DISTRIBUTION, ABUNDANCE AND HABITAT ASSOCIATIONS OF BEAVERS, MUSKRATS, MINK AND RIVER OTTERS IN THE AOSERP STUDY AREA, NORTHEASTERN ALBERTA

by

Gary F. Searing

LGL LIMITED

for

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

Project LS 23.2

August 1979

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONCLUDED)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

A synthesis of the published literature on the habitat preferences of beavers, muskrats, mink and river otters is presented. Field studies conducted during the late autumn of 1978 included aerial surveys and track counts in snow. A total of 249 active beaver lodges were seen on 2550 km of transects. Densities of active beaver lodges were calculated from surveys of streams and lakes to be 1 lodge per 3.1 km of stream and 1 lodge per 7.2 km of lakeshore. A total of 26 muskrat houses were seen on three lakes within the AOSERP study area. The Peace-Athabasca Delta was not surveyed.

Beavers used deciduous, white spruce and willow-fen habitats proportionately more than these habitats were available. Beavers avoided locating their lodges in jack pine and black spruce-tamarack habitats. Tracks of mink were found to occur in greater numbers in willow and aspen vegetation types than would be expected by the availability of these habitats. Habitat preferences of muskrats and river otters could not be determined because too few data were collected on these species. Recommendations for habitat management that would benefit semi-aquatic furbearers are made.

ACKNOWLEDGEMENTS

Research was funded by the Alberta Oil Sands Environmental Research Program (AOSERP), a joint federal-provincial program established to fund, direct and co-ordinate environmental research in the Athabasca Oil Sands area of northeastern Alberta.

I am especially grateful to the following LGL employees. Jens Roland was involved in many aspects of the study. Rick Salter and Jim Steele assisted with the literature review on semi-aquatic mammals. Maggie Ballantyne helped conduct the track counts and Phil Lulman and Brian Harvie assisted in the habitat analysis. Jeff Green and John Richardson provided many useful editorial comments on the report. Rick Dressler drafted the figures. The LGL secretaries took much time and care to produce the various drafts of this report.

I am appreciative of all the co-operation and logistic support given me by AOSERP personnel, especially Karl Closs. This study could not have been completed without the untiring efforts of the pilots; I thank Norbert Greczmiel of Alert Aviation, and Fred Wiskar and Dave White of Lift Air. Jack Burgheim of the Department of Highways granted us special permission to use the Hangingstone River campground out of season. Lucille Plank and Arlen Todd of Alberta Fish and Wildlife Division and Gordon Miller of the Canadian Wildlife Service provided many useful references and unpublished information. Fred Gilbert, University of Guelph, reviewed the manuscript.

In any study there are numerous people whose contribution, though small, is certainly not insignificant. I extend my thanks to all who have helped in any way. Finally, I am especially grateful to Alan Birdsall and Nancy Morgan of LGL, whose able administration helped this study run smoothly.

INTRODUCTION

The trapping of furbearing mammals has probably been carried out in North America ever since man first arrived on this continent. Trappers, especially the men who came to trap and trade for the pelts of beavers, were largely responsible for the early development of western Canada. The art and industry of trapping continues to have a major impact on the economics and lifestyles of many residents of northern Canada.

From 1970 to 1975, the average cash value of furbearer pelts in the AOSERP study area (Figure 1) was approximately $1250 per trapline per year. Of this value, 59% resulted from the sale of beaver, muskrat, mink and river otter pelts (Todd 1976). In comparison, in the entire Province of Alberta, these semi-aquatic furbearer species contributed 42% of the trapping income (Boyd 1977), indicating that semi-aquatic furbearers are more important to trappers in the AOSERP study area than to trappers elsewhere in Alberta.

During the past decade, an increasing amount of furbearer habitat has been lost as a result of industrial development and resource exploitation centred around the Athabasca Tar Sands. Although reclamation efforts are planned, the rehabilitation of aquatic habitats is exceptionally difficult and expensive. Furthermore, the habitat requirements of mink and river otters are poorly known and certain aspects of habitat use by beavers and muskrats are not well understood.

This study was undertaken to document the distribution and habitat preferences of four species of semi-aquatic mammals: beavers, muskrats, mink and river otters. The general objectives of the study as outlined by AOSERP were to:

1. 'Determine the relationship of each species of semi-aquatic mammals to their habitat requirements.'
2. 'Determine the relative densities (numbers and distribution) of semi-aquatic mammals by species, in representative habitat types in the AOSERP study area.'

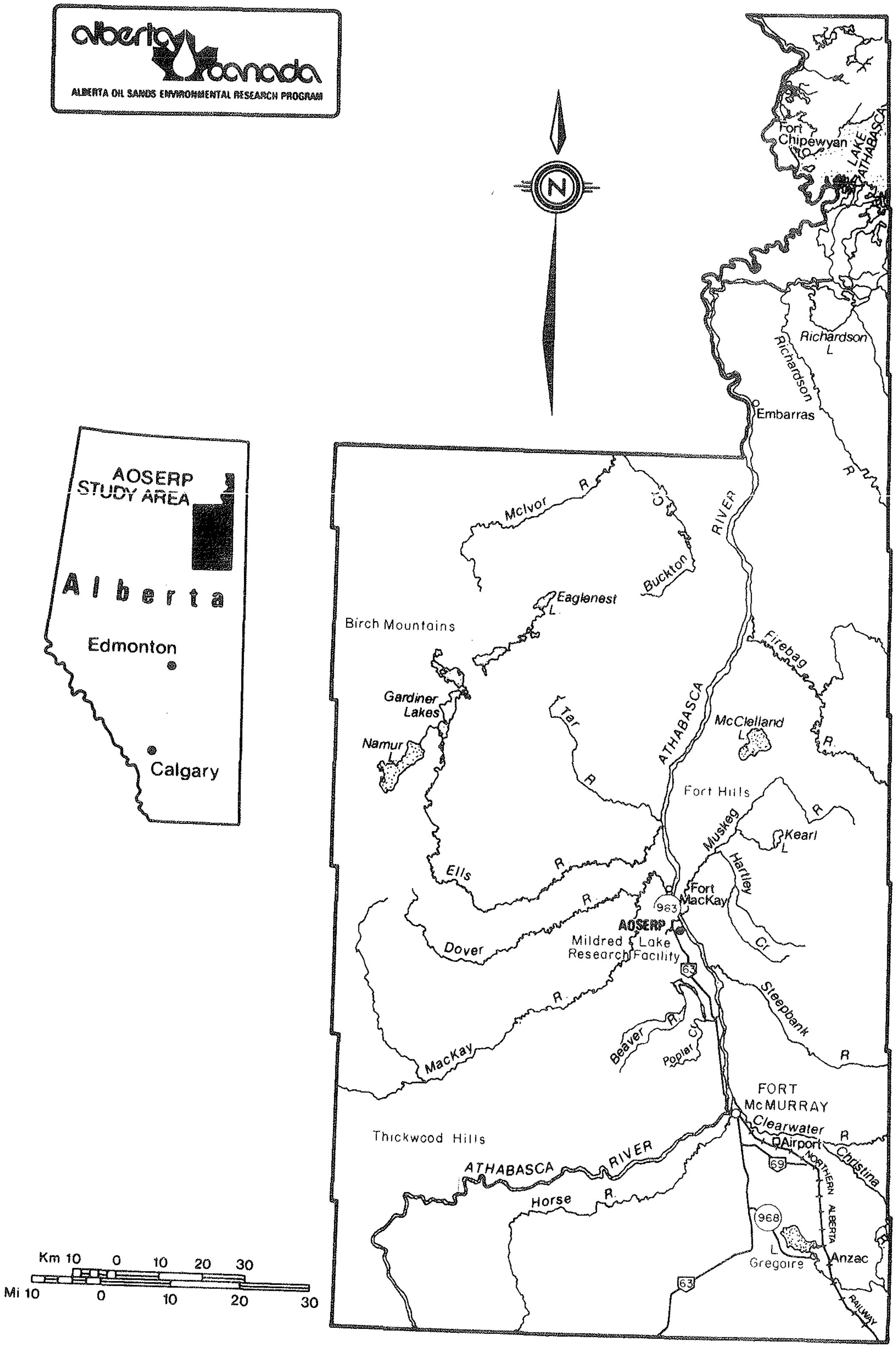


Figure 1. Map of the AOSERP study area, northeastern Alberta.

In order to fulfill these objectives to the greatest degree within the time and logistic constraints of the project, the following specific objectives were outlined:

1. Determine the distribution and abundance of beaver lodges and muskrat houses in various habitat types over a broad area on the AOSERP study area;
2. Determine the habitat associations of mink and river otters along selected rivers and streams in the AOSERP study area by track counts along ground transects;
3. Review and synthesize the literature on habitat preferences of beavers, muskrats, mink and river otters and relate the findings of the field study to published findings; and
4. Recommend management strategies and habitat improvement methods on reclaimed minesite areas that will enhance populations of semi-aquatic furbearers.

The following report consists of three parts. Part 1 is a review of the habitat preferences of beavers, muskrats, mink and river otters as documented in the literature. In Part 2, the results of field studies conducted during the autumn and early winter periods of 1978 are presented and discussed. Part 3 is a bibliography pertaining to the habitat relationships of semi-aquatic furbearers.

PART 1. HABITAT USE AND PREFERENCES OF BEAVERS, MUSKRATS, MINK AND RIVER OTTERS: A LITERATURE REVIEW.

1. INTRODUCTION

The following literature review describes the habitat preferences and relationships of four species of semi-aquatic furbearers that occur on the AOSERP study area: beavers, muskrats, mink and river otters. Because of the widespread distribution of these species, much of the published literature is not relevant to the boreal forest environment of the AOSERP study area. Throughout the review, emphasis has been placed on studies that are most applicable to conditions in northeastern Alberta. Where there is a paucity of information, studies from other regions of North America and from Europe are included.

This section is not meant to be an exhaustive review of every reference to habitat use by semi-aquatic furbearers. In order to maintain a readable report, selective use of the most relevant and informative sources was made. For those readers who are interested in a more exhaustive treatment of semi-aquatic furbearer habitats, a bibliography is presented at the end of Part 2 of this report.

Because the suitability of habitats is often governed by food availability, any discussion of habitat preferences would be incomplete without a treatment of food habits. Therefore, a brief description of the food habits of each species is presented.

Habitat use is determined both by extrinsic (vegetation, topography) and intrinsic (behavioural) parameters. The major parameters that determine habitat use are discussed for each species. This approach is somewhat artificial because it ignores physical and social interactions that affect habitat use. However, individual treatment of the various parameters permits one to investigate specific components of habitat use in considerably more depth.

2. BEAVER

2.1 INTRODUCTION

The beaver (*Castor canadensis*) is distributed throughout most of the United States and Canada (Figure 2). A closely related species, *C. fiber*, is widely distributed throughout northern Europe and Asia (Walker 1968). As a semi-aquatic mammal, the primary component of the habitat of beavers is an adequate water supply (Williams 1965, cited by Tufts 1967; Slough and Sadlier 1977). Because, in northern latitudes, beavers spend part of each year beneath a thick layer of ice, the water must be sufficiently deep so that it does not freeze to the bottom (Hiner 1938; Cowan 1948, cited by Novakowski 1965; Murray 1961; Alberta Recreation, Parks and Wildlife [ARPW], in prep.).

The vegetative characteristics of an area also affect local potential for beaver habitation (Tufts 1967). According to Slough and Sadlier (1977) beavers are most commonly associated with deciduous tree and shrub communities, or other sub-climax plant communities. In interior Alaska, Boyce (1974) found that beaver densities were highest in alder-willow, willow and poplar habitats, and lowest in spruce bog, mature stands, gravel-willow herbaceous and alder-birch bogs.

The factor most limiting to the success of a beaver colony is not unanimously agreed upon. For example, Williams (1965, cited by Tufts 1967) suggested that water conditions are of primary importance; Rasmussen (1940) and Stegeman (1954) indicated that availability of an appropriate food source is the most critical factor defining suitable habitat. It is likely that a combination of factors may determine the potential of an area as beaver habitat.

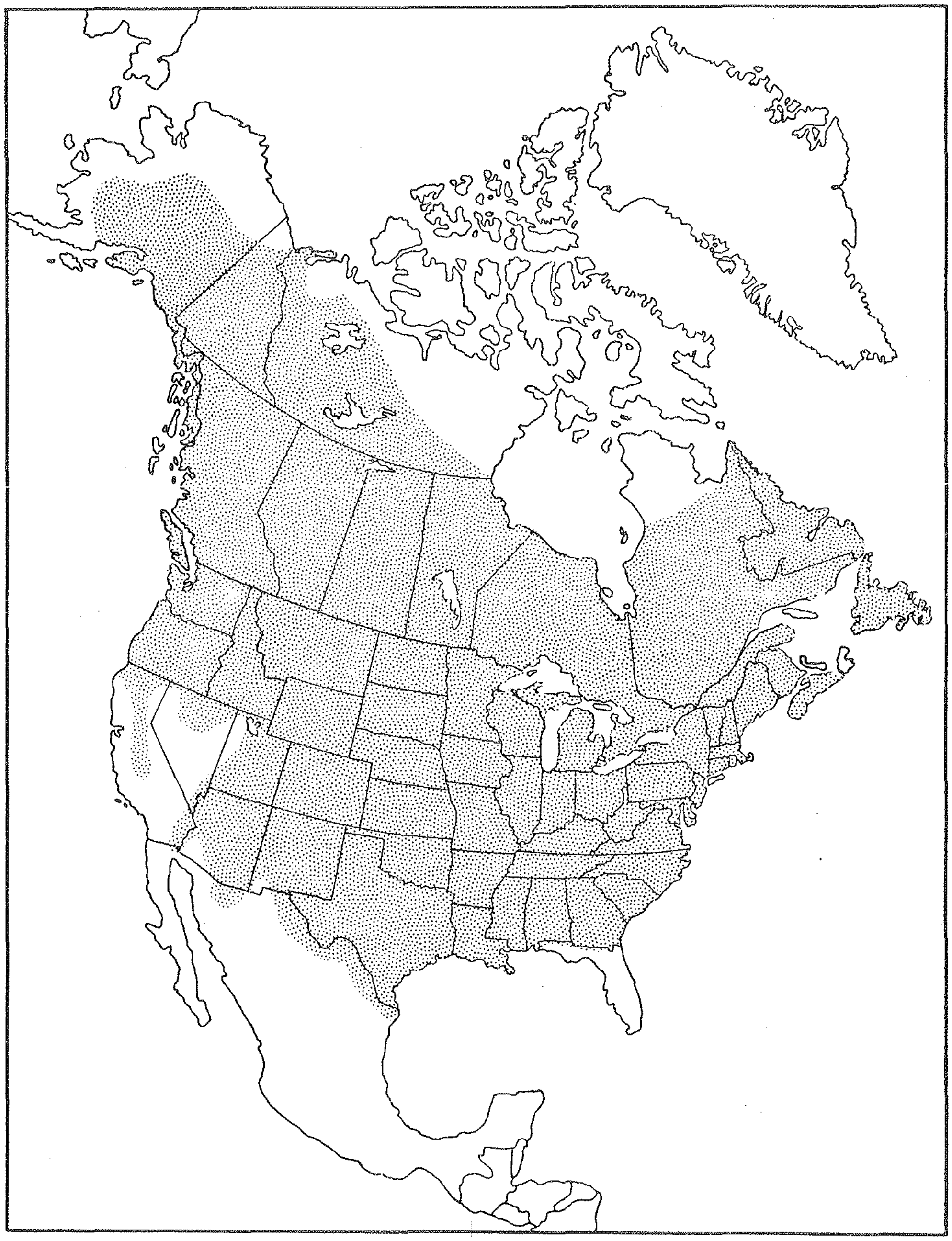


Figure 2. North American distribution of the beaver. (Adapted from Hall and Kelson 1953.)

Atwater (1940) has proposed a classification system for beaver habitat based on aquatic, physical, vegetative, and territorial requirements. He outlined the following criteria:

Most favorable

1. ample forage of preferred types,
2. sufficient room for expansion,
3. reliable water supply, and
4. favourable topography for lodge and dam construction.

Favorable habitat

1. ample forage of preferred types,
2. room for expansion is limited by topography,
3. reliable water supply, and
4. favourable topography for lodge and dam construction.

Fair habitat

1. preferred forage species not abundant, or forage consists of less desirable species,
2. room for expansion is severely limited, and
3. water supply is variable.

Marginal habitat

1. forage consists mostly of undesirable types,
2. room for expansion is severely limited,
3. water supply is unreliable, and
4. topography steep and rocky.

Unfavourable habitat

No criteria given.

Using similar criteria, several other authors have also developed habitat classifications for beavers (Retzer *et al.* 1956; Dennington *et al.* 1973; Thomasson 1973; Watson *et al.* 1973; Traversy 1974; ARPW, in prep.).

Beavers in Alberta occupy both streams and lakes that have an ample supply of aspen, willow, poplar and birch along their shorelines (Soper 1964). Throughout most of their ranges in the province, beavers require a minimum water depth of 0.9 m to 1.5 m and prefer banks consisting of fine-textured soils. 'Provided that basic requirements are met, the relative quality of the habitat in any given area is enhanced by sufficient quantities of one or more food species, [by] stable water levels, and by optimum distribution of land and water. Wetland configurations which increase shoreline length relative to surface area generally provide a greater amount of potential habitat...' (ARPW, in prep.).

2.2 VEGETATIVE REQUIREMENTS

2.2.1 Food Quality

A complete list of all the plant species used by beavers would include virtually every aquatic and terrestrial plant in the vicinity of the colony (Bradt 1947; Taylor 1953, cited by Tufts 1967; Crawford *et al.* 1976). However, aspen (*Populus tremuloides*) is the preferred food of the beaver (Bailey 1927; Soper 1937; Aldous 1938; Bradt 1938; Shadle and Austin 1939; Scheffer 1941; Beer 1942; Gese and Shadle 1943; Tevis 1950; Stegeman 1954; Pearson 1958; Hall 1960; Murray 1961; Brenner 1962; ARPW, in prep.). Aspen and poplar (*Populus* sp.) appear to be so highly preferred by beaver that the abundance and distribution of beaver colonies may be limited by the availability of these species (Rasmussen 1940; Stegeman 1954; Hodgdon and Hunt 1953).

In the absence of aspen and poplar, willow is a favoured food for beavers. Willow is of equal or greater importance as a food source at higher elevations and more northerly latitudes (Fomicheva 1957; Murray 1961; Northcott 1963, cited by Tufts 1967; Rutherford 1964; Novakowski 1965; Sverre 1972; Slough and Sadlier 1977).

Aleksiuk (1970) reported that willow (*Salix* sp.), and to a lesser extent balsam poplar (*P. balsamifera*) and alder (*Alnus crispa*), were the preferred food species of beavers in the Mackenzie

Delta. Soon after break-up the bark of willow was heavily used, but with the onset of plant growth beavers consumed mostly leaves and the apical portions of willows and, occasionally, poplars. In fall, bark was once again the main food material. Apparently this seasonal alteration in food habits allows beavers to obtain food with the highest available protein content.

Huey (1956) found that food quality affected the reproductive potential of beavers in New Mexico. Females taken from aspen-dominated and cottonwood-dominated habitats produced averages of 4.20 and 2.75 embryos per individual, respectively. Females taken from overused willow habitats produced only 2.06 embryos per individual.

The use of other species of hardwoods and ericaceous shrubs is well documented. Beavers have been observed to use ash, alder, birch, dogwood, maple, oak, and various species of coniferous trees (Brenner 1962; Knudsen 1962; O'Brian 1938; Tufts 1967; Sverre 1972).

Aquatic vegetation forms an important part of the diet of beavers, particularly in summer (Beer 1942; Tevis 1950; Grasse and Putnam 1955; Hodgdon and Hunt 1953; Pearson 1958; ARPW, in prep.). Northcott (1972) recovered 30 complete yellow water lily plants (*Nuphar* sp.) from a food cache, and Bradt (1938) reported beaver using *Potamogeton* sp., *Sagittaria* sp., *Lemna* sp., *Elodea* sp., *Nymphaea* sp., and *Nymphozanthus* sp. as summer foods.

2.2.2 Food Quantity

Food quantity, as well as quality, has a profound effect on the suitability of habitat for beavers. Hall (1960) stated that if trees are abundant, beavers may cut more trees than are needed for food. This may be especially true in the case of aspen. Scheffer (1941) observed that a group of beavers relocated to an area surrounded by a nearly pure stand of aspen quickly cut down all the available trees; the resultant exhaustion of the food supply was followed by emigration of the beavers.

The most important causative agent for relocation of beavers is food shortage (Rutherford 1964). After abandonment, the regeneration of preferred food species may result in re-colonization of the area by beavers (Lawrence 1952). Fire may be an important causative agent in the abandonment and recolonization of beaver lodges (Murray 1961). Destruction by fire of the food supply of beavers may be complete, but early stages of forest succession favour growth of aspen, poplar, birch and willow and thus enhance the food supply of beavers (Patric and Webb 1953; Murray 1961; Kelsall *et al.* 1977).

Many authors (Aldous 1938; Beer 1942; Bradt 1947; Brenner 1962; Knudsen 1962; Crawford *et al.* 1976, and others) have documented the numbers per year and diameters of trees cut by a colony of beavers. The number of trees cut is highly variable, and is affected by factors such as number of beavers in the colony, time of year, density of suitable species, composition of plant communities, amount of aquatic vegetation available, age of colony, and the average size of woody plants available (Knudsen 1962).

2.2.3 Distance Travelled for Food

One of the factors that most affects food availability is the distance that beavers will travel for food (Tufts 1967). The distance travelled over land varies with local topography (Sverre 1972). Gentle slopes extend the effective foraging radius of beavers because of the ease with which food and building materials can be transported downhill (Bailey 1927; Hiner 1938; MacDonald 1956, cited by Tufts 1967).

The reported distances that beavers will travel inland to obtain food range from 60 m to 245 m and include: 60 m (Boyce 1974; Bradt 1947; Hodgdon and Hunt 1953; Rutherford 1964), from 62-123 m (Orr 1933, cited by Bradt 1947), 104 m (Gilbert, pers. comm.), 185 m (Hammond 1943, cited by Tufts 1967), and 154-245 m

(Northcott 1963, cited by Tufts 1967). Gilbert (1978) found that beavers in northeastern Alberta travelled an average of 29 m inland for food. It is generally agreed that beavers use trees closest to water; as the supply of trees diminishes, beaver will travel increasing distances from water to forage (Tufts 1967).

Beavers will travel much greater distances in water than on land to obtain food. Hiner (1938) and Longley and Moyle (1963) observed beavers foraging up to 370 m from the cache along streams or ponds. They also stated that beavers may swim greater distances in lakes. Boyce (1974) observed that beavers cut food material as much as 800 m upstream, 300 m downstream, and 600 m along sloughs or lakes from the cache. Murray (1961) also noted that beavers would forage up to 800 m from the lodge.

2.3 LODGE SITE REQUIREMENTS

An adequate site for construction of lodges or dens is an important habitat requirement for beavers. Shelters constructed by beavers include island lodges, bank dens or burrows, and bank lodges.

The island lodge typically takes the form of a conical mound of sticks and mud, hollowed from the inside (Hodgdon and Hunt 1953). The island lodge is usually built in the middle of an impoundment so that it is completely surrounded by water (Soper 1937; Hodgdon and Hunt 1953; Rutherford 1964). Apparently, the island lodge is built when suitable banks for dens are not available (Bradt 1938; Longley and Moyle 1963).

Burrows are constructed in suitable banks and are often used as temporary dwellings by beavers. Permanent bank dens generally have several chambers; access to these chambers is normally under water (Longley and Moyle 1963).

The bank lodge is usually located where the banks are high and composed of stable, gravel-free material (Bradt 1938; Nash 1951; Hodgdon and Hunt 1953; Symington and Ruttan 1956). Beavers in the Mackenzie Delta use bank lodges more than island lodges because the volume of flow makes the construction of dams and island lodges difficult (Gill 1972; Dennington *et al.* 1973). Bank dens are often converted to bank lodges as the number of beavers using the dens increases (Hodgdon and Hunt 1953). In some cases bank lodges may evolve from repairs to a bank den (Soper 1937).

2.4 DAM SITE REQUIREMENTS

The sizes, number and locations of dams constructed by a colony of beavers are functions of local conditions such as stream flow, water depth, availability of building materials (Bradt 1947) and availability of food (Longley and Moyle 1963). Longley and Moyle (1963) suggested that, after food is located, the first constricted region downstream of the food source is selected as the dam site.

Dams are not normally constructed on lakes or large rivers (Soper 1937; Hodgdon and Hunt 1953). Streams having high banks require short dams of sufficient height to create an adequate impoundment (Grasse and Putnam 1955); broad valleys on flat land will require a much larger dam in order to impound sufficient water (Tufts 1967), as illustrated by a Saskatchewan dam about 1.6 km in length (Symington and Ruttan 1956). Soper (1937) noted that a stream with a low gradient requires only a low dam to impound a substantial amount of water.

In the Mackenzie Delta, where flow rates prohibit the building of dams, beavers may take advantage of the shallow reservoirs of meander scroll depressions and adjacent food supplies. These depressions are landforms that have evolved from movement and deposition of riverbed materials. Beavers may dam the lower rim of the depression and after sufficient water depth from accumulated runoff is achieved, they may build a lodge and establish a colony (Gill 1972).

2.5 CANALS

Canals are excavations approximately 0.6 m wide and 0.3 m or more deep (Bailey 1927; Longley and Moyle 1963) used by beavers to aid in the transport of food and building materials from inland areas (Hodgdon and Hunt 1953; Grasse and Putnam 1955). Canal lengths are variable, and many colonies do not construct canals at all (Tufts 1967). The presence or absence of canals is a function of local topography (Hodgdon and Hunt 1953). The terrain must be flat and the soil must be soft in order to be suitable for canal construction (Tufts 1967).

2.6 SOIL REQUIREMENTS

The stability of streambed substrates is an important consideration in suitability of a stream for beavers. Soils derived from igneous rocks are most stable, but tend to be shallow and unproductive. Glacial till, because of its porosity, is the least prone to movement and is usually associated with good quality beaver habitat (Rutherford 1964). Soils whose parent material is shale rock are more fertile but far more prone to shifting and erosion and are generally unsuitable for use by beavers (Retzer *et al.* 1956, cited by Tufts 1967; Yeager and Rutherford 1957; Rutherford 1964). Retzer (1955) and Retzer *et al.* (1956, cited by Tufts 1967) classified streambed stability as follows:

1. stable; consists of glacial till, granite, or schist;
2. less stable; consists of rhyolitic rock; and
3. unstable; consists of shale, interbedded shale, or sandstone.

Soil type also governs whether or not a bank den can be constructed. A relatively high, stable, gravel-free material is required for excavation (Bradt 1938; Hodgdon and Hunt 1953). Clay soils are optimum for bank den excavations, for securing the outside of the lodge, and for securing the upstream side of the dam (Zharkov and Solokov 1967; Sverre 1972). Murray (1961) found that lodges constructed in the upper Tanana River valley of Alaska were consistently built over a muck substrate.

2.7 WATER REQUIREMENTS

Water must be present in sufficient quantity to prevent freezing past a critical depth during winter (Hiner 1938; Slough and Sadlier 1977; ARPW, in prep.). Water also affords protection from predators, covers the lodge entrance, facilitates travel to food supplies, and facilitates storage of the food supply (Williams 1965, cited by Sverre 1972). It is critical that ice does not hinder access to the food cache during winter (Bailey 1927; Hiner 1938; Grasse and Putnam 1955; Yeager and Rutherford 1957; Novakowski 1965; ARPW, in prep.). Apparently, beaver activity between the lodge and the food cache can moderate the thickness of ice in this area (Murray 1961).

Water requirements vary with latitude. Cowan (1948, cited by Novakowski 1965) estimated a minimum water depth requirement of 2.7 m for beavers in the Aklavik area of the Mackenzie Delta. Murray (1961) documented that the minimum water depth at lodge entrances of beavers in the Tanana Valley, Alaska, was about 1 m; however, his study was conducted during a low water period in summer. Bailey (1927) postulated a minimum depth of 1.5-1.8 m in the Great Lakes area of the United States. Henderson (1960, cited by Tufts 1967) suggested that beavers in Kansas required a depth of 1 m. Semyonoff (1951, cited by Tufts 1967) estimated a minimum water depth of optimum beaver habitat in the U.S.S.R. of 1.5-2 m. The Alberta Land Inventory (ARPW, in prep.) suggested that 0.9-1.5 m was the minimum depth of water required for beavers in Alberta.

The area of water impounded varies from less than 0.4 ha to more than 20 ha (Knudsen 1959, cited by Tufts 1967). According to Knudsen (1962), the area of the beaver impoundment is a function of stream gradient, width of flood plain, and height of the beaver dam. Lakes are also used by beavers. On large lakes, lodges are usually located in sheltered areas where they receive protection from waves and damage by ice (Johnston 1927; Nash 1951; Shaw 1948; Shelton 1966, cited by Tufts 1967; Murray 1961).

Sudden changes in water level can have pronounced deleterious effects on a beaver colony (Murray 1961). Spring flooding and flash floods can shift river channels and damage or destroy dams and lodges (Yeager and Rutherford 1957; Rutherford 1964). In contrast, Shelton (1966, cited by Tufts 1967) noted that colonies were deserted when flow rates were insufficient to maintain water levels during periods of little precipitation. Consistent flow of water through most of the year is an important characteristic of beaver habitat (Shaw 1948; Taylor 1953; MacDonald 1956; Stains and Baker 1958; Henderson 1960, cited by Tufts 1967).

According to Knudsen (1962), typical habitat before impoundment would include a stream of discernible but low rate of flow. Several authors (Nash 1951; Taylor 1953, cited by Tufts 1967; Knudsen 1962) state that streams of low velocity are preferred by beavers. Retzer (1955, cited by Neff 1957) listed three criteria that affect water velocity and thus stream suitability:

1. gradient;
2. width of floodplain; and
3. streambed substrate.

Stream gradient is an important factor in colony establishment. Swank (1949, cited by Sverre 1972) suggested that beavers concentrated in level areas; Crawford *et al.* (1976) and Retzer (1955, cited by Yeager and Rutherford 1957) suggested that areas suitable for impoundment had gentle gradients with some degree of floodplain development in the valley. Beavers in the Porcupine Hills did not dam creeks with more than a 6% grade (Sverre 1972). Most researchers have stated that gradients less than 3% are preferred by beavers (Smith 1950, cited by Tufts 1967; Hodgdon and Hunt 1953; Shelton 1966, cited by Tufts 1967). Rutherford (1964) proposed that quality of beaver habitat improves as stream gradient decreases and valley width increases. He classified the habitat potential of a drainage as follows:

EXCELLENT: Grade = 0-6%
Valley width is greater than 46 m;

GOOD:	Grade = 7-12% Valley width is greater than stream width;
QUESTIONABLE:	Grade = 13-15% Valley width is wider than channel width, but is usually narrow; and
UNSUITABLE:	Grade = 15%+ Valley width is seldom wider than channel width.

The fact that more colonies occur on stream courses with low gradients (Rutherford 1964) supports this system of classification. Rivers with high flow rates and swift currents are undesirable habitats regardless of abundance of food species (Soper 1937; Atwood 1938).

2.8 SPATIAL REQUIREMENTS

It has been well documented that, just before a resident adult female gives birth to new young, 2-year-old offspring emigrate or are driven from the parent colony and establish themselves elsewhere. Emigration of 2-year-old beavers is of direct benefit to the parent colony because it prolongs the period of activity of the colony by reducing colony size and thereby conserves the food supply (Bradt 1947). Aleksiuk (1968, cited by Bergerud and Miller 1977) postulated that this type of behaviour serves as a regulatory influence in stabilizing populations.

One theory for dispersal is that parents force 2-year-old beavers from the colony (Bradt 1938). However, Bergerud and Miller (1977) and Novakowski (1965) have observed 2-year-old beavers at colonies in the presence of kits with no apparent aggression on the part of the adults. They attribute this failure to disperse to a lack of available habitat suitable for colonization.

3. MUSKRAT

3.1 INTRODUCTION

The muskrat (*Ondatra zibethicus*) occupies a broad geographic range within its native North America (Figure 3), and has recently been introduced to northern Europe and Asia where large populations now occur (Artimo 1960; Chu and Yien 1964; Marcström 1964; Danell 1977). Optimum muskrat habitat is characterized by an abundant food supply (emergent and submergent plants), a relatively stable water level, and bank or shoreline development that permits access beneath ice during winter (McLeod *et al.* 1947; McLeod 1949; Stevens 1955; Dennington *et al.* 1973). Highest densities are found in freshwater marshes (Errington 1963), although under favourable climatic conditions virtually any habitat, including habitats with intermittent water supplies may be occupied (Errington 1939, 1948).

Muskrat habitat in central and northern Alberta consists of 'weedy lakes, ponds, sloughs, marshes and sluggish streams, supporting an abundance of food plants' (Soper 1964). The distribution and interspersion of these wetlands depends to a large extent on landform; excessively flat topography 'limits the development or permanency of wetlands', whereas excessively steep topography 'limits the development or permanency of streams, or the attractiveness of existing permanent streams due to high gradients and resultant discharge fluctuations' ... this 'limitation may also arise in large river valleys having steep slopes' (ARPW, in prep.). The suitability of habitat also depends on the successional stage of the vegetation--the best muskrat habitats are comprised of subclimax biotic communities that depend on periodic flooding for their maintenance (McLeod *et al.* 1947, 1951; Fuller and La Roi 1971; Westworth 1974).

Figure 3. North American distribution of the muskrat. (Adapted from Hall and Kelson 1953.)

3.2 FOOD REQUIREMENTS

Muskrats are generally considered to be opportunistic feeders (Errington 1941), although some studies have demonstrated seasonal preferences for various plants or plant parts (e.g. Takos 1947; McLeod 1949; Bellrose 1950; Westworth 1974). In a recent review of muskrat food habits studies, Willner *et al.* (1975) concluded that in North America cattail (*Typha* sp.) and bulrush (*Scirpus* sp.) are the most important food items, although a variety of other species also are used. When emergent plants are not available, muskrats can subsist entirely on submergents (Fuller 1951; Stevens 1955). Experiments with captive adult muskrats have shown that daily intake of forage is approximately 340 g wet weight during summer (McLeod 1948). Lavrov (1960) reported that daily intake was approximately one-third of body weight; adult body weight averaged 1020 g for 9311 muskrats in Maryland (Dozier and Allen 1942) and 997.9 g for 134 adult males and 966.2 g for 117 adult female muskrats in the Mackenzie Delta (Hawley 1963, 1964, 1965).

Food availability may be a limiting factor during winter when ice cover prevents access to much of the food supply (Fuller 1951; McEwen 1955; Stevens 1955; Schmitke 1959). Where ice cover is continuous for long periods, muskrats construct push-ups (domes of submergent vegetation, beneath which a plunge hole is kept open through the ice) to extend their feeding range. MacArthur (1978) found that there was a progressive reduction in foraging radius as winter progressed, and theorized that this might be adaptive because it would tend to preserve nearby food sources until late winter when distant sources would be unavailable or energetically unfeasible to exploit.

3.3 COVER/SHELTER REQUIREMENTS

Muskrats depend on aquatic and semi-aquatic vegetation for food and, in most areas, for cover. Bank burrows and houses constructed from available vegetation are used for protection from predators, for raising litters (Fuller 1951; Errington 1963), to extend feeding range in winter and to limit climatic stress (Revin 1975; MacArthur 1978).

3.3.1 Cover Type Requirements

Although a broad range of cover types are successfully exploited, muskrat populations reach their highest densities in waterbodies with emergent vegetation. Chu and Yien (1964) have pointed out that 'it is not the kinds of plants, but their relative abundance, which may constitute a limiting factor'. Aquatic vegetation cover *per se* is not necessarily required (e.g. viable populations exist in the Mackenzie Delta area where the habitat is characterized by a lack of emergents [Stevens 1955]). The length of shoreline supporting emergent vegetation, the species and density of emergent vegetation, the width of the emergent belt, and the availability of submergents all affect habitat selection and carrying capacity (Bellrose and Brown 1941; Stevens 1955; Verts 1956; Ambrock and Allison 1973; Neal 1977; Danell 1978).

Apart from their use as a building material and food, stands of emergent vegetation provide shelter from winds, wave action and predators (McLeod *et al.* 1947). Also, emergent vegetation traps snow and thus reduces depth of ice formation (Fuller 1951; Stevens 1955; Vampiloff 1957; Westworth 1974). Riparian growth and adjacent woodlands provide resting places for stranded muskrats during high water periods; availability of such habitat may be crucial to survival (Errington 1937a; Bellrose and Low 1943).

Some limitations on land capability for muskrat production in Alberta are directly related to vegetation cover (ARPW, in prep.). These are:

'Shoreline conditions - Physical features preclude optimum shoreline conditions. The limitation may arise from topographic features or substrate characteristics which limit development of suitable plant communities along shorelines or otherwise reduce utilization by ... muskrat.

Present land use - Land use which adversely affects habitat quality. Examples are excessive land clearing or industrial and urban developments.'

3.3.2 House Site Requirements

McLeod *et al.* (1949) listed cover and availability of building material as being among the major factors governing house location. Certain features within zones of emergent vegetation (e.g. dense cover [McLeod *et al.* 1949], locally elevated points [Danell 1978b]) are preferred as construction sites. Seasonal differences in location of houses with regard to cover type (Ambrock and Allison 1973; Westworth 1974; Danell 1978b) are probably related to selection for water depth rather than to selection for specific plant associations *per se* (see Section 3.5).

Houses are constructed by gathering materials from the immediately surrounding area. Emergent plants are the primary building materials, although submergents, weeds, sticks, etc. may also be used (McLeod *et al.* 1947; Fuller 1951; Schmitke 1959; Pelikan *et al.* 1970; Akkermann 1975a; Danell 1978b). Westworth (1974) found that in many cases all emergent and submergent plant growth in a 3-7 m radius around the house was used in house-building by muskrats in the Peace-Athabasca Delta; fall or winter houses (which were generally larger than summer houses) had an average height of 0.49 m and an average diameter of 2.4 m. Pelikan *et al.* (1970) reported that in a central European study area approximately 4% of annual cattail biomass production was used in house-building.

During floods or periods of high water, houses may be located in riparian vegetation (Bellrose and Low 1943; McLeod *et al.* 1949; Ambrock and Allison 1973).

3.3.3 Burrow Site Requirements

Muskrats construct extensive burrow systems in suitable banks adjacent to waterbodies or streams; these may be used for seasonal or year-long shelter as well as for raising young. They typically consist of one or more submergent entrances leading to interconnecting tunnels and nest chambers above the waterline. In most areas, both houses and burrows are constructed, although there may be seasonal differences in intensity of use (Fuller 1951; Schmitke 1959). Exclusive use of burrows (as in the Slave River delta [Law 1950], the Mackenzie River delta [Stevens 1955] and the Old Crow Flats [Ruttan 1974]) may be related to inherent preferences or to lack of emergent vegetation for house construction (Stevens 1955).

Physical requirements for burrow location vary from area to area. In the Old Crow Flats, bank dens were located on steep shores and appeared to be most numerous where the shoreline had collapsed from thermokarst action (Ruttan 1974). In the Mackenzie Delta, nearly all bank dens were built into shallow lake shores (Stevens 1955). Muskrats in the Slave River delta located their burrows in solid clay banks of 0.3 m or more in height in protected areas--exposed or weathered banks were never used (Law 1950).

Riparian vegetation contributes to the bank stability required for extensive development of burrow systems, and the roots provide a framework for dens (Errington 1937a). Ruttan (1974) noted that in the Old Crow Flats bank dens were found on shores protected by dense shrubs and thick moss mats. Coulter (1948) found that breeding animals in Maine preferred banks with dense shrub cover.

3.4 SOIL REQUIREMENTS

Soil type influences the construction of burrow systems in banks, the accessibility of rootstocks of aquatic macrophytes, and the growth and development of food and cover plants.

Correlations between soil types and construction of burrow systems have been noted in several studies. Clay soils appear to be most favourable for construction of extensive burrow systems (Errington 1937a; Law 1950; Beshears and Haugen 1953; Earhart 1969) although use of sandy soils for construction of temporary winter burrows has been noted in California (Earhart 1969). In Sweden, Danell (1978a) found that there were significantly more burrows per kilometre on shores composed of fine-grade sediments than on those composed of coarse-grade sediments; burrows were also constructed in peaty lakeshores, but were not constructed in gravel or pebble substrates. McLeod *et al.* (1947) noted that in the Saskatchewan River delta area muskrats are restricted to areas with soft, mucky soils in which they can dig. In permafrost regions, burrow development is dependent upon the distribution and depth of the active layer (Ruttan 1974).

Freezing of soil in lake or marsh bottoms in winter restricts availability of rootstocks of aquatic macrophytes; however, instances of muskrats digging for food in frozen soil have been documented (Errington 1963; Turner 1970). It is noteworthy that in the Peace-Athabasca Delta, bottom type (i.e. whether frozen or unfrozen) had no significant effect on whether or not houses were active during winter (Ambrock and Allison 1973).

Soil-related factors may limit development of muskrat habitat in Alberta (APRW, in prep.):

> 'Excessive soil moisture - precludes optimum growth of vegetation necessary for food and cover.
>
> Fertility - Lack of nutrients in the soil or water for optimum plant growth.
>
> Deficient soil moisture - Poor water-holding capacity of soils which adversely affects the formation and permanency of wetlands or the development of suitable plant communities.

<u>Adverse soil characteristics</u> - Excessive salinity, alkalinity, acidity, lack of essential trace elements, or abundance of toxic elements may limit the development of plant and animal communities essential for muskrat production.

<u>Soil depth</u> - Restriction of the rooting zone by bedrock or other impervious layers which limits development of suitable plant communites.'

3.5 WATER REQUIREMENTS

Water requirements of muskrats during the open water season are flexible. Although drought can cause increased predation (Errington 1939, 1945, 1963) and flooding results in mortality through drowning, loss of nest sites, destruction of shelters, etc. (Errington 1937b; Bellrose and Low 1943; Ambrock and Allison 1973), muskrats can survive under a variety of water regimes as long as climatic conditions are not too harsh and adequate food and shelter are available (Neal 1977).

Optimum water depths during summer correspond largely to the tolerance range of emergent plants--to depths of several metres depending upon local conditions. Summer houses are located primarily in the zone of emergent vegetation (0-50 cm water depth) (Bellrose 1950; Harris and Marshall 1963); within this zone water depth does not appear to be a major determinant of house location. Westworth (1974) found that during summer there was a tendency for muskrats to construct houses on former feeding platforms without regard for water depth. McLeod *et al.* (1949) found that average depth at houses in the Saskatchewan River delta was 41.6 cm--if houses were located in water deeper than 51 cm, there was the danger that they would float and disintegrate. In Illinois, optimum depth for lodge construction has been reported to be 30-46 cm (Bellrose and Brown 1941). In a long-term study in Sweden, 96% of all houses were located in the water or within 1 m from it; mean water depth at house sites was 0.2 m (Danell 1978b).

Bank burrows require enough water to cover and protect the den entrance (Stevens 1955). Use of burrows decreases with declining water levels (Westworth 1974); however, tunnels or trenches to open water may be built (McLeod 1949).

In northern areas muskrats are confined under ice during winter. Complete freezing of shallow water decreases the amount of accessible habitat, and consequently sites suitable as summer habitat may be completely uninhabitable during winter (Stevens 1955; Ruttan 1974). For example, Ambrock and Allison (1973) reported that about 70% of the lakes in the Peace-Athabasca Delta were too shallow for winter survival of muskrats.

The extent of winter habitat shrinkage depends upon ice thickness and upon waterbody depth and gradient. Minimum depths of 1.2-1.8 m are required in far northern areas such as the Mackenzie Delta and Old Crow Flats, where ice thicknesses may reach 1.2 m or more (Stevens 1955; Ruttan 1974). Water depth requirements decrease with decreasing climatic severity; in the Peace-Athabasca and Saskatchewan River deltas water depths of 0.6-0.9 m are adequate for muskrat survival (McLeod *et al.* 1947; Stevens 1950; Ambrock and Allison 1973). A thick layer of insulating snow early in the season results in reduced depth of ice formation (Fuller 1951; Stevens 1955; Ambrock and Allison 1973; Westworth 1974).

Gradient and location of deep water in relation to shallow water are important determinants of winter habitat availability, because freezing of extensive shallow areas may prevent access to deeper water from houses and bank dens at shore (Ruttan 1974). Thus, Stevens (1955) concluded that, in the Mackenzie River delta (where muskrats made exclusive use of bank dens), steep-sided lakes were more valuable as winter habitat than those with a shallow gradient. However, depths greater than 3.6 m were not used because they did not support forage growth. Danell (1978a) found that muskrats in Sweden did not build burrows where distance from shore to 0.5 m water depth exceeded 40 m.

The importance of total water body depth during winter is illustrated by relationships between depth and activity at pushups. Surrendi and Jorgenson (1971) reported that in the Peace-Athabasca Delta the percent of pushups that were active increased from 0% at 0.3 m total depth to 100% at 1.4 m total depth; mean total depth of ice and water at active pushups was 0.9 m. They concluded that for optimum winter survival, muskrats should have access to total depths from 0.8-2.1 m.

In areas where muskrats construct houses there are seasonal differences in locations of new houses in relation to water depth (Westworth 1974; Danell 1978b). Westworth (1974) reported that in the Peace-Athabasca Delta, houses were built over deeper water during fall than during summer, and that as houses in shallow areas became frozen muskrats made greater use of houses in deeper parts of their home range. He reported that over 50% of the houses located in water deeper than 30 cm were still in use during April.

In another study in the Peace-Athabasca Delta, Ambrock and Allison (1973) found that the percent of houses still active during March was positively correlated with total ice and water depth; 37% of houses in 3-31 cm of ice and water were active, compared with 51% in 34-61 cm, 65% in 64-91 cm, and 78% in 94-122 cm. Approximately 69% of the active houses were found between total depths of 34 cm and 76 cm (Surrendi and Jorgenson 1971), which is similar to preferred winter depths reported from other areas (e.g. 46-76 cm in Maine [Coulter 1948]; approximately 0.33 cm in Sweden [Danell 1978b]; greater than 61 cm in central Alberta [Schmitke 1959]).

It is noteworthy that although there is a positive correlation between total depth and percent of houses and pushups remaining active over winter, the presence of water is not necessarily required. Ambrock and Allison (1973) reported that during 2 years of study, 44-71% of active houses were in areas where no detectable water was present in late winter; similarly, Surrendi and Jorgenson (1971) found that 27% of all active pushups were in areas with no detectable water. However, active houses and pushups may have had pockets of water immediately below them, or tunnels or runways to surrounding water areas (Surrendi and Jorgenson 1971).

Water-related characteristics that may limit development of muskrat habitat in Alberta (ARPW, in prep.) include:

> 'Aridity - Regional drought or aridity which results in low water levels or seasonal drying of aquatic habitats.
>
> Excessive water flow - Inhibits development of suitable habitat along stream edges.
>
> Inundation - Flooding or excessive water level fluctuation which adversely affects the habitat or the production and survival of ... muskrats.
>
> Exposure - The limiation is exposure to wave action on windward sides of large lakes which may prevent the development of optimum ... muskrat habitat.
>
> Excessive water depth - Limits the development of optimum aquatic plant communities.'

3.6 SPATIAL REQUIREMENTS

Spatial requirements of muskrats are related to the extrinsic factors of availability of food, cover and water, as well as to intrinsic factors such as sex, age and breeding condition of individual animals. Home ranges and territory sizes reflect the interaction of these factors; both provide measures of the area within which habitat requirements are met, and provide insight into how available resources are partitioned.

Muskrats are relatively sedentary animals. Except for spring, fall or emergency dispersal movements (which may be undertaken by only a small segment of the population [Errington 1940, 1963; Wragg 1955; Mathiak 1966]), they generally remain within home ranges 200 m or less in diameter (Aldous 1947; Shanks and Arthur 1952; Krear 1953; Mathiak 1953; Sather 1958; Schmitke 1959; Mallach 1971; Westworth 1974). Translocation studies involving returns of up to 4000 m have shown strong attachment to these areas by individual muskrats (Mallach 1972).

Home range size varies with habitat quality. Dauphiné (1965) concluded that in the central Adirondacks, muskrats maintained larger home ranges in marginal habitats than in more favourable habitats. In streams and ditches, home ranges tended to be linear in shape; Stewart and Bider (1974) reported that in southern Quebec approximately 365 m of collection ditch containing permanent water was needed to support each breeding female.

Part of the home range may be defended as territory, particularly by females during the breeding season (Errington 1963), but the extent of territoriality and home range overlap appears to vary from region to region. Westworth (1974) found that muskrats on the Peace-Athabasca Delta occupied non-overlapping family home ranges. These results agreed with the results of Sather's (1958) study in Nebraska, but Erickson (1959) reported overlapping home ranges in central New York and Neal (1968) found no evidence of territoriality in northwestern Iowa. In Germany, males and females defended territories of up to 500 m^2 during spring (Akkerman 1975b). Shanks and Arthur (1952) reported that stream-dwelling muskrats in Missouri appeared to be territorial.

Territory sizes depend in part on population density, and during cyclic highs their centres may be separated by only 18-37 m (Errington 1963). Territoriality has an important influence on habitat use; for example, Fuller (1951) noted that in late summer and autumn muskrats forced from marginal habitats by lack of water or severe frosts may have to fight their way into fully occupied favourable habitats. Muskrats that attempt to build houses in territories with occupied burrows may be driven away by competitors (Danell 1978a).

In northern regions, ice cover restricts winter home range size and/or movements (Stevens 1955; Westworth 1974). MacArthur (1978) found that winter movements on the Delta Marsh in Manitoba rarely exceeded 150 m; most foraging occurred within a 10 m radius of a lodge or pushup. Territoriality during winter may result in 'zonation' of winter habitat, each zone being used by a relatively discrete group of muskrats (Stevens 1955).

4. MINK

4.1 INTRODUCTION

The mink (*Mustela vison*) is a widely distributed (Figure 4) semi-aquatic predator that occurs along streams, lakeshores, marsh edges and marine coastlines. Some use is also made of woodlands adjacent to watercourses. Soper (1964) has characterized mink habitat in Alberta as 'the borders of streams, ponds and soggy-shored lakes, preferably in low-lying quaggy terrain cut by meandering, sluggish streams'. Primary habitat requirements are an abundant food supply and adequate denning sites.

4.2 FOOD REQUIREMENTS

Mink are opportunistic predators whose food habits vary widely within their geographic range. Various food habits studies in North America and Europe have indicated that seasonal or annual diets may be composed primarily of small mammals (Dearborn 1932; Hamilton 1936, 1940, 1959; Sealander 1942, 1943; Yeager 1943; Harbo 1958; Korschgen 1958; Burns 1964; Schnell 1964; Hoglund 1966; Erlinge 1969; Grigor'ev and Egorov 1969), waterfowl (Everhardt 1973; Sargeant *et al.* 1973), fish (Burns 1964; Egorov 1966; Gerell 1967a; Akande 1972; Hatler 1976), aquatic invertebrates (Dearborn 1932; Gerell 1967a), or marine invertebrates (Harbo 1958; Hatler 1976). In some areas the muskrat is the primary prey species (Dearborn 1932; Hamilton 1940; Sealander 1942, 1943; Yeager 1943); muskrats are particularly vulnerable under conditions of drought or overpopulation (Errington 1954).

Seasonal and areal differences in food habits are caused by differences in prey availability (Dearborn 1932; Errington 1943, 1954; Waller 1962; Gerell 1967a; Erlinge 1969). Gerell (1967a, 1968) found that differences in diet among mink in different habitats in Sweden were most marked during summer, when a greater variety of prey was available. Fluctuations in prey density may be a factor in large population fluctuations of mink (Harbo 1958).

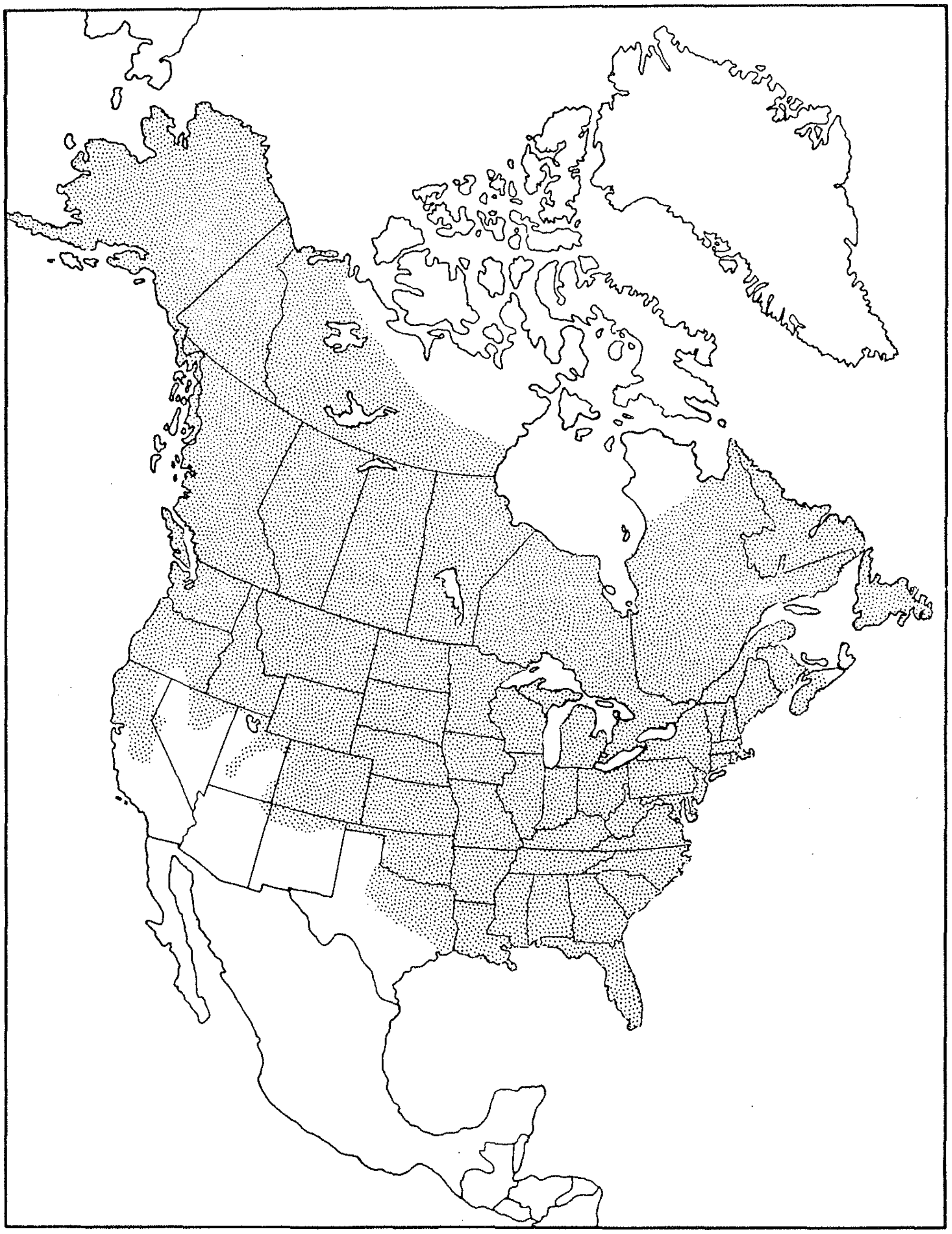


Figure 4. North American distribution of the mink. (Adapted from Hall and Kelson 1953.)

Food requirements are met primarily in aquatic and semi-aquatic habitats, although diet composition indicates that some foraging is done in terrestrial habitat adjacent to wetlands or watercourses.

4.3 COVER/SHELTER REQUIREMENTS

Mink frequent emergent, riparian, tundra and bottomland forest communities where prey is available. For example, Korschgen (1958) concluded that in Missouri 'good mink habitat would seem to include land adjacent to water from which vegetation is not over-grazed, burned or cut ... such areas are productive of the foods most utilized by mink'. Northcott *et al.* (1974) noted that good muskrat habitat generally supports sizeable populations of mink. Knudsen (1962) attributed use of beaver ponds by mink to food abundance, deeper water, and more dissected edge and shoreline. Erlinge (1972) noted that in Sweden 'lakes rich in crayfish and streams with marshes inhabited by small mammals are favourable habitats to the mink in summer'.

Viable populations of mink occur even in agricultural areas or where forest cover is discontinuous (Sealander 1943; Gerell 1967b; Soper 1964), as long as suitable watercourses are available. Watercourses also constitute the major lanes of travel and dispersal (Ritcey and Edwards 1956; Harbo 1958; Gerell 1967b; Northcott *et al.* 1974). Coastal mink summer in upland muskegs and along rivers and streams, but during winter are confined to a narrow zone along the beach (Croxton 1960).

Mink do not construct shelters from available vegetation; instead they occupy abandoned or appropriated burrows (primarily of muskrats) or naturally formed den sites (Marshall 1936; Errington 1946; Harbo 1958; Burns 1964; Gerell 1967b; Erlinge 1972). Dens are used both for raising young and for shelter (Marshall 1936; Harbo 1958; Burns 1964). Availability of den sites is one of the factors determining mink population densities (Errington 1946; Gerell 1967b, 1970; Erlinge 1972). Northcott *et al.* (1974) partly attributed the failure of mink to spread into mountainous and sub-alpine areas of Newfoundland to the absence of suitable den sites.

Dens are variously located in creek banks (Marshall 1936; Burns 1964), peat bogs (Gerell 1967b), pingoes (Burns 1964), under tree roots (Marshall 1936; Harbo 1958; Gerell 1967b), in beaver or muskrat houses (Hensely and Twining 1946; Harbo 1958; Knudsen 1962; Errington 1963), in brush and in rock piles (Harbo 1958; Gerell 1967b). Suitable dens are situated near water (Harbo 1958; Gerell 1967b; Schladweiler and Storm 1969), but not necessarily near water-bodies that fulfill habitat requirements of mink throughout the year. Burns (1964) found that in Alaska, females occupied summer dens in low-lying swampy areas a considerable distance from deep streams and sloughs. Harbo (1958) noted that all dens found on his study area in Alaska were above summer high water levels.

Vegetation cover provides protection for the den site and also influences soil/burrow characteristics. In the Yukon-Kuskokwim Delta area, natal dens were always in areas of deep annual thaw under *Spiraea* or *Salix* cover; soil was most friable under this cover type and roots provided stability for the subterranean tunnel system (Burns 1964). The most heavily used winter dens were also in this cover type, possibly as a result of the protection afforded by the thick snow layer held by the shrubs. Harbo (1958) found that most dens were surrounded and covered by dense vegetation that provided concealment.

4.4 WATER REQUIREMENTS

Water *per se* is not a critical habitat requirement for mink; their association with aquatic and semi-aquatic habitats is related primarily to prey availability. Nevertheless, mink habitat can be broadly characterized in terms of waterbody type, water depth and flow rate.

In Alberta, mink are associated with standing waterbodies and low-gradient streams. Seasonal differences in habitat use are related to water depth; there may be local dispersal from large, deep streams used during winter to smaller watercourses used as spring and summer habitat (Soper 1964).

During winter, mink cope with freezing of aquatic habitats by moving to deeper water, by congregating at open watercourses (Knudsen 1962; Erlinge 1972), and by foraging in terrestrial habitats (Marshall 1936; Harbo 1958; Soper 1964); they also spend much time hunting in extensive air spaces that develop beneath nearshore ice as water levels recede after freeze-up (Harbo 1958; Soper 1964).

4.5 SPATIAL REQUIREMENTS

Spatial requirements, as reflected by home range size, are inversely related to the quality of local habitat for hunting (Mitchell 1961; Hatler 1976). Also, males tend to have a much greater range than do females (Marshall 1936; Harbo 1958; Gerell 1970; Hatler 1976). Home range sizes of females of 8-20 ha have been reported (Marshall 1936; Mitchell 1961), whereas males may have home ranges of over 400 ha (McCabe 1949). During winter, activities are restricted to portions of the home range where food is readily available (Gerell 1970).

Both adult males and adult females have been reported to be territorial (Harbo 1958; Mitchell 1961; Gerell 1970), but the influence of territoriality on spatial requirements is poorly understood. Gerell (1970) concluded that the size of the home range was related to both population density and carrying capacity of the habitat; territoriality seemed to be the chief regulating factor.

5. RIVER OTTER

5.1 INTRODUCTION

The river otter (*Lutra canadensis*) is a semi-aquatic predator and one of the rarest indigenous furbearer in North America (Edwards and Cowan 1959). It is distributed over a broad geographic range and occupies habitats similar to those of beavers, muskrats and mink. A closely related species, the European otter (*L. lutra*) occupies analogous habitats in Europe (Erlinge 1972). River otters occur on a variety of creek and river types that have suitable amounts of forest and shrub cover. Otters will also use back waters, beaver ponds, and lakes (Peterson 1966; Erlinge 1967b; Soper 1970). There is little information on habitat use by river otters in North America; much of the information presented below has been obtained by researchers studying the European otter.

5.2 FOOD REQUIREMENTS

River otters select prey on the basis of vulnerability and thus are opportunistic feeders (Greer 1955; Ryder 1955; Waller 1962, cited by Gilbert 1978; Erlinge 1967b; Gerell 1967). Some factors affecting the feeding habits of otters include availability of food, vulnerability of prey (intense predation usually occurs when prey is easy to catch [e.g., spawning]), and food preference. Food quantity and food availability are dictated by the abundance and agility of the prey species, the habitat in which prey is found, time of day during which river otters hunt, fish spawning periods, effects of ice in winter, water temperatures, and seasonal changes in stratification of the waterbody.

River otters tend to hunt in shallow, weedy water; coarse fish are the primary prey species. Erlinge (1972) stated that cyprinids, pike (*Esox lucius*), and burbot (*Lota lota*) form

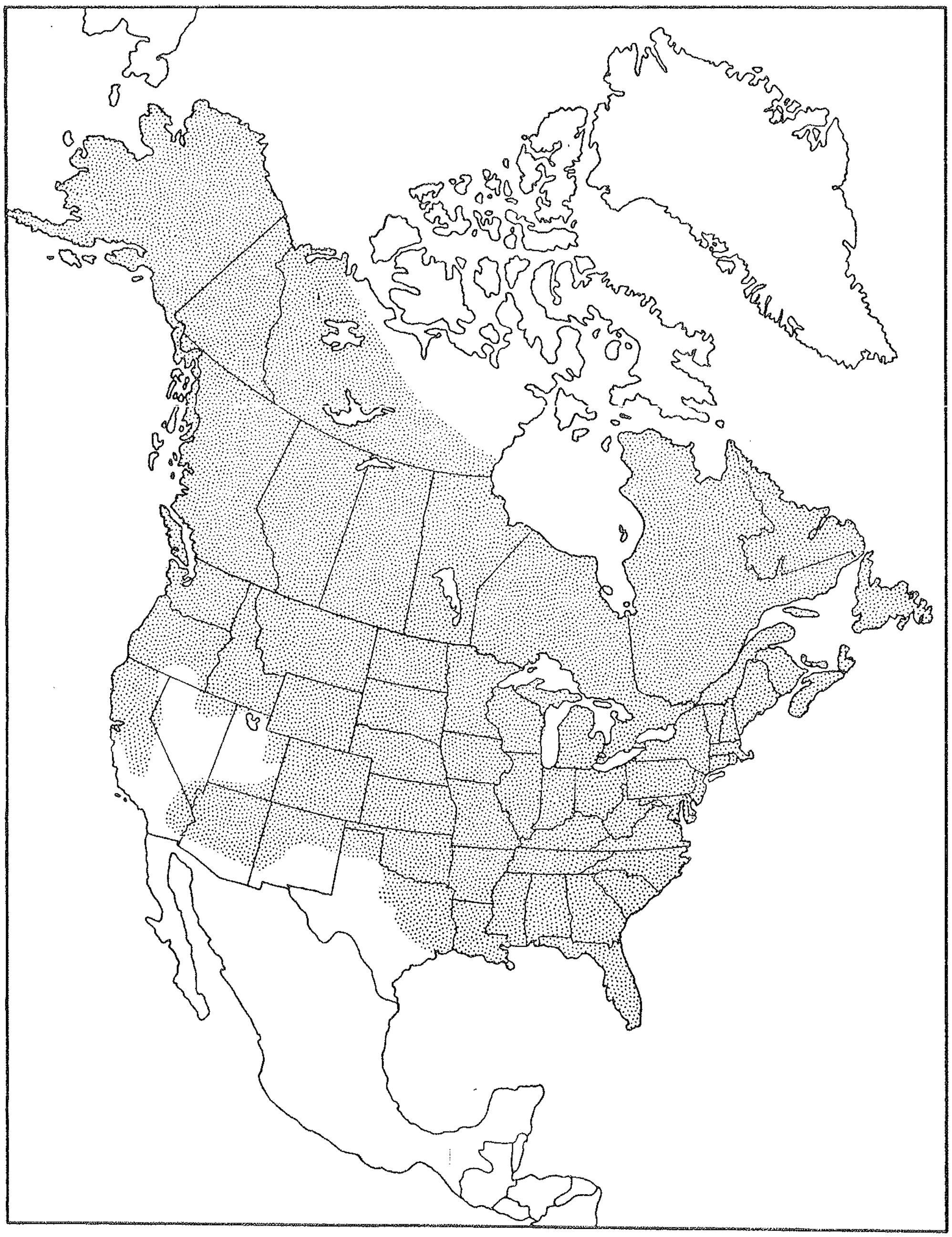


Figure 5. North american distribution of the river otter. (Adapted from Hall and Kelson, 1953.)

the basis of the dietary requirements of the European otter in southern Sweden. Fish that remain in deep water during daylight hours form a negligible part of the river otter's diet (Sheldon and Toll 1964).

The otter's preference for fish has been well documented (Yeager 1938; Lagler and Ostenson 1942; Ryder 1955; Sheldon and Toll 1964; Soper 1964; Erlinge 1967a, 1967b, 1968, 1972; Gilbert 1978). Crayfish are a major food source in more southerly latitudes (Lagler and Ostenson 1942; Erlinge 1972; Yeager 1938); in marshy areas amphibians are also taken (Erlinge 1967a). River otters also prey on birds and small mammals (Soper 1964) and occasionally eat ericaceous shrubs such as blueberries (*Vaccinium* sp.) (Sheldon and Toll 1964; Petersen 1966). The selection for prey such as waterfowl and semi-aquatic mammals does not appear to be great, and the use of ericaceous shrubs as a food source is not widely documented. Because of the stable nature of the river otter's main prey base, otter population sizes fluctuate less than those of other mustelids whose prey may undergo large fluctuations in numbers (Erlinge 1968).

5.3 COVER/SHELTER REQUIREMENTS

River otters do not construct their own dens (Liers 1951); they adapt muskrat burrows or abandoned bank burrows, bank dens, or lodges of beavers to suit their own requirements. River otters will also use cavities among the roots of trees, hollow logs, and rock crevices, or they may build a nest-like structure of grasses located on the ground among the bases of dense shrubs (Yeager 1938; Liers 1951; Stephens 1957; Soper 1964; Erlinge 1967).

5.4 WATER REQUIREMENTS

Water is the primary requirement for suitable river otter habitat. Den sites of river otters are frequently provided by other semi-aquatic mammals such as beavers and muskrats; also the otter's prey is almost totally aquatic.

During summer, otters inhabit areas that offer optimum habitat in terms of prey. These areas can include eutrophic lakes (Erlinge 1972) as well as streams and rivers with suitable cover (Soper 1964). During winter, however, otters use open stretches of water, such as those near the headwaters of rivers and streams where the water is swift and turbulent, open areas below waterfalls, or openings in the ice of beaver ponds (Green 1932; Hodgdon and Hunt 1955; Knudsen 1962; Soper 1964).

5.5 SPATIAL REQUIREMENTS

The otter is described as having an undefined home range and has been noted to travel up to 97 km of stream per year. River otters normally range over 5-16 km of stream per season (Liers 1951).

Territories of the European otter normally do not overlap. However, at high densities, territories of the wider-ranging dog otters (adult males) may overlap considerably (Erlinge 1968).

Females with young tend to have a more defined home range than males, but tend to extend their home range as the young grow older. Distinct, non-overlapping territories ensure an abundance of food for family groups and provide sufficient space for the establishment of dens, rolling places, slides, runways, and paths within the territory (Erlinge 1968).

Topography and access to open water in winter are of primary importance; food supply and population densities are also concerns in the establishment of a territory. The size of home range for dog otters varies with local topography and the occurrence of other otters (Erlinge 1967a).

During spring, river otters are highly mobile. Breakup of fast-ice on streams and lakes gives access to new feeding areas. Summer activities tend to centre around the eutrophic portions of lakes and several preferred streams; there is little movement to other areas. Mobility increases again during fall, but returns to a low level during winter. During winter, river otters tend to remain in areas that provide access to open water (Erlinge 1967a). If, however, during the course of the winter, pockets of water become limited, river otters may travel considerable distances to locate open water, where prey is available (Petersen 1966).

PART 2. A FIELD STUDY OF THE DISTRIBUTION AND HABITAT ASSOCIATIONS OF SEMI-AQUATIC FURBEARERS IN THE AOSERP STUDY AREA.

1. INTRODUCTION

During 1977, AOSERP commissioned a field study of semi-aquatic furbearers (Gilbert 1978). This study concentrated on food habits and population characteristics of beavers, muskrats, mink and river otters, primarily in the general vicinity of Fort MacKay. The study was designed to be intensive rather than extensive in nature. As a result, semi-aquatic furbearers were not studied in large portions of the AOSERP study area.

The present study has been conducted to determine the distribution and habitat relationships of four species of semi-aquatic furbearers throughout the AOSERP study area.

A combination of air and ground transect surveys were used to determine the distribution and habitat use of semi-aquatic furbearers and to determine the abundance of beavers and muskrats in the AOSERP study area.

2. METHODS AND STUDY AREA

2.1 AERIAL SURVEYS FOR BEAVER LODGES

2.1.1 Timing of Surveys

Aerial transect surveys were flown during October in order to document the distribution and abundance of beavers in the AOSERP study area. An attempt was made to fly the surveys as close to the date of freeze-up as possible (before lakes and ponds became snow-covered), because most winter food caches are in place by this time and can be readily observed. Because of the uncertainty of the date of freeze-up, a preliminary survey was flown on 11 and 12 October 1978 -- before signs of freeze-up had commenced. Freeze-up appeared imminent towards the end of this preliminary survey and a second aerial survey was flown from 17-20 October 1978. During this survey, many ponds in the Birch Mountains were already frozen and a trace of snow covered much of the AOSERP study area.

A series of aerial surveys of streams and lakes was also flown during October. Streams and lakes, primarily in the Birch Mountains, were overflown with a fixed-wing aircarft on 13 October 1978. On 21 and 22 October 1978, aerial surveys of streams in other regions of the study area were conducted using a helicopter.

2.1.2 Aerial Survey Procedures

A combination of aerial survey methods was used. Linear transects were flown both in the preliminary survey and in the survey conducted from 17-20 October. Transect surveys were conducted from a Cessna 180 aircraft at an altitude of approximately 70 m above ground level (AGL) and a ground speed of approximately 160 km/h. The preliminary survey was conducted primarily with one observer although two observers were present for part of the time. Two observers were present for all other linear surveys. Surveys of streams and lakes were conducted from a Cessna 180 aircraft on 13 October and from a Hughes 500-C helicopter on 21 and 22 October. The fixed-wing survey was conducted with one observer and flown at approximately 50 m AGL and a ground speed of approximately 130 km/h. The helicopter survey was conducted with two observers and flown at a variable speed (usually less than 70 km/h) at approximately 50 m AGL.

2.1.3 Survey Locations

The approximate locations of transect lines flown during the preliminary survey are shown in Figure 1[1]. Transect lines surveyed from 17 to 20 October are presented in Figure 2. The streams and lakes (or portions thereof) that were surveyed by fixed-wing or rotary-wing aircraft are depicted in Figure 3.

2.1.4 Data Recording

Each observer plotted on a map the locations of all beaver lodges and muskrat pushups seen during each survey[2]. Special emphasis was placed on recording lodges within 200 m of the aircraft (i.e., on a transect 400 m wide or, during the preliminary survey when only one observer was present, on a transect 200 m wide).

The status (active, inactive) of each lodge seen was noted. For each active beaver lodge recorded on transect, the following data were recorded during surveys from 17-20 October:

1. time (for locational purposes);
2. waterbody type (lake, stream, wetland);
3. vegetation mosaic around pond (in terms of herb, shrub and tree layer); and
4. forest type.

During the preliminary surveys, on 11-12 October only the status of beaver lodges was consistently recorded. Additional data were noted when time was available. When an active dam or a beaver was observed, but no lodge was seen on transect, it was assumed that an active lodge was present nearby, but off transect.

---

[1]More exact locations of aerial survey lines are available at the office of LGL Limited, 10110-124 Street, Edmonton, Alberta

[2]All other mammals seen during surveys were also recorded and these data are presented in Appendix 1.

An attempt to have a third observer record general vegetation types along the 400 m wide transect failed after completion of three transect lines because of continued observer air sickness. Accordingly, habitat availability was determined by plotting the route of aerial surveys on forest cover maps (Alberta Forest Cover Series, map sheets 74D, 74E, 84A, and 84H) and then by measuring the distance of the transect line in each forest type. Distances were totaled and the proportions of the transect lines in each habitat type were calculated. Finer resolution of habitat types and updating of the forest cover maps were achieved by using habitat maps developed for AOSERP by Intera Environmental Consultants. Because the entire AOSERP study area has not been mapped by Intera at this time, it was necessary to develop a correction factor, based on Intera's maps and limited field truthing, that was applied to portions of the AOSERP study area that were not mapped by Intera. Although there are several problems associated with this approach, it was apparent that the resulting data were sufficiently accurate to assess general habitat preferences of beavers.

During the stream and lake surveys, the entire width of each stream and the entire shoreline of each lake was surveyed. The locations of lodges were recorded on a map. During these surveys the following data were also recorded:

1. forest type;
2. estimate of stream speed (class 1 to 5); and
3. estimate of stream width (in metres).

2.2 TRACK-COUNT SURVEYS

In order to determine the distributions of mink and river otters in relation to riparian habitats, systematic track counts were conducted along streams and lake shores from 24 November 1978[1] - 19 December 1978. Streams were skiied whenever possible; when

[1] 24 November 1978 was approximately the earliest date after freeze-up when streams were solid enough to travel on. Regions of thin ice and open water remained on the rivers and streams throughout the period of this study.

Figure 1. Map of portion of AOSERP Study Area showing route of preliminary aerial survey and locations of beaver lodges seen during survey.

LEGEND

On transect

● Active beaver lodge

○ Inactive beaver lodge

Off transect

■ Active beaver lodge

□ Inactive beaver lodge

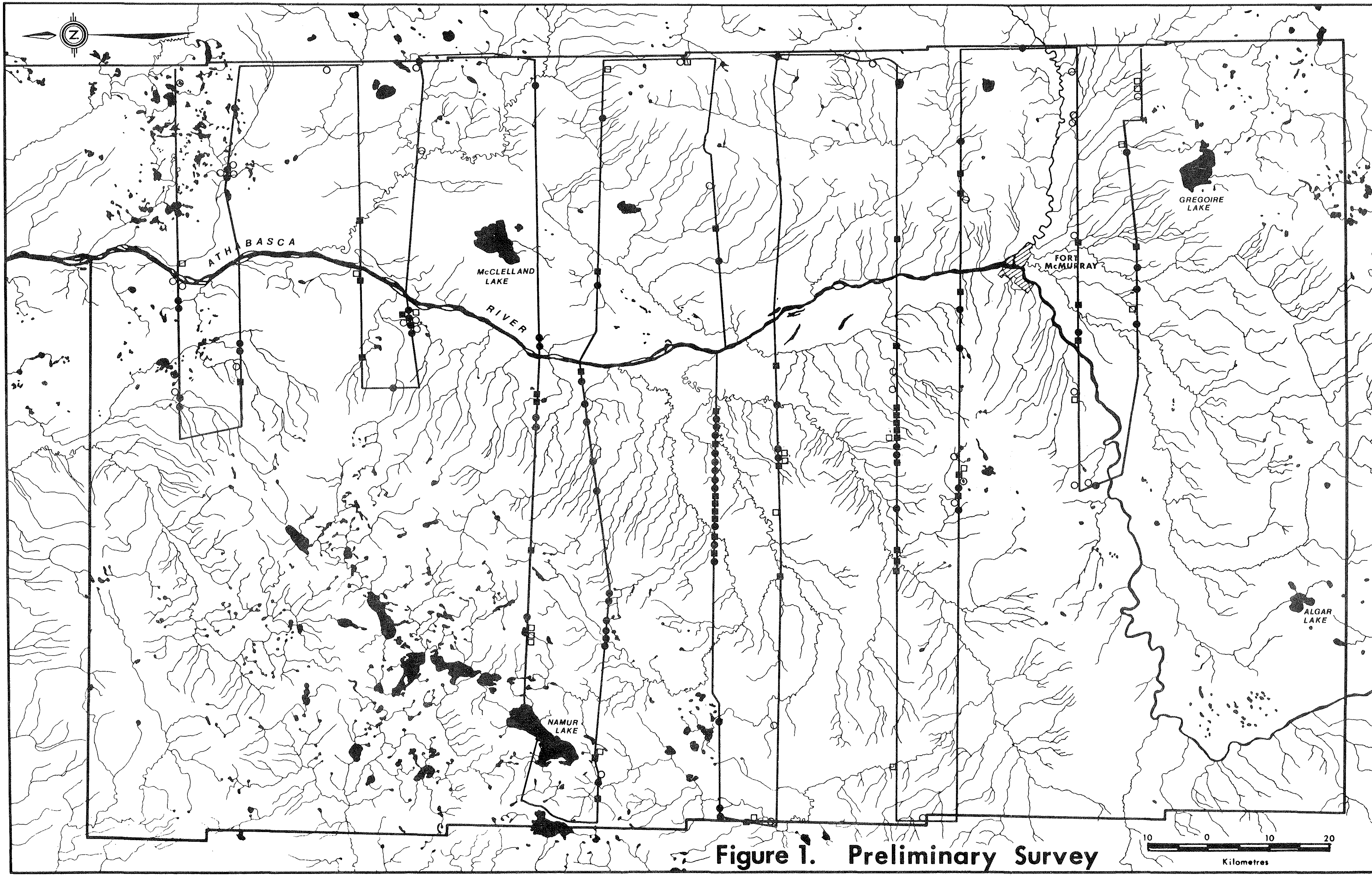


Figure 1. Preliminary Survey

Figure 2. Map of portion of AOSERP Study Area showing route of aerial survey flown 17-20 October 1978 and locations of beaver lodges seen during survey.

LEGEND

On transect

● Active beaver lodge

○ Inactive beaver lodge

Off transect

■ Active beaver lodge

□ Inactive beaver lodge

△ Unknown status

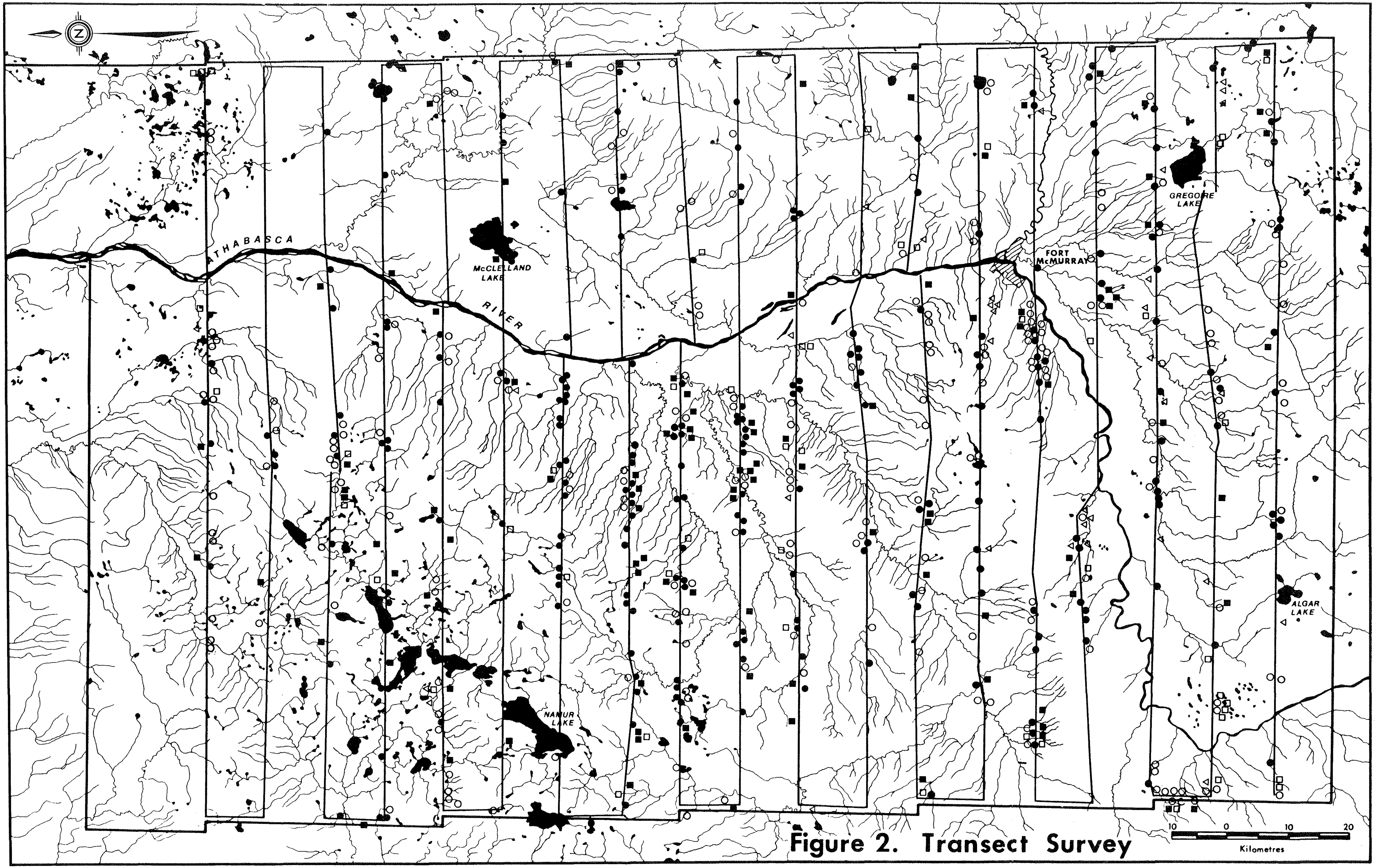


Figure 2. Transect Survey

Figure 3. Map of portion of AOSERP Study Area showing waterbodies surveyed by fixed-wing or rotary-wing aircraft.

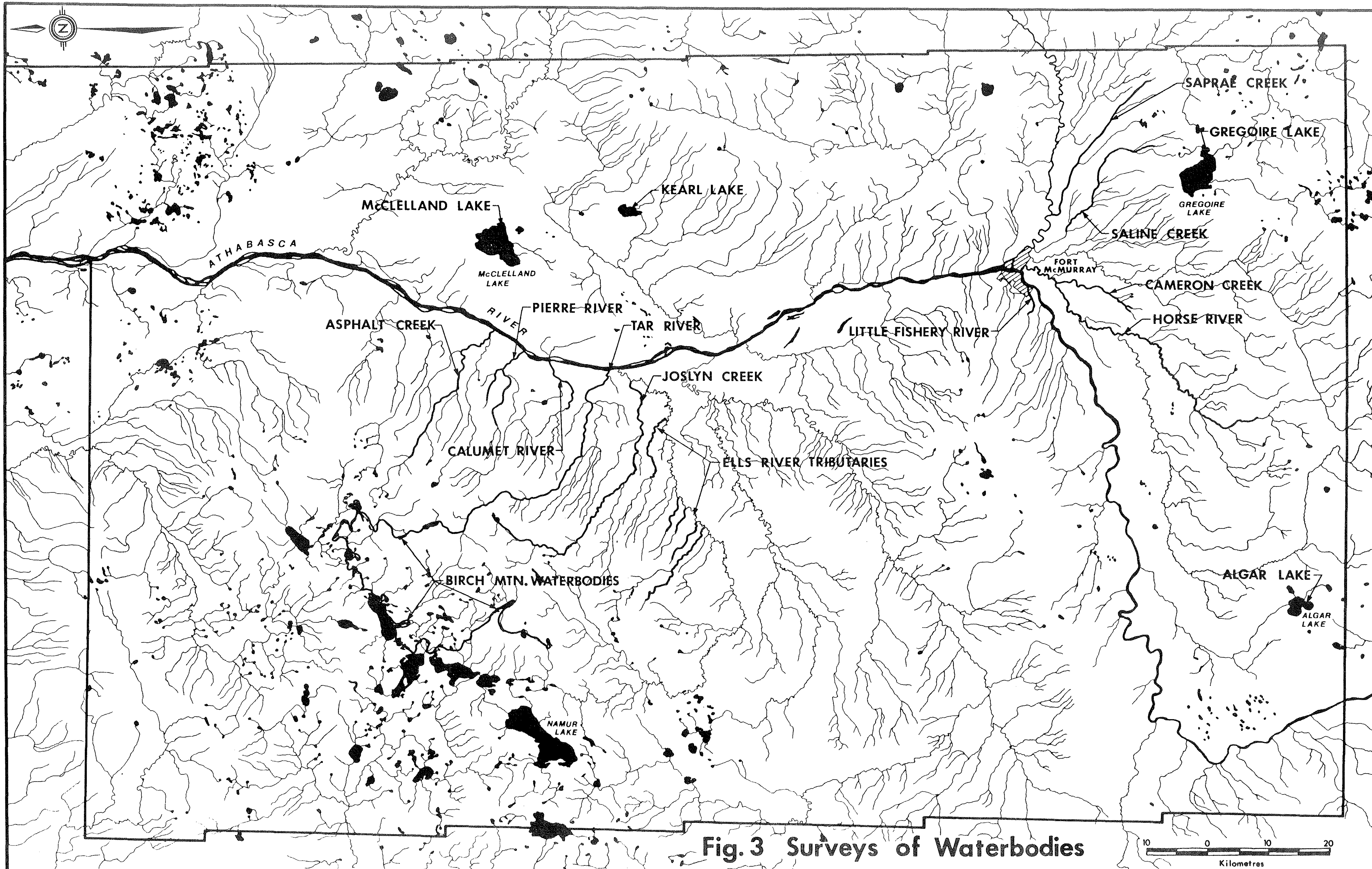


Fig. 3 Surveys of Waterbodies

vegetation across the streams was too dense to ski through, track counts were conducted by walking along the stream or its bank. The following parameters were recorded:

1. snow accumulation during last 24 h period;
2. maximum and minimum daily temperature;
3. estimated average daily cloud cover;
4. estimated average daily wind speed;
5. vegetation type for each 0.5 km of stream
   a) dominant shrub species,
   b) average height class of shrub species (0-1 m, 1-3 m, 3 m),
   c) average density class of shrub species (sparse, moderate, dense), and
   d) dominant tree species;
6. number of tracks of each species of furbearers, snowshoe hares and ungulates on each 0.5 km of stream;
7. vegetation (as in 5) associated with each set of tracks other than snowshoe hare tracks; and
8. location of beaver lodges and associated vegetation (as in 5).

The number of tracks per night was taken to be the number of tracks divided by the number of nights since the most recent snowfall of sufficient magnitude to obscure mink or river otter tracks.

The location of each track-count survey is presented in Figure 4. Large scale maps showing the exact location, length and survey dates of each survey route are presented in Appendix 2.

3. RESULTS

3.1 PRELIMINARY AERIAL SURVEYS

The distribution of lodges sighted along transect lines during the preliminary aerial survey is presented in Figure 1. A total of 70 active lodges were seen on transect and 45 active lodges were seen off transect along approximately 1250 km of transect lines. In addition, 36 inactive lodges were seen on transect and 21 inactive lodges were seen off transect.

Lodges were widely distributed over the surveyed area. Approximately 37% of the total active lodges seen were located in the drainages of the MacKay, Dover, Ells and Tar rivers, while only 18% of the transect coverage was in this same area. Few lodges were seen east of the Athabasca River (north of Ft. McMurray).

Of the 32 lodges for which habitat information was recorded, 84% were located on streams, 13% were on lakes, and the remainder were in wetland areas (Table 1). The dominant forest types associated with beaver lodge sites were as follows: 161 lodges (50%) were in aspen dominated forests, 7 (22%) were in white-spruce forest, 6 (19%) were in black spruce forest, and one was in each of birch, jackpine and tamarack forest types. Eighty-eight percent of the lodges were located in habitats in which either aspen or birch was either dominant or the most abundant subordinate forest species.

3.2 AERIAL TRANSECT SURVEYS

The distribution of lodges sighted along transect lines during the aerial survey conducted from 17-20 October 1978 is presented in Figure 2. A total of 249 active lodges were seen on transect and 100 active lodges were seen off transect along approximately 2550 km of transect lines. Also, 204 inactive lodges were seen on transect, 48 inactive lodges were seen off transect, and the statuses of 34 other lodges seen off transect were undetermined.

Figure 4. Map of portion of AOSERP Study Area showing locations of track-count surveys. Larger scale maps of the surveyed areas are presented in Appendix 2.

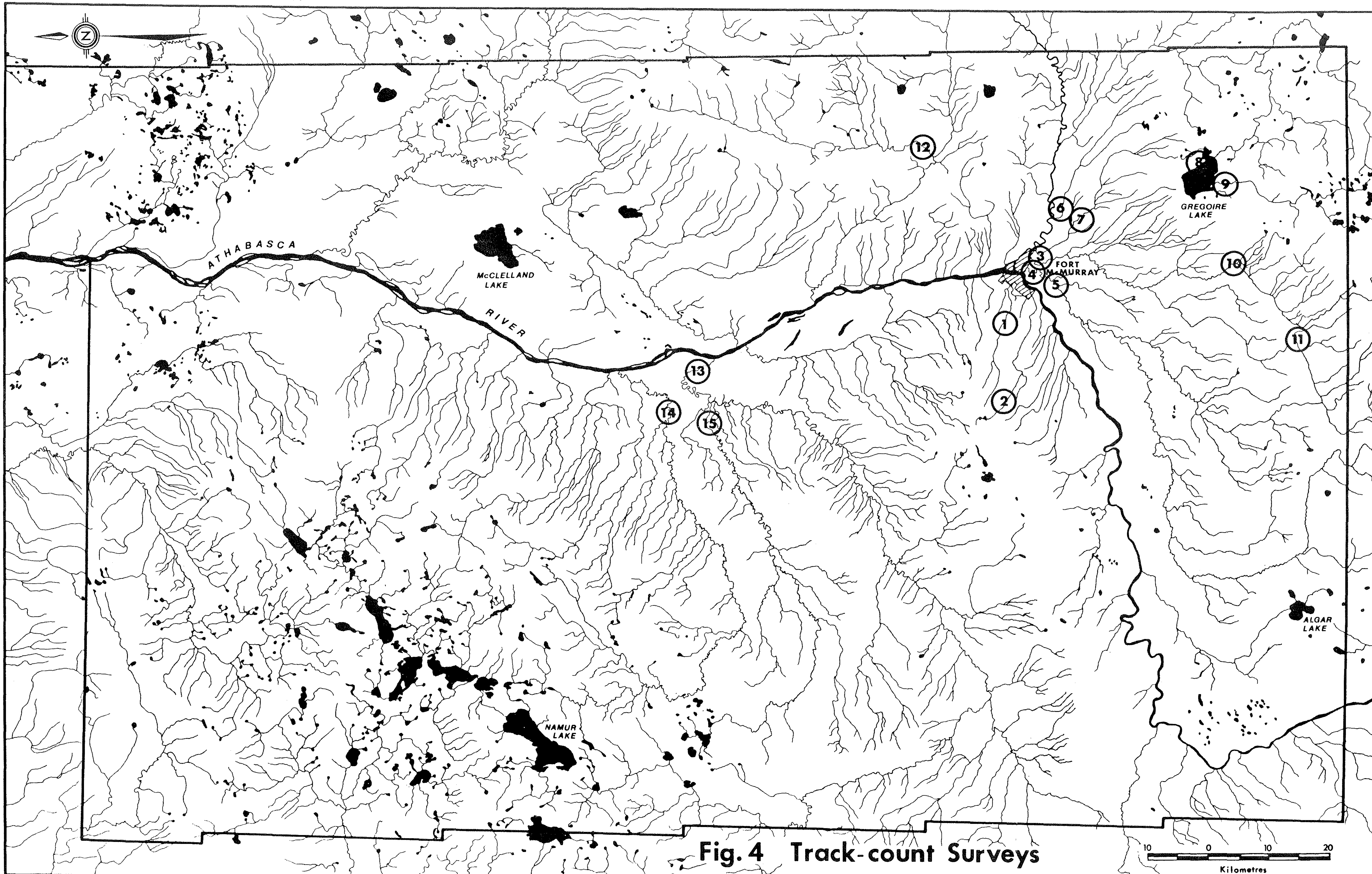


Fig. 4 Track-count Surveys

Table 1. Number of beaver lodges seen during preliminary aerial survey by forest and waterbody types[a].

Waterbody Type	Forest Types						Total Number of Lodges
	Aspen	Birch	White Spruce	Jack Pine	Black Spruce	Tamarack	
Lake	0	0	2	0	2	0	4
Stream	16	1	5	0	4	1	27
Wetland	0	0	0	1	0	0	1
Total	16	1	7	1	6	1	32

[a]Vegetation data were not recorded at locations of 38 other lodges.

Distributional results were similar to those obtained during the preliminary survey. While active lodges were located throughout the AOSERP study area, 40% of the active ldoges seen were located in the drainages of the MacKay, Dover, Ells and Tar rivers, which included only 20% of the transect coverage. Relatively few lodges were present in the region east of the Athabasca River (north of Ft. McMurray). Elsewhere in the AOSERP study area, lodges appeared to be relatively uniformly distributed.

Of the 249 lodges sighted on transect, 78% were located on streams, 16% were on lakes and 6% were in wetland areas (Table 2). Thirty-nine percent of all beaver lodges were located in forest types dominated by aspen, 22% were in white spruce forest, 14% were in black spruce, 9% were in willow habitat; jack pine and birch forest types each contained 7% of the lodges seen, and less than 1% were in each of tamarack forest and fen. Sixty-five percent of the lodges were located in habitats in which aspen, birch or willow were either dominant or the most abundant subordinate forest species.

An analysis of the distribution of beaver lodges relative to the availability of habitats indicated that beavers preferentially selected certain habitats for lodge sites (χ^2=231.25; df=4; $p \ll 0.001$). Beavers used deciduous, white spruce and willow-fen habitats more frequently than expected if there were no preference for these habitats (Table 3). Beavers avoided locating their lodges in jack pine and black spruce-tamarack habitats.

3.3 WATERBODY SURVEYS

Aerial surveys of waterbodies indicated that 178 active beaver lodges were present along approximately 553 km of streams that were surveyed and that 25 active lodges were present on 179 km of lakeshore. The average density was one lodge per 3.1 km of stream and one lodge per 7.2 km of lakeshore. However, lodge densities differed greatly among watercourses (one per 0.5 km-one per 14.4 km; see Table 4). Fifty-eight percent of the streams that were surveyed had an average of more than one active lodge per 2 km.

Table 2. Number of beaver lodges seen during aerial survey conducted from 17 to 20 October by waterbody and vegetation types.

Waterbody Type	Vegetation Types								Total Number of Lodges
	Aspen	Birch	White Spruce	Jack Pine	Black Spruce	Tamarack	Willow	Fen	
Lake	14	3	9	6	6	0	0	2	40
Stream	81	14	47	12	25	1	15	0	195
Wetland	2	0	0	0	4	0	8	0	14
Total	97	17	56	18	35	1	23	2	249
% of Total	39	7	22	7	14	<1	9	<1	
Proportion of Vegetation Types Surveyed	21.7%		8.5%	8.9%	57.2%		3.7%		-

Table 3. Beaver habitat use analysis using the bonferroni Z statistic (Neu *et al.* 1974).

Vegetation Type	Proportion of Total Area (P_i)	Number of Lodges Seen	Proportion of Lodges Seen	Habitat Selection[a]
Aspen-Birch	0.217	114	0.4578	+
White Spruce	0.085	56	0.2249	+
Jack Pine	0.089	18	0.0722	-
Black Spruce-Tamarack	0.572	36	0.1446	-
Willow-Fen	0.037	25	0.1004	+

[a]Habitat selection represents habitat preference (+) or habitat avoidance (-) based on 95% Confidence Interval. No habitats were used in proportion to their occurrence.

Table 4. Densities of active beaver lodges determined from aerial surveys of waterbodies.

Waterbody	Approximate Length Surveyed (km)	Number of Active Beaver Lodges Seen	Density (km/lodge)
Streams			
Calumet River and Tributary	10.0	19	0.5
Cameron Creek	18.0	21	0.9
Little Fishery River	6.5	6	1.1
Pierre River and Tributary	28.5	16	1.8
Saline Creek	24.0	13	1.8
Saprae Creek	28.2	16	1.8
Tributaries of Ells River	50.0	27	1.9
Tar River	64.2	17	3.8
Birch Mountain Streams	62.5	12	5.2
Asphalt Creek	29.4	4	7.4
Horse River and Tributary	160.0	22	7.3
Joslyn Creek	72.0	5	14.4
	553.3	178	3.1
Lakes			
McClelland	24.0	9	2.7
Algar	13.0	3	4.3
Kearl	10.0	1	10.0
Birch Mountain Lakes	105.0	10	10.5
Gregoire	27.0	2	13.7
	179	25	7.2

Most beaver lodges were seen at stream locations with low water velocities (Figures 5 and 7) and narrow widths (Figures 6 and 7). Streams were used approximately according to their availability in terms of velocity (assuming that stream gradient and velocity are directly related) (Figure 8). Data on the availability of streams in terms of width were not available. No statistical analyses were conducted on these data because of the lack of precision of the data. Intensive ground work would be necessary to assess preferences for stream velocity and width.

All muskrat houses that were seen were observed while surveying lakes. Houses were observed only on McClelland (17), Algar (5) and Gardiner (4) lakes. Because few muskrats in northern regions such as northeastern Alberta use dwellings that are observable from the air (Law 1950; Fuller 1951; Stevens 1955; Schmitke 1959; Ruttan 1974), the distribution and abundance of houses identified during this study does not represent the true distribution or abundance of muskrats in the AOSERP study area.

3.4 TRACK-COUNT SURVEYS

The distribution of tracks along waterbody transects is presented in Appendix 3. Totals of 60 mink tracks and 8 river otter tracks were encountered during track-count surveys. In addition, 30 active beaver lodges were noted. Tracks of other mammals that were seen during track-count surveys are presented in Appendix 3. The results of the analyses of habitat associations as determined from track distributions are presented below.

Table 5 gives the results of a χ^2 test for goodness of fit for each of the habitat variables measured and for the tracks of each species for which habitat data were recorded. A detailed analysis of these data is limited here to mink, river otters and beavers. A significantly disproportionate number of mink tracks were found in habitats dominated by certain shrub species (χ^2=7.593; df=1) and by certain tree species (χ^2=12.7; df=2). Tracks of mink were distributed proportionately to the availability of the various height and density classes of shrubs. A more detailed analysis of

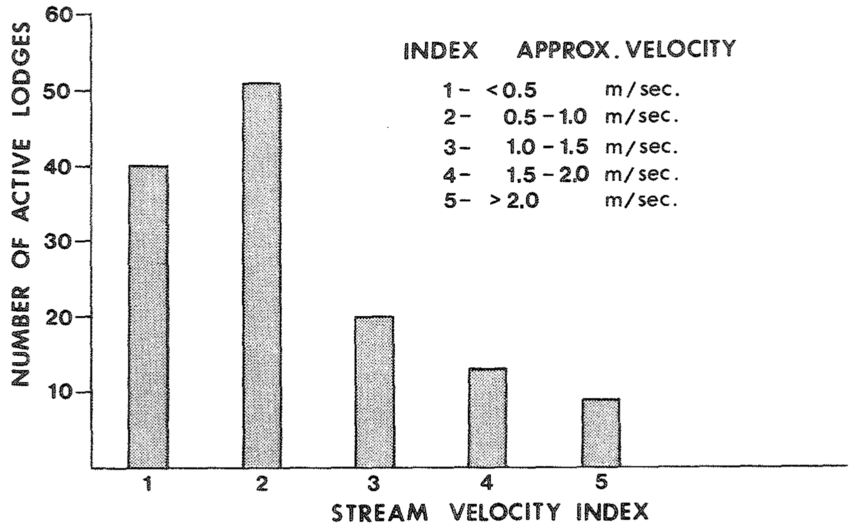


Figure 5. Frequency of active beaver lodges relative to stream velocity.

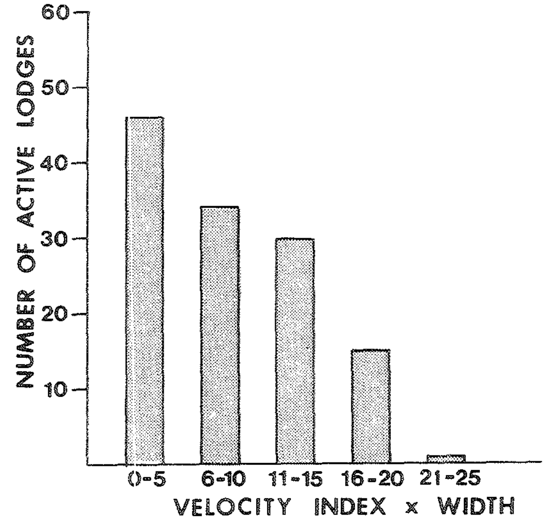


Figure 7. Frequency of active beaver lodges relative to an index of stream flow rate.

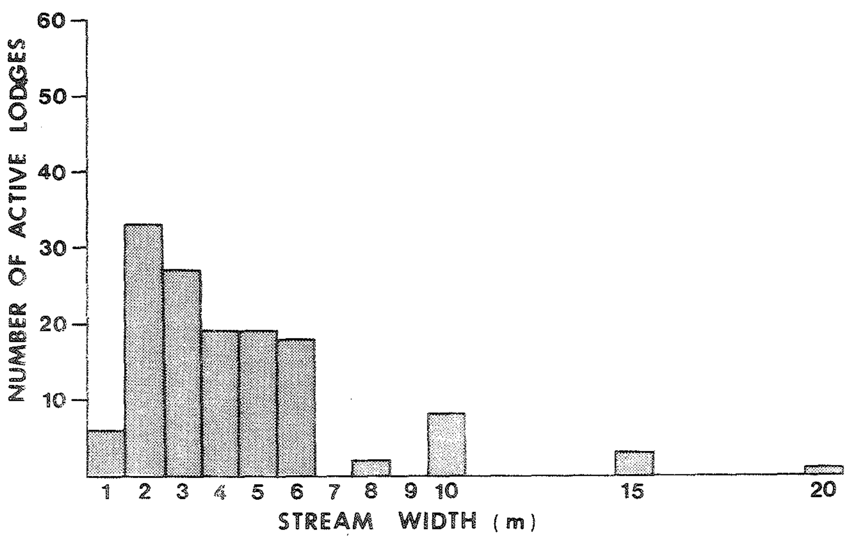


Figure 6. Frequency of active beaver lodges relative to stream width.

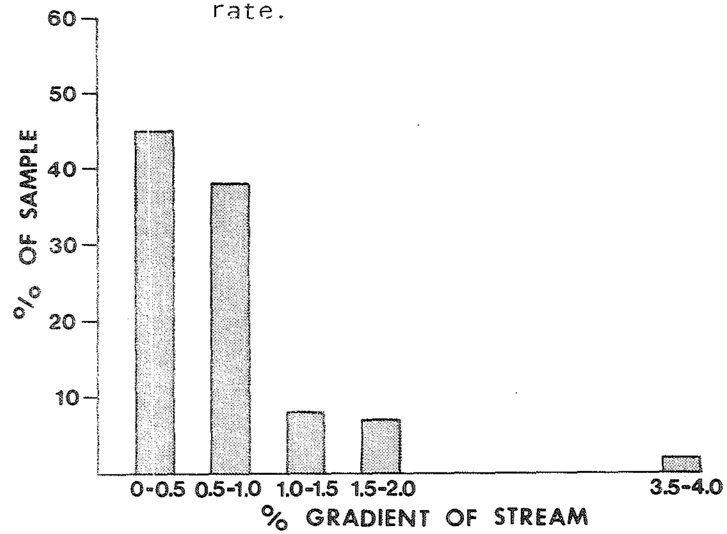


Figure 8. Relative amounts of streams sampled (for which data are available) with various gradients (data from RRCS n.d.).

Table 5. Results of χ^2 test for goodness of fit[a].

Habitat Parameter	Species								
	Mink	River Otter	Beaver	Weasel	Wolf	Coyote	Red Squirrel	Deer	Moose
Shrub Species	**	0	NS	NS	0	0	**	0	0
Shrub Height	NS	0	NS	NS	NS	(*)	NS	0	*
Shrub Density	NS	0	NS	NS	*	0	(*)	0	0
Tree Species	***	0	NS	(*)	*	NS	***	0	NS

[a] Significance Levels
NS not significant
(*) $0.1 \geq P \geq 0.05$
* $0.05 \geq P \geq 0.01$
** $0.01 \geq P \geq 0.005$
*** $P \leq 0.005$
0 sample size too small for statistical analysis

the habitat associations using the Bonferroni Z statistic is presented in Table 6. Results indicate that significantly more mink tracks were located in willow and aspen vegetation types than expected if there were no preference for these habitats. No significant difference was noted in the use of vegetation types dominated by other species.

Mink selected areas of the same (61%) or lower (36%) height classes than were available (n=59). Similarly, mink selected areas of the same (59%) or lower (29%) density classes than were predominantly available (n=59). While no significant difference could be demonstrated in mink selection of shrub density classes (Table 5), 34% of all mink tracks sighted were found in low density shrub areas; these areas comprised approximately 19% of the area that was surveyed.

Too few river otter tracks were encountered to assess habitat use by this species. Only eight tracks were recorded, four were in alder dominated areas and four were in willow dominated areas. Five of the eight sets of tracks were on streams located in aspen dominated forests and three were on streams in white spruce forests.

No significant habitat preferences were identified for active beaver lodge sites (Table 5). This may have been the result of the small sample size because results from aerial surveys presented above indicated that beavers preferred deciduous, white spruce and willow habitats.

Table 6. Mink habitat use analysis using the bonferoni Z statistic.

Vegetation Type	Proportion of Total Area (P_i)	Number of Tracks Seen	Proportion of Tracks Seen	Habitat Selection[a]
Shrubs				
Alder	0.83	35	0.593	-
Willow	0.16	22	0.373	+
Other	0.02	2	0.034	
Trees				
White Spruce	0.59	23	0.426	-
Aspen	0.30	25	0.463	+
Other	0.11	6	0.111	0

[a]Habitat selection represents habitat preference (+), habitat avoidance (-) or use of habitats in proportion to their occurrence (0) based on 95% Confidence Interval.

4. DISCUSSION

4.1 BEAVERS

4.1.1 Distribution and Abundance

Although beavers were widely distributed throughout the entire AOSERP study area, concentrations of lodges were noted in the region of the east slope of the Birch Mountains. The highest density of active beaver lodges was noted on the Calumet River and tributary on the east side of the Birch Mountains; however, streams in this region did not have consistently higher densities than streams in other regions of the AOSERP study area. The large amounts of deciduous forest (or mixed-wood forest) on the east slopes of the Birch Mountains and the preference of beavers for deciduous forest types are probably the major reasons for concentrations of beavers in this area.

During this study, streams that were surveyed for beaver lodges were located either west of the Athabasca River or south of Fort McMurray. During a previous study (Gilbert 1978), several streams and lakes in the Muskeg River area east of the Athabasca River and north of Fort McMurray were surveyed for beaver lodges. Densities of active lodges on seven waterbodies were calculated from maps presented by Gilbert (Table 7). The average density of active beaver lodges in the Muskeg River area ($\bar{x}$=1 lodge/2.5 km; range=1 lodge/4.3-1.0 km) was slightly higher than the average density found elsewhere on the AOSERP study area during the present study ($\bar{x}$=1 lodge/3.1 km; range=1 lodge/14.4-0.5 km). However, only Snipe Creek had a density of active beaver lodges in excess of 1 lodge/2 km of stream whereas 7 of 12 streams (58%) surveyed during fall, 1978, had densities that exceeded this figure.

The average density of active lodges on lakes in the Muskeg River area (includes Kearl and McClelland lakes surveyed during the present study) was considerably higher ($\bar{x}$=1 lodge/3.4 km; range=1 lodge/10.0-2.7 km) than the average density of lodges on lakes elsewhere in the AOSERP study area ($\bar{x}$=1 lodge/9.7 km; range=1 lodge/13.7-4.3 km). However, many of the small lakes

Table 7. Densities of active beaver lodges in the Muskeg River area[a].

Waterbody	Dates Surveyed	Approximate Length Surveyed (km)	Number of Active Lodges Seen	Density (km/lodge)
Streams				
Snipe Creek	10 May, 6-11 August, 16-25 November 1977	4.9	5	1.0
Hartley Creek	10 June, 8 July 1977	16.9	8	2.1
Kearl Creek	30 May-25 June 1977	3.9	1	3.9
Muskeg River	10 June, 8 July 1977	21.4[b]	5	4.3
		47.1	19	2.5
Lakes				
Clear Water Lake	12-14 May, 18-23 July 1977	4.4	1	4.4
Dover Lake	12-14 May, 13-23 July 1977	10.3	5	2.1
Pelican Lake	10 May, 6-11 August, 16-25 November 1977	6.3	0	-
		21.0	6	3.5

[a] Data calculated from maps presented by Gilbert (1978) and Gilbert (pers. comm.).

[b] Less than 21.4 km of the Muskeg River may have been surveyed by Gilbert (1978). Hence the density presented in column 5 may be too low.

each containing seven or eight cobbles 8 to 10 cm in diameter, collected from a nearby deposit of glacial gravel, were attached to a line, dropped to the bottom of the river, and tied to each buoy. A sixth site was chosen on an outcrop of Devonian limestone but neither buoy nor baskets could be stationed here since it was within the navigation channel.

Four weeks later, on 21 June, the buoys at Site 4 and 5 had disappeared and the baskets at Site 2 had been buried by sand and could not be raised. The baskets at Sites 1 and 3 were pulled slowly to the surface and enclosed in a 200 μm mesh net before being lifted into the boat. The upstream sides of the baskets were covered with varying amounts of organic debris (sticks, leaves, grass, etc.) and close inspection revealed that very few, if any, organisms were living on the stones although the debris contained large numbers of benthic animals. Since it was impossible to separate the animals associated with the debris from those associated with the rocks or to estimate how long the debris had been on the baskets, the use of artificial substrates was abandoned. In late August, it was discovered that the buoys at Sites 4 and 5 had been dragged beneath the surface by the baskets which had been rolled downstream. Even after three months in the river, essentially no animals appeared to be living on the rocks, but the debris on the outside of the baskets and the mooring lines contained a rich fauna.

A 15 cm^2 Ekman grab and an airlift were used to take three samples from mud or coarser sediments at each site at approximately four-week intervals from June through October. The airlift was constructed of 5 cm i.d. aluminum pipe in sections of various lengths which could be screwed together as needed, according to the depth at the site. The nozzle (Barton and Hynes in press) was built into one section and the top section had two 90° bends with a rim around the final aperture to hold the drawstring of a 202 μm mesh collecting bag. A SCUBA tank was used as an air supply. The airlift was operated over the stern while the boat was tied at the bow to the buoy marking the sampling site. The pipe was held vertically in active lodges in excess of the levels proposed by Fuller and Novakowski.

4.1.2 Habitat Use

Most beavers in the AOSERP study area established colonies along streams rather than in lakes or other types of wetland areas. The preferred streams, apparently, were those that flowed through deciduous forest or shrubland or through white spruce forest. Because of the strong preference of beavers for aspen (see Tufts 1967 for review) and other deciduous woody species (Rutherford 1964; Novakowski 1965; Tufts 1967; Aleksiuk 1970; Slough and Sadlier 1977) as food items, the proximity of deciduous trees to beaver colonies is important. Beavers avoided locating their lodges in pure stands of conifers. The extensive use of white spruce habitats can probably be attributed to the abundance of birch and aspen trees that commonly are successional precursors of white spruce forests.

Some data were collected that indicated that beavers established their lodges along low-gradient (low-velocity) sections of stream. Similar observations were made by Soper (1937), Swank (1949, cited by Sverre 1972), Retzer (1955, cited by Yeager and Rutherford 1957) and Crawford *et al.* (1976).

These general habitat preferences of beavers are similar to those of beavers in other areas of Alberta (Soper 1964) and North America (Tufts 1967). More subtle habitat preferences may exist that are unique to northern populations of beavers (Boyce 1974), but detailed ground-level studies would be needed to identify these differences.

4.2 MUSKRATS

Muskrats are not common in the AOSERP study area south of the Peace-Athabasca Delta. During this study, muskrats were noted to be present on three lakes: McClelland, Gardiner and Algar lakes. Gilbert (1978) reported muskrats on Kearl and Pelican lakes and in the Ruth Lake-Mildred Lake area. A total of 76 houses were counted during complete aerial coverage of the latter area. Muskrats may

Records of turbidity and daily discharge of the Athabasca River below Fort McMurray during 1978 were obtained from the Inland Waters Directorate, Water Survey of Canada.

3.1.2 Results

The discharge of the Athabasca River averaged about 210 $m^3 \cdot s^{-1}$ during the first three months of 1977, and increased to 1217 $m^3 \cdot s^{-1}$ before the ice broke on 29 April. Daily discharge from May through October is shown in Figure 23. The temperature rose from near $0^{\circ}C$ under ice-cover to 12° by late May and over 18° during June, July, and August, then dropped steadily from September until ice covered the river on 12 November. Turbidity increased with discharge, ranging from 1 to 8 Jackson units under ice-cover to over 100 during peak flows in June and July.

Fluctuating discharge effected changes in the nature of the sediments at Sites 2, 3, and 4 (Table 12). Erosion or deposition of sediment at each of these sites appeared to be related to a combination of discharge, topography of the river bed, and the nature of the sediments in the area.

The composition of the benthic fauna varied on each of the principle types of substrate. A total of 114 taxa were collected during this study, of which 31 appeared in over 65% of all the samples from any given substrate (Table 13). (A complete list of invertebrates is given in Appendix 6.1.) Orthocladiinae B was the most frequently collected species, occurring on all substrates except debris, and dominated the fauna on coarse sand through June and July. The proportion of rare taxa tended to decrease with increasing stability of the substrate (Table 13). Changes in the specific and percentage composition of the fauna at each site, as indicated by low values of CC and PSC, tended to be greatest during the first three months of the study (Table 14) as a result of emergence of adult insects (especially 'Orthocladiinae B') and erosion or deposition of sediments.

4.4 RIVER OTTER

River otters occur throughout most of the AOSERP study area (Boyd 1977); their signs were observed on the MacKay and Hangingstone rivers and Saprae and Conn creeks. The highest frequency of otter tracks was noted along Conn Creek where dense alder vegetation proliferated.

Although river otters are present in low densities throughout their range, they are comparatively more abundant in northeastern Alberta (Boyd 1977). Boyd attributed this fact to the large fish populations (hence abundant river otter food supply) supported by the Peace-Athabasca Delta complex and adjacent river systems.

Too few data were collected to assess the habitat preferences of river otters.

5. RECOMMENDATIONS

We do not know all of the habitat requirements of semi-aquatic furbearers; this is especially true for northern areas. This report has identified a number of apparent habitat preferences of beavers, muskrats, mink and river otters, but specific studies on the habitat requirements of these species are lacking. In view of this lack of information on the detailed habitat requirements of semi-aquatic furbearers, it would be premature to discuss any but the major characteristics of semi-aquatic furbearer habitats at this time. The primary characteristics that must be present in the proper type and ratio are water, soil and vegetation. If these requirements are met, it is likely that food, shelter and spatial requirements will also be fulfilled. The following discussion is limited to these three major habitat features.

From data presented in this report, it is apparent that a major habitat component of semi-aquatic furbearers is flowing water in the form of creeks and rivers. In addition to streams, moderately shallow lakes of high productivity are used by all four species of semi-aquatic furbearers in the AOSERP study area. It is probably not sufficient to provide only one or the other -- either streams or lakes. Muskrats prefer shallow lakes and marshes with emergent vegetation; lakes are also used considerably by beavers, mink and river otters. Streams are widely used and are probably the most important waterbodies for semi-aquatic furbearer populations. Beavers, mink and river otters are most commonly found along streams. The modification of streams into a series of ponds by beavers benefits other semi-aquatic furbearers and many other species of wildlife (Bradt 1947; Grasse and Putnam 1950; Beard 1953; Hodgdon and Hunt 1955; Knudsen 1962).

The creation of waterbodies is not sufficient to guarantee the presence of semi-aquatic furbearers. Many other habitat components must be present in adequate proportions and proximity. For beavers, stable water conditions or suitable sites for dams must exist. Low gradient streams generally provide the best dam sites because large amounts of water can be impounded with a relatively low dam (Soper 1937).

All semi-aquatic furbearers require suitable soil conditions. A major factor in the habitat requirements of semi-aquatic furbearers is waterbody substrate that is suitable for aquatic vegetation (beavers, muskrats, mink), aquatic invertebrates (mink, river otters), and fish (mink, river otters). Stable soil conditions along the banks of rivers and lakes are also necessary, primarily for the construction of dens. Clay soils are superior to other types of soil for denning; sandy or rocky soils are least suited for den excavation.

Vegetation preferences of species often reflect the habitat requirements of forage or prey species. Beavers, for example, are typically found on streams and lakes in areas with a supply of deciduous trees; in northern areas the preferred species are usually aspen, birch or willow. Muskrats rely on emergent vegetation, primarily cattail and bulrush, for food and usually inhabit marshes or lakes in which these plants are plentiful. Mink eat a variety of food items of which the majority are usually small rodents. Sizeable small mammal populations are frequently present in areas dominated by shrubs such as edges of forests and along streams, and mink are frequently found in these types of habitats. The river otter's food requirements are met largely in the aquatic environment; otters are indirectly influenced by aquatic vegetation. River otters are most abundant both along nutrient rich streams with abundant stocks of fish and invertebrates, and in eutrophic lakes.

The importance of vegetation as cover must also be considered. Cover requirements are especially important for muskrats which most often select areas of tall and dense emergent vegetation regardless of the vegetation type.

As semi-aquatic mammals, beavers, muskrats, mink and river otters are largely associated with riparian habitats. These habitats are maintained by the action of streams and lakes as secondary seres or subclimax communities with a considerable edge-effect. It is probably correct to assume that in northeastern Alberta a mosaic of naturally occurring riparian habitats provides ample food and cover requirements for sizeable semi-aquatic furbearer populations to exist. Artificially propogated or maintained climax forests (e.g., jack pine, white spruce) and/or continued alterations of riparian habitats would probably result in low numbers of semi-aquatic furbearers on reclaimed lands.

The emphasis of most efforts to reclaim mined or otherwise disturbed land has centred around terrestrial systems (Hutnik and Davis 1973). There have been few successful attempts to restore waterbodies on reclaimed lands. Waterbodies that have been created on reclaimed lands have usually been created by default (i.e., a hole fills with water and becomes a lake). To my knowledge, no stream, complete with surface and subsurface drainages, has been restored by man after having been completely destroyed by mining. Therefore, restoration of semi-aquatic furbearer habitat after mining will not be an easy task. It is also possible, in view of the fact that the habitat requirements of semi-aquatic furbearers are not completely understood, that even if wetland reclamation efforts are successful in creating habitats that meet the criteria discussed above permanent use of these areas by semi-aquatic furbearers may not occur.

In summary, proper soil and water conditions are of paramount importance to the establishment of semi-aquatic furbearer populations; however, these conditions are very difficult and expensive to restore. In view of this, a management option for semi-aquatic furbearers is the prevention of development in major, and a selection of key secondary, watercourses and waterbodies. Further preventive measures to preserve subsurface flow patterns of streams are also necessary. Protection of lakes, streams and riparian habitats that are essential for the perpetuity of semi-aquatic furbearers can be achieved by identifying corridors along streams and around lakes in which no major development activities are allowed. The corridor widths would be determined on ecological and hydrological engineering bases. This option appears to be the only realistic solution to a potentially major impact on semi-aquatic furbearers in northeastern Alberta.

PART 3. SELECTED BIBLIOGRAPHY ON THE HABITAT RELATIONSHIPS OF BEAVERS, MUSKRATS, MINK AND RIVER OTTERS.

References that have been cited in the text of this report are indicated by an asterisk in the left margin.

*Akande, M. 1972. The food of the feral mink *(Mustela vison)* in Scotland. J. Zool., Lond. 167:475-479.

*Akkermann, V.R. 1975a. Untersuchungen zur Ökologie und Populationsdynamik des Bisams (*Ondatra zibethicus* L.) an einem nordwestdeutschen Verlandungssee. I. Bauten. Z. Angew. Zool. 62:39-81. [In German, German and English summaries].

Akkermann, V.R. 1975. Untersuchungen zur Ökologie und Populationsdynamik des Bisams (*Ondatra zibethicus* L.) an einem nordwestdeutschen Verlandungssee. II. Nahrung und Nahrungsaufnahme. Z. Angew. Zool. 62:173-218. [In German, German and English summaries].

*Akkermann, V.R. 1975b. Untersuchungen zur Ökologie und Populationsdynamik des Bisams (*Ondatra zibethicus* L.) an einem nordwestdeutschen Verlandungssee. III. Verhalten und Populationsdynamik. Z. Angew. Zool. 62:281-338. [In German, German and English summaries].

*Alberta Recreation, Parks and Wildlife. in prep. Methodology report on Alberta Land Inventory-Furbearers. Unpubl. Rep., Alberta Fish and Wildl. Div., Edmonton. 62 p.

Alcorn, G.D. 1934. Unusual home of beaver. Murrelet 15:82.

*Aleksiuk, M. 1968. Scent-mound communication, territoriality, and population regulation in beaver (*Castor canadensis* Kuhl). J. Mammal. 49:759-762.

*Aleksiuk, M. 1970. The seasonal food regime of arctic beavers. Ecology 51:264-270.

*Aldous, S.E. 1938. Beaver food utilization studies. J. Wildl. Manage. 2:215-222.

*Aldous, S.E. 1947. Muskrat trapping on Sand Lake National Wildlife Refuge, South Dakota. J. Wildl. Manage. 11:77-90.

Alexander, M.M. 1955. Variations in winter muskrat habitats and harvests. Am. Midl. Nat. 53:61-70.

*Ambrock, K. and L. Allison. 1973. Status of muskrat on the Peace-Athabasca Delta. 67 p. *In:* Peace-Athabasca Delta Project. Ecological Investigations. Vol. 2. Technical Appendices. Appendix L.

Anderson, W.L. 1948. Level ditching to improve muskrat marshes. J. Wildl. Manage. 12:172-176.

Arata, A.A. 1957. Ecology of muskrats in strip-mine ponds in southern Illinois. M.S. Thesis, Southern Illinois Univ., Carbondale.

Arata, A.A. 1959. Ecology of muskrats in strip-mine ponds in southern Illinois. J. Wildl. Manage. 23:177-186.

Artimo, A. 1949. Suomi tuottavana piisamimaana [Finland, a profitable muskrat land]. Suomen Riista 4:7-61. [In Finnish, English summary].

Artimo, A. 1952. Pissamituoton tehostaminen [How to increase muskrat production]. Suomen Riista 7:22-38;183-184. [In Finnish, English summary].

*Artimo, A. 1960. The dispersal and acclimatization of the muskrat, *Ondatra zibethicus* (L.) in Finland. Papers Game Res. (Helsinki) 21:1-101.

*Atwater, M.M. 1940. South Fork (Montana) beaver survey: 1939. J. Wildl. Manage. 4:100-103.

*Atwood, E.L., Jr. 1938. Some observations on adaptability of Michigan beavers released in Missouri. J. Wildl. Manage. 2:165-166.

*Bailey, V. 1927. Beaver habits and experiments in beaver culture. U.S. Dep. Agric., Tech. Bull. No. 21. 39 p.

Banfield, A.W.F. 1946. A preliminary investigation of the muskrat resources of the Mackenzie Delta. Unpubl. Rep., Can. Wildl. Serv., Edmonton. 26 p.

*Beard, E.B. 1953. The importance of beaver in waterfowl management at the Seney National Wildlife Refuge. J. Wildl. Manage. 17:398-436.

*Beer, J. 1942. Notes on the winter food of beavers in the Palouse Prairies, Washington. J. Mammal. 23:444-445.

*Bellrose, F.C. 1950. The relationship of muskrat populations to various marsh and aquatic plants. J. Wildl. Manage. 14:299-315.

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

*Bellrose, F.C., Jr. and J.B. Low. 1943. The influence of flood and low water levels on the survival of muskrats. J. Mammal. 24:173-188.

*Bergerud, A.T. and D.R. Miller. 1977. Population dynamics of Newfoundland beaver. Can. J. Zool. 55:1480-1492.

*Beshears, W.W., Jr. and A.O. Haugen. 1953. Muskrats in relation to farm ponds. J. Wildl. Manage. 17:450-456.

*Boyce, M.S. 1974. Beaver population ecology in interior Alaska. M.S. Thesis, Univ. of Alaska, Fairbanks. 161 p.

*Boyd, M. 1977. Analysis of fur production records by individual furbearing species for registered trapping areas in Alberta, 1970-75. Unpubl. Rep., Alberta Recreation, Parks and Wildl., Fish and Wildl. Div., Edmonton. 72 p.

*Bradt, G.W. 1938. A study of beaver colonies in Michigan. J. Mammal. 19:139-162.

*Bradt, G.W. 1947. Michigan beaver management. Michigan Dep. Conservation, Game Div. 56 p.

Brander, T. 1951. Om bisamråttan ur jaktvårdssynpunkt [On muskrat from the point of view of game management]. Suomen Riista 5:84-142. [In German, English summary].

*Brenner, F.J. 1962. Foods consumed by beavers in Crawford County, Pennsylvania. J. Wildl. Manage. 26:104-107.

Buckley, J.L. 1950. The ecology and economics of the beaver (*Castor canadensis* Kuhl) with a plan for its management on the Huntington Wildlife Forest Station. Ph.D. Thesis, State Univ. of New York, Syracuse. 251 p.

Burns, J.J. 1964. The utilization of pingos by mink in the Yukon-Kuskokwim Delta, Alaska. Proc. Alaska Sci. Conf. 14:64-65.

*Burns, J.J. 1964. The ecology, economics and management of mink in the Yukon-Kuskokwim Delta, Alaska. M.S. Thesis, Univ. of Alaska, Fairbanks. 114 p.

Call, M.W. 1966. Beaver pond ecology and beaver-trout relationships in southeastern Wyoming. Unpubl. Rep., Wyoming Game and Fish Comm. FW-014-R-03. 305 p.

Carter, T.D. 1922. Notes on a Saskatchewan muskrat colony. Can. Field-Nat. 36:176.

*Chu, C. and C.T. Yien. 1964. [Habitats and densities of the muskrat, *Ondatra zibethicus* Linnaeus]. Acta Zool. Sinica 16:354-371. [In Chinese]. Sci. Abstr. China, Biol. Sci. No. 817. 1965.

Collins, T.C. 1976. Population characteristics and habitat relationships of beavers, *(Castor canadensis)*, in northwest Wyoming. Ph.D. Thesis, Univ. of Wyoming, Laramie. 188 p.

Cottle, W.H. 1951. A study of the ecology of beaver in central British Columbia. M.A. Thesis, Univ. of British Columbia, Vancouver. 58 p.

*Coulter, M.W. 1948. A study of movements and habitat preferences of muskrats in Maine. M.S. Thesis, Univ. of Maine, Orono. 114 p.

*Cowan, I.M. 1948. Preliminary wildlife survey in the Mackenzie Delta with special reference to the muskrat. Unpubl. Rep. 36 p.

Cowan, I.M. and C.J. Guiguet. 1956. The mammals of British Columbia. B.C. Prov. Mus. Handbook No. 11. 414 p.

Crawford, B.T. 1950. Some specific relationships between soils and wildlife. J. Wildl. Manage. 14:115-123.

*Crawford, H.S., R.G. Hooper and R.F. Harlow. 1976. Woody plants selected by beavers in the Appalachian Ridge and Valley Province. U.S. Dep. Agric., Forest Ser. Res. Paper NE-346. 6 p.

*Croxton, L.W. 1960. A southeastern Alaska mink management study. M.S. Thesis, Univ. of Alaska, Fairbanks. 74 p.

*Danell, K. 1977. Dispersal and distribution of the muskrat (*Ondatra zibethica* L.) in Sweden. Viltrevy 10:1-26. [In English, Swedish summary].

*Danell, K. 1978a. Use by muskrats of an area in Sweden containing highly differentiated habitats. J. Wildl. Manage. 42:908-913.

*Danell, K. 1978b. Intra- and interannual changes in habitat selection by the muskrat. J. Wildl. Manage. 42:540-549.

Danell, K. 1978. Ecology of the muskrat in northern Sweden. Nat. Swedish Environ. Protection Board Rep. SNV PM 1043. 157 p.

*Dauphiné, T.C. 1965. Biology and ecology of the muskrats in a central Adirondack area. M.S. Thesis, Syracuse Univ., Syracuse, New York. 140 p.

Dean, F.C. 1957. Age criteria and kit growth of central New York muskrats. Ph.D. Thesis, State Univ. of New York, Syracuse. 79 p.

*Dearborn, N. 1932. Foods of some predatory fur-bearing animals in Michigan. Univ. of Michigan, Ann Arbor, School Forest Conservation Bull. 1.

Dennington, M.C. and B.E. Johnson. 1974. Studies of beaver habitat in the Mackenzie Valley and Northern Yukon. Environmental-Social Comm., Northern Pipelines, Task Force on Northern Oil Development. Rep. No. 74-39. 172 p.

*Dennington, M.C., B.E. Johnson and H.A. Stelfox. 1973. Atlas of beaver and muskrat habitat maps. *In:* Wildlife Habitat Inventory of the Mackenzie Valley and the Northern Yukon. Can. Wildl. Serv., Environmental-Social Program, Northern Pipelines.

Donohoe, R.W. 1961. Muskrat reproduction in areas of controlled and uncontrolled water-level units. M.S. Thesis, Ohio State Univ., Columbus. 280 p.

Donohoe, R.W. 1966. Muskrat reproduction in areas of controlled and uncontrolled water-level units. J. Wildl. Manage. 30:320-326.

Doude Van Troostwijk, W.J. 1974. Bibliography of the muskrat *Ondatra zibethicus* (Linnaeus, 1758). Lutra 16:23-24.

Dozier, H.L. 1945. Sex ratio and weights of muskrats from the Montezuma National Wildlife Refuge. J. Wildl. Manage. 9:232-237.

*Dozier, H.L. 1948. Estimating muskrat populations by house counts. Trans. N. Am. Wildl. Conf. 13:372-389.

Dozier, H.L. 1950. Muskrat trapping on the Montezuma National Wildlife Refuge, New York, 1943-1948. J. Wildl. Manage. 14:403-412.

*Dozier, H.L. and R.W. Allen. 1942. Color, sex rations, and weights of Maryland muskrats. J. Wildl. Manage. 6:294-300.

*Earhart, C.M. 1969. The influence of soil texture on the structure, durability, and occupancy of muskrat burrows in farm ponds. Calif. Fish and Game 55:179-196.

*Edwards, R.Y. and I.M. Cowan. 1959. Fur production of the boreal forest region of British Columbia. J. Wildl. Manage. 21:257-267.

*Egorov, Y.E. 1966. Relationship between American mink and otter in Bashkiria. Pages 57-58. *In:* A.I. Yanushevich (ed.). Acclimatization of Animals in the USSR. Israel Program for Scientific Translations, Jerusalem. 250 p. [Translated from Russian].

Elm, R. 1970-71. [The migration of the muskrat *(Ondatra zibethicus)* into the Rhineland]. Decheniana 123:223-233. [In German].

*Erickson, H.R. 1959. Muskrat reproduction, growth, and movement in small water areas of central New York. Ph.D. Thesis, Cornell Univ., Ithaca, New York. 106 p.

*Erlinge, S. 1967a. Home range of the otter *Lutra lutra* L. in Southern Sweden. Oikos 18:186-209.

*Erlinge, S. 1967b. Food habits of the fish-otter, *Lutra lutra* L., in south Swedish habitats. Viltrevy 4:371-443. [In English, Swedish summary].

*Erlinge, S. 1968. Territoriality of the otter *Lutra lutra* L. Oikos 19:81-98.

*Erlinge, S. 1969. Food habits of the otter *Lutra lutra* L. and the mink *Mustela vison* Schreber in a trout water in Southern Sweden. Oikos 20:1-7.

*Erlinge, S. 1972. Interspecific relations between otter *Lutra lutra* and mink *Mustela vison* in Sweden. Oikos 23:327-335.

*Errington, P.L. 1937a. Habitat requirements of stream-dwelling muskrats. Trans. N. Am. Wildl. Conf. 2:411-416.

*Errington, P.L. 1937b. Drowning as a cause of mortality in muskrats. J. Mammal. 18:497-500.

*Errington, P.L. 1939. Reactions of muskrat populations to drought. Ecology 20:168-186.

Errington, P.L. 1940. Natural restocking of muskrat-vacant habitats. J. Wildl. Manage. 4:173-185.

*Errington, P.L. 1941. Versatility in feeding and population maintenance of the muskrat. J. Wildl. Manage. 5:68-89.

*Errington, P.L. 1943. An analysis of mink predation upon muskrats in north-central United States. Iowa Agric. Exp. Sta. Res. Bull. 320:798-924.

*Errington, P.L. 1945. Reduction in productivity of muskrat pelts on an Iowa marsh through depredations of red foxes. J. Agric. Res. 71:137-148.

*Errington, P.L. 1946. Predation and vertebrate populations. Quart. Rev. Biol. 21:144-177, 221-245.

*Errington, P.L. 1948. Environmental control for increasing muskrat production. Trans. N. Am. Wildl. Conf. 13:596-607.

Errington, P.L. 1951. Concerning fluctuations in populations of the prolific and widely distributed muskrat. Am. Nat. 85:273-292.

*Errington, P.L. 1954. The special responsiveness of minks to epizootics in muskrat populations. Ecol. Monogr. 24:377-393.

*Errington, P.L. 1963. Muskrat Populations. Iowa State University Press, Ames. 665 p.

Errington, P.L., R.J. Siglin and R.C. Clark. 1963. The decline of a muskrat population. J. Wildl. Manage. 27:1-8.

Eveland, T.E. and L.M. Rymon. 1977. Preliminary analysis of the population, distribution, and habitat preferences of otters in Pennsylvania. Unpubl. Rep., Pennsylvania Game Comm. 11 p.

*Everhardt, R.T. 1973. Some aspects of mink-waterfowl relationships on prairie wetlands. Prairie Nat. 5:17-19.

Field, R.J. 1970. Winter habits of the river otter *(Lutra canadensis)* in Michigan. Michigan Acad. Sci. 3:49-58.

Folliott, P.F., W.P. Clary and F.R. Larson. 1976. Observations of beaver activity in an extreme environment. Southwest. Nat. 21:131-133.

*Fomicheva, N.I. 1957. Experimental planting of willows in beaver habitat in the Tchetchersk District. Pages 106-109. *In:* Translations of Russian Game Reports. Vol. 1. (Beaver, 1951-1955). Can. Dep. Northern Affairs and National Resources. 109 p. [Translated from Russian].

Fowle, C.D., R.O. Stanfield and A. Fyvie. 1954. The beaver in Ontario. Fed.-Prov. Wildl. Conf. 18:27-34.

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

*Fuller, W.A. 1951. Natural history and economic importance of the muskrat in the Athabasca-Peace Delta, Wood Buffalo Park. Can. Wildl. Serv., Wildl. Manage. Bull., Ser. 1, No. 2. 82 p.

*Fuller, W.A. 1953. Aerial surveys for beaver in the Mackenzie District, Northwest Territories. Trans. N. Am. Wildl. Conf. 18:329-335.

*Fuller, W.A. and G.H. LaRoi. 1971. Historical review of biological resources of the Peace-Athabasca Delta. Pages 153-173. *In:* Proc. Peace-Athabasca Delta Symp. Water Resources Centre, Univ. of Alberta, Edmonton.

Georgievskaya, Z.I. 1975. [Data on the ecology of beavers in the Kondo Sosvinsk Natural Reserve, USSR]. Byulleten Moskovskogo Obshchestva Ispytatelei Prirody, Otdel Biologicheskii (Formerly Sinba)-Cisti 80(4):69-77. [In Russian].

*Gerell, R. 1967a. Food selection in relation to habitat in mink *(Mustela vison* Schreber*)* in Sweden. Oikos 18:233-246.

*Gerell, R. 1967b. Dispersal and acclimatization of the mink *(Mustela vison* Schreb.*)* in Sweden. Viltrevy 5:1-38. [In English, Swedish summary].

*Gerell, R. 1968. Food habits of the mink, *Mustela vison* Schreb., in Sweden. Viltrevy 5:119-211. [In English, Swedish summary].

*Gerell, R. 1970. Home ranges movements of the mink *Mustela vison* Schreber in southern Sweden. Oikos 21:160-173.

*Gese, E.C. and A.R. Shadle. 1943. Reforestation of aspen after complete cutting by beavers. J. Wildl. Manage. 7:223-228.

Giesbrecht, L. and A. Todd. 1977. A preliminary study on the winter food habits of Alberta mustelids. Unpubl. Rep., Alberta Recreation, Parks and Wildl., Fish and Wildl. Div., Edmonton. 35 p.

*Gilbert, F.F. 1978. Interim report on semi-aquatic mammal studies, 1977-1978. Draft report prepared for the Alberta Oil Sands Environmental Research Program. 222 p.

*Gill, D. 1972. The evolution of a discrete beaver habitat in the Mackenzie River delta, Northwest Territories. Can. Field-Nat. 86:233-239.

Gingras, J. 1967. Etude de l'ecologie du castor dans la région du Lac Monroe, Parc du Mont Tremblant, P. Qué. M.Sc. Thesis, Univ. de Montréal, Montréal. 96 p. [In French].

Glass, B.P. 1952. Factors affecting the survival of the plains muskrat, *Ondatra zibethica cinnamomina*, in Oklahoma. J. Wildl. Manage. 16:484-491.

*Grasse, J.E. and E.F. Putnam. 1955. Beaver management and ecology in Wyoming. Wyoming Game and Fish Comm. Bull. No. 6. 75 p.

Grater, R.K. 1936. An unusual beaver habitat. J. Mammal. 17:66.

*Green, H.U. 1932. Observations on the occurrence of otter in the Riding Mountain National Park, Manitoba, in relation to beaver life. Can. Field-Nat. 46:204-206.

Green, J.E. in prep. Baseline states of small mammal populations in the AOSERP study area. Interim Report 1. Prepared for Alberta Oil Sands Environmental Research Program by LGL Limited, Edmonton.

Greer, K.R. 1953. Yearly food habits of the river otter in the Thompson Lakes Region, northwestern Montana as indicated by scat analysis. M.S. Thesis, Montana State College, Bozeman. 30 p.

*Greer, K.R. 1955. Yearly food habits of the river otter in the Thompson Lakes Region, northwestern Montana, as indicated by scat analyses. Am. Midl. Nat. 54:299-313.

*Grigor'ev, N.D. and Y.E. Egorov. 1969. Kvoprosu biotsenotich-eskikh svyazei amerikanskoi norki s rechnoi vydroi v Bashkirskoi ASSR. [The biocoenotic connections of the mink with the common otter in the Bashkirian SSR.]. Sb. Tr. Vses. Nauch-Issled. Inst. Zhivotn. Syr'ya Pushniny 22:26-32. Biol. Abstr. No. 6547. 1970. [Abstract translated from Russian].

Gullion, G.W. 1958. Habitat evaluation and improvement. Unpubl. Rep., Nevada Fish and Game Comm. Project W-027-R-02. Job 7. 14 p.

Gunson, J.R. 1970. Dynamics of the beaver of Saskatchewan's northern forest. M.Sc. Thesis, Univ. of Alberta, Edmonton. 122 p.

Hakala, J.B. 1952. The life history and general ecology of the beaver *(Castor canadensis* Kuhl*)* in interior Alaska. M.S. Thesis, Univ. of Alaska, Fairbanks. 181 p.

*Hall, E.R. and K.R. Kelson. 1959. The Mammals of North America. Ronald Press, New York. 2 Vol.

*Hall, J.G. 1960. Willow and aspen in the ecology of beaver on Sagehen Creek, California. Ecology 41:484-494.

*Hamilton, W.J., Jr. 1936. Food habits of the mink in New York. J. Mammal. 17:169.

*Hamilton, W.J., Jr. 1940. The summer food of minks and raccoons on the Montezuma Marsh, New York. J. Wildl. Manage. 4:80-84.

*Hamilton, W.J., Jr. 1959. Foods of mink in New York. N.Y. Fish and Game J. 6:77-85.

*Hammond, M.C. 1943. Beaver on the Lower Souris Refuge. J. Wildl. Manage. 7:316-321.

*Harbo, S.J., Jr. 1958. An investigation of mink in interior and southeastern Alaska. M.S. Thesis, Univ. of Alaska, Fairbanks. 108 p.

Hartman, A.M. 1975. Analysis of conditions leading to the regulation of water flow by a beaver. Psychol. Rev. 25:427-432.

Harris C.J. 1968. Otters: A Study of the Recent Lutrinae. The World Naturalist. Wedenfeld and Nicolson, London. 397 p.

*Harris, S.W. and W.H. Marshall. 1963. Ecology of water-level manipulations on a northern marsh. Ecology 44:331-343.

*Hatler, D.F. 1976. The coastal mink on Vancouver Island, British Columbia. Ph.D. Thesis, Univ. of British Columbia, Vancouver.

*Hawley, V.D. 1963. Muskrat studies in the Mackenzie Delta, Project M3-2-1. Unpubl. Rep., Can. Wildl. Serv., Edmonton. 37 p.

*Hawley, V.D. 1964. Muskrat studies in the Mackenzie Delta, Project M3-2-1. Unpubl. Rep., Can. Wildl. Serv., Edmonton. 40 p.

*Hawley, V.D. 1965. Muskrat studies in the Mackenzie Delta, Project M3-2-1. Unpubl. Rep., Can. Wildl. Serv., Edmonton. 37 p.

Hay K.G. and W.H. Rutherford. 1963. A guide to beaver trapping and pelting. Pages 65-77. *In:* W.H. Longley and J.B. Moyle. The Beaver in Minnesota. Minnesota Dep. of Conservation, Div. of Game and Fish. Tech. Bull. No. 6.

*Henderson, F.R. 1960. Beaver in Kansas. State Biol. Surv. and Mus. Nat. Hist., Univ. of Kansas, Misc. Publ. No. 26. 85 p.

Henry, D.B. 1967. Age structure, productivity, and habitat characteristics of the beaver in northeastern Ohio. M.S. Thesis, Ohio State Univ., Columbus. 75 p.

*Hensley, A.L. and H. Twining. 1946. Some early summer observations on muskrats in a northeastern California marsh. Calif. Fish and Game. 32:171-181.

Hewitt, O.H. 1942. Management of an artificial marsh in southern Ontario for ducks and muskrats. Trans. N. Am. Wildl. Conf. 7:277-282.

Hewson, R. 1971. Some aspects of the biology of feral mink, *Mustela vison* Schreber, in Banffshire. Glasgow Nat. 18:539-546.

*Hiner, L.E. 1938. Observations on the foraging habits of beavers. J. Mammal. 19:317-319.

*Hodgdon, K.W. and J.H. Hunt. 1953. Beaver management in Maine. Maine. Dep. Inland Fish. and Game, Game Div. Bull. No. 3. 102 p.

Hoffmann, M. 1973. Bibliographie der Bisamratten *(Ondatra)*-Literatur: 3. Nachtrag. Z. Angew. Zool. 60:113-175. [In German].

*Hoglund, N.H. 1966. On the food of the Swedish wild mink *(Mustela vison)*. Zool. Revy. 28:91-96. [In Swedish, English summary].

Huey, W.S. 1955. Effects of habitat on beaver productivity. Unpubl. Rep., New Mexico Dep. Game and Fish. Project W-066-R-03. Job 7. 3 p.

*Huey, W.S. 1956. New Mexico beaver management. New Mexico Dep. Game and Fish. Bull. No. 4. 49 p.

*Hutnik, R.J. and G. Davis (ed.). 1973. Ecology and reclamation of devastated land. Gordon and Breach, New York. Vol. 2. 495 p.

Jackson, A.W. 1953. Development of a method of beaver range evaluation. Unpubl. Rep., Arizona Game and Fish Dep. Project W-069-R-01. 11 p.

Jackson, A.W. 1954. Development of a method of beaver range evaluation. Unpubl. Rep., Arizona Game and Fish Dep. Project W-069-R-02. 7 p.

*Johnson, C.E. 1927. The beaver in the Adirondacks: Its economics and natural history. Roosevelt Wildl. Bull. 4:501-641.

Jonas, R.J. 1955. A population and ecological study of the beaver *(Castor canadensis)* of Yellowstone National Park. M.S. Thesis, Univ. of Idaho, Moscow. 193 p.

Kelsall, J.P., R. Salter, L. Sharp, P. Kellerhals and S. Zoltai. 1973. Fish and wildlife inventory of Driedmeat Lake. Unpubl. Rep. prepared for Alberta Dep. Environment, Planning Div. by LGL Limited, Edmonton. 180 p.

*Kelsall, J.P., E.S. Telfer and T.D. Wright. 1977. The effects of fire on the ecology of the boreal forest with particular reference to the Canadian north: a review and selected bibliography. Can. Wildl. Serv., Occas. Pap. No. 32. 58 p.

Knudsen, G.J. 1959. The case for the beaver pond. Wisconsin Conservation Bull. 16(2):11-15.

*Knudsen, G.J. 1962. Relationship of beaver to forests, trout and wildlife in Wisconsin. Wisconsin Conservation Dep., Tech. Bull. No. 25. 50 p.

*Korschgen, L.J. 1958. December food habits of mink in Missouri. J. Mammal. 39:521-527.

Korsakov, G.K. 1969. Vliyanie usykhaniya ozer kachestvo vodnykh okhotnich'ikh ugodii v lesostepi Zapadnoi Sibiri i Severnogo Kazakhstana. [The effect of the drying up of the lakes on the quality of the aquatic game lands in the forest-steppe of Western Siberia and Northern Kazakhstan]. Sb. Tr. Vses. Nauch Issled. Inst. Zhivotn. Syr'ya Pushniny 22:47-74. Biol. Abstr. No. 5857. 1970. [Abstract translated from Russian].

Kostron, K. 1941. Berichte über die Biberansiedlungsforschungen *(Castor fiber visulanus* Matschie*)* des Rokitno-sumpfgebietes. [Cartographic mapping and description of the habitat of the beaver in the Rokitno swamps]. Zoogeographica 4:111-126. [In German].

Kowand, M. (ed.). 1975. Bibliography of the river otter *(Lutra canadensis)*. Unpubl. Rep., Prepared for Can. Wildl. Serv. by Biological Information Serv., Los Angeles, California.

*Krear, H.R. 1953. An ecological study of the muskrat in the Laramie area. M.S. Thesis, Univ. of Wyoming, Laramie. 172 p.

Labutin, Y.V. and M.V. Popov. 1973. [Role of environment in the population dynamics of the muskrat in Yakutia]. Sov. J. Ecol. 4:238-243. [Translated from Russian].

*Lagler, K.F. and B.T. Ostenson. 1942. Early spring food of the otter in Michigan. J. Wildl. Manage. 6:244-254.

*Lavrov, N.P. 1960. Acclimatization of muskrats in the USSR. 150 p. *In:* Translations of Russian Game Reports, Vol. 7. Canada Dep. Northern Affairs and National Resources. 150 p. [Translated from Russian].

*Law, C.E. 1950. An initial study of the ecology of the muskrat *(Ondatra zibethica spatulata* Osgood*)* of the Slave River delta with particular reference to the physical environment. Unpubl. Rep., Can. Wildl. Serv., Edmonton. 96 p.

*Lawrence, W.H. 1952. Evidence of the age of beaver ponds. J. Wildl. Manage. 16:69-79.

Lawrence, W.H. 1964. Michigan beaver populations as influenced by fire and logging. Ph.D. Thesis, Univ. of Michigan, Ann Arbor. 232 p.

Leighton, A.H. 1933. Notes on the relations of beavers to one another and to the muskrat. J. Mammal. 14:27-35.

*Libby, W.L. 1954. A basis for beaver management in Alaska. M.S. Thesis, Univ. of Alaska, Fairbanks. 80 p.

*Liers, E.E. 1951. Notes on the river otter *(Lutra canadensis)*. J. Mammal. 32:1-9.

*Longley, W.H. and J.B. Moyle. 1963. The beaver in Minnesota. Minnesota Dep. of Conservation, Div. of Game and Fish. Tech. Bull. No. 6. 87 p.

*MacArthur, R.A. 1978. Winter movements and home range of the muskrat. Can. Field-Nat. 92:345-349.

*MacDonald, D. 1956. Beaver carrying capacity of certain mountain streams in North Park, Colorado. M.S. Thesis, Colorado A. and M. College, Fort Collins. 136 p.

MacDonald, S.M., C.F. Mason and I.S. Coghill. 1978. The otter and its conservation in the River Teme catchment. J. of Applied Ecol. 15:373-384.

*Mallach, N. 1971. [Attempts at marking for the analysis of the area of activity and movements of the muskrat *(Ondatra zibethicus* L.*)*]. Anz. Schädlingsk. Pflanzenschutz 44:129-136. [In German, French summary].

*Mallach, N. 1972. [Translocation tests with muskrats *(Ondatra zibethicus* L.*)*]. Anz. Schädlingsk. Pflanzenschultz 45:40-44. [In German, French summary].

*Marcström, V. 1964. The muskrat *Ondatra zibethicus* L. in northern Sweden. Viltrevy 2:329-407. [In English, Swedish summary].

*Marshall, W.H. 1936. A study of the winter activities of the mink. J. Mammal. 17:382-392.

Maryland Department of Game and Inland Fisheries. 1956. Wetland development survey. Unpubl. Rep., Maryland Dep. Game and Inland Fish. Project W-030-R-05. Job 1. 69 p.

*Mathiak, H.A. 1953. Experimental level ditching for muskrat management. Wisconsin Conservation Dep., Tech. Wildl. Bull. No. 5. 35 p.

Mathiak, H.A. 1966. Muskrat population studies at Horicon Marsh. Wisconsin Conservation Dep., Tech. Bull. No. 36. 56 p.

*McCabe, R.A. 1949. Notes on live-trapping mink. J. Mammal. 30:416-423.

*McEwen, E.H. 1955. Muskrat population studies in the Mackenzie Delta. Unpubl. Rep., Can. Wildl. Serv., Edmonton. 24 p.

*McLeod, J.A. 1948. Preliminary studies on muskrat biology in Manitoba. Trans. Royal Soc. Canada 42:1-14.

*McLeod, J.A. 1949. Some aspects of muskrat management in Manitoba. Intern. Assoc. Game, Fish and Conservation Comm., Winnipeg. 16 p.

*McLeod, J.A., S. Baldwin and M. Levin. 1947. A biological investigation of the Saskatchewan River delta with special reference to muskrat production. Unpubl. Rep., Can. Wildl. Serv., Winnipeg.

*McLeod, J.A., S.L. Baldwin and R.E. McGirr. 1949. An interim report on a biological investigation of muskrat production in Manitoba, 1948. Unpubl. Rep., Can. Wildl. Serv., Winnipeg.

*McLeod, J.A., G.F. Bondar, and A. Diduch. 1951. An interim report on a biological investigation of the muskrat in Manitoba - 1950 and 1951. Unpubl. Rep., Manitoba Dep. of Renewable Resources and Transportation Serv., Winnipeg. 65 p.

*Mitchell, J.L. 1961. Mink movements and populations on a Montana river. J. Wildl. Manage. 25:48-54.

*Murray, D.F. 1961. Some factors affecting the production and harvest of beaver in the upper Tanana River, Alaska. M.S. Thesis, Univ. of Alaska, Fairbanks. 103 p.

Myrberget, S. and O. Froiland. 1972. The otter, *Lutra lutra*, in Norway about 1970. Fauna (Oslo) 25:149-159. [In Norwegian, English summary].

Nagel, W.O. 1953. The harvests, economic values, and soil-fertility relationships of Missouri furbearers. Unpubl. Rep., Missouri Dep. of Conservation. Projects W-009-R and W-005-R. 43 p.

*Nash, J.B. 1951. An investigation of some problems of ecology of the beaver *Castor canadensis canadensis* Kuhl, in northern Manitoba. M.Sc. Thesis, Univ. of Manitoba, Winnipeg. 74 p.

*Neal, T.J. 1968. A comparison of two muskrat populations. Iowa State J. Sci. 43:193-210.

*Neal, T.J. 1977. A closed trapping season and subsequent muskrat harvests. Wildl. Soc. Bull. 5:194-196.

*Neff, D.J. 1957. Ecological effects of beaver habitat abandonment in the Colorado Rockies. J. Wildl. Manage. 21:80-84.

*Neu, C.W., C.R. Byers and J.M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

*Nordstrom, W.R. 1972. Comparison of trapped and untrapped beaver populations in New Brunswick. M.Sc. Thesis, Univ. of New Brunswick, Fredericton. 104 p.

*Northcott, T.H. 1963. An investigation of the factors affecting carrying capacity of selected areas in Newfoundland for the beaver, *Castor canadensis caecator* Bangs, 1913. M.Sc., Thesis, Memorial Univ., St. John's. 144 p.

Northcott, T.H. 1971. Feeding habits of beaver in Newfoundland. Oikos 22:407-410.

*Northcott, T.H. 1972. Water lilies as beaver food. Oikos 23:408-409.

*Northcott, T.H., N.F. Payne and E. Mercer. 1974. Dispersal of mink in insular Newfoundland. J. Mammal. 55:243-248.

*Novakowski, N.S. 1965. Population dynamics of a beaver population in northern latitudes. Ph.D. Thesis, Univ. of Saskatchewan, Saskatoon. 154 p.

*O'Brien, F. 1938. A qualitative and quantitative food habit study of beaver in Maine. M.S. Thesis, Univ. of Maine, Orono.

*Orr, L.W. 1933. What of Itasca's future? Minnesota Conservationist 1(May-June):15-25.

Palmisano, A.W. 1972. The distribution and abundance of muskrats *(Ondatra zibethicus)* in relation to vegetative types in Louisiana coastal marshes. Proc. S.E. Assoc. Game and Fish Comm. 26:1-31.

Pashkevich, V.Y. 1964. Znachenie biotekhnicheskikh meropriyatii v ondatrovykh ugod'yakh poimy reki Obi. [Significance of bioengineering measures in muskrat lands in the flood-plain of the Ob' River]. Sb. Nauch-Tekh. Inform. Vses. Nauch-Issled. Inst. Zhivotn. Syr'ya Pushniny 10:24-34. Biol. Abstr. No. 90755. 1966. [Abstract translated from Russian].

*Patric, E.F. and W.L. Webb. 1953. A preliminary report on intensive beaver management. Trans. N. Am. Wildl. Conf. 18:533-539.

*Pearson, A.M. 1958. Studies of growth correlated with habitat of beavers in Prince Albert National Park. B.Sc. Thesis, Univ. of British Columbia, Vancouver. 35 p.

Pearson, A.M. 1960. A study of the growth and reproduction of the beaver *(Castor canadensis* Kuhl*)* correlated with the quality and quantity of some habitat factors. M.Sc. Thesis, Univ. of British Columbia, Vancouver. 103 p.

*Pelikan, J., J. Sroboda and J. Kret. 1970. On some relations between the production of *Typha latifolia* and a muskrat population. Zool. Listy 19:303-320.

*Penner, D.F. 1976. Preliminary baseline investigations of fur-bearing and ungulate mammals using Lease No. 17. Syncrude Canada, Environmental Research Monograph 1976-3. 181 p.

*Peterson, R.L. 1966. The Mammals of Eastern Canada. Oxford University Press, Toronto. 465 p.

*Rasmussen, D.I. 1940. Beaver-trout relationship in the Rocky Mountain region. Trans. N. Am. Wildl. Conf. 5:256-263.

*Renewable Resources Consulting Services Limited. No Date. Northeast Alberta Regional Plan Project. Fishery Resources. Vol. 2. Technical Appendices. Unpubl. Rep. prepared for Ekistic Design Consultants Limited. 389 p.

*Retzer , J.L. 1955. Physical environmental effects on beavers in the Colorado Rockies. Western Assoc. State Game and Fish Comm. 35:279-287.

*Retzer, J.L., H.M. Swope, J.D. Remington and W.H. Rutherford. 1956. Suitability of physical factors for beaver management in the Rocky Mountains of Colorado. Colorado Div. of Wildlife, Tech. Bull. 2. 33 p.

*Revin, Y.V. 1975. [Adaptation of *Ondatra zibethicus* to thermal conditions of north-eastern Yakutia]. Zool. Zh. 54:763-767. [In Russian, English summary].

*Ritcey, R.W. and R.Y. Edwards. 1956. Live trapping mink in British Columbia. J. Mammal. 37:114-116.

Roben, P. 1974. Zum Vorkommen des Otters, *Lutra lutra* (Linné, 1798), in der Bundesrepublik Deutchland. Saeugertierk. Mitt. 22:29-26. [In German, English summary].

Rutherford, W.H. 1954. Interrelationships of beavers and other wildlife on a high-altitude stream in Colorado. M.S. Thesis, Colorado A. and M. College, Fort Collins. 134 p.

*Rutherford, W.H. 1964. The beaver in Colorado, its biology, ecology, management and economics. Colorado Game, and Parks Dep., Tech. Publ. No. 17. 49 p.

*Ruttan, R.A. 1974. Muskrat studies on Old Crow Flats, Yukon Territory, 1972. 104 p. *In:* R.A. Ruttan and D.R. Wooley (ed.). Studies of Furbearers Associated with Proposed Pipeline Routes in the Yukon and Northwest Territories. Arctic Gas Biol. Rep. Ser. Vol. 9. Chap. 4.

Ruttan, R.A. and D.R. Wooley. 1974. A study of furbearers associated with proposed pipeline routes in the Yukon Territory and Mackenzie River Valley, 1971. Arctic Gas Biol. Rep. Ser. Vol. 8. 118 p.

*Ryder, R.A. 1955. Fish predation by the otter in Michigan. J. Wildl. Manage. 19:497-498.

Salo, L.J. 1970. A comparison of management practices and economic importance of moose, muskrat, hare and ptarmigan in Alaska and Finland. M.S. Thesis, Univ. of Alaska, Fairbanks. 129 p.

Salvesen, S. 1928. The beaver in Norway. J. Mammal. 9:99-104.

*Sargeant, A.B., G.A. Swanson and H.A. Doty. 1973. Selective predation by mink, *Mustela vison*, on waterfowl. Am. Midl. Nat. 89:208-214.

*Sather, J.H. 1958. Biology of the great plains muskrat in Nebraska. Wildl. Monogr. 2:1-35.

*Scheffer, V.B. 1941. Management studies of transplanted beavers in the Pacific Northwest. Trans. N. Am. Wildl. Conf. 6:320-325.

*Schladweiler, J.L. and G.L. Storm. 1969. Den-use by mink. J. Wildl. Manage. 33:1025-1026.

*Schmitke, R.G. 1959. Some aspects of muskrat ecology at Big Island Lake, Alberta, 1958 report. Unpubl. Rep., Alberta Dep. Lands and Forests, Fish and Wildl. Div., Edmonton. 62 p.

Schmitke, R.G. 1971. Some aspects of muskrat ecology at Big Island Lake, Alberta. M.S. Thesis, Utah State Univ., Logan. 54 p.

*Schnell, J.H. 1964. A mink exterminates an insular cotton rat population. J. Mammal. 45:305-306.

*Sealander, J.A. 1942. Studies on trapped mink *(Mustela vison mink)* in southern Michigan. M.S. Thesis, Michigan State Coll., East Lansing. 94 p.

*Sealander, J.A. 1943. Winter food habits of mink in southern Michigan. J. Wildl. Manage. 7:411-417.

*Semyonoff, B.T. 1957. The river beaver in Archangel Province. Pages 5-45. *In:* Translations of Russian Game Reports. Vol. 1. (Beaver, 1951-1955). Can. Dep. Northern Affairs and National Resources. 109 p. [Translated from Russian].

*Shadle, A.R. and T.S. Austin. 1939. Fifteen months of beaver work at Alleghany State Park, N.Y. J. Mammal. 20:299-303.

*Shanks, C.E. and G.C. Arthur. 1952. Muskrat movements and population dynamics in Missouri farm ponds and streams. J. Wildl. Manage. 16:138-148.

*Shaw, S.R. 1948. The beaver in Massachusetts, Massachusetts Dep. Wildl., Div. Wildl. Research and Manage., Research Bull. No. 11. 45 p.

*Sheldon, W.G. and W.G. Toll. 1964. Feeding habits of the river otter in a reservoir in central Massachusetts. J. Mammal. 45:449-455.

*Shelton, P.C. 1966. Ecological studies of beavers, wolves and moose in Isle Royale National Park, Michigan. Ph.D. Thesis, Purdue Univ., Lafayette, Indiana. 308 p.

Shump, A.U., K.A. Shump Jr., G.A. Heidt and R.J. Aulerich. 1976. A bibliography of mustelids. Part II. Mink. Michigan Agric. Exp. Sta. Publ. 7390. 156 p.

Shump, K.A., Jr., A.U. Shump, R.A. Aulerich and G.A. Heidt. 1976. A bibliography of mustelids. Part V: Otters. Michigan Agric. Exp. Sta. Publ. 7759. 32 p.

Slough, B.G. 1976. A land capability classification system for beaver. M.Sc. Thesis, Simon Fraser Univ., Burnaby, British Columbia.

Slough, B.G. 1978. Beaver food cache structure and utilization. J. Wildl. Manage. 42:644-646.

*Slough, B.G. and R.M.F.S. Sadleir. 1977. A land capability classification system for beaver *(Castor canadensis* Kuhl*)*. Can. J. Zool. 55:1324-1335.

*Smith, A.E. 1950. Effects of water run-off and gradient on beaver in mountain streams. M.S. Thesis, Univ. of Michigan, Ann Arbor. 34 p.

*Soper, J.D. 1937. Notes on the beavers of Wood Buffalo Park, Alberta. J. Mammal. 18:1-13.

*Soper, J.D. 1964. The Mammals of Alberta. Hamly Press, Edmonton. 402 p.

*Soper, J.W. 1970. The mammals of Jasper National Park, Alberta. Can. Wildl. Serv., Rep. Ser. No. 10. 80 p.

*Stains, H.J. and R.H. Baker. 1958. Furbearers in Kansas: A guide to trapping. Univ. of Kansas Mus. Nat. Hist., Misc. Publ. No. 18. 100 p.

Stearns, L.A., D. MacCreary and F.C. Daigh. 1939. Water and plant requirements of the muskrat on a Delaware tidewater marsh. New Jersey Mosquito Extermination Association. 26:212-221.

Stearns, L.A., D. MacCreary and F.C. Daigh. 1940. Effect of ditching for mosquito control on the muskrat population of a Delaware tidewater marsh. Univ. of Delaware Agric. Exp. Sta. Bull. 225. 55 p.

*Stegeman, L.C. 1954. The production of aspen and its utilization by beaver in the Huntington Forest. J. Wildl. Manage. 18:348-358.

*Stephens, M.N. 1957. The Natural History of the Otter. U.F.A.W., London. 88 p.

Stevens, W.E. 1950. Report of fur investigations in the delta of the Saskatchewan River. Unpubl. Rep., Can. Wildl. Serv., Edmonton. 23 p.

Stevens, W.E. 1953. The northwestern muskrat of the Mackenzie Delta, Northwest Territories, 1947-48. Can. Wildl. Serv., Wildl. Manage. Bull., Ser. 1, No. 8. 40 p.

*Stevens, W.E. 1955. Adjustments of the northwestern muskrat *(Ondatra zibethicus spatulatus)* to a northern environment. Ph.D. Thesis, Univ. of British Columbia, Vancouver. 196 p.

*Stewart, R.W. and J.R. Bider. 1974. Reproduction and survival of ditch-dwelling muskrats in southern Quebec. Can. Field-Nat. 88:429-436.

Stewart, R.W. and J.R. Bider. 1977. Summer activity of muskrats in relation to weather. J. Wildl. Manage. 41:487-499.

*Surrendi, D. and C. Jorgenson. 1971. Some aspects of muskrat winter ecology on the Peace-Athabasca Delta. Unpubl. Rep., Can. Wildl. Serv., Edmonton. 113 p.

*Sverre, S.F.S. 1972. Some ecological effects of beaver upon the watersheds in the Porcupine Hills, Alberta. M.Sc. Thesis, Brock Univ., St. Catherines, Ontario. 134 p.

*Swank, W.G. 1949. Beaver ecology and management in West Virginia. West Virginia Conservation Comm., Div. Game Manage., Bull. No. 1. 65 p.

Swank, W.G. 1963. Grading of beaver pelts and manufacture of fur coats. Pages 78-80. *In:* W.H. Longley and J.B. Moyle. The Beaver in Minnesota. Minnesota Dep. of Conservation, Div. of Game and Fish. Tech. Bull. No. 6.

*Symington, D.F. and R.A. Ruttan. 1956. Beaver in Saskatchewan. Saskatchewan Dep. Natural Resources Conservation Bull. No. 1. 17 p.

Tabor, J.E. 1974. Productivity, survival, and population status of river otter in western Oregon. M.S. Thesis, Oregon State Univ., Corvallis. 62 p.

Takos, M.J. 1942. An ecological study of a muskrat habitat in Central Maine. M.S. Thesis, Univ. of Maine, Orono. 86 p.

*Takos, M.J. 1947. A semi-quantitative study of muskrat food habits. J. Wildl. Manage. 11:331-339.

Tarasoy, M.P. 1964. Ondatrovye ugod'ya severa Irkutskoi oblasti (bassein reki Nizhnei Tungurski). [Muskrat *(Ondatra zibethica)* grounds in the northern Irkutsk oblast (basin of the Lower Tungus River)]. Sb. Nauch-Tekh. Inform. Vses. Nauch-Issle. Inst. Zhivotn. Syr'ya Pushniny. 10:3-9. Biol. Abstr. No. 90759. 1966. [Abstract translated from Russian].

*Taylor, D.L. 1953. Life history and management of the beaver in North Carolina. North Carolina Wildl. Resources Comm., Game Div. Leaflet. 13 p.

Teodoreanu, M. 1976. Über die Lebensweise der Bisamratte, *Ondatra zibethicus* (Linné, 1766), unter den veränderlichen Bedingungen der Teiche in der Siebenbürger Ebene. Saeugetierk. Mitt. 24:238-240. [In German, English summary].

*Tevis, L., Jr. 1950. Summer behavior of a family of beavers in New York State. J. Mammal. 31:40-65.

*Thomasson, R.D. 1973. Ontario land inventory methodology series: wildlife. Unpubl. Rep., Ontario Ministry of Natural Resources, Toronto. 71 p.

*Todd, A. 1976. Analysis of fur production records for registered traplines in the A.O.S.E.R.P. area, 1970-75. Unpubl. Rep., Alberta Recreation, Parks and Wildl., Fish and Wildl. Div., Edmonton. 15 p.

Toll, W.G. 1961. The ecology of the river otter *(Lutra canadensis)* in the Quabbin Reservation of central Massachusetts. M.S. Thesis, Univ. of Massachusetts, Amherst. 45 p.

*Traversy, N. 1974. Méthode experimentale de classement potential de l'habitat pour le castor de la Baie James. Unpubl. Rep., Qué. Minist. Tourisme, Chasse Peche, Québec. [In French].

*Tufts, P.D. 1967. A comparative study of some environmental factors affecting beaver colony site locations. M.Sc. Thesis, Acadia Univ., Wolfville, Nova Scotia. 121 p.

*Turner, B. 1970. Muskrat study Point Pelee National Park--summer 1970. Unpubl. Rep., National and Historic Parks Branch, Ottawa. No. 33-1-14. 100 p.

*Vampiloff, V.N. 1957. Increase of food production and improvement of nesting and shelter conditions in muskrat habitat in the Selenga Delta (East Baikal District). *In:* Translation of Russian Game Reports. Vol. 2. (Muskrat, 1951-55). Can. Dep. Northern Affairs and National Resources. 224 p. [Translated from Russian].

Veen, J. 1975. [Data on the occurrence and behaviour of the otter, *Lutra lutra* (L.), the province of Nord-Holland, the Netherlands]. Lutra 17:21-37. [In Dutch, English summary].

*Verts, B.J. 1956. An evaluation of wildlife and recreational values of a strip-mined area. M.S. Thesis, Southern Illinois Univ., Carbondale. 61 p.

*Walker, E.P. 1968. Mammals of the World. Johns Hopkins Press, Baltimore. 2 Vol.

*Waller, D.W. 1962. Feeding behavior of minks at some Iowa marshes. M.S. Thesis, Iowa State Univ., Ames. 90 p.

Warren, E.R. 1926. A study of the beaver in the Yancey Region of Yellowstone National Park. Roosevelt Wildl. Ann. 1:13-191.

*Watson, G.H., W.H. Prescott, E.A. de Bock, J.W. Nolan, M.C. Dennington, H.J. Poston and I.G. Stirling. 1973. An inventory of wildlife habitat of the Mackenzie Valley and the northern Yukon. Environmental-Social Comm., Northern Pipelines, Task Force on Northern Oil Development. Rep. No. 73-27. 152 p.

*Westworth, D.A. 1974. Ecology of the muskrat *(Ondatra zibethicus spatulatus)* on the Peace-Athabasca Delta, Wood Buffalo National Park. M.Sc. Thesis, Univ. of Alberta, Edmonton. 147 p.

*Williams, R.H. 1965. Beaver habitat and management. Idaho Wildl. Rev. 17:3-7.

*Willner, G.R., J.A. Chapman and J.R. Goldsberry. 1975. A study and review of muskrat food habits with special reference to Maryland. Maryland Wildl. Admin., Publ. in Wildl. Ecol. No. 1. 25 p.

*Wooley, D.R. 1974. Population surveys of beaver *(Castor canadensis)*. 22 p. *In:* R.D. Jakimchuk (ed.). Surveys of Mammals Along the Proposed Gas Pipeline in Alberta. Arctic Gas Biol. Rep. Ser. Vol. 25. Chap. 3.

Wragg, L.E. 1954. The effect of D.D.T. and oil on muskrats. Can. Field-Nat. 68:11-13.

Wragg, L.E. 1955. Notes on movements of banded muskrat. Can. Field-Nat. 69:9-11.

*Yeager, L.E. 1938. Otters of the delta hardwood region of Mississippi. J. Mammal. 19:195-201.

*Yeager, L.E. 1943. Storing of muskrats and other foods of minks. J. Mammal. 24:100-101.

*Yeager, L.E. and K.G. Hay. 1955. A contribution toward a bibliography on the beaver. Colorado Dep. Game and Fish, Tech. Bull. No. 1. 91 p.

*Yeager, L.E. and W.H. Rutherford. 1957. An ecological basis for beaver management in the Rocky Mountain region. Trans. N. Am. Wildl. Conf. 22:269-299.

Zejda, J. 1976. On the interaction between the water vole *(Arvicola terrestris)* and the muskrat *(Ondatra zibethicus)* in habitat selection. Zool. Listy 25:229-238.

Zharkov, I.V. 1970. [On the classification of beaver areas in the USSR]. Intern. Congr. Game Biol. 8:337-341. [In Russian, English summary].

*Zharkov, I.V. and V.E. Sokolov. 1967. [The European beaver (*Castor fiber* Linnaeus, 1758) in the Soviet Union]. Acta Theriol. 12:27-46. [In Russian, English abstract].

APPENDICES

Appendix 1. Other mammals seen during aerial surveys, October 1978.

LEGEND

B - Black Bear

W - Wolf

WT - White-tailed Deer

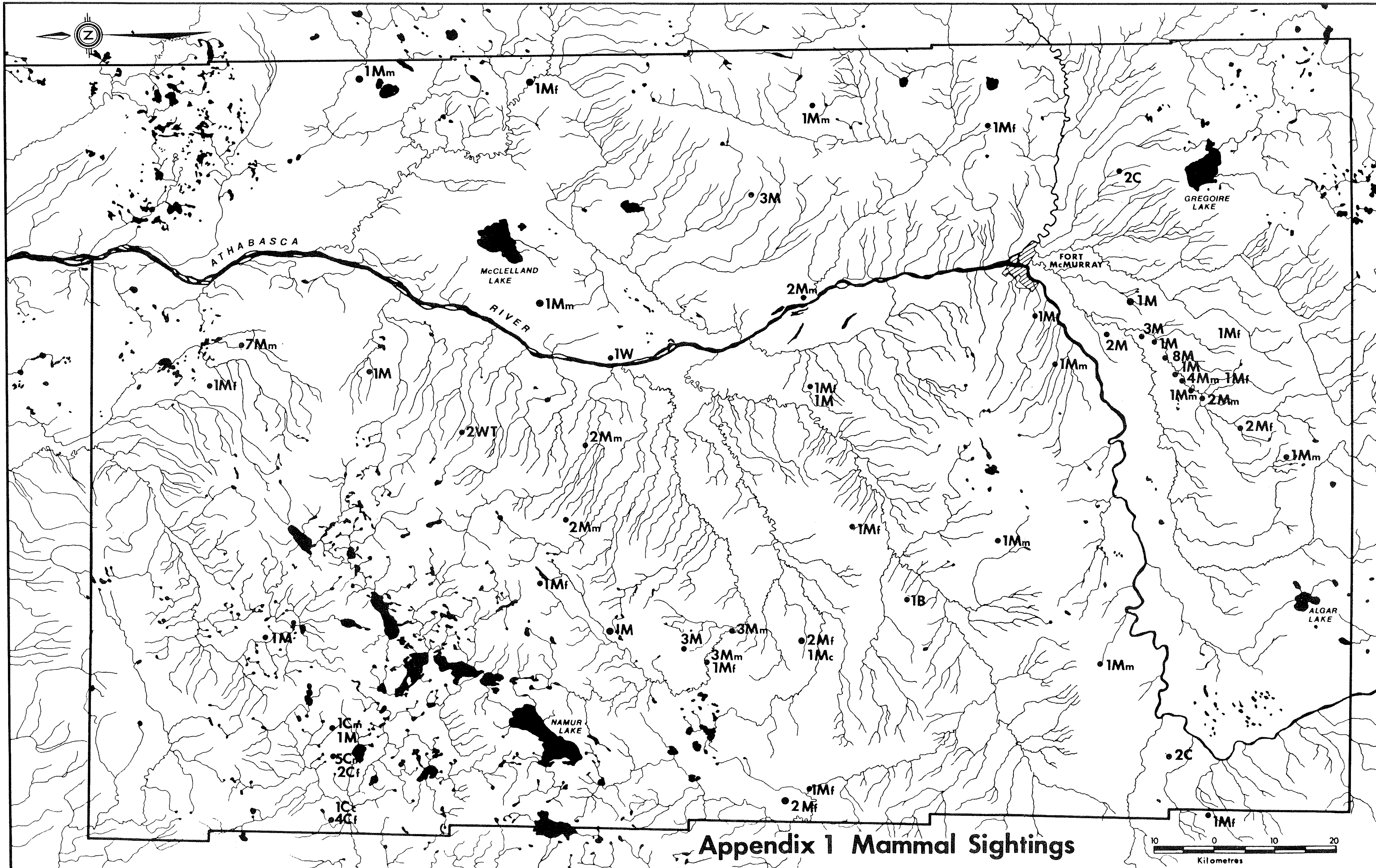
C - Caribou

M - Moose

m - male

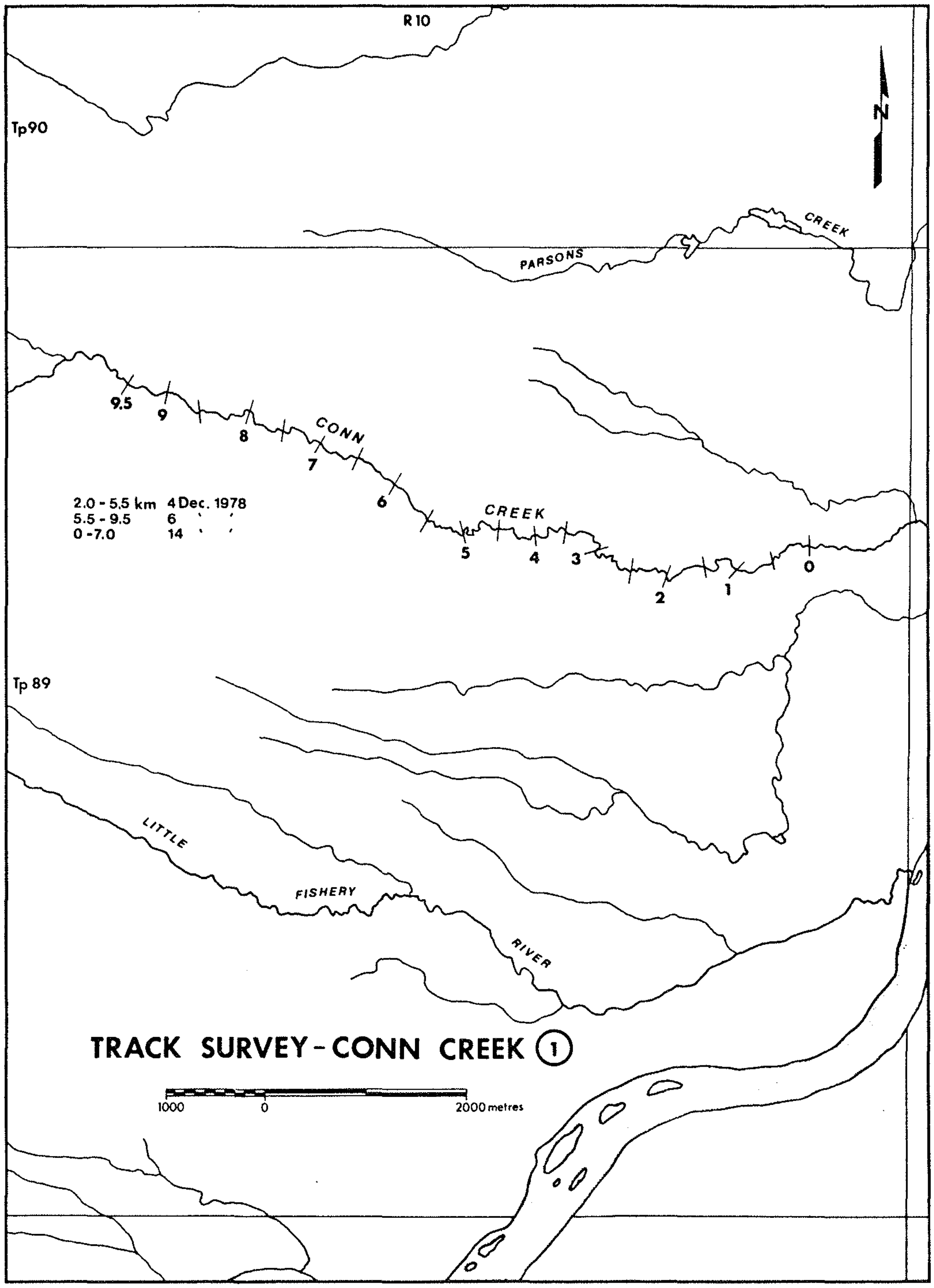
f - female

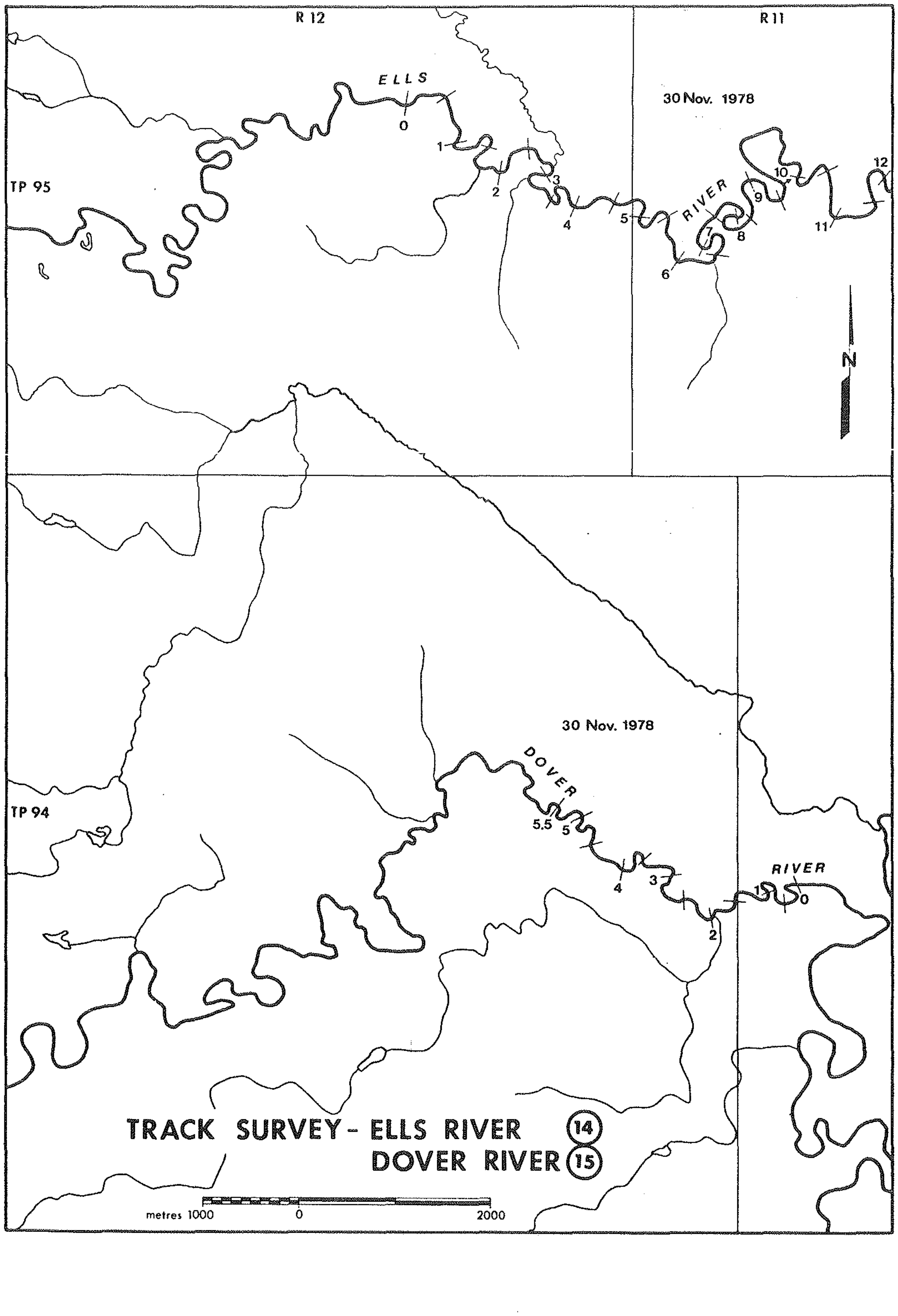
c - calf



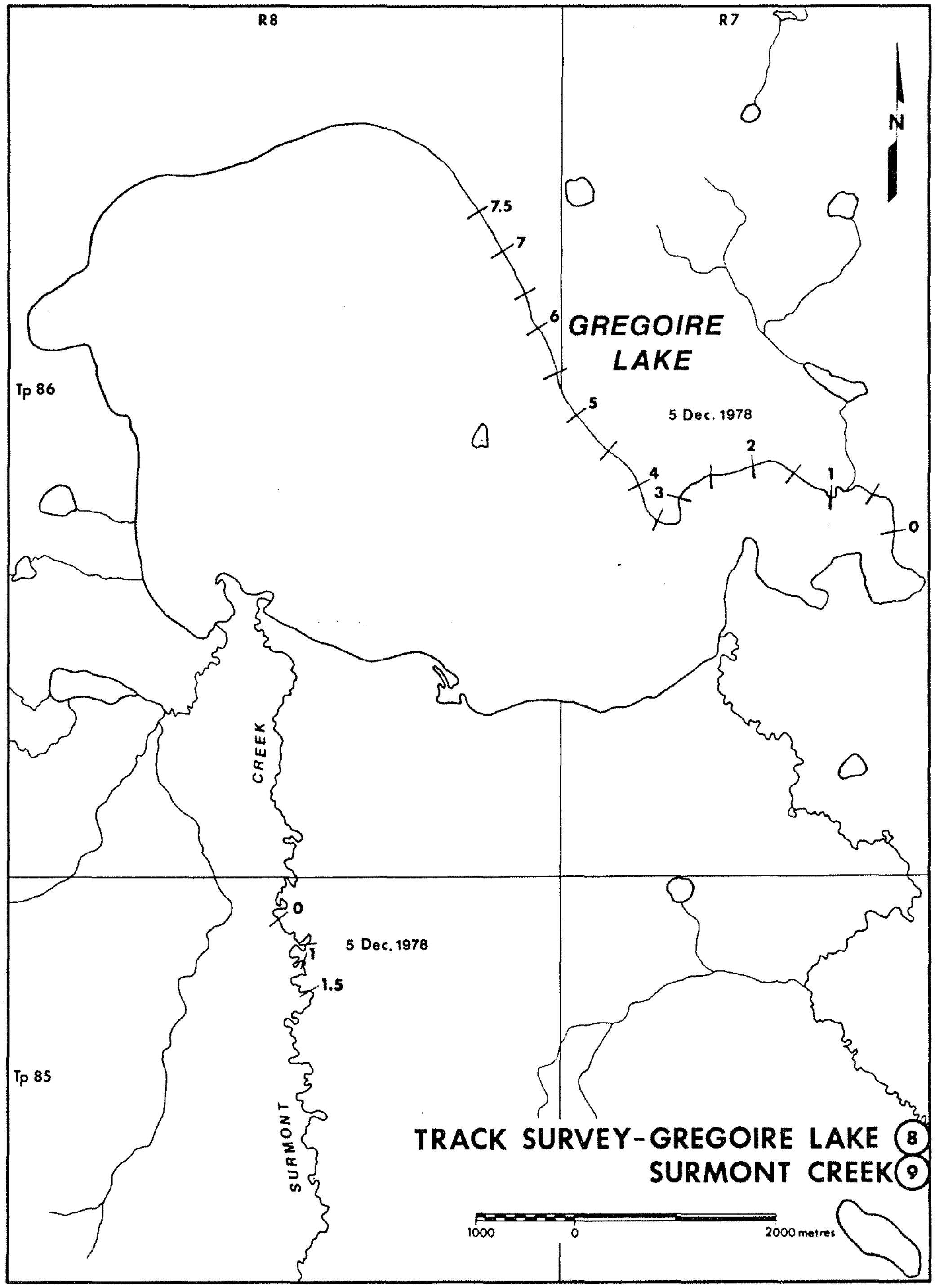
Appendix 1 Mammal Sightings

Appendix 2. Specific location of track-count surveys. The number following each waterbody name refers to locations in Part 2, Figure 4. Distances indicated along waterbodies are in 0.5 km segments. Distances and dates surveyed are identified on the individual maps. Tracks seen on each segment are presented in Appendix 3.

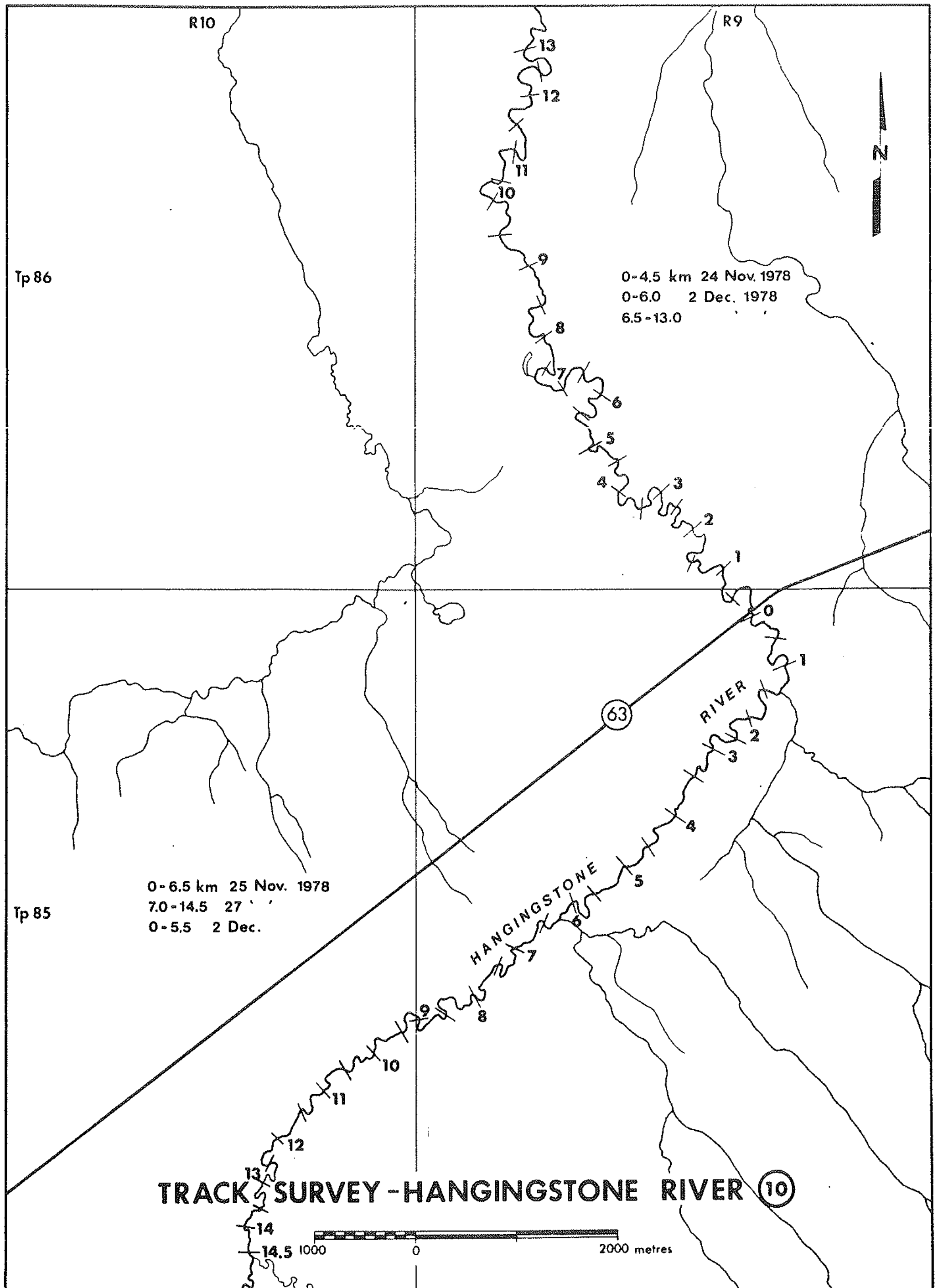

R 10
Tp90
N
PARSONS
CREEK
9.5
9
8
CONN
7
6
2.0 - 5.5 km 4 Dec. 1978
5.5 - 9.5 6 " "
0 - 7.0 14 " "
CREEK
5
4
3
2
1
0
Tp 89
LITTLE
FISHERY
RIVER
TRACK SURVEY - CONN CREEK ①
1000
0
2000 metres

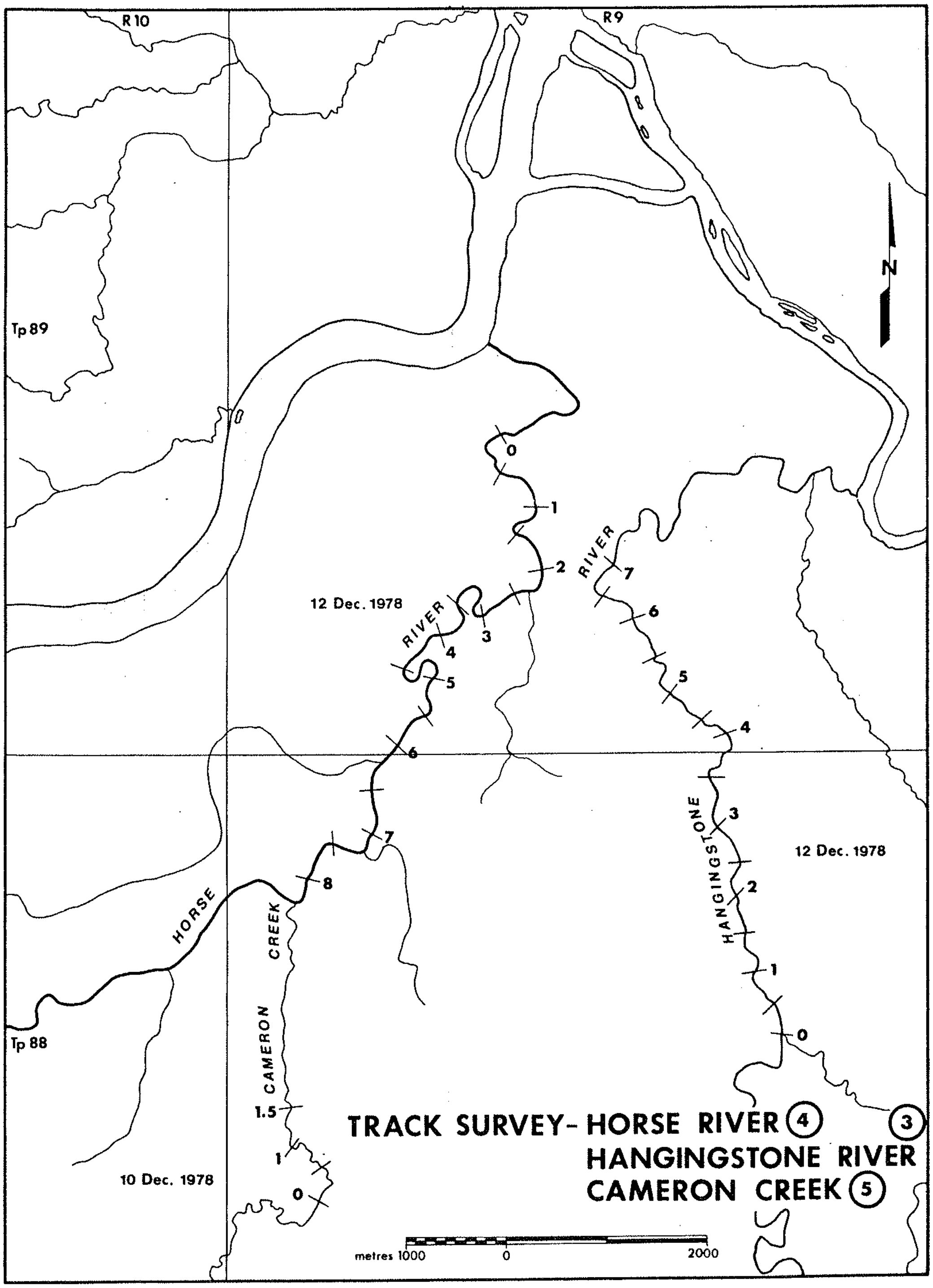


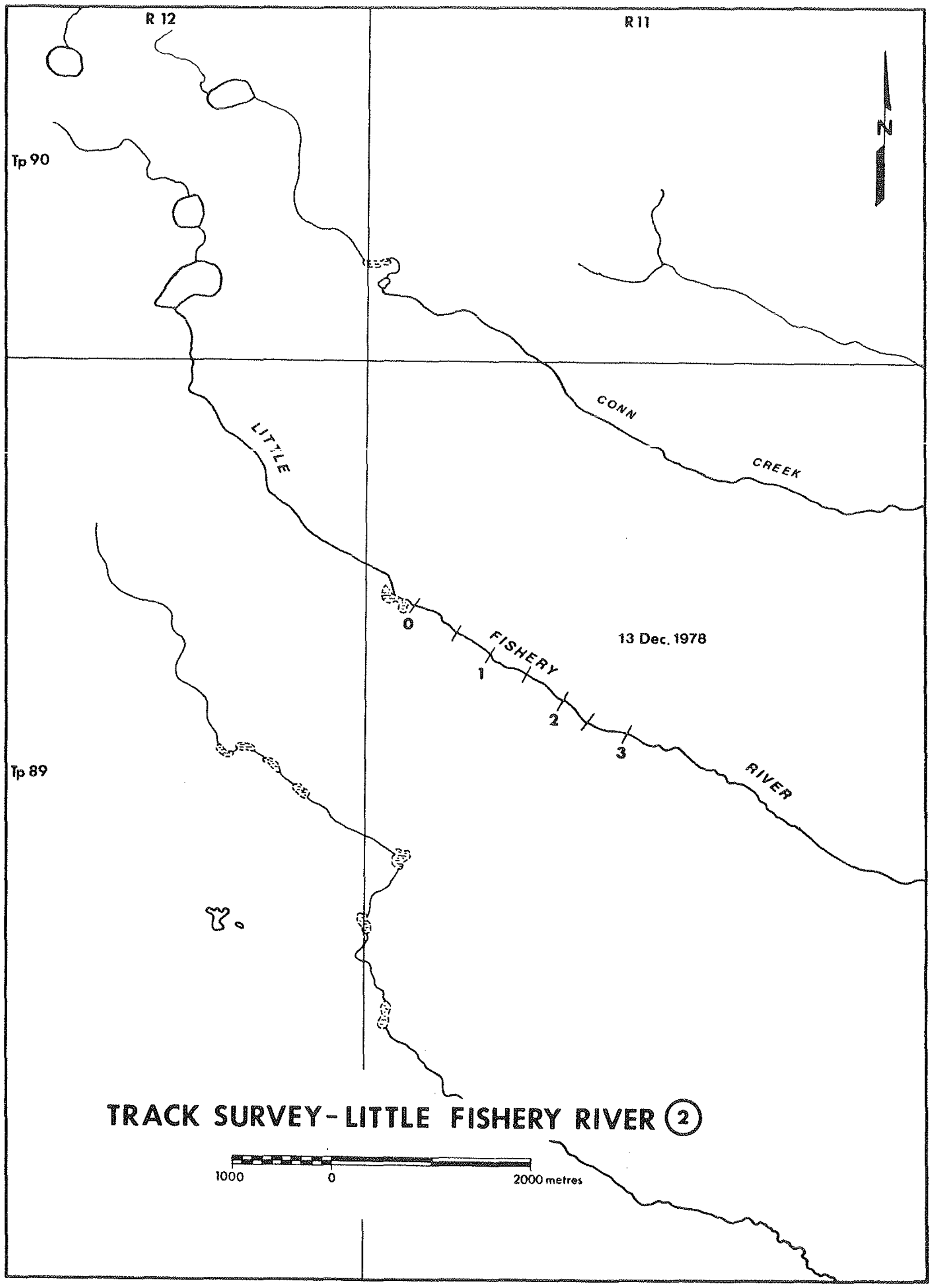
TRACK SURVEY - ELLS RIVER (14)
DOVER RIVER (15)



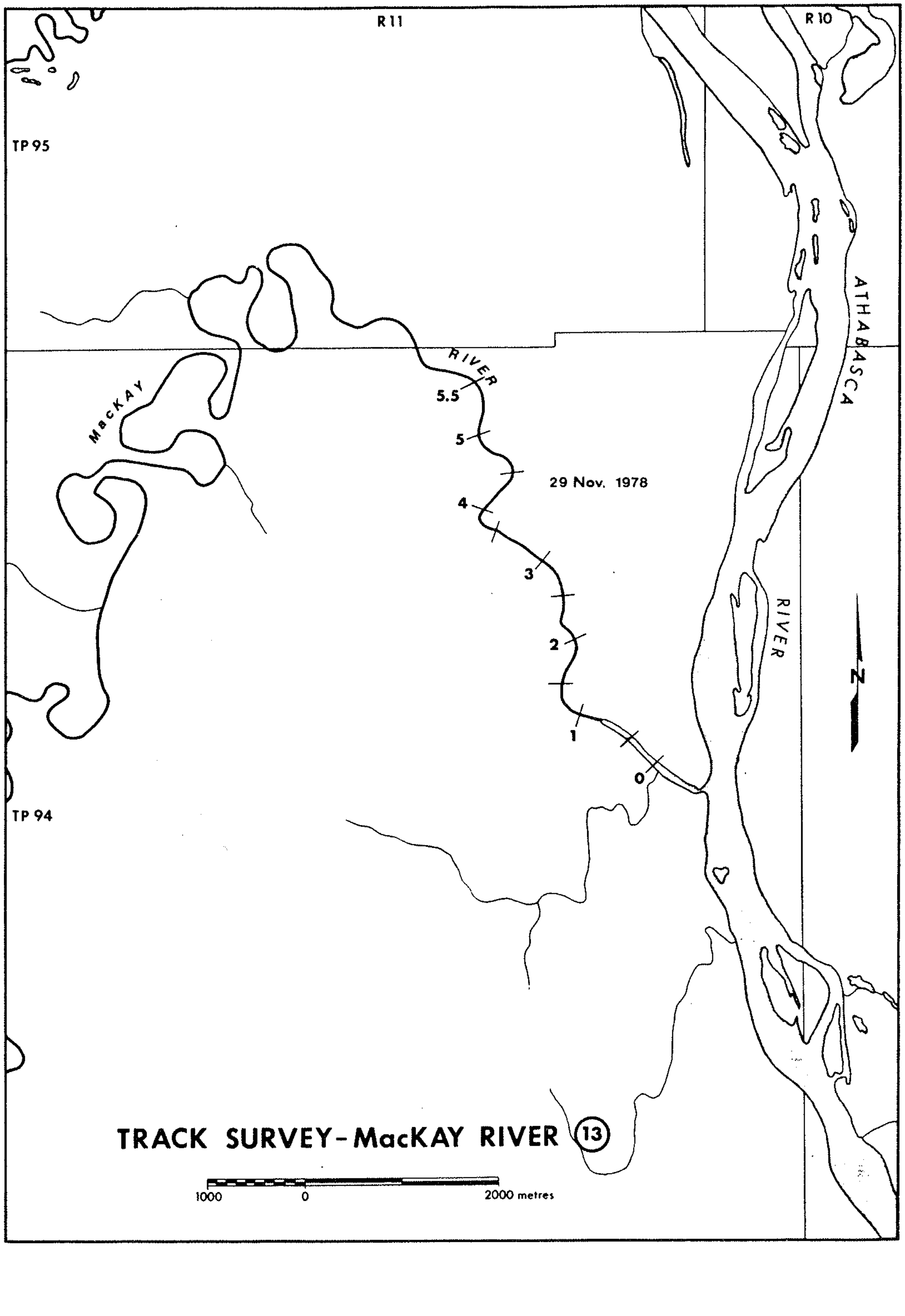
TRACK SURVEY-GREGOIRE LAKE (8)
SURMONT CREEK (9)


R10
R9
Tp 86
Tp 85
N
0-4.5 km 24 Nov. 1978
0-6.0 2 Dec. 1978
6.5-13.0
0-6.5 km 25 Nov. 1978
7.0-14.5 27
0-5.5 2 Dec.
63
HANGINGSTONE
RIVER
TRACK SURVEY - HANGINGSTONE RIVER 10
1000
0
2000 metres

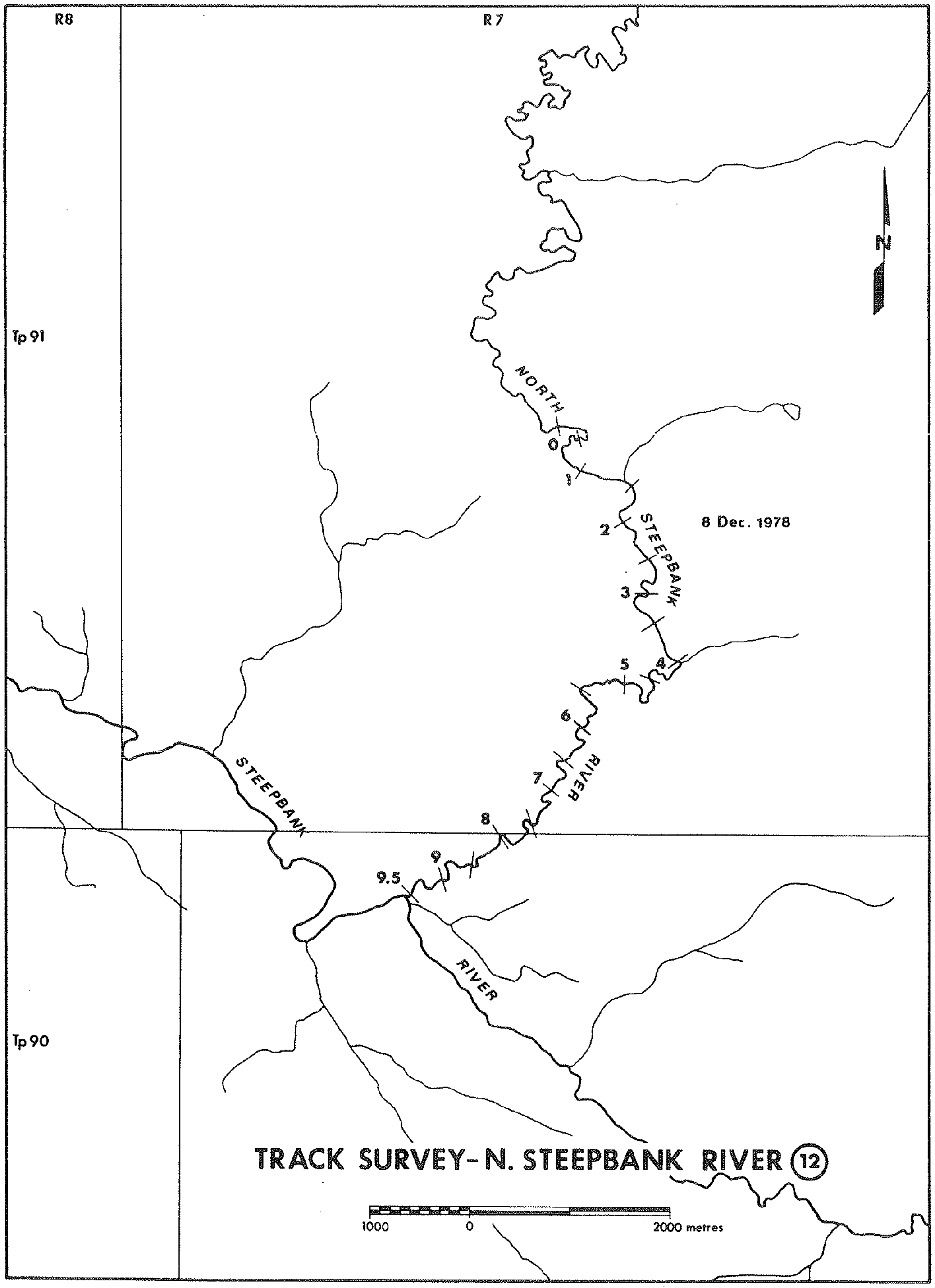

R10
R9
Tp 89
Tp 88
N
12 Dec. 1978
RIVER
12 Dec. 1978
HORSE
CREEK
CAMERON
HANGINGSTONE
RIVER
10 Dec. 1978
metres 1000 0 2000
TRACK SURVEY- HORSE RIVER (4)
(3) HANGINGSTONE RIVER
CAMERON CREEK (5)

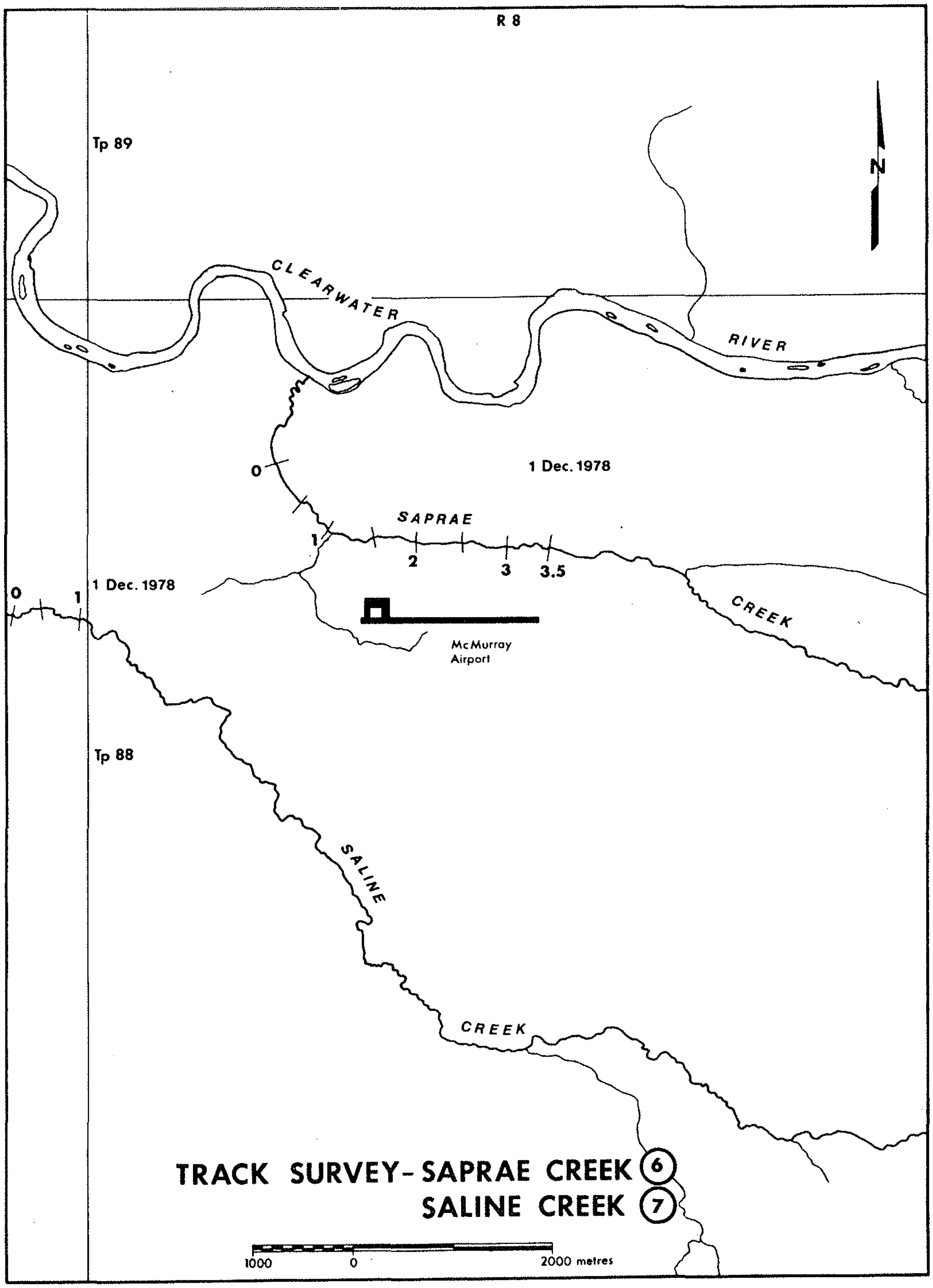


TRACK SURVEY - LITTLE FISHERY RIVER (2)

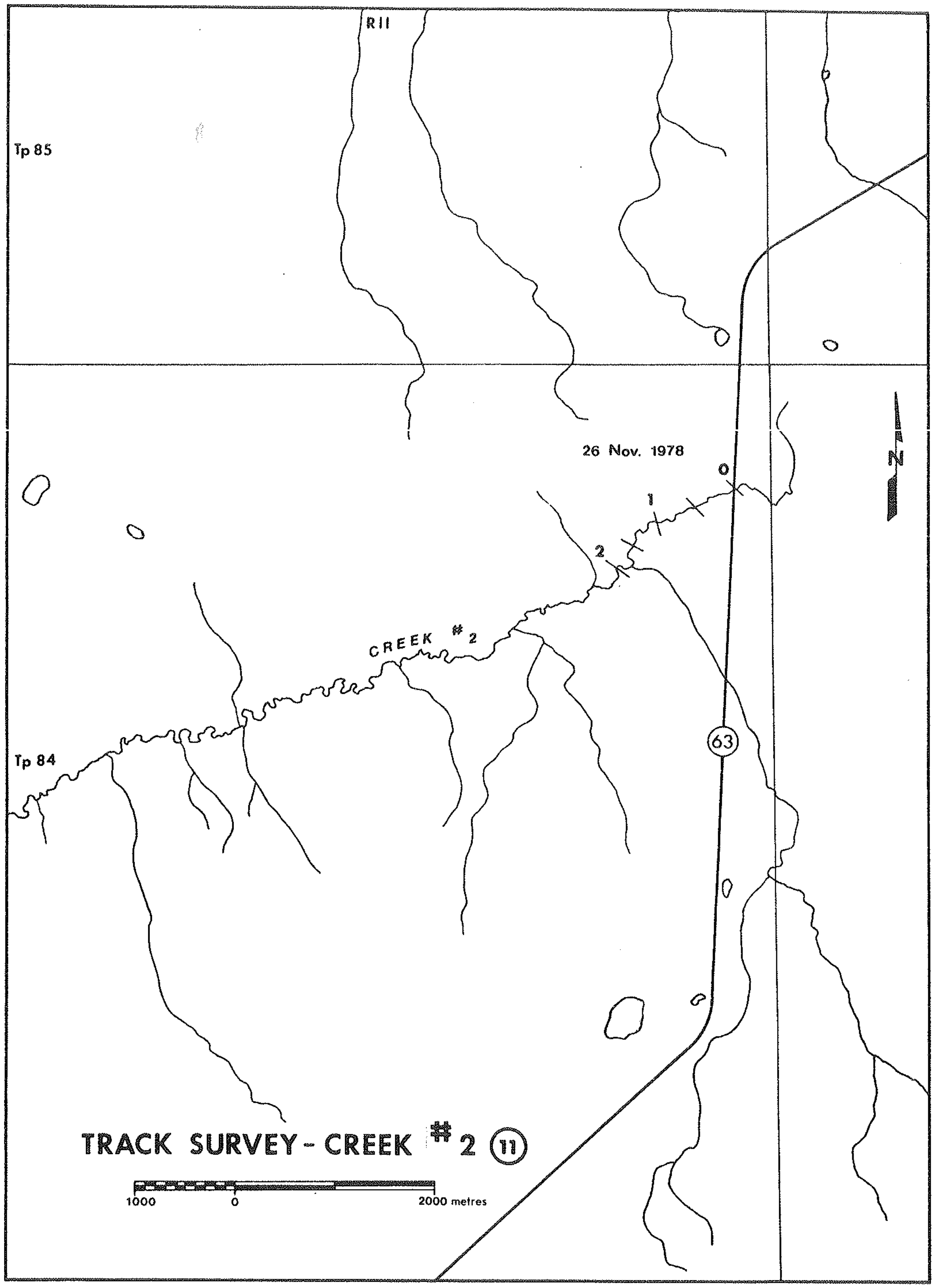


TRACK SURVEY-MacKAY RIVER (13)


R8
R7
Tp 91
Tp 90
N
NORTH
STEEPBANK
RIVER
STEEPBANK
RIVER
8 Dec. 1978
0
1
2
3
4
5
6
7
8
9
9.5
TRACK SURVEY- N. STEEPBANK RIVER (12)
1000
0
2000 metres



TRACK SURVEY-SAPRAE CREEK (6)
SALINE CREEK (7)



RII
Tp 85
26 Nov. 1978
0
1
2
CREEK # 2
Tp 84
63
N
TRACK SURVEY - CREEK # 2 (11)
1000
0
2000 metres

Appendix 3. Animal tracks and beaver lodges recorded along 0.5 km intervals of streams and lakes in the AOSERP Study Area. Only those intervals in which tracks were noted are listed.

Waterbody, Distance Travelled and Number of Track-nights	Interval	Mink	River Otter	Beaver Lodge	Wolf	Coyote	Weasel	Red Squirrel	Snowshoe Hare	Deer	Moose
Cameron Creek	0.0-0.5			2					Not Recorded		
0.0-1.0 km	0.5-1.0	1		1				1			
0.5 track-nights											
Cameron Creek	0.0-0.5			1			1		Not Recorded		
1.0-1.5 km											
0.5 track-nights											
Conn Creek	0.0-0.5								47		
0.0-2.0 km	0.5-1.0						3	1	82		
4.5 track-nights	1.0-1.5						1		83		
	1.5-2.0					1	1		124		
Conn Creek	2.0-2.5	1									
2.0-5.5 km	3.0-3.5			1					Not Recorded		
0.5 track-nights	4.0-4.5		1								
	5.0-5.5	1	1								
Conn Creek	2.0-2.5						1				
2.0-7.0	2.5-3.0	2					1				
4.5 track-nights	3.0-3.5	1									
	3.5-4.0	2					1		Not Recorded		
	4.5-5.0	2						1			
	5.0-5.5	2		1							
	5.5-6.0	1					1				
	6.0-6.5	2	1								
	6.5-7.0	2	1								
Conn Creek	5.5-6.0								24		
5.5-8.0 km	6.0-6.5	1	1	1,I[a]			1		49		
	6.5-7.0	1		I					24		
	7.0-7.5	2		1			2		31		
	7.5-8.0	1					1		37		
Conn Creek	8.0-8.5	1					2		28		
8.0-9.5 km	8.5-9.0	2					1		28		
1 track-night	9.0-9.5			1			2		50		
Dover River	0.0-0.5								1		
0.0-5.5 km	0.5-1.0	1							7		
2 track-nights	1.0-1.5	1					2		4		
	1.5-2.0						1		11		
	2.0-2.5	1					2		14		
	2.5-3.0				2		2		9		
	3.0-3.5				1				7		
	3.5-4.0	1					1		7		
	4.0-4.5						1		4		
	4.5-5.0						1		3		
	5.0-5.5						1		1		
Ells River	0.0-0.5	1							12		5
0.0-12.0 km	0.5-1.0								18		1
2 track-nights	1.0-1.5				1		1		4		
	1.5-2.0			1			2		6		
	2.0-2.5								1		
	2.5-3.0								6		
	3.0-3.5						1		5		
	3.5-4.0								16		
	4.0-4.5			1					11		
	4.5-5.0						2		10		

...continued

Appendix 3. Continued.

Waterbody, Distance Travelled and Number of Track-nights	Interval	Mink	River Otter	Beaver Lodge	Wolf	Coyote	Weasel	Red Squirrel	Snowshoe Hare	Deer	Moose
	5.5-6.0	1		1					1		
	6.0-6.5								6		
	6.5-7.0								4		
	7.0-7.5						1		4		
	7.5-8.0								4		
	8.0-8.5								5		
	8.5-9.0								2		
	9.0-9.5			1					2		
	9.5-10.0								3		
	10.0-10.5								4		
	10.5-11.0								3		
	11.0-11.5								5		
	11.5-12.0								5		
Gregoire Lake	0.5-1.0	2		2					4		
0.0-7.5 km	1.0-1.5	1							10		
1 track-night	1.5-2.0								15		
	2.0-2.5					1			7		
	2.5-3.0								12		
	3.0-3.5								12		
	4.0-4.5						1		7		
	4.5-5.0								7		
	5.0-5.5						1		9		
	5.5-6.0								11		
	6.0-6.5								6		
	6.5-7.0								4		
	7.0-7.5								3		
Hangingstone River	0.0-0.5				1						
North of Highway	1.0-1.5			1					Not		
0.0-4.5 km	2.0-2.5				1				Recorded		
0.5 track-nights	4.0-4.5			1							
Hangingstone River	0.0-0.5	1						2	11		
North of Highway	0.5-1.0	1						1	8		
0.0-6.0 km	1.5-2.0				1		1		19		3
4 track-nights	2.0-2.5					1	1		7		
	2.5-3.0						3		8		
	3.0-3.5						1		13		
	3.5-4.0								19		
	4.0-4.5						3		8		
	4.5-5.0						1		6		1
	5.0-5.5				1		4		7		
	5.5-6.0								21		
Hangingstone River	6.5-7.0			1			1		8		
North of Highway	7.0-7.5				1				12		
6.5-13 km	7.5-8.0	1						1	13		
1.5 track-nights	8.0-8.5						1		10		
	8.5-9.0	1							13		
	9.0-9.5	1							7		
	9.5-10.0	1						1	7		
	10.0-10.5							1	9		
	10.5-11.0	1						1	3		
	11.0-11.5	1						1	3		
	11.5-12.0	2							2		
	12.0-12.5							1	8		
	12.5-13.0								7		2

...continued

Appendix 3. Continued.

Waterbody, Distance Travelled and Number of Track-nights	Interval	Mink	River Otter	Beaver Lodge	Wolf	Coyote	Weasel	Red Squirrel	Snowshoe Hare	Deer	Moose
Hangingstone River	0.0-0.5	1							1		
South of Highway	0.5-1.0								2		
0.0-6.5 km	1.0-1.5						1	1	13	1	
0.5 track-nights	1.5-2.0	1		1			1		1		
	2.0-2.5				1						
	2.5-3.0								3		
	3.0-3.5	1		I						1	
	3.5-4.0								1		
	4.0-4.5			1					2		
	4.5-5.0							1			
	5.0-5.5			1			1				
	5.5-6.0			1				2			
	6.0-6.5							1			
Hangingstone River	0.0-0.5				1		1		31		
South of Highway	0.5-1.0						1		26		
0.0-5.5 km	1.0-1.5								20		
4 track-nights	1.5-2.0						4		11		
	2.0-2.5						4		12		
	2.5-3.0						5		13		
	3.0-3.5						4		8		
	3.5-4.0						4		17		
	4.0-4.5						3	1	19		
	4.5-5.0						3		10		
	5.0-5.5						3	1	30		
Hangingstone River	0.0-0.5	1			1				34		
South of Ft. McMurray	0.5-1.0								15		
0.0-7.0 km	1.0-1.5				1				31		
2.5 track-nights	1.5-2.0							1	25		
	2.0-2.5								20		
	2.5-3.0	1							22		
	3.0-3.5						1		14		
	3.5-4.0								5		
	4.0-4.5								9	2	
	4.5-5.0								4		
	5.0-5.5								2		
	5.5-6.0								20		
	6.0-6.5				1				6		
	6.5-7.0								3		
Hangingstone River	7.5-8.0		1								
South of Highway	9.0-9.5			1							
7.0-14.5 km	11.5-12.0			I					Not		
0.5 track-nights	13.0-13.5						2		Recorded		
	13.5-14.0						1				
	14.0-14.5			I							
Horse River	0.0-0.5									1	
0.0-8.5 km	0.5-1.0	1				1			1	1	
2.5 track-nights	1.0-1.5					2			5		
	1.5-2.0								3		
	2.0-2.5								2		
	3.5-4.0	1				1					
	4.0-4.5								3		
	4.5-5.0	2					1	2	1		
	5.0-5.5				1				1		
	5.5-6.0								10		
	6.0-6.5	1			1				7		
	6.5-7.0							1	7		
	7.0-7.5	1						2	6		
	7.5-8.0	1					1	9			
	8.0-8.5								2		

...continued

Appendix 3. Concluded.

Waterbody, Distance Travelled and Number of Track-nights	Interval	Mink	River Otter	Beaver Lodge	Wolf	Coyote	Weasel	Red Squirrel	Snowshoe Hare	Deer	Moose
Little Fishery River	0.0-0.5			1				1	50		
0.0-3.0 km	0.5-1.0							1	46		
3.5 track-nights	1.0-1.5						1	1	58		
	1.5-2.0	1					1	2	85		
	2.0-2.5			1					23		
	2.5-3.0							1	?		
Mackay River	1.0-1.5		1								
0.0-5.5 km	2.5-3.0						1		Not		
1 track-night	3.5-4.0						3		Recorded		
	5.0-5.5	1									
North Steepbank River	0.0-0.5				3		1	1	27		1
0.0-9.5 km	0.5-1.0				1				46		
3 track-nights	1.0-1.5			1		1	1		35		
	1.5-2.0				1		1		24		
	2.0-2.5			1			1		20		
	2.5-3.0								27		
	3.0-3.5					1	2	1	33		
	3.5-4.0								38		
	4.0-4.5				1		1		41		
	4.5-5.0				2		3		48		
	5.0-5.5				1		2		29		
	5.5-6.0			1			3		20		
	6.0-6.5				1		1		26		
	6.5-7.0	1			2		2		38		
	7.0-7.5								59		
	7.5-8.0				1		1	1	79		
	8.0-8.5						1	1	26		
	8.5-9.0				1				40		
	9.0-9.5						1		42		
Poplar Creek	0.0-0.5	1			1						
0.0-0.5											
1 track-night											
Saline Creek	0.0-0.5	1					6		37		
0.0-1.0 km	0.5-1.0			1			3		43		
3 track-nights											
Saprae Creek	0.0-0.5		1			1	2		6		
0.0-3.5 km	0.5-1.0								4		
3 track-nights	1.0-1.5						4		19		
	1.5-2.0						3		17		
	2.0-2.5	1					3		6		1
	2.5-3.0						1		21		
	3.0-3.5						1		15		
Surmont Creek	0.0-0.5						3		31		
0.0-1.5 km	0.5-1.0				1		1		26		
1 track-night	1.0-1.5								10		
Unnamed Creek #2	0.0-0.5								11		
0.0-2.0 km	0.5-1.0						1				
0.5 track-nights	1.0-1.5			1					13		
	1.5-2.0								7		

[a] Inactive beaver lodge.

AOSERP RESEARCH REPORTS

1.		AOSERP First Annual Report, 1975
2.	AF 4.1.1	Walleye and Goldeye Fisheries Investigations in the Peace-Athabasca Delta--1975
3.	HE 1.1.1	Structure of a Traditional Baseline Data System
4.	VE 2.2	A Preliminary Vegetation Survey of the Alberta Oil Sands Environmental Research Program Study Area
5.	HY 3.1	The Evaluation of Wastewaters from an Oil Sand Extraction Plant
6.		Housing for the North--The Stackwall System
7.	AF 3.1.1	A Synopsis of the Physical and Biological Limnology and Fisheries Programs whithin the Alberta Oil Sands Area
8.	AF 1.2.1	The Impact of Saline Waters upon Freshwater Biota (A Literature Review and Bibliography)
9.	ME 3.3	Preliminary Investigations into the Magnitude of Fog Occurrence and Associated Problems in the Oil Sands Area
10.	HE 2.1	Development of a Research Design Related to Archaeological Studies in the Athabasca Oil Sands Area
11.	AF 2.2.1	Life Cycles of Some Common Aquatic Insects of the Athabasca River, Alberta
12.	ME 1.7	Very High Resolution Meteorological Satellite Study of Oil Sands Weather: "A Feasibility Study"
13.	ME 2.3.1	Plume Dispersion Measurements from an Oil Sands Extraction Plant, March 1976
14.		
15.	ME 3.4	A Climatology of Low Level Air Trajectories in the Alberta Oil Sands Area
16.	ME 1.6	The Feasibility of a Weather Radar near Fort McMurray, Alberta
17.	AF 2.1.1	A Survey of Baseline Levels of Contaminants in Aquatic Biota of the AOSERP Study Area
18.	HY 1.1	Interim Compilation of Stream Gauging Data to December 1976 for the Alberta Oil Sands Environmental Research Program
19.	ME 4.1	Calculations of Annual Averaged Sulphur Dioxide Concentrations at Ground Level in the AOSERP Study Area
20.	HY 3.1.1	Characterization of Organic Constituents in Waters and Wastewaters of the Athabasca Oil Sands Mining Area
21.		AOSERP Second Annual Report, 1976-77
22.	HE 2.3	Maximization of Technical Training and Involvement of Area Manpower
23.	AF 1.1.2	Acute Lethality of Mine Depressurization Water on Trout Perch and Rainbow Trout
24.	ME 4.2.1	Air System Winter Field Study in the AOSERP Study Area, February 1977.
25.	ME 3.5.1	Review of Pollutant Transformation Processes Relevant to the Alberta Oil Sands Area

26. AF 4.5.1 Interim Report on an Intensive Study of the Fish Fauna of the Muskeg River Watershed of Northeastern Alberta

27. ME 1.5.1 Meteorology and Air Quality Winter Field Study in the AOSERP Study Area, March 1976

28. VE 2.1 Interim Report on a Soils Inventory in the Athabasca Oil Sands Area

29. ME 2.2 An Inventory System for Atmospheric Emissions in the AOSERP Study Area

30. ME 2.1 Ambient Air Quality in the AOSERP Study Area, 1977

31. VE 2.3 Ecological Habitat Mapping of the AOSERP Study Area: Phase I

32. AOSERP Third Annual Report, 1977-78

33. TF 1.2 Relationships Between Habitats, Forages, and Carrying Capacity of Moose Range in northern Alberta. Part I: Moose Preferences for Habitat Strata and Forages.

34. HY 2.4 Heavy Metals in Bottom Sediments of the Mainstem Athabasca River System in the AOSERP Study Area

35. AF 4.9.1 The Effects of Sedimentation on the Aquatic Biota

36. AF 4.8.1 Fall Fisheries Investigations in the Athabasca and Clearwater Rivers Upstream of Fort McMurray: Volume I

37. HE 2.2.2 Community Studies: Fort McMurray, Anzac, Fort MacKay

38. VE 7.1.1 Techniques for the Control of Small Mammals: A Review

39. ME 1.0 The Climatology of the Alberta Oil Sands Environmental Research Program Study Area

40. WS 3.3 Mixing Characteristics of the Athabasca River below Fort McMurray - Winter Conditions

41. AF 3.5.1 Acute and Chronic Toxicity of Vanadium to Fish

42. TF 1.1.4 Analysis of Fur Production Records for Registered Traplines in the AOSERP Study Area, 1970-75

43. TF 6.1 A Socioeconomic Evaluation of the Recreational Fish and Wildlife Resources in Alberta, with Particular Reference to the AOSERP Study Area. Volume I: Summary and Conclusions

44. VE 3.1 Interim Report on Symptomology and Threshold Levels of Air Pollutant Injury to Vegetation, 1975 to 1978

45. VE 3.3 Interim Report on Physiology and Mechanisms of Air-Borne Pollutant Injury to Vegetation, 1975 to 1978

46. VE 3.4 Interim Report on Ecological Benchmarking and Biomonitoring for Detection of Air-Borne Pollutant Effects on Vegetation and Soils, 1975 to 1978.

47. TF 1.1.1 A Visibility Bias Model for Aerial Surveys for Moose on the AOSERP Study Area

48. HG 1.1 Interim Report on a Hydrogeological Investigation of the Muskeg River Basin, Alberta

49. WS 1.3.3 The Ecology of Macrobenthic Invertebrate Communities in Hartley Creek, Northeastern Alberta

50. ME 3.6 Literature Review on Pollution Deposition Processes

51. HY 1.3 Interim Compilation of 1976 Suspended Sediment Date in the AOSERP Study Area

52. ME 2.3.2 Plume Dispersion Measurements from an Oil Sands Extraction Plan, June 1977

53.	HY 3.1.2	Baseline States of Organic Constituents in the Athabasca River System Upstream of Fort McMurray
54.	WS 2.3	A Preliminary Study of Chemical and Microbial Characteristics of the Athabasca River in the Athabasca Oil Sands Area of Northeastern Alberta
55.	HY 2.6	Microbial Populations in the Athabasca River
56.	AF 3.2.1	The Acute Toxicity of Saline Groundwater and of Vanadium to Fish and Aquatic Invertebrates
57.	LS 2.3.1	Ecological Habitat Mapping of the AOSERP Study Area (Supplement): Phase I
58.	AF 2.0.2	Interim Report on Ecological Studies on the Lower Trophic Levels of Muskeg Rivers Within the Alberta Oil Sands Environmental Research Program Study Area
59.	TF 3.1	Semi-Aquatic Mammals: Annotated Bibliography
60.	WS 1.1.1	Synthesis of Surface Water Hydrology
61.	AF 4.5.2	An Intensive Study of the Fish Fauna of the Steepbank River Watershed of Northeastern Alberta
62.	TF 5.1	Amphibians and Reptiles in the AOSERP Study Area
63.		An Overview Assessment of In Situ Development in the Athabasca Deposit
64.	LS 21.6.1	A Review of the Baseline Data Relevant to the Impacts of Oil Sands Development on Large Mammals in the AOSERP Study Area
65.	LS 21.6.2	A Review of the Baseline Data Relevant to the Impacts of Oil Sands Development on Black Bears in the AOSERP Study Area
66.	AS 4.3.2	An Assessment of the Models LIRAQ and ADPIC for Application to the Athabasca Oil Sands Area
67.	WS 1.3.2	Aquatic Biological Investigations of the Muskeg River Watershed
68.	AS 1.5.3 AS 3.5.2	Air System Summer Field Study in the AOSERP Study Area, June 1977
69.	HS 40.1	Native Employment Patterns in Alberta's Athabasca Oil Sands Region
70.	LS 28.1.2	An Interim Report on the Insectivorous Animals in the AOSERP Study Area
71.	HY 2.2	Lake Acidification Potential in the Alberta Oil Sands Environmental Research Program Study Area
72.	LS 7.1.2	The Ecology of Five Major Species of Small Mammals in the AOSERP Study Area: A Review
73.	LS 23.2	Distribution, Abundance and Habitat Associations of Beavers, Muskrats, Mink and River Otters in the AOSERP Study Area, Northeastern Alberta
-	--	Interim Report to 1978
74.	AS 4.5	Air Quality Modelling and User Needs

These reports are not available upon request. For further information about availability and location of depositories, please contact:

Alberta Oil Sands Environmental Research Program
15th Floor, Oxbridge Place
9820 - 106 Street
EDMONTON, Alberta T5K 2J6