 a.m.)	Sky Condition
1	48.2	21.2	34.7	-	107	Clear
2	42.0	14.4	28.2	-	69	Cloudy
3	50.0	22.0	38.5	-	143	Cloudy
4	51.5	29.4	40.5	-	77	P. Cloudy
5	54.5	18.0	36.3	-	103	Clear
6	43.3	29.5	36.4	-	108	P. Cloudy
7	52.2	14.8	33.5	-	76	P. Cloudy
8	46.5	21.8	34.2	-	88	P. Cloudy
9	51.8	17.0	34.4	-	72	Clear
10	56.3	15.2	35.8	-	124	Clear
11	50.0	17.0	33.5	-	110	P. Cloudy
12	39.2	19.3	29.3	2.8	144	Cloudy
13	21.8	12.1	17.0	2.7	73	Cloudy
14	27.0	12.8	19.9	0.8	80	Cloudy
15	34.1	18.5	26.3	T	72	P. Cloudy
16	36.5	17.2	26.9	-	130	Cloudy
17	32.8	13.5	23.2	T	69	P. Cloudy
18	52.8	21.0	36.9	-	121	P. Cloudy
19	59.2	30.5	44.9	-	142	P. Cloudy
20	53.0	26.0	39.5	2.1	94	Cloudy
21	35.6	18.6	27.1	1.3	52	Cloudy
22	45.8	32.7	39.3	-	154	Cloudy
23	49.9	28.6	39.3	-	132	P. Cloudy
24	57.6	33.6	45.6	-	279	Clear
25	55.0	37.4	46.2	-	167	Clear
26	55.5	25.0	40.3	-	103	Cloudy
27	44.2	28.5	36.4	-	134	Cloudy
28	44.7	22.7	38.7	-	159	Cloudy
29	60.2	31.7	46.0	T	129	Clear
$\bar{X}$	46.6	22.4	34.5	9.7	114	

Table 6e: March 1968

Date	(° F) Air Temperature Max.	Min.	Mean	(inches) Snowfall	Wind Miles Past 65 Ft. Tower (7 a.m. to 7 a.m.)	Sky Condition
1	62.1	23.4	47.8	-	92	Clear
2	51.5	27.7	39.6	.3	106	Cloudy
3	48.5	14.0	31.3	.1	101	Clear
4	60.2	20.3	40.3	-	92	Clear
5	63.1	24.3	43.7	-	117	Clear
6	62.0	24.8	43.4	-	96	P. Cloudy
7	60.0	25.6	42.8	-	161	Cloudy
8	55.8	36.7	46.3	-	120	Cloudy
9	50.0	32.4	41.2	.9	114	Cloudy
10	33.2	23.8	28.5	1.7	63	Cloudy
11	31.2	16.6	23.9	2.4	79	P. Cloudy
12	43.0	10.0	26.5	-	62	P. Cloudy
13	54.5	25.1	39.8	-	128	Cloudy
14	54.5	35.4	45.0	-	169	Clear
15	52.3	29.3	40.8	-	80	Clear
16	48.9	22.1	35.5	-	70	Cloudy
17	63.7	25.2	44.5	-	149	P. Cloudy
18	52.3	31.2	41.8	-	146	P. Cloudy
19	43.5	17.0	30.3	0.1	159	P. Cloudy
20	38.0	21.8	29.9	1.8	95	Cloudy
21	39.3	12.0	25.7	T	183	P. Cloudy
22	56.0	21.0	38.5	-	159	Clear
23	64.3	23.8	44.1	-	139	Cloudy
24	64.0	42.9	53.5	-	198	Clear
25	64.5	31.0	47.8	-	129	P. Cloudy
26	64.6	34.2	49.4	-	295	P. Cloudy
27	63.0	25.1	44.1	-	84	Clear
28	73.5	26.3	49.9	-	106	P. Cloudy
29	73.7	36.8	55.3	-	114	Clear
30	73.7	33.9	53.8	T	240	Cloudy
31	54.1	32.0	43.1	-	144	Clear
$\overline{X}$	55.5	26.0	40.8	8.3	129	

<u>Figure 6</u>: Mean maximum and minimum air temperatures of five-day intervals during months November through March, 1967-68.



Ice-Free Water

Ice-free water on each reservoir was classified according to the apparent causative agents (Table 7). During the first aerial count, January 11, seven waterfowl concentrations were found. The birds were congregated around and in small ice-free spots estimated to total 2.16 acres. Most (1.88 acres) were classified as being kept open by waterfowl-use (Table 7). These areas persisted, increased in size and did not freeze with marked decreases in air temperature. However, they partially froze with fluctuation in air temperature. The amount of ice-free water ranged from 2.12 to 25.0 acres during the freeze period.

As winter progressed several other ice-free areas appeared on the reservoirs. They were primarily the result of the introduction of warmer water from inflowing canals and the depths of other reservoirs. A specific example of the latter occurred on South Grey Reservoir. This body of water is divided by a soil dike into two segments which are connected by an inlet gate. The northern segment is somewhat higher than the southern. On January 31, warmer water entering from the upper segment kept the lower portion almost entirely open. Heavy waterfowl-use followed. This also occurred during the following week on Water Supply and Storage Reservoir 4 with warmer water entering from Kluver Reservoir and Water Supply and Storage Reservoir 3. However, very little waterfowl-use resulted until late in the field period. Numerous smaller areas were noted where warmer canal and stream water removed ice.

Introduction of warmer water provided the greatest source of ice-free water during February. However, these areas were subject to partial, if not total freeze with marked decreases in air temperature and, in general, were less used than areas originally classified as kept open by waterfowl use. Note in Table 7 that the amount of ice-free water (4.1 acres) maintained by warmer, "foreign" water increased significantly at the 0.05 level in late January. Then, air temperatures were rising and irrigation companies were beginning to move water through the canals. Most major canals were ice-free by early February and remained open. By February 7 warmer water was responsible for 18.2 acres of ice-free water. The much colder air temperatures of mid February (Fig.6), discussed previously, resulted in a very significant decrease at the .05 level to less than 8 acres. The amount of ice-free water increased to 15.2 acres with milder air temperatures during the following week (Table 7). By February 28 complete thaw of the reservoirs had begun.

Table 7: Amount of ice-free water on reservoirs by apparent causative agent* and minimum and mean air temperatures for each aerial count date during the period of wetlands freeze.

	Surface Acres of Ice-Free Water By Cause				(°F) Air Temperatures	
Date	Due to Water-Fowl Use	Warmer* Water From Canals, Streams, Inlets, Etc.	Undecided	Total	Min.	Mean
1-11	1.88	0.21	0.07	2.16	14.8	26.0
1-20	3.97	0.04	0.08	4.09	27.5	40.8
1-24	2.43	0.79	0.08	3.30	31.0	45.9
1-31	5.09	4.12	0.29	9.50	26.4	39.2
2-07	5.50	18.20	1.10	24.80	14.8	33.5
2-16	4.30	7.98	1.06	13.34	17.2	26.9
2-20	5.22	15.20	1.91	22.33	26.0	39.5

* Refers to warmer water entering reservoirs from various sources thereby maintaining some ice-free water.

Ice-free water classified as kept open by waterfowl-use did not exceed 5.5 acres and remained relatively stable during the latter half of the field period (Table 7). However, during the severe weather of mid-February a decrease of 1.2 acres occurred. Open water on the Cache la Poudre River steadily increased from January through February 1, never falling below an estimated 25 percent. The river was 95 percent open by February 20.

An aerial photograph (Fig. 7) of an ice-free area on the north side of Lindenmeier Lake typifies those areas classified as "kept open by waterfowl use". This area was open during the entire freeze period and increased in size with time. The dark fecal stains on the ice surrounding the water indicates heavy waterfowl-use. Observations revealed that during the day most ducks sat on the ice near the water. The probable result was ice melt due to the absorption of solar radiation by the dark fecal material and an increase in open water. In many instances, on several reservoirs margins of the open water had a heavily serrated appearance indicating ice melt. Other waterfowl factors that possibly affect water temperature are discussed in the section dealing with the duck-water temperature experiments.

Fig. 8 is an aerial photograph of an ice-free area near the southern shore of Boyd Lake. This area appeared in late January 1968 and was typical of areas on several other reservoirs receiving warmer canal water during this period. In some instances canal or stream water would enter and move along the short melting ice for a short distance. Open waters of this type were generally well utilized by ducks probably because of the shallow water.

Figure 7: Aerial photograph of an ice-free area on the north side of Lindenmeier Lake kept open by waterfowl-use.

Figure 8: Aerial photograph of an ice-free area off the southern shore of Boyd Lake kept open by warmer canal water.

Waterfowl-Water Temperature Relationship

The findings of the initial field period indicated that waterfowl can, by various means, maintain some ice-free water and are indeed affected by water temperatures and related weather factors. However, as the winter progressed these relationships became less defined. During the period immediately following initial freeze of the wetlands (mid-December to mid-January), the amount of ice-free water on the reservoirs was clearly limited. At this time daily air temperatures were the coldest of the winter and ducks and geese were densely concentrated on the small ice-free spots.

Undoubtedly, the birds affected water temperature and did maintain small amounts of ice-free water. With increases in daily air temperature and movement of canal water, the amount of ice-free water increased significantly and became more widely distributed in the study area. By late January the number of birds per unit area of ice-free water was far too small to indicate a direct waterfowl effect on water temperature (see duck-water temperature experiments). However, when air temperatures fell, sufficient numbers of birds were usually present to prevent a total freeze of these areas. A combination of warmer air temperatures and waterfowl-use appeared to be responsible for the ice-free water classified as kept open by waterfowl-use during this period. Several instances were noted where ducks and geese were seen using areas which had then broken ice cover apparently formed during the night.

Fig. 5 indicates that there is a relationship between the number of ducks and the amount of ice-free water, particularly during the colder weather of mid-February. At this time significant (0.05 level) corresponding decreases in ice-free water and the number of ducks occurred. However, this drop in the number of ducks was probably due mainly to their intolerance of the more severe weather rather than to the decrease in the available open water on the reservoirs. During this period more than 12 acres of ice-free water were estimated (Table 7). Based on past observations, this amount would have been adequate for the number of birds present at the estimated rate of increase.

Diurnal Use of Wetlands by Waterfowl

Observations of individual wetlands were initiated during the first field period to determine the diurnal use of wetlands by waterfowl. Data were quite limited but some observations were obtained at Lindenmeier Lake. During the observations the lake had approximately one acre of open water and had an approximate maximum duck-and goose-use of 300 to 400 birds.

Duck-use was quite stable from early morning to late afternoon, with very little movement to and from the lake. However, just before sunset most ducks would depart from the lake followed a few minutes later by the influx of a small number. Due to limited visibility, it was not known if these birds were among those that left the area. Geese, on the other hand, showed more erratic use of the lake. Few geese were present in early morning. There was a steady movement of geese onto the lake from about 9 a.m. to a peak at approximately 10:30 a.m. For a half-hour following the peak, 40 to 50 percent of the geese moved to nearby fields. During mid-afternoon another build-up occurred. Geese began moving off the lake about one-half-hour before sunset, followed by an influx of approximately the same number during a few minutes before and after sunset. It was not known if these were the same birds. It was interesting to note that most of the ducks and geese began moving into the ice-free water approximately one-half-hour before sunset.

Duck-Water Temperature Experiments

It was assumed that ducks affect water temperature, directly or indirectly, in four ways:

1. By direct conduction of heat from the body to the water in combination with heat dispersal due to turbulence created by the stirring action of the feet and legs (Gates 1962);

2. By direct conduction of heat from feces deposited in the water;

3. By reducing the freezing point of the water through cumulative fecal deposition; and/or

4. By promoting ice melt due to the absorption of radiation by feces deposited on ice.

Ten experiments were conducted under controlled conditions to determine the effect of adult mallards (*Anas platyrhynchos*) on low water temperatures. The results are arranged by experimental groups in Table 8. Increases in water temperature with equal duck use (3 hours) varied in magnitude with differences in water surface area per duck and differences in the initial temperature of the water before duck-use.

Table 9 shows the per duck characteristics of each experiment and experimental group. Water depths of four inches were used in all experiments. The greatest average increase in water temperature per duck (2.07° F) occurred in the first group of experiments which had a small water surface area per duck (0.75 ft.^{2}) and the highest average initial water temperature (36.48° F). Group III showed the second highest temperature increase per duck (1.78° F) and differed from group I only in the average initial water tempe rature before duck-use (32.63° F). Group II, which had the largest surface area per duck (0.90 $ft.^2$) and an initial water temperature of 36.34° F, showed the lowest average temperature increase per duck (1.10° F).

A significant difference (0.05 level) in the average effect per duck on water temperature occurred between groups I and II, with an increase in water surface area of 0.15 square foot per duck. Variation in initial water temperatures between the two groups was very small (Table 8). Differences also occurred between groups I and III (29° F) and groups II and III (29° F) and groups II and III (0.68° F), but were not significantly different at the 0.05 level.

Table 8: Results and Characteristics of the Duck-Water Temperature Experiments, 1968.

Exp. No.	Water Temp. at Start (° F)	Liters of Water	Surface Area of Water (Ft.^{2})	No. of Ducks	(Inches) Water Depth	Total (° F) Temp. Increase (3 Hours)
			Experimental Group I			
1	36.30	14.16	1.5	2	4	4.90
2	36.50	14.16	1.5	2	4	3.65
3	36.60	14.16	1.5	2	4	3.84
4	36.50	14.16	1.5	2	4	4.14
X	36.84					4.13
			Experimental Group II			
5	36.30	25.44	2.7	3	4	3.32
6	36.20	25.44	2.7	3	4	3.72
7	36.53	25.44	2.7	3	4	2.87
X	36.34					3.30
			Experimental Group III			
8	32.35	14.16	1.5	2	4	3.73
9	33.30	14.16	1.5	2	4	3.73
10	32.23	14.16	1.5	2	4	3.17
X	32.63					3.54

Table 9: Comparison of Water Temperature Increases Per Duck and Feces Deposited Per Duck Per Hour, 1968

Exp. No.	Group No.	Water Surface Area Per Duck (^{o} F)	Cubic Inches Water Per Duck	Feces Deposited* /Duck/Hour of Water Use (Grams)	Temp. Increase Per Duck (3 Hours)
1		.75	432	0.472	2.45
2		.75	432	0.268	1.83
3	I	.75	432	1.133	1.92
4		.75	432	0.513	2.07
Means & Confidence Interval **					2.07± .44
5		.90	517	0.933	1.11
6	II	.90	517	0.989	1.24
7		.90	517	0.537	0.96
Means & Confidence Interval **				0.820	1.10± .34
8		.75	432	0.254	1.87
9	III	.75	432	0.537	1.87
10		.75	432	0.325	1.59
Means & Confidence Interval **				0.372	1.78± .39

* Corrected for the dissolved solids in the well water used (390 mg/1)
** .05 level used

Table 10 is a comparison of mean air and water temperatures during the experiments and demonstrates that the air temperature of the cold room had little or no affect on the water temperature increases. Mean air temperatures were lower than the initial water temperature of the experimental containers in 80 percent of the experiments. The remaining 20 percent were insignificantly higher. Average water temperatures of the control containers were colder than the experimental containers during the first two experimental groups. This was due to the position of the containers in the cold room. These positions were switched during the third group of experiments to attain the coldest temperature possible.

Table 10: Comparison of air and water temperatures during the duck-water temperature experiments, 1968.

Exp. No.	Water Temperatures At Start			*Mean Water Temperature Of Control Container During Exp.	* Mean Air Temperatures of Cold Room During Experiment
	Exp. Container	Control Container	Mean	(° F)	(° F)
1	36.30	35.70	36.00	35.66	36.03
2	36.50	36.10	36.30	35.96	36.20
3	36.60	36.08	36.34	35.97	36.14
4	36.50	36.07	36.29	35.98	36.06
5	36.30	36.03	36.17	35.96	36.16
6	36.20	36.03	36.13	35.96	36.16
7	36.53	35.80	36.17	35.88	36.51
8	32.35	32.80	32.58	32.69	32.04
9	33.30	33.65	33.48	33.59	32.70
10	32.23	32.72	32.48	32.75	32.33

* Mean obtained from seven observations at 30-minute intervals.
** This mean of the air temperature was higher than usual due to excess disturbance of the cold room.

Fig. 9 is a graphical illustration of the average water temperature increase per duck by half-hour intervals in thousandths of a calorie per square inch of water surface area for each group of experiments. Also shown in Fig. 9 are the average percentages of the total temperature increase by half-hour intervals for all these experiments combined. These percentages are accurate since the variation between experimental groups was significant at the 0.05 level. An average of 36 percent of the total temperature increase occurred during the first half-hour of the experiments. Fifty-five percent occurred within one hour, 68 percent within 1.5 hours, 81 percent within two hours and 90 percent within 2.5 hours. At the end of the third hour the final water temperature increase was recorded. An average total of 0.0246 calorie of heat per square inch was transmitted to the water during three hours of duck use in the group I experiments, 0.0085 in the Group II and 0.0186 in the Group III experiments.

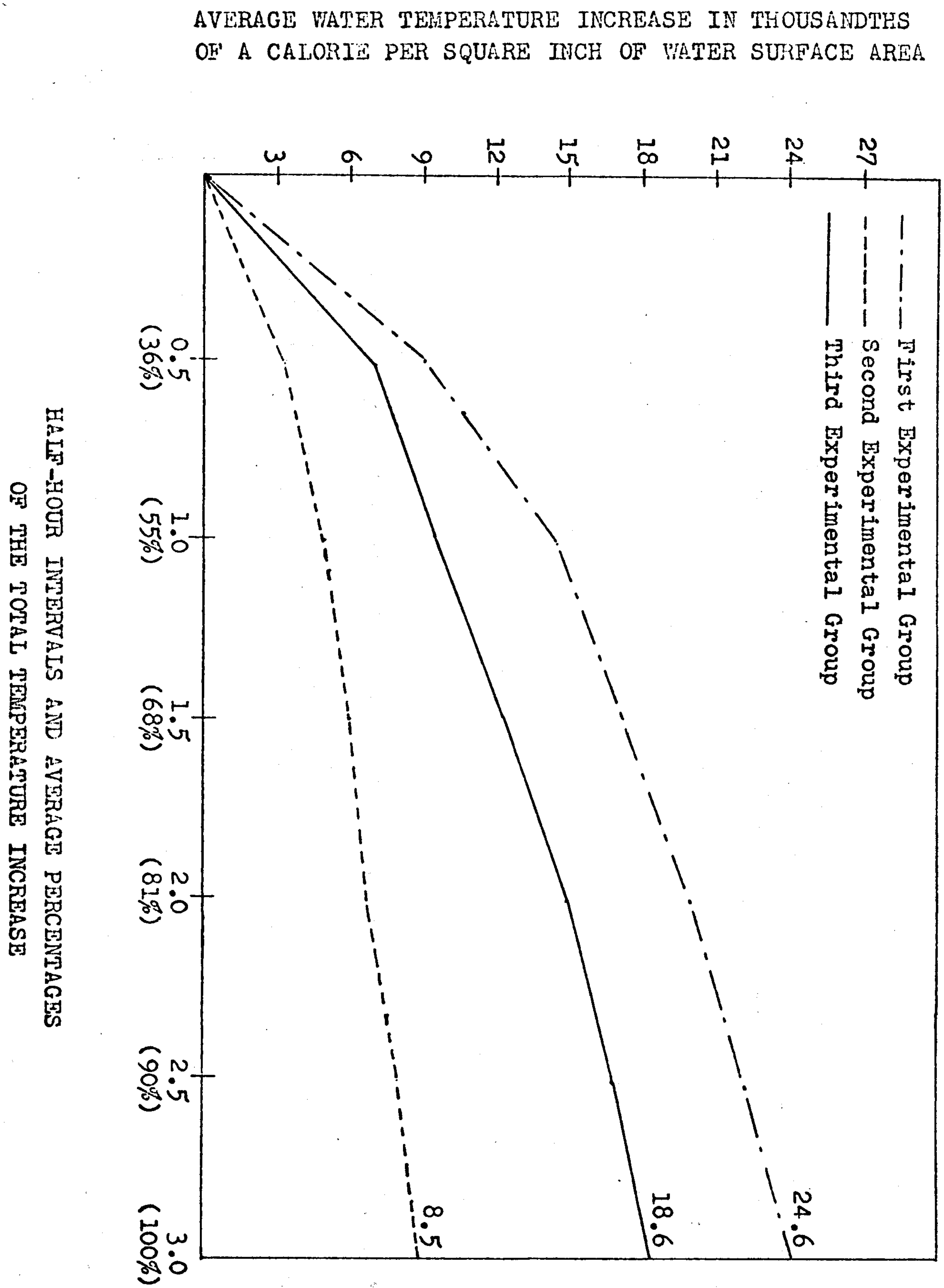
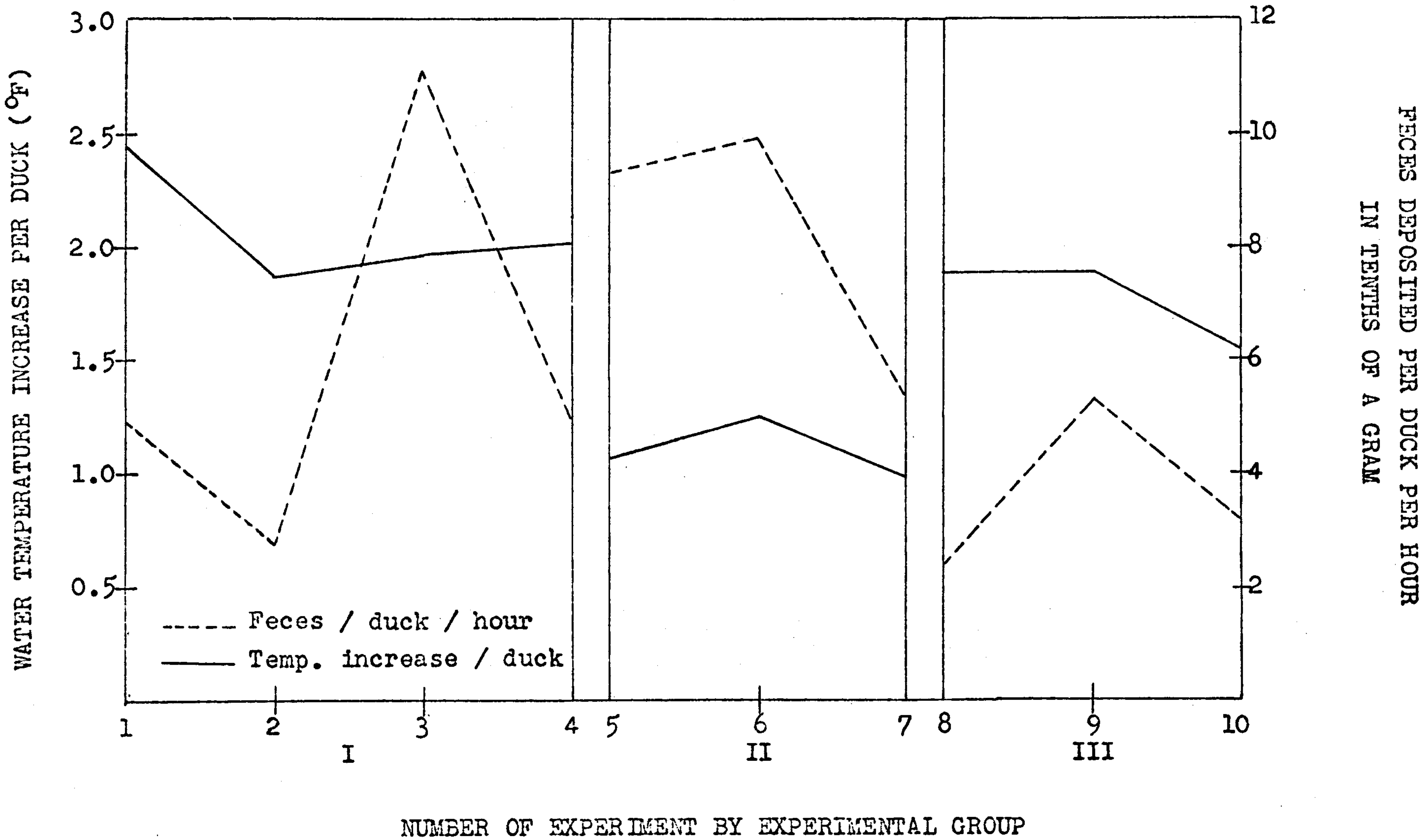


Figure 9: Cumulative average water temperature increase at half-hour intervals in thousandths of a calorie per square inch of water surface area for each experimental group. Average percentages of the total temperature increase indicated for each half-hour interval.

Water samples were taken following each experiment to determine the amount of feces deposited per duck per hour. The results are shown in Table 9. Fig. 10 is a graphical comparison of water temperature increase per duck and feces deposited per duck per hour for each experiment. There appeared to be a relationship between feces deposited and temperature increase. Variations, however, were too great to conclude or determine just what relationship existed.

It was interesting to note that the greatest amount of feces was deposited in Group II experiments which had the largest water surface area per duck. The smallest amount occurred in Group III experiments which had a small surface area per duck and the coldest initial water temperature.

<u>Figure 10</u>: Comparison of water temperature increases per duck and feces deposited per duck per hour for each experiment and experimental group.



A separate study was initiated to determine the mean defecation rate of captive adult mallards. Mean defecation rate was 6.8 droppings per hour and 1.8 grams dry weight per hour (Table 11). In all duck-water temperature experiments, with the exception of number three (Table 9), the amount of feces deposited per duck per hour was significantly lower at the 0.05 level than the observed mean grams dry weight per hour (1.8) shown in Table 11. The most probable cause of this significant difference was due to pre-experimental disturbance of the ducks. Based on these observations, probably the results of the water temperature experiments may be an underestimate of the potential effect of ducks on water temperature under natural conditions.

Table 11: Defecation rates for captive adult male mallards. *

Duck Band Number	Duck Weight (grams)	No. Droppings Per Hour		(grams) Dry Weight Feces Per Hour	
		Number	Mean	Weight	Mean
717-16182	1025	6	9.5	2.52	3.49
		13		4.46	
717-16184	1000	11	10.0	2.24	2.16
		9		2.08	
717-16180	990	6	5.5	1.53	1.47
		5		1.41	
717-16176	935	4	5.0	0.93	0.94
		6		0.94	
717-16178	1030	6	6.0	1.24	1.38
		6		1.52	
717-16179**	975	5	5.0	1.37	1.37
Confidence Limits***		6.8±3.91		1.80± 1.54	

* Two observations per duck.
** Accidentally released before second observation.
*** For five degrees of freedom at the .05 level equals 2.57.

Ducks can exert an appreciable influence on the temperature of water, but, as expected, the effect diminishes with progressively larger water surface areas per duck. Just as important, but less pronounced, is the decline in effect with colder initial water temperatures. Apparently, the assumed increase in heat loss of birds at lower environmental temperatures (LeFebvre and Raveling 1967) is nor proportionate to the decrease in the initial water temperature before use.

The 1967-68 winter's experiments were limited to small surface areas of water and shallow depths. The results of these experiments may or may not be applicable to actual field conditions. Their primary purpose was to supply an index of the effect of ducks on water temperature which may be used in comparison with field observations.

ABSTRACT OF MASTER OF SCIENCE THESIS

"WATERFOWL-WATER RELATIONS IN WINTER"

by

Thomas M. Pojar

The objective of this study was to investigate the ability of waterfowl to winter north of the $0^{o}C$ isotherm. The study was conducted during the winters of 1969 and 1970 in Larimer County, Colorado.

Aerial photographs were made of selected waterfowl concentration areas where waterfowl maintain patches of open water. The number of birds using the area and the size of the area were estimated from the aerial photographs. The area of open water per bird and ambient temperature appear to be directly related. Other parameters, such as physical properties of the lake, were not investigated but probably affect the area of open water. It is speculated that the effect of these lake parameters progressively diminishes with decreasing ambient temperature resulting in a more direct relationship between air temperature and number of birds per area of open water at lower temperatures.

The metabolism of 13 Mallard ducks (Anas platyrhynchos) was studied in the laboratory to compare heat loss from the feet and legs when exposed to cold water ($0^{o}C$) (test conditions) and when exposed to cold air ($0^{o}C$) (control). Ducks under test conditions produced significantly ($p<0.001$) more heat than ducks under control conditions. The 95 percent confidence interval of the

mean difference was 1.599±0.522 kcal/kg-hr. The means of 13 control runs and 13 test runs were 7.029 and 8.628 kcal/kg-hr, respectively. The test conditions metabolism represents an increase of 22.7 percent over the control metabolism. Whether or not the heat added to the water from the feet and legs of ducks is sufficient to prevent ice from forming under field conditions depends mainly on the concentration of birds per unit volume of water and climatic conditions.

Nocturnal behavior of Redhead ducks (Aythya americana) on a pond was observed during freezing weather. Activity (swimming and bathing) seemed to remain at a high level during the night when the air temperature was below freezing. Nocturnal activity appeared to be reduced when the air temperature was above freezing.

A sample of duck feces that was collected under controlled conditions was analyzed for N, P, K, Ca, Mg, Zn, Fe, Cu and Mn.

SUMMARY

Waterfowl that winter north of the $0^{\circ}C$ isotherm must survive under somewhat stressful conditions. The gradient between body temperature of the bird and ambient temperature taxes the physiological ability of the bird to produce heat to maintain homeothermy. The need for open water for roosting and loafing is usually provided by the effect of a raft of waterfowl on a body of water to keep portions of it ice free. Maintaining homeothermy and maintaining open water are activities of waterfowl during winter that require a ready source of high energy foods. Grain farming in some of the northern states provide this source of food when grain fields are not covered with snow.

There appears to be a direct relationship between ambient temperature and area of open water per bird. The greater social tolerance during adverse environmental conditions permits the birds to become more concentrated on an area of open water. The concentration of birds also concentrates the effects of the heat lost from the feet and legs and the heat produced by mechanical agitation of the water by the swimming activity of the birds. The mechanical agitation, if intense enough, would also prevent ice crystals from forming if the water temperature dropped to $0^{\circ}C$.

The amount of excrement deposited by waterfowl at concentration sites is debatable and is probably affected by weather conditions. The feces of waterfowl can have a fertilizing effect and increase the productivity of the lake if sufficient quantities are deposited.

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