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An Ecological Survey of the Muskrat at Locomotive Springs, Box Elder County, Utah, 1950-51

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AN ECOLOGICAL SURVEY OF THE MUSKRAT AT LOCOMOTIVE SPRINGS, BOX ELDER COUNTY, UTAH, 1950-51

by

Robert A. McCullough

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

Master of Science

in

Wildlife Management

Utah State Agricultural College

1951

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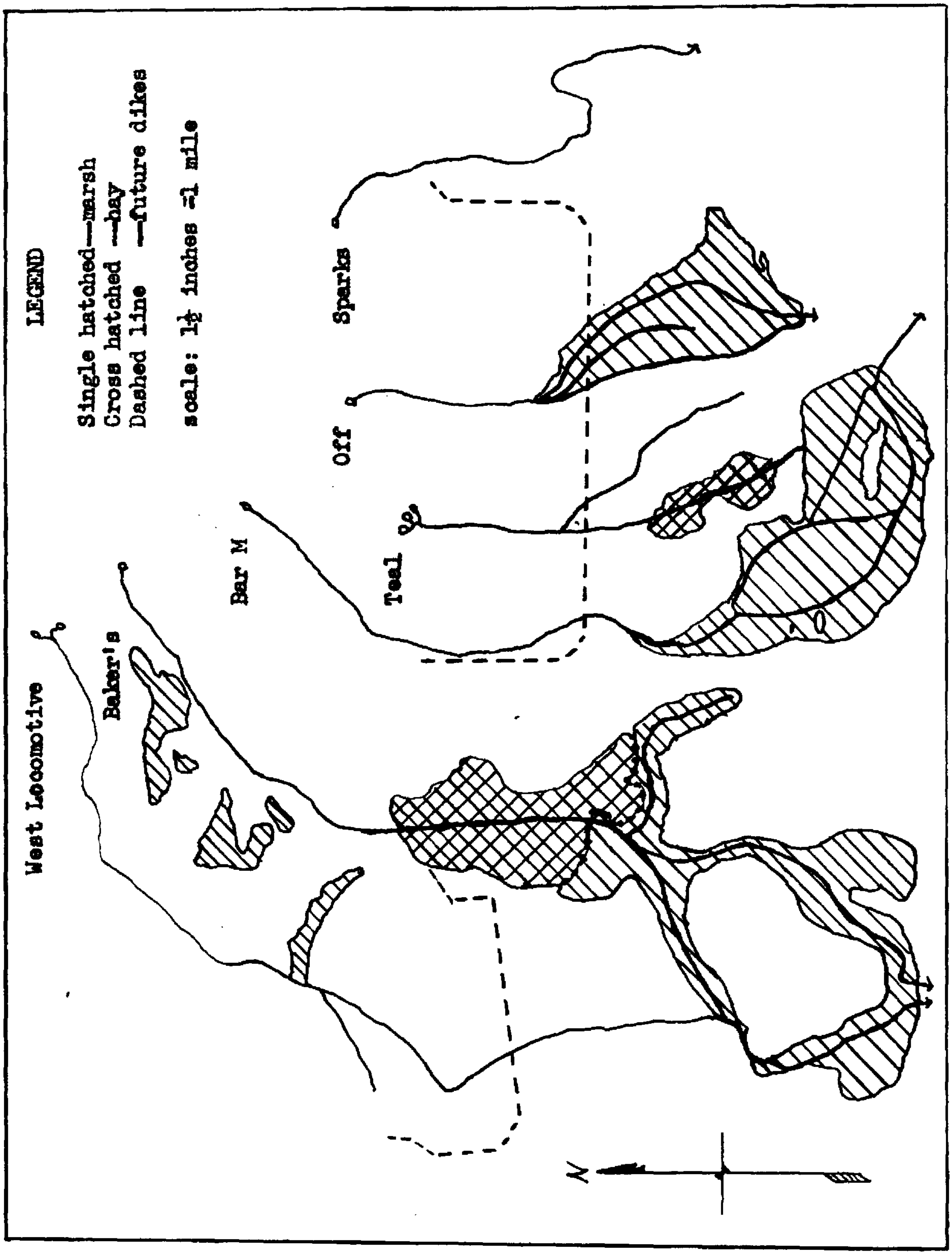

Frontispiece. Map of Locomotive Springs Refuge, 1929.

ACKNOWLEDGEMENTS

I wish to acknowledge the helpful assistance and patient understanding given to me by my wife, Phyllis; for advice, help, aerial photography, and equipment, Dr. J. B. Low; for permission to use the refuge and house, the State of Utah; for help, data and aerial work, Mr. Virgil Wiedman; for data and equipment, Mr. Lyle Anderson and the Spring Valley Cattle Raisers Association; for identification of parasites, Mr. G. M. Kohls; for identification of skulls, Mr. Stanley Young; for use of equipment, Messrs. Scott Peterson and Lyle Hansen; for data and helpful assistance, Dr.'s E. J. Gardner, D. M. Hammond, J. S. Williams, and F. B. Wann, Messrs. J. E. Anderson, James Wood, Lee Kay, and Noland Nelson.

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INTRODUCTION

The Locomotive Springs Migratory Waterfowl Refuge, located on the north shore of Great Salt Lake, Utah, is a state-owned area of about 12,000 acres. Six springs arise from the desert floor and flow south and south-east toward Great Salt Lake. The refuge encompasses these springs and their outflows. The area, while predominately vegetated by the Sarcobatus-Atriplex type, has 1,200 acres of open water and about 2,560 acres of marsh and stream-channel edges. The area was purchased by the State of Utah in 1934 with the express purpose of providing waterfowl hunting for the general public who could not afford to hunt on the privately-owned duck clubs that encompassed much of the better water-fowl marsh areas of Great Salt Lake (Cook, 1932).

At the time of the purchase it was expected that the muskrat harvest would pay for the operation of the project. The annual harvest of muskrat pelts previous to state acquisition averaged between 2,500 and 3,000 with a peak year of 6,000.

Accordingly, the trapping rights were purchased for 2,600 dollars. However, since 1934, the area was trapped only 7 out of 16 years and the combined tally of pelts was only 2,129. This is a 95 percent reduction in yield on the basis of the former minimum average of 2,500 per year. During that 16 year period the refuge should have produced at least 40,000 muskrat pelts.

Granted an initial breeding stock the reason or reasons for the apparent low muskrat productiveness of this area would necessarily fall somewhere within the following categories:

1. It did not reproduce.
2. It did reproduce and this increase migrated from the refuge or was decimated prior to harvest.
3. The harvest was inefficient or dishonest.
4. A radically reduced muskrat habitat resulted from state operation.

Not knowing wherein these categories the answer to the problem of the reduced harvest lay, the writer decided upon a general approach. While perhaps necessary because of the nature of the problem, this precluded intensive work on any one phase. The author feels this lack strongly.

The method of procedure used, in part, was a more or less daily visitation to some part of the area. To accomplish this the author and his family lived at the refuge house on the Bar M Spring from June 10, 1950, to September 16, 1950 and December 20, 1950 to March 18, 1951. In between and subsequent to these periods, trips were made to the area to give a complete one year cycle of observations. The study was terminated by a relatively complete harvest of the muskrat population.

HISTORY OF THE AREA

GEOLOGICAL

The area now occupied by the refuge lies within the Basin and Range Province on the Plain of Great Salt Lake. It occupies parts of Townships 10, 11 and 12N., Range 9 and 10 W., Salt Lake Meridian. It is a flat, low lying country of lacustrine deposition that occurred while the area was covered to a depth of 1,000 feet by Lake Bonneville in the Pleistocene Period. It was submerged in both the Bonneville and Provo Stages (Gilbert, 1890). Tertiary basaltic outcroppings occur immediately to the north and north-west of the refuge.

The refuge is apparently crossed by a fault line, and the springs appear to rise along this fault line. This topic is treated more fully in the section on water levels.

HISTORICAL

No reference could be found as to the first white man who visited these springs. The Stansbury Expedition (1852) was probably the first to survey the north shore of Great Salt Lake. This expedition made two circuits of the lake--one on horseback and one by boat--but apparently on neither trip did they encounter these springs. This is regretable as his fine description of the country traversed would be invaluable in ascertaining the original character of the area.

The general area was then inhabited by Shoshone Indians and the remains of their camps were found near all potable springs (Stansbury, 1852). The writer found several obsidian arrowheads and flint birdpoints between Bar M Spring and Sparks Spring, and, according to several reports, they were previously much more prevalent.

The subsequent history is quite sketchy. Cattle ranching apparently began around the year 1885--the area being used as a winter range while the herds were summered nearby in Idaho. Marsh hay was cut on all the lower spring reaches with the possible exception of Sparks. The area continues to the present day to be used as a cattle wintering range.

Another enterprise that was attempted on the area was the large scale raising of sugar beets with the help of Japanese labor. To accomplish this the springs were dammed to raise the water to an extensive system of ditches with the expectation that the spring water would leach out the salts in the soil sufficiently to permit sugar beets to be grown. It was soon found out, however, that damming of the springs decreased the flow. Therefore the dams were opened and a large pump was installed at Bar M Spring (figure 6). It was only then discovered that the spring water itself was too alkaline to effect the desired leaching, and the project was abandoned. The extensive ditch system still remains visible at many places on the area.

In 1931 the Fish and Game Commission of the State of Utah, under the commissionership of Newell B. Cook, undertook the negotiation for the improvement of the area for waterfowl. Two dikes, canals, and some roads were put in subsequently by P. W. A. funds. This topic is more fully treated in the section on water levels.

The National Airways later put in an emergency air-field. A radio-beam station and a beacon were installed. The beam station was subsequently removed and in 1950 the beacon service was discontinued.

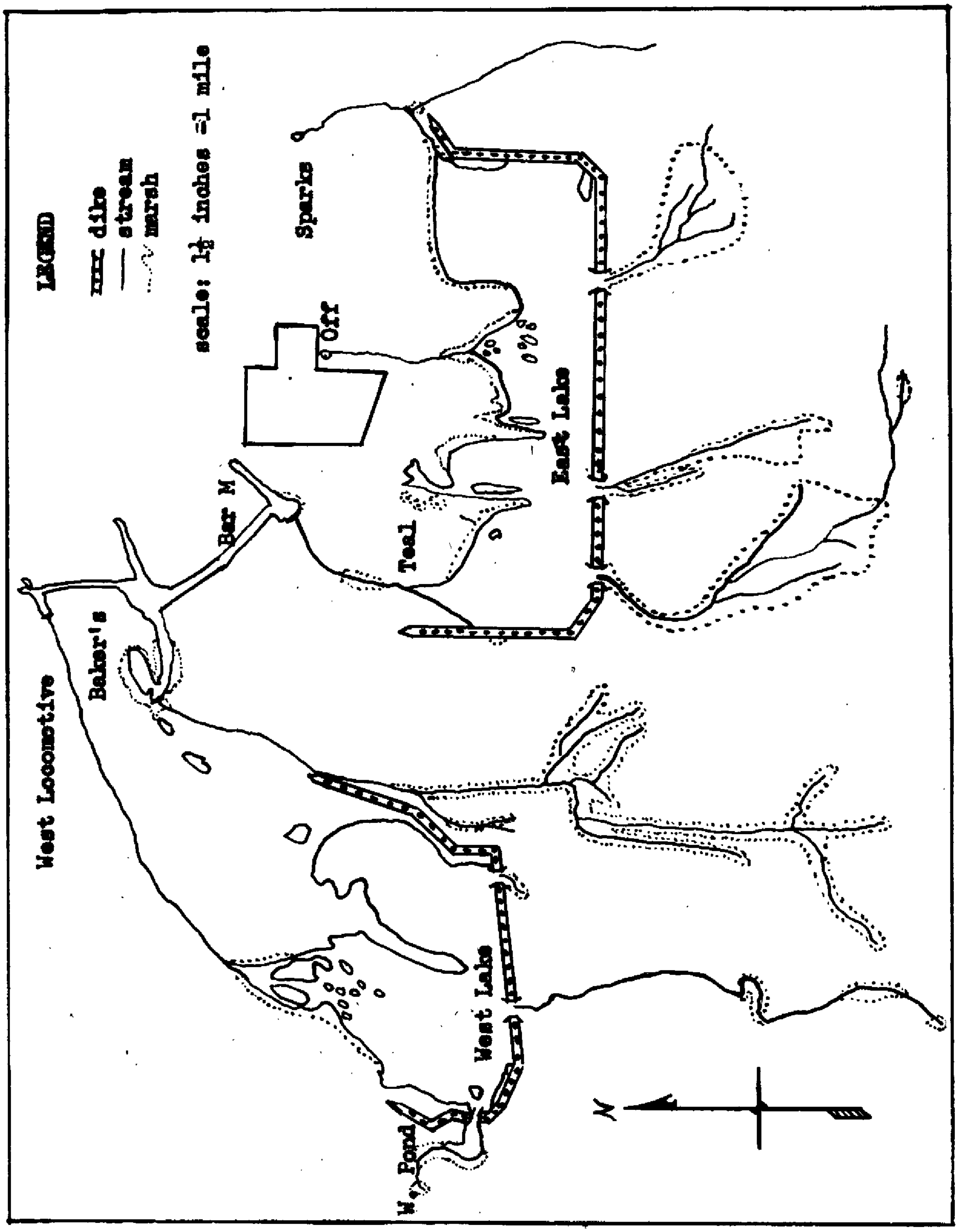

Figure 1. Map of Locomotive Springs Refuge, 1950(after M. Nelsen).

DESCRIPTION OF AREA

Figure 1 portrays the layout of the refuge. Beginning on the west the line of springs, in order, are West Locomotive, Baker's, Bar M, Teal, Off, and Sparks. They all flow in a general southernly direction. The area above the diked impoundments is flat and here the spring runs assume a streamlike character.

With the exception of Baker's, all the springs run into either West or East Lake. These spring flows, with the exception of Sparks, continue below the dike-line. Below East Lake they immediately assume a marshlike character while below West Lake the streamlike character persists for over a mile before changing into a marsh.

Baker's flows between the two lakes. It is on Baker's, largely below the West Lake dike-line, that the cattlemen grow marsh hay, and, to a large extent, winter their cattle.

The only trees on the area are those few transplanted to the heads of Bar M and Baker's springs. A few scattered tamarisk appear to be invading the refuge.

Dirt roads connecting both dikes with Bar M Spring have been made. County dirt roads to Snowville and Hansel Valley intersect at Baker's Spring giving access to the populated centers.

The only habitable dwellings occur on the heads of Bar M and Baker's Springs. These dwellings are the property of the State and cattlemen, respectively.

MUSKRAT ENVIRONMENT

An animal is never an isolated entity. It can not be separated from an environment. This environment conditions the animal and in turn is conditioned itself by that animal. Any study of animal populations must take their environment into consideration.

An animal species can be looked upon as simply a biotic potential that is conditioned by its environment. Therefore, in the study of a reduced biotic achievement, the environment must receive its due share of investigation. In a case such as the present work, studies on the animal species itself would only indicate its reaction to these environmental pressures.

The environmental needs of any animal species are food and cover. Those environmental factors conditioning food and cover that were investigated follow.

CLIMATE

The climate of the Locomotive Springs area is more or less typical of the large expanses of upland desert that lie within the Great Basin. This desert is typified by sage brush (*Artemesia tridentata* Nutt.) in the higher elevations and greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.) in the lower reaches.

The only available climatic data for the study area is that formerly kept at Kelton which lies ten miles to the north-west. The flat nature of the country should make this data applicable to the refuge also. However, Kelton lies much closer to the Raft River Mountains and, if anything, has more precipitation than Locomotive Springs. These data are given in table 1, along with comparable data for the weather stations at Corrine, Ogden, and Farmington. These latter three stations should roughly compare with the three state-owned refuges at Public Shooting Grounds, Ogden Bay Bird Refuge, and Farmington Bay, respectively.

Table 1. Climatic data representing Locomotive Springs (Kelton), Public Shooting Grounds (Corrine), Ogden Bay Bird Refuge (Ogden), and Farmington Bay Bird Refuge (Farmington), Utah(anon. 1941).

Station	Avg. date killing frost: last in spring	Avg. date killing frost: first in fall	Growing season (days)	Temperature: Jan. avg. °F.	Temperature: July avg. °F.	Annual precipitation (inches)
Kelton	May 26	Sept.22	119	22.2	72.2	7.04
Corrine	May 14	Sept.30	139	21.3	74.9	13.88
Ogden	May 6	Oct. 8	155	27.4	74.7	17.92
Farmington	May 2	Oct. 6	157	28.4	74.5	20.21

This table shows that Locomotive Springs has only one-half or less of the precipitation that occurs at the other refuges. In no month does the average precipitation even approach that of the other refuges. The average length of the growing season between frost-free days at Locomotive Springs is 20 days shorter than at the Public Shooting Grounds and 35 days shorter than at the other 2. The average temperature difference is slight, being generally cooler.

The prevailing winds of the area are determined by the proximity of Great Salt Lake--being on-shore during the day and off-shore at night. The wind attains a velocity above fifty miles per hour at times.

The cattlemen report that the average snow cover on the area is light with a maximum depth being about 6 inches on the level. The winter of 1950-51 was one of abnormal snowfall for the area reaching eighteen inches on the level for a 10 day period--February 7th to 11th. For this period the north and north-west wind blew steadily from 30 to 40 miles per hour (as measured on the 37 mile per hour wind-sock at the airfield) with the thermometer at zero $\pm$ 5°F. During this period the bulk of the wintering waterfowl population sought the spring heads for protection from the wind. After the wind subsided, the writer counted 23 dead ducks, mostly mallards, around Off, Teal, and Bar M Springs. Other ducks apparently were so weakened by the wind that they died later. The muskrat population, on the other hand, being much better protected apparently suffered no ill effects from the prolonged wind.

SOILS

The refuge is located on the Plain of Great Salt Lake (Gilbert, 1890) and the soil thereon is a sierozen which is classified as Portneuf-Sagemore (Annon., 1938). It is typified as a treeless, very slightly sloping land that has been derived from lascustrine clays and weathered basalt.

A sandy area exists south-east of Off Marsh. The rest of the area is clay in nature. In the marsh areas the clay is mixed with humus, although not to any great depth.

Personnel of the Utah Cooperative Wildlife Research Unit (Jensen and Dargan in an undated, anonymous paper in the Unit file) sampled the soil and water salinities on the refuge in 1938. They found the soil of East Lake had soil salinities ranging from 0.38 to 0.44 percent, while West Lake averaged slightly higher or 0.47 percent. The salinity of all water tested ranged from 0.37 to 0.49 percent.

The writer obtained soil samples from the rootstock zone on various parts of the refuge. These were tested at the Soils Laboratory at the Utah State Agricultural College. The results are tabulated in table 2.

Table 2. Percent of soluable salts in soil samples from the rootstock zone, Locomotive Springs Refuge, 1950-51.

Sample No.	Collection Data	Total soluable salts (%)
1	Scirpus Olneyi, center Bar M Marsh	0.35
2	Scirpus Olneyi, center Off Marsh	0.38
3	Scirpus Olneyi, marsh, lower West Locomotive	0.45
4	Scirpus Olneyi, shore, West Lake	0.85
5	Scirpus paludosus, lower Bar M Marsh	1.08
6	Algae only, shore, East Lake	1.38

Table 2 shows a general increase in alkalinity (1) from S. Olneyi through S. paludosus to halophillic algae; (2) from the springs downstream; and (3) from old channels to lands inundated by the dikes. Due to the small number of samples, these generalizations are merely indicative.

Table 3. Salinity and alkalinity tolerance ranges of various aquatic plants. (McAtee, 1939)

Species	Sodium Chloride (%)	Alkalinity (%)
Scirpus Olneyi	1.68--0.55	---
Typha angustifolia	1.68--0.00	---
Typha latifolia	1.13--0.00	---
Distichlis spicata	4.97--0.55	---
Phragmites communis	2.04--0.00	---
Ruppia maritima	---	7.73--0.04
Potamogeton pectinatus	---	3.58--0.03

The maximum salt and alkali tolerances of the plants listed in table 3 are generally appreciably higher than the alkalinity ranges in the water areas of the refuge that have been tested. It would appear that the percent of total alkalinity, in and of itself, was not a limiting factor in plant distribution, although, apparently, the percent of alkalinity is correlated with the species distribution.

The pH of the soil in the center of the Bar M Marsh was 7.8. The salinity of the water of the Bar M Spring was .51 percent for March 16, 1951.

WATER LEVELS

Introduction

The adverse effects of fluctuating water levels on aquatic life have been described by many workers (Bellrose and Low, 1943; Lay and O'Neal, 1942; Wiebe, 1946; Anon., 1932, et al.). Maximum muskrat productivity is attainable only under stable water levels. Wherever the water level varies from this mean the productivity is reduced (Errington, 1948). The muskrat population is affected both directly and indirectly by this variation. Flooding causes considerable drowning especially in young muskrats under 10 days old (Errington, 1937). In addition the population is forced into less space where overcrowding occurs with its resultant increase in intraspecific strife, susceptibility to disease, predation and reduced food supplies. Young muskrats that escape from flooded dens are very susceptible to adverse environmental factors such as rain (Errington, 1937).

The Utah Cooperative Wildlife Research Unit's file contained several reports by trappers who had viewed the study area in regards to the cause of the muskrat reduction. Although several diverse opinions were expressed, one theme was common to all of them -- namely, water levels. With these thoughts in mind, a rather intensive study of the water flow of the area was made.

Natural Flow

The entire source of water for the refuge is derived from the flow of 6 springs and precipitation. The latter factor is of minor importance in this desert region of low

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rainfall and high evaporation rate.

The 6 springs lie roughly on a line running east to west. One report supposed that these springs arose from the edge of a basaltic lava cap. In this writer's opinion, however, it would seem more logical that they arise along a fault line, of which more will be said later.

All of the springs arise in roughly circular bowls and flow southermly. The Baker's and Bar M Springs are the largest while the other 4 are smaller and appear to be roughly comparable in size. The temperature of the water as it leaves the ground averages between 58 and 78°F. the year around.

Apparently there are no records of the volume flow for these springs prior to state acquisition of the area. Carpenter (1913) in his ground water survey of Box Elder County made none, nor mentioned any previous measurements. His only comment was that the water from Locomotive Springs was undesirable for drinking.* The Central Pacific Railroad had taken no measurements either.

The first available recordings of the spring flows were made in 1939 (table 4.). An undated listing of the measurements used in the certification of water diversion was probably made earlier, but this is not certain. The types of measurement used were not recorded, but the note added that the type used by Mr. Griffiths would probably yield larger totals than that used by Mr. Morgan (table 4).

*Personal letter to writer from F. E. Kalbough, Superintendent, Southern Pacific Company, Ogden, Utah, dated April 13, 1951.

Table 4. Recorded measurements of spring flows at Locomotive Springs Refuge (in cubic feet per second).

	Springs*				
	Bar M	Teal	Off	Sparks	Total
W. H. Griffiths July 20, 1939	14.9	---	2.3	2.28	19.2
E. R. Morgan March 24, 1939	10.33	2.8	2.27	2.49	16.89
Average	12.0	2.8	2.3	2.4	19.5
Measurements used in certification of water diversion (no date)	15.3	2.8	2.3	2.5	22.9
R. A. McCullough August 27, 1950	---	---	1.1	0.78	---
R. A. McCullough March 14, 1951	---	---	0.9	---	---

*No measurements recorded for West Locomotive or Baker's Springs.

Several notations were found estimating the total flow of all springs at from 35 to 40 cubic feet per second. A cryptic notation was found stating that "the 'three springs' were listed in 1931 at 25.9 second feet." What 3 springs comprised the "three springs" is unknown. If one assumes that these three are West Locomotive, Baker's and Bar M (the size of the flow and the geographical location would indicate this) then the total measured flow would be near 33.5 cubic feet per second. On an area where over 100,000 dollars have been spent on water structures and where water is of the utmost importance, it is quite surprising that only fragmentary and erratic measurements have been made. All of the applicable notations perused coincided in the opinion that the total volume of flow fluctuated very little during the year or years.

Table 5. Average flow of water over spillboxes in cubic feet per second on the Locomotive Springs Refuge 1950-51.

Location	May-July	July-Aug.	Aug.-Sept.	Oct.-May
Springs				
West Loco.	2.5	9.9	0.7	17(1)
Baker's(2)	9.8	0.0	17.5	0.2
Bar M	5.0(3)	7.5(3)	0.5(3)	1.0(3)
Total	17.3	17.4	18.7	18.2
Dikes				
West Loco.	3.4	5.7	1.8	12.0
Bar M	5.6	7.7	4.2	4.1
Teal	4.4	7.2(4)	3.8	5.2
Off	1.5	4.0	2.3	5.4
Total flow below dikes	24.7	24.6	29.4	26.9

1. Approximate--no drop.
2. Baker's change dates (1950)
   July 24 -- off
   Sept.11 -- on
   Oct. 5 -- off
3. Plus considerable seepage
4. Cleared day previous--probably high

The nature of the West Locomotive, Baker's and Bar M complex is such that individual measurement of these springs proved impossible--seepage even precluding the possibility of an accurate total. Table 5 shows that the average measured total for these three springs was between seventeen and eighteen cubic feet per second. Too many assumptions are made here though to draw any concrete conclusions as to this reduction in flow. However, evidence from other sources tend to support this finding. Table 5 shows that the total flow for all 6 springs as measured on the dike spillways averaged between 25 and 27 cubic feet per second. The evaporation factor would intervene between this total and the spring flow total, but it would probably not be of the magnitude to account for the 10 cubic feet per second discrepancy between the 1950 measurements and the 1931 and 1939 figures.

Further support for the hypothesis of reduced spring flow was found when the writer erected weirs on Off and Sparks Springs. While these weirs were of a temporary nature, they did show the total flow at the time. Using the average of the 1939 measurements these springs showed a reduction of 52.2 percent for Off and 66.6 percent for Sparks (figures 8 and 9). No reason can be advanced at this time for the differential reduction. As the summer of 1950 was comparatively dry, it was thought that these measurements may have been unrepresentative because of the general drought. Therefore, after the spring run-off had subsided (March 14, 1951), the weir at Off was reconstructed and the flow again measured. Instead of being higher in this period when the water table apparently should be highest, it showed a further reduction of 0.2 cubic feet per second. All water measurements used in the study were derived from the tables in Christiansen (1947).

These measurements are nothing more than indicators. They need considerable amplification over a longer period of time. However they do indicate that the flow is not constant and that there has been a general reduction in total flow for the area. This reduction may be in the neighborhood of 28 percent in 10 years. This reduced flow is serious in view of the water requirements of muskrats and waterfowl. Although there is probably little that can be done about it, it should be known more exactly and the reduction compensated for as far as possible by efficient water manipulation.

On this general topic, the belief by the writer that these springs arise through a fault in a lava bed rather than from along the edge of it is considered to be important. At Monument Point, five miles east of the Bar M Spring, a series of circular springs arise. These waters contain 11 percent total solids, mostly sodium chloride. It is the general consensus of opinion of people on the area that prior to 1934 these springs were dry holes. On March 24, 1934, there were several severe earthquakes on a fault line that runs from Hansel Valley through Monument Point and toward, if not through, the Locomotive Springs Refuge and on to Kelton.

The severity of these shocks is shown by the rating they received of 8 plus on the modified Mercalli intensity scale (Williams, 1948). The vertical displacement was from 2 to 20 inches with the down-throw to the east. Little exact data could be found as to the effect of this faulting upon the spring flows. However, it appears that the dry holes at Monument Point began to flow at this time; a slow flowing well at Kosmo (east of Monument Point) became artesian in nature for a while and then slackened; and the flow of the wells at Kelton (10 miles west of the refuge) were greatly increased. Baily* told the writer that when he visited the region immediately after the earthquakes he noticed that a number of large springs had come into existence and that the Locomotive Springs greatly increased in flow for a period of time. However, again no measurements were made.

It would appear that this fault is a likely suspect in the reduction of spring flow. The future water supply to this area is thus largely in doubt, especially as this fault is quite active having contributed 14 out of 123 or, 11.3 percent, of all recorded earthquakes with rateable intensities in Utah (Williams, 1948).

The effect of these natural fluctuations in volume flow upon the muskrat and its environment can only be conjectured. However, a 28 percent reduction in the water available for the muskrat habitat would surely result in a reduction of that habitat.

Water Manipulation

Aside from these natural fluctuations the manipulation of the water on the area called for intensive study. Although hard to follow, the pattern before state acquisition appeared

*Personal letter to writer from Mr. Reed Baily, Director of the Intermountain Forest and Range Experiment Station, Ogden, Utah, dated April 13, 1951.

to be thusly: A number of ditches were dug throughout the marshes and low spreader-dams were used on the spring runs to water the lower areas. The frontispiece, reduced from a cover map drawn in 1929, shows these water courses and the marsh areas associated with them. At that time (1929) hay was being cut only on the Baker's and Teal Marshes. However, at one time or another to judge from the abandoned stackyard fences (figure 16), hay was cut on all the lower marshes except Sparks. Probably these hayfields were watered during the growing season and then drained to permit the use of haying equipment. Much the same procedure is in use today. Although actual proof could not be obtained, it appeared that the draining of these hayfields was of a local nature and not on the more or less grand scale that occurs today. Local water diversion would not have a major consequence to the muskrat population as a whole. It would affect only small groups and these, if forced to move, could largely be absorbed by the unaffected surrounding areas.

It would appear then that the water manipulation prior to state acquisition was not a major adverse factor in muskrat ecology.

In 1934 the State of Utah erected 2 east-west dikes to form East and West Lakes. The East Lake dike was thrown across the flows of Bar M, Teal and Off Springs. The flow of Sparks Spring was diverted into this lake. Three spillways were installed. The West Lake dike was thrown across the spring run of West Locomotive and again 3 spillways were installed. The east spillway led to a ditch, the center spillway to the former West Locomotive channel and the west spillway to a new overflow outlet to Spring Bay. Baker's flowed as before, between the two lakes (figure 1).

Also in 1934 a diversion canal was constructed connecting West Locomotive, Baker's and Bar M Springs. A spillbox was installed on each spring. This arrangement allowed the total flow of all three of these springs to be spilled to any one, or two, or all three of the respective stream channels.

The key to the water manipulation pattern on the area lies with the Baker's Spillbox. It is over this spillbox that water for the irrigation of the hayland on Baker's is regulated.

The general pattern is thus: From October to May there is a minimum of water spilled. In fact there is only enough to water their cattle at a point midway on the length of the stream. In May, generally, after the cattle have been moved to the summer range about 10 cubic feet per second is spilled to water the lower hay land. This flow continues until the latter part of July when the flow is stopped entirely to allow the marsh to dry out for the cutting and stacking of hay (figure 2). Usually 1 month later, the water is again spilled down Baker's, only this time the volume is between 17 and 18 cubic feet per second. This reportedly is in order to "water some far knolls" (figure 3). This high flow continues until the first part of October when it is again shut off for the winter except for the stock watering.

Thus on Baker's there is a winter low, a summer high, a late summer low, a fall very high, and a winter low. This pattern designates Baker's as a very fluctuating stream. This fluctuating nature precludes any large muskrat population on the hayfield area. Some do manage to exist on the deeper channel above the dike line which does not go entirely dry. It is quite apparent that this general marsh draining has a greater environmental effect upon the muskrat population of Baker's than did the local diversion formerly in use.

This irrigation is not for the production of hay alone, of which approximately 100 tons were cut in 1950, but also for the watering of the entire lower Baker's Marsh for winter grazing. The hay itself is a mixture of *Typha*, *Scirpus*, *Carex* and *Eleocharis* and is cut along the stream and ditch-banks where the growth is lush. Figure 26 shows the spotty nature of this haying in 1950. As far as could be ascertained, the above is the general pattern of water manipulation over the Baker's Spillbox since 1934. In former years the dates may have varied somewhat as there are no set dates for the flow changes.

A rainy haying season well might alter the pattern, i.e. lengthen the summer dry period and render unnecessary the following very high flow.

It is evident that due to these fluctuations the Baker's Marsh can very largely be discounted as a muskrat producing area. This in itself may not be too great a price to pay for the use of the rest of the area for muskrat and waterfowl propagation. The entire Baker's area could be erased from trapping and the remainder of the area might logically produce more than 2,500 muskrats annually.

The effect of the fluctuation on Baker's, however, is not confined to that stream. On the contrary the effects are felt over the entire refuge. The general pattern of the rest of the area is the converse of the Baker's pattern--namely, high in the winter, low in the summer, high in the late summer, very low in the late fall and high again during the winter.

Table 5 gives the measurements of the water released over the spillways during each period for 1950. From data in this table it is evident that the entire refuge, with the exception of the Sparks and Off Spring runs (Teal Spring run being more or less flooded) has been changed from a relatively stable water level area to one of a semi-stable or fluctuating nature.

Because of the relatively high 1950-51 harvest of pelts (1,766), it is not readily apparent that this degree of fluctuation (table 5) is materially detrimental to the muskrat population. Nevertheless several factors lend weight to the hypothesis that this fluctuation is a major if not the crucial factor in the muskrat reduction.

The cattlemen do not measure the water that they turn down Baker's. They keep pulling out boards until "it looks right." If in May at the 10 cubic feet per second setting it "did not look right", they would take out another 6 inch plank and probably take 13 instead of 10 cubic feet per second. Support to this is found in the fact that a considerable head of water is held behind the West Locomotive, Baker's, and Bar M Springs complex. This head requires more than one day to be equalized through the canals. The cattlemen visit the area only long enough to pull out boards and do not wait to see what the equalized or terminal flow "looks like." They see only the head and admittedly that is difficult to judge. In addition there is no reason to believe that the 10 cubic feet per second setting for May-July, 1950, is an intrinsically desired setting. It may well be that 13 or even 17 cubic feet per second is closer to the previous normal. As no measurements were recorded it is doubtful as to whether this will ever be known. What has been said here concerning the 10 cubic feet per second setting perhaps is even more applicable to the 17 cubic feet per second setting in August and September.

A minor note on this concerns the low (0.5 cubic foot per second) setting for August and September, 1950, on the Bar M Spring spillbox (table 5). Considerable seepage now occurs at this spillway which cannot be measured. However, during the low water periods, this seepage contributes greatly to the maintenance of East Lake. In all probability when the spillway was new this seepage approached zero. If then the flow down the Bar M Spring run was only 0.5 cubic foot per second then the entire area below the East Lake dike would be in a drought or near-drought condition.

Table 5 also shows a marked winter increase of flow down West Locomotive amounting to about 17 cubic feet per second. This resulted from boards having been pulled from the West Locomotive Spring spillbox in October by an unknown person or persons. The general opinion is that duck hunters, wanting more water in the marshes south of West Lake, pulled them. They remained in that setting all winter.

West Locomotive shows the most fluctuation of any of the streams on the area other than Baker's.

Reports, mostly from conversation with different parties, showed that the water level of West Locomotive, both above and below West Lake has fluctuated strongly since 1934. One state employee several years ago was reported on at least two occasions to have pulled the boards out of the spillway on West Locomotive Springs in the winter after the ice had formed. That this would have an adverse effect upon the muskrat population is obvious. The percent of loss in such a situation would be very high. In addition it would also be felt on the entire East Lake area, lowering the water there perhaps even to the point of extensive freezeouts.

The cattlemen formerly drained West Lake in the winter. They would drain it through the west spillway thus stranding the entire population of West Locomotive below the dikes. A note in the Utah Cooperative Wildlife Research Unit's file states that irrigation on Baker's in the summer of 1942 entirely dried up West Lake and the dependent West Locomotive Slough below it.

The winter of 1950-51 saw a new feature not hitherto practiced on the area. At the request of the cattlemen, because 13 head of cattle drowned in the barrow pit of East Lake during the 2 winters of 1948-49 and 1949-50, the lake was drained in the latter part of November, immediately after the close of the waterfowl hunting season. Although complete drainage was contemplated, it was found that silting in front of the spillways had progressed to the point where a draw-down of only 10 inches could be effected. While apparently this drawdown did not have any adverse effect on the lower marshes, the draw-down being completed in steps, it did strand the muskrat population inhabiting the north shores of East Lake (figure 17). While stranding the muskrats, it did not accomplish the original purpose. Although no cattle drowned in the lake during the winter of 1950-51, this did not result from the lake drawdown as the barrow-pits remained lethal in depth (figure 24).

It is quite obvious that there has been an unplanned policy of water use on the area. It appeared to be the general concensus of opinion of local residents that the cattlemen were entitled to the entire flow of all the springs during the irrigation period. The original contract signed in 1934, however, appears to state otherwise. The appertaining sections follow:

> WHEREAS, the first parties (State of Utah) are desirous of granting to second parties (cattlemen) the right and privilege of grazing their horses and cattle on the above described lands owned by the first parties, in exchange....for the right to propogate muskrats on all the second parties lands....together with all waters arising on or underlying said lands, for the purpose of creating a bird refuge, game sanctuary, muskrat farm, public shooting ground, and for the propogation of fish.
>
> In consideration thereof (grazing rights), second parties hereby grant unto the first parties the right and privilege to use that part of the said lands owned by second parties....all water arising upon or underlying said lands, for the purpose of creating a bird refuge, game sanctuary, muskrat farm,

public shooting ground, and the propogation of fish, and HEREBY GIVES AND GRANTS to first parties the right and privilege to flood, dike, and dam any part of said lands, sloughs or springs....

The said spillways and headgate (four including the spillway on Baker's) shall be so constructed and operated that the water impounded behind said dikes shall not be lowered or raised to such an extent that the fish, wild fowl, or muskrats, or their propogation shall be endangered, and, at the same time, the parties hereto shall permit as much water to go over said spillways as can be reasonably done, having due regard for the protection of the wild fowl, fish, and muskrats above mentioned....In addition to the water and water rights owned by the first parties in what is commonly known as Locomotive Springs, IT IS AGREED that first parties shall have the exclusive right to the use of the water from West Locomotive Springs during the entire year, save and except such times as said water may be needed by second parties for the irrigation of their hay lands and for the watering of their livestock.*

IT IS MUTUALLY UNDERSTOOD AND AGREED that this agreement shall be in full force and effect for a period of fifty years from date hereof and all rights herein granted shall continue during said time.

IT IS FURTHER MUTUALLY AGREED that the parties hereto shall, at all times, work for the best interest of each other, and that first parties will use their best efforts to protect the horses and cattle grazed by the second parties upon said lands, and that second parties will use and exercise their best judgment and efforts to protect the first parties' interest, including game of every kind....(copy in Utah Cooperative Wildlife Research Unit file--dated January 8, 1934)

As the writer interprets this contract, it was designed to expressly prohibit the type of water level manipulation that now occurs on the area. The present water level manipulation is patently of the extent that the muskrats, wild fowl and their propagation are endangered. The common misunderstanding of the water rights on the area is believed to have arisen from a misinterpretation of the italicized

* Italics are the author's.

clause. The current concept would follow if the name West Locomotive Springs were read instead as Locomotive Springs.

It would appear then that there are no legal impediments to stabilizing the water levels.

Effect Upon Vegetation

Bellrose and Brown (1941) believe that the direct effect of water levels is more determining in muskrat densities than the indirect effect of these variations upon vegetation types. However, the combination of the two would be even more determining than either acting alone.

Many workers have reported that cattail (Typha latifolia L.) is the number 1 muskrat food. Bellrose and Brown (1941) report that while cattail constituted only 0.2 percent of their study area, it had the highest number of houses per acre. Errington (1948) reports that the highest muskrat densities were found in cattail. Hodgson (1930) also reports cattail to be the most preferred muskrat food.

John Anderson (in conversation) stated that fully 80 percent of the lower Bar M Marsh originally was vegetated with cattail. Cattail was also reported prevalent on the Baker's and West Locomotive Marshes.

At the time of the study period only a few scattered small patches of Typha latifolial L. were to be found on the Bar M Marsh. These were scattered through the dominant Olneyi's bullrush (Scripus Olneyi A. Gray). These patches of cattail would comprise not more than 3 acres (figure 22). The sharp decrease in this important muskrat food is definitely associated with the water level manipulation.

The replacement of the cattail by Olneyi's bullrush reduces the potential value of the marsh as a muskrat habitat. The exact cause of the difference is not fully known. Dozier (1945) found that the protein content of _T. angustifolia_ L. and _S. Olneyi_ were roughly the same (5.03 percent and 4.24 percent) and postulated that the great difference in size between muskrats raised on cattail and those raised on bullrush was in the fact that the former puts out a number of tender green shoots in the fall and these remain available under the ice through the winter furnishing excellent muskrat food. Olneyi's bullrush on the other hand does not have these shoots.

More evident however is the cause of the replacement of the cattail by the bullrush. Large tracts of cattail grow along the ditches and streams of Baker's Marsh. This area gets a good supply of water through the growing season, whereas the Bar M Marsh has no dependable source of water for this period. Two growing seasons wherein the marsh is dried out would probably kill the cattails, especially if later exposed to flooding. Roundstem bullrush (_S. acutus_ Muhl.) forms lush growths on Baker's but is not found on Bar M Marsh.

A notation in the Utah Cooperative Wildlife Research Unit file states that unit personnel in 1938 (Jenson and Dargan) found West Lake to be the highest producing body of water in the state. Aquatic vegetation reached a density of 3,840 pounds (dry weight) per acre in West Lake and 1,180 pounds per acre in East Lake. Although no quadrants were measured in 1950, it was very evident that West Lake was no longer as high a producer as formerly. The contrast between former and present yield is nowhere better observed than at the west spillway. Here, in what the writer termed West Pond, is the only wholely stable water area, during the growing season, on the entire refuge. The growth of submerged vegitation (Ruppia maritima L. and Potamogeton pectinatus L.) is rank, covering the entire bottom. Just the width of a dike away, the near-barren bottom of West Lake is mute evidence of the adverse effect of fluctuating water upon aquatic vegetation. Sparse stands of muskgrass (Chara spp.) here and there are all that remain. Elsewhere on the lake a few scattered clumps of widgeongrass (R. maritima L.) exist, but the whole lake gives one the impression of barrenness. East Lake, while not as barren, probably is reduced from the 1938 yield. During the 1950 study the West Lake water level dropped 6 inches in 11 days. While this amount of fluctuation may not seem large, on this shallow lake with its shelving bottom, a 6 inch drop reduces the surface area by one-half.

Low and Peterson (field note) surveyed the study area in November, 1944, and reported that the bullrush was dead and dying on the spring runs as a result of excessive water level fluctuation during the growing season. This condition even existed on the spring run of Baker's.

The cover maps made in 1941 show very little marsh vegetation growing on the then newly inundated north shore of East Lake. At the time of the present study, however, a line of alkali bullrush (Scirpus palusosus A. Nels.) pioneers was fringing the shore with a depth varying from a few feet to 100 feet. They were never far from the shore and by their more or less stunted growth indicated that the soil was quite close to their upper alkalinity tolerance. Nevertheless this fringing growth supported a moderate muskrat population until the winter drawdown of water forced them to move.

It is evident from the comparison of tables 4 and 5 that an accurate reapportionment of water to the marshes below East Lake has not been accomplished. As a result there has been a general increase in flow to Off and Teal Marshes and a general decrease to the Bar M Marsh. Because of the ditch-like nature of Teal Marsh, plant successional changes are difficult to determine, but Off Marsh exhibits it strikingly. The 1941 cover map showed Off Marsh as a vegetated scapula-shaped area lying between two barren salt flats. Three-quarters of this area was in salt grass (Distichlis spicata (Torr.) Rydb.) and the remainder in bullrush (Scirpus olneyi and S. paludosus). During the 1950 study it was found that 90 percent of the former salt grass area had been revegetated by bullrush. The leaching effect of the increased flow has allowed the S. paludosus to pioneer far lakeward until minute plants, barely 3 inches tall, mark the point of lethal alkalinity.

MUSKRAT POPULATION CHARACTERISTICS

SPECIES

When the present study began it was assumed that the race of muskrats on the area was *Ondatra zibethicus osoyoosensis* Lord, as that race is the typical muskrat of the eastern Great Basin (Anthony, 1928; Marshall, 1937). Consequently the skulls of only an adult female and an adult male were collected, prepared and sent to the U. S. Fish and Wildlife Service for classification. They reported, however, that the skulls more closely resembled *O. z. zibethica* L. than any other race. The normal range of *O. z. zibethica* is in the eastern part of the U. S. and Canada.

The cattlemen told the writer that Eli Anderson had transplanted some muskrats to the study area. Further inquiry revealed that around 1920 Mr. Anderson had imported an unknown number of "black muskrats" from Canada. Most of these were released in Salt Creek near Thatcher, Utah, while the rest were released at Locomotive Springs. In 1923 he transplanted between 500 and 600 muskrats from the Salt Creek marshes to Locomotive springs. He could detect no resultant difference in size or color due to either transplanting.

The reason for the transplanting in the first place was to increase the size and color--since the Locomotive Springs muskrats were both smaller and lighter in color than the imported "black muskrats."

Until a larger series of skulls are examined, the exact classification of this population must remain in doubt. The evidence indicates, however, that a difference in genetic pattern does exist.

The particular race of muskrats at Locomotive Springs was found to have abberant pelage character. This character consisted of the replacement of dorsal areas of underfur by a more or less flimsy white or "cotton" underpelage. The area involved varied with the individual but typically it consisted of paired dorso-lateral, roughly circular to oval areas in the lumbar region comprising an average area for each section of about 15 square centimeters. This genetically associated defect, while not obvious on an animal whose fur is dry, is readily seen by blowing the covering guard hairs back. In a drowned animal it is readily apparent because the guard hairs are matted together and the sides of the muskrat look white. It appears to be similar to a condition that sometimes occurs in mink pelts. These abberant mink pelts are termed "cotton." However, in mink the cotton area is of greater extent--often comprising the entire underfur in the specimens which the writer has collected. Cotton mink lose two-thirds of their value due to the added dye process needed.

The muskrat pelts from the western United States are used by the fur trade mainly in natural pelage styles. In natural pelage garments, pelts are matched as to size and color, and thus no dyeing is required. The presence of these white areas, especially as they occur on the dorsal surface would necessitate a dyeing process. This would greatly decrease the value of the pelts from the study area. Bachrach (1949) states that there is no morphological difference between the white and the natural colored underfur in mink except in pigment quantity. The defect in the muskrat at Locomotive Springs, however, appears to involve more than a pigment difference. The white areas appear flimsy and weak-fibered. When the fur is wetted the white areas require twice as long to dry as does the normal gray underpelage. If this observation is verified it would mean that these white areas would have to be cut out of the pelt. This would in effect make 92.3 percent (see below) of the pelts classify as damaged.

No previous reference could be found referring to this condition in the muskrat. A total of 457 muskrats were checked for this condition and it was found in 92.3 percent of them. A less severe form--a distinct light gray color of smaller extent, was found in 6.2 percent while only 1.5 percent were completely free of it in field inspection.

In discussing this matter with Dr. E. J. Gardner (geneticist, U. S. A. C.), he brought out that the high percentage of occurrance (92.3 percent) would indicate a dominant factor. For an introduced dominant allele or dominant mutation (apparently with no survival value) to become so widespread throughout a population would necessitate hundres of generations (years in muskrats). The fact that this quality has not hitherto been reported in the several reports concerning pelt size and quality of the Locomotive Springs muskrat would indicate that it is of more recent appearance.

An explanation resolving this conflict appears if one hypothesizes that environmental factors at some not too distant date reduced the population to a few breeding pairs. If the quality in question was present then, it would be radiated out with the population build-up.

A supplementary genetic condition, the occurrance or non-occurance of a white tip on the tail, was checked on 153 muskrats. The white tip appears to be accumulative--running from 2 muskrats with it extending cephally for over 5 cm. with all intergrades between to the appearance of a single white hair on the tip of the tail. Those with any white hairs on the tail were classified in one group and those without white hairs in another. The ratio of white tip to normal was 100:84.3. This character is not confined to the refuge as the writer has noticed it in muskrats from several widely separated areas in Utah. To the writer's knowledge, however, this is the first quantitative work on this genetic character.

TRAPPING HISTORY

Harvests Prior to 1934

The former muskrat productivity on Locomotive Springs was investigated by interviews with Mr. John E. Anderson, Thatcher, and Mr. Lyle Anderson, Logan. These men had both trapped muskrats on the area with their brother Eli. Mr.

Al Joadason had trapped the area previous to the Andersons. John Anderson did not remember what Joadason's catch had been. Eli Anderson started trapping on Locomotive Springs around 1914. John spring trapped 2,500 muskrats there in 1915, and was of the opinion that 2,500 muskrats would be an average minimum harvest for the area. Most of the muskrats were trapped on the West Locomotive, Baker's, and Bar M Marshes. The other three springs, Teal, Off, and Sparks produced relatively few muskrats. This harvest of 2,500 to 3,000 continued more or less to either 1924 or 1925 in which year they harvested over 6,000 muskrats. They then decided to let the population stockpile and did not trap the following season. In the fall of 1926 or 1927 (the year following) a fall observation showed "muskrats all over the place. On the Baker's head in the evening they were like coots--they were so thick." But during the winter they died off---"dead rats were everywhere." That spring's catch was only a few hundred. John estimated that the fall population that season was between 8,000 and 10,000 muskrats. This was the only die-off in muskrats observed by these men although the black-tailed jackrabbit population of the same valley had recurrent die-offs.

Predation was probably high in those days; Anderson reported that "many coyotes" lived upon the area. Mr. Virgil Weidman reported that Eli Anderson trapped 4,000 muskrats in 1931 and 2,800 in 1932. Thus it may be assumed that the annual harvest before state acquisition of the area was 2,500 muskrats or more.

Table 6. Muskrat harvests subsequent to state acquisition, Locomotive Springs Refuge, 1934-51.

Area	1934	1941	1942	1943*	1944	1949	1950	1951
Above dikes							12	62
West Loco								
Baker's								140
Bar M	27	40		50			87	59
Teal	54			50				27
Off		19		50			19	37
Sparks				50				9
East Lake								39
Below dikes								
West Loco		34						57
Baker's	314							
Bar M	197							626
Teal							166	282
Off							104	434
Sparks								
Totals	236	284	270	195	135	213	400	1766

*Rough estimate in distribution by Noel.

Harvests Subsequent to 1934.

Table 6 tabulates the reported harvest of muskrat pelts since state acquisition of the area. Data are quite sparse on these figures. However field notes, letters, etc., in the Utah Cooperative Wildlife Research Unit's file enlarges on some of the tallies. These are given below by years:

1934 Joseph Hansen ran an extensive population survey in the spring of 1934. He mentions in several places that there was considerable evidence of heavy trapping in the fall and winter of 1933-34. No mention is made of who trapped or what the catch was. The reported 632 muskrats for that spring was separate from the winter trapping.

1935-40 No records could be found for these years.

1941 Marcus Nelson states that only the upper spring runs were trapped in 1941. Just prior to the trapping a house and den survey led to an estimate of 4,000 muskrats on the area. Because of the scattered distribution of the muskrats, concentration on the spring runs and relatively low numbers in the lower marshes, he did not consider the refuge well-stocked.

1942 Marcus Nelson recommended trapping only the upper spring runs for the spring of 1942.

1943 Floyd C. Noel in a memorandum to Ross Leonard dated March 30, 1943, reported that Arnold Christensen and Floyd Adams did the "necessary" trapping at Locomotive Springs. They trapped from March 25th to 29th. Noel refers to the "4 sloughs." Elsewhere throughout the literature the term "slough" is used to designate the marshes below the dike but the reference here is to East Lake, and as only 3 marshes exist below the dike while 4 springs are above it, it is considered that the reference was to the 4 spring runs.

1944-1948 No records could be found for these years.

1949 No reference could be found for this year. However, the cattlemen report that the man who trapped that season trapped only the spring runs. He had remarked to them that there was a very high percentage of juveniles.

<u>1950</u> The data on the trapping in the spring of 1950 were obtained from Mr. Virgil Weidman. The trappers were Dave Holdaway and Floyd Gardner and they trapped from February 15 to Marsh 3rd using 200 traps. This apparently was the first time that the area below the dikes was trapped since 1934. Weidman reported that these trappers were pleased when their combined daily catch was 50 muskrats, unhappy when the catch was 25 and they quit when it reached 15. They stopped trapping March 3rd. They trapped some muskrats from the spring runs, but the bulk of their catch was from Off and Teal Marshes. The spring of 1950 was slow in breaking, and trapping of these sloughs for the first 18 days probably did not allow the marshes time enough to open-up fully. For some unknown reason the trappers only trapped a few hundred yards south on the Bar M Marsh.

The writer visited the area for the first time April 3, 1950, and the muskrat sign on the Bar M Marsh was good. No house counts were taken at that time. However, in retrospect, it appeared to be near the same as in the spring of 1951 when 626 muskrats were harvested from this marsh. Moreover, at the time of the April, 1950, visit the marsh was more opened-up than it was at the same date the following spring.

The trapping history of this area is too interwoven with past population fluctuations to discuss it out of that context. Therefore a discussion of this section will be presented with the discussion on population numbers.

The writer obtained a permit to trap the area in the winter and spring of 1950-51. Tom and Lyle Stokes of Snowville also trapped on the area in the spring of 1951. One hundred sixty six muskrats were taken on the spring runs from December 20, 1950, to February 11, 1951. Trapping was suspended from February 11th to February 15th. The writer placed his traps on the Bar M Marsh and the Stokes brothers placed their traps on Teal and Off Marshes upon the opening of the season (February 15th - April 1st). These marshes, while not yet fully opened-up, were opened enough to allow the initial settings. The break-up continued and the traps were moved along with it. The Off and Teal Marshes were slower in opening up than the Bar M. After one complete traverse of the two east marshes by the Stokes brothers, they removed some of their traps, obtained others, and set them on the spring runs and the West Lake area. The writer elected to remain on the Bar M Marsh as he had to commute to Logan the last two weeks of the season. Due to this and the slow spring break-up the area was not considered fully trapped--the lower half of lower West Locomotive and lower Baker's were not trapped at all, and West Pond was just creamed. A total of 1,766 muskrats were taken by both parties. It is the considered opinion of the writer and the Stokes brothers that perhaps 250 more muskrats could have been harvested from the refuge without harming the seed stock if the season had lasted another week. This would have given a total yield of 2,000 muskrats.

Table 7. Population numbers by house and den counts on Locomotive Springs Refuge.

Season Year Observer	Spring 1934 Hansen		Winter 1941 Nelson		Fall 1944 Low		Fall 1949 Low		Summer 1950 McCullough	
Area	D(1)	H(2)	D	H	D	H	AH	IH(3)	D	H
Above dike										
West Loco	93	13	71	124					54	13
Baker's	105	25							29	2
("ponds)	29	9	4	7						
Bar M	48	30	56	6					24	4
Teal									10	0
Off	9	25(4)	86	2					20	4
Sparks									10	0
E. L. shore									20	10
Below dike										
West Loco.	93	75	47	65	8				20	3
Baker's									21	2
Bar M			50	75	17	5	83	127(5)	59	95
Teal			13	59			36	72(7)	4	40
Off					30	16	59	161	21	23

1. D-active den; H-active house.
2. House built in fall of 1933.
3. Ah-active house; IH-inactive house.
4. Partial--$\frac{1}{4}$ mile.
5. Partial. probably X 3, (249--381).
6. Counted 105. Estimated 225.
7. Partial. Probably add 1/3, (48--96).

Numbers and Distribution

The previous censuses of the muskrat population on the refuge have been more or less erratic and spasmotic and, as a result, it is difficult to follow past population trends from data of this nature. Table 7 tabulates these counts.

Hansen's 1934 count is probably as good a picture of the former density and distribution as will ever be obtained. By the high percent of dens it clearly shows the original stream-like character of the spring flows above the then-proposed dike line.

Nelson's 1941 count shows the early effect of the forming of West Lake by the 950 percent increase in the number of houses on West Locomotive over Hansen's 1934 house count.

The first complete census was made by the writer in June and July, 1950. Every muskrat habitat-type area on the refuge was traversed on foot and the population tallied by the number of active houses and dens. Tagging operations were concomitant with this work; therefore, each and every muskrat house was opened to discern whether or not a litter was present. In this manner a very accurate house count was obtained. A house was considered active if: (1) it had a litter in it; (2) if it had a dry nest in the central chamber; (3) if muskrats were seen entering or leaving it; or (4) if fresh cuttings and sign were found inside. If none of these signs were found the house was classified as inactive.

Dens presented more of a problem as they could not be checked for dry nest chambers or litters. The dens were found as a general rule along the more steeply banked spring runs. An active den was counted if: (1) while walking along a stream a muskrat was seen to enter it; or (2) after a stretch of stream with a dearth of sign, a sign concentration area was encountered--tracks, cuttings, dung, and runways. Two dens close together would necessarily be tallied as one den. The tallying of dens along shores exposed by the lowered water levels was more accurate than those tallied through marshy-shored areas because of the extensive runway system in the former. Admittedly there is more chance for error in the den tally than in the house count. However the den tally, due to the writer's conservatism, represents the minimum number of dens while the house count is fairly representative and accurate.

Table 8 gives the relative distribution of the inhabited dwellings. If the assumption is made that each occupied house or den is occupied by one breeding pair, the summer distribution of the 1950 breeding population can be made. This table shows that 71 percent of the area's breeding population was on the East Lake half of the refuge. Seventy one percent of this was below the dikeline on the 3 marshes, Bar M, Teal, and Off.

The total number of breeding pairs censused on the entire Locomotive Springs Refuge by the writer in 1950 was 488.

Table 8. Comparative area productivity, Locomotive Springs Refuge, 1950-51.

	Number of houses & dens (Summer, 1950)	Percent of population	Number of pelts taken (1950-51)	Percent of population
East Lake area				
Above dike	102	29	165	11
Below dike	242	71	1342	89
West Lake area				
Above dike	98	69	202	78
Below dike	46	31	57*	22
Both lake areas				
Above dikes	200	41	367	21
Below dikes	288	59	1399	79
East Lake area	344	71	1507	85
West Lake area	144	29	259	15

* Partially trapped

Table 9. Den to house ratios from the summer, 1950 population census, Locomotive Springs Refuge.

Area	Total Dens - Houses	Ratio dens to house (approx.)
East Lake area	168-176	1:1
West Lake area	124-20	6:1
E. Lake above dike	84-18	4:1
W. Lake above dike	83-15	4:1
E. Lake below dike	84-158	1:2
W. Lake below dike	41-5	8:1
Above dikes	167-33	4:1
Below dikes	125-163	1:1.1

For at least 17 years previous to state acquisition the area steadily produced a yearly harvest of over 2,500 muskrat pelts. The reference by Hansen to heavy late fall and winter trapping in 1933-34 in addition to the reported spring catch of 632 indicates that the population remained at a relatively high level to the spring of 1934. The dikes were constructed in 1934. The harvest has been relatively low subsequent to that date with the exception of the season of 1950-51. Two possibilities as to the cause of the muskrat decline immediately present themselves--namely, the dikes and the trapping procedure.

The construction of the dikes created East and West Lakes. The stream channels thus innundated were lost as muskrat habitat--at least until suitable vegetation could ecize on the area. The formation of these two lakes exposed 1200 acres of open water surface to evaporation. The rate of evaporation in the desert air was not determined, but Gilbert (1890) figured that there was an annual evaporation rate of from 60 to 80 inches from Great Salt Lake. Harding (in Meinzer, 1949) indicates that the annual evaporation rate is closer to 40 inches in the general region of the refuge. In addition to thus decreasing the total volume of water spilling to the lower areas, the greater surface exposure would tend to make this water warmer in the summer and colder in the winter. The salinity would increase both from the evaporation and from the leaching of the newly inundated land. While these factors exist, they are not of the magnitude to account for the radical population size change. They would only serve to act secondarily to more basic factors.

Other than these factors there would be no intrinsic difference between the presence or absence of the dikes to the muskrat population as a whole. An extrinsic factor associated with the dikes, however, is of crucial importance--namely, water level manipulation. This is treated in a separate section.

The second apparent possibility of the cause in the population reduction is under-trapping. Under-trapping leads to overpopulation which in turn results in: (1) an increase in intraspecific strife with resultant losses; (2) increased demands upon the food supply with resultant eat-outs; (3) decreased reproduction; (4) increased susceptibility to disease and parasites; and (5) increased predation due to an influx of predators to an abundant food supply. The effects of under-trapping were graphically displayed in 1926 or 1927 when Eli and John Anderson tried to stockpile the muskrat population.

Under-trapping as a basic cause of the muskrat decline is indicated by the trapping returns (table 6). The complete absence of trapping for the 6 years from 1935 to 1940 would strongly indicate that the high population in 1934 was allowed to increase beyond the carrying capacity of the area. In 1941 Nelson (field note) estimated a total population of 4,000 yet only 284 or 7 percent were trapped. The area below the dikes was not trapped for 15 years and the entire refuge was not trapped for 10 seasons. The spring runs are scattered and relatively harder to trap than the marsh areas. The several references to the population being concentrated on the spring runs coupled with the relatively small catches at least indicate under-trapping as a possibility to be investigated.

Areas devoid of emergent vegetation of from one-half to 10 acres were observed on the Bar M Marsh. Figure 23 is of one of the larger of these areas while figure 27 shows their distribution on the Bar M Marsh. They are characterized by a soil relatively high in organic matter and supporting a fair stand of widgeongrass (Ruppia maritima L.). These areas are rather sharply defined and there appears to be little if any invasion by the emergent species that adjoin them. Studies on the Gulf Coast (Lynch, O'Neil and Lay, 1937) show that eat-outs occurring on a clay subsoil marsh are revegetated in 1 or 2 seasons. These open areas on the Bar M Marsh show no sign of being revegetated by emergent vegetation. Therefore they may or may not represent eat-outs.

Fluctuating water levels can cause an artificial overpopulation when the muskrats are flooded or forced by receeding water into less and less space. The possibility of this type of overpopulation is definitely indicated on the area. (See the section on water level manipulation.)

There is little need of management practices to increase a given population if that increase is not harvested. Considerable evidence (Errington, 1948, and others) shows that the relative reproduction in a high density population is low whereas in an understocked area it is high. Surely some years do occur when the population has been drastically reduced by disease, flooding, etc. where partial or even no trapping is indicated. But this writer does not believe that the trapping, or rather the lack ot it--especially from 1935-40, was dictated with these thoughts in mind.

Under-trapping, as a major factor in the reduced muskrat yield from Locomotive Springs is indicated by the records. However, due to the lack of definite large scale eat-outs, it would appear as if this factor were not the limiting factor in the reduction, but only accentuated by another factor or factors.

Movements

As nothing was known on the migration of the muskrat at Locomotive Springs, it was intended to ear tag a number of kits in order to study this phase of muskrat ecology. It was also hoped that growth rates could be established by this method. Growth rates would be especially valuable in studying the reproduction on the area. Errington (1939) has worked out these rates for *Ondatra zibethica zibethica* L. and other workers in the field (Gashwiler, 1950 and Cowan, 1948) have applied them to different races. Cowen points out however that it is questionable as to whether they apply to other races or not. Twenty kits comprising part or all of 9 litters were ear tagged on the area May 10, 1949, by Dr. Jessop B. Low.

The method used by the writer was that developed by Aldous (1946) in which Monel fingerling tags are fastened to the ears. Tagging began June 20, 1950. Seventy-six kits representing all or part of at least 21 litters were tagged at various places on the refuge. Until June 30th, one litter or litter-part was encountered for every 5 to 6 houses examined. From that date on the ratio widened rapidly until by July 9-12 the ratio was 1 to 30 houses and more. As this condition continued to exist, it was believed that the disturbance to the population was not commeasurate with the results and was discontinued. On July 5, Mr. E. V. Saunders (in conversation) told the writer that at Forsegren's marsh near Corinne, Utah, he was finding 1 litter for every 2 to 3 houses at that time.

To further study the migration tendencies, live trapping was done with Havahart live traps. The results, like those of Cowen (1948) were more or less indifferent. Many kinds of sets were used, and the baits included carrots, parsnips, turnips, watermelon rinds and split cattail rootstocks. The latter proved to be the best, but all were disappointing. Commercial scent was also used. The live-trapping produced only 7 muskrats for tagging, 2 adults and 5 subadults. Two of the sub-adults were caught at one time in a runway between 2 houses. They were of different ages. Another subadult was recaptured 3 days after the initial capture. It was drowned in 1 inch of water. Three adults were captured for tagging by grasping their tails when the opportunity presented itself in the marshes.

The returns of tagged animals were few. All muskrats trapped by the writer were inspected at the point of capture.

Only 1 tag return was found for the 812 muskrats trapped. This tag return was an adult male that had been live trapped July 23, 1950, on the Bar M Spring run. Recapture was made within 75 yards of the initial point of capture on February 23, 1951. The initial and final body measurements of both the tail and total length were identical. However there was an increase of 270 grams in weight. This male had been tagged on both ears. One of the tags had been lost and that ear lobe was split. The other tag was attached solidly.

At least 2 tagged muskrats were caught by the Stokes brothers. However, the carcases of those muskrats were discarded before the fact of their being tagged was noticed. The first return was from the lower end of Off Marsh. This kit had been tagged as a nestling on the upper Teal Marsh. They only remembered that the pelt had been "large." The second return was not noticed until they were selling their pelts. They did not record the tag number.

Intermarsh movements during the spring trapping season were quite evident on the moist, barren salt flats between the marshes.

As the trapping dropped off in the upper areas of the Bar M Marsh the traps were moved further south. However, after a period of 10 days to 2 weeks the sign in the trapped area was again abundant indicating that intramarsh dispersion was quite active. The writer did not retrap these areas on the Bar M Marshes whereas the Stokes brothers did work each area over several times on the Teal and Off Marshes.

The summer, 1950, house counts showed a low number of active houses on Teal and Off Marshes following moderate trapping in the spring of 1949-50. The following winter house count (table 18) showed a very marked increase in the number of houses on each area--amounting to an increase of 320 percent on Teal, an 852 percent on Off over the summer house count. This increase may have been due largely to dispersion from the Bar M Marsh that had not been trapped.

Observation along the storm line bordering the salt flats to the south showed that while muskrats would go out on the barren flats up to 50 feet, they would go no further.

One adult muskrat was found dead one mile east of the head of Sparks Spring. The cause of death was not in evidence. This is the furthest from water that a muskrat was found on the area.

Mr. Jim Wood, operator of the salt plant at Monument Point 5 miles east of the refuge, reported that in 1949 he saw a live muskrat in his salt gardens. Monument Point is about equidistant between the refuge and the marsh areas in Hansel Valley. Therefore it is problematical as to which area it was from.

Conversation with cattlemen, trappers, and ranchers in the area indicate little mass migration. The muskrat population at Locomotive Springs is relatively isolated. A marked spring dispersal occurs within the area, but there is little evidence that it extends beyond the refuge in any magnitude.

COMPOSITION

Reproduction

Because of the possibility that the lowered productivity of the area may have been caused by a reduced reproduction rate, this particular phase of the study was intensely investigated.

Much of the literature on the muskrat has dealt with the derivation of age ratios by various means. While some of these are fairly satisfactory tools where muskrats are trapped in the fall and early winter, most fail when applied to spring caught muskrats. No wholly satisfactory technique has yet been found. Several of these methods were checked both for the purpose of obtaining needed data and for checking the method itself--many of which were reported on the basis of small samples.

Lavrov (Shanks, 1948) first pointed out that the young of the year muskrat pelts show a bilaterally symmetrical pattern of pigmentation on the flesh side. Older individuals show a mottled or asymmetrical pattern. Several writers have further reported on this (Beer, 1949, and Applegate and Predmore Jr., 1947).

Table 10. Age ratios of muskrats as derived from molt patterns, Locomotive Springs Refuge, December 20, 1950 to February 11, 1951.

Sex	No	Adult	Juvenile	Ratio
Male	73	32	41	100:128
Female	69	34	35	100:103
Both	142	66	76	100:115

The actual age ratio of the females as determined by the presence or absence of placental scars was 100 adults per 142 juveniles (table 11). There is a wide divergence between the age ratio of the females as derived from the molt pattern method and that derived by the placental scar method. Petrides (1950) and others found a closer agreement between the 2 methods. The writer believes that the present discrepancy is due to differential priming of the bilaterally symmetrical pattern of the juveniles--thus giving them a mottled appearance. The molt pattern method would appear then, in addition to losing its usefulness as the priming process progressed, would lose its validity. In this winter group of pelts 12 or 7.8 percent were too prime to classify by this method.

The method of aging female pelts by the size of the teat scars was also checked. Petrides (1950) used the diameter of 1.5 millimeters as the dividing point--above being adult and below being juvenile. In addition, the presence or absence of pigment was noted. A pelt with darkly pigmented teat scars was classfied as adult whereas no pigmentation indicated it as a juvenile. If valid this method would be very useful in aging large groups of spring caught female peltries.

Table 11. Female age ratios derived from teat marks and placental scars, Locomotive Springs Refuge, 1950-51.

Area	Ratio-Adult: Juveniles by teat size	Ratio-Adult: Juvenile by teat pigmentation	Season	Ratio-Adult: Juvenile by placental scars
Spring runs	100:99	100:200	Winter	100:142
Off-Teal marshs	100:63	100:193	Spring	- - - -
Bar M marsh	100:91	100:39	Spring	100:172

Table 11 tabulates the age ratios derived from the teat size and pigmentation methods compared with those obtained by the placental scar technique. In this study it was assumed that the placental scar technique would give age ratios quite close to the actual ratio. The wide divergence of the ratios derived by the 2 teat methods from the actual would indicate that these methods were of little value on the study area.

Two items of interest were discovered in the process of checking these age ratios: 1. an adult male showing the five pairs of mammary glands on the pelt. The finding of this individual introduces an error, admittedly small, into the sexing of pelts by the teat marks. 2. A supernumary mammary gland, pectoraly placed, was found in 7 percent of the females (7 out of 102 females). No cases of paired supernumary glands were found.

Petrides (1950) mentions the use of the degree of ossification of the wrist bones in the forepaws of muskrats for age determination. The method was apparently of no use on other than early fall-caught muskrats. However, he made no mention of a similar fluoroscopic examination of the caudal vertebrae. A small sample of 7 muskrats was checked in this manner by Dr. J. B. Low and the results indicated further investigation. Consequently a large series of tails were collected. Upon fluorescopic examination, however, both known age groups separated at random. This method cannot be used for aging spring caught muskrats.

The methods of aging muskrats by the size, shape, and color of the penis, presence or absence of a vaginal seal and the condition of the sexual organs were investigated, but were found to include too high a percent of intermediate individuals that could not be classified. From the indications, though, these methods should prove useful in aging fall caught muskrats on the area.

Many workers in the field have used the placental scar method of age determination in the females of the population (McCann, 1944; Sooter, 1946; Beer, 1949, et al.). This method proved to be the only valid age criterion for use on the spring caught muskrats. All females captured were examined for the presence or absence of placental scars. Those with these scars were classified as adults while those without were classified as juveniles.

At least 2 errors are possible in this technique. The resorption of the pigmented areas would tend to increase the number of juveniles per adult. This was not indicated to be of significant importance in this study.

The intensity of the pigmentation did increase from December through March, but most of the scars were quite visible up to April 1st when the season ended. Only 3 percent of the adult females taken on the Bar M Marsh were noted as "hard to see." Gashwiler (1950) reported that the placental scar method cannot be used as an age criterion in the spring season in Maine due to resorption, but the trapping season there is one month later than at Locomotive Springs. Placental scars were still present on 3 females with embryos although difficult to count because of the distention of the uteri.

Barren adult females would also tend to increase the number of juveniles. The extent of this error is unknown. Petrides (1950) compiled the data on this subject and the range of barren adult females was from 5 to 20 percent of the adult females. If females breed in their first summer it would increase the number of adults. No evidence was observed that they did breed in their first summer. Four females (4.6 percent) were trapped that had an undifferentiated placental scar total of under 7 scars each. This probably indicates one litter. It may be that these were adults that had borne one litter only that year; or it may be that they indicate young of the year breeding or both.

In using the placental scar technique one unevaluated basic assumption must be made--namely, that there is no age differential selectivity in the trapping. The writer tried to lessen any effect of this by using a very diverse trapline with many different types of sets interspersed, placed at varying distances from houses and dens, and with varying lengths of time at one spot. It is believed that this technique lessened the unknown effect of age selectivity.

Age ratios are useful as indices to the relative effect of environmental influences. Since water level fluctuations were found to be of prime importance on the refuge, the supplementary data in table 12 are arranged to divide the data into that above and that below the dikes.

The muskrat habitat above the dikes is primarily streamlike in character, while the area below the dikes is marshland. Water level changes are more marked on streams than on marshes. The stream, being enclosed within its banks, must rise sharply with an increase in flow whereas the same increase upon a marsh not so enclosed would cause a mush more moderate raise. In addition a decrease in water volume in a stream exposes the muskrats more to adverse environmental influences than a similar decrease in a marsh where food and cover remain abundant. For the above reasons this area distinction is carried throughout the other biotic investigations.

Table 12 shows that there was no great difference in the average number of implanted fetuses above and below the dikes.

Table 12. Supplementary reproduction data derived by the placental scar method, Locomotive Springs Refuge, 1950-51.

Area	Avg. number of placental scars	Average size of last litter	Ratio: juvenile ♀ per 100 adult ♀	Ratio: juveniles per adult pair	Juvenile mortality (%)
Above dikes	16.5	8.0	142	284	82.8
Bar M Marsh	16.9	6.11	172	344	79.4

The average last litter figures show a rather marked difference. This difference could be: 1. the contrast between 2 and 3 litters during the study year; 2. it could mean an increase in size in the last litter above the dikes to compensate for earlier losses; or 3. it could signify, as previously stated, a differential resorption. The muskrats from above the dikes were trapped in the winter and those below in the spring.

A significant difference occurs between the female age ratios derived for the 2 areas, being appreciably larger on the marshes than on the streams. Assuming a 50:50 sex ratio the breeding pairs on the Bar M Marsh raised an average of 0.60 more young than did similar pairs above the dike line.

The juvenile mortality percentages (table 12) are derived by computing the percentage loss between the average number of placental scars and the number of young raised per adult pair. There is very little difference between the two areas as shown by these values. However in comparison with McCann's (1944) figure of 47 percent for Minnesota muskrats both areas have a relatively high percentage loss.

The 16.9 and 16.5 average placental scar counts are high in comparison with the reports of other workers (McCann, 1944 - 11.5; Sooter, 1946 - 14.08; Beer, 1949 - 14.9). This range was from 6 to 27 placental scars per adult female. This may indicate a compensatory increase in young production to some adverse environmental factor.

In addition Low (1950) reports that an average of 100 more juveniles per 100 adults are taken from stream areas over the same number taken from marshes. This would tend to even further accentuate the difference between the two areas.

Low (1950) also reported that the adult to juvenile ratio in Utah ranged from 1:3.3 on a small regularly trapped marsh to 1:6.7 in an exceptional year on Utah Lake. Further, he believes that a muskrat population conservatively trapped over a number of years will yield an age ratio of 3.5 to 4.0 juveniles per adult pair.

The age ratio from the Bar M Marsh essentially falls within this grouping (3.44). However, if this hypothetical area was not trapped the ratio of juvenile to adult would decrease due to the lowered reproduction accomanying under-trapping. The Bar M Marsh had not been trapped for 15 years prior to 1950-51. This would indicate that the reproduction, instead of being low normal, is actually relatively high.

Table 13. Sex and age ratios of muskrats trapped at Locomotive Springs Refuge, 1950-51.

Area	Total No.	No. ♂	No. ♀	Ratio ♂/100 ♀	No. Juven. ♀	No. Adult ♀	Ratio J♀/100 A♀
Above dikes East Lake							
Sparks	2	2	0	---	--	--	---
Off	24	8	16	50	9	7	128
Teal	11	5	6	83	3	3	100
Bar M	46	24	22	109	9	13	69
Total all springs	83	39	44	88	21	23	91
East Lake*	36	16	20	80	12	8	150
All East Lake area	92	43	49	87	26	23	113
West Lake							
West Loco	34	19	15	127	8	7	114
West Lake	11	5	6	83	6	0	---
West Pond	17	12	5	240	4	1	400
All West Lake area	62	36	26	138	18	8	225
Total above dike	154	79	75	105	44	31	142
Below dikes							
Bar M	626	387	239	162	152	87	172
Grand total	780	466	314	148	183	131	139

* Includes the mouth of Off Spring run

An alternate possibility exists in the fact that the Teal and Off Marshes were trapped the year previous. These then relatively underpopulated areas may have created a steep diffusion gradient from the denser populated Bar M Marsh during the spring distributional shift. Such a diffusion from the Bar M Marsh would compare with conservative trapping. Probably both factors were operative.

Within the spring run grouping several ratios deserve enlargement (table 13). The only actually stable water level area was West Pond lying west of West Lake. The age ratio there of juveniles per adult pair was 8:1. An even higher though incalculable ratio was obtained from West Lake, but this was considered to be non-representative due to possible age selectivity in under-ice den trapping. Age differential catches probably occurred on the north shore of East Lake. There the muskrats were being forced out by the lake draw-down. If these factors are taken into consideration, then the reproduction on the spring runs would indicate a relatively low reproductive rate. This low rate would approach that of a stable population.

It would appear then that a low reproductive rate existed through 1950 on the spring runs but that the reproduction approached normal on the lower marshes.

Evidence of breeding in the spring of 1951 was first observed in the jump tracks of a muskrat on January 14th. Nothing has been found published on this, but it seems to follow logically. The track resembles a mink track in that the feet are always paired, a looping tail mark shows at each jump, and every den and hole is investigated.

It is believed by the writer that these tracks are made by sexually excited male muskrats in search of females. This type of track was noticed frequently after the first observation.

Swollen uteri in the proestrous condition were first noticed on February 16th and 17th. They were not again in evidence until March 9th after which they regularly occurred in about 30 percent of each day's catch of females.

The first embryos were found March 17th. A total of three adult and 2 sub-adult (females born in 1950) gravid females were taken. They gave an average litter size of 7.6 with a range of 5 to 9. The embryos were not developed enough for sexing. No lactating females were caught. Six females with swollen vaginal openings and large amounts of secretion in and around that orfice were believed to have been bred just previous to being caught. The first occurrence was on February 21st and was found scatteringly thereafter.

Sealed vaginal orfices were regularly found to February 23rd although in steadily decreasing numbers. Subsequent to that date only 3 were noted, the last being on March 13th in an apparently sick animal.

The 1951 breeding season on the study area began in the second week of March. Table 14 shows the 1950-51 reproduction on the Ogden Bay Bird Refuge.

The reproduction on Locomotive Springs in 1950-51 appears to be delayed by at least 20 days. Two possible explanations of this delay present themselves: 1. The average growing season at Locomotive Springs is 35 days less than at Ogden Bay (Table 1) 2. That the first estral cycle passed without any appreciable conception (as previously noted). Beer (1949) gives the length of the estral cycle as 28.7 days with a spread of 24 to 34 days. As traps were first placed on the Bar M Marsh on February 15th, it may well be that the next 2 days just caught the tail end of the first estral cycle and those caught on March 9th represented the lead end of the second estral cycle. If this were the case, then the time interval would be about right. It would appear logical that these 2 factors were correlated--the former conditioning the latter.

Table 14 Muskrat reproduction on the Ogden Bay Bird Refuge, spring season, 1951 (Saunders, in conversation).

Time period	Age	Percent of trapped females with embryos
February 16 - 28	Adult	27.9
	Sub-adult	3.6
March 1 - 15	Adult	35.1
	Sub-adult	6.3
March 16 - 31	Adult	84.0
	Sub-adult	17.7

Sex Ratios

The sex ratios taken from the muskrats trapped at Locomotive Springs are listed in table 13. The winter ratios listed for East Lake show a large percentage of females, both adult and sub-adult. This apparently was caused by the differential migration following the lake draw-down. The

West Lake area was near normal.

Commercial scent and blind sets were used on the spring runs above the dikes. On the Bar M Marsh, however, a sex selective scent was utilized. This was prepared by chopping up the ovaries, uterus, bladder, and vulva of adult females and mixing it with their urine. This scent has a higher attractive potential for males than for females. With this scent the ratio of 1.62 males per female was obtained for the entire spring season.

The writer received for processing the State's share of all the pelts trapped by the Stokes brothers. The sex ratio of 477 of their pelts was 0.82 males per females. Two explanations of how this low ratio may be possible: 1. the method of trapping (i.e. close to houses, retrapping trapped areas, leaving traps in one place too long, non-use of a male selective scent, etc.) could account for the higher percentage of females; 2. the State's half of the pelts that the writer examined was not a random sample of each day's catch. Probably both factors were responsible.

No major sex differential mortality factor was evident on the area during the study period.

Size and Weight

All reports subsequent to state acquisition were unanimous in one respect--namely, that the muskrat pelts from Locomotive Springs were both larger and of better quality than those from other state areas.

John Anderson, however, told the writer that the

Locomotive Springs muskrats were both inferior in size and color to those from Salt Creek (near Thatcher, Utah) when he trapped the area; hence the introduction of the "big black muskrats."

Table 15. Size composition of muskrat pelts, Locomotive Springs Refuge, 1950-51.

Area	Number of pelts	Percent of Pelts					
		Ex-large	Large	Medium	Small	Kit	Damaged
Area above dikes (winter)	166	3.7	38.1	35.0	20.6	2.5	---
Area below dikes (spring)	626	0.7	20.0	50.7	26.1	2.3	---
Snyder-ville, Utah (fall, 1936)	237	3.4	34.7	38.1	8.3	15.3	---
Ogden Bay Refuge* (spring 1945)	585	---	81.8**	14.7	0.7	0.0	3.6

* data from Low (1950)
** Large and extra-large combined

Disregarding the genetic factor discussed in the section on species the writer found that the pelts taken from the area in the 1950-51 season were neither of exceptional size nor of top quality. Only 7 pelts out of 1,289 graded by the writer were definite extra-larges. Table 15 shows the size composition of 2 other pelt collections are included. Both winter and spring collections from Locomotive Springs are quite similar to the fall collection from Snyderville, Utah. Extrapolating the latter to spring would leave the former as relatively small muskrats. Comparison with the Ogden Bay data emphasizes this size difference.

The non-marsh area of Locomotive Springs had the higher percentage of large muskrat pelts. This could either indicate a strain of larger muskrats or a smaller percent of young. The writer believes that only the latter is indicated.

The occurrence of grossly damaged pelts ran 9.4 percent, while the total number of damaged (any with cuts or bites--fresh or old--on the back of the pelt) ran 15.4 percent.

Because of the lack of standardization, pelt size and percent of damaged pelts are no more than indicators. But as indicators they are valuable.

The color of the muskrat pelts collected was generally light. No black pelts were taken, nor were any albinos, although several pallid golden pelts were observed.

More time was available when trapping the area above the dikes, and, therefore, the daily catch was measured for total-, tail-, and hind foot lengths. Each muskrat was weighed with a Chatillon spring scale to the nearest 10 grams. Time limitations precluded similar measurements for the spring trapping season. However, every spring caught muskrat was weighed. These results are listed in table 16.

Table 16. Size and weight averages of muskrats trapped at Locomotive Springs Refuge, 1950-51.

Area	Grouping	No.	Total length (mm.)	Tail length (mm.)	Hind foot (mm.)	Weight (gms.)
Above dikes:						
West Lake						
	Adult ♀	8	560	240	77	1103.7
	Juven.♀	17	539	229	77	1039.4
	All ♀	25	546	233	77	1060.0
	All ♂	35	555	238	78	1060.9
East Lake						
	Adult ♀	22	556	237	77	1101.4
	Juven.♀	25	504	221	76	796.0
	All ♀	47	529	228	77	938.9
	All ♂	40	543	235	77	960.0
Both Lakes						
	Adult ♀	30	557	238	77	1102.0
	Juven.♀	42	518	224	77	894.5
	All ♀	72	535	230	77	981.0
	All ♂	75	548	237	77	1010.8
	All 'rats	147	542	234	77	975.6
Below dikes:						
Bar M Marsh						
	Adult ♀	78	---	---	--	978.6
	Juven.♀	147	---	---	--	897.5
	All ♀	225	---	---	--	923.7
	All ♂	364	---	---	--	1043.6
	All 'rats	590	---	---	--	997.8
All muskrats		737	---	---	--	993.4

The largest female weighed 1,340 grams and the largest male, 1,470 grams. Table 16, when considered by the East and West Lake areas, shows a distinct difference in the linear measurements and weight. Those from the East Lake area were the lesser in all measurements. The key to this difference lies in the comparison of the two juvenile female groups. The magnitude of the difference would indicate: 1. an additional litter on the East Lake area; or 2. the general loss of the last litter on West Lake. Placental scar counts (table 12) would indicate the losing of a litter rather than the non-production of it.

The Bar M Marsh muskrats were weighed only. Although they had the benefit of 1 to 2 months of extra growth, they were not appreciably larger than the muskrats from above the dikes. In the writer's opinion this discrepancy was caused by a higher juvenile mortality above the dikes.

The average weight of the juvenile females from the Bar M Marsh, with 2 additional months of growth, failed to reach the average weight of the West Lake juvenile females. This only exemplifys the probable late litter loss on the latter area.

The hind foot lengths, although quite variable, averaged out very close. There appeared to be no correlation of the hind foot length with age or sex.

Low (1950) reports that the average weights of fall trapped muskrats on the Ogden Bay Refuge were: adult females, 992.2; subadult females, 771.1; and adult males, 1020.6 grams. Exterpolation to spring weights would indicate that the two populations are roughly comparable to each other.

The former reports of the large size and high quality of pelts from the area can be explained by either of 2 ways: 1. a genetically-caused reduction in size (but the writer saw no evidence of this), and 2. the reproduction on the area was largely ineffective with the result that the main population was adult. This could account for both the large size of the pelts (by a lack of "smalls" and "kits"), and the top quality (by a low percentage of damaged pelts due to under-population).

Condition

All of the previous reports seem to indicate that the muskrats trapped on the area were in good condition. During the study period notations were made at the time of skinning as to the condition of each muskrat. Five classifications were used from very fat to poor. The results are tabulated in table 17. Admittedly appearance is not an accurate quantitative measure, but is should prove indicative. There is a decrease in the percent of muskrats classified as fat above the dikes as compared with the marshes below. There is no great difference between different age and sex groupings except as regards adult females on the Bar M Marsh (6.9 percent of this group were very poor). This condition appeared to have some correlation with the presence of small, 0.5 to 4 millemeters in diameter, roughly circular, mutilobed, hard, yellow cystelike formations occurring between the uteral mesenteries. The number varied from 1 to 11 per female.

Table 17. Relative condition of the muskrat population on Locomotive Springs Refuge, 1950-51.

Area	Grouping	Very Fat	Fat	Good	Fair	Poor	No.
Above dikes East Lake							
	Juven. ♀	8.0	68.0	20.0	4.0	0.0	25
	Adult ♀	9.1	50.0	31.8	9.1	0.0	22
	All ♀	8.5	59.6	25.5	6.3	0.0	47
	All ♂	7.3	34.1	43.9	12.2	2.4	41
West Lake							
	Juven. ♀	23.5	52.9	23.5	0.0	0.0	17
	Adult ♀	0.0	62.5	25.0	12.5	0.0	8
	All ♀	16.0	56.0	24.0	4.0	0.0	25
	All ♂	0.0	47.2	44.4	8.3	0.0	36
Both areas above dike							
	All ♀	11.1	58.3	25.0	5.5	0.0	72
	All ♂	3.9	39.1	44.1	10.4	1.3	77
	All musk-rats	7.4	49.0	34.9	8.1	0.6	149
Below dikes (Bar M)							
	Juven. ♀	13.0	78.8	8.2	0.0	0.0	146
	Adult ♀	13.8	68.4	10.9	0.0	6.9	77
	All ♀	13.0	75.8	9.0	0.0	2.2	223
	All ♂	6.2	87.9	4.7	0.0	1.2	321
	All musk-rats	9.0	83.0	6.4	0.0	1.6	544

Time limitations precluded further investigations into this abnormality. However, an apparently similar sample from the Ogden Bay Bird Refuge was previously reported "to be enlargements due to inflammatory action. Bacterial forms were not present though fibrin and pus cells made up the bulk of the enlargement. The condition was probably secondary to infection in some other part of the body."* This condition while not limited to the Bar M. Marsh appeared to be concentrated there.

AREA PRODUCTIVITY

Table 18 lists the number of houses per acre and the average number of muskrats caught per house. The number of active dens were not taken into consideration as they could not be accurately tallied during the winter and the spring breakup. However, the denning area on these marshes is limited and the number of dens should remain fairly constant through the years.

Table 18. House and area productivity, Locomotive Springs Refuge, 1950-51.

Area	Acreage	Winter house count (1950-51)	Houses per acre	Muskrats trapped per house	Muskrats trapped per acre
Bar M	870	257	0.298	2.43	0.72
Teal	352	128	0.363	2.18	0.80
Off	650	196	0.301	2.21	0.67
Total	1872	581	0.310	2.31	0.72

* Letter from D. R. Coburn to J. B. Low, November 21, 1946.

Low (1950) reports that the average yield for Utah marshlands was 0.5 muskrats per acre. The yield of the lower marshes were considerably higher than this. He further gives the range of houses per acre of marshland as 0.02 to 0.43. In this respect the lower marshes in the winter of 1950-51 were in the upper brackets.

It proved impossible to get accurate estimates of the acreage involved with the areas above the dikes. The productivity there, however, was quite reduced from that of the marsh area below the dikes.

BIOTIC MORTALITY FACTORS

Disease

Tularemia had a long history at Locomotive Springs. Perhaps the largest known outbreak of that disease in humans occurred there in 1935. At that time the State Health Commission reported 30 cases in the C.C.C. camp. The disease appears to be endemic to the area. The cattlemen reporting that it was only a matter of time before one would contract the disease if he stayed on the area.

They estimated that at least 25 men (in addition to the C.C.C. cases) had contracted tularemia on the area within their memories. Two fishermen from Howell became afflicted after a week-end fishing trip to the Springs in the summer of 1950. As far as could be determined, only one human death could be attributed to tularemia on the study area.

Tularemia is transmitted by the bites of ticks and deer flies. It also appears that it is transmitted by contact.

Karpoff and Antonoff (1936) showed that the causative organism (Pasteurella tularense) can be spread through the medium of water. The infected stream water can further be diluted to over 1:1000 and retain its virulence (Jellison, in conversation). Anonymous (in Hagen, 1948) reports that the pathogen enters the water from the bodies of infected water animals.

At the beginning of the study period a dense population of blacktailed jackrabbits (Lepus californicus deserticola Mearns) occurred on the area. Knowing the history of tularemia on the area, all dead rabbits were field autopsied. The first dead rabbit showing the gray granular foci on the liver and spleen was found June 25, 1950, north of the Bar M Spring. Six more were found the following day. From then on until August 12th a total of 130 freshly dead jackrabbits were counted on or near the area while making daily visits to the marshes and running coyote traps. Daily autopsies were at first performed on all rabbits found; but after a few days of 100 percent diagnosis of tularemia this practice was discontinued on the assumption that the cause of death in subsequent finds would be tularemia.

Decomposition was very rapid; thus precluding a sizable error due to double counting. A large number of juvenile rabbits were observed early in June; but, after the epidemic set in, there was apparently little if any reproduction.

The writer had two dogs with him on the area. When he first arrived the jackrabbits could outrun the dogs easily. After the epidemic set in very few rabbits could escape from the one dog. But in the fall after the disease had subsided, they again out-ran him constantly. Apparently the entire population was reduced in virility. One of the dogs contracted tularemia in July and died.

The jackrabbit population was largely in or near the greasewood (Sarcobatus vermiculatus (Hook.) Torr.) areas. Very few rabbits were found near the lower marshes. When a rabbit was sick with tularemia, it seemed to become quite thirsty and proceeded to the nearest water. It stayed there until it died. This was indicated by the high number of dead rabbits found near the spring heads and runs (26). Nine rabbits were found lying in the various spring heads. They furnished an excellent source of tularemia for water transmission throughout the area. Thus the potentiality of a general outbreak of tularemia in the muskrat population existed. It did not materialize, and no evidence of any muskrats dying from the disease was observed although closely watched for.

The reason that an epizootic did did not materialize probably lies in the little known field of natural immunity. In this writer's opinion the fact that it did not occur was an indication that the muskrat population was relatively secure. If the population had been made insecure by other adverse environmental factors, an epizootic would probably have occurred. Admittedly this is speculatatory but evidence tends to support it.

The epitzootic died out in August, 1950, and late fall influx of jackrabbits gave the area a substantial winter population.

Although several hearsay reports were heard concerning a major muskrat die-off (or several?) on the area at this time, nothing concrete could be ascertained.

One family group (6 or 7) of cottontail rabbits (Sylvilagus nuttalli Bachman) at the Bar M Spring contracted the disease and all but one died. The scabby symptoms were predominant in this species.

No evidence of any disease operating on the muskrats was found. Mention should be made, however, of the paper by Schillinger (1938) in which he states that the possibility of an epizootic of coccidiosus is greatly enhanced by the direct effect of lowered water levels. He cites a case where three-quarters of a large muskrat population was dead from coccidiosus after a 3 week's drought. In this same vein, lowered water levels have been shown to greatly increase the percentage of endoparasitic infestation in muskrats (Myer and Reilly, 1950). While no evidence was seen of either during the study year, the possibility of their acting on previous years must not be discounted.

A total of 16 adults and 12 kits were found dead during the summer and fall of 1950. Nine had definitely died of intraspecific strife, 9 had fallen to predators and 10 were dead of unknown causes. As many houses were opened in the tagging operations, in addition to the rather intensive daily observation, this total was surprisingly small. When Dr. J. B. Low (field notes) visited the area in the spring of 1949, a total of 12 dead muskrats were found in one day. No causes were listed.

During the spring trapping season this writer found 2 dead muskrats and the Stokes brothers found 3. All of these were fresh enough to be skinned. Nothing could be detected in 1, 2 appeared to have gastric enteritis, 1 apparently starved to death and one died as a result of a former wring-off. The observed losses appeared to be quite small considering the size of the population.

Parasites

One-third of the nestling muskrats observed in the houses, as well as about 10 percent of all adults, were obviously infested with mites. With the exception of 2 nestlings which were literally covered with these arthropods, the infestation did not appear to be excessive.

Upward of 20 adult muskrats were given macroscopic intestinal examinations. No evidence of endoparasites was seen. Slides of caecal matter from an apparently sick female showed a nematode cyste and a single *Trichomonas* sp.

Toward the end of the trapping season the feeling of every trapped muskrat's ears for ear tags produced 3 female ticks from 2 muskrats. These muskrats were on the extreme lower Bar M Marsh, 2 miles from the nearest greasewood area. Kohls* identified them as probably *Ixodes muris* Bishop and Smith. Positive identification would require males which were not in evidence. Kohls remarked that hitherto this species has not been reported west of Michigan where there

* Personal letter to writer from Mr. Glen H. Kohls, Rocky Mountain Laboratory, Hamilton, Montana, dated April 18, 1951.

is 1 record of a female I. Muris from a muskrat in Massachusetts. The isolated appearance of I. Muris at Locomotive Springs is probably another ramification of the importation of the "black muskrats."

Three out of every 4 jackrabbits that had died of tularemia were infested with the tick Dermacentor parumapterus Neumann.

The ectoparasites collected from a cottontail rabbit on the Bar M Spring were identified as the flea Cediopsylla inaequalis Baker.

Predators

Past studies have shown that a large percentage of a coyotes diet is furnished by the muskrat on Utah marshes (Low, 1950). Eighty-two coyotes scats collected by Low in April, 1946, at Locomotive Springs and analysed by Eldon Smith (field note) showed muskrats occurring in 65 with a frequency of 79.3 percent. Microtus spp. gave comparable figures of 67 and 81.7 percent.

John Anderson told the writer that coyotes were "numerous" on the area prior to state acquisition. Although about 200 coyotes were taken from area immediately surrounding Locomotive Springs during the winter of 1941-42, there was no indication of damage to the muskrats by coyotes (memo in the Utah Cooperative Wildlife Research Unit file).

In May, 1945, Low (field note) reported finding a number of coyotes dens on the knolls west of West Locomotive below the dikes. He collected 60 to 70 scats from this denning area.

The poisoning campaign of the Fish and Wildlife Service has definitely reduced the potentiality of extensive coyote predation. A close check was kept on coyotes during the study period. Two bitches with their litters were the sole summer resident coyotes. Two additional adults crossed the area but apparently did not linger there. One of the litters ranged around West Lake, the other the Off Marsh and eastward. There were 5 pups in the West Lake litter. During the first low water period on West Locomotive, their tracks were continually encountered along the stream bank. On two occasions they attempted the digging out of muskrat dens (figure 19). In these attempts they apparently weren't successful as the dens remained active.

Three of the pups of the West Lake litter and one of the Off Marsh litter were collected. From the evidence these coyotes did prey on the muskrats--especially those exposed by lowered water levels. The amount of work put into the attempted digging out of the dens would indicate, however, that they were not subsisting on muskrats alone. A coyote's natural adversion to water would indicate that the muskrat population situated with stable water levels would not be greatly affected by coyote predation. Lowered water levels on the other hand would increase the predation.

A note on waterfowl is indicated here. The nesting ducks and geese appear to concentrate on the Baker's and lower West Locomotive Marshes for their post-nuptial molt. While in this condition they are very exposed to coyote predation as evidenced by observations made by the writer with his dogs. Control of coyotes is indicated by this study, but their total effect, except when accentuated by the fluctuating water levels, is not limiting.

The coyote population on the area during the winter was low. Apparently no more than 3 were on the area at any one time. Coyote hunters in airplanes flew over the area several times during the winter. This appears to be a regular procedure. One pup was killed by them on Teal Marsh. The lower marshes were frozen over with 4 inches of ice and the houses themselves were frozen. As almost all muskrat activity was confined to beneath the ice, very little predation could have occurred.

Other mammalian predators were very little in evidence. The track of a large male mink was seen on Off Marsh in June. The remains of 2 muskrat kits eaten by it were found in a nearby house.

Old male mink are well known for their wandering. The fact that no mink were ever reported as being trapped at Locomotive Springs indicates that mink predation can be largely discounted.

Although the study area appears as if it were an ideal habitat for weasel, only 2 weasels inhabited the area. In addition 1 weasel that had died in the spring of 1950 was found near West Pond.

Skunks were previously reported on the area but were absent during the study year. A spotted skunk was observed at Monument Point during the winter of 1950-51.

Only one swift fox has ever been observed by the cattlemen on the area. That was in 1944.

Badgers occur there but are not numerous.

Pouching was reported by John Anderson prior to 1934. The distance and reduced muskrat population would tend to reduce the loss by this source. The cattlemen reported seeing no evidence of it.

Table 19. Owl and hawk pellet analysis, fall and winter, 1949-50, Locomotive Springs Refuge.

Food Item	Marshes							
	Bar M		Teal		Off		West Loco.	
	Oc.	Freq.	Oc.	Freq.	Oc.	Freq.	Oc.	Freq.
<u>Ondatra</u>	3	5.3	0	0.0	9	19.6	0	0.0
<u>Microtus</u>	30	52.6	0	0.0	9	19.6	12	80.0
<u>Peromyscus</u>	2	3.5	0	0.0	0	0.0	0	0.0
<u>Dipodomys</u>	0	0.0	2	66.6	4	8.6	0	0.0
<u>Lepus</u>	0	0.0	0	0.0	2	4.3	2	13.3
<u>Sylvilagus</u>	0	0.0	0	0.0	0	0.0	0	0.0
<u>Sorex</u>	0	0.0	0	0.0	0	0.0	0	0.0
Unident. rodent	1	1.7	0	0.0	0	0.0	0	0.0
Bird	10	17.5	1	33.3	15	32.6	1	6.6
Egg	0	0.0	0	0.0	2	4.3	0	0.0
Insect	10	17.5	0	0.0	4	8.6	0	0.0
Cattle hair	0	0.0	0	0.0	0	0.0	0	0.0
Plant	1	1.7	0	0.0	0	0.0	0	0.0

The area supported an estimated summer population of 12 short-eared owls along with a varying number of marsh hawks. The only direct predation observed was seen when a female marsh hawk killed a young jackrabbit early in June.

However the collection of pellets was carried on during the observational trips. The results are tabulated in tables 19 and 20.

Table 20. Owl and hawk pellet analysis, spring, summer, and fall, 1950, Locomotive Springs Refuge.

Food Item	Marshes							
	Bar M		Teal		Off		West Loco.	
	Oc.	Freq.	Oc.	Freq.	Oc.	Freq.	Oc.	Freq.
Ondatra	28	20.3	6	12.8	10	13.7	12	10.2
Microtus	37	26.8	17	36.1	41	56.2	73	61.9
Peromyscus	4	2.9	0	0.0	1	1.4	0	0.0
Dipodomys	0	0.0	3	6.3	0	0.0	4	3.4
Lepus	3	2.3	0	0.0	3	4.1	0	0.0
Sylvilagus	1	0.7	0	0.0	0	0.0	0	0.0
Sorex	1	0.7	0	0.0	0	0.0	0	0.0
Unident. rodent	2	0.7	0	0.0	0	0.0	0	0.0
Bird	28	20.6	19	40.4	10	13.7	26	22.0
Egg	0	0.0	0	0.0	0	0.0	1	0.8
Insect	30	21.7	2	4.2	3	4.0	0	0.0
Cattle hair	0	0.0	0	0.0	4	5.4	0	0.0
Plant	3	2.3	0	0.0	1	1.4	2	1.6

The pellets when collected were classified as old or current. The old probably represent, fall and winter pellets, 1949-50, while the current ones represent spring, summer and fall, 1950. There is definite increase in predation during the summer compared with the winter. Fifty-seven winter pellets were examined on the Bar M Marsh in the early spring of 1951. No occurrance of muskrat was detected and the predominant species represented was the meadow mouse (Microtus sp.).

Errington (1932) reported that whereas the bones in owl pellets are not greatly broken they are in the pellets of marsh hawks. It was attempted to separate the collected pellets by this technique, as well as by size--the larger being those of the owls. But the presence of many pellets of intermediate bone breakage and size precluded any definite separation. A few pellets were definitely those of hawks, but they were in the minority. Therefore all pellets are tabulated together.

Evidently the muskrat population is as well protected from owls and hawks in the winter as it is from coyotes. The highest predation on muskrats occurred on the Bar M Marsh. As this area was not trapped the year previous while the 2 other lower marshes were, the initial population density would be highest on the Bar M Marsh. Increased predation would follow from the greater relative availability.

Marsh hawks contribute to the number of damaged pelts early in the spring season by eating on trapped muskrats. For some unknown reason this type of damage dropped to near zero after Marsh 10th.

Crows and ravens are common over the area throughout most of the year. Two raven nests were found on the study area. The effect of these birds upon the muskrat population was probably light. However, if the muskrat population was exposed by drought conditions, one could expect a large influx of these birds. During January a party of 14 rabbit hunters hunted the area between Bar M and Sparks Springs killing a large number of jackrabbits. The previous crow and raven population of 1 or 2 per day was suddenly increased to an estimated 50 the day following the hunt. Other avian predators possibly include the members of the heron family, gulls and pelicans. Their effect, if any, is probably low.

Snakes were not numerous enough to have much effect in predation.

Cattle

The possibility of large scale losses to the muskrat population by cattle wintering on the area was closely investigated. The pattern of cattle distribution through the winter has an important bearing on this subject. The adverse effect of the cattle on the muskrat would vary directly with the severity of the winter. The winter of the study period was relatively light; still the pattern could be discerned. The bulk of the range stock that was in good condition was wintered on the desert north of the refuge. This herd was continually cut-through and the springers, cows with calves, and the weaker animals were moved down onto the refuge. In very severe winters, as in 1948-49, most or all of the cattle were moved onto the refuge. A further segregation on the same line occurs within the refuge--the stronger animals of this group being wintered on the other marshes and spring runs and only the weaker ones being fed hay and grain on lower Baker's. The total number of cattle wintering there was not known, because it is a pooled outfit. However, the total number of cattle wintering both on and north of the refuge is between 1,000 and 1,200 head.

On the lower marshes the cattle confined themselves to the salt grass borders of the marshy areas during the winter of 1950-51. The number of houses destroyed by cattle action on the Bar M Marsh was typical of the lower marshes--1.17 percent of the total active houses. The destroyed houses were constructed in the salt grass area (figures 12 and 13). Figure 10 shows the effect of grazing upon _Phragmites communus_ Trin. on the heavily grazed winter runs. On West Lake 60 percent of the muskrat houses were damaged or destroyed by cattle. The lower marsh areas are relatively secure from cattle damage as long as the ice is thick enough to safely support the cattle. Reports by the cattlemen indicate that most of the tromping of houses occurs when the ice is breaking up.

Cattle wintered on the area all the time that the former large muskrat yields were obtained. It would seem doubtful, therefore, that cattle would be a major cause of the muskrat reduction. In a severe winter, as in 1948-49, when the supply of hay is exhausted prior to the spring breakup, a large loss in the muskrat population is to be expected.

MANAGEMENT RECOMMENDATIONS

Any management recommendations for the refuge must consider that the muskrat is secondary to the primary purpose of the area--namely, a waterfowl refuge. However, the efficient management of the muskrat both increases the waterfowl habitat, and provides an income which should more than pay for the cost of improvements.

The primary recommendation for the study area is the stabilization of the water levels. All other improvements would be more or less ineffective if this one limiting factor were not removed. There are several ways of accomplishing this, but primary to all of them is the determination, setting and maintenance of specified flows to each area that would not be varied.

As the largest part of the waterfowl and muskrat habitat is connected with East Lake, this area should be stabilized if complete stabilization of both lakes cannot be attained. If the flow over the Bar M Spring spillway was stabilized, then this entire East Lake area would become stable.

Permanent weirs and measuring devices should be installed on all the springs, and measurements taken to determine the natural flow of the springs.

All changes in water flow settings on the spillways should be done accurately and with both cattlemen and state personnel present. In addition the settings should be locked to keep unauthorized persons from changing them. All gates should be maintained so they would not be clogged by debris.

The small natural flow of Sparks Spring (0.78 cubic feet per second), now diverted from its former channel to East Lake, would be of more value to waterfowl and muskrats if allowed to return to its former channel. The original Scirpus olneyi still maintains itself there (figure 21), and this change would create valuable new habitat for both waterfowl and muskrats.

Controlled burning is recommended on the Off and Bar M Marshes. Over large areas of these marshes the rank mat of past years' growth prevents sufficient light passage to allow the current years crop to grow.(figure 11). Spring burning of these areas every third year would increase the available marsh habitat for the inhabitants.

Teal Marsh with its ditch-like character (figures 20 and 28) is very inefficient in waterfowl and muskrat production due to its low edge effect. Blasting spreader ditches across the main channel at regular intervals would greatly increase the aquatic habitat on this marsh. The same technique should also be applied to the Bar M Marsh. There the entire east fork has silted in and the west fork is undergoing the same process. Below, on the storm line, a large flow of water is wasted. This water could be spread much more than it is now.

If the lakes are to be regularly drained they should be re-filled from the spring run-off (February and March). If attempted later it would necessitate a serious decrease in the flows to the lower marshes.

Regular house and den surveys should be taken and the trapping regulated from the results of these surveys. Accurate tallies of the catch from each area should also be kept.

The white underfur factor should be checked both for its depreciatory effect, and for dominance by breeding it with normal muskrats. If it is dominant, care should be taken that it does not spread to other areas.

There are very few areas where the muskrat is as isolated as at Locomotive Springs. This area would therefore be ideal for experimenting with nutria and other aquatic exotics.

It has been said that the reason that this refuge has not had the attention that similar state refuges have had is that too few hunters visit it to make it worthwhile. This writer believes the converse. There are no signs on U. S. Highway 30 directing hunters to the refuge. The best waterfowl hunting occurs during wet weather, yet that is the time that it is the hardest to get to the area. Although an all-weather road exists to within 1 mile of the refuge, it is not marked. The shorter route from Snowville would probably be tried by the newcomer. This is impassible in wet weather. The short stretch of road from the railroad grade to Baker's Spring should be graveled and graded, and the entire Hansel Valley route marked for wet-weather travel.

Installation of cattle guards instead of wire gates would decrease much potential friction between hunters and cattlemen.

Many hunters knew nothing of the marshes below the dikes. A permanent map at Bar M Spring would correct this.

As long as the East Lake dike is impassible for vehicles it should be so marked, as it is very difficult to turn around once on the dike.

The Locomotive Springs Refuge has great potentialities, but these have to be brought out--they won't come out by themselves.

CONCLUSIONS

Although the study year proved to be atypical in that a relatively large number of muskrats was harvested, the patterns of past events were in evidence.

The reduced muskrat productivity of Locomotive Springs first occurred after the construction of the dikes. In general this reduction existed over the entire refuge and was continuous for 14 years. This widespread continuity would indicate a general causative factor that was associated either with the dikes or with state ownership. There were only 2 factors that fulfilled both of these stipulations--namely, undertrapping and water level fluctuation.

Undertrapping was strongly indicated by the trapping records--especially the period from 1935 to 1940. The absence of extensive eatouts would, however, indicate that this factor was not limiting in itself.

Water level fluctuation was indicated by both the past effect and present pattern. The inhibiting effect of this 1 limiting factor has in turn amplified the effect of other, usually non-limiting, factors such as plant succession, water flow reapportionment, undertrapping, predation, and reduction in natural spring flow. The effect of this combination of factors upon the muskrat population was decisive--instead of thriving, it merely existed.

The particular muskrat population at Locomotive Springs, because of its isolation and the importation of an alien race of muskrats, has apparently evolved to a hybrid racial status. Concurrent with this change has been the appearance of a detrimental pelage character.

SUMMARY

1. A 95 percent decrease, extending for a 15 year period, in the yield of muskrat pelts from the Locomotive Springs Migratory Waterfowl Refuge, Box Elder County, Utah was investigated in 1950-51.
2. A reduction in the natural flow of the springs was noted. This may amount to as much as 28 percent.
3. Whereas formerly the irrigation of the hay land affected only that hay land, the irrigation now affects the water levels over the entire refuge.
4. Cattail has been largely replaced by bullrush in the marshes probably as a result of fluctuating water levels.
5. West Lake which formerly was the highest duck-food producing lake in the state has been reduced to near barrenness by fluctuating water levels.
6. The race of muskrats on the area appears to be the eastern muskrat, Ondatra zibethica zibethica L., instead of the indigenous Rocky Mountain Muskrat, O. Z. osoyoosensis Lord. This follows a former introduction of Canadian muskrats.
7. A detrimental pelage character existed in 92.3 percent of the pelts.
8. Although undertrapping was indicated by the records since state acquisition, it was not in evidence during the study year.
9. The evaluation of several methods of deriving age ratios

was attempted.

10. The harvest of muskrat pelts in the spring of 1950-51 was 1,766 or 77 percent of the former minimum yield.

11. The sex ratio of 780 muskrats trapped was 148 males per 100 females.

12. The age ratio of the marsh muskrats was 3.44 juveniles per adult pair, while for the stream areas it was 2.84.

13. The average number of placental scars per adult female was 16.5 for the stream areas and 16.9 for the marsh areas.

14. The average juvenile mortality was 80 percent.

15. The 1951 breeding season was 3 or more weeks later than at Ogden Bay Bird Refuge.

16. The harvest on the marsh areas produced 0.72 muskrats per acre and 2.31 muskrats per house.

17. The muskrats trapped were not as large as previously reported. The average weight was 993.4 grams.

18. Food was not a limiting factor.

19. A severe epizootic of tularemia occurred in the jack-rabbit population but did not affect the muskrats.

20. The first Western record of the tick *Ixodes muris* Bishopp and Smith was probably made.

21. Predation during the study year was non-limiting.

22. Damage to the muskrat population by cattle was not indicated.

23. Several recommendations for management are given.

24. The study indicated that the past low yields were results of fluctuating water levels amplifying other

usually non-limiting factors.

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Figure 2. Baker's Spring run with the water turned off at Baker's Spillway for haying.

Figure 3. Baker's Spring run with the water turned on at Baker's Spillway to water some far knolls.

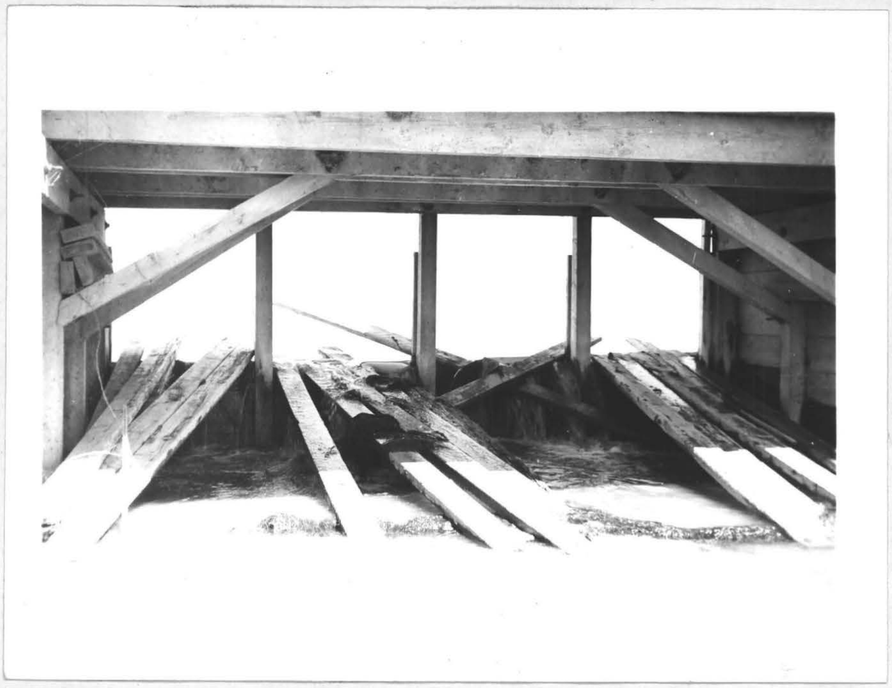

Figure 4. Off Spillway showing type of spillway and clogged condition.

Figure 5. Break in dike 120 yards east of Teal Spillway. Basic cause of break was non-rock fill on old stream channel; secondarily by muskrats.

Figure 6. Bar M Spring looking north. Old dam in foreground.

Figure 7. Off Spring run immediately below Off Spring showing small size of natural flow.

Figure 8. Off Spring with temporary weir.

Figure 9. Temporary weir on Sparks Diversion
below dam.

Figure 10. The effects of differential grazing on Phragmites communis Trin., West Locomotive Spring run. Cattle on near side; not on far side.

Figure 11. Dead areas of matted Scirpus Olneyi A. Gray of past years, Teal Marsh.

Figure 12. Muskrat house on East Lake destroyed by cattle, 1949-50.

Figure 13. Muskrat houses undamaged by heavy cattle grazing, Bar M Marsh, spring, 1951.

Figure 14. A small eatout on Off Marsh.

Figure 15. Muskrats start to move as soon as the ice begins to break up in the spring.

Figure 16. Muskrat house in old stackyard, lower Bar M Marsh, showing the change from dry ground to marsh.

Figure 17. Muskrat house left dry by East Lake draw-down following the hunting season. Muskrat tracks (by hatchet) show mid-winter surface movements not seen in well watered areas.

Figure 18. Middle Off Marsh looking north. Scirpus Olneyi A. Gray in foreground.

Figure 19. Muskrat den on West Pond that coyotes had unsuccessfully attempted to dig out.

Figure 20. Upper Teal Marsh showing the ditch-like character of this stream.

Figure 21. The former Sparks channel below the diversion dam. The marsh vegetation still persists although the stream has not flowed for 15 years.

Figure 22. A small isolated patch of <u>Typha latifolia</u> L. on the lower Bar M Marsh.

Figure 23. Large area devoid of emergent vegetation, lower Bar M Marsh.

Figure 24. The effect of the 10 inch draw-down on East Lake following the hunting season. Looking southeast from the west dike. The barrow pits(foreground)remained lethal to cattle.

Figure 25. Goose nest on muskrat house, lower Bar M Marsh.

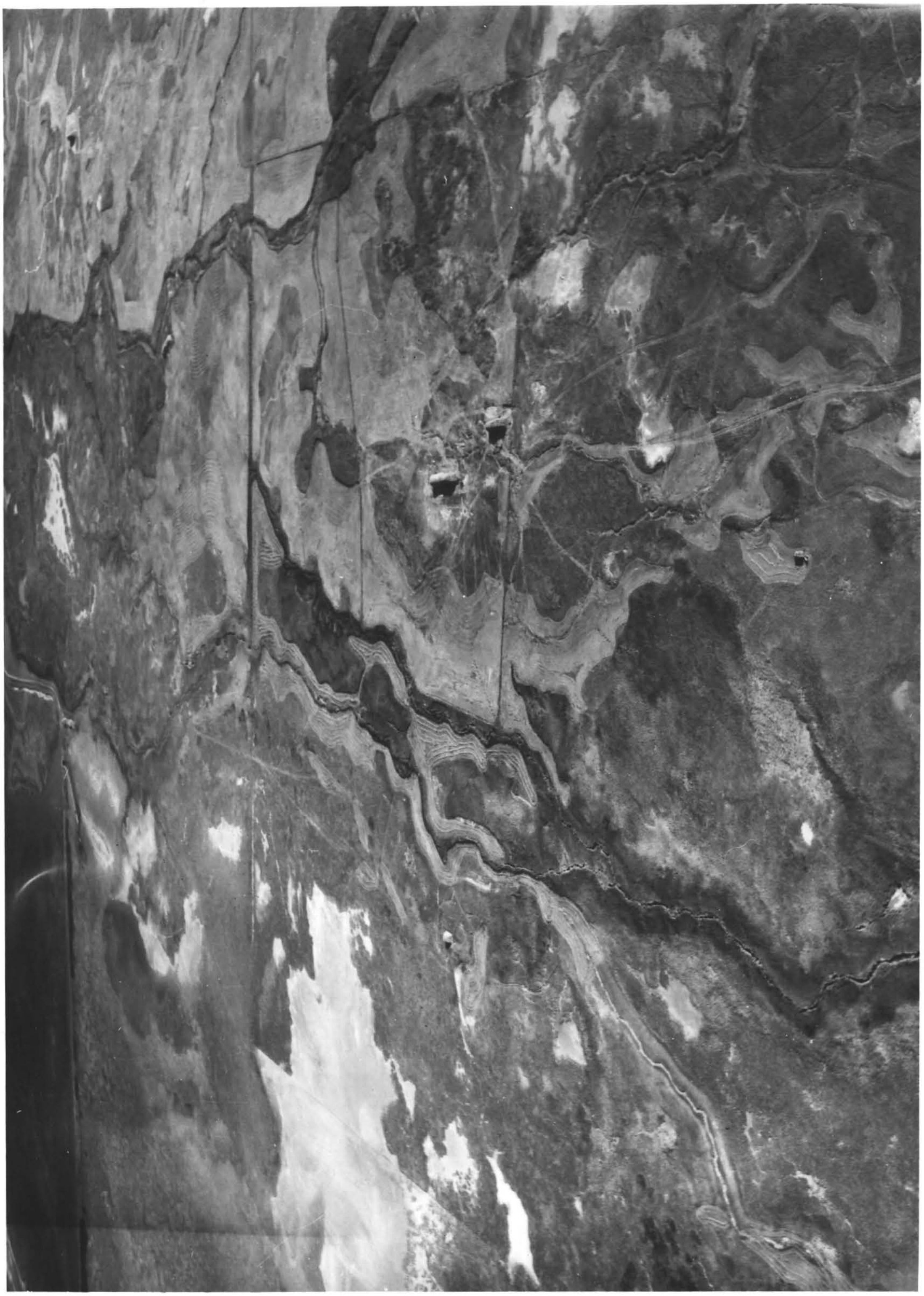

Figure 26. Aerial photograph of middle Baker's showing the spotty nature of the haying.

Figure 27. Aerial photograph of lower Bar M Marsh showing the areas devoid of emergent vegetation.

Figure 28. Aerial photograph of Teal Marsh showing the ditch-like character of this marsh.

Figure 29. Aerial photograph of Baker's Spring showing the spillway and interconnecting canals.