Fish Populations in the Peace-Athabasca Delta and the Effects of Water Control Structures on Fish Movements

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Fisheries and Marine Service

Manuscript Report 1465

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FISH POPULATIONS IN THE PEACE-ATHABASCA DELTA AND THE EFFECTS OF WATER CONTROL STRUCTURES ON FISH MOVEMENTS

by

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This is the sixth Manuscript Report
from the Western Region, Winnipeg

SCIENTIFIC AUTHORITY'S PREAMBLE

This work was originally conducted under a Department of Supply and Services contract which specified that the results of the investigation be produced only as a report to the immediately concerned agencies (Federal, Alberta and Saskatchewan). The results proved to be valuable and a decision was made to publish an edited version of the report as a Department of Fisheries and the Environment, Fisheries and Marine Service, Manuscript Report. The original authors supplied me, as Scientific Authority on the study, with their edited version, from which the present report was composed and typeset. I wish to thank both authors for their cooperation and also Miss M. Kays for her devotion to the production of the master copy of this report.

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ABSTRACT

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Goldeye was the most abundant species in catches obtained from five sampling areas within the Peace-Athabasca Delta. Approximately 16,680 goldeye, 2,140 northern pike, 800 lake whitefish, 350 walleye, 200 longnose sucker and 25 white sucker were tagged in 1976. Goldeye and northern pike experienced 0.6% and 0.0% mortality, respectively, during experiments designed to determine the effects of capture, handling and tagging on fish.

Five-year-old goldeye comprised 77% of the total goldeye catch in the Delta. Age structures of goldeye captured in the Claire-Mamawi lakes system, Chenal des Quatre Fourches, Revillon Coupé and Rivière des Rochers were similar, but the goldeye catch obtained in Lake Athabasca contained proportionately more fish less than five years of age than did catches obtained in the other sampling areas. As in 1975, growth rates were decreased for goldeye belonging to the 1971 cohort and neighboring year classes. Age structures of walleye sampled in the Claire-Mamawi lakes system, Rivière des Rochers and Lake Athabasca differed. Growth rates of seven- to ten-year-old walleye captured in Lake Athabasca were faster than those in other areas sampled.

There was considerable movement of goldeye among the five sampling areas within the Delta. Tagged goldeye and walleye moved between the Delta and the Athabasca River (as far south as Fort MacKay). The maximum recorded movement of a goldeye tagged during the study was 244 km. The Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches were utilized by goldeye migrating to and from the Claire-Mamawi lakes system and/or Lake Athabasca. Over twice as many fish appeared to utilize each of the two rivers, the Chenal des Quatre Fourches and Revillon Coupé, as the Rivière des Rochers during the summer-autumn migration from the Delta. The peak period of out-migration of goldeye was over one month later in 1976 than in previous years. Recaptures in 1976 of goldeye and lake whitefish tagged between 1972 and 1974 show that these two species manifest some degree of fidelity to the Delta from year to year.

An estimated 1,169,000 goldeye, 17,200 lake whitefish, 16,300 northern pike and 9,800 walleye were present in the Peace-Athabasca Delta waters sampled between 31 May and 21 October, 1976. The reproductive potential of the 1971 cohort of goldeye in 1979 is estimated to be 4,065,000 young-of-the-year which will represent approximately 96% of the total goldeye reproduction in 1979.

Significant numbers of fish accumulated downstream of the Little Rapids weir during periods of high hydraulic head (high velocities) across the weir. An estimated maximum of 210,000 fish were present downstream of the weir during a period when hydraulic head across the weir remained above 2.2 ft. Fish tended to disperse (presumably upstream) during periods when hydraulic head across the weir was relatively low. Some fish remained on the downstream side of the Little Rapids weir even when hydrological conditions appeared suitable for upstream movement across the weir. On two occasions large numbers of fish moved upstream through the fishway around the Little Rapids weir when hydraulic head decreased below 2.5 ft. Fish were also concentrated downstream of the Revillon Coup weir during early June.

Key words: goldeye; walleye; pike, northern; whitefish, lake; tagging; movement; weirs; fishways; age; growth; fishery management.

RESUME

Kristensen, J. and S.A. Summers. 1978. Fish populations in the Peace-Athabasca Delta and the effects of water control structures on fish movements. Can. Fish. Mar. Serv. MS Rep. 1465: vi + 62 p.

Chez la laquaiche aux yeux d'or, les sujets de cinq ans constituaient 77% de la population. La pyramide des âges de l'espèce a étéeidentique dans l'ensemble des lacs Claire et Mamawi, dans le Chenal des Quatre Fourches, le Revillon Coupé et al Rivière des Rochers; tandis que dans le Lake Athabasca, ceux de moins de cinq ans étaient proportionnellement plus nombreux. Comme on l'avait déjà noté en 1976, les générations de 1971 et des années voisines croissaient lentement. Dans l'ensemble des lacs Clairè et Mamawi, dans la Rivière des Rochers et le Lake Athabasca, la pyramide des âges du brochet différait. Dans le Lake Athabasca, les brochets de sept à dix ans ont eu le taux de croissance le plus élevé.

Dans les cinq aires d'échantillonnage, on a observé des mouvements considérables de la population de laquaiches. Les brochets et les laquaiches se déplaçaient entre le delta et l'Athabasca River (vers le sud, jusqu'au Fort Mackay). La laquaiche ayant franchiela plus grande distance durant l'étude a parcourue244 km. Les laquaiches ont migrées dans les deux sens, entre la Rivière des Rochers, le Revillon Coupé et le Chenal des Quatre Fourches d'une part, le réseau des lacs Claire et Mamawi ou le Lake Athabasca de l'autre. Au cours de la période migratoire de l'été et de l'automne, au moins deux fois plus de poissons ont empruntésle Chenal des Quatre Fourches et le Revillon Coupé plutôt que la Rivière des Rochers pour se rendre dans le delta. En 1976, la période de pointe de l'émigration de la laquaiche a débutéeun mois plus tard que les années précédentes. Les captures de laquaiches et de grands corégones, étiquetés entre 1972 et 1974, montrent que les deux espèces ont tendance à revenir dans le delta chaque année.

On estime qu'il ya avail 1,169,000 laquaiches, 17,200 grands corégones, 16,300 brochets et 9,800 dorés dans les eaux du Peace-Athabasca Delta, échantillonnées entre le 31 mai et le 21 octobre 1976. On prévoit qu'en 1979, la génération de laquaiches de 1971 sera en mesure de produire 4,065,000 alevins, ce qui représentera alors 96% de reproduction totale de l'espèce.

Un nombre important de poissons se sont ramassés au pied du barrage de Little Rapids lorsque sa charge hydraulique s'est élevée (l'eau y circulant à grande vitesse). Environ 210,000 poissons au maximum se trouvaient en aval du barrage à l'époque où la charge hydraulique s'y maintenait à plus de 2.2 pieds. Les poissons avaient tendance à se disperser (présumément en amont du barrage) quand la charge hydraulique diminuait. Certains poissons sont toutefois demeurés au pied du barrage même lorsqu'ils auraient pu le franchir. A deux reprises, lorsque la charge hydraulique est tombée au-dessous de 2.5 pieds, un grand nombre de poissons ont contourné le barrage en empruntant la passe migratoire. Au début de juin, ils se sont aussi concentrés dans les eaux inférieures du Revillon Coupé.

Mots-clés: laquaiche aux yeux d'or; doré; brochet; grande corégone; étiquettage; mouvement; barrage; passe migratoire; âge; croissance; aménagement des ressources halieuthiques.

INTRODUCTION

The Peace-Athabasca Delta is one of the largest freshwater deltas in the world and one of North America's most valuable natural resources. Areas within the Delta support the world's largest herd of free-roaming bison, provide nesting and staging habitat for waterfowl, and support large numbers of muskrat, beaver and mink which have traditionally been trapped by the residents of Fort Chipewyan. In addition, Delta waters support a variety of fish species. Commercial fishing for walleye (*Stizostedion vitreum*) and goldeye (*Hiodon alosoides*) has played an important role in the economy of Fort Chipewyan. (The commercial fishery for goldeye was terminated in 1966 (Kooyman 1973).) Domestic fishing for lake whitefish (*Coregonus clupeaformis*), northern pike (*Esox lucius*), longnose sucker (*Catostomus catostomus*), white sucker (*Catostomus commersoni*), walleye and goldeye has provided an essential food resource for local inhabitants and their sled dogs.

It is this composite of aesthetic and economic values of natural resources within the Peace-Athabasca Delta that caused well-deserved attention to be focused on the area when the completion and closure of the W.A.C. Bennett Dam in 1968 interrupted natural water regimes in the Delta and threatened to permanently change the environment of the region. Located in British Columbia, approximately 1170 km upstream of the Delta, the Bennett Dam controls about 50% of the flow in the Peace River near the Delta (Peace-Athabasca Delta Project Group 1973). Following completion of the dam, natural flood levels in the Peace River were reduced by as much as 3.7 m.

The hydrological cycle within the Delta is complex (Peace-Athabasca Delta Project Group 1973). To summarize, during most of the year water enters the Delta system, primarily through the Athabasca and Birch rivers, and leaves through several channels that flow north to the Peace River. Each spring, during breakup, ice jams on the lower Peace River or upper Slave River cause a major backwater effect and Peace River water floods into the Delta and Lake Athabasca. This annual flooding is necessary to recharge the Delta system. During this period, high water levels of the Peace River prevent or decrease outflow from Lake Athabasca and the Delta. As Peace River water levels subside, water flows out of the Delta and Lake Athabasca into the Peace River through the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches (Fig. 1). Due to the decreased flow of the Peace River, caused by the construction of the Bennett Dam, water from Lake Athabasca and the Delta has been flowing out at a much faster rate than usual and annual flooding has been much reduced.

The problem of decreasing water levels in the Delta was deemed so urgent that the Peace-Athabasca Delta Project Group was established in January 1971 and a number of ecological and hydrological studies were initiated in the same year. Several of the ensuing ecological studies indicated that low water levels may increase the natural aging process of the Delta (Dirschl 1973), and may be detrimental to some faunal and floral species of this system (Peace-Athabasca Delta Project Group 1973). On the basis of recommendations made by the Peace-Athabasca Delta Project Group (1973), a temporary rockfill dam was constructed on the west channel of Quatre Fourches in the fall of 1971 to slow water flowing out of the Claire-Mamawi lakes system.

It was subsequently recommended by the Peace-Athabasca Delta Project Group that water control structures be built on the Rivière des Rochers and Revillon Coupé to decrease the rate of water flowing out of Lake Athabasca and the Delta. Submerged weirs were completed at Little Rapids on the Rivière des Rochers in the fall of 1973, and on the Revillon Coupé (Fig. 1) in the spring of 1976. Upon completion of the Little Rapids weir, the temporary dam at Quatre Fourches was removed. There were several reasons for the removal of the Quatre Fourches structure; one in particular was given by the Peace-Athabasca Delta Project Group (1973:128):

> "It is a barrier to fish migration between wintering sites and major spawning lakes. Even with the installation of adequate fishways, changes in the natural flow patterns may affect fish movement. If possible, barriers across major fish migration routes should be avoided."

Construction of weirs to partly restore natural water levels should be generally beneficial to most components of the Delta. However, as suggested above, the presence of weirs may block or hinder traditional fish migrations. Preliminary observations in October, 1975, indicated that fish may, depending upon water levels and velocities, find it difficult to move across the Little Rapids weir (Kristensen et al. 1976). Although a fishway was constructed beside this weir, Smith and Hammond (1975) reported water velocities in the fishway that would in all likelihood preclude fish movement upstream through this structure.

The importance of the Rivière des Rochers to various migrating fish species (particularly goldeye, which is locally the most abundant species) is largely unknown. However, past studies suggested that goldeye were present (Donald and Kooyman 1974) or abundant (Kristensen et al. 1976) in this river.

Fernet (1971), Kooyman (1973) and Donald and Kooyman (1974) indicated that, during spring, goldeye migrate from the Peace River into the Peace-Athabasca Delta where they spawn and feed, and then, during summer and autumn, return to the Peace River where they overwinter. Kooyman (1973) and Donald and Kooyman (1974) suggested that the Chenal des Quatre Fourches is a major spring and summer-autumn migration route for goldeye of both sexes and all ages. However, the relative numbers and destinations of fish using the three major channels connecting the Peace-Athabasca Delta with the Peace River (=Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches) are unknown. It is of paramount importance that the above gaps in our knowledge of fish movement within and beyond the Peace-Athabasca Delta be filled, before we may fully assess the impacts on fish populations of building water control structures in the Delta.

The primary objective of this study was to investigate movement of fish in the vicinity of the weirs. The Little Rapids weir appeared to be a greater obstacle to fish movement than did the weir on the Revillon Coupé; therefore, most research was conducted in the former area. More specific objectives of this study were the following:

1. document the magnitude and timing of fish migration through the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches;

2. determine whether or not the Little Rapids weir hinders traditional fish movements;

3. determine the efficiency of the fishway around the Little Rapids weir;

4. obtain information about fish movements in other parts of the Peace-Athabasca Delta, and

5. compare respective age structures of goldeye and walleye captured from various waterbodies within the Peace-Athabasca Delta.

STUDY AREA

The Peace-Athabasca Delta encompasses an area of approximately 3800 square kilometres (Peace-Athabasca Delta Project Group 1973). Most of the Delta is situated within Wood Buffalo National Park at the west end of Lake Athabasca (Fig. 2). This study was conducted in several areas in the Peace-Athabasca Delta, specifically within the following waterbodies: Lake Athabasca, Lake Claire, Mamawi Lake, Rivière des Rochers, Chenal des Quatre Fourches and associated channels, Revillon Coupé and Prairie River (Fig. 1).

Because the specific areas studied are composed of a representative cross section of features found in the Delta, a brief general description of the Delta is given below.

Consisting of predominantly flat terrain, the Peace-Athabasca Delta is formed mainly by the deposition of silt carried into the area by the Peace, Athabasca and Birch rivers. Outcrops of Precambrian granite appear in the east and northeast areas of the Delta, and delimit the western edge of the Canadian Shield. Active parts of the Delta consist of major rivers, smaller streams and open basin lakes (Dirschl 1973). The four major lakes within the Delta (Claire, Mamawi, Richardson and Baril) (Fig. 1) are extremely shallow, ranging in depth from 0.6 to 3.0 m (Peace-Athabasca Delta Project Group 1973). Semiactive portions of the Delta include many shallow perched basins and oxbow lakes, while closed basins located in higher and older areas comprise the inactive parts of the Delta (Dirschl 1973).

Of major concern during this study were the water control structures on the Rivière des Rochers (Little Rapids) and on the Revillon Coupé (Fig. 1). Both weirs were constructed of granite rockfill in locations where the respective rivers were naturally constricted. The weir at Little Rapids (Fig. 3) consists of two submerged structures, one on each side of the river that permit flow between and over them. A fishway was constructed beside the weir along the northeast bank of the river (Fig. 3). The partially submerged weir on the Revillon Coupé was constructed across approximately three-fourths of the width of the river and permits some flow over it but most flow passes through an open channel along the southwest bank of the river (Fig. 4).

MATERIAL AND METHODS

This study was conducted from 31 May to 21 October, 1976, in the area illustrated in Fig. 5. Different regions were sampled with varying intensity and at different times (Fig. 6) to fulfill the major objectives of the study.

CAPTURE OF FISH

Gill nets

Previous studies in the Peace-Athabasca Delta have indicated that a wide size range of fish, excluding young-of-the-year, was most successfully caught in gill nets with stretched mesh sizes ranging from 3.81 cm (1.5 in) to 8.89 cm (3.5 in) (Kristensen et al. 1976). Gangs of gill nets used during this study were 45.7 m (150 ft) long and were composed of three monofilament 15.2-m (50-ft) x 2.5-m (8-ft) panels of 3.81-cm, 6.35-cm (2.5-in) and 8.89-cm stretched mesh.

Gill nets were set at various locations within the Delta (Fig. 5) between 3 June and 21 October, 1976 (Fig. 6). In lakes, nets were set as close to shoreline as possible and in water sufficiently deep to permit nets to hang freely off the bottom whenever possible. In rivers, nets were set where backwater (eddy) conditions decreased the current sufficiently to permit proper setting and provided shallow water (2.5 m) for the nearshore anchoring of nets. Other considerations in selecting gill net sites involved proximity to weirs, accessibility by boat and availability of fish.

In most cases, gill nets were set at right angles to shore by tying the nearshore ends to anchor poles driven into the substratum and anchoring the offshore ends to the bottom by means of mushroom or hook anchors.

Nets were set for varying lengths of time, from less than 20 min during warm water periods or when catch rates of fish were high, to more than 120 min during cold water periods or when catch rates were low. Care was taken to prevent injury of fish in the nets, since the majority of fish caught were to be tagged and released. With the exception of two diel studies, gill netting was restricted to daylight hours.

Fish trap

To determine the extent of utilization of the Little Rapids fishway as a fish passage structure, a large fyke trap (Hallock et al. 1957) was installed at the upstream entrance to the fishway (Fig. 3). The cylindrical trap (3.7 m long and 2.4 m in diameter) was constructed of galvanized steel pipe (2.54 cm inside diameter) framing. The entire cylinder was enclosed in 3.8-cm mesh poultry wire. Cones constructed of the same material were fitted at each end of the trap to allow inward passage of fish and minimize escapement. The trap was divided into two sections of equal size by a poultry wire partition that segregated upstream from downstream captures.

Poultry wire wings were constructed from the downstream entrance of the trap to the shorelines at either side of the mouth of the fishway. When properly in place, the trap effectively caught all fish moving upstream through the fishway. The trap, by design and location, was not as efficient in capturing fish moving downstream through the fishway. The authors felt that monitoring potential movement of fish in this direction through the fishway was relatively less important, since fish moving downstream in the Rivière des Rochers were probably not hindered from doing so by the Little Rapids weir. The trap fished continuously between 3 June and 27 July and between 22 August and 19 September.

Access to fish within the trap was by means of a hinged wire closure running the length of the trap. Fish were removed from the trap with long-handled dip nets.

Seine nets

Seining was attempted on a limited scale using a 9.14-m (30-ft) by 1.22-m (4-ft) bag seine with 0.64-cm (0.25-in) mesh. One end of the seine was anchored on shore and the other end of the net was hauled by boat in a 180° arc back to shore. Results of three seine hauls indicated that this technique was inefficient in areas sampled and it was therefore not subsequently employed.

Hook and line

Angling was employed sporadically throughout the field season. Spinning gear, with barbless hooks to minimize injury to fish, was most often used. The technique was used most successfully with northern pike, although some goldeye were caught in a similar manner.

TAGGING OF FISH AND RECORDING OF DATA

All fish were placed in a water-filled polyethylene holding tub prior to processing. A complete representation of information recorded for each fish captured is presented in Fig. 7. Weights of fish were recorded to the nearest ounce (rather than to the nearest tenths of grams as shown in Fig. 7) and were then converted to grams prior to data analysis. Sex and state of sexual maturity were not recorded for all fish captured. "Condition" on the data-recording sheet denotes condition of the fish upon release. Scale samples were taken from between the dorsal fin origin and the lateral line from subsamples of goldeye (approximately 500 from each of five areas sampled) and nearly all walleye for subsequent age analyses. Fish exhibiting signs of serious injury were measured and weighed and released untagged.

Fish were tagged with numbered, international orange, nylon anchor tags using a cartridge-fed model No. FDM-68 tagging gun (Floy Tag and Manufacturing Company, Seattle, Washington) fitted with either a 2.54- or a 3.81-cm needle. Tags were inserted on the left side of the fish and anchored between the interneural bones associated with the dorsal fin to minimize loss of tags (Dell 1968).

EFFECTS OF CAPTURE, HANDLING AND TAGGING ON FISH

In an attempt to detect any deleterious effects of capture, handling and tagging on fish, groups of fish processed as described in the preceding section, were retained in holding pens for varying lengths of time.

Groups of six goldeye were held from 24 to 81 h in a rectangular holding pen (2.4 m x 1.1 m x 1.1 m) enclosed with plastic screening. Between 15 July and 9 August, the pen was placed in a small tributary of the Prairie River, and between 12 and 26 September, it was placed in a small tributary of the Chenal des Quatre Fourches. At both locations the pen was placed in water approximately 0.6 m deep. Water and air temperatures were recorded and fish were checked twice daily. Prior to their release, fish were checked for stress by noting any engorgement of blood in the fins. Conditions of the tag and point of tag insertion were also examined before fish were released.

A separate experiment was carried out between 22 and 30 September with goldeye and northern pike in the Flett bypass channel (Fig. 3). The enclosure, a 1.2-m x 1.2-m cylinder constructed of wooden rings and enclosed with cloth netting, was placed in 2.0 m of water. Groups of five to 14 fish processed as described above were held for 24-h periods. Observation and release of fish were conducted in a manner similar to that described above.

HYDROLOGY

Because it was not possible to directly measure point water velocities across the Little Rapids weir, hydraulic head, which is directly influenced by water levels on both sides of the weir, was calculated on a daily basis during this study. It was therefore necessary to monitor water levels both upstream and downstream of the weir. The Alberta Department of the Environment installed staff gauges upstream and downstream of the fishway entrances (Fig. 3). Readings were taken twice daily from the time gauges were installed (20 June) until they were removed (15 October).

Two velocity profile stations were established in the fishway, one at the upstream end where velocities were greatest, and one at the lower end in a wider, slower section of the fishway. A Price-Gurley #625 flow meter was used to measure point velocities along the cross sections. Point velocities were measured at 0.2 and 0.6 of the water depth at one-foot intervals along the profile transect. Measurements were made under varying hydraulic head conditions in order to give some indication of minimum and maximum water velocities in the fishway.

During this study, hydrological measurements were made using English rather than metric units, as were those measurements made by the Alberta Department of the Environment used in this report. Almost all hydrological measurements which appear in this report will therefore be in English units.

LABORATORY TECHNIQUES AND DATA ANALYSIS

Techniques used in the analysis of standard fisheries data, including gill net selectivity, diel activity of fish and catch per unit effort, conformed to those described by Carlander (1950), Lagler (1956) and Ricker (1975).

Estimates of mortality caused by the capture, handling and tagging of goldeye and northern pike were made on the basis of observations of tagged fish in holding pens.

Criteria used in the aging of goldeye and walleye scales were those of Chugunova (1963), and included the identification of annuli by spacing of circuli and crossing-over of circuli in the lateral field of scales. Each scale sample was aged independently by two experienced readers. Goldeye scales were mounted between glass slides and aged directly using a Bausch and Lomb microprojector. Scale impressions on acetate slides were used for aging walleye, and were viewed with a Bausch and Lomb stereomicroscope.

Discrepancies in goldeye age estimates between readers were resolved by re-reading the scale samples in question. Disagreements in walleye age estimates were resolved by using a back-calculation nomograph (for four- to seven-year olds) or by re-reading those scales in question (for one- to three-year olds and those older than seven years). The back-calculation nomograph was constructed from measurements of those scales for which there was agreement between agings (Miller 1966).

Goldeye scales were examined for formation of terminal annuli to determine the time of formation of the 1976 annulus for each age group.

As pointed out by Everhart et al. (1975), it is important to establish the criterion upon which the assigning of ages is based. During this study, the age assigned to a fish was equal to the total number of annuli present on scales following formation of the 1976 annulus. One year was added to the number of annuli present on scales of fish captured immediately prior to formation of the 1976 annulus.

Comparisons of age structure and growth were conducted for goldeye and walleye from five and three locations in the Delta, respectively. Those areas for which these analyses were performed for goldeye were the Claire-Mamawi lakes system, Lake Athabasca, Rivière des Rochers, Chenal des Quatre Fourches and Revillon Coupé; and for walleye all but the last two.

Data obtained from fish recaptures were used to document movements of fish within the Delta. Special attention was paid to the movement of fish across the Little Rapids weir and fishway.

Population estimates were made on the basis of mark-recapture data for goldeye, northern pike, lake whitefish and walleye, using the Chapman modification of the Schnabel multiple census method (Ricker 1975). Population estimates excluded all fish less than 200 mm fork length (220 mm for northern pike) since fish of these sizes were not tagged nor specifically sought during this study.

Data were initially coded onto data forms in a manner suitable for key-punching (Fig. 7). After key-punching and key-verification, the data were entered into the University of Alberta computing system and stored as files on disc or tape. Validation programs were used to check for obvious errors. After validation, editing and sorting, further data processing consisted of producing lists of data in formats amenable to analyses.

The raw data appear in table, figure and computer print-out format in Kristensen and Summers (1979).

RESULTS

NUMBERS OF FISH CAPTURED THROUGH USE OF DIFFERENT FISHING TECHNIQUES

Table 1 presents the numbers of six fish species captured in 1976 through use of various fishing techniques. Gill nets were found to be more efficient than other gear in capturing fish and therefore were used most often. Ninety-two percent of all fish captured during this study were taken with gill nets. Almost all of the fish captured in the fish trap (Table 1) were moving upstream through the fishway. Angling and seining as means of capturing fish proved of marginal value and were not often employed. A total of 81 fish was caught by angling and only one northern pike was captured during three seine hauls.

GILL NET SELECTIVITY

Because the greatest fishing effort occurred at Little Rapids, the following results pertain primarily to fishing in that area. Figure 8 and Table 2 show that of the mesh sizes used (3.81, 6.35 and 8.89 cm), the most efficient in terms of total numbers of fish captured was the 6.35-cm mesh net. However, differences in gill net selectivity were apparent when species were considered separately (Table 2). Most goldeye (70%) and approximately 51% of northern pike captured downstream of the Little Rapids weir were captured in 6.35-cm mesh nets. (Nets of the same mesh size captured similar proportions of goldeye and northern pike in other parts of the Delta.) More lake whitefish (41%) were captured in the 3.81-cm mesh nets than in each of the larger mesh nets, while the 8.89-cm mesh nets captured more walleye (44%) than each of the smaller mesh nets.

Larger fish were usually captured in larger mesh nets (Table 2). However, this relationship was not always proportional among species, primarily because of the large differences between maximum sizes of the various species. The standard deviations exhibited in Table 2 indicate that relatively wide size ranges of goldeye, northern pike, lake whitefish and walleye were captured in the 3.81-cm mesh nets.

DIEL VARIATION IN CATCHABILITY OF FISH

Since almost all gill netting was conducted during daylight hours in 1976, the relationship between catchability and time of day was examined 28 and 29 July and 7 and 8 August; results of these studies appear in Fig. 9. A daytime pattern of activity was suggested by higher catch rates during daylight hours with peaks in the morning and near mid-day (1000-1100 and 1300-1400 during 28 and 29 July, and 0900-1000 and 1200-1300 during 7 and 8 August). The mean numbers of fish captured per hour between 0500 and 2100 (day) and between 2100 and 0500 (night) were 23.4 (S.D., 8.4) and 10.7 (S.D., 7.0), respectively, during the 28 and 29 July study, and 34.5 (S.D., 11.3) and 29.7 (S.D., 5.8), respectively, during the 7 and 8 August study.

EFFECTS OF CAPTURE, HANDLING AND TAGGING ON FISH

Because mortality caused by the capture and tagging of fish could seriously bias the results of movement analyses and population estimates, a series of experiments was conducted in the field to determine the effects of gill netting, handling and tagging on goldeye and northern pike. Similar experiments were not conducted with walleye, lake whitefish, longnose sucker or white sucker.

The results of mortality experiments for goldeye and northern pike held between 24 and 81 h in waters ranging from 6 to 24°C are presented in Table 3. In the 24 separate holding experiments involving a total of 164 goldeye (range of sample size, 6-14 fish/experiment), 0.6% mortality occurred. No mortality occurred among the 45 northern pike held in five separate experiments (range of sample size, 5-12 fish/experiment).

Mortality caused by the handling and tagging of fish captured in the fish trap was not studied. Each half of the trap could hold 200 or more fish at a time. With an increase in numbers, increased stress of fish was observed, probably a result of overcrowding and/or fish swimming against the poultry wire enclosure. However, stress in fish caused by the trap was probably no greater than that caused by gill nets.

Although mortality caused by angling and subsequent handling and tagging was not studied, it is doubtful that this method of capture resulted in greater mortality than that caused by gill netting, since a high proportion (approximately 15%) of the fish caught with hook and line 31 May were recaptured at later dates and in locations different from where they were initially captured and tagged.

IMMEDIATE RECAPTURE OF FISH

To avoid bias in fish movement analyses and population estimation, it was necessary to make a distinction between the immediate recapture of fish and the recapture of fish following such time probably necessary for captured fish to mix with other fish. "Immediate recapture" is defined, in this study, as the recapture of a fish within 24 h of its previous capture.

Efforts were made to release fish in such a manner as to avoid their immediate recapture. In most cases, tagged fish were either released downstream from gill nets in rivers, or were taken to the end of gill net gangs in water-filled tubs before being released.

The rate of immediate recapture of fish increased with an increase in the numbers of fish being handled in a given period (Table 1 (Kristensen and Summers 1979)) or when gill nets were set across nearly the entire width of small channels. The overall immediate recapture rate of fish captured in gill nets during this study (all locations and species combined), was 5.1% of the total catch with a high of 50 fish per day and lows of zero fish per day.

The rate of immediate recapture of fish captured in the fish trap was relatively low (1.5%) (Table 1 (Kristensen and

AGE STRUCTURE AND GROWTH OF GOLDEYE AND WALLEYE

Goldeye

Time of annulus formation: One of the major problems encountered in aging fish using their scales is that correct ages cannot be assigned until the time of annulus formation is known. If scales are collected from fish immediately prior to annulus formation, ages will be underestimated by one year. For this reason, an attempt was made to determine the time period within which the 1976 annulus was formed on the scales of goldeye in the Peace-Athabasca Delta.

A time series of goldeye scales samples collected from 5 June to 16 September was examined. The 1976 annulus was identified according to the amount of growth beyond the last annulus, in conjunction with the time of sample collection. For example, if there was significant growth beyond the outermost annulus on a scale collected in early June, that annulus was considered formed in 1975, whereas if significant growth occurred beyond the outermost annulus on a scale collected in September that annulus was considered formed in 1976.

Results of the determination of timing of 1976 annulus formation for goldeye are presented in Table 4. If two or fewer marginal circuli appeared beyond the 1976 annulus, that annulus was considered terminal, but if more than two circuli appeared beyond the 1976 annulus, that scale was considered to possess growth beyond this annulus. A terminal annulus appeared on many scales collected from 5 June to 19 July, with peak annulus formation occurring between 27 June and 19 July. All scales collected after 11 August, except 1% of those aged as five-year olds, revealed growth beyond the annulus formed in 1976. Although scales were not collected prior to 5 June nor between 19 July and 11 August, data in Table 4 suggest that annuli were being formed during these periods as well.

Aging: The percent agreement between two independent readings of goldeye scales collected from five sampling areas was 84.1% when all collections were combined. When those collections taken during annulus formation were combined and those taken following annulus formation were combined, percent agreements were 81.3 and 91.9, respectively. This difference is significant (χ^2 = 39.16, df = P < 0.001) and reflects the relative difficulty of aging goldeye scales collected during annulus formation.

Age structure: Age frequencies of goldeye captured in five sampling areas are presented in Table 5 and age groups are graphed as percents of the total in Fig. 10. It is obvious that members of the 1971 cohort, now in the five-year-old group, dominate the goldeye population of the Delta. Figures 10A, B, C and D reveal a fairly uniform age structure for goldeye within most of the Delta. The age composition of goldeye in the western region of Lake Athabasca (Fig. 10E) differed from that of goldeye in the other areas; the younger age groups were more strongly represented in Lake Athabasca than elsewhere.

Although the age group distributions of goldeye in the Claire-Mamawi lakes system, Chenal des Quatre Fourches, Revillon Coupé and Rivière des Rochers appear similar (Fig. 10), statistical comparison using an RxC G-test of independence (Sokal and Rohlf) 1969) showed that the hypothesis that they were the same could be rejected ($G = 85.28$, $df = 27$, $P < 0.001$). The differences between the number of three-year-old goldeye in the Chenal des Quatre Fourches and Rivière des Rochers samples, and between the number of six- to ten-year-old goldeye in the Claire-Mamawi lakes system and Revillon Coupé samples contributed most to the G-value. When the sample from Lake Athabasca was included in the comparison, the additional sample produced a much larger G-value ($G = 291.51$, $df = 36$, $P << 0.001$). It should be noted that several of the contingency table cells in these RxC G-tests contained small numbers or zeros. In order to ensure that the high G-values were not artifacts of the small sample sizes of age groups 1 and 2 and 7 to 10 (Table 5), the tests were repeated after these groups were lumped. Similarly very low probabilities resulted.

Figure 11 compares the age structures of goldeye captured in 1975 (Kristensen et al. 1976) and 1976 in the Claire-Mamawi lakes system and Chenal des Quatre Fourches. Approximately 85% of the catch in 1975 and 77% of the catch in 1976 were composed of goldeye from the 1971 year class.

Growth: Age-length and age-weight relationships of goldeye captured in 1947-48 (Kennedy and Sprules 1967), 1973 (Donald and Kooyman 1974), 1975 (Kristensen et al. 1976) and 1976 (this study) are exhibited in Fig. 12. Because of similarities among age-length relationships for fish captured in the five areas sampled in 1976 (Appendix 1), they were combined to produce one age-length curve in Fig. 12. Age-weight relationships were combined for the same reason (Appendix 1). Slight age-length and age-weight differences among fish captured in the five areas were likely related to differences among times of scale collection (Table 4).

Walleye

Aging: Percent agreement between two independent readings of walleye scale impressions for the five areas sampled in 1976 (combined) was 78.9%, while that obtained by two independent readings of impressions of walleye scales collected from Lake Athabasca in 1975 (Kristensen et al. 1976) was only 40.7%. No explanation is apparent for this difference between aging agreements. Agreement between readers decreased with increasing age of scales, primarily because of the close proximity of annuli on scales of older walleye.

Efforts were made to resolve walleye aging discrepancies by measuring the distance from the focus of a scale to each annulus, using only those scales for which there was agreement between two independent agings. These measurements, each expressed as a percent of the total distance from the focus to the antero-lateral scale margin, were compared to similar measurements for scales where aging discrepancies occurred. An estimated age was then assigned to these problem scales.

The ranges of the percent distances for each annulus are presented in Table 6 for age groups 4 through 7 . Ranges are not shown for scales of younger age groups because discrepancies between agings of these scales were relatively few and easily resolved by re-reading the scales. It was found that for scales of fish eight years old and older, ranges overlapped to such an extent that they became unreliable in terms of resolving age disagreements. Aging discrepancies for scales of fish older than seven years of age could therefore be resolved only by re-reading and studying them more carefully. Thus, this technique can only be described as moderately successful since it does not solve the basic problem of aging old walleye.

Age structure: The age frequencies of walleye captured in five sampling areas appear in Table 7, and age groups are presented as percents of the total for three sampling areas in Fig. 13. Small sample sizes for the Revillon Coupé and Chenal des Quatre Fourches precluded the presentation of age groups as percents of the total catches for these two sampling areas.

When the age structures of walleye in the Claire-Mamawi lakes system, Rivière des Rochers and Lake Athabasca were compared statistically, the probability that the samples were taken from populations with the same age group distribution was found to be very low ($G = 135.95$, $df = 28$, $P << 0.001$). When age groups 1 to 4 and 9 to 15 were lumped, a similarly low probability was obtained.

Age structures of walleye captured in Lake Athabasca (Alberta only) in 1975 (Kristensen et al. 1976) and 1976, are compared in Fig. 14. In 1975, gill net gangs included the following stretched mesh sizes which were not utilized in 1976: 1.91 cm (0.75in), 2.54 cm (1.0 in), 5.08 cm (2.0 in), 7.62 cm (3.0 in), 10.16 cm (4.0 in), 11.43 cm (4.5 in) and 12.70 cm (5.0 in). Numerous young-of-the-year (age group 0) walleye were captured in the 1.91-cm mesh nets in 1975; the larger mesh sizes (10.16, 11.43 and 12.70 cm) caught very few walleye (B.S. Ott, unpublished data).

Growth: Age-length relationships for walleye captured in 1975 (Kristensen et al. 1976) and 1976 are compared in Fig. 15. Comparisons among growth curves must be made cautiously because sample sizes in 1976 were small (Table 7).

RELATIVE ABUNDANCE AND DISTRIBUTION OF FISH

As a result of the intensive fishing effort in 1976, considerable amounts of data are available concerning distribution and relative abundance of larger members of the fish community at the sampling locations in the Delta. Since most fishing was carried out in the Rivière des Rochers, data from this location are most complete, especially in relation to seasonal variation in abundance. The following sections briefly describe the relative abundance of six species at sampling locations.

Goldeye

Goldeye was the most abundant species captured at all sampling locations (Table 8). It contributed 79.4% of the total catch and from 59.6% (in Lake Athabasca) to 91.0% (in the Revillon Coupé and Chenal des Quatre Fourches) of the catch from individual sampling areas (Table 9). Catch rates of goldeye were low in Lake Athabasca in comparison with those from other areas, never exceeding 12.5 goldeye per hour (Fig. 16B). Donald and Kooyman (1974) also reported relatively low numbers of goldeye in Lake Athabasca. Between 70% and 80% of the total catches in the Claire-Mamawi lakes system and the Rivière des Rochers were goldeye; the goldeye catch in the latter area contained the largest percentage (8.9%) of small individuals (Table 10). Catch rates (Fig. 16C) were similar to those of Donald and Kooyman (1974) for the Claire-Mamawi lakes system.

Catch rates of goldeye in the Revillon Coupé, Rivière des Rochers and Chenal des Quatre Fourches declined during the last few weeks of the study (Fig. 16). The relative seasonal abundance of goldeye in the Rivière des Rochers is more fully analyzed in the EFFECTS OF WEIRS AND FISHWAY section.

Northern pike

Northern pike was the second most abundant species captured, contributing 10.4% of the total catch (Table 9). This species contributed similarly high proportions of 14.8% and 13.2% of the catches from the Claire-Mamawi lakes system and the Rivière des Rochers, respectively.

A dramatic increase in pike abundance was observed in September in the Rivière des Rochers when the peak catch rate exceeded 13.0 pike per hour (Fig. 17A). Smaller fluctuations in the apparent abundance of pike were also noted in June, July and August. The other channels sampled (Revillon Coupé and Chenal des Quatre Fourches) appeared to be similar to the Rivière des Rochers in terms of physical habitat but the relative abundance of pike in these regions was low (Table 9). Small pike (less than 220 mm in fork length) did not contribute significantly toward the total pike catch in any of the sampling areas (Table 10) and were absent from catches in the Revillon Coupé and Chenal des Quatre Fourches.

Lake whitefish

Lake whitefish, the third-most common fish captured (Table 8), was most common (relative to other species) in catches from Lake Athabasca (23.2% of catch) followed by the Rivière des Rochers (10.5% of catch) (Table 9). It comprised less than 5% of the catch from each of the remaining three areas.

Catch rates of lake whitefish in the Rivière des Rochers (the only location where fishing was carried out continuously throughout the study period) were slightly higher in the latter half of the season (Fig. 18A). Catch rates of lake whitefish in the Revillon Coupé were relatively low whenever gill netting was performed (Fig. 18B); however, this species appeared to be especially less numerous in this channel during October.

Except for the Claire-Mamawi lakes system, the distribution and relative abundance of lake whitefish less than 200 mm in fork length were quite similar in all areas sampled, ranging from 40.0% to 53.3% of the total lake whitefish catch in each area (Table 10). Few (10.5% of the total lake whitefish catch) small lake whitefish were captured in the Claire-Mamawi lakes system (Table 10); large individuals were also relatively uncommon (Table 8) in this system.

Walleye

Of the six species considered, walleye were only slightly more numerous than suckers in relation to total catch (Table 9). Large differences were apparent in their relative abundance in different areas. As shown in Table 9, walleye were relatively abundant only in Lake Athabasca (10.1% of the catch) and were relatively rare at all other sampling sites, especially in the Revillon Coupé where only eight individuals were captured (Table 8).

Walleye appeared to be moderately more abundant in the Rivière des Rochers in late August and early September than during other periods of the study (Fig. 19A). As indicated in Table 10, individuals less than 200 mm in fork length were captured only in Lake Athabasca and the Rivière des Rochers.

Longnose and white suckers

Longnose and white suckers were least common (of the species considered), together comprising only 1.1% of the total number of fish captured (Table 9). They were rare in the Chenal des Quatre Fourches (0.5% of the catch) and in the Revillon Coupé (0.6% of the catch). Greatest relative numbers (1.8% of the catches) of suckers were captured in the Claire-Mamawi lakes system and Lake Athabasca (Table 9). Seasonal catch rates (Fig. 20) in the Rivière des Rochers suggest that suckers were abundant in that area in July and August. No explanation is given for the exceedingly high catch rates of suckers in the Claire-Mamawi lakes system in mid-July and early August.

Except in Lake Athabasca where equal numbers of longnose and white suckers were captured, the longnose sucker was much more numerous than the white sucker (Table 8); no white suckers were taken in the Chenal des Quatre Fourches.

FISH MOVEMENT AND MIGRATION

The following sections analyze fish movement and migration as determined by (1) recapture of tagged fish, and (2) catch rates of fish during summer and autumn. Local fish movements in the vicinity of the Little Rapids weir and fishway are analyzed in the EFFECTS OF WEIRS AND FISHWAY section.

Movement and migration as determined from mark-recapture data

Results of the analysis of fish movement and minimum distances travelled by fish between waterbodies are presented in Table 11 and Appendix 2, respectively. Analysis of recapture data was facilitated by division of the data into two periods (1 June to 31 August and 1 September to 20 October), with the former period roughly corresponding to 1976 goldeye movements toward the Delta and the latter period to movements toward the Peace River (Table 11). However, some overlap undoubtedly occurred and the periods must be viewed as those of convenience. In the following analysis, code numbers such as A06, Q02 and R04, refer to locations of gill netting stations shown in Fig. 5. The lack of longnose and white sucker recaptures during this study (Table 8) precluded any analysis of their movements based on mark-recapture data.

Goldeye: Twelve (43%) of the 28 goldeye recaptured between 1 June and 31 August moved from the Rivière des Rochers, Revillon Coupé or Chenal des Quatre Fourches into the Claire-Mamawi lakes system or the western end of Lake Athabasca (Table 11). Between 1 June and 31 August, two (7%) of the 28 goldeye exhibiting inter-waterbody movement travelled from the Claire-Mamawi lakes system into one of the three channels connecting the Delta with the Peace River.

Several goldeye were recaptured between 1 June and 31 August close to the mouth of one of the Athabasca River channels. One goldeye tagged in each of the following waterbodies was recaptured close to the mouth of Big Point Channel (A06): Revillon Coupé (E01), Mamawi Lake (M01), Chenal des Quatre Fourches (Q02) and Rivière des Rochers (R04). In addition, a goldeye tagged in the Rivière des Rochers (R02) was recaptured 13 August at sampling site A11 close to the mouth of Goose Island Channel.

The following two goldeye were recaptured between 1 June and 31 August (Table 11) in the Athabasca River. The first, tagged 16 June at Quatre Fourches (Q02), was recaptured 20 August in the Athabasca River, approximately 120 km, by way of this river, south of the tagging site. The second, which travelled the greatest recorded distance of any fish tagged during this study, was tagged downstream of the Little Rapids weir (R27) 6 June and recaptured in the Athabasca River approximately 75 km north of Fort McMurray 14 July. This represented a movement of approximately 244 km upstream in the Rivière des Rochers and Athabasca River in a maximum of 38 days.

Ten (36%) of the 28 goldeye recaptured between 1 June and 31 August travelled among the three channels connecting the Delta with the Peace River. One goldeye moved from the Claire-Mamawi lakes system into Lake Athabasca, and one goldeye travelled from Quatre Fourches to the confluence of the Slave and Hornaday rivers, a distance of about 117 km.

Between 1 September and 20 October, 21% (6 of 28) of the goldeye recaptured moved from Lake Athabasca or the Claire-Mamawi lakes system into the three channels connecting the Delta with the Peace River. Three of these fish were recaptured in the Chenal des Quatre Fourches (Table 11). The majority (22 of 28; 79%) of the goldeye recaptured between 1 September and 20 October exhibited inter-channel movement.

A goldeye tagged 31 July, 1976, approximately 40 km north of Fort McMurray (close to Fort MacKay) in the Athabasca River by Alberta Oil Sands Environmental Research Program (AOSERP) fisheries biologists (D.K. Berry, personal communication) was recaptured 19 September at the Revillon Coupé weir by LGL personnel.

Approximately 4,375 goldeye were tagged between 1972 and 1974 by the Canadian Wildlife Service in the Peace-Athabasca Delta (primarily at Quatre Fourches) (D.B. Donald, personal communication). Of these, 24 goldeye were recaptured during this study by LGL fishing crews or local fishermen. Eighteen of the 24 goldeye were recaptured in the Claire-Mamawi lakes system. Of the six remaining goldeye, five were recaptured in the Chenal des Quatre Fourches and one was recaptured in the Peace River close to the confluence of the Chenal des Quatre Fourches and Peace River.

Lake whitefish, northern pike and walleye: The small numbers of recaptures of lake whitefish (N = 10), northern pike (N = 7) and walleye (N = 5) (Table 11) provided little information concerning natural movements of these species in 1976. The following analysis is limited to the few movements that appeared to be interpretable and to recaptures of fish tagged by the Canadian Wildlife Service.

Movement among waterbodies within relatively short time periods is indicated by the recapture of 10 lake whitefish tagged in 1976 (Table 11). These data suggest that more movement occurred during late summer and fall. Approximately 200 lake whitefish were tagged in 1974 by the Canadian Wildlife Service at Quatre Fourches (D.B. Donald, personal communication). Three of these fish were recaptured during this study.

Almost all northern pike that travelled between waterbodies (6 of 7) (Table 11) moved randomly between the three channels connecting the Delta with the Peace River. No patterns of movement could be discerned.

All of the walleye (N = 5) that moved between sampling areas were travelling either from lake to lake or into a lake (Table 11). One walleye tagged 6 May, 1976, approximately 40 km north of Fort McMurray in the Athabasca River by AOSERP fisheries biologists (D.K. Berry, personal communication) was recaptured in September (precise date unknown), approximately 1.5 km south of Fort Chipewyan in Lake Athabasca by a local fisherman.

Movement and migration as determined from catch rates of fish

The relative importance of the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches to the movement of fish (primarily goldeye) out of the Delta toward the Peace River may be investigated through comparisons of catch rates obtained simultaneously in the three rivers. Two of the rivers, the Rivière des Rochers and Chenal des Quatre Fourches, were monitored simultaneously beginning 17 August. When catch rates of goldeye increased in the Chenal des Quatre Fourches in early September (Fig. 16C), fishing was initiated in the Revillon Coupé. Thus, intensive fishing was conducted simultaneously in the three rivers between 5 September and 21 October. During this period, gill netting was conducted at Q05, Q08, Q09, Q10 and Q11 on the Chenal des Quatre Fourches, at the weir site on the Revillon Coupé, and at Little Rapids on the Rivière des Rochers (Fig. 5).

Catches per unit effort for goldeye, northern pike, lake whitefish, walleye, and longnose and white suckers (combined) captured between 5 September and 21 October are illustrated in Figs. 16, 17, 18, 19 and 20, respectively. Low catches of longnose and white suckers (combined) and walleye precluded analysis of their movements through the three rivers. The mean catch per unit effort for each species (suckers combined) in each of the three rivers during the period 5 September to 21 October is shown in Table 12.

On 3 September, there was a substantial increase in the catch rate of goldeye in the Chenal des Quatre Fourches, with maximum catches obtained 21 and 28 September (Fig. 16C). By 1 October, catch rates of goldeye in the Chenal des Quatre Fourches had decreased to rates similar to those obtained prior to 3 September. Although the Revillon Coupé was not monitored continuously until 5 September, peaks in catch rates of goldeye in this river approximately coincided in time with those obtained in the Chenal des Quatre Fourches (Fig. 16), and mean catch rates for goldeye in the two rivers were similar (Table 12).

The mean catch rate of goldeye in the Rivière des Rochers was less than one-half that calculated for each of the other two rivers (Chenal des Quatre Fourches and Revillon Coupé) (Table 12).

Catch rates of northern pike and lake whitefish were substantially higher at Little Rapids during September and October than in the Chenal des Quatre Fourches and Revillon Coupé (Figs. 17 and 18, and Table 12).

POPULATION ESTIMATES

Table 8 lists the numbers of fish captured and tagged in the Delta in 1976; recaptures of tagged fish by LGL personnel and domestic fishermen are also given. These data form a basis for estimates of the abundance of some fish species, especially goldeye, in Delta waters.

Since it was not possible to assume that each sampling area was a discrete and closed system, mark and recapture data from five sampling areas (Rivière des Rochers, Revillon Coupé, Chenal des Quatre Fourches, Claire-Mamawi lakes system and Lake Athabasca) were combined to produce a single population estimate for each of goldeye, walleye, northern pike and lake whitefish. This procedure was substantiated by the recapture of tagged fish (Table 11) that travelled among the five sampling areas during the course of the field season. Absence of recapture data for longnose and white suckers (Table 8) precluded estimation of their numbers. Prior to the calculation of population sizes, several corrections were introduced to the mark-recapture data: (1) all fish less than 200 mm in fork length (220 mm for northern pike) were excluded, since fish of these sizes were not tagged; (2) all tagged fish that were recaptured by local fishermen (Table 8) were subtracted from the total number of fish recaptured because fishermen who returned tags were unable to report their total catches by species (which is information necessary to the estimation of population sizes (Ricker 1975)); (3) fish recaptured within seven days of the initiation of the mark-recapture program were eliminated because of probably incomplete mixing and/or aberrant behavior, and (4) fish recaptured within 24 h of their previous capture were excluded from the total number of fish recaptured, since fish sometimes swam back into the gill nets immediately following their release (see IMMEDIATE RECAPTURE section).

The numbers of goldeye, lake whitefish, northern pike and walleye, within certain size ranges and ages, estimated to occur in the Peace-Athabasca Delta between June and November, 1976 are shown in Table 13. It must be emphasized that the numbers in Table 13 are underestimates of the true population size of each species, since all fish less than 200 mm in fork length (220 mm for northern pike) were excluded from the mark and recapture data. For goldeye and walleye, fish less than 200 mm in fork length corresponded to age groups 0, 1 and 2 and age groups 0 and 1, respectively (based on the 1976 age-length relationships of these two species (Figs. 12 and 15)). Similar age-length relationships for northern pike and lake whitefish in the Delta are unknown since the age and growth characteristics of these species were not studied.

Adjustments to include the one- and two-year-old groups of goldeye and one-year-old age group of walleye in the population estimates were made by multiplying initial estimates by the percentage which these age groups contributed toward the population (see AGE AND GROWTH section). Hence 1.32% or 1.0132 x 1,153,772 = 1,169,002 goldeye (excluding young-of-the-year) and 1.79% or 1.0179 x 9,676 = 9,849 walleye (excluding young-of-the-year) were estimated to be present in the Delta between June and November, 1976.

Estimates of the number of goldeye and walleye in each age group based on their percent contribution to the 1976 catch are presented in Table 14. As shown in Fig. 10, the five-year-old age group dominated the goldeye samples.

EFFECTS OF WEIRS AND FISHWAY

Hydrology

Little Rapids and Revillon Coupé weirs: The weir at Little Rapids on the Rivière des Rochers (Figs. 3 and 21) is a center-slot, submerged structure which holds back water by partial damming and constriction. Mean water velocities over the Little Rapids weir were calculated using cross-sectional areas, water levels and discharges. As shown in Fig. 21, the calculated minimum and maximum mean velocities were 8.3 and 13.7 ft/sec, respectively, between January and October, 1976. It is highly probable that this range is minimal, since hydrological data were unavailable on a continuous basis. Although actual point velocities across the weir were not measured, a crude estimate obtained using the floating chip method indicated a surface velocity of approximately 15 ft/sec on 7 September. This estimate was greater than those calculated (Fig. 21) because the former was an estimate of surface velocity, while the latter were calculated estimates of means of velocities occurring throughout the cross-sectional area shown in Fig. 21.

Staff gauge readings upstream and downstream of the Little Rapids weir from 1 June to 15 October and calculated hydraulic head across the weir appear in Tables 2 and 3, and Fig. 8 (Kristensen and Summers 1979), respectively. During this period, hydraulic head varied by as much as 4.8 ft, from a low of approximately 0.2 ft on 24 August, to a high of approximately 5.0 ft on 2 October (see Fig. 25B).

The weir on the Revillon Coupé is a partially submerged structure which directs water through a channel along the southwest bank of the river (Fig. 4). A cross-sectional profile of the weir is shown in Fig. 22, as well as a range of mean water velocities at the weir, calculated in a similar manner to those at Little Rapids. Minimum and maximum mean velocities were 0.0 and 17.1 ft/sec, respectively, between 6 April and 17 August, 1976. These data must be interpreted carefully, for reasons similar to those given above. On 17 August, Peace River water levels were sufficiently high so that water at the Revillon Coupé weir reversed direction and flowed toward the Rivière des Rochers at a mean velocity of 0.9 ft/sec. Comparisons of mean velocities on similar dates at the Little Rapids (Fig. 21) and Revillon Coupé (Fig. 22) weirs show that water velocities at similar water levels above the weirs were greater at the Little Rapids weir than the Revillon Coupé weir, except when water levels were very low (e.g., on 6 April).

Surface velocity and hydraulic head were not estimated at the Revillon Coupé weir, due to the less intense sampling program conducted at this site.

Little Rapids fishway: Two velocity profile stations were monitored on four occasions at the Little Rapids fishway. Gradient profile, channel configuration, and location of the velocity profile stations are shown in Fig. 23, while Fig. 24 illustrates the cross-sectional profiles of the upstream and downstream velocity stations.

Mean width of the fishway was 20.4 ft and its total length (excluding meanders) was 584.0 ft (Fig. 23). Mean water depths at the upstream and downstream velocity profile stations varied from 3.5 to 4.4 ft, and from 4.1 to 4.3 ft, respectively.

At the upstream station, mean velocities ranged from 3.3 to 6.5 ft/sec (Fig. 24A) with point velocities at one-foot intervals along the profile transect varying from 0.4 to 18.9 ft/sec under high hydraulic head conditions and from 0.1 to 14.3 ft/sec under low hydraulic head conditions. Mean velocities at the downstream station (1.0 to 2.1 ft/sec) were considerably lower than those calculated for the upstream station on the same dates (Fig. 24), a result of the lower gradient and increased channel width at the downstream end of the fishway (Fig. 23). Point velocities at the downstream station under high and low hydraulic head conditions ranged from 1.5 to 13.0 ft/sec and from 0.3 to 1.0 ft/sec, respectively. The low point velocities obtained during the period of low hydraulic head were a consequence of increased water levels downstream of the weir.

Fish distribution and movement

Six fish (two northern pike and four goldeye), tagged downstream of the weir, were recaptured on the upstream side of the weir. Movement through the fishway was monitored, and it is known that these individuals did not utilize that route. One goldeye was tagged and recaptured within 10 minutes, and swam upstream across the weir when the hydraulic head was nearly 3 ft. Another goldeye was tagged and recaptured within seven hours, and moved upstream when the hydraulic head was approximately 2.3 ft. It is unknown what point velocities these fish encountered.

Relationships between hydraulic head and fish catches downstream of the weir and through the fishway are shown in Fig. 25. There was a definite positive correlation between hydraulic head and catch rates of fish downstream of the weir until mid-September. For example, high catch rates were obtained downstream of the weir from 4 to 29 June and decreased dramatically during the period of low head from 3 to 21 July.

Simultaneous catch rates of fish (species combined) upstream and downstream of the weir appear in Fig. 26 and catch rates for each species upstream and downstream of the weir are shown in Appendices 3, 4, 5, 6 and 7. In most cases, catch rates downstream of the weir were considerably higher than those upstream of the weir. However, between 4 and 7 July, during a period of low hydraulic head across the weir, uniformly low catch rates were obtained upstream and downstream of the weir.

Mark-recapture data from gill netting sites R01, R25, R26, R27 and R29 (Fig. 5) were used to estimate the number of fish that were concentrated downstream of the Little Rapids weir during a period of relatively high hydraulic head conditions. Between 1 and 24 June, when the hydraulic head across the weir remained above 2.2 ft (Fig. 25B), it was estimated that 205,120 goldeye*, 3,282 northern pike*, 1,266 lake whitefish* and 77 walleye* were present immediately downstream of the weir. Census methods and corrections similar to those outlined in the MATERIALS AND METHODS and POPULATION ESTIMATES sections were utilized in making the above estimates. An additional correction introduced was the elimination of all fish recaptured downstream of the weir that were tagged in locations other than downstream of the weir.

Approximately 92%, 77%, 60% and 38% of the goldeye, northern pike, walleye and lake whitefish, respectively (excluding immediate recaptures), tagged and recaptured downstream of the weir remained downstream of the weir during periods of relatively low hydraulic head (< 2.5 ft) (Table 15). Only 13 goldeye and one northern pike (excluding immediate recaptures) were tagged and recaptured upstream of the weir.

DISCUSSION

GILL NET SELECTIVITY

An extremely small fraction of the total number of goldeye taken were captured in 8.89-cm mesh nets, most probably because there were so few large goldeye in the Delta during this study. It is thought that the proportions of lake whitefish and walleye captured in the 3.81- and 8.89-cm mesh nets, respectively (Table 2), do not reflect the efficiency of these two mesh sizes in all parts of the Delta fished, but rather indicate the relative abundance of small lake whitefish (mean fork length = 184.7 mm) and large walleye (mean fork length = 419.5 mm) downstream of the Little Rapids weir.

The fact that relatively wide size ranges of goldeye, northern pike, lake whitefish and walleye were captured in the 3.81-cm mesh nets may be explained for those species with numerous and relatively large teeth (goldeye, northern pike and walleye), since small fish of these species are held behind the opercula by gill net strands, and large fish of these species often get caught by their teeth and subsequently entangle themselves. Kennedy and Sprules (1967) found a great spread in the size range of goldeye taken by a given mesh size, because these fish have a tendency to be caught by their teeth. It is not known why a relatively wide size range of lake whitefish was also captured in the 3.81-cm mesh net during this study, since members of this species are almost always captured behind the gills.

DIEL VARIATION IN CATCHABILITY OF FISH

Information collected during two 24-h gill netting studies suggest that at least some species exhibit daytime activity patterns and may be more susceptible to gill netting during daylight hours.

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* Ninety-five percent confidence limits for these estimates are the following:

goldeye	= 83,382 to 410,241
northern pike	= 1,628 to 6,160
lake whitefish	= 378 to 2,201
walleye	= 23 to 134

Because most fish captured during the diel studies were goldeye, results do not support suggestions made by Kennedy and Sprules (1967) and Scott and Crossman (1973) that goldeye are most active at night.

EFFECTS OF CAPTURE, HANDLING AND TAGGING ON FISH

Results of field experiments strongly suggest that mortality among goldeye and pike due to capture (by gill net), handling and tagging need not be considered as a variable during this study in analyses of movement and estimation of population sizes utilizing mark-recapture data. Donald (1972) retained 25 goldeye that had been captured in gill nets and tagged. After 30 h, all fish were released alive and active. Similar experiments by B. Munsen (personal communication) with goldeye in the North Saskatchewan River yielded quite different results. Approximately 50% (N = 50) of the goldeye held in running water (temperature range 16-22°C) after handling and tagging died within 48 hours. Munsen attributed this high mortality rate to the effects of chemical and/or physical composition of the water upon goldeye in conjunction with external damage caused by capture and handling.

AGE STRUCTURE AND GROWTH OF GOLDEYE AND WALLEYE

Goldeye

Time of annulus formation: The annulus was not formed on scales of goldeye captured in Alberta, Saskatchewan, Manitoba and Ontario (Kennedy and Sprules 1967), nor on scales of mooneye (*Hiodon tergisus*) captured in Manitoba (Glenn 1975), until immediately prior to the initiation of rapid growth during spring or summer. Results obtained during this study support these findings.

Kennedy and Sprules (1967) found that the new annulus formed on goldeye scales between late May and late June, with most scales showing a new annulus by early June. Glenn (1975) reported annulus formation between 28 May and 12 June for mooneye sampled in the Assiniboine River at Brandon, Manitoba. When compared with data presented by Kennedy and Sprules (1967), the longer time period within which the new annulus was being formed on goldeye scales collected during this study may be a result of a delayed initiation of growth in goldeye in 1976. Comparing data presented by Glenn (1975) with those collected in 1976 indicates that latitude may have some effect on the synchrony of growth initiation for members of the family Hiodontidae. That is, the new annulus of goldeye captured in the Peace-Athabasca Delta in 1976 appeared as a terminal annulus over a much longer time period than did that of mooneye sampled in the Assiniboine River, Manitoba.

Aging: Results of aging indicate that if no other factors are involved, goldeye scale samples may be most reliably aged if collections are obtained between mid-August and May of the following year. Goldeye scales were collected from the Peace-Athabasca Delta in 1975 (Kristensen et al. 1976) primarily following the peak period of annulus formation. Agreement during 1975 occurred on 89.7% of the scale samples aged, which is similar to the 91.9% agreement obtained between readings of scales collected in 1976 following annulus formation.

Age structure: Studies conducted by Kooyman (1973) and Donald and Kooyman (1974) initially documented that the 1971 year class of goldeye was extremely successful. Three major factors may have contributed to the success of this year class (Donald and Kooyman 1974) and thus explain the predominance of five-year olds in the 1976 samples (Fig. 10). First, in 1971, the previously strong year class of 1964 entered the spawning population. Second, mature goldeye migrated into the Delta earlier in 1971 than in 1972 and 1973, and spawning in 1971 was therefore completed about one week earlier than during the following two years. Third, the stomachs of young-of-the-year goldeye contained more food in 1971 than in 1972 and 1973, which probably indicated a more plentiful food source during 1971. The combination in 1971 of abundance of spawners, increased length of the growing season and an abundant food supply presumably enhanced the success of the 1971 year class.

The 1969 to 1974 year classes of goldeye comprised approximately similar proportions of the total samples in 1975 and 1976 (Fig. 11). The relatively unchanged proportions of these year classes in the total catches for the two years suggest similar mortality rates for these year classes between 1975 and 1976. Sample sizes for fish older than six years of age were too small to compare mortality rates between the two years.

Although statistically significant differences ($P < 0.001$) were found among the age structures of goldeye captured in the Claire-Mamawi lakes system, Chenal des Quatre Fourches, Revillon Coupé and Rivière des Rochers, age structure varied only slightly among catches. The age structure of goldeye captured in Lake Athabasca also differed statistically ($P << 0.001$) from age structures of goldeye sampled in the other areas. In this case, it was evident that there were proportionately more fish less than five years of age in the sample from Lake Athabasca. It is possible that a discrete goldeye group (as defined by Marr 1957:1) inhabits Lake Athabasca, and that by sampling at the western end of this lake, a mixture of this group and that of the Delta was taken. An alternative reason for the observed goldeye age structural differences is that the Claire-Mamawi lakes system is optimal habitat for goldeye, and that competition for some environmental commodity results in the dispersal of younger fish into other areas. Therefore, the observed age structural differences may be a result of differential age-related distribution of goldeye within the Peace-Athabasca Delta and Lake Athabasca, rather than the existence of two discrete goldeye groups.

Growth: As revealed in Fig. 12, the growth rate of goldeye in 1975 decreased for four- and five-year-old fish when compared with the 1973 growth rate of the same two age groups. Because approximately 85% of the goldeye collected in 1975 were four years old, it was suggested that this decreased growth rate was significant (Kristensen et al. 1976). Two possible reasons were given by Kristensen et al. (1976) for the apparent decrease in growth rate: (1) It may have been an artifact produced by collection of the 1973 and 1975 scale samples during different time periods within the season, or (2) it is possible that competition among members of the 1971 year class and fish of similar size had increased with time as they became larger. The 1976 age-length and age-weight relationships (Fig. 12) indicate that five- and six-year-old goldeye are experiencing pronounced decreased growth rates, and support results obtained by Kristensen et al. (1976) for four- and five-year-old fish in 1975. Since scales were collected from goldeye during similar time periods within the season in 1973 (Donald and Kooyman 1974) and 1976, the most plausible reason for decreased growth rates of five- and six-year-old fish in 1976 is the increased competition among fish of similar size.

Walleye

Age structure: Walleye captured in 1976 from Lake Athabasca, the Rivière des Rochers and the Claire-Mamawi lakes system differed in age structure. For a variety of reasons, catches may not have been representative of walleye in the sampling areas. Hence, some differences illustrated in Fig. 13 may be artifactitious. For example, all sample sizes were relatively small. Also, scales were collected from walleye in western Lake Athabasca between the middle and end of August. Bidgood (1971) reported that older walleye migrate east into the deeper portion of Lake Athabasca during the summer; therefore, our sample may not have adequately represented walleye in Lake Athabasca as a whole, but only those present in the western portion of this lake during August.

However, if we assume that the walleye age structures derived in this study were representative of those in each of the areas sampled, the following comments may be made. Walleye were commercially fished in the west end of Lake Athabasca in the vicinity of Big Point for approximately three weeks in June, 1976. Commercial fishing for walleye is normally carried out during late spring. Fishing gear used by commercial fishermen selects for large walleye which probably accounts for the low numbers of older walleye in Lake Athabasca (Fig. 13C). Domestic fishing for walleye also occurs to a limited extent in the Claire-Mamawi lakes system, again with fishing gear selecting the larger fish. This may account for the low number of older walleye in the Claire-Mamawi lakes system (Fig. 13A). However, there was a greater proportion of older walleye in the sample from the Claire-Mamawi lakes system than in the Lake Athabasca sample. This may be explained by the much more intense commercial fishing pressure in Lake Athabasca than domestic fishing pressure in the Claire-Mamawi lakes system. The relatively even distribution of age groups and the abundance of walleye older than 10 years in the Rivière des Rochers (Fig. 13B) were in all probability a consequence of little or no commercial or domestic fishing in this river. The observed walleye age structural differences among the sampling areas were therefore most likely a result of differential commercial and/or domestic fishing pressure in these areas.

A larger proportion of the total walleye catch was composed of older fish in 1976 than in 1975 (Fig. 14), even after young-of-the-year fish captured in 1975 were excluded for the sake of comparing age structures. Because gill netting for walleye in Lake Athabasca was conducted during approximately the same time in August in both years, age structural differences between the two years cannot be explained by time-related differences between catches of fish. Location of sampling in the two years was not variable; in 1975, gill netting for walleye in Lake Athabasca took place near the mouth of the Athabasca River and in 1976 almost all Lake Athabasca walleye used for age structural analysis were caught near the mouth of the same river. Differences between age structures of walleye sampled in the two years may be a consequence of small sample size in 1976; however, Kristensen et al. (1976) noted older walleye in the 1975 catch than in catches obtained in 1971. They attributed the presence of older walleye in 1975 to the termination of commercial fishing in Richardson Lake in 1967 and reduced fishing in Lake Athabasca in recent years. The present data also suggest that older walleye are becoming relatively more numerous in Lake Athabasca.

Growth: Although sample sizes in 1976 were small, available data suggest that growth rates of seven- to ten-year-old walleye sampled in Lake Athabasca (1975 and 1976) were faster than those of walleye of similar ages sampled in the Rivière des Rochers in 1976 (Fig. 15). Since commercial fishing pressure in Lake Athabasca selects for older walleye, as previously discussed, decreased numbers of older walleye in this lake may ease general competition and thereby permit increased growth of those large walleye remaining in the lake. The presence of relatively large numbers of older, slow-growing walleye, as in the Rivière des Rochers where fishing pressure is absent, is characteristic of unexploited fish populations.

REPRODUCTIVE POTENTIAL OF THE 1971 GOLDEYE COHORT

Approximately 85% of the goldeye sampled in 1975 (Kristensen et al. 1976) and 77% of the goldeye sampled in 1976 were members of the 1971 year class. An important consideration in determining the effects of this large cohort on future goldeye numbers is the dependence of sexual maturity on age and size. Kennedy and Sprules (1967) reported that 2% and 55% of seven- and eight-year-old female goldeye, respectively, collected in 1947-48 in the Peace-Athabasca Delta were mature. Kooyman (1973) found that, with the exception of one male, all six-year-old goldeye sampled in 1971 were mature. On the basis of these data, in conjunction with differential growth rates of goldeye in 1947-48 and 1971, Kooyman (1973:F9) stated that,

> "Size, as well as age, is a factor in the onset of sexual maturity. Goldeye in the Peace-Athabasca Delta are maturing at an earlier age than in the past because of faster growth rates. The accelerated growth rates in recent years may be the result of lessened competition amongst goldeye, due to their decreased numbers during the early 1960's".

Growth rates of goldeye belonging to the 1971 year class, as well as those of neighbouring year classes, decreased in 1975 (Kristensen et al. 1976) and 1976; this may be a result of the abundance of fish of similar size and consequently increased intraspecific competition among these fish. Mean fork lengths of five- and six-year-old goldeye sampled in 1976 more closely approximated those of goldeye of similar ages captured in 1947-48 (Kennedy and Sprules 1967) than those of goldeye sampled between 1971 and 1973 (Kooyman 1973, Donald and Kooyman 1974) (Fig. 12). Because of this decreased growth rate, it is possible that a large proportion of female goldeye belonging to the 1971 year class will mature at age seven or eight (Kennedy and

Sprules 1967) rather than at age six (Kooyman 1973).

On the basis of the following assumptions, approximately 4,065,000 postlarval young-of-the-year goldeye could be produced in 1979 by the 1971 year class.

1. Presence of 897,557 five-year-old goldeye in 1976 (Table 14).

2. A 1:1 sex ratio (Schultz 1955; Kennedy and Sprules 1967; Kristensen et al. 1976).

3. A minimum annual mortality rate of 51% (Donald and Kooyman 1977).

4. 55% of females mature at age eight (Kennedy and Sprules 1967).

5. Mean fecundity of 14,000 eggs (Kennedy and Sprules 1967).

6. All eggs are fertilized.

7. 99% egg and larval mortality. (Ricker (1971) cites 99.5% for smelt eggs; Paetz and Nelson (1970) state 90% for "most" Alberta fish.)

Assumptions 3 and 6 above probably result in an overestimate of goldeye production in 1979, while assumption 7 may result in an underestimate. If a similar estimate is made on the basis of the total number of spawners estimated to be present in 1979 (as determined from population estimates shown in Table 14), approximately 4,241,000 postlarval young-of-the-year goldeye could be produced in 1979. On the basis of these two estimates, the 1971 cohort would contribute approximately 96% (4,065,004/ 4,241,000) of the total reproductive success in 1979. Regardless of how tenuous these estimates are, the relative importance of the 1971 cohort to future reproductive potential of goldeye is obvious.

An estimated 2,839,000 (modified from Kooyman (1973) by Kristensen et al. (1976)) young-of-the-year goldeye were present in the Claire-Mamawi lakes system in 1971, as compared to an estimate of only 549,000 in 1975 (Kristensen et al. 1976). Although these estimates were based on sampling programs which included sampling for large young-of-the-year fish (presumably following a period when some post-larval mortality may have occurred), the projected estimate for 1979 reflects a substantial increase over those of 1971 and 1975. This is very significant since production in 1971 was considered extremely successful (Kooyman 1973; Donald and Kooyman 1974). On the basis of these data, the importance of the 1971 year class is again evident. If this year class is to contribute significantly to the goldeye population of the Delta in future years, it is imperative that goldeye continue to have access to their spawning grounds in the Peace-Athabasca Delta.

RELATIVE ABUNDANCE AND DISTRIBUTION OF FISH

The extremely high catch rates of over 80 goldeye per hour in the Rivière des Rochers in June and in the Chenal des Quatre Fourches in September were almost certainly functions of different phenomena. High catch rates in the former area were caused by concentration of fish downstream of the Little Rapids weir, while those in the latter area were due to the passage of large numbers of goldeye during their migration to the Peace River.

Relatively high proportions of northern pike were obtained in catches from the Claire-Mamawi lakes system and the Rivière des Rochers. Habitat in the former area appeared to be optimal for pike with large, shallow, weedy areas, warm water temperatures and large numbers of forage fishes. Of these features, only the last occurred in the Rivière des Rochers, where pike appeared to be just as abundant as in the Claire-Mamawi lakes system. Observed changes in seasonal and overall abundance of pike in the Rivière des Rochers may have been due to the effects of the Little Rapids weir.

Lake whitefish less than 200 mm in fork length comprised high proportions of total lake whitefish catches in all areas sampled, except the Claire-Mamawi lakes system. During the autumn spawning season, lake whitefish are known to occur in Lake Athabasca and Flett Lake (local fishermen, personal communication), which is in close proximity to and drains into the Rivière des Rochers. Hence, relatively large numbers of small lake whitefish in Lake Athabasca and the Rivière des Rochers can be expected. (Catch rates (Figs. 18A and B) also indicate that lake whitefish of all sizes were most abundant in the Rivière des Rochers and Lake Athabasca.) However, small lake whitefish also comprised high percentages of the total whitefish catches in the Revillon Coupé and Chenal des Quatre Fourches. Such data suggest that other spawning areas exist or that young lake whitefish become widely dispersed throughout much of the Delta.

Large lake whitefish were also relatively uncommon in the Claire-Mamawi lakes system (Table 8). Such a low relative abundance of lake whitefish in this system might be attributed to the warm water temperatures in summer due to the shallowness of the lakes. Lake whitefish tend to inhabit cool water lakes (Paetz and Nelson 1970; Scott and Crossman 1973; Edsall and Rottiers 1976).

The presence of small walleye (those less than 200 mm in fork length) in Lake Athabasca can be explained in view of previous research (Bidgood 1973; Dietz 1973) which indicated that young-of-the-year walleye migrate out of Richardson Lake toward Lake Athabasca. The facts that similar proportions of small walleye (less than 200 mm) were caught at Little Rapids and Lake Athabasca, and that no small individuals were obtained from other sampling areas, may indicate either that (1) maintenance areas for small walleye are discontinuous, or that (2) different groups (Marr 1957) of walleye are involved. Fishing methods in 1976 were not geared to capture small individuals; hence, no conclusive data concerning diffferential distribution of small walleye are available. However, as noted in the discussion of age structure, differences are evident in the age compositions of walleye samples from Little Rapids and from Lake Athabasca. This appears to be evidence supportive of point (2) above.

FISH MOVEMENT AND MIGRATION

An objective of this study was to obtain information concerning the relative importance of the three major channels connecting the Peace River with the Delta to fish (primarily goldeye) migration into the Delta. Kooyman (1973) and Donald and Kooyman (1974) documented that the Chenal des Quatre Fourches was a migration route for goldeye moving into the Delta from the Peace River during spring and back to the Peace River during summer and autumn. However, such use of the Revillon Coupé and Rivière des Rochers was not documented. Unfortunately, field work in 1976 did not commence until 31 May. Donald and Kooyman (1974) found that most goldeye had already completed their spring migration and were in the Claire-Mamawi lakes system by that date. Therefore, data gathered in 1976 on spring goldeye movement into the Delta were probably obtained from only a small fraction of the population.

Movement and migration as determined from mark-recapture data

Results of the analysis of fish movement must be interpreted carefully, because fishing effort and fishing periods varied among areas (Fig. 6). For example, the fact that approximately 47% of the fish recaptured in other waterbodies were tagged in the Rivière des Rochers (Little Rapids) (Table 11) does not necessarily imply that fish movement from this area was of greater magnitude than that from other areas; it may only reflect the greater number of fish tagged at Little Rapids. Effects of aberrant behavior due to capture, handling and tagging were thought to be minimized by elimination of immediate recaptures from the data.

Goldeye: Several patterns or trends became evident when movements of tagged goldeye were analyzed in relation to dates and locations of recaptures (Table 11).

The movements of 12 tagged goldeye from the Rivière des Rochers, Revillon Coupé or Chenal des Quatre Fourches into the Claire-Mamawi lakes system or western end of Lake Athabasca between 1 June and 31 August (Table 11) may represent the late spring movement of goldeye from the Peace River into the Delta lakes, because all of these fish were tagged in June or early July. Nine of the 12 goldeye moving into the lakes during this period were tagged in the Rivière des Rochers, suggesting that this river was utilized by some proportion of the goldeye moving into the Delta. In all probability these data were collected after the peak spring migration period had passed.

A shift in the movement pattern of goldeye during late summer and autumn became evident when recaptures of goldeye between 1 September and 20 October were considered (Table 11). No goldeye recaptured between 1 September and 20 October exhited movement into the Delta lakes from the three channels connecting the Peace River with the Delta. This may have been due to the lack of fishing by LGL crews in the lakes during this period (Fig. 6); however, fairly intensive domestic fishing took place in the lakes during this period and no tag returns were recorded.

The movement of tagged goldeye during September and October from the Claire-Mamawi lakes system or Lake Athabasca through the Chenal des Quatre Fourches, Revillon Coupé and Rivière des Rochers indicates that goldeye utilize all three channels during their summer-autumn migration to the Peace River. Twenty-two of 28 goldeye recaptured between 1 September and 20 October appeared to travel between channels. However, 15 of these fish were tagged in June or early July and had sufficient time to move into the Delta lakes for some period and then move back into the channels. Therefore, these movements may be late summer and autumn movements out of the Delta toward the Peace River, rather than inter-channel movements.

Although 42% of the goldeye tagged during this study were tagged in the Rivière des Rochers (Table 8), only 7% of the goldeye recaptured between 1 September and 20 October and exhibiting inter-waterbody movement were recaptured in this river (Table 11). Of the goldeye recaptured during this period, 54% were recaptured in the Revillon Coupé and 39% in the Chenal des Quatre Fourches. These data suggest that more goldeye utilized the Revillon Coupé and Chenal des Quatre Fourches than the Rivière des Rochers during their summer-autumn migration out of the Delta.

Eighteen goldeye tagged at Quatre Fourches by the Canadian Wildlife Service between 1972 and 1974 were recaptured in 1976 in the Claire-Mamawi lakes system. These data, in conjunction with the fact that Lake Claire and Mamawi Lake usually freeze to the bottom during winter (Peace-Athabasca Delta Project Group 1973) or that at least the shallow waters of these lakes stagnate under winter ice cover (Kooyman 1973), indicate the traditional movement of goldeye into and out of this system.

Two recaptures of goldeye (Table 11) document that the Athabasca River provides summer feeding habitat for at least some members of the Delta population. The recapture at the Revillon Coupé weir of a goldeye tagged close to Fort MacKay suggests that goldeye move from the Athabasca River toward the Peace River during late summer. Several recaptures indicate movement of goldeye from other parts of the Peace-Athabasca Delta toward the mouth of the Athabasca River. Together, these recaptures indicate that goldeye move back and forth between the Peace-Athabasca Delta and the Athabasca River (as far south as Fort MacKay).

Although data are limited, the movement of tagged goldeye between the Peace-Athabasca Delta and the Athabasca River in 1976 suggests that goldeye inhabiting these two areas are members of the same group (Marr 1957). A comparison of the age structures of goldeye captured in the Delta in 1975 (Kristensen et al. 1976) and in the Athabasca River (between Fort McMurray and Fort MacKay) in 1975 (McCart et al. 1977) supports this suggestion. Four-year-old fish were most abundant in both areas, 85% and 74% of the respective total samples. On the basis of a lack of ripe and young-of-the-year goldeye captured in the Athabasca River, McCart et al. (1977) also suggested that goldeye which frequent this area primarily to feed spawn in the Peace-Athabasca Delta.

Available information indicates that goldeye are highly mobile, utilizing optimal areas within larger regions for spawning, feeding and overwintering. Numerous long-distance movements have been reported for goldeye. Donald and Kooyman (1974) documented goldeye movements of up to 780 km between Quatre Fourches and the Smoky River near the town of Peace River. McCart and Jones (1975) reported movements of up to 497 km between the Red Deer and South Saskatchewan rivers, and B. Munsen (personal communication) has evidence of a goldeye moving up to 2415 km from its point of tagging (Edmonton) in the North Saskatchewan River.

Lake whitefish and walleye: The fact that three lake whitefish tagged at Quatre Fourches in 1974 by the Canadian Wildlife Service were recaptured in the Delta (Little Rapids fishway, Big Point and Quatre Fourches) during this study, indicates that lake whitefish manifest some degree of fidelity to the Delta waters from year to year.

The movement of a tagged walleye between Fort MacKay and Fort Chipewyan in 1976 indicates that there may be more extensive movement of walleye between the Peace-Athabasca Delta and the upper Athabasca River. On the basis of tag recoveries, Dietz (1973) reported an indication of a relatively minor movement of walleye from Richardson Lake (Fig. 1) upstream in the Athabasca River. It is possible that Richardson Lake is utilized for spawning by some walleye found in the Athabasca River (as far upstream as Fort MacKay), as well as by those found in Lake Athabasca (Bidgood 1973; Dietz 1973).

Movement and migration as determined from catch rates of fish

Goldeye: High catch rates of goldeye downstream of the Little Rapids weir during June probably represented some portion of the late spring migration of juvenile goldeye toward the Delta. It therefore appears that the Rivière des Rochers is important to at least the spring migration of immature goldeye. Donald and Kooyman (1974) reported that the migration of immature goldeye follows that of mature goldeye by a period of one to two weeks. In view of these findings, it is probably that mature goldeye also utilize this channel earlier in the spring.

Catch rates of goldeye obtained simultaneously in the Chenal des Quatre Fourches, Revillon Coupé and Rivière des Rochers during September and October indicate that the Chenal des Quatre Fourches and Revillon Coupé may be equally important to goldeye migrating out of the Delta. Catch rates of goldeye in the Rivière des Rochers were less than one-half those obtained in each of the other two channels during September and October. This suggests that the Rivière des Rochers is not as important to goldeye movement out of the Delta as the Chenal des Quatre Fourches or the Revillon Coupé.

Migration of goldeye from the Delta appeared to be later than usual in 1976. Peak catch rates of goldeye were obtained in the Chenal des Quatre Fourches and Revillon Coupé between 16 and 29 September with relatively high numbers taken throughout September (Fig. 16). The peak period of goldeye migration to the Peace River was from mid-July to mid-August in 1972 and 1973 (Donald and Kooyman 1974). It is possible that the summer-autumn migration of goldeye out of the Delta in 1976 was delayed by the fairly continuous flow of water into the Claire-Mamawi lakes system between 14 August and 2 September. The normal direction of flow during this period is out of this system toward the Peace River (as determined from hydrological records of Alberta Department of the Environment).

Northern pike and lake whitefish: High catch rates of northern pike at Little Rapids during September and October may be an artifact caused by the creation of ideal feeding habitat downstream of the weir, since most of the pike captured at Little Rapids were captured downstream of the weir (see EFFECTS OF WEIRS AND FISHWAY section).

Lake whitefish appeared to be approximately five and 10 times as abundant in the Rivière des Rochers as in the Revillon Coupé and Chenal des Quatre Fourches, respectively, during September and October. Approximately 66% of the lake whitefish captured in the Rivière des Rochers (Little Rapids) during this period were 270 mm or greater in fork length. McCart et al. (1977) found that some lake whitefish in the Athabasca River (between Fort McMurray and Fort MacKay) attained maturity at 270 mm fork length. These data, in conjunction with the fact that most lake whitefish appear to spawn in lakes in fall (Scott and Crossman 1973), suggest that the relatively high catch rates of lake whitefish in this river between 5 September and 21 October represented spawning movements toward Lake Athabasca or Flett Lake. Lake whitefish are abundant in both lakes in autumn (local fishermen, personal communication), which suggests that they spawn in these lakes.

In most years, including 1976, domestic catch rates of lake whitefish are high at Quatre Fourches during autumn (local fishermen, personal communication), probably a result of the fish moving toward Lake Athabasca to spawn. Gill netting during this study was conducted downstream of Quatre Fourches in the Chenal des Quatre Fourches and may explain the low catch rates of lake whitefish obtained in this river between 5 September and 21 October.

POPULATION ESTIMATES

The estimate of 897,557 five-year-old goldeye in the Peace-Athabasca Delta in 1976 represents an approximate 68% reduction of the 1971 year class within a five-year period, since Kooyman (1973) estimated that 2,839,000 young-of-the-year were present in the Claire-Mamawi lakes system in 1971. Of the 548,940 young-of-the-year golddye estimated to be present in the Claire-Mamawi lakes system in 1975 (Kristensen et al. 1976), only 9,677 were estimated to have remained in the population as one-year olds in 1976 (Table 14). These data represent an approximate 98% reduction of the 1975 year class between 1975 and 1976. Possible reasons given for the success of the 1971 year class (see discussion of age and growth) may account for the difference between the mortality rate for the 1971 year class between 1971 and 1976 (68%) and that for the 1975 year class between 1975 and 1976 (98%). The difference between the two mortality rates may also be an artifact caused by (1) an underestimation of the number of one-year olds in the 1976 population, (2) an overestimation of the number of five-year olds in the 1976 population, and/or (3) incorrect estimation of the number of young-of-the-year goldeye present in 1971 (Kooyman 1973) or in 1975 (Kristensen et al. 1976).

Approximately 59% of the estimated number of walleye occurring in the Delta in 1976 were four to seven years old (Table 14). As previously discussed, commercial and domestic fishing appear to effectively reduce the numbers of walleye in older age groups, especially in Lake Athabasca.

Population estimates for goldeye, lake whitefish, northern pike and walleye (Table 13) are speculative, since many assumptions were involved (Ricker 1975), and violations of these assumptions undoubtedly contributed to errors in estimates. As shown in Table 8, the majority of the mark and recapture effort occurred in the Rivière des Rochers.

Therefore, the resulting population estimates, based on this unequal fishing effort, are not realistic assessments of the number of fish inhabiting the whole study area, but are probably biased toward the number of fish utilizing the Rivière des Rochers. This is especially true for the estimates of northern pike, lake whitefish and walleye since almost all recaptures of each of these species used for the population estimates were taken from the Rivière des Rochers (approximately 95%, 96% 100%, respectively (Table 8)).

EFFECTS OF WEIRS AND FISHWAY

Results of this (Figs. 25 and 26) strongly indicate that fish (primarily goldeye) became concentrated downstream of the Little Rapids weir because they were unable to move across the structure during periods of high hydraulic head. During periods of low hydraulic head, fish dispersed away from the downstream side of the weir and indications are that they moved in an upstream direction over the weir.

A strong tendency toward upstream movement was shown by high catch rates in the fishway (Fig. 25C) in June. These high catch rates corresponded to periods when hydraulic head was less than 2.5 ft and when extremely high catch rates of fish were obtained downstream of the weir (Fig. 25). It appears that large numbers of fish were present in the area during these periods, at least some of which moved upstream through the fishway. An extreme rise in catch rate of fish moving upstream through the fishway on two occasions (18 and 28 June (Fig. 25C)) likely indicated the hydraulic head level (2.0 to 2.5 ft) which first allowed passage of large numbers of fish through this structure. It is not known how many fish moved across the weir during these periods of high hydraulic head because it was not possible to directly monitor fish movements across this structure. However, on the basis of mark-recapture data previously given, it is known that at least some goldeye moved upstream across the weir when hydraulic heads were approximately 2.3 and 3.0 ft.

Estimates of the numbers of fish present immediately downstream of the Little Rapids weir during a period of relatively high hydraulic head conditions are likely maximal, since in- and out-migration of fish were uncontrolled and it is known that catch rates of fish moving through the fishway were high during some portions of this time period.

That large numbers of fish were present immediately downstream of the Little Rapids weir does not necessarily imply that all fish were hindered from swimming upstream over the weir. Data gathered during 1976 (Table 15) suggest that some fish preferred the area downstream of the weir and may have been residents of this area. However, because the length of time between tagging and recapture dates for fish considered as residents varied from one to 137 days (Table 15), the term "resident" applies only loosely in some cases. It is also possible that these fish moved away from the area and then returned at a later date.

After mid-September, high catch rates of fish downstream of the weir were no longer obtained under conditions of high hydraulic head. This period corresponded to the out-migration of goldeye from the Delta to the Peace River in 1976, a period when the Little Rapids weir would not have presented an obstacle to fish migrating downstream.

Fishing techniques captured all fish moving upstream through the fishway, but some unknown proportion (probably a small fraction) of fish swimming upstream over the weir. For this reason it was not possible to completely assess the importance of the fishway to fish movement. However, data presented in Fig. 25 strongly suggest that (1) large scale movement through the fishway occurred only when the hydraulic head was below 2.5 ft, (2) little upstream movement occurred during periods of high hydraulic head, and (3) during periods of low hydraulic head (and subsequently low velocities), there was little reason for fish to utilize the fishway, since velocities would not have impeded movement across the weir.

Although the effects of the Revillon Coupé weir on fish movement were not studied in detail, a few general comments may be made based on a limited amount of data. Catch rates of fish (species combined) upstream and downstream of the weir were approximately 12.4 and 28.3 fish/45.7-m net/hour, respectively, between 5 and 8 June, a period when mean water velocities were relatively high (excluding water velocities under the ice (6 April)) (Fig. 22). The higher catch rate downstream of this weir probably represented a concentration of fish in that area during a period when goldeye may still have been migrating toward the Delta. It may also have been that the large area of back-water eddies downstream of the weir was utilized as a feeding area and attracted large numbers of fish.

Comparison of mean water velocities calculated for the Revillon Coupé and Little Rapids weirs on similar dates (Figs. 21 and 22) suggests that the weir on the Revillon Coupé would hinder fish movement toward the Delta to a much lesser extent than would the weir on the Rivière des Rochers.

How the above findings interrelate and what effects water control structures may have on fish populations, especially goldeye, in the Delta are complex.

Of extreme importance is the early spring migration of mature goldeye from the Peace River to their spawning grounds in the Claire-Mamawi lakes system. As a result of late initiation of the field program in 1976, the relative importance of the Chenal des Quatre Fourches, Revillon Coupé and Rivière des Rochers to the spring migration of goldeye cannot be assessed. Nevertheless, large numbers of juvenile goldeye were present in the Rivière des Rochers from June to September, and it appears highly probable that this channel is also utilized by migrating mature goldeye during early spring.

Donald and Kooyman (1974) reported mature goldeye at Quatre Fourches on 12 March, 1973 and concluded that during late winter mature goldeye are already moving into the Chenal des Quatre Fourches from the Peace River. If such early movement toward the Delta also occurred through the Rivière des Rochers in 1976, it is extremely doubtful that it was successful, due to the presence of the Little Rapids weir. Estimated mean velocities across the weir were 12.7 and 13.7 ft/sec on 20 January and 6 April, 1976, respectively (Fig. 21).

A major movement of mature goldeye through Quatre Fourches began on 11 May in 1972 and 19 May in 1973, shortly after flow direction at Quatre Fourches changed and water began flowing back toward the Peace River (Donald and Kooyman 1974). Thus, at least part of the spawning migration of goldeye to the Delta was an upstram migration. Under present conditions, any fish migrating upstream through the Revillon Coupé and Rivière des Rochers will encounter potential barriers due to the weirs on these channels. The magnitude of their hinderance to fish migrations depends of (1) water levels in the Peace River, (2) water levels in the Delta, (3) presence and precise locations of ice jams on either the Slave or Peace rivers, and (4) timing of the spawning migration.

Present data indicate that during late spring and summer goldeye concentrate downstream of the weirs but that at least some goldeye move upstream over the Little Rapids weir under conditions of low and moderate hydraulic head. Presupposing a strong natural drive for migrating mature goldeye to enter the Claire-Mamawi lakes spawning region and the occurrence at some point in the season of water levels conducive to fish passage, it is unlikely that either weir would completely stop spawning migrations.

Of crucial importance to the overall welfare of the Delta goldeye population is the successful spawning and survival of fish belonging to the 1971 cohort, members of which comprised approximately 77% of the population in 1976 (excluding young-of-the-year). This year class will contribute significantly toward reproduction from 1977 to at least 1980 (depending upon present age at maturity of goldeye). Donald and Kooyman (1974) have shown that the mere presence of large numbers of spawning goldeye does not guarantee successful reproduction and survival of young. They indicate that the success of the 1971 year class may have been attributable to the early arrival of mature goldeye on the spawning grounds and abundance of food. Hence, timing of spawning migrations may have some importance to reproductive success, and the Little Rapids and Revillon Coupé weirs have the potential to delay spring migrations, depending on spring water levels each year. While the effects of delayed entrance to the spawning grounds are unknown in relation to the reproductive success of the goldeye population (e.g. mortality of eggs, larvae and young-of-the-year, growth rates of young-of-the-year), they could be critical.

Juvenile goldeye were concentrated on the downstream side of the Little Rapids weir during intervals from early June to mid-September. Donald and Kooyman (1974) documented that immature goldeye normally move into the Delta about one to two weeks after mature goldeye. On the basis of information presented by Donald and Kooyman (1974), immature goldeye enter the Delta during the latter half of May. The timing of their spring migration makes immature goldeye potentially more vulnerable than mature goldeye to effects of longterm delays caused by weirs. This is due to the fact that ice jams on the Slave and/or Peace rivers in April or May, and spring flood conditions in late June or July in the Peace River usually create conditions on two separate occasions when Peace River waters flow into the Delta or at least lower hydraulic heads across the weirs. It is likely that immature goldeye migrate between these two periods of optimal conditions at the weirs. Peak catch rates downstream of the Little Rapids weir were obtained prior to a period of high water conditions (as indicated by high water levels downstream of the weir (Kristensen and Summers 1979)) in the Peace River in early July. Catch rates were lower in this area for the remainder of the season and especially low during and shortly after the high water period in July which significantly reduced hydraulic head across the weir. In view of the facts that substantial numbers of goldeye were concentrated on the downstream side of the Little Rapids weir during June, and fish exhibited tendencies toward upstream movement (Fig. 25), the above data suggest that (1) upstream migration was interrupted due to adverse conditions at the Little Rapids weir, and (2) high water levels in the Peace River in July permitted upstream movement.

Although the consequences to immature goldeye of early spring migration to the Delta are unknown, it can be assumed that disruption of natural patterns of behavior by delays at weirs will not be helpful. Delta waters could provide optimum feeding habitat, and exclusion from such habitat even for short periods could decrease growth rates of fish. This is especially important since growth of goldeye is extremely slow or insignificant during the winter, as revealed by the spacing of circuli on scales and information given by Kennedy and Sprules (1967).

Other potential effects of less than optimal habitats on goldeye are increased predation, increased age at maturity, and a lowering of reproductive potential. Predation of goldeye downstream of the weir may have been significant in 1976 because northern pike occurred in large numbers in this area. (Kennedy and Sprules (1967) indicated that pike are principal predators of goldeye.)

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Dr. D.P. Scott, Science Advisor, Western Region, Fisheries and Marine Service, Fisheries and Environment Canada, was scientific advisor for this project. He contributed to data analysis and reviewed earlier versions of this report. Other people who made valuable suggestions during various stages of the project include A.H. Kooyman, Canadian Wildlife Service; R.J. Paterson, Director, Environmental Secretariat, Western Region, Fisheries and Marine Service, Fisheries and Environment Canada, and Dr. S.B. Smith, Program Director, Alberta Oil Sands Environmental Research Program.

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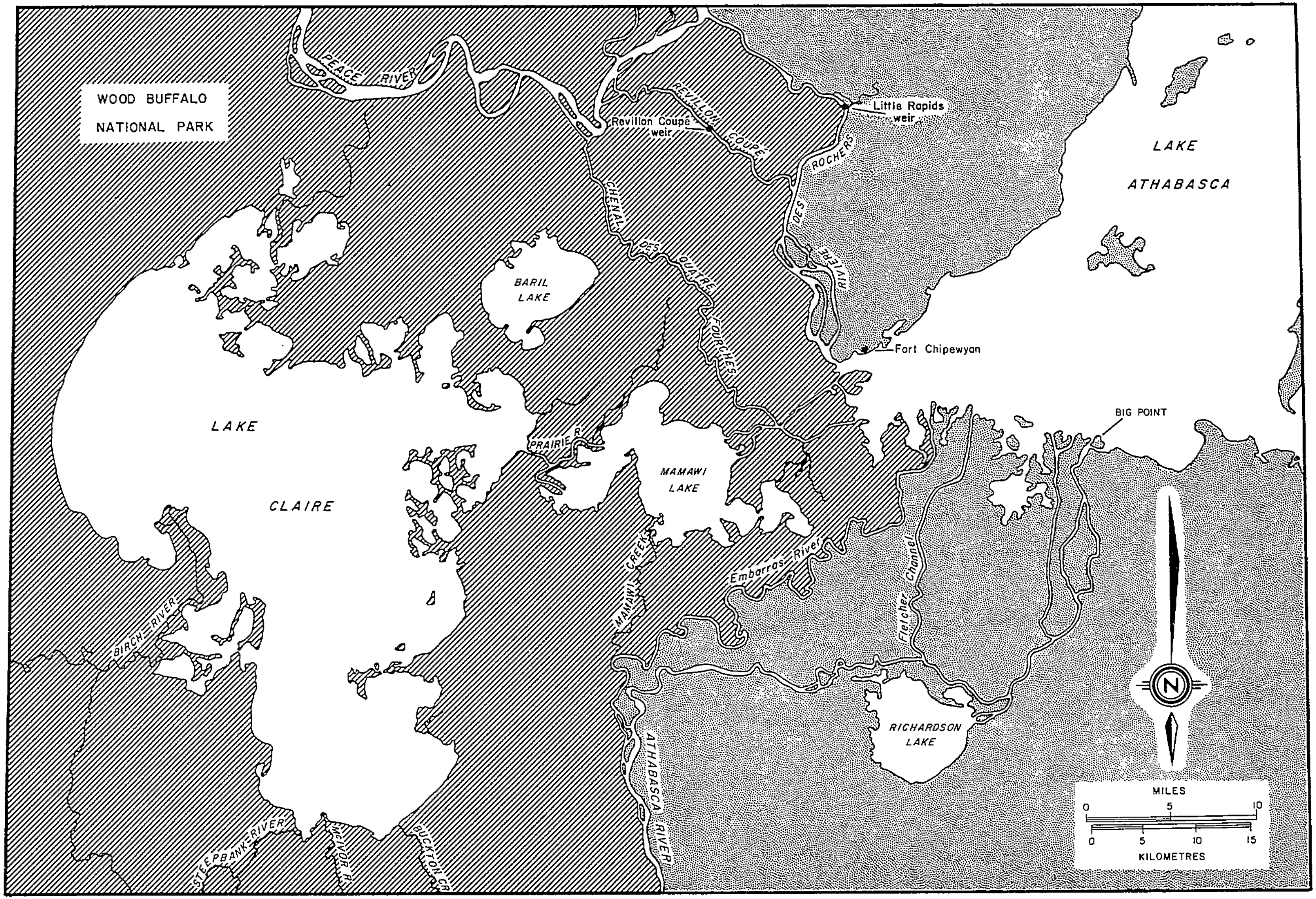


Fig. 1. The Peace-Athabasca Delta, showing locations of the water control structures on the Rivière des Rochers and the Revillon Coupé.

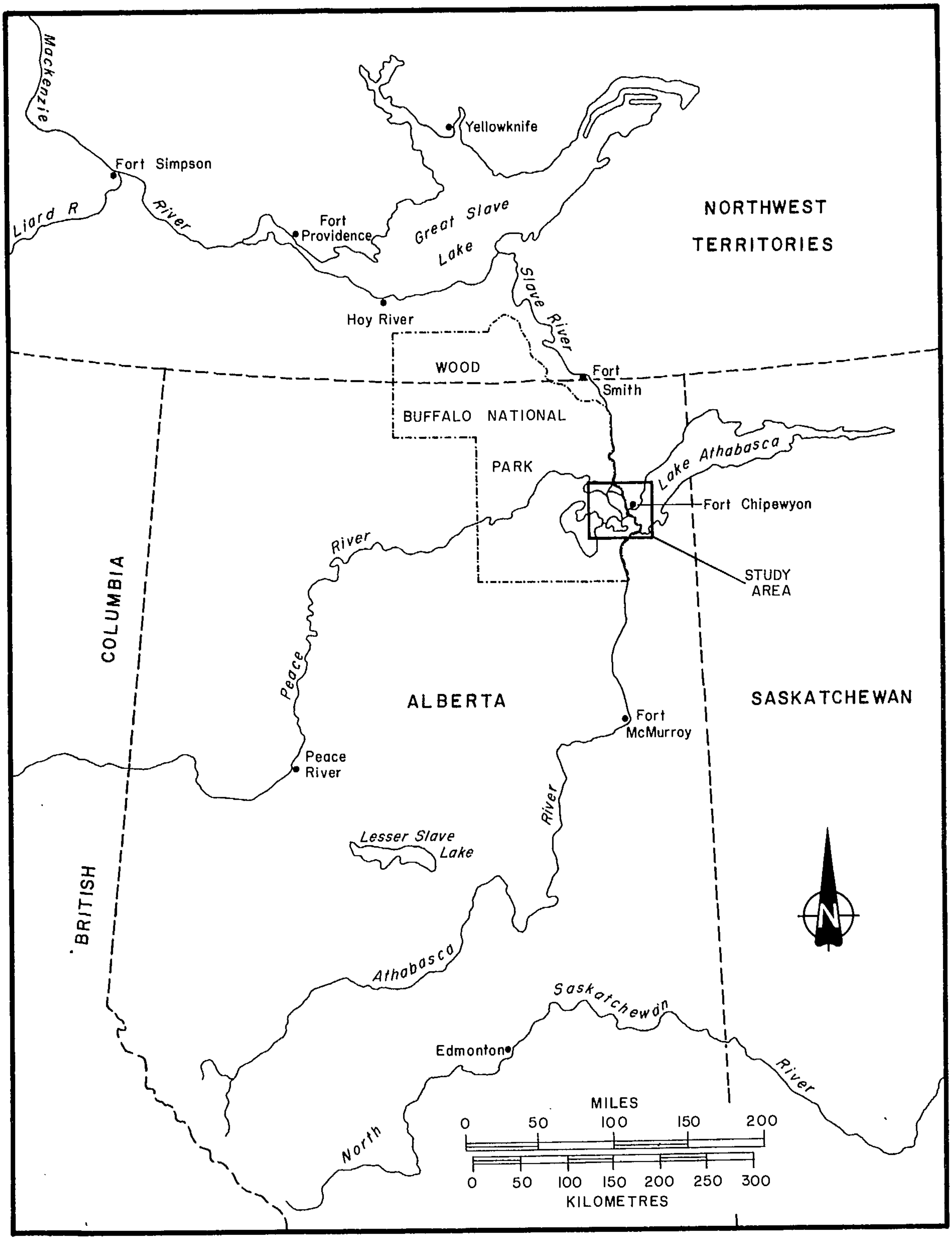


Fig. 2. Location of 1976 study area in Alberta.

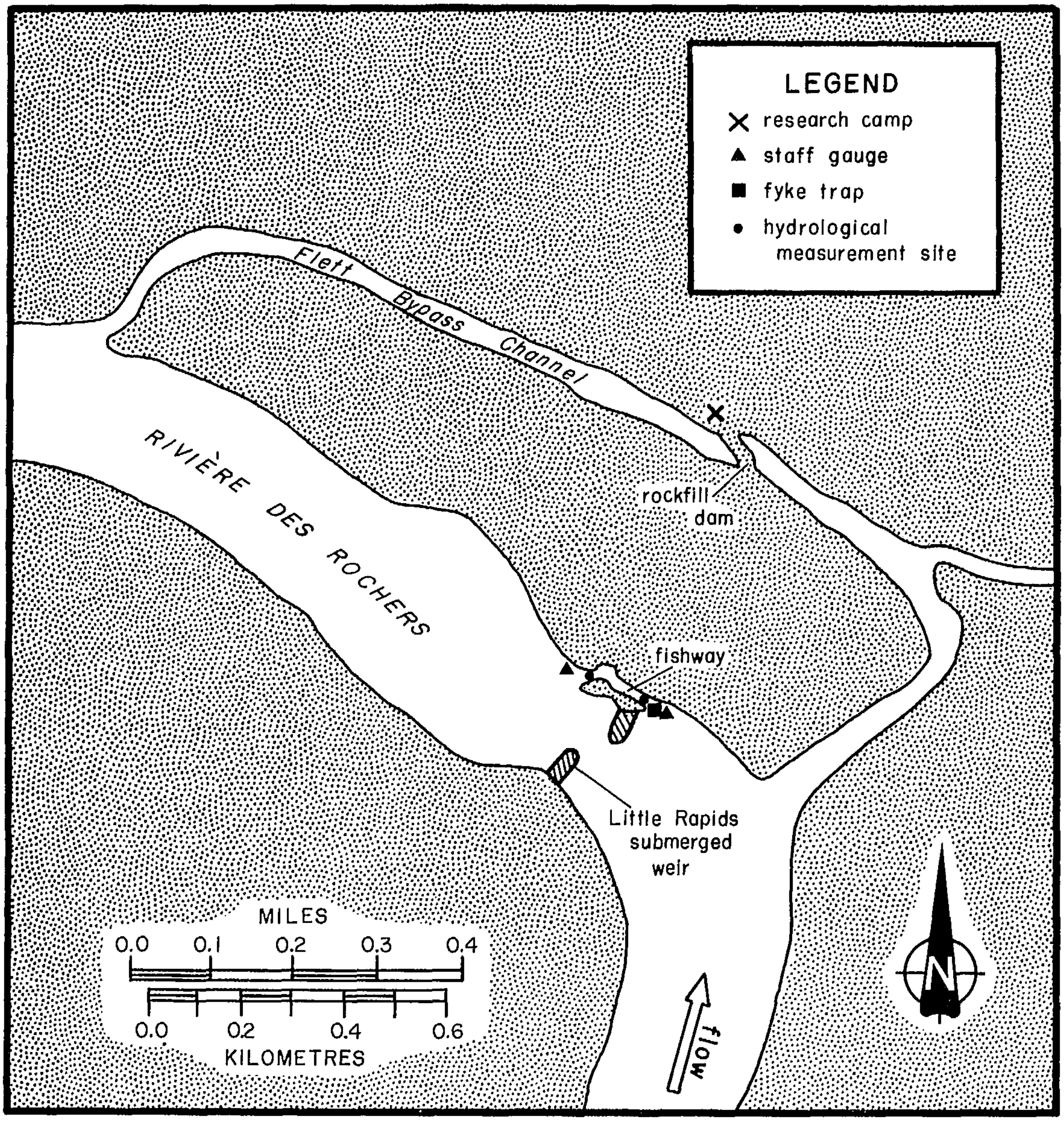


Fig. 3. Little Rapids weir and fishway. (Modified from map by Smith and Hammond (1975).)

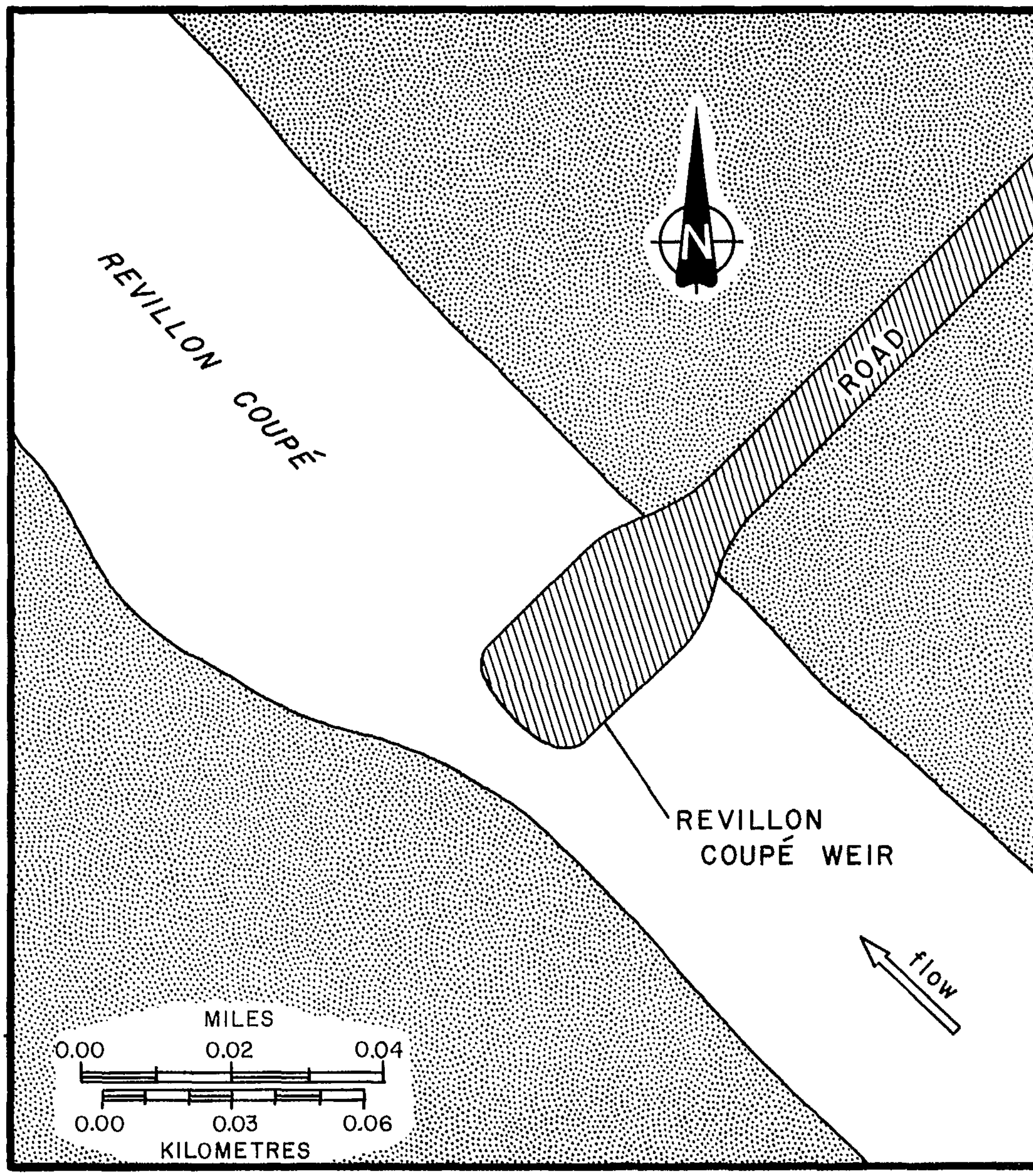


Fig. 4. Revillon Coupé weir. (Modified from plan by Canada Department of Regional Economic Expansion (1975).)

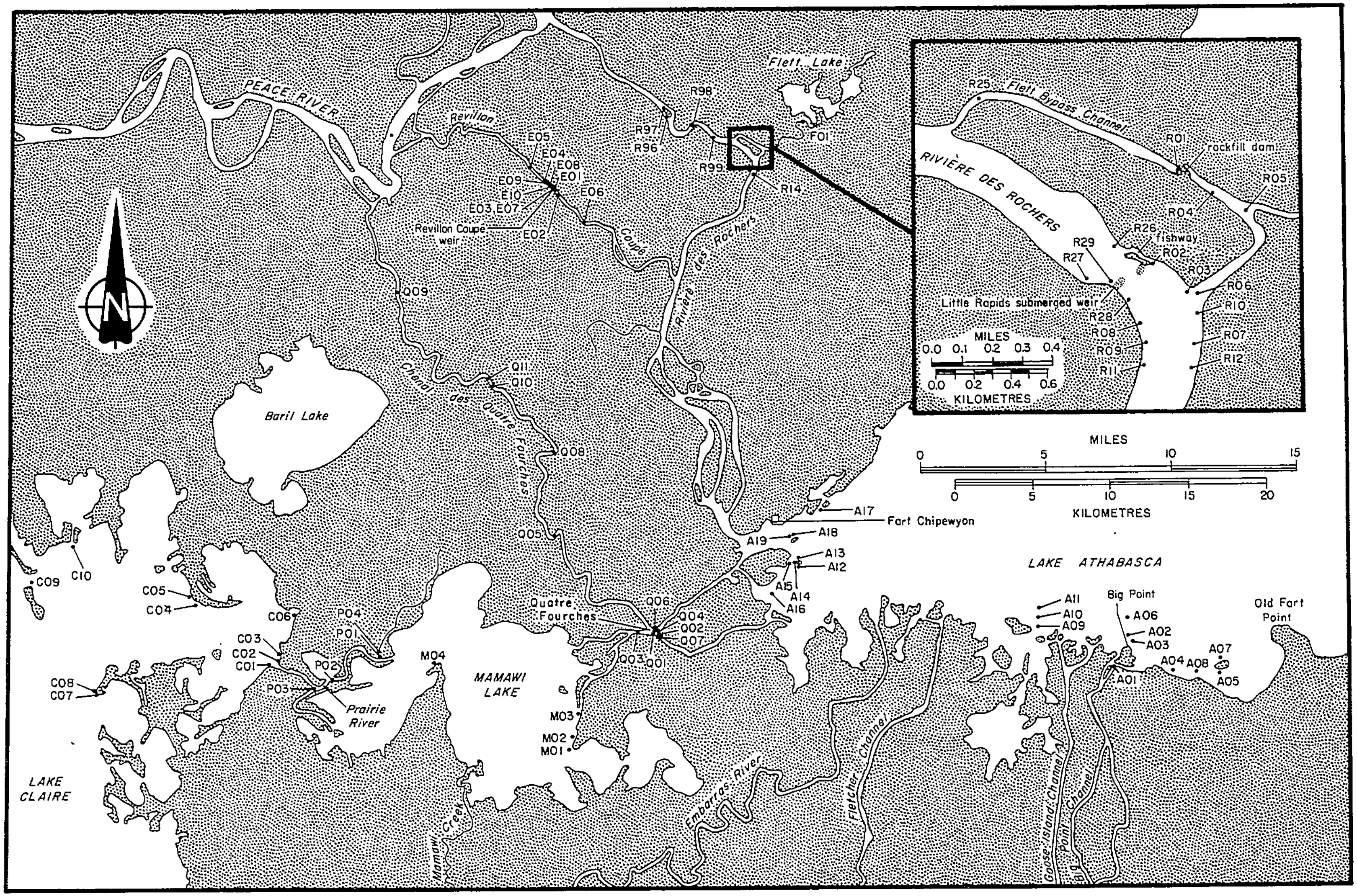


Fig. 5. Locations of sampling stations in the Peace-Athabasca Delta, 1976.

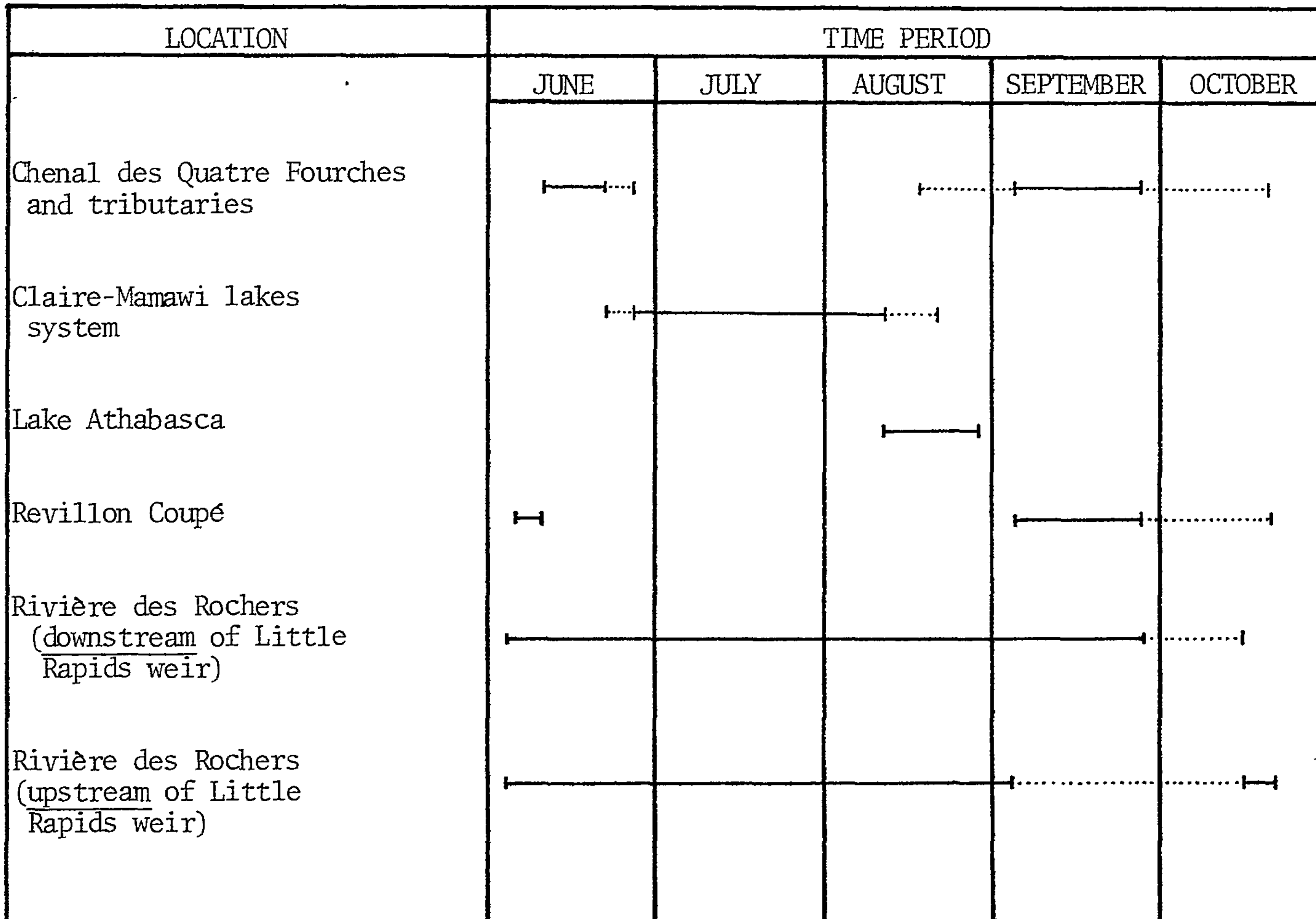


Fig. 6. Schedule of sampling (gill netting) in the Peace-Athabasca Delta, 1976. Solid line signifies continuous fishing; dotted line signifies discontinuous fishing.

L.G.L LIMITED

ENVIRONMENTAL RESEARCH ASSOCIATES
FISHERY SHEET ONE

LOCATION .... PROJECT .... DATE ....

CODER .... CHECKER .... PAGE .... OF ....

DATE			LOCATION	TAG NUMBER	SPECIES	WEIGHT IN TENTHS OF GRAMS	FORK LENGTH MILLIMETERS	TOTAL LENGTH MILLIMETERS	SEX	MATURITY	CONDITION	SCALES	AGE	MESH SIZE	SET NUMBER	TIME	INVESTIGATOR	LENGTH OF SET	AIR TEMP °C	WATER TEMP °C	REMARKS	CONTINUATION
YEAR	MO	DAY																				

COMMENTS:

CODE:

SPECIES COL. 16, 17
1 GOLDEYE
2 NORTHERN PIKE
3 LAKE WHITEFISH
4. WALLEYE
5. LONGNOSE SUCKER
6. WHITE SUCKER
7. BURBOT
8. FLATHEAD CHUB
9. EMERALD SHINER
10. SPOTTAIL SHINER
11. TROUT-PERCH

SEX COL. 34
1. MALE
2. FEMALE

MATURITY COL. 35
3. MATURE
4. IMMATURE
5. YOY

COND. COL. 36
1. GOOD
2. FAIR
3. POOR (FLOATER)

MESH SIZE COL. 40, 41
¾" - 1
1" - 2
1½" - 3
2" - 4
2½" - 5
3" - 6
3½" - 7
4" - 8
4½" - 9

SETCODE COL. 42-46
G = GILLNET
F = FYKE
S = SEINE

Fig. 7. Data-recording sheet used during this study.

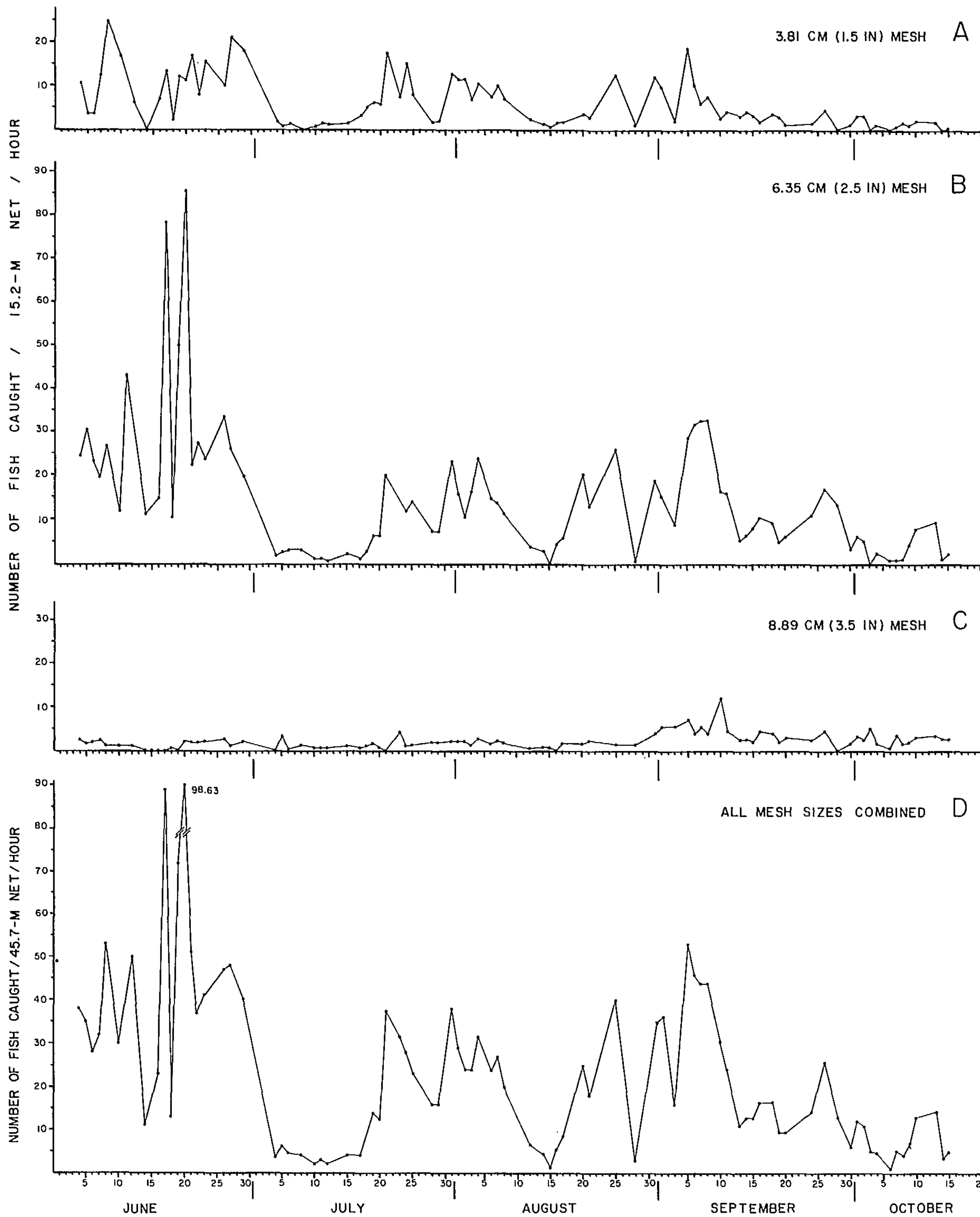


Fig. 8. Daily mean catch per unit effort by gill net mesh size for all species combined downstream of Little Rapids weir.

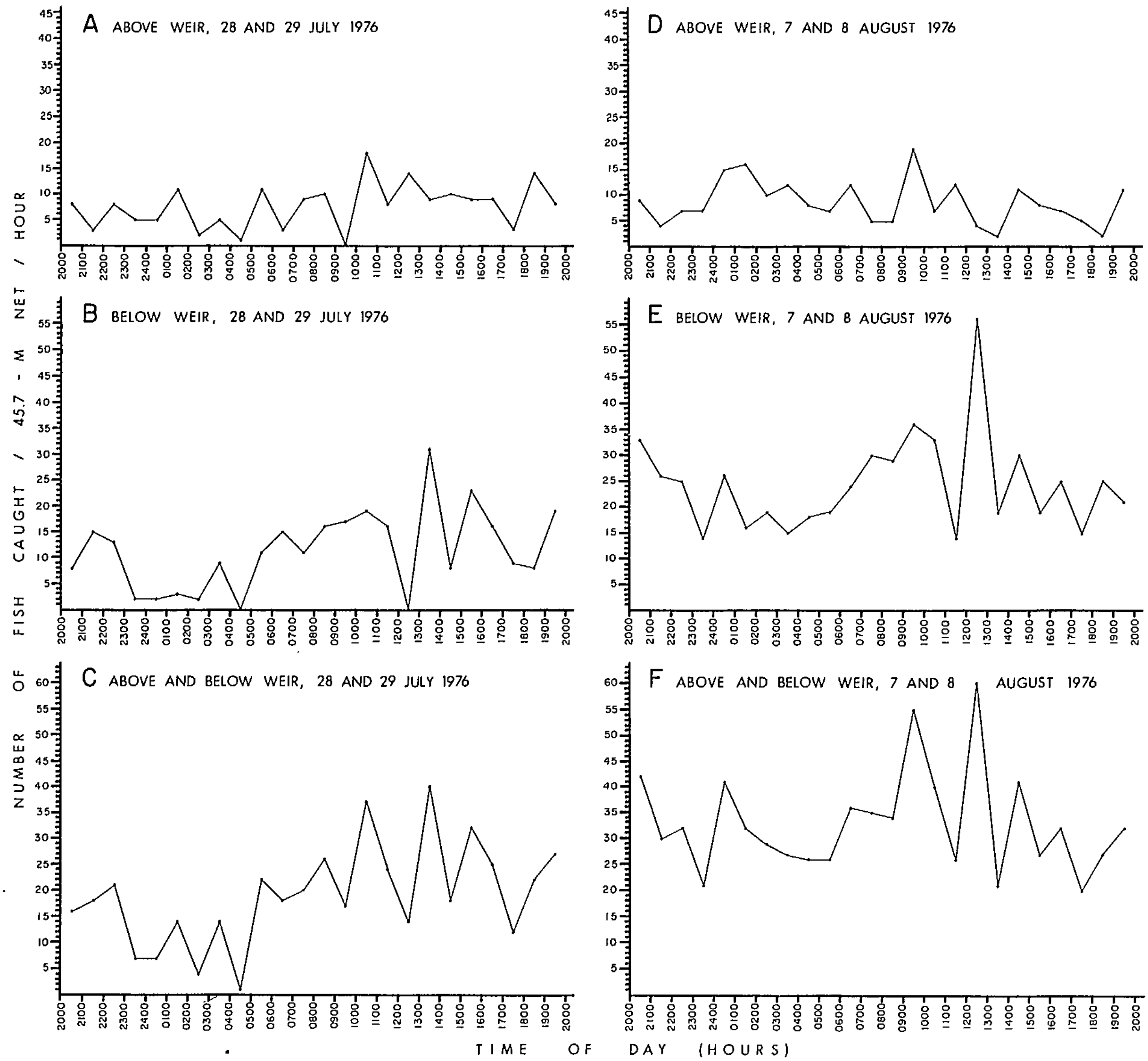


Fig. 9. Diel variation in catchability of all species combined at Little Rapids weir.

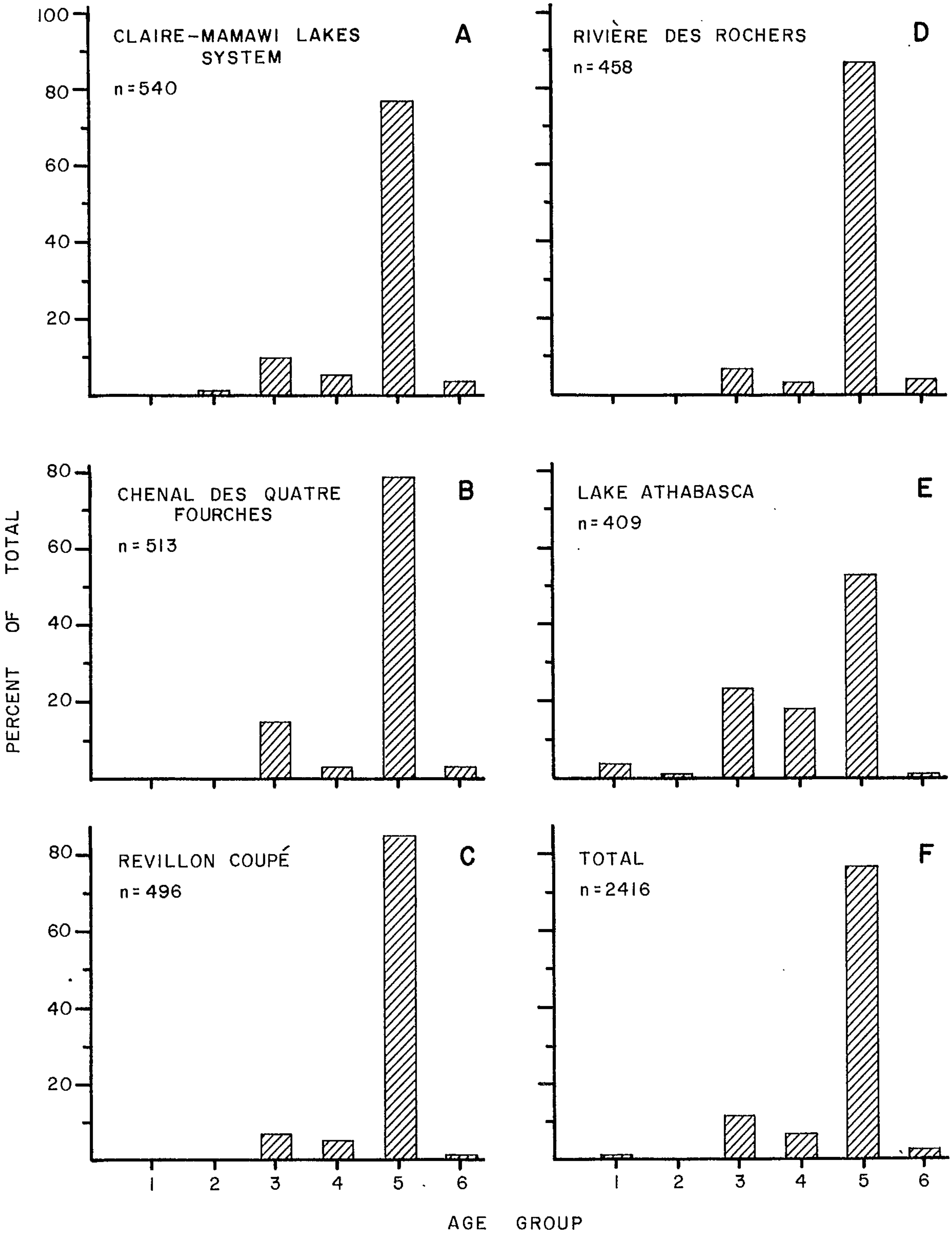


Fig. 10. Age structure (percent composition) of goldeye captured in the Peace-Athabasca Delta, 1976. Age groups comprising less than 1% of the total samples are not shown.

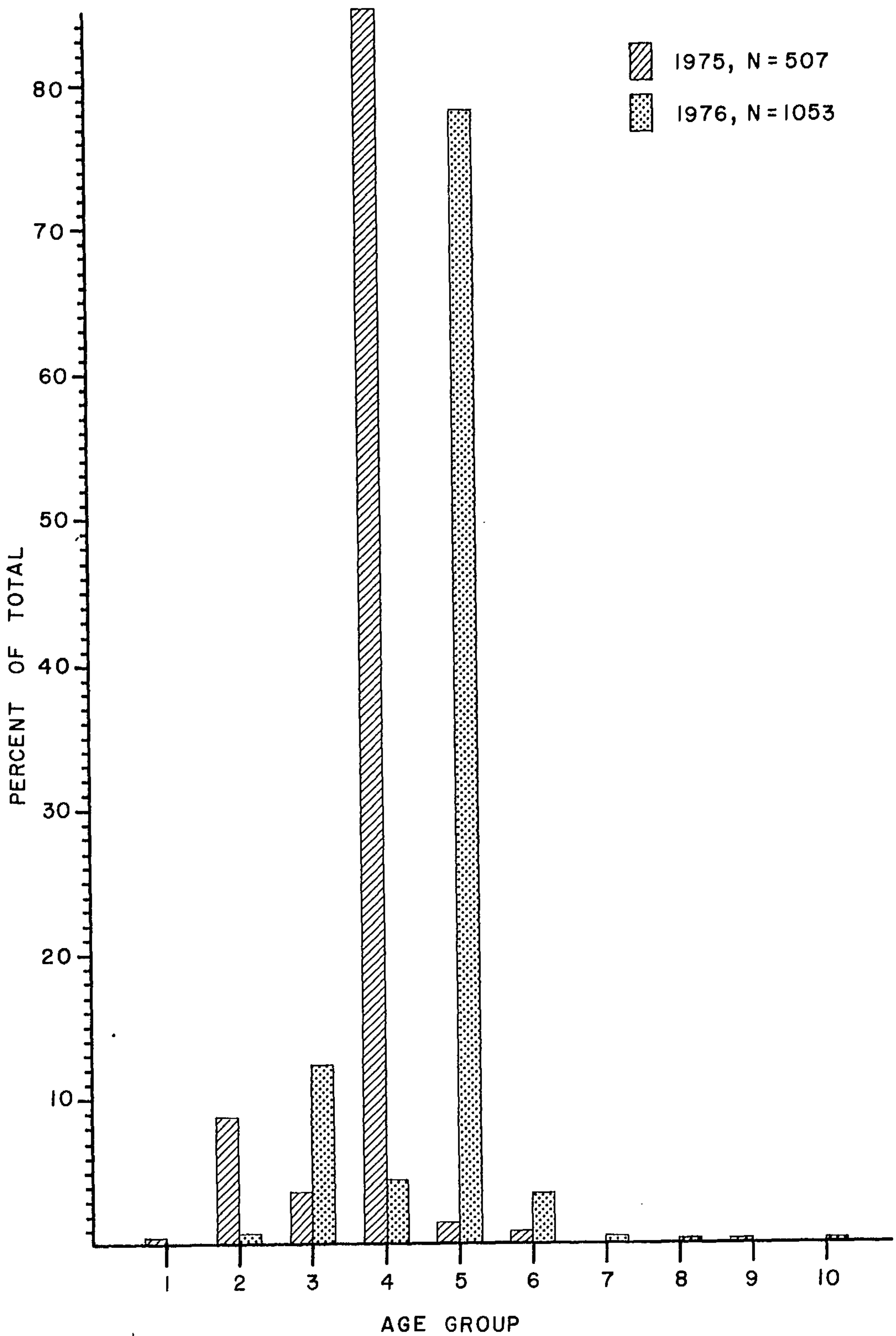


Fig. 11. Age structure of goldeye captured in the Claire-Mamawi lakes system and Chenal des Quatre Fourches, 1975 and 1976.

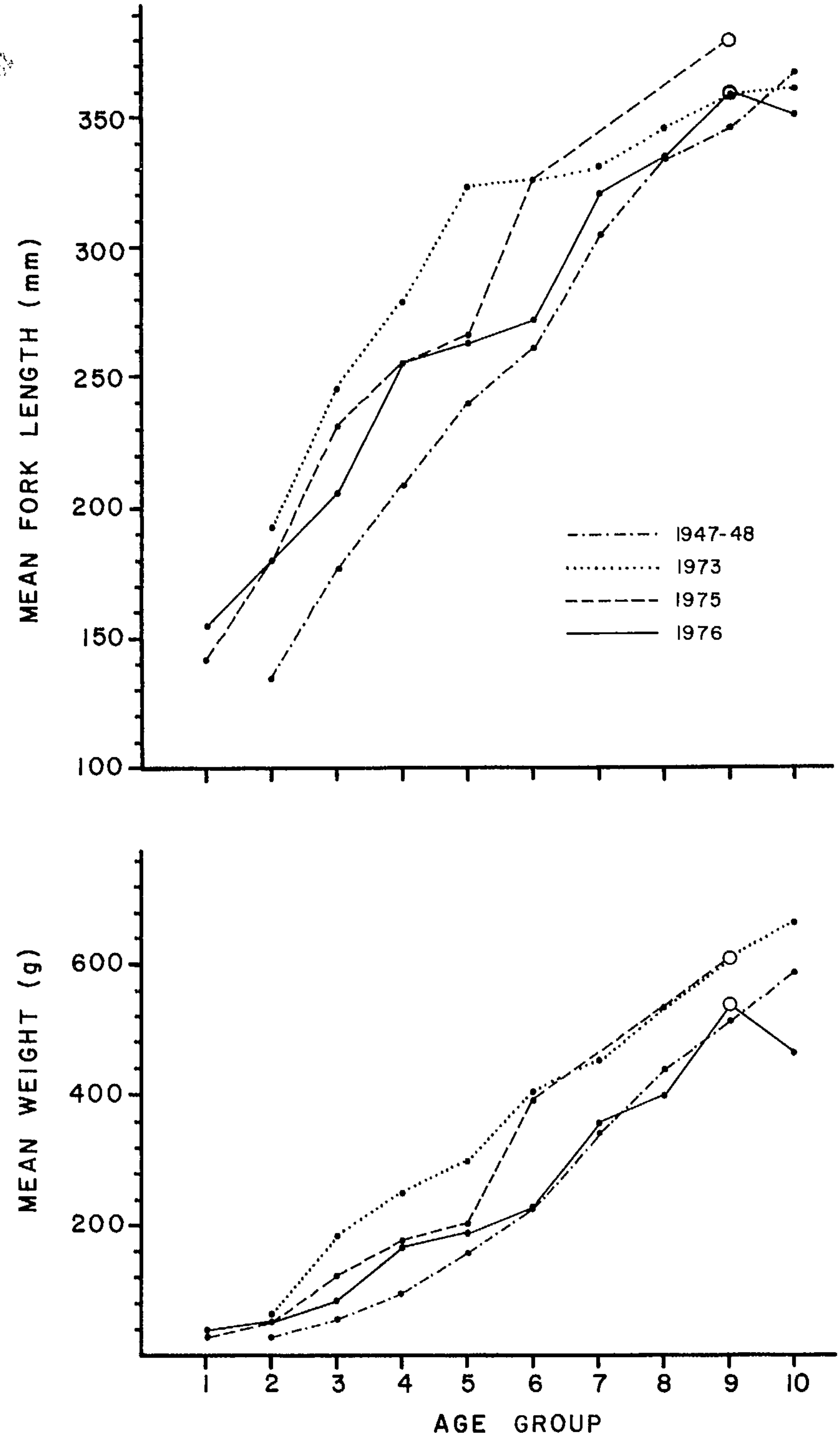


Fig. 12. Age-length and age-weight relationships for goldeye captured in the Peace-Athabasca Delta, 1947-48, 1973, 1975 and 1976. Open circles represent sample sizes of one.

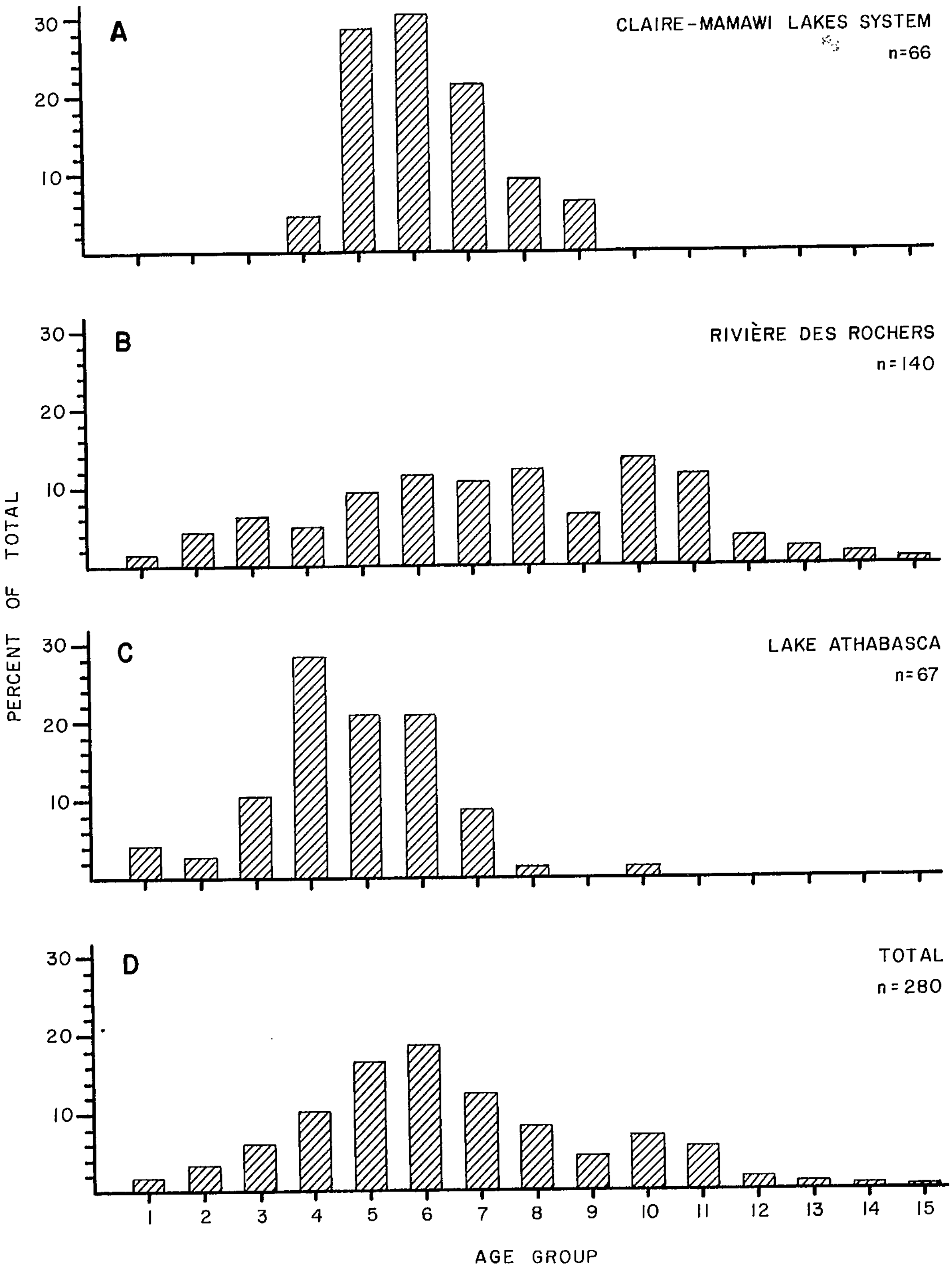


Fig. 13. Age structure (percent composition) of walleye captured in the Peace-Athabasca Delta, 1976. The few walleye captured in the Chenal des Quatre Fourches and Revillon Coupé are included in Fig. 13D.

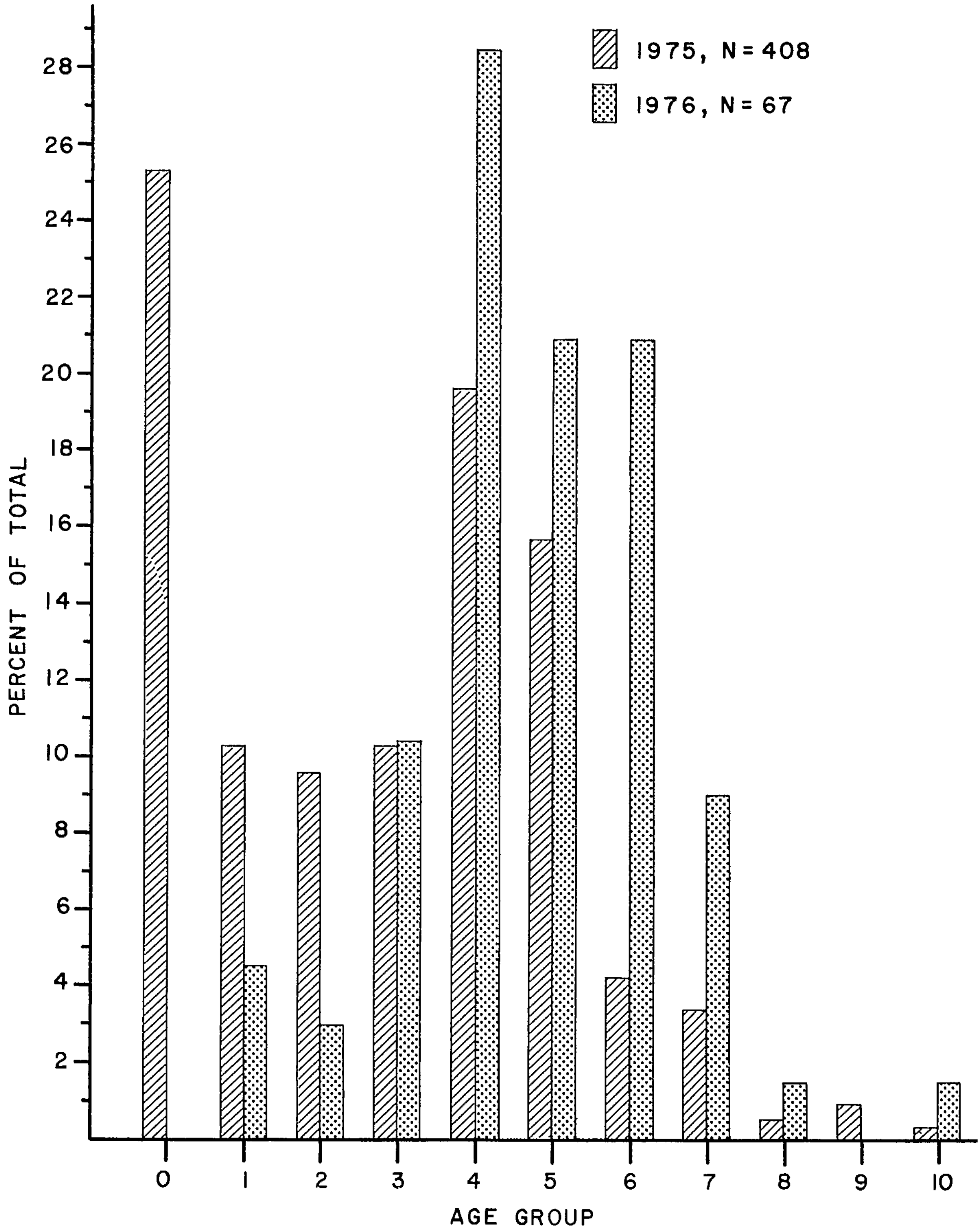


Fig. 14. Age structure of walleye captured in Lake Athabasca, 1975 (Alberta only) and 1976.

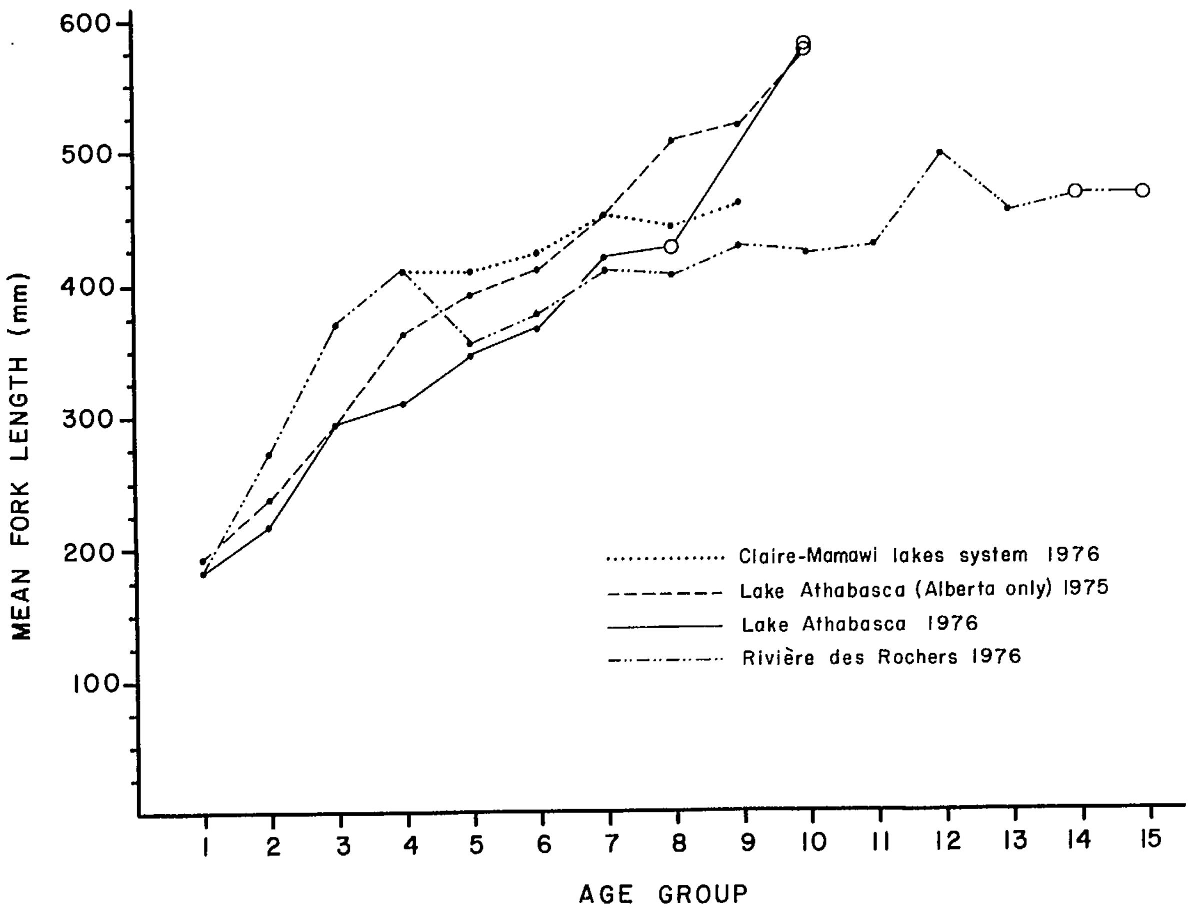


Fig. 15. Age-length relationships for walleye captured in the Peace-Athabasca Delta, 1975 and 1976. Open circles represent sample sizes of one.

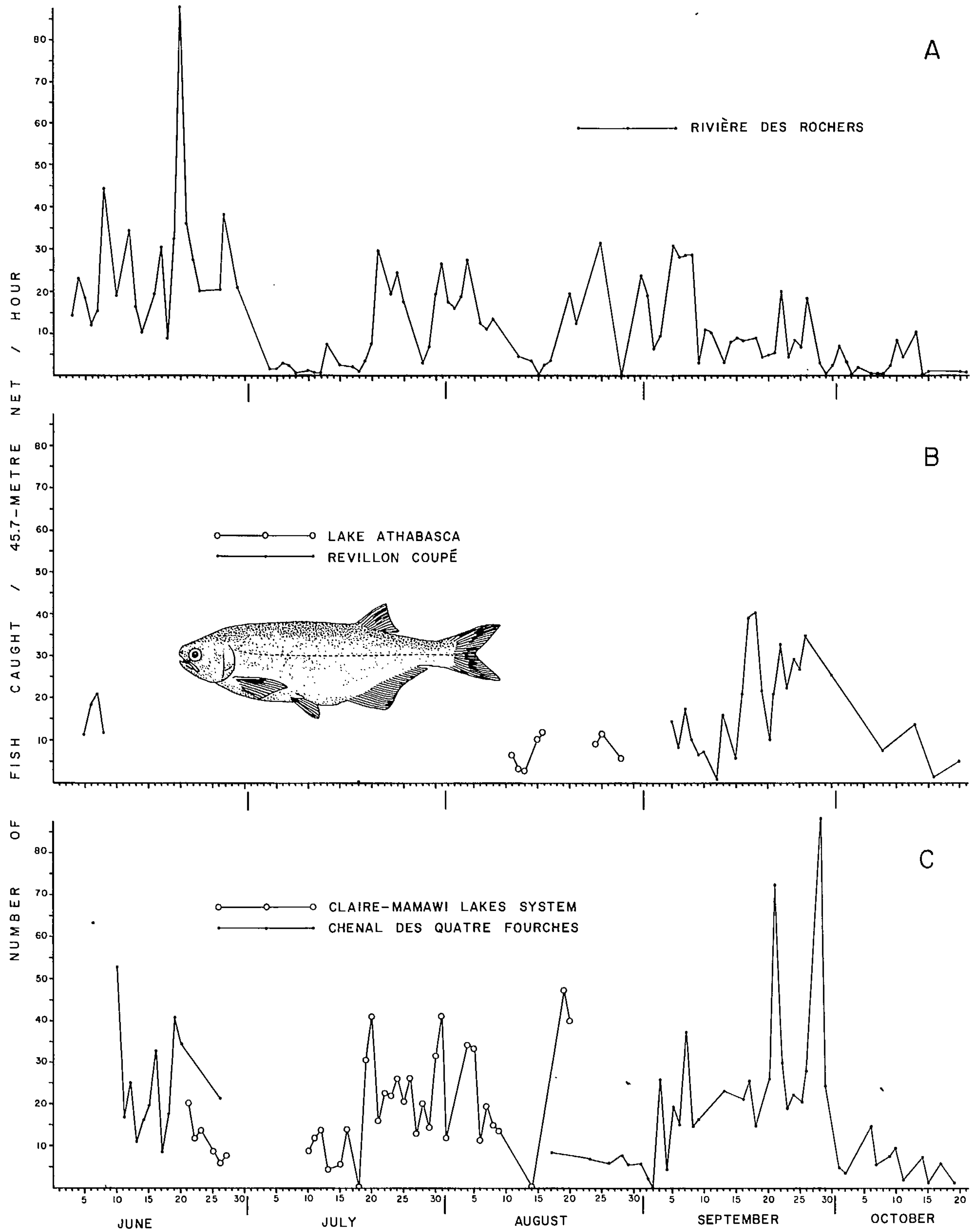


Fig. 16. Daily mean catch per unit effort for goldeye in five sampling areas.

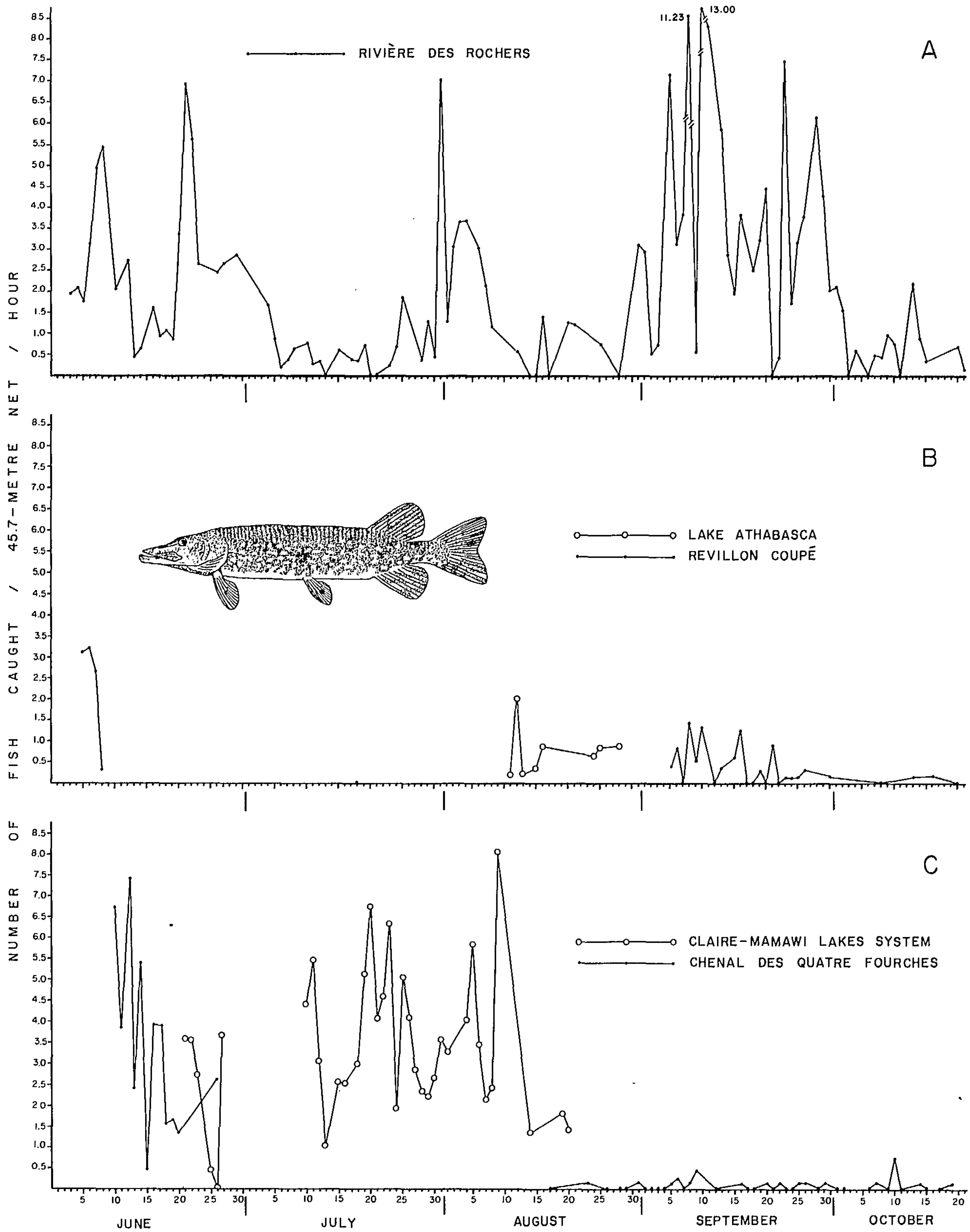


Fig. 17. Daily mean catch per unit effort for northern pike in five sampling areas.

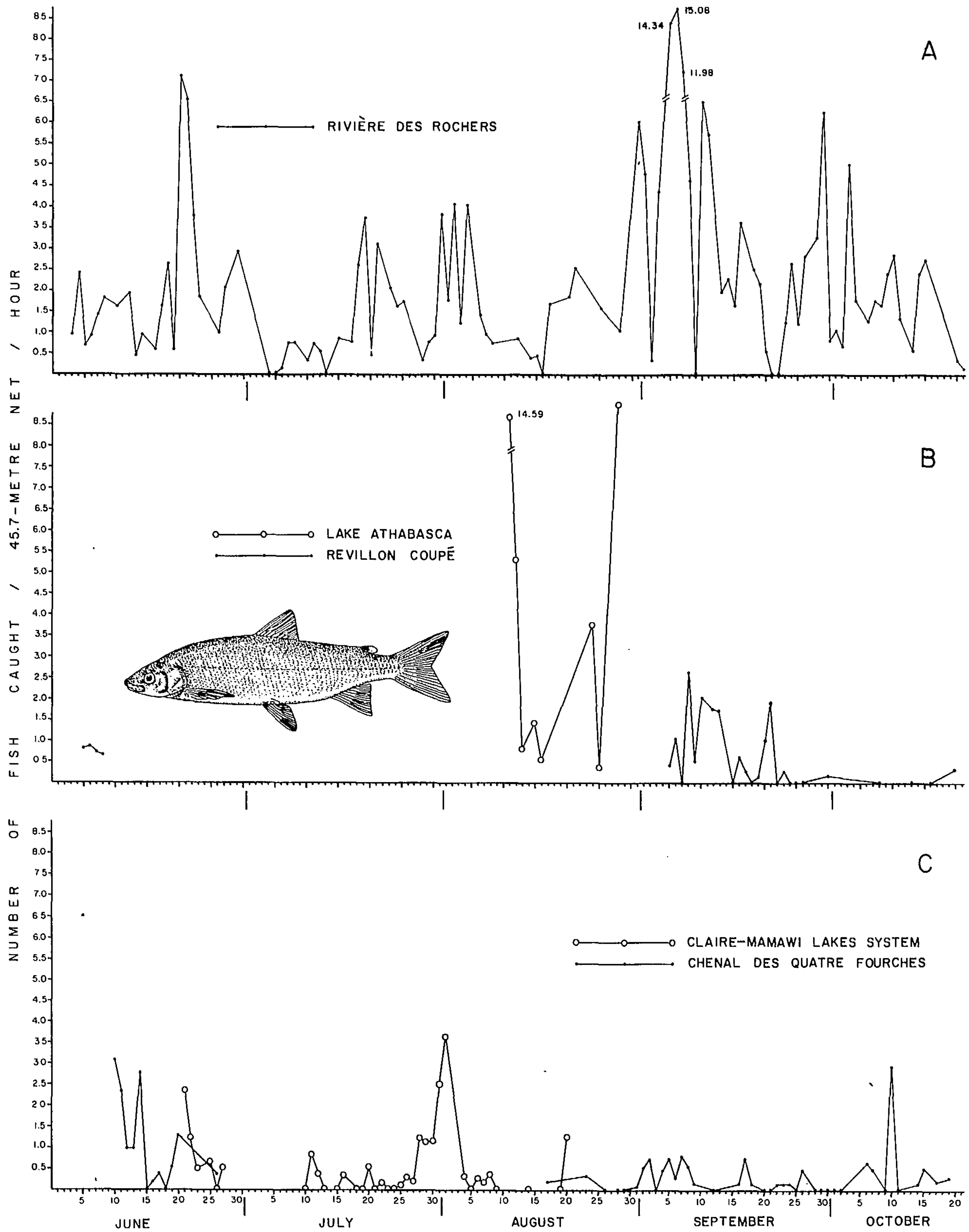


Fig. 18. Daily mean catch per unit effort for lake whitefish in five sampling areas.

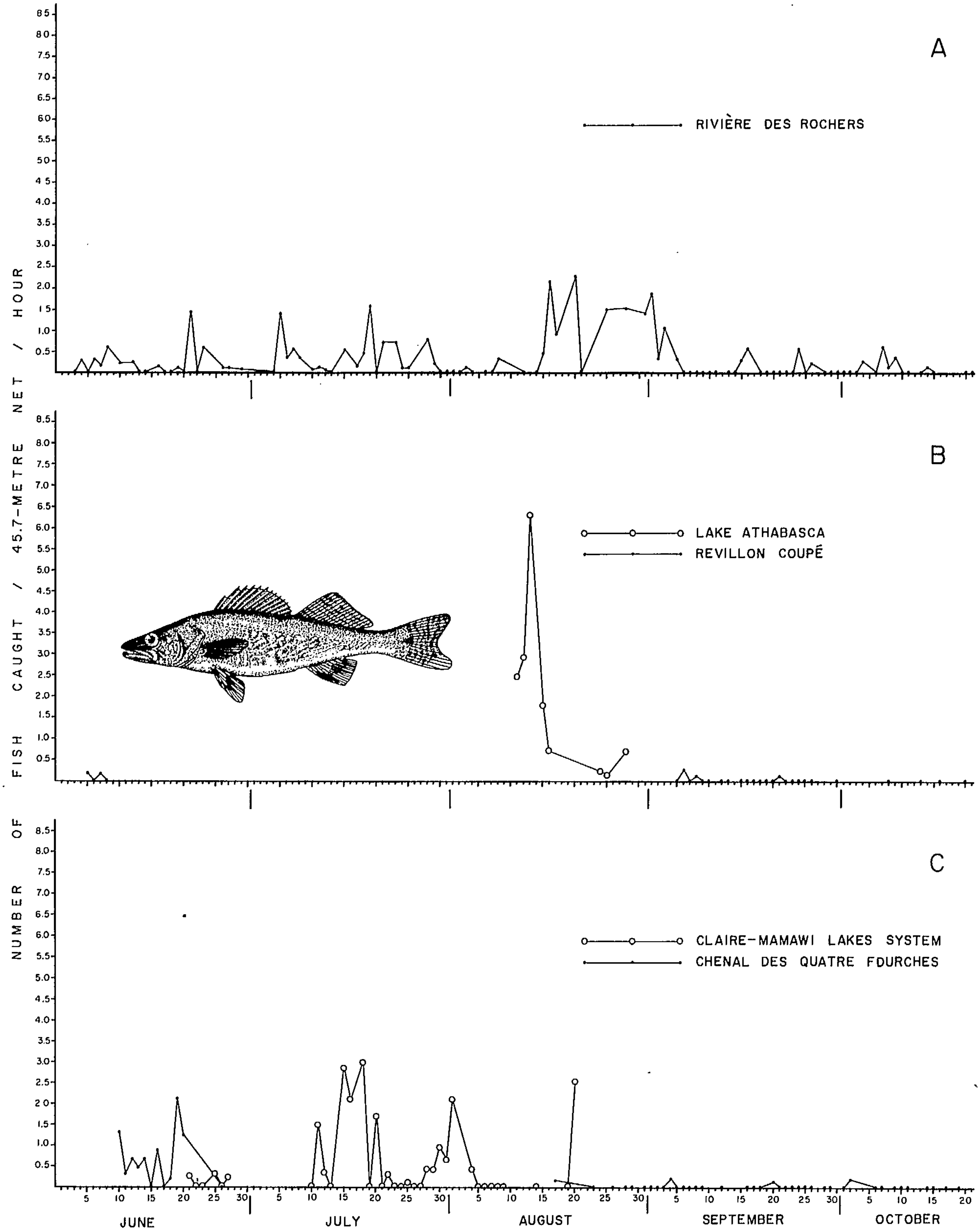


Fig. 19. Daily mean catch per unit effort for walleye in five sampling areas.

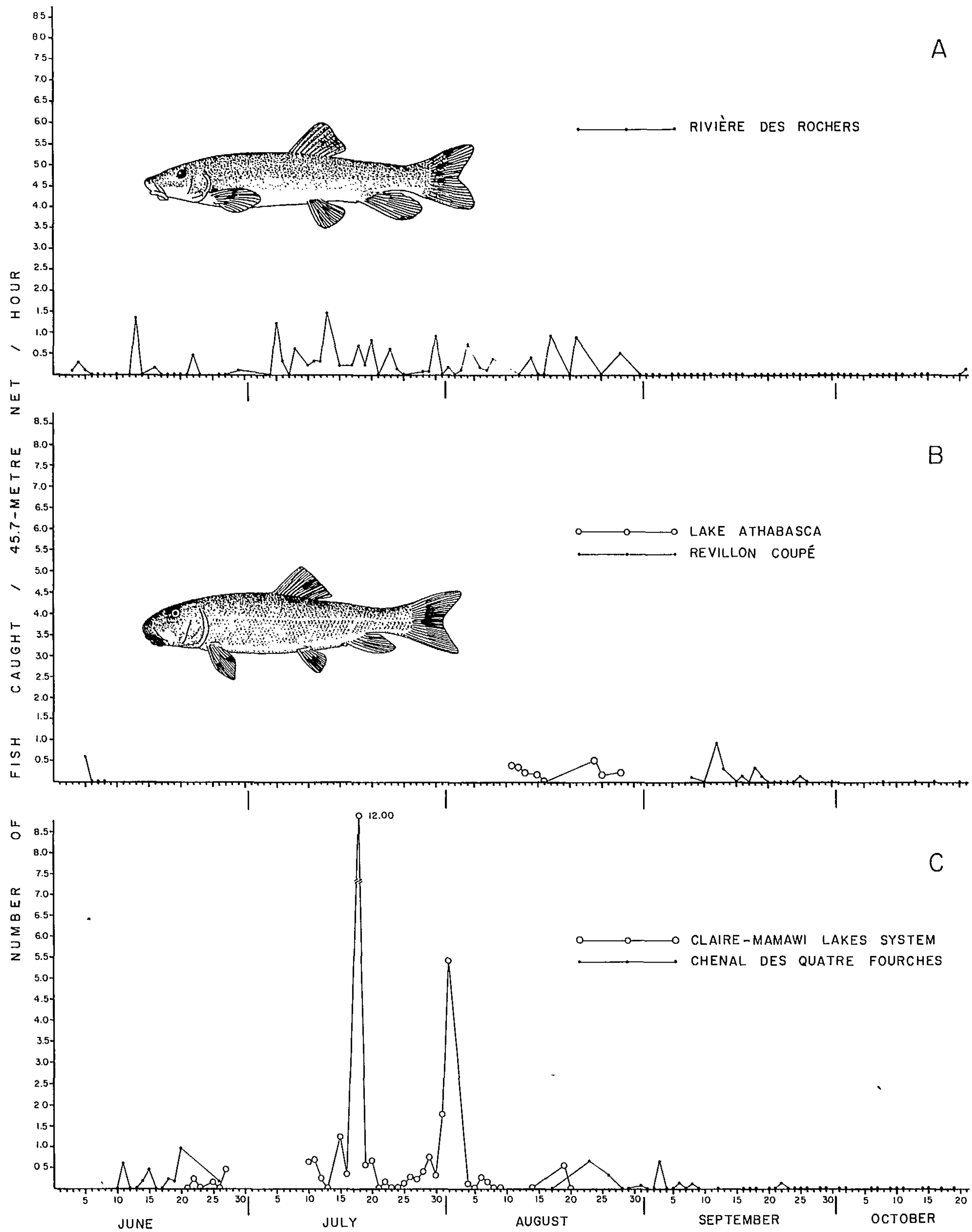
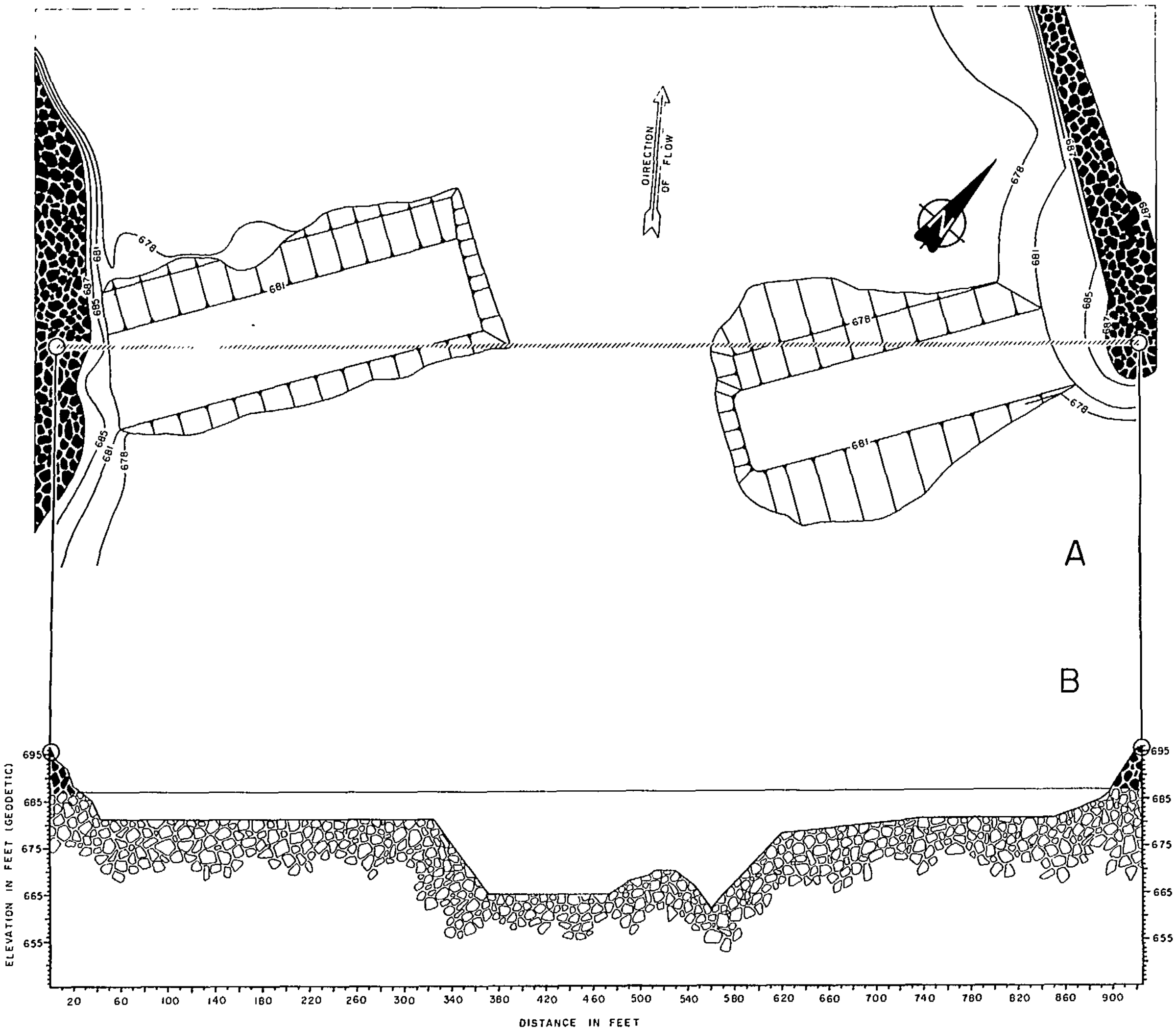


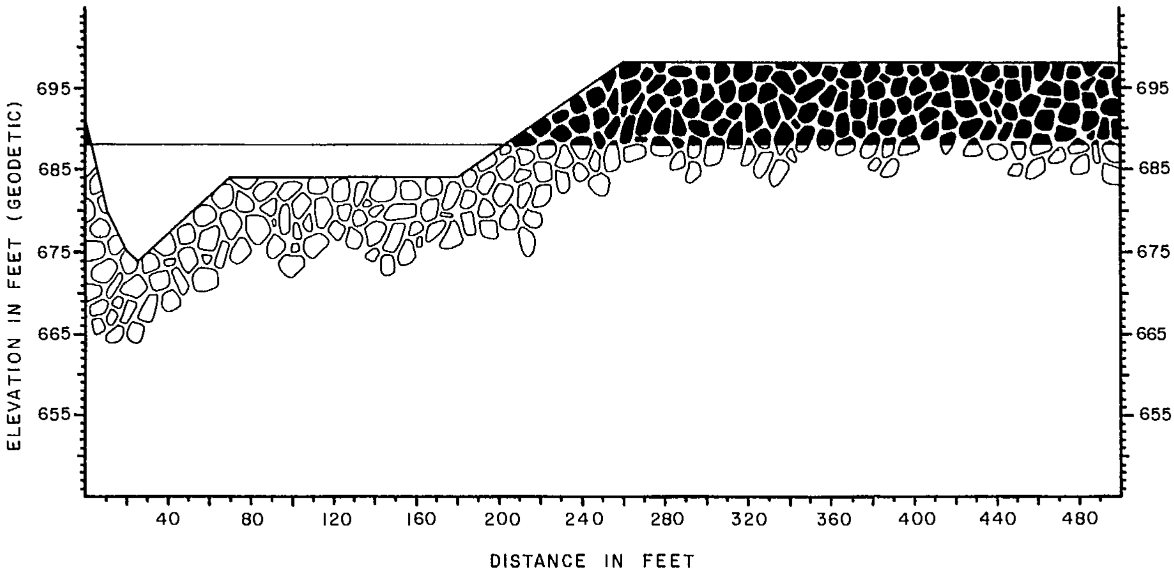
Fig. 20. Daily mean catch per unit effort for longnose and white suckers (combined) in five sampling areas.



Date (1976)	Staff Gauge Height (ft)[1] Upstream of weir	Staff Gauge Height (ft)[1] Downstream of weir	Discharge[1] (cubic ft/sec)	Area (ft^2)	Mean Velocity (ft/sec)
20 January	684.20	679.79	35,000	2747	12.7
6 April	683.29	679.36	25,300	1844	13.7
22 June	686.04	682.88	53,500	4553	11.8
20 July	686.79	684.64	51,600	5273	9.8
17 August	687.67	686.00	50,300	6039	8.3
28 September	687.02	681.63	62,900	5456	11.5
13 October	687.01	681.55	68,500	5456	12.6

Fig. 21. Cross-sectional profile of and hydrological data for the Little Rapids weir. (From plan by Canada Department of Regional Economic Expansion (1975).)

[1]Water levels and discharges were obtained from Alberta Department of the Environment hydrological station numbers 28 and 07NA001.



Date (1976)	Staff Gauge Height (ft)[1] (Upstream of weir)	Discharge[1] (cubic ft/sec)	Area (ft^2)	Mean Velocity (ft/sec)
6 April	682.91	819	48	17.1
1 June	685.91	2080	432	4.8
22 June	685.87	1990	1839	1.1
20 July	686.54	0	2217	0.0
17 August	687.29	1930	2137	0.9 (Reverse flow)

Fig. 22. Cross-sectional profile of and hydrological data for the Revillon Coupé weir. (From plan by Canada Department of Regional Economic Expansion (1975).)

[1]Water levels and discharges were obtained from Alberta Department of the Environment hydrological station number 27.

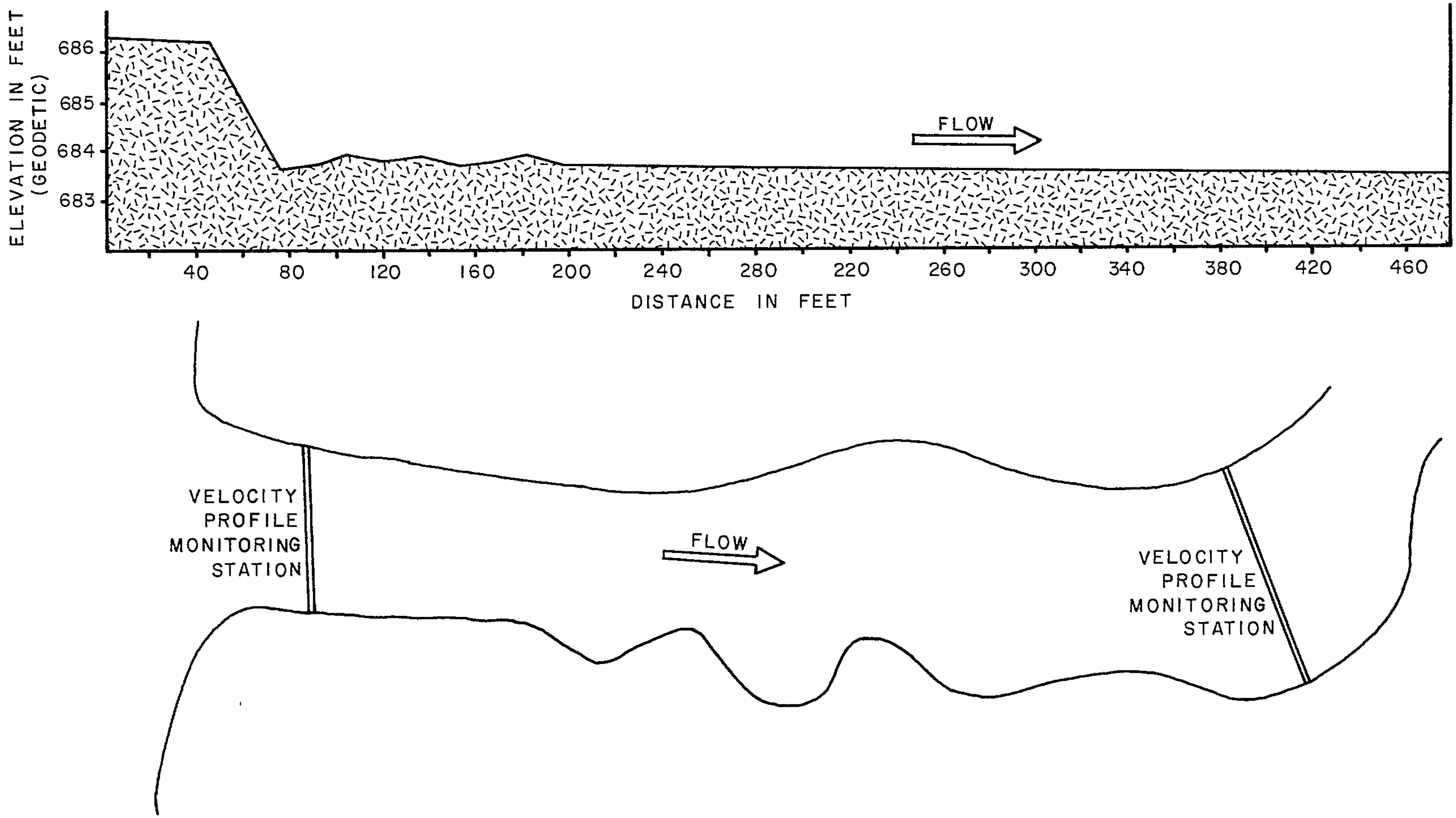
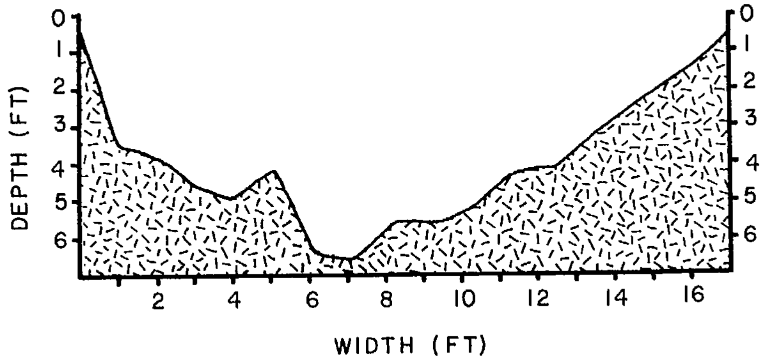


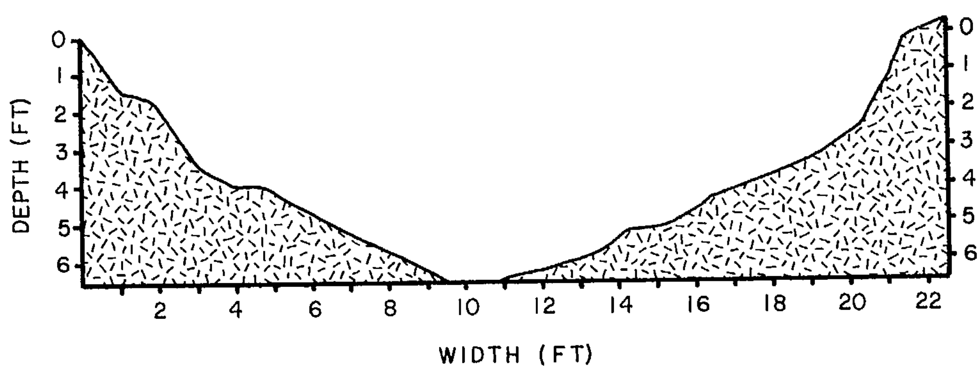
Fig. 23. Gradient profile (partial), channel configuration, and velocity profile stations at Little Rapids fishway. (From Alberta Department of the Environment Water Survey (1976).)

A



Date (1976)	Staff Gauge Height (ft) Upstream of weir	Staff Gauge Height (ft) Downstream of weir	Mean Velocity (ft/sec)	Area (ft^2)	Discharge (cubic ft/sec)
14 June	685.84	682.78	3.4	47.7	164.2
1 July	685.81	683.64	6.5	63.2	279.2
3 July	686.07	685.74	3.3	45.2	156.4
10 July	686.42	686.24	4.4	54.8	263.5

B



Date (1976)	Staff Gauge Height (ft) Upstream of weir	Staff Gauge Height (ft) Downstream of weir	Mean Velocity (ft/sec)	Area (ft^2)	Discharge (cubic ft/sec)
14 June	685.84	682.78	1.5	109.1	162.3
1 July	685.81	683.64	2.1	131.2	275.6
3 July	686.07	685.74	1.0	155.1	147.2
10 July	686.42	686.24	1.6	164.3	265.0

Fig. 24. Cross-sectional profiles of Little Rapids fishway and hydrological data for upstream (A) and downstream (B) velocity profile stations.

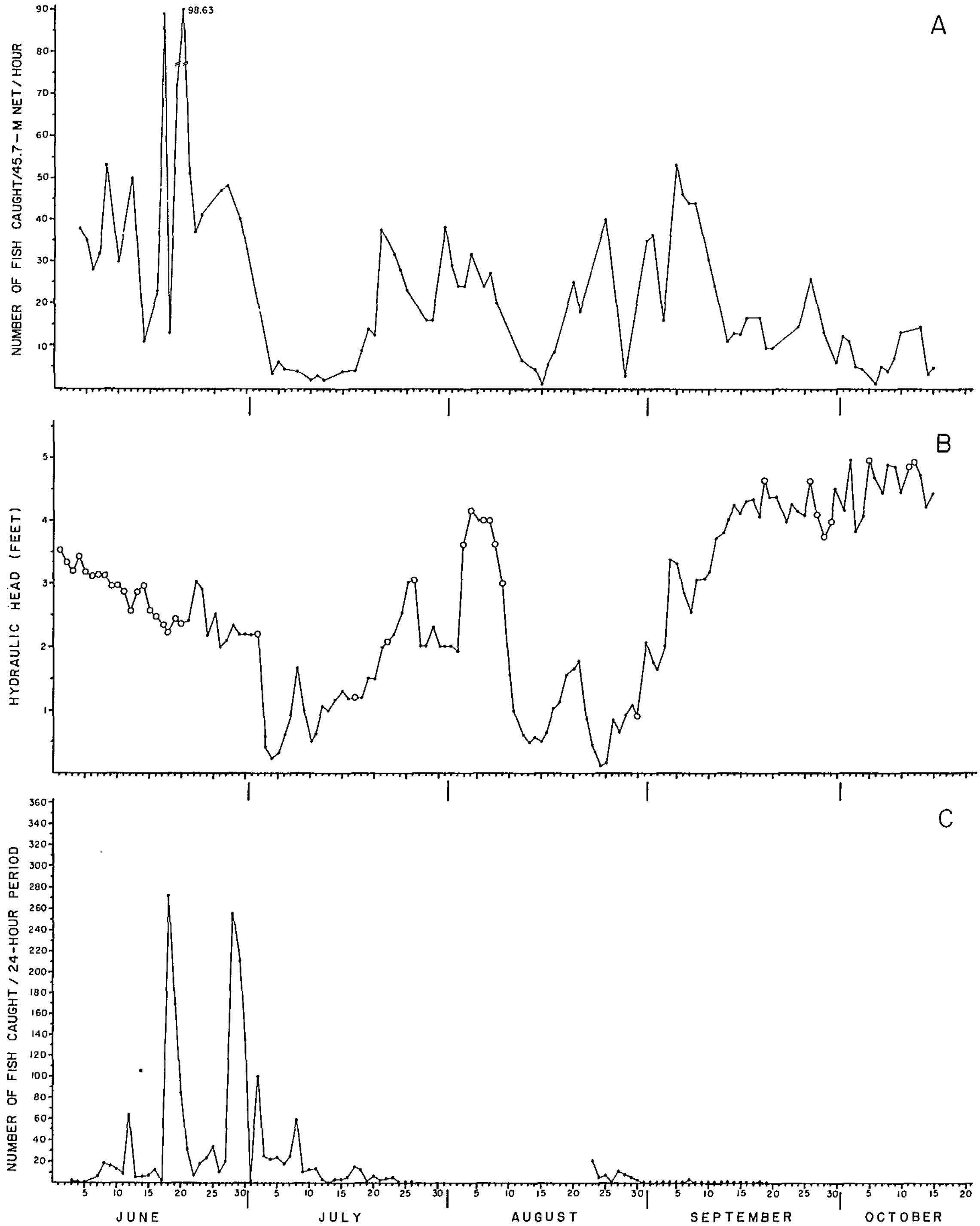


Fig. 25. Daily mean catch per unit effort (species combined) downstream of Little Rapids weir (A), hydraulic head across Little Rapids weir (B) and catch rate (species combined) of fish moving upstream through the Little Rapids fishway (C). Open circles in Fig. 25B represent calculations based on data obtained from Alberta Department of the Environment.

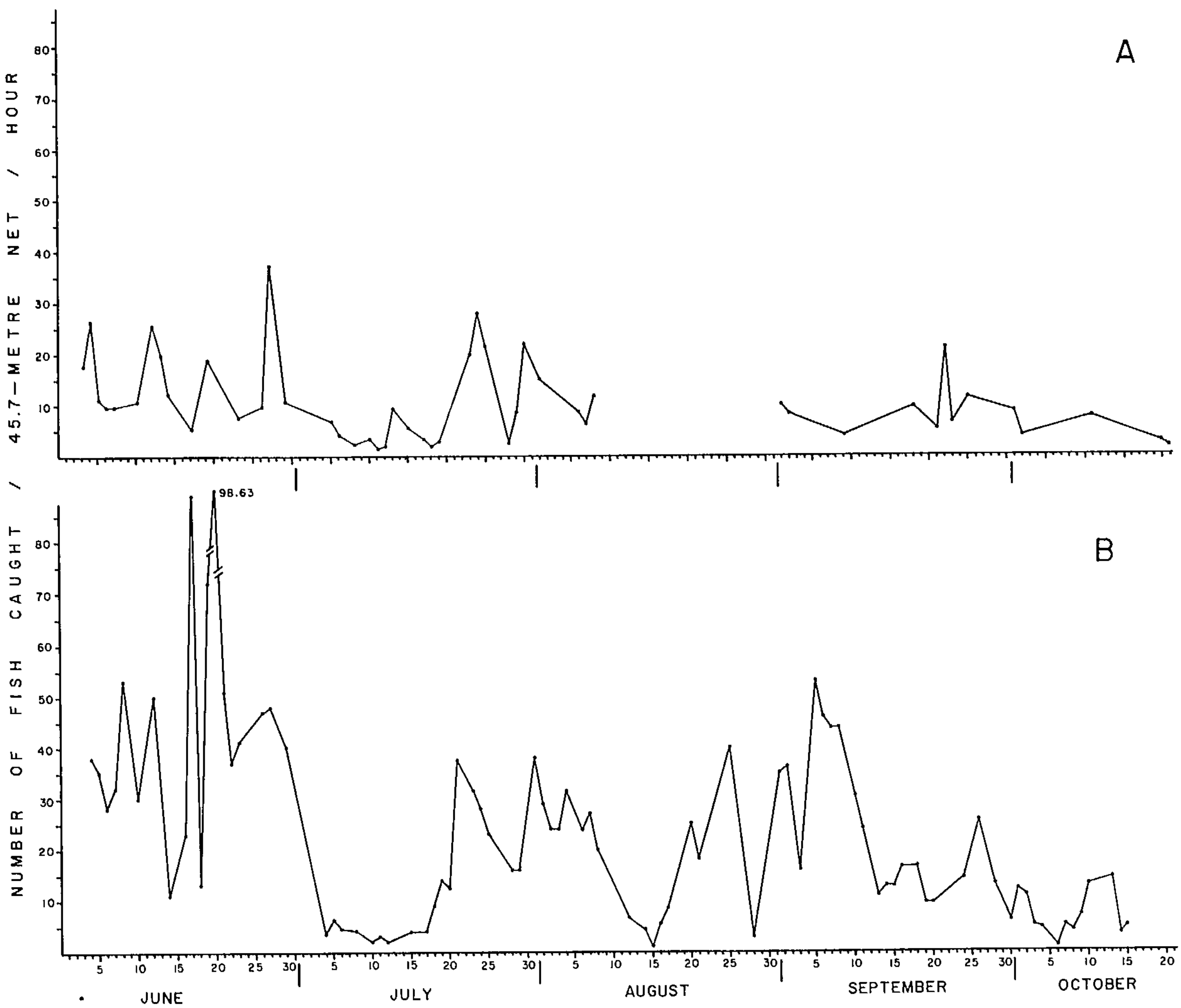


Fig. 26. Daily mean catch per unit effort for all species combined upstream (A) and downstream (B) of Little Rapids weir.

Table 1. Numbers of fish caught through use of various techniques in 1976.

METHOD	GOLDEYE	NORTHERN PIKE	LAKE WHITEFISH	WALLEYE	LONGNOSE AND WHITE SUCKER*	TOTAL
Gill net	17848	2101	1764	393	245	22351
Fish trap	1448	372	44	24	28	1916
Hook and line	30	51	0	0	0	81
Seine net	0	1	0	0	0	1
TOTALS	19326	2525	1808	417	273	24349

*Because very few white suckers were captured during this study, longnose and white suckers were combined.

Table 2. Gill net selectivity for the most abundant species of fish captured downstream of the Little Rapids weir.

SPECIES	MESH SIZE (cm)	NUMBER OF FISH	MEAN FORK LENGTH (mm)	STANDARD DEVIATION
Goldeye	3.81	1184	232.9	35.0
	6.35	2958	262.1	17.0
	8.89	65	278.1	27.9
Northern Pike	3.81	109	487.8	102.8
	6.35	416	507.5	73.2
	8.89	291	565.8	65.0
Lake Whitefish	3.81	327	184.7	54.3
	6.35	226	306.7	48.3
	8.89	203	358.3	37.9
Walleye	3.81	24	281.3	131.9
	6.35	60	394.4	64.0
	8.89	66	419.5	48.2
Total (above species combined)	3.81	1644		
	6.35	3660		
	8.89	625		

Table 3. Results of mortality experiments for goldeye and northern pike, 1976.

Location	Dates	Water Temp. Range (°C)	Species Tested	Number of Fish/Experiment	Duration of Experiment (hr)	Number of Survivors	Number of Deaths	Percent Mortality	Condition of Survivors Upon Release*
Small Tributary to Prairie River	15-17 July	16-22	Goldeye	6	40	6	0	0.0	Excellent
	19-20 July	17-21	Goldeye	6	33	6	0	0.0	Excellent
	21-24 July	16-22	Goldeye	6	72	6	0	0.0	Good
	25-27 July	16-22	Goldeye	6	46	5	1	16.7	Good
	28-29 July	16	Goldeye	6	24	6	0	0.0	Excellent
	29-30 July	16-20	Goldeye	6	24	6	0	0.0	Good
	31 July-1 Aug.	20-24	Goldeye	6	24	6	0	0.0	Good
	4-5 Aug.	17-20	Goldeye	6	24	6	0	0.0	Good
	5-6 Aug.	20-22	Goldeye	6	24	6	0	0.0	Good
	6-7 Aug.	19-22	Goldeye	6	24	6	0	0.0	Good
	7-8 Aug.	19	Goldeye	6	24	6	0	0.0	Good
	8-9 Aug.	21	Goldeye	6	24	6	0	0.0	Good
Small Tributary to Chenal des Quatre Fourches	12-16 Sept.	11-12	Goldeye	6	81	6	0	0.0	Good
	16-18 Sept.	10-14	Goldeye	6	46	6	0	0.0	Good
	18-20 Sept.	10-12	Goldeye	6	33	6	0	0.0	Good
	20-21 Sept.	10-13	Goldeye	6	33	6	0	0.0	Good
	22-23 Sept.	8-10	Goldeye	6	24	6	0	0.0	Good
	23-24 Sept.	7-8	Goldeye	6	24	6	0	0.0	Good
	24-25 Sept.	7	Goldeye	6	24	6	0	0.0	Good
	25-26 Sept.	6-7	Goldeye	6	24	6	0	0.0	Good
Flett Channel (Rivière des Rochers)	22-23 Sept.	11	Goldeye	10	24	10	0	0.0	Excellent
	23-24 Sept.	11	Goldeye	12	24	12	0	0.0	Excellent
	24-25 Sept.	11	Goldeye	8	24	8	0	0.0	Excellent
	25-26 Sept.	11	Goldeye	14	24	14	0	0.0	Excellent
	26-27 Sept.	11-12	Pike	12	24	12	0	0.0	Excellent
	27-28 Sept.	12	Pike	10	24	10	0	0.0	Excellent
	28-29 Sept.	12	Pike	5	24	5	0	0.0	Excellent
	29-30 Sept.	12	Pike	9	24	9	0	0.0	Excellent
	30 Sept.-1 Oct.	12	Pike	9	24	9	0	0.0	Excellent
TOTALS	Goldeye	6-24		164	24-81	163	1	0.6	
	Pike	11-12		45	24	45	0	0.0	

*Fish released in "excellent" condition showed no signs of stress (fins not engorged with blood); fish released in "good" condition showed some stress (fins slightly red).

Table 4. Annulus formation on scales collected from goldeye in the Peace-Athabasca Delta, 1976. Numbers of fish are expressed as percents (to the nearest whole number) of the totals for each age group.

LOCATION	TIME PERIOD SCALES COLLECTED	AGE																														N[1]
		1			2			3			4			5			6			7			8			9			10			
		G[2]	T[3]	W[4]	G	T	W	G	T	W	G	T	W	G	T	W	G	T	W	G	T	W	G	T	W	G	T	W	G	T	W	
Revillon Coupé	5-10 June		*			*		0	15	85	0	80	20	0	2	98	0	0	100	0	0	100		*			*			*		271
Chenal des Quatre Fourches	10-20 June		*			*		11	43	46	0	71	29	0	23	77	0	6	94		*			*			*			*		513
Rivière des Rochers	12-29 June		*			*		43	40	17	8	42	50	4	22	74	0	6	94		*			*			*		0	100	0	458
Mamawi Lake	21-27 June		*			*		18	36	46	31	44	25	4	19	77	0	0	100		*			*			*			*		215
Prairie River	27 June-13 July		*		0	100	0	100	0	0		*		14	38	48	0	0	100		*			*			*			*		24
Lake Claire	10-19 July	100	0	0	100	0	0	96	4	0	64	36	0	37	56	7	28	22	50	0	100	0	67	33	0	0	100	0	33	67	0	301
Lake Athabasca	11-25 August	100	0	0	100	0	0	100	0	0	100	0	0	99	1	0	100	0	0		*			*			*			*		409
Revillon Coupé	4-16 September	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0		*			*			*		225

[1]N=Sample size.

[2]G=Growth beyond the annulus formed in 1976.

[3]T=Terminal annulus formed in 1976.

[4]W=1976 annulus not yet formed.

*=(sample size = 0).

Table 5. Age frequency of goldeye captured in the Peace-Athabasca Delta, 1976.

LOCATION	AGE GROUP 1	2	3	4	5	6	7	8	9	10	TOTAL
Claire-Mamawi lakes system	1	7	54	30	416	21	4	3	1	3	540
Chenal des Quatre Fourches	0	0	76	17	404	16	0	0	0	0	513
Revillon Coupé	3	1	35	28	419	9	1	0	0	0	496
Rivière des Rochers	0	0	30	12	397	18	0	0	0	1	458
Lake Athabasca	16	4	93	74	219	3	0	0	0	0	409
All sampling areas (above)	20	12	288	161	1855	67	5	3	1	4	2416

Table 6. Use of annulus position as an aid to aging walleye scales. Ranges of annulus positions expressed as percents of total distance from focus to antero-lateral margin of scale, for four- to seven-year-old walleye.

AGE	ANNULUS NUMBER 1	2	3	4	5	6
4 n=27	29-33	58-63	74-84			
5 n=35	18-28	37-50	56-66	75-85		
6 n=42	19-26	33-46	47-65	71-80	85-90	
7 n=31	17-24	28-38	42-55	57-73	66-88	85-93

Table 7. Age frequency of walleye captured in the Peace-Athabasca Delta, 1976.

LOCATION	AGE GROUP 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
Claire-Mamawi lakes system	0	0	0	3	19	20	14	6	4	0	0	0	0	0	0	66
Chenal des Quatre Fourches	0	1	1	0	0	2	0	0	0	0	0	0	0	0	0	4
Revillon Coupé	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	3
Rivière des Rochers	2	6	9	7	13	16	15	17	9	19	16	5	3	2	1	140
Lake Athabasca	3	2	7	19	14	14	6	1	0	1	0	0	0	0	0	67
All sampling areas (above)	5	9	17	29	47	53	36	24	13	20	16	5	3	2	1	280

Table 8. Number of fish captured, tagged and recaptured by species at five sampling areas within the Peace-Athabasca Delta, 31 May to 21 October, 1976.

Species	Location	Captured	Tagged	Recaptured By: LGL Personnel[1]	Recaptured By: Fishermen
Goldeye	Rivière des Rochers	8,658	7,038	74	0
	Revillon Coupé	2,671	2,458	24	0
	Claire-Mamawi lakes system	3,294	2,863	12	5
	Chenal des Quatre Fourches	4,235	3,910	22	6
	Lake Athabasca	468	409	2	5
Sub-totals		19,326	16,678	134	16[2]
Northern pike	Rivière des Rochers	1,564	1,243	156	7
	Revillon Coupé	104	97	1	2
	Claire-Mamawi lakes system	614	569	8	6
	Chenal des Quatre Fourches	201	194	0	3
	Lake Athabasca	42	40	0	0
Sub-totals		2,525	2,143	165	18
Lake whitefish	Rivière des Rochers	1,242	526	22	0
	Revillon Coupé	134	56	0	3
	Claire-Mamawi lakes system	95	75	0	2
	Chenal des Quatre Fourches	155	86	1	3
	Lake Athabasca	182	59	0	1
Sub-totals		1,808	802	23	9
Walleye	Rivière des Rochers	210	171	6	0
	Revillon Coupé	8	8	0	0
	Claire-Mamawi lakes system	78	69	0	6
	Chenal des Quatre Fourches	42	41	0	1
	Lake Athabasca	79	57	0	2
Sub-totals		417	346	6	9
Longnose sucker	Rivière des Rochers	126	101	0	0
	Revillon Coupé	17	12	0	0
	Claire-Mamawi lakes system	70	65	0	0
	Chenal des Quatre Fourches	21	20	0	0
	Lake Athabasca	7	3	0	0
Sub-totals		241	201	0	0
White sucker	Rivière des Rochers	17	12	0	0
	Revillon Coupé	1	1	0	0
	Claire-Mamawi lakes system	7	6	0	0
	Chenal des Quatre Fourches	0	0	0	0
	Lake Athabasca	7	6	0	0
Sub-totals		32	25	0	0
TOTALS		24,349	20,195	328	52

[1]Does not include fish recaptured within 24 h of previous capture.

[2]Three goldeye were recaptured by fishermen outside the Peace-Athabasca Delta, and are not included.

Table 9. Percent composition of total catch by species for each of five sampling areas*.

Location	Longnose and White Sucker	Walleye	Lake Whitefish	Northern Pike	Goldeye
	SPECIES				
Lake Athabasca	1.8	10.1	23.2	5.3	59.6
Revillon Coupé	0.6	0.3	4.6	3.5	91.0
Claire-Mamawi lakes system	1.8	1.9	2.3	14.8	79.2
Chenal des Quatre Fourches	0.5	0.9	3.3	4.3	91.0
Rivière des Rochers	1.2	1.8	10.5	13.2	73.3
Above areas combined	1.1	1.7	7.4	10.4	79.4

*Calculations based on data in Table 8.

Table 10. Numbers of fish less than 200 mm fork length* and percent of total catch by species.

LOCATION	SPECIES									
	Longnose and White Sucker		Walleye		Lake Whitefish		Northern Pike		Goldeye	
	No.	%	No.	%	No.	%	No.	%	No.	%
Lake Athabasca	0	0	7	8.9	97	53.3	1	2.4	19	4.1
Revillon Coupé	0	0	0	0	71	53.0	0	0	22	0.8
Claire-Mamawi lakes system	0	0	0	0	10	10.5	8	1.3	83	2.5
Chenal des Quatre Fourches	0	0	0	0	62	40.0	0	0	40	0.9
Rivière des Rochers	0	0	16	7.6	520	41.9	64	4.1	770	8.9

*220 mm for northern pike.

Table 11. Movement of tagged fish between waterbodies within or associated with the Peace-Athabasca Delta, 1976.

LOCATION[1] OF TAGGING		LOCATION[1] OF RECAPTURE	NUMBERS OF FISH BY DATE OF RECAPTURE							
			1 JUNE-31 AUGUST				1 SEPTEMBER-20 OCTOBER			
			Goldeye	Northern Pike	Lake Whitefish	Walleye	Goldeye	Northern Pike	Lake Whitefish	Walleye
Q	→	CM	1	-	-	1	-	-	1	-
E	→	CM	-	-	-	-	-	-	-	-
R	→	CM	5	-	-	-	-	-	-	-
Q	→	A	1	-	-	-	-	1	-	-
E	→	A	1	-	-	-	-	-	-	-
R	→	A	4	-	-	1	-	-	1	-
Q	→	AR	1	-	-	-	-	-	-	-
E	→	AR	-	-	-	-	-	-	-	-
R	→	AR	1	-	-	-	-	-	-	-
Q	→	HR	1	-	-	-	-	-	-	-
Q	→	E	-	-	-	-	5	-	-	-
Q	→	R	5	1	1	-	1	-	1	-
E	→	Q	-	-	-	-	1	-	-	-
E	→	R	1	1	-	-	-	-	2	-
R	→	E	-	-	-	-	8	2	2	-
R	→	Q	4	1	-	-	7	1	-	-
CM	→	Q	1	-	-	-	3	-	1	-
CM	→	E	-	-	-	-	1	-	-	-
CM	→	R	1	-	-	-	1	-	-	-
A	→	Q	-	-	-	-	-	-	1	-
A	→	E	-	-	-	-	1	-	-	-
A	→	R	-	-	-	-	-	-	-	-
CM	→	A	1	-	-	1	-	-	-	-
C	→	M	-	-	-	2	-	-	-	-
TOTALS			28	3	1	5	28	4	9	0

[1]A = Lake Athabasca
AR = Athabasca River
C = Lake Claire
CM = Claire-Mamawi lakes system
E = Revillon Coupé
HR = Hornaday River
M = Mamawi Lake
Q = Chenal des Quatre Fourches
R = Rivière des Rochers

Table 12. Mean catches per unit effort for fish captured in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches, 5 September to 21 October, 1976.

SPECIES	LOCATION					
	Rivière des Rochers		Revillon Coupé		Chenal des Quatre Fourches	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Goldeye	7.98	8.66	17.85	11.73	19.78	18.88
Lake whitefish	3.08	3.61	0.62	0.83	0.34	0.59
Northern pike	2.96	3.14	0.37	0.46	0.10	0.16
Walleye	0.09	0.18	0.02	0.06	0.01	0.04
Longnose and white sucker (combined)	<0.01	0.02	0.09	0.21	0.01	0.04

Table 13. Population estimates for four species of fish in the Peace-Athabasca Delta (31 May to 21 October, 1976) using the Chapman modification of the Schnabel multiple census method (Ricker 1975).

Species	Population Estimate	95% Confidence Limits	Comments
Goldeye	1,153,772	972,613-1,367,820	excluding age groups 0, 1 and 2
	1,169,002	-	excluding young-of-the-year
Lake whitefish	17,167	11,639-26,411	excluding fish less than 200 mm fork length
Northern pike	16,309	14,013-18,972	excluding fish less than 220 mm fork length
Walleye	9,676	4,805-21,166	excluding age groups 0 and 1
	9,849	-	excluding young-of-the-year

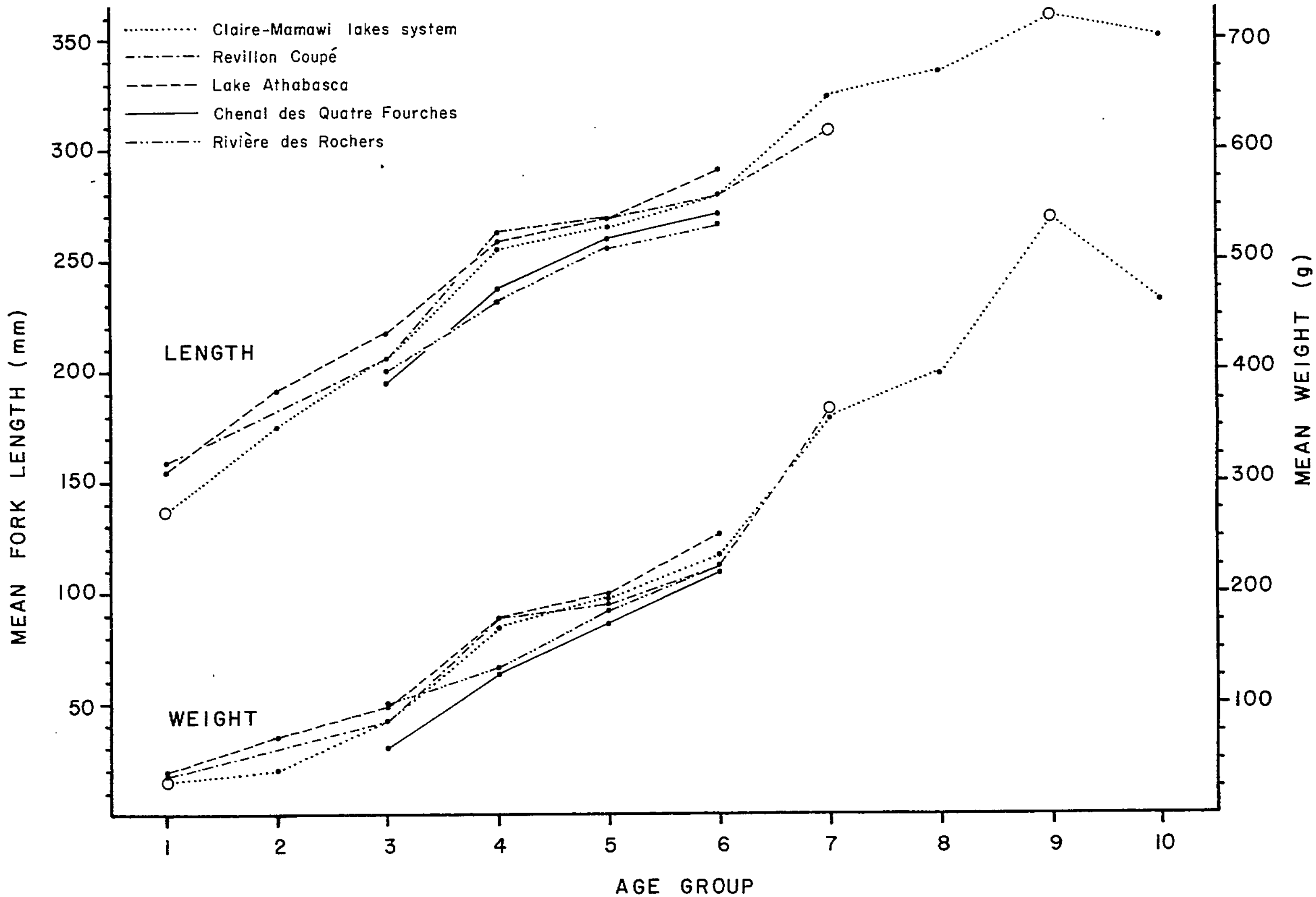
Table 14. Estimated numbers of goldeye and walleye by age group based on their 1976 age compositions.

Age Group	Year Class	Estimated Number of	
		Goldeye	Walleye
1	1975	9,677	176
2	1974	5,806	316
3	1973	139,351	599
4	1972	77,901	1,020
5	1971	897,557	1,654
6	1970	32,419	1,864
7	1969	2,420	1,267
8	1968	1,452	844
9	1967	484	457
10	1966	1,935	703
11	1965	-	563
12	1964	-	176
13	1963	-	105
14	1962	-	70
15	1961	-	35
TOTAL		1,169,002	9,849

Table 15. Numbers of fish tagged and recaptured* downstream of Little Rapids weir in relation to minimum hydraulic head between tagging and recapture dates.

NUMBER OF DAYS BETWEEN TAGGING AND RECAPTURE DATES	HYDRAULIC HEAD							
	LOW (< 2.5 ft)				HIGH (> 2.5 ft)			
	Northern Pike	Goldeye	Lake Whitefish	Walleye	Northern Pike	Goldeye	Lake Whitefish	Walleye
1	-	1	-	-	-	-	-	-
2	2	3	-	-	3	1	-	-
3	1	-	-	-	4	-	-	-
4	1	1	1	-	2	-	2	1
5	-	1	-	-	1	-	1	-
6	2	-	-	-	1	-	-	-
7	1	1	1	1	-	-	-	-
8	1	1	-	-	1	-	1	-
9	4	-	-	-	1	-	1	-
10	1	-	-	-	-	-	-	-
11	2	1	-	-	-	1	-	-
12	2	-	-	-	3	-	-	-
13	1	2	-	-	-	-	1	1
14	3	1	-	-	1	-	-	-
15	2	1	-	-	1	-	-	-
17	1	-	-	-	-	-	-	-
18	-	1	-	-	-	-	-	-
19	1	-	-	-	-	-	1	-
20	-	1	-	-	-	-	-	-
21	2	-	-	-	-	-	-	-
22	1	1	-	-	-	-	-	-
23	-	1	-	-	-	-	-	-
24	1	-	1	-	-	-	1	-
25	-	1	-	-	1	-	-	-
26	2	-	-	-	-	-	-	-
27	2	-	-	-	-	-	1	-
28	1	-	-	-	-	-	1	-
29	-	-	1	-	1	-	-	-
30	2	-	1	-	1	-	-	-
31	1	3	-	-	-	-	-	-
33	-	-	-	1	-	-	-	-
34	2	-	-	-	1	-	-	-
35	3	-	-	-	-	-	-	-
36	1	-	-	-	-	-	-	-
37	1	-	-	-	-	-	-	-
38	1	-	-	-	-	-	-	-
39	1	-	-	-	-	-	-	-
40	1	1	-	-	-	-	-	-
41	1	-	-	-	-	-	-	-
42	3	1	-	-	-	-	-	-
43	-	-	1	-	-	-	-	-
46	2	-	-	-	-	-	-	-
47	1	-	-	-	-	-	-	-
49	2	-	-	-	-	-	-	-
50	1	-	-	-	-	-	-	-
51	-	1	-	-	-	-	-	-
53	1	-	-	-	-	-	-	-
55	1	-	-	-	-	-	-	-
58	1	-	-	-	-	-	-	-
60	1	-	-	-	-	-	-	-
62	1	-	-	-	-	-	-	-
63	1	-	-	-	-	-	-	-
65	1	-	-	-	-	-	-	-
68	1	-	-	-	-	-	-	-
69	1	-	-	-	-	-	-	-
72	2	-	-	-	-	-	-	-
74	1	-	-	-	-	-	-	-
76	1	-	-	-	-	-	-	-
81	1	-	-	-	-	-	-	-
82	1	-	-	-	-	-	-	-
92	1	-	-	-	-	-	-	-
96	1	-	-	-	-	-	-	-
102	-	-	-	1	-	-	-	-
137	1	-	-	-	-	-	-	-
TOTALS	75	24	6	3	22	2	10	2

*Immediate recaptures are not included.



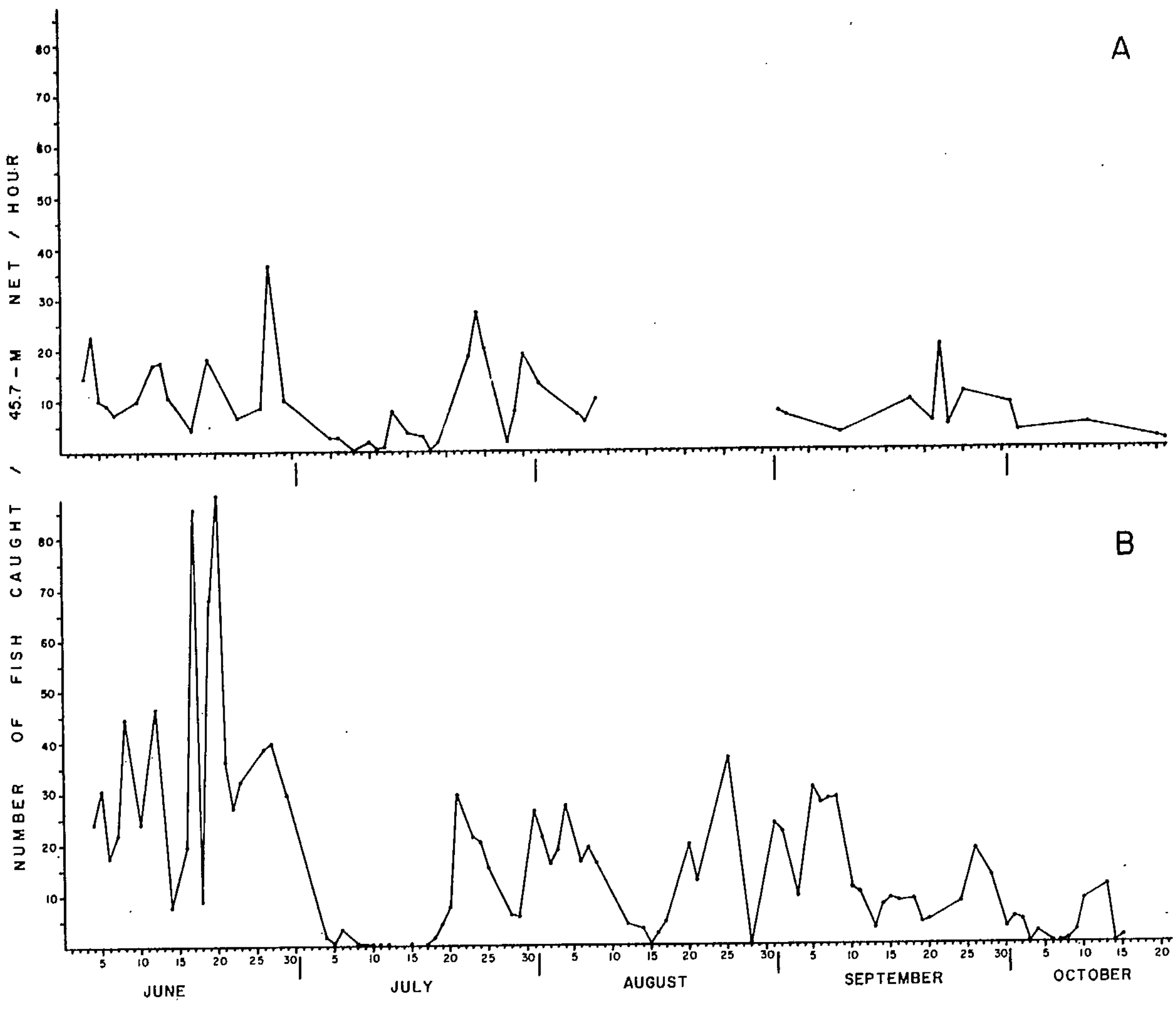
Appendix 1. Age-length and age-weight relationships for goldeye captured in five sampling areas within the Peace-Athabasca Delta, 1976. Open circles represent sample sizes of one.

Appendix 2. Minimum distances travelled by tagged fish between waterbodies within or associated with the Peace-Athabasca Delta, 1976.

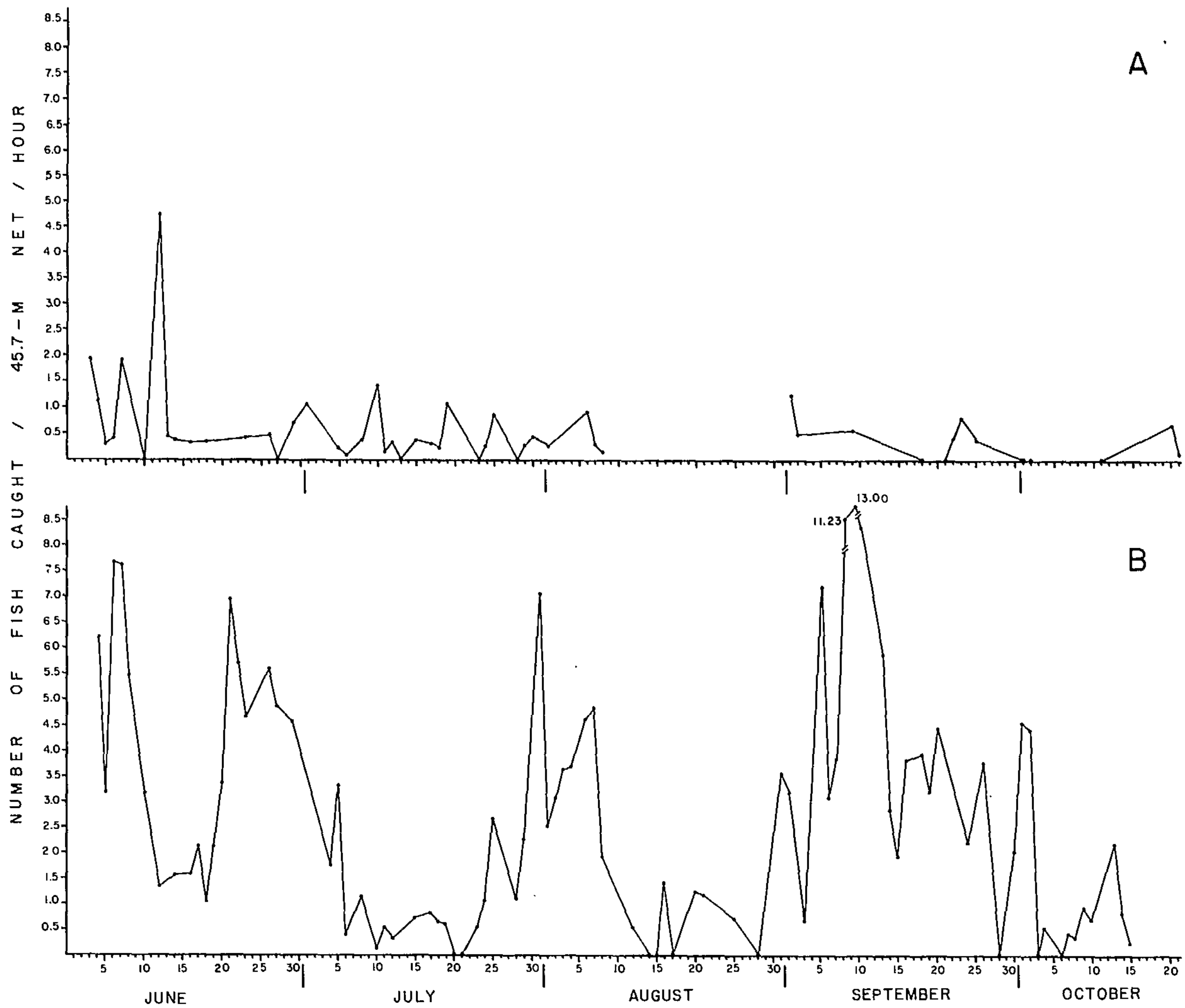
Location[1] Of Tagging (1)		Location[1] Of Recapture (2)	Minimum Distance[2] (km) Between (1) and (2)	NUMBER OF FISH				
				Goldeye	Lake Whitefish	Northern Pike	Walleye	Total
A	→	E	35	1	0	0	0	1
A	→	Q	37	0	1	0	0	1
C	→	A	61	0	0	0	1	1
C	→	E	72	1	0	0	0	1
C	→	M	23	0	0	0	2	2
C	→	Q	27-37	4	1	0	0	5
C	→	R	64-68	2	0	0	0	2
E	→	A	58	1	0	0	0	1
E	→	Q	21	1	0	0	0	1
E	→	R	23	1	2	1	0	4
M	→	A	43	1	0	0	0	1
Q	→	A	34	1	0	0	0	1
Q	→	AR	120	1	0	0	0	1
Q	→	C	27	1	1	0	0	2
Q	→	E	42	5	0	0	0	5
Q	→	HR	117	1	0	0	0	1
Q	→	M	10	0	0	0	1	1
Q	→	R	37-53	6	2	2	0	10
R	→	A	32-63	4	1	0	1	6
R	→	AR	244	1	0	0	0	1
R	→	C	64-68	5	0	0	0	5
R	→	E	23	8	2	2	0	12
R	→	Q	37-53	11	0	2	0	13
			TOTAL	56	10	7	5	78

[1]A = Lake Athabasca
AR = Athabasca River
C = Lake Claire
E = Revillon Coupé
HR = Hornaday River
M = Mamawi Lake
Q = Chenal des Quatre Fourches
R = Rivière des Rochers

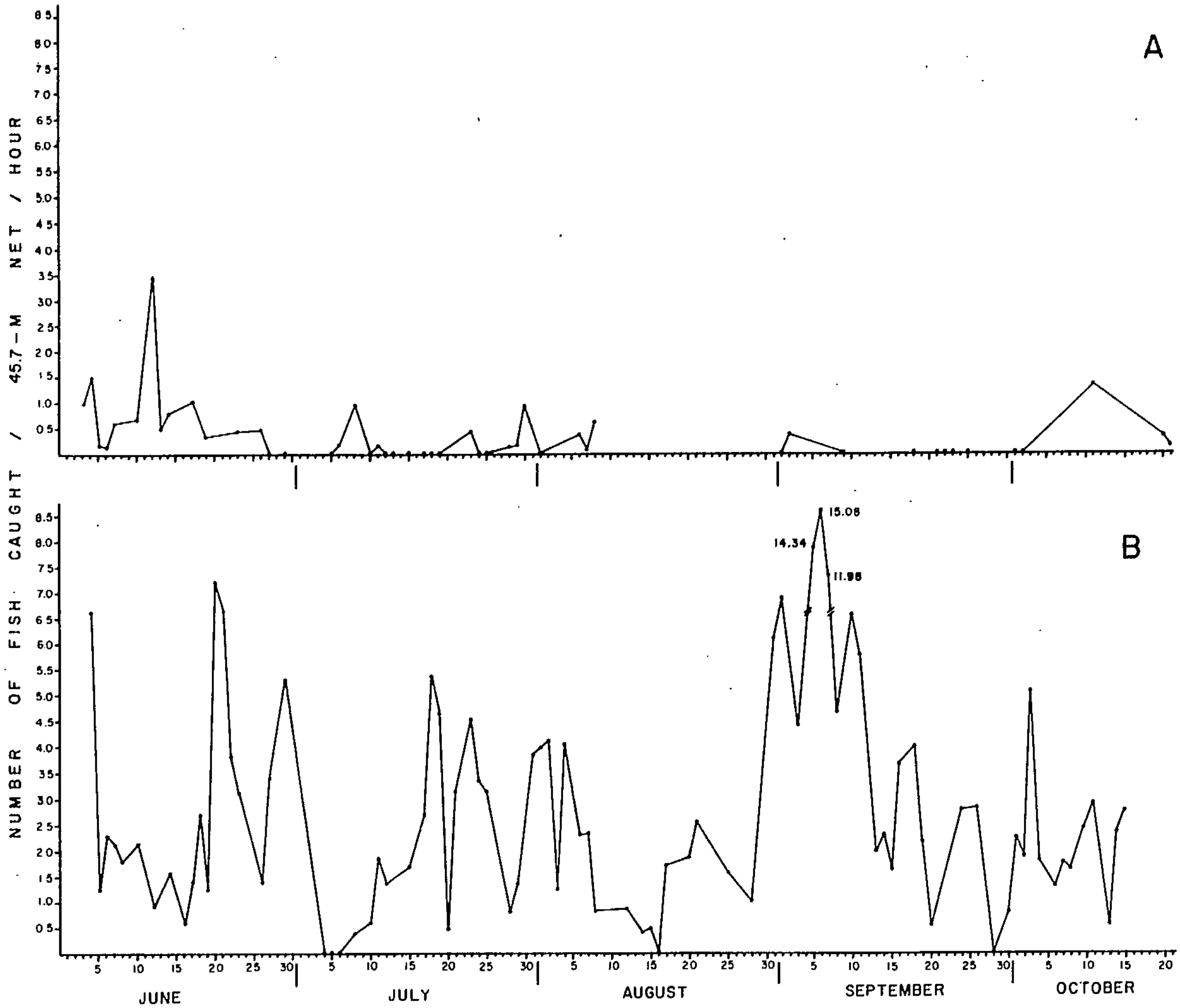
[2]In some cases, the minimum distance between (1) and (2) varies, depending upon the precise locations of sampling stations between which tagged fish moved. In all cases, distance is by water.



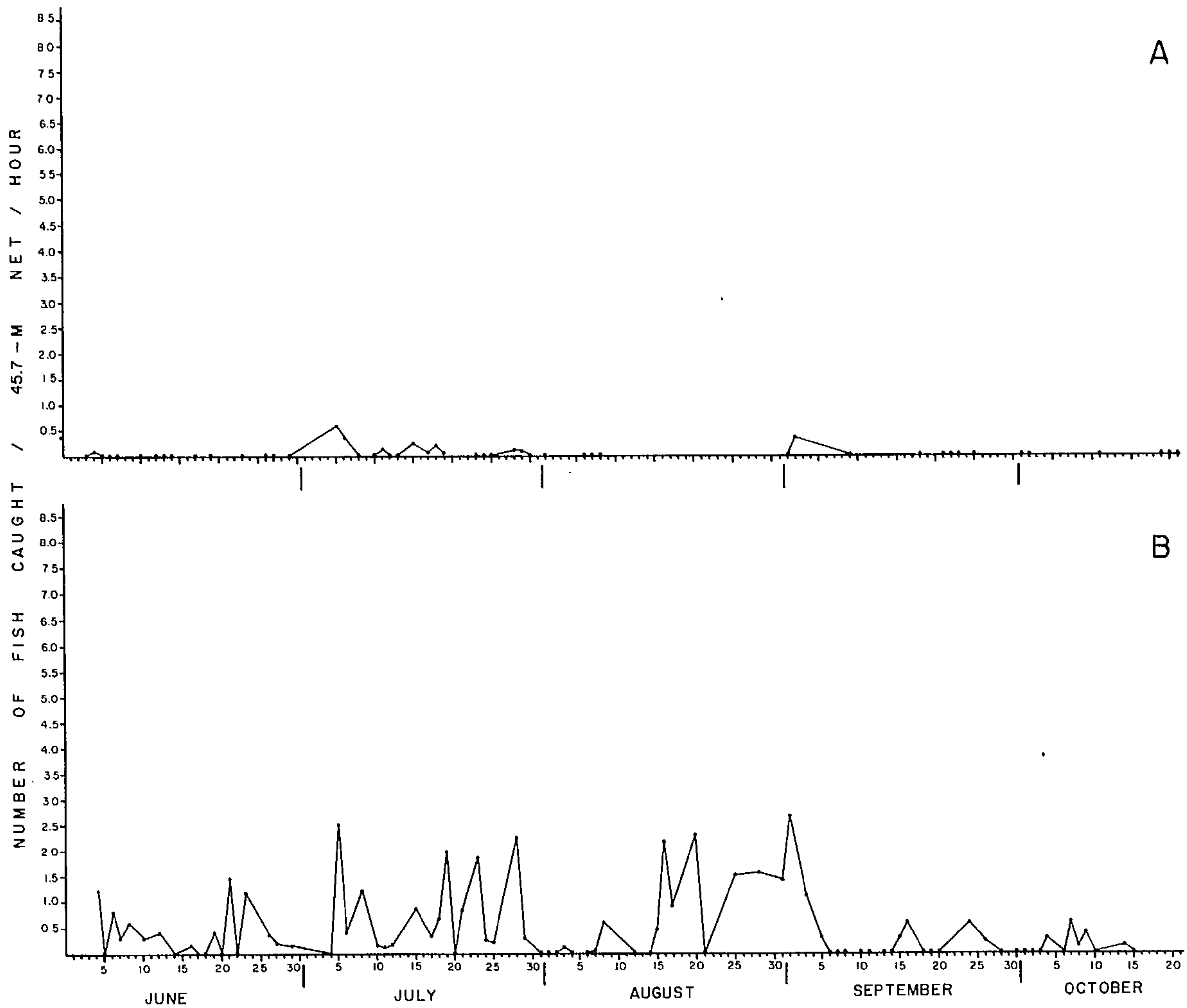
Appendix 3. Daily mean catch per unit effort for goldeye upstream (A) and downstream (B) of Little Rapids weir.



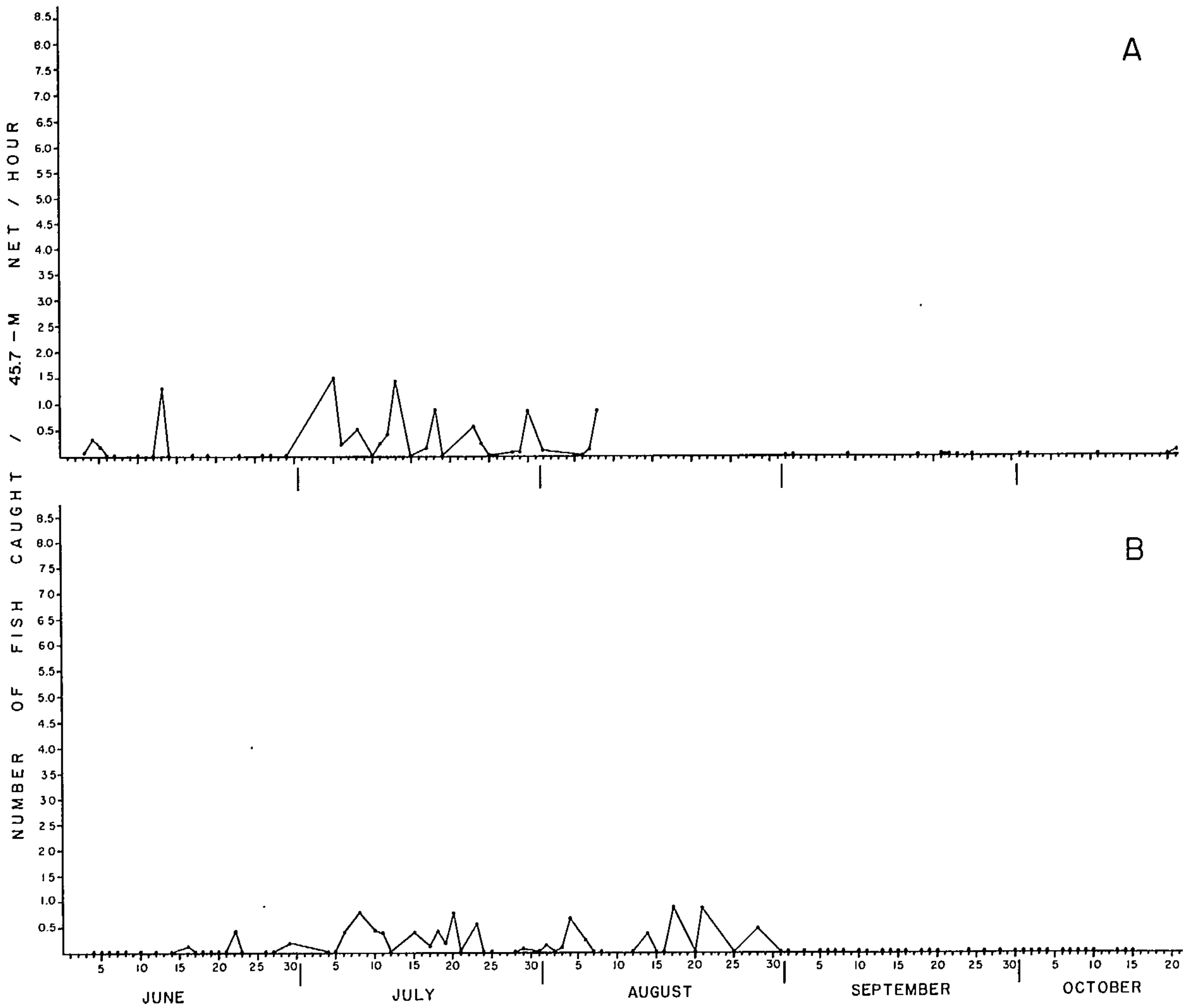
Appendix 4. Daily mean catch per unit effort for northern pike upstream (A) and downstream (B) of Little Rapids weir.



Appendix 5. Daily mean catch per unit effort for lake whitefish upstream (A) and downstream (B) of Little Rapids weir.



Appendix 6. Daily mean catch per unit effort for walleye upstream (A) and downstream (B) of Little Rapids weir.



Appendix 7. Daily mean catch per unit effort for longnose and white suckers (combined) upstream (A) and downstream (B) of Little Rapids weir.

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