SOME ASPECTS OF MUSKRAT ECOLOGY

AT

BIG ISLAND LAKE, ALBERTA

by

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

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in

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PREFACE

The untimely death brought to a stop the work on his Master of Science degree and a termination of a promising career in the conservation field. Drowned in the line of duty was Roger Schmitke on June 10, 1965, in the Redwater River near Edmonton, Alberta, Canada.

Prior to his death, Roger had worked diligently on his research assignment and had collected all of the data deemed necessary for the completion of the thesis. Partial analysis of the data had been made. The present volume is an attempt to bring together his data and analyses for presentation to his graduate committee. It is understandably not in the form in which he meticulously would have presented it, but it does present the data on this important study. Many months of field research went into the project and additional time was spent in analysis of data.

It was a pleasure to have been associated with Roger and his family during his academic career at Utah State University. His pleasing personality and professional approach to the problem of the class and field were always refreshing and stimulating. It is with regrets that we must present this work instead of having Roger do so himself. Wherever possible, the text was retained in the wording of Roger.

Respectfully submitted,

J. B. Low
Major Professor
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My thanks to many others who also helped on autopsies and to other personnel of the Provincial Game Branch of Alberta. For field guidance and manuscript review, I am indebted to Dr. J. B. Low, Leader, Utah Cooperative Wildlife Research Unit and to Allen G. Smith, Biologist, Bureau of Sport Fisheries and Wildlife, Brigham City, Utah. Lastly, my wife, Marion, gave me courage to continue.

Dr. Low and Dr. George H. Kelker, Wildlife Resources Department, Utah State University, visited me in the field in central Alberta. These visits were heartening and encouraging to the student pioneering in this kind of work.

Roger G. Schmitke
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ABSTRACT

Some Aspects of Muskrat Ecology at Big Island Lake, Alberta by
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Utah State University, 1966

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Annual productivity varied from 16.2 to 22.8 young per adult female based on placental scar counts. Summer juvenile mortality approximated 30 percent and annual mortality approximated 90 percent. Mortality of 90 percent each year resulted whether the population was trapped or not. Trapping took the place of other types of mortality. Adverse winter conditions were reflected in reduced muskrat body weights. Best quality furs were obtained in early winter—late October and November. Interspecific strife and food shortages appeared to be the most important mortality factors, although predation, movements, weather and parasites and diseases were known to have some adverse effect on the population. Most females produced two litters per season but some had three litters. Estimated density of 5.4 to 9.7 muskrats per acre was determined for the Big Island Lake marsh.

(55 pp.)
INTRODUCTION

The muskrat is, and long has been, the most important wild fur-bearing mammal in Alberta. The value of the annual muskrat fur harvests in recent years has ranged between $300,000 and $550,000. The muskrat is of particular importance as a supplementary income to agricultural people of the regions.

The numbers of muskrats harvested have shown marked fluctuations that cannot be accounted for by price and demand alone. Evidently then, changes in numbers available to harvest are due to fluctuations of favorable elements of their environment.

While the muskrat has been extensively studied in North America and Europe, muskrats of the Parkland ecotone of central Alberta have received little or no attention until recently.

Because of the Parkland muskrats' economic importance and the lack of local ecological knowledge, it seemed desirable to acquire knowledge of its population dynamics for that locality. In 1958, a four-year study of the population ecology was initiated at Big Island Lake, Alberta. If for no other reason, such a study would indicate whether or not the generally understood population dynamics of muskrats is applicable to the Parkland ecotone. It was further hoped that additional knowledge of population change would be forthcoming to further aid in the general understanding of muskrat ecology.

The objectives of the study were:

1. To develop an understanding of population turn-over for the area. This is done by noting:
a. Rates of increase, potential and realized; and how the rate during any given season is regulated by favorable extrinsic and intrinsic factors.

b. Rates of decrease, and how they may be modified by detrimental extrinsic and intrinsic factors.

2. To develop an understanding of sustained optimum harvest potential with respect to numbers, quality, and time.
The different structures muskrats use in their daily lives are well described in the literature. Dozier (1953) especially describes the houses, feeding huts, push-ups and bank dens. The nest is mentioned briefly by Dozier (op. cit.), Errington (1939) and Wragg (1953). Houses and feeding huts are built in late August to early September (Bellrose, 1950) while push-ups are placed on top of the ice in straight lines radiating from the house (Fuller, 1951).

Not all authors agreed that muskrats are monogamous. Errington (1940) said they were "loosely monogamous", whereas, Dozier (1953) said "at times males are highly polygamous." At Delta, muskrats are promiscuous in early spring and monogamous during summer (Olsen, 1957).

Aldous (1947) studied in detail the intramarsh movements of muskrats and found that 54.4 percent did not move from the place of first capture and only 15.2 percent moved more than 31 rods. Sother (1958) and Errington (1940) also discuss spring dispersal within a marsh and spring migration between marshes.

Muskrats seem to feed on what is available and what is most easily obtained (Errington, 1941 and Takos, 1947). Sother (1958) found a seasonal change in food preference. Bellrose (1950) said muskrats have a marked preference for some plants and that they select the more nutritious and palatable plants and parts of plants when available. Cattail headed his list of muskrat food preferences.

Errington (1940) and several other authors discussed the social structure in muskrats. Olsen (1957) and Sother (1958) both reported
family groups with representatives of two litters present in one den with little antagonism. Dozier (1948) however, reports only adults and their last litter of the season live together. Family groups are not split up until the spring dispersal.

To find the total and breeding populations, three methods have been standardly employed in the literature. Sather (1958) found Errington's method (Errington, 1943) the most suitable. Fuller (1951) was the first to employ the Linclon Index to muskrats but its validity is questionable. Dozier (1948) used the house count method but a major drawback of this is that bank dens are not brought into consideration.

Placental scar counts and observations of young in nests are widely used methods of obtaining the total production per adult female (McCann, 1944; Beer and Traux, 1950; Sother, 1958; Fuller, 1951). Errors may result from placental scar counts because of reabsorption and abortion of embryos and superimposed placental scars (Davis and Emlen, 1948). These counts, nevertheless, are regarded as measures of productivity. Fuller (1951) found the mean number of placental scars to be 17.4, McCann (1944) found 11.5 and Beer and Traux (1950), 15.5. The number of young produced seems to vary with the location and consequently the race or subspecies of the muskrat.

The muskrat estrous cycle was studied intensively by Beer (1950) and McLeod, 1950; Bondar, 1952; Diduch, 1952) with very different findings. Beer found a mean cycle length of 28.7 days. McLeod and associates found normal cycle durations of six to ten days. Gestation periods of 28 or 29 days is considered normal for muskrats (Dozier, 1953), with known variations of 18 to 35 days (Olsen, 1957).

Growth curves have been used by some (Dorney and Rusch, 1953 and
Olsen, 1957) in order to age juvenile muskrats. Live weights of known-aged muskrats were taken to establish the curves. Errington (1939) thought that wet pelage and the contents of the alimentary canal affects the weight of the muskrats. Another measure of growth is the tail length. This must be taken on live muskrats since the tail shortens after death (Dorney and Rusch, 1953). Errington (1939) found that a fungus retarded tail growth and also caused some young muskrats to chew off the ends of their tails.

By knowing the age of birth, the peak periods of production could be determined. Sother (1958) found Nebraska muskrats produced in three peak periods, the middle period occurring in June with the most litterbirths. In Manitoba and Wisconsin up to five peak periods of production occur (McLeod et al., 1951 and Dorney and Rusch, 1953). May had the largest production peak with smaller peaks thereafter at 30-day intervals.

The sex ratio of muskrats is nearly even at birth (Olsen, 1959; Beer and Truax, 1950). Mortality seems to affect juvenile females soon after birth because a predominance of males is found in the fall (Fuller, 1951; McLeod et al., 1951; Beer and Truax, 1950; Gashwiler, 1950; Dozier, 1942; Sother, 1958). Between their first and second winters mortality factors act primarily on males (Sother, 1958).

Various causes of mortality are present among a muskrat population. Disease often is found under high densities, Sother (1958) found hemorrhagic disease present in his study, while Udall (1954) reported that this disease kills the animal quickly. Certain parasites, when infections are heavy, cause hemorrhaging of internal organs and possible death (Chandler, 1930 and Monning, 1945). Errington (1954) and many other authors found
that mink and coyotes were two predators on muskrats although they often scavenge on dead muskrats. Intraspecific strife in the early spring at the onset of the breeding season is another mortality factor.

The time muskrats are harvested has a direct bearing on the economic value of each fur. Aldous (1947) found that fall skins average smaller and a majority had a lower degree of primeness as compared to those taken later. Both Aldous (1947) and Sother (1958) recommended winter trapping season as best.
DESCRIPTION OF STUDY AREA

Features of the General Area

Big Island Lake is approximately 12 miles east of Edmonton, Alberta, Canada, in sections 9, 16, and 17; township 52; range 22; west of the 4th Meridian (Fig. 1 and 2). This is within the Aspen-Parkland ecotome. The terrain of this area is drumlin with numerous small lakes, sloughs, and some small muskegs. The lake lies within the Cooking Lake gray wooded soils area. The soil is a silt clay loam with fair to low fertility. About 50 percent of the land is cultivated. Mixed farming with emphasis on dairying is the major type of agriculture in the district; and therefore much cultivated land has been seeded to pasture and hay.

The natural vegetation is an interspersion of mixed grasslands and aspen (Populus sp.) groves. Associated with the aspen are occasional spruce (Picea sp.). Shrubs and arborescent plants make up the edge and undergrowth of the aspen groves and are common flora in the waste lands. The more common shrubs and arborescent plants include: snowberry (Symphoricarpus sp.), wild rose (Rosa spp.), sackatoon berry (Amelanchier alnifolia), buffalo berry (Shepherdia canadensis), beaked hazelnut (Corylus cornuta), and pin cherry and choke cherry (Prunus spp.). Willows (Salix spp.) frequent the peripheral area of water bodies. Herbs and grasses are common aspen grove floor cover and are also abundant in the waste land areas. Dense grass stands prevail on the open uncultivated land.

The climate of Alberta's parkland region has extreme weather variation. Winter temperatures of -30° F or less are not uncommon, whereas,
Fig. 1. Location of study area in relation to Edmonton, Alberta, Canada and a cover map of Big Island Lake.
Fig. 2. Aerial photograph of Big Island Lake, Alberta, Canada,
midsummer temperatures of 80° F or greater are just as common. Effective snow depth of two or more feet prevails during some winters but other winters have much less snow cover. Similarly, annual rainfall varies from inadequate to more than ample for good vegetation growth, the average annual rainfall being about 17 inches.

Features of the Intensive Study Area

Big Island Lake has 305 acres of water surface subject to variation with fluctuating water levels. There are four islands in the lake during high water levels, but two of these, Small Island and Freddy's Island, join when the water drops sufficiently (Fig. 1). This occurred during late summer of 1958. Big Island has 18.5 acres of land area, Grass Island 0.8 acre, Freddy's Island 1.1 acres, and Small Island 2.3 acres.¹

Grass Island and Freddy's Island are flat, and under high water conditions may be inundated. The drainage system entering at the south end and leaving by the north end of the lake may control inundation. Although Big Island and Small Island rise abruptly a few yards back from shore, banks of Big Island Lake and its islands generally have a gradual slope; and in most places an off shore distance of about 20 yards is required to reach a water depth of two feet. Associated with most of the shore, there is a floating bog of about 20 yards width and 10 inches thick. The shoreward edge of this bog often merges with the bank and thus in some areas it is difficult to ascertain what is shore (Fig. 3). Small pieces of bog have also been observed drifting

¹Island nomenclature of local appellation.
Fig. 3. The shoreward edge of the bog and the bank.
across open water during high winds. The lake bottom is silt clay except for a few small areas of sand clay along the east shore.

The small accumulated water level drop of 15 cm. by late August is in contrast with much of Alberta's parklands where considerable drying of marshes occurred in 1958. The 15 cm. drop was not sufficient to change seriously the amount or quality of the muskrat habitat. Rains during September replenished the lake, and at the time of freeze-up, the water level was similar to the midsummer level (see Fig. 4).

There are 49 acres of emergent\(^2\) and 44 acres of wet land\(^3\) vegetation on Big Island Lake. Submergent and free floating plants are also common in much of the lake. Cattail (\textit{Typha latifolia}), and sedges (\textit{Carex} spp.) are the predominant marsh plants. Dense stands of cattail reaching seven feet in height prevail on most of the floating bogs. Sedges are the predominant plants of the wet land area and are also frequently found as emergents. Manna grass (\textit{Glyceria} sp.) is common in association with the sedges and cattail. Bulrush (\textit{Scirpus acutus}), an ecologically important plant to muskrats (Bellrose, 1950, p. 307), is present in a limited amount only. Interspersions of these and other marsh plants including bur reed (\textit{Sparganium eurycarpum}) and rush (\textit{Juncus} sp.) are common in the area. This is by no means a complete list of marsh plants of the area but merely presents the most prevalent species. Similarly the most prevalent submergent and free floating plants include pondweeds (\textit{Potamogeton} spp.), duckweeds (\textit{Lemma minor} and \textit{L. trisulca}) and algae.

\(^2\)Emergent vegetation in this paper includes vegetation growing on floating bog.

\(^3\)Wet land in this paper refers to the peripheral area landward from shore that is usually muddy.
Fig. 4. The water level at the time of the freeze-up and midsummer
Two different types of habitat are present on Big Island Lake. A two-thirds mile section of the northeast shore is quite barren of emergent vegetation and has no floating bog (Fig. 1). The northeast shore is typical of many parkland sloughs. Most of the remaining shore, including that of the islands, has floating bog associated with it. This bog supports dense stands of emergent vegetation. Because of the floating bog the major part of the lake is somewhat atypical of parkland marshes, and other similar marshes of the northern coniferous forest biome.

Aspen tree cover surrounds about one-half of the lake. Big Island is also covered with aspens; Small Island is covered with shrubby and arborescent plants and a few aspens. Grass Island and Freddy's Island have a cover of sedges. The unwooded surrounding land is all pasture except for a one-half mile tract on the east side which is a grain field.

Grazing is the major land use, and cattle are pastured on the open and wooded land. Stock is allowed to range to the lake for water along all pastured land. Considerable grazing then occurs on the wet land.

Big Island Lake is used extensively for duck hunting in fall. While ducks were present, hunters visited the lake almost every day of legal duck hunting in 1958. Early in the season it was common for 30 or 40 hunters to be present on the lake at once. Winter use of the lake is almost nil; light muskrat trapping is conducted some years. During the summer, the lake is the site of an occasional Boy Scouts field trip. Human activities on Big Island Lake are not detrimental to the muskrat population.
Recent History of the Study Area

The present historical knowledge of the Big Island Lake region was supplied by Ralph Sanford, long-time district resident. Sanford, a keen and able outdoorsman, for many years gained part of his living by trapping. He is able to recall events of the early twentieth century, just prior to which his father and others homesteaded the immediate surrounding lands of Big Island Lake.

In 1900 Big Island and Small Island supported mature coniferous forests with trees up to four feet in diameter. Starting in 1903 or 1904, this resource was exploited for construction in the settlement of Clover Bar, northeast of Edmonton. Following this the Sanfords pastured sheep on Big Island (Sanford, 1958).

Trapping constituted the major early lake use. In roughly 1910, approximately 1000 muskrat pelts were harvested from Big Island Lake by settlers and trappers of mixed Caucasian-Amerindian blood. During the 1920's, the Sanfords annually harvested about 300 muskrat pelts from the east, north, and northwest portion of the lake. Muskrats virtually disappeared from the lake during the 1930's, but became numerous again in the 1940's. Recent muskrat trapping has been light, annual harvests ranging from virtually nil to approximately 200 pelts. These harvests were effected by Ralph Sanford and poachers (Sanford, 1958).

In 1905 Big Island Lake was about one-third of its 1958 size, whereas, between 1912 and 1915 the water levels were much higher than in 1958. Sanford observed that large muskrat populations accompanied periods of high water.

The water during the early twentieth century was much "fresher" (presumably less turbidity and algal growth), and the drainage system
was active until 1916. Although Sanford made no mention of amount of water during the dry 1930's, it was probably low as was the case for many small lakes at that time.

Big Island Lake vegetation has also varied in the past 60 years. Bur reed at times has been much more abundant, and 1958 observations of scattered young plants suggested this species may be spreading. Bulrush and cattail have alternately been the predominate species. Bur marigold (*Biden cernua*) was abundant in 1905 (Sanford, 1958).
METHODS OF STUDY

Live trapping, tagging and recapture was the technique used to obtain data for population size and composition. Trapping was conducted according to a stratified restricted randomization sampling design.

This design was employed to determine on what sections of the lake trapping was to be conducted during each trapping period. Musk-rat habitat was confined to the periphery of the lake and its islands; therefore, trapping was concerned with this area. Two major types of habitat were present on the lake. One type, designated Unit I, comprised 90 percent of the periphery, was marshy, and supported dense stands of emergent vegetation. The other type, designated Unit II, comprised 10 percent of the periphery, and was a rather barren mud shore habitat.

The entire periphery of the lake and islands was divided into ten replicas, nine falling into Unit I and one into Unit II. Each replication consisted of approximately 4,065 feet of shoreline. Each replication was in turn, divided into five sections of approximately 813 feet of shoreline. For clarity, corresponding sections of each replication were assigned a color on the map; sections 1 are orange, sections 2 green, sections 3 brown, sections 4 blue, and sections 5 red.

All of the active dens on 60 percent of the lake could be feasibly trapped during a given two week trapping period. To select this 60 percent area, five tags, corresponding to sections were numbered from 1 to 5 inclusively and placed in a bowl, from which three were drawn
at random. These three randomly selected sections by color presented
the trapping areas for all replicas of both Unit I and Unit II. For
each subsequent trapping period the drawing process was repeated and
all five sections again had an equal and independent chance of being
drawn for trapping. However, since three out of five sections were
drawn for each trapping period, trapping on at least one section was
repeated during consecutive periods.

Once trapping sections were drawn for a particular trapping period,
the investigator proceeded to set family traps at all the occupied dens
in these sections. About three sections, or one replication was worked
each night, depending on the number of active dens. Traps were left in
position for only one night and then moved to the next sections, regard­
less if animals were caught (or not). After the captured animals were
tagged, biological data taken, and released, the den was left undis­
turbed for one night. The second day after setting family traps, baited
trap-door type traps were set near the den entrances in an endeavor to
capture a sample of marked and unmarked animals for application of the
Lincoln Index. This provided data for calculating the population of the
lake. The estimated population on three sections for all replicas was
then multiplied by 100 and divided by 60 to estimate the 100 percent
population for the entire lake shore habitat.

From this technique various data were obtained. First of all,
tagged animal recaptures allowed the Lincoln Index census method to be
used. Population composition was found by noting age and sex ratios
throughout the trapping period. By measuring tail length and weighing
the juveniles a growth curve was established similar to the one by
Dorney and Rusch (1953). Lastly, intramash and intermarash movements
were noted by the trapping on Big Island Lake and few adjacent marshes.

Most of the muskrats were trapped with a modified submarine trap developed by Snead (1950), and known as the family type trap. The particular traps used in the study were a simplified model that the investigator constructed from mink wire. It was set in entrances to dens and captured all animals attempting to enter or leave the den. Catches of up to 18 live animals in one setting were obtained with this trap. Other live traps used were baited trap door types, including Havaharts, mink catching cages, and some constructed from mink wire by the investigator. Of the trap door types, the latter two proved more useful, being less bulky and less susceptible to tripping.

Muskrats were handled safely by placing them headfirst into a chicken wire cone. Animals were tagged in both ears to reduce the chance of lost identity (Kelker, 1958, personal note). Monel metal fingerling tags, size 1, style 4F-1005, of the National Bank and Tag Co., were found suitable in this study, and by Aldous (1946) and Snead (1950).

Censusing

Four types of censusing methods were attempted, three of them successfully. Errington's method was used which employs the number of spring breeding territories determined by field observation multiplied by the average annual production per adult female. The Lincoln Index, based on the ratio of tagged to untagged animals in a trapped sample, was first employed in muskrat censusing by Fuller (1951) and was also used in this study. House counts have been used widely in large scale muskrat censusing management. The number of "active" houses and the
average number of muskrats per house were determined for the marsh. Then the product of these mean values gives the estimated population for a given marsh. An attempt was made to census bank dens by noting turbid water and runways through the vegetation from an airplane. Subsequent ground surveys indicated this method to be inaccurate.

To get a better understanding of the food habits of muskrats in the area, field observations of muskrats eating certain plants and the examination of feeding platforms were used in this study.

Predation on muskrats was investigated through collection of coyote and mink scats and raptor pellets and subsequent examination for muskrat remains.

Post-mortem examinations were of two types. First of all, autopsies were performed by the Alberta Department of Agriculture Veterinary Laboratory and the investigator to determine what pathogens and parasites are found in muskrats. Secondly, uteri were removed from each adult female and placental scars counted to determine the annual production of each female (Davis and Emlen, 1948).

A pre-determined percentage of the muskrats were harvested each year. Pelts were used for a study of correlation between harvest time and pelt grades as determined by the Edmonton Fur Auction. A different percentage of the total population was harvested each year to help determine what could be the maximum sustained harvest each fall and still have maximum reproduction the next spring.
RESULTS AND DISCUSSION

Use of Structures

Five types of muskrat structures are commonly mentioned in the literature. Dozier (1953) best described these as:

(1) Houses are dome-shaped structures of submergent and emergent plant roots, stems and leaves; located in water, and rise from 16 inches to four feet above the surface. They are dwellings and contain a dry nest chamber.

Spring break-up of ice in Alberta usually destroys muskrat houses, and only two houses were present on Big Island Lake during the 1958 breeding season. Both were occupied but unrepai red and one is known to have contained a litter in late July. First sign of new house construction in the form of a small mound was noted on July 31. Numerous other mounds and enlargements of some were noted through August. House construction material was mostly dead, consisting of algae, free floating and emergent plant material brought up from the lake bottom. Small amounts of fresh emergent plant material were used in some houses during the latter phases of construction. All the houses were built on floating bog.

Starting on September 3, bi-weekly counts of houses and feeding huts were made on four representative areas of the marsh. During the first two counts, house and feeding huts were not differentiated because most were still incomplete. Data on the increase in number of structures are presented in Figure 5. These data show house building continued until inhibited by the ice formation. Family groups occupied houses in
Fig. 5. Bi-weekly numbers of houses and feeding huts on a portion of Big Island Lake, Alberta, Canada, 1958.

September and presumably all members participated in the construction.

Seasonal construction and use of houses in central Alberta differs from findings in more southerly portions of North America where houses are used throughout the year (Dorney and Rusch, 1953; Olsen, 1957; Sother, 1958). In Northern Alberta, Fuller (1951) found seasonal use of bank dens and houses similar to that on Big Island Lake.

(2) Feeding huts are similar to houses in construction but they are smaller (rising 12 to 16 inches above the water surface), and contain only a platform on which the animals sit to feed and rest.

Feeding huts were constructed of the same material, in the same manner and general locality, and at the same time as houses with the
exception of a few that were completed a little later (Fig. 8). Feeding huts were built in association with houses and a few were built off shore from bank dens.

(3) Push-ups are similar to feeding huts in size and shape, but constructed primarily of submergent plants. Built over a hole cut through the ice, they serve as resting and feeding places. Push-ups appeared shortly after freezing over of the lake on November 6, 1958. Construction material consisted mostly of three-star duckweed and lesser amounts of algae. Fuller (1951) observed push-ups built in more or less straight lines radiating from the houses and were frequently built over a crack in the ice. The same phenomenon was observed on Big Island Lake. This indicated that the phenomenon of lines of push-ups result through convenience rather than design on the part of the muskrats.

(4) Bank dens are burrows tunneled into the bank, which usually have two or three entrances, are branched, and have dry nest chambers at the terminal ends.

Bank dens are used as dwellings and rearing places for paired adults and their litters during the spring and summer. This was evident by capture of adults together with litters in family type traps set at den entrances. Adults with representatives of two litters were common, and little antagonism toward other members of the family group was evident. These findings agree with those of Olsen (1957) and Sother (1958) who report such family groups occupying houses. However, Dozier (1948) reports only adults and their last litter of the season live together, and earlier litters were driven from the natal den just prior to birth of a subsequent litter.

Some bank dens received continuous occupancy into winter while
others were abandoned in fall.

(5) Muskrats used a nest-like structure during the summer. Muskrat use of open retreats is reported with little importance attributed to these as natal dens. Wragg (1953) reports muskrats "maintain the winter house in spring, only if an early litter arrives. Otherwise the house is abandoned, and adults live in open nests. During summer they build and maintain a house only while actually raising a litter."

Five open nests that were constructed and used by muskrats were observed on Big Island Lake during July and August 1958. These were difficult to find as they were located in dense clumps of dead cattail on the floating bog. The cattail stocks formed a covering over the nest in teepee-like fashion. A small opening through the parted cattail led to the nest proper which consisted of finely shredded cattail. The nest was similar in appearance to a diving duck nest (Fig. 6).

Fig. 6. Muskrat nest within cattail clump.
The exact purpose and use of muskrat nests is not known. The following observations pertaining to them were made. On July 2, an adult followed by a juvenile about 45 days old entered a nest about midmorning. On July 4, juveniles about 20 days old were seen freely entering and leaving a different nest. Four of these were captured from the nest by hand and tagged. Adults also came within a few inches of the nest. On July 30 two juveniles about 70 days old were flushed from yet another nest. Two possible uses are suggested. Nests may serve only as secondary resting places for animals with other home dens, or they may be the sole type dwelling of some family groups and may be used for rearing young.

Nests as natal dens could be important during years of dense breeding populations, especially in areas such as Big Island Lake where emergent vegetation is abundant. In such areas breeding pair densities could easily exceed the number of sites suited to bank dens, and use of nests would add much to the stability and productivity of the populations.

Mating

Monogamy prevailed during the entire study. Only two possible exceptions were noted in 1958. One family trap set at a bank den captured two adult females and representatives of three litters which, by their age, could not have been from the same mother. At yet another den, an adult male and female were captured at one den, and these animals fought violently while in the trap until the female was dead. At all other den sites, only one adult of each sex was captured. Pairs could be repeatedly recaptured at the home den.
Intramash Movements

Live trapping and tagging with 255 recaptures provided information on intramarsh movements. However, trapping was irregular and much data that might have been obtained on home range were obscured. Of 506 animals tagged during 1958, 178 were recaptured once, 51 twice, 23 thrice, and 3 four times. Data on distances and times between handlings of muskrats are presented in Figure 7.

Muskrats on Big Island Lake were relatively sedentary during 1958. Only 1.2 percent of the recaptures were over 500 yards from the site of previous handling. The longest movement noted was 670 yards. Over 90 percent of the noted movements were less than 200 yards. Slightly over six percent of the recaptures showed no movement after 30 days following the last handling. This may be largely due to the trapping period in September (approximately 60 days after trapping started) when the first trapping at houses was carried out. This resulted in recapture of many animals previously tagged at banks. Table 1 presents data on seasonal movement of muskrats from known dwellings.

Table 1. Movements of First Recaptured Muskrats with Known Dwellings.

<table>
<thead>
<tr>
<th>Month</th>
<th>Dwellings when Tagged</th>
<th>Distance Moved and Dwelling when Recaptured Yards</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*BK **HS</td>
<td>0</td>
</tr>
<tr>
<td>July</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>August</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>September</td>
<td>21</td>
<td>31</td>
</tr>
<tr>
<td>October</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>November</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>December</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>75</td>
<td>40</td>
</tr>
</tbody>
</table>

* Bank
** House
Fig. 7. Distance and time between handling of 178 muskrats (recaptures)
Of 21 muskrats originally tagged at bank dens 20 were recaptured at houses during September, indicating a shift from bank to house dens. This shift undoubtedly started with and paralleled house construction from August through to freeze-up; however, trapping did not detect this.

September house trapping was intensive with traps often set at the same house for three or four nights in order to account for all animals using a house. Subsequently, many animals were recaptured at the same place and within five days of the last handling (Fig. 7). These recaptures are of little significance.

However, trapping at houses did point out united movements of whole family groups. Five of ten houses contained animals previously tagged elsewhere (Table 2).

Table 2. Composition of tagged and untagged muskrats using ten houses in early fall, 1958.

<table>
<thead>
<tr>
<th>House No.</th>
<th>Previously tagged animals</th>
<th>Animals tagged at house</th>
<th>Total Catch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adults</td>
<td>Adults</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Males Females</td>
<td>Males Females</td>
<td>Males Females</td>
</tr>
<tr>
<td>1</td>
<td>2 (1) 1 1 7 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2 1 6 9 17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1 3 1 5 3 13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4 4 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1 5 3 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1 (2) 5 1 6 2 16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1 5 9 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1 4 7 2 14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>5 4 1 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1 1 2 4 3 11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) One of questionable age.
(2) See text.
Previously tagged animals recaptured at the houses included representatives of family groups consisting of adults and two litters, or adults and one litter, or in some cases adults were not recaptured. At house 6 representatives of two previously tagged litters (one family group) were recaptured. In addition an adult female (not the mother of the above litters) and probably some of her untagged young were caught. A few days later the mother (tag no. 344) of the previously tagged litters were recaptured, along with two other animals captured at the house, in baited traps set about 100 yards from the house. Because these animals were found in close association, adult female no. 344 is also assumed to have occupied the house. Data from house 6 suggest two family groups merged and lived harmoniously together. This is the only such case noted in the fall, and I feel such mergers were exceptional.

"Sign" associated with three of the 10 houses intensively trapped indicated that bank dens were being used simultaneously with the house.

Muskrat movements were generally less than 200 yards. Family groups remained together as groups during the summer, fall, and probably the winter. There was a shift of most family groups which had been using bank dens to using houses in the fall. In some cases, this shift was not complete and family groups simultaneously used bank dens and houses.

Intermarsh Movements

Some muskrats were tagged at pot-holes surrounding Big Island Lake. None of these was later recaptured at Big Island Lake. No fall trapping at surrounding pot-holes was carried out to detect emigration from the lake. Daily observation through the fall and early winter failed to
note any muskrats or their tracks wandering overland around Big Island Lake. Even though definite supporting data were not obtained, I feel sure that muskrat immigration to or emigration from Big Island Lake was negligible in 1958.

Food Habits

Muskrat food habits data were collected as opportunity permitted during the 1958 and 1959 study. Feeding platforms and huts were examined for food remains and the plant species eaten, and the relative abundance of surrounding plant species were recorded (Table 3). Sedges, cattail, and manna grass were most frequently used.

<table>
<thead>
<tr>
<th>Food Plants</th>
<th>Percent of platforms with remains</th>
<th>Present</th>
<th>Abundant</th>
<th>Common</th>
<th>Scarce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typha</td>
<td>72.0</td>
<td>91.2</td>
<td>67.7</td>
<td>17.7</td>
<td>5.9</td>
</tr>
<tr>
<td>Carex</td>
<td>67.7</td>
<td>92.6</td>
<td>79.4</td>
<td>5.9</td>
<td>5.9</td>
</tr>
<tr>
<td>Glycina</td>
<td>35.4</td>
<td>51.5</td>
<td>8.5</td>
<td>25.0</td>
<td>14.7</td>
</tr>
<tr>
<td>Ranunculus</td>
<td>7.4</td>
<td>5.9</td>
<td>5.9</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Scirpus</td>
<td>4.4</td>
<td>16.2</td>
<td>4.4</td>
<td>5.9</td>
<td>5.9</td>
</tr>
<tr>
<td>Sparganium</td>
<td>4.4</td>
<td>8.5</td>
<td>1.5</td>
<td>4.4</td>
<td>5.9</td>
</tr>
<tr>
<td>Juncus</td>
<td>4.4</td>
<td>5.9</td>
<td>0.0</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Aster</td>
<td>4.4</td>
<td>4.4</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Daisy</td>
<td>2.9</td>
<td>4.4</td>
<td>1.5</td>
<td>0.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Potamogeton*</td>
<td>4.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Grasses*</td>
<td>4.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Abundance was not recorded.
Leaves and stems were the most commonly used plant parts. However, roots were utilized to some extent, particularly cattail roots after freeze-up. Data in Table 3 show that Big Island Lake muskrats used food plants proportionately to abundance. Perhaps a slight preference for manna grass was exhibited, since manna grass abundance was relatively lower.

Excepting manna grass, all plants listed in Table 3 are commonly reported as important muskrat foods by Butler (1940); Errington (1941); Takos (1947); and Bellrose (1950). No literature was found that reported manna grass as an important muskrat food. Errington (1941) found that Iowa muskrats can adapt themselves to feed on what is available and frequently feed on convenient plants. Such seems to be the behavior of Big Island Lake muskrats.

Observations of feeding muskrats revealed that lesser duckweed was frequently utilized (Table 4). This food failed to register in feeding platform data because the entire plant is eaten.

Table 4. Observed feeding habits of muskrats, July through October, Alberta, Canada, 1958.

<table>
<thead>
<tr>
<th>Food Plants</th>
<th>Percent of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesser duckweed</td>
<td>41.9</td>
</tr>
<tr>
<td>Cattail</td>
<td>29.0</td>
</tr>
<tr>
<td>Pondweeds</td>
<td>12.9</td>
</tr>
<tr>
<td>Carex</td>
<td>9.8</td>
</tr>
<tr>
<td>Manna grass</td>
<td>6.4</td>
</tr>
</tbody>
</table>
The same reason may account for more frequent use of pondweeds recorded by observations.

The process by which the muskrats obtained substantial quantities of the small free-floating duckweed is of interest. Feeding on lesser duckweed is facilitated by the muskrat sitting on its haunches in shallow water, its mouth just at water level. Then the muskrat makes continuous quick inward strokes in the water with its forepaws. This creates a water current which carries the floating duckweed to its mouth.

Following freeze-up, food habits data were not recorded in detail. However, steel trapping operations afforded many opportunities to observe food utilization. Three-star duckweed, cattail roots, and pondweed were the only food plant fragments noted. Three-star duckweed was by far the most frequently used, pondweeds were only occasionally noted. Typha stocks were dead and unavailable after freeze-up. Typha rhyzomes were generally available until ice thickness reached 12 inches. With 12 or more inches of ice, most of the Typha in the floating bog and along the shallow shore was unavailable. Generally, by mid-December, most emergent vegetation was unavailable to the muskrats.

Stored food consisting entirely of cattail roots was noted occasionally in feeding huts (Fig. 8 a, b, and c). The quantity of stored food in any one hut was small, definitely not sufficient to sustain even one muskrat through the winter. Bank dens were not excavated and examined for stored food; however, Sanford (1958) told me he had opened banks and found the side tunnels packed with cattail roots. Life sustaining quantities of food could perhaps be stored in the mud banks.
Figure 8.

a. Muskrat feeding hut before opening.

b. Same feeding hut with side removed to expose food.
Errington (1941) noted that Iowa muskrats stored ear corn in bank dens but found no sign of stored food in houses. He concluded that muskrats generally obtain their food as they need it.

Food storage was not a general phenomenon on Big Island Lake, and the investigator believed that there was only a tendency to store food brought about by the diminishing food supply.

Animal foods were not a substantial part of the muskrat's diet. Carrion from hunter-crippled and dead ducks was noted occasionally during the hunting season. Cannibalistic feeding within the live traps was noted on two or three occasions. This probably was largely the result of extreme stress conditions brought about by confinement. Substantial feeding on animal matter has been noted of muskrats in Delaware, Iowa, Kansas, and other places (Stearns and Goodwin, 1941; Errington, 1941; Sother, 1958). However, such feeding seems to be rather sporadic.
and non-essential.

Muskrat feeding at Big Island Lake was varied during the summer and fall. Generally, food plants were consumed in proportions relative to abundance. The variety and quantity of food plants were reduced with the onset of winter. This probably induced the tendency for muskrats to store food. Animal foods, however, were not important parts of the muskrat's diet.

Social Structure

Live trapping records showed that there was little dispersal of litters until the spring following their birth. Occasionally some tagged animals did show up with other family groups, but these were isolated instances. Repeated recaptures at home range locations showed that the animals in association with siblings, parents, and other litters were from the same family.

Breeding Population

Data on breeding populations were obtained by a summer census of home ranges each year (Table 5). Since there was little mixing or dispersal of family groups, the number of home ranges closely approximated the number of breeding pairs.

The data of Table 5 shows a general inverse relationship of the number of pairs to the number of young produced, as first shown by the late Dr. Errington (1939). However, the inversity is inconsistent. The density decrease was from one pair per 2.2 acres to one pair per 2.75 acres; or probably more meaningful from a density spacing of houses from 271 to 339 yards of shore per muskrat.
Table 5. Breeding populations of muskrats at Big Island Lake, Alberta, Canada, 1958 through 1961.

<table>
<thead>
<tr>
<th>Year</th>
<th>1958</th>
<th>1959</th>
<th>1960</th>
<th>1961</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enumerated home ranges</td>
<td>78</td>
<td>47</td>
<td>39</td>
<td>47</td>
</tr>
<tr>
<td>Estimated number of pairs</td>
<td>80</td>
<td>50</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Acres of habitat/pair</td>
<td>1.38</td>
<td>2.20</td>
<td>2.75</td>
<td>2.20</td>
</tr>
<tr>
<td>Yard of shore/pair</td>
<td>169</td>
<td>271</td>
<td>339</td>
<td>271</td>
</tr>
<tr>
<td>Mean number of placental scars/Adult female (sample)</td>
<td>16.2 (20)</td>
<td>17.8 (15)</td>
<td>22.8 (21)</td>
<td>17.6 (20)</td>
</tr>
</tbody>
</table>

The investigator was unable to distinguish litters in close examinations of placental scars. On the basis of an arbitrary breakdown of scars, it was thought that the increase in productivity came as an additional litter. The presence of third litters in one season was most evident in the 1960 live trapping (Table 6), noted on occasions in 1958 or 1961. Although the litter composition is arbitrary, actual litter size tends to support its accuracy. During 1959, 11 nesting litters, considered to be complete, were handled. In addition, two pregnant adult females were posted. The mean litter size was 8.3. In 1960, nine litters were handled for a mean size of 7.56. These means are not significantly different at the 95 percent level of confidence. Combined, the mean litter size is 8.00. On the basis of the arbitrary classification, there was a total of 156 litters with a mean size of 9.1 represented by placental scar counts.
Table 6. Productivity of Big Island Lake muskrats as indicated by placental scars, 1958 through 1961, Alberta, Canada.

<table>
<thead>
<tr>
<th>Year</th>
<th>1958</th>
<th>1959</th>
<th>1960</th>
<th>1961</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean number of scars</td>
<td>16.2</td>
<td>17.8</td>
<td>22.8</td>
<td>17.6</td>
</tr>
<tr>
<td>No. of animals examined</td>
<td>20</td>
<td>15</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>Female scar sample range</td>
<td>0-25</td>
<td>7-27</td>
<td>18-28</td>
<td>0-26</td>
</tr>
<tr>
<td>% Females not producing</td>
<td>5.0</td>
<td>0</td>
<td>0</td>
<td>5.0</td>
</tr>
<tr>
<td>% Females producing 1 litter*</td>
<td>15.0</td>
<td>13.3</td>
<td>0</td>
<td>5.0</td>
</tr>
<tr>
<td>% Females producing 2 litters**</td>
<td>75.0</td>
<td>73.3</td>
<td>52.4</td>
<td>85.0</td>
</tr>
<tr>
<td>% Females producing 3 litters***</td>
<td>5.0</td>
<td>13.3</td>
<td>47.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Calculated mean number of litters per female</td>
<td>1.80</td>
<td>2.00</td>
<td>2.48</td>
<td>1.90</td>
</tr>
</tbody>
</table>

* Up to 11 scars
** 12 to 23 scars
*** 24 plus scars

Time Distribution of Production

A growth regression curve of tail length to age was developed from known aged animals (Fig. 9). Tail length was believed to be a more reliable measurement to determine the growth stage of juveniles than weight when considering the amount of food that may be or may not be present in the stomach. A growth curve showing variations among muskrats from Big Island Lake, Alberta, Delta, Manitoba, and Wisconsin is given in Figure 10.

The tail-length curve developed was workable for assigning ages to animals up to 80 days old. Beyond this, the rate of growth was too slow to be representative of the older animals.
Fig. 9. Growth regression curve of tail length to age.
Fig. 10. A growth curve of tail lengths showing variation among muskrats.
The simplest method of determining time distribution of births is to fall trap a sample and assign ages according to a system devised for this area and time. However, this could not be done because at no time was production complete.

Therefore, each period of production had to be sampled separately, and the number of young born during that time period related to a standard base. To accomplish this, juveniles born during each half-month time period were sampled at a time when they were between 31 and 76 days old.

This data, as derived by the above method, is presented in Figure 11. May births, which are virtually all first litters, are fairly evenly distributed to the first and second half of the month, with slightly more in the second half. Each year the bulk of the production was during May and June. In 1958, which was largely a two-litter year, the productivity built to one peak in early June. In 1959 and 1960, there was a tendency for two peaks with a 30-day interval. However, these peaks were not nearly as marked as in the writings by McLeod (1952), Sother (1958), and Olsen (1957).

The percentage of July births increased from 1958 through 1960. This is believed to be a result of the birth of third litters. The July production was 14, 20, and 25 percent of all births in 1958, 1959, and 1960 respectively.

**Sex Ratios of Juveniles**

Sex ratios in muskrats have been widely studied. In general, it was found that males predominate. There is also strong evidence that early in life there is female selective mortality. Later in life, mortality
Fig. 11. Semi-monthly distribution of muskrat births at Big Island Lake, Alberta, Canada, 1958 through 1960.
becomes male selective.

Olsen (1957) noted a strong increase in the percentage of males as animals matured from 0 to 28 days (a change from 48 to 75 percent males). He also noted that males dominated the early season litters.

Big Island Lake muskrat sex ratio data were analyzed for the month of birth, litter order, and change with age (Figure 12 and Table 7). There is definite correlation of sex ratios with month of birth, since early born animals have a predominance of males. There is also an indication that the proportion of males may decrease with age. However, the proportion of males in the first born litter diminish with progression of the breeding season (Figure 12).

There was evidence of extensive juvenile mortality during the first day of life. If the primary sex ratio is assumed to be 1:1, then the first disproportionate sex mortality must have been in utero.

Table 7. Sex ratios of juvenile muskrats by litter order and month of birth, Big Island Lake, Alberta, Canada, 1958 through 1960.

<table>
<thead>
<tr>
<th>Month of Birth</th>
<th>First litter</th>
<th>Second litter</th>
<th>Third litter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Males</td>
<td>% Males</td>
<td>% Males</td>
</tr>
<tr>
<td></td>
<td>Sample</td>
<td>Sample</td>
<td>Sample</td>
</tr>
<tr>
<td>May</td>
<td>62.9</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>313</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>June</td>
<td>53.5</td>
<td>54.0</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>142</td>
<td>313</td>
<td>--</td>
</tr>
<tr>
<td>July</td>
<td>42.9</td>
<td>47.3</td>
<td>50.9</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>93</td>
<td>59</td>
</tr>
<tr>
<td>Unknown</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>136</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>Totals</td>
<td>59.5</td>
<td>52.8</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>612</td>
<td>424</td>
<td>60</td>
</tr>
</tbody>
</table>
Fig. 12. Sex ratios of juvenile muskrats at Big Island Lake, Alberta, Canada, 1958 through 1961.
Over-all Population Change

In order to find the summer mortality of juvenile muskrats, it is necessary to know the initial number of young produced and the number of juveniles present at the end of the summer. There was no evidence of juvenile mortality in the form of carcasses found in the field as the animals matured. The initial number of juveniles per adult female was found by counting placental scars of a sample of adult females. The results are found in Table 8. The ratio of September juveniles per adult female was found by live-trapping a sample. An adult mortality correction factor is included in this figure.

The mortality over the summer is then found by subtracting the initial number of juveniles by the September figure to find out how many have died and dividing this number by the maximum or initial number present at the start of the summer.

The exact cause of the mortality is not known. Some stress mortality triggered by trapping was recorded, but mortality out of the traps was not noted. Perhaps weather was a mortality factor since it was hot and dry and water levels went down. No explanation can be offered for the high mortality in 1961.

In 1958 and 1961, samples were taken to determine the size of the family group in September. The estimated population could then be derived from these figures and compared with the estimated population derived from age ratios. The population density was then calculated by dividing the estimated fall population by the 110 acres of habitat. The 9.7 animals per acre for 1958 is considerably lower than the value considered maximal by Errington (1943). He expected a cattail marsh to support 20 muskrats per acre. I have no explanation as to why such low
densities were present on Big Island Lake.

The causes for the percentages of annual population turnover in Table 8 is not clear. Mortality is not the only factor involved in the population turnover. Immigration to and emigration from Big Island Lake also were present. In 1960 anywhere from 10 to 45 percent of the surrounding potholes were populated by muskrats moving out of Big Island Lake.

Table 8. Age composition, mortality, and fall densities of muskrats at Big Island Lake, Alberta, Canada, 1958 through 1961.

<table>
<thead>
<tr>
<th>Year</th>
<th>1958</th>
<th>1959</th>
<th>1960</th>
<th>1961</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial juveniles/adult female (no mortality)</td>
<td>16.2</td>
<td>17.8</td>
<td>22.8</td>
<td>17.6</td>
</tr>
<tr>
<td>Sept. juveniles/adult female (sample)</td>
<td>11.5</td>
<td>15.4</td>
<td>15.2</td>
<td>7.0</td>
</tr>
<tr>
<td>Juvenile mortality to Sept. (percent)</td>
<td>29</td>
<td>14</td>
<td>33</td>
<td>60</td>
</tr>
<tr>
<td>Mean Sept. family group size</td>
<td>12.4</td>
<td>--</td>
<td>--</td>
<td>11.9</td>
</tr>
<tr>
<td>Estimated population (by age ratios)</td>
<td>1070</td>
<td>855</td>
<td>675</td>
<td>440</td>
</tr>
<tr>
<td>Estimated population (by family group size)</td>
<td>992</td>
<td>--</td>
<td>--</td>
<td>595</td>
</tr>
<tr>
<td>Estimated density (animals/acre of habitat)</td>
<td>9.7</td>
<td>7.1*</td>
<td>6.1</td>
<td>5.4</td>
</tr>
<tr>
<td>Annual population turnover (percent)</td>
<td>93</td>
<td>92</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

* Based on 1959 September population estimated by Lincoln Index = 778 animals.
Harvests

The original intent of the study was to harvest during the first year of the study a very small percent of the total muskrat population; during the second year a medium percent; and finally a large percent in order to find the optimum harvest for the population and still have sufficient breeding stock the next year. Although no specific figures could be found to substantiate this, a harvest of 10 percent in 1958, 20 percent in 1959-60, and 85 percent in 1960-61 was carried out. With these different harvest rates there was no apparent effect on the carry over of the muskrat population in each succeeding winter.

Table 9. Monthly juvenile muskrat pelt grades, Big Island Lake, 1958 through 1959-60.

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample</td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>Damaged</td>
</tr>
<tr>
<td>1958</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov.</td>
<td>40</td>
<td>20</td>
<td>60</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Dec.</td>
<td>46</td>
<td>44</td>
<td>35</td>
<td>-</td>
<td>22</td>
</tr>
<tr>
<td>1959-60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Oct.</td>
<td>26</td>
<td>-</td>
<td>69</td>
<td>31</td>
<td>-</td>
</tr>
<tr>
<td>Late Oct.</td>
<td>17</td>
<td>-</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nov.</td>
<td>18</td>
<td>-</td>
<td>94</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Jan.</td>
<td>12</td>
<td>-</td>
<td>42</td>
<td>25</td>
<td>33</td>
</tr>
<tr>
<td>Feb.</td>
<td>8</td>
<td>-</td>
<td>63</td>
<td>13</td>
<td>25</td>
</tr>
</tbody>
</table>

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample</td>
<td>X Large</td>
<td>Large</td>
<td>Medium</td>
<td>Small</td>
</tr>
<tr>
<td>1958</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov.</td>
<td>40</td>
<td>-</td>
<td>55</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>Dec.</td>
<td>46</td>
<td>-</td>
<td>35</td>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>1959-60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Oct.</td>
<td>26</td>
<td>-</td>
<td>73</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td>Late Oct.</td>
<td>17</td>
<td>-</td>
<td>88</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>Nov.</td>
<td>18</td>
<td>-</td>
<td>44</td>
<td>50</td>
<td>6</td>
</tr>
<tr>
<td>Jan.</td>
<td>8</td>
<td>-</td>
<td>25</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>Feb.</td>
<td>6</td>
<td>-</td>
<td>17</td>
<td>83</td>
<td>-</td>
</tr>
</tbody>
</table>
The muskrats harvested in the 1958 and 1959-60 seasons were pelted in an attempt to find the most desirable harvesting period. Although samples were small, the pelts taken in the late October period appeared to be of the highest quality. The pelt grade (Table 9) and value (Table 10) was greatest at that time.

Table 10. Mean month muskrat pelt values, Big Island Lake, 1958 and 1959-60.

<table>
<thead>
<tr>
<th>Month</th>
<th>1958</th>
<th>1959-60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early October</td>
<td>$0.43</td>
<td></td>
</tr>
<tr>
<td>Late October</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>$0.52</td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>0.36</td>
<td></td>
</tr>
</tbody>
</table>

During late October, harvesting is relatively easy. Also, more animals are present, since winter mortality has not taken its toll. Therefore, early harvesting would result in more muskrats of equal or higher value.

Mortality Factors

Parasites and Diseases. To determine if pathogens or parasites were significant mortality factors, live trapping casualties and steel trapped muskrats were given post mortem examinations by the investigator
and by a parasitologist from Ontario Veterinary College, Guelph and by a pathologist from the Alberta Department of Agriculture. Although a few internal parasites were found, they were not considered serious. However, they may reduce the vigor of the animal to an extent where it may be indirectly considered a mortality factor.

A serious disease producing organism, Pasteurella multicauda, was isolated but no evidence was found that it reached epizootic proportions.

**Predation.** Several muskrat predators were present on the study area as indicated by "sign". These include coyotes (Canis latrans), mink (Mustela vison), and several raptors. Examination of scats and pellets revealed some muskrats were being taken. No direct observation of predation was recorded. The general impression is that predation on muskrats was not a serious limiting factor.

**Intraspecific Strife.** Animal populations may become self-limiting through their own abundance. The muskrat in particular, because of its high reproduction potential and confined habitat, often reaches densities detrimental to itself. Every animal requires a certain amount of space to carry on life processes. When this space is limited, the animal is subjected to psychological and physical stresses. Such conditions in a population may result in reduced reproductive rates, retarded growth and generally less vigorous animals, forced emigration, and abnormal fighting within the population. Factors other than intraspecific strife help to bring about the above effects.

Indications of intraspecific strife existed within the Big Island Lake muskrat population especially during 1958. The reproductive rate of 1.8 litters per female appeared to be below the potential maximum.

The presence of scars on the pelts taken in fall and early winter
are also an indication of intraspecific strife. Whereas fighting wounds in the spring are a result of mating behavior, excessive antagonism and fighting in the fall probably results from over-crowded conditions.

Weather. Weather conditions may act directly or indirectly in limiting and/or reducing muskrat populations. Late arrival of spring could delay breeding and reduce reproduction. Droughts reduce the amount of habitat, whereas flooding drives muskrats from established dens. Extended winters may result in exhausted food supplies.

Possibly the most important weather factor in this area is the winter season. At freeze-up a dense population is confined to a relatively small space. This crowding can result in increased intraspecific strife which, in turn, reduces vigor and makes the animals more susceptible to disease. Perhaps more important was the fact that the muskrats' food supply of roots and plants was practically encased in ice by mid-winter. In mid-December of 1958 ice was 15 inches thick completely encasing the floating bog and consequently the roots of emergent plants. Houses were built on the floating bog where water was usually about two feet deep. If the water froze to the bottom, the effect on the muskrat population would be disastrous. One possible result of this reduced food supply is the reduction in weight of both juveniles and adults during the winter months. This loss of weight can be seen in Figures 13 and 14.
Fig. 13. Mean monthly juvenile muskrat weights in grams at Big Island Lake, Alberta, Canada, 1958 through 1961.
Fig. 14. Mean monthly adult muskrat weight in grams at Big Island Lake, Alberta, Canada, 1958 through 1961.
SUMMARY

The study of muskrats at Big Island Lake, Alberta, Canada, had the following objectives:

1. To develop an understanding of population turnover for the area. This was done by determining:
   a. Population increase, potential and realized, and how changes are regulated by extrinsic and intrinsic factors.
   b. Population decrease and how it may be modified by extrinsic and intrinsic factors.

2. To develop an understanding of sustained optimum harvest potential with respect to numbers, quality and time.

Over 1500 tagged muskrats with close to 1000 recaptures provided data on population composition changes at Big Island Lake from 1958 to 1961 inclusive. Productivity, population composition and mortality were related to time, social, and ecological factors affecting the population.

Annual productivity varied from 16.2 to 22.8 young per adult female. Summer juvenile mortality approximated 30 percent and annual mortality approximated 90 percent. Extent of mortality is not affected much by different levels of harvest. Close family bonds lasting until sexual maturity of juveniles results in large family groups being confined to a small denning area with the onset of winter. These conditions are conducive to intraspecific strife and food shortages, both important mortality factors. The adverse winter conditions were reflected in reduced muskrat body weights and fur quality. Muskrat trapping seasons should be set in late October and November to obtain maximum yields and benefits.
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VITA

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