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NATURAL HISTORY AND ECONOMIC IMPORTANCE OF THE MUSKRAT IN THE ATHABASCA-PEACE DELTA, WOOD BUFFALO PARK

by

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TABLE OF CONTENTS

Part I

ORGANIZATION AND ORIENTATION

1. Introduction

The history of the fur industry has followed the same general pattern in various regions of the North American continent. In the beginning there was a dense population of fur-bearers which was exploited with increasing intensity by an ever-growing number of pioneer trappers. The more valuable species inevitably disappeared except in the most inaccessible places. The more prolific species were reduced in numbers and sometimes all but exterminated over much of their former range. Under even rudimentary forms of management, however, the prolific species were able to regain something of their original abundance and become the mainstay of the industry. In the heyday of the beaver trapper the muskrat was considered too insignificant to repay the energy required to trap and skin it, but it is now regarded as the most important of the fur-bearers.

In modern concept, the management of a wild animal species involves more than the mere preservation of the species. It includes the attempt to produce and harvest a crop, following in a broad way the principles of scientific agriculture. Any such attempt requires as a starting point certain basic information about the species being managed and its relationship to the land on which it is produced and to the other animals associated with it. It is also important to study the means of harvesting the crop and the factors affecting its market value.

Northern Canada was the last frontier of the early, heedlessly exploitive type of trapping. This area has now reached the point where management of a positive nature is a necessity.

It was against this background that a survey of the muskrat on the Peace-Athabasca Delta was begun in the summer of 1947.

The muskrat has received the attention of naturalists on many previous occasions, and numerous studies have been reported in the literature. The prime necessity of this particular investigation was to determine whether any of the characteristics of the species have been altered to meet the rigorous conditions of northern existence. It was also intended to fit what is already known about the species into the background forced upon it by the climate, habitat, vegetation, associated fauna and economic needs of the trappers. The work of previous authors will be drawn on extensively to fill gaps in the knowledge acquired at first hand.

2. Outline of Method

The method used may be described under three general heads.

(a) Visual inspection

This was accomplished, in the main, during the summer of 1947 when canoe trips were made through most of the generally accessible water routes, including Baril River and Birch River. Signs of muskrat activity and the suitability of the habitat

for muskrat occupation were noted. This method is not quantitative, but enables one to say on the basis of a subjective analysis that one given area appears to be more, or less, productive than another. For example certain characteristics of the delta of Peace River make it generally less suitable for muskrats than most of the Athabasca delta.

(b) Natural history study on a specially chosen area

For this phase more intensive work was done on the trapping area of Solomon Lacaille. The population was sampled by both live and dead trapping, measurements and weights were secured, parasites were collected, age and sex ratios were obtained, and a study of the effects of predators was made. A special study of primeness and aging as revealed by the moult pattern of the pelts was also undertaken on the area.

Mr. Lacaille's valuable assistance in the work is gratefully acknowledged. His experience extended far enough into the past to provide a history of muskrat production in the area and his knowledge of past conditions made it possible to arrive at a reasonably accurate figure for the sustained yield. Other phases of the study, such as the role of predators, greatly profited from his comprehensive knowledge of wildlife in the vicinity and his acute powers of observation.

(c) Productivity studies

The problem was approached in a new way, using the live trap tag and release technique and the so-called Lincoln index. Knowing the figures for the productivity of the restricted area and the productivity of the delta region as a whole, and having

at least some idea of the productivity of some of the best areas, it was possible to make a preliminary estimate of the abundance and possible yield of muskrats in the Athabasca Delta.

3. Description of the study area

(a) Geology and geography

The Peace-Athabasca delta, including Lakes Claire and Mamawi, is all that remains of the basin of a much larger glacial lake, formed by ponding of the waters of the Athabasca and Peace Rivers at the foot of the retreating ice sheet. It is underlain by palaeozoic rock, probably of Devonion age, concealed by a thick covering of glacial drift, and it is bordered on the east by the Precambrian shield. Outliers of granitic rock from the latter formation appear as islands rising above the general low level of the surrounding plains.

With the retreat of the ice and the resumption of a northerly drainage, deltas were formed by the two large rivers. Eventually these deltas coalesced and thus cut off the Mamawi-Claire basin from the west end of Lake Athabasca. Siltation is still proceeding but at a much slower rate than formerly. The Athabasca has been pushing channels farther to the east and is now laying down extensive mudflats on the south shore of Lake Athabasca, east of the present park boundary. Most of the water of the Peace is carried off to the northward by the Slave, and it is only in time of flood that its water flows through the Quatre Fourches River into Lake Mamawi, and through the Baril River into Baril Lake and Lake Claire.

It is interesting to note that Mackenzie, in 1792 travelled "through the smaller lakes westward of Lake Athabasca (and) entered the Peace." (Preble 1908). No such route is possible now, and I am not aware that any of the present residents of Ft. Chipewyan have used, or even know of, such a route. Even more recent changes have been noticed. Gull River was a recognized water route from the head of the Embarras River to Mamawi Lake as recently as 20 years ago. Today a portage of approximately one mile is needed at its upper end. A small creek, known as Pine River was navigable between Lake Claire and Peace River in 1946, when two men made a successful muskrat hunt along it. Patrolman Mandeville reported "plenty" of water in it in June 1947. In August, 1948, the bed of the stream was barely damp.

The lakes are bordered by broad bands of swamp and mud flat which represent the youngest portions of the encroaching land mass. These bands are intersected by abandoned channels and dotted with shallow lakes and sloughs.

The oldest parts of the delta, extending for some distance up the larger rivers, have higher, dry ground built up by the deposit of successive layers of silt. Abandoned channels occur here also in great profusion.

Sand ridges in the extreme southeast corner provide the only relief in the entire area except for the granite hills previously mentioned. The sand ridges appear to be continuations of the rolling sand dunes along the south shore of Lake Athabasca which have been referred to the late Precambrian by many authors.

Mr. Lacaille's area is located on the west (left) bank of the Athabasca River at about latitude 58° 20'. It extends about six miles in a roughly north and south direction along the river and from 1½ to about 2½ miles inland. The inner or western boundary is formed by an easily recognized sand ridge, 50 or more feet high, which is about 2½ miles from the river at the north end, approaches to within 1½ miles at the south end, and finally intersects the river near the 27th base line. The area is located just above the source of the Embarras River which is the first still-active channel of the delta proper. In comparatively recent times, however, other channels were open between the Athabasca and Lake Claire, and many of the best muskrat sloughs in Lacaille's area are ponded sections of the old stream beds.

Two creeks pass through Lacaille's area but their currents are negligible except at the time of spring flood. Pine Creek flows roughly parallel to the Athabasca, which it enters on a bend about three miles below the north end of Lacaille's area. Big Snye rises in a slough at the base of a smaller sand ridge and is connected with Lake Mamawi by a maze of waterways. The area contains three large sloughs, a number of potholes, which usually hold water the year round, and several marshy areas which dry up in late summer or autumn.

The most productive slough, which will hereafter be called the "Main Slough", lies in a southeast to northwest direction, separated at the south end from the Athabasca by only about 500 feet and at the north end from Pine Creek by

an even shorter distance. The slough at the head of the Big Snye, and usually spoken of as "Big Snye", is the second biggest producer. A portion of this slough is trapped by the Indians of Napoleon (Snowbird) Martin's band. The third large slough is called the "Big Lake" and is trapped about one-third by Lacaille and two-thirds by his southern neighbour, W. Daniels.

(b) Vegetation

The order of plant succession in the delta is observable when one ascends a stream such as the Embarras from Lake Athabasca to its source. Barren mudflats, which may be covered in high water, give way to a zone of sedges, rushes, and grasses, whose lower portions may also be submerged for a considerable part of the summer. As definite banks (natural levees) begin to appear along the stream, a few willows are noted, becoming denser as the banks become higher. The first grove of black poplar (*Populus balsamifera*) occurs five to six miles above the lake and no more are seen for several more miles. Farther still, a few white spruce (*Picea glauca*) appear in otherwise pure stands of poplar. Gradually the spruce becomes dominant and at the headwaters of the stream, Embarras Portage, occurs as a nearly pure stand. Here the immediate banks are lined with willows (*Salix spp.*), real osier (*Cornus stolonifera*), and alders (*Alnus sp.*) throughout. The same stages of succession obtain in the Peace delta and can be observed, though not as clearly, on the Quatre Fourches and Baril Rivers.

Trembling aspen (Populus tremuloides) is not common in the lowlands, but occasional groves may be seen. White birch is thinly distributed throughout the spruce forest.

The sandhills in the southeast corner of the park are clothed in a pure stand of jack pine (Pinus Banksiana). Stunted jack pine occurs, along with spruce and birch on the granite outcrops in the Quatre Fourches region.

The balsam fir, (Abies balsamea) extends into the park in the narrow alluvial plain between Athabasca River and the sandhills in the southeast corner. It is a common tree in the immediate vicinity of the warden's cabin near the 27th base line, but is much less common 10 to 15 miles downstream on Lacaille's area. Raup reports the species about 10 miles farther down at Reid's (Embarras) Portage.

The vegetation of the sloughs and ponded streams is of particular interest. On Lacaille's Main Slough which is typical of the upper Athabasca delta, three zones are clearly recognizable. The emergent vegetation consists mainly of Typha latifolia, Equisetum sp., Carex rostrata, C. trichocarpum, Scirpus validus and Sparganium multipedunculatum. In the littoral zone, extending in a band of varying width into three or four feet of water Nuphar variegatum is dominant and forms a dense mat. Beneath this mat, in the shallower water, are Anacharis canadensis, Sagittaria cuneata, Polygonum natans, Ranunculus trychophyllus and Sparganium angustifolium.

Extending into the deeper portions of the littoral zone are Utricularia vulgaris, Ceratophyllum demersum, Myriophyllum

exalbescens, Potamogeton zosteriformis, P. natans, and a few examples of Nymphea sp. The profundal zone extends from depths of three or four feet to the maximum depth or the limit of plant growth. In this zone, practically the only species visible from a canoe are Potamogeton richardsonii, P. vaginatus, P. gramineus and a small amount of P. pusillus. The duckweeds, Lemna minor and L. trisulca, were not abundant except on one bay of this slough, but thick mats of these plants were observed in other, mostly smaller, sloughs. Mare's tail, Hippurus sp., was not identified in Lacaille's slough or in any of the three sloughs behind the warden's cabin at 27th base line.

Sloughs in the upper Peace delta have relatively steep, clean banks, and, therefore, have practically no room for emergent growth except where the ends may slope off gradually. A slough examined in detail was about one mile long and had a maximum depth of 3½ feet. The long end bay supported a good stand of Carex and Equisetum, and there was a narrow emergent zone of Carex 15 to 20 feet wide. Alisma sp. was common in a few inches of water and there were a few patches of Eleocharis sp. Polygonum natans and Potamogeton vaginatus practically complete the list of plants in this slough. The water level had been lower for several years as shown by the fact that willows and even young aspens were found growing in 18 inches of water, well out from shore. Obviously the carrying capacity of such a slough would be much lower than that of a slough of similar size in the Athabasca delta.

For a more complete description of the vegetation of the delta plains, the reader is referred to Raup (1930, 1935). Additional material pertaining to the geology and geography of the region may be found in Camsell and Malcolm (1921), Hume (1923) and Soper (1939).

(c) Climate

Meteorological data contained in Table 1 and Figures 1-3 were obtained from the weather station at Embarras Airport. This station has only been in operation since 1945 and records prior to September 1946 are not complete. The arrangement of the data, beginning with September instead of January, permits easy reference to trapping seasons rather than calendar years.

Table 1. Meteorological data from Embarras Weather Station, September, 1946 to May, 1949.

	Year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Mean daily maximum	1946-7	57.4	38.1	19.0	-3.7	2.9[i]	0.6	20.9	34.7	53.8
	1947-8	55.3	46.7	19.8	11.1	13.7	4.9	17.7	33.4	61.5[2]
	1948-9	59.6	52.1	26.2	2.8	2.9	0.4	29.2	51.6	56.7
Mean daily minimum	1946-7	35.9	26.1	2.8	-21.5	-17.8	-24.0	-2.3	12.8	33.3
	1947-8	37.3	33.2	6.9	-5.5	-8.2	-19.6	-12.7	4.5	37.7
	1948-9	43.2	31.5	10.6	-4.6	-19.1	-26.5	-18.6	30.9	35.0
Total snow	1946-7	0.30	1.04	0.42	0.75	1.72	0.81	9.00	1.08	0.07
	1947-8	tr.	0.19	0.93	0.44	2.21	8.30	13.30	0.70	0.40
	1948-9	tr.	0.70	17.60	1.52	14.40	4.60	7.90	5.60	0.20

[i] Lowest temperature recorded during this period was -59.8° on January 30, 1947.

[2] Highest temperature recorded was 87.8° on May 22, 1948.

The temperature records (Figs. 1 and 2) show that February tends to be the coldest month of the winter, with a mean daily minimum of -20°F or colder. The mean daily maximum for February was 0° to + 5°F. December recorded lower mean daily maxima than January, but the January minima tended to be lower. Both graphs show relatively little variation in October and November temperatures for the three years recorded. Warming in March and April was about as rapid as cooling in October and November. The rapid rise in 1949, from a mean minimum of -26.5° in February to +18.6° in March is a striking feature.

The amount and seasonal distribution of the snowfall bear an important relation to the thickness of the ice and thus to the fate of the muskrats in the shallower sloughs. The only point clearly brought out by the graph (Fig. 3) is the complete variability in these factors. There was a more than three-fold difference in amount of snowfall between 1946-47 (15.2 inches) and 1948-49 (52.5 inches). Also, in the first two years, the heavy snowfalls came late - in February and March - while in the last winter, 17.6 inches fell in November. Thus while the lowest temperatures were encountered in January and February, 1949, the thick blanket of snow prevented excessive mortality of muskrats.

The freeze-up of the Athabasca River occurs normally about October 20, a week or 10 days after the first crust of ice has formed on the sloughs. However, in 1947, navigation was not impossible until November 7, and in 1948 canoe travel was impossible after November 6. The Main Slough first froze over

on October 20. A few days later a channel opened up which persisted for two or three days before freezing permanently.

There is also a fluctuation of about 10 days in the dates of the break-up, which occurs normally about April 20, but in the past two seasons has been delayed until early May. The sloughs may be free of ice a few days before the larger rivers. The break-up is accompanied by a flood about one year in three.

Anemones were blooming at Fort Smith in the first week of May 1949. Catkins appeared on the willows about the same time. Aspens budded a few days later and were not fully leafed out until June 10. Autumn coloring appears in the aspen leaves during late August, but in 1948 the leaves were not shed until early October.

Part II

BEHAVIOUR PATTERNS

1. Construction and Use of Shelters

The most conspicuous phase of muskrat activity is the construction of shelters. In the latitude of Wood Buffalo Park these are of three kinds: (1) winter houses; (2) pushups; (3) bank dens. Much has been written about muskrat shelters by earlier writers so that there is no need to go into great detail in the present account.

(a) Winter houses

There was little house building in progress on Lacaille's main slough during the last week in August, 1948.

Construction began in earnest late in September and proceeded rapidly until October 8, when I left the slough. Observations were resumed October 22 at which time Pine Creek and the main slough were frozen over and presumably house building was completed.

Before October 8 live traps set on floating plants were almost invariably hidden by a mass of vegetation the following morning, indicating a great amount of activity during the night. (Fig. 24).

Traps were occasionally set on partially completed houses. Both adults and young muskrats were caught in such sets indicating that all the animals take part in building the houses.

The size and shape of the houses are extremely variable. None were measured, but Figure 25 shows houses on the Big Snye nearly as tall as a man (Patrolman Spreu). The average height of the houses on Lacaille's sloughs was from two to three feet and the average diameter from three to four feet.

The winter house is usually destroyed by the spring floods which are characteristic of the delta region. A few houses may escape the flood but no instance was noted of an attempt to keep a house in repair through the summer.

The houses are usually constructed of the broad leaved cattail *Typha latifolia*, but *Scirpus spp.* is also regularly used and discarded portions of most of the food plants may be found in the walls. *Utricularia* was often noted and may act as a sort of filler.

(b) Pushups

Pushups are merely domes of frozen vegetation covering a plunge hole in the ice. They provide protection for the open hole and slow the process of freezing. Visits by the muskrats serve to circulate the water and break up skims of ice. Deep snow provides considerable insulation at least during the early part of the season.

Daily observations on the sloughs behind the 27th base line cabin from November 9 to 14 revealed that small holes remained open as the ice formed (Fig. 26). On November 9, the ice was barely able to support a man's weight and since there was no snow, visibility through the ice was good. At that time numerous air bubbles were present just under the ice (Figs. 27 and 28).

There are two possible explanations for the origin of pushups: (1), holes are kept open from the time of ice formation, and (2), new holes are gnawed through the ice, probably where an air pocket reduces the thickness of ice to be gnawed and supplies a source of oxygen. Some such explanation must account for new pushups in late winter when the ice may be two or more feet thick.

The dome of the pushup is made of rejected portions of food items, most of which are parts of submerged aquatic plants. Anacharis, Myriophyllum, Utricularia, and several species of Potamogeton are the usual constituents. (Fig. 29).

The purpose of the pushup undoubtedly is to enable the muskrat to extend its feeding range. Since the dome is porous,

the animal is able to renew its oxygen supply there and can thus feed at a greater distance from the main house.

Lacaille has observed and demonstrated to me that pushups tend to be located in roughly straight lines radiating out from a house. It is also demonstrable that houses are built each year in certain favourable spots on the periphery of the slough, and that the radiating lines of pushups cover the same territory each year with individual pushups located in almost precisely the same positions in successive seasons.

The distinction between a house and a pushup is of some legal importance, since under the present regulations only the houses are protected. Several characteristics differentiate the structures. Probably none of them has universal application, but taken in combination they should provide an adequate guide. These are: (1), the house is built before the ice forms and is therefore usually based on or anchored to some object for example a log, a clump of willows or a large feed platform, but the pushup, being formed after the ice, is supported only by the ice; (2), the house is composed largely of emergent types of vegetation, the pushup of submerged plants; (3), the house usually has a comparatively large nest chamber and often two plunge holes, the pushup usually contains only a small chamber and commonly has a single approach; (4), the house is usually near the margin of the slough, while many pushups are found well away from shore.

(c) Bank Burrows

Bank burrows are used by stream-dwelling muskrats

the year round and by the slough-dwellers through the summer months at least. Mr. Lacaille believes that the slough-dwellers continue to inhabit the burrows through the winter, using burrows and houses alternately for shelter.

Brood nests are made in the bank burrows except possibly in years of severe flood when the females may be forced to brood in relatively exposed situations.

A number of bank dens were excavated in late June and early July 1948 in an unsuccessful attempt to capture and tag the young animals. Chambers were found which had obviously been prepared as nests for the young but the young animals must have been large enough at this time to make their escape since none were taken.

2. Feeding and Food Storage

A wide range of food plants is available in summer to the muskrats in this region. Their preference seems to be for the more common species. A list of species in order of preference, based on examination of numerous feeding places, is as follows:

Emergent Vegetation	Submerged Vegetation
Typha latifolia	*Potamogeton spp.*
Equisetum spp.	*Myriophyllum sp.*
Scirpus validus	*Anacharis canadensis*
Scirpus spp.	*Ceratophyllum sp.*
Sparganium spp.	*Sparganium sp.*
Carex spp.	*Nuphar sp.*
Sagittaria spp.	
Eleocharis sp.	

In September and October evenings, the writer has sat quietly in a canoe and heard muskrats cutting feed only a few feet away. Occasionally one would swim in front of the canoe carrying a piece of freshly cut vegetation in its mouth. In every instance in which it was possible to identify the potential food, it was a short length of Equisetum.

The critical season is the winter period when the sloughs are ice-covered. In many cases, the water levels have dropped so low that the emergent plants are completely unavailable after ice has formed and the degree of abundance of submerged flora then determines survival or death for the muskrat populations.

On the best sloughs, at least some of the emergent plants still stand in water at the beginning of winter. Their dry and barren stalks catch the snow as it falls or drifts. Snow so held does not pack but remains light and filmy and forms a thick insulating cover which reduces the depth of freezing.

During the summer months the food is usually eaten on a definite feeding platform which may be a log or other floating object, or a floating mass of vegetation. (Fig. 33).

A peculiar feeding habit was observed on Pine Lake, May 23, 1949 at 7.30 p.m. A rat swam perhaps 200 feet out from shore and dived. In the space of fifteen or twenty seconds he reappeared, slowly swam a circle, and dived again. This process was repeated many times and apparently the rat submerged at the same point each time.

It seems to be generally agreed that muskrats do not store food in houses. However, Errington, Beer and the writer have found stored food in bank burrows. In July, 1948, several nests contained Equisetum stems cut into neat sections, six to eight inches long. That no other food was found in the limited number of nests examined may well indicate a seasonal food preference for Equisetum.

3. Disposition

Muskrats are vicious and dangerous when captured. They were observed to fight both live traps and steel traps with considerable ferocity. Even after release, a number of the animals attacked the canoe or the paddle, others voiced their displeasure by means of an ominous chattering of the teeth before submerging or disappearing among the cattails.

4. Relationship to Other Wildlife

(a) Commensal relations - beaver

Muskrats benefit from the improved water levels usually resulting from the erection of beaver dams. Beavers dammed the tiny outlet to the Main Slough in the spring of 1948 and the water level of the slough raised appreciably. At one time beavers dammed a rill deriving from several springs, and formed against the base of the sandhills a pond from which Lacaille used to harvest 75 muskrats annually. After the beavers disappeared, conditions degenerated to such an extent that his 1948 catch in the pond was reduced to 12.

Many trappers believe that the muskrat acts as a sentinel for the beaver. If the beaver hunter is seen by a muskrat and the hunter allows the rat to escape into the water, beaver almost never show themselves and the hunt is therefore fruitless. This theory has not been tested by personal observation.

Leighton (1933) believes that the muskrat lives with the beaver by preference but that the beaver's toleration of the muskrat is no more than passive dislike.

(b) Neutral relations

In July, 1948 the vertebrate population of the main slough included one pair of loons, an estimated six to eight families of golden-eye ducks, a large colony (more than 100) of nesting smoky terns, redwing black birds, and a few northern pike which came in with the flood waters.

In the fall and spring large numbers of waterfowl utilize the main slough as a temporary resting and feeding place. There is thus potential competition for food. Food is found in such abundance, however, in the summer and fall that no serious competition develops. A large influx of waterfowl in the spring before plant growth was well underway might induce a shortage, but since the waterfowl invasion is temporary and the muskrat population is then at its annual low, no results comparable with the complete destruction of some marsh plants in the southern wintering grounds of waterfowl are to be anticipated.

Most noticeably in the early part of the winter, field mice of the genus Microtus were living in association with the rats. They had constructed numerous tunnels through the snow which covered houses and pushups and were no doubt utilizing the building materials for food.

5. Movements

(a) Autumn movements

The map, Figure 36 shows trap sites on the Main Slough. Broken lines link sites where the same animal was captured after an interval of one or more days. The number of animals and the number of recaptures are too small to allow for sweeping generalizations but it can be pointed out that no large scale movements were detected. The greatest distance travelled was less than 500 feet. Rats were many times observed crossing open water without hesitation, and the trapping results also show that the animals cross open water freely. There is apparently a weak form of territoriality since animals caught in one group of traps several times were never taken in any other group. There seemed to be at least four separate entities along the south shore of the portion of the slough where traps were set.

Late in the autumn, when the ice is forming, migrations may be undertaken by some rats. On November 5, 1948, when ice was running in the Athabasca River two rats were seen in a four mile stretch of river. No migrations on Lacaille's main slough were observed but rats were tracked for considerable distances on Pine Creek and on the Athabasca River. (Figure 35).

Late autumn movements have been observed at Fort Smith as well. In all cases, the tracks could be traced back to a submarginal habitat. The significance of late autumn movements will be discussed in a later section.

(b) Spring movements

It is well-known that there is much shuffling of the muskrat population in spring, but since most of it takes place after snow has gone, it is more difficult to observe. In years of flood, trappers consistently report encounters with rats travelling in surprising places. Others are seen swimming in the large rivers. The animals have been observed to desert sloughs near Fort Smith in the autumn, and to reappear in the same slough soon after the ice was gone in the following spring.

Spring movements are of great significance in muskrat ecology. Repopulation of areas which have been depopulated through overtrapping, drought, predation, or other causes takes place almost entirely at this time. The movement is greatly facilitated by high water following the spring breakup.

Part III

REPRODUCTION AND VITAL STATISTICS

1. Reproductive Cycle

(a) Enlargement of testes

The most obvious and most easily measured criterion of sexual activity is the enlargement and descent of the testes in the male. In 1947-48 recordings, the length of the testes was

taken to the nearest millimeter. A more accurate expression of size was used in 1948-49 when testicular volumes were taken in a centrifuge tube graduated in tenths of a milliliter. Table 2 summarizes the information obtained.

Table 2

Weights and Measurements of Muskrat Testes

	1947-48					1948-49		
		Length in mm.		Diameter in mm.			Volume in ml.	
	No. of Spec.	Ave.	Range	Ave.	Range	No. of Spec.	Ave.	Range
Nov. 16-30	0					14	.10	
Dec. 1-15	11	8.3	5-11			6	0.10	
Dec. 16-31	9	9.3	8-12			14	0.13	0.1-0.2
Jan. 1-15	12	10.4	7-14			10	0.13	0.1-0.2
Jan. 16-31	13	10.4	8-12			6	0.20	0.1-0.3
Feb. 1-14	9	16.0	13-18	10.7	9-12	0		
Feb. 15-29	10	16.0	11-20	10.3	7-13	0		
March 1-15	10	16.3	9-21	11.2	6-14	5	2.02	1.7-2.3
March 16-31	0					7	2.10	2.0-2.3

Data regarding animals considered to be adults have been excluded from Table 2. In December 1947 the testes of three adults averaged 16.6 mm. in length. In November and December, 1948, the volume of adult testes measured 0.2 to 0.3 ml. (two to three times as large as immatures). One adult taken in January, 1948 had testes measuring 0.48 ml. in volume. In February and March, no difference could be seen between the testes of adults and those of young of the year.

The testes do not begin to descend until early March. About one-half the males examined in late March, 1949, had at least one testis in the scrotal position. The testes were still scrotal in one adult examined December 6, 1947.

(b) Changes in the female tract

No histological studies of the female tract were deemed necessary, and none were made. Consequently, the changes cannot be quantitatively described. Immature females ranging from the smallest animals handled to full grown rats taken in March, had imperforate vagina and small, thin, transparent uteri. In March there is a slight enlargement and a creamy-white opacity. The uteri of adults remain thickened, opaque and bloodshot after the breeding season, but the congestion becomes less noticeable as the winter progresses. Placental sites were still visible on some uteri in November and December of both years. The vagina apparently remains perforate, at least in the majority of adults.

(c) Time of mating

The time of mating seems to be determined by the time of break-up of the ice cover. The process has not been witnessed by the writer, but all reports indicate that it occurs a few days after the appearance of open water. The date varies from year to year, but, on the average, will fall between April 20 and May 1.

(d) Birth and weaning of first litter

The gestation period is 29 to 30 days (Asdell 1946), and the first litter is born, on the average, during the last week in May. In 1948, the break-up came unusually late on May 3 and the births took place in early June. Errington (1937) states, and it is generally agreed, that the young become independent during their fourth week. This agrees with observations

in the first week of July that the young were old enough to vacate the nest when disturbed, yet were not seen to be active in the evenings. It is likely that they were being weaned at that time.

(e) Production of the second litter

The muskrats of Iowa (Errington 1937) and of Wisconsin (Beer, 1949) have a post partum estrus meaning that the second litter may be conceived while the female is lactating and born shortly after the first young are weaned. Evidence is incomplete but indicates that this is not the case among muskrats in the Athabasca-Peace delta. Second matings probably occur late in or at the conclusion of the lactation period and the second litter arrives late in July. The fact that a female containing seven embryos judged to be close to term was taken on July 20 lends support to this theory. Also, the fact that young of the second litter were active and apparently independent on August 26 indicates that they were born late in July.

(f) Possibility of a third litter

There is still a widespread belief among local trappers that adult muskrats produce three litters of young in a season. Detailed observations in 1948 convinced the writer that there was no third litter in that year. Well over 200 muskrats were handled between late August and late October. Most of these were young animals, and there were only two weight classes. There was no evidence of recent parturition or lactation in adult females. Less complete observations indicated that there was no third litter

in 1947. It has already been mentioned that these two years were extraordinarily late both in the spring break-up and the fall freeze-up. It was also mentioned that the second litter had been weaned by late August, so that there was ample time for the production and weaning of a third.

While these observations throw grave doubts on the three-litter theory they do not entirely eliminate the possibility. Lateness of the freeze-up seems not to be a factor. An unusually early spring break-up may, however, induce the onset of breeding at a sufficiently early date to allow some, at least, of the females to bear a third litter.

(g) Regression of reproductive organs

The testes showed signs of regression in October when they appeared flaccid and slightly purplish in hue. The volume varied from 2.25 ml. (breeding size) to 0.3 ml. (about one-tenth of breeding size). By November, all males examined had testes measuring 0.2 to 0.3 ml. The testes return to the abdominal position in November and December.

The uteri of females showed placental scars through September, although they were recorded as being faint on September 28. A female was taken October 8 in which the scars were unreadable. In November, two sets were deciphered with assurance, one with hesitation and one set was too faint to count. One set of readable scars was seen December 31 and the latest recorded was January 8.

Vascularity of the reproductive tract was much reduced by October. The uteri also quickly diminished in size

but retained their opacity.

2. Vital Statistics

(a) Number of litters

It has been shown in the preceeding section that there is little likelihood that the birth of a third litter in one season is of more than sporadic occurrence. It is apparent that the season of open water is long enough to assure the success of two litters. While the number of casualties probably lowers the population average somewhat, for practical purposes we may assume that nearly every female will bear two litters.

(b) Number of young per litter

There is a scarcity of data on this point because other events intervened to keep the writer out of the field at the times when the young were being born, and because the writer was reluctant to kill breeding females in the summer on Lacaille's area where most of the work was done.

There is only one record of a pregnant female. It was taken on July 20 and carried seven embryos near term.

Placental scar counts in seven females averaged 17.4, or 8.7 per female per litter.

Reabsorption of embryos and other intra-uterine factors probably reduce the number of young surviving after birth below the number of placental scars.

An examination of the literature reveals that six to eight young is considered normal for the more northerly subspecies of muskrat in Iowa and Manitoba. It is also

recognized that the breeding success varies markedly from year to year. Many factors, such as drought, predation, overcrowding, and food shortage may affect the number of young per litter. If our small sample is truly representative of the population as a whole, conditions must have been nearly optimum, since an average in excess of eight young at a birth represents exceptional success.

(c) Young to adult ratios and survival of young

Reliable information about the survival of the young muskrats was obtained by live trapping in summer and by examination of muskrats taken in winter trapping.

Table 3. Catch of muskrats by age and sex, August 24 to 31 and September 26 to October 8.

	Adult		Juvenile		Total	
	M	F	M	F	M	F
live-trapped	8	10	84	66	92	76
dead in traps and specimens	3	2	19	7	22	9
totals	11	12	103	73	114	85

Table 3 summarizes the data obtained from all live trapping. The ratio of juveniles to adult females, obtained from the totals in Table 3, is 176 to 12 or 14.6 to 1.

Table 4. Catch of muskrats by age and sex Lacaille's Main Slough, September 26 to October 8.

	Male	Female	Total
Adult	4	8	12
Juvenile	64	51	115
Total	68	59	127

Table 4 summarizes similar data for a smaller sample taken from a single locality, Lacaille's Main Slough, and during a shorter period of time. The ratio in this case is 115 to 8 or 14.4 to 1. Since this ratio checks so well with the one obtained from the larger sample in Table 3, it may be safely used for comparison with the results of winter trapping which was carried on in the same locality.

Table 5. Winter age ratios, Lacaille's Main Slough, 1947-48 and 1948-49.

Date	Adult Female	Juvenile	Ratio
December	6	76	12.7
January	6	70	11.7
March 1-15	4	47	11.8

Table 5 shows the combined results of the winter trapping. Aging was done by the pelt-primeness method (Applegate and Predmore,

1947; Shanks, 1948) and by examination of the reproductive system. Figures for February trapping are omitted from the table because no adult females were taken in that month.

Table 6. Survival rates of young muskrats based on annual increase of 17.4 per adult female and no adult mortality.

Date	Ratio	% survival	% of fall population
Oct. 1	14.4	83	100
Dec. 15	12.7	73	88
Jan. 15	11.7	67	81
Mar. 1-15	11.8	68	82

Table 6 tabulates percentages of survival of the young calculated from the ratios obtained in Tables 4 and 5. This method of calculation is based on two assumptions: (1), that there is no mortality of adult females, and (2), that trapping is non-selective as regards age and sex and the samples are representative of the population as a whole. The table shows that about 83 per cent of the young survive until October 1. About 10 per cent more are lost by December, and there is a small loss in January. From that time there is no appreciable decline in the population of juveniles before March 1, when the season opens for muskrat trapping in the delta.

Since there is no doubt a small loss of adult females the survival rates can be considered maximal.

Use of the results of the calculations summarized in Tables 3 to 6 will be made in a following section.

(d) Sex ratios

Three sex ratios are usually distinguished. These are: (1), the primary sex ratio or ratio at conception; (2), the secondary ratio, or ratio at birth, and (3), the tertiary ratio, or ratio at sexual maturity. The ratios are compared to determine whether there is differential mortality during the life history of the sexes.

No primary sex ratio was determined in this study. The nearest approach to obtaining a secondary sex ratio was during the live trapping program in the autumn of 1948. Some information on the adult ratio was obtained at this time, and more was secured in both years during the winter trapping period when the entire population was at sexual maturity. The data are all presented in Table 7.

Table 7. Sex ratios of northern muskrats.

Month	Year	Adult			Juvenile			All ages		
		M	F	M/100F	M	F	M/100F	M	F	M/100F
Oct.	47-8	-	-	-	-	-	-	110	82	134
	48-9	11	11	100	99	71	139			
Nov.	47-8	-	-	-	-	-	-	21	14	150
	48-9	5	2	250	16	12	133			
Dec.	47-8	3	3	100	20	15	133	51	37	138

Table 7. (cont'd)

Month	Year	Adult			Juvenile			All ages		
		M	F	M/100F	M	F	M/100F	M	F	M/100F
Dec.	48-9	3	3	100	25	16	156			
Jan.	47-8	3	4	75	22	10	220	49	33	148
	48-9	3	2	150	21	17	124			
Feb.	47-8	3	0	300	16	9	178	19	9	211
	48-9	-	-	-	-	-	-			
Mar.	47-8	46	48	96				255	220	116
	48-9	209	172	122						
Apr.	47-8	24	15	160				188	112	168
	48-9	164	97	169						
May	47-8	14	6	234				14	6	234
	48-9	-	-	-						
	Total	488	363	134	219	150	146	707	513	138
	1947-48	93	76	122	58	34	170	151	110	137
	1948-49	395	287	138	161	116	139	556	403	138

In general, the ratios are overbalanced in favour of the males. The overbalance is greater in the juvenile age groups than in the adult, indicating selective mortality against the males in their second year, a subject which is discussed in detail later in this report. Other conclusions may be drawn regarding changes from year to year and through the winter months or the trapping season.

(i) Year to year changes

There was no significant difference in the over-all sex ratio during the two years of the study. There is some indication of an upward

trend in the adult class, but this is entirely due to the sample taken near Ft. Smith in April, 1949, which can be excluded on geographical grounds. Without this sample, the adult ratios are identical for the two years (122 males per 100 females or 55 per cent males).

The adults in the autumn and early winter of 1948-49 were survivors from the trapping season of 1948. For 40 known adults taken between October, 1948, and January, 1950, the ratio was 22 males to 18 females (122:100 or 55 per cent males). The over-all ratio in the preceding winter was 137 males per 100 females (58 per cent males). There seems, therefore, to have been some reduction in the number of excess males. The reduction may be due to the males being more susceptible to trapping (see below) or to their wandering more extensively in the spring. The wandering males are more susceptible to predation, and they are also lost simply by egress from the locality.

(ii) Changes through the winter

There may be a slight differential mortality of males during the winter months. Small samples taken during the first winter showed an excess of males in the total of both age groups in December (23 to 18 or 128:100) and a slight excess of females in March (96:100). The second winter there was a reduction from 134 to 122 in the number of males per 100 females.

(iii) Changes during the trapping season

The data for both years appear to show clearly that more males are taken in the late part of the season. In 1948 the samples were small but showed a clear cut progression from

96 males per 100 females in March to 160 in April and 234 in May. In 1949 satisfactory samples were examined but the April one is open to some question since it is from a different locality. The ratio of males to 100 females increased from 122 to 169.

This is strong evidence that many of the excess males are removed during the trapping season (see above).

(e) Evidence of Monogamy

The trend toward an equal sex ratio in the spring is suggestive of a greater degree of monogamy than has been attributed to the muskrat by many writers. Cowan (1947) on the basis of live trapping results, concluded that there was a high degree of monogamy among muskrats in the Mackenzie delta. Similar evidence is available regarding the muskrats on Lacaille's Main Slough although based on a small number of rats.

In two cases it was believed that a battery of traps was sampling only one family group. The first battery consisted of four traps set near a house under construction. Eighteen individuals were captured, eight of them twice. None of the 18 was subsequently caught in any other location, nor was any rat previously caught and marked in another trap recaptured in any of the four traps which composed this battery. One adult male and 17 immature rats (11 females, 7 males) were taken. The adult female eluded capture, or more probably, had met with a fatal accident. It appears significant that only one adult male was captured. It is interesting to note

that the total number of young captured agrees well with the average litter size of 17.4 calculated from other evidence.

There is less evidence of the family unity of the second group which was caught in a battery of eight traps. Three of the animals repeated, one of them three times, each time in a different trap. One adult female and 19 immatures were taken. In this instance the adult male was not captured. There is some doubt concerning the inclusion of one of these traps, which was set at some distance from the other seven. Excluding it would eliminate one juvenile of each sex leaving 17 young (10 males, 7 females) and one adult.

Assuming a low incidence of promiscuity, we must conclude that a sufficient supply of males is probably necessary for maximum reproduction. All schemes and arguments, therefore, aimed only at the protection of females as essential to reproductive success, should be regarded with suspicion.

3. Population of Lacaille's Main Slough

One of the important objects of the tagging program was to assist in estimating the autumn population. The method used, which has been previously applied in fisheries research and in the study of waterfowl populations, assumes that the tagged individuals constitute a sample of the population. Animals taken during the open season constitute a second sample in which tagged specimens should occur in direct proportion to their representation in the entire population. Knowing (a) the total number tagged, (b) the total catch, (c) the number of tagged animals recaptured, the original population (d) may be calculated by the simple formula $\frac{c}{a} = \frac{b}{d}$ or $d = \frac{ab}{c}$.

On Lacaille's main slough 168 rats were tagged of which six died during the trapping period, leaving 162 (a). Lacaille's catch amounted to 763 (b). The number of tagged rats recovered was 102 (c). The estimated autumn population was therefore $d = \frac{162 \times 763}{102} = 1{,}212$.

In corroboration of this estimate, the house count may be of some importance. A figure of five to six per house is widely used in estimating populations from house counts. Lacaille counted 187 houses on the slough exclusive of one bay where he estimated there might be as many as 50 more. Five times the maximum of 237 houses equals 1,185 and six times a minimum of 200 equals 1,200. These numbers are in the same order of magnitude as the estimate based on live trapping and tagging.

In 1923, the year before Lacaille began to trap this area, two trappers are reported to have taken 1,800 muskrats, and to have trapped the rats in the Main Slough virtually to extinction in doing so. If the reports are correct, probably 1,500 rats were taken from the Main Slough that year. This is credible for although 1948-49 was definitely a very good year, Lacaille has seen more plentiful rat "sign" in one or two previous years, and a population of over 1,500 on the Main Slough is not inconceivable.

4. Population turnover

Summarizing the information presented in the preceding six subsections, we may attempt to set up a model annual

population chart. It is recognized that there are inadequacies in the data, but it is believed that the evidence in general is qualitatively adequate even if not quantitatively accurate. In any case the statistics are subject to wide annual variation and quantitative results are of limited use for prediction purposes.

The known factors are (1), the autumn population; (2), the differential autumn and winter mortality of young (Table 6); (3), the number removed by trapping; (4), the adult sex ratio (45 per cent female); (5), the average litter size and number of litters; (6), the differential summer mortality of immatures.

The only unknown factor is the amount of adult mortality. It is believed, however, that adult mortality is comparatively slight except in the trapping and breeding seasons, which coincide, and during which trap mortality far exceeds mortality from all other causes. Since calculation of the survival of young is based on the ratio of young to adults in Table 6, it will be subject to correction if some adult mortality is assumed. An example will make this clear. An average of 17.4 young per adult female are born. In October, there were 14.4 young per female. The survivors, assuming no loss of adults, would therefore be 14.4 of 17.4 or 83 per cent. But if in the meantime, five per cent of the adults die the true survival rate would be $\frac{14.4}{17.4} \times \frac{95}{100} = 78.5$ per cent. This consideration is used in correcting the juvenile mortality rates.

Given a total autumn population of 1,212, a sex ratio of 122 males per 100 females, and a young to adult female ratio of 14.4 to 1, the structure of the population would be adult males 89, adult females 73, immatures 1,050. Assuming autumn and winter adult mortality of five per cent, the juvenile mortality = $100-\left(\frac{11.7 \times 95}{14.4\ 100}\right)$ = 23 per cent. The pre-trapping population then would total 963. Since the catch was 763, the breeding population remaining after the trapping season would be 200, of which 90 would be females.

For the purpose of calculation it is assumed that all 90 females each produce a litter during the first estrus period and that only 85 produce a second litter. It is assumed also that a further 5 per cent of the adults die between birth of the second litter and the October sampling period, that adult males die at the same rate as adult females through this period, and that the two litters are equal in size, each averaging 8.7 young per female.

On this basis, the first litter would be subject to 25.5 per cent mortality and the second to 21.2 per cent mortality. (It is logical to suppose that the first litter, which has been exposed for a longer period, should suffer the greater mortality).

The second year October population would be composed of 81 adult females, 99 adult males, and 1,166 immatures, or a total of 1,346. This represents a net gain of about 11 per cent. The results of the above analysis do not seem to be inconsistent with known conditions. The population of

of this slough did in fact increase in 1947 over 1946, and again in 1948 over 1947 and according to Lacaille the 1949 fall population was the heaviest he has seen in 25 years in this locality (letter December, 1949).

This section has dealt with the reproductive potential of the muskrat and the construction of a model scheme of the annual changes in population levels. The following section will discuss in more detail the factors which cause the mortality postulated in the scheme.

Part IV

POPULATION LIMITING FACTORS

1. Introduction

It is important to realize that animal populations are not fixed or static. Rather they are fluid, dynamic equilibria produced by the interaction of two opposing sets of factors--one tending to cause an increase and one a decrease. The preceding chapter was devoted to an examination of the reproductive potential of the muskrat, during the course of which examination it was necessary to assume a mortality of about 41 per cent of the juveniles in the period from their birth to the next trapping season. If this mortality is considered apart from all other factors, it must surely be deemed a serious loss. Yet, in spite of it there was an increase in the population.

Any given animal habitat will have sufficient food and shelter for a fairly definite maximum number of animals. The normal reproductive capacity of the animal will always tend to produce an excess over the maximum. If the limiting

factors are in proper adjustment, the excess animals, and only the excess, will be removed. But if overpopulation occurs, the habitat may be damaged by too close cropping of the vegetation and excessive mortality will result. Some unnatural cause of mortality, such as an epizootic, may have a similar reductive effect.

Some of the limiting factors are relatively fixed, e.g. the size of the slough and to a certain degree, the food supply. Other influences, such as predation, are quite variable. As a general rule, the variable factors cannot be considered apart from climatic variations.

2. Important limiting factors.

(a) Density

Obviously there must be a limit to the number of muskrats which can live in a given slough or marsh at a given time, quite apart from questions of food or cover. Any animal requires a certain amount of space in which to carry on its life processes. Many animals have adverse "psychological" reactions against overcrowding. In the winter months the ice-covered sloughs become virtual prisons. The available space is sharply delimited, and overcrowding probably results in increased mortality.

(b) Variations in Climatic Conditions

Seasonal variations in climatic conditions sometimes place the muskrat population under stress. The spring floods almost invariably destroy the houses and may force the animals from their burrows. First litters may be born on floating

platforms or in similarly exposed situations. In late summer smaller bodies of water may dry up and become uninhabitable. Winter frosts seal the lakes and sloughs containing the choicest foods and may turn the shallow ones to solid blocks of ice, forcing eviction of the muskrats living in them. If, however, frosts are light and snowfall heavy, even shallow lakes may be so well insulated that they do not freeze solid and the muskrats may survive in them through most or all of the winter.

There may also be long term climatic effects. A drought extending over a period of years may cause shrinkage of habitat and may induce changes in succession of the food plants on which muskrats subsist.

The suddenness or severity of the climatic change may be important. Rats can leave a slough which slowly dries up during the summer and seek quarters elsewhere without incurring great risk. But if forced from a frozen marsh they will be in unfavourable circumstances and will have a difficult time finding shelter. They will be exposed to extreme cold, food shortage, predators, and the opposition of other muskrats. Similarly a flash flood, by its very suddenness, leaves all the muskrat population in an exposed condition.

It should be pointed out that environmental stresses may be a direct, if minor, cause of death. But usually they are important in predisposing the population to mortality from other causes.

(c) Food supply

Since food is essential to life, the amount available will exert a limiting effect on an animal population. The effect varies markedly with the quality of the habitat and the season of the year. Muskrats can subsist on a wide variety of foods, so that even in winter starvation is seldom the direct cause of death. Lack of preferred foods in marginal habitats may lead to malnutrition and the necessity of foraging outside the confines of the slough. These in turn may predispose the rats to parasites, diseases, excessive predation, and accidental death.

(d) Intraspecific strife

This term was originally used by Errington to describe fighting among muskrats and has since been used by many other workers studying a variety of animals. A certain amount of fighting may occur seasonally, for example during the mating season, in species of animals which at other times of the year are tolerant, gregarious, and amiable with others of their kind. In other species the individual may be continually intolerant of all others of the same species except the members of its immediate family.

The muskrat is not particularly tolerant of others in its species, although its mode of life requires it to be semi-colonial. Live-trapping results in Wood Buffalo Park and elsewhere indicate that family groups retain a loose organization, at least through the summer and autumn, but there is also abundant evidence that the adults will attack

and kill their own young. In the late summer and autumn, rats forced from submarginal habitats by lack of water or severe frosts may have to fight their way into more favourable habitats already fully occupied. The most severe fighting, however, undoubtedly takes place during the first mating period at spring break-up. Some idea of the extent of the spring fighting may be gained from the following figures, obtained by examination of muskrats taken by Mr. Lacaille and by William Schaffer of Ft. Smith. Neither of these men continued trapping until the final day of the season, since they realized that late caught pelts are not of good quality. Nevertheless, a sample of 20 pelts taken by Lacaille on May 5, 1948, showed 12 with damage due to fighting. Schaffer's entire catch of 261 taken just at the time of break-up (approximately April 20 to May 2, 1949) was examined and 88, approximately one-third of the catch, were found to have fight wounds. The proportion was slightly higher among the males and correspondingly lower among the females.

Apart from the breeding season, fighting seems to be directly associated with population density. Thus in years when the numbers are low, it will be unimportant, while in years of peak numbers, it may be important as a factor limiting populations.

(e) Diseases and parasites

Approximately 500 carcasses were autopsied in the field. A part of each autopsy was a search for parasites or

abnormalities associated with a diseased condition. When large samples were on hand and a limited time available, as during the monthly visits to Lacaille's, the examinations were necessarily brief and many cases of light parasitism probably went undetected. Very little effort was made to discover blood parasites, and no smears of intestinal contents were made for the purpose of studying intestinal protozoa. Muskrat diseases, except in a superficial way, are beyond the scope of the present investigation and of the writer.

Diseases and parasites seem to be inevitable in all animal populations, and may be important limiting factors. Epidemics of such diseases as plague and typhus have been more efficient than any of the great wars in controlling human populations and the parasites of hookworm and malaria have profoundly influenced the history of tropical lands. It was natural then, that biologists should invoke epizootics to explain the periodic die-offs in "cyclic" species. Although this explanation lacks confirmation, epizootics do occur and may decimate an animal population in a very short period. One such epizootic has occurred on Lacaille's area in the past 25 years in 1929 or 1930. A high autumn population promised a successful spring hunt, but when the trapping season arrived, the trappers found only frozen pushups and dead rats.

The parasites recovered from the muskrats were forwarded for study to Dr. Ian McT. Cowan of the University of British Columbia and he has supplied the following list of forms:

Hymenolepis evaginata - small intestine

Quinqueserialis quinqueserialis - caecum

Notocotylus urbanensis - colon

Cladotaenia sp. - cysticercus in liver

There was also an abcess with a caseous centre, similar to some found in muskrats in British Columbia. The cause of the abcess is not known.

The significance of parasites in mortality of the muskrats became apparent only after examination of the seasonal incidence of parasites and the age of the affected animals. About 200 carcasses were examined during the winter of 1947-48 (December to March) and the low incidence of parasites was striking. Few animals were infected and infection was not severe - usually only one or two worms were found in each case.

During the first week of live-trapping, in late August, three juvenile rats died in the traps, apparently of exposure. Autopsies showed that all were heavily parasitized. Knots of cestodes in the small intestine completely occluded the lumen. The sample was small but there can be little doubt that the parasites were at least indirectly responsible for the death of these animals. No unparasitized animals of the same size and age were found dead under similar circumstances.

Between the 23rd and 27th of October, 22 muskrats were taken in steel traps for specimens. Temperatures were freezing and near freezing but sloughs were not completely frozen over. Nine of the 22 were parasitized, three heavily, and five moderately with Hymenolepis evaginata and one lightly (two cysts) with Cladotaenia sp.

Two conclusions may be drawn. (i) Heavily parasitized muskrats, especially juveniles, are less resistant to exposure to cold and probably also to other environmental stresses. (ii) Since heavily parasitized animals are found during October but not later in the winter, they must be weeded out with the onset of cold weather. Thus any factor which increases the incidence of parasites in the autumn population, may produce a serious decline of population with the onset of winter. One such possible factor is the density of the muskrat population since the spread of parasites would presumably be facilitated by close crowding. Other important factors might be the number and abundance of intermediate hosts and the mode of reinfection of the muskrat. Evaluation of these factors must await further knowledge of the life-histories of the parasites in this region.

(f) Predation

(i) Introduction

This important question has been deliberately postponed. It is such an obvious factor that too much importance is easily assigned to it.

Predation can be a limiting factor, but usually only in association with one or more of the factors mentioned previously. Thus, adverse climatic effects such as flood or drought may increase the vulnerability of the muskrats. Malnutrition and disease may weaken individuals and render them more susceptible. Intolerance induced by overcrowding may force outcasts to wander or to try to exist in marginal habitats where they would be an easy prey for predators. Where any such combination of factors exists, the remedy is not to be found only in removal of the predators. A parasitized or starving muskrat wandering overland through six inches of snow in sub-freezing temperatures may be a welcome addition to the menu of a mink, fox or horned owl, but he is doomed before the jaws snap or the talons close.

Predation is probably most serious when the muskrat population is low; for example, in the first few years following prolonged drought. There may be an expanding habitat, abundance of food, and no overcrowding to induce intraspecific strife or a high incidence of disease. Under these conditions an abundance of predators might appreciably retard the increase of muskrats. But no case of predators destroying a population over a significant area is known to the writer either from experience or from study of the literature.

(ii) Important Predators

Mink - Without a doubt this animal ranks first as a predator on muskrats. He is adapted to follow the muskrat anywhere and is powerful enough to kill adults as well as young. A muskrat surprised on land or in open water is probably easy prey, but a muskrat cornered in a confined space, such as a lodge or a runway, where the mink would be permitted only a frontal attack, must be a formidable foe. There are instances on record of muskrats actually chasing mink (Cram 1923).

Mink sign was rare on Lacaille's main slough throughout the period of this study, though common on Pine Creek. In the late fall and early winter the mink hunt the smaller sloughs which are often dry by December and covered by "hanging ice". Sign is common in such locations, and it is here that Lacaille has his greatest success in mink trapping. The distribution of mink activity is significant in the ecology of muskrat-mink relations. The mink seem to realize that they will find easier prey in the inferior habitats and they are not a serious control factor in the better ones. By the time the trapping season opens in March there are too few rats remaining in the small, dry sloughs to make it worth while to trap them even without mink predation, so the trapper suffers relatively little loss as a result of mink predation. The trapper may also reap some benefit by catching the mink, each of which may be worth as much as 15 muskrats.

Agitation for removing mink from the protected list is frequently encountered among the trappers, but its overall abundance in the delta is low. Lacaille caught only four in 1947-48, and two in 1948-49, and according to the sign, he caught most, if not all, the residents of the area. At their present density, they are not having a detrimental effect on the muskrat population.

Colored Fox - Foxes may be effective against rats on the ground or on the ice, but not in water. Most muskrats in this area live in sloughs or creeks of considerable depth, rather than in shallow marshes, and the fox is not considered to be a serious predator in summer on well-situated rat populations.

During the late fall, when many rats are forced to leave submarginal habitats, foxes may capture some of the wanderers. Direct evidence of a fox capturing a rat was read from a "sign" on Pine Creek, November 2, 1948. Between November 7 and 18, 1949, ten fox scats were picked up and examined at 27th Base Line and on Lacaille's area. Seven of these contained remains of muskrats and the other three remains of meadow mice.

Later in the winter, foxes regularly visit muskrat pushups. In the minds of the trappers this is evidence that they are hunting muskrats, but it is difficult to envision a fox breaking through a frozen pushup quickly enough to capture a muskrat. Occasionally a broken pushup is found,

and the evidence indicates that a fox is the guilty party, but, taking into account the rarity of these instances and the probable escape of the muskrats, losses from this source may be considered extremely light.

An interesting observation probably explains the persistence of the fox in an apparently fruitless endeavour. The field mouse, Microtus, seems to find the pushup suited to his needs for a winter home. If one examines the push-ups, he will find in many of them the subnivean burrows and runways of the muskrat's smaller cousin. The writer is satisfied that the fox is more interested in the field mouse than in the muskrat when he breaks into a pushup.

In any event, foxes are not numerous in the delta. An average catch for Lacaille is between five and ten in a season. Fox trappers east of Fort Smith would think they had a poor season if they did not get four or five times that number in the same time.

Coyote - The hunting habits and abilities of the coyote are similar to those of the fox. Being stronger, the coyote may have more success against muskrats in pushups, but there are few instances where pushups are known to have been broken into by coyotes. Lacaille observed three such pushups on November 4, 1948, but the sign did not indicate that any muskrat had been caught and eaten or dragged away. On November 12, he saw evidence of a coyote kill on the main slough and a second one on a pothole. The animals killed were probably autumn wanderers. On November 17 and 20 I tracked coyotes which caught Microtus on a

pushup and left remains nearby. Three scats picked up on November 20 all contained Microtus remains. In addition one showed a few hairs of the varying hare and only one some identifiable muskrat remains.

Since coyotes are much less common than foxes, their net effect on the muskrat population is believed to be negligible.

Other mammalian predators - Wolves, weasels, lynx and otter probably kill muskrats whenever they have a chance. Of these, only weasels are common and they are too small to attack muskrats except under circumstances favourable to them. None of these predators is therefore considered important.

Hawks and owls - The great horned owl and the buteo hawks are not common in the delta area. Large hawks were seen only occasionally and in the summer months. The nocturnal owl betrays his presence more by sound than by movement, but Lacaille camps out at all seasons of the year and reports that the hooting of the owls is not frequently heard. This is in spite of the fact that the mating season, and thus the time of maximum hooting, probably extends into the muskrat season when Lacaille is most active. Raptorial birds are not therefore believed to be a menace to the muskrat population.

(g) Accidental Deaths

No direct evidence of death by accident was observed during this study, although several cases of this kind have

been reported in the literature. Of most frequent occurrence is the loss of suckling young when the female is disturbed. The young may be carried some distance from the house and part of the litter may never be recovered. This is probably not an important factor.

(h) Exploitation

The activities of trappers constitute one of the major drains on the muskrat population. Since these activities are also of importance from the viewpoint of the trapper, a later section of this report is devoted to consideration of this relationship.

3. Discussion

Many methods are employed by animals to cope with the vicissitudes of existence. Migration and hibernation help many species to escape the winter; protective coloration, secretive habits, and great speed aid them to baffle predators. Most species are capable of producing many more young than would be necessary to maintain the population if all reached maturity, and in some species, of which the muskrat is one, fecundity seems to be the main adaptation for survival of the race. It is an obvious but often overlooked fact, that in any species which reproduces sexually, if two of the offspring of each pair live to maturity and reproduce, the population is maintaining itself, and if more than two survive, the population is growing. The muskrat population could be maintained in spite of about 85 per cent mortality of the young before maturity if each pair produced two litters of seven young.

It would not even be necessary for the parents to survive and breed again in succeeding years.

A second principle to be borne in mind is that there is an upper limit to population. Almost any factor may be the limiting one. If it is removed, the population will increase until another factor becomes limiting. For example predation by mink may be holding a population in check. Reducing the number of mink may result in an increased number of muskrats until they become too numerous for the existing food supply. Planting additional food species will remove this restriction and allow further increase until there are too many rats for the physical size of the habitat, when intraspecific strife or egress may carry off not only the excess, but most residents.

A third principle worth recalling has been called "compensation" by Errington. It depends on the obvious fact that a muskrat can only die once, so that if a predator gets a rat, parasites or starvation cannot. Thus, when predation is severe many of the victims will be animals which would otherwise have died from another cause, so the net effect is less serious than it would appear from consideration of the severity of the predation alone.

Management often consists in identifying the limiting factor and estimating the means and practicability of eliminating it. Predators can be reduced in number; water levels can be controlled to provide more suitable

habitat; food plants can be introduced; parasites can sometimes be eliminated. Little can be done to prevent losses resulting from adverse climatic conditions once the most superior habitat is provided. Using the principle of compensation, however, it may be good management to substitute a more desirable form of mortality (autumn trapping) for a less desirable one (winter kill).

Good management should also involve prophylaxis--the detection and prevention of abnormal mortality, notably epizootics. The danger signals are imperfectly known, but overpopulation is usually considered to predispose a species to epizootics. In this case increased trapping might be employed to relieve an overcrowded condition and lessen the danger.

One of the difficulties is to convince the trapper that most of the embryos in the pregnant female are not potential pelts on the stretcher, but represent a buffer between the survival of the muskrat as a race and the adversities it faces in an essentially hostile world.

Part V

ABUNDANCE AND ECONOMIC IMPORTANCE

1. Variations in Abundance

Animal populations are not fixed. They are subject to variation in numbers which may be sporadic or regularly recurring. The regularly recurring variations or fluctuations may be short term or long term ones. Both

types are discussed below.

(a) Sporadic variation

Population declines caused by irruptions of elk, deer and other species may be classed under this head. Little is known of this type of population behaviour in muskrats. Sudden die-offs such as have occurred in muskrat populations in the north may be sporadic or they may be associated with cyclic fluctuations.

(b) Regularly recurring variation

(i) Annual cycle of abundance

This has been discussed in detail in a previous section. Figure 37 illustrates graphically how a small breeding population undergoes rapid increase during the summer, reaches a peak in autumn, declines through the winter and falls sharply in the trapping season. The graph may vary from year to year, but its general shape remains fairly constant.

(ii) Long term cycle

Elton and Nicholson (1942) present rather convincing evidence of the existence of a ten-year cycle of abundance in the Canadian muskrat. Their study terminated in 1939 at which time they foresaw that a peak would probably occur about 1941. On the basis of their analysis a "low" should have occurred about 1946 and another peak is due about 1951.

In Wood Buffalo Park there was a pronounced low from 1945 to 1947 which has been followed by two much better years. The outlook for 1950 seems to be for a peak crop. This area of the Park seems to be in a phase with the postulated "cycle".

Many theories have been proposed to account for the cycle but all have been found wanting. This does not disprove the existence of a cycle. Regardless of the outcome of future investigations into population phenomena, we must proceed at the present time on the hypothesis that, in the normal, undisturbed course of events, a decline is at hand.

Many investigators believe that the crash decline is in some way related to the density of the population and the theory has much to commend it. High densities favour the spread of parasites and diseases, though no specific pathogen has been discovered which would account for a high mortality. Overpopulation may also result in food shortage, perhaps not in the gross amount of food available but in the supply of some trace element or vitamin. Assuming that density is in some way connected with the crash, a possible management scheme would be to curtail the rate of increase by attacking the population as it reaches a maximum. In the case of the muskrat this would involve an autumn reduction in population to bring it to a "safe" winter level, since any tendency to overpopulation must be aggravated by the ice-bound and shrinking condition of the habitat in winter.

It is significant that fluctuation has been less intense on the portion of the area trapped by Lacaille where the population has been held in check by systematic cropping, apparently neither too intense nor too lax.

2. Provisional Estimate of Productivity

In the light of the preceding discussion it is obvious that no estimate of average potential productivity will have much meaning. It will be too low when the population is at a peak and vice versa. It may be close to the mark at one stage in the periodic increase and again during part of the decrease. The estimate which follows is almost entirely subjective, and is based on the picture the writer formed as a result of ground and aerial observations. Probably the best which can be said for it is that it represents an order of magnitude. All areas were compared with Lacaille's for which an average productivity was reliably obtained.

The estimates are shown in Table 8 and the areas referred to are outlined on the map, Figure 38. A considerable area north of Lake Claire has been omitted as has a similar area south of Lake Claire. No information is available concerning the possible productivity of these areas, but it is known that at present they are not being exploited to any extent and thus are not contributing significantly to the catch. They consist of wet meadows and floating bogs. The former do not provide suitable winter habitat, and the latter are difficult of access and difficult to trap.

Table 8. Provisional estimated productivity of Peace-Athabasca Delta.

Subdivision	Area Sq. Mi.	Productivity	Rats per Sq. Mi.	Acres per Rat
Upper Athabasca				
Lacaille	10	1,200	120	5.3
General	165	16,500	100	6.4
Lower Athabasca	120	9,600	80	8.0
Peace	150	7,500	50	12.8
Special				
Egg Lake	100	5,000	50	12.8
Dempsey	55	4,400	80	8.0
Total	590	43,000	73	8.8

Under the registered trapping area system it will be possible to collect data on the actual productivity of these areas. In using this information, however, allowance will have to be made for the diligence of the trappers concerned. In other words, the actual harvest may well be less than the potential harvest at all phases of the cycle.

A more reliable means of estimating population trends would be to take an annual census of muskrat houses on specially chosen sloughs representative of each of the major divisions. The count should be made as early as possible to take advantage of the good travelling conditions and better visibility obtainable before the snow becomes too deep.

3. Place of the Muskrat in the Economy of the Trappers

The prime object of this survey was to devise means for more efficient management of an important resource for the benefit of those who are dependent on the resource. It is important therefore, to understand something of the way of life of the trappers. Most of the licensed

trappers are Indians, so the discussion which follows is concerned with the Indian economy.

(a) Distribution of income

The Indians derive cash income from two sources--sale of goods and sale of services. The goods which an Indian has for sale are those which he harvests from natural sources. Furs are by far the most important of these. With the development of the goldeye fishery in Lake Claire, fishing has become a cash industry available to all who wish to take advantage of it. Incidental sources of income may be important for individuals or families; for example the manufacture of snowshoes by Isadore Simpson at Peace Point and of leather goods by others, although this latter work seems to have been largely preempted by half-breed women and even among them the art is dying out.

The services which an Indian may sell fall generally under the heading of unskilled labour. This usually implies a low wage. A few Indians and half-breeds secure better-paid jobs as river pilots or as guides and interpreters for government or other agencies. The great majority either make no effort or are unable to sell their services.

Certain non-cash items are important in the native economy. Fish and wild game are usually available for food; berries and other edible plant products abound and there is plenty of wood for fuel. The Indians make limited

use of wild fruit in season, but do not attempt to preserve it. Lacaille, on the other hand, may spend ten days picking blueberries and raspberries and put up as much as 200 quarts for later use.

Moose and caribou leather is still an essential for certain items of apparel. It is seldom used now for teepees, dog harness, sleigh wrappers and many other purposes for which it was once used. Canvas and linen thread, which must be purchased, have all but replaced skins and sinews which cost only the work of preparation. This is very characteristic of the loss of independence which the Indian has undergone in the past century and a half.

A very few Indians still make essential items of equipment which are required for transportation or the hunt. Alex Gibot, for example, manufactures his own sleighs from birch and in the summer of 1948 constructed a canoe. Many Indians make snowshoes, some of excellent quality, others of very poor quality.

A few individual whites and the missions have proved that limited agriculture, at least the cultivation of a garden, is entirely feasible. Lacaille's garden is a source of pride and pleasure and a major factor in his economy.

The seasonal distribution of income is also important. Trapping may be carried on from November 1 to early May. From May to October the rivers and lakes are free of

Table 9. Income from Fur of 14 Wood Buffalo Park Trappers.

	Muskrat			Squirrel			Ermine			Mink			Other		
	No. pelts	Value $	% of total value	No. pelts	Value $	% of total value	No. pelts	Value $	% of total value	No. pelts	Value $	% of total value	Value $	% of total value	Total value $
Lacaille	651	1,302	74.5	403	181.00	10.4	67	114.50	6.6	4	124	7.1	23.75	1.4	1,745.25
Flett	150	300	36.1	1	00.45	--	300	513.00	61.7	-	-	-	18.00	2.2	831.45
Paquette	175	350	100.0	-	--	--	-	--	--	-	-	-	-	-	350.00
Campbell	24	48	54.2	70	31.50	35.6	5	8.55	9.7	-	-	-	.50	0.6	88.55
Subtotal	349	698	54.9	71	31.95		305	521.55	41.0				18.50	1.5	1,270.00
Cascammon	250	500	70.1	200	90.00	12.66	--	--	--	-	-	-	124.00*	17.4	714.00
Gladu	245	490	76.7	234	105.00	16.5	7	12.00	1.9	-	-	-	31.75*	5.0	638.75
Descoines	285	570	55.4	240	108.00	10.5	68	116.00	11.3	7	217	21.6	19.50	1.9	1,030.50
Martin, J.	264	528	75.0	200	90.00	12.8	50	85.50	12.1	-	-	-	-	-	703.50
Martin, M.	100	200	83.5	50	22.50	9.4	10	17.10	7.1	-	-	-	-	-	239.60
Ratfat	170	340	90.4	80	36.00	9.6	--	--	--	-	-	-	-	-	376.00
Simpson Jr.	126	252	100.0	-	--	--	--	--	--	-	-	-	-	-	252.00
Tourangeau	260	520	71.8	50	22.50	3.1	70	120.00	16.6	2	62	8.6	-	-	724.00
Vermillion	37	74	38.6	116	52.00	27.2	9	15.40	8.0	-	-	-	50.00*	26.1	191.40
Whitago	315	630	76.6	300	135.00	16.4	15	25.50	3.1	1	31	3.8	-	-	821.50
Subtotal	2,052	4,104	72.0	1,470	661.00	11.6	229	391.50	6.9	10	310	5.4	225.25	4.0	5,691.25
Total	3,052	6,104	70.1	1,944	874.00	10.0	601	1,027.55	11.8	14	434	5.0	267.50	3.1	8,707.00

*Includes Marten

Average Fur Prices used in Calculating Values in Table 9

			Other		
Muskrat	=	$2.00	Lynx	=	$15.00
Squirrel	=	.45	Wolf	=	3.00
Ermine	=	1.71	Marten	=	25.00
Mink	=	31.00	Fox	=	2.25

ice and fish are available. Some other natural products have more restricted seasons, either by law (moose) or by their nature (ripening of berries, migration of caribou). Employment for wages is usually possible only in summer because it is connected with the movement of freight, construction of buildings and so forth. It must also be borne in mind that in most cases, summer jobs take the men away from their homes so that they have no opportunity to grow a garden, take proper care of their families and dogs or lay in fuel for the winter.

(b) Distribution of income derived from fur

Table 9 is a summary of the catch of Sy Lacaille and 13 other Wood Buffalo Park trappers chosen at random from the list prepared by Chief Warden Kirkby for the 1947-48 season. Every tenth name on the list was chosen. The first four men are not Indians, the remainder are.

The average income of the Indians was about $569. This compares favourably with Kirkby's estimate of $559 for all Park Indians and suggests that the sample is representative. Market conditions are, of course, subject to much variation. The low price for fox is perhaps unusual, but is at least partially offset by the high price of squirrel, ermine and mink and the restricted open season on marten.

Of particular importance is the contribution of muskrat--about 70 per cent of the value of all fur taken. Muskrats were the only furs traded by two of the trappers. One of these, Paquette, is a permanent employee of the mission at Chipewyan who is given time off each spring for a muskrat hunt. The other, Simpson Jr., is a youth, still dependent on his father.

The only case of muskrat contributing less than 50 per cent was that of Vermillion, a widow from the Upper Peace. In her case squirrels and two marten were each almost as important as muskrat. There is a possibility that the marten were donated by another member of the family who caught more than his limit, but the old widow could easily have taken them in her squirrel traps. Squirrel and weasel are often the only furs available to the aged and infirm.

Ratfat and M. Martin are examples of shiftless trappers. Each could easily have doubled his catch.

Descoines traps the Birch River, and this is the reason for the greater variety of furs in his catch--seven mink, one lynx and one wolf. The catch of fine furs tends to minimize the importance of his muskrat catch which contributed $570.

Cascammon traps the lower Peace, taking muskrats south of the river and ranging north for fine fur. Three marten, two lynx and three wolves formed a significant part of his catch.

Lacaille, who makes a business of trapping and goes about it in a careful and methodical way derived 75 per cent of his income from muskrats. He has no cash income from any source other than fur. His case is good evidence that an earnest trapper in the delta proper will depend on the muskrat for 70 to 80 per cent of his income.

The seasonal distribution of income is also important. With a spring season only, the trapper must exist from November to March on 30 per cent of his income from fur while 70 per cent is earned in the next two and one-half months. There are two evils inherent in this system. First, there is a hardship imposed during the winter, when other sources of income, both cash and non-cash, are few. Second, the Indian finds himself in a position of sudden wealth in May, when living is easy and the temptation to gamble or squander his fur money is usually too great to be resisted.

4. Factors Affecting the Value of the Resource

On analysis, there seem to be four important classes of factors affecting the monetary value of the muskrat as a resource, particularly as it concerns the individual trapper.

(a) The quality of the pelt

The quality of muskrat pelts depends on the condition, size and colour of skins harvested. These vary according to the season of the year.

In any sample of muskrats, the majority will be young animals of the year. These animals are not fully grown until they attain sexual maturity in March, so autumn and winter samples must contain a high proportion of medium and small muskrats. Then too, immature rats, like other rodents, undergo a continuous succession of moults from birth to sexual maturity. As a result of the overlapping of the growth and moulting stages of succeeding generations of hair, these immatures are seldom found in a "prime" condition. From the point of view of the manufacturer, pelts from such animals are undesirable since they are not likely to stand up well to tanning and other preparatory processes.

After sexual maturity is attained, the muskrats moult in a different fashion. Small, irregular areas are being replaced almost constantly through the summer, autumn and winter, and consequently the skins are in a semi-prime condition during all of this time. With the onset of reproductive activity in early spring, the growth and replacement of hair is inhibited and the pelt becomes fully prime. Thus although the muskrat grows very little in its second or any subsequent year the pelt value varies seasonally because of moulting.

The term "condition" applies to other factors as well as "primeness", which, in its restricted sense, is the condition attained when all the hairs have reached maturity or full growth, are firmly fastened to the pelt, and should have their maximum

sheen and "life". Prime pelts may still be "burned", "rubbed" or in some other way damaged by natural processes. Primeness is easily recognized because it is associated with a creamy white coloration of the pelt. Experienced buyers, however, examine closely the hair itself for evidence of other condition factors.

Size is more important than condition in determining the value of the pelt. Color is of little importance since almost all muskrat is dyed in the manufacturing process.

Table 10 and Figure 39 illustrate changes in the value of muskrat pelts from October 1948 to March, 1949.

Table 10. Seasonal variation in value of muskrat pelts, Wood Buffalo Park, 1948-49.

	Average Value	% of Top Price	Number of Specimens
October	$0.92	33	24
November	1.14	41	36
December	1.48	54	47
January	1.65	60	43
March	2.40	88	51
Total			201

The percentages are based on the top price available during the period which was $2.74 for XL semi-heavy pelts. This price was realized by some of the March pelts.

Exception may be taken to this method of comparison, since the tariff was not the same throughout the winter. The top price available for October pelts was

$2.30, or less than 100 per cent of the top price in March. In effect, what we are measuring is the comparison between the value of pelts harvested in the autumn and what the same pelts might have brought in March. Changes in market conditions, as well as changes in quality of individual pelts, are influencing this curve, and autumn pelts are therefore shown at the greatest possible disadvantage. The curve representing average weight of the rats in each monthly sample is also plotted. The general similarity in the two curves indicates that pelt size is probably the major factor influencing pelt value.

The writer is indebted to A. J. Cooke and the Saskatchewan Fur Marketing Service for their many courtesies in evaluating and reporting on the individual pelts in this series.

(b) Number of pelts harvested

Other things being equal it is obvious that the trapper will profit in direct proportion to the number of pelts taken.

(c) Care of the pelts

Shooting, careless skinning, too-quick drying, and improper stretching, all lower the value of the skin. These differ from other "condition" factors because they are independent of the life history of the muskrat and season, and are almost wholly within the power of the trapper to control. The general mechanical damage resulting from bullet wounds, knife cuts or fight wounds devalues the pelt in proportion to the size of the area of the pelt which is damaged. A pelt which is dried too quickly becomes brittle

and incapable of further treatment. Similarly over-stretching and understretching produce undesirable effects and reduce the value of the pelt and in some cases render it valueless.

Carelessness by trappers in preparing pelts for market is deplorable because it is a needlessly wasteful practice and results in a lowered income.

(d) Fluctuations in market conditions

In recent years, muskrats have sold locally for as little as 30 cents and as much as three dollars. It is obvious that such wide fluctuation must exert a profound influence on the economy of a community such as Ft. Chipewyan.

(e) Interrelationships of factors affecting value

The care with which pelts are prepared for market is related to each of the other three factors. The larger the catch the greater the tendency to speed up the skinning, stretching and drying, and thus the greater the likelihood of damage to the pelts. Damaged pelts cause lowered quality and bring a price lower than their potential value. As already pointed out, however, the trapper has it within his power to minimize this factor.

The rate of growth and sequence of moults are on the contrary, relatively fixed and not under the control of the trapper. Individual pelts will always reach optimum size and condition in March unless drastic changes occur in the environment or organization of the animal. Balanced against this is the winter kill which results in fewer pelts

being available in March than earlier in the winter. Many pelts of lower quality could probably be harvested in the late fall without appreciably lowering the spring catch of high quality pelts if the fall trapping was confined to surplus animals.

Another important relationship exists between market fluctuations and the number of pelts required to provide the trapper with an adequate income. The trapper may regulate his catch according to the ability of the muskrat to withstand the exploitation, but he has very little, if any control over market conditions. At this time it is only necessary to point out that as the market price declines the trapper must increase his catch or suffer a reduction in income. Most of the trappers can ill afford a reduction in earnings; neither can the muskrat population stand exploitation beyond reasonable limits. Further analysis of this important question will be found in the following section.

Part VI

PROBLEMS OF HARVESTING AND MARKETING

1. Factors Affecting the Time of Harvesting

The question of whether an autumn, spring or split season is the most desirable is a difficult one. A solution worked out on paper may be unworkable in practice. The following points seem worthy of consideration:

(a) The annual population peak occurs in the autumn

After the annual maximum is reached in autumn there is a frittering away of a significant portion of the population. According to current views of some wildlife managers the lost animals are a biological surplus over and above the winter carrying capacity of the environment. Since these animals will not be present in the spring, it may be desirable to harvest them in autumn. This is an application of the principle of substituting a desirable form of mortality of an undesirable one.

(b) Many muskrat summer in habitats unsuitable for winter occupancy.

Figures 40 to 42 illustrate habitats which cannot support any muskrats in winter. The whole population of such habitats is a surplus. Here autumn trapping cannot affect the spring population and must result in a profit.

Figure 40 shows a portion of the bank of an island in the Athabasca River, near Lacaille's, which is separated from the mainland by a narrow, shallow channel. Because of sandbars above and below the island there is very little current, so that the channel simulates a lake. The bottom, pure sand, is barren. On the shores, there are dense stands of Equisetum which are capable of supporting a number of muskrats in the summer. After the ice forms nothing is available unless the rats leave the water to get it, and even if they do, frozen Equisetum is pretty scanty fare. In the close-up, Figure 41, a number of burrow entrances

one below another may be seen. These were constructed as the water level in the river dropped during the summer. Twenty-four rats were removed from this channel in late October, 1948. Although they were worth only 33 per cent of top quality spring pelts they sold for $22.15 or an average of $0.92. Trapping in autumn is easy and such returns amply repay the trapper for his effort.

(c) There is a long period of low earning power in late autumn and winter.

A limited amount of autumn trapping would enable some trappers to distribute their income more equally over the year, and to increase their earnings in the critical period between freeze-up and the spring muskrat season.

(d) Much useful information can be obtained from pelts taken in autumn.

Using the pelt-primeness method of age-determination and the presence or absence of nipples for sex identification, two important statistics can be obtained easily from examination of autumn-caught pelts. These are the age-composition of the population and the sex ratio, both essential in predicting population trends.

(e) The danger of overpopulation is greatest during the winter months.

If overpopulation predisposes a population to a crash decline, and there is at least some evidence that it does, then it is important to prevent such overpopulation. It is obvious that winter is the critical period

since any effects of overpopulation will be intensified in the much restricted, and securely sealed, winter habitat. The time to reduce the population, therefore, is in the autumn.

(f) Waterfowl mortality due to late spring trapping and illegal kill of waterfowl by late trappers.

Accidental capture of ducks in traps is much less serious in the Athabasca-Peace delta than it appears to be in Maine (Gashwiler, 1949). Lacaille catches from 10 to 15 ducks each spring. Trappers who depend less on trapping and more on shooting in open water probably take fewer ducks accidentally. The amount of illegal shooting of waterfowl seems to be less than formerly. An early closing date for taking muskrats will keep the illegal shooting at a minimum, since the trappers have no reason to be in the bush after the muskrat season ends.

(g) Decline in quality of the pelts after the end of March.

Unavoidably there are no quantitative data on the amount of the decline, but subjective evidence and the opinion of many fur buyers indicate that the decline is real, and that for this reason it is not economical to continue trapping long after the breakup.

The high incidence of fighting correlated with the mating season, produces a large proportion of damaged pelts at that time, and this fact should also be considered.

(h) In the late spring, the population is at its lowest level of the year.

At this time the population consists of the individuals that have survived the dangers of autumn and winter and must be depended on to produce the next crop.

2. Methods of Harvesting

(a) Trapping versus shooting

In general, trapping is to be preferred to shooting for several reasons.

Trapping produces fewer damaged pelts and such damage as does occur is usually less serious in trapped specimens since it is confined to the region of the limbs and the ventral (less valuable) side of the pelt.

Shooting can only be done after the break-up of the ice. By this time the skins are lighter, the condition is deteriorating, and damage due to fighting is considerable.

It is more difficult to exercise control over a rifleman than over a trapper. This applies to the movements of the man himself as well as to the number of animals killed by him in a given period of time. A rifleman may poach his neighbour's rats with little danger of detection; it is more difficult to do so with traps.

Certain habitats such as streams can only be harvested when they are free of ice. In many cases, shooting will be the most efficient means of harvesting these areas.

(b) Setting of traps in houses

The present regulation protecting muskrat houses is in many respects a wise one and should probably remain in effect for the present. There have been however, numerous requests for relaxation of this restriction and there are arguments which have considerable weight in favour of the requests.

The chief reason for protecting the house is that it is the muskrat's defence against predators and adverse weather conditions. This is probably important, although Lacaille feels certain that the animals on his slough also have bank burrows to which they can retreat if necessary. It seems certain that a careful trapper can repair a house or a pushup, after setting his trap in it, in such a way that there is no danger of its freezing or otherwise becoming untenable. A house is actually in less danger of freezing as a result of careful disturbance than is a pushup. Although the consequences of destruction are more serious in the case of a house than of individual pushups, the loss of a large portion of pushups must be a serious matter for the muskrats. Instructing the trappers in the techniques and importance of careful trapping would largely obviate the most serious objection to house trapping.

Of minor importance is the fact that on many small sloughs no pushups are built. The trapper cannot harvest the rats in these sloughs through the ice under existing

regulations, so he either lets them go or takes them late in the season after they have passed their peak value.

3. Care of the Pelts

Carelessness in preparing pelts for market costs muskrat trappers many hundreds of dollars annually. When carelessness results in wasted pelts, it is the legitimate concern of those entrusted with management of the resource to investigate it. The nature and causes of such carelessness are many but the result is always pelts of lowered value.

Some of the undesirable practices can be ended by legislation; for example by preventing the sale or purchase of unskinned animals or green pelts. The root of the trouble, however, lies in the attitude of the trappers, and this can only be altered by a program of education. For the most part, the trappers understand the methods of preparing skins, but do not understand the desirability and importance of taking proper care. It seems to be difficult for the Indians to differentiate between "money" and "more money". If some money can be had for very little work, why do more? The present system of buying furs on the basis of a quickly calculated average price instead of by evaluating each pelt on its merits, does nothing to give the Indian an appreciation of the value of a well-prepared skin.

4. Marketing

It is realized that marketing of the pelts per se is not strictly speaking, within the province of the present

writer. However, it is important to point out the intimate relationship which the fluctuation in price bears to the conservation of the muskrat.

It has already been noted that approximately 70 per cent of the income from furs of Wood Buffalo Park trappers is derived from muskrats. If market prices are steady, income varies directly as the number of rats harvested. On the other hand, if the income is to remain at about the same level, the size of the harvest and the market price must stand in inverse relation to one another. Obviously there is a limit above which the catch cannot rise without detriment to the muskrat population. Also, this limit varies in a more or less regular pattern as the abundance fluctuates in the apparent ten year cycle.

Moderate fluctuations in price can be absorbed by varying the trapping intensity, by adjustments in the trapper's income, or by a combination of the two. Extreme fluctuations unavoidably bring hardship on the trapper, the muskrat population, or both. One year of overtrapping, it must be remembered, may result in lower catches for one or more succeeding years, so that the hardship may be prolonged even if the market recovers.

It is extremely doubtful that any management program can produce or maintain a 50 per cent increase in the muskrat catch. But a rise or fall in the market may well cause a 50 per cent decrease in the income of the

trapper. It has been mentioned previously that the price at Ft. Chipewyan increased tenfold within a 10-year period. This should be sufficient proof that market fluctuations are of basic importance in the management of the muskrat in an area which is so dependent on that one resource.

Part VII

SUMMARY

The area considered in this report is the joint delta of the Peace and Athabasca Rivers at the west end of Lake Athabasca. The geological changes which have influenced its formation are briefly discussed and evidence is presented to show that similar geological processes are actively at work at the present time, laying down beds of silt, altering the course of the rivers, closing old channels, and cutting new ones. The nature of the vegetative cover is described. The climax type is forest of white spruce but all intermediate phases between barren mud flats and the climax forest may be found.

Certain aspects of the life history and population dynamics of the muskrat are described in some detail, and particular attention is devoted to means of realizing the greatest monetary value from this resource. An attempt to relate this phase of the study to the sociological and economic peculiarities of the lives of the Indian and mixed-blood trappers is made.

It is obvious that the muskrat is the most important crop produced in this area. Management, at the present time,

is being carried on at a low level of intensity, and depends mainly on restrictive legislation alone for the conservation and optimum utilization of the muskrat crop. An increase in the intensity of management practices is indicated, not, however, to the extent that is required on more southern marshes, as for example in Manitoba or the United States.

In the course of this study approximately 160 muskrats were live-trapped, tagged and released and approximately 100 were subsequently recovered. About 400 autopsies were made and individual grades were obtained on an equal number of muskrat pelts taken at intervals throughout the winter. The sex and age composition of the population was investigated by examination of some 1,200 pelts and carcasses.

A variety of food is available in abundance during the summer months but winter food is restricted in kind and amount to that which can be reached under the ice. Cattail, Typha latifolia, seems to be the most important food plant.

Stream-dwelling muskrats use bank burrows for shelter the year round. Slough-dwelling rats also use burrows in summer and probably to a limited extent in winter, but, in addition, they construct houses in the fall and push-ups in the winter. A house may be distinguished from a pushup by one or more of the following characteristics: it is built on a firm base or otherwise anchored in place; it contains a well-defined chamber; it is usually on the periphery of the slough; and it is constructed largely of

emergent vegetation rather than submerged plants.

Much overland movement takes place in the autumn and is interpreted to indicate that rats in secure habitats are seeking more security for the winter.

Spring movements are less frequently detected since most travelling probably takes place in the water which is then at its highest level. Repopulation of vacant habitats has been observed.

Testes of the males begin to enlarge in January, and attain 10 times the resting volume in March, in which month they descend to the scrotum. Breeding begins when the ice leaves the sloughs, usually in late April. All evidence to date indicates that two litters are produced. The number of young per litter has been high in the past two years--seven to ten per female. There is some evidence of pairing, at least for the season.

The sex ratio in a sample of 1,200 muskrats shows a clear cut prepoderance of males (138:100). This is higher among juveniles (146:100) than among adults (122:100). The disproportionate reduction in the number of males seems to be brought about by differential trap mortality and possibly also by fighting and the greater tendency of the males to wander.

The age composition in the fall may run as high as 88 per cent young of the year. Mortality of juveniles from birth to March 1 seems to be about 40 per cent.

Population limiting factors discussed are density, climate, winter food supply, intraspecific strife, diseases and parasites, predators, and accidents. Interactions among these factors are complex and should be taken into account in assessing the importance of a given factor. Climatic variations are extreme at this latitude and often predispose the population to mortality from other causes.

The population undergoes a marked annual cycle of increase and decrease, and apparently also a longer cycle of approximately ten years duration. An increase has been apparent for the past three years so that a decline is to be anticipated.

The productivity of the delta is conservatively estimated to be 40,000 pelts annually. In peak years this figure may be exceeded.

The mode of life of the trappers is briefly discussed. Cash income is derived largely from the sale of furs. The muskrat accounts for about 70 per cent of the value of all furs taken. Other natural products, such as fish and wild fruits, are available in summer and there is also greater opportunity for remunerative employment at this season. The most difficult period for the trapper extends from the end of the summer to the beginning of the muskrat trapping season.

Greater effort should be made to encourage the

Indians and mixed-bloods to raise gardens and utilize more efficiently the wild crops they harvest in order to avoid unnecessary purchases of substitute materials.

If the Indian is to reap full benefit from an increased income, a far-reaching program of education and reorientation is urgently required. There are innumerable ways in which his physical standard of living can be improved, and cultural aspects should not be ignored. Opportunity for creative work is a necessity, whether it be decorative leather work, wood working, or a less practical art. An intelligent and co-operative body of trappers is perhaps the most effective factor in conserving the fur resources.

The value of the resource depends on the value of individual pelts, the number of pelts taken, the care the pelts receive, and the state of the market. The first two are subject to regulation by legislation, the third, by legislation and education. The fourth is in need of further study.

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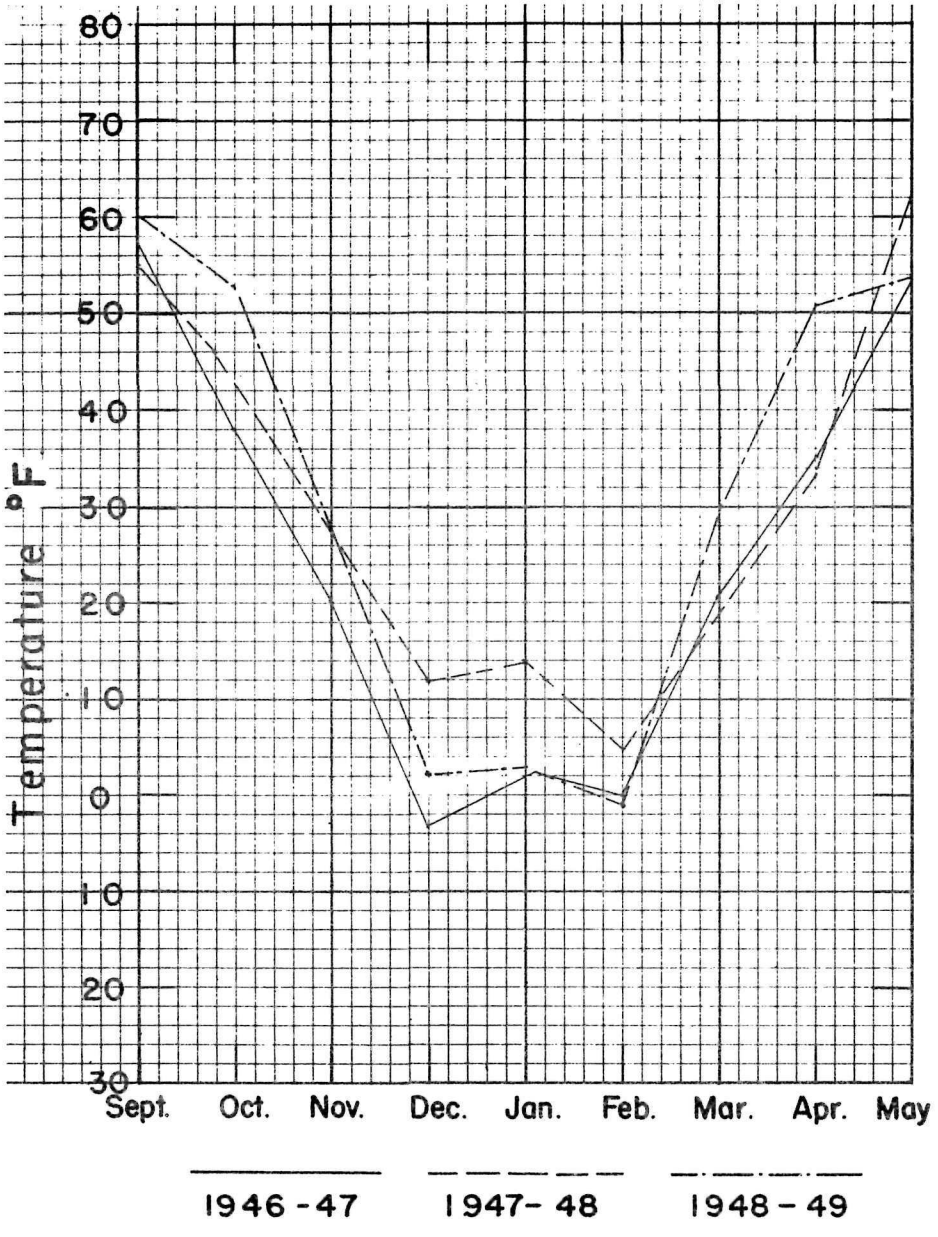


Figure 1

Mean Daily Maximum

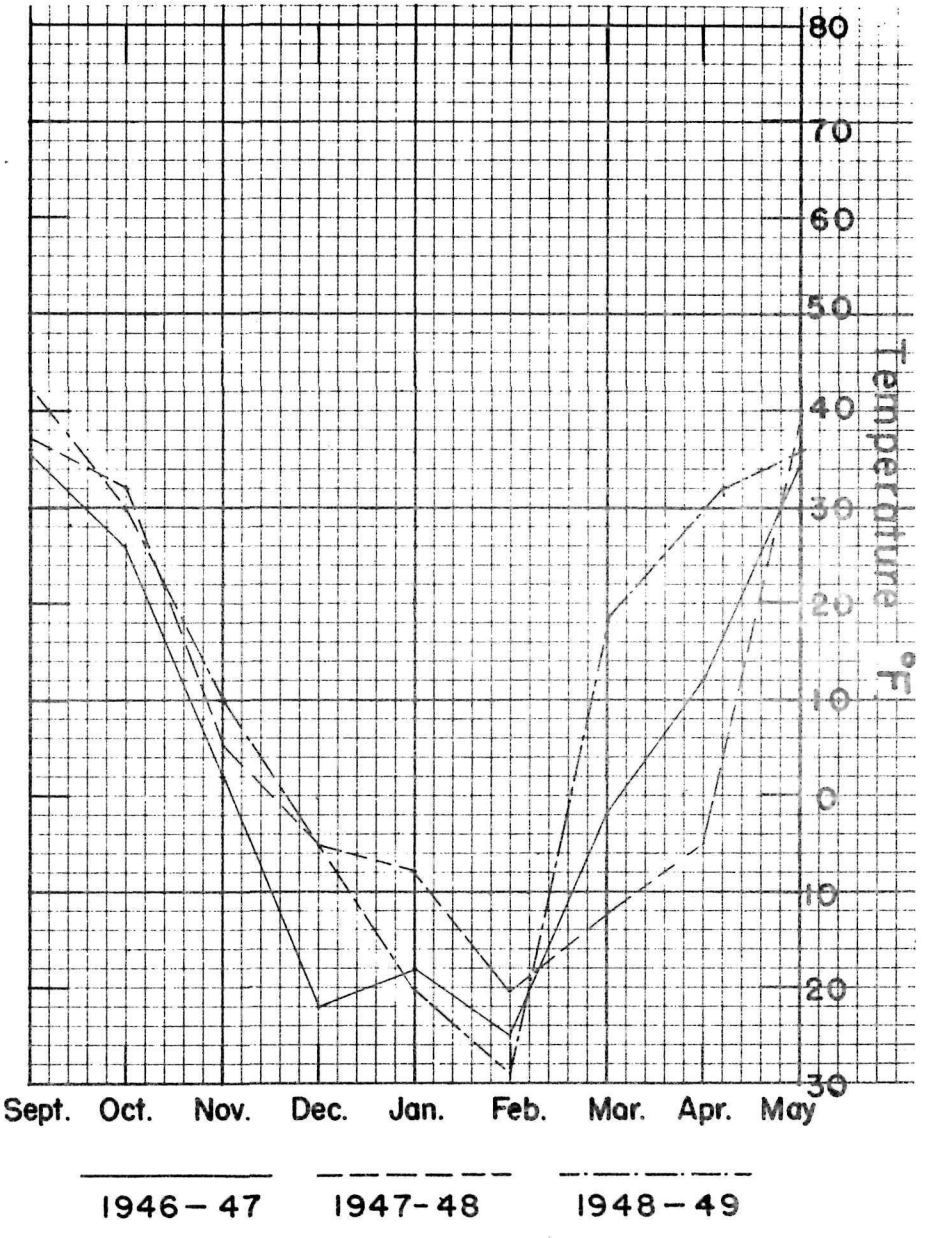


Figure 2

Mean Daily Minimum

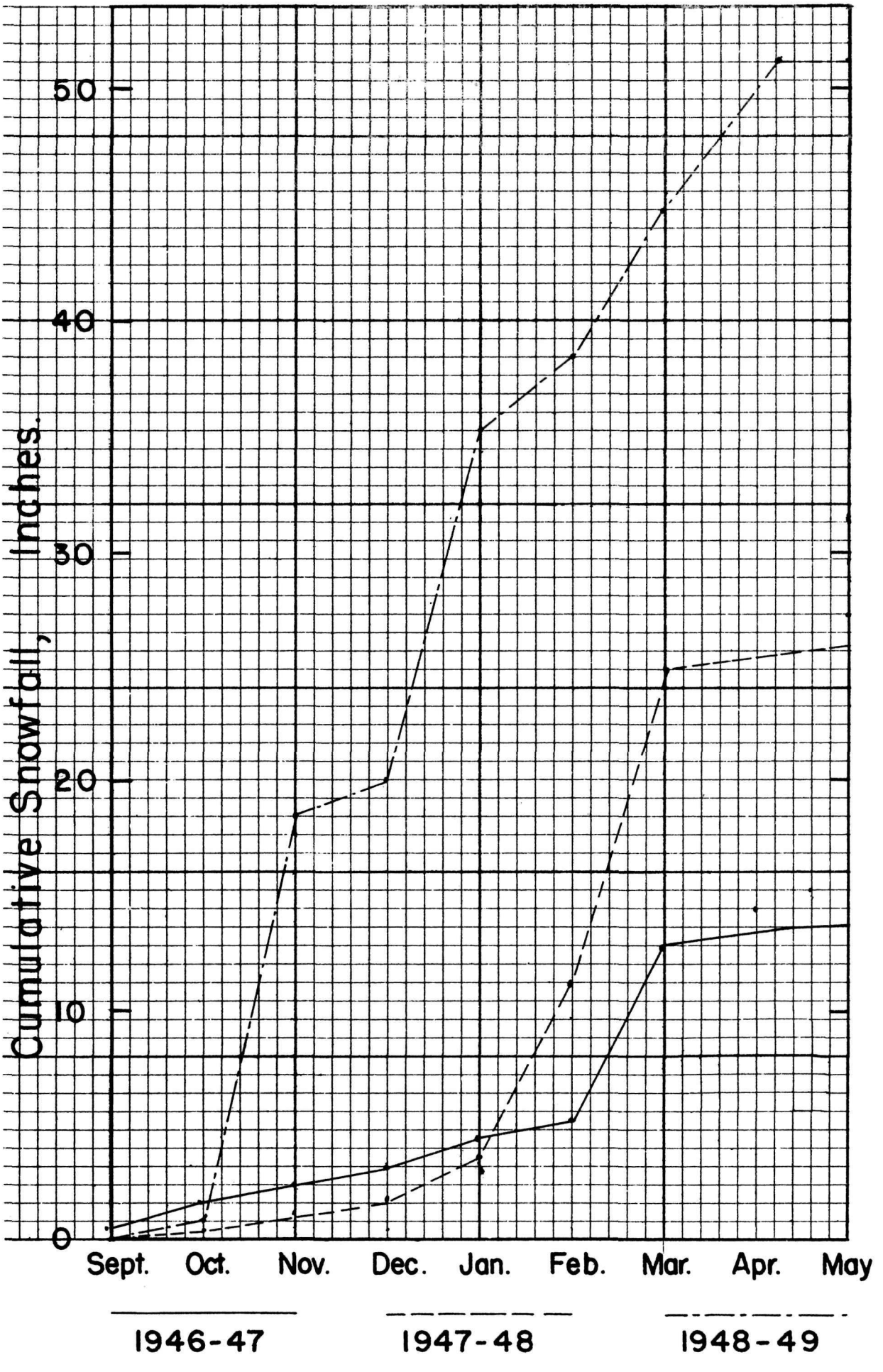

Cumulative Snowfall, Inches.
50
40
30
20
10
0
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
1946-47
1947-48
1948-49

Figure 3

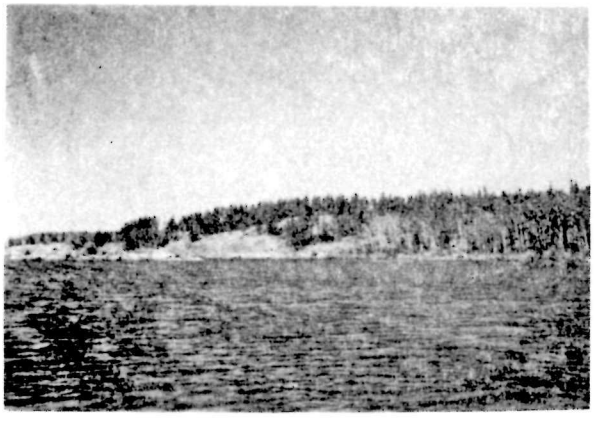


Figure 4.

Pushup Lake in the Egg Lake area. The productivity of lakes bounded by precambrian granites is low. Only a small portion of the Peace-Athabasca delta lies in precambrian country.

Figure 5.

Head of Chilawa's Snye, Egg Lake area. Islands of precambrian rocks are seen in the distance.

Figures 6 and 7.

Two views of the delta of Baril River as it enters Baril Lake from the north (Peace River). There is abundant feed for muskrats in this comparatively small area.

Figure 8.

Baril Creek which flows between Baril Lake and Lake Claire. Muskrats are found in small numbers along its entire length. The extensive wet meadows through which it flows are poor winter habitat.

Figure 9.

Solomon Lacaille's cabin on the west bank of the Athabasca River. Note the character of the river bank which is being eroded and the size of the mature timber.

Figure 10.

Solomon Lacaille on one of his trails showing typical spruce wood in winter. Note regeneration and dense under story.

Figures 11 and 12.

Aerial views of Lacaille's Main Slough. Note the large patches of emergent vegetation extending well out from shore which provide abundant, and always available, winter food. The Athabasca River shows in Figure 11 with Lake Mamawi in the distance.

Figures 13 and 14.

Summer views on the Main Slough showing marginal growth of cattail and abundance of yellow pond lily.

Figure 15.

Appearance of the Main Slough in winter.

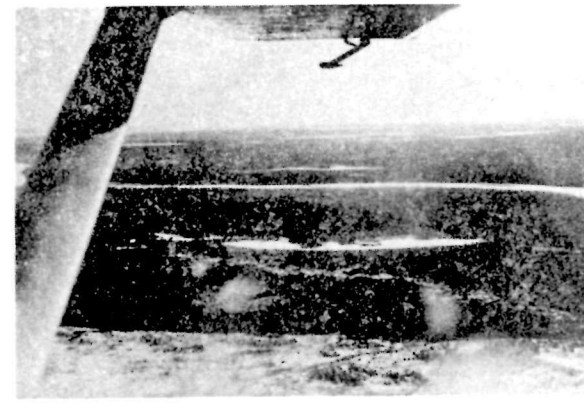


Figure 16.

The slough known as Big Snye in the middle distance, between sand ridge (foreground) and the Athabasca River. Note the extensive growth of emergent vegetation on the far side of this slough.

Figure 17.

Potholes on Lacaille's area between Pine Creek (foreground) and the Athabasca River. Some of these smaller sloughs produce 50 to 100 muskrats per year. There is a colony of beavers on this section of Pine Creek and another in the most centrally located pothole.

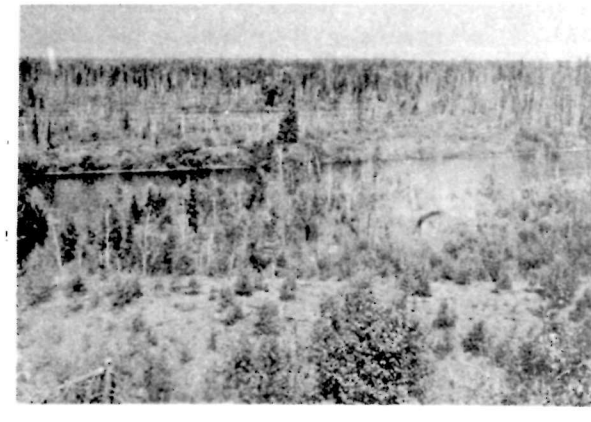


Figure 18.

Junction of Otter Creek and Big Snye (extreme left) in sand hill country. Cranes nest here and beaver were planted in 1949 in Otter Creek at the site of an old colony.

Figure 19.

The "Second Slough" behind the 27th base line cabin. Note that the marginal growth is predominantly bullrush rather than cattail.

Figure 20.

An aerial view of some of the abandoned and ponded stream channels and potholes of Athabasca delta between Lake Claire, which shows in the distance, and the river, which is just out of the picture to the right (east). These sloughs are for the most part similar to Lacaille's Main Slough in potential muskrat productivity.

Figures 21 and 22.

Floating sets in a runway and in open water.

Figure 23.

Trap set on a feeding platform.

Figure 24.

Captured muskrat. Note detritus piled on trap.

Figure 25.

Examples of very large muskrat houses on the Big Snye

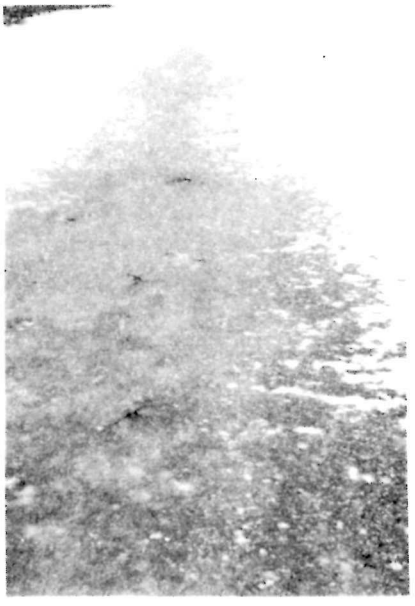
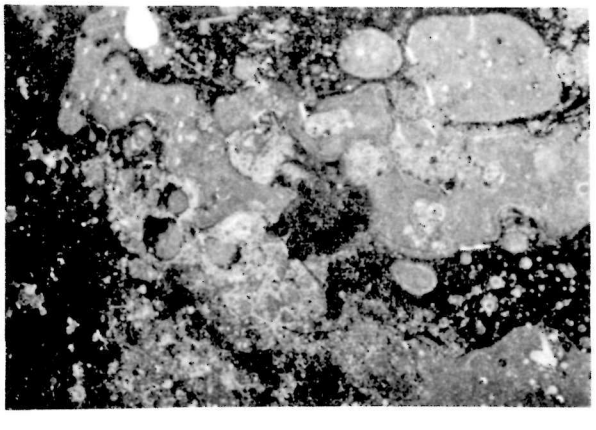


Figure 26.

A line of small, star-shaped holes in newly formed ice on the second slough, behind 27th base line cabin, November 10, 1948.



Figures 27 and 28.

Air bubbles on newly formed ice, 27th base line, November 8, 1948.

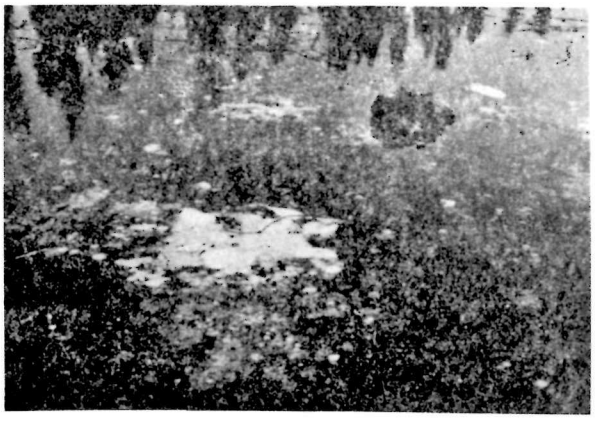


Figure 29.

Pushup on newly formed ice, 27th base line, November 8, 1948.

Figures 30--32

Examples of available muskrat food plants. Note the height of the Typha in Figure 31.

Figure 33.

Muskrat feeding platform on
Lacaille's Lake, July 6, 1948.

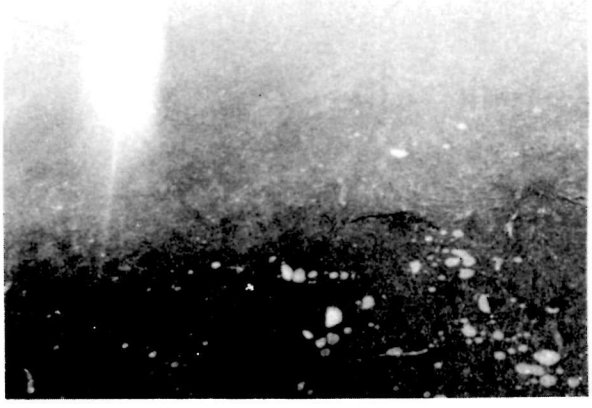


Figure 34.

Muskrat under newly formed
ice, 27th Base Line,
November 8, 1948.

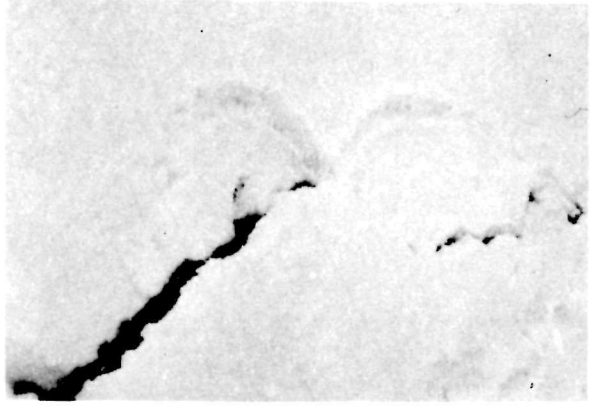


Figure 35.

Trail of a muskrat seeking shelter
along the bank of the Athabasca River
November 18, 1948. This animal was
tracked for about one-quarter of a mile.
It investigated many crevices, none of
which afforded sufficient shelter and
protection.

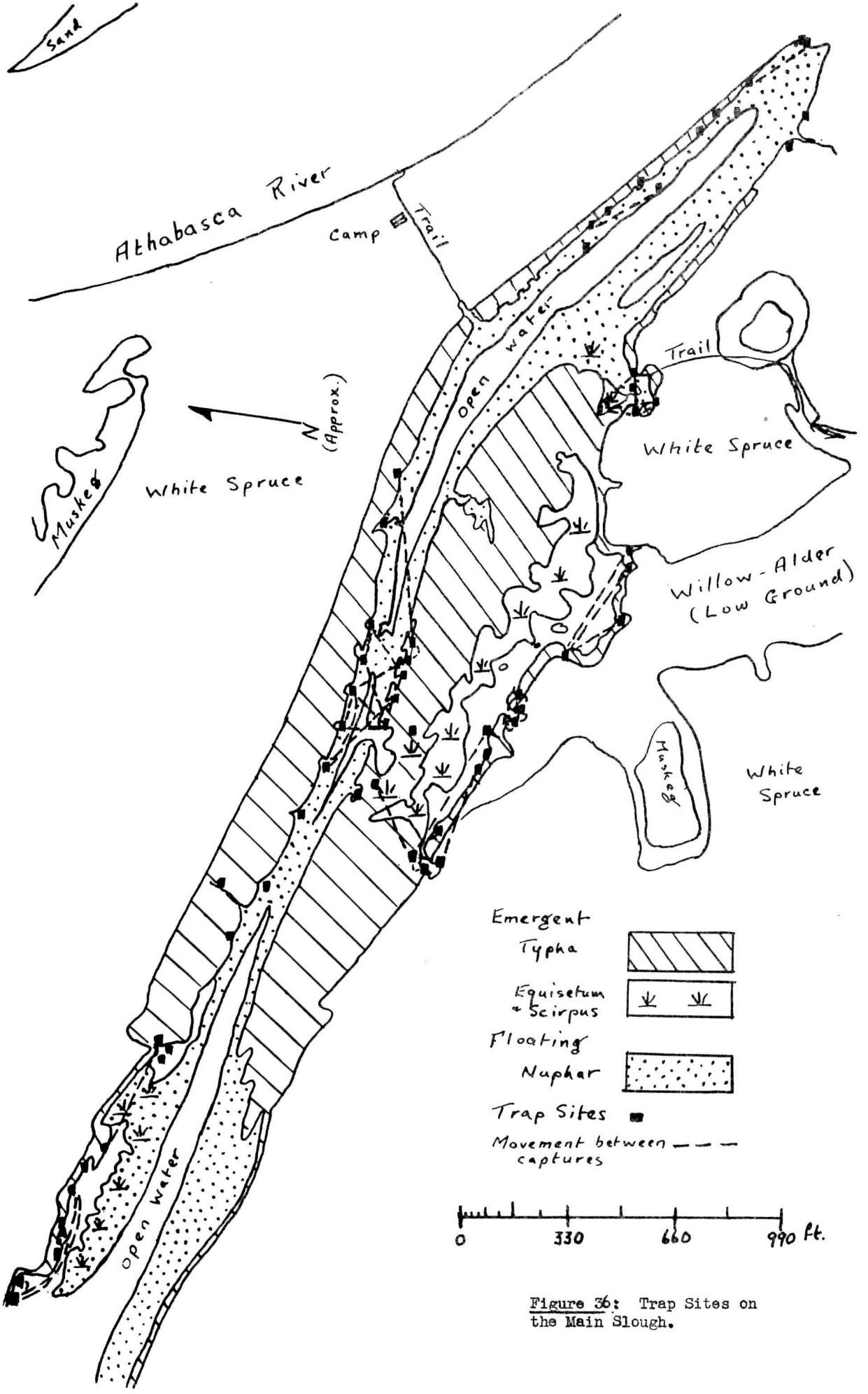


Figure 36: Trap Sites on the Main Slough.

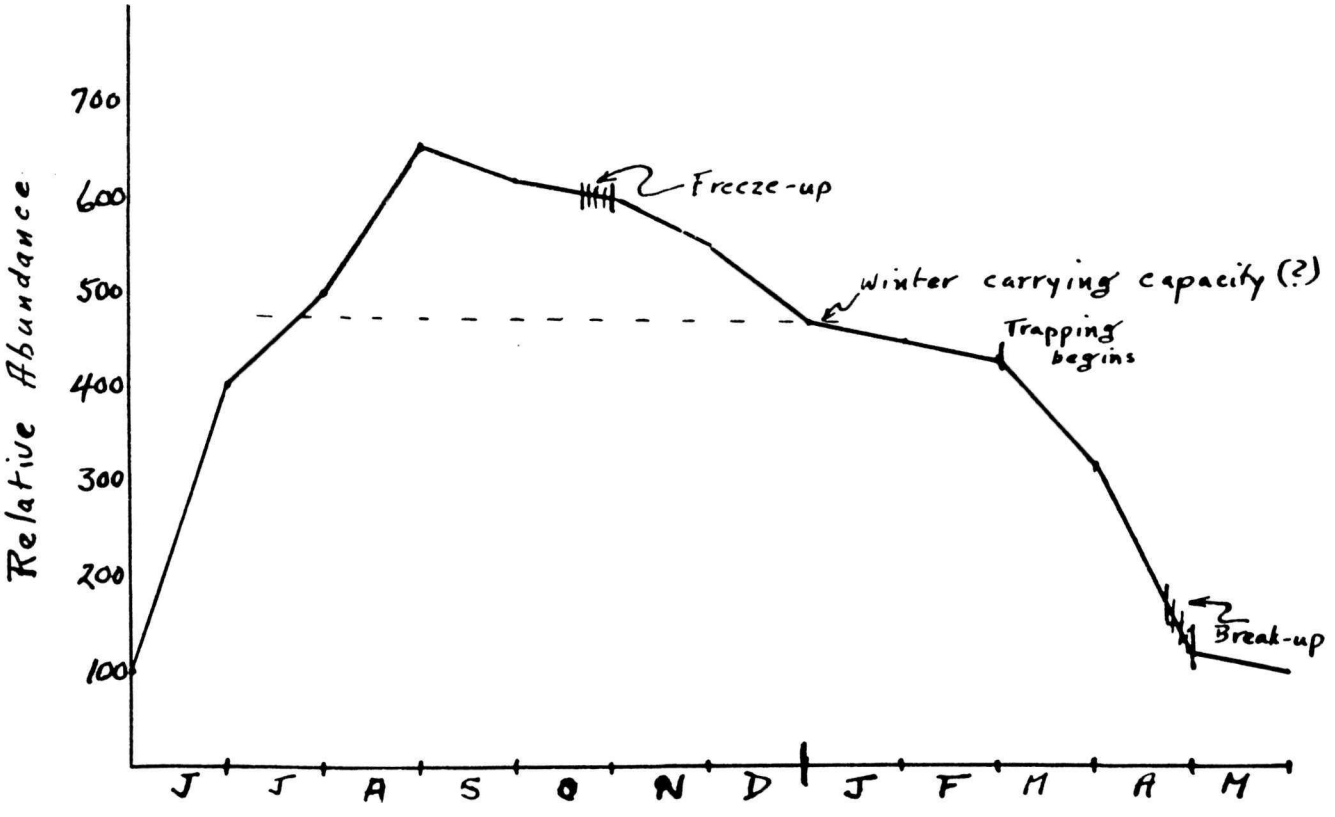


Figure 37. Approximate fluctuations in muskrat populations.

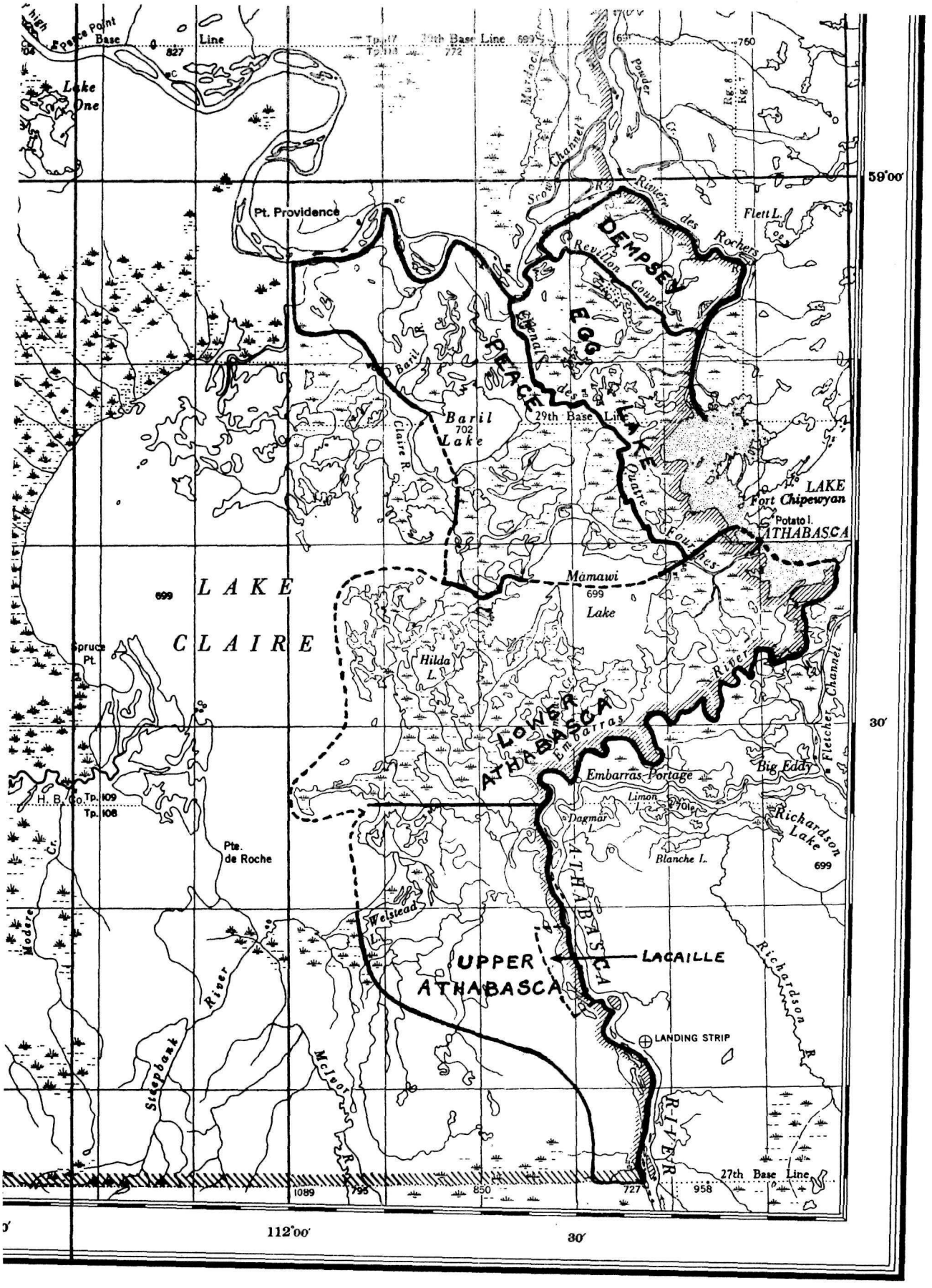


Figure 38 - Subdivisions of Athabasca Peace Delta as used in this report.

Figure 39 - Increase in value received & in size of roto as weeks progress.

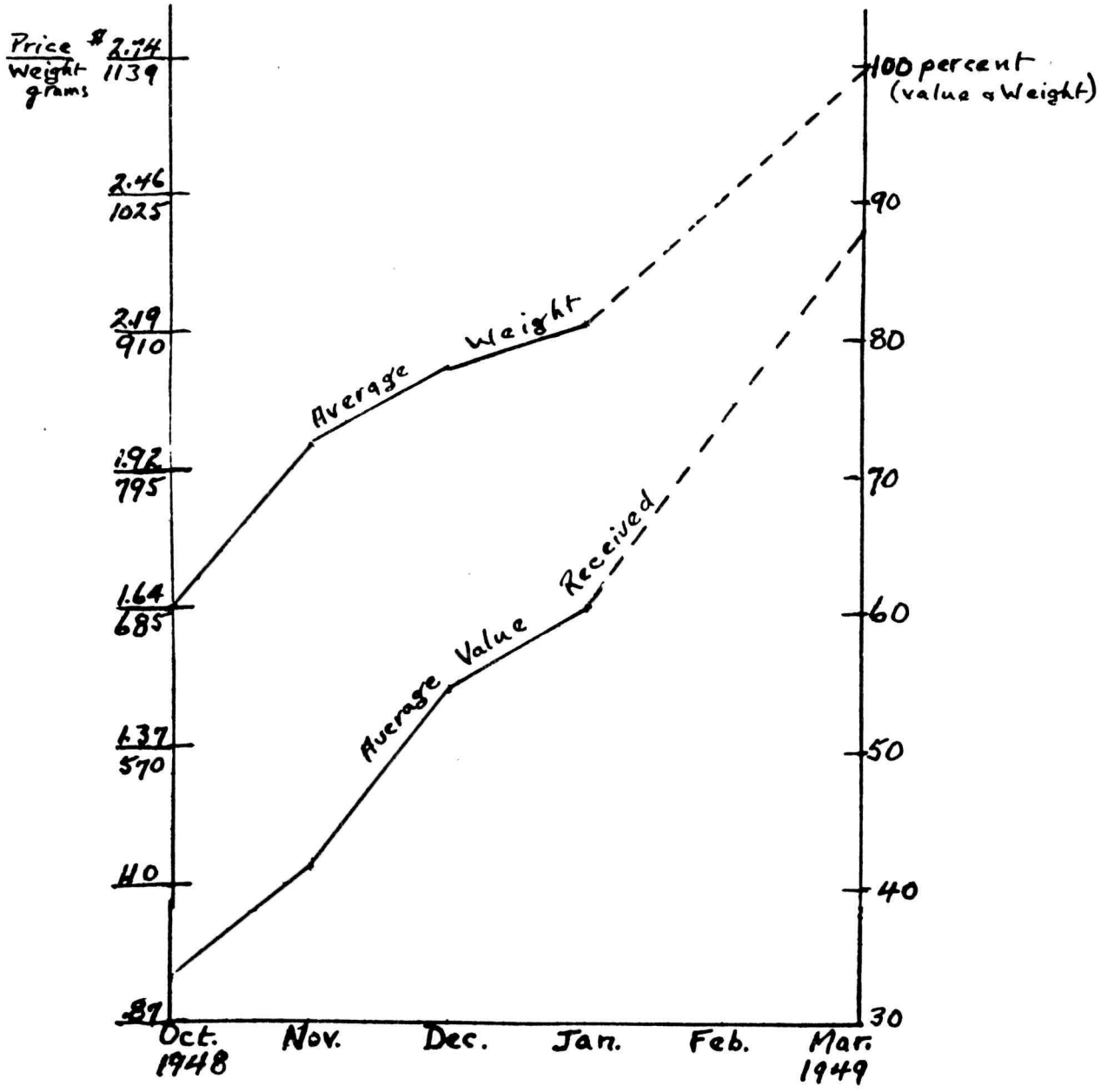


Figure 40.

Slack channel of the Athabasca River looking downstream. Note the Equisetum on the island in the foreground and the lack of other aquatic vegetation--also note the sandbar across the lower end.

Figure 41.

A close-up of a portion of the river bank on the island. Note the vertical series of burrow entrances constructed to keep pace with falling water levels.

Figure 42.

A small slough near Fort Smith typical of many hundreds of sloughs or bogs in late stages of succession to wet meadows. Tolerable in summer but a death trap in winter. Note the runway in the foreground.