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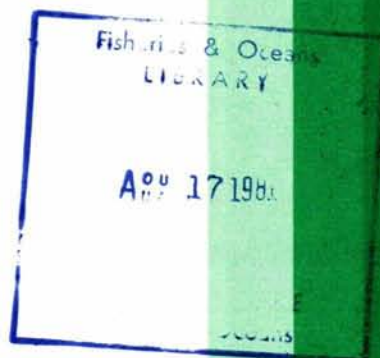


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Investigations of Goldeye and Other Fish Species in the Wood Buffalo National Park Section of the Peace - Athabasca Delta, 1977

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May 1981

INVESTIGATIONS OF GOLDEYE AND OTHER FISH SPECIES IN THE
WOOD BUFFALO NATIONAL PARK SECTION OF THE
PEACE-ATHABASCA DELTA, 1977

by

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ABSTRACT

Kristensen, J. 1981. Investigations of goldeye and other fish species in the Wood Buffalo National Park section of the Peace-Athabasca Delta, 1977. Can. MS Rep. Fish. Aquat. Sci. 1560: v + 64 p.

Mark-recapture information and catch rates suggest that goldeye migrated from the Peace River to the Claire-Mamawi lakes system or Lake Athabasca through the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches during the spring of 1977. Catch rates of goldeye were approximately three times higher in each of the Rivière des Rochers and Revillon Coupé than in the Chenal des Quatre Fourches during spring migration. Goldeye accumulated downstream of the Rivière des Rochers and Revillon Coupé weirs during portions of the spring sampling period. Comparisons of meristic characters, age structure, growth and movement of goldeye that were captured in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches suggest that goldeye that migrate through the three rivers during spring are members of the same group. Goldeye that were tagged in the Peace-Athabasca Delta moved as far upstream in the Peace River as Peace Point and as far south in the Athabasca River as Fort MacKay.

The 1971 year class dominated and comprised approximately 68% of the total goldeye catch in 1977. Approximately 545,000 juvenile and adult goldeye were estimated to have been present in the Delta during the study period. On the basis of population estimates, fecundity and rates of maturation, the reproductive potential of the Delta goldeye population was estimated to have been approximately 1,297,000 postlarval young-of-the-year. The reproductive potential of goldeye in 1977 was low because very few mature females were captured and because the mean fecundity of female goldeye was low (3,172). Approximately 88% of the 1977 reproductive potential was contributed by the 1971 year class. On the basis of trawl net catches, approximately 1,536,000 postlarval young-of-the-year goldeye were estimated to have been present in Lake Claire and Mamawi Lake. Young-of-the-year goldeye were captured in almost all of the waterbodies sampled within the Delta; these data suggest that goldeye spawn throughout the region. The distribution of young-of-the-year goldeye and other species that were captured in trawl nets appeared related to some, but not to other, environmental parameters.

Key words: goldeye; mark; movement; weir; meristics; age; growth; reproductive potential.

RESUME

Kristensen, J. 1979. Investigations of goldeye and other fish species in the Wood Buffalo National Park section of the Peace-Athabasca Delta, 1977. Can. MS Rep. Fish. Aquat. Sci. 1560: v + 64 p.

Les données sur le marquage et la recapture et les taux des prises semblent indiquer que, au printemps 1977, la laquaiche aux yeux d'or a migré de la Peace River au système des lacs

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Claire et Mamawi en passant par la Rivière des Rochers, le chenal Revillon Coupé et le Chenal des Quatre Fourches. Les taux des prises de cette espèce étaient environ trois fois plus élevés dans la Rivière des Rochers et le chenal Revillon Coupé que dans le Chenal des Quatre Fourches pendant la migration printanière. Les laquaiches s'accumulaient en aval des déversoirs de la Rivière des Rochers et du chenal Revillon Coupé pendant certaines parties de la période d'échantillonnage du printemps. Des comparaisons des caractères méristiques, de la structure par âge, de la croissance et du mouvement des laquaiches capturées dans la Rivière des Rochers, le chenal Revillon Coupé et le Chenal des Quatre Fourches semblent indiquer que les individus qui passent dans ces trois rivières au printemps appartiennent au même groupe. Des spécimens marqués dans le delta Peace-Athabasca ont remonté la Peace River jusqu'à la pointe Peace, et l'Athabasca River jusqu'à Fort MacKay.

La classe 1971 dominait et composait environ 68% des prises totales de 1977. On estime à quelque 545,000 juvéniles et adultes le nombre des laquaiches présentes dans le delta pendant la période d'étude. A partir des estimations des populations, de la fécondité et du taux de maturation, le potentiel de reproduction de la population de laquaiche du delta a été estimé à environ 1,297,000 jeunes de l'année au stade post-larvaire. En 1977, le potentiel de reproduction de la laquaiche était bas, car on a capturé très peu de femelles, et parce que leur fécondité moyenne était basse (3,172). On attribue environ 88% du potentiel de reproduction de 1977 à la classe 1971. A partir des prises réalisées au chalut, on estime à environ 1,536,000 le nombre de jeunes de l'année au stade post-larvaire présents dans les lacs Claire et Mamawi. On a capturé des jeunes laquaiches dans presque toutes les eaux échantillonnées dans le delta, ce qui semble indiquer que cette espèce fraie dans l'ensemble de la région. La distribution des jeunes de l'année de la laquaiche et d'autres espèces capturées au chalut semblait en rapport avec certains paramètres environnementaux.

Mots-clés: marquage; déplacement; déversoirs; dénombrements méristiques; âge; croissance; potentiel de reproduction.

INTRODUCTION

The completion and closure of the W.A.C. Bennett Dam in 1968 interrupted natural water regimes in the Peace-Athabasca Delta (Fig. 1) and threatened to permanently alter the environment of the Delta. The Bennett Dam, which is located in British Columbia approximately 1170 km upstream from the Delta, controls approximately 50% of the flow in the Peace River near the Delta (Peace-Athabasca Delta Project Group 1973). Following completion of the dam, the natural flood levels in the Peace River were reduced by as much as 3.7 m. This reduction in Peace River flow led to a reduction of the annual flooding in the Delta.

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 ecological studies indicated that low water levels might increase the natural aging process of the Delta (Dierschl 1973), and might 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 in order to slow the water that flowed 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 flow out of Lake Athabasca and the Delta. Submerged weirs were completed at Little Rapids on the Rivière des Rochers in the fall of 1975, and on the Revillon Coupé (Fig. 2) in the spring of 1976. Upon completion of the Little Rapids weir, the temporary dam at Quatre Fourches was removed.

Although the construction of weirs to partly restore the natural water levels should be generally beneficial to most components of the Delta, the presence of such structures may block or hinder traditional fish migrations. In fact, one of the major reasons for the removal of the temporary dam at Quatre Fourches in 1975 was the possibility that the structure might act as "a barrier to fish migration between wintering sites and major spawning lakes" (Peace-Athabasca Delta Project Group 1973:128). Investigations of fish movement in the Peace-Athabasca Delta in 1976 (Kristensen and Summers 1978) indicated that significant numbers of fish (primarily goldeye, *Hiodon alosoides*) accumulated downstream of the Little Rapids weir during periods of high hydraulic head (high velocities) across the weir. The fishway that had been constructed beside the Little Rapids weir was of limited use; large numbers of fish moved upstream through it on only two occasions. Fish were also concentrated downstream of the Revillon Coupé weir during early June 1976.

Kooyman (1973) indicated that goldeye migrate during spring from the Peace River into the Peace-Athabasca Delta, where they spawn and

feed, and that they then return to the Peace River during summer and autumn where they overwinter. He suggested that the Chenal des Quatre Fourches is a major spring and summer-autumn migration route for goldeye. Results of research in 1976 (Kristensen and Summers 1978) indicated that the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches were all used by goldeye migrating to and from the Claire-Mamawi lakes system and Lake Athabasca. The relative importance of the three rivers to goldeye migrating from the Delta during summer and autumn was determined in 1976, but because the 1976 field study did not commence until the migration of goldeye from the Peace River to the Delta was already well underway, the relative importance of the three migration routes to the spring migration of goldeye could not be determined.

A delay in the spring migration of goldeye from the Peace River caused by the weirs at Little Rapids or on the Revillon Coupé, might result in decreased spawning in the Claire-Mamawi lakes system. If the weirs hindered the movement of goldeye toward their spawning grounds, the significance of these effects would be greater if discrete goldeye groups (as defined by Marr, 1957) exist in the Delta and if these groups manifest fidelity to specific migration routes from the Peace River to their spawning grounds in the Delta. A delay in spring migration might also have much more serious effects when the majority of the 1971 goldeye year class, which presently dominates the Delta population (Kristensen and Summers 1978), attains sexual maturity and attempts to move into the Delta to spawn.

Information on both the relative importance of the three rivers to the spring goldeye migration and the biological characteristics of goldeye in the three rivers is thus essential in order to fully assess the impacts of the water control structures on goldeye in the Peace-Athabasca Delta. The present study was accordingly conducted to obtain this information. Primary objectives of the study were the following:

1. to determine the relative importance of the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches to spring goldeye migration from the Peace River into the Peace-Athabasca Delta;
2. to document the effects of the Little Rapids and Revillon Coupé weirs on the spring migration of goldeye, and
3. to compare the meristic characters of goldeye that were collected from the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches, in an attempt to determine whether discrete groups of goldeye utilize the three rivers.

Secondary objectives of the study were the following:

1. to document the age structure and growth rates of goldeye in order to follow the success of the dominant 1971 year class;

2. to estimate the numbers of adult and juvenile goldeye present in the Peace-Athabasca Delta;

3. to estimate the reproductive potential of goldeye in the Peace-Athabasca Delta and the spawning success of goldeye in the Claire-Mamawi lakes system, and

4. to determine the distribution of young-of-the-year goldeye in the Peace-Athabasca Delta and the effects of several environmental parameters on their distribution.

Information was also collected concerning the movement, distribution and abundance of other fish species in the Delta.

STUDY AREA

The Peace-Athabasca Delta--one of the largest freshwater deltas in the world--encompasses an area of approximately 3800 km² (Peace-Athabasca Delta Project Group 1973). Most of the Delta is situated within Wood Buffalo National Park at the west end of Lake Athabasca (see Fig. 1). The Delta consists of predominantly flat terrain, formed primarily by the deposition of silt that has been carried into the area by the Peace, Athabasca and Birch rivers. Outcrops of Precambrian granite, which delimit the western edge of the Canadian Shield, occur in the eastern and northeastern areas of the Delta.

Active parts of the Delta consist of major rivers, smaller streams and open basin lakes (Dirschl 1973). The four major lakes within the Delta (Clair, Mamawi, Richardson and Baril, see Fig. 2) are extremely shallow, ranging in depth from 0.6 to 3.0 m (Peace-Athabasca Delta Project Group 1973). The two largest lakes, Lake Claire and Mamawi Lake, are approximately 1435 km² and 164 km² in area, respectively. The very shallow western end of Lake Athabasca is also included in the Delta. Semi-active portions of the Delta include many shallow perched basins and oxbow lakes; closed basins located in higher and older areas comprise the inactive parts of the Delta (Dirschl 1973).

The hydrological cycle within the Delta is complex (Peace-Athabasca Delta Project Group 1973). During most of the year, water enters the Delta primarily through the Athabasca and Birch rivers, and leaves through several channels that flow north to the Peace and Slave rivers. Each spring during break-up, ice jams on the lower Peace River or upper Slave River cause a major backwater effect, and Peace River water floods into the Delta. This annual flooding is necessary to recharge the Delta system. During this period, high water levels of the Peace River decrease or prevent outflow of water from the Delta. As the Peace River water levels subside, water flows out from the Delta into the Peace and Slave rivers through the Rivière des Rochers, the Revillon Coupé, and the Chenal des Quatre Fourches.

This study was conducted in several areas within the Peace-Athabasca Delta--specifically, in the following waterbodies: Lake Athabasca, Lake Claire, Mamawi Lake, Baril Lake, Rivière des Rochers, Chenal des Quatre Fourches and associated channels, Revillon Coupé, Prairie River, Birch River and Baril River (see Fig. 2).

The water control structures on the Rivière des Rochers (Little Rapids) and on the Revillon Coupé were of major concern during this study. Both weirs were constructed of granite rockfill at 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 along the northeast bank of the river to bypass the weir. The partially submerged weir on the Revillon Coupé was constructed across approximately three-fourths of the width of the river. This weir permits some flow over it, but most flow passes through an open channel along the southwest bank of the river (Fig. 3).

METHODS

FIELD TECHNIQUES

Sampling with gill nets

Gill netting for adult and juvenile fish was conducted simultaneously by three crews in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches from 11 May to 15 June 1977. During this period most of the sampling was carried out in the vicinity of the weirs on the Rivière des Rochers and Revillon Coupé at sampling sites Q05, Q09, Q11, Q12 and Q13 (Fig. 3) on the Chenal des Quatre Fourches. Sporadic sampling with gill nets was conducted in other waterbodies from 19 May to 22 August 1977.

Previous studies in the Peace-Athabasca Delta (Kristensen and Sekerak 1976) 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 that range from 3.8 cm (1.5 in) to 8.9 cm (3.5 in). Gangs of three monofilament gill nets of different mesh sizes were used during this study. The individual nets were 15.2 m (50 ft) long and 2.5 m (8 ft) deep; the three mesh sizes used were 3.8 cm, 6.4 cm (2.5 in) and 8.9 cm stretched mesh.

In lakes, nets were set perpendicular to and near the shoreline. In rivers, nets were set in locations where backwater (eddy) conditions decreased the current sufficiently to permit proper setting. Nets were set for varying lengths of time, depending on the purpose of the sets. If fish were to be tagged and released, the sets were of short duration (usually less than 1 h); if fish were to be collected, sets were of longer duration.

Data collected from the gill net sets were coded onto data forms in a manner that was suitable for key-punching and computer analyses. Figure 4 illustrates one of these forms and the types of data that were recorded. It should be noted that

weights of goldeye were recorded to the nearest 5 g whereas weights of other species were recorded to the nearest ounce. 'Condition' on the date-recording sheet denotes condition of the fish upon release.

Eight species of fish were tagged with numbered, international-orange, nylon anchor tags. Tags were applied with a cartridge-fed model No. FDM-68 tagging gun (Floy Tag and Manufacturing Company, Seattle) that was fitted with either a 2.5- or a 3.8-cm needle. Tags were inserted on the left side of the fish and anchored between the pterygiophore bones below the dorsal fin in order to minimize loss of tags (Dell 1968). Only those fish that appeared to be in good condition were tagged and released.

An attempt was made to determine the sex of goldeye in the field, based on the shape of the anal fin, and to determine the state of sexual maturity by gently squeezing goldeye for eggs or milt. However, sex can be readily determined externally only for the larger goldeye and eggs or milt of goldeye are very difficult to obtain by the squeezing (stripping) method (Kennedy and Sprules 1967). As a result of these difficulties, selected subsamples of goldeye from the Rivière des Rochers, Revillon Coupé, Chenal des Quatre Fourches and the Claire-Mamawi lakes system were sacrificed and either examined in the field or preserved in 10% formalin and examined in the laboratory. Ovaries of all of the ripe female goldeye that were sacrificed were also preserved in 10% formalin for later analysis of fecundity.

Scales were taken from between the dorsal fin origin and the lateral line from selected subsamples of goldeye for subsequent age analysis.

Sampling with trawl nets

Of the young-of-the-year (Y-O-Y) goldeye captured in lakes, Kristensen and Sekerak (1976) and Donald and Kooyman (1977) captured most within approximately 700 m of the shorelines. Kristensen and Sekerak (1976) found that representative samples of Y-O-Y goldeye could be obtained by sampling at a few selected shoreline sites of a waterbody and that those results could be extrapolated to the entire shoreline of the waterbody. On the basis of this information, and in order to make the results of several studies comparable, a sampling program similar to those of Kristensen and Sekerak (1976) and Donald and Kooyman (1977) was used in 1977 to determine the movement, distribution and abundance of primarily Y-O-Y goldeye in the Peace-Athabasca Delta. Approximately the same sampling stations that were used in previous studies were used in 1977.

Small fish species and Y-O-Y fish of larger species were sampled with trawl nets between 11 June and 27 August 1977 at the stations shown in Fig. 5. Each trawl net was constructed of aluminum tubing that formed an 83-cm square and a bag made of 3.2-mm oval mesh nylon net that tapered to a point approximately 150 cm from the square frame. Two nets were towed—one on each side of a 6-m boat that was powered by a 14.9 kW (20 hp) engine, which was operated at full throttle for 2 min at each sampling station. In lakes, trawls were conducted as close to the shore as possible in water that was between 0.9 and 1.0 m deep; trawls

were conducted such that trawl nets almost touched the substratum. In rivers, trawls were also conducted as close to the shore as possible, with the net nearest the shoreline in water that was approximately 1.0 m deep.

Data collected for each trawl were coded onto data forms in a manner that was suitable for key-punching and computer analyses. Figure 6 illustrates one of these forms and the types of data that were recorded. Several additional types of data were recorded in unused columns of the data form. These included the fork lengths of Y-O-Y goldeye, the wind direction in relation to the shoreline for sampling stations in lakes and the substratum type and hardness at all sampling stations. A small Ekman grab was used to collect samples of substratum material, which were classified into broad categories; the hardness of the substratum was tested subjectively by sticking a wooden paddle into the substratum. The dominant plant species or genera that occurred along the shoreline at each sampling station were recorded in the approximate order of dominance (up to a maximum of four species or genera); each such group of plants has been referred to as a vegetation complex.

Hydrological measurements

The water temperature was recorded whenever sampling was conducted at each gill net or trawl sampling station. Records were kept of the current direction in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches from 13 May to 15 June. Surface velocities of water that flowed over the Little Rapids and Revillon Coupé weirs and through the Little Rapids fishway were estimated from the latter part of May to mid-June through use of the floating chip method. Reading of Alberta Department of Environment staff gauges, which were located immediately northwest and southeast of the Little Rapids weir, were taken twice daily from 18 May to 15 June. All other hydrological data that appear in the report were obtained from the Alberta Department of Environment office at Fort Chipewyan. (In some cases, recent hydrological data were unverified by Alberta Environment at the time this report was prepared.)

Because hydrological measurements for this study were made using English rather than metric units, all hydrological measurements that appear in this report are given in English units.

LABORATORY TECHNIQUES AND DATA ANALYSES

Determination of age

Goldeye scales (four to six per fish) were mounted between glass slides, and ages were determined independently by two readers through use of a Bausch and Lomb microprojector. The criteria used to determine the ages of goldeye scales were those of Chugunova (1963); they included the identification of annuli by the spacing of circuli, and the sudden cessation of circuli in the lateral field of scales. As discussed by Kristensen and Summers (1978), it was essential to determine the approximate time of the 1977 annulus formation, so that correct ages could be assigned to scales. Discrepancies in

goldeye age estimates between readers were resolved by re-reading the scale samples in question.

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 that of the total number of annuli present on scales following formation of the 1977 annulus. One year was added to the number of annuli that were present on scales of fish that were captured immediately prior to formation of the 1977 annulus.

Determination of sex and state of maturity

Sex and state of sexual maturity were determined for almost all collected goldeye on the basis of an examination of gonads and the criteria given by Battle and Sprules (1960) and Kennedy and Sprules (1967). Because it was often difficult to distinguish between mature males and males that were approaching their first year of maturity (testes are convoluted in both groups), these two groups were combined. These two groups of females can be easily distinguished. Females captured in spring or early summer contain small white eggs if they are going to spawn the following spring. Mature females just prior to spawning and females captured late in the summer that will spawn the following spring contain eggs that are large (close to 2.0 mm in diameter) and grey or blue in colour.

The fecundities of 12 mature goldeye were estimated by counting the eggs in a 10% (by weight) subsample of each ovary, and then multiplying this count by 10. Eggs were first allowed to air dry and harden in order to facilitate counting. The technique was substantiated by comparing two total egg counts with the estimates obtained by counting eggs in only 10% of the same two ovarian samples; the errors between the two counts were only 2% and 1%.

Meristic characters of goldeye

Several meristic characters were counted on selected subsamples of goldeye that were collected from the Revillon Coupé, Rivière des Rochers, and Chenal des Quatre Fourches. Attempts were made to conduct meristic counts for equal numbers of males and females collected from each of the three rivers. Meristic characters counted were as follows: (1) lateral line scales, (2) scales around the caudal peduncle, (3) dorsal fin rays, (4) anal fin rays, (5) gill rakers on the upper gill arch, (6) gill rakers on the lower gill arch and (7) vertebrae. All counts were made on the left side of fish unless a specific character was incomplete or mutilated on that side, in which case the count was made on the right side. The lateral line scale count included all scales with sensory pores. The horizontal rows of scales around the narrowest part of the caudal peduncle were counted. Only the principal dorsal and anal fin rays were counted (i.e., all branched rays plus one anterior unbranched ray). Gill raker counts were made on the anterior gill arch and included bony rudiments at the ends of the arch. The gill raker count for the lower arch included the raker in the angle of the arch. Vertebral counts included the anterior-most vertebra, but excluded the posterior hypural complex. The counting of vertebrae was facilitated with radiographs produced using Dupont Coronex 6

plus film and the following exposure techniques: 50 kVp, 100 mA, 0.7-sec exposure time and 102-cm focal distance.

Population estimation

Population estimates of juvenile and adult fish were made on the basis of mark-recapture data for goldeye, northern pike (*Esox lucius*), lake whitefish (*Coregonus clupeaformis*), walleye (*Stizostedion vitreum*) and longnose sucker (*Catostomus catostomus*) using the Chapman modification of the Schnabel multiple census method (Ricker 1975). The formula for this census method is as follows:

$$N = \frac{C_t M_t}{R + 1}$$

where N = population estimate,

C_t = total sample taken on day t,

M_t = total number of marked fish at large at the start of day t, and

R = total number of recaptures during the experiment.

To avoid bias in population estimation and in the analysis of fish movement, it was necessary to make a distinction between the immediate recapture of fish and the recapture of fish following such time as is necessary for tagged fish to become randomly distributed among other fish. 'Immediate recapture' is defined in this study as the recapture of a tagged fish within 24 h of its previous capture. Efforts were made to release fish in such a manner as to avoid their immediate recapture; tagged fish were usually either released downstream of gill nets in rivers or taken to the end of gill net gangs in water-filled tubs before being released. Analyses of the rates of immediate recapture of fish were conducted in 1976 (Kristensen and Summers 1978).

Population estimates of Y-0-Y goldeye and walleye were made on the basis of the following formulae, which were used by Fernet (1971) and Kristensen and Sekerak (1976):

- 1) possible number of sample trawls = $\frac{\text{surface area within 700 m of shore}}{\text{surface area in one two-minute trawl}}$
- 2) population estimate = possible number of sample trawls x mean number of fish per trawl.

RESULTS

FISH MOVEMENT AND DISTRIBUTION BASED ON GILL NET CATCHES

Table 1 presents the numbers of fish that were captured, tagged and released, and recaptured in 1977 by LGL fishing crews in six sampling areas within the Peace-Athabasca Delta. Approximately 78%, 81% and 83% of the fish that were captured, tagged, and recaptured, respectively, during this study were goldeye. Because fishing effort was concentrated at the Rivière des Rochers, Revillon

Coupé and Chenal des Quatre Fourches from 11 May to 15 June, relatively high numbers of fish were captured in these sampling areas.

White sucker (*Catostomus commersoni*), round whitefish (*Prosopium cylindraceum*) and cisco (tullibee) (*Coregonus artedii*) are not further discussed in this section because of the small numbers of these species that were captured (Table 1). It is important to note, however, that the occurrence of round whitefish in Alberta had not been positively determined (Paetz and Nelson 1970; E.J. Crossman, pers. comm.) prior to this study. One of the two round whitefish that was captured during this study has been turned over to the Department of Zoology Museum, University of Alberta.

Catch rates

During the intensive sampling period (11 May to 15 June) mean catch rates for the seven major fish species were generally highest in the Rivière des Rochers (Fig. 7): lake whitefish, northern pike, walleye, longnose sucker and burbot (*Lota lota*) were most abundant in this channel. The mean catch rates of goldeye in the Rivière des Rochers and Revillon Coupé were equally high (approximately 20 fish/h); that in the Chenal des Quatre Fourches was only slightly above seven fish/h. Flathead chub (*Platygobio gracilis*), were more common in the Revillon Coupé and Chenal des Quatre Fourches than in the Rivière des Rochers.

Catch rates of fish from 11 May to 15 June in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches differed considerably (Fig. 8 and Appendix 1). Fluctuations in the catch rates of goldeye in the Rivière des Rochers and Revillon Coupé during this period were very marked. A major peak in the goldeye catch rate in the Rivière des Rochers occurred on 5 June; smaller peaks occurred on 16 and 27 May. Catch rates of goldeye in the Revillon Coupé were generally high except during the period 17 to 25 May. Goldeye catch rates in the Chenal des Quatre Fourches were, on the average, much lower than those in the Rivière des Rochers or Revillon Coupé. However, moderate catch rates were obtained in this river on 13 May from 2 to 5 June. The increase in catch rates from 30 May to 5 June in the Chenal des Quatre Fourches was approximately coincident in time with a northwest flow of water (toward the Peace River) in this river (Fig. 8). Catch rates of goldeye were low in all channels by 10 June.

Figure 9 shows the catch rates of fish (all species combined) on both sides of the Little Rapids weir from 11 May to 15 June and the estimated surface water velocities over the weir from 18 May to 15 June. The calculated hydraulic heads over the weir and the estimated surface water velocities through the Little Rapids fishway are given in Appendix 2. Because goldeye was by far the most common species captured, the catch rates shown in Fig. 9 are essentially the same as those of goldeye. Mean catches tended to be higher downstream (northwest) of the weir than they were upstream (southeast) of the weir. The relationship between the numbers of fish captured downstream of the weir and the surface water velocities over the weir is unclear.

Relatively high catch rates of fish were obtained on both sides of the Revillon Coupé weir

up to 16 May (Fig. 10). Surface water velocities over the weir during this period were very low (however, they were not recorded during this period). When high catch rates northwest and southeast of the weir occurred 15 May and 16 May, respectively, the current was either flowing or about to flow toward the Peace River. During the period from 27 May to 4 June, the current was flowing northwest toward the Peace River and surface water velocities over the weir remained close to or above 5 ft/sec; catch rates during this period were high downstream of the weir. After the current had changed direction and begun to flow southeast toward the Rivière des Rochers and the surface water velocities over the weir had decreased below 5 ft/sec (5 June), catch rates of fish on both sides of the weir decreased and remained low. High catch rates of fish were obtained southeast of the weir on three occasions when the current direction was toward the Peace River; on two occasions (26 May and 4 June) surface water velocities over the weir were less than 5 ft/sec, and on one occasion (28 May) the surface water velocity over the weir was approximately 10 ft/sec.

Mark-recapture information

Fish tagged and recaptured in 1977: The movements of fish tagged and recaptured in 1977 are listed in Table 2; immediate recaptures have been excluded. The tag-recapture information was analyzed by dividing the data into the following periods, based on recapture dates: May, June, July, August and September to November. Recovery periods of fish tagged and recaptured in 1977 are given in Appendix 3.

GOLDEYE: Thirteen (81%) of the goldeye that were recaptured in May had remained in the same rivers that they were tagged in (Table 2). Ten of these fish were tagged and recaptured in the vicinity of the Revillon Coupé weir. During a period when the current was flowing toward the Delta in May, two tagged goldeye remained on the northwest side of the Revillon Coupé weir and six tagged goldeye travelled southeast across the weir. Three goldeye were tagged and recaptured northwest (downstream) of the Little Rapids weir in May, during a period when surface water velocities over the weir were as low as approximately 3 ft/sec.

Of the goldeye recaptured in June, 52% had remained in the same rivers that they were tagged in. Again, most of these fish (10 of 16) were tagged and recaptured in the vicinity of the Revillon Coupé weir. Four of the 16 fish were tagged and recaptured downstream (northwest) of the Little Rapids weir during a period when surface water velocities over the weir varied from approximately 3-7 ft/sec. Eight (26%) of the 31 goldeye recaptured in June had moved from rivers to Lake Athabasca. The rest of the goldeye recaptured in June (seven fish) had moved among rivers. Two of these fish were tagged in late May (29 and 30 May) immediately northwest of the Revillon Coupé weir and were recaptured six days later at sampling station Q11 (Fig. 3) on the Chenal des Quatre Fourches. During this period, the current in the Revillon Coupé was flowing toward the Peace River and surface water velocities over the Revillon Coupé weir were high (Fig. 10); the current was also flowing toward the Peace River in the Chenal des Quatre Fourches (Fig. 8).

Of the 10 goldeye recaptured in July, three had travelled from rivers (the Chenal des Quatre Fourches and Revillon Coupé) to the Claire-Mamawi lakes system and six goldeye had travelled from the three channels (the Chenal des Quatre Fourches, Revillon Coupé or Rivière des Rochers) to Quatre Fourches.

Four (33%) of the goldeye recaptured in August had moved from rivers to lakes (three had moved from the Revillon Coupé to the Claire-Mamawi lakes system and one had travelled from the Rivière des Rochers to Lake Athabasca). Movement from the Revillon Coupé or Rivière des Rochers to Quatre Fourches was exhibited by 42% of the goldeye recaptured in August.

Twenty percent of the goldeye recaptured from September to November had travelled from the Chenal des Quatre Fourches to the Peace River, 20% had moved from the Revillon Coupé to the Peace River and 10% had travelled from the Claire-Mamawi lakes system to the Peace River (Peace Point in all cases). Five (50%) of the 10 goldeye recaptured from September to November were recaptured at Quatre Fourches.

A summary of the movement of goldeye tagged in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches in 1977 is shown in Fig. 11. Of the goldeye tagged in the Revillon Coupé, Rivière des Rochers and Chenal des Quatre Fourches and later recaptured, 41%, 44% and 67%, respectively, were recaptured in shallow waterbodies (the Claire-Mamawi lakes system or the western end of Lake Athabasca) or at Quatre Fourches (which is en route to these waterbodies); and 41%, 50% and 11%, respectively, were recaptured in the same rivers that they were tagged in. The remainder of the goldeye that were tagged in these three channels and later recaptured had moved to other channels or to the Peace River.

OTHER SPECIES: Numbers of recaptures of species other than goldeye were low (Table 2). Nine (45%) of these recaptures were recaptured in the same waterbodies that they were tagged in. Of the three walleye recaptured in Lake Athabasca (near Big Point) in June by commercial fishermen, one was tagged in Revillon Coupé and two were tagged in the Rivière des Rochers. One northern pike tagged at the Revillon Coupé weir in late May was recaptured in early November at Sand Point, near Burntwood Island in Lake Athabasca.

Fish tagged in 1976 and recaptured in 1977: The movements of fish tagged in 1976 (Kristensen and Summers 1979) and recaptured in 1977 are listed in Table 3. Analysis of tag-recapture information was facilitated by dividing the data into monthly periods on the basis of recapture dates.

GOLDEYE: Two goldeye tagged in July 1976 close to the mouth of the Prairie River in Lake Claire were recaptured by domestic fishermen in February 1977 under the ice at the confluence of the Birch River and Modere Creek. Of the goldeye tagged in 1976 and recaptured during May and June 1977, 33% and 46%, respectively, were tagged in the Rivière des Rochers, Revillon Coupé, Chenal des Quatre Fourches or at Quatre Fourches and were recaptured in Lake Athabasca. Twenty-six percent and 23% of the goldeye tagged in 1976 and recaptured during May and June 1977, respectively, were tagged in one of the three rivers that

connect the Delta with the Peace River and were recaptured in a different one of these three rivers. Many of the goldeye tagged in 1976 and recaptured in 1977 either were tagged at Quatre Fourches and recaptured in the Rivière des Rochers, Revillon Coupé or Chenal des Quatre Fourches, or were tagged in one of these three rivers and recaptured at Quatre Fourches; this occurred for 5%, 7%, 56%, 43% and 44% of the 1976-tagged goldeye that were recaptured in May, June, July, August and September, respectively. Numerous goldeye were tagged in one of the three rivers (the Rivière des Rochers, Revillon Coupé or Chenal des Quatre Fourches) and recaptured in the Claire-Mamawi lakes system or were tagged in the Claire-Mamawi lakes system and recaptured in one of the three rivers; such was the case for 13%, 4%, 17% and 19% of the 1976-tagged goldeye that were recaptured in May, June, July and August 1977, respectively.

Nine goldeye tagged in the Delta in 1976 were recaptured in the Athabasca River in 1977 by Alberta Oil Sands Environmental Research Program (AOSERP) fishing crews or by domestic fishermen. The southern-most of these recaptures was at the confluence of the Athabasca and Mackay rivers, and represented the longest recorded movement of a goldeye during this study (approximately 272 km from its point of tagging at sampling station Q09 (Fig. 3). Two, two and one goldeye that were tagged in the Rivière des Rochers, the Claire-Mamawi lakes system and the Chenal des Quatre Fourches in 1976, respectively, were recaptured in the Peace River in the autumn of 1977 as far upstream as Peace Point.

OTHER SPECIES: Relatively high numbers of species other than goldeye that were tagged in waterbodies other than Lake Athabasca in 1976 were recaptured during May and June 1977 in Lake Athabasca (Table 3).

Approximately 44% of the northern pike tagged in 1976 and recaptured in 1977 were tagged and recaptured in the same waterbodies or general areas. Two northern pike tagged in Lake Claire in 1976 were recaptured in January 1977 under the ice in the Prairie River. Two northern pike tagged at Little Rapids in 1976 were recaptured in the Slave River in 1977, one at the confluence of the Slave and Bocquene rivers and the other at Fort Smith downstream of Mountain Rapids. A northern pike tagged at Little Rapids in 1976 was recaptured in 1977 by AOSERP biologists close to the confluence of the Athabasca and Embarras rivers.

Three walleye tagged in Lake Claire in 1976 were recaptured by domestic fishermen in February 1977 at the confluence of the Birch River and Modere Creek. A walleye tagged in 1976 at Little Rapids was recaptured at the confluence of the Athabasca and Mackay rivers in 1977 by an angler--a movement of approximately 264 km. Two lake whitefish tagged in the Delta in 1976 were recaptured in the Athabasca River in 1977 between Embarras Portage and Fort Mackay.

Recaptures in 1977 of fish tagged in other studies: In addition to the tagging programs of LGL Limited in 1976 (Kristensen and Summers 1979) and in 1977, two other programs have involved the tagging of fish near or in the Delta. Alberta Oil Sands Environmental Research Program (AOSERP) biologists have tagged fish of various species in the Athabasca River between Fort McMurray and the

Delta in 1976 and 1977 (D.K. Berry, AOSERP, pers. comm.). Canadian Wildlife Service (C.W.S.) conducted a tagging program primarily at Quatre Fourches during the period 1972 to 1974; this tagging program concentrated almost exclusively on goldeye (Donald and Kooyman 1977). Many of these tagged fish were recaptured in 1977 either by LGL Limited biologists or by commercial fishermen who turned the tags over to LGL Limited biologists. These particular recaptures are discussed in the following sections.

GOLDEYE: A number of the goldeye that were recaptured in the Delta in 1977 were tagged in 1977 by AOSERP biologists in the Athabasca River (D.K. Berry, pers. comm.). At least one goldeye that was tagged near Fort MacKay on the Athabasca River in 1977 was recaptured at Big Point on Lake Athabasca. Numerous goldeye that were tagged in the Athabasca River in the vicinity of Embarras Portage from May to August 1977 (D.K. Berry, pers. comm.) were recaptured by domestic fishermen at Quatre Fourches in September. One goldeye that was tagged by AOSERP biologists in the lower Athabasca River in July 1977 was recaptured at Peace Point on the Peace River 13 October by a domestic fishermen.

Several of the goldeye that were recaptured in the Delta in 1977 were tagged in 1976 by AOSERP biologists near Fort MacKay (D.K. Berry, pers. comm.). Recaptures occurred as far north as Quatre Fourches. Of the approximately 4,375 goldeye that were tagged primarily at Quatre Fourches by C.W.S. between 1972 and 1974 (Donald and Kooyman 1977), seven were recaptured in the Delta in 1977 (three were tagged in 1973 and four were tagged in 1974). Five of these fish were recaptured in Lake Claire or Mamawi Lake, one at Quatre Fourches, and one at Big Point.

OTHER SPECIES: Numerous walleye and long-nose sucker that were recaptured in 1977 by commercial fishermen at Big Point were tagged by AOSERP biologists near Fort MacKay in 1977 (D.K. Berry, pers. comm.). Three lake whitefish that were tagged near Fort MacKay during September and October 1977 and one lake whitefish that was tagged near Embarras Portage in September 1977 were recaptured at Quatre Fourches by domestic fishermen in late October or early November.

A number of the walleye and lake whitefish that were recaptured in 1977 by commercial fishermen at Big Point were tagged in 1976 by AOSERP biologists near Fort MacKay (D.K. Berry, pers. comm.). Two lake whitefish tagged in 1974 at Quatre Fourches (D.B. Donald, C.W.S., pers. comm.) were recaptured in the Delta in 1977.

AGE STRUCTURE AND GROWTH OF JUVENILE AND ADULT GOLDEYE

Determination of age

Ages were determined for 499 goldeye that were captured between 19 May and 22 August from the Claire-Mamawi lakes system and for 602 goldeye that were captured between 20 May and 15 June from the Chenal des Quatre Fourches, Rivière des Rochers and Revillon Coupé. Agreement in ages between readers occurred for 85.2% (938/1101) of the scale samples read. This agreement was similar to the 89.7 and 84.1 percents agreement

obtained between independent readings of goldeye scales collected in 1975 (Kristensen and Sekerak 1976) and in 1976 (Kristensen and Summers 1978), respectively. Most scale samples collected in 1977 were collected during the period of new annulus formation (May and early June). Kristensen and Summers (1978) found that the percent agreement between two scale readings was significantly lower for scales that were collected during annulus formation (81.3%) than for scales that were collected following annulus formation (91.9%).

Age structure

Age structures of goldeye captured in the Claire-Mamawi lakes system, Chenal des Quatre Fourches, Rivière des Rochers and Revillon Coupé appear very similar (Table 4, Fig. 12), although there was a statistically significant ($P < 0.005$) difference among them (as determined through use of the $R \times C$ G-test of independence (Sokal and Rohlf 1969)).

From 64% to 78% of the 1977 goldeye catches at the four sampling locations were comprised of 6-year-old goldeye (1971 year class) (Fig. 12). When the four samples were combined (Fig. 12E), 6-year-olds comprised approximately 68% of the total goldeye catch. The age structures of goldeye caught from 1975 to 1977 in the Claire-Mamawi lakes system and the Chenal des Quatre Fourches (two areas combined) are shown in Fig. 13. Goldeye of the 1971 year class comprised approximately 85%, 77% and 64% of the catches in 1975 (Kristensen and Sekerak 1976), 1976 (Kristensen and Summers 1978) and 1977, respectively. In 1973, the same year class comprised about 90% of the total goldeye catch in the Delta (Donald and Kooyman 1977).

Growth

Age-length and age-weight relationships of goldeye captured in 1947-48 (Kennedy and Sprules 1967), 1973 (Donald and Kooyman 1974), 1975 (Kristensen and Sekerak 1976), 1976 (Kristensen and Summers 1978) and 1977 (this study) are shown in Fig. 14. Age-length and age-weight relationships for goldeye captured in 1977 were based on those for goldeye captured in four sampling areas within the Delta (Fig. 15). As shown in Table 4, sample sizes of fish older than 7 years were small in 1977; data points for these age groups (Fig. 14) should consequently be viewed cautiously. The growth rate of goldeye in 1977 decreased for 6- and 7-year-old fish (1970 and 1971 year classes). Growth rates of the same two year classes were also suppressed in 1975 and 1976, when these fish were 4 and 5, and 5 and 6 years old, respectively. The sizes of 4- to 7-year-old goldeye in 1977 were more similar to those of the same age groups in 1947-48 than to those of the same age groups in 1973.

MERISTIC CHARACTERS OF GOLDEYE

Means, standard deviations and ranges of the following meristic counts for goldeye collected from the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches are presented in Table 5: lateral line scales, scales around caudal peduncle, dorsal fin rays, anal fin rays, gill rakers (upper arch), gill rakers (lower arch) and vertebrae. Ranges in counts of the same characters that have been

cited by McPhail and Lindsey (1970), Paetz and Nelson (1970) and Scott and Crossman (1973) are shown in Table 6. The only counts obtained during this study that fell within previously-recorded ranges were those of anal fin rays.

If natural selection operates in a manner that changes the frequency of some meristic counts in populations, those counts would be expected to vary among fish of different ages. In order to determine whether meristic counts varied with age of fish, a correlation matrix was calculated, with age and the above-mentioned seven meristic characters as variables (Table 7). None of the seven meristic characters was significantly correlated with age of goldeye. It is interesting to note that the only significant ($P < 0.05$) positive correlation occurred between number of lateral line scales and number of vertebrae. This is not surprising since both characters were counted along the same axis of the fish.

On the basis of meristic counts presented in Table 5, the following null hypothesis was tested. Goldeye that migrate through the three rivers, the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches, are members of the same group. 'Group', as defined by Marr (1957:1), is 'a fraction of a population with distinctive characteristics, the nature of which (phenotypic or genotypic) has not yet been determined'. In contrast, Marr's definition of 'subpopulation' is 'a fraction of a population that is itself genetically self-sustaining', and his definition of 'stock' is 'a population or a portion of a population, all members of which are characterised by similarities which are not heritable, but are induced by the environment'.

The null hypothesis was tested by conducting a stepwise multiple discriminant analysis (SMDA), in which the meristic characters of goldeye in the three rivers were compared. A one-factor analysis of variance for each of the seven characters (variables) showed that only dorsal fin ray counts were significantly ($0.025 < P < 0.05$) different among the channels and that the differences in anal fin ray counts approached statistical significance ($0.05 \leq P < 0.1$) (Table 5). These two characters, when included in the SMDA, were only close to significantly ($0.05 \leq P < 0.1$) discriminating fish from the three channels. No other characters, when subsequently included in the SMDA, increased the degree of discrimination.

When all seven meristic characters were considered simultaneously, the degree of discrimination among channels was only close to statistical significance ($0.05 \leq P < 0.1$), and the only two meristic counts that were significantly ($0.025 \leq P < 0.05$) different among the rivers were dorsal and anal fin ray counts (Table 5). A classification matrix produced by the SMDA gave an indication of how well the collection site of a newly caught fish could be predicted by considering the seven meristic characters. According to this predictive matrix, over one-half of the goldeye whose meristic characters were studied were misclassified (i.e., they were classified as having been collected from a river other than that from which they were actually collected).

POPULATION ESTIMATES OF JUVENILE AND ADULT FISH

The numbers of fish that were captured and

recaptured in 1977 in the Peace-Athabasca Delta by LGL Limited personnel (Table 1) provide a basis for estimates of the abundance of several species in the Delta during the period from mid-May to late August 1977. Mark-recapture data from five sampling areas (the Rivière des Rochers, Revillon Coupé, Chenal des Quatre Fourches, Claire-Mamawi lakes system and the western end of Lake Athabasca) were combined to produce a single population estimate for each goldeye, northern pike, lake whitefish, walleye and longnose sucker. Mark-recapture information from the different sampling areas was combined for the following reasons:

1. It was not possible to assume that each sampling area was a discrete and closed system.

2. Mark-recapture data indicated that movement of fish occurred among the sampling areas in 1977 (Table 2).

3. There were insufficient numbers of recaptures upon which to base population estimates for each waterbody within the study area (Table 1).

As pointed out by Donald and Kooyman (1977), the following assumptions must be met if population estimates are to be reliable:

1. that tagged fish become randomly distributed throughout the population;

2. that tagged and untagged fish are equally vulnerable to the fishing gear;

3. that tagging does not affect the mortality of fish; and

4. that tagged fish do not lose their tags.

These assumptions all appear to have been met. Results of Donald et al. (1979) suggest that assumptions 1. and 2. are correct; data presented by Kristensen and Summers (1977) suggest that short-term mortality of goldeye and northern pike caused by capture, handling and tagging is negligible; and although a total of over 27,000 fish (all species combined) were tagged in 1976 and 1977, very few examples of tag loss were observed.

Prior to the calculation of population estimates, the following corrections were introduced to the mark-recapture data:

1. Because fish less than 200 mm in fork length (220 mm for northern pike) were not tagged, fish of these sizes were excluded from the calculations.

2. All tagged fish that were recaptured by local fishermen were excluded from this analysis, because fishermen who returned tags were unable to report their total catches by species (which is information that is necessary for the calculation of population estimates (Ricker 1975)).

3. Fish that were recaptured within seven days of the initiation of the mark-recapture program were eliminated because of probable incomplete mixing and/or aberrant behaviour.

4. Because fish sometimes swam back into the gill nets immediately following their release, immediate recaptures were excluded from the total number of fish recaptured.

Estimates of the numbers of goldeye, lake whitefish, northern pike, walleye and longnose sucker, within certain size ranges and ages, that inhabited the Peace-Athabasca Delta (excluding the southeastern portion of the Delta) from 11 May to 22 August 1977 are presented in Table 8. Because goldeye less than 200 mm in fork length were excluded from the mark-recapture data, adjustments were made to include fish of this size in the population estimate. On the basis of data presented in Fig. 14, 1- and 2-year old goldeye were less than 200 mm in fork length in 1977. Age groups 1 and 2 comprised approximately 0.82% of the goldeye for which ages were determined (Table 4). The population estimate can thus be increased by 0.82% to 545,466 goldeye. Similar adjustments can not be made to the lake whitefish, northern pike, walleye and longnose sucker population estimates, because the age and growth characteristics of these species were not studied in 1977. Population estimates of these species must therefore be considered conservative, because fish less than 200 mm in fork length (220 mm for northern pike) were not included.

Numbers of goldeye, lake whitefish, northern pike and walleye that are estimated to have occurred in the Peace-Athabasca Delta from 31 May to 21 October 1976 (Kristensen and Summers 1978) are also shown in Table 8. The estimated number of goldeye present in the Delta in 1977 was less than one-half that in 1976. Population estimates for lake whitefish and northern pike were higher in 1977 than in 1976 by factors of approximately 1.4 and 5.3, respectively. Less than one-third as many walleye were estimated to have occurred in the Delta in 1977 as in 1976.

Estimated numbers of goldeye by age group and year class in 1976 and 1977 are shown in Table 9. These estimates were calculated on the basis of the percent contribution that each age group made to the total goldeye samples for which ages were determined. Estimates for most year classes were lower in 1977 than in 1976.

REPRODUCTIVE PARAMETERS OF GOLDEYE

The overall sex ration (male:female) of goldeye captured in four sampling areas (the Claire-Mamawi lakes system, Chenal des Quatre Fourches, Rivière des Rochers and Revillon Coupé) was 52.4:47.6 (Table 10) and did not vary significantly from an equal sex ration (as determined through use of a chi-square test in which $P < 0.05$ was the level of statistical significance considered). Female goldeye comprised approximately 57% of a goldeye sample taken in 1947-48 from Lake Claire (Kennedy and Sprules 1967) and about 52% of a goldeye sample collected from the Peace River, Alberta in 1968/70 (Bishop 1975). The sex ratio of goldeye that comprised the dominant 1971 year class did not vary significantly from 1:1 in 1973 (Donald and Kooyman 1974) or in 1977, but did in 1975 ($P < 0.5$) (Kristensen and Sekerak 1976); female goldeye comprised approximately 50%, 58%, and 52% of the 1971 year class in 1973, 1975, and 1977, respectively. Males comprised larger proportions of the 4- and 5-year-old goldeye catches in 1977 than did females (Table 10). The sex ratio of 4-year-olds did not vary significantly from 1:1, but the sex ratio of 5-year-olds did ($P < 0.005$). Sex ratios of goldeye in 1977 in age groups 2, 7, 8, 10 and 13 must be considered cautiously because of small sample sizes.

Table 10 also shows the proportions of female goldeye collected that were mature in 1977, and the proportions of males that were mature or were approaching their first year of maturity. Convoluting testes appeared in males as young as 4 years old, indicating that some 4-year-old males were either mature or were approaching their first year of maturity. Over one-half of the 5- and 6-year-old males collected in 1977 were mature or would mature in 1978. Sample sizes of collected males older than 6 years were very small. Only one-third of the 7-year-old males collected were mature or were approaching their first year of maturity. Higher proportions of mature males or males that would mature in 1978 were collected from the Chenal des Quatre Fourches and Revillon Coupé than from the Rivière des Rochers and the Claire-Mamawi lakes system. Higher proportions of 4- and 5-year-old males that were mature or were approaching their first year of maturity were captured in the Chenal des Quatre Fourches than in any of the other sampling areas.

Very few (13) mature females were collected in 1977. Mature females were not collected for age groups younger than 6, and only 11 (3.7%) of the 6-year-old females collected were mature. None of the 7-year-old females collected was mature. The one 10-year-old female collected from the Claire-Mamawi lakes system and the one 13-year-old female collected from the Revillon Coupé were spawned-out, and contained small white eggs that would ripen by the following spring. Approximately 5% of the females collected from each of the sampling areas, the Claire-Mamawi lakes system and the Revillon Coupé, were mature in 1977. Less than one-half this proportion of the females collected from each of the other two sampling areas, the Chenal des Quatre Fourches and Rivière des Rochers, were mature in 1977. The highest proportion of females that would mature in 1978 was collected from the Claire-Mamawi lakes system (Table 11). No female goldeye that would mature in 1978 were collected from the Chenal des Quatre Fourches or Rivière des Rochers.

One, three and four ripe females (about to spawn) were collected from the Chenal des Quatre Fourches, Rivière des Rochers and Revillon Coupé, respectively, between 22 May and 14 June 1977. Four ripe females were collected from Lake Claire between 24 May and 6 July. Estimated egg counts and related statistics of these goldeye are presented in Table 12. The mean egg count was 3,172 (standard deviation = 833) and counts ranged from 2,260 to 5,310. There does not appear to be any relationship between size of female and egg count. Because all of the ripe females for which ages were determined were 6 years old, the relationship between age and fecundity cannot be analyzed. Kennedy and Sprules (1967) reported fecundity estimates of from 5,761 to 25,238 ($\bar{x} = 14,150$; standard deviation = 5,265) for 15 goldeye collected from several waterbodies in Manitoba. All but one of these goldeye were older than age 6. One large female goldeye (fork length = 415 mm) that was collected from the Peace River, Alberta contained an estimated 12,240 eggs (Bishop 1975).

Based on 10 eggs per female goldeye collected in 1977, the mean egg diameter ranged from 1.6 to 1.9 mm. Battle and Sprules (1960) and Bishop (1975) reported egg diameters of 2.0 mm for goldeye just prior to spawning.

On the basis of data presented in Tables 9, 10 and 12, the reproductive potential of the Delta goldeye population in 1977 can be estimated. Because the goldeye population estimate was based on mark-recapture information obtained from the entire Delta, it was not possible to estimate reproductive potential of goldeye for individual waterbodies within the Delta. The number of mature female goldeye in the population can be calculated on the basis of the estimated numbers of goldeye in each age group for which mature females were collected. Each estimate can then be multiplied by the percent female composition and by the percent of mature females for that age group. There were, for example, 373,553 6-year-old goldeye, 52.0% of which were female, and 3.7% of which were mature--a total of 7,187 mature 6-year-old female goldeye. The total estimate of mature female goldeye in the Delta in 1977 was 8,178. If this estimate is multiplied by the mean egg count, an estimated 25,941,000 eggs were produced in 1977. An estimated 1,297,000 young-of-the-year goldeye survived past the larval stage in the Delta in 1977, under the assumption that all eggs were fertilized and that 95% mortality of eggs and larvae occurred. (The egg and larval mortality is an average of those cited by Ricker (1971) of 99.5% for smelt and by Paetz and Nelson (1970) of 90% for 'most' Alberta fish.)

FISH DISTRIBUTION AND ABUNDANCE BASED ON TRAWL NET CATCHES

This section deals primarily with the distribution and abundance of young-of-the-year (Y-O-Y) goldeye, but it also presents information concerning parameters that may affect the distribution and abundance of other species that were captured in trawl nets. Catch per unit effort, when used in the context of trawling, refers to the total number of fish that were captured in two trawl nets per two-minute trawl. Numbered sampling stations referred to in this section are shown in Fig. 5. The few juveniles and adults of larger species (goldeye, northern pike, lake whitefish, walleye, longnose sucker and burbot) that were captured in trawl nets were not considered in the following analyses.

Distribution and abundance of young-of-the-year goldeye

Y-O-Y goldeye were captured in waterbodies throughout the study area (Table 13). In most cases, catch rates in the various waterbodies were highly variable among sampling periods.

Catch rates in Lake Claire were very similar during three of the four sampling periods. However, as is evident from the standard deviations of catch rates in Table 13, catches during each sampling period varied markedly among sampling stations. During late June, most of the Y-O-Y goldeye that were captured in Lake Claire were captured along the east shore. Almost all of the Y-O-Y goldeye that were captured in this lake during early July and most of the Y-O-Y goldeye that were captured there during late July were captured along the west and north shores. The highest catch rate obtained in Lake Claire (35 Y-O-Y goldeye in one two-minute trawl) was on 25 July at sampling station 54. Most of the Y-O-Y goldeye that were captured during the late August sampling period in Lake Claire were captured along the east shore.

Highest catch rates in Mamawi Lake on 1 July were obtained in the west bay of the lake; whereas highest catch rates on 4 August were obtained along the east shore near the outlet channels from the lake. Y-O-Y goldeye were not captured in this lake during the other sampling periods.

Once goldeye were large enough to be caught in the sampling gear, catch rates in the Prairie River (which connects Lake Claire and Mamawi Lake) and tributaries of this river were comparatively high, particularly on 28 June and 14 July (Table 13). Most of the Y-O-Y goldeye that were captured in this sampling area were captured close to Lake Claire in small creeks that flow between the Prairie River and Lake Claire (sampling stations 6 and 11).

High catch rates of Y-O-Y goldeye were obtained in the Rivière des Rochers on 19 July (Table 13). Almost all (88%) of the Y-O-Y goldeye that were captured on this date were captured immediately upstream or downstream of the Little Rapids weir; and most of these were captured in the large eddies downstream of the weir (sampling stations 171 and 172).

Extremely high catch rates of Y-O-Y goldeye were obtained both times that sampling was conducted in the Revillon Coupé. On 20 July, most of the Y-O-Y goldeye (81%) that were captured in this river were captured close to the confluence of the Revillon Coupé and Rivière des Rochers at sampling station 178, which was located along the inside of a bend in the river where the water was almost standing still. Catch rates of Y-O-Y goldeye in the Revillon Coupé were also high on 20 July and 15 August at sampling station 188, which was located in a shallow slow-moving channel that connects the Peace River with the mainstream of the Revillon Coupé.

During the two July sampling periods in the Chenal des Quatre Fourches, catch rates of Y-O-Y goldeye were moderate but not as high as those obtained in the Rivière des Rochers or Revillon Coupé during July. Most of the Y-O-Y goldeye that were captured in the Chenal des Quatre Fourches during July were captured in the southern section of the river. Catch rates from 13 to 15 August in the Chenal des Quatre Fourches, Rivière des Rochers and Revillon Coupé were lower than those obtained in the respective rivers during July.

Most of the Y-O-Y goldeye that were captured during July in the channels that connect Mamawi Lake and Lake Athabasca were captured either at Quatre Fourches (station 1) or near Lake Athabasca (station 99).

Few Y-O-Y goldeye were captured in the other sampling areas. Small Y-O-Y goldeye were captured in two small bays in Lake Athabasca immediately east of Fort Chipewyan on 27 June. One Y-O-Y goldeye was captured on 25 July in the Birch River about 4 km from the mouth of this river. Two Y-O-Y goldeye were captured on 28 July in the Baril River near its confluence with the Peace River.

Parameters that may affect fish distribution and abundance

Donald and Kooyman (1977) suggested that most of the Y-O-Y goldeye that were captured in lakes, were captured within approximately 700 m of the

shorelines. Kristensen and Sekerak (1976) presented data which suggested that the distribution and abundance of Y-O-Y goldeye were related to several other factors, including the presence of other fish species, and the type of vegetation along shorelines or some other factor that affects shoreline vegetation. On the basis of these preliminary findings, one of the objectives of the 1977 study was to further analyse the potential effects of several selected parameters on the distribution and abundance of Y-O-Y goldeye. Similar data are presented for other fish species that were captured in trawl nets because of the possible relationship between their distribution and abundance and those of Y-O-Y goldeye. In the following sections, the level of statistical significance considered was $P < 0.05$.

INTERRELATIONSHIP OF DISTRIBUTIONS OF VARIOUS FISH SPECIES

Table 14 presents the results of Spearman rank correlation coefficient tests (Siegel 1956) between each possible pair of catch rates of the 14 species of fish that were captured in trawl nets. Catch rates of goldeye were positively and significantly correlated with those of walleye, longnose sucker, ninespine stickleback (*Pungitius pungitius*), and trout perch (*Percopsis omiscomaycus*). Goldeye catch rates were negatively and significantly correlated with those of northern pike. Fourteen significant positive correlations and seven significant negative correlations occurred between various other pairs of fish catch rates as shown in Table 14.

SHORELINE VEGETATION

Table 15 presents the results of Spearman rank correlation coefficient tests between the catch rates of 14 fish species captured in trawl nets and the dominant plant species found along the shorelines of sampling sites. Mean catch rates of fish in relation to shoreline vegetation complexes at lake and river sampling stations are given in Appendices 4 and 5, respectively; only those vegetation complexes for sampling stations at which goldeye were captured are presented in these appendices. High mean catch rates of goldeye (up to 4 fish/trawl) were obtained along shorelines of lakes where the vegetation complexes were dominated by *Juncus* sp. (Appendix 4) and along shorelines of rivers (up to more than 19 fish/trawl) where the vegetation complexes were dominated by *Equisetum* sp. (Appendix 5). However, correlation coefficients between goldeye catch rates and the presence of these two plant genera were not significant (although that between goldeye catch rates and the presence of *Juncus* sp. was nearly significant) (Table 15). The highest negative correlation between goldeye catch rates and a shoreline plant species occurred when *Potamogeton* sp. dominated the shoreline vegetation complex.

As is evident from Table 15, catch rates of 11 species of fish were positively and significantly correlated with the dominance of one or more species of shoreline vegetation; catch rates of four fish species were negatively and significantly correlated with the dominance of one or more species of shoreline vegetation. The extremely high correlation that occurred between the catch rate of brook stickleback (*Culaea inconstans*) and the dominance of *Alnus tenuifolia* is an artifact of small sample

size; only one brook stickleback was captured during this study.

OTHER PARAMETERS

Mean catch rates of fish in relation to substratum material and hardness, wind direction at lake sampling stations and waterbody type (lake or stream) are shown in Table 16. The results of Spearman rank correlation coefficient tests between fish catch rates and the above-mentioned parameters (plus water temperature) at sampling stations are presented in Table 17. Appendix 7 explains how the parameters in Table 17 (except water temperature) were ordinarily arranged in order that the Spearman rank correlation coefficient test could be conducted with the data.

Of the parameters listed in Table 17, catch rates of goldeye were significantly and positively correlated with only one parameter--wind direction in relation to lake shorelines. As evident from data in Table 16, the mean catch rate of goldeye in lakes was highest when the wind was blowing toward the shoreline. Although not statistically significant, a moderate correlation occurred between the catch rates of goldeye and water temperature (Table 17). The mean catch rate of goldeye was higher at sampling stations where the substratum material was clay and at stations where the substratum hardness was medium (Table 16); however, these differences were not statistically significant (Table 17). Goldeye catch rates were also higher in streams or rivers than they were in lakes, but this difference was not statistically significant.

Significant and positive correlations occurred between catch rates of walleye and water temperature, substratum material and substratum hardness at sampling stations. In other words, catch rates were more often higher in warmer water, at sampling stations where the substratum material was sand or rock and at sampling stations where the substratum hardness was medium to hard. Catch rates of walleye were significantly and negatively correlated with waterbody type (i.e., catch rates were more often higher in lakes than they were in streams).

There were an additional eight positive and seven negative correlations that were significant between catch rates of other fish species and the various selected parameters at sampling sites (Table 17).

POPULATION ESTIMATES OF YOUNG-OF-THE-YEAR FISH

If estimates of the numbers of Y-O-Y goldeye are to be representative of the actual numbers of Y-O-Y goldeye produced, they should be based on the catch rates of fish soon after they have hatched in order that mortality of fish from the time of hatching to the time of sampling would be minimal. However, it is also necessary to base estimates on catch rates of fish that were obtained at a time when most of the fish were large enough to be captured by the sampling gear. Although Y-O-Y goldeye were captured in 1977 as early as 21 June, it was probable that some small fish (in late larval or early postlarval stages) were not susceptible to the sampling gear by this time. For these reasons, estimates were based on catch rates of postlarval Y-O-Y goldeye obtained approximately mid-way through the sampling period in 1977 (24 July to 4 August)

Estimated numbers of postlarval Y-0-Y goldeye in Lake Claire and Mamawi Lake in 1971, 1975 and 1977 are presented in Table 18. Before these estimates were calculated, the following adjustments were made to the data presented by Fernet (1971), Kooyman (1973) and Kristensen and Sekerak (1976):

1. The surface areas within approximately 700 m of the shorelines in Lake Claire and Mamawi Lake were recalculated and were found to be different from those presented by Fernet (1971) and subsequently by Kooyman (1973) and Kristensen and Sekerak (1976) to estimate numbers of Y-0-Y goldeye in the Claire-Mamawi lakes system in 1971 and 1975, respectively. (Therefore, 1971 and 1975 estimates of Y-0-Y goldeye presented in Table 18 differ from those presented by Kooyman (1973) and Kristensen and Sekerak (1976).)

2. In order to make the 1971, 1975 and 1977 estimates comparable, the 1975 estimates were recalculated on the basis of catch rates obtained between 8 and 18 August in that year. (Estimates of Y-0-Y goldeye in 1975 had been calculated on the basis of catch rates obtained during the entire sampling period in 1975 (Kristensen and Sekerak 1976).)

Y-0-Y goldeye estimates were based on the numbers of fish that inhabited a certain surface area of water rather than volume because most of the water within approximately 700 m of the shorelines of Lake Claire and Mamawi Lake was less than or equal to 1.0 m in depth. (The trawl nets almost touched the substratum during trawls in lakes.) Estimates of the numbers of Y-0-Y goldeye were not calculated for the Prairie River (as was done by Kooyman (1973) and Kristensen and Sekerak (1976) because it would have been necessary to consider the volume of water rather than the area; the extent to which areas in rivers, other than shorelines, are used by Y-0-Y goldeye is not known at the present.

The total estimates of Y-0-Y goldeye in Lake Claire and Mamawi Lake for 1975 and 1977 were similar (Table 18). However, the total estimate of Y-0-Y goldeye present in these lakes in 1971 was approximately four times that in either 1975 or 1977.

On the basis of calculations similar to those used to estimate the numbers of Y-0-Y goldeye, the estimated numbers of Y-0-Y walleye within approximately 700 m of the shorelines of Lake Claire and Mamawi Lake from 21 June to 1 July 1977 were 1,705,000 and 219,000, respectively. During this period, Y-0-Y walleye were found to be equally distributed along the shorelines of Lake Claire and Mamawi Lake. Kooyman (1973) also reported high numbers of Y-0-Y walleye in the Claire-Mamawi lakes system in 1971. The presence of such high numbers of Y-0-Y walleye in this system suggests that walleye spawn in these waters. It is highly unlikely that Y-0-Y walleye moved into this system from other areas, because they were caught as early as 11 June 1977, when they were probably too small to have travelled very far from their hatching grounds.

GROWTH OF YOUNG-OF-THE-YEAR GOLOEYE

The first Y-0-Y goldeye that were captured in 1977 were captured in Lake Claire on 21 June. By this time, Y-0-Y goldeye were approximately 18 to 20 mm in fork length (Fig. 16). By the end of August, Y-0-Y goldeye in Lake Claire had grown to lengths of approximately 68 mm. The data suggest that Y-0-Y goldeye that were captured in Lake Claire in 1977 were smaller than those that were captured on similar dates in other sampling areas.

A comparison of the growth rates of Y-0-Y goldeye in the Peace-Athabasca Delta in four different years (Fig. 17) shows that Y-0-Y goldeye, during late June and early July of 1977, were approximately equal in size to Y-0-Y goldeye in 1972 and 1973 on approximately the same dates. (Unpublished data of O. B. Donald for 1971, 1972 and 1973 were used in Fig. 17.) Donald and Kooyman (1977) collected goldeye larvae on 4 June 1972 and on 1 June 1973. These larvae were similar in appearance to the prolarvae described by Battle and Sprules (1960), which indicated that they had recently hatched. It is thus probable that goldeye in 1977 hatched about the same time as did those in 1972 and 1973--the last week in May or the first week in June.

On the basis of the size of Y-0-Y goldeye in relation to date in 1971 (Fig. 17), it appears that goldeye hatched earlier in that year than they did in 1972, 1973 or 1977. In addition, the growth rates of Y-0-Y goldeye in 1971 were faster than those of Y-0-Y goldeye in 1972 or 1977. Therefore, as evident from Fig. 17, Y-0-Y goldeye were larger at the end of the summer in 1971 than in 1972, 1973 or 1977.

DISCUSSION

MOVEMENT AND DISTRIBUTION OF JUVENILE AND ADULT FISH

Catch rates

Donald and Kooyman (1977) found that the peak spring migration of adult goldeye at Quatre Fourches in 1973, 1974 and 1975 occurred on 11 May, 11 May and 14 May, respectively, and occurred one to two weeks following break-up at Quatre Fourches in each year. Break-up at Quatre Fourches in 1977 occurred on 23 April. If the peak migration of mature goldeye occurred through Quatre Fourches one to two weeks following break-up in 1977 (i.e., between approximately 30 April and 7 May), we would not have recorded it because intensive fishing did not begin until 11 May. Donald and Kooyman (1977) indicated that the spring migration of juvenile goldeye occurs one or two weeks after the migration of adult goldeye.

On the basis of this information, goldeye that were recorded moving from the Peace River through the Rivière des Rochers, Revillon Coupé and Chenail des Quatre Fourches from 11 May to 15 June 1977 should have been primarily juveniles. The female goldeye that were captured during this period were primarily juveniles; few mature females were cap-

tured in the three channels during the spring. However, because the proportions of mature females collected from the three migration routes and from the spawning grounds (the Claire-Mamawi lakes system) were low and not appreciably different, it seems unlikely that a major migration of mature females occurred through the three rivers to the Claire-Mamawi lakes system before the sampling period started on 11 May.

Although it was difficult to distinguish between mature males and males that were approaching their first year of maturity, the fact that such high proportions of 5-year-old male goldeye that were collected from the three rivers were either mature or were approaching their first year of maturity suggests that high proportions of the 6-year-old males captured in the three rivers during the sampling period were mature (this is discussed later in the report). And because the age structures of goldeye captured in the three rivers in 1977 were dominated by 6-year-old fish, high proportions of the males captured in the three rivers from 11 May to 15 June were probably mature, and it is unlikely that a large portion of the spring migration of mature male goldeye occurred before sampling commenced. It thus appears unlikely that a major migration of mature goldeye occurred shortly after break-up in 1977.

One of the major objectives of this study was to determine the relative importance of the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches to the spring migration of goldeye into the Delta. Catch rates suggest that approximately three times as many goldeye migrated through each of the two rivers, the Rivière des Rochers and Revillon Coupé, as migrated through the Chenal des Quatre Fourches during the spring sampling period in 1977. This suggests that the Rivière des Rochers and Revillon Coupé are at least as important as the Chenal des Quatre Fourches to the spring migration of goldeye.

The numbers of goldeye captured in the Rivière des Rochers and Revillon Coupé from 11 May to 15 June were probably affected, in part, by the presence of the weirs on these two rivers. Large numbers of fish (primarily goldeye) accumulated northwest of both weirs during portions of the spring sampling period in 1977. There are at least two potential reasons for this accumulation of goldeye downstream of the weirs. First, goldeye migrating from the Peace River to the Delta may have been unable to swim upstream across the two weirs during the existence of certain hydrological conditions at the weirs. For example, large numbers of goldeye and other species frequently accumulated northwest of both weirs when the water in both rivers was flowing toward the Peace River. In addition, goldeye and other species accumulated northwest of the Revillon Coupé weir when the surface water velocities across this weir were in most cases close to or greater than 5 ft/sec (and the water flowed toward the Peace River). The second reason, as suggested by Kristensen and Summers (1978), is that some fish possibly prefer to remain in the large eddies downstream of the weirs, perhaps because of abundant food supplies there.

Some data collected during this study do not support the first suggestion but may support the second suggestion. For example, on 31 May when the surface water velocity across the Little

Rapids weir was high (close to 7 ft/sec), catch rates of fish (primarily goldeye) northwest (downstream) of the weir were relatively low (less than 15 fish/h). In addition, on 5 June when the surface water velocity over the Little Rapids weir was relatively low (4 ft/sec), the highest catch rate (close to 175 fish/h) during the entire sampling period was obtained downstream of the weir. In other words, high numbers of fish did not always accumulate downstream of the Little Rapids weir when the surface water velocity across this weir was high, and high numbers of fish were captured downstream of the Little Rapids weir on at least one occasion when water velocities probably did not hinder fish movement upstream across this weir.

Because mature male and female goldeye migrated through the Rivière des Rochers and Revillon Coupé, as well as through the Chenal des Quatre Fourches during the spring of 1977, the weirs on the Rivière des Rochers and Revillon Coupé have the potential to affect not only the movement of juvenile goldeye as discussed by Kristensen and Summers (1978), but also the migration of mature goldeye toward their spawning grounds. Should critical hydrological conditions at the weirs prevail during the migration of mature goldeye toward their spawning grounds, such that this migration were delayed, successful reproduction of goldeye could be seriously jeopardized. As indicated by Donald and Kooyman (1977) in the context of the successful 1971 year class, the timing of spawning migrations may have an important effect on reproductive success.

The relationship between goldeye migration and the current direction in migration routes is not fully understood. The spring migration of goldeye from the Peace River to Quatre Fourches may be either upstream or downstream (Donald and Kooyman 1977). In 1972 and 1973, the main migration of goldeye into Mamawi Lake did not occur until several days after the current had commenced to flow out of this lake (Donald and Kooyman 1974). In 1977, catch rates of goldeye were, in most cases, relatively low in the Chenal des Quatre Fourches while the water was flowing toward Quatre Fourches. When the current changed direction and started to flow toward the Peace River, catch rates of goldeye gradually increased. Immediately after the current changed and the water started to flow back toward Quatre Fourches again, goldeye catch rates decreased. Catch rates of fish in the Revillon Coupé were, in most cases, relatively low when the flow was toward the Rivière des Rochers and high when the flow was toward the Peace River or was in the process of changing toward the Peace River. These data suggest that the movement of goldeye toward the Delta is accelerated by the flow of water toward the Peace River. As pointed out by Donald and Kooyman (1977), if goldeye were to migrate into the Delta when the Peace River waters were flowing toward the Delta, they might be stranded in inland lakes during years when significant flooding occurs. If goldeye were to wait to migrate into the Claire-Mamawi lakes system until spring flooding had ceased and water started to flow back to the Peace River, they would not likely have access to perched basins in which they might otherwise have become stranded. Because the flow in the Rivière des Rochers was toward the Peace River during the entire sampling period, it was not possible to study the effects of current direction on goldeye migration in this river.

Low catch rates of goldeye in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches from 10 June to the end of the principal sampling period in 1977 (15 June) probably indicated that the major spring migration of goldeye toward the Delta had been completed by 10 June.

Mark-recapture information

Mark-recapture data concerning fish movements must be interpreted carefully, because fishing effort and fishing periods of LGL crews, domestic fishermen, commercial fishermen and sport fishermen varied among areas. For example, because most fish tagged in 1977 were tagged in the Rivière des Rochers, Revillon Coupé or Chenal des Quatre Fourches, the probability of recapturing fish that were tagged in these three rivers was much higher than the probability of recapturing fish that were tagged in other waterbodies. Also, the information derived from considering the movement of fish between their tagging and recapture locations may not be complete; i.e., the fish may have travelled to and from other locations during the period between tagging and recapture. Whenever routes of movement are discussed in the following sections, they are only suggested routes; alternative routes were usually present. Although the recorded movements of tagged fish in 1977 represented movements of relatively few fish, they were probably indicative of similar movements by many other fish.

GOLDEYE

Most of the goldeye that were tagged in 1977 and recaptured during May and June 1977 had remained in the same rivers that they were tagged in. Almost all of these goldeye were tagged and recaptured in the immediate vicinities of the Little Rapids and Revillon Coupé weirs. Some of these goldeye had travelled upstream across the Little Rapids weir and downstream across the Revillon Coupé weir (in southeasterly directions in both cases); others appeared to have remained northwest of the Revillon Coupé weir when the water was flowing toward the Rivière des Rochers or northwest of the Little Rapids weir when surface water velocities across this weir (toward the Peace River) would not have hindered their movement toward the Delta. These data suggest that, although some goldeye crossed the weirs in a southeasterly direction (possibly heading toward the Delta), other goldeye remained in the vicinity of the weirs by choice, perhaps because of the large feeding areas that were created by the large eddies at the two weirs.

The two goldeye that were tagged immediately northwest of the Revillon Coupé weir in late May and recaptured six days later in the Chenal des Quatre Fourches (station Q11) appeared to have been unable to travel upstream across the Revillon Coupé weir against high surface water velocities, and swam back to the Peace River and then moved upstream in the Chenal des Quatre Fourches toward the Delta. This occurred during one of the only periods that relatively high catch rate of goldeye were obtained in the Chenal des Quatre Fourches. It is thus possible that goldeye that are unable to cross either of the two weirs will migrate to the Delta through the Chenal des Quatre Fourches, on which there is no obstruction to their movement.

Approximately 25% of the goldeye that were tagged in 1977 and recaptured during June 1977 were tagged in the Rivière des Rochers, Revillon Coupé or Chenal des Quatre Fourches, and were recaptured in Lake Athabasca. Although the numbers of these recaptures may, in part, be an artifact of the intensive commercial fishing for walleye in Lake Athabasca during May and June, they do indicate that some of the goldeye that inhabit Lake Athabasca during spring migrate from the Peace River through each of the three rivers, the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches. Results of Kristensen and Summers (1978) also support this indication. The occurrence of goldeye in Lake Athabasca at this time suggests that they spawn in the shallow western end of the lake.

Most of the goldeye that were tagged in 1977 and recaptured during July and August 1977 exhibited movement from the Revillon Coupé, Rivière des Rochers or Chenal des Quatre Fourches to or toward the Claire-Mamawi lakes system. These records probably represented the movement of goldeye from the Peace River to preferred feeding or spawning areas.

One-half of the goldeye that were tagged in 1977 and recaptured between September and November 1977 had travelled to the Peace River where they probably overwintered.

It is much more difficult to interpret the movements of goldeye that were tagged in earlier years and recaptured in 1977 because of the length of time between tagging and recapture dates. It is also important to consider the fact that fish can only remain in Lake Claire and Mamawi Lake from May to mid-winter, because these lakes usually freeze to the bottom during late winter (Donald and Kooyman 1977).

The fact that two goldeye tagged in Lake Claire in 1976 were recaptured by domestic fishermen in February 1977 under the ice at the confluence of the Birch River and Modere Creek suggests that some goldeye that inhabit the Claire-Mamawi lakes system during summer overwinter in the Birch River. Local fishermen (pers. comm.) frequently catch goldeye in the Birch River during winter. It is not known what proportion of the goldeye that inhabit the Claire-Mamawi lakes system during summer overwinter in the Birch River; however, because this river is usually relatively free of visible suspended sediments, it is unlikely that substantial numbers of goldeye overwinter in this river. (Paetz and Nelson (1970) stated that goldeye appear to prefer water of high turbidity.)

The high numbers of goldeye that were tagged in 1976 in the Rivière des Rochers, Revillon Coupé, Chenal des Quatre Fourches or at Quatre Fourches and that were recaptured during May and June 1977 in Lake Athabasca suggest that many goldeye that probably overwinter in the Peace River inhabit Lake Athabasca during some portion of their life cycles.

Numerous goldeye that were tagged in 1976 or 1977 in the Peace-Athabasca Delta were recaptured in the Athabasca River as far south as Fort MacKay, and numerous goldeye that were tagged in 1976 or 1977 in the Athabasca River as far south as Fort MacKay were recaptured in the Delta and as far north as Peace Point on the Peace River. These

data strongly suggest that goldeye move freely between the Peace-Athabasca Delta and the Athabasca River (at least as far south as Fort MacKay) and that these goldeye are members of the same group (as defined by Marr 1957). Data collected in 1976 (Kristensen and Summers 1978) also support this suggestion.

Tag-recapture information obtained in 1976 (Kristensen and Summers 1978) and in 1977, and catch rates of goldeye obtained during the spring of 1977 and during the summer and autumn of 1976 suggest that goldeye migrate between the Peace River and the Claire-Mamawi lakes system or the western end of Lake Athabasca through the three rivers, the Rivière des Rochers, Revillon Coupé, and Chenal des Quatre Fourches. During the spring of 1977, more goldeye appeared to migrate to or toward the Delta through the Rivière des Rochers and Revillon Coupé than through the Chenal des Quatre Fourches. During the summer and autumn of 1976 (Kristensen and Summers 1978) more goldeye appeared to migrate from the Delta toward the Peace River through the Chenal des Quatre Fourches and Revillon Coupé than through the Rivière des Rochers. It is possible that the relative importance of the three rivers to the migration of goldeye varies from spring to summer and autumn, and varies from year to year, depending on hydrological conditions in the three rivers.

OTHER SPECIES

The following are brief comments on the movements of tagged species other than goldeye.

The recapture of northern pike in January 1977 under the ice in the Prairie River that were tagged in Lake Claire in 1976 indicates that this river provides overwintering habitat for at least some of the northern pike that inhabit Lake Claire during summer. Local fishermen (pers. comm.) catch many northern pike in the Prairie River during the winter. Because three walleye that were tagged in Lake Claire in 1976 were recaptured in February 1977 under the ice at the confluence of the Birch River and Modere Creek, the Birch River appears to provide overwintering habitat for some of the walleye that inhabit Lake Claire during summer.

Not only goldeye appear to move freely between the Peace-Athabasca Delta and the Athabasca River; numerous walleye, lake whitefish and long-nose sucker that were tagged in 1976 or 1977 by AOSERP or LGL biologists had travelled between the Athabasca River (as far south as Fort MacKay) and the Delta (as far north as Quatre Fourches). Information gathered in 1976 (Kristensen and Summers 1978) also indicated the movement of walleye between the Delta and the Athabasca River.

AGE STRUCTURE AND GROWTH OF JUVENILE AND ADULT GOLDEYE

Age structure

Data presented in this study and in previous studies (Kristensen and Sekerak 1976; Donald and Kooyman 1977; Kristensen and Summers 1978) indicate that goldeye of the 1971 year class have dominated the goldeye catches in recent years. Donald and Kooyman (1977) cited several factors that could

have contributed to the success of the 1971 year class.

1. In 1971, goldeye of the previously-successful 1964 year class entered the spawning population for the first time as mature fish.

2. Mature goldeye entered the Claire-Mamawi lakes system one or two weeks earlier in 1971 than they did in 1972 to 1975 and spawning was completed earlier; earlier spawning resulted in larger young-of-the-year goldeye at the end of the 1971 growing season.

3. There was an abundance of food in 1971 for young-of-the-year goldeye that probably contributed to the increased size of the fish.

Goldeye of the 1971 year class comprised approximately 90%, 85%, 77% and 64% of the catches in 1973 (Donald and Kooyman 1977), 1975 (Kristensen and Sekerak 1976), 1976 (Kristensen and Summers 1978) and 1977 (this study), respectively, that were obtained from the Claire-Mamawi lakes system and Quatre Fourches (two areas combined). Based on the rate of decrease in the percent dominance of the 1971 year class during the period 1973 to 1977, goldeye of this year class will remain well represented in catches for several years, and will play an important role in the future reproductive potential of goldeye in the Peace-Athabasca Delta.

Although there was a statistical difference among the age structures of goldeye that were captured in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches in 1977, these differences were a result of minor differences among the proportions of several age groups in catches from the three rivers. The three goldeye age structures were basically very similar, with 6-year-olds dominating the catches and 4- and 5-year-olds comprising the majority of the remainder of the catches in the three rivers.

Growth

Differences in the age-length and age-weight relationships between goldeye captured in the three rivers, the Rivière des Rochers, Chenal des Quatre Fourches and Revillon Coupé (considered together), and the Claire-Mamawi lakes system were generally small and were most likely a result of differences among the dates that fish were captured. Scales and measurements were collected from goldeye in the three rivers during the same time period (before 15 June). Some of this information was collected from goldeye after 15 June in the Claire-Mamawi lakes system. As a result, the average fork length and weight of goldeye for each age group in the Claire-Mamawi lakes system were greater than those of goldeye in the other sampling areas.

There is an indication that, in 1977, goldeye up to age 6 that were captured in the Rivière des Rochers and Revillon Coupé were slightly smaller than goldeye of similar ages that were captured in the Chenal des Quatre Fourches during the same time period. This difference may be related to differences in the abundance of food in these three rivers, to differences in stress on fish or, because the differences in size were relatively minor, they may be due to sampling error. If these size differences are related to stress, perhaps the weirs on the Rivière des Rochers and Revillon Coupé affect the stress of goldeye that migrate through these rivers.

In 1975, 1976 and 1977, the growth rates of goldeye of the 1970 and 1971 year classes were depressed in comparison with the growth of other year classes. These depressed rates were discussed in some detail by Kristensen and Summers (1978). A possible reason for decreased growth rates of goldeye belonging to the 1970 and the dominant 1971 year classes would be increased competition among fish of similar size for food, space or some other environmental commodity.

POPULATION ESTIMATES OF JUVENILE AND ADULT GOLDEYE

In order to compare the 1976 and 1977 population estimates, it is important to consider the fishing effort in each sampling area. In 1977, fishing effort was intensive and of similar magnitude in each of the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches; it was lower in the Claire-Mamawi lakes system; and much lower in the western end of Lake Athabasca. In 1976, fishing effort was very intensive in the Rivière des Rochers; it was lower and of similar magnitude in the Revillon Coupé, Chenal des Quatre Fourches and the Claire-Mamawi lakes system; and lowest in Lake Athabasca (Kristensen and Summers 1978). As a result of this unequal fishing effort, goldeye population estimates are not realistic estimates of the numbers of goldeye that inhabited the entire study area, but are probably biased toward the numbers of goldeye that were present in the Rivière des Rochers in 1976 and in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches in 1977.

On the basis of mark-recapture information, the number of goldeye estimated to have been present in the Peace-Athabasca Delta from May to August in 1977 was less than one-half that from May to October in 1976. As expected, there was a decrease from 1976 to 1977 in the estimated numbers of goldeye of most year classes; however, estimated numbers of goldeye of the 1964, 1967 and 1972 year classes were higher in 1977 than in 1976. Differences between the estimated numbers of goldeye in 1976 and 1977 comprising the 1964 and 1967 year classes may well be artifacts of small sample sizes in both years; but sample sizes of goldeye comprising the 1972 year class were not small. This suggests that fish of the 1972 year class were either under-represented in the 1976 catch or were over-represented in the 1977 catch.

Mortality rates of goldeye between 1976 and 1977 varied from approximately 57% (1973 year class) to 100% (1966 year class). The mortality rate of the dominant 1971 year class between 1976 and 1977 was approximately 58%. These mortality rates were high when compared with the annual mortality rate of 51% for adult goldeye that was cited by Donald and Kooyman (1977). Not only were the mortality rates of goldeye high between 1976 and 1977, but the recruitment by 1-year-olds was extremely low (only 496 1-year-olds were estimated to have occurred in the Delta in 1977). The low recruitment by 1-year-olds in 1977 suggests that spawning success of goldeye in 1976 was poor. Because there was no sampling for young-of-the-year goldeye in 1976 however, supportive data are not available.

REPRODUCTIVE PARAMETERS AND SPAWNING SUCCESS OF GOLDEYE

On the basis of data collected in recent years (including this study), the sex ratio of goldeye in the Peace-Athabasca Delta is approximately one male to one female.

It was not possible to precisely determine the age at maturity of male goldeye in 1977 because it was not possible to accurately distinguish between mature males and males that would mature in 1978. However, because 4-year-old males that were either mature in 1977 or were approaching their first year of maturity were collected during this study, at least some proportion of the males that will be 5 years old in 1978 will be mature. Bishop (1975) found that male goldeye in the Peace River upstream of the Peace-Athabasca Delta matured at age 4; it is also possible that some of the 4-year-old males that were collected in 1977 were actually mature. Based on the relatively high proportions of 5-year-old mature males or males that would mature in 1978 that were collected in 1977, high proportions of 6-year-old males in 1978 will be mature. If it can be assumed that high proportions of males in 1977 and 1978 would attain sexual maturity at the same age, then high proportions of 6-year-old males were also mature in 1977. Together, the above-mentioned data indicate that male goldeye in the Peace-Athabasca Delta may mature at age 5 and possibly at age 4, but that high proportions of males do not mature until age 6.

Only 3.4% of the female goldeye that were collected in 1977 were mature. The youngest mature females collected were 6 years old; however, most of the 6-year-old females collected were not mature in 1977 nor would they be mature in 1978. This means that the earliest year that most of the 6-year-old females that were captured in 1977 could mature would be 1979 when they will be 8 years old. Because most females that were captured in 1977 were 6 years old, there will probably be significant increase in the number of spawning females in 1979.

Kooyman (1973) found that essentially all 6-year-old male goldeye that were captured in the Delta in 1971 were mature. Kennedy and Sprules (1967) reported that in 1947-48 very few 6-year-old males but most 7-year-old males were mature in Lake Claire. In 1971, all of the 6-year-old female goldeye that were collected were mature (Kooyman 1973); whereas none of the 6-year-old females that was collected in 1947-48 was mature (Kennedy and Sprules 1967). In 1947-48, 2% of 7-year-old, 55% of 8-year-old and 96% of 9-year-old females that were captured in Lake Claire were mature. High proportions of male goldeye in 1977 appeared to mature at the same age (6 years) as did males in 1971. However, in 1977, female goldeye appeared to be maturing at rates more similar to those of females in 1947-48 than to those of females in 1971. As pointed out by Lagler et al. (1977), size and age of fish are factors that affect the onset of sexual maturity. Kooyman (1973) suggested that goldeye matured at an earlier age in 1971 than in 1947-48, because of faster growth rates of goldeye in 1971. Faster growth rates in 1971 were attributed to decreased competition among goldeye--a result of their decreased abundance during the early 1960's which

was affected by the intensive commercial fishery for goldeye during and prior to this period. As discussed earlier in this report, the sizes of 6- and 7-year-old goldeye in 1977 were more similar to those of the same age groups in 1947-48 than they were to those of the same age groups in 1973. This decreased growth rate is possibly a result of the recent increased competition among large numbers of goldeye of similar size. The increased age at sexual maturity of female goldeye in 1977, when compared with that of females in 1971, may be due to this recent decrease in goldeye growth rates.

Because approximately 19.6% of the females collected from the Claire-Mamawi lakes system in 1977 would mature in 1978, whereas from only 0% to 4% of the females collected from the Riviere des Rochers, Revillon Coupé and Chenal des Quatre Fourches would mature in 1978, female goldeye approaching their first year of sexual maturity appeared to have migrated into the Claire-Mamawi lakes system before 11 May when intensive sampling commenced in the three rivers. However, females that were mature in 1977 and males that were mature or were approaching their first year of maturity in 1977 did not appear to have migrated into this system before 11 May.

In 1977, the mean fecundity of female goldeye that were collected from the Peace-Athabasca Delta was 3,172, which was much lower than the mean fecundity (14,150) of goldeye that were captured from several lakes in Manitoba (Kennedy and Sprules 1967) and was also lower than the fecundity (12,240) of a female that was collected from the Peace River (Bishop 1975). In fact, the highest egg count obtained from a goldeye in the Delta (5,310) was lower than the lowest egg count obtained from a goldeye in Manitoba (5,761). The fecundity of an individual female is related to several factors including age and size (Lagler et al. 1977). Almost all of the female goldeye for which egg counts were obtained in Manitoba were older and larger, and the goldeye captured in the Peace River was larger than the goldeye for which egg counts were obtained in the Peace-Athabasca Delta. This may explain the marked discrepancy in egg counts. Lagler et al. (1977) stated that conditions of the female in relation to factors like food availability, water temperature and season also affect fecundity. As discussed previously, the recent decrease in growth rates of goldeye of the 1970 and 1971 year classes is possibly a result of recent increased competition among these fish. If this competition were for food, it may explain the low egg counts of females in 1977 (all of which belonged to the 1971 year class).

Estimated of the numbers of postlarval young-of-the-year (Y-0-Y) goldeye produced in Lake Claire and Mamawi Lake in 1971, 1975 and 1977 are considered minimal for the following reasons:

1. estimates of the numbers of Y-0-Y goldeye in the Prairie River, where catch rates were high, are not included;
2. there was undoubtedly some unknown degree of mortality of fish between the time of hatching and the time of sampling, and
3. some goldeye were probably able to avoid the trawl nets

Estimates of the numbers of postlarval Y-0-Y goldeye that were present in Lake Claire and Mamawi Lake in 1975 and 1977 suggest that similar numbers of Y-0-Y goldeye were produced in these two years. The 1975 year class was not well represented in gill net catches in 1976 or 1977. Assuming that goldeye of the 1975 and 1977 year classes experience similar mortality rates, it is highly probable that the 1977 year class will not be well represented in catches in future years. The estimate of the numbers of Y-0-Y goldeye that were present in Lake Claire and Mamawi Lake in 1971 is approximately four times that in either 1975 or 1977. As discussed previously, the 1971 year class has been very well represented in gill net catches during recent years.

Following the closure of the Bennett Dam in 1968, there was much concern about the effects that decreased water levels in the Peace-Athabasca Delta might have on the many faunal species, including goldeye, that inhabited the Delta. Figure 18 shows water levels at Lake Claire and Mamawi Lake in 1971, 1975 and 1977. Water levels in these lakes during 1971 when goldeye reproduction was very successful, were appreciably lower than they were in 1975 and 1977 when reproductive success of goldeye was much lower than in 1971. These data indicate that relatively low water levels in the Claire-Mamawi lakes system in 1971 were not necessarily detrimental to the reproductive success of goldeye.

On the basis of population estimates, sex ratios, proportions of females that were mature for each age group and mean egg count, the estimated reproductive potential of goldeye in the Delta in 1977 was 1,297,000 postlarval Y-0-Y goldeye. Based on trawl net catch rates and area of water most probably utilized by Y-0-Y goldeye, the estimated number of postlarval Y-0-Y goldeye that were present in Lake Claire and Mamawi Lake in 1977 was 1,536,000. At first glance, these two estimates appear similar and one would be tempted to say that the estimated number of postlarval Y-0-Y goldeye produced in 1977 was somewhere between 1,297,000 and 1,536,000. However, several points of information complicate the comparison of these two estimates. First, the Y-0-Y goldeye estimate based on trawl net catch rates is considered minimal (as discussed above). Second, the reproductive potential estimate was based on fish captured in the entire study area, whereas the estimated number of Y-0-Y goldeye based on catch rates was based on sampling only in Lake Claire and Mamawi Lake. Although data suggest that many of the Y-0-Y goldeye that were produced in the Delta were produced in Lake Claire and Mamawi Lake, data were collected in 1977 which suggest that goldeye spawn in other waterbodies within the Delta as well. Therefore, the number of postlarval Y-0-Y goldeye that were present in the entire study area in 1977 was most likely higher than 1,536,000.

The low reproductive potential of goldeye in 1977 was primarily as result of two factors:

1. low numbers of mature females, and
2. very low egg counts for mature females.

It is thought that the reproductive success of goldeye will be high in 1979 when large numbers of females of the dominant 1971 year class will probably attain sexual maturity. In addition,

because females of the 1971 year class will be two years older in 1979, egg counts for these females may be higher and thereby further contribute to increased reproductive success of goldeye in 1979. If goldeye of the 1971 year class are to contribute significantly to the numbers of goldeye in the Peace-Athabasca Delta in future years, it is important that they reach their spawning grounds in 1979.

Although few of the 6-year-old female goldeye that were collected during this study were mature, because the 1971 year class dominated the 1977 age composition, this year class contributed approximately 88% to the total reproductive potential of goldeye in the Delta in 1977.

DISTRIBUTION OF YOUNG-OF-THE-YEAR GOLDEYE

When interpreting results of the trawl net sampling program, it is important to consider the fact that very small, recently-hatched individuals of various species were often not captured in the sampling gear. For example, Y-O-Y goldeye first became susceptible to the sampling gear at a size of approximately 18 to 20 mm in fork length. Goldeye smaller than this were able to slip through the 3.2-mm oval mesh trawl nets.

Y-O-Y goldeye were captured in 1977 in Lake Claire, Mamawi Lake, Lake Athabasca, the Prairie River and tributaries, Birch River, Rivière des Rochers, Revillon Coupé, Chenal des Quatre Fourches, Baril River and in the channels that connect Lake Athabasca and Mamawi Lake. Based on the distribution of Y-O-Y goldeye that were captured in trawl nets, Donald and Kooyman (1977) indicated that goldeye spawn in Lake Claire, Mamawi Lake, the Prairie River, at Quatre Fourches and in Baril Lake. Data collected in 1977 support these findings. The small sizes of Y-O-Y goldeye that were captured during June and early July 1977 in the Chenal des Quatre Fourches and along the north shore of Lake Athabasca close to Fort Chipewyan suggest that goldeye also spawn in these two waterbodies.

Data presented by Kristensen and Sekerak (1976) and Donald and Kooyman (1977) indicate that Y-O-Y goldeye in Lake Claire were most abundant along the north and west shores, and suggest that these were the preferred spawning areas of goldeye in this lake. Y-O-Y goldeye appeared to have been most abundant along the east shore of Lake Claire early in the 1977 sampling period (late June), indicating that significant spawning occurred along this shoreline in 1977. As discussed by Donald and Kooyman (1977), precise spawning locations of goldeye within the Peace-Athabasca Delta vary from year to year.

Donald and Kooyman (1977) stated that Y-O-Y goldeye began to migrate out of the Claire-Mamawi lakes system sometime after mid-July and that this migration continued at least until November. Only limited information obtained during this study revealed a migration of Y-O-Y goldeye out of the Claire-Mamawi lakes system in 1977. The facts that highest catch rates of Y-O-Y goldeye in Lake Claire and Mamawi Lake during August were obtained along the east shores of both lakes and that catch rates were higher along other shorelines of these lakes during July, may be indicative of a movement of Y-O-Y fish out of these lakes

during August. If the migration of Y-O-Y goldeye out of this system is a gradual one, as suggested by Donald and Kooyman (1977), it could be difficult to detect.

This high catch rates of Y-O-Y goldeye in the Rivière des Rochers in July and in the Revillon Coupé in July and August are difficult to interpret. Because these high catch rates were obtained after mid-July, they may represent the migration of Y-O-Y goldeye out of the Delta through these two rivers. If this were the case, these two rivers were utilized as migration routes by Y-O-Y goldeye in 1977 to a greater extent than was the Chenal des Quatre Fourches. Most of the Y-O-Y goldeye that were captured in the Rivière des Rochers and Revillon Coupé were captured either in large eddies or in shallow, slow-moving sections of the rivers. These types of areas may be used for spawning by goldeye (i.e., Y-O-Y goldeye that were captured in these areas in 1977 may have hatched there). Kennedy and Sprules (1967) stated that goldeye spawn in pools in turbid rivers. It is interesting to speculate about the extent to which such riverine areas might be used for spawning in years when goldeye might not have access to the Claire-Mamawi lakes systems (e.g., during years of late ice-lift and break-up in this system, or during years when goldeye that migrate through the Rivière des Rochers or Revillon Coupé might not be able to cross the weirs on these two rivers).

As discussed by Donald and Kooyman (1977), when the variance in the numbers of organisms for a series of samples taken from a population is larger than the mean number, the population is said to have a clumped distribution. As shown in Table 13, Y-O-Y goldeye that were captured in 1977 revealed this type of distribution in most waterbodies during most sampling periods. An obvious question arising from this observation is whether or not these clumped distributions of Y-O-Y goldeye are related to any environmental factors. This question is explored in the following paragraphs.

Kristensen and Sekerak (1976) found that Y-O-Y goldeye inhabit areas that also contain a relatively greater number of other fish species. However, the relationship between goldeye catch rates and those of other particular species was not investigated. Information collected in 1977 indicate that Y-O-Y goldeye were abundant in areas where ninespine stickleback, trout-perch, Y-O-Y longnose sucker and Y-O-Y walleye were also abundant, but that Y-O-Y goldeye were not common in areas where Y-O-Y northern pike were abundant.

When the relationship between Y-O-Y goldeye catch rates and shoreline vegetation at sampling sites was investigated in 1975, highest mean catch rates of Y-O-Y goldeye were obtained along shorelines where *Senecio* sp. and grasses (numerous species) were dominant, and low catch rates were obtained where *Equisetum* sp. was dominant (Kristensen and Sekerak 1976). In 1977, highest catch rates of Y-O-Y goldeye were obtained where *Juncus* sp. and *Equisetum* sp. dominated vegetation complexes along lake and river shorelines, respectively. When results of 1975 and 1977 are considered simultaneously, it does not appear that dominant shoreline vegetation influences the distribution of Y-O-Y goldeye in the Peace-Athabasca Delta, or if it does, the influences vary from year to year. Therefore, the statement made

by Kristensen and Sekerak (1976)--that vegetation type, or a factor affecting vegetation type, influences Y-O-Y goldeye distribution along shorelines--does not appear to be true.

Results of correlating Y-O-Y goldeye catch rates with several other parameters indicate that wind direction in relation to shorelines of lakes affects the distribution of Y-O-Y goldeye. Catch rates of Y-O-Y goldeye were, on the average, much higher along lake shorelines when the wind was blowing toward the shorelines that were being sampled. Y-O-Y goldeye may have moved to shorelines where the wind had concentrated food supplies or Y-O-Y goldeye may have been concentrated by the wind along windward shorelines. The fact that the mean catch rate of Y-O-Y goldeye was higher in rivers or streams than in lakes, lends support to the suggestion made earlier in the report that goldeye in the Peace-Athabasca Delta spawn more extensively in rivers than has been thought in the past.

It is difficult to assess the relative importance of the above-mentioned environmental factors to the distribution of Y-O-Y goldeye in the Peace-Athabasca Delta. There are many other parameters which were not investigated in 1977 that might affect Y-O-Y goldeye distribution. Their distribution is probably not affected only by one factor, but is probably influenced by several interrelated factors.

GROWTH OF YOUNG-OF-THE-YEAR GOLDEYE

Y-O-Y goldeye that were captured in Lake Claire were smaller than those that were captured on similar dates in other sampling areas. This size discrepancy may be related to the period of peak hatch in the various waterbodies which, in turn, is a direct result of when goldeye spawned in each of these waterbodies. Because goldeye that migrate from the Peace River have to travel further in order to reach Lake Claire, it follows that spawning may take place later in this lake than in other waterbodies.

In 1972 and 1973, break-up in the Chenal des Quatre Fourches occurred on 2 May and 3 May, respectively (Donald and Kooyman 1974). Break-up at Quatre Fourches in 1977 occurred on 23 April. Assuming that the ice in Mamawi Lake and Lake Claire lifted and broke within approximately the same period of time following break-up at Quatre Fourches in each of these years, goldeye were able to enter the Claire-Mamawi lakes system earlier in 1977 than they were in 1972 and 1973. However, goldeye appeared to have hatched approximately the same time in 1972, 1973 and 1977. These data suggest that goldeye do not necessarily spawn early in years when they have early access to their spawning grounds.

In 1971, Y-O-Y goldeye were larger than were Y-O-Y goldeye on similar dates in 1972, 1973 and 1977. As discussed by Donald and Kooyman (1977), the facts that spawning was completed early in 1971 and that there was an abundant food supply in 1971 probably contributed to the larger size of Y-O-Y goldeye in that year.

GOLDEYE GROUPS IN THE PEACE-ATHABASCA DELTA

Potential effects of the weirs on the Rivière des Rochers and Revillon Coupé would be much more significant if discrete goldeye groups (as defined by Marr 1957) exist in the Peace-Athabasca Delta and if these groups display fidelity to specific migration routes from the Peace River to their spawning grounds. For example, it is possible to assume that goldeye that migrate through the Rivière des Rochers spawn in areas different from those in which goldeye that migrate through the other two channels spawn, and that these goldeye have developed and maintained some degree of genetic integrity which causes their migration from the Peace River to the Delta to occur through the Rivière des Rochers every year. If mature individuals that were migrating toward the Delta were unable to cross the weir or pass through the fishway at Little Rapids in a given year, it is possible that these fish would not attempt to enter the Delta through alternative routes. This blockage of fish movement would then mean that the segment of the Delta goldeye population that migrates through the Rivière des Rochers would probably not spawn successfully that year. If this were to occur for several successive years, or in a year when dominant age groups attained sexual maturity, effects on the total reproductive success of the Delta goldeye population could be severe.

Several characteristics of goldeye have been studied in an attempt to determine whether or not goldeye that migrate through the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches are members of the same group. These include age structure, growth, movement and meristic comparisons. As discussed by Taning (1952) and Marr (1957), meristic characters have traditionally been studied by fishery biologists in an attempt to describe and define subpopulations, stocks or groups of fish (see definitions in RESULTS).

The null hypothesis--that goldeye that migrate through the three rivers are members of the same group--was tested statistically (using a stepwise multiple discriminant analysis) on the basis of seven meristic counts that were obtained from approximately equal samples of goldeye that were collected from the three rivers. The degree of statistical discrimination among channels when all seven characters were considered simultaneously was only marginally significant ($0.05 \leq P < 0.1$). Based on this statistic, and if we accept 0.05 as the level of statistical probability, we may accept the null hypothesis. When all characters were considered simultaneously, the only two meristic counts which were significantly ($0.025 \leq P < 0.05$) different among the channels were dorsal and anal fin ray counts. Based on the dorsal and anal fin ray counts only, we may reject the null hypothesis (i.e., goldeye that were collected from the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches are not members of the same group).

There are several important points that should be considered when interpreting these statistical results. When the classification matrix produced by the stepwise multiple discriminant analysis was analysed, over one-half of the goldeye whose meristic characters were studied were

classified as having been collected from a river other than that from which they were actually collected. This result questions the usefulness of the seven meristic characters, when considered simultaneously, in distinguishing goldeye from the three rivers. We may therefore wish to consider only those meristic counts of goldeye which were significantly different among the three rivers--dorsal and anal fin ray counts. Of these two counts, the number of dorsal fin rays appeared to differ the most (based on the one-factor analysis of variance). Tåning (1952) found that the number of dorsal fin rays in *Salmo trutta trutta* was phenotypically determined, because their number was determined (or fixed) at a late stage during the ontogenetic development of the embryo and was significantly influenced by environmental factors (primarily temperature). The number of anal fin rays was more genotypically determined, because their number was determined at an earlier stage during ontogenetic development and was therefore not influenced as greatly by environmental factors. Because dorsal fin ray and, to a lesser extent, anal fin ray numbers appear to be influenced by temperature, it is not safe to use the counts of these two characters as markers of generic variation among fish, especially when the mean counts differ as little as they did among goldeye captured in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches. On the basis of this discussion, the observed variation in dorsal and anal fin ray counts may be grounds for stating that goldeye collected from the three rivers are members of discrete groups, but is probably not grounds for stating that they are members of discrete subpopulations.

Comparison of age structure, growth and movement of goldeye in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches provide support for the null hypothesis. Although statistically different, the age structures of goldeye that were captured in the three rivers were very similar; 6-year-olds dominated the catches, and 4- and 5-year-olds comprised the majority of the remainder of the catches. Slight differences in growth rates of goldeye among the three channels were most probably environmentally related. Because differences in age structures and growth rates of goldeye among the three rivers were minor, they may be due to sampling error. The movements of tagged goldeye among the three migration routes (the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches) and between the spawning grounds (the Claire-Mamawi lakes system and western end of Lake Athabasca) and the three migration routes in 1976 and 1977 suggest that genetic mixing of these goldeye occurs.

Based on the above discussion, goldeye that migrate through the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches are almost certainly not members of discrete subpopulations. Minor differences in the various characteristics studied (excluding movement) among these goldeye are probably environmentally related, and are not of sufficient magnitude to warrant considering these fish as being members of discrete stocks (and hence, groups). Therefore, the potential effects of the weirs on the goldeye population in the Peace-Athabasca Delta are probably not as significant as they would be if discrete goldeye groups had been shown to migrate through the Rivière des Rochers. Revillon Coupé

and Chenal des Quatre Fourches. Goldeye that might not be able to cross one of the weirs during their spring migration toward their spawning grounds are thus probably not traditionally bound to migrate through any one river, and would therefore probably attempt to reach the Delta through an alternative route.

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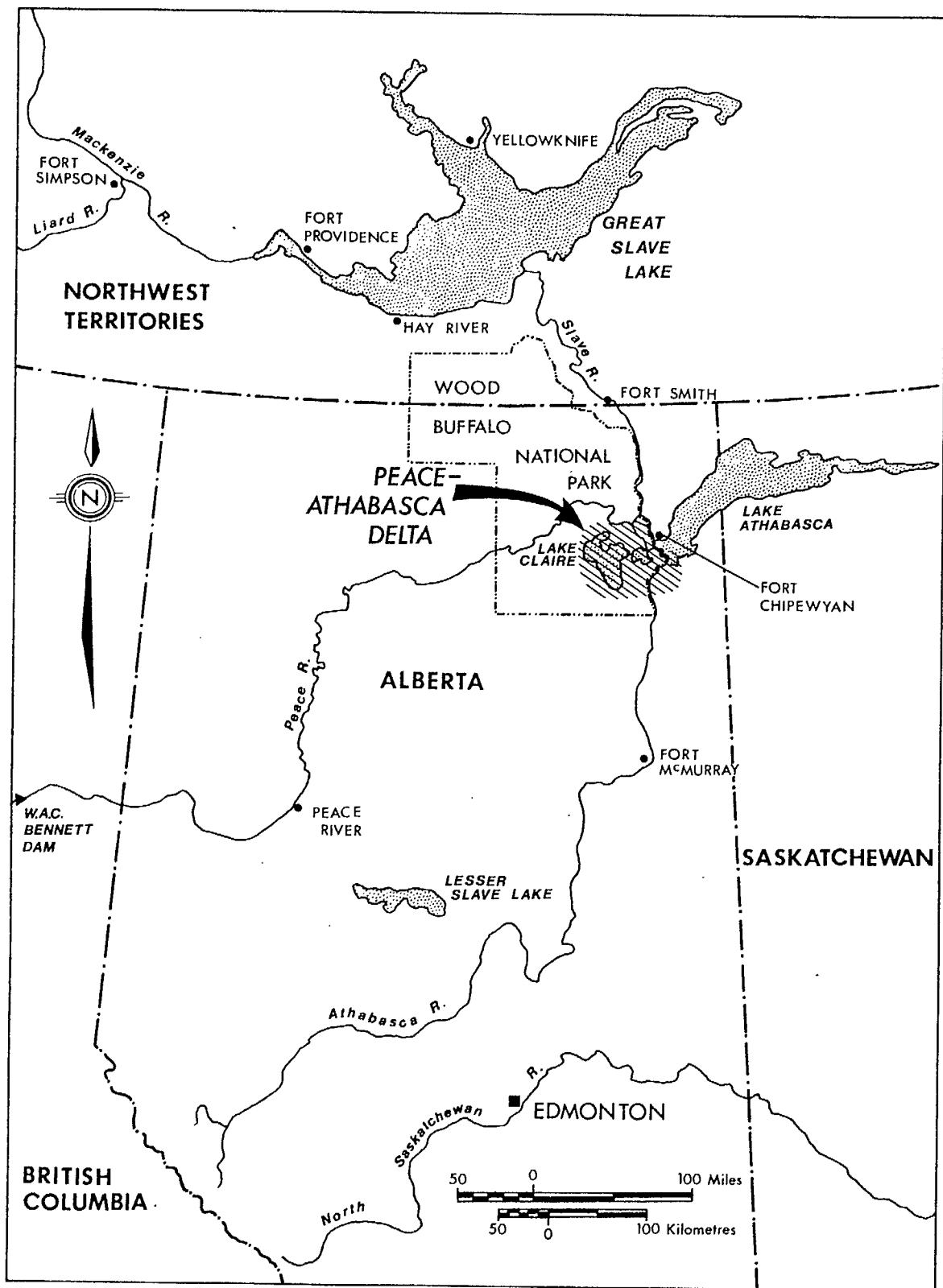


FIGURE 1. The Peace-Athabasca Delta.

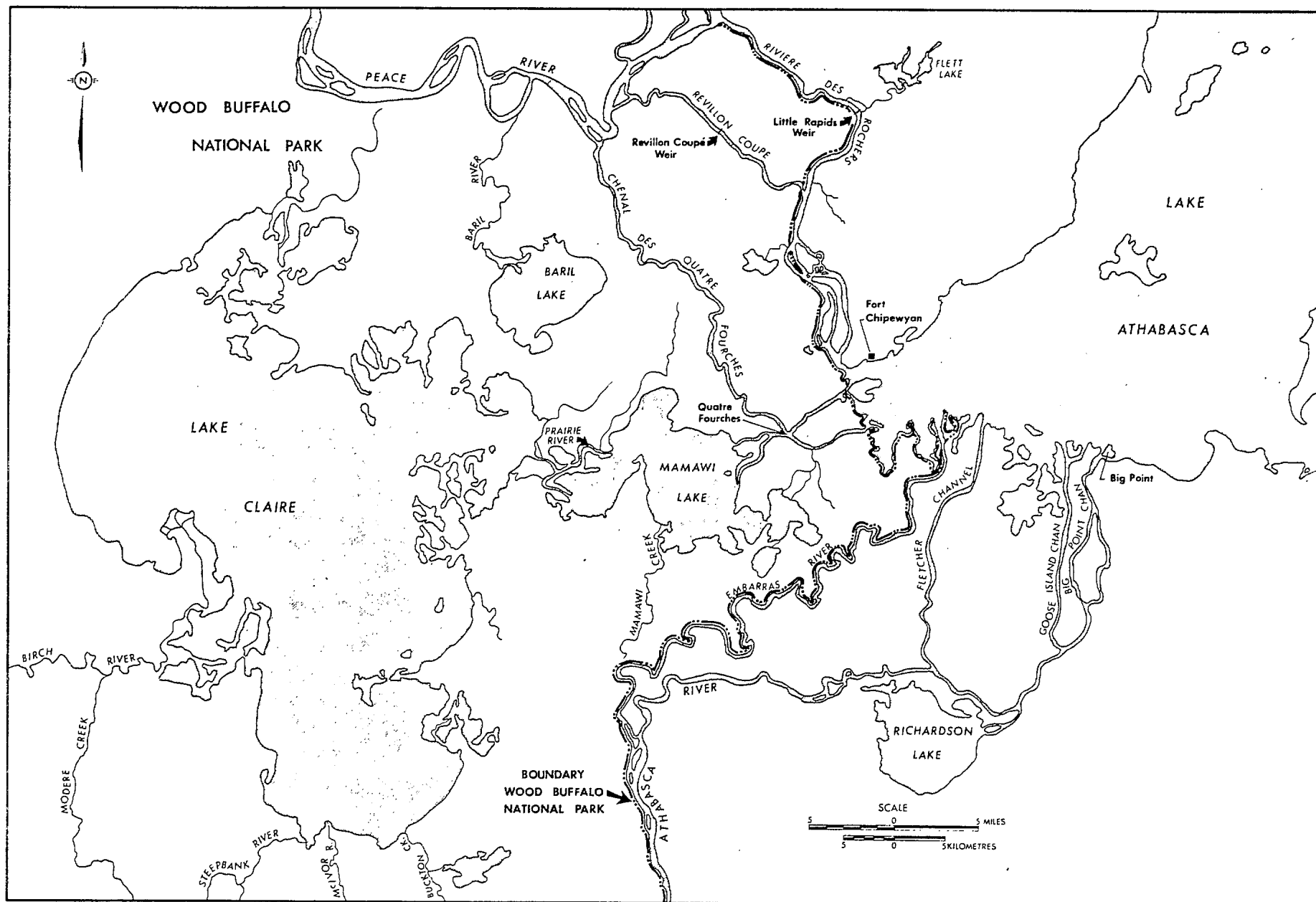


FIGURE 2. The Peace-Athabasca Delta, Showing Locations of the Water Control Structures on the Rivière des Rochers and the Revillon Coupé.

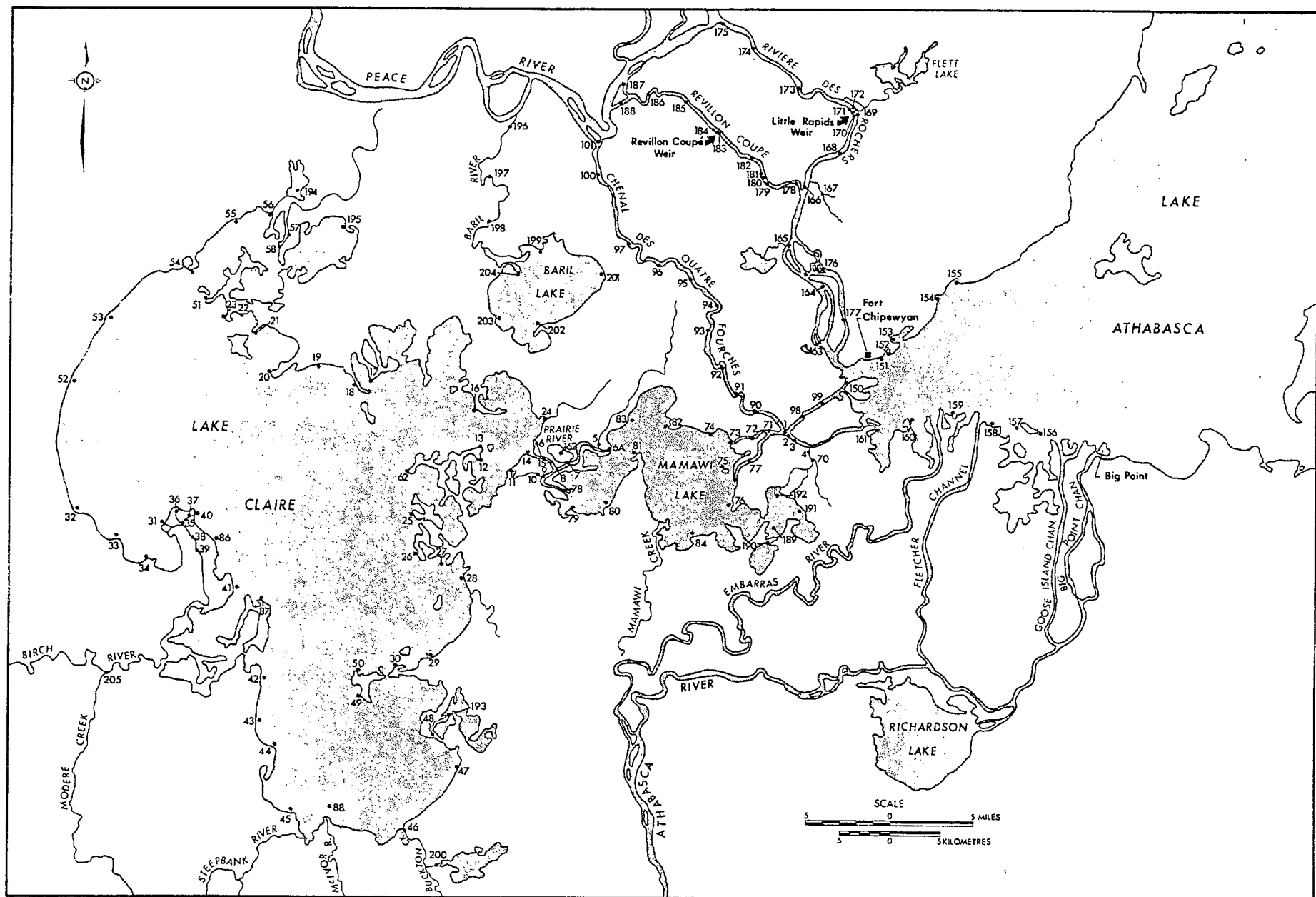


FIGURE 5. Locations of Trawl Net Sampling Stations in the Peace-Athabasca Delta, 1977.

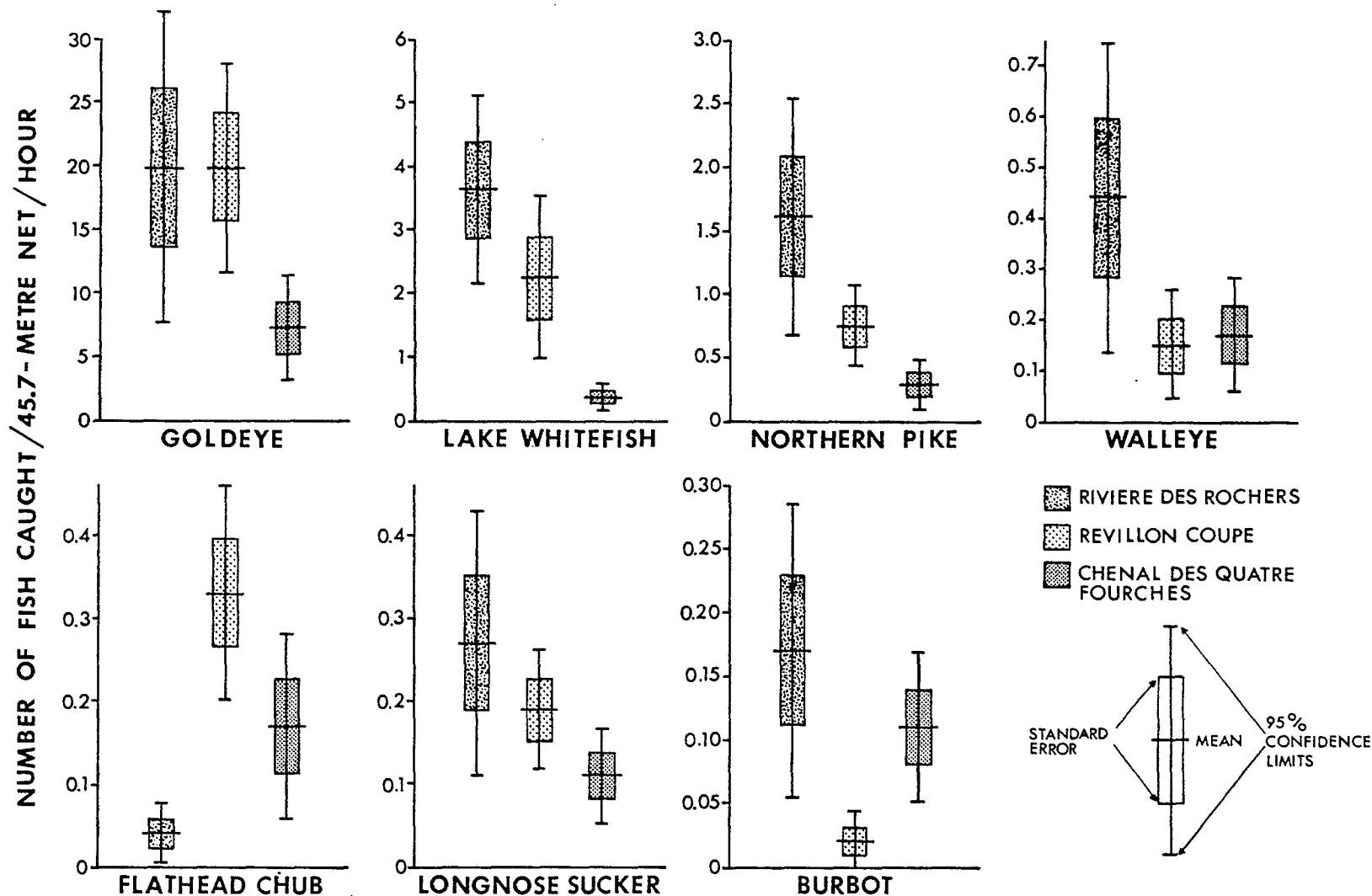


FIGURE 7. Mean Catch Per Unit Effort for Seven Species of Fish Captured in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches, 11 May to 15 June 1977.

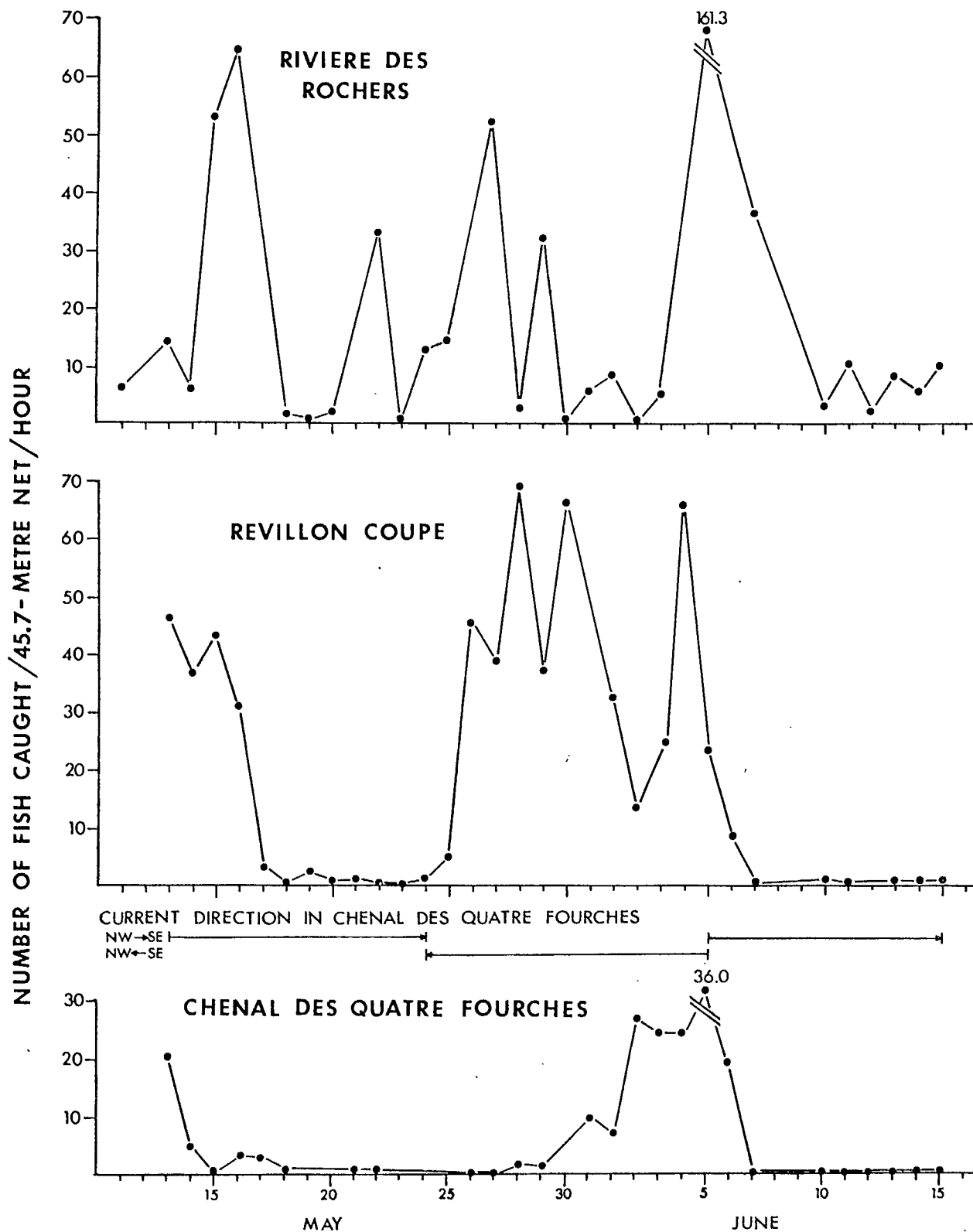


FIGURE 8. Daily Mean Catch Per Unit Effort for Goldeye Captured in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches, 11 May to 15 June 1977.

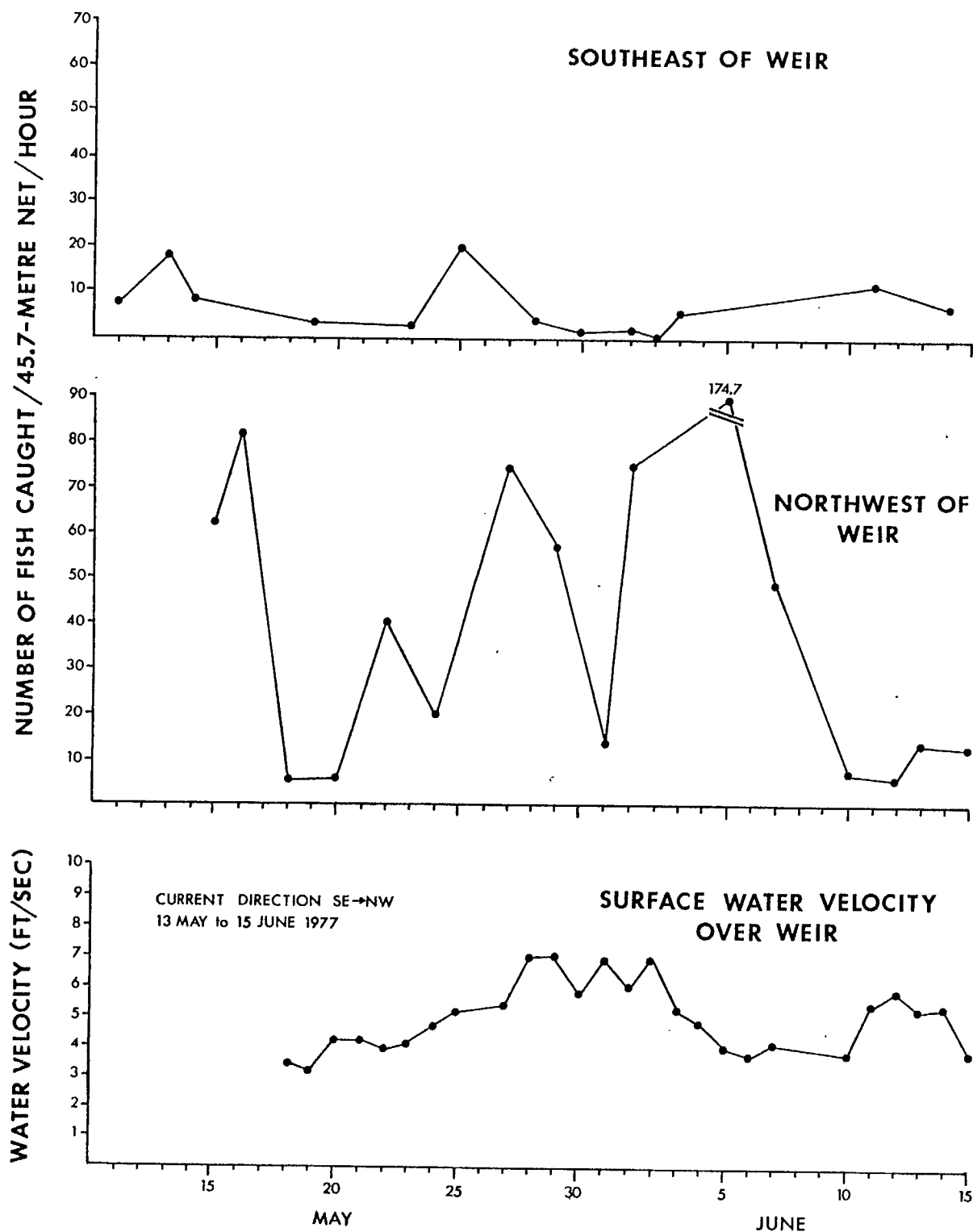


FIGURE 9. Daily Mean Catch Per Unit Effort for Fish (all species combined) Captured on Both Sides of the Little Rapids Weir, and Hydro-logical Measurements at the Weir.

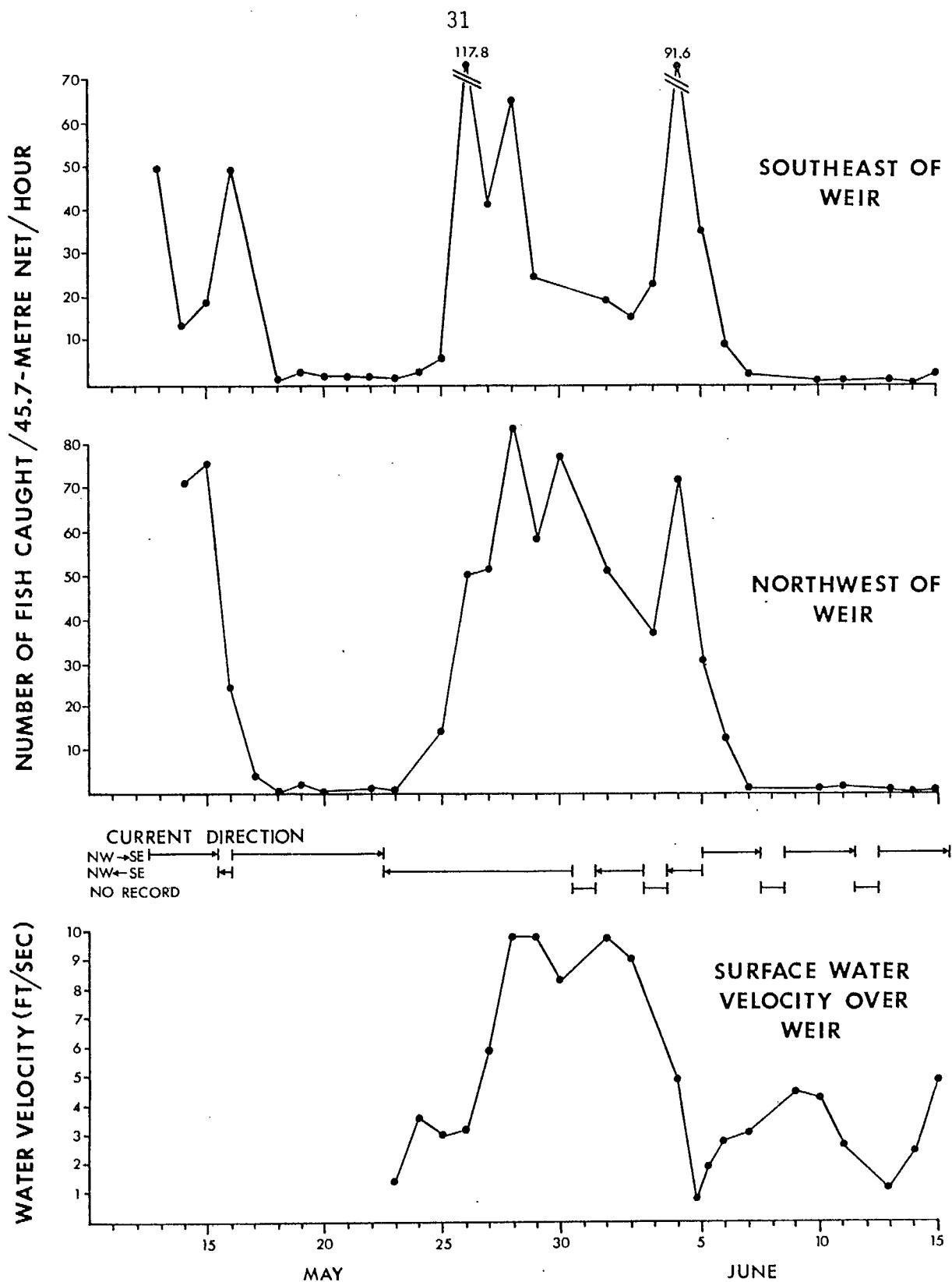


FIGURE 10. Daily Mean Catch Per Unit Effort for Fish (all species combined) Captured on Both Sides of the Revillon Coupé Weir, and Hydro-logical Measurements at the Weir.

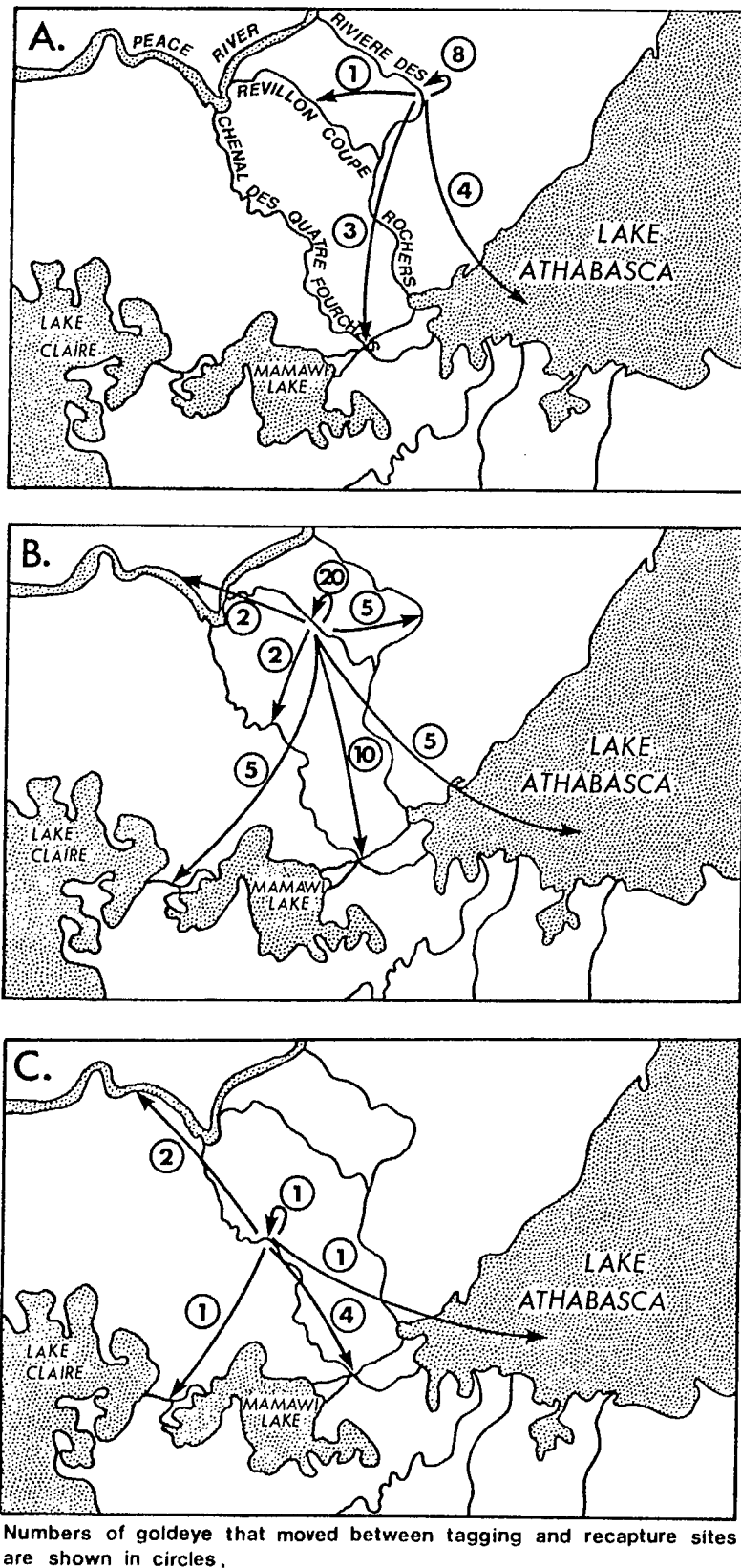


FIGURE 11. Movements of Goldeye Tagged in the Rivière des Rochers (A), Revillon Coupé (B) and Chenal des Quatre Fourches (C) in 1977.

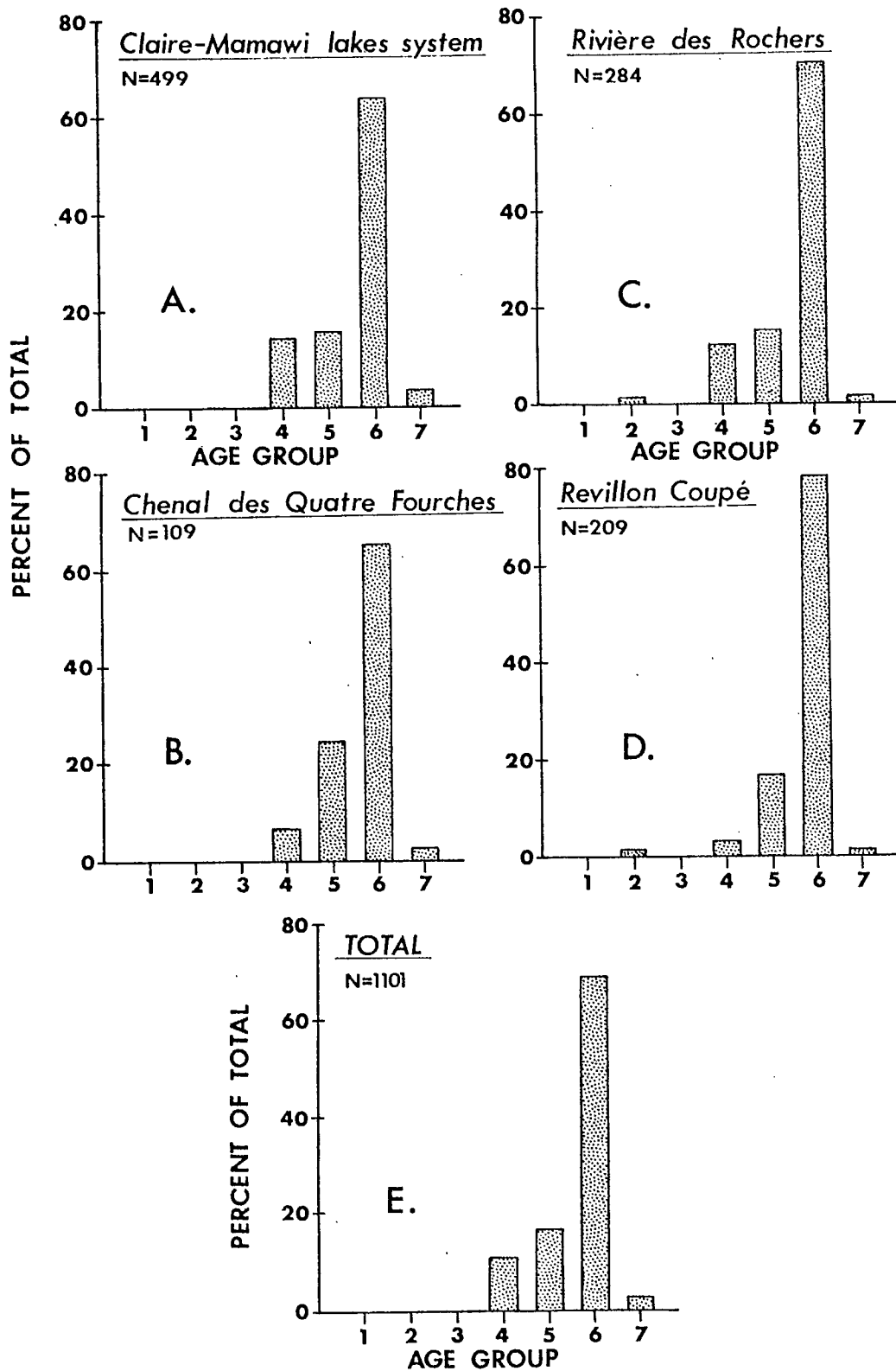


FIGURE 12. Age Structure of Goldeye Captured in the Peace-Athabasca Delta, 1977. (Age groups comprising less than 1% of the total samples are not shown.)

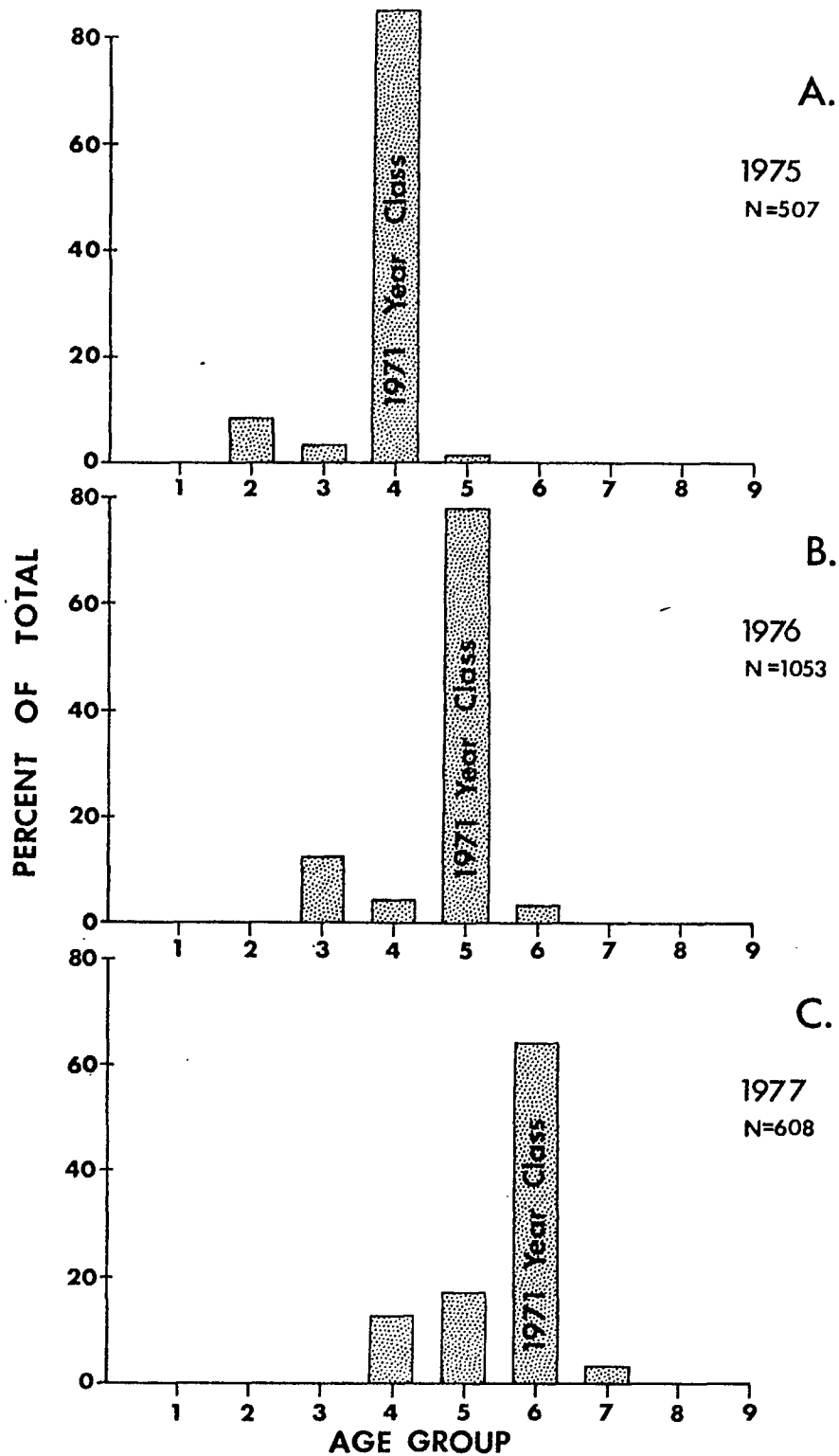


FIGURE 13. Age Structure of Goldeye Captured in the Claire-Mamawi Lakes System and Chenal des Quatre Fourches, 1975, 1976 and 1977. (Age groups comprising less than 1% of the total samples are not shown.)

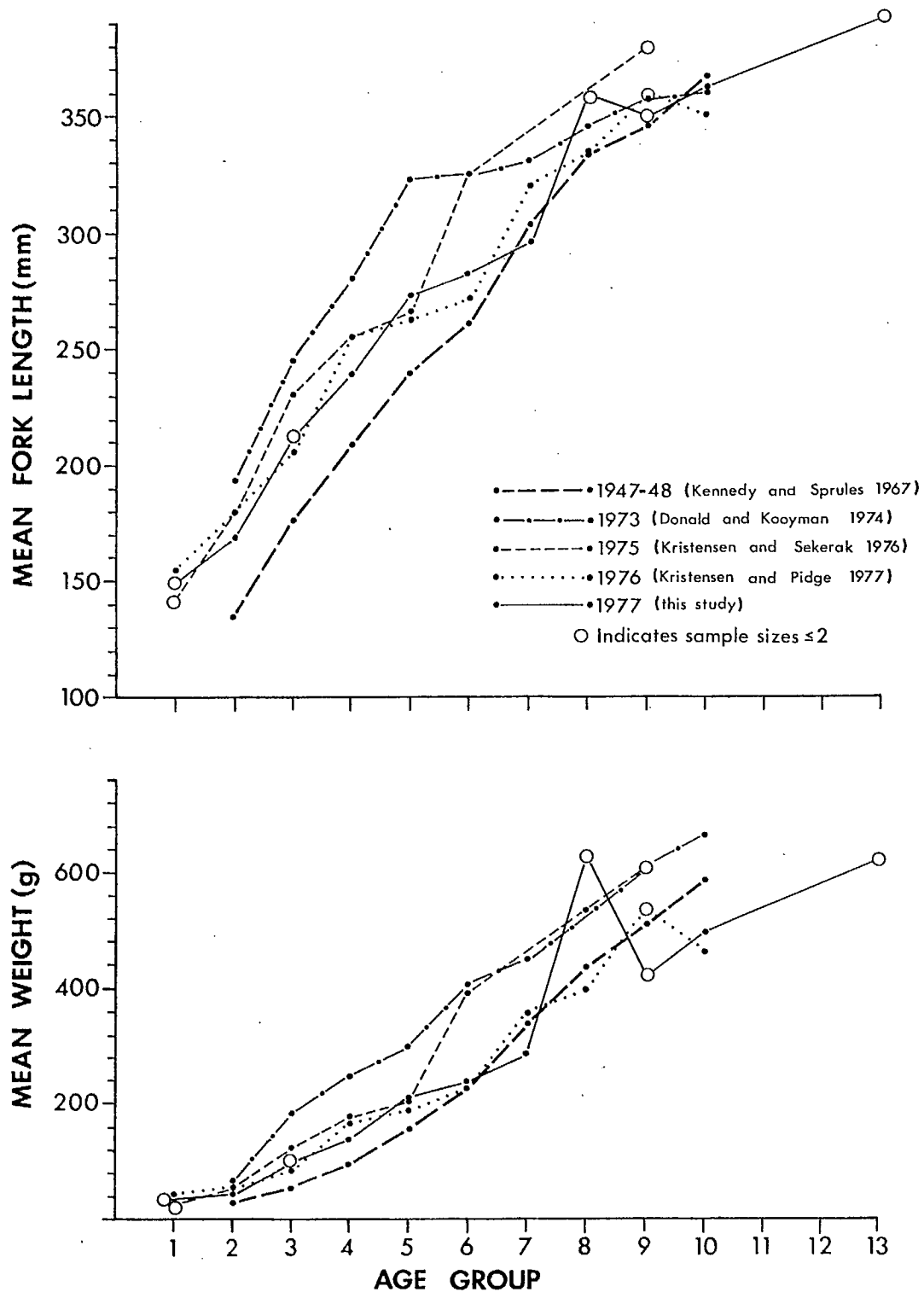


FIGURE 14. Age-Length and Age-Weight Relationships for Goldeye Captured in the Peace-Athabasca Delta. (Sampling areas combined.)

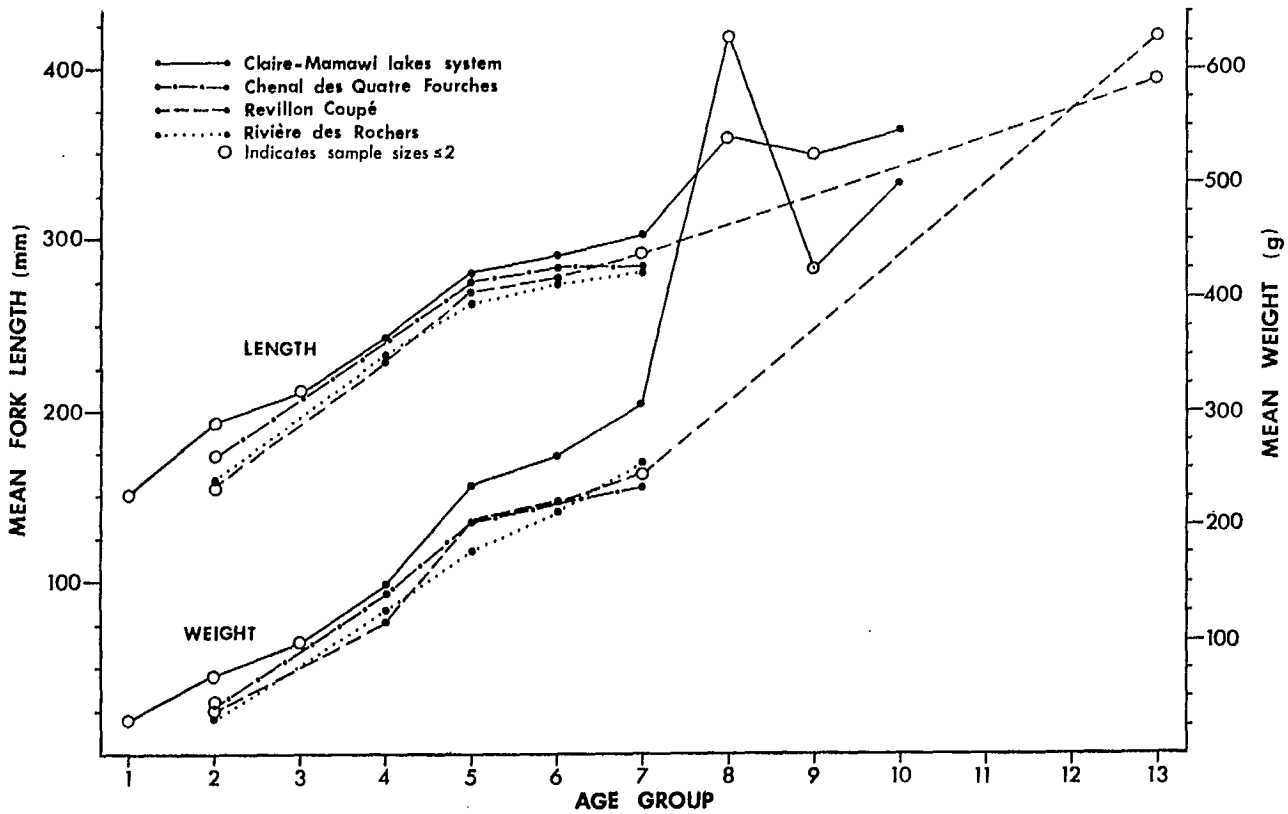


FIGURE 15. Age-Length and Age-Weight Relationships for Goldeye Captured in Four Sampling Areas within the Peace-Athabasca Delta, 1977.

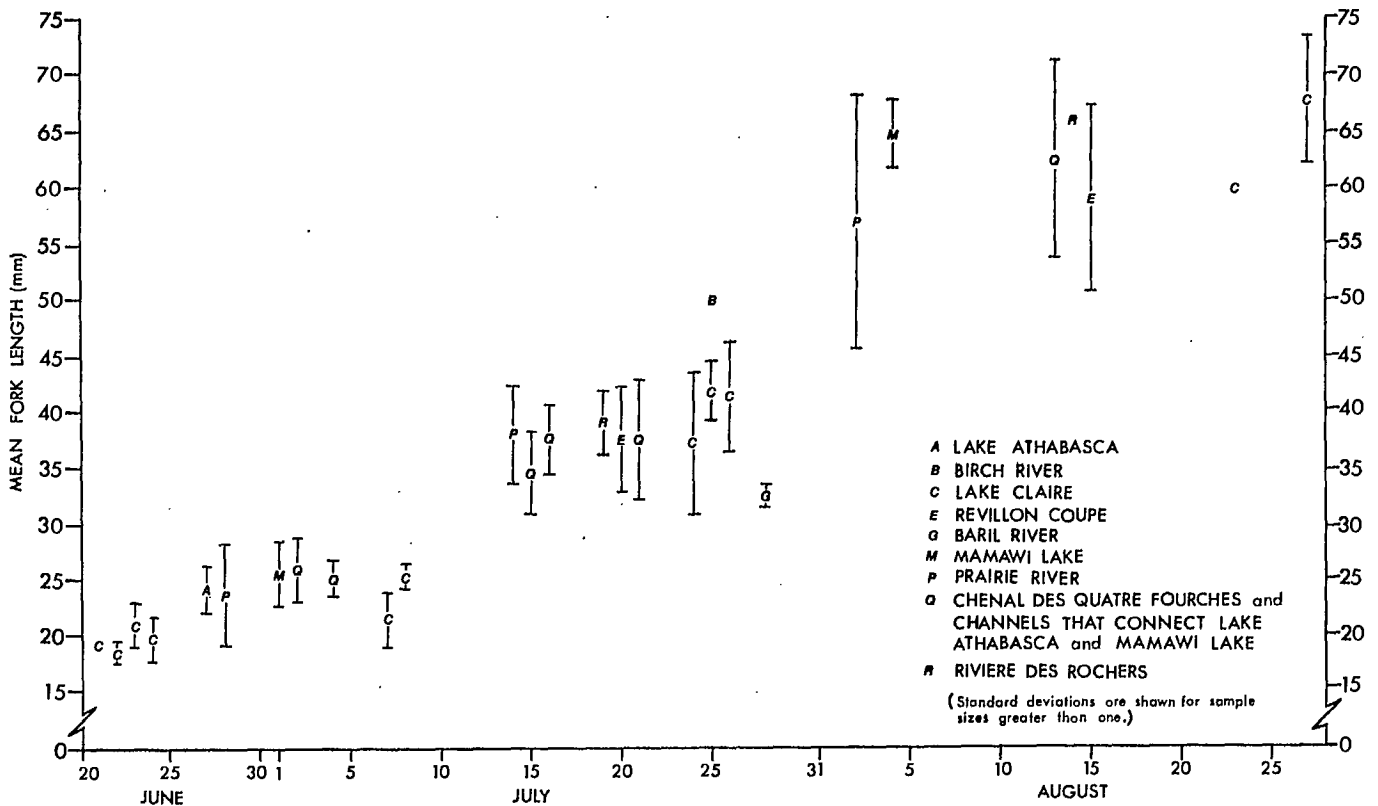


FIGURE 16. Growth of Young-of-the-Year Goldeye in Nine Waterbodies within the Peace-Athabasca Delta, 1977.

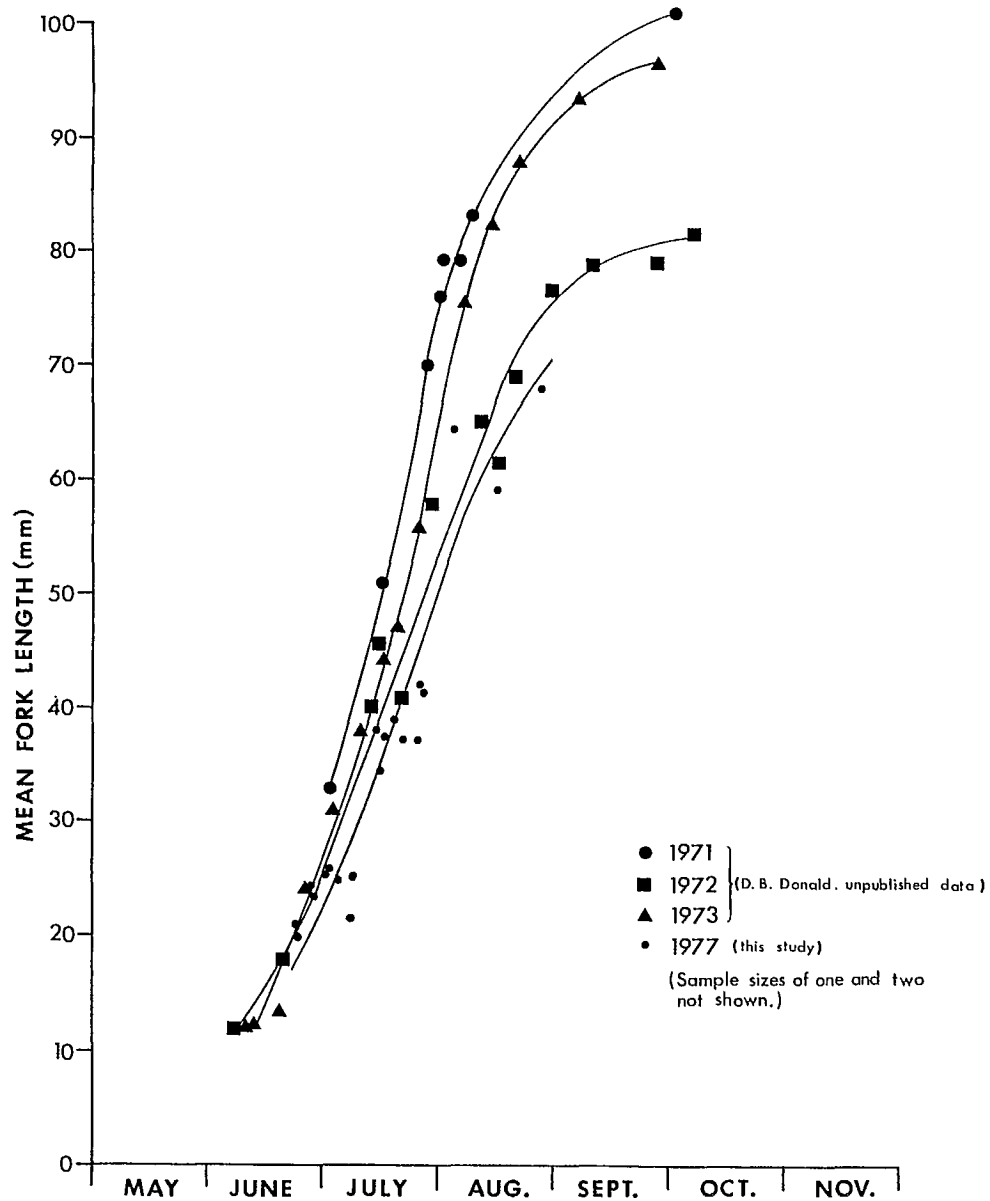


FIGURE 17. Growth of Young-of-the-Year Goldeye in the Peace-Athabasca Delta, 1971, 1972, 1973 and 1977.

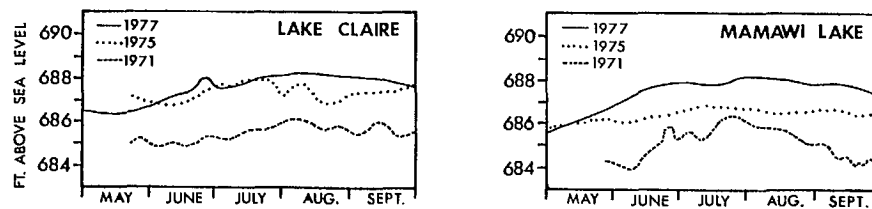


FIGURE 18. Water Levels at Lake Claire and Mamawi Lake, 1971, 1975 and 1977.

TABLE 1. Numbers of Fish Captured, Tagged and Released, and Recaptured* in 1977 by LGL Ltd. within the Peace-Athabasca Delta.

Species		Sampling Area [†]						Total
		1	2	3	4	5	6	
Goldeye	Captured	1,909	2,578	2,255	772	190	26	7,730
	Tagged and released	1,235	2,096	1,602	481	151	15	5,580
	Recaptured	12	21	7	0	0	0	40
Northern pike	Captured	223	102	100	214	12	1	652
	Tagged and released	203	90	67	132	10	1	503
	Recaptured	0	1	0	0	0	0	1
Lake whitefish	Captured	450	246	110	88	13	1	908
	Tagged and released	189	79	58	50	5	1	382
	Recaptured	1	2	0	0	0	0	3
Walleye	Captured	58	25	49	22	10	1	165
	Tagged and released	48	20	22	12	5	1	108
	Recaptured	2	1	0	0	0	0	3
Longnose sucker	Captured	46	33	76	28	0	0	183
	Tagged and released	43	32	70	24	0	0	169
	Recaptured	1	0	0	0	0	0	1
White sucker	Captured	2	3	0	1	1	0	7
	Tagged and released	2	3	0	1	1	0	7
	Recaptured	0	0	0	0	0	0	0
Burbot	Captured	29	5	26	1	0	0	61
	Tagged and released	21	4	17	1	0	0	43
	Recaptured	0	0	0	0	0	0	0
Flathead chub	Captured	5	71	83	28	1	2	190
	Tagged and released	4	52	49	15	1	2	123
	Recaptured	0	0	0	0	0	0	0
Round whitefish	Captured	2	0	0	0	0	0	2
	Tagged and released	1	0	0	0	0	0	1
	Recaptured	0	0	0	0	0	0	0
Cisco	Captured	2	6	0	0	0	0	8
	Tagged and released	0	0	0	0	0	0	0
	Recaptured	0	0	0	0	0	0	0
Total	Captured	2,726	3,069	2,699	1,154	227	31	9,906
	Tagged and released	1,746	2,376	1,885	716	173	20	6,916
	Recaptured	16	25	7	0	0	0	48

*Fish tagged in 1976 and recaptured in 1977 are not included; immediate recaptures are also not included.

†Sampling areas: 1 Rivière des Rochers
 2 Revillon Coupé
 3 Chenal des Quatre Fourches (including Quatre Fourches)
 4 Claire-Mamawi lakes system
 5 Lake Athabasca
 6 Baril Lake and River

TABLE 2. Movement of Fish Tagged and Recaptured[†] in 1977.^{††}

Location* of Tagging	Location* of Recapture	Numbers of Fish by Date of Recapture																Summary					
		May		June					July			August			September		October	November	G	NP	LW	W	LS
		G**	W	G	NP	LW	W	LS	G	NP	LW	G	NP	W	G	NP	G	NP					
<u>Inter-Waterbody Movement</u>																							
River to Lake																							
Q	CM	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-
E	CM	-	-	-	-	-	-	-	2	-	-	3	-	-	-	-	-	-	5	-	-	-	-
Q	A	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
E	A	1	-	4	-	-	1	-	-	-	-	-	-	-	-	-	-	1	5	1	-	1	-
R	A	-	-	3	-	-	2	-	-	-	-	1	2	-	-	-	-	-	4	2	-	2	-
River to River																							
Q	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	-	-	-	-
E	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	-	-	-	-
R	D	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-
E	R	2	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	5	-	-	-	-
E	Q	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
E	QF	-	-	1	-	-	-	-	3	1	-	4	-	-	2	-	-	-	10	1	-	-	-
R	QF	-	-	1	1	-	-	-	1	-	-	1	-	-	-	-	-	-	3	1	-	-	-
R	E	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Q	QF	-	-	-	-	-	-	-	2	-	1	-	-	-	2	1	-	-	4	1	1	-	-
Lake to River																							
CM	QF	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-
CM	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-
<u>Intra-Waterbody Movement</u>																							
Rivers																							
Q	Q	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
E	E	10	-	10	1	2	1	-	-	-	-	-	-	-	-	-	-	-	20	1	2	1	-
R	R	3	1	5	-	1	1	1	-	1	-	-	-	-	-	-	-	-	8	1	1	2	1
QF	QF	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	-	-	-
Lakes																							
CM	CM	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-
Total		16	1	31	2	3	5	1	10	2	1	12	2	1	5	1	5	1	79	8	4	7	1

[†] Does not include immediate recaptures.^{††} See Appendix 3 for detailed tag-recapture data.

* A = Lake Athabasca

CM = Claire-Mamawi lakes system

D = Peace River

E = Revillon Coupé

Q = Chenal des Quatre Fourches

QF = Quatre Fourches

R = Rivière des Rochers

** G = goldeye

NP = northern nike

LW = lake whitefish

W = walleye

LS = longnose sucker

40

40

40

TABLE 4. Age Frequency of Goldeye Captured in the Peace-Athabasca Delta, 1977.

Sampling Area	Age Group													Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	
Claire-Mamawi lakes system	1	2	2	72	78	320	18	2	1	3	0	0	0	499
Chenal des Quatre Fourches	0	1	0	7	27	71	3	0	0	0	0	0	0	109
Rivière des Rochers	0	3	0	34	43	201	3	0	0	0	0	0	0	284
Revillon Coupé	0	2	0	7	35	162	2	0	0	0	0	0	1	209
Total	1	8	2	120	183	754	26	2	1	3	0	0	1	1101

TABLE 5. Mean Counts of Seven Meristic Characters of Goldeye Collected from the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches, 1977.

Meristic Character	Sampling Area												P for F-value* when each character considered by itself	P for F-value* when characters considered simultaneously
	Rivière des Rochers N=43				Revillon Coupé N=40				Chenal des Quatre Fourches N=45					
	$\bar{X}^{\dagger}$	S [†]	Min.	Max.	$\bar{X}$	S	Min.	Max.	$\bar{X}$	S	Min.	Max.		
Lateral line scales	62.33	1.629	59	65	62.58	1.631	58	65	62.82	1.051	60	65	0.25 ≤ P < 0.5	0.1 ≤ P < 0.25
Scales around caudal peduncle	17.33	0.644	16	19	17.08	0.656	16	19	17.20	0.694	16	19	0.1 ≤ P < 0.25	0.1 ≤ P < 0.25
Dorsal fin rays	9.63	0.691	8	11	9.95	0.597	9	11	9.89	0.611	9	11	0.025 ≤ P < 0.05	0.025 ≤ P < 0.05
Anal fin rays	31.77	1.043	30	34	31.98	0.660	31	33	31.51	0.843	30	33	0.05 ≤ P < 0.1	0.025 ≤ P < 0.05
Gill rakers (upper arch)	5.81	0.546	5	8	5.80	0.516	5	7	5.80	0.505	5	7	P > 0.75	P > 0.75
Gill rakers (lower arch)	10.33	0.474	10	11	10.35	0.580	10	12	10.16	0.601	9	12	0.1 ≤ P < 0.25	0.1 ≤ P < 0.25
Vertebrae	55.91	0.684	54	57	55.93	0.971	54	58	55.96	0.767	54	57	P > 0.75	P > 0.75

*Obtained by conducting a stepwise multiple discriminant analysis, in which the meristic characters of goldeye in the three rivers were compared.

[†] $\bar{X}$ = mean

S = standard deviation

TABLE 6. Ranges in Counts of Seven Meristic Characters of Goldeye Cited in Other Literature Sources.

Meristic Character	Range		Comments	Source
	Minimum	Maximum		
Lateral line scales	58	62	includes all pored scales	McPhail and Lindsey (1970)
	55	61	counts end at caudal flexure	Paetz and Nelson (1970)
	57	62	counts end at caudal flexure	Scott and Crossman (1973)
Scales around caudal peduncle	15	17		Paetz and Nelson (1970)
Dorsal fin rays	9	10		McPhail and Lindsey (1970), Paetz and Nelson (1970), Scott and Crossman (1973)
Anal fin rays	29	35		McPhail and Lindsey (1970)
	30	33		Paetz and Nelson (1970)
	29	34		Scott and Crossman (1973)
Gill rakers (upper arch)	6	7		McPhail and Lindsey (1970), Scott and Crossman (1973)
	5	6		Paetz and Nelson (1970)
Gill rakers (lower arch)	10	11		McPhail and Lindsey (1970)
	9	10		Paetz and Nelson (1970), Scott and Crossman (1973)
Vertebrae	58	61		McPhail and Lindsey (1970)
	56	61	includes last whole centrum	Scott and Crossman (1973)

TABLE 7. Correlation Matrix* of Age and Seven Meristic Characters of Goldeye Collected in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches, 1977.

Variable	Variable							
	Age	Lateral Line Scales	Caudal Peduncle Scales	Dorsal Fin Rays	Anal Fin Rays	Gill Rakers (Upper Arch)	Gill Rakers (Lower Arch)	Vertebrae
Age	1.000	0.069	0.042	-0.022	0.003	-0.019	-0.124	0.197
Lateral line scales		1.000	0.137	-0.157	0.037	-0.162	-0.022	0.364
Caudal peduncle scales			1.000	-0.152	0.103	0.093	-0.002	0.056
Dorsal fin rays				1.000	0.043	-0.012	0.116	0.021
Anal fin rays					1.000	-0.111	-0.048	0.230
Gill rakers (upper arch)						1.000	0.077	-0.071
Gill rakers (lower arch)							1.000	-0.009
Vertebrae								1.000

*Obtained by conducting a stepwise multiple regression analysis.

TABLE 8. Population Estimates of Five Species of Fish in the Peace-Athabasca Delta, 31 May to 21 October 1976 and 11 May to 22 August 1977.

Species	1976		1977		Comments
	Population Estimate	95% Confidence Limits	Population Estimate	95% Confidence Limits	
Goldeye	1,153,772 1,169,002	972,613 - 1,367,820 -	541,030 545,466	395,368 - 739,537 -	excluding age groups 0, 1, 2 excluding age group 0
Lake whitefish	17,167	11,639 - 26,411	24,288	9,913 - 60,719	excluding fish <200 mm fork length
Northern pike	16,309	14,013 - 18,972	86,767	26,293 - 157,758	excluding fish <220 mm fork length
Walleye	9,676	4,805 - 21,166	2,792	1,139 - 6,979	excluding fish <200 mm fork length
Longnose sucker	-	-	7,483	2,268 - 13,605	excluding fish <200 mm fork length

TABLE 9. Estimated Numbers of Goldeye by Age Group in the Peace-Athabasca Delta, 31 May to 21 October 1976 and 11 May to 22 August 1977. (Based on their 1976 and 1977 age compositions.)

Age Group	1976		1977	
	Year Class	Estimated No.	Year Class	Estimated No.
1	1975	9,677	1976	496
2	1974	5,806	1975	3,963
3	1973	139,351	1974	991
4	1972	77,901	1973	59,451
5	1971	897,557	1972	90,663
6	1970	32,419	1971	373,553
7	1969	2,420	1970	12,881
8	1968	1,452	1969	991
9	1967	484	1968	495
10	1966	1,935	1967	1,486
11	1965	0	1966	0
12	1964	0	1965	0
13	1963	0	1964	496
Total		1,169,002		545,466

TABLE 10. Sex Ratio[†] and Age at Sexual Maturity of Goldeye Captured in the Peace-Athabasca Delta, 1977.

Sampling Area	Age Group																Total	
	2		4		5		6		7		8		10		13		Total	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Claire-Manawí lakes system																		
Sample size	1	0	16	10	25	4	67	83	0	4	1	0	2	1	0	0	112	102
Sex ratio (%)	100.0	0	61.5	38.5	86.2	13.8	44.7	55.3	0	100.0	100.0	0	66.7	33.3	-	-	52.3	47.7
% mature ^{††}	0	-	6.2	0	44.0	0	71.6	4.8	-	0	100.0	-	100.0	100.0	-	-	56.3	4.9
Chenal des Quatre Fourches																		
Sample size	0	1	4	2	18	9	39	31	1	2	0	0	0	0	0	0	62	45
Sex ratio (%)	0	100.0	66.7	33.3	66.7	33.3	55.7	44.3	33.3	66.7	-	-	-	-	-	-	57.9	42.1
% mature ^{††}	-	0	25.0	0	94.4	0	84.6	3.2	0	0	-	-	-	-	-	-	82.3	2.2
Rivière des Rochers																		
Sample size	2	1	20	14	29	14	88	107	2	1	0	0	0	0	0	0	141	137
Sex ratio (%)	66.7	33.3	58.8	41.2	67.4	32.6	45.1	54.9	66.7	33.3	-	-	-	-	-	-	50.7	49.3
% mature ^{††}	0	0	15.0	0	44.8	0	47.7	1.9	50.0	0	-	-	-	-	-	-	41.8	1.5
Revillon Coupé																		
Sample size	0	2	5	2	21	15	81	77	0	2	0	0	0	0	0	1	107	99
Sex ratio (%)	0	100.0	71.4	28.6	58.3	41.7	51.3	48.7	0	100.0	-	-	-	-	0	100.0	51.9	48.1
% mature ^{††}	-	0	0	0	81.0	0	86.4	5.2	-	0	-	-	-	-	-	100.0	81.3	5.1
Sampling areas combined																		
Sample size	3	4	45	28	93	42	275	298	3	9	1	0	2	1	0	1	422	383
Sex ratio (%)	42.9	57.1	61.6	38.4	68.9	31.1	48.0	52.0	25.0	75.0	100.0	0	66.7	33.3	0	100.0	52.4	47.6
% mature ^{††}	0	0	11.1	0	62.4	0	70.2	3.7	33.3	0	100.0	-	100.0	100.0	-	100.0	61.6	3.4

[†]Based only on those fish for which age and state of sexual maturity were determined.^{††}Mature males or males approaching their first year of sexual maturity were combined because it was often difficult to distinguish between the two categories (testes are convoluted for both categories).

TABLE 11. Number of Female Goldeye Collected in 1977 that Would Mature in 1978.

Sampling Area	No. Females Collected	% That Would Mature in 1978
Claire-Mamawi lakes system	102	19.6
Chenal des Quatre Fourches	45	0
Rivière des Rochers	137	0
Revillon Coupé	99	4
Sampling areas combined	383	6.3

TABLE 12. Fecundity and Related Statistics of Twelve Mature Goldeye Collected in the Peace-Athabasca Delta, 1977.

Capture Location*	Weight (g)	Fork Length (mm)	Age	Total No. of Eggs	Mean Egg Diameter (mm) †
Q11	275	301	6	2260	1.6
C17	265	299	6	2460	1.9
C19	330	310	6	3270	1.7
R11	240	286	6	3510	1.7
R27	340	312	6	3580	1.9
C13	250	287	6	2327	-
C16	300	309	6	2760	1.9
E01	315	320	-	5310	1.9
H01	255	289	6	3070	1.9
E01	260	289	6	3450	1.7
H10	320	313	6	2570	1.8
R26	255	296	-	3500	1.9

*Coded locations are shown in Figure 3.

†Each mean is based on the diameters of 10 eggs (measured after ovaries had been preserved in 10% formalin).

TABLE 13. Mean Catch Per Unit Effort for Young-of-the-Year Goldeye in the Peace-Athabasca Delta, 1977.

Sampling Area	Date	No. of Sampling Sites	Catch Per Unit Effort*	Standard Deviation	Variance
Lake Claire	June 21-24	46	0.37	0.95	0.90
	July 5 - 8	45	0.38	0.83	0.69
	July 24-27	48	1.08	5.07	25.70
	Aug. 23-27	43	0.33	1.69	2.84
Mamawi Lake	June 11	10	0.00	0.00	0.00
	July 1	10	0.40	0.70	0.49
	July 15	10	0.00	0.00	0.00
	July 23	4	0.00	0.00	0.00
	Aug. 4	10	0.30	0.67	0.45
Prairie River and tributaries	June 12	9	0.00	0.00	0.00
	June 28	10	0.90	1.85	3.42
	July 14	9	0.89	1.54	2.37
	Aug. 2	9	0.22	0.44	0.19
Birch River	June 22	5	0.00	0.00	0.00
	July 7	5	0.00	0.00	0.00
	July 25	5	0.20	0.45	0.20
	Aug. 24	3	0.00	0.00	0.00
	Aug. 25	3	0.00	0.00	0.00
Rivière des Rochers	July 19	15	1.13	2.61	6.81
	Aug. 14	14	0.07	0.27	0.07
Revillon Coupé	July 20	11	4.36	11.57	133.86
	Aug. 15	10	1.80	5.35	28.62
Chenal des Quatre Fourches	June 14	9	0.00	0.00	0.00
	July 4	10	0.60	0.84	0.71
	July 21	10	0.70	0.67	0.45
	Aug. 13	10	0.20	0.42	0.18
Channels that connect Lake Athabasca and Mamawi Lake	June 13-18	11	0.00	0.00	0.00
	July 2 - 3	11	1.18	2.75	7.56
	July 15-16	11	0.64	1.03	1.05
	Aug. 3	11	0.00	0.00	0.00
Lake Athabasca	June 27	12	0.25	0.62	0.38
	July 10-13	12	0.08	0.29	0.08
	Aug. 18-20	11	0.00	0.00	0.00
Baril River	July 28	8	0.25	0.71	0.50

*Catch per unit effort = number of goldeye captured per two-minute trawl.

TABLL 14. Correlations[†] between Catch Rates of 14 Species of Fish Captured in Trawl Nets in the Peace-Athabasca Delta^{††}, 1977.

Species	Species ^{†††}													
	Goldeye	Northern pike	Lake whitefish	Walleye	Longnose sucker	Ninespine stickleback	Trout-perch	Emerald shiner	Spottail shiner	Flathead chub	Burbot	Brook stickleback	Cisco	Lake chub
Goldeye	0.00	-2.00*	0.26	4.84***	2.31*	2.55*	3.04**	1.27	1.22	0.49	0.62	-0.49	1.43	-1.10
Northern pike		0.00	1.29	0.13	3.33***	-1.75(*)	2.90**	-1.04	-1.82(*)	5.05***	-0.53	-0.20	-0.60	-0.45
Lake whitefish			0.00	0.70	-0.40	-2.00*	1.33	2.14*	-0.16	-0.65	-0.37	-0.14	-0.42	-0.31
Walleye				0.00	3.83***	-2.71**	7.15***	2.28*	-1.41	-1.20	1.03	-0.47	-0.66	0.17
Longnose sucker					0.00	1.24	-3.21**	-5.05***	-1.31	2.27*	0.94	-0.48	0.15	-1.07
Ninespine stickleback						0.00	-4.09***	-1.59	5.79***	3.75***	-2.61**	-0.97	1.50	-1.53
Trout-perch							0.00	4.47***	-1.78(*)	0.68	-0.18	-0.60	-1.05	0.33
Emerald shiner								0.00	6.18***	-1.14	-1.93(*)	-1.57	-2.05*	-0.59
Spottail shiner									0.00	2.18*	-1.29	-0.75	2.15*	-0.77
Flathead chub										0.00	-0.61	-0.23	-0.69	-0.51
Burbot											0.00	-0.13	-0.39	-0.29
Brook stickleback												0.00	-0.15	-0.11
Cisco													0.00	-0.33
Lake chub														0.00

†Numbers shown are t-values associated with Spearman rank correlation coefficients;

statistical significance of t-values is as follows: (*) 0.05 < P < 0.1
 * 0.01 < P < 0.05
 ** 0.001 < P < 0.01
 *** P < 0.001

††Lake and river sampling sites have been combined.

†††Only Y-O-Y for goldeye, northern pike, lake whitefish, walleye, longnose sucker and burbot;
 other species include Y-O-Y, juveniles and adults.

TABLE 15. Correlations[†] between Catch Rates of 14 Species of Fish Captured in Trawl Nets and Dominant Shoreline Vegetation^{††} at Sampling Sites.^{†††}

Fish Species ^{†††}	Shoreline Vegetation Dominated By											
	<i>Alnus tenuifolia</i>	<i>Betula papyrifera</i>	<i>Calamagrostis</i> sp.	<i>Carex</i> sp.	<i>Cornus stolonifera</i>	<i>Equisetum</i> sp.	<i>Juncus</i> sp.	<i>Phragmites communis</i>	<i>Potamogeton</i> sp.	<i>Salix</i> spp.	<i>Scirpus validus</i>	<i>Typha latifolia</i>
Goldeye	0.62	0.18	-0.75	-0.36	-0.98	0.35	1.91 ^(*)	-0.42	-1.50	0.46	-0.77	-0.25
Northern pike	-0.57	-0.40	-1.19	-1.13	2.22*	-0.76	-1.20	-0.53	0.44	3.08**	-0.54	-0.49
Lake whitefish	-0.40	-0.28	-0.83	0.59	-0.28	1.09	-1.31	-0.37	-0.91	0.55	1.39	-0.34
Walleye	-1.35	2.68**	0.38	0.63	-0.95	-1.87 ^(*)	0.47	-1.26	1.09	-0.55	0.94	-0.01
Longnose sucker	-0.56	2.62**	-1.99*	-1.31	0.53	2.30*	-4.29***	0.79	3.38***	1.04	0.25	-1.18
Ninespine stickleback	-0.08	-1.40	0.07	0.96	-1.96 ^(*)	0.40	-0.35	1.35	-0.45	-0.30	0.46	0.24
Trout-perch	-1.09	-1.21	0.94	1.53	-1.21	-1.06	4.93***	-0.93	-1.87 ^(*)	-2.46*	-0.01	0.29
Emerald shiner	-0.74	1.20	-0.72	0.46	-1.26	-3.62***	7.14***	-0.40	-1.41	-2.26*	0.94	-0.05
Spottail shiner	1.76 ^(*)	-0.43	-0.46	-0.43	-0.36	4.52***	0.82	-0.71	-3.44***	-0.22	-1.90 ^(*)	0.50
Flathead chub	-0.65	1.80 ^(*)	-1.37	-0.40	-0.46	1.70 ^(*)	-1.00	-0.61	-1.50	2.44*	-0.86	-0.56
Burbot	2.46*	-0.26	-0.78	-0.74	-0.26	1.30	-1.22	-0.35	1.78 ^(*)	-0.02	-0.90	-0.32
Brook stickleback	7.65***	-0.10	-0.29	-0.28	-0.10	-0.37	-0.46	-0.13	-0.32	-0.64	-0.34	-0.12
Cisco	2.02*	-0.30	-0.88	0.45	-0.30	4.05***	-1.39	-0.39	-0.97	-0.42	-1.02	-0.36
Lake chub	-0.31	-0.22	-0.66	1.12	4.49***	0.52	0.15	-0.29	-0.72	-0.43	-0.76	-0.27

†Numbers shown are t-values associated with Spearman rank correlation coefficients;

statistical significance of t-values is as follows: (*) 0.05 < P < 0.1

* 0.01 < P < 0.05

** 0.001 < P < 0.01

*** P < 0.001

††Vegetation ordinally arranged as follows: not present = 0; present = 1.

†††Lake and river sampling sites have been combined.

††††Only Y-O-Y for goldeye, northern pike, lake whitefish, walleye, longnose sucker and burbot; other species include Y-O-Y, juveniles and adults.

TABLE 16. Mean Catch Per Unit Effort* for Fish Captured in Trawl Nets in Relation to Several Selected Variables.

Variable Measured	Goldeye	Northern pike	Lake whitefish	Walleye	Longnose sucker	Ninespine stickleback	Trout- perch	Emerald shiner	Spottail shiner	Flathead chub	Burbot	Brook stickleback	Cisco	Lake chub
Substratum material at sampling sites:														
1. Clay, N = 109	0.72	0.05	0.02	0.61	1.51	41.73	2.71	85.05	6.02	0.69	0.02	0.01	0.31	0.01
2. Sand, N = 21	0.27	0.04	0.00	0.92	1.22	4.19	6.50	35.77	0.98	0.02	0.02	0.00	0.00	0.01
3. Rock, N = 1	0.25	0.00	0.00	1.00	1.25	0.25	0.00	49.25	1.00	0.25	0.00	0.00	0.00	0.00
Substratum hardness at sampling sites:														
1. Soft, N = 71	0.43	0.06	0.02	0.50	1.30	67.68	2.33	93.90	6.61	1.02	0.02	0.01	0.13	0.02
2. Medium, N = 26	1.29	0.02	0.02	0.84	1.72	5.01	4.63	75.41	4.83	0.11	0.03	0.00	0.00	0.00
3. Hard, N = 44	0.50	0.02	0.00	0.75	1.23	5.01	3.60	40.47	2.22	0.02	0.01	0.00	0.56	0.01
Wind direction at lake sampling sites:														
1. Away from shoreline. N = 50	0.14	0.06	0.02	1.20	2.08	13.88	1.60	49.28	0.54	0.02	0.04	0.00	0.00	0.00
2. Nil in relation to shore- line, N = 79	0.24	0.00	0.01	0.89	0.52	48.70	5.03	73.01	1.65	0.11	0.01	0.00	0.00	0.03
3. Toward shoreline, N = 119	0.71	0.03	0.00	0.69	0.97	5.32	5.07	80.33	2.34	0.02	0.00	0.00	0.00	0.00
Sampling site in relation to waterbody type:														
1. Lake, N = 74	0.45	0.03	0.01	0.85	1.05	20.86	4.35	71.74	1.75	0.05	0.01	0.00	0.00	0.01
2. Stream or river, N = 71	0.66	0.08	0.03	0.48	1.83	14.84	3.18	52.84	7.47	1.37	0.03	0.00	0.34	0.92

*Catch Per Unit Effort = number of fish captured per two-minute trawl.

TABLE 17. Correlations[†] between Catch Rates of 14 Species of Fish Captured in Trawl Nets and Several Selected Parameters^{††} at Sampling Sites.^{†††}

Species ^{††††}	Water Temp (°C)	Substratum Material	Substratum Hardness	Wind Direction at Lake Sampling Sites	Waterbody Type
Goldeye	1.43	0.04	-0.49	2.41*	0.71
Northern pike	0.00	-0.13	-1.04	-0.66	1.29
Lake whitefish	0.04	-1.41	-1.86(*)	-1.44	1.61
Walleye	4.02***	2.81**	3.03**	-0.36	-4.64***
Longnose sucker	1.15	-0.32	0.95	0.55	1.81(*)
Ninespine stickleback	-0.23	0.24	-0.15	0.28	1.38
Trout-perch	2.75**	3.01**	1.56	2.43*	-3.65***
Emerald shiner	-0.77	1.66(*)	2.91**	1.98*	-5.17***
Spottail shiner	-3.82***	-2.95**	-2.94**	0.93	5.13***
Flathead chub	-1.08	-0.59	-2.30*	-0.48	2.34*
Burbot	-2.09*	-0.38	-1.24	-1.45	1.31
Brook stickleback	0.39	-0.50	-0.96	0.00	1.06
Cisco	-0.32	-1.50	-0.67	0.00	3.26**
Lake chub	-1.52	0.00	-1.17	-0.75	0.59

†Numbers shown are t-values associated with Spearman rank correlation coefficients; statistical significance of t-values is as follows:

(*) $0.05 < P < 0.1$
 * $0.01 < P < 0.05$
 ** $0.001 < P < 0.01$
 *** $P < 0.001$

††See Appendix 7 for explanation of how some parameter categories were ordinally arranged.

†††Unless otherwise noted, lake and river sampling sites have been combined.

††††Only Y-O-Y for goldeye, northern pike, lake whitefish, walleye, longnose sucker and burbot; other species include Y-O-Y, juveniles and adults.

TABLE 18. Estimated Numbers of Young-of-the-Year Goldeye in Lake Claire and Mamawi Lake, 1971, 1975 and 1977. (Based on sampling conducted from 10 July to 18 August.)

	Surface Area (m ²) Within 700m of Shore ("A")*	Surface Area (m ²) in One Two-Minute Trawl (Nets Combined)	Possible No. of Sample Trawls in "A"	Mean No. of Goldeye Captured Per Two-Minute Trawl	Estimated No. of Goldeye In Waterbody	
Lake Claire 1971	360,742,000.	150	2,405,000	2.87	6,902,000	
1975	360,742,000	387	932,000	1.90 [†]	1,771,000	
1977	360,742,000	328	1,100,000	1.33	1,463,000	
Mamawi Lake 1971	79,856,000	150	532,000	0.20	106,000	Σ
1975	79,856,000	387	206,000	0.20 [†]	41,000	
1977	79,856,000	328	243,000	0.30	73,000	
Total						
1971					7,008,000	
1975					1,812,000	
1977					1,536,000	

*Recalculated in 1977 and differ from areas of Fernet (1971) and Kristensen and Sekerak (1976).

†Recalculated in 1977 on the basis of trawls conducted from 10 July to 18 August 1975.

APPENDIX 1. Daily Mean Catch Per Unit Effort[†] for Fish Captured in the Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches,
11 May - 15 June 1977.

May																					
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	

APPENDIX 1. (cont'd)

June														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
<u>Rivière des Rochers</u>														
			*		*		*	*						
Goldeye	8.2	0.1	5.0		161.3		36.7		3.4	10.3	2.1	8.2	5.7	10.3
Lake whitefish	1.0	0.1	0.3		7.9		8.5		3.0	1.1	2.2	3.4	1.5	2.0
Northern pike	1.2	0.1	0.4		4.1		3.1		1.1	0.3	0.3	0.5	0.1	0.5
Walleye	0.1	0.0	0.0		1.4		0.6		0.0	0.0	0.7	1.4	0.1	0.2
Flathead chub	0.0	0.0	0.0		0.0		0.0		0.0	0.0	0.0	0.0	0.0	0.0
Longnose sucker	0.0	0.0	0.5		0.0		0.0		0.0	1.2	0.0	0.2	0.3	0.0
Burbot	0.0	0.0	0.0		0.0		0.0		0.0	0.2	0.4	0.5	0.0	0.0
<u>Revillon Coupé</u>														
							*	*			*			
Goldeye	32.5	13.3	24.1	65.9	23.5	8.4	0.4		0.8	0.0		0.0	0.2	0.6
Lake whitefish	2.7	2.1	6.8	14.8	6.9	0.9	0.4		0.0	0.0		0.0	0.0	0.9
Northern pike	1.0	0.0	2.4	2.1	1.6	0.6	0.2		0.0	0.0		0.0	0.0	0.0
Walleye	0.0	0.0	0.0	0.0	0.2	1.3	0.2		0.0	0.4		0.0	0.0	0.0
Flathead chub	0.0	0.0	0.0	0.0	0.2	0.2	0.0		0.0	0.2		0.2	0.4	0.0
Longnose sucker	0.2	0.0	0.3	0.0	0.4	0.2	0.2		0.0	0.4		0.6	0.1	0.6
Burbot	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.2	0.0	0.0
<u>Chenal des Quatre Fourches</u>														
							*	*						
Goldeye	7.0	26.9	24.7	24.5	36.3	19.1	0.2		0.1	0.1	0.2	0.6	0.3	0.3
Lake whitefish	0.2	1.6	1.4	0.7	1.2	1.8	0.2		0.2	0.1	0.0	0.0	0.0	0.1
Northern pike	0.3	1.5	0.0	1.1	0.1	2.0	0.2		0.1	0.0	0.0	0.0	0.0	0.1
Walleye	0.4	0.4	1.0	1.1	0.1	0.2	0.0		0.0	0.0	0.1	0.0	0.0	0.0
Flathead chub	0.3	0.0	0.0	0.0	0.0	0.2	0.0		0.2	0.2	0.0	0.1	0.0	0.2
Longnose sucker	0.2	0.0	0.0	0.0	0.0	0.2	0.2		0.1	0.0	0.0	0.2	0.0	0.1
Burbot	0.0	0.0	0.3	0.2	0.1	0.2	0.2		0.0	0.0	0.0	0.0	0.0	0.0

†Catch per unit effort = number of fish captured per 45.7-metre net per hour.

*Fishing not conducted.

APPENDIX 2 . Hydrological Data for the Little Rapids Weir.

Date	Mean Water Level (ft)		Hydraulic Head Over Weir (ft)	Surface Water Velocity (ft/sec)	
	SE of Weir	NW of Weir		Over Weir	Through Fishway
May 18	686.2	685.4	0.8	3.4	-
19	686.0	685.3	0.7	3.2	-
20	686.1	685.2	0.9	4.2	-
21	685.9	684.8	1.1	4.2	-
22	685.8	684.3	1.5	3.9	4.3
23	685.9	684.1	1.8	4.1	5.3
24	686.2	684.1	2.1	4.7	5.5
25	685.8	683.8	2.0	5.2	5.8
26	-	-	-	-	-
27	685.8	683.2	2.6	5.4	6.1
28	686.2	683.2	3.0	7.0	6.7
29	686.9	683.4	3.5	7.0	7.9
30	686.5	683.1	3.4	5.8	7.5
31	686.2	683.0	3.2	7.0	7.6
June 1	686.2	682.8	3.4	6.0	7.9
2	686.8	683.3	3.5	7.0	8.0
3	686.0	683.1	2.9	5.2	6.6
4	686.2	683.8	2.4	4.8	6.8
5	686.1	684.4	1.7	4.0	4.4
6	686.3	685.1	1.2	3.7	4.1
7	686.8	685.8	1.0	4.1	3.5
8	-	-	-	-	-
9	-	-	-	-	-
10	686.8	686.2	0.6	3.8	3.7
11	687.0	685.9	1.1	5.4	4.0
12	687.1	685.7	1.4	5.9	6.0
13	686.8	685.6	1.2	5.3	5.2
14	687.1	685.9	1.2	5.4	5.1
15	687.3	686.7	0.6	3.8	3.0

APPENDIX 3. Recovery Periods for Fish Tagged and Recaptured[†] in 1977.

Location* of Tagging	Location* of Recapture	Date of Tagging	Date of Recapture	Recovery Period (Days)	Species
<u>Inter-Waterbody Movement</u>					
River to Lake					
Q	CM	5 June	15 July	40	goldeye
E	CM	27 May	14 July	48	goldeye
E	CM	14 May	29 July	76	goldeye
E	CM	28 May	4 Aug.	68	goldeye
E	CM	27 May	4 Aug.	69	goldeye
E	CM	14 May	10 Aug.	88	goldeye
Q	A	4 June	21 June	17	goldeye
E	A	15 May	25 May	10	goldeye
E	A	26 May	8 June	13	goldeye
E	A	14 May	8 June	25	goldeye
E	A	14 May	15 June	32	goldeye
E	A	6 June	16 June	10	walleye
E	A	26 May	16 June	21	goldeye
E	A	27 May	3 Nov.	160	northern pike
R	A	29 May	14 June	16	walleye
R	A	27 May	18 June	22	goldeye
R	A	25 May	18 June	24	goldeye
R	A	22 May	18 June	27	goldeye
R	A	20 May	21 June	32	walleye
R	A	25 May	15 Aug.	82	goldeye
R	A	27 May	15 Aug.	80	northern pike
R	A	18 May	21 Aug.	95	northern pike
River to River					
Q	D	3 June	19 Oct.	138	goldeye
Q	D	1 June	24 Oct.	145	goldeye
E	D	13 May	16 Oct.	156	goldeye
E	D	4 June	31 Oct.	149	goldeye
R	D	22 May	7 Aug.	77	walleye
E	R	14 May	21 May	7	goldeye
E	R	16 May	21 May	5	goldeye
E	R	4 June	11 June	7	goldeye
E	R	13 May	11 June	29	goldeye
E	R	26 May	10 July	45	goldeye
E	Q	29 May	4 June	6	goldeye
E	Q	30 May	5 June	6	goldeye

APPENDIX 3. (cont'd)

Location* of Tagging	Location* of Recapture	Date of Tagging	Date of Recapture	Recovery Period (Days)	Species
E	QF	29 May	18 June	20	goldeye
E	QF	5 June	2 July	27	goldeye
E	QF	28 May	13 July	46	goldeye
E	QF	26 May	18 July	53	northern pike
E	QF	26 May	28 July	63	goldeye
E	QF	30 May	14 Aug.	76	goldeye
E	QF	3 June	15 Aug.	73	goldeye
E	QF	29 May	17 Aug.	80	goldeye
E	QF	26 May	19 Aug.	85	goldeye
E	QF	14 May	7 Sept.	116	goldeye
E	QF	30 May	16 Sept.	109	goldeye
R	QF	20 May	12 June	23	northern pike
R	QF	16 May	30 June	45	goldeye
R	QF	29 May	3 July	35	goldeye
R	QF	5 June	27 Aug.	83	goldeye
R	E	25 May	1 June	7	goldeye
Q	QF	31 May	13 July	43	goldeye
Q	QF	5 June	13 July	38	lake whitefish
Q	QF	5 June	19 July	44	goldeye
Q	QF	5 June	1 Sept.	88	goldeye
Q	QF	22 July	1 Sept.	41	northern pike
Q	QF	3 June	20 Sept.	109	goldeye
Lake to River					
CM	QF	22 Aug.	1 Sept.	10	goldeye
CM	D	22 Aug.	18 Oct.	57	goldeye
Intra-Waterbody Movement					
Rivers					
Q	Q	2 June	10 June	8	goldeye
E	E	14 May	16 May	2	goldeye
E	E	14 May	16 May	2	goldeye
E	E	14 May	16 May	2	goldeye
E	E	14 May	16 May	2	goldeye
E	E	13 May	23 May	10	goldeye
E	E	14 May	25 May	11	goldeye
E	E	15 May	26 May	11	goldeye
E	E	15 May	26 May	11	goldeye
E	E	16 May	27 May	11	goldeye
E	E	28 May	29 May	1	goldeye

APPENDIX 3. (cont'd)

Location* of Tagging	Location* of Recapture	Date of Tagging	Date of Recapture	Recovery Period (Days)	Species
E	E	1 June	3 June	2	goldeye
E	E	27 May	4 June	8	goldeye
E	E	29 May	5 June	7	goldeye
E	E	3 June	5 June	2	northern pike
E	E	1 June	6 June	5	lake whitefish
E	E	26 May	6 June	11	goldeye
E	E	4 June	6 June	2	goldeye
E	E	27 May	6 June	10	goldeye
E	E	5 June	6 June	1	goldeye
E	E	30 May	6 June	7	goldeye
E	E	16 May	7 June	22	walleye
E	E	27 May	10 June	14	goldeye
E	E	30 May	15 June	16	lake whitefish
E	E	4 June	15 June	11	goldeye
R	R	16 May	27 May	11	goldeye
R	R	22 May	27 May	5	goldeye
R	R	22 May	27 May	5	goldeye
R	R	20 May	31 May	11	walleye
R	R	16 May	5 June	20	goldeye
R	R	24 May	5 June	12	goldeye
R	R	20 May	5 June	16	goldeye
R	R	22 May	5 June	14	goldeye
R	R	23 May	11 June	19	longnose sucker
R	R	6 June	12 June	6	lake whitefish
R	R	29 May	13 June	15	walleye
R	R	13 May	14 June	32	goldeye
R	R	29 May	31 July	63	northern pike
QF	QF	30 June	8 Aug.	39	goldeye
QF	QF	30 July	20 Aug.	21	goldeye
Lakes					
CM	CM	9 Aug.	23 Aug.	14	goldeye

+ Does not include immediate recaptures.

* A = Lake Athabasca

CM = Claire-Mamawi lakes system

D = Peace River

E = Revillon Coupé

Q = Chenal des Quatre Fourches

QF = Quatre Fourches

R = Rivière des Rochers

APPENDIX 4. Mean Catch Per Unit Effort* for Fish Captured in Trawl Nets in Relation to Shoreline Vegetation at Lake Sampling Sites.

Vegetation Complex ⁺	Goldeye ⁺⁺	Northern pike	Lake whitefish	Walleye	Longnose sucker	Ninespine stickleback	Trout- perch	Emerald shiner	Spottail shiner	Flathead chub	Burbot	Lake chub
JTQD	4.00	0.00	0.00	0.25	0.00	7.50	53.50	159.25	19.25	0.00	0.00	0.00
JDU	3.33	0.00	0.00	0.33	0.00	3.50	1.92	40.83	1.00	0.00	0.00	0.00
JDQ	1.50	0.00	0.00	1.75	0.00	2.00	25.00	55.75	3.75	0.25	0.00	0.00
SD	1.33	0.00	0.00	2.33	0.33	0.00	4.00	29.33	0.00	0.00	0.00	0.00
JEDU	0.75	0.00	0.00	1.50	0.00	3.50	16.75	125.25	5.00	0.00	0.00	0.00
JDQU	0.75	0.00	0.00	1.00	0.00	3.75	8.50	147.75	0.75	0.00	0.00	0.00
JDS	0.63	0.00	0.00	0.88	0.13	3.88	4.25	90.63	1.88	0.00	0.00	0.00
TSUO	0.50	0.00	0.00	1.00	0.00	5.00	5.25	21.00	1.50	0.00	0.00	0.00
TDS	0.50	0.00	0.00	2.00	0.25	0.50	0.00	18.75	0.25	0.00	0.00	0.00
SIMD	0.50	0.00	0.00	1.75	0.00	49.50	8.50	23.75	1.50	0.50	0.00	0.00
SIJ	0.50	0.00	0.00	0.00	0.00	3.25	0.00	43.00	0.75	0.00	0.00	0.00
SID	0.50	0.00	0.00	0.75	0.00	1.75	0.75	21.00	1.00	0.00	0.00	0.00
PTD	0.50	0.17	0.00	0.33	0.00	3.33	1.33	16.00	0.00	0.00	0.00	0.00
JDTU	0.50	0.00	0.00	0.25	0.00	1.00	4.25	12.00	0.25	0.00	0.00	0.00
JBDS	0.50	0.25	0.00	0.00	0.00	6.00	3.75	110.75	1.50	0.00	0.00	0.00
DS	0.50	0.00	0.00	0.25	0.00	0.25	0.75	5.50	0.25	0.00	0.00	0.00
LS	0.33	0.00	0.00	0.00	2.67	10.00	0.00	81.33	0.33	0.00	0.00	0.00
TEUD	0.25	0.25	0.00	0.25	0.00	5.25	3.00	50.50	2.25	0.25	0.00	0.00
TEJD	0.25	0.00	0.25	5.00	0.00	5.50	2.75	127.75	2.25	0.00	0.00	0.00
STD	0.25	0.00	0.00	1.00	2.25	2.25	0.25	29.50	0.00	0.00	0.00	0.00
PJED	0.25	0.00	0.00	0.25	0.00	2.75	0.25	18.25	0.00	0.00	0.00	0.00
EDTS	0.25	0.00	0.00	0.75	0.00	2.25	1.00	17.75	0.25	1.50	0.00	0.00
DTE	0.25	0.00	0.00	0.50	0.00	8.75	3.00	56.50	0.25	0.00	0.00	0.00
DJEU	0.25	0.00	0.00	0.25	0.00	21.25	0.00	18.00	1.00	0.00	0.00	0.00
CNAS	0.25	0.00	0.00	1.00	1.25	0.25	0.00	49.25	1.00	0.25	0.00	0.00
PTL	0.22	0.11	0.00	2.56	10.44	7.67	0.00	3.67	0.56	0.00	0.22	0.00
PTE	0.17	0.00	0.00	7.17	7.67	0.83	0.00	40.67	1.00	0.00	0.17	0.00
T	0.14	0.00	0.00	0.00	0.43	2.00	0.14	93.86	1.29	0.00	0.00	0.00
JUDE	0.13	0.00	0.00	0.25	0.00	4.00	3.50	51.50	0.75	0.00	0.00	0.00
JTDS	0.13	0.00	0.00	0.00	0.00	2.13	11.38	28.38	1.88	0.00	0.00	0.13

*Catch Per Unit Effort = number of fish captured per two-minute trawl.

+Vegetation codes are explained in Appendix 6; only those vegetation complexes for sampling sites at which goldeye were captured are presented.

++Mean catch per unit effort values for goldeye are listed from highest to lowest.

APPENDIX 5. Mean Catch Per Unit Effort* for Fish Captured in Trawl Nets in Relation to Shoreline Vegetation at River Sampling Sites.

Vegetation Complex [†]	Goldeye ^{††}	Northern pike	Lake whitefish	Walleye	Longnose sucker	Ninespine stickleback	Trout- perch	Emerald shiner	Spottail shiner	Flathead chub	Burbot	Cisco	Lake chub
ISAD	19.50	0.00	0.00	1.00	2.00	25.00	0.50	35.00	33.50	0.00	0.00	0.00	0.00
I	10.50	0.00	0.00	1.00	0.00	4.50	3.00	11.50	77.00	1.00	0.00	1.50	0.00
ASHI	5.00	0.00	0.00	0.00	0.00	23.50	0.00	494.50	42.50	0.00	0.00	0.50	0.00
EISD	2.75	0.00	0.00	15.25	0.00	1.50	80.75	169.50	3.25	0.00	0.00	0.00	0.00
AIH	2.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	1.00	0.00	0.00	0.00	0.00
SI	1.71	0.00	0.00	0.57	0.86	3.57	22.71	76.71	1.14	0.00	0.00	2.14	0.00
SIE	1.50	0.00	0.00	0.00	1.00	42.00	0.00	271.50	33.00	0.00	0.00	1.50	0.00
SLAW	1.50	0.00	0.00	0.50	1.50	6.00	0.00	170.00	7.50	0.00	0.00	0.00	0.00
SWD	1.25	0.00	0.00	0.00	1.25	1.50	0.00	9.50	0.25	0.00	0.00	0.00	0.00
SH	1.00	0.00	0.00	0.00	0.50	3.50	0.00	14.50	4.00	0.00	0.00	0.00	0.00
SEW	1.00	0.00	0.00	0.00	0.00	10.50	0.00	25.50	11.00	0.00	0.00	0.00	0.00
ISAM	0.75	0.00	0.00	0.50	1.25	1.25	2.25	7.75	19.75	0.00	0.00	0.00	0.00
EWSD	0.75	0.25	0.00	1.25	0.00	33.75	1.75	141.00	0.25	0.25	0.00	0.00	0.00
SIA	0.60	0.00	0.00	0.20	0.50	7.00	0.80	21.40	6.90	0.20	0.10	0.00	0.00
SAIH	0.50	0.00	0.00	0.00	0.75	1.25	0.25	10.00	6.75	0.25	0.00	0.00	0.00
SAHI	0.50	0.00	0.00	0.00	0.00	3.25	0.00	9.25	3.00	0.00	0.25	0.00	0.00
IAS	0.50	0.00	0.00	0.00	1.00	5.50	0.00	32.50	7.00	0.00	0.00	0.00	0.00
DEWS	0.50	0.00	0.00	1.50	0.75	8.25	4.25	35.50	1.00	0.00	0.00	0.00	0.00
ISWE	0.33	0.00	0.00	2.00	1.67	0.33	0.00	49.67	14.67	0.00	0.00	0.00	0.00
WESI	0.25	0.00	0.00	1.00	0.00	5.75	2.75	17.75	2.75	0.00	0.00	0.00	0.00
SED	0.25	0.00	0.25	0.00	0.00	4.50	0.75	8.75	0.50	0.25	0.00	0.00	0.00
SDAH	0.25	1.00	0.00	0.00	23.00	0.00	0.00	14.75	1.25	0.00	0.00	0.00	0.50
ISHD	0.25	0.00	0.00	0.00	0.25	4.75	0.25	3.75	4.75	0.00	0.25	0.25	0.00
ISDV	0.25	0.00	0.25	0.00	0.25	2.50	0.25	6.00	0.00	0.00	0.00	0.00	0.00
ESTW	0.25	0.00	0.25	0.00	4.75	2.00	0.00	65.75	2.75	0.00	0.00	0.00	0.00
ISA	0.19	0.00	0.00	0.06	1.06	4.13	0.44	14.56	8.19	0.06	0.06	0.06	0.00
SID	0.13	0.00	0.13	0.00	0.25	2.13	0.13	16.13	0.13	0.00	0.00	0.00	0.00
SDE	0.13	0.38	0.13	0.00	0.00	23.00	4.50	14.25	1.25	0.25	0.00	0.00	0.00

*Catch Per Unit Effort = number of fish captured per two-minute trawl.

†Vegetation codes are explained in Appendix 6; only those vegetation complexes for sampling sites at which goldeye were captured are presented.

††Mean catch per unit effort values for goldeye are listed from highest to lowest.

APPENDIX 6. Vegetation Codes Used in Appendices 4 and 5.

Code	Plant Species
A	<i>Alnus tenuifolia</i>
B	<i>Alopecurus</i> sp.
C	<i>Betula papyrifera</i>
D	<i>Calamagrostis</i> sp.
E	<i>Carex</i> sp.
F	<i>Ceratophyllum demersum</i>
G	<i>Cicuta</i> sp.
H	<i>Cornus stolonifera</i>
I	<i>Equisetum</i> sp.
J	<i>Juncus</i> sp.
K	<i>Nuphar variegatum</i>
L	<i>Phragmites communis</i>
M	<i>Plantago</i> sp.
N	<i>Populus balsamifera</i>
O	<i>Populus tremuloides</i>
P	<i>Potamogeton</i> sp.
Q	<i>Potentilla anserina</i>
R	<i>Sagittaria cuneata</i>
S	<i>Salix</i> spp.
T	<i>Scirpus validus</i>
U	<i>Senecio</i> sp.
V	<i>Sium suave</i>
W	<i>Typha latifolia</i>
X	<i>Urtica gracilis</i>

APPENDIX 7. Use of the Spearman Rank Correlation Coefficient Test for Data in Table 17.

Before it was possible to perform the Spearman rank correlation coefficient test (Siegel 1956) with some paired parameters in Table 17, categories within parameters were ordinally arranged as follows:

- a) Substratum material at sampling sites was ordered on the basis of smallest to largest particle size: clay = 1; sand = 2; rock = 3.
 - b) Substratum hardness at sampling sites was ordered on the basis of least to greatest hardness: soft = 1; medium = 2; hard = 3.
 - c) Wind direction at lake sampling sites was ordered on the basis of least to greatest wind blowing toward the shoreline: away from shoreline = 1; nil in relation to shoreline (either no wind or wind blowing parallel to shoreline) = 2; toward shoreline = 3.
 - d) Sampling site in relation to waterbody type was simply ordered as lake = 1; stream or river = 2.
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