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AN INTENSIVE STUDY OF THE FISH FAUNA OF THE MUSKEG RIVER WATERSHED OF NORTHEASTERN ALBERTA

by

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ABSTRACT

The fish fauna of the Muskeg River was studied during the open water period in 1976 and 1977. Additional work in 1978 served to define the aquatic habitat of this watershed in terms of various physical parameters. Fish movements into and out of the Muskeg River were monitored by means of a two-way counting fence. The fence was operated from 28 April to 30 July 1976, and from 28 April to 15 June 1977. Small mesh beach seines were used throughout the watershed to collect small fishes. Tags were applied to 3898 migrant fish in order to determine the length of time spent in the Muskeg River watershed by individual fish, and to define migration patterns within the lower Athabasca River system. The general biology of the various fish species was described in terms of their age and growth patterns, food habits, fecundity, etc.

White and longnose suckers were the most abundant fish taken at the upstream trap in both years of the study. These two species occurred in equal numbers in 1976 when they accounted for 92% of the 6153 fish enumerated. Arctic grayling (5%) and northern pike (2%) made up most of the remainder. The total 1977 catch at the upstream trap was 5275 fish, of which 56% were white suckers, 31% were longnose suckers, 8% were northern pike, and 3% were Arctic grayling. Upstream runs of white suckers, longnose suckers and Arctic grayling represented spawning movements. Some pike also spawn within the Muskeg River system although most of the pike movement observed appeared to be associated with feeding. Small numbers of mountain whitefish, lake whitefish and walleye also undertook spring feeding movements into the Muskeg River.

After spawning in the lower 35 km of the Muskeg River and in the lower reaches of Hartley Creek, suckers of both species began to leave the Muskeg River watershed. Most spawners had probably left the stream by mid-June. Sucker fry hatched and began to migrate out of the Muskeg River watershed in early June. Arctic grayling remained in the Muskeg River throughout the summer to feed. Young-of-the-year grayling may overwinter in the Muskeg

River, and join the migrant population in the autumn of their second year.

Only 2% of all fish tagged were recaptured outside the Muskeg River watershed. Recaptures suggest that white and longnose suckers that spawn in the Muskeg River are part of the Lake Athabasca population and return to the lake to overwinter. A homing tendency was demonstrated by both species. Northern pike showed little tendency to move around.

The resident fish fauna of the Muskeg River consists largely of brook stickleback, lake chub, longnose dace, and slimy sculpin.

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1. INTRODUCTION

The proposed development of the Athabasca Oil Sands may introduce disturbance to some lake and river systems of the lower Athabasca River drainage. Especially susceptible is that section of the surface-mineable area for which the Alberta Energy Resources Conservation Board (AERCB) has granted development approval. Local disruption in the form of land clearing, muskeg drainage and removal, stream diversions, and the construction of access routes may affect the water quality and quantity of streams in addition to the physical alterations produced. Other activities that could affect water quality include tailings pond seepages and saline minewater discharges. The diversion or blockage of streams may affect fish spawning runs. Traditional fish rearing, feeding, and overwintering areas may be disturbed or lost altogether. In the case of migrant fish populations, such local disruptions could be felt over much wider areas.

In order to provide information that could be used to minimize the adverse effects of development on fish populations of the Athabasca River and its tributaries, the Alberta Oil Sands Environmental Research Program (AOSERP) through its Aquatic Fauna Technical Research Committee, initiated an integrated series of projects to assess the baseline state of the fish resources of the area. The work, which began in 1976, involves a broadly based fisheries investigation of the Athabasca River as well as site-intensive study of selected tributaries. Tributaries selected for intensive study are those considered to be most immediately imperilled by future surface mining operations or by increased pressure from a growing human population.

The Muskeg River, a medium sized watershed on the east side of the Athabasca River, was the first tributary selected for intensive study. Initially, this tributary was selected because a large portion of its drainage lies within the surface-mineable area and because the AERCB was involved in considering the construction there of two synthetic crude oil plants. The possibility was anticipated that construction of one or both of these plants could involve massive watershed disturbance including the eventual diversion of both the Muskeg River and its major tributary, Hartley Creek. Development plans for this area have recently changed with the proposal by the Alsands Project Group, a consortium of nine oil companies, to develop a single plant north of the Muskeg River. The new proposal will not require the diversion of either the Muskeg River or Hartley Creek, and total destruction of this watershed will, therefore, be avoided. However, construction and operation of the proposed plant, the construction of a proposed new town, and increased access through extension of roadways are expected to place considerable pressure on the fish populations of the Muskeg River.

The present study was conducted over a period of three years with the general objective, as outlined in the terms of reference agreed to by AOSERP and the Department of Fisheries and Environment, of describing the baseline states of the fish resources of the Muskeg River watershed and providing a quantitative estimate of the significance of the watershed to the fisheries of the Athabasca River system.

Specific objectives for the study were as follows:

1. To enumerate the migrant populations of those fish species utilizing the Muskeg River watershed on a seasonal basis;
2. To describe the timing of the seasonal and daily movements of the various fish populations into and out of the Muskeg River watershed, and to obtain information concerning the age and growth, sex ratio, fecundity, food habits, etc., of these fish;
3. To determine the extent of movement of the various non-resident fish populations within the Muskeg River watershed, and to locate critical spawning and nursery areas;
4. To apply conventional (Floy) tags to migrant fish to permit definition of their migration routes within the Athabasca River system;

5. To monitor the downstream migration of fry of various species hatched within the Muskeg River watershed, and to estimate recruitment of these species to the Athabasca River system; and
6. To assess the resident fish species of the Muskeg River watershed in terms of relative abundance, distribution and general biology.

During the second year of the study it was also our objective to describe in detail the aquatic habitat of the Muskeg River watershed. This work was postponed until year three because the classification system and key adopted by AOSERP for this purpose was unavailable in 1977.

Results of work done in 1976 have already been reported in interim form (Bond and Machniak 1977). This report presents the results of work done in 1977 and attempts to draw together the results from both years. It also presents results of the habitat characterization done in 1978 and attempts to relate habitat to fish utilization.

2. RÉSUMÉ OF CURRENT STATE OF KNOWLEDGE

Prior to 1976, information relative to the fish fauna of the Muskeg River was limited to that generated by Griffiths' (1973) preliminary survey and subsequent baseline studies conducted by Lombard-North Group Ltd. (1973) and Renewable Resources Consulting Services Ltd. (1974). The latter two studies were performed as part of an environmental assessment of Shell's lease 13 mining project and a summary of the work is included in the lease 13 environmental impact assessment that was filed with Alberta Environment in 1975 (Shell Canada Ltd. 1975).

Since Griffith's work was part of a broad regional study intended to evaluate the sport fishery potential of a large number of streams in the oil sands area, his treatment of any one stream was, of necessity, cursory. He did, however, document the occurrence of eight fish species in the Muskeg River and identified the presence of a grayling population in the lower reaches. He did not examine the upper Muskeg River watershed nor did he sample Hartley Creek.

The work by Lombard-North Group Ltd. (1973) and Renewable Resources Consulting Services (1974), while extending knowledge of the fish fauna of the Muskeg River, left many questions unanswered. These studies suggested an important role for the Muskeg River in terms of providing spawning areas for longnose suckers and white suckers although they were unable to enumerate the runs. The capture of Arctic grayling, longnose and white suckers, and mountain whitefish in Hartley Creek suggested a greater importance for that tributary than was predicted by Griffiths. The significance of the mouth region for fish populations from the Athabasca River was implied and an attempt was made to relate fish utilization to habitat type. However, because these studies concentrated on the region within leases 13 and 30, they provided no information on the resident fish populations of the upper watershed or the extent to which this region is utilized by migrant populations. Since no attempt was made to capture small fish, the likely presence of several species was not detected, nor were the younger age classes of larger species sampled. Small sample sizes precluded an adequate description of the life history and general biology of several species.

Previous studies did not permit an adequate description of the fish resources of the Muskeg River watershed. Quantification of the migrant populations that utilize the Muskeg River watershed on a seasonal basis and a clear description of such seasonal utilization patterns were required. Areas within the watershed that may be critical in the life histories of the various species required definition. The composition and distribution of resident fish populations required description. Life history patterns and general biological features of all species required further elucidation.

3. DESCRIPTION OF THE STUDY AREA

The Muskeg River originates in the Muskeg Mountain uplands and travels approximately 100 km before joining the Athabasca River 58 km downstream from Fort McMurray (Figure 1). The total area drained by the Muskeg River system is 1464 km^2, of which 80% is forest and 20% muskeg (Northwest Hydraulic Consultants Ltd. 1974). Only 2% of the total watershed area is lakes, the largest of which, Kearl Lake (Figure 2), is only 5.4 km^2 in surface area and 2 m in maximum depth. Hartley Creek (Figure 2), the major tributary of the Muskeg River, drains 325 km^2 to the south of the main stream and enters the Muskeg River about 33 km upstream from its confluence with the Athabasca River. The water of the Muskeg River and Hartley Creek is stained brown as a result of the presence of humic and fulvic acids.

The climate of the study area is continental, characterized by cold winters, short, cool summers, and wide temperature fluctuations (Intercontinental Engineering of Alberta Ltd. 1973). Precipitation records for the Muskeg Mountains show the annual precipitation to be 49.8 cm, of which 33.6 cm falls between May and September (NHCL 1974).

The upper portion of the Muskeg River (Figure 3) is well drained and vegetated by mixed spruce and areas of treed muskeg. Surficial deposits consist of relatively thick drift composed mainly of till (NHCL 1974) while the bedrock material is largely Cretaceous shales and sandstones. The large central area of the watershed is flat, poorly drained and covered with marshland and treed muskeg (Figure 4). A thin surficial layer of outwash sand is underlain in this area by the McMurray Oil Sands Formation. The Muskeg River leaves the flat, central portion of its watershed in the lower 16 km of its course and begins to cut through the McMurray Oil Sands and Waterways limestone (NHCL 1974). The lower reaches of the river valley are stream cut and the channel is frequently confined by limestone outcroppings. The stream channel in this area is fairly stable, the substrate, consisting of large areas of gravel (Figure 5) with occasional areas of boulders and

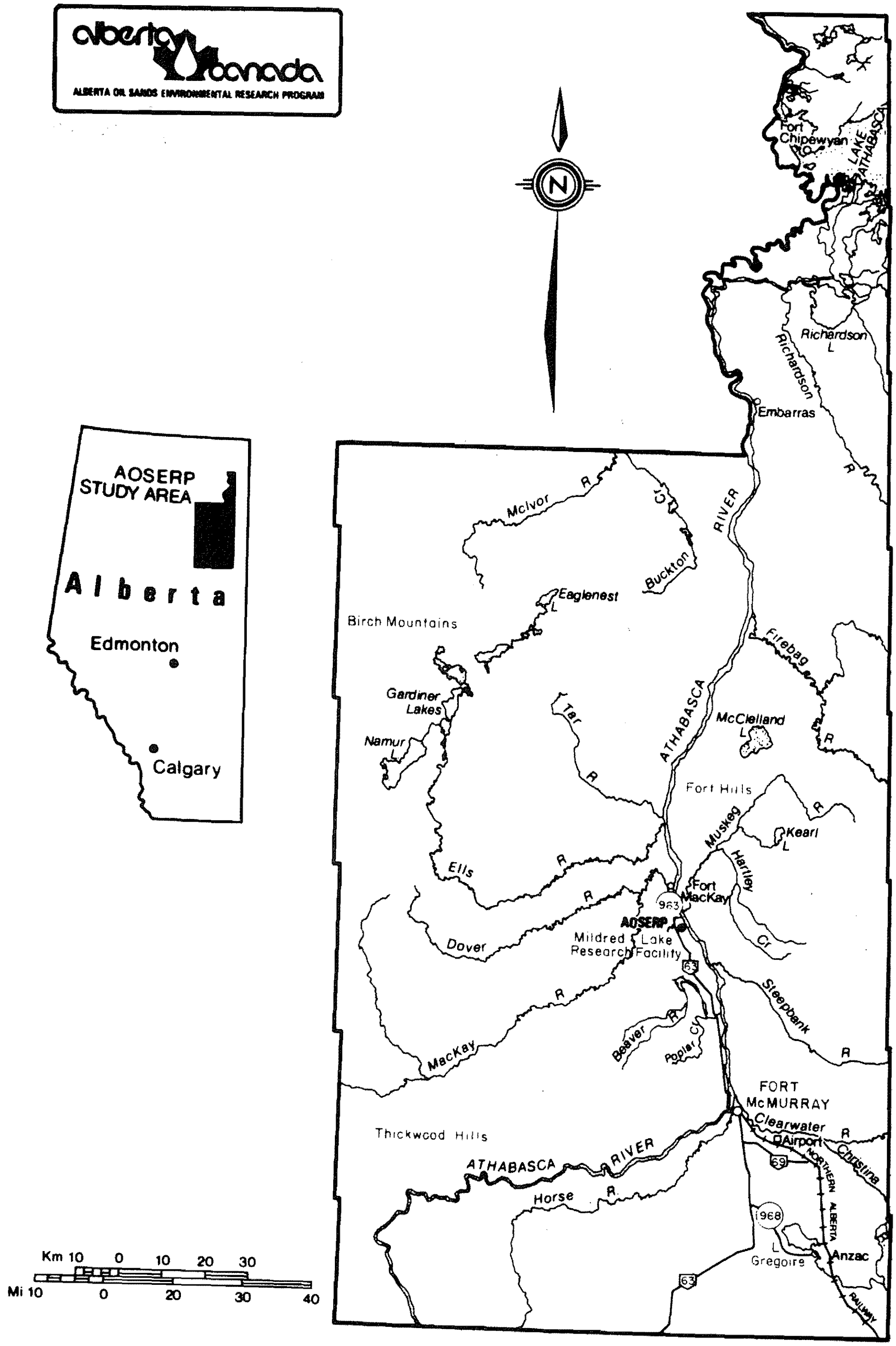

Figure 1. Map of the AOSERP study area indicating the location of the Muskeg River.

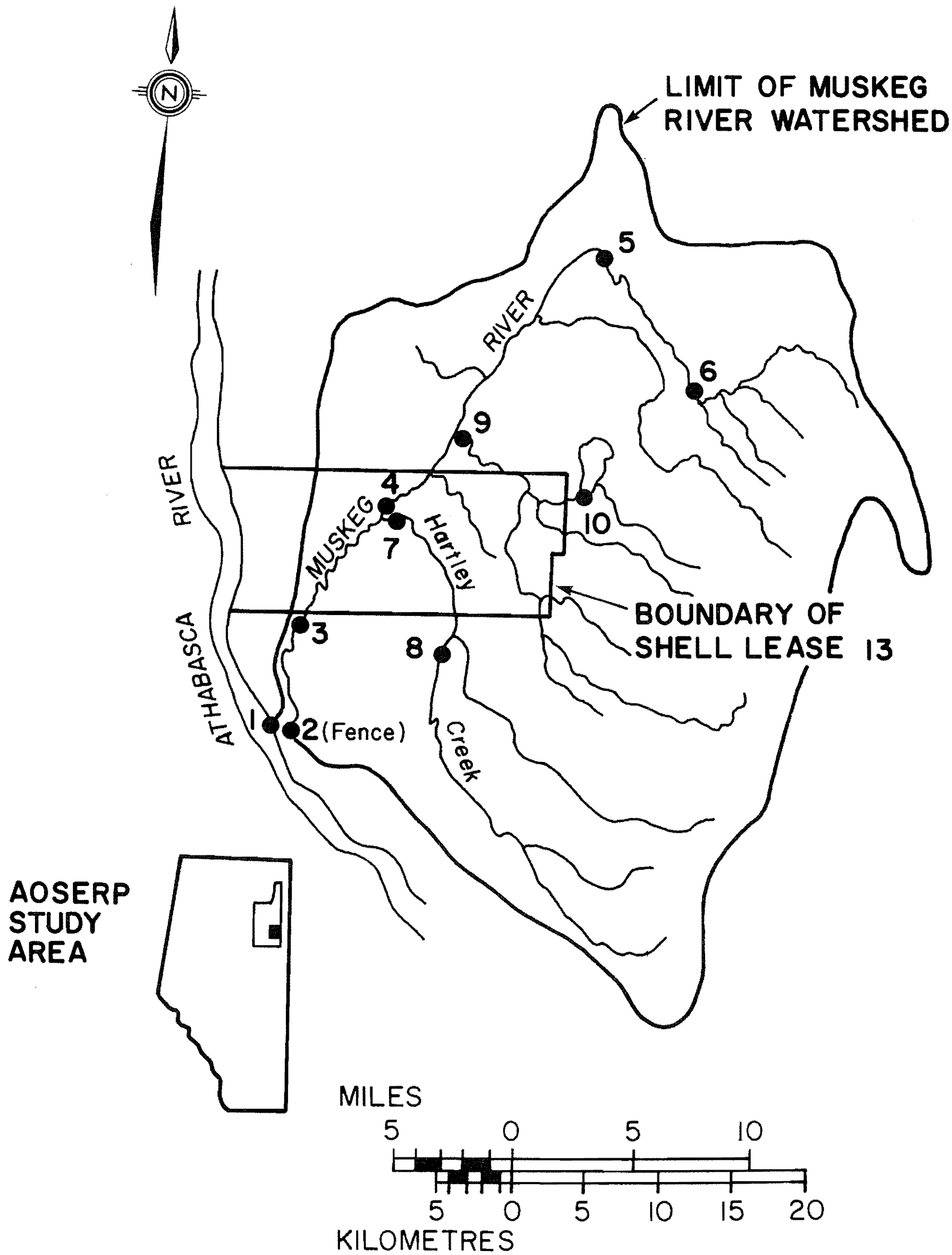

Figure 2. Map of the Muskeg River drainage basin indicating the location of the counting fence and small fish collection sites.

Figure 3. The upper Muskeg River at small fish collection Site 6.

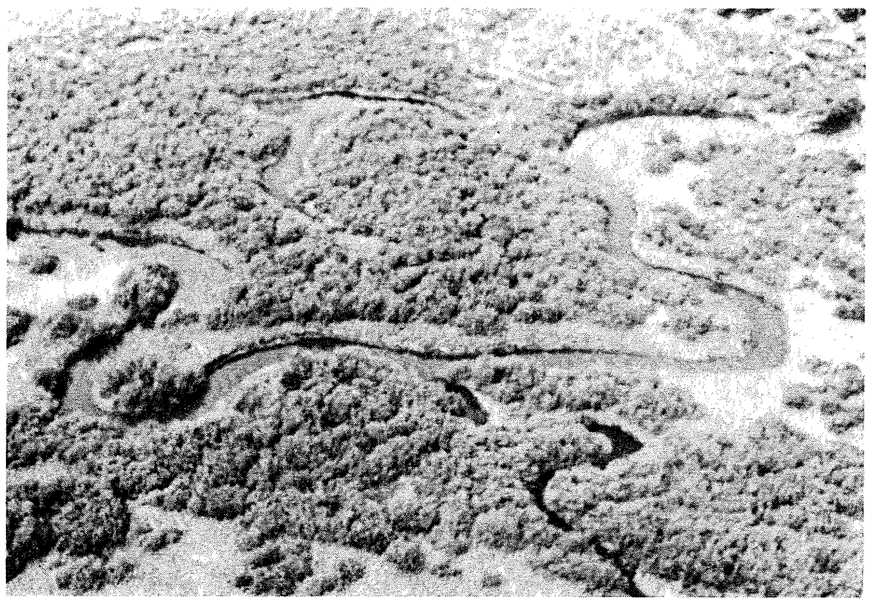

Figure 4. The confluence of the Muskeg River and Kearl Creek at small fish collection Site 9.

Figure 5. The Muskeg River downstream of the counting fence.

bedrock (Figure 6).

The Muskeg River generally freezes over in late October and remains ice-covered until late April. Ice left the stream on 15 April in 1976 and on 22 April in 1977. Under ice cover, water temperatures remain near 0°C but the stream can warm quickly in the spring and reach high temperatures in mid-summer. A maximum water temperature of 25°C was recorded in 1976 and daily temperature fluctuations of up to 8°C were observed (Bond and Machniak 1977).

Discharge records for the Muskeg River (Water Survey of Canada 1978) showed a mean daily discharge in 1977 of 2.3 m^3/s (range 0.2 to 13.5 m^3/s). After the spring flood, water levels generally decline through the summer although considerable fluctuation may occur as a result of heavy precipitation (Figures 7 and 8).

A brief description of the physical and chemical characteristics of Muskeg River water is given in Table 1. More complete physical and chemical data for this stream are presented by Seidner (in prep.).

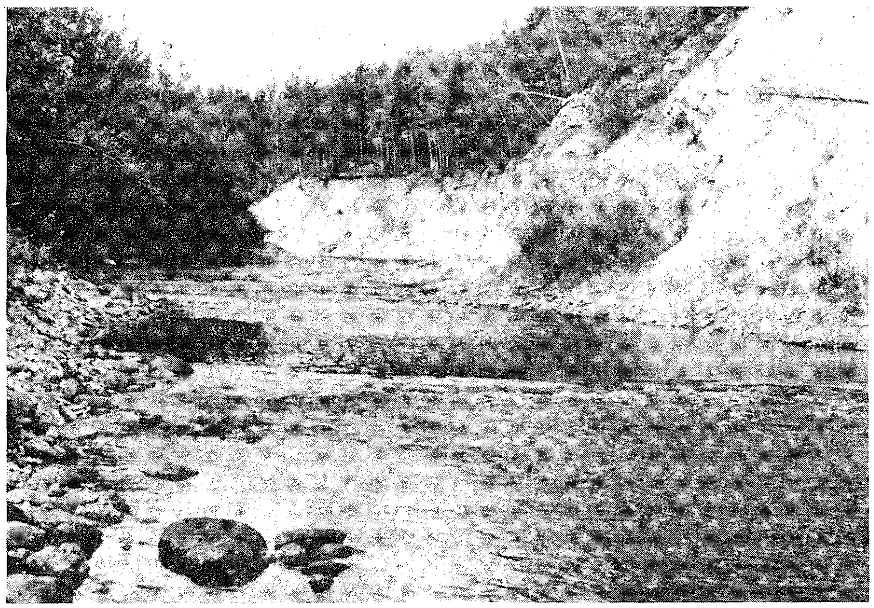

Figure 6. The canyon section of the Muskeg River.

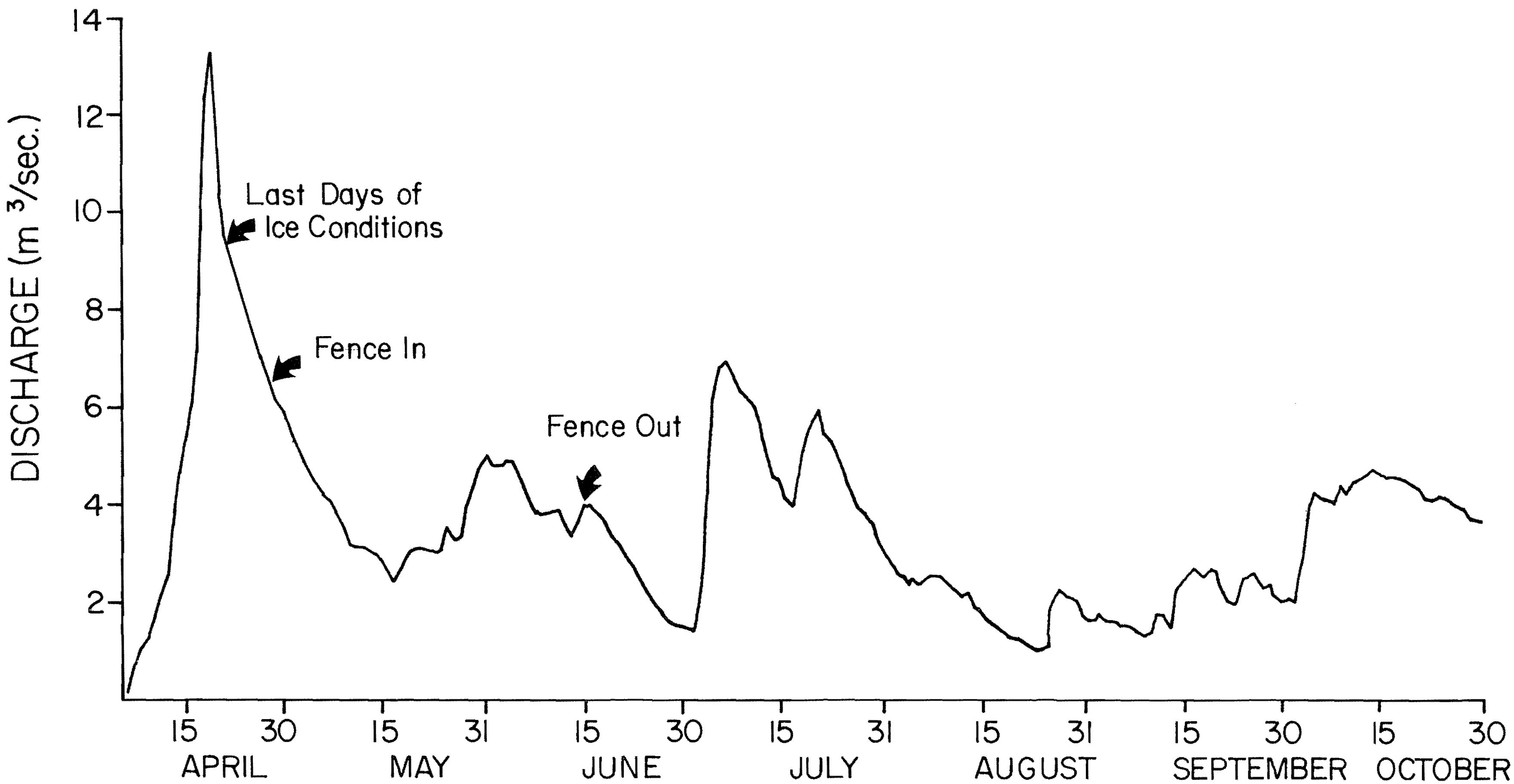

Figure 7. Discharge of the Muskeg River from 1 April to 31 October 1977.

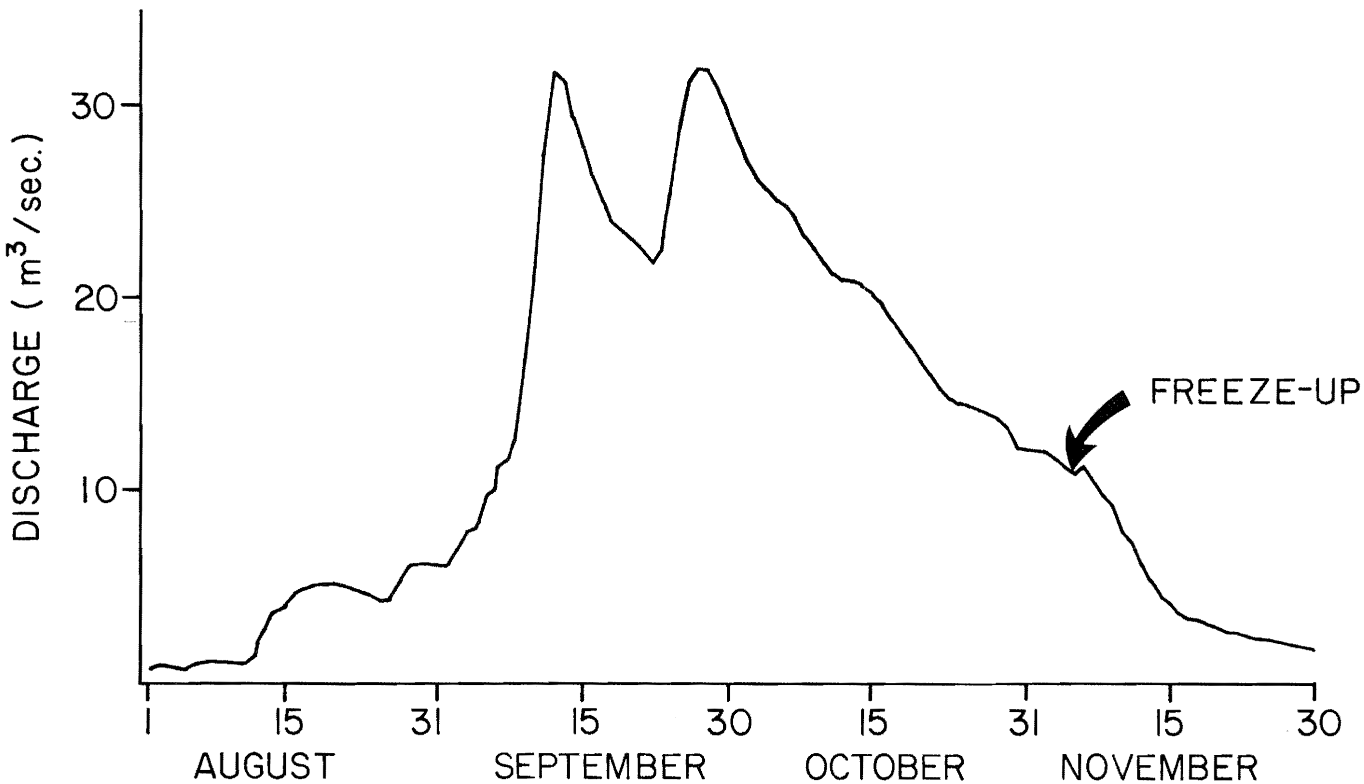

Figure 8. Discharge of the Muskeg River from 1 August to 30 November 1978.

Table 1. Summary of physical and chemical characteristics of the Muskeg River on several dates, 1976[a].

Parameter[b]	Date			
	11 Feb	14 May	27 July	7 Sept
Discharge (m^3/s)	0.4	2.6	0.9	2.9
pH (pH units)	7.7	8.1	7.8	7.8
Specific conductance (µmhos/cm @ 25C)	367	259	380	270
Turbidity (JTU)	6.3	2.8	17.0	14.6
Apparent colour (Relative units)	65	70	35	80
Total alkalinity	119	136	228	148
Total hardness	139	137	196	137
Humic acid	8	4	9	8.5
Fulvic acid	10	20	9	8.5
Filterable residue	ND	181	276	162

[a] Data provided by Mr. C. R Froelich, Alberta Oil Sands Environmental Research Program.
[b] Except as indicated, data are expressed as mg/L.

4. MATERIALS AND METHODS

The fish fauna of the Muskeg River was studied during the open water period of 1976 and 1977. During spring and summer of both years various methods were employed to collect fish throughout the watershed although the major emphasis was placed on the construction and operation of a two-way fish counting fence to monitor spring movements of fish into and out of the Muskeg River. The fence was established approximately 1 km upstream of the mouth of the tributary, thus permitting enumeration of a large proportion of the fish moving from the Athabasca River into the Muskeg River watershed. The counting fence was operated from 28 April to 30 July in 1976 and from 28 April to 15 June in 1977.

The absence of a fall fence operation in 1976 and 1977 was seen as a serious omission in the study and it was planned to conduct such an operation in 1978. However, extremely high water in September and October (Figure 8) made this impossible.

During June 1978, a biophysical inventory of the Muskeg River was conducted in order to describe the aquatic habitats of the watershed and relate habitat types to fish utilization.

4.1 COUNTING FENCE CONSTRUCTION

The counting fence (Figure 9) was constructed of 2.5 cm by 2.5 cm welded wire fabric and was installed in such a way as to form a complete temporary barrier to fish. Fish travelling upstream or downstream encountered the fence at some point and were led into one of the holding boxes where they could be worked with. Complete details of construction and installation are given in Bond and Machniak (1977).

4.2 COUNTING FENCE OPERATION

The operation of a counting fence of this type is highly labour intensive, especially during the high water period generally encountered in the spring. Debris carried by the river tends to clog the openings in the wire mesh, placing great pressure on the structure. Frequent cleaning is required to remove such debris and prevent the fence being washed out.

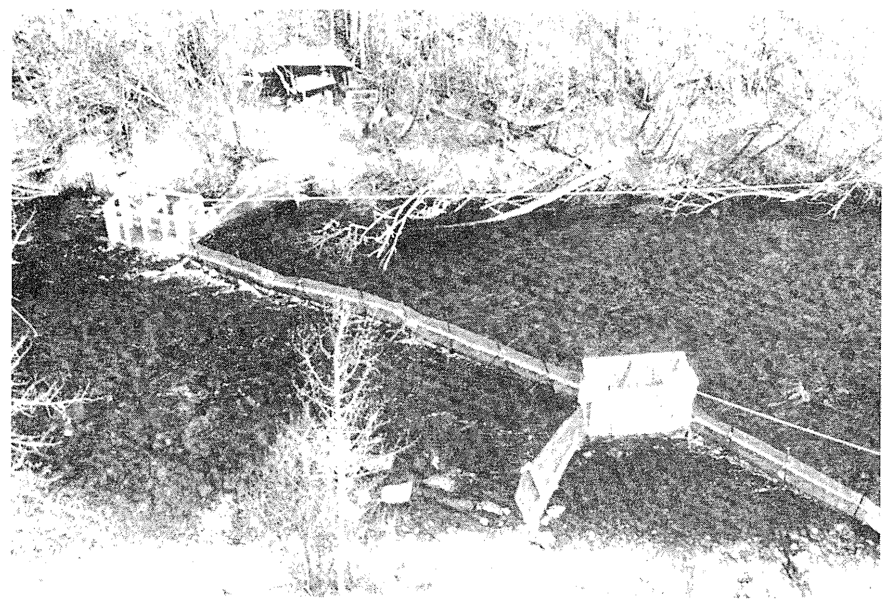

Figure 9. The Muskeg River counting fence.

4.2.1 Sampling Schedule

The 1977 counting fence was operated from 28 April to 15 June. The downstream trap, however, was kept closed until 12 May to prevent upstream migrants from drifting into it. The upstream trap was checked six or more times daily as required during the early part of May when fish movement was intense. After 12 May, the traps were usually checked three or four times daily (Table 2).

4.2.2 Trap Checks

Each trap check was performed by two persons, one working inside the trap and the other serving as recorder. The number of fish of each species was recorded and as many fish as possible were measured and sexed. The development of pearl organs by male white and longnose suckers often made it possible to distinguish between the sexes for these species without sacrificing the fish. Smaller fish, that were either females or immature males, could not be sexed by this method, and where doubt existed, no sex was recorded. Handling of fish was minimized by using a scoop constructed of PVC pipe and rochelle netting, and fish were passed through the fence in the direction in which they were moving.

Relative water level was recorded at each trap check using a metre stick anchored in the stream. A continuous record of stream temperatures was provided by a Ryan Model D15 recording thermometer. Temperature data are summarized in Appendix 8.1. The fence was cleaned as required and examined regularly for holes.

4.2.3 Tagging

Numbered Floy anchor tags (Type FD-68B) were applied to as many fish (mainly suckers and pike) as was practicable. Tags were inserted into the left side of the fish near the base of the dorsal fin. The risk of infection was minimized by rinsing the tagging gun in disinfectant and in fresh water before each insertion. Suckers, retained in a holding pen for up to 15 minutes, rarely showed any ill effects. However, in 1976,

Table 2. Sampling schedule for Muskeg River counting fence, 1977.

Date	Time of Fence Check[a]						
	0300	0900	1200	1500	1800	2100	2400
28 April					+	+	
29		+	1300	1600		+	
30			+		+	+	
1 May			+			+	+
2		+	+	+	+	+	+
3		+	+	+	+	+	+
4	+		+	+	+	+	+
5	+		1300		+	2200	+
6	+		+	+	+	+	+
7	+	0500	+	+	+	+	+
8	+	0600	+	+	+	+	+
9	+	0500	+	+	+	+	+
10	+		+	+	+	+	+
11	+		+	+	+	+	+
12	+		+		+	+	+
13			+		+	+	+
14			+		+	+	+
15			+		+	+	+
16			+		+		+
17			+			+	+
18			+			+	+
19			+		+	+	+
20			+			+	+
21			+			+	+
22			+		+	+	+
23			+		+		+
24			+		+	+	+
25			+		+		+
26			+				+
27			+			+	+
28			+		+		+
29			+				
30		+		+			+
31			+			+	+
1 June	+		+		+		+
2			+				+
3			+		+		+
4			+		+		+
5			+		+		+
6			+		+		+
7			+		+		+
8			+		+		+
9			+		+	+	+
10			+	+	+	+	+
11			+			+	+
12			+	+		+	+
13			+	+	+	+	+
14			+			+	+
15			+	Operations terminated			

[a] Actual check time indicated where different from scheduled check time.

grayling did not appear to cope well with the stress imposed by the application of Floy tags. Therefore, metallic clip tags were utilized for this species in 1977. These tags were affixed to the left operculum and no mortality was observed.

Depending on the species, either fork or total length (±1.0 mm) was recorded for each fish tagged and the sex was noted if possible. Tagged fish were not weighed and no body structures were retained for age determination. Tagging was done only during the day in 1976 but in 1977, floodlights, operated from a portable generator, enabled the fence crew to tag fish during the late evening and at night. Care was taken at all times not to impede the progress of the fish any more than necessary. When fish were observed to be backing up in front of the trap, tagging was curtailed and the remaining fish were simply passed through and enumerated.

The tagging program was well publicized by posters and press releases and a two dollar reward was offered for returned tags. Tag returns were made by sport fishermen along the Athabasca River, by domestic fishermen on the Athabasca River and Lake Athabasca, and by commercial fishermen on Lake Athabasca. Personnel of LGL Ltd., Environmental Research Associates, Edmonton, and Aquatic Environments Ltd., Calgary, also returned tags, while others were recovered by fishery crews working on the Athabasca River (Bond and Berry in prep.b), the Steepbank River (Machniak and Bond in prep.), and the MacKay River (Machniak et al. in prep.).

4.2.4 Dead Samples

Small numbers of fish were sacrificed each day for biological analysis. Fork or total length (±1.0 mm) and weight (±20 g) were recorded for each fish. Weights of some small fish were determined on a triple beam balance (±0.1 g). Sex and stage of maturity were determined by examination of the gonads. A fish was considered to be mature if it appeared that it would spawn or had already spawned in the year of capture. A ripe fish was a mature fish whose gonads were close to spawning condition and from which sexual products could be expressed by application of light pressure to the abdomen. A spent or spawned out fish was a mature fish which had obviously spawned shortly prior to its capture. Ovaries for fecundity work were removed from a number of longnose suckers, white suckers, and Arctic grayling and weighed fresh on a triple beam balance (±0.1 g). These ovaries were then preserved in Gilson's fluid. Stomach contents were noted and a small number of stomachs were preserved in 10% formalin for a more detailed assessment of food habits. Scales were removed from the appropriate body location (Hatfield et al. 1972) for ageing of grayling, mountain whitefish, pike, walleye, and lake whitefish. Otoliths (ear bones) were taken from burbot, and for suckers, the left pectoral fin was retained for age determination.

4.3 OTHER FISH COLLECTION TECHNIQUES

Apart from the counting fence, fish were collected by various methods including small mesh beach seines (3.2 mm oval mesh), commercial minnow traps, gill nets, electrofishing, drift nets, dip nets, and angling. Large fish captured by these methods were either dead sampled or measured and tagged. Small fish were initially preserved in 10% formalin and later transferred to 40% isopropyl alcohol.

An attempt was made to monitor the downstream fry migrations in 1977 using a bomb drift sampler (Burton and Flannagan 1976). However, the 202 µm Nitex utilized in the construction of the sampler quickly became clogged with debris, rendering the sampler ineffective. Drift samplers, as a consequence, were useful only in identifying the starting time of the fry migration.

4.3.1 Small Fish Collection Sites

Small fish were collected from 10 general areas of the Muskeg River watershed. The sampling sites utilized in 1977 were essentially the same as were sampled in 1976 (Bond and Machniak 1977). Sampling Sites 1, 2, and 3 were located downstream of Shell lease 13, Sites 5, 6, 8, 9, and 10 were upstream of the lease, while Sites 4 and 7 were situated within the lease boundaries

(Figure 2). Each site consisted of from 10 m to 3 km of stream channel that was sampled in such a way as to obtain a representative sample of the fish population of the area. No standard unit of effort was used. The dates on which each location was sampled in 1977 are shown in Table 3. Numerous collections were made at Sites 1, 2 and 3 on dates other than those indicated in Table 3 and these fish were included in the results.

4.4 LABORATORY TECHNIQUES

4.4.1 Fish Identification and Measurement

Preserved fish specimens were identified using taxonomic keys and descriptions given by Paetz and Nelson (1970) and McPhail and Lindsey (1970). While most fish could be identified to species, larval catostomids could often be identified only to genus.

Small, preserved fish specimens were measured to the nearest 1.0 mm (0.5 mm for some larval fishes) and weighed to the nearest 0.1 g on a triple beam balance.

4.4.2 Age Determination

Ages were determined by the scale method for Arctic grayling, mountain whitefish, lake whitefish, walleye, and northern pike. Several scales from each fish were cleaned and mounted between two glass slides and the annuli were interpreted from the image produced by an Eberback microprojector.

Longnose and white suckers were aged from cross sections of pectoral fin rays as described by Beamish and Harvey (1969) and Beamish (1973). After embedding the dried fin rays in epoxy, thin sections (0.5 to 1.0 mm) were cut by hand using a jeweller's saw with No. 6 or No. 7 blades. The sections were then mounted in Permount on glass slides and read under a compound microscope.

Ages for all other fish were determined from otoliths. Otoliths were stored in a 1:1 glycerine and water mixture and read whole under a dissecting microscope using reflected light. Where required, the otolith was ground by hand on a carborundum.

Table 3. Dates of small fish collections at each collection site, Muskeg River watershed, 1977[a].

Site No.	Date of Collection						
	20 May	19 June	18 July	30 July	16 Aug.	15 Sept.	13 Oct.
1		+	+	+	+		
2	+	+	+	+	+		
3	+	+	+		+	+	+
4	+	+	+			+	+
5		+	+				
6		+		+	+	+	+
7	+	+	+				
8	+		+		+	+	+
9		+	+		+		
10	+	+	+	+			+

[a] In addition to the above, samples were collected from Site 1 on 5 June and 6 August; from Site 2 on 10 other dates; from Site 3 on five other dates, and from Site 7 on 3 June 1977.

Independent age determinations were made by three people in all cases. Where discrepancies existed among the three results, the readers conferred until a consensus was achieved.

4.4.3 Fecundity

Fecundity was determined for longnose and white suckers using the gravimetric method of estimation described by Healey and Nicol (1975). The ovarian tissue was removed from the sample and the separated eggs dried to constant weight. The weight of a subsample of eggs was determined and the total number of ova then derived by extrapolation. The accuracy of the estimates was assessed by performing total counts on several ovaries.

4.4.4 Food Habits

The stomach contents of preserved fish were removed and the food items identified to the lowest possible taxon using keys and descriptions from Pennak (1953). Results were expressed as percentage frequency of occurrence, percentage of total number, and, in some cases, percentage of total volume.

4.4.5 Data Analysis

Biological data were analyzed for graphic and tabular presentation using a Hewlett-Packard Model 9810-A programmable calculator.

Length-weight relationships were described by the power equation:

$$\log_{10}W = a + b\,(\log_{10}L); \quad sb =$$

where: W = weight in grams

L = fork or total length in millimetres

a = y-intercept

b = slope of the regression line, and

sb = standard deviation of b.

Data summaries and raw data are presently on file at the Freshwater Institute in Winnipeg.

4.5 AQUATIC HABITAT ANALYSIS

An effort was made to characterize the aquatic habitat of the Muskeg River utilizing the procedures described by Brown et al. (1978). In this system, streams are divided into reaches which differ from each other in their physical characteristics. A helicopter survey is used to produce average values for various parameters over each entire reach and site-specific information is gathered from sample points within each reach.

4.5.1 Reach Definition and Description

A reach is a section of stream whose physical properties (habitat characteristics) are relatively homogeneous throughout its length. According to Brown et al. (1978), "reach boundaries are located in regions where the topography changes drastically, or significant changes in water quality, channel form and/or flow character" occur.

Tentative reach boundaries for the Muskeg River and Hartley Creek were assigned by reference to National Topographical Series maps (1:50,000) and available gradient information (RRCS 1975). These were later verified in the field. Aerial photo interpretation, a recommended method for assigning tentative reach boundaries, was not used in the present study.

General descriptions of each reach were acquired during an aerial survey of the Muskeg River. At that time observations were recorded on various aspects of the aquatic habitat. These characteristics, which include velocity, substrate, pools, riffles, riparian vegetation etc., are presented as averages of these parameters over the length of the reach.

4.5.2 Point Samples

Site-specific information on biological and physical parameters was collected on 22 and 23 June 1978. The sites sampled included small fish collection sites utilized in 1976 and 1977 plus several additional locations.

At each site, stream width was measured and the depth was taken at three locations across the channel. A rough estimate of stream velocity was obtained by floating a small chip a distance of 5 m and timing it. This was also done at three locations across the channel. The substrate composition at the site was estimated in terms of fines (< 2 mm), gravel (2 to 64 mm), larges (> 64 mm) and bedrock. Riparian vegetation and aquatic vegetation were noted and water temperature was recorded using a pocket thermometer. At every second site, dissolved oxygen was determined using a Hach field kit (Model AL-36-B) and pH was estimated by means of colour comparator. Specific conductance was measured using a Beckman RB-3 conductivity meter.

From five to seven seine hauls (3.2 mm oval mesh) were made at each location. Fish captured were preserved in 10% formalin in the field and were later identified to species, measured, and weighed. Benthic macroinvertebrates were collected using the kick method and a net fitted with 202 µm Nitex. These were also preserved in 10% formalin. Kick samples were later divided into major groups (Chironomidae, Ephemeroptera, Plecoptera, Trichoptera, Simuliidae, Oligochaeta and "others"). No attempt was made to identify these samples further as extensive invertebrate data from the Muskeg River watershed have already been presented by Barton and Wallace (in prep.).

4.5.3 Mapping Procedures

A map of that portion of the Muskeg River watershed surveyed was prepared at a scale of 1:50 000 to summarize the biophysical data gathered during this study. Fish data collected in 1978 were supplemented by those gathered during 1976 and 1977.

4.6 LIMITATIONS OF METHODS

The primary objective of the present study was to enumerate and describe the migrant fish populations that utilize the Muskeg River on a seasonal rather than a year-round basis. The best possible means of achieving such an objective is undoubtedly a counting fence. However, this apparatus, like any other, has certain limitations.

The 2.5 x 2.5 cm wire mesh used in the construction of the counting fence is believed to have been highly effective in catching fish longer than 150 mm in fork length. Smaller fish, although sometimes taken in the trap, were able to pass through the apertures. Seasonal movements of small fish (such as trout-perch) could not, therefore, be monitored.

The Muskeg River counting fence could be operated effectively only at discharge rates of less than 7 m^3/s. Thus, the fence could not be installed until the spring flood had begun to subside, and fish movements occurring during the peak of the flood could not be monitored. Once the fence was installed, no problems were encountered in either year of the study as water levels remained low during the period of operation.

Because of the highly compacted nature of the substrate at the fence site, little problem was encountered with holes developing under the structure. Although small numbers of fish may have avoided the traps through such holes, we believe the number to be small relative to the total number counted.

We believe that our catch data are highly representative of the nature and timing of the upstream migrations. Suckers moving upstream quickly located the entrance to the trap and showed no hesitation in entering it. At times of heavy upstream movement, suckers backed below the fence but continued actively to seek a way through. Their progress was delayed as little as possible by continuous trap work at such times. Downstream data are considered to be less representative. The downstream trap, especially in 1976 (Bond and Machniak 1977), was inefficient in terms of holding fish. This problem was considerably reduced in 1977 by a modification of the trap entrance, whereby the entrance was offset from the long axis of the trap. The second problem encountered in monitoring the downstream run was the apparent reluctance of suckers to enter the downstream trap. Fish moving downstream would often stop just ahead of the entrance to the trap and hold there. Many times they would refuse to enter and would move back upstream. Thus, the situation in the Muskeg River was similar to that described by Kendel (1975) where post-spawning, downstream movements of longnose suckers were delayed by the presence of a counting fence.

The counting fence was operated from 28 April to 30 July 1976, and from 28 April to 15 June 1977. Thus, spring and early summer fish movements in the Muskeg River have been fairly accurately described. The exception appears to be Arctic grayling, many of which undoubtedly passed upstream prior to fence installation. The absence of a fall fence operation leaves a serious gap in the study. No firm plans for a fall operation were included in the 1976 and 1977 studies. High water thwarted a planned fall operation in 1978 and prevented a complete enumeration of Arctic grayling during their downstream migration which is suspected to occur just prior to freeze-up.

The small mesh seines (3.2 mm) used in the present study are considered to have been highly effective in capturing small fish in the Muskeg River watershed. However, in deep water and in areas with an uneven bottom (rocks, logs etc.) their value was limited. Such areas might have been more efficiently sampled by an electrofisher or toxicant.

Because no winter sampling was conducted, the present study produced no information on fish utilization of the Muskeg River at that time of the year.

5. RESULTS AND DISCUSSION

5.1 FISH FAUNA OF THE MUSKEG RIVER

Nineteen fish species representing nine families (Table 4) were captured in the Muskeg River watershed during 1977. All species taken in 1976 (Bond and Machniak 1977) were represented in the 1977 catch with the exception of spottail shiner. Species captured in 1977 that represent additions to the 1976 results include Dolly Varden, fathead minnow, yellow perch, ninespine stickleback, and lake cisco.

The fish fauna of the Muskeg River can be divided into three categories on the basis of the extent to which this watershed forms part of the home range of the various populations. The first category includes a number of species that appear to be more typical of the Athabasca River or other areas outside the Muskeg watershed. It includes lake whitefish, walleye, yellow perch, burbot, Dolly Varden, lake cisco, fathead minnow, ninespine stickleback, and spottail shiner. These species are seldom encountered upstream of the fence site and are most likely to be taken in the vicinity of the river mouth, an area that may be of considerable importance in terms of providing resting areas during migrations within the Athabasca River or nursery areas for young-of-the-year.

The second category includes five species that appear to have established resident populations within the Muskeg River watershed and whose home range is more or less restricted to that watershed. These are lake chub, brook stickleback, longnose dace, slimy sculpin, and pearl dace. For these species the Muskeg River satisfies all requirements of all life stages on a year round basis.

The third category includes a number of species to which the Muskeg River represents a small but important portion of their home range. These species, while inhabiting areas outside of, and, in some cases, great distances from the Muskeg River for part or most of the year, return to the tributary periodically to spawn and/or feed. The Muskeg River watershed may also provide

Table 4. List of fish species captured in the Muskeg River drainage during 1976 and 1977.

Family and Species Names	Common Names
Family Coregonidae	
Coregonus clupeaformis (Mitchill)	Lake whitefish
Prosopium williamsoni (Girard)	Mountain whitefish
Coregonus artedii Lesueur[a]	Lake cisco
Thymallus arcticus (Pallas)	Arctic grayling
Salvelinus malma (Walbaum)[a]	Dolly Varden
Family Esocidae	
Esox lucius Linnaeus	Northern pike
Family Cyprinidae	
Semotilus margarita nachtriebi (Cox)	Northern pearl dace
Couesius plumbeus (Agassiz)	Lake chub
Rhinichthys cataractae (Valenciennes)	Longnose dace
Notropis hudsonius (Clinton)[b]	Spottail shiner
Pimephales promelas Rafinesque[a]	Fathead minnow
Family Catostomidae	
Catostomus commersoni (Lacépède)	White sucker
Catostomus catostomus (Forster)	Longnose sucker
Family Percopsidae	
Percopsis omiscomaycus (Walbaum)	Trout-perch
Family Gadidae	
Lota lota (Linnaeus)	Burbot
Family Gasterosteidae	
Culaea inconstans (Kirtland)	Brook stickleback
Pungitius pungitius (Linnaeus)[a]	Ninespine stickleback
Family Cottidae	
Cottus cognatus Richardson	Slimy sculpin
Family Percidae	
Stizostedion vitreum vitreum (Mitchill)	Walleye
Perca flavescens (Mitchill)[a]	Yellow perch

[a] Captured in 1977 but not in 1976.
[b] Captured in 1976 but not in 1977.

rearing and overwintering areas for juvenile members of some of these populations. Species included in this group are white sucker, longnose sucker, Arctic grayling, mountain whitefish, northern pike, and, perhaps, trout-perch.

5.2 RELATIVE ABUNDANCE AND DISTRIBUTION

A total of 5275 fish (10 species) were passed through the upstream trap between 28 April and 15 June 1977 (Table 5). As in 1976 (Bond and Machniak 1977), white suckers (56.3%) and longnose suckers (31.1%) dominated the catch. Northern pike (8.2%), Arctic grayling (3.1%), and mountain whitefish (1.1%) accounted for most of the remainder.

By 15 June, 2487 fish had been counted at the downstream trap (Table 5). Remaining in the watershed beyond 15 June were 1505 white suckers (53.4% of the total number of white suckers enumerated at the upstream trap), 637 longnose suckers (38.8%), 150 Arctic grayling (93.2%), 374 northern pike (86.4%), and small numbers of several other species. These numbers are certainly conservative, especially in the case of Arctic grayling which probably began to move into the Muskeg River several days prior to fence installation.

Collections throughout the Muskeg River watershed during the summer produced 2619 small fish (Table 6). Suckers accounted for 75.5% of this total, the majority (>96%) being young-of-the-year. Excluding suckers, brook stickleback was the most abundant small fish in the samples accounting for 47.9% of the total catch. Also occurring commonly were lake chub (25.7%), slimy sculpin (6.2%), and longnose dace (4.4%). Pearl dace, which dominated the resident fish population in the Steepbank River (Machniak and Bond in prep.), comprised only 1.7% of the small fish sample in the Muskeg River in 1977 and only 0.4% in 1976 (Bond and Machniak 1977).

Brook stickleback were captured at eight of the 10 sampling sites in 1977, but, as in 1976 (Bond and Machniak 1977), they were most abundant in the more tranquil water upstream of Site 3. Lake chub were also taken at eight locations and were found in association with brook stickleback at Site 6. However, this

Table 5. Summary of fish recorded at the Muskeg River counting fence, 1977.

Species	Number of Fish	
	Upstream Trap	Downstream Trap
White sucker	2970	1385
Longnose sucker	1641	1004
Arctic grayling	161	11
Northern pike	433	59
Mountain whitefish	57[a]	17
Lake whitefish	0	6
Walleye	8	5
Burbot	1	0
Lake cisco	1	0
Dolly Varden	3	0
Total	5275	2487

[a] Includes a small number of lake whitefish which were misidentified prior to 11 May 1977.

Table 6. Number of fish captured by seine, minnow trap, drift net and dipnet at each small fish collection site in the Muskeg River Drainage, 1977.

	Muskeg River														Hartley Creek				Kearl Creek				Total	
	Area 1		Area 2		Area 3		Area 4		Area 5		Area 6		Other		Area 7		Area 8		Area 9		Area 10			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Arctic grayling	1	0.2	5	0.5	13	4.0									1	1.8							20	0.8
Pearl dace			10	1.0																	1	1.4	11	0.4
Lake chub	6	0.9	37	3.7	54	16.7	7	2.3			42	35.3			6	10.7	12	48.0	1	2.6			165	6.3
Longnose dace	6	0.9	19	1.9	1	0.3							1	5.3			1	4.0					28	1.1
Sucker spp.	610	92.1	857	86.8	174	53.8	275	91.1															1916	73.2
White sucker			5	0.5	18	5.6	2	0.7			2	1.7			21	37.5	1	4.0	4	10.3			53	2.0
Longnose sucker			1	0.1			4	1.3							2	3.6							7	0.3
Trout-perch	6	0.9	1	0.1																			7	0.3
Burbot			3	0.3																			3	0.1
Brook stickleback					56	17.3	13	4.3	15	100.0	75	63.0	14	73.7	25	44.6	5	20.0	34	87.2	71	98.6	308	11.8
Slimy sculpin	6	0.9	18	1.8	5	1.5							4	21.1	1	1.8	6	24.0					40	1.5
Northern pike			6	0.6			1	0.3															7	0.3
Fathead minnow			1	0.1																			1	<0.1
Lake whitefish			14	1.4	2	0.6																	16	0.6
Yellow perch	27	4.1	6	0.6																			33	1.3
Ninespine stickleback			1	0.1																			1	<0.1
Mountain whitefish			3	0.3																			3	0.1
Totals	662		987		323		302		15		119		19		56		25		39		72		2619	

species seems to be most abundant at Sites 2 and 3. In 1976, chub were taken in large numbers at Site 7 of Hartley Creek (Bond and Machniak 1977). Longnose dace were captured as far upstream as Site 3 and one was reported from Site 7 of Hartley Creek in 1976 (Bond and Machniak 1977). However, this species appears to be most abundant in the lower reaches of the watershed (Sites 1 and 2) as is also the slimy sculpin (Sites 1, 2, and 3).

5.3 TAGGING RESULTS

5.3.1 Tag Releases and Recaptures

Floy tags were applied to 1629 fish during 1977, bringing to 3898 the total number of fish tagged over two years (Table 7). The majority of fish tagged were longnose suckers (51.9%), white suckers (42.8%), and northern pike (4.9%). Fish were tagged during both the upstream and downstream runs.

Recaptures at the downstream trap in 1976 provided an indication of the length of time spent by some individual fish in the Muskeg River watershed (Bond and Machniak 1977). Recaptures of 1976 tags at the fence site in 1977 demonstrated a homing tendency in both white and longnose suckers.

Considering only fish that were tagged at the fence site and recaptured outside the Muskeg River watershed, 77 recaptures have been reported for a tag return rate to date of 2.0% (Table 7). The highest recapture rates obtained outside the watershed were for northern pike (14.1%). White and longnose suckers had recapture rates of 1.9 and 0.8% respectively.

In addition to the Floy tags mentioned above, metal clip tags were applied to 40 Arctic grayling in 1977, of which one has been recaptured.

5.3.2 Movement of Tagged Fish

The recapture of tagged fish can provide useful information concerning the extent and timing of fish movements. However, a degree of caution usually must be exercised in the interpretation of the results. In the first place, one can never

Table 7. Summary of tag releases and recaptures by species for fish tagged at Muskeg River counting fence, 1976 and 1977, and recaptured outside the Muskeg River watershed.

Species	Number Tagged		Percent of Total Number Tagged	Number Recaptured	Percent Recaptured
	1976	1977			
White sucker	876	793	42.8	32	1.9
Longnose sucker	1267	757	51.9	17	0.8
Northern pike	119	73	4.9	27	14.1
Arctic grayling	3	2	0.1	1	20.0
Walleye	4	4	0.2	0	0.0
Total	2269	1629	100.0	77	2.0

be absolutely certain that the movement exhibited by an individual fish is representative of all fish in the population. Secondly, since it is obvious that no tags will be recovered from areas where no fishing effort occurs, it can be argued that recaptures serve merely to identify fishing areas.

There is no question that, in the AOSERP study area, considerably more fishing effort is expended downstream from Fort McMurray than upstream. As well, in some cases, low recovery rates make it impossible to form firm conclusions as to general movement trends. Nevertheless, results from the present and several other recent studies (Machniak and Bond in prep.; Bond and Berry in prep.a, in prep.b; Machniak et al. in prep.; Jones et al. 1978; Kristensen and Pidge 1977) are beginning to identify patterns of fish movements within the AOSERP study area.

5.3.2.1 White suckers. Floy tags were applied to 1669 white suckers in the Muskeg River during 1976 and 1977, of which 32 have been recaptured outside the Muskeg River watershed (Appendix 8.2) (Bond and Machniak 1977). Of this number, 12 fish were recaptured in the lower Athabasca River or Lake Athabasca. Only three white suckers were recaptured upstream of the Muskeg River, none of which was taken upstream of the Steepbank River. One fish, tagged 20 May 1976 as it left the Muskeg River, was recaptured at the Muskeg River upstream trap on 8 May 1977 and subsequently in the Athabasca delta on 21 June 1977. Another was recaptured at the Muskeg River downstream trap on 27 May 1977, 16 days after it had entered the tributary. This fish was recaptured again on 15 May 1978 at the upstream fence of the MacKay River (Machniak et al. in prep.), and in June 1978, it was recaptured in Lake Athabasca at the mouth of the Athabasca River. Four other white suckers, tagged in the Muskeg River in 1977, were also recaptured in the MacKay River upstream trap in 1978. Another fish, tagged in May 1976 in the Muskeg River had been at large for 724 days when it was recaptured at the MacKay River trap on 14 May 1978. One Muskeg River fish was recaptured in the Steepbank River. This fish, tagged 16 July 1976, was recaptured moving upstream in the Steepbank River on 4 May 1977. A total of 176 white suckers, tagged in 1976, were recaptured in the Muskeg river during 1977.

Tag return evidence from this and other studies (Bond and Berry in prep.b; Machniak and Bond in prep.; Shell Canada Ltd. 1975; Machniak et al, in prep.) suggests that white suckers that spawn in the Muskeg River and other tributaries of the AOSERP study area belong to the Lake Athabasca population and return to the lake during summer or fall to overwinter. There is also an indication of a strong homing tendency on the part of this species although some individuals apparently enter other tributaries.

5.3.2.2 Longnose suckers. A total of 2204 longnose suckers were tagged in the Muskeg River during 1976 and 1977, of which 17 have been recaptured outside the Muskeg River watershed (Appendix 8.2) (Bond and Machniak 1977). Three fish, tagged in May 1977, were recaptured in Lake Athabasca between 31 May and 22 June, indicating a rapid downstream movement of from 264 to 296 km. One sucker, tagged 13 June 1976, was recaptured at the Muskeg River fence on 9 June 1977 and was recaptured again at the mouth of Clark Creek (km 11) in the Athabasca River on 23 June. Another, tagged 29 May 1976, was observed spawning in the lower reaches of Beaver Creek on 14 May 1977 (D. Tripp, Fishery Biologist, Aquatic Environments Ltd. verbal communication with W. A. Bond, June 1977). Nine longnose suckers, tagged in the Muskeg River in 1976, were recaptured in May 1977 at the Steepbank River counting fence while one fish, tagged 18 May 1977, was recaptured on 1 May 1978 at the MacKay River upstream trap. A total of 260 longnose suckers, tagged in 1976, were recaptured in the Muskeg River during 1977.

Tag return evidence from this and other studies (Bond and Berry in prep.b; Machniak and Bond in prep.; Machniak et al. in prep.) suggests that longnose suckers that spawn in the Muskeg River and other tributaries of the AOSERP study area belong to the Lake Athabasca population and return to the lake during summer or fall to overwinter. There is also an indication of a strong homing tendency in this species although some individuals apparently enter other tributaries.

5.3.2.3 Northern pike. Fourteen percent of all pike tagged in the Muskeg River in 1976 and 1977 have been recaptured outside the Muskeg River watershed or near the tributary mouth (Appendix 8.2) (Bond and Machniak 1977). Although Bond and Machniak (1977) noted that one pike moved 72 km between tagging and recapture, pike in general demonstrated little tendency to move around and most were recaptured within 15 to 20 km of the tagging site. Bond and Berry (in prep.a, in prep.b) and Machniak and Bond (in prep.) reported similar results.

Pike in the AOSERP study area appear to concentrate in the lower reaches of tributary streams during the summer and to move up and down the tributaries to some extent. They probably leave the tributaries in late summer or fall to overwinter in the Athabasca River.

5.3.2.4 Arctic grayling. Floy tags were appled to only five Arctic grayling, one of which has been recaptured (Appendix 8.2). This fish, tagged in the Muskeg River on 30 April 1976, was recaptured 10 October 1977 moving downstream in the Steepbank River. It had been at large for 528 days at the time of its recapture. One grayling, tagged with a metal clip at the upstream trap in May 1977, was recaptured near small fish collection site 4 during August 1977.

5.4 LIFE HISTORIES OF FISH SPECIES

5.4.1 White Suckers

5.4.1.1 Seasonal timing of upstream migration. White sucker spawning migrations appear to be initiated by increasing water temperatures following spring break-up, and often begin when the daily maximum water temperature in the spawning stream approaches 10°C (Geen et al. 1966; Bond 1972). White suckers were present in small numbers and moving upstream in the Muskeg River on 28 April 1977, on which date the maximum daily water temperature was 9°C. Water temperature decreased to 5°C during the next two days and few fish entered the trap. The number of migrant suckers then increased daily from 1 to 6 May as the water temperature rose steadily (Table 8, Figure 10). The main part of the migration occurred between 7 and 9 May, the first three days on which the maximum daily water temperature exceeded 10°C. On these days, 45.9% of the total migration passed through the upstream trap. The upstream run was essentially complete by 12 May although small numbers of fish continued to move up after this date. The 1977 white sucker run into the Muskeg River followed by several days the migration into the adjacent Steepbank River, but the pattern was similar in both cases. The Steepbank River first reached 10°C on 1 May and the peak of the upstream white sucker run occurred between 2 and 4 May (Machniak and Bond in prep.).

5.4.1.2 <u>Diel timing of upstream migration</u>. Bond and Machniak (1977) reported that, in 1976, most white suckers migrated into the Muskeg River between noon and midnight. They observed that maximum movement occurred in the late afternoon and early evening, just following the time of highest daily water temperature. Geen et al. (1966) and Machniak and Bond (in prep.) reported similar results. A different pattern, however, was observed in the Muskeg River during 1977 as most fish moved upstream at night when the water temperature had dropped considerably below the daily maximum. The majority of fish (78%) moved upstream between 2100 and 1200 h (Table 9). Thus it is evident that the diel timing of white sucker migrations can vary considerably from year to year.

5.4.1.3 <u>Spawning period</u>. As will be discussed later, the majority of white suckers moving upstream in the Muskeg River between 28 April and 5 May were immature fish. The main upstream migration of spawners commenced approximately 6 May. Most mature females observed at the fence site were not fully ripe (freely running eggs) until about 6 to 8 May.

White suckers were observed spawning downstream of the counting fence during the second week of May. Eggs were collected in drift nets as early as 9 May 1977 and, while not confirmed,

Table 8. Summary of fish enumerated during the counting fence operation in the Muskeg River, 1977.

Date	Upstream Trap						Downstream Trap					
	Longnose sucker	White sucker	Arctic grayling	Northern pike	Mountain whitefish	Daily Totals	Longnose sucker	White sucker	Arctic grayling	Northern pike	Mountain whitefish	Daily Totals
28 April	7	3	5	0	0	15						
29	8	27	10	9	9	63						
30	0	16	5	21	0	42						
1 May	13	58	13	19	0	103						
2	92	83	7	33	4	220[a]						
3	64	170	9	53	3	299						
4	241	184	15	39	3	482						
5	258	221	10	24	1	514						
6	116	211	8	22	0	357		Trap Closed				
7	71	520	6	24	0	621						
8	102	562	4	7	0	675						
9	63	282	2	10	1	358						
10	42	110	1	30	3	188[a]						
11	49	187	1	29	4	271[a]						
12	22	81	8	20	3	134	3	83	1	4	1	93[b]
13	148	44	5	4	6	208[a]	8	68	0	1	0	77
14	42	30	5	9	2	88	24	46	1	5	0	77[b]
15	33	32	4	3	0	72	67	87	2	1	0	158[b]
16	9	1	0	0	0	9	10	3	0	2	3	18
17	3	8	2	2	1	16	35	10	2	2	1	51[b]
18	5	3	2	3	0	13	67	26	1	0	1	95

continued ...

Table 8. Continued.

Date	Upstream Trap: Longnose sucker	White sucker	Arctic grayling	Northern pike	Mountain whitefish	Daily Totals	Downstream Trap: Longnose sucker	White sucker	Arctic grayling	Northern pike	Mountain whitefish	Daily Totals
19 May	17	12	4	0	1	34	69	26	0	2	2	99
20	28	13	0	3	1	46[a]	73	58	0	1	1	133
21	16	14	4	0	1	35	6	13	0	1	0	21[b]
22	17	8	6	4	3	39[a]	114	91	0	2	1	207
23	15	13	3	3	0	34	29	11	0	2	0	42
24	22	7	0	3	0	32	41	62	0	2	0	105
25	13	4	3	3	1	24	45	66	0	2	0	115[b]
26	20	5	2	2	0	29	24	23	0	3	0	50
27	8	8	3	4	0	23	30	15	0	1	0	47[b]
28	2	9	2	0	2	15	28	29	1	1	1	60
29	0	3	0	1	0	4	20	6	1	0	0	27
30	13	7	4	1	0	25	26	66	0	0	0	92
31	2	6	0	6	1	15	11	76	1	3	0	91
1 June	27	9	0	3	2	41	54	51	0	1	0	106
2	11	0	3	9	0	23	7	11	0	4	0	23[b]
3	5	4	0	3	0	13[a]	13	20	0	3	0	37[b]
4	8	2	3	5	1	20[a]	22	20	0	2	0	45[b]
5	13	2	1	5	1	23[a]	14	20	0	0	0	34
6	1	0	1	2	1	6[a]	42	31	1	0	1	75
7	5	1	0	3	0	10[a]	0	12	0	0	1	13
8	1	2	0	3	0	6	23	38	0	4	2	67

continued ...

Table 8. Concluded.

Date	Upstream Trap						Downstream Trap					
	Longnose sucker	White sucker	Arctic grayling	Northern pike	Mountain[c] whitefish	Daily Totals	Longnose sucker	White sucker	Arctic grayling	Northern pike	Mountain whitefish	Daily Totals
9 June	3	0	0	1	1	5	11	45	0	2	1	59
10	1	2	0	2	0	6[a]	14	70	0	2	0	86
11	0	2	0	0	0	2	20	58	0	1	1	80
12	1	0	0	3	0	4	9	63	0	1	0	73
13	1	2	0	1	0	4	14	29	0	3	0	46
14	2	0	0	2	0	4	17	28	0	1	1	47
15	1	2	0	0	1	4	14	24	0	0	0	38
Total	1641	2970	161	433	57	5275	1004	1385	11	59	17	2487
%	31.1	56.3	3.1	8.2	1.1		40.4	55.7	0.4	2.4	0.7	

[a] Other species counted through upstream trap: one lake cisco, 2 May; one burbot, 13 May; eight walleye, 10 May (two fish), 11 May, 20 May, 22 May, 3 June, 4 June and 10 June; three Dolly Varden, 5 June, 6 June and 7 June.

[b] Other species counted through downstream trap: five walleye, 12 May, 17 May, 21 May, 3 June and 4 June; and six lake whitefish, 14 May, 15 May, 25 May (two fish), 27 May and 2 June.

[c] Numbers shown for mountain whitefish between 28 April and 11 May probably include a few lake whitefish that were erroneously identified.

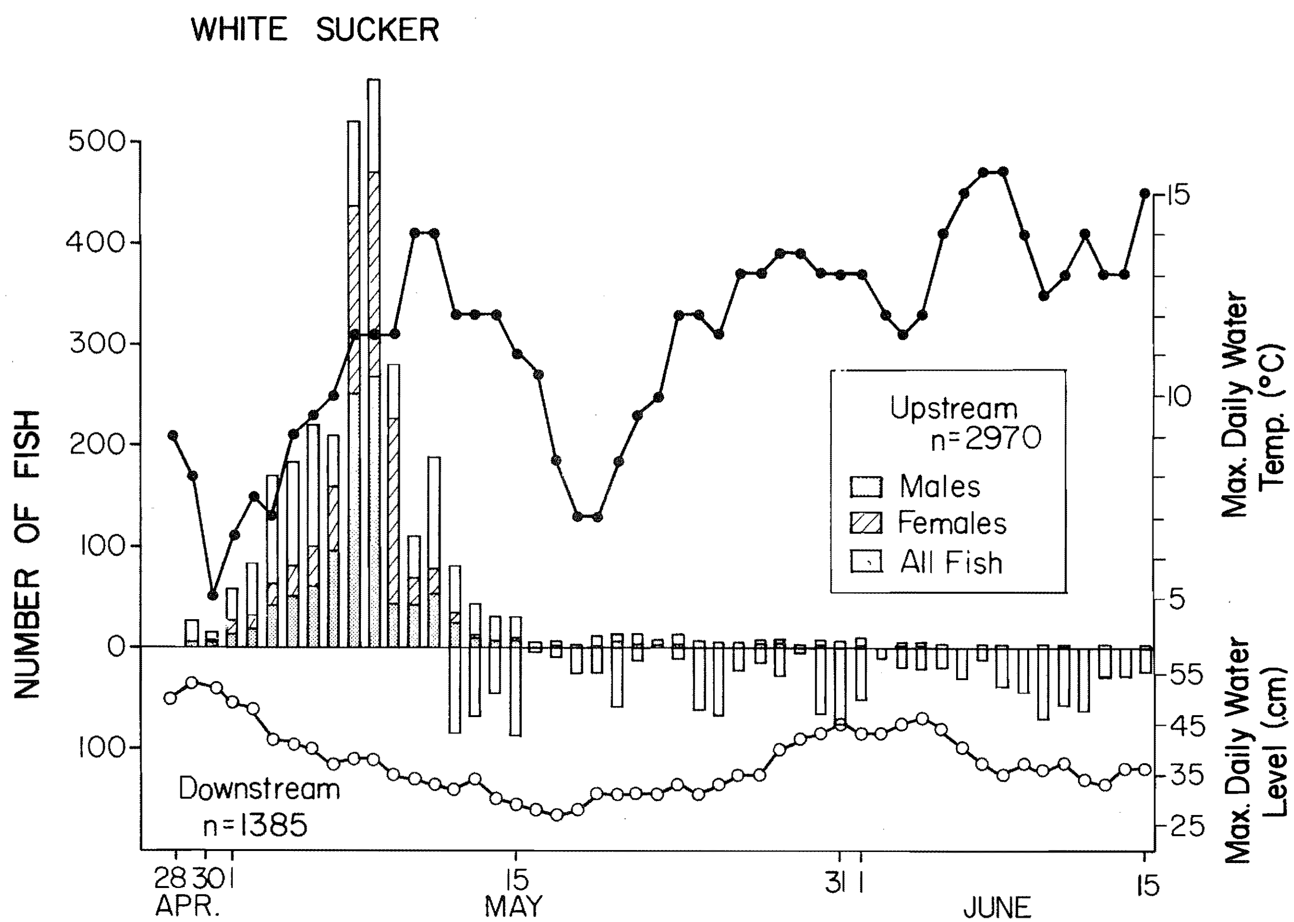

Figure 10. Seasonal timing of the white sucker migration in the Muskeg River, 1977.

Table 9. Summary of diel timing of the upstream migration of white suckers in the Muskeg River, 1977. Fish that were counted at times other than those indicated were included in the next check period.

Date	Number of Fish Counted at Each Check						Total
	0900 (0300)[a]	1200	1500	1800	2100	2400	
28 April	ND	ND	ND	0	3	ND	3
29	16	ND	8	2	1	ND	27
30	ND	14	ND	1	1	ND	16
1 May	ND	5	ND	ND	10	43	58
2	21	0	3	3	19	37	83
3	98	0	7	1	0	64	170
4[a]	75	41	7	11	7	43	184
5[a]	125	ND	57	6	ND	33	221
6[a]	79	25	1	18	6	82	211
7[a]	152	126	37	51	37	117	520
8[a]	128	187	87	57	42	61	562
9[a]	106	85	11	10	42	28	282
10[a]	27	20	1	8	13	41	110
11[a]	51	18	25	10	8	75	187
12[a]	50	9	ND	20	2	trap closed	81
13	ND	21	ND	7	ND	16	44
14	ND	23	ND	1	1	5	30
15	ND	27	ND	0	0	5	32
16	ND	1	ND	0	ND	0	1
17	ND	6	ND	ND	1	1	8
18	ND	2	ND	ND	0	1	3
19	ND	2	ND	0	1	9	12
20	ND	0	ND	ND	3	10	13
21	ND	4	ND	ND	0	10	14
22	ND	0	ND	0	2	6	8
23	ND	9	ND	2	ND	2	13
24	ND	1	ND	0	1	5	7
25	ND	0	ND	0	ND	4	4
26	ND	2	ND	ND	ND	3	5
27	ND	3	ND	ND	2	3	8
28	ND	2	ND	1	ND	6	9
29	ND	3	ND	ND	ND	ND	3
30	1	ND	2	ND	ND	4	7
31	ND	0	ND	ND	4	2	6
1 June[a]	3	2	ND	1	ND	3	9
2	ND	0	ND	ND	ND	0	0
3	ND	0	ND	2	ND	2	4
4	ND	0	ND	1	ND	1	2
5	ND	1	ND	1	ND	0	2
6	ND	0	ND	0	ND	0	0
7	ND	0	ND	0	ND	1	1
8	ND	0	ND	0	ND	2	2
9	ND	0	ND	0	0	0	0
10	ND	0	0	0	0	2	2
11	ND	0	ND	0	ND	2	2
12	ND	0	0	ND	0	0	0
13	ND	1	0	0	0	1	2
14	ND	0	ND	ND	0	0	0
15	ND	2		operations		terminated	2
Totals	932	642	246	214	206	730	2970
% Grand Total	31.4	21.6	8.3	7.2	6.9	24.6	

[a] Checks were made at 0300 h rather than 0900 h during the peak of the runs.

these were thought to be white sucker eggs. The first spent white suckers were taken at the downstream trap on 12 May and by 18 May virtually all fish were spawned out.

The white sucker spawning period in the Muskeg River in 1977 was almost identical to that observed in 1976 (Bond and Machniak 1977). However, as the initiation of white sucker spawning migrations appears to be closely related to stream temperature (Geen et al. 1966; Tremblay 1962), the precise timing of this event can be expected to vary considerably from year to year.

5.4.1.4 Spawning areas. White suckers have been reported to spawn in a variety of habitats, including lake margins and quiet reaches in the mouths of streams (Scott and Crossman 1973). However, optimal conditions probably involve shallow water running over a gravel substrate (Geen 1958). Bond (1972) suggested that the presence of deep pools adjacent to the spawning sites may also be an important factor. Within the lower 35 km of the Muskeg River system there are many areas that appear to satisfy these conditions.

As in 1976 (Bond and Machniak 1977), white suckers were observed spawning below the fence site during the second week of May 1977. Although spawning was not seen upstream of the fence, young-of-the-year suckers were abundant at Sites 3 and 4 (Figure 2) by mid-June. Few sucker fry were captured in Hartley Creek either in 1976 or 1977 although some spawning probably occurs in that tributary downstream of Site 8. Only one young-of-the-year sucker was captured from the Muskeg River upstream of Site 4 during the two years of this study. This fish was taken at Site 6 (Figure 2) on 16 August 1977.

5.4.1.5 Length of time spent in the Muskeg River. By 15 June 1977, when trap operations ceased, only 46.6% of the white suckers counted through the upstream trap had returned downstream. The downstream migration observed clearly represented the departure of spawners from the tributary and began approximately one week following the passage of this group through the upstream trap (see Section 5.4.1.8). On the other hand, fewer than 10% of the immature migrants (<350 mm) had returned downstream as of 15 June.

No analysis of the 1977 tag data was performed to indicate the length of time spent in the tributary by individual fish. However, the 1976 data indicated that this time varied considerably (from three to 84 days) for fish that had left the Muskeg River by 30 July. On that date, 40.9% of the white suckers enumerated at the upstream trap still remained in the tributary (Bond and Machniak 1977). Many immature white suckers may remain in the Muskeg River until freeze-up as was the case in the Steepbank River (Machniak and Bond in prep.).

5.4.1.6 Seasonal and diel timing of downstream migration. The first spent fish were observed upstream of the counting fence on 12 May 1977, on which date the downstream trap was opened. White suckers moved downstream from 12 May through 15 June, the final day of trap operations (Table 8 and Figure 10). While the number of fish passing through the downstream trap varied each day, the downstream run was not characterized by a discrete peak. Bond and Machniak (1977) reported that, after a definite peak between 15 and 20 May, white suckers continued to pass downstream through 30 July.

The majority of downstream migrants were captured at night as 71.2% were taken between 2100 and 1200 h (Table 10). A similar timing of downstream movement was observed in the Steepbank River (Machniak and Bond in prep.). The maximum movement of white suckers occurred each day following the period of highest water temperature. Bond (1972) noted that the downstream migration usually occurred when stream temperatures were decreasing.

5.4.1.7 Spawning mortality. Only a few white suckers were found dead prior to the termination of fence operations on 15 June 1977. Results in 1976, however, indicated that the number of mortalities increased and the general condition of the fish

Table 10. Summary of diel timing of the downstream migration of white suckers in the Muskeg River, 1977. Fish that were counted at times other than those indicated were included in the next check period.

Date	Number of Fish Counted at Each Trap Check				Total
	1200	1800	2100	2400	
12 May	trap opened	18	4	61	83
13	3	31	ND	34	68
14	7	22	0	17	46
15	4	43	10	30	87
16	2	0	ND	1	3
17	0	ND	3	7	10
18	7	ND	2	17	26
19	5	6	0	15	26
20	6	ND	6	46	58
21	1	ND	3	9	13
22	2	41	18	30	91
23	1	2	ND	8	11
24	0	2	7	53	62
25	49	17	ND	trap closed	66
26	18	ND	ND	5	23
27	5	ND	7	3	15
28	29	0	ND	0	29
29	6	ND	ND	ND	6
30	2	15	ND	49	66
31	44	ND	11	21	76
1 June	43	4	ND	4	51
2	9	ND	ND	2	11
3	5	2	ND	13	20
4	17	0	ND	3	20
5	4	3	ND	13	20
6	15	9	ND	7	31
7	7	1	ND	4	12
8	12	11	ND	15	38
9	14	11	8	12	45
10	33	19	5	13	70
11	24	22	ND	12	58
12	34	7	9	13	63
13	9	12	2	6	29
14	11	ND	7	10	28
15	24	operations		terminated	24
Total	452	298	102	533	1385
% Grand Total	32.7	21.5	7.4	38.5	

decreased between 18 June and 30 July (Bond and Machniak 1977). Fish taken at that time were often blind in one or both eyes, displayed signs of physical deterioration, and were heavily infested with the parasitic copepod *Argulus* sp. A mortality rate of 16 to 20% was observed by Geen et al. (1966) for spawning white suckers in Frye Creek, British Columbia.

5.4.1.8 Size composition of migrant white suckers. Fork lengths were determined for 1551 white suckers during the upstream migration in 1977 (Table 11, Figure 11). Migrant suckers ranged in fork length from 157 to 599 mm, but the length-frequency distribution varied considerably as the migration proceeded.

The early stages of the upstream migration (28 April to 3 May) were dominated by fish in the 180 to 280 mm fork length range (Figure 12). Fish of this size remained abundant on 4 and 5 May, but at that time a second group of migrants appeared whose fork lengths ranged from about 300 to 400 mm. The large group of immature fish comprising the smaller mode either did not occur in the Muskeg River in 1976 or it had already passed upstream by the time that fence operation began. The middle mode in the length frequency distribution (Figure 11) consists largely of maturing fish. A certain proportion of these fish probably spawned for the first time in 1977, although most were likely non-spawners. Fish in this size range dominated the Muskeg River white sucker run in 1976 (Bond and Machniak 1977) and comprised the vast majority of the 1977 run in the Steepbank River (Machniak and Bond in prep.). In both streams, these immature fish were proceeding upstream while maximum daily water temperatures ranged from 5 to 9°C.

Between 6 and 10 May 1977, the migration was dominated by large fish ranging in fork length from about 400 to 600 mm (Figure 12). This segment is believed to have comprised the main spawning group of white suckers in the Muskeg River in 1977 and was also well represented in the 1976 run. Within this mode, but in neither of the other two, females were clearly larger than males (Figure 11). Interestingly, this large mode did not appear in the Steepbank run in 1977 (Machniak and Bond in prep.).

Table 11. Length-frequency distribution of white suckers during the upstream migration in the Muskeg River, 1977.

Fork Length (10 mm intervals)	Male	Female	Unknown	Total	Fork Length (10 mm intervals)	Male	Female	Unknown	Total
150 - 159	1	0	0	1	390 - 399	11	8	8	27
160 - 169	0	0	0	0	400 - 409	12	10	2	24
170 - 179	1	1	7	9	410 - 419	9	15	6	30
180 - 189	2	1	9	12	420 - 429	7	14	2	23
190 - 199	7	4	23	34	430 - 439	22	15	4	41
200 - 209	8	2	28	38	440 - 449	24	16	3	43
210 - 219	15	4	41	60	450 - 459	19	5	2	26
220 - 229	16	4	53	73	460 - 469	30	9	1	40
230 - 239	17	3	49	69	470 - 479	31	21	1	53
240 - 249	11	1	43	55	480 - 489	25	18	0	43
250 - 259	12	2	52	66	490 - 499	20	20	1	41
260 - 269	14	2	45	61	500 - 509	16	20	0	36
270 - 279	4	0	25	29	510 - 519	4	23	0	27
280 - 289	7	0	19	26	520 - 529	2	32	0	34
290 - 299	17	0	17	34	530 - 539	1	22	0	23
300 - 309	5	2	29	36	540 - 549	0	11	0	11
310 - 319	8	5	26	39	550 - 559	0	12	0	12
320 - 329	5	4	37	46	560 - 569	0	10	0	10
330 - 339	19	11	36	66	570 - 579	0	1	0	1
340 - 349	14	4	42	60	580 - 589	0	1	0	1
350 - 359	15	15	36	66	590 - 599	0	1	0	1
360 - 369	17	11	19	47					
370 - 379	17	9	21	47	Totals	474	380	697	1551
380 - 389	9	11	10	30					

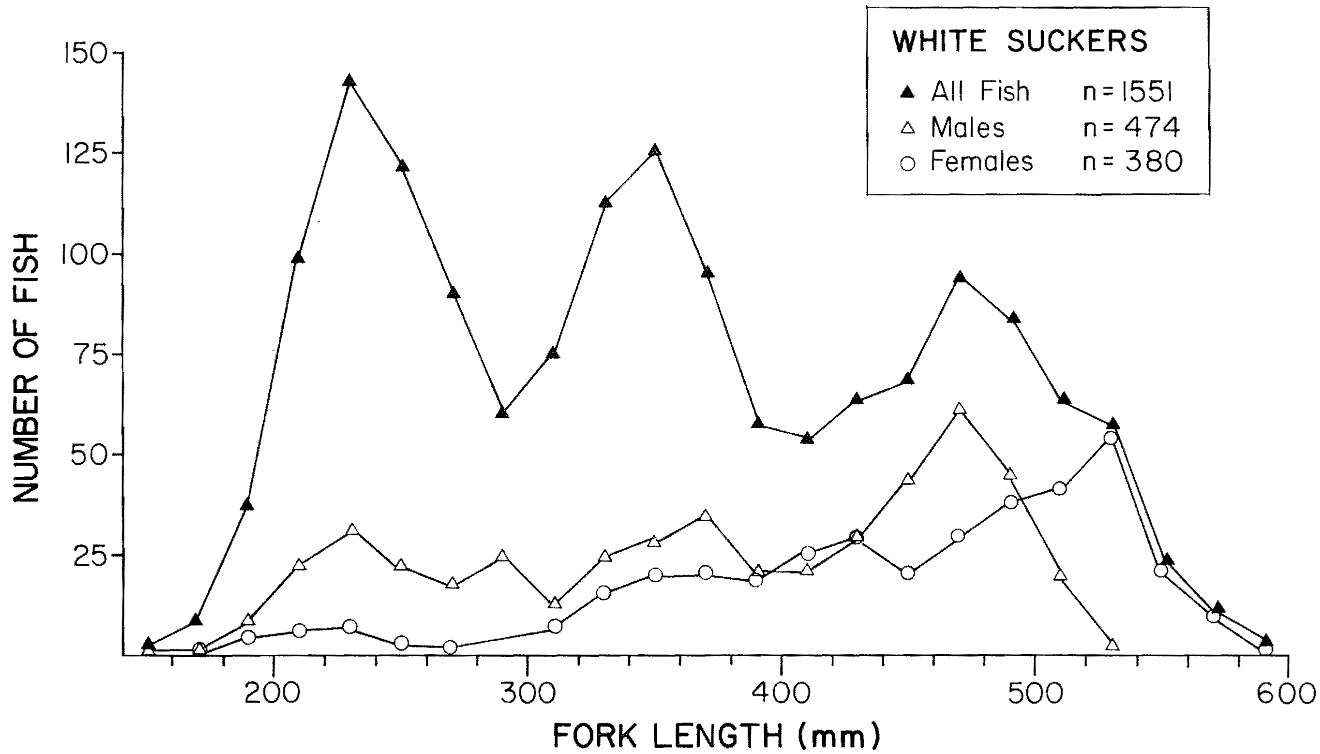

Figure 11. Length-frequency distribution for white suckers during the upstream migration in the Muskeg River, 1977.

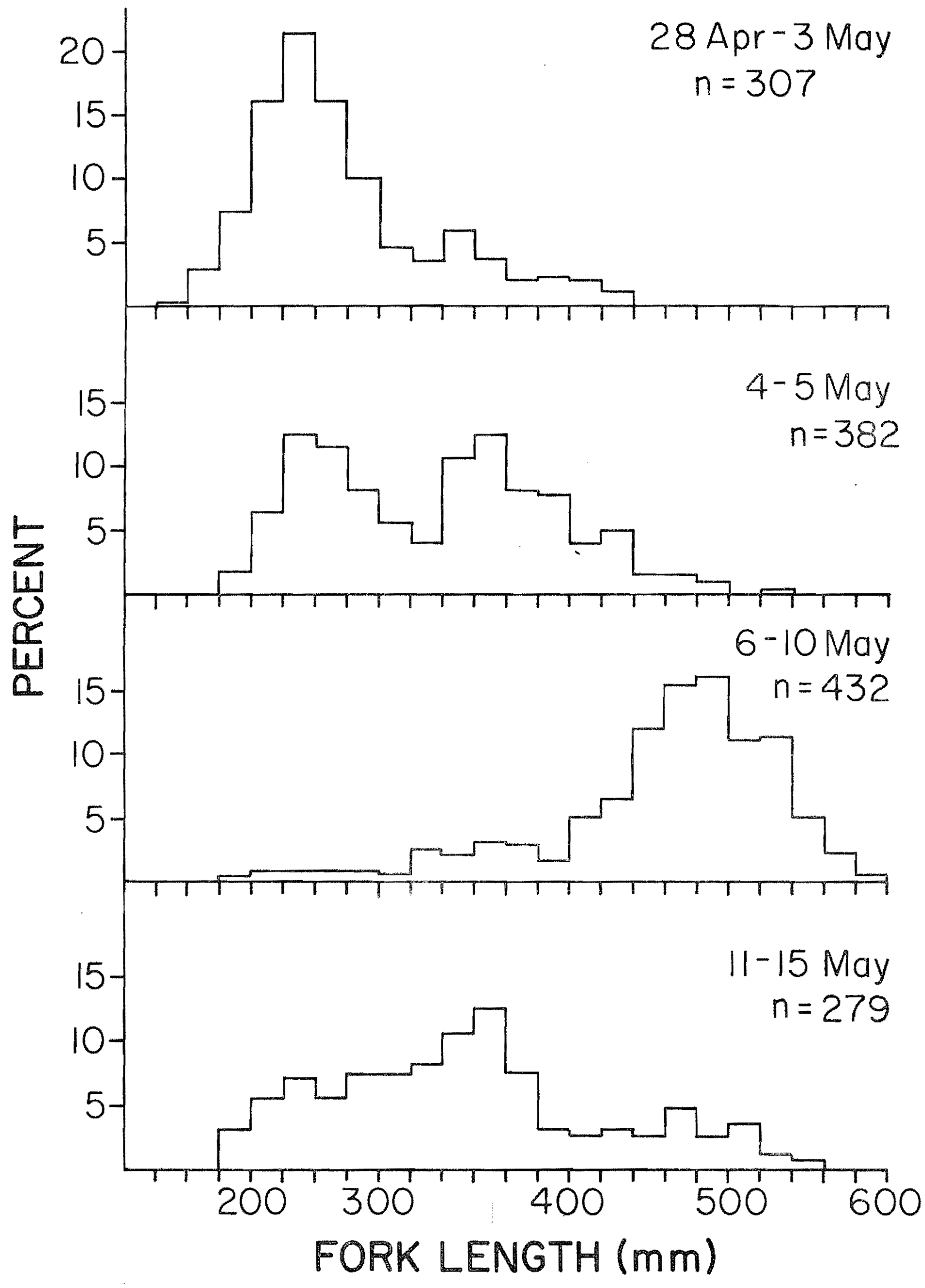

Figure 12. Seasonal changes in length-frequency distribution for white suckers during the upstream migration in the Muskeg River, 1977.

Fork lengths were obtained from 1050 white suckers during the downstream migration, of which approximately 95% were longer than 350 mm. Most of the downstream fish not measured (n = 335) had been tagged previously, and most of these fish also exceeded 350 mm fork length. The length-frequency distribution of downstream migrants remained constant from 12 May to 15 June (Figure 13).

The virtual absence of small white suckers from our downstream counts suggests that immature fish tend to remain in the tributary longer than spawners. This is supported by evidence from the adjacent Steepbank River. In that study, spawners also left the stream first, while fish that remained in the tributary through the summer tended to be small individuals. Eighty-five percent of the white suckers captured during the fall fence operation in September and October were less than 350 mm in length (Machniak and Bond in prep.).

5.4.1.9 Age composition of migrant white suckers. Because our age sample was not drawn randomly, it may not reflect accurately the age composition of the white sucker migration. However, the data do illustrate the age range of migrant suckers and our knowledge of the age and growth characteristics of this population (presented in a later section), combined with the length-frequency data (Table 11, Figure 11) permit a fairly accurate description of the age composition of these fish.

White suckers in the run ranged in age from three to 16 years (Figure 14). The early part of the migration was dominated by young fish (age 3 and 4) but the age composition shifted toward older age groups as the migration progressed. The main spawning group (>400 mm fork length) consisted largely of fish age 7 and older with most spawners belonging to age groups 8 to 12 inclusive.

5.4.1.10 Sex ratio of migrant white suckers. Sex was determined for 1850 white suckers during the upstream migration, of which 1014 (54.8%) were males (Table 12). This represents a significant deviation from the usual 1:1 ratio (X^2=17.2; P<0.01).

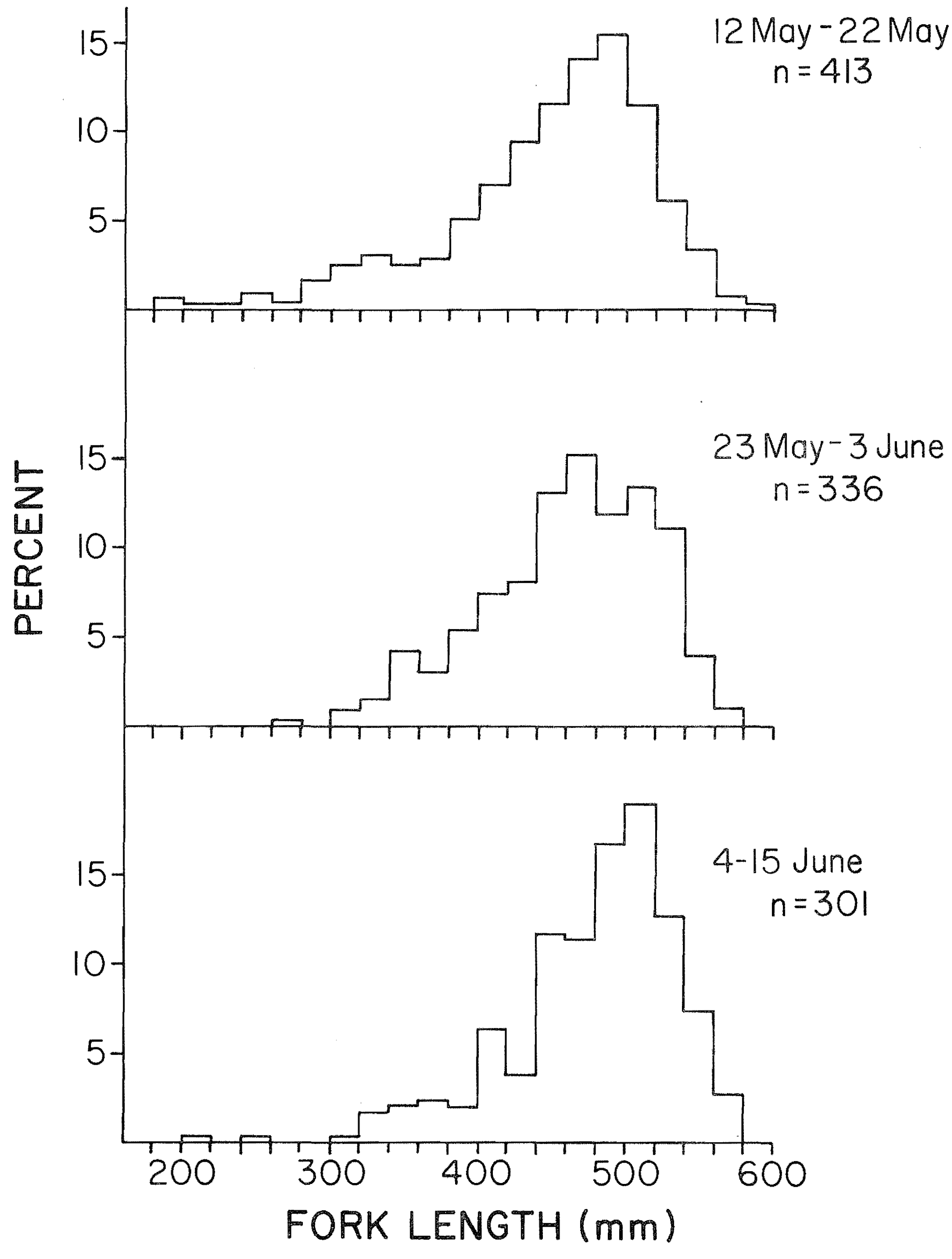

Figure 13. Length-frequency distribution for white suckers during three time periods in the downstream migration in the Muskeg River, 1977.

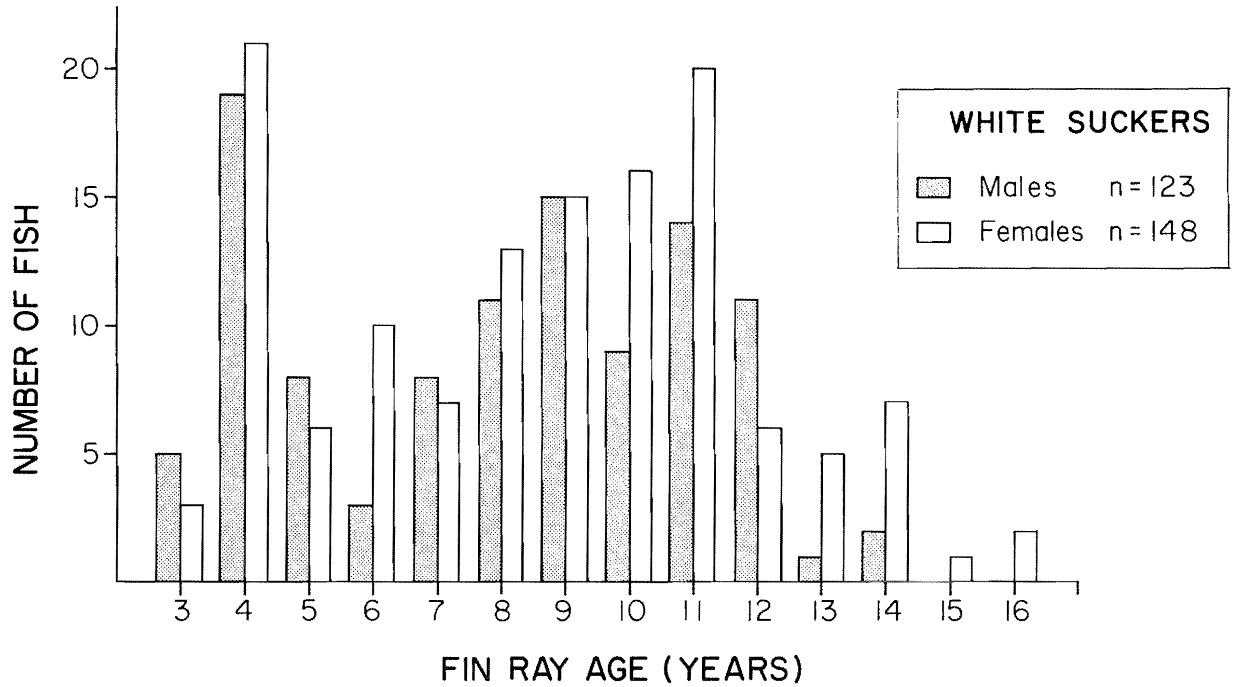

Figure 14. Age composition for white suckers sampled during the counting fence operation, Muskeg River, 1977.

Table 12. Sex ratio for white suckers during the upstream migration, Muskeg River, 1977.

Date	Number of Fish				Percent Males[a]
	Males	Females	Unknown	Total	
28 April	0	0	3	3	0
29	1	3	23	27	25
30	9	1	6	16	90
1 May	14	12	32	58	54
2	18	13	52	83	58
3	41	22	107	170	65
4	50	30	104	184	63
5	60	40	121	221	60
6	95	64	52	211	60
7	251	185	84	520	58
8	269	201	92	562	57
9	44	183	55	282	19
10	27	42	41	110	39
11	53	26	108	187	67
12	25	9	47	81	74
13	9	2	33	44	82
14	6	0	24	30	100
15	7	1	24	32	88
16	0	0	1	1	0
17	2	0	6	8	100
18	0	0	3	3	0
19	1	0	11	12	100
20	6	0	7	13	100
21	3	0	11	14	100
22	2	0	6	8	100
23	3	0	10	13	100
24	0	0	7	7	0
25	0	0	4	4	0
26	0	0	5	5	0
27	4	0	4	8	100
28	5	0	4	9	100
29	2	0	1	3	100
30	1	0	6	7	100
31	0	0	6	6	0
1 June	2	2	5	9	50
2	0	0	0	0	0
3	1	0	3	4	100
4	2	0	0	2	100
5	0	0	2	2	0
6	0	0	0	0	0
7	0	0	1	1	0
8	0	0	2	2	0
9	0	0	0	0	0
10	0	0	2	2	0
11	1	0	1	2	100
12	0	0	0	0	0
13	0	0	2	2	0
14	0	0	0	0	0
15	0	0	2	2	0
Totals	1014	836	1120	2970	
%	55	45			

[a] Based on fish of known sex.

Male white suckers usually precede the females onto the spawning grounds (Geen et al. 1966; Bond 1972; Bond and Machniak 1977). However, because of the large number of immature fish in the 1977 Muskeg River migration this trend is not immediately obvious. Among the fish captured between 28 April and 4 May (mostly immatures), males outnumbered females every day. During the main spawning run, however, which occurred from 6 to 10 May, males outnumbered females on the first three days while females were dominant on 9 and 10 May. The ratio of males to females in the downstream run showed no clear pattern.

5.4.1.11 Homing of white suckers. Tagging studies by several authors (Olsen and Scidmore 1963; Geen et al. 1966) have indicated a tendency on the part of white suckers to return to the same spawning stream each year in preference to other streams that might be available. During 1977, clear evidence was produced to indicate that white suckers in the AOSERP study area behave in a similar manner. If, as we suspect, Muskeg River white suckers are part of the Lake Athabasca population, these fish are performing in excess of a 500 km round trip to return to this stream.

During the 1976 study (Bond and Machniak 1977), Floy tags were applied to 876 white suckers in the Muskeg River. Twenty-one tagged fish are known to have been dead prior to the 1977 migration, but of the remainder, 20.6% were recaptured in the Muskeg River during the 1977 study.

White suckers demonstrated considerable fidelity to the Muskeg River. The counting fence operation on the Steepbank River, for instance, recovered only one tagged white sucker from the 1976 study. McCart et al. (in prep.) in a 1977 study of the MacKay River, did not recover any tagged white suckers from the Muskeg River although five were recorded in a counting fence operation on this tributary in 1978 (Appendix 8.2).

5.4.1.12 Fecundity. Fecundity was estimated gravimetrically for 10 female white suckers from the Muskeg River. The data in

Table 13 represent additions to those given by Bond and Machniak (1977). Considering the fecundity data for both years, the estimated total number of eggs per female (fork length 397 to 525 mm) ranged from 21 402 to 64 175 with a mean of 42 729 ova per female. Actual counts on five ovaries revealed errors of from +3.2% to -0.5% for the estimated values. Bond (1972) reported white sucker fecundity ranging from 15 983 to 60 242 with an average of 34 502 per female.

Length-relative fecundity for white suckers ranged from 539.1 to 1222.4 ova per cm of fork length while weight-relative fecundity varied from 22.7 to 41.1 eggs per g of body weight. The right ovary contained more eggs than the left in nine out of 10 cases.

Regression analysis indicated a significant ($P < 0.01$), positive correlation between fecundity and fork length ($n = 10$; $r = 0.887$). The mathematical relationship between fecundity and fork length for Muskeg River white suckers is expressed by the equation:

$$\log_{10}\text{Fecundity} = 2.954\log_{10}\text{Fork Length (mm)} + 3.260;$$

$$sb = 0.543$$

Fecundity also correlated positively with body weight ($r=0.866$, range 800 to 2680 g). The mathematical relationship between fecundity and body weight is described by the equation:

$$\log_{10}\text{Fecundity} = 1.182\log_{10}\text{Body Weight (g)} + 2.280;$$

$$sb = 0.241$$

5.4.1.13 Age and growth. Age and growth results from 1977 (Tables 14 and 15) were similar to those of 1976 (Bond and Machniak 1977) (Figure 15). Muskeg River suckers grew more slowly than those from George Lake, Ontario (Beamish 1970) but faster than those in the Bigoray River, Alberta (Bond 1972). Suckers from Muskellunge Lake, Wisconsin (Spoor 1938) grew more rapidly than Muskeg River suckers during their first few years but more slowly after age four (Figure 15).

Table 13. Fecundity estimates for white suckers sampled during the 1977 Muskeg River spawning migration.

Fork Length (mm)	Weight (g)	Number of Eggs			Relative Fecundity	
		Left Ovary	Right Ovary	Total	(cm)	(g)
495	2000	19 268	26 200	45 468	918.6	22.7
497	1820	20 695	23 316	44 011	885.5	24.2
525	2680	31 609[a] (+3.2%)[b]	32 566	64 175	1222.4	23.9

[a] Actual egg counts.

[b] Deviation of estimated counts from actual number.

Table 14. Age-length relationship (derived from fin rays and otoliths) for white suckers captured in the Muskeg River watershed, 1977, sexes separate and combined sample (includes unsexed fish).

Age	Males				Females				All Fish				t-test
	N	Mean	S.D.	Range	N	Mean	S.D.	Range	N	Mean	S.D.	Range	
1	17	49.8	10.63	38-82	15	50.5	9.36	35-75	43	48.7	9.30	35-82	0.196
2	0				1	107.0			1	107.0			
3	5	179.4	13.74	157-193	3	187.7	11.37	175-197	12	184.8	11.88	157-197	0.875
4	19	232.4	28.96	177-293	21	234.1	34.61	182-264	48	230.4	30.23	177-293	0.168
5	8	313.0	24.83	268-343	6	304.7	54.28	237-381	17	309.8	42.14	237-381	0.386
6	3	346.0	67.67	296-423	10	386.2	47.10	315-447	13	376.9	52.32	296-447	1.187
7	8	411.6	48.48	347-442	7	406.3	14.59	382-422	15	409.1	35.69	347-442	0.277
8	11	434.7	37.23	366-494	13	452.6	33.75	375-508	24	444.4	35.77	366-508	1.236
9	15	457.1	29.31	409-495	15	480.9	23.16	437-530	30	469.0	28.64	409-530	2.467[a]
10	9	463.8	27.73	408-498	16	478.4	35.46	415-527	25	473.2	33.07	408-527	1.062
11	14	467.4	28.42	425-514	20	498.4	30.84	424-547	34	485.6	33.25	424-547	2.976[a]
12	11	468.4	24.70	423-505	6	524.7	11.08	510-540	17	488.2	34.48	423-540	5.242[a]
13	1	509.0			5	510.6	38.71	443-539	6	510.3	34.63	443-539	
14	2	465.0	12.73	456-474	7	530.9	18.78	504-562	9	516.2	33.59	456-562	
15	0				1	525.0			1	525.0			
16	0				2	526.5	2.12	525-528	2	526.5	2.12	525-528	
Totals	123				148				297				

[a] Indicates significant difference between means for males and females (Student's t-test, $P < 0.05$).

Table 15. Age-weight relationship for white suckers captured in the Muskeg River watershed, 1977, sexes separate and combined sample (includes unsexed fish).

Age	Males				Females				All Fish				t-test
	N	Mean	S.D.	Range	N	Mean	S.D.	Range	N	Mean	S.D.	Range	
1	17	1.59	1.48	0.5-6.8	15	1.47	0.98	0.3-4.5	43	1.38	1.13	0.3-6.8	0.136
2	0				1	13.3			1	13.3			
3	5	68.0	17.89	60-100	3	80.0	20.0	60-100	12	74.6	17.25	60-100	0.882
4	19	147.9	75.76	60-300	21	165.7	103.36	75-220	48	150.8	84.47	60-300	0.616
5	8	385.0	124.10	240-520	6	393.3	231.14	150-780	17	396.5	173.13	150-780	0.087
6	3	610.0	334.51	360-990	10	865.0	371.99	420-1600	13	806.2	367.34	360-1600	1.060
7	8	1018.8	390.33	520-1360	7	874.3	126.34	700-1060	15	951.3	297.63	520-1360	0.934
8	11	1270.0	363.76	710-1660	13	1430.8	433.62	720-2280	24	1357.1	402.90	710-2280	0.973
9	15	1525.3	410.12	1040-2400	15	1564.0	179.91	1280-1780	30	1544.7	311.79	1040-2400	0.335
10	9	1488.9	311.27	940-1820	16	1603.8	385.88	890-2100	25	1562.4	358.51	890-2100	0.762
11	14	1587.9	477.71	1060-2870	20	1935.5	481.54	790-2920	34	1792.4	503.56	790-2920	2.078[a]
12	11	1536.4	282.60	1150-1980	6	2055.0	268.46	1780-2540	17	1719.4	371.09	1150-2540	3.676[a]
13	1	1914.0			5	1794.0	347.10	1200-2100	6	1814.0	314.30	1200-2100	
14	2	1460.0	113.14	1380-1540	7	2211.4	120.06	2020-2360	9	2044.4	349.58	1380-2360	
15	0				1	1880.0			1	1880.0			
16	0				2	2410.0	381.84	2140-2680	2	2410.0	381.84	2140-2680	
Total	123				148				297				

[a] Indicates significant differences between means for males and females (Student's t-test, $P < 0.05$).

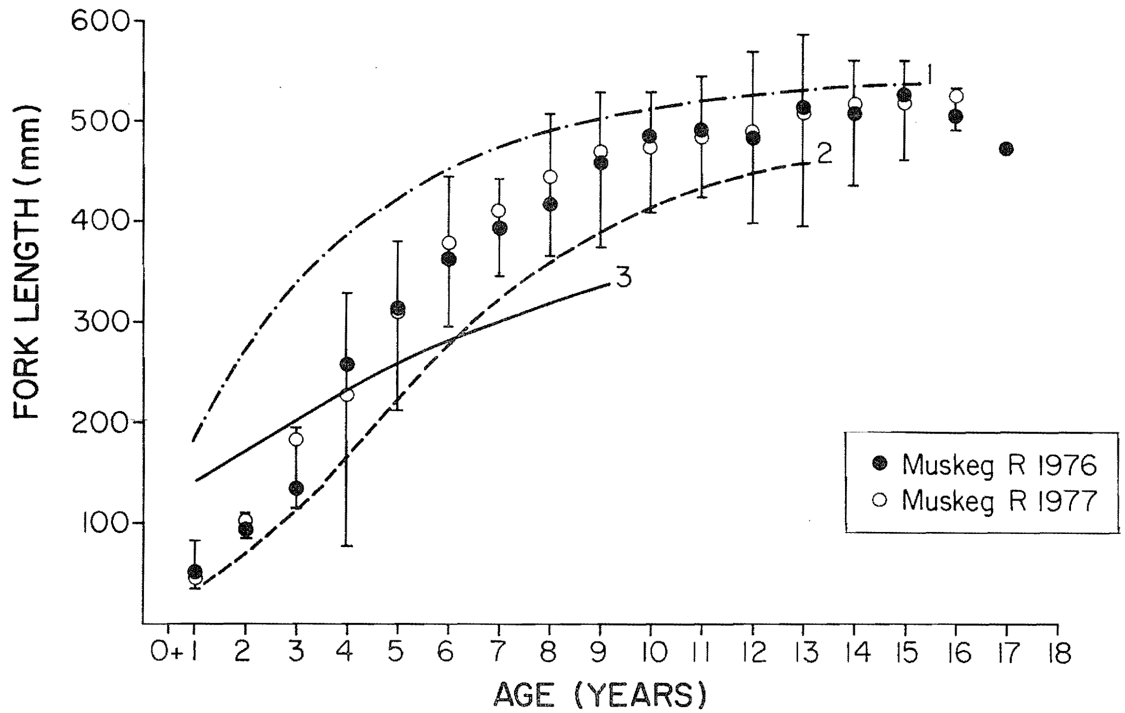

Figure 15. Growth in fork length for white suckers from the Muskeg River and from several other areas: 1. George Lake, Ont. (Beamish 1970); 2. Bigoray River, Alta. (Bond 1972); and 3. Muskellunge Lake, Wis. (Spoor 1938). Circles represent means and vertical lines the ranges in fork length within age groups for Muskeg River fish.

Muskeg River suckers added length at a relatively constant rate during their first eight to 10 years, after which age little length increase occurred. Females were generally longer than males of the same age. Bond and Machniak (1977) found this difference between the sexes to be significant only at age 14 in 1976, but in 1977, significant differences occurred in age groups 9, 11, and 12 (Table 14). Female suckers also tended to be heavier than males of equal age but significant differences occurred only in age groups 11 and 12 during 1977 (Table 15). Females outnumbered males in age groups 13 to 16 in our 1977 sample, suggesting that they tend to live longer than males. Other investigators have also reported that female white suckers grow larger and live longer than males (Spoor 1938; Raney and Webster 1942; Smith 1952; Hayes 1956; Lalancette 1973).

The maximum age for Muskeg River suckers was 17 years in 1976 (Bond and Machniak 1977) and 16 years in 1977. Maximum fin ray ages reported by Verdon (1977) were 19 to 25 years for white suckers in the James Bay area of Quebec.

5.4.1.14 Sex and maturity. Age and sex were determined for 271 white suckers in 1977, of which 148 (55%) were females (Table 16). The sexes were equally represented in the younger age classes. However, females made up 60% of all fish age 10 and older.

The youngest mature white sucker observed in the Muskeg River was a three year old male captured in 1976 (Bond and Machniak 1977). The earliest age of maturity observed in 1977 was four years in both sexes. Spoor (1938) reported that, in Wisconsin, males matured at age 5 or 6 and females at age 6 or 7. Geen (1958) stated that, in British Columbia, white suckers do not spawn before age 6. Bond (1972) captured no spent suckers less than six years old in the Bigoray River, Alberta. Muskeg River data, collected over two years, show that 36, 56, 67, and 86% of male white suckers were mature at ages 5, 6, 7, and 8 respectively. For females at the same age, the corresponding values were 37, 58, 61, and 88%. A major discrepancy appears to exist, however, when the maturity data for four year old fish are examined. Table 16 shows that, in 1977, 47% of male and 5% of female white suckers were

Table 16. Age-specific sex ratios and maturity for white suckers from the Muskeg River drainage, 1977. Sex ratios were based only on fish for which sex was setermined.

Age	Females			Males			Unsexed Fish	Total
	N	%	% Mature	N	%	% Mature		
1	15	47	0	17	53	0	11	43
2	1	100	0	0	0	0	0	1
3	3	38	0	5	62	0	4	12
4	21	53	5	19	47	47	8	48
5	6	43	50	8	57	38	3	17
6	10	77	90	3	23	67	0	13
7	7	47	86	8	53	100	0	15
8	13	54	100	11	46	100	0	24
9	15	50	100	15	50	100	0	30
10	16	64	100	9	36	100	0	25
11	20	59	100	14	41	100	0	34
12	6	35	100	11	65	100	0	17
13	5	83	100	1	17	100	0	6
14	7	78	100	2	22	100	0	9
15	1	100	100	0	0	0	0	1
16	2	100	100	0	0	0	0	2
Totals	148	55%		123	45%		26	297

mature at four years of age while in 1976, the corresponding figures are 77 and 30%. Such values for four year old suckers seem too high. Although some males in the 200 to 300 mm size range appeared to be ripe at the time of their upstream migration (i.e. they were running milt and had developed small tubercles), the virtual absence of fish this size from the downstream results (Figure 13) suggests that most of these small fish did not spawn.

During 1976 (Bond and Machniak 1977), a few white suckers with undeveloped ova were noted among the older age classes. The presence of such fish suggests that some white suckers do not spawn every year.

5.4.1.15 Length-weight relationship. The following length-weight relationships were determined from white suckers captured during the 1977 counting fence operation on the Muskeg River. Both upstream and downstream fish were included in the calculations.

The mathematical relationship between fork length and body weight for male suckers ($n = 106$, $r = 0.993$, range 157 to 514 mm) is described by the equation:

$$\log_{10}W = 3.338\,(\log_{10}L) - 5.832;\ sb = 0.040$$

The equivalent expression for female white suckers ($n = 134$, $r = 0.985$, range 175 to 562 mm) is:

$$\log_{10}W = 3.177\,(\log_{10}L) - 5.316;\ sb = 0.048$$

Analysis of covariance indicated a significant difference ($P > 0.05$) between the slopes ($F = 9.653$), but not the adjusted means ($F = 0.084$) of the length-weight relationships of male and female white suckers.

5.4.1.16 Growth of young-of-the-year. Information on first year growth of white suckers in the Muskeg River is presented by Bond and Machniak (1977). At age 1, white suckers ranged in fork length from 35 to 82 mm and weighed from 0.3 to 7.5 g. White suckers in the Bigoray River had a mean fork length of 42.2 mm and a mean weight of 0.89 g at the end of their first year (Bond 1972).

5.4.1.17 <u>Food habits</u>. Sixty-three white sucker stomachs were examined in the field during 1977 and most (93%) contained no food. Similar observations were recorded in 1976 (Bond and Machniak 1977). The stomachs of six adult white suckers examined in the laboratory contained insect remains, Gastropoda, Pelecypoda, digested material, and debris (Table 17). Debris (sand) made up 48.9% of the total volume of material found in sucker stomachs. Bond (1972) found that adult suckers fed almost exclusively on immature insects.

The stomachs of 14 young-of-the-year and juvenile white suckers contained mostly digested material (Table 18). Small suckers in the Bigoray River (Bond 1972) fed mainly on chironomid larvae, small Crustacea, Rotifera, diatoms, and desmids.

5.4.1.18 <u>Rearing area</u>. Young-of-the-year suckers (two species) were first captured in the Muskeg River on 30 May 1977. By 15 June they could be found in large numbers from the mouth of the tributary to Site 4 (Figure 2) approximately 35 km upstream. Throughout this section of river these small fish were concentrated in small back eddies near shore. Although most young-of-the-year drifted out of the Muskeg River during June, July, and August, the entire lower section must be considered important in terms of rearing of this species. Young-of-the-year were still common at Site 3 in lake August although they were obviously less abundant than they had been earlier in the year.

5.4.1.19 <u>Overwintering</u>. While most young-of-the-year suckers leave the Muskeg River during their first summer, a small percentage probably remains in the tributary over the winter. Yearling white suckers were captured at Sites 7, 8, and 9 (Figure 2) in May and June 1977, and at the mouth of Kearl Creek (Site 9) in June 1976 (Bond and Machniak 1977). Small numbers of two and three year old white suckers may also overwinter in the Muskeg River drainage. Tagging results suggest that the larger and older fish overwinter in Lake Athabasca.

Table 17. Food habits of adult longnose suckers, white suckers and lake whitefish captured from the Muskeg River, 1977.

Food Items	Longnose Suckers			White Suckers			Lake Whitefish		
	% Freq.[a]	% No.	% Vol.	% Freq.[a]	% No.	% Vol.	% Freq.[a]	% No.	% Vol.
Class Insecta									
Diptera									
Simuliidae									
larvae	16.7	74.9	6.5	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera	33.3	2.7	3.6	0.0	0.0	0.0	0.0	0.0	0.0
Plecoptera	0.0	0.0	0.0	0.0	0.0	0.0	100.0	50.0	57.1
Ephemeroptera	0.0	0.0	0.0	0.0	0.0	0.0	100.0	50.0	42.9
Insect Remains	16.7	0.0	2.0	16.7	0.0	3.8	0.0	0.0	0.0
Miscellaneous									
Gastropoda	0.0	0.0	0.0	33.3	4.9	7.6	0.0	0.0	0.0
Pelecypoda	33.3	22.5	80.0	50.0	24.4	19.8	0.0	0.0	0.0
Vegetation	33.3	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
Digested Matter	16.7	0.0	1.9	50.0	0.0	19.8	0.0	0.0	0.0
Debris (gravel, sand)	16.7	0.0	1.9	66.7	70.7	48.9	0.0	0.0	0.0
Total Stomachs	7			6		1			
Empty (% of Total)	14.3			0.0					

[a] Percentage frequency of occurrence, based on stomachs that contained food.

Table 18. Food habits of young-of-the-year and juveniles of the larger species captured in the Muskeg River, 1977.

Food Items	White Suckers	Longnose Suckers	Northern Pike		Lake Whitefish		Yellow Perch		Burbot	
	% Frequency[a]	% Frequency[a]	% Freq.[a]	% No.	% Freq.[a]	% No.	% Freq.[a]	% No.	% Freq.[a]	% No.
Class Insecta										
Diptera										
Chironomidae	0.0	33.3	0.0	0.0	0.0	0.0	33.3	40.0	0.0	0.0
Unidentified Dipterans	0.0	66.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera	0.0	0.0	0.0	0.0	50.0	50.0	33.3	10.0	0.0	0.0
Plecoptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeroptera	0.0	0.0	40.0	44.4	0.0	0.0	66.7	50.0	100.0	100.0
Hemiptera	0.0	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Insect Remains	10.0	0.0	20.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0
Miscellaneous										
Nematomorpha	0.0	0.0	0.0	0.0	25.0	50.0	0.0	0.0	0.0	0.0
Fish										
Longnose suckers	0.0	0.0	20.0	22.2	0.0	0.0	0.0	0.0	0.0	0.0
White suckers	0.0	0.0	20.0	22.2	0.0	0.0	0.0	0.0	0.0	0.0
Cyprinids	0.0	0.0	20.0	11.1	0.0	0.0	0.0	0.0	0.0	0.0
Digested Matter	80.0	66.7	0.0	0.0	50.0	0.0	0.0	0.0	100.0	0.0
Debris (sand, gravel)	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total stomachs	14	3	6		5		3		2	
Empty (% of Total)	28.5	0.0	16.7		20.0		0.0		50.0	

[a] Based on stomachs that contained food.

5.4.2 Longnose Suckers

5.4.2.1 Seasonal timing of upstream migration. Longnose sucker spawning migrations appear to be initiated by increasing water temperatures following the spring break-up. Geen et al. (1966) observed that the spawning migration was associated with a water temperature of 5°C in British Columbia. Bailey (1969) reported that, in the Brule River, Wisconsin, spawning runs (over a seven year period) peaked at an average water temperature of 13°C (range 10.9 to 14.4°C). Longnose suckers were moving upstream in the Muskeg River in late April 1976 when the daily maximum water temperature was 9.5°C (Bond and Machniak 1977). However, the most intensive portion of that run occurred on 9 and 10 May when daily maximum water temperatures were 12 and 14°C respectively. The 1977 Muskeg River longnose sucker run began on 2 May at a water temperature of 7°C (Table 8, Figure 16). Most upstream movement (63.9%) took place between 2 and 10 May with peak migrations occurring on 4 and 5 May when daily maximum water temperatures were 9 and 9.5°C respectively. The longnose run in the Steepbank River commenced 25 April but the largest portion of the migration took place on 2 to 4 May when stream temperatures were between 10 and 12°C (Machniak and Bond in prep.).

The 1977 longnose sucker run into the Muskeg River apparently involved considerably fewer fish (n = 1641) than did the 1976 run (n = 2837). Since the ice is known to have left the Muskeg River between 20 and 22 April 1977, it is possible that some upstream movement occurred prior to the installation of the counting fence. It seems more likely though, considering the small numbers of fish taken during the first few days of the study, that the lower numbers observed in 1977 were simply a reflection of natural year to year fluctuations that might be expected to occur.

5.4.2.2 Diel timing of upstream migration. The majority of longnose suckers (83.1%) moved upstream between noon and 0300 h with maximum movement usually occurring between 2100 and 2400 h (Table 19). Similar results have been observed for other longnose

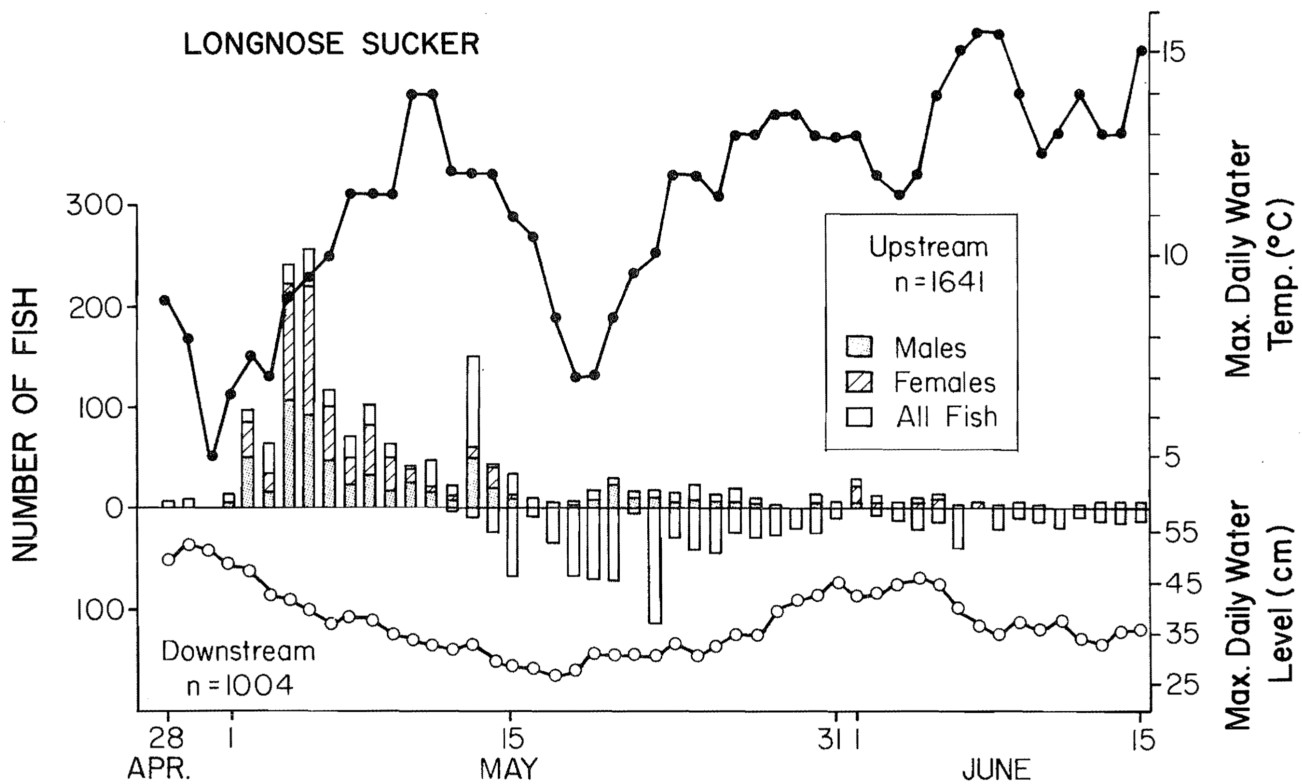

Figure 16. Seasonal timing of the longnose sucker migration in the Muskeg River, 1977.

Table 19. Summary of diel timing of the upstream migration of longnose suckers in the Muskeg River, 1977. Fish that were counted at times other than those indicated were included in the next time check.

Date	Number of Fish Counted at Each Check						Total
	0900 (0300)[a]	1200	1500	1800	2100	2400	
28 April	ND	trap opened		5	2	ND	7
29	5	ND	0	0	3	ND	8
30	ND	0	ND	0	0	ND	0
1 May	ND	0	ND	ND	3	10	13
2	0	0	1	8	49	34	92
3	5	ND	0	0	0	59	64
4[a]	36	4	4	91	35	71	241
5[a]	129	ND	9	44	ND	76	258
6[a]	32	7	1	30	24	22	116
7[a]	19	16	2	4	5	25	71
8[a]	29	36	10	11	7	9	102
9[a]	11	13	1	5	17	16	63
10[a]	17	3	1	3	0	18	42
11[a]	11	1	1	0	2	34	49
12[a]	10	4	ND	6	2	trap closed	22
13	ND	40	ND	71	ND	37	148
14	ND	25	ND	1	4	12	42
15	ND	19	ND	0	3	11	33
16	ND	0	ND	0	ND	9	9
17	ND	1	ND	ND	2	0	3
18	ND	1	ND	ND	0	4	5
19	ND	0	ND	1	13	3	17
20	ND	3	ND	ND	16	9	28
21	ND	1	ND	ND	0	15	16
22	ND	1	ND	2	2	12	17
23	ND	3	ND	7	ND	5	15
24	ND	3	ND	9	1	9	22
25	ND	2	ND	0	ND	11	13
26	ND	17	ND	ND	ND	3	20
27	ND	0	ND	ND	6	2	8
28	ND	0	ND	0	ND	2	2
29	ND	0	ND	ND	ND	ND	0
30	1	ND	12	ND	ND	0	13
31	ND	1	ND	ND	0	1	2
1 June[a]	6	8	ND	9	ND	4	27
2	ND	10	ND	ND	ND	1	11
3	ND	0	ND	1	ND	4	5
4	ND	1	ND	1	ND	6	8
5	ND	8	ND	5	ND	0	13
6	ND	1	ND	0	ND	0	1
7	ND	1	ND	2	ND	2	5
8	ND	0	ND	1	ND	0	1
9	ND	2	ND	0	0	1	3
10	ND	0	0	0	0	1	1
11	ND	0	ND	0	ND	0	0
12	ND	1	0	ND	0	0	1
13	ND	0	0	0	0	1	1
14	ND	0	ND	ND	1	1	2
15	ND	1		operations		terminated	1
Totals	311	234	42	317	197	540	1641
% Grand Total	18.9	14.3	2.6	19.3	12.0	32.9	

[a] Checks were made at 0300 h rather than 0900 h during the peak of the runs.

sucker runs, both within the AOSERP study area (Machniak and Bond in prep.) and elsewhere (Geen et al. 1966).

5.4.2.3 Spawning period. The 1977 spawning period for longnose suckers in the Muskeg River probably lasted from one to two weeks. Ripe males were first noted on 2 May and most females were ripe by 4 May. Ripe males and females were captured as late as 14 and 15 May respectively but virtually all fish observed were spent by 13 May. Most fish entering the upstream trap after 13 May were spawned out and had probably been recently passed through the downstream trap. Geen et al. (1966) reported a spawning period of short duration with some adults leaving the spawning stream as early as five days after the migration began.

The 1977 spawning period occurred at about the same time as in 1976, but because the timing of this event is temperature dependent, it can be expected to vary considerably from year to year.

5.4.2.4 Spawning areas. Spawning of longnose suckers was not observed in the lower 2 km of the Muskeg River despite daily surveillance by field personnel. They apparently did not spawn downstream of the fence site where white suckers spawned despite the fact that the two species have rather similar spawning requirements. No attempts were made to locate fish on spawning grounds in the upstream areas. However, on 3 May 1976, a fish fitting the description of a male longnose sucker in spawning colouration was observed in Hartley Creek (Dr. R. Hartland-Rowe, University of Calgary, verbal communication with W. A. Bond, 4 May 1976). From the distribution of young-of-the-year suckers (two species) we conclude that longnose suckers do not utilize areas upstream of Site 4 in the Muskeg River or upstream of Site 8 in Hartley Creek (Figure 2) for spawning purposes. Young-of-the-year suckers were abundant at Sites 3 and 4 by mid-June 1977 and small numbers were captured in the lower reaches of Hartley Creek in mid-June 1976.

5.4.2.5 Length of time spent in Muskeg River. By 15 June 1977, 61.2% of the longnose suckers counted through the upstream trap had returned downstream. Bond and Machniak (1977) observed that downstream movements continued until at least 30 July, by which time 77.2% of the migrants had returned downstream. Their results showed that the length of time spent in the tributary can vary greatly (from two to 87 days) although the majority of fish that had moved downstream by 30 July (81.6%) had been in the Muskeg River less than 30 days. Machniak and Bond (in prep.) recaptured longnose suckers in a downstream trap in the Steepbank River and suggested that some individuals may stay in the tributary throughout the summer. They stated that immature longnose suckers tend to remain in the tributary longer than the spawners. A similar situation may occur in the Muskeg River as well.

5.4.2.6 Seasonal and diel timing of downstream migration. The first spent fish were observed upstream of the fence on 12 May 1977, on which date the downstream trap was opened. This was eight to 10 days after the beginning of the main upstream run. Longnose suckers continued to move downstream through 15 June (Table 8, Figure 16) when operations were terminated. However, the majority of fish taken at the downstream trap (72.7%) were captured prior to 1 June. As mentioned previously, longnose suckers continued their downstream movement through 30 July in 1976, although 66.9% of them had passed the fence by 31 May (Bond and Machniak 1977).

The downstream migration of longnose suckers took place mainly at night as only 30% of the fish were captured between noon and 2100 h (Table 20). Geen et al. (1966) reported that downstream movement of spent longnose suckers ceased in the early morning when water temperatures reached their daily minimum.

5.4.2.7 Spawning mortality. Prior to the 15 June termination date in 1977 only a few longnose suckers were found dead in the Muskeg River. Bond and Machniak (1977) reported finding 63 dead longnose suckers between 18 June and 30 July. Geen et al. (1966)

Table 20. Summary of diel timing of the downstream migration of longnose suckers in the Muskeg River, 1977. Fish that were counted at times other than those indicated were included in the next time check.

Date	Number of Fish Counted at Each Check				Total
	1200	1800	2100	2400	
12 May	trap opened	1	0	2	3
13	2	4	ND	2	8
14	0	7	4	13	24
15	8	26	12	21	67
16	2	0	ND	8	10
17	0	ND	23	12	35
18	0	ND	43	24	67
19	3	40	0	26	69
20	0	ND	1	72	73
21	0	ND	0	6	6
22	20	50	10	34	114
23	8	0	ND	21	29
24	0	2	2	37	41
25	32	13	ND	trap closed	45
26	20	ND	ND	4	24
27	26	ND	2	2	30
28	28	0	ND	0	28
29	20	ND	ND	ND	20
30	0	16	ND	10	26
31	11	ND	0	0	11
1 June	53	0	ND	1	54
2	6	ND	ND	1	7
3	8	0	ND	5	13
4	21	0	ND	1	22
5	8	2	ND	4	14
6	36	6	ND	0	42
7	0	0	ND	0	0
8	19	1	ND	3	23
9	4	2	2	3	11
10	5	5	2	2	14
11	4	9	ND	7	20
12	4	1	1	3	9
13	7	2	3	2	14
14	4	ND	8	5	17
15	14	operations		terminated	14
Total	373	187	113	331	1004
% Grand Total	37.2	18.7	11.3	33.0	

produced mortality estimates of from 11 to 28%, and considered survival of spawning longnose suckers to be very high.

5.4.2.8 Size composition of migrant longnose suckers. Longnose suckers measured during the 1977 upstream migration ranged in fork length from 120 to 514 mm, although the majority (88.3%) were between 320 and 449 mm (Table 21 and Figure 17). Within this length range, females were clearly longer in fork length than males (Figure 17). This situation was practically identical to that observed in 1976 in the Muskeg River (Bond and Machniak 1977) and in 1977 in the Steepbank River (Machniak and Bond in prep.). Unlike the situation observed for white suckers, where many juvenile fish took part in the run, the longnose migration was comprised mainly of adult fish (spawners).

5.4.2.9 Age composition of migrant longnose suckers. Age was determined for 132 longnose suckers captured during the 1977 migration, of which sex was determined in 108 cases (Figure 18). Migrant suckers ranged in age from four to 13 years with the majority being seven to 11 years old inclusive. Similar results were obtained in 1976 (Bond and Machniak 1977).

Although our age sample was not drawn at random and cannot, therefore, be said to describe accurately the age composition of the population, an analysis of the length frequency distribution of the run (Table 21) in the light of our knowledge of the age and growth characteristics of this population supports the conclusion that the migration consisted largely of fish between seven and 11 years of age.

5.4.2.10 Sex ratio of migrant longnose suckers. Sex was determined for 1,130 longnose suckers during the upstream migration, of which 599 (53%) were males (Table 22). This is a significant deviation from the expected 1:1 ratio ($X^2 = 4.10$, $P < 0.001$).

The main upstream movement of spawning longnose suckers occurred between 2 and 10 May. During this period the sex ratio was not constant as reported by Geen et al. (1966) for longnose

Table 21. Length-frequency distribution of longnose suckers during the upstream migration in the Muskeg River, 1977.

Fork Length (10 mm intervals)	Male	Female	Unknown	Total	Fork Length (10 mm intervals)	Male	Female	Unknown	Total
120 - 129	0	1	0	1	360 - 369	69	14	32	115
160 - 169	0	0	1	1	370 - 379	95	20	40	155
170 - 179	0	0	0	0	380 - 389	79	33	33	145
180 - 189	0	0	0	0	390 - 399	63	55	38	156
190 - 199	0	0	6	6	400 - 409	45	53	25	123
200 - 209	1	2	11	14	410 - 419	19	57	21	97
210 - 219	2	1	6	9	420 - 429	7	59	7	73
220 - 229	1	0	6	7	430 - 439	5	53	0	58
230 - 239	0	1	2	3	440 - 449	0	21	0	21
240 - 249	2	0	7	9	450 - 459	1	11	0	12
250 - 259	0	1	3	4	460 - 469	1	4	0	5
260 - 269	2	0	5	7	470 - 479	0	0	0	0
270 - 279	4	0	3	7	480 - 489	1	1	0	2
280 - 289	3	0	9	12	490 - 499	1	0	0	1
290 - 299	0	0	14	14	500 - 509	1	0	0	1
300 - 309	0	1	19	20	510 - 519	0	1	0	1
310 - 319	1	0	11	12					
320 - 329	3	4	18	25	Totals	482	407	371	1260
330 - 339	7	2	19	28					
340 - 349	21	5	16	42					
350 - 359	48	7	19	74					

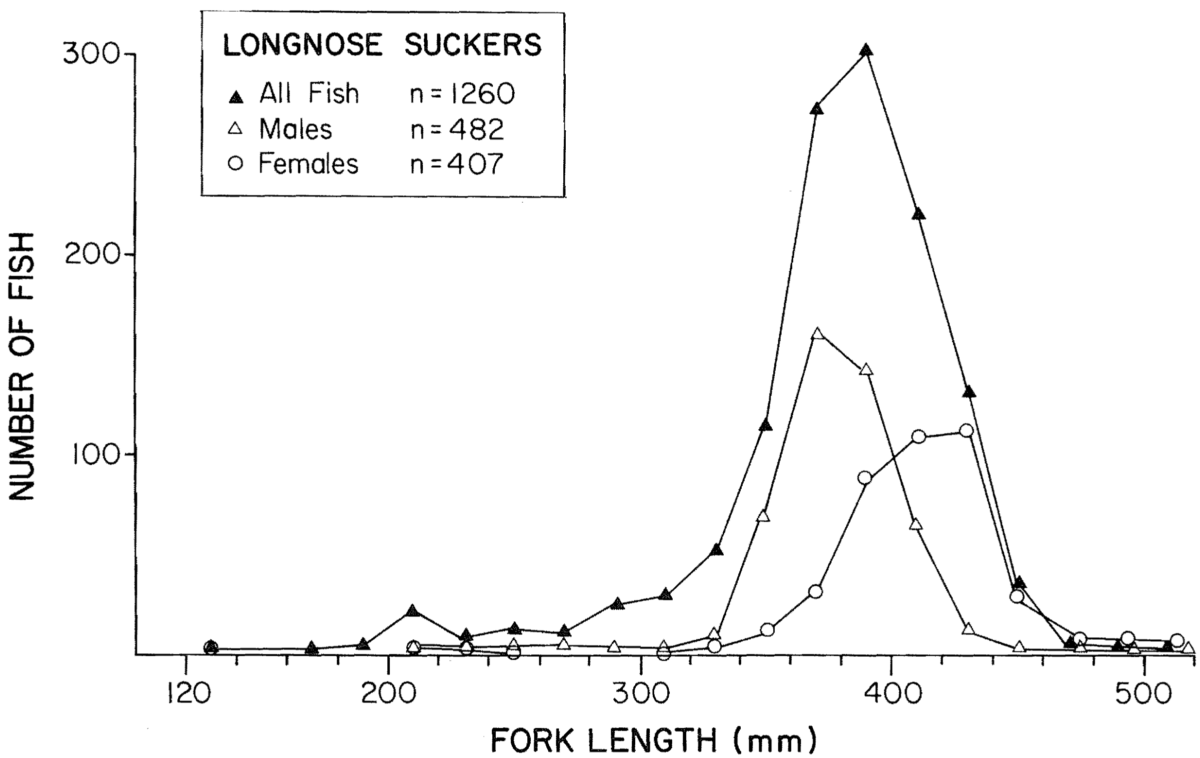

Figure 17. Length-frequency distribution for longnose suckers during the upstream migration in the Muskeg River, 1977.

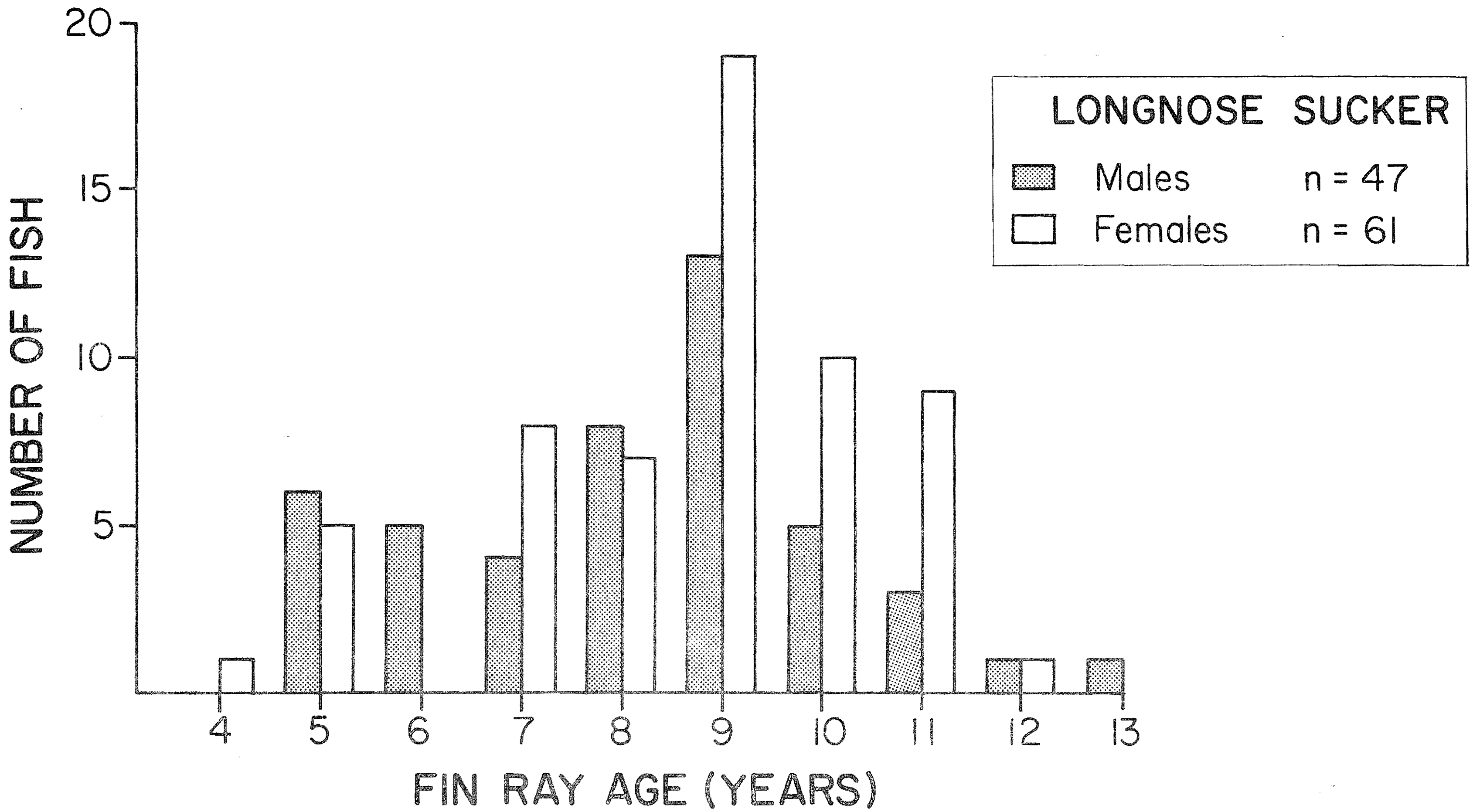

Figure 18. Age composition for longnose suckers sampled during the counting fence operation, Muskeg River, 1977.

Table 22. Sex ratio for longnose suckers during upstream migration, Muskeg River, 1977.

Date	Number of Fish				Percent Males[a]
	Males	Females	Unknown	Total	
28 April	0	0	7	7	0
29	1	0	7	8	100
30	0	0	0	0	0
1 May	5	1	7	13	83
2	49	35	8	92	58
3	17	17	30	64	50
4	107	114	20	241	48
5	93	124	41	258	43
6	47	53	16	116	47
7	22	28	21	71	44
8	32	49	21	102	40
9	17	32	14	63	35
10	24	15	3	42	62
11	17	5	27	49	78
12	7	5	10	22	58
13	49	12	87	148	80
14	14	6	22	42	78
15	12	2	19	33	86
16	0	0	9	9	0
17	3	0	0	3	100
18	3	0	2	5	100
19	8	2	7	17	80
20	19	2	7	28	90
21	6	1	9	16	86
22	9	0	8	17	100
23	3	0	12	15	100
24	6	1	15	22	86
25	6	2	5	13	75
26	4	0	16	20	100
27	3	0	5	8	100
28	0	1	1	2	0
29	0	0	0	0	0
30	3	0	10	13	100
31	1	0	1	2	100
1 June	4	12	11	27	25
2	1	2	8	11	33
3	1	1	3	5	50
4	1	3	4	8	25
5	2	5	6	13	29
6	0	0	1	1	0
7	0	3	2	5	0
8	0	0	1	1	0
9	1	0	2	3	100
10	0	0	1	1	0
11	0	0	0	0	0
12	1	0	0	1	100
13	0	1	0	1	0
14	0	0	2	2	0
15	1	0	0	1	100
Totals	599	531	511	1641	
%	53	47			

[a] Based on fish of known sex.

suckers in Frye Creek. Rather, males tended to outnumber females on the first few days, while females were more numerous in the later stages of the run (Table 22). The sex ratio was also observed to vary with the time in the Steepbank River with males dominating the early stages of the upstream run (Machniak and Bond in prep.).

5.4.2.11 Homing of longnose suckers. Geen et al. (1966) indicated that longnose suckers in Frye Creek tended to return each year to the same spawning stream. Bailey (1969) demonstrated a similar tendency in Brule Creek, Wisconsin. During 1977, evidence from tag returns clearly indicated that longnose suckers of the Muskeg River return to that tributary to spawn in subsequent years in preference to other tributaries. Floy tags were applied to 1267 longnose suckers during their 1976 migration into the Muskeg River (Bond and Machniak 1977). Ten of these fish were known to have been dead prior to the beginning of the 1977 run. Of the remainder, 270 (20.7%) were recaptured in the Muskeg River during the 1977 study. If, as we believe, Muskeg River longnose suckers are part of the Lake Athabasca population, these fish had undertaken a round trip in excess of 500 km between their overwintering area and their spawning grounds.

As was the case with white suckers, longnose suckers demonstrated considerable fidelity to the Muskeg River. At the 1977 Steepbank fence operation, for example, only nine longnose suckers, tagged during the 1976 Muskeg River study, were recovered out of 3811 fish counted. One fish was recovered at a fence operation on the MacKay River in 1978 (Appendix 8.2).

5.4.2.12 Fecundity. Fecundity was estimated gravimetrically for 13 female longnose suckers from the Muskeg River. The data in Table 23 represent additions to those given by Bond and Machniak (1977). Considering the fecundity data for both years, the estimated total number of eggs per female (fork length 370 to 440 mm) ranged from 16 068 to 33 060 with an average of 23 639 per female. Actual counts on eight ovaries revealed errors of from +7.2% to -4.4% for the estimated values.

Table 23. Fecundity estimates for longnose suckers sampled during the 1977 Muskeg River spawning migration.

Fork Length (mm)	Weight (g)	Number of Eggs			Relative Fecundity	
		Left Ovary	Right Ovary	Total	(cm)	(g)
370	700	11 218[a] (-1.9%)[b]	10 567[a] (-4.2%)[b]	21 785	588.8	31.1
407	1120	15 310[a] (+2.0%)[b]	17 750	33 060	812.3	29.5
411	820	11 125	12 500	23 625	574.8	28.8
419	950	15 143	12 260	27 403	654.0	28.9
420	930	9 680	12 785	22 465	534.9	24.2
423	1110	14 303	16 250	30 553	722.3	27.5

[a] Actual egg count.

[b] Deviation of estimated counts from actual number.

Length-relative fecundity for longnose suckers ranged from 390.0 to 812.3 ova per cm of fork length, while weight-relative fecundity varied from 17.9 to 33.2 eggs per g of body weight. These values are similar to those reported for this species by McCart et al. (1977), Machniak and Bond (in prep.) and Bond and Berry (in prep.b) in other studies within the AOSERP area.

Although a positive correlation was found between fecundity and fork length, this correlation was not statistically significant ($n = 13$, $r = 0.233$). The mathematical relationship between fecundity and fork length is described by the equation:

$$\log_{10}\text{Fecundity} = 1.408 \log_{10} \text{Fork Length (mm)} + 0.677;$$

$$sb = 1.775$$

Whereas fecundity correlated poorly with fork length, a better but still insignificant positive correlation was seen between fecundity and body weight ($r = 0.633$). The relationship between fecundity and body weight for the above 13 fish (range 700 to 1120 g) is described by the equation:

$$\log_{10}\text{Fecundity} = 1.195 \log_{10} \text{Weight (g)} + 0.830;$$

$$sb = 0.441$$

5.4.2.13 Age and growth. Age and growth results from 1977 (Tables 24 and 25) were similar to those of 1976 (Bond and Machniak 1977) (Figure 19). Most growth in length was achieved during the first eight years of life. After age 8 the rate of growth decreased considerably. Growth in length for Muskeg River fish is identical to that reported for longnose suckers by other studies in the AOSERP area (McCart et al. 1977; Machniak and Bond in prep; Jones et al. 1978; Bond and Berry in prep.a, in prep.b). Muskeg River suckers (Figure 19) grow faster than those from Pyramid Lake, Alberta (Rawson and Elsey 1950), but more slowly than suckers from Yellowstone Lake (Brown and Graham 1954), Great Slave Lake (Harris 1962), and Lake Superior (Bailey 1969).

Female longnose suckers from the Muskeg River were generally longer than males of equal age. This difference was significant in age groups 7 to 11 both in 1976 (Bond and Machniak 1977) and in 1977 (table 24). Also as reported in 1976,

Table 24. Age-length relationship (derived from fin rays and otoliths) for longnose suckers captured in the Muskeg River watershed, 1977, sexes separate and combined sample (includes unsexed fish).

Age	Males				Females				All Fish				t-test
	N	Mean	S.D.	Range	N	Mean	S.D.	Range	N	Mean	S.D.	Range	
1	0				1	53.0			2	50.5	3.54	48-53	
2	1	82.0			0				1	82.0			
3	0				0				0				
4	0				1	193.0			5	191.8	15.51	165-204	
5	6	228.7	25.18	203-270	5	221.4	22.77	200-253	27	218.2	18.74	200-270	0.499
6	5	273.2	29.76	240-321	0				10	277.8	23.25	240-300	
7	4	281.3	7.41	271-288	8	358.4	43.82	293-420	13	329.2	51.15	271-420	3.414[a]
8	8	365.9	16.81	345-397	7	386.0	10.94	371-396	15	375.3	17.33	345-397	2.699[a]
9	13	383.2	17.62	356-411	19	403.2	20.25	358-438	32	395.1	21.41	356-438	2.885[a]
10	5	378.0	12.90	357-391	10	401.3	25.84	369-450	15	393.5	24.62	357-450	1.878[a]
11	3	381.7	25.38	361-410	9	414.2	20.99	385-445	12	406.1	25.59	361-445	2.223[a]
12	1	430.0			1	411.0			2	420.5	13.44	411-430	
13	1	381.0			0				1	381.0			
Totals	47				61				135				

[a] Indicates significant difference between means for males and females (Student's t-test, $P < 0.05$).

Table 25. Age-weight relationship for longnose suckers captured in the Muskeg River watershed, 1977, sexes separate and combined sample (includes unsexed fish).

Age	Males				Females				All Fish				t-test
	N	Mean	S.D.	Range	N	Mean	S.D.	Range	N	Mean	S.D.	Range	
1	0				1	1.55			2	1.33	0.32	1.10-1.55	
2	1	6.55			0				1	6.55			
3	0				0				0				
4	0				1	110.0			5	100.0	15.81	80-120	
5	6	131.7	56.01	80-220	5	124.0	43.36	80-180	27	115.0	36.82	80-220	0.250
6	5	256.0	129.73	150-480	0				10	257.0	92.26	150-480	
7	4	365.0	210.16	250-680	8	592.5	210.76	290-930	13	498.5	229.70	250-930	1.764
8	8	585.0	78.92	520-770	7	697.1	31.99	640-740	15	637.3	83.11	520-770	3.502[a]
9	13	684.2	106.85	540-840	19	822.1	152.81	560-1120	32	766.1	150.70	540-1120	2.811[a]
10	5	610.0	70.00	540-720	10	750.0	131.66	590-1060	15	703.3	131.19	540-1060	2.199[a]
11	3	716.7	193.48	600-940	9	966.7	186.68	640-1140	12	904.2	211.98	600-1140	1.994[a]
12	1	920.0			1	820.0			2	870.0	70.71	820-920	
13	1	640.0			0				1	640.0			
Totals	47				61				135				

[a] Indicates significant difference between means for males and females (Student's t-test, $P < 0.05$).

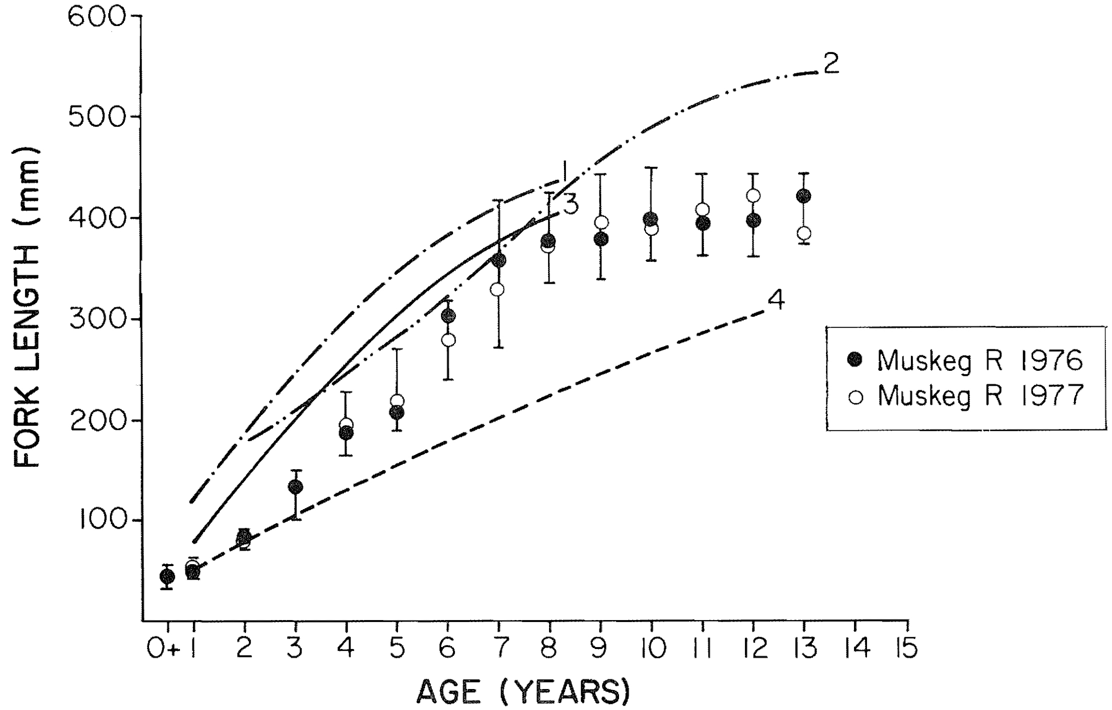

Figure 19. Growth in fork length for longnose suckers from the Muskeg River and from several other areas: 1. Yellowstone Lake, Wyo. (Brown and Graham 1954); 2. Great Slave Lake (south), N.W.T. (Harris 1962); 3. Lake Superior (Bailey 1969); and 4. Pyramid Lake, Alta. (Rawson and Elsey 1950). Circles represent means and vertical lines the ranges in fork length within age groups for Muskeg River.

the 1977 data indicâte females to be significantly heavier than males of the same age in age groups eight to eleven inclusive (Table 25). The divergence in growth rate between males and females apparently commences at about the age of first sexual maturity. Brown and Graham (1954) and Lalancette and Magnin (1970) also reported that female longnose suckers grew faster than the males. However, Harris (1962) found no difference in growth rate for longnose suckers in Great Slave Lake.

On the basis of our Muskeg River data for both years of the study we can detect no tendency for one sex to live longer than the other as suggested by Scott and Crossman (1973).

The maximum age of 13 years recorded in the present study was also reported for longnose suckers in the AOSERP area by Machniak and Bond (in prep.) and by Jones et al. (1978). Bond and Berry reported a 19 year old longnose sucker (aged from fin rays) from the Athabasca delta. Tripp and McCart (1974) found that most spawning run suckers in the Donnelly River, N.W.T. were 11 to 18 years old with a maximum age of 22 years.

5.4.2.14 Sex and maturity. Of 108 longnose suckers for which both age and sex were determined, 56% were females (Table 26). The 1976 sample of 182 fish contained 53% males (Bond and Machniak 1977).

The youngest mature longnose sucker observed during the two years of the study was a five year old male. However, most suckers probably do not spawn until seven or eight years of age (Table 26). Hayes (1956) stated that longnose suckers reach sexual maturity at the age of two years in Colorado, while in the Northwest Territories, suckers do not mature until age nine (Harris 1962; Tripp and McCart 1974).

5.4.2.15 Length-weight relationship. Analysis of covariance indicated no significant difference ($P > 0.05$) between adjusted means ($F = 0.914$) or slopes ($F = 0.066$) of the length-weight regressions for male and female longnose suckers sampled in 1977. The mathematical relationship for the combined sample (including

Table 26. Age-specific sex ratios and maturity for longnose suckers from the Muskeg River drainage, 1977. Sex ratios were based only on fish for which sex was determined.

Age	Females			Males			Unsexed Fish	Total
	N	%	% Mature	N	%	% Mature		
1	1	100	0	0	0	0	1	2
2	0	0	0	1	100	0	0	1
3	0	0	0	0	0	0	0	0
4	1	100	0	0	0	0	4	5
5	5	45	0	6	55	0	16	27
6	0	0	0	5	100	20	5	10
7	8	67	88	4	33	25	1	13
8	7	47	100	8	53	88	0	15
9	19	59	100	13	41	100	0	32
10	10	67	100	5	33	80	0	15
11	9	75	100	3	25	67	0	12
12	1	50	100	1	50	100	0	2
13	0	0	0	1	100	100	0	1
Totals	61	56%		47	44%		27	135

unsexed fish) between fork length and body weight for longnose suckers from the Muskeg River as determined from 1977 data ($n = 131$, $r = 0.984$, range 120 to 450 mm) is described by the equation:

$$\log_{10}W = 3.103\,(\log_{10}L) - 5.179;\ sb = 0.048$$

For male longnose suckers ($n = 47$, $r = 0.963$, range 203 to 430 mm) the calculated values for the slope (b), intercept (a) and standard deviation of b (sb) were 3.119, -5.225 and 0.130 respectively. The corresponding values for females ($n = 63$, $r = 0.987$, range 120 to 450 mm) were 3.085, -5.126 and 0.064.

5.4.2.16 Growth of young-of-the-year. Although young suckers were abundant throughout the lower 35 km of the Muskeg River by mid-June in both years of the study, the two species were indistinguishable at that time of the year. By the time young suckers were large enough to be identified to species, most of the fish present appeared to be white suckers. Few verified young-of-the-year longnose suckers were captured in the Muskeg River either in 1976 or 1977. Bailey (1969) also reported difficulty in locating longnose sucker fry in spawning streams in western Wisconsin and suggested that they drift to the lake soon after hatching. Perhaps young-of-the-year longnose suckers in the Muskeg River behave similarly. On the other hand, Machniak and Bond (in prep.) reported no difficulty in locating young longnose suckers in the Steepbank River.

The available information suggests that longnose suckers that remain in the Muskeg River attain a fork length of approximately 50 mm by the end of their first year (Bond and Machniak 1977). However, the growth rate of such "resident" young suckers may differ considerably from that of those that drift back to Lake Athabasca.

5.4.2.17 Food habits. Field analysis of longnose sucker stomachs during the spring spawning migration indicated that suckers fed little at that time (Bond and Machniak 1977). Suckers whose stomach contents were examined in the laboratory ($n = 7$) had fed primarily on Simuliidae larvae, Trichoptera larvae, Pelecypoda, and vegetable matter (Table 17). Young-of-the-year had consumed mainly small aquatic insects (Table 18). The diet of longnose suckers is known to be highly variable consisting largely of benthic invertebrates (Scott and Crossman 1973).

5.4.2.18 Rearing areas. The lower 35 km of the Muskeg River appear to be important as a rearing area for white suckers during June, July, and August. However, as few young-of-the-year suckers verified to be longnose were captured in the Muskeg River either in 1976 or 1977, no definite statement can be made concerning this species. Longnose sucker fry may leave the tributary more rapidly after hatching than white sucker fry. Alternatively, 1976 and 1977 may have been sub-normal years for longnose sucker spawning, with poor reproductive success.

5.4.2.19 Overwintering. No winter sampling was done in the Muskeg River during this study. However, small numbers of yearlings were captured at Site 7 Hartley Creek and Site 9 the mouth of Kearl Creek in mid-June 1976, suggesting that some young-of-the-year spend at least one winter in the Muskeg River watershed. Tagging results suggest that larger and older longnose suckers overwinter in Lake Athabasca.

5.4.3 Arctic Grayling

5.4.3.1 Spring movements. Arctic grayling spawning migrations appear to be initiated by increasing water temperatures and often begin with ice break-up (Brown 1938; Rawson 1950; Reed 1964; Schallock 1966; Bishop 1971). Tack (1972) reported that, in Alaska, the first grayling arrived on the spawning grounds when the water temperature was $0^{\circ}C$. Ice left the Muskeg River between 20 and 22 April 1977, and the daily maximum water temperature exceeded $8^{\circ}C$ on 24 April. An upstream migration of Arctic grayling was in progress in the Muskeg River on 28 April when the counting fence operation began. By 6 June, 161 grayling had passed through the upstream trap with 73.3% of them moving up prior to 15 May.

This represented approximately half the number of grayling counted in 1976 (Bond and Machniak 1977). Only 11 grayling were captured in the downstream trap (Table 8).

As in 1976, most grayling (86.1%) moved upstream between noon and midnight with the heaviest movements occurring between 1500 and 2100 h (56.7%). The 1977 Steepbank River migration also occurred mainly during the daytime as 70% of the grayling moved upstream between 0900 and 2100 h (Machniak and Bond in prep.).

Failure to catch the entire upstream grayling migration in 1976 was the major reason for repeating the fence study in 1977. Angling results during the summer of 1976 suggested that the Muskeg River supported considerably more grayling than our fence results had indicated, and it was hoped that more accurate counts could be achieved in 1977. Unfortunately we were unable to do this. An attempt to fulfill this objective by operating a downstream trap in the fall of 1978 was also thwarted, this time by extremely high water (Figure 8).

5.4.3.2 Size of migrant grayling. Fork lengths were taken from 149 grayling captured during the 1977 upstream migration. These fish ranged in length from 175 to 389 mm (Table 27) with the length-frequency distribution exhibiting three modes (Figure 20). These three modes represent fish of age groups 2, 3, and 4 as indicated by age and growth information given by Bond and Machniak (1977) and in a later section of the present report.

The length-frequency distribution did not remain constant during the period of fence operation in 1977. The early stages of the migration (25 April to 5 May) were dominated by grayling smaller than 260 mm fork length while most grayling passing upstream after this date exceeded 260 mm (Figure 20). The initial phase of the upstream grayling migration in the Steepbank River consisted of large, mature fish which were followed by smaller, immature fish in the later stages of the run (Machniak and Bond in prep.). Craig and Poulin (1975) demonstrated a similar pattern of upstream movement for grayling in northern streams. The small grayling captured in the Muskeg River between

Table 27. Length-frequency distribution of Arctic grayling during the upstream migration in the Muskeg River, 1977.

Fork Length (10 mm intervals)	Male	Female	Unknown	Total
170-179	1	0	1	2
180-189	0	1	0	1
190-199	2	1	5	8
200-209	2	3	5	10
210-219	1	3	8	12
220-229	1	0	6	7
230-239	1	0	6	7
240-249	2	0	10	12
250-259	1	3	4	8
260-269	1	2	11	14
270-279	1	1	6	8
280-289	1	0	8	9
290-299	2	0	3	5
300-309	3	6	2	11
310-319	3	4	3	10
320-329	5	1	4	10
330-339	6	0	1	7
340-349	1	3	0	4
350-359	2	0	0	2
360-369	0	0	0	0
370-379	0	0	0	0
380-389	2	0	0	2
Totals	38	28	83	149

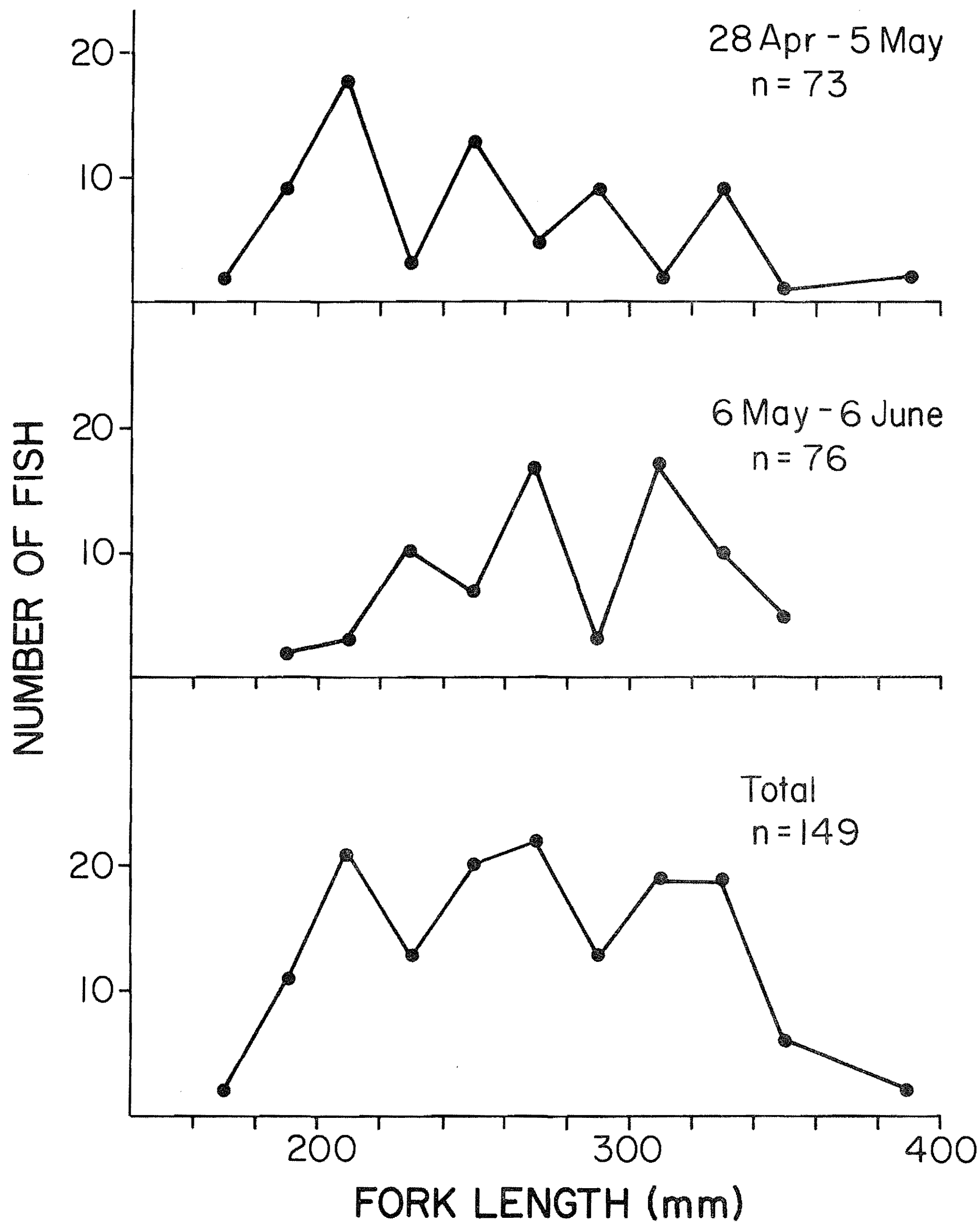

Figure 20. Length-frequency distribution for Arctic grayling during the upstream migration in the Muskeg River, 1977.

28 April and 5 May are thought to represent the late stages of the main upstream run. Most spawners are believed to have passed the counting fence prior to 28 April. The larger fish taken after 5 May may have spawned in other tributaries before entering the Muskeg or they may have spawned in the Muskeg River below the fence site and then moved upstream to summering areas.

5.4.3.3 Spawning. Grayling usually spawn over gravel or rocky bottom with water depth appearing not to be an important factor (Fabricius and Gustafson 1955; Kruse 1959; Bishop 1971). Grayling in tributaries of the southern Athabasca River drainage spawn in May at stream temperatures of 4.5 to 11°C (Ward 1951). Tack (1972) noted that, in Alaska, spawning was first observed when the stream temperature was 4°C and that by 10°C spawning was completed. Records over a 10 year period at Black Lake, a shield lake in northern Saskatchewan, indicate that, although spawning occurs over a three week period, the peak spawning period lasts only three days to a week (Johnston 1971; Kratt and Smith 1977).

Spawning of Arctic grayling was not observed in the Muskeg River either in 1976 or 1977. However, the lower 35 km of the main river and the lower reaches of Hartley Creek provide many areas that appear suitable for this purpose. Spawning probably occurred during the last week of April and first week of May in both years. Young-of-the-year were taken on 15 June 1976 (range 32 to 42 mm) and on 3 June 1977 (range 18 to 24 mm) at Site 3 (Figure 2). As well, fry were captured between 16 and 21 June 1976 (range 27 to 38 mm) and on 19 June 1977 (38 mm) at Site 7 in Hartley Creek. While most grayling spawning is believed to occur upstream of our fence site, there is a possibility that some fish spawn below this site. Grayling fry were captured between the fence site and the tributary mouth on 15 June 1976 (range 32 to 42 mm) and on 7 June 1977 (range 26 to 27 mm). As mentioned previously, the capture of spawning size grayling in the 1977 upstream trap after 6 May (Figure 20) suggests either that these fish had spawned in other tributaries and were now moving into the Muskeg River or that they had spawned in the Muskeg River below the fence and were now moving into upstream areas.

5.4.3.4 <u>Summer residence of Arctic grayling</u>. Arctic grayling did not leave the Muskeg River after spawning in 1976 and 1977 but remained in the tributary throughout the summer. This is unlike the situation in most northern streams (Craig and Poulin 1975) but similar to that reported by Ward (1951) and Machniak and Bond (in prep.) for other streams in the Athabasca River drainage.

During summer 1976, angling produced considerable numbers of grayling in the lower 10 km of the Muskeg River. Ten angler hours, applied to this area on 8 to 10 August, produced 28 Arctic grayling, aged one to four years (Bond and Machniak 1977). Dr. D. Barton (University of Waterloo, verbal communication with W. A. Bond, April, 1978) reported angling grayling from the area just downstream of the mouth of Hartley Creek (Site 4) throughout the summer of 1977 as well as in Hartley Creek itself (Site 7) and at Site 3 (Figure 2) on the Muskeg River. Dr. Barton stated that most grayling occurred in areas where water up to 1 m deep flowed with a moderate current over beds of macrophytes and sand. Within the canyon portion of the Muskeg River, most grayling were found near the upstream ends of pools, just below riffles. Grayling were never observed in the Muskeg River upstream of Hartley Creek. Grayling were still abundant in the Muskeg River on 1 October 1977, when anglers captured 28 fish at Site 3 (Figure 2). These fish had a mean fork length of 308.9 mm, ranging from 225 to 355 mm.

The situation in the Muskeg River is probably similar to that described by Machniak and Bond (in prep.) in the adjacent Steepbank River. In that tributary an upstream run of Arctic grayling took place in April and May. The grayling remained in the tributary through the summer, returning to the Athabasca River between 6 and 15 October, just prior to freeze-up.

AOSERP fishery crews working on the Athabasca River captured few grayling during the summer, but reported fish showing up in their catches between 6 and 20 October 1977 (Bond and Berry in prep.b). Jones et al. (1978) took 25 grayling during their study on the Athabasca River upstream of Fort McMurray, but none was captured prior to mid-October.

Although a fence operation was not possible during autumn 1978, a limited amount of angling was conducted in the lower 5 km of the Muskeg River between 25 September and 13 October in an attempt to verify the presence of large grayling. During this period the overnight low water temperature decreased from 6.7 to 3.9°C, but these temperatures were warmer than those recorded at the time of the downstream grayling run in the Steepbank River (Machniak and Bond in prep.). Two grayling, a male and female measuring 385 and 360 mm respectively in fork length, were captured on 30 September. Another male (342 mm) and female (328 mm) were captured on 13 October. The 1978 grayling migration out of the Muskeg River probably took place between 15 October and freeze-up, which occurred on 5 November (Figure 8).

5.4.3.5 Age and growth. Growth of Arctic grayling in the Muskeg River is described in detail by Bond and Machniak (1977). Additional growth information gathered in 1977 is presented in Tables 28 and 29. Muskeg River grayling have almost identical growth patterns to those reported for populations in southern tributaries of the Athabasca River (Ward 1951) and in other tributaries of the AOSERP study area (Griffiths 1973; Machniak and Bond in prep.).

Muskeg River grayling grew at a rate similar to that reported for grayling from Great Bear Lake (Falk and Dahlke 1974), Great Slave Lake (Bishop 1967), and the Mackenzie River (Hatfield et al. 1972) for their first year or two, but thereafter, they grew more slowly than the lake populations but faster than Mackenzie River fish (Figure 21). Grayling from the Muskeg River grew considerably faster than those from the Kavik River (Craig and Poulin 1975).

The maximum scale age recorded for Arctic grayling in the Muskeg River is seven years (Bond and Machniak 1977). This was also the maximum age observed in the Steepbank River (Machniak and Bond in prep.). The oldest grayling reported to date from the AOSERP study area is a 12 year old male, aged from otoliths (Jones et al. 1978). Grayling appear to live longer in the northern

Table 28. Age-length relationship (derived from scales) and age-weight relationship for mountain whitefish and Arctic grayling captured in the Muskeg River, 1977, sexes combined (includes unsexed fish).

Age	Fork Length (mm)			Weight (g)			Male	Female	Total
	Mean	S.D.	Range	Mean	S.D.	Range			
Arctic grayling									
2	204.8	14.19	175-231	91.2	18.67	60-140	7	9	17
3	251.0	4.85	247-258	182.0	44.94	140-240	2	2	5
4	312.5	13.44	303-322	330.0	42.43	300-360	1	1	2
Totals							10	12	24
Mountain whitefish									
3	245.3	16.86	226-257	173.3	46.19	120-200	2	1	3
5	342.4	11.04	327-358	551.4	43.66	475-600	2	5	7
6	368.5	7.05	364-379	580.0	59.44	510-650	1	2	4
7	392.0			1000.0			0	1	1
Totals							5	9	15

Table 29. Size and weight relationships for young-of-the-year and juveniles of larger fish species collected from the Muskeg River, 1977.

Species/Age	Fork Length (mm)			Weight (g)			Total
	Mean	S.D.	Range	Mean	S.D.	Range	
Yellow perch							
0+ (July-Aug.)	39.2	6.62	23-49	0.7	0.30	0.2-1.2	33
Arctic grayling							
0+ (June)	23.4	4.50	18-38	0.1	0.10	0.1-0.5	17
(July)	79.0			3.6			1
(Aug.)	89.0			8.0			1
Lake whitefish							
0+ (June-July)	29.5	4.99	24-38	0.3	0.15	0.1-0.5	16
Northern pike							
0+ (June)	26.5	4.95	23-30	0.2	0.00		2
(July)	107.0	15.56	96-118	6.9	1.20	6.0-7.7	2
(Aug.)	126.0	4.24	123-129	14.0	2.12	12.5-15.5	2
1+ (May)	167.0			34.0			1
Burbot [a]							
0+ (July)	54.0			0.8			1
1+ (May)	107.5	3.54	105-110	7.0	0.42	6.7-7.3	1

[a] Total length.

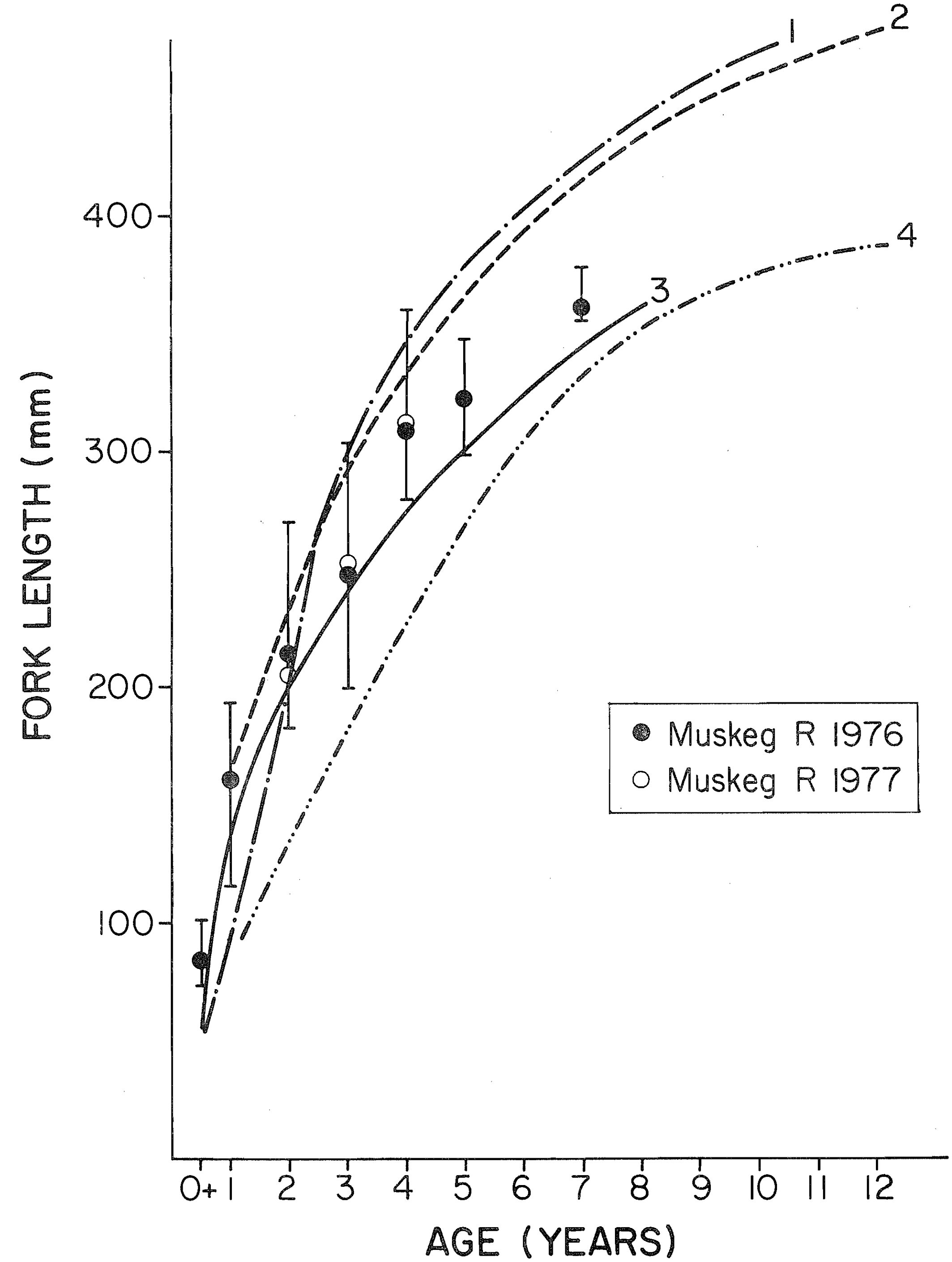

Figure 21. Growth in fork length for Arctic grayling from the Muskeg River and from several other areas. 1. Great Bear Lake (Falk and Dahlke 1974); 2. Great Slave Lake (Bishop 1967); 3. Mackenzie River (Hatfield et al. 1972); 4. Kavik River (Craig and Poulin 1975). Circles represent means and vertical lines the ranges in fork length within age groups for Muskeg River fish.

part of their range than in the south. A maximum scale age of 12 years is reported from Great Slave Lake (Bishop 1967) and Great Bear Lake (Falk and Dahlke 1974). Craig and Poulin (1975) recorded an otolith age of 22 years in the Firth River, Yukon Territory.

5.3.4.6 Length-weight relationship. Comparison of length-weight relationships in 1976 indicated no significant difference ($P > 0.05$) between the regressions for male and female grayling from the Muskeg River and the data for the two sexes were combined (Bond and Machniak 1977).

Length and weight data are available for only 24 grayling from the 1977 study ($r = 0.971$, range 175 to 322 mm). The mathematical relationship between fork length and body weight for this sample is expressed by the equation:

$$\log_{10}W = 3.098\,(\log_{10}L) - 5.203;\ sb = 0.162$$

5.4.3.7 Sex and maturity. Sex and age were determined for only 22 Arctic grayling in 1977, of which 10 were males (Table 28). Males accounted for 62% of the sample in 1976 (Bond and Machniak 1977).

Bond and Machniak (1977) reported that, for Muskeg River grayling, the earliest age of sexual maturity was two years for males, three years for females, and that 50% of both sexes were mature at age three. By age four virtually all grayling were sexually mature. Similar findings were reported by Ward (1951) and Machniak and Bond (in prep.). Craig and Poulin (1975) reported that grayling in Alaska reached sexual maturity between age five and age eight, the oldest age of maturity for grayling in North America.

5.4.3.8 Fecundity. Total egg counts were performed on two Muskeg River grayling in 1976 (Bond and Machniak 1977). One fish (fork length 225 mm) contained 2719 ova, while the other (fork length 308 mm) contained 6971 eggs. Fecundity in Steepbank River grayling varied from 2206 to 8546 (mean 4.689) for seven fish ranging in fork length from 275 to 365 mm (Machniak and Bond in prep.). The average fecundity for this species is probably between 4000 and 7000 (Scott and Crossman 1973), although counts on individual fish have ranged from 574 (Ward 1951) to 15 907 (Bishop 1971).

5.4.3.9 Food habits. Studies of the food habits of Arctic grayling indicate that this species is extremely opportunistic, feeding on a great variety of food items. Many authors have stressed the importance of aquatic insects in the diet (Kruse 1959; Bishop 1967; Reed 1964), while others (Miller 1946; Rawson 1950; Wojcik 1955; Schallock 1966) have found terrestrial insects to make up a large proportion of the food. Fish, fish eggs, lemmings, and amphipods have also been found in grayling stomachs (Miller 1946; Reed 1964; McPhail and Lindsey 1970).

Sixty grayling stomachs were examined in the field during 1976 of which only 10 were empty (Bond and Machniak 1977). Most were one-quarter to one-half full, the contents consisting mainly of aquatic insects. During 1977, 21 additional stomachs were examined in the field, of which only one, a ripe female, contained no food. The remaining stomachs were one-half full to full, the principle food being aquatic insects of the orders Trichoptera, Plecoptera, Odonata and Hemiptera.

The stomach contents of 20 adult grayling were examined in more detail in the laboratory. The results of this analysis (Table 30) showed that aquatic insects occurred in all stomachs examined, with immature stages of the orders Diptera, Plecoptera, Trichoptera, Hymenoptera, and Odonata accounting for most of the food.

The stomachs of four adult grayling captured from the Muskeg River in September and October 1978 were gorged with Plecoptera nymphs and Corixidae adults, and also contained small numbers of Trichoptera and Diptera larvae, Odonata nymphs, and Coleoptera adults.

The stomachs of young-of-the-year grayling also contained mostly immature insects (Table 30) (Bond and Machniak

Table 30. Food habits of Arctic grayling collected from the Muskeg River during 1976 and 1977.

Food Items	May (1976/77)			July (1976)			August (1976)			Y-O-Y (1977)	
	% Freq.[a]	% No.	% Vol.	% Freq.[a]	% No.	% Vol.	% Freq.[a]	% No.	% Vol.	% Freq.[a]	% No.
Class Insecta											
Diptera											
Chironomidae											
larvae	0.0	0.0	0.0	0.0	0.0	0.0	26.7	5.6	0.8	33.3	40.9
pupae	0.0	0.0	0.0	0.0	0.0	0.0	13.3	9.9	0.7	33.3	11.4
Unidentified Dipterans											
larvae	66.7	25.4	4.8	0.0	0.0	0.0	86.7	36.0	11.0	33.3	4.5
adults	0.0	0.0	0.0	0.0	0.0	0.0	6.7	1.2	0.1	0.0	0.0
Trichoptera	33.3	31.7	4.3	0.0	0.0	0.0	40.0	13.7	4.6	16.7	2.3
Plecoptera	100.0	19.1	41.8	0.0	0.0	0.0	60.0	14.3	14.5	33.3	22.7
Coleoptera	0.0	0.0	0.0	100.0	66.7	20.2	6.7	0.6	0.6	0.0	0.0
Hemiptera	0.0	0.0	0.0	0.0	0.0	0.0	13.3	2.5	1.5	16.7	2.3
Corixidae	33.3	3.2	2.1	0.0	0.0	0.0	6.7	0.6	0.3	0.0	0.0
Notonectidae	33.3	3.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hymenoptera											
Formicidae	33.3	1.6	1.1	50.0	16.7	4.2	40.0	6.2	2.6	0.0	0.0
Odonata	66.7	9.5	37.9	0.0	0.0	0.0	26.7	7.5	3.7	16.7	2.3
Lepidoptera	33.3	1.6	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeroptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	13.6
Insect Remains	0.0	0.0	0.0	0.0	0.0	0.0	73.3	0.0	35.9	16.7	0.0
Miscellaneous											
Arachnida	100.0	6.3	2.6	50.0	16.7	8.4	13.3	1.2	2.2	0.0	0.0
Vegetation (algae, seeds)	0.0	ND	ND	0.0	ND	ND	6.7	ND	3.7	16.7	ND
Fish	0.0	0.0	ND	0.0	0.0	ND	6.7	0.6	9.3	0.0	ND
Digested Matter	0.0	ND	ND	0.0	ND	ND	13.3	ND	7.4	16.7	ND
Debris (sticks, stones)	0.0	ND	ND	50.0	ND	67.2	6.7	ND	0.6	16.7	ND
Number of stomachs	3			2			15			6	
Empty (% of Total)	0			0			0			0	

[a] Percentage frequency of occurrence, based on stomachs that contained food.

1977). Scott and Crossman (1973) state that young grayling initially feed on zooplankton but undergo a shift to immature insects as they increase in size.

5.4.3.10 Rearing areas. The entire lower 35 km of the Muskeg River, and the lower 10 km of Hartley Creek are utilized as rearing areas by Arctic grayling. Many young-of-the-year were observed throughout the summer of 1977 in the area just downstream from Hartley Creek as well as near Site 3 (Figure 2). As mentioned previously, fry were captured at Site 7 as well as at Sites 2 and 3 during both summers. In the canyon section of the Muskeg River, approximately 6 to 8 km upstream from the mouth of the tributary, many young-of-the-year were observed on 10 August 1976. These small fish occupied long shallow pools where a moderate current flowed over a very uniform gravel bottom.

5.4.3.11 Overwintering. We believe, for several reasons, based on our observations on the Muskeg and Steepbank rivers, that young-of-the-year grayling in both streams remain in the tributaries over their first winter, and do not join the migrant population until the autumn of their second year. Firstly, despite intensive sampling with small mesh beach seines, few young-of-the-year grayling have been captured in the Athabasca River within the AOSERP study area (Bond and Berry in prep.a, in prep.b). Secondly, upstream grayling runs in the Muskeg River in 1976 and 1977 and in the Steepbank River in 1977 (Machniak and Bond in prep.) included no one year old fish. Although such fish could pass through the 2.54 x 2.54 cm mesh used in the fence, some, had they been present, would have been captured, if not in the fence at least by seines or minnow traps. Thirdly, the downstream migration in the Steepbank River in October 1977 (Machniak and Bond in prep.) included fish in the 130 to 230 mm size range that are thought to have been age 1+ fish. These small fish were the last to leave the Steepbank River. Lastly, D. Barton (University of Waterloo, verbal communication with W. A. Bond, December 1976) reported sighting six to 10 juvenile grayling through the ice at Site 7 Hartley

Creek, on 30 October 1976. Overwintering within the tributaries would appear to enhance the survival chances of young fish which would not be exposed to the rigors of migration or to predation by piscivorous fish. Migrant grayling (age 1+ and older) probably overwinter in the Athabasca or Clearwater rivers upstream of Fort McMurray.

5.4.4 Northern Pike

5.4.4.1 Movements and distribution. A total of 433 northern pike were passed through the upstream trap of the 1977 Muskeg River counting fence (Table 8, Figure 22). The majority of pike (76.4%) passed the fence between 30 April and 12 May, during which period the daily maximum water temperature increased from 5 to 14°C. Pike demonstrated a pronounced diel periodicity during their upstream run as 62% of those captured through 12 May were taken between 1200 and 2100 h, the largest movements occurring after 1500 h. Franklin and Smith (1963) reported that pike began moving into spawning streams or flooded marshes at water temperatures of 1 to 4.5°C, and that most movement takes place at night. This represents a sharp contrast to the situation observed in the Muskeg River.

By 15 June, 59 pike had moved through the downstream trap, leaving 374 still upstream of the counting fence. Pike continued passing through the downstream trap through 30 July 1976 (Bond and Machniak 1977). During the summer months, northern pike seem to be confined largely to the lower reaches and mouth area of the Muskeg River, although individual fish may ascend the tributary for considerable distances. Angling results in 1976 suggested that most pike do not ascend more than 6 or 7 km upstream (Bond and Machniak 1977). However, in 1977, "quite a few" pike were angled in the vicinity of small fish collection Site 3 (13 km upstream)(Dr. D. Barton, University of Waterloo, verbal communication with W. A. Bond, April 1978). One young-of-the-year 96 mm in fork length, was captured in a seine at Site 4 (Figure 2) on 18 July 1977.

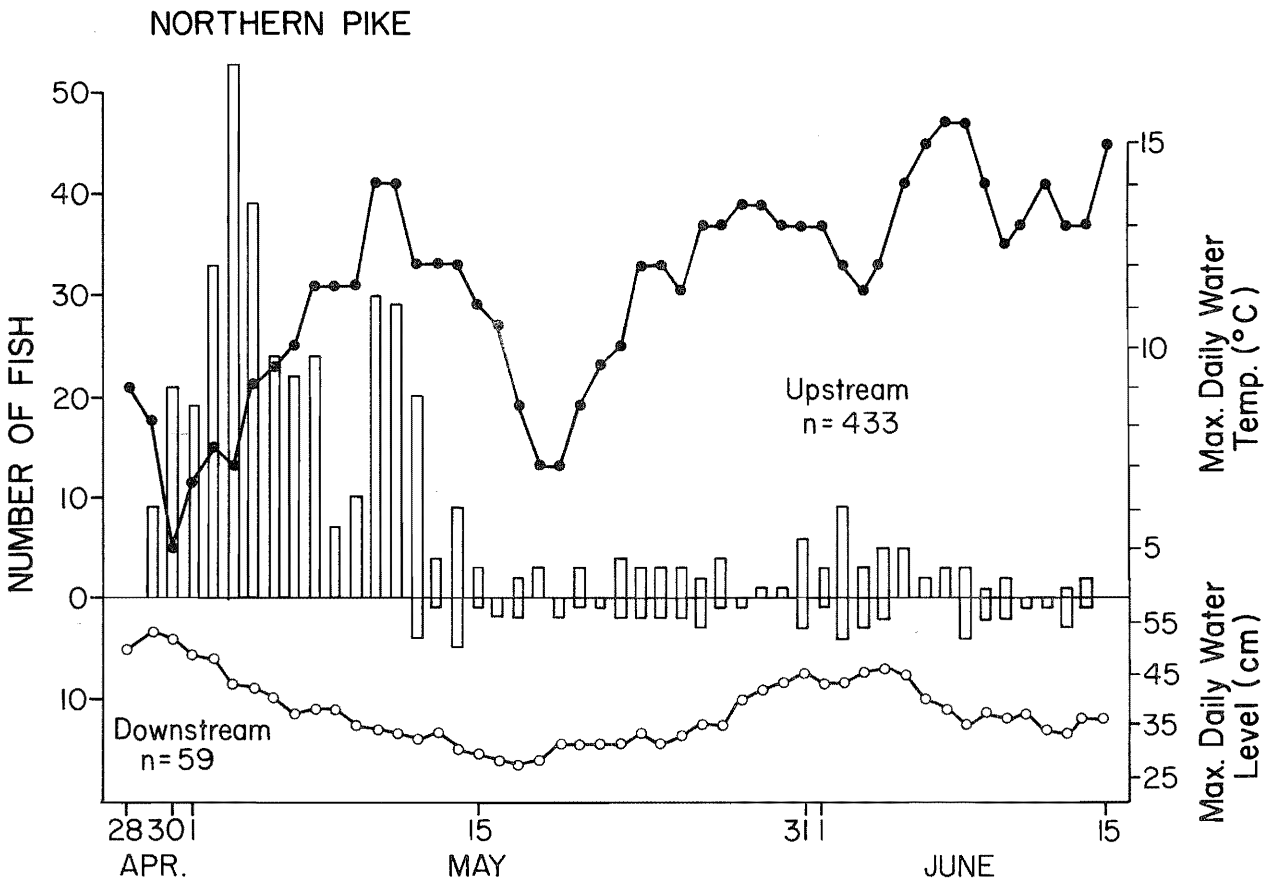

Figure 22. Seasonal timing of the northern pike migration in the Muskeg River, 1977.

Although there is no direct evidence, most pike probably left the Muskeg River before freeze-up to overwinter in the Athabasca River. Most pike in the Steepbank River had apparently left that stream during the summer, and 42 fish were were captured moving out of the watershed during September and October (Machniak and Bond in prep.).

Within the AOSERP study area, northern pike appear to move around very little. Tagging results from the present study (Bond and Machniak 1977)(Appendix 8.2) show that most pike recaptured outside the Muskeg River watershed had travelled less than 20 km from the point of tagging. Similar results were obtained by Machniak and Bond (in prep.) and Bond and Berry (in prep.a, in prep.b).

5.4.4.2 Spawning. Northern pike usually spawn in April and early May immediately after ice breakup at water temperatures of 4.4 to 11.1°C (Scott and Crossman 1973). While pike may spawn in a variety of habitats, a requirement of the spawning site appears to be the presence of vegetation (Machniak 1975). Marshes or marsh-like conditions along small streams seem to be preferred areas. Such areas are uncommon in the Muskeg River and it is felt that any spawning that does occur in this tributary is minor. This belief is supported by the fact that most of the pike passed through the upstream trap are thought to have been immature or maturing fish that would not have spawned in 1977. Of 40 fish whose gonads were inspected, only four were ripe. Machniak and Bond (in prep.) also reported many immature and spent fish in the Steepbank River migration.

Despite its probable minor nature, some northern pike spawning apparently does occur in the Muskeg River. Two small young-of-the-year pike (23 and 30 mm) were captured on 12 June 1977 approximately 0.5 km downstream of the fence site. Four others (96 to 129 mm) were captured in the Muskeg River between 18 July and 13 August, one of which was taken at Site 4 (Figure 2). Four pike fry were captured on 22 June 1978 near the upper part of the canyon, approximately 9 km upstream from the mouth of the tributary.

Bond and Berry (in prep.b) captured ripe pike in the Athabasca River from 27 April to 9 May 1977, and spent fish from 7 May on. Young-of-the-year measuring 19 to 36 mm were captured between 16 and 18 June.

5.4.4.3 Length-frequency distribution. Pike captured during the 1977 upstream run in the Muskeg River ranged in fork length from 244 to 788 mm, with the majority (86.3%) being in the 300 to 524 mm size range (Figure 23). Male pike varied from 244 to 565 mm while females had fork lengths between 330 and 788 mm. Fish less than 400 mm in fork length made up 59.2% of the total sample, whereas in the Steepbank River, 66.7% of all pike measured exceeded 400 mm fork length (Machniak and Bond in prep.).

5.4.4.4 Age and growth. Northern pike examined during 1977 ranged in age from 0+ to seven years, with most fish (75.0%) being three to five inclusive. Seven was also the maximum age reported during the 1976 study (Bond and Machniak 1977). The maximum age reported for pike in the AOSERP study area is 13 years (McCart et al. 1977).

Pike increased in fork length at a constant rate throughout life. Females tended to be longer than males of the same age with significant differences ($P < 0.05$) occurring in age groups 3, 4, and 5 (Table 31). The growth rate of northern pike compares favourably with that reported in previous studies on pike in the AOSERP study area (Griffiths 1973; McCart et al. 1977; Machniak and Bond in prep.; Bond and Berry in prep.a, in prep.b; Jones et al. 1978). Muskeg River pike grew more rapidly than those from Lake Athabasca and Great Bear Lake (Miller and Kennedy 1948) and the Kakisa River (Falk and Dahlke 1975), but slower than was reported by Pinsent (1967) for pike from Beaver Lake, Alberta (Figure 24).

Northern pike gained weight slowly up to age 3, but more rapidly thereafter. Female pike were significantly heavier ($P > 0.05$) than males in age groups 4 and 5 (Table 32).

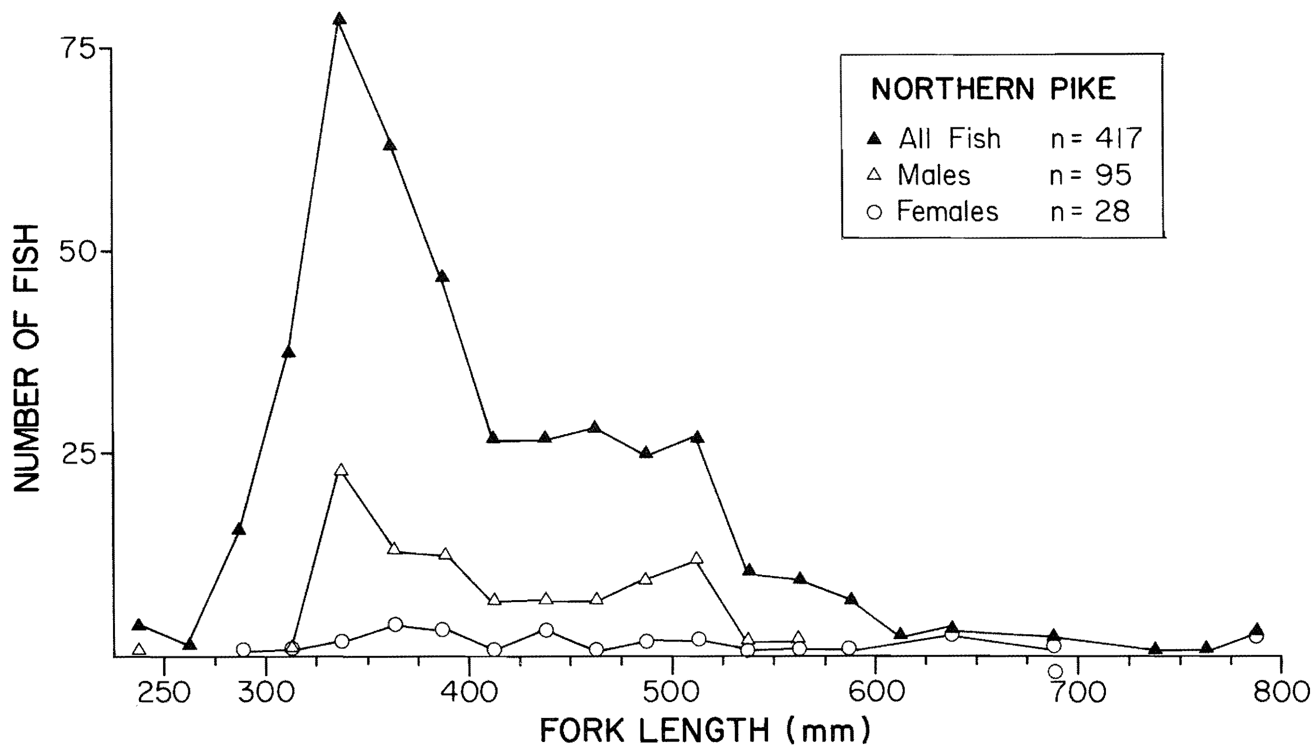

Figure 23. Length-frequency distribution for northern pike during the upstream migration in the Muskeg River, 1977.

Table 31. Age-length relationship (derived from scales) for northern pike captured in the Muskeg River, 1977, sexes separate and combined sample (includes unsexed fish).

Age	Males				Females				All Fish				t-test
	N	Mean	S.D.	Range	N	Mean	S.D.	Range	N	Mean	S.D.	Range	
0+	1	129.0			1	123.0			6	86.5	47.84	23-129	
1	0				1	167.0			1	167.0			
2	0				2	275.0	26.87	256-294	2	275.0	26.87	256-294	
3	13	337.4	14.78	315-364	9	352.1	19.76	320-378	23	342.7	18.08	315-378	2.000[a]
4	6	384.2	28.74	356-434	5	428.8	26.39	395-469	11	404.5	35.14	356-469	2.657[a]
5	8	469.9	16.92	442-497	6	524.7	45.13	448-560	14	493.4	41.58	442-560	3.184[a]
6	1	522.0			1	599.0			2	560.5	54.45	522-599	
7	0				1	648.0			1	648.0			
Totals	29				26				60				

[a] Indicates significant difference between means for males and females (Student's t-test, $P < 0.05$).

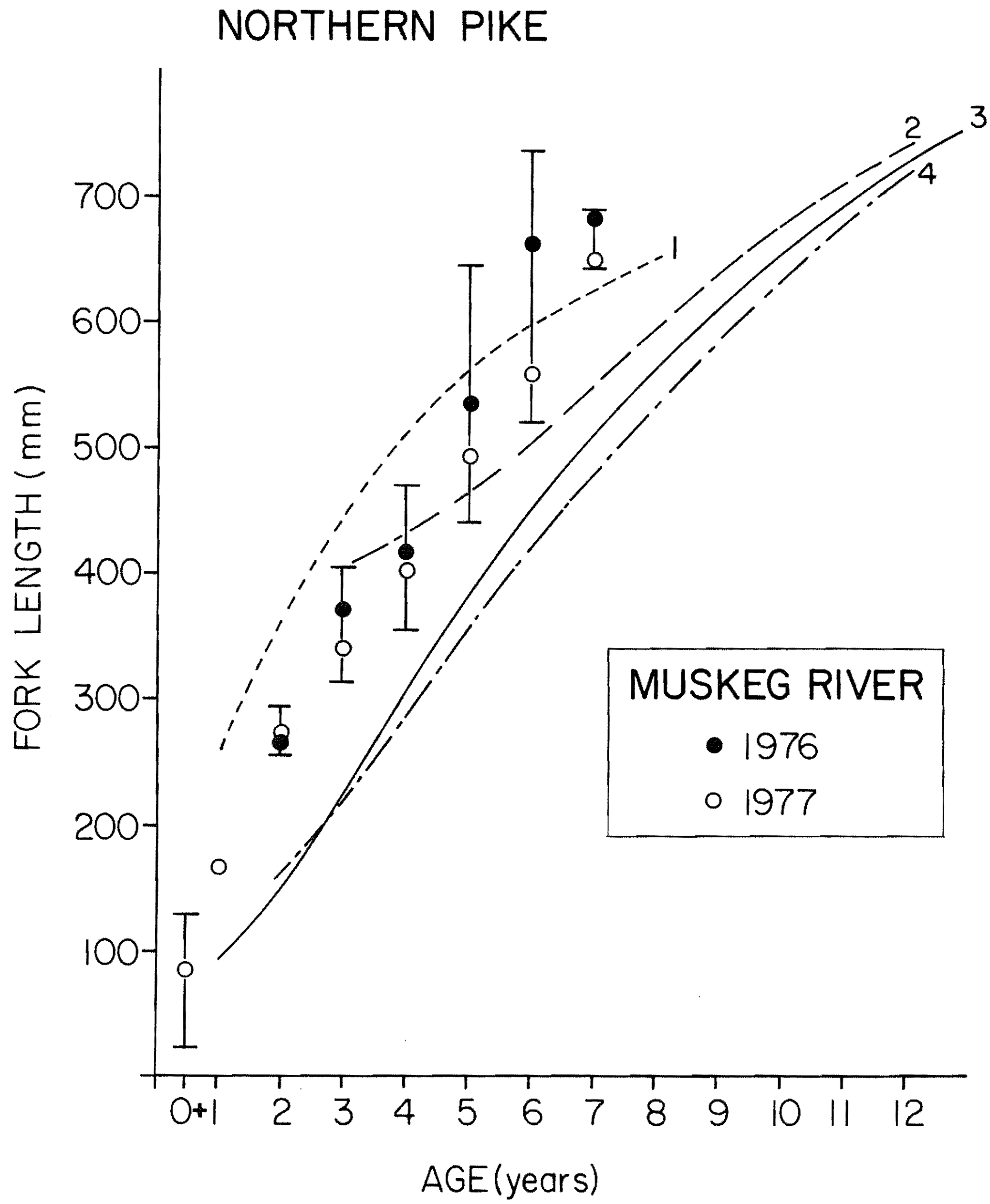

Figure 24. Growth in fork length for northern pike from the Muskeg River and from several other areas. 1. Beaver Lake, Alta. (Pinsent 1967); 2. Kakisa River, N.W.T. (Falk and Dahlke 1975); 3. Lake Athabasca, Alta. (Miller and Kennedy 1948); and 4. Great Bear Lake, N.W.T. (Miller and Kennedy 1948). Circles represent means and vertical lines the ranges in fork length within age groups for Muskeg River fish.

Table 32. Age-weight relationship for northern pike captured in the Muskeg River, 1977, sexes separate and combined sample (includes unsexed fish).

Age	Males				Females				All Fish				t-test
	N	Mean	S.D.	Range	N	Mean	S.D.	Range	N	Mean	S.D.	Range	
0+	1	15.5			1	12.5			6	7.0	6.27	0.2-15.5	
1	0				1	34.0			1	34.0			
2	0				2	205.0	134.35		2	205.0	134.35	110-300	
3	13	263.8	47.18	180-340	9	280.0	50.25	220-370	23	267.8	48.52	180-370	0.771
4	6	396.7	79.41	340-540	5	544.0	109.91	420-720	11	463.6	117.92	340-720	2.583[a]
5	8	713.8	111.73	600-860	6	916.7	177.16	700-1160	14	800.7	172.20	600-1160	2.633[a]
6	1	1320.0			1	1220.0			2	1270.0	70.71	1220-1320	
7	0				1	2330.0			1	2330.0			
Totals	29				26				60				

[a] Indicates significant difference between means for males and females (Student's t-test, $P < 0.05$).

Growth data for young-of-the-year pike are presented in Table 29. Two fish, captured 12 June, measured 23 and 30 mm in fork length, two taken in July had lengths of 96 and 118 mm, while two pike caught in August measured 123 and 129 mm. A one year old pike captured 3 May 1977 had a fork length of 167 mm. Bond and Berry (in prep.b) reported young-of-the-year pike to range in fork length from 19 to 36 mm in mid-June, from 39 to 44 mm at the end of June, and to reach a maximum size of 185 mm and 41.6 g by mid-October.

5.4.4.5 Length-weight relationship. For male northern pike taken from the Muskeg River in 1977 (n = 30, r = 0.973, range 129 to 522 mm), the length-weight relationship is described by the equation:

$$\log_{10}W = 3.084\,(\log_{10}L) - 5.372;\ sb = 0.444$$

The corresponding equation for female pike (n = 26, r = 0.986, range 123 to 648 mm) is:

$$\log_{10}W = 2.899\,(\log_{10}L) - 4.913;\ sb = 0.099$$

No significant difference was found between the slopes of the regression lines (F = 0.905) for male and female pike.

5.4.4.6 Sex and maturity. Age and sex were determined by by gonadal inspection for 55 pike of which 29 (53%) were males (Table 33). Bond and Berry (in prep.a) found that male and female pike in the Athabasca River occurred in equal numbers, while Jones et al. (in prep.) reported female pike (58%) outnumbered males in late fall.

Both sexes appear to achieve sexual maturity for the first time at age 3 (Table 33). Over two years, 22% of females and 33% of males were mature at this age. The earliest age of sexual maturity for pike in the Steepbank River was three years for males and four years for females while Bond and Berry (in prep.a, in prep.b) reported that some pike in the Athabasca River may spawn at age 2.

5.4.4.7 Fecundity. Total egg counts were performed for two northern pike captured at the Muskeg River counting fence in 1977.

Table 33. Age-specific sex ratios and maturity for northern pike from the Muskeg River, 1977. Sex ratios were based only on fish for which sex was determined.

Age	Females			Males			Unsexed Fish	Total
	N	%	% Mature	N	%	% Mature		
0+	1	50	0	1	50	0	4	6
1	1	100	0	0	0	0	0	1
2	2	100	0	0	0	0	0	2
3	9	41	22	13	59	46	1	23
4	5	45	60	6	55	83	0	11
5	6	43	83	8	57	100	0	14
6	1	50	100	1	50	100	0	2
7	1	100	100	0	0	0	0	1
Totals	26	47%		29	53%		5	60

One fish (fork length 599 mm) contained 26 155 eggs while the other (648 mm) had 36 763 (Table 34). Bond and Berry (in prep.b) reported pike from the Athabasca River (544 to 656 mm fork length) to have an average fecundity of 28 896 eggs per female (range 17 764 to 42 962). Fecundities reported for Athabasca River pike by McCart et al. (1977) ranged from 20 267 to 53 295 with a mean of 32 452 eggs per female (fork length 528 to 710 mm).

5.4.4.8 Food habits. During 1977, the stomachs of 42 northern pike were examined in the field, of which 25 (59.5%) contained no food. The remaining stomachs all contained fish, the food species including white sucker, burbot, brook stickleback, Arctic grayling, and northern pike. Bond and Berry (in prep.b) also report AOSERP area pike to be mainly piscivorous with the major food species being flathead chub, suckers, and trout-perch. These authors determined that insects, Plecoptera, Odonata and Lepidoptera accounted for 1.4% of the food volume, while frogs and mice made up 4.1%. Jones et al. (1978) found remains of rodents in 5% of the stomachs they examined. Young-of-the-year pike from the Muskeg River (Table 18) had fed mainly on Ephemeroptera nymphs and fish, including white suckers, longnose suckers, and cyprinids.

5.4.4.9 Rearing and overwintering. Some pike do utilize the Muskeg River for rearing purposes as small numbers of young-of-the-year were captured in 1977 and 1978. These small fish were taken in quiet, weedy areas along the stream margin, out of the main current. One such area was found to be near the top of the canyon, 9 km upstream of the river mouth, while another was a side slough situated approximately 0.5 km downstream of the fence site.

Whether or not northern pike overwinter in the Muskeg River is unknown. It is believed, however, that the larger pike that participated in the spring upstream migration left the tributary prior to freeze-up to overwinter in the Athabasca River.

Table 34. Actual egg counts of two northern pike females sampled during the 1977 spawning period, Muskeg River.

Fork Length (mm)	Weight (g)	Number of Eggs			Relative Fecundity	
		Left Ovary	Right Ovary	Total	(cm)	(g)
599	1220	11 483	14 672	26 155	436.6	21.4
648	2330	18 613	18 150	36 763	567.3	15.8

5.4.5 Mountain Whitefish

5.4.5.1 Spring movements and distribution. Approximately 50 mountain whitefish were counted through the upstream trap in 1977, with 68.4% of them passing the fence prior to 14 May (Table 8). Seventeen mountain whitefish had returned downstream by 15 June. During the 1976 study, only 33 mountain whitefish were captured moving upstream, but 101 were taken in the downstream trap (Bond and Machniak 1977). The suggestion was that mountain whitefish did not spend the summer in the Muskeg River but returned to the Athabasca River. The 1977 fence was not operated long enough to detect such a downstream run in the second year. In the Steepbank River, a spring run of mountain whitefish had not returned downstream by 29 May (Machniak and Bond in prep.). The counting fence in that study was not operated during the summer but a fall operation failed to detect any downstream movement of whitefish between 12 September and 15 October. Whether mountain whitefish left the Steepbank River during the summer or remained in the tributary beyond 15 October was unknown.

Davies and Thompson (1976) observed a complex movement pattern for mountain whitefish in the Sheep River, Alberta, involving spring feeding, summer feeding, prespawning, spawning, and post-spawning-overwintering movements. They found that whitefish enter tributaries during the spring to feed and leave in June, returning to the larger rivers when water levels decline and water temperatures rise in the smaller tributaries. A similar pattern of movement may also occur in the AOSERP study area, although it should be noted that some stream-dwelling populations remain in tributaries all summer. In Idaho, mountain whitefish are reported to move into tributaries during late spring and early summer, remain in the upper reaches until spawning in November, and then return to the large rivers to overwinter (Pettit and Wallace 1975).

The locations occupied by mountain whitefish in the Muskeg River are unknown as no specimens were captured in the watershed during the present study apart from those taken at the counting fence. Shell (1975) reported capturing no mature mountain whitefish in the Muskeg River during their study, although eight juvenile fish were taken in Hartley Creek during August 1974.

5.4.5.2 Spawning. Mountain whitefish usually spawn in October and early November, the young hatching about March (Paetz and Nelson 1970). No young-of-the-year mountain whitefish were taken in the Muskeg River in 1976 or 1977, and spawning is not believed to occur in the tributary. Machniak and Bond (in prep.) found no evidence that this species spawns in the Steepbank River. Griffiths (1973), however, reported finding large numbers of young-of-the-year mountain whitefish in the High Hill River as well as the Clearwater River in late August and September. Tripp and McCart (in prep.) located young-of-the-year mountain whitefish at the mouths of tributary streams in the Athabasca River upstream of the Cascade Rapids.

5.4.5.3 Length-frequency distribution. Mountain whitefish captured in the upstream trap in 1977 varied in fork length from 198 to 395 mm with the majority (57%) being in the 320 to 379 mm size range (Figure 25).

5.4.5.4 Age and growth. During 1977, only 15 mountain whitefish were sacrificed for biological analysis (Table 28). These fish ranged in age up to seven years, which appears to be the maximum age for mountain whitefish in the Muskeg River. Machniak and Bond (in prep.) recorded a maximum age of eight years in the Steepbank River. Eight was also the maximum age for stream populations in Montana (Brown 1971) and in the Sheep River, Alberta (Thompson and Davies 1976). Maximum ages reported for lake populations of mountain whitefish are 17 to 18 in Bow Lake, Alberta (McHugh 1942) and 16 in Rock Lake, Alberta (Lane 1969).

The growth rate observed for mountain whitefish from the Muskeg River (Figure 26) was similar to that reported for the Steepbank River (Machniak and Bond in prep.) and ranks among the fastest reported for this species. Stream dwelling mountain

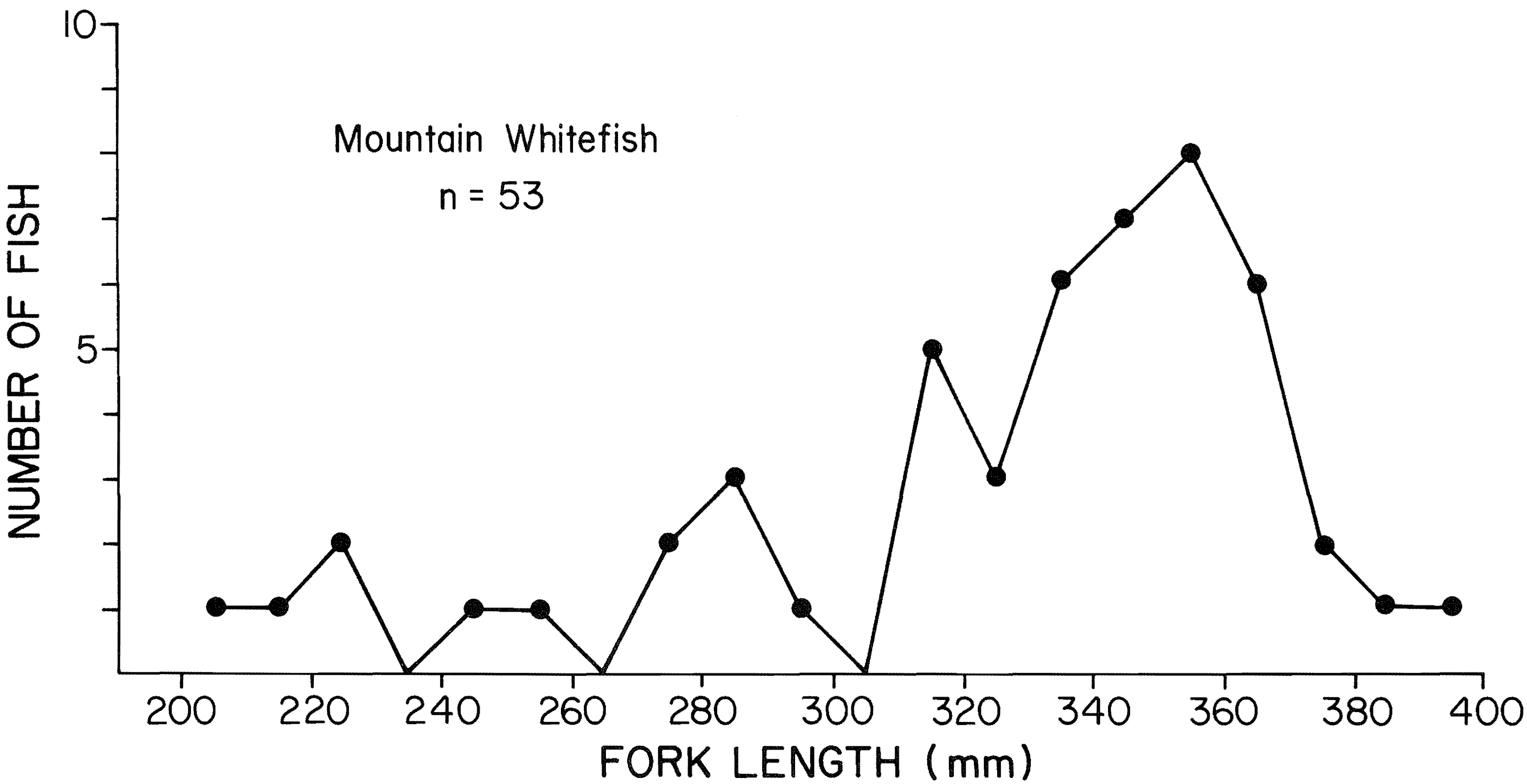

Figure 25. Length-frequency distribution for mountain whitefish during the upstream migration in the Muskeg River, 1977.

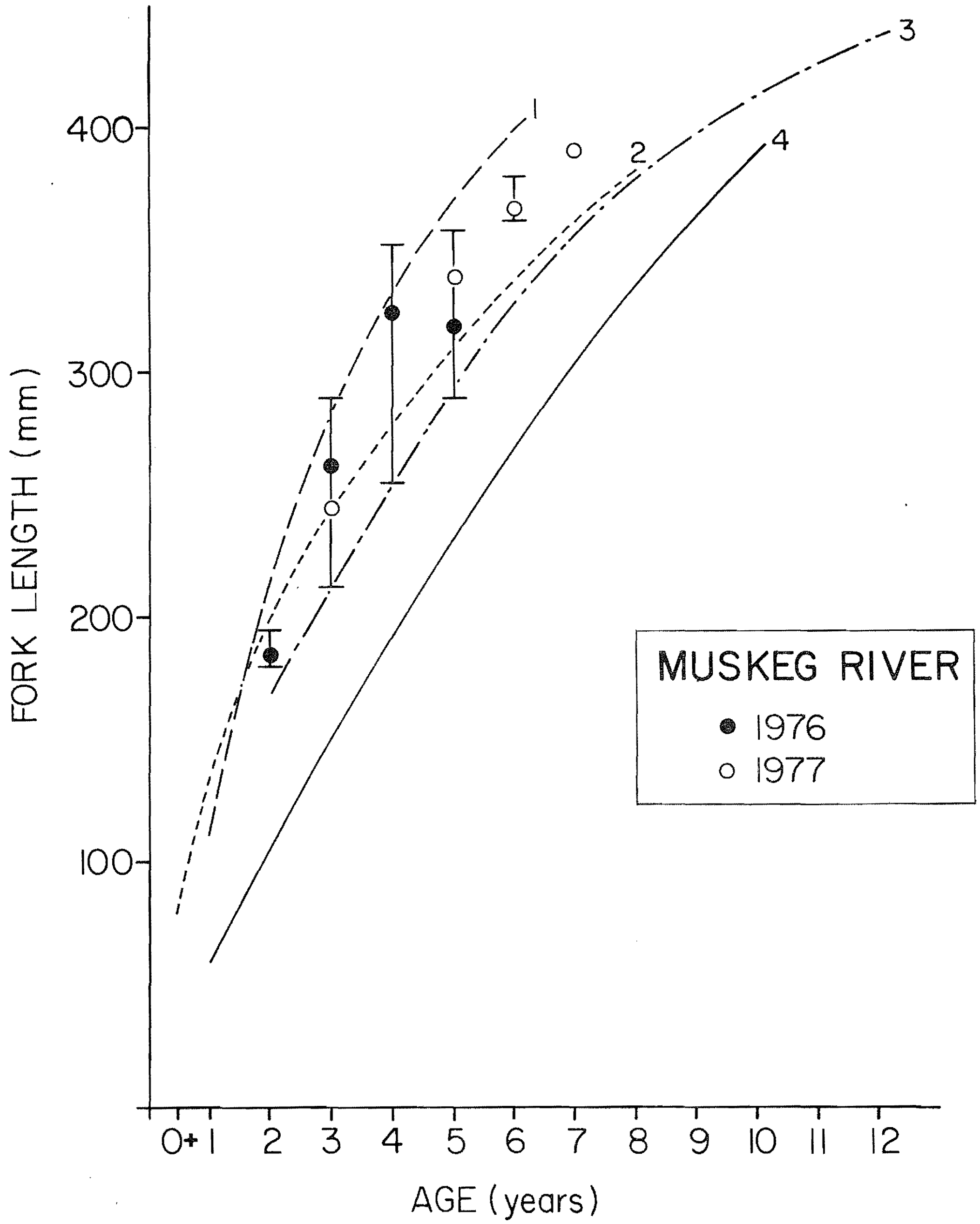

Figure 26. Growth in fork length for mountain whitefish from the Muskeg River and from several other areas. 1. Montana streams (Brown 1971); 2. Sheep River, Alta. (Thompson and Davies 1976); 3. Rock Lake, Alta. (Lane 1969); and 4. Pyramid Lake, Alta. (Rawson and Elsey 1950). Circles represent means and vertical lines the ranges in fork length within age groups for Muskeg River fish.

whitefish (this study; Brown 1971; Thompson and Davies 1976) appear to grow faster than most reported lake populations in Alberta (Lane 1969; Rawson and Elsey 1950) although the latter achieve greater maximum ages.

5.4.5.5 Sex and maturity. Sex was determined for only 14 mountain whitefish in 1977, of which five were males (Table 28). Fish of both sexes appear to reach sexual maturity at age 3 in the Muskeg River (Bond and Machniak 1977). Machniak and Bond (in prep.) reported that, in the Steepbank River, the earliest age of maturity was two years for males and three years for females.

5.4.5.6 Length-weight relationship. Based on 1976 data (Bond and Machniak 1977), the length-weight relationship for Muskeg River mountain whitefish ($n = 23$, $r = 0.977$, range 159 to 353 mm) is described by the equation:

$$\log_{10}W = 2.751\,(\log_{10}L) - 4.301;\ sb = 0.131$$

5.4.5.7 Food habits. Twenty-nine mountain whitefish stomachs were examined in the field during the two years of the study, of which 21 contained no food. The remainder contained traces of insects but only Hemiptera (Corixidae) could be identified. Mountain whitefish are usually reported to be bottom feeders consuming a variety of organisms but mainly immature aquatic insects (Scott and Crossman 1973).

5.4.6 Other Large Fish Species

5.4.6.1 Lake whitefish. Small numbers of lake whitefish were taken at the counting fence in 1976 (Bond and Machniak 1977) and again in 1977 (Table 8). Machniak and Bond (in prep.) also report the movement of small numbers of lake whitefish into the lower Steepbank River during the spring migrations of other species.

No young-of-the-year lake whitefish were reported from the Muskeg River in 1976. During 1977, however, 16 whitefish fry were collected in the lower reaches (Table 6). Fourteen of these fish were collected at Site 2 on 12 and 13 June at a time when the Athabasca River was backed up into the Muskeg River. Whitefish fry ranged in fork length from 24 to 38 mm with a mean of 29.5 mm (Table 19) and had fed mainly on aquatic insects (Table 18).

Lake whitefish are known to migrate through the AOSERP study area in large numbers during late summer and fall (Bond and Berry in prep.a, in prep.b). Spawning occurs below Mountain and Cascade rapids, upstream of Fort McMurray in the Athabasca River (Jones et al. 1978). The mouth of the Muskeg River is known to be used as a resting area by lake whitefish in September during the spawning migration as AOSERP fishery crews, working on the Athabasca River, reported capturing large numbers in the river mouth at that time. There is no evidence, however, that lake whitefish utilize the Muskeg River for spawning purposes. Machniak and Bond (in prep.) reported no fall migration of lake whitefish into the adjacent Steepbank River.

5.4.6.2 Burbot. Only one burbot was captured at the counting fence in 1977 (Table 8) while three were taken during the 1976 operation (Bond and Machniak 1977). One young-of-the-year burbot (total length 54 mm) was seined from Site 2 (Figure 2) on 10 July 1977, while two yearlings (105 and 110 mm) were collected from the same area on 25 and 29 May. During May 1976, three immature burbot were captured in minnow traps at Site 2 (Bond and Machniak 1977).

Bond and Berry (in prep.b) found large burbot to be common in the Athabasca River during the early spring and reported fry appearing in June. They speculated that burbot utilize the Mildred Lake area of the Athabasca River or areas upstream of it for spawning purposes. Recent evidence suggests that burbot may spawn in the Clearwater River (Figure 1) upstream of its junction with the Christina River (Tripp and McCart in prep.).

5.4.6.3 Walleye. Although large numbers of walleye pass through the AOSERP study area in April on their way to spawning grounds (Bond and Berry in prep.a, in prep.b), they do not appear to utilize the Muskeg River for this purpose. Eight walleye were captured in the Muskeg River upstream trap between 10 May and 10 June 1977 while five were taken moving downstream between 12 May and 4 June (Table 8). Small numbers of walleye were also taken during the 1976 fence operation (Bond and Machniak 1977).

Post-spawning movements of immature and spent male walleye have been observed in the Steepbank River (Machniak and Bond in prep.) and the MacKay River (Machniak et al. in prep.).

5.4.6.4 Dolly Varden. Three Dolly Varden were recorded at the upstream trap of the Muskeg River counting fence in 1977 (Table 8). The one fish sampled was an immature, three year old male, with a fork length of 202 mm and a weight of 77.0 g.

Dolly Varden are common in the headwaters of the Peace, Athabasca, Red Deer, Bow, and Oldman drainages (Paetz and Nelson 1970). Their occurrence in the AOSERP area is rare although several were taken in the Steepbank River (Machniak and Bond in prep.) and Athabasca River (Bond and Berry in prep.b) during 1977.

5.4.6.5 Lake cisco. One lake cisco was captured at the upstream trap on 2 May 1977. Cisco are common in lakes of the Birch Mountains (Turner 1968) and lakes in the southern Athabasca River drainage such as Lesser Slave Lake and Lac la Biche (Paetz and Nelson 1970).

5.4.6.6 Yellow perch. A total of 33 young-of-the-year yellow perch were captured at Sites 1 and 2 of the Muskeg River between 18 July and 13 August 1977. These fish ranged in size from 23 to 44 mm and had a mean fork length of 39.2 mm (Table 29). Of 18 fish for which sex was determined, 10 were males. The stomachs of three young-of-the-year perch contained chironomid and Trichoptera larvae and Ephemeroptera nymphs (Table 18).

Perch are thought to have originated from headwater lakes of the Athabasca River drainage and drifted down to the study area. They are commonly found around tributary mouths in the AOSERP study area during July and August (McCart et al. 1977; Bond and Berry in prep.a, in prep.b).

5.4.7 Brook Stickleback

5.4.7.1 Distribution and relative abundance. A total of 308 brook stickleback were collected from the Muskeg River in 1977. Excluding suckers, this species accounted for 48% of all small fish taken (Table 6). Although captured at nine of the small fish collection sites, brook stickleback were particularly abundant in the upper reaches of the watershed. Over two years this species accounted for 84% of all small fish captured upstream of Site 3 (excluding suckers).

5.4.7.2 Age and growth. Brook stickleback, captured from the Muskeg River watershed in 1977, ranged from 15 to 71 mm in total length. However, the length-frequency distribution (Figure 27) varied throughout the summer. Stickleback captured in June were predominantly one year old fish, most of which ranged from 36 to 49 mm in total length. Young-of-the-year first appeared in late June and fish of this age class (15 to 35 mm) made up 83.7% of the total catch during July and August.

Age-length and age-weight relationships (Table 35) are similar to those reported in the 1976 results (Bond and Machniak 1977) and to those presented by Machniak and Bond (in prep.) for brook stickleback from the Steepbank River.

The maximum age recorded for brook stickleback in the Muskeg River is three years. Eight age 3 stickleback were captured during 1976 and 1977 of which only one was a female.

5.4.7.3 Sex and maturity. Female brook stickleback comprised 54% of all fish for which sex was determined (n = 160). However, the sex ratio was not significantly different from unity ($X^2 = 0.90$, $P > 0.05$).

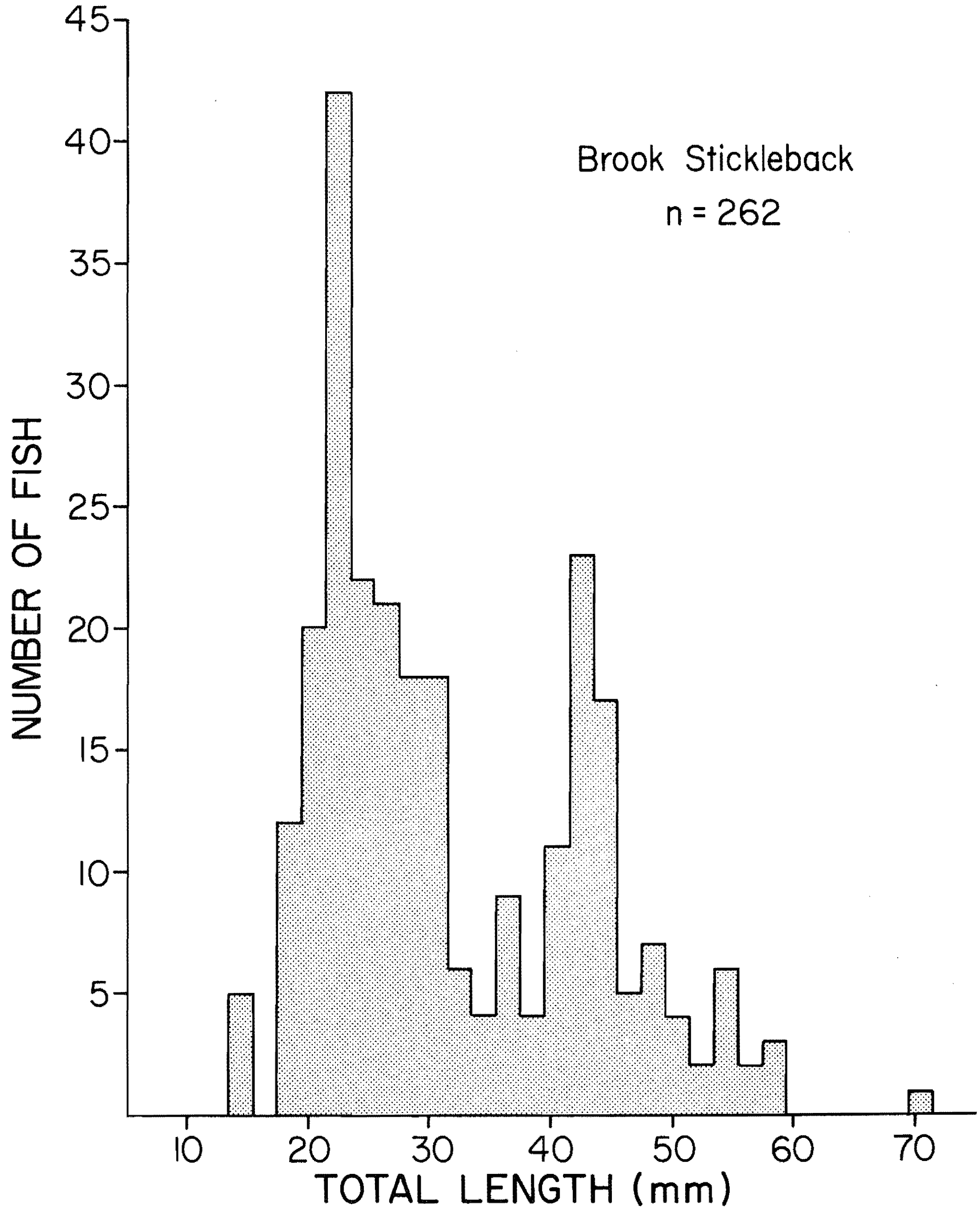

Figure 27. Length-frequency distribution for brook stickleback from the Muskeg River, 1977.

Table 35. Age-length (derived from otoliths) and age-weight relationships, age-specific sex ratios and maturity of small fishes captured in Muskeg River, 1977.

Species/Age	Females			Males			Unsexed Fish	Sample Size	Fork or Total[a] Length (mm)			Weight (g)		
	N	%	% Mature	N	%	% Mature			Mean	S.D.	Range	Mean	S.D.	Range
Brook stickleback[a]														
0+	6	50	0	6	50	0	10	22	25.3	5.80	15-36	0.2	0.13	0.1-0.5
1	14	48	79	15	52	80	2	31	39.3	5.49	29-49	0.6	0.27	0.2-1.3
2	5	33	100	10	67	100	0	15	51.1	4.18	47-58	1.4	0.32	1.2-2.0
3	1	25	100	3	75	100	0	4	60.0	7.62	54-71	2.3	1.22	1.5-4.1
Totals	26			34			12	72						
Lake chub														
0+	2	100	0	0			16	18	28.3	5.39	19-36	0.3	0.16	0.1-0.6
1	13	45	0	16	55	0	3	32	41.1	5.60	33-58	0.7	0.42	0.3-2.4
2	1	100	0	0			1	2	60.0	0.00	70-81	2.2	0.14	2.1-2.3
3	1	50	100	1	50	100	0	2	75.5	7.78		4.3	1.48	3.2-5.3
4	1	100	100	0			0	1	93.0			10.2		
Totals	18			17			20	55						
Slimy sculpin[a]														
0+	0			1	100	0	8	9	28.2	6.32	17-36	0.3	0.16	0.1-0.5
1	7	54	0	6	46	0	1	14	43.1	3.99	37-50	0.9	0.35	0.4-1.7

continued ...

Table 35. Continued.

Species/Age	Females			Males			Unsexed Fish	Sample Size	Fork or Total[a] Length (mm)			Weight (g)		
	N	%	% Mature	N	%	% Mature			Mean	S.D.	Range	Mean	S.D.	Range
Slimy sculpin[a]														
2	2	67	0	1	33	0	0	3	55.0	1.00	54-56	2.2	0.15	2.1-2.4
3	0			1	100	100	0	1	76.0			4.4		
Totals	9			9			9	27						
Longnose dace														
0+	1	100	0	0			3	4	22.3	5.38	16-29	0.2	0.06	0.1-0.2
1	5	56	0	4	44	0	0	9	43.1	5.60	34-49	0.9	0.44	0.3-1.5
2	2	100	50	0			0	2	59.0	2.83	57-61	2.3	0.42	2.0-2.5
Totals	8			4			3	15						
Pearl dace														
1	3	50	0	3	50	0	1	7	38.0	7.28	27-47	0.6	0.27	0.2-1.0
4	0			1	100	100	0	1	103.0			10.9		
Totals	3			4			1	8						
Trout-perch														
0+	0			4	100	0	1	5	38.0	2.55	35-41	0.6	0.12	0.4-0.7
1	0			1	100	0	0	1	43.0			0.9		

continued ...

Table 35. Concluded.

Species/Age	Females			Males			Unsexed Fish	Sample Size	Fork or Total[a] Length (mm)			Weight (g)		
	n	%	% Mature	N	%	% Mature			Mean	S.D.	Range	Mean	S.D.	Range
Trout-perch														
2	0			1	100	100	0	1	54.0			1.0		
Totals	0			6			1	7						
Ninespine stickleback[a]														
0+	1	100	0	0			0	1	35.0			0.3		
Total	1			0			0	1						
Fathead minnow														
2	0			1	100		0	1	56.0			1.8		
Total	0			1			0	1						

The smallest mature fish were observed in the 25 to 29 mm length range for males and in the 30 to 34 mm range for females (Table 36). Results from 1976 showed the smallest mature stickleback to be males in the 20 to 24 mm range while all fish were mature in the 40 to 44 mm group (Bond and Machniak 1977). Sexual maturity is first achieved at age 1 in both sexes (Table 35).

5.4.7.4 Length-weight relationship. The common length-weight relationship for brook stickleback captured from the Muskeg River in 1977 (n = 262, r = 0.962, range 15 to 71 mm) is described by the equation:

$$\log_{10}W = 2.764\,(\log_{10}L) - 4.628;\ sb = 0.049$$

The value of the exponent (2.764) is intermediate between that calculated for Muskeg River stickleback in 1976 (3.0435) and that reported by Machniak and Bond (in prep.) for Steepbank River fish (2.4260).

5.4.7.5 Spawning. Most brook stickleback in Alberta spawn in late spring and early summer (Paetz and Nelson 1970). Mature and ripe females were captured between 3 and 19 June 1977 at Site 3 (Muskeg River) and Site 7 (Hartley Creek). The first young-of-the-year (19 mm total length) were collected at Site 10 (Kearl Creek) on 19 June. Many young-of-the-year stickleback were observed in Kearl Creek on 22 June 1978. A sample of 39 fish captured on this date ranged in total length from 11 to 18 mm.

By 18 July 1977, young-of-the-year stickleback, captured at Site 10, ranged in total length from 19 to 27 mm while fish taken 30 July at Site 6 had total lengths of 15 to 24 mm. Stickleback fry captured 13 October at Site 6 ranged from 23 to 36 mm in total length.

5.4.7.6 Food habits. Brook stickleback from the Muskeg River watershed had fed primarily on immature aquatic insects of the orders Diptera, Trichoptera, Plecoptera, Ephemeroptera, and Hemiptera. Other food items included Ostracoda, Nematoda, and Nematomorpha (Table 37). Scott and Crossman (1973) report brook

Table 36. Sex and maturity ratios, by size class, for brook stickleback captured from the Muskeg River watershed, 1977. Sex ratios were based only on fish for which sex was determined.

Total Length (mm)	Sample Size	Maturity				% Unsexed	Sex Ratio	
		Males		Females				
		% Immature	% Mature	% Immature	% Mature		% Female	% Male
0-14	0							
15-19	17	100	0	100	0	76	50	50
20-24	75	100	0	100	0	72	86	14
25-29	47	83	17	100	0	60	63	37
30-34	26	92	8	90	10	15	45	55
35-39	16	56	44	20	80	13	36	64
40-44	38	0	100	33	67	3	63	34
45-49	25	0	100	0	100		48	52
50-54	8	0	100				0	100
55-59	9	0	100	0	100		22	8
60-64	0							
65-69	0							
70-74	1			0	100		100	0
Totals	262					39%	54%	46%

Table 37. Food habits of small fishes collected from the Muskeg River, 1977.

Food Items	Brook stickleback		Lake Chub		Slimy Sculpin		Longnose Dace		Pearl Dace	
	% Freq.[a]	% No.	% Freq.[a]	% No.	% Freq.[a]	% No.	% Freq.[a]	% No.	% Freq.[a]	% No.
Class Insecta										
Diptera										
Chironomidae										
larvae	40.0	66.1	0.0	0.0	33.0	72.7	28.6	89.3	0.0	0.0
pupae	20.0	16.1	5.6	5.9	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified Dipterans	5.0	1.7	11.1	23.5	13.3	9.1	0.0	0.0	16.7	50.0
Trichoptera	10.0	2.5	0.0	0.0	13.3	3.9	0.0	0.0	0.0	0.0
Plecoptera	5.0	0.8	0.0	0.0	13.3	9.1	14.3	10.7	0.0	0.0
Ephemeroptera	10.0	3.4	0.0	0.0	6.7	1.3	0.0	0.0	0.0	0.0
Hemiptera	10.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Insect Remains	30.0		64.7		40.0		42.9		16.7	
Miscellaneous										
Nematoda	5.0	2.5	16.7	41.2	13.3	2.6	0.0	0.0	0.0	0.0
Nematomorpha	5.0	1.7	0.0	0.0	6.7	1.3	0.0	0.0	16.7	50.0
Ostracoda	10.0	3.4	5.6	11.8	0.0	0.0	0.0	0.0	0.0	0.0
Vegetation (algae, seeds)	0.0		5.6	17.6	0.0		0.0	0.0	0.0	
Digested Matter	20.0		27.8		20.0		14.3	0.0	33.3	
Debris (sand, gravel)	5.0		5.6		6.7		0.0	0.0	16.7	
Total stomachs	24		24		15		8		8	
Empty (% of Total)	16.7		25.0		0.0		12.5		25.0	

[a] Percentage frequency of occurrence, based on stomachs that contained some food.

stickleback to consume aquatic insects and crustacea as well as Gastropoda, Oligochaetes, Arachnida, and fish eggs. Some individuals are also reported to feed on algae (Winn 1960).

5.4.8 Lake Chub

5.4.8.1 Distribution and relative abundance. Excluding suckers, lake chub made up 26% of all small fish captured in the Muskeg River watershed during 1977 (Table 6). This species was present throughout the watershed and was taken at eight of the 10 collection sites. Chub were taken at Sites 2, 3, 4, 6, 7, 8, and 9 during both years of the study, but were never captured at Sites 5 and 10 (Figure 2). The largest catches of this species were made at Site 7 of Hartley Creek during 1976 (Bond and Machniak 1977) and at Site 3 in 1977. Lake chub occurred in association with brook stickleback at Site 6.

5.4.8.2 Age and growth. Lake chub, captured from the Muskeg River watershed in 1977, ranged in fork length from 19 to 93 mm (Figure 28), with those in the 25 to 44 mm size range accounting for 82% of the total sample. The length-frequency distribution was not constant throughout 1977, but varied, largely as a result of the disappearance of one year old fish (mostly 34 to 45 mm) in late June and the appearance and subsequent growth of young-of-the-year in July and August. Young-of-the-year captured in July had a mean fork length of approximately 27 mm (range 21 to 31 mm) while those taken in August averaged about 30 mm in fork length (range 19 to 41 mm). One year old chub, captured in June, ranged from 31 to 49 mm in length.

Otolith ages were determined for 55 lake chub, the oldest being a four year old female, 93 mm in fork length (Table 35). Five years appears to be the maximum age for lake chub in the Muskeg River (Bond and Machniak 1977) and in the adjacent Steepbank River (Machniak and Bond in prep.). Lake chub live to age 4 in western Labrador (Bruce and Parsons 1976) and age 5 in British Columbia (Geen 1955).

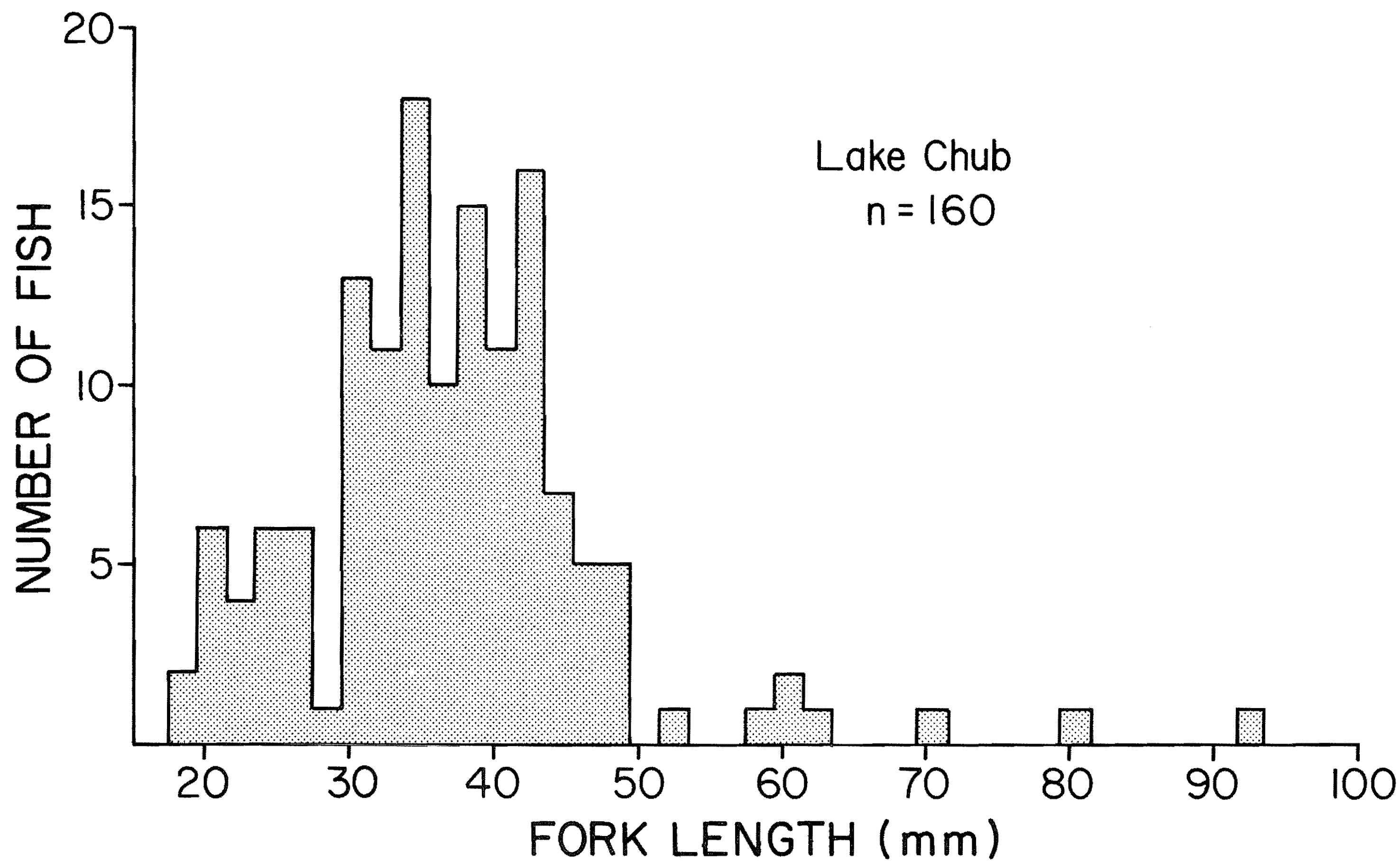

Figure 28. Length-frequency distribution for lake chub from the Muskeg River, 1977.

Growth rates, determined from 1977 data (Table 35), are similar to those produced in 1976 (Bond and Machniak 1977) for the Muskeg River as well as to those for lake chub in the Steepbank River (Machniak and Bond in prep.). Geen (1955) reported that females grow faster and live longer than males.

5.4.8.3 Sex and maturity. Sex was determined for 85 lake chub, of which 51% were females. Most chub examined were immature. Only five fish, two males and three females, were judged to be sexually mature. Sexual maturity in Muskeg River lake chub appears to occur at age 3 for both sexes (Table 35)(Bond and Machniak 1977).

The smallest size at sexual maturity was 62 mm for males and 70 mm for females. Bond and Machniak (1977) found the smallest mature males and females to be in the 55 to 59 and 70 to 74 mm size classes respectively.

5.4.8.4 Length-weight relationship. The length-weight relationship for lake chub (sexes combined) captured from the Muskeg River drainage during 1977 ($n = 146$, $r = 0.961$, range 19 to 33 mm) is described by the equation:

$$\log_{10}W = 2.950\,(\log_{10}L) - 4.892;\ sb = 0.071$$

5.4.8.5 Spawning. Lake chub probably spawn in late May or early June in the Muskeg River watershed. A mature male (62 mm) was captured on 3 June 1977 at Site 3 (Figure 2) and a spent male (81 mm) and female (70 mm) were taken 19 June at Site 7 (Hartley Creek). The first young-of-the-year were captured on 18 July at Sites 2 (21 to 29 mm) and 3 (27 to 31 mm). Young-of-the-year lake chub were also captured later in the year at Sites 1, 6, and 8 (Figure 2). Machniak and Bond (in prep.) report capturing a ripe lake chub on 7 May in the Steepbank River. Lake chub in the Montreal River, Saskatchewan, spawn in shallow water (about 5 cm) amongst and underneath large rocks at water temperatures of 10°C (Brown 1969).

5.4.8.6 Food habits. Muskeg River lake chub fed primarily on aquatic insects, Nematoda, Ostracoda, and plant materials (Table 37). A similar diet was reported for lake chub in the Steepbank River (Machniak and Bond in prep.). Stomachs of lake chub from the Athabasca River contained immature insects of seven orders as well as some fish remains (Bond and Berry in prep.b).

5.4.9 Slimy Sculpin

5.4.9.1 Distribution and relative abundance. The slimy sculpin is a common forage fish in gravelly areas of the lower Muskeg River and Hartley Creek. It was taken at Sites 1, 2, 3, and 7 during both years of the study, but was never captured at sites upstream of Hartley Creek (Sites 4, 5, 6, 9, and 10). Excluding suckers, this species accounted for 6% of all small fish captured in the Muskeg River in 1977. However, in 1976, sculpins made up 26% of all small fish captured (Bond and Machniak 1977) and are probably more abundant than our 1977 data indicate.

5.4.9.2 Age and growth. Slimy sculpins captured in the Muskeg River watershed during 1977 ranged from 7 to 76 mm in total length (Figure 29). Otolith ages were determined for only 27 sculpins, the oldest of which was a three year old male, 76 mm in total length. The maximum age reported for slimy sculpins in the AOSERP area is four years (Bond and Machniak 1977; Machniak and ond in prep.).

Growth patterns for slimy sculpins in the Muskeg River (Table 35)(Bond and Machniak 1977) are similar to those reported for the Steepbank River (Machniak and Bond in prep.), the Chandalar River, Alaska (Craig and Wells 1976), and the Mackenzie Delta (de Graaf and Machniak 1977).

5.4.9.3 Sex and maturity. Sex was determined for 18 slimy sculpins, of which 50% were males. Only one mature sculpin was captured during 1977, that being a three year old male, 76 mm in total length (Table 35). Most slimy sculpins captured in 1976

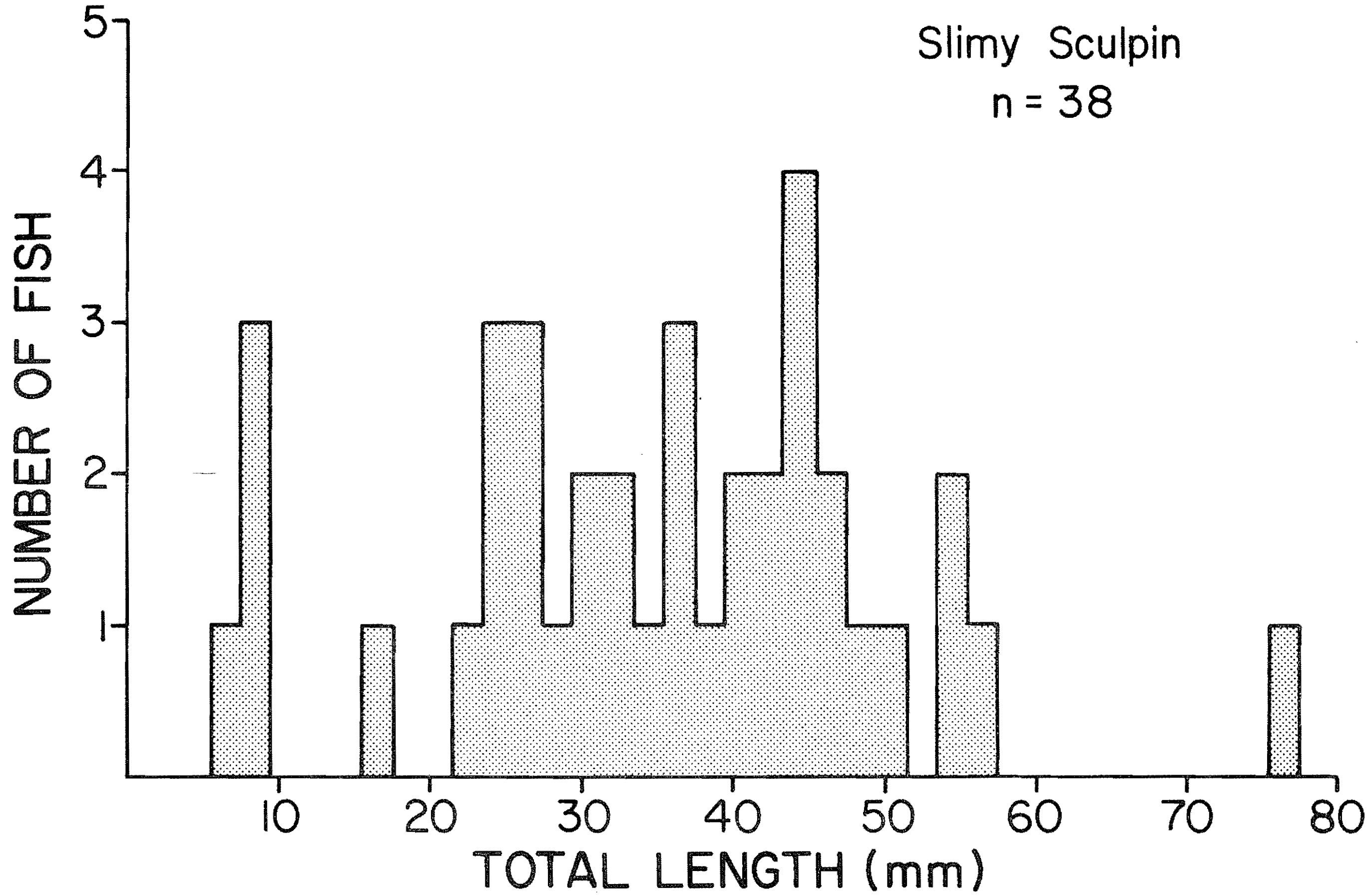

Figure 29. Length-frequency distribution for slimy sculpin from the Muskeg River, 1977.

were also immature fish. The smallest size at sexual maturity was 60 to 64 mm for males and 75 to 79 mm for females (Bond and Machniak 1977). In the Steepbank River, the smallest mature sculpins were males in the 45 to 49 mm size class and both sexes matured at age 2 (Machniak and Bond in prep.).

5.4.9.4 Length-weight relationship. The mathematical relationship between total length and body weight for slimy sculpins (sexes combined) captured in the Muskeg River during 1977 ($n = 34$, $r = 0.941$, range 17 to 76 mm) is described by the equation:

$$\log_{10}W = 3.059\ (\log_{10}L) - 5.059;\ sb = 0.194$$

5.4.9.5 Spawning. Slimy sculpins spawn in the early spring over rocky bottoms. Spawning occurred in late April in Valley Creek, Minnesota fry were first observed in June (Petrosky and Waters 1975). Craig and Wells (1976) estimated that slimy sculpins spawned a week after spring breakup in the Chandalar River drainage, Alaska. Scott and Crossman (1973) state that sculpins spawn at water temperatures of $8^{o}C$ in northern Saskatchewan with the eggs hatching in about four weeks. Slimy sculpins spawned between late April and mid-May in the Muskeg River, both in 1976 and 1977. In the first year, ripe slimy sculpins were captured on 8 and 9 May at Site 2 and young-of-the-year, 11 mm in total length, were taken on 9 June in Hartley Creek (Bond and Machniak 1977). Young-of-the-year ($n = 4$), 7 to 9 mm in total length, were captured in a drift net near the fence site on 6 and 7 June 1977.

5.4.9.6 Food habits. Slimy sculpins had fed primarily on Chironomidae and other Diptera larvae, Trichoptera, Plecoptera, and Ephemeroptera (Table 37). Petrosky and Waters (1975) indicated that the most important foods of Minnesota sculpins were *Gammarus* (Amphipoda), Diptera and Trichoptera larvae, and Gastropoda. Other food items included Ephemeroptera, Isopoda, Coleoptera adults and larvae, Annelida, Ostracoda, Nematoda, and sculpin eggs.

5.4.10 Longnose Dace

5.4.10.1 Distribution and relative abundance. Longnose dace are characteristic of gravel or bouldery areas of swift-flowing streams (Scott and Crossman 1973). Because adults live in crannies between stones, they are difficult to capture (McPhail and Lindsey 1970) and, therefore, are probably under-represented in seine catches. Only 28 longnose dace were captured from the Muskeg River in 1977. They were most commonly found in the lower reaches of the Muskeg River (Site 2), where 19 specimens were collected (Table 6). Of 73 longnose dace captured in 1976, 72 were found at Site 2 (Bond and Machniak 1977). Over two years, six longnose dace were taken at Site 1, while single specimens were captured at Sites 3, 7, and 8 (Figure 2).

5.4.10.2 Age and growth. Longnose dace captured in the Muskeg River in 1977 ranged from 15 to 62 mm in fork length (Figure 30) and from 0+ to two years in age (Table 35). The largest dace taken in 1976 was 89 mm long and three years old (Bond and Machniak 1977).

5.4.10.3 Sex and maturity. Only two mature longnose dace were captured in the Muskeg River during the two years of the study. Both were females, one two years old and the other age 3.

5.4.10.4 Length-weight relationship. The mathematical relationship between fork length and body weight for longnose dace (sexes combined) captured in the Muskeg River during 1977 ($n = 28$, $r = 0.968$, range = 15 to 62 mm) is described by the equation:

$$\log_{10}W = 2.827\,(\log_{10}L) - 4.722;\ sb = 0.143$$

5.4.10.5 Spawning. Bartnik (1970) reported that, in streams of southern Manitoba, longnose dace spawned in late May when daily maximum water temperatures exceeded 15°C, and that spawning occurred over a gravel substrate in water velocities greater than 45 cm/s. However, in Alberta, dace are reported to spawn from

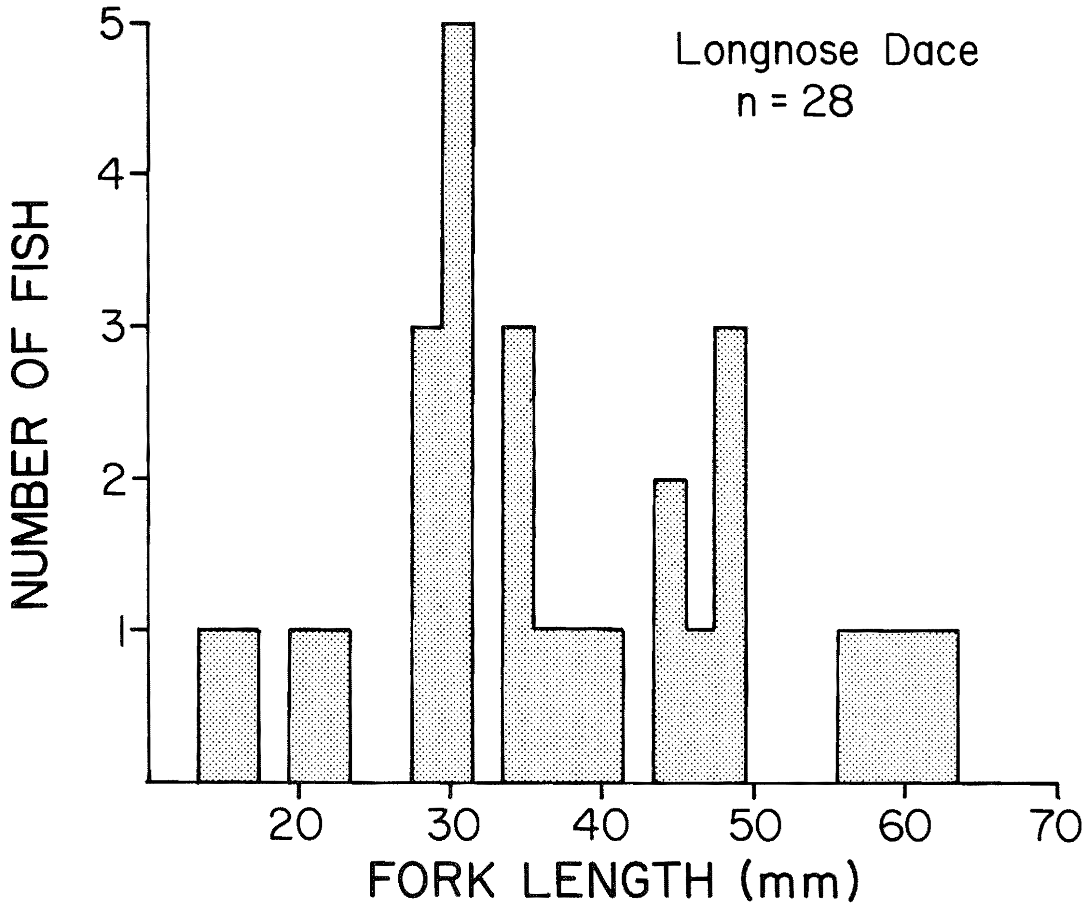

Figure 30. Length-frequency distribution for longnose dace from the Muskeg River, 1977.

early June to mid-August (Paetz and Nelson 1970). Spawning in the Muskeg River probably occurs between late May and early July. The only ripe longnose dace (not yet free running) was taken near the fence site (Site 2) in early May 1976. During 1977, young-of-the-year (n = 4) were first collected from the mouth of the Muskeg River on 16 July (range 15 to 23 mm). Dace fry were also captured at Site 2 during early August 1976. At that time fork lengths ranged from 18 to 37 mm (Bond and Machniak 1977). Young-of-the-year dace captured in the lower Steepbank River between 18 July and 2 August 1977 had a mean fork length of 21.5 mm and varied from 17 to 25 mm (Machniak and Bond in prep.).

5.4.10.6 Food habits. Stomach analysis of 8 longnose dace revealed the main food in the Muskeg River to be Diptera (Chironomidae) larvae which comprised 89.3% of the identifiable food items (Table 37).

5.4.11 Other Small Fish Species

5.4.11.1 Pearl dace. Pearl dace are a common forage fish in the AOSERP study area. This species was found throughout the Steepbank River watershed and made up 31% of all small fish taken in that stream (Machniak and Bond in prep.). However, they do not appear to be abundant in the Muskeg River as sampling over a two year period produced only 15 specimens. Fourteen of these were captured at Site 2 while one specimen was taken at Site 10, the outlet of Kearl Lake (Table 6)(Bond and Machniak 1977). The largest pearl dace taken was a four year old male, 103 mm in fork length (Table 35). Pearl dace had fed primarily on aquatic insects.

5.4.11.2 Trout-perch. Trout-perch are widely distributed throughout the AOSERP study area and are extremely abundant in the Athabasca River (Bond and Berry in prep.a, in prep.b). Ripe males and females can be found in the Athabasca River in late April and early May. These fish move into tributaries during May to spawn in late May or early June. Trout-perch are known to spawn in the lower reaches of the Ells River as W. A. Bond collected ripe males and a 10 mm long fry there on 8 June 1977. Spawning also occurs in the lower Steepbank River (Machniak and Bond in prep.) and in the MacKay River (Machniak et al. in prep.). From our observations in 1976 and 1977, it would appear that the lower Muskeg River (downstream of the fence site) also serves as a spawning area for this species. During 1976, a ripe three year old female was captured near the fence site on 14 May and young-of-the-year (10 to 17 mm) were caught near the mouth of the tributary (Site 1) on 15 June (Bond and Machniak 1977). Five young-of-the-year (35 to 41 mm) were captured at Site 1 on 13 August 1977 (Table 35).

The food habits of trout-perch were not examined during the present study. However, in the Athabasca River, trout-perch were observed to have fed primarily on immature aquatic insects, Copepoda and Ostracoda (Bond and Berry in prep.b).

5.4.11.3 Ninespine stickleback. One young-of-the-year ninespine stickleback (35 mm total length) was captured at Site 2 of the Muskeg River on 6 August 1977 (Table 35). This species is rarely found in the AOSERP study area, either in tributaries or in the Athabasca River. Intensive sampling of the Athabasca River with small mesh seines produced only two ninespine stickleback during 1977 (Bond and Berry in prep.b).

5.4.11.4 Fathead minnow. Fathead minnows are common in the upper Athabasca watershed and Wood Buffalo National Park (Paetz and Nelson 1970). They appear to be rare in the Athabasca River downstream of Fort McMurray (Bond and Berry in prep.a, in prep.b), although Tripp and McCart (in prep.) captured them in considerable numbers in the Athabasca River upstream of Fort McMurray. Only one fathead minnow was captured in the Muskeg River during the present study. That specimen was a two year old male, 56 mm in fork length (Table 35).

5.4.11.5 Spottail shiner. No spottail shiners were taken in the Muskeg River in 1977 and only one was captured during 1976 (Bond and Machniak 1977). They are reported to be common in the Athabasca River, and Bond and Berry (in prep.a, in prep.b) provide information relative to the life history of this species in the AOSERP study area.

5.5 HABITAT ANALYSIS

5.5.1 Muskeg River Mainstem

The mainstem of the Muskeg River was divided into five reaches on the basis of gradient differences, flow characteristics, substrate, channel form, and other physical features (Table 38, Figure 31). Point samples taken at nine locations during June 1978 provided site-specific information with respect to certain physical and chemical parameters (Table 39) as well as additional information on fish (Table 40) and benthic macroinvertebrates (Table 41). This information collectively defines the aquatic habitat of the Muskeg River mainstem and permits an assessment of fish utilization in each reach.

5.5.1.1 Reach 1M. This reach extends from the confluence of the Muskeg and Athabasca rivers to approximately 0.5 km upstream. Because it lies within the flood plain of the Athabasca River it is subject to periodic flooding by Athabasca River water which can greatly affect its width and depth. This mouth region has little gradient (0.3 m/km), low velocity, and pool-like conditions often prevail. The substrate is very homogeneous, comprised mainly of fines (90%) and small gravels (10%).

Because Reach 1M is frequently inundated by Athabasca River water it is to be expected that, at some time or other, virtually all fish species occurring in the Muskeg or Athabasca rivers will be found in this area. That this is so is demonstrated by Table 42 which shows that documented fish presence in this reach includes the adults of eight species and the fry and/or juveniles of 20 species.

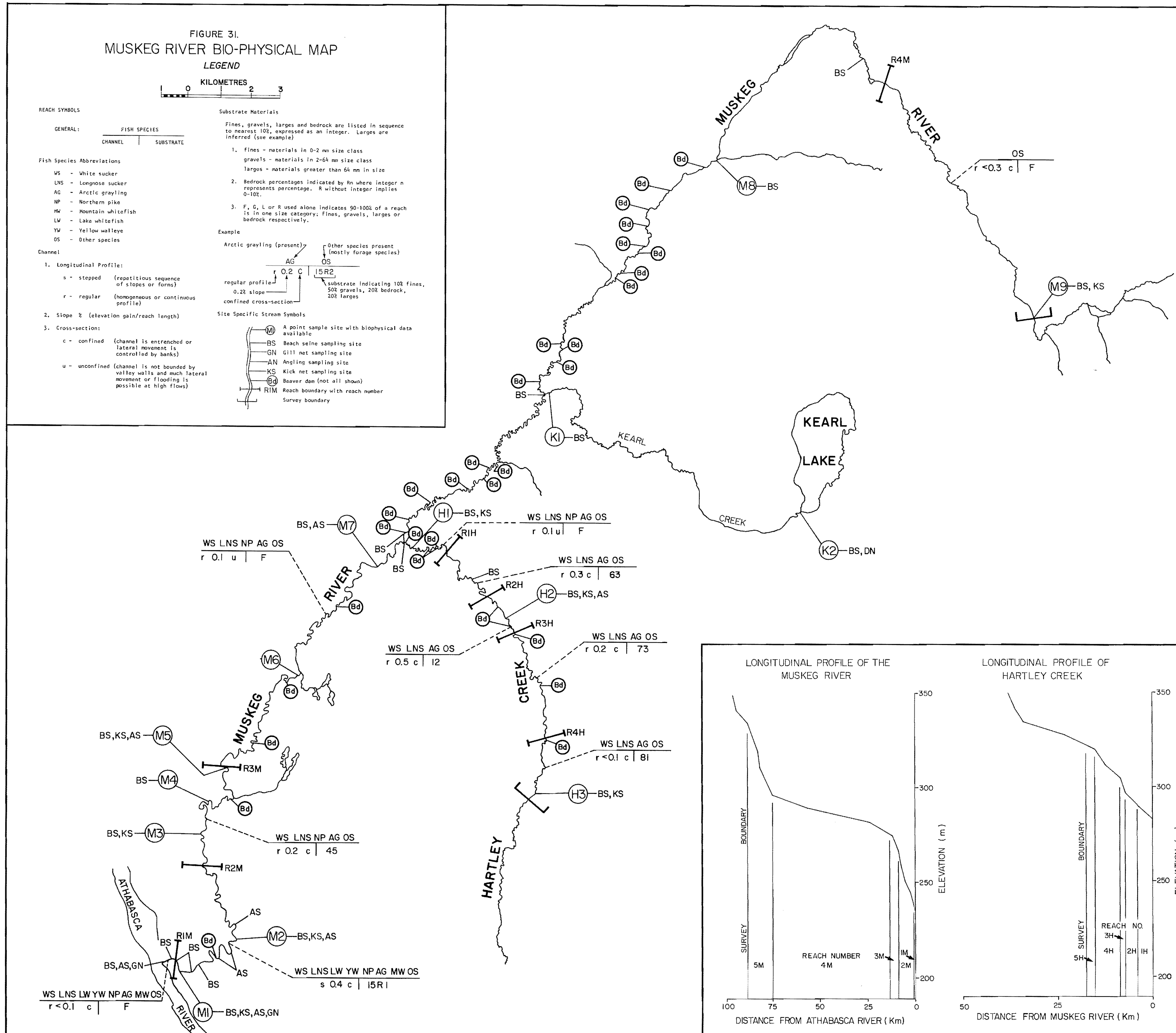

FIGURE 31.
MUSKEG RIVER BIO-PHYSICAL MAP

Table 38. Physical characteristics of the Muskeg River mainstem, 22 to 23 June 1978.

	Reach 1M	Reach 2M	Reach 3M	Reach 4M	Reach 5M
Distance Upstream of Confluence (km)	0 - 0.5	0.5 - 8	8 - 13	13 - 75	75 - 88[a]
Width (m)	16	14	15	13	9
Gradient (m/km)	0.3	4.1	1.5	0.4	2.9
Velocity (m/s)[b]	ND	1.0	0.9	0.4	0.6
Mean Depth (m)[b]	ND	0.6	0.5	0.9	0.2
Substrate Composition (%)					
Fines (<2 mm)	90	10	40	90	90
Gravels (2 - 64 mm)	10	50	50	5	5
Larges (>64 mm)	0	30	10	5	5
Bedrock	0	10	0	0	0
Riparian Vegetation (%)					
Coniferous Trees	0	20	5	0	10
Deciduous Trees	70	65	40	10	20
Deciduous Shrubs	25	10	50	80	65
Grasses	5	5	5	10	5
Bank Materials	clay, sand	clay, gravel, larges bedrock	clay, sand, gravel	clay	clay
River Channel Characteristics					
Thread	single	single	single	single	single
Form	straight	meandering	straight, irregular	irregular meander	straight to irregular
Flow Character	placid	swirling to broken	placid	placid	placid

[a] Survey ended at km 88 - not necessarily end of reach.

[b] Based on data from point samples.

Table 39. Summary of physical and chemical information collected at each sampling point in the Muskeg River watershed, 22 to 23 June 1978.

Parameter	Muskeg River Mainstem									Hartley Creek			Kearl Creek	
	M1	M2	M3	M4	M5	M6	M7	M8	M9	H1	H2	H3	K1	K2
Stream width (m)	15	13	14	15	44	13	16	11	9	8	10	5	6	16
Mean depth (m)	0.6	0.6	0.7	0.5	0.3	1.0	0.7	1.5	0.2	0.7	0.4	0.7	0.5	0.4
Velocity (m/s)	1.0	1.0	1.0	0.8	0.9	0.5	0.5	0.2	0.5	0.3	1.1	0.4	0.3	Nil
Substrate (%)														
Fines (<2 mm)	20	0	5	20	30	80	90	100	0	100	5	10	100	100
Gravels (2 to 64 mm)m	80	50	75	80	70	0	0	0	10	0	20	15	0	0
Larges (>64 mm)	0	50	20	0	0	20	10	0	90	0	75	75	0	0
Bedrock	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bank Stability	Stable	Stable	Stable	L-Stable R-Unstable	L-Unstable R-Stable	Stable	Stable	Stable	Stable	Unstable	Stable	Stable	Unstable	Quaking
Bank Materials	Sand Gravel	Gravel Larges	Gravel Larges	L-gravel R-sand,clay	Sand Gravel	Clay	Clay	Clay	Clay Larges	Sand,clay	Clay,larges	Clay	Clay	Ground
Riparian vegetation														
Grasses	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Dogwood	+	+		+		+						+		Typhaceae
Willows	+		+	+	+	+	+	+	+	+	+	+	+	+
Alder	+		+	+				+	+	+	+			
Aspen			+								+			
Aquatic vegetation														
Algae				Cladophora	Cladophora		Cladophora		Cladophora		+	+		
Vascular			+	+	+		+		+	+		+	+	+
Time of day (hr)	0900	1145	1215	1245	1315	1445	1600	1130	1030	1430	1600	1630	1300	0930
Water temperature (°C)	14.0	ND	14.5	ND	14.0	ND	14.0	13.0	13.0	14.0	14.0	13.0	14.0	16.0
pH	8.5	ND	8.5	ND	8.5	ND	8.0	8.0	8.5	8.5	8.0	8.0	8.0	8.0
Conductivity (µmhos/cm@25°C)	305	ND	305	ND	310	ND	300	300	260	200	190	195	220	160
Dissolved oxygen (mg/l)	9	ND	9	ND	9	ND	8	7	8	9	10	9	8	8

Table 40. Number of fish captured in small mesh seines at each sampling point in the Muskeg River watershed, 22 to 23 June 1978.

Species	Muskeg River Mainstem									Hartley Creek			Kearl Creek		Total	
	M1	M2	M3	M4	M5	M6	M7	M8	M9	H1	H2	H3	K1	K2	Number	%
Arctic grayling	0	21	4	22	7	ND	0	ND	0	0	0	0	0	0	54	23.8
Northern pike	0	0	4	0	0	ND	0	ND	0	0	0	0	0	0	4	1.8
Trout-perch	1	0	0	0	0	ND	0	ND	0	0	0	0	0	0	1	0.4
Longnose dace	2	0	1	0	0	ND	0	ND	0	0	0	0	0	0	3	1.3
White sucker	1	0	1	1	2	ND	1	ND	0	0	0	0	0	0	6	2.6
Longnose sucker	0	0	0	0	0	ND	0	ND	0	1	0	0	1	0	2	0.9
Brook stickleback	0	0	1	0	0	ND	1	ND	23	30	0	1	21	39	116	51.1
Lake chub	0	0	0	0	20	ND	1	ND	1	18	0	0	0	0	40	17.6
Pearl dace	1	0	0	0	0	ND	0	ND	0	0	0	0	0	0	1	0.9
Total	5	21	11	23	29	ND	3	ND	24	49	0	1	22	39	227	99.9

Table 41. Percentage composition by numbers for the major benthic macro-invertebrate groups taken at each sampling point in the Muskeg River watershed, 22 to 23 June 1978

	Muskeg River Mainstem									Hartley Creek			Kearl Creek	
	M1	M2	M3	M4	M5	M6	M7	M8	M9	H1	H2	H3	K1	K2
Chironomidae	25	6	10	ND	10	ND	ND	40	92	18	47	46	29	44
Ephemeroptera	11	20	47	ND	66	ND	ND	0	4	19	7	8	< 1	2
Plecoptera	0	0	0	ND	0	ND	ND	0	0	0	0	0	0	0
Trichoptera	9	21	14	ND	3	ND	ND	0	2	13	21	7	2	< 1
Simuliidae	0	0	0	ND	0	ND	ND	0	0	0	0	0	47	0
Oligochaeta	< 1	< 1	1	ND	1	ND	ND	0	< 1	2	7	12	5	7
Other taxa	55	53	27	ND	20	ND	ND	60	1	48	18	27	16	48
Number Animals Counted	453	683	985	ND	897	ND	ND	10	1393	738	431	303	154	657
Percentage of Sample Counted	50	25	13	ND	25	ND	ND	6	13	25	13	13	25	25

Table 42. Documented distribution of adult and young fish in the Muskeg River mainstem based on catch data obtained in 1976-1978, and on reports by other individuals.

Species	Reach 1M		Reach 2M		Reach 3M		Reach 4M		Reach 5M	
	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles
Lake whitefish	+	+	+	+		+				
Mountain whitefish	+	+[a]	+	+						
Lake cisco				+						
Arctic grayling	+	+	+	+	+	+	+	+		
Dolly Varden		+		+						
Northern pike	+	+	+	+	+	+	+[c]	+		
Pearl dace				+						
Redbelly dace		+[b]								
Lake chub		+		+	+	+	+	+	+	+
Longnose dace		+	+	+		+				
Emerald shiner		+[a]								
Spottail shiner		+								
Fathead minnow		+[b]		+						
White sucker	+	+	+	+		+	+[c]	+		+
Longnose sucker	+	+	+	+		+	+[c]	+		

continued ...

Table 42. Concluded.

Species	Reach 1M		Reach 2M		Reach 3M		Reach 4M		Reach 5M	
	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles
Trout-perch	+[c]	+	+							
Burbot		+		+						
Brook stickleback		+	+	+	+	+	+	+	+	+
Ninespine stickleback		+								
Slimy sculpin		+	+	+		+				
Walleye	+	+	+	+						
Yellow perch		+		+						

[a] Reported by Bond and Berry (in prep.a).

[b] Reported by Bond and Berry (in prep.b).

[c] Reported by Shell Canada Ltd. (1975) in mouth of Hartley Creek.

Reach 1M has little potential for spawning by any species encountered within the Muskeg River. Although white suckers, longnose suckers, northern pike, Arctic grayling, and (probably) trout-perch are known to migrate through this reach in April and May in order to reach spawning areas upstream in the Muskeg River, none of these species, with the possible exception of northern pike, is believed to spawn in Reach 1M. The placid water conditions of this reach appear to provide excellent rearing habitat for the young of most species. Young-of-the-year suckers, brook stickleback, slimy sculpin, yellow perch, mountain whitefish, Arctic grayling, and ninespine stickleback have all been captured from this reach. These young-of-the-year probably came from upstream areas of the Muskeg River as well as from the Athabasca River. Although no benthos was collected from Reach 1M during the study, the small particle size of the substrate and the lack of substrate diversity would indicate a sparse bottom fauna. Thus, poor feeding conditions obtain for such fish as lake whitefish, mountain whitefish, white and longnose suckers, that feed predominantly on benthic invertebrates. On the other hand, the large numbers of young-of-the-year fish (especially suckers) found in the mouth area of the Muskeg River, would provide excellent forage for piscivorous species such as northern pike and walleye. Reach 1M appears to be of importance to lake whitefish, and probably also walleye, in terms of providing resting areas during upstream spawning migrations in the Athabasca River (Bond and Berry in prep.a, in prep.b). The potential of Reach 1M as an overwintering area is unknown.

5.5.1.2 Reach 2M. Reach 2M, the canyon of the Muskeg River, extends from km 0.5 to approximately km 8 (Figure 31). Through this region the stream has cut a deep, narrow, tortuously meandering channel into Waterways limestone, by which it is largely confined. The gradient in this reach is generally steep (4.1 m/km) and the water velocity is rapid (1.0 m/s). However, the river is stepped in such a way that riffles and pools alternate providing a wide range of habitat types. In the upper canyon (Figure 6), short rapid riffles alternate with long shallow pools while in the lower end of Reach 2M (Figure 5) the pools are generally smaller and separated by long gravel riffles. The substrate in Reach 2M is mostly gravels (50%) and larges (30%) but some silt occurs with gravel in pool areas and the stream passes occasionally over limestone ledges. Substrate particle size tends to decrease from the upper to the lower end of this reach. Riparian vegetation was estimated as 65% deciduous trees (aspen, alder), 20% spruce, and 10% deciduous shrubs (willows). In many areas, however, where the river contacts the limestone cliffs little riparian vegetation is found. At low water levels, much gravel and bounder is exposed and the riparian vegetation seldom overhangs the stream.

Benthic samples were taken at two sites (M1 and M2) within Reach 2M. At the lower site, where the substrate consisted primarily of small gravels (Table 39), the most abundant benthic forms were Chironomidae, Ephemeroptera, and Trichoptera which made up 25, 11, and 9% of the sample respectively (Table 41). Trichoptera (21%) and Ephemeroptera (20%) were the most common invertebrates taken at point M2 where the substrate consisted of gravels and larges in approximately equal amounts. The diversity of substrates found in Reach 2M and the combination of pools and riffles lead one to expect a great diversity of benthic forms in this region. This is confirmed by the work of Barton and Wallace (in prep.) who identified 166 invertebrate taxa within Reaches 2M and 3M.

The documented fish fauna of Reach 2M includes adult fish of 11 species and fry and/or juveniles of 17 species (Table 42). Spawning potential in Reach 2M is excellent for white suckers which have been seen spawning over gravel riffles at the lower end of the reach. The riffle areas of this reach also provide excellent spawning areas for longnose suckers, Arctic grayling, longnose dace, slimy sculpins, lake chub, and trout-perch. Areas suitable for northern pike and brook stickleback spawning are few and limited to side sloughs out of the main current. Although the Muskeg River in Reach 2M contains areas suitable for spawning of mountain whitefish, lake whitefish, and walleye, these species are not believed to spawn within this watershed. Rearing for Arctic grayling is excellent in the shallow gravel riffles and shallow pools found in Reach 2M. Although young-of-the-year grayling have been taken all along this reach, they are apparently most abundant in the middle and upper portion. At low water levels, small back eddies develop along the shoreline of 2M in which large numbers of sucker fry are found during June, July, and August. Rearing in this reach is also good for longnose dace and slimy sculpins. Within the canyon, large grayling were found immediately below riffle areas at the extreme upstream ends of pools. Northern pike are extremely limited by the current in this reach and usually occur in quiet pools and back eddies. Most pike that enter the Muskeg River in the spring probably remain in the downstream areas of Reach 2M, although some are known to traverse the canyon. The extremely abundant bottom fauna in Reach 2M provides an excellent food source for Arctic grayling, longnose and white suckers, and virtually all fish species found in this section of the river. Forage for northern pike and walleye is also excellent in the form of sucker fry. Of the fish species captured at the Muskeg River upstream trap, only Arctic grayling, northern pike, white suckers, and longnose suckers have been recorded upstream of Reach 2M (Table 42). This suggests that such species as lake whitefish, walleye, lake cisco, Dolly Varden, and burbot, although entering the Muskeg River in small numbers, probably do not ascend the tributary for any great distance. The extent of overwintering in Reach 2M is unknown. Measurements taken near the downstream end of this reach in February 1975 (NHCL 1975) indicate a water depth of 0.1 m under 0.4 m of ice and a discharge of 0.3 m^3/s suggesting that overwintering may be possible for some fish in this reach.

5.5.1.3 Reach 3M. Reach 3M comprises approximately 5 km of stream between km 8 and km 13 (Figure 31), and is a transitional zone between the low gradient Reach 4M and the steep gradient Reach 2M. The top of this reach marks the approximate point at which the Muskeg River leaves the flat central portion of its watershed and begins to cut through the McMurray Oil Sands formation that overlies the Waterways limestone referred to in Reach 2M. Although the gradient is moderate (1.5 m/km) and the stream velocity rapid (0.9 m/s), the river flows fairly smoothly over a uniform substrate of fines (40%, mostly sand) and small gravels (50%). The current increases and the substrate material gets coarser in the vicinity of point sample M3 (Figure 31) as the stream begins to enter the canyon. Riparian vegetation in Reach 3M was mostly deciduous trees (40%) and shrubs (50%). The stream banks in the upper parts of the reach were largely sand and clay and were easily eroded. However, at the downstream end of the reach, stable banks of gravel and larges occurred.

Benthic samples taken at sites M3 and M5 revealed a diverse invertebrate fauna consisting largely of Ephemeroptera, Trichoptera, and Chironomidae (Table 41). As mentioned previously, Barton and Wallace (in prep.) identified 166 invertebrate taxa between point M5 and point M1. Because the substrate particle size is smaller in most of the region between sites M5 and M3 than it is at those sites, the invertebrate fauna is probably less diverse through much of this reach than is indicated by Barton and Wallace.

The fish fauna of Reach 3M appears to be limited to eight or nine species (Table 42). Spawning potential for Arctic grayling is excellent in the coarse gravel areas found at the upstream and downstream ends of this reach, but is low in areas of sandy substrate. Gravel areas also provide good spawning sites for longnose and white suckers, longnose dace, lake chub and slimy sculpins. The occasional area of quiet water with emergent vegetation provides good spawning habitat for pike and brook stickleback, but such areas are few in number. Rearing for Arctic grayling, slimy sculpin, and longnose dace is good in shallow, gravelly areas of Reach 3M. Back-eddies, out of the main channel, which become choked with weeds afford protection for young-of-the-year suckers, pike, and brook stickleback. The abundant benthic fauna, especially at the upper and lower ends of the reach, provides an excellent food source for all fish species. The only piscivore taken in Reach 3M was northern pike for which abundant forage occurs during the summer, especially in the form of young suckers. No winter flow data are available for Reach 3M and it is not known if overwintering conditions exist in this area.

5.5.1.4 Reach 4M. Reach 4M extends from km 13 to km 75, running through the large central area of the watershed. This area is flat, poorly drained, and covered with marshland and treed muskeg. This low gradient (0.4 m/km) reach is typically deep, slow moving (0.4 m/s) and cluttered with large numbers of beaver dams. The occurrence of such dams increases greatly upstream of Hartley Creek (Figure 31). Through most of the reach the substrate is composed of sand, silt, mud, and organic debris with occasional bouldery areas. The low clay banks are vegetated with willows and grasses. During periods of flood, water overflows these banks through much of the reach and the limits of the stream become almost impossible to define. Benthos was sampled only at point M8 (Figure 31) in which area the maximum depth exceeds 1.5 m. Chironomidae comprised 40% of this sample (Table 41). Barton and Wallace (in prep.) identified 81 invertebrate taxa from the same area and found that Chironomidae (56%) and Oligochaeta (11%) accounted for the majority of animals taken. They captured virtually no Ephemeroptera, Plecoptera, or Trichoptera. Thus, the very uniform physical conditions to be found in Reach 4M are reflected in the benthic community by a greatly reduced species diversity.

The fish community in Reach 4M is also severely restricted. There appears to be little spawning potential in this area for any species other than brook stickleback. Although large numbers of sucker fry have been captured in Reach 4M downstream of, and for approximately 300 m upstream of the confluence of Hartley Creek, it seems more likely that these fish were spawned in Hartley Creek than in the Muskeg River itself. Ripe pike and longnose and white suckers have been reported from the mouth of Hartley Creek (Shell Canada Ltd. 1975). Reach 4M of the Muskeg

River, with its reduced current and abundance of small chironomid larvae provides very good rearing habitat for young-of-the-year fish. However, the only fry captured in large numbers in this area were suckers and brook stickleback. Small numbers of young-of-the-year grayling, pike, and lake chub have been taken from Reach 4M downstream of Hartley Creek. The lower regions of Reach 4M, between Hartley Creek and the lower boundary of the reach, provide summer feeding grounds for adult Arctic grayling. Grayling in this region are said to be found where water up to 1 m deep flows with moderate current over beds of macrophytes and sand (Dr. D. Barton, University of Waterloo, verbal communication with W. A. Bond, April 1978). Winter measurements taken just upstream of the mouth of Hartley Creek and near point 8M (Figure 31) by NHCL (1975) indicate a water depth of from 0.5 to 0.7 m in mid-February. This would suggest the potential exists for overwintering in Reach 4M, depending on dissolved oxygen levels. Although no winter fish sampling was conducted in this study, yearling white and longnose suckers have been captured in early spring at the mouth of Kearl Creek which suggests overwintering by the young of these species. Brook stickleback, the dominant fish species in Reach 4M, is undoubtedly a year round resident of this reach.

5.5.1.5 Reach 5M. Upstream of Reach 4M the gradient of the Muskeg River increases (2.9 m/km), but the flow is reduced in most areas by beaver dams. The substrate in Reach 5M consists mainly of sands and silts (90%) and the clay banks are well vegetated with willows (80%) and grasses. The only point sample in this reach was taken at the upper limit of our survey (Figure 3, Table 39) at a site that was atypical of the reach as a whole. At this site (Figure 3) the stream bed was strewn with moss-covered boulders and thick mats of *Cladophora* were found. The benthic fauna was dominated numerically by Chironomidae which made up 92% of our sample (Table 41). Barton and Wallace (in prep.) identified only 78 invertebrate taxa from the vicinity of point M9. The samples showed Chironomidae (31%) and Oligochaeta (27%)

to be the most abundant benthic invertebrates in this area.

The fish fauna at point M9 is restricted to brook stickleback and lake chub which are, undoubtedly, year round residents of this reach. Movement of fish between Reach 5M and downstream areas is restricted by beaver dams, although one young-of-the-year sucker fry did manage to ascend as far as site M9.

5.5.2 Hartley Creek and Kearl Creek

Hartley Creek was divided into five reaches on the basis of gradient differences, flow characteristics, substrate, and channel form (Table 43, Figure 31). Point samples were taken at only three sites, one each in Reaches 1H, 3H, and 5H (Figure 31). At these locations, site-specific information was collected with respect to certain physical and chemical parameters (Table 39), fish (Table 40), and thic macro-invertebrates (Table 41). This information, in combination with fish data gathered in 1976 and 1977, permits an assessment of fish utilization in each reach and defines the aquatic habitat of this tributary. Point samples were also taken at two locations on Kearl Creek (Figure 31). One of these was situated just upstream from the Muskeg River and the other at the outlet from Kearl Lake.

5.5.2.1 Reach 1H. The lower 3.0 km of Hartley Creek are characterized by relatively low gradient (1.0 m/km), slow current (0.3 m/s), and sandy substrate (Table 43). The riparian vegetation is mostly willows and grasses, and beaver activity is evidenced by the presence of several beaver dams (Figure 31). The most abundant invertebrate groups in samples taken at point H1 (Figure 31, Table 41) were Chironomidae (18%), Ephemeroptera (19%), and Trichoptera (13%).

Six species of fish have been documented from Reach 1H (Table 44). Ripe Arctic grayling, white suckers, and longnose suckers have been reported from this reach by Shell Canada Ltd. (1975) but were not captured during the present study. The spawning potential of Reach 1H is considered to be poor for these species. However, they probably migrate through it to reach

Table 43. Physical characteristics of Hartley Creek, 22 to 23 June 1978.

	Reach 1H	Reach 2H	Reach 3H	Reach 4H	Reach 5H
Distance Upstream of Confluence (km)	0 - 3.0	3.0 - 6.7	6.7 - 8.2	8.2 - 14.7	14.7 - 17.0[b]
Width (m)[a]	8	ND	10	ND	5
Gradient (m/km)	1.0	2.9	5.1	2.3	ND
Velocity (m/s)[a]	0.3	ND	1.1	ND	0.4
Mean Depth (m)[a]	0.7	ND	0.4	ND	0.7
Substrate Composition (%)					
Fines (< 2 mm)	100	60	10	70	80
Gravels (2 to 64 mm)	0	30	20	30	10
Larges (> 64 mm)	0	10	70	0	10
Bedrock	0	0	0	0	0
Riparian Vegetation (%)					
Coniferous Trees	0	10	10	10	0
Deciduous Trees	10	60	70	60	10
Deciduous Shrubs	70	20	20	30	80
Grasses	20	10	0	0	10
Bank Materials	clay, sand	sand, clay	clay, gravel larges	sand, clay	clay
River Channel Characteristics					
Thread	single	single	single	single	single
Form	irregular, meandering	irregular, meandering	straight	irregular, meandering	irregular, meandering
Flow Character	placid	moderate	swift	moderate	placid

[a] Based on data from single point samples.

[b] End of survey, but not necessarily end of reach.

Table 44. Documented distribution of adult and young fish in Hartley Creek and Kearl Creek based on catch data obtained in 1976-1978, and on reports by other individuals.

	Hartley Creek										Kearl Creek			
	Reach 1H		Reach 2H		Reach 3H		Reach 4H		Reach 5H		Point K1		Point K2	
	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles	Adults	Fry/ Juveniles
Mountain whitefish[a]														
Arctic grayling	+[b]		+	+	+	+	+			+				
Northern pike	+[b]													
Pearl dace													+	
Lake chub	+	+	+	+		+				+		+		
Longnose dace				+		+				+				
White sucker	+[b]	+		+		+				+		+		
Longnose sucker	+[b]	+		+	+[c]	+						+		
Brook stickleback	+	+	+	+	+	+			+	+	+	+	+	+
Slimy sculpin			+	+	+	+				+				

[a] Reported by Shell Canada Ltd. (1975) but location not given.

[b] Ripe specimens trapped near mouth of Hartley Creek in May 1973 (Shell Canada Ltd. 1975).

[c] Reported by Dr. R. Hartland-Rowe (University of Calgary, verbal communication with W. A. Bond, May 1976).

suitable spawning areas further upstream. Shell also reported ripe northern pike from the mouth of Hartley Creek. Some pike spawning may occur near the mouth of the tributary but beaver dams probably limit the upstream movement of this species. Reach 1H has good spawning potential for brook stickleback and lake chub. The beaver ponds and placid water conditions of Reach 1H provide favourable rearing conditions for young fish but the fry of only four species were captured in this region (white and longnose suckers, lake chub, and brook stickleback). Winter measurements, taken in Hartley Creek just upstream of its confluence with the Muskeg River in February 1975, showed a water depth of 0.5 m (NHCL 1975). This would suggest some overwintering potential in this area, depending on oxygen levels.

5.5.2.2 Reaches 2H, 3H and 4H. Upstream of Reach 1H the gradient of Hartley Creek increases for approximately the next 12 km. This region has been divided into three reaches because of the extremely steep nature of the stretch between km 6.7 and km 8.2 (Table 43). The stream gradient within Reach 3H is 5.1 m/km and the water velocity is more than 1 m/s. The substrate consists mainly of larges with smaller areas of gravel. Because of the very rapid current and large substrate size the spawning potential of much of Reach 3H may be limited, although some Arctic grayling may spawn there. No fish were collected from most of the reach because the nature of the substrate and the water velocity made seining very difficult. The larger boulders in this reach, however, do provide holding places for Arctic grayling which can be captured from this area throughout the summer by angling (Mr. R. Crowther, International Environmental Consultants, Calgary, Alberta, telephone communication with W. A. Bond, January 1979). Upstream and downstream of Reach 3M, the stream gradient is 2.3 to 2.9 m/km and the velocity is somewhat less than 1 m/s. Conditions in Reaches 2H and 4H are very similar. The substrate is largely sand (60 to 70%) with gravel riffles accounting for about 30%. The gravel in Reaches 2H and 4H provide excellent spawning potential for Arctic grayling, suckers, slimy sculpins, and longnose dace. Although no fish sampling was conducted in Reach 4H, fry of seven species were taken in Reaches 2H and 3H (Table 44). Sucker, lake chub, and brook stickleback fry were captured in quiet back eddies and in beaver ponds, while young longnose dace, slimy sculpin, and Arctic grayling were taken in gravel riffles. Overwintering potential apparently occurs within Reaches 2H, 3H, and 4H. Not only have yearling and two year old white and longnose suckers been captured in this area, but young-of-the-year grayling were observed through the ice at point H2 on 31 October 1976 (Dr. D. Barton, University of Waterloo, verbal communication with W. A. Bond, December, 1976).

5.5.2.3 Reach 5H. Upstream of Reach 4H, Hartley Creek flows through flat, poorly drained terrain in which there is little gradient and pool conditions prevail. Beaver activity is extensive through this reach. Reach 5H was sampled only at its extreme downstream end (Figure 31) and the fish fauna at this point (Table 44) is probably more similar to that in Reach 4H than to that in most of Reach 5H.

5.5.2.4 Kearl Creek. Point samples were taken at two locations on this tributary (Figure 31). Point K1 was situated near the mouth of the stream, a short distance upstream of the confluence of the tributary with the Muskeg River (Figure 4). This part of Kearl Creek lies within the flat, poorly drained area typical of most of Reach 4M of the Muskeg River. There is little gradient at this point. The stream is fairly deep (0.5 m), slow flowing (0.3 m/s), and typical pool conditions prevail. The clay banks are vegetated with willows and grasses and show some signs of erosion. The substrate consists of clay and silts and is littered with organic debris.

Only four species of fish were taken at point K1 (Table 44). The capture of yearling white and longnose suckers in June suggests that such fish can and do overwinter in this region. However, the area appears to have little potential for sucker spawning. Fish movement into the area from downstream is probably restricted by the increased incidence of beaver dams upstream of Hartley Creek (Figure 31). Brook stickleback and lake chub, the only resident fish in the upper Muskeg River watershed, were also captured at point K1.

Kearl Creek was also sampled at its upstream end where it exits from Kearl Lake (Figure 31). Marsh-like conditions occurred at this site as the stream passed through an area of reeds and sedges. There was no perceptible current, and the substrate consisted of silts covered with organic debris. The benthos collected was largely Chironomidae and Oligochaeta (Table 41). Barton and Wallace (in prep.) identified 87 invertebrate taxa from this location with Oligochaeta accounting for 48% of their sample. The fish fauna at this site consists almost exclusively of brook stickleback which inhabit Kearl Lake in large numbers. The reedy area of point K2 is believed to function as a spawning and nursery area for this species as large numbers of newly-hatched fry were observed here on 23 June 1978. The only other fish captured at this location was a 103 mm, four year old pearl dace taken in 1977 (Table 35).

6. CONCLUSION

The Muskeg River provides spawning habitat for white suckers, longnose suckers, and Arctic grayling that migrate into the tributary from the Athabasca River in late April and early May. White suckers were observed spawning over gravel riffles in the lower 1 km of the Muskeg River. No other precise spawning areas were located although potential spawning sites for these species occur and young-of-the-year of these species were captured throughout the lower 35 km of the Muskeg River and in the lower 15 km of Hartley Creek. Northern pike and trout-perch from the Athabasca River also appear to spawn within the Muskeg River watershed to a limited extent.

White and longnose suckers began to leave the Muskeg River by mid-May, approximately two to three weeks after the commencement of the upstream runs. This exodus continues at least through July and probably throughout the summer. Sucker fry began to emerge by the end of May and drifted out of the watershed during the summer. Small numbers of young-of-the-year suckers apparently overwintered within the Muskeg River watershed. However, most fry, as well as the adults, probably overwinter in Lake Athabasca.

Suckers are seldom highly ranked when considered in terms of their direct importance to man. However, they occur in large numbers in the lower Athabasca drainage and are known to spawn in several other tributaries in addition to the Muskeg River. Because of their high fecundity, an enormous amount of sucker biomass is contributed annually to the system. Although the significance of this contribution has not been quantified, it is likely that such piscivorous fishes as pike, walleye, burbot, and goldeye depend on young suckers for a large part of their annual food intake.

Arctic grayling, unlike suckers, did not leave the Muskeg River following the spawning period but remained in the tributary throughout the summer to feed. Grayling were never observed in the Muskeg River upstream of the confluence of Hartley Creek. However, they are known to occur as far upstream as Site 8 in Hartley Creek. Between Sites 3 and 4 of the Muskeg River, grayling occurred in areas where water up to 1 m deep flowed with a moderate current over beds of macrophytes and sand. Within the canyon, most grayling occupied the upstream end of the pools. Although it was not possible to monitor the fall downstream migration this event probably occurs just prior to freeze-up as was reported in the Steepbank River (Machniak and Bond in prep.). Large grayling still occurred in the Muskeg River on 13 October 1978. Young-of-the-year grayling are believed to overwinter within the Muskeg River watershed and join the migrant population at the end of their second summer. Thus, the Muskeg River provides not only spawning habitat for Arctic grayling, but also summer feeding areas for adults and juveniles, rearing and overwintering sites for young-of-the-year. It is also possible that, in the tributary, grayling (especially young-of-the-year) are less susceptible to predation and severe environmental fluctuations than would be the case in the Athabasca River, thereby increasing their survival rate.

The grayling population in the Muskeg River does not appear to be as large as that in the Steepbank River. Its proximity to the proposed Alsands project places this population in considerable jeopardy. This species is highly susceptible to habitat disturbances and is easily over-exploited by angling. Without adequate protection of its habitat and application of a sound fisheries management program, this population will be quickly lost.

The Muskeg River provides some summer feeding for northern pike and small numbers of mountain whitefish, walleye, and lake whitefish. Pike have been observed as far upstream as Hartley Creek, but most are believed to remain in the lower reaches of the tributary throughout the summer. We found no evidence to suggest that mountain whitefish, lake whitefish, or walleye utilize the Muskeg River for spawning purposes and most of these fish are thought to leave the Muskeg River before freeze-up. The mouth region of the Muskeg River may be important as a resting area for walleye and lake whitefish during spawning migrations in the Athabasca River, and may provide nursery areas for young-of-the-year fish of several species.

The resident fish fauna of the Muskeg River watershed consists largely of four species of forage fish. The fauna of the upper watershed is dominated by brook stickleback, a large population of which occupies Kearl Lake Lake chub are most abundant in the mid-reaches of the watershed (Sites 3 and 7) and were found in association with brook stickleback at Site 6. Slimy sculpin and longnose dace were most common in gravelly areas of the lower Muskeg River and Hartley Creek (Sites 1, 2, 3, and 7). Pearl dace, which are abundant in the adjacent Steepbank River, apparently occur only in small numbers in the Muskeg River watershed.

Several species of fish considered to be more typical of the Athabasca River than of the Muskeg are sometimes taken in the extreme lower reaches of the tributary. Their presence in the Muskeg River is probably incidental and it is felt that they seldom proceed more than 1 km upstream in the tributary.

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8. APPENDICES

8.1 MAXIMUM AND MINIMUM DAILY WATER TEMPERATURES RECORDED AT THE MUSKEG RIVER COUNTING FENCE, 1977.

Table 45. Maximum and minimum daily water temperatures recorded at the Muskeg River counting fence, 1977.

Date		Daily Water Temperatures (°C)		
		Maximum	Minimum	Mean
April	28	9.0		
	29	8.0		
	30	5.0	4.0	4.50
May	1	6.5	4.0	5.25
	2	7.5	4.0	5.75
	3	7.0	5.5	6.25
	4	9.0	6.0	7.50
	5	9.5	6.5	8.00
	6	10.0	6.0	8.00
	7	11.5	5.0	8.25
	8	11.5	8.0	9.75
	9	11.5	7.0	9.25
	10	14.0	9.0	11.50
	11	14.0	10.0	12.00
	12	12.0	10.0	11.00
	13	12.0	8.0	10.00
	14	12.0	7.5	9.75
	15	11.0	7.0	9.00
	16	10.5	9.0	9.75
	17	8.5	5.5	7.00
	18	7.0	5.0	6.00
	19	7.0	5.5	6.25
	20	8.5	6.0	7.25
	21	9.5	5.0	7.25
	22	10.0	6.0	8.00
	23	12.0	7.0	9.50
	24	12.0	8.5	10.25
	25	11.5	9.0	10.25
	26	13.0	10.0	11.50
	27	13.0	10.0	11.50
	28	13.5	8.5	11.00
	29	13.5	10.0	11.75
	30	13.0	9.0	11.00
	31	13.0	9.5	11.25
June	1	13.0	10.0	11.50
	2	12.0	9.0	10.50
	3	11.5	9.0	10.25
	4	12.0	9.0	10.50
	5	14.0	10.0	12.00
	6	15.0	10.5	12.75
	7	15.5	11.5	13.50
	8	15.5	12.5	14.00
	9	14.0	11.0	12.50
	10	12.5	10.5	11.50
	11	13.0	9.5	11.75
	12	14.0	10.0	12.00
	13	13.0	11.0	12.00
	14	13.0	12.0	12.50
	15	15.0	12.5	13.75

8.2 DATES OF TAGGING AND RECAPTURE, LOCATION OF RECAPTURE, DISTANCES TRAVELLED, AND ELAPSED TIME BETWEEN RELEASE AND RECAPTURE FOR FISH TAGGED AT THE MUSKEG RIVER COUNTING FENCE IN 1976 AND 1977, AND SUBSEQUENTLY RECAPTURED OUTSIDE THE MUSKEG WATERSHED IN 1977 AND 1978.

Table 46. Dates of tagging and recapture, location of recapture, distances travelled, and elapsed time between release and recapture for fish tagged at the Muskeg River counting fence in 1976 and 1977, and subsequently recaptured outside the Muskeg watershed in 1977 and 1978.

Species	Date Tagged	Location Recaptured	Date Recaptured	Distance Travelled[a] (km)	Elapsed Time (Days)
White sucker	20 May/76	Muskeg River Upstream Trap	8 May/77	0	353
	Second Recap.	Athabasca Delta	21 June/77	-224	399
	19 May/76	Mouth MacKay River	24 April/77	-5	340
	10 May/76	Mouth MacKay River	27 April/77	-5	352
	19 May/76	Mouth MacKay River	2 May/77	-5	348
	24 May/76	Mouth MacKay River	14 May/77	-1	355
	20 May/76	MacKay River Upstream Trap	14 May/78	-13	724
	16 July/76	Steepbank River Upstream Trap	4 May/77	+18	282
	6 May/76	Muskeg River Downstream Trap	20 May/76	0	14
	Second Recap.	Muskeg River Upstream Trap	8 May/77	0	367
	Third Recap.	Near GCOS Intake (Athabasca River)	28 June/77	+16	418
	9 May/77	Mouth Muskeg River	19 June/77	-1	41
	14 May/77	Mouth Athabasca River[b]	19 June/77	-250	36
	18 May/77	Old Fort Bay[b]	19 June/77	-272	32
	24 May/77	Mouth Fletcher Channel[b]	16 June/77	-250	23
	11 May/77	Muskeg River Downstream Trap	27 May/77	0	16
	Second Recap.	MacKay River Upstream Trap	15 May/78	-13	369
	Third Recap.	Mouth Athabasca River[b]	June/78	-250	385-415
	25 May/77	MacKay River Upstream Trap	15 May/78	-13	355
	4 May/77	MacKay River Upstream Trap	3 May/78	-13	364
	17 May/77	Mouth Athabasca River[b]	June/78	-250	380-410
	6 May/77	Muskeg River Downstream Trap	26 May/77	0	20
	Second Recap.	Mouth Athabasca River[b]	June/78	-250	369-399

continued ...

Table 46. Continued.

Species	Date Tagged	Location Recaptured	Date Recaptured	Distance Travelled[a] (km)	Elapsed Time (Days)
White sucker	6 May/77	Muskeg River Downstream Trap	22 May/77	0	16
	Second Recap.	Mouth Athabasca River[b]	June/78	-250	369-399
	10 May/77	Muskeg River Downstream Trap	25 May/77	0	15
	Second Recap.	Mouth Athabasca River[b]	June/78	-250	386-416
	13 May/77	Mouth Athabasca River[b]	June/78	-250	389-419
	13 May/77	Mouth Athabasca River[b]	June/78	-250	389-419
	3 May/77	MacKay River Upstream Trap	30 April/78	-13	362
	11 May/77	Muskeg River Downstream Trap	25 May/77	0	14
	Second Recap.	MacKay River Upstream Trap	15 May/78	-13	369
Longnose suckers	27 May/76	Mouth Muskeg River	23 April/77	-1	331
	4 May/76	Steepbank River Upstream Trap	4 May/77	+18	365
	22 May/76	Steepbank River Downstream Trap	14 May/77	+18	357
	22 May/76	Steepbank River Upstream Trap	1 May/77	+18	344
	29 May/76	Steepbank River Upstream Trap	8 May/77	+18	344
	Second Recap.	Steepbank River Downstream Trap	24 May/77	+18	360
	29 May/76	Steepbank River Upstream Trap	2 May/77	+18	338
	5 June/76	Steepbank River Upstream Trap	2 May/77	+18	331
	Second Recap.	Steepbank River Downstream Trap	24 May/77	+18	341
	10 June/76	Steepbank River Downstream Trap	15 May/77	+18	339
	28 June/76	Steepbank River Upstream Trap	7 May/77	+18	313
	16 July/76	Steepbank River Upstream Trap	4 May/77	+18	292
	13 July/76	Muskeg River Upstream Trap	6 May.77	0	358
	Second Recap.	Muskeg River Downstream Trap	9 June/77	0	361
	Third Recap.	Mouth Clark Creek	23 June/77	+46	375

continued ...

Table 46. Concluded.

Species	Date Tagged	Location Recaptured	Date Recaptured	Distance Travelled[a] (km)	Elapsed Time (Days)
Longnose sucker	29 May/76	Lower Beaver River	14 May/77	+2	350
	15 May/77	Goose Island[b]	22 June/77	-264	38
	28 May/77	Old Fort Bay[b]	19 June/77	-280	22
	25 May/77	Old Fort Bay[b]	31 May/77	-296	6
	18 May/77	MacKay River Upstream Trap	1 May/78	-13	348
Northern pike	21 July/76	Mouth Muskeg River	15 Sept/76	-1	56
	Second Recap.	Mouth Muskeg River	24 Ju.y/77	-1	369
	24 July/76	Mouth Muskeg River	27 Sept/77	-1	430
	14 May/76	Mouth Poplar River	8 May/77	+29	360
	2 May/77	Mouth Muskeg River	24 July/77	-1	83
	2 May/77	Mile 27 (km 43) Athabasca River	28 Sept/77	+13	149
	3 May/77	Mile 60 (km 96) Athabasca River	5 Oct/77	-41	155
	3 May/77	Muskeg River Downstream Trap	13 June/77	0	41
	Second Recap.	Mouth MacKay River	21 Aug/77	-5	110
	3 May/77	Mouth MacKay River	22 Sept/77	-5	142
	4 May/77	Mouth MacKay River	16 June/77	-5	43
Arctic grayling	30 April/76	Steepbank River	10 Oct/77	+18	528

[a] Distance shown is approximate distance from counting fence to recapture point and + or - designates upstream or downstream from Muskeg River in the Athabasca River. On occasion movement was upstream or downstream in the Athabasca and then upstream in a tributary.

[b] Lake Athabasca.

9. 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 <u>In Situ</u> 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:

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