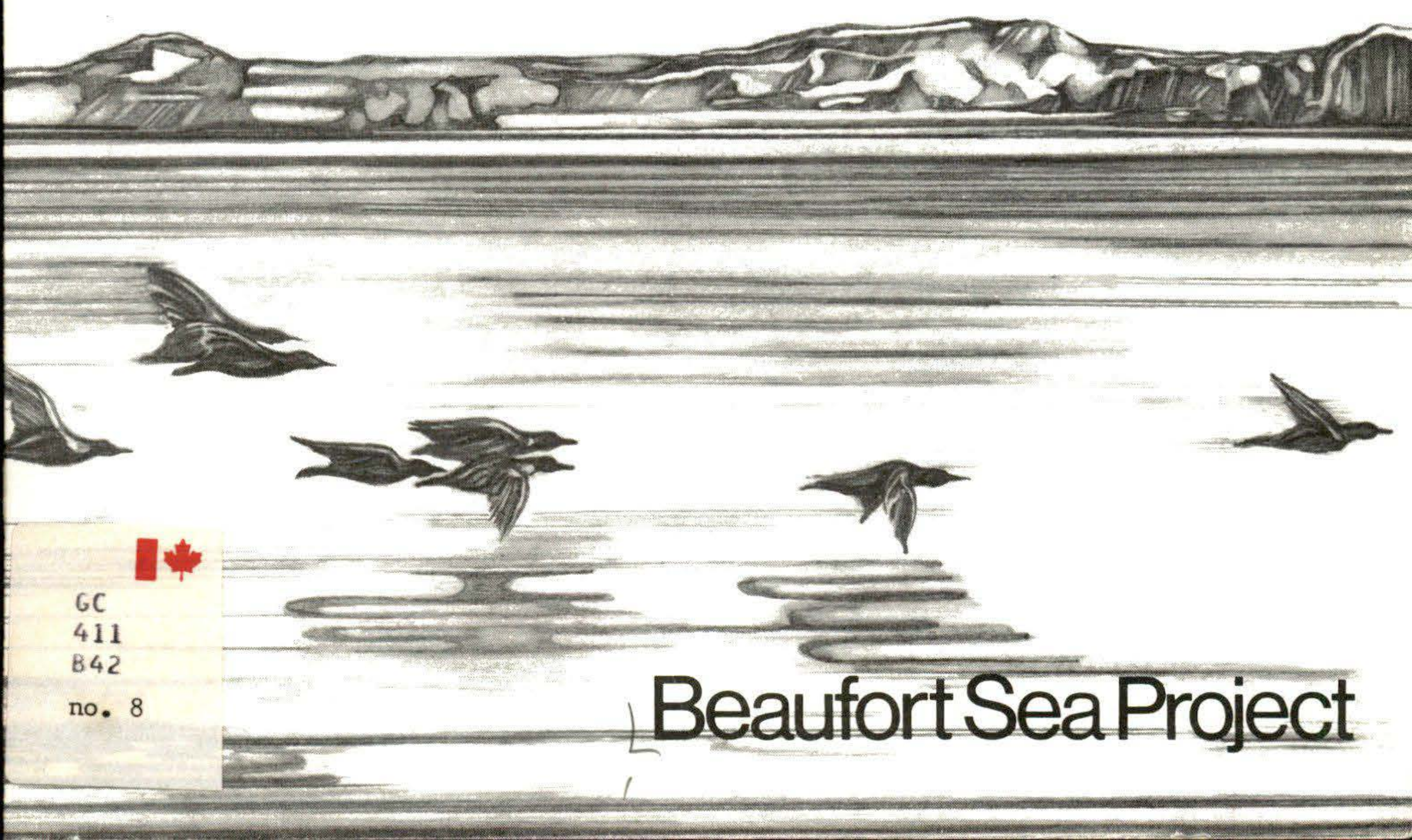
Fishes of the Outer Mackenzie Delta

ROGER PERCY

Technical Report No. 8



Beaufort Sea Project

FISHES OF THE OUTER MACKENZIE DELTA

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1. SUMMARY

Baseline information was gathered in 1974 and 1975 on 23 species of freshwater, anadromous and marine fishes in the outer Mackenzie Delta and nearshore Beaufort Sea. The biological data presented include numerical abundance, summer and winter distributions, nursery areas, food habits, migration and age-length relationships.

The possible impact of offshore exploratory drilling to the fish resources is discussed. Although the major impact would arise from an oil well blowout, the cumulative effects of other disturbance factors, such as seismic activity, disposal of drilling fluids and "housekeeping waters" will also be significant over the long term.

An effective program of monitoring studies for the renewable resources is essential to facilitate the identification and resolution of potentially dangerous environmental problems at the earliest possible stage.

2. INTRODUCTION

In May of 1974, Fisheries and Marine Services, Central Region, in conjunction with the Beaufort Sea Project, undertook an eighteen-month study of the anadromous and freshwater fish resources of the outer Mackenzie Delta. Although this investigation relates specifically to the exploratory phase of offshore drilling, it also represents a natural extension of similar baseline fisheries data being collected for an impact assessment of the proposed Mackenzie Valley pipeline.

A number of specific objectives were defined at the outset of the study:

(1) Determine species distribution, migration routes and timing of major fish species utilizing the lower delta;

(2) Locate significant overwintering areas;

(3) Review baseline knowledge of fish populations of the Mackenzie Delta and coastal Beaufort Sea by compiling and incorporating existing literature (especially in describing habitat critical to the maintenance of the resource);

(4) Examine the food habits of the fish to determine their dependence on food organisms which may be adversely affected by contaminants associated with offshore exploration;

(5) Establish the seasonal and geographic sensitivity of the resource; and

(6) Examine lagoons subject to inundation from the Beaufort Sea and ascertain their role in the life history of major species.

The principal concern of fisheries biologists and of local residents during the exploratory phase of offshore drilling is the potential for massive oil spills in an Arctic ecosystem and the resultant damage to the aquatic resource. However, other disturbance factors inherent in offshore drilling activity, such as discharge of drilling fluids and offshore seismic must also be considered.

The following is a final report based on field data obtained during 1974 and 1975. Pertinent biological results are presented and discussed; the appendix contains analyzed data in the form of figures and tables.

The outer Mackenzie Delta cannot be considered a separate entity since adjacent coastal and upper delta areas are critical in the life history of fish species caught there. An attempt is made to incorporate relevant biological data from other government and industry-funded studies in the discussion.

Although a prime function of this investigation was to gather baseline environmental information, areas within the outer Delta essential to the maintenance of the fish resource were identified.

These results complimented similar government fisheries investigations conducted along the Beaufort Sea coast and nearshore waters to the east and west of the Mackenzie River Delta, and in offshore marine waters.

The majority of the fish taken in the outer Mackenzie Delta are freshwater and anadromous species, i.e. fish which return from the sea to spawn in fresh water. Many of the marine fish species in Beaufort Sea waters are of southern origin. Only 10 of 29 are found in the high Arctic whereas 20 reach either Pacific or Atlantic waters (McAllister, 1962). A number of freshwater and anadromous species are important to the commercial and domestic fishery, not only within the Delta but also throughout much of the Mackenzie River system (principally Coregonid and Salmonid species). At the present time, there is little exploitation of marine fish in the southern Beaufort Sea, although the potential exists (Dunbar, 1973). They are, however, an important food source for marine mammals and birds.

3. RESUMÉ OF CURRENT STATE OF KNOWLEDGE

Information on the fish resource of the Beaufort Sea and particularly the outer Mackenzie Delta area is very fragmentary prior to 1970. Fish distributions are discussed in a general way by Wynne-Edwards (1952); McAllister (1962) describes the distribution and taxonomy of fish on the fringes of the study area. Riske (1960) carried out a comparative study of Pacific herring, *Clupeaharengus pallasi* (Valenciennes), caught in the North Pacific and those from western Arctic Canada and concluded that both populations formed a single taxonomic group. Hunter (MS 1975) briefly discussed Mackenzie River and coastal fishes in terms of resource utilization.

Several recent reference texts include distribution and general fish biology in Arctic waters (McPhail and Lindsey, 1970; Hart, 1973 and Scott and Crossman, 1973). However, only *Freshwater Fishes of Northwestern Canada and Alaska* (McPhail and Lindsey, 1970) makes repeated reference to fish found within the outer Mackenzie Delta.

In anticipation of an application to construct a Mackenzie Valley gas and/ or oil pipeline, a series of reports for the Environmental-Social Program have been published (Hatfield *et al.*, 1972a,b; Stein *et al.*, 1973; Bryan *et al.*, 1973; Jessop *et al.*, 1974 and Jessop and Lilley, 1975). These papers deal with the freshwater migration and ecology of anadromous species which reside within the outer Delta area and are therefore of significance to the present investigation.

Baseline fisheries and invertebrate information is also available from an environmental assessment of East Mackenzie Bay (F.F. Slaney, 1973a,b) carried out in response to construction of artificial islands commencing in 1972. Life history and distribution data has recently been published for Arctic cisco (Craig and Mann, 1974; Griffiths *et al.*, 1975), Arctic char (McCart *et al.*, 1974), fourhorn sculpin (Griffiths *et al.*, 1975) and Arctic grayling (McCart *et al.*, 1972; de Bruyn and McCart, 1974) caught along the Yukon and Alaskan coast of the Beaufort Sea.

Beluga whales, hunted domestically on their calving grounds in the southern Beaufort Sea, usually have empty stomachs; however, ciscoes and capelin (Pers. Communication, D. Sergeant - Environment Canada), boreal smelt and saffron cod (Slaney, 1975) have been reported. The importance of polar cod, *Boreogadus saida* (Leprechin), in the whales' diet is unknown since no whale specimens from offshore Beaufort Sea waters have yet been examined.

Polar cod is numerically an important marine fish species found throughout much of the Arctic. They have been captured with mid-water trawls in the southern Beaufort Sea beyond the major influence of the Mackenzie discharge (Galbraith and Hunter, 1976).

Bray (MS 1975) estimated the biomass of groundfish (Pacific herring, boreal smelt, fourhorn sculpin, Arctic and least cisco) in the vicinity of Tuktoyaktuk in 1961 to be in the order of 10,000 lbs per square mile. Beyond 2 miles offshore the estimated poundage dropped to 3,000 per square mile. Moreover, during the study he was unable to detect large fish concentrations using echo sounding techniques.

North of Tuktoyaktuk along the Peninsula boreal smelt, Arctic and least cisco comprised about 90 percent of the gillnet catch in both 1973 and 1974 (Galbraith and Hunter, 1976). The most abundant fish species to the west of the Mackenzie Delta along the Yukon coast were ciscoes (84 percent), Arctic char (4.5 percent) and fourhorn sculpin (2.5 percent); however, humpback whitefish, inconnu, boreal smelt and Arctic flounder were also found there (Kendel *et al.*, 1976). Annual variations in species distribution and abundance along the coast appear to be dramatic.

A limited amount of winter fisheries data for the Mackenzie Delta has been documented (Jessop *et al.*, 1974; Jessop and Lilley, 1975; Mann, 1975). These studies indicated that lakes and channels are potentially important to overwintering fish. Immature humpback whitefish and mature least cisco were the most abundant of 12 species overwintering in the outer Delta (Mann, 1975). Shallow Bay was evaluated as an unsuitable overwintering site. However, prior to the present study, there was no information available on the importance of the large bays and lagoons in the outer delta as overwintering habitat.

Delta channels are extensively used as feeding, spawning and rearing areas and as migration corridors (Stein *et al.*, 1973; Jessop *et al.*, 1974; Jessop and Lilley, 1975) for a number of spring and fall spawning species. Migration routes and timing have been intensively studied since 1973 with the release of over 20,000 tagged fish in the Mackenzie Delta. These tag returns have been compiled (Jessop *et al.*, 1974; Jessop and Lilley, 1975) and are briefly summarized in this report.

Recent reviews of the literature on the toxicity of petroleum products to fish have been authored by Kemp *et al.* (1971), Moulder and Varley (1971), Smith (1974) and Wilson and Hunt (1975). Jones (1971) gives tables of median tolerance limits for petrochemicals in temperate waters.

Some fish species are apparently able to avoid drilling fluids by visual and olfactory means (Lawrence and Scherer, 1974). There is no evidence to suggest that fish also avoid oil. Although fish gills are mucous-coated, effectively repelling minute quantities of oil, they are incapable of accommodating a major polluting incident. If gills become oil-coated, respiration and ion exchange are severely limited. This ultimately leads to death since there is no self-cleaning mechanism. Fish are more likely to come into intimate contact with oil in a dispersed form than with floating slicks; moreover, oil in emulsion appears to adhere to gill tissue more readily (Smith, 1974). Solution of the lighter saturated and aromatic components of oil (also the most toxic to fish) in the water column occurs early in the life of an oil slick. An offshore spill would therefore tend to lose its most toxic components before reaching the nearshore zone.

Pollutants such as oil often cause nervous and gastric disorders in fish. Fish of different species, size and age vary in their resistance to pollutants. Once within the circulatory system and body tissues, hydrocarbons are largely insulated from biodegradative processes, though metabolism of this contaminant is thought to occur in at least some fishes. Hydrocarbons are available for passage through the food chain, although as yet there is no evidence to suggest that food web magnification of petroleum hydrocarbons takes place in the marine environment. Physiological and behavioural changes brought about by pollutants will interfere with the ability of fish to cope with the "normal" stresses in an already harsh environment.

Flocculation and sinking readily take place in estuarine locations since suspended sediments are available as adsorptive nuclei for oil. The benthic flora and fauna upon which many fish species depend may, as a result, be reduced or contaminated for extended periods. Free oil and emulsions can also coat algae and other plankton causing them to settle to the bottom, out of reach of pelagic fishes (McKee and Wolf, 1963). The presence of even small quantities of petroleum hydrocarbons in the flesh of fish can produce disagreeable flavour and odours (Smith, 1974). This is an important aspect considering the domestic and commercial utilization of the resource in the southern Beaufort Sea.

Seismic techniques have been used extensively in the nearshore and offshore Beaufort Sea as a major tool in the search for potentially productive geological formations. This activity will continue during the exploratory drilling phase as a means of delineating gas and oil fields, determining the extent of permafrost layers and ascertaining where abnormal pressures may be encountered. The small amount of information available in the literature dealing with the effects of seismic activity on fish has been recently reviewed (Falk and Lawrence, 1973b).

High velocity explosives as well as air guns are currently in use; the former provide the best information on the geology of substrata; however, charges of this type are also the most lethal to the marine fauna. Fish with gas bladders are most susceptible; such fish (including all the domestically and commercially important species) generally die because they are unable to adjust to rapid pressure changes. Demersal fishes such as flatfishes and sculpins, which are more common offshore, are relatively insensitive to seismic activity.

Drilling fluids are used in exploratory drilling in large quantities to equalize hydrostatic pressures, to remove drilled cuttings and to lubricate the drill bit. They usually consist of a water-clay mixture although many chemicals are added to the muds for viscosity improvement, pH adjustment, anti-corrosive properties, weight and a host of other desirable factors for drilling.

Drilling fluids from the Mackenzie Delta and nearshore Beaufort Sea have been shown in a number of studies to be acutely toxic to fish in freshwater (Falk and Lawrence, 1973a; Logan *et al.*, 1973) and more recently to both fish and intertidal invertebrates in marine waters (B.C. Research Ltd., 1975). Most samples of drilling fluids tested were toxic (96-hr LC50) to seawater acclimated salmonid fishes and invertebrates at concentrations of less than 8 percent (V/V). The elevated pH values normally associated with the samples were not found to be the toxic factor in seawater as was initially suspected.

The toxicity to aquatic biological systems of the individual components of drilling fluids has been reviewed by Land (1974). He concluded that suspended solids, which can be present at 75,000 to 300,000 ppm in drilling fluids can harm fish in experimental tanks at levels of less than 400 ppm. Potassium chloride, often added to drilling fluids at 20,000 ppm potentially harms fish and crustacean zooplankton at 100 to 1,000 ppm. A number of other components used, such as bacteriacides, are also toxic to fish.

Discharged brines usually contain small quantities of oil. These soluble fractions are once again those most deleterious to marine organisms. Chronic contamination from offshore sites would have important local implications for the resource. Although fish are not found in large concentrations offshore, there is evidence (especially from the oil fields in the Gulf of Mexico) to suggest that those present often congregate near offshore drilling structures and thus become susceptible to chronic contamination.

In normal land-based drilling, drilling fluids, brines and cuttings along with "housekeeping wastes" are contained for extended periods in earthen sumps and treated to render them innocuous. However, this procedure will probably not be feasible in offshore drilling where space will be a limiting factor. Since the composition of drilling fluids varies widely from well to well and within a well the toxicity to the aquatic fauna is also quite variable. Guidelines are presently being formulated by the Environmental Protection Service to ensure that deleterious quantities of these contaminants are not discharged into northern waters.

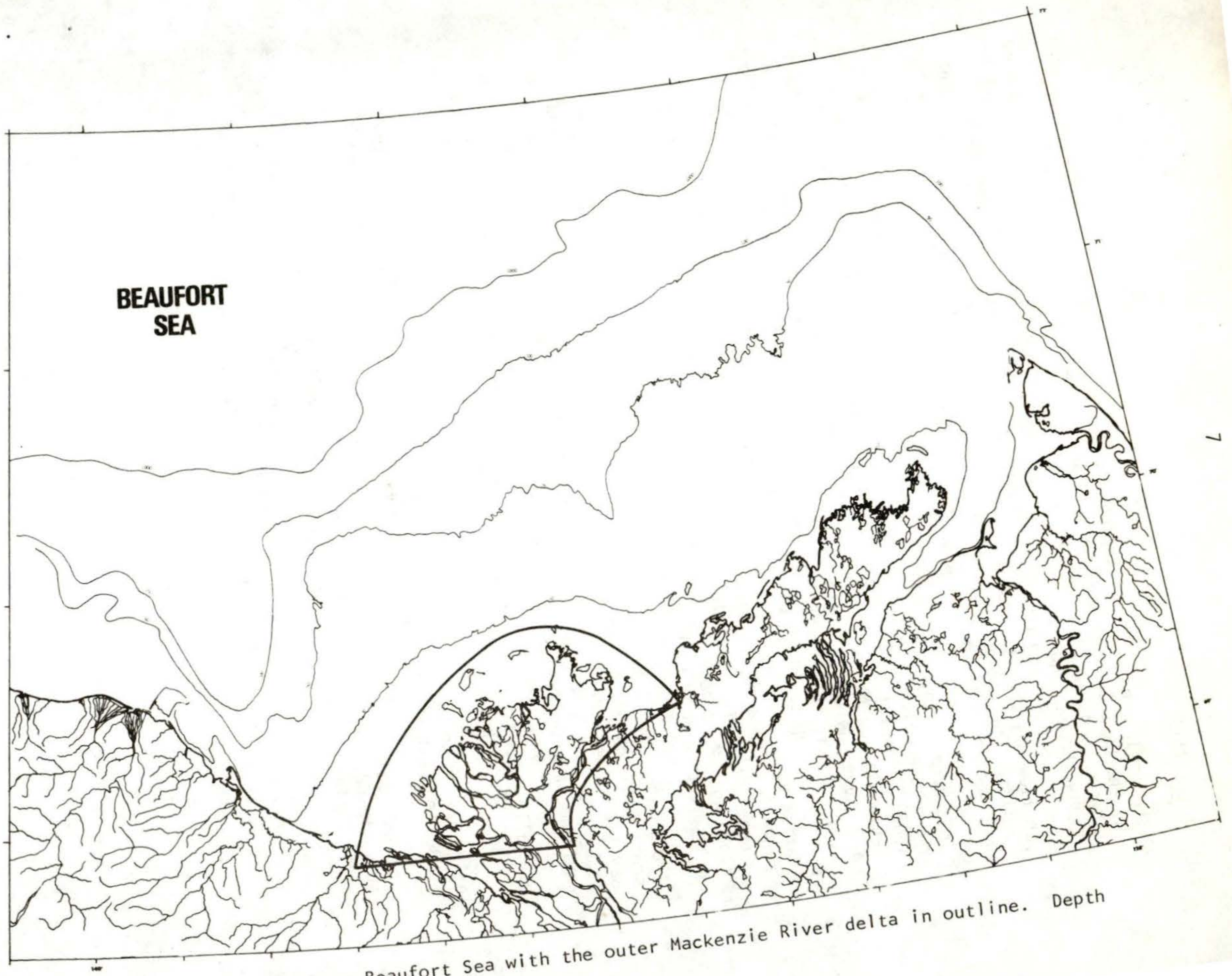

Figure 1. The southern Beaufort Sea with the outer Mackenzie River delta in outline. Depth contours are in meters.

4. STUDY AREA

The study area (Fig. 1) includes that part of the Mackenzie Delta bounded by the East Channel and the Reindeer Channel known as Richards Island. It also extends into the nearshore zone as far as the barrier islands (Garry, Pelly, Hooper and Pullen) and into Kugmallit Bay as far east as Hendrickson Island and the town of Tuktoyaktuk on the Tuktoyaktuk Peninsula. Shallow Bay and its shoreline to the west of Richards Island is also included. For the purposes of this report, the area described above is designated as the outer or lower Mackenzie Delta.

This area encompasses parts of two distinct physiographic regions, the Mackenzie Delta (Fig. 2) and Pleistocene Coastlands (Fig. 3) (MacKay, 1963). The latter comprises Richards Island, the coast of Tuktoyaktuk Peninsula and the outlying islands in Mackenzie Bay. It is part of a sand and gravel delta laid down by an ancient river; the predominant vegetation is dry tundra. The coastline here is rapidly receding; relief is generally higher (up to 60 m) than found in the Mackenzie Delta (average elevation about 6 m) and the open water season slightly shorter (3.5 to 4 months). The area contains numerous small, clear and isolated lakes, whereas "typical" delta lakes are large, shallow and turbid due to spring flooding. More detailed information on the geology and geography of the area are presented by MacKay (1963).

The Beaufort Sea covers a shallow shelf extending some 80 to 120 km offshore from the Delta. With the exception of major river channels, Mason Bay (21 m deep) and Mallik Bay (12 m deep) water depths throughout the study area are less than 3 m. The most important feature of the aquatic environment along the coast is the interface of warm, turbid Mackenzie River water with cold, saline Beaufort Sea water (Fig. 4). Open water generally extends 160 km offshore from the delta, although in the summer of 1974 the pack ice was held close to shore by prevailing winds.

In the spring an estimated 2.1 x 10^6 metric tons of suspended solids are transported each day by the Mackenzie River and 7.4 x 10^2 metric tons per day during the winter (Brunskill *et al.*, 1973). In lower East Channel suspended sediment loads in mid-summer approximate 100-200 mg/ℓ and are reduced to 62.1 mg/ℓ by October and 10.7 mg/ℓ by November (Mann, 1975). Surface salinity readings at some sites have been reported to vary from less than 1 to more than 15 parts per thousand (ppt), depending on the magnitude of flow in the Mackenzie River and direction and strength of the prevailing winds (Brunskill *et al.*, 1973). Dramatic haloclines are present in Mason and Mallik Bays.

Figure 2. An aerial view of the upper Mackenzie River Delta.

Figure 3. Embayments along the Pleistocene coastlands.

5. METHODS

The sampling program in the outer Mackenzie Delta was coordinated from a basecamp on Richards Island at 69°10'N - 135°W. Fish collection commenced in mid-June immediately following breakup and was terminated during freeze-up at the end of September. Spring netting was carried out under the ice in March 1974 and 1975.

5.1 Phasing of the Work

Initial field preparations were completed in Aklavik by early May 1974 and a tent camp erected on Richards Island by mid-June. Air support for the project was drawn from Inuvik and Tuktoyaktuk. At the end of the first season, equipment was stored in Aklavik in readiness for the 1975 spring survey. Spring sampling was carried out for three week periods in March 1974 and 1975.

Interim findings of numerical abundance, percent composition, species distribution, seine catch identification and age and growth have been reported previously (Percy *et al.*, 1974).

5.2 Field Techniques

Standard 18.3 m (60 ft) net gangs were utilized for index fishing. These multiple mesh nylon nets are useful in obtaining a representative sample (Figs. 5 and 6) in terms of number of species and size range of individuals present without depleting the resource. Each net gang was composed of six panels of equal lengths of 3.8, 5.1, 7.6, 10.2, 12.7 and 14.0 cm meshes (1.5, 2, 3, 4 and 5.5 inches). Each site was sampled at least twice during the season; some representative areas were netted on a regular basis. Locations sampled during open water (Fig. 7) and under ice (Fig. 8) are plotted on maps. For under ice fishing two net gangs joined end to end were used.

Along the coast, nets were generally set from a 21 foot Boston Whaler or rubber Canova; in more protected waters, a canoe or aluminum runabout proved more useful. Fork length (mm), wet weight (gm), sex and maturity were determined for fish caught by gillnet. The numerical abundance and percent composition for the gillnet catch is summarized in Table 2 and for seine hauls in Table 3. Length-frequency data for gillnetted fish are presented in Figures 9 to 13. Sex and maturity of commonly captured species are indicated in Table 4 and for less common species in Table 5.

Scales and/or otoliths were taken for age determinations. The latter were stored in a 50 percent glycerin solution. Records were kept of all sampled fish to indicate whether stomachs were full or empty. Full stomachs were preserved in 10 percent formalin for subsequent analysis.

Sweep nets 45 m long and with a 1.3 cm mesh size (150 ft, 0.5 inch mesh) and seines 9.1 m long and with 0.6 cm mesh size (30 ft, 0.24 inch mesh) were used extensively for capturing fry in potential nursery areas. Commercial minnow traps were set at winter sampling locations; these proved to be inefficient, however. Small fish were preserved in 10 percent formalin for later analysis and the larger specimens tagged and released. Length frequency of fry is presented in Table 6.

Trap nets and a backpack electro-shocker (Tiny tiger, Model 5001-1) were also used to collect fish in shallow waters.

5.3 Tagging Program

When large numbers of fish were captured by gillnets or seine, healthy individuals over 15 cm (6 inches) in length were tagged and released. Coded vinyl floy tags (carrying a reward value of one dollar) were inserted by means of a cartridge-fed tagging gun, at the posterior base of the dorsal fin. Tag return data are presented in Table 7.

Domestic recaptures from the present study as well as those from Mackenzie Pipeline studies are discussed. Over 20,000 tagged fish have been released within the Delta since 1972; see Stein *et al.*, 1973; Jessop *et al.*, 1974; Jessop and Lilley, 1975 for detailed tag return analyses.

5.4 Catch Per Unit Effort

Four river locations were chosen for regular monitoring of fish movements through the outer Delta. These sites were situated on the Harry Channel at basecamp (69°10'N - 135°W), on Reindeer Channel (68°5'N - 134°22'W) and on the Main Channel at Camp Farewell (69°12'N - 135°W).

In sampling these locations, three 29.9 m sections (25 yd) of 3.8, 7.6 and 12.7 cm meshes were alternated with similar sections of 5.1, 10.2 and 14.0 cm meshes (1.5, 3, 5 and 2, 4, 5.5 inches respectively) each week throughout the field season. Where possible, nets were set for a continuous period of 24 hours each week.

'Catch per unit-effort' is a measure of the change in relative abundance of fish populations during the open water season; the data are summarized in Figures 14 to 17. The sampling site on East Channel (loc. 70) was moved to a less suitable backeddy near the opposite shore during a brief period July 14 to July 29. This resulted in a noticeable reduction in the number of fish caught. By sampling here, interferring with the commercial fishery, which annually utilizes the original fishing location, was avoided.

5.5 Water Chemistry

At each new sample location, a Hach Kit (Model AA-36-WR) was used to measure dissolved oxygen, temperature, hardness and pH. Tests were repeated at representative sites throughout the open-water season and during early spring surveys. Turbidity values were measured with a Secchi disc and salinity determined with a Hach Chloride Kit (Model 7-P). In winter a salinometer (Kahl Scientific; Model 118 WA 300) was used. Water chemistry data is presented in Tables 8 and 9. Water temperature measurements at the four catch per unit-effort sites are tabulated separately to permit direct comparison with the abundance of each fish species. More detailed information on water quality of the Mackenzie River basin has been published elsewhere (Reeder, 1973).

5.6 Laboratory Analysis

Seine catches were identified to species using taxonomic keys in McPhail and Lindsey (1970). Larval coregonids generally were keyed only to genus. Fry were analyzed for fork length, age and stomach contents. Data for seined fish is tabulated separately because of the sampling bias for small fish inherent in the techniques. Moreover, regurgitation of stomach contents which can occur in gill-netted fish is not a problem in seined specimens.

Age determinations were based, where possible, on six specimens from each 10 mm length interval. Saffron cod, Arctic flounder, lake trout, ninespine sticklebacks and fourhorn sculpins were aged from otoliths while other species were aged from scales. Scales were taken for aging Pacific herring, however, they were found to be unsuitable since distinct annuli were often absent; scale regeneration was also apparent in many of the fish. Most fish were aged using scales in order to permit a tagging program to be carried out. Otoliths (ear bones) require dissection from dead specimens.

Otoliths were sawn in half, the ends polished with carborundum and burned in a bunsen flame to enhance the annuli (Lawler and McRae, 1961). Scales were read on a trichinoscope. The ages reported (Figs. 18 to 25) are the number of annuli observed on scales and/or otoliths.

All stomach samples were examined to determine the identity, numerical abundance and volume of the contents. Volume was determined by displacement of liquid in a volumetric flask. The data for both adults and fry are presented in bar graphs (Figs. 26 to 35). It should be noted that the number of empty stomachs is included in the fry analysis; however, percent occurrence and percent by volume in adult fish is based on full stomachs only. Cestoda have been included in stomach contents, even though they are probably parasites rather than food items.

5.7 Data Analysis

Field data were coded for computer analysis. Information on species distribution, percent composition, catch per unit effort and length frequency were obtained. Tag returns from fish taken by local residents were combined with our own recaptures to briefly describe fish movements and migration routes. Age and growth data for the commercial fish catch at Holmes Creek are provided in Table 11. Length-weight relationships were calculated by sex and maturity for important fish species (Table 12). Length-weight relationships have been presented in the form of natural logarithms.

$$\text{Log } W = \text{Log } a + b\ (\text{Log } L)$$

where

W = weight (g)
L = length (mm)
a = Y-intercept
b = regression coefficient (slope)

The value b is also known as the ponderal index or condition factor and changes during transition periods in the life history such as metamorphosis, a change in environment (as in anadromous fish), or maturity.

Meristic characters were recorded for a small sample of broad and humpback whitefish (Table 13). Scale counts were made along the lateral line of the fish extending from the bony shoulder girdle to the caudal flexure. Gill rakers (a series of bony projections along the anterior edge of the gill arches) were counted under magnification. The counts are presented separately for the upper and lower left gill arch. The number of pyloric caeca (pouches arising from the intestinal tract behind the stomach) were recorded; all tips of branched caeca were enumerated.

'Catch per unit-effort' or number of fish/standard series of nets/hr was calculated for the four sites on a two-week cycle throughout the open water season.

Species distributions (Figs. 36 to 46) are plotted on maps of the outer delta.

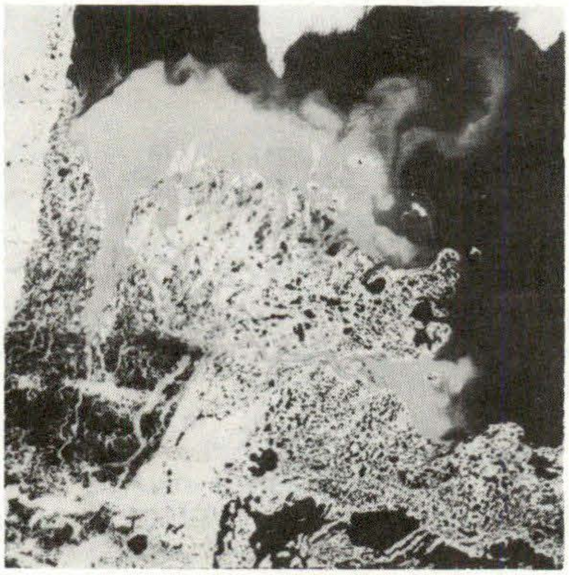

Figure 4. ERTS photograph showing the input of silt laden Mackenzie River water into the Beaufort Sea.

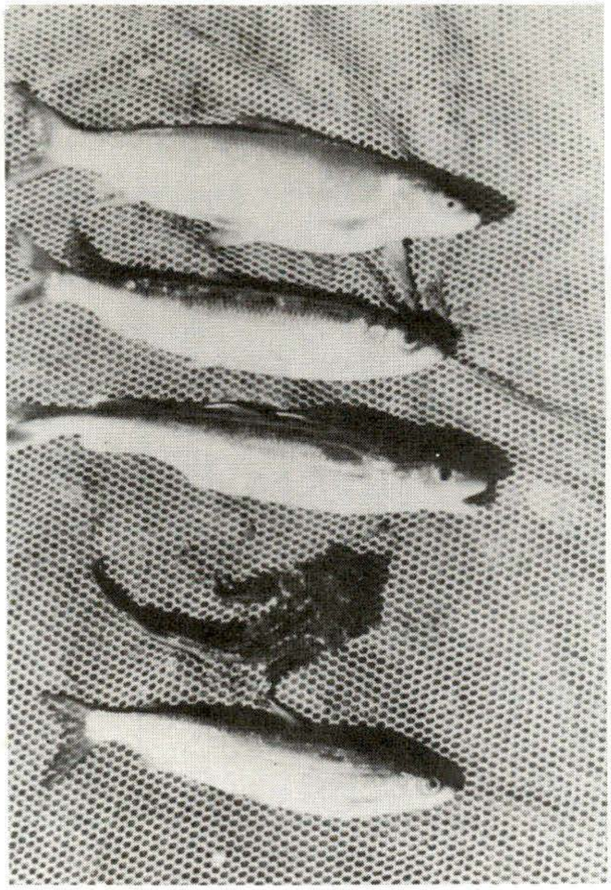

Figure 5. An Arctic cisco, pacific herring, saffon cod, fourhorn sculpin and least cisco caught in Mason Bay.

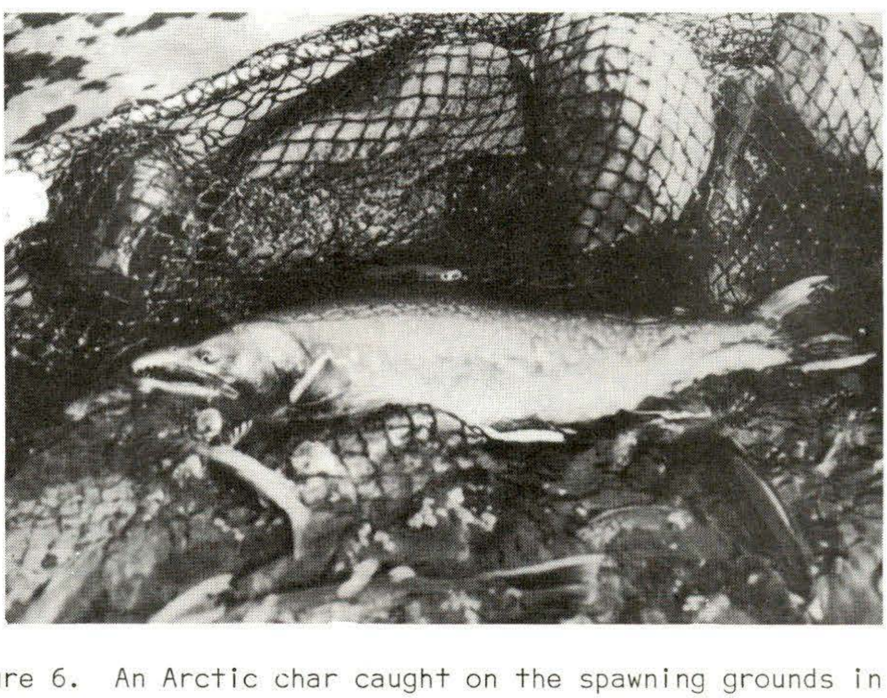

Figure 6. An Arctic char caught on the spawning grounds in the upper Delta.

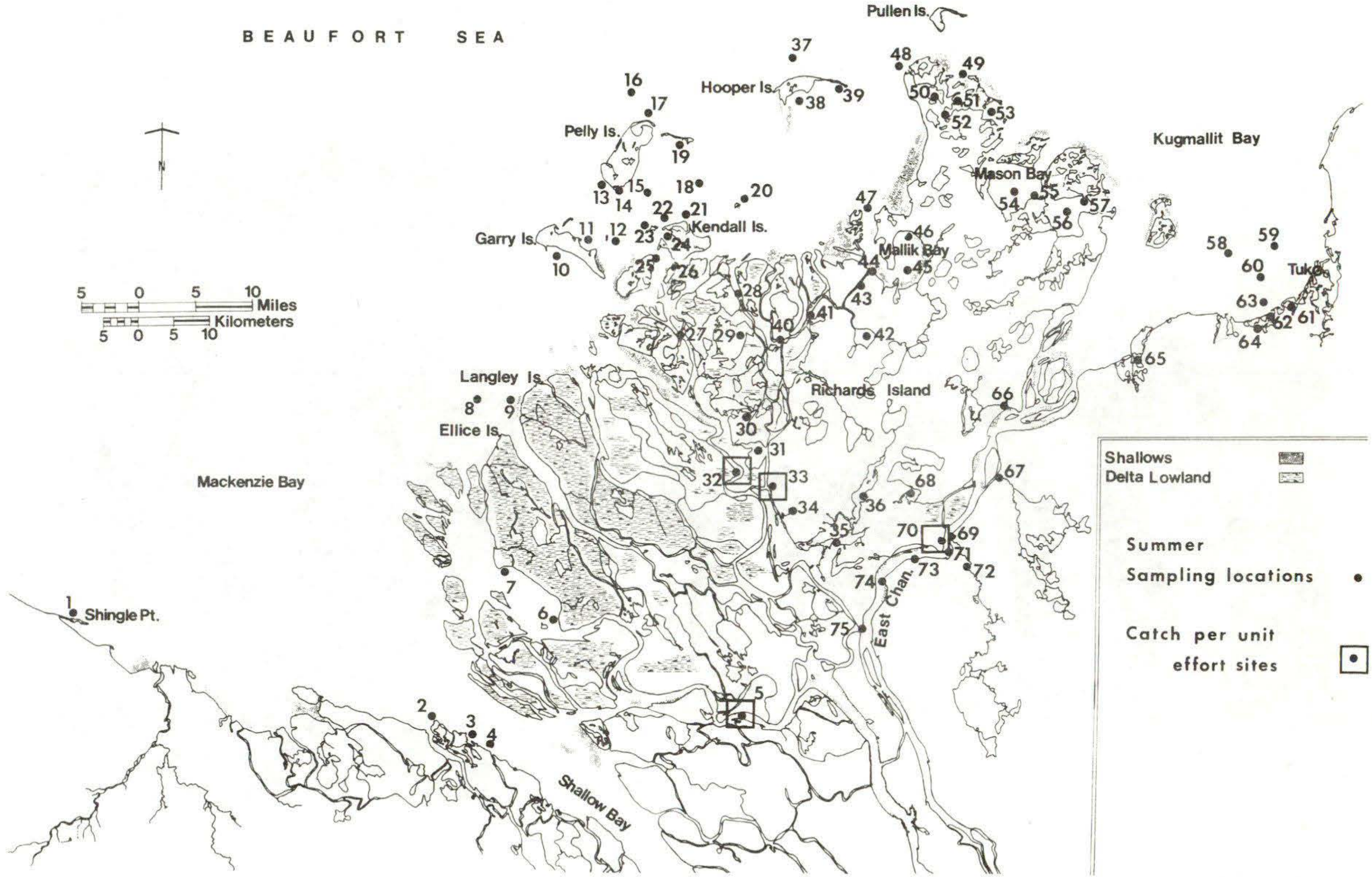

Figure 7. Summer sampling locations in the outer Mackenzie Delta (1974, 1975).

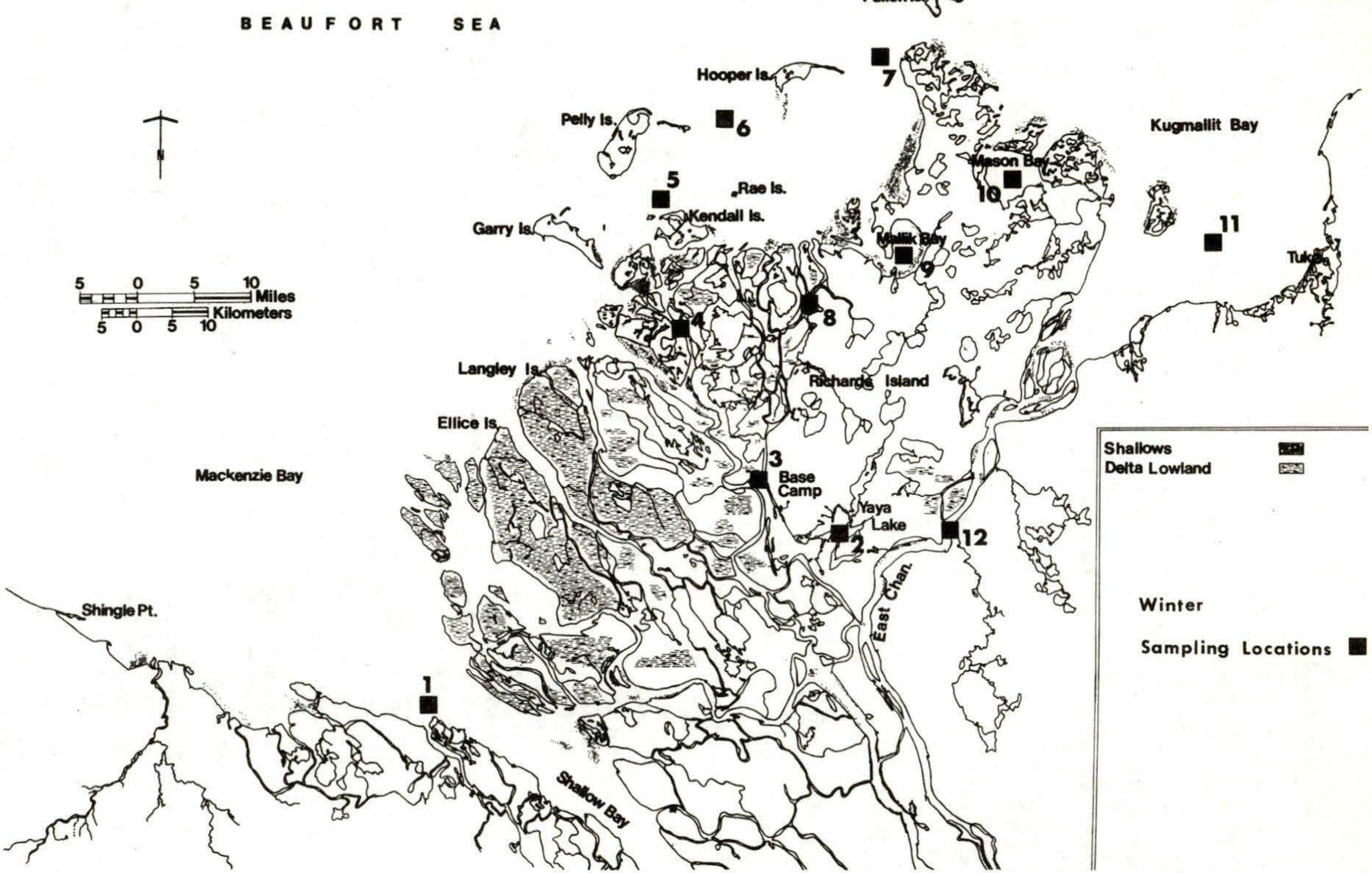

Figure 8. Winter survey sample locations in the outer Mackenzie Delta (1974, 1975).

6. RESULTS AND DISCUSSION

A total of 4,919 fish of 23 species was caught during the study. A list of generic nomenclature associated with the common fish names appears in Table 14. Approximately 18 percent (899) of these were tagged and released. Five species (saffron cod, Pacific herring, fourhorn sculpin, Arctic and starry flounder) are typically brackish water or marine forms and accounted for 9 percent of the total catch. Seven anadromous species made up 79 percent of the catch. Least and Arctic cisco were the predominant species in both gill net (38 percent) and seine samples (33 percent). Offshore migrations of fish appear to be restricted; most of the anadromous species, except for boreal smelt, frequent shallow nearshore areas. The remaining 11, strictly freshwater, species accounted for 12 percent of the catch. Burbot, lake trout, longnose suckers and northern pike were the only freshwater species found within the study area in relatively large numbers.

Fish migrations in 1974 were generally 1 to 2 weeks later than in "normal" ice years.

6.1 Marine and Brackish Water Species

6.1.1 Fourhorn Sculpin

Sculpins are demersal fish characteristic of cold northern seas. Fourhorn sculpin, *Myoxocephalus quadricornis quadricornis* (Linnaeus), comprised 9 percent of the coastal gillnet catch (Table 2); they were widely distributed in brackish water throughout the nearshore zone (Fig. 37). Within the study area sculpins are able to tolerate the wide range in salinities caused by seasonal changes in the Mackenzie River discharge and by changes in wind direction. This species has been collected along the Tuktoyaktuk Peninsula (Galbraith and Hunter, 1976) and in Yukon coastal waters (Kendel *et al.*, 1974; Roguski and Komarek, 1971 and Kogl, 1971).

Gillnet-caught specimens ranged from 170 to 340 mm in fork length (Fig. 19) with approximately 70 percent in the 200 to 250 mm size range. Sculpins caught by gillnet along the Alaskan coast ranged from 99 to 310 mm fork length (Roguski and Komarek, 1971). Fourhorn sculpins appear to reach sexual maturity at age 3 (Tables 4 and 10). Seventy-four percent of the gillnetted specimens were in the 5 to 8 year age classes (Fig. 19), and the maximum age was 14.

Eleven percent of the fish sexed (N = 170) were males. Larger fish caught all appeared to be female (Table 4), also the case for Alaska and Yukon fish (Roguski and Komarek, 1971; Griffiths *et al.*, 1975).

The fourhorn sculpin probably spawns in late winter since both ripe and spent fish were taken through the ice in Mallik Bay (Fig. 8) in March 1975. Overwintering sculpins were also captured in Mason Bay (Table 8). At break-up in the Shingle Point area (June 27 to 29, 1973), sculpins were caught; they were also taken at Shingle Point in April 1974 (Kendel *et al.*, 1976).

Stomach analysis of gillnetted fish showed that sculpins were principally feeding on isopods and amphipods (Fig. 31). Nematodes, pelecypods, odonata, crustacean remains and fish remains were also identified. Forty-nine of 81 stomachs examined were empty. Sculpin fry were feeding on chironomids, mysids, amphipods and isopods principally (Fig. 35). Nematodes, oligochaetes and fish remains were also identifiable in the stomach contents.

Fourhorn sculpin fry and juveniles were caught principally along the coast (Fig. 37). However, some were also caught in the East Channel suggesting that spawning can occur either in freshwater or in brackish waters such as Mallik Bay. Yearling and young-of-the-year fish fell within the 20 to 80 mm length range (Table 6). Alaskan fry ranged from 11 to 52 mm fork length (Roguski and Komarek, 1971).

6.1.2 Arctic Flounder

A total of 55 Arctic flounder, *Liopsetta glacialis* (Pallas), was caught by gillnet (Table 2) and 8 by seine (Table 3). The former ranged from 153 mm to 440 mm (Fig. 12) and the latter 46 mm to 150 mm in length. The majority of the gillnetted specimens were in the 200 to 300 mm length interval. This species has also been reported from lagoons along the Beaufort Sea Coast in Alaska (Roguski *et al.*, 1971), where specimens (185 to 280 mm length) were caught in waters of 1 ppt salinity. No fry were captured in seine hauls in the Alaskan study.

Within the study area this species tends to inhabit brackish and saline waters (Fig. 38), predominantly along the northeast coast of Richards Island, in Mallik Bay and offshore near the barrier islands. Arctic flounder were caught through the ice of Mallik Bay in the winter of 1975 (Table 8). Two of four fish sampled at that time had empty stomachs; the others were feeding only on amphipods. In summer, fourteen of 21 adult Arctic flounder stomachs examined were empty; the remainder contained pelecypods, isopods and amphipods (Fig. 31). Seven fish 46 mm to 58 mm in length were all less than one year old (Table 12); their diet included chironomids, mysids, copepods and oligochaetes (Fig. 34).

Forty-four percent of the fish from the outer Delta that were sexed were males. Five Alaskan fish examined for sex were all female (Roguski *et al.*, 1971). The ponderal indices for this species are relatively large (Table 12). Gonadal development is apparent in flounder over 200 mm in length; sexual maturity therefore appears to be first reached by about the fifth year. The maximum otolith age for a subsample of 30 specimens was 12 years (Table 10).

6.1.3 Starry Flounder

The starry flounder, *Platichthys stellatus* (Pallas), is one of the most widely distributed flounders being found in coastal waters off the Pacific and Arctic Oceans. Within the Mackenzie Delta region they are, however, much less abundant and less widely distributed than the Arctic flounder. Only seven specimens ranging from 171 to 340 mm in length were caught in this study. These were netted in Mallik Bay and a few inshore sites along the west coast of Tuktoyaktuk Peninsula (Fig. 38). A single specimen was caught through the ice in Mallik Bay (Table 8). Starry flounder are more abundant in Tuktoyaktuk Harbour (F. Slaney, 1973b) and are frequently taken in the domestic fishery.

This euryhaline species prefers a soft sand or mud substrate and has a wide depth tolerance, from the shallow inshore zone to 150 fathoms or more. The starry flounder exhibits only limited migration (Manzer, 1952).

Only 3 fish were aged (Table 10); the maximum otolith age was 15 years. Fish from the outer delta appear to have a considerably slower rate of growth than fish in the Pacific Ocean off the California coast (Orcutt, 1950). The latter reached sexual maturity by their third and fourth year; females tended to grow faster than the males.

The juvenile starry flounder is a planktonic pelagic feeder prior to metamorphosis into the adult form (Orcutt, 1950). Stomachs of the adult specimens examined from the outer Delta contained isopods and plant remains (Fig. 31). In temperate regions, however, plant material is not an important component of the diet. Miller (1967) suggests that there is a seasonal trend in the feeding intensity of this flounder. The cessation of feeding during the months of lowest water temperature may also be related to pre-spawning behaviour. Spawning takes place once a year, between November and February, in shallows at river mouths.

No fry of this species were taken in seines in this study.

6.1.4 Saffron Cod

Saffron cod, *Eleginus navaga* (Pallas), were caught in saline bays along the outer Delta as well as offshore (Fig. 40). Specimens have also been reported from Tuktoyaktuk Harbour (Riske, 1960; Slaney, 1973b).

Saffron cod are often found in beluga whale stomachs (A. Smith, F.F. Slaney and Co., Vancouver, pers. comm.). This may indicate a substantial offshore population of this species.

The 21 fish taken in this study ranged in length from 310 mm to 450 mm (Fig. 12). Two distinct age groups were apparent (Table 10), although few fish were aged (n = 12). Fish were either 5 to 6 or 15 to 16 years old. This may have resulted from year class failures since a wide range of mesh sizes were employed eliminating sampling bias.

Saffron cod breed at sea (McPhail and Lindsey, 1970); this may explain why fry were absent from the coastal area. Seventy-six percent of the fish sexed were males and all displayed only minor gonadal development (Table 5).

The diet of this species included isopods, amphipods, pelecypods, mysids, nematodes and plant material (Fig. 31). Only one of 10 stomachs examined was empty.

6.1.5 Pacific Herring

Pacific herring, *Clupeaharengus pallasi* (Valenciennes), from western Arctic Canada and those from the Pacific Ocean constitute one taxonomic unit (Riske, 1960). In the Pacific this species supports a substantial commercial fishery. In the Arctic they have been captured previously in the Cape Bathurst area, at the mouth of the Coppermine River, in the Eskimo Lakes and in the vicinity of Tuktoyaktuk. They have also been taken, on occasion, along the Yukon coast and at Point Barrow in Alaska. Sea herring have been domestically fished in the past in the Cape Bathurst area (Hunter, 1975).

In the present study, Pacific herring were usually caught in the lagoons and bays along the northeast coast of Richards Island during the open water season (Fig. 39); however, 4 specimens were also caught in the brackish waters of Mallik Bay in March 1975.

The 48 fish captured ranged from 190 to 320 mm (Fig. 12) with 83 percent greater than 240 mm in length.

Herring congregate nearshore during winter and spawn in spring in shallow brackish water of coastal bays and river mouths (Riske, 1960). Fish caught in Mason Bay in September, immediately prior to freeze-up, exhibited advanced sexual development; mature females had a considerably greater weight relative to length than males. A breakdown of the length-weight relationship by maturity is given in Table 12. Sixty percent of the fish sexed (N = 35) were males. Riske (1960) reported considerably fewer males than females in sampling at Tuktoyaktuk.

Herring in the North Pacific mature at age 3 and spawn annually. In contrast, fish from the Tuktoyaktuk and Eskimo Lakes area do not mature until their sixth year (Riske, 1960). Spawning takes place in Alaska in spring at water temperatures of 3-6°C (Turner - in Andriashev, 1975). In the outer Delta spawning must take place in spring also; fish caught in March had not spawned, whereas those caught in mid-July (water temperature = 10°C) had.

No fry were captured during the present investigation. In the Pacific, fry reach lengths of 70-100 mm in their first summer (Riske, 1960) and move out to sea during the winter.

Ages were not determined because distinct annuli were not present on the scales collected. Similarly, Riske (1960) reported great difficulty in aging this species (for the same reason); regenerated scales were frequent on fish age 6 and older. Those otoliths he successfully aged from fish caught at Tuktoyaktuk were between 3 and 14 years of age and 186 to 331 mm in fort length. Comparison of the length-frequencies for fish within the study area with the age-length data for the Tuktoyaktuk sample suggests that all but 2 of the fish were age 6 and older.

Riske (1960) reports that herring from the Pacific are plankton feeders throughout life; this does not appear to hold true for Beaufort Sea fish. Seven full stomachs of 20 analyzed from those caught in summer contained mysids, copepods and amphipods (Fig. 31) and all 4 specimens caught through the ice in March had fed exclusively on amphipods.

6.2 Anadromous Species

6.2.1 Boreal Smelt

The boreal smelt, *Osmerus eperlanus* (Linneaus), is a pelagic species abundant throughout the Mackenzie Delta and along the Beaufort Sea coast (Fig. 36). This species is not harvested by the local domestic fishery.

The boreal smelt is anadromous; migrating into the Mackenzie system prior to break-up in the spring. Ripe fish were taken through the ice in the East Channel (Fig. 8, loc. 12) in March 1974 and 1975. A single ripe smelt was also taken in the Middle Channel, through the ice, in April 1974 (McPhail and Lindsey, 1970). The Arctic Red River is a suspected spawning area (Stein *et al.*, 1973).

Boreal smelt disappear from net collections in the upper Delta by mid-June (Stein *et al.*, 1973); however, a small number of individuals was captured in the turbid lakes of Richards Island throughout the summer.

Smelt began declining in abundance at 'catch per unit-effort' fishing sites in the outer Delta (Figs. 14 to 16) from the start of fishing at break-up, and were absent from these channel locations by early July. No smelt were taken in Reindeer Channel (Fig. 7, loc. 5) suggesting that this may not be an important migration route for the species.

Boreal smelt comprised 14 percent of the coastal gillnet catch (Table 2). They were abundant offshore throughout the summer months, especially in Kugmallit Bay (Fig. 36) where they usually made up 100 percent of gillnet catches. This species has been reported elsewhere along the Beaufort Sea coast (Slaney, 1973a, 1975; Kendel *et al.*, 1976; Galbraith and Hunter, 1976).

The fish ranged from 100 to 305 mm in fork length (Table 10); 89 percent of the gillnet catch was between 160 to 270 mm (Fig. 9). Approximately 53 percent of the total number sexed (N = 296) were males. The ponderal index (Table 12) for females was not significantly higher than for males as reported by Stein *et al.* (1973). This probably resulted because the fish caught in the outer Delta had not undergone as advanced sexual maturation (ovaries are much larger than testes) as those caught in the upper Delta.

Approximately 77 percent of the gillnetted fish that were aged were in the 5 and 6 year age classes, although specimens ranged from 3 to 8 years old (Fig. 18). Fish 0+ and 1 year old were also included in seine catches. No fish less than age 6 was mature and no immature specimens were taken upriver at the 'catch per unit-effort' sites. Spent fish in a downstream run at Arctic Red River were all 6 to 8 years old (Stein *et al.*, 1973). This implies that only older individuals participate in the spawning migrations.

Ages for boreal smelt were estimated using otoliths, scale age tends to underestimate otolith age by 1 to 2 years. Females grow larger and faster than males (t-test at 90 percent level of significance); similar results were reported in southern latitudes by Bailey (1964) and McKenzie (1964).

Eighty-nine percent of all adult smelt stomachs examined were empty. Amphipods were present in 49 percent of the full stomachs (Fig. 28); also included in the diet were isopods, mysids, coleoptera and fish remains. Smelt undergoing spawning migration appear to cease feeding. Stomachs of ripe fish caught through the ice in March were empty. Similarly, fish in the post-spawning run had empty stomachs (Stein *et al.*, 1973). Within the outer Delta boreal smelt fry were found to feed on mysids, chironomids and copepods (Fig. 35). Larval smelt are an important forage species for offshore fish (Galbraith and Hunter, 1976). In the present study they were an important food item in the diet of inconnu (Fig. 30) and burbot (Fig. 29).

Boreal smelt fry were caught in brackish water along the coast as well as in the East Channel approximately 24 km from the mouth (Fig. 7, loc. 69). The fry ranged from 25 to 70 mm in fork length (Table 6). Fry caught at Pelly Island spit (Fig. 7, loc. 19) in early July ranged from 47 to 52 mm in length whereas those taken near the mouth of West Channel

(Fig. 7, loc. 2) in early August ranged from 24 to 34 mm in size. This latter group probably represents new recruits to the population and supports the hypothesis that the fry "drop down" to sea in their first summer (McPhail and Lindsey, 1970).

6.2.2 Inconnu

The inconnu or "cony", *Stenodus leucichthys nelma* (Pallas), an anadromous species, is extremely important to the domestic fishery of the Mackenzie Delta. Tag return data indicate that inconnu from the lower 500 to 700 miles of the Mackenzie River system return to the Delta and Beaufort Sea coast to feed and overwinter (Jessop *et al.*, 1974; Jessop and Lilley, 1975). A total of 1,114 inconnu have been tagged and released in the Delta and adjacent coastal area. To date, 15 percent have been recaptured.

Inconnu utilize many Delta channels as summer migration corridors including the East, Middle, Harry and West Channels of the Mackenzie. Fish tagged in Cony Lake near the mouth of West Channel in spring 1972 were recaptured in the fall as far upstream as Aklavik (137 km) and Fort McPherson (393 km) (Jessop *et al.*, 1974). Other inconnu tagged in spring 1972 have been recaptured 3 and 4 years later at their point of release (unpublished data), suggesting that the fish return to the same part of the outer Delta after spawning. Spawning probably takes place in the upper Peel, Arctic Red and Mackenzie rivers during September and early October. A distinct downstream run of inconnu occurs during October (Jessop *et al.*, 1974). The majority of the 646 specimens caught in the present study were taken along the immediate coastal zone (Table 2, Fig. 41).

Gillnetted fish ranged from 110 to 900 mm fork length (Fig. 11). Approximately 58 percent of the fish aged from the outer Delta were 7 to 11 years old (Table 10); whereas in the inner Delta, 57 percent were in the 9 to 13 year age group (Stein *et al.*, 1973). Fifty-two percent of those sexed (N = 384) were males. The majority of large individuals were female (Table 4). The maximum age for inconnu was 16 years, although a 22 year old specimen has been reported from the inner Delta (Stein *et al.*, 1973). Maximum ages reported elsewhere in the north are 13 years for southern Yukon fish (Alt, 1969), 14 years for Nowitna River fish in Alaska (Alt, 1974) and 9 years for those from the Porcupine drainage (Bryan *et al.*, 1973). Inconnu were not captured in an extensive netting program along the Alaskan Beaufort Sea coast (Roguski *et al.*, 1971).

Inconnu from the outer Delta grow at a slightly slower rate than those from the Porcupine and Yukon rivers in Alaska (Alt, 1973) and considerably slower than fish from Great Slave Lake (Fuller, 1955).

The length-weight relationships by sex and maturity are presented in Table 12; in general no consistent differences exist between immature and mature fish, or between the sexes.

Inconnu were present in turbid lakes of Richards Island at spring break-up and throughout the summer. They were also abundant in Mallik Bay and Mason Bay (Fig. 41) throughout the open water season. Most fish were not approaching reproductive readiness for fall spawning. Large concentrations of immature inconnu reside in the outer Delta during the summer. The seasonal change in gillnet catches at channel locations are given in Figures 14 to 17. Although inconnu declined in abundance within the channels during the summer months, a large population was present in lake and coastal areas such as Mallik and Mason Bays throughout this period.

An upstream spawning migration, peaking in July in the inner Delta, is documented (Stein *et al.*, 1973; Jessop *et al.*, 1974). Immature or non-spawning fish are not caught on the spawning grounds in Alaskan rivers (Alt, 1969). This information suggests that the outer Delta is an important summer residence for age 2+ and older. It is still not known whether inconnu spawn in consecutive or alternate years. If the latter is the case, this might explain the numerous large fish within the study area following the normal migratory period.

The percentage of inconnu in the catch at Kendall Island (Fig. 7) began to increase during September; these fish were probably moving to overwintering sites in the mouths of nearby channels. This is a yearly phenomenon according to domestic fishermen. Inconnu have been taken in lower Delta lakes and channels in winter (Mann, 1975). During winter surveys in 1974 and 1975, inconnu were captured at Tent Island, Swimming Point on the East Channel and Mallik Bay (Table 8, Fig. 8). Ten of the 16 fish caught through the ice in Mallik Bay had fed on least cisco. The diet of 380 inconnu gillnetted during the summer is summarized in Figure 30. It shows that amphipods, chironomids, mysids and isopods are found in the stomach contents but that fish such as least cisco, ninespine stickleback, smelt, inconnu, sculpin and flounder are the more important prey. Inconnu at one location (Fig. 7, Loc. 41) were also feeding heavily on lamprey ammocoetes in late August.

Only one inconnu fry (1+ year old, 155 mm fork length) was caught in the lower Delta (Fig. 41); the study area is probably not an important nursery for young-of-the-year and yearling fish.

6.2.3 Broad Whitefish

Broad whitefish, *Coregonus nasus* (Pallas), are an important commercial and domestic fish species utilizing the Mackenzie River system. They have been captured throughout the lower Mackenzie as far south as Fort Simpson (Stein *et al.*, 1973).

However, they are most abundant in the Delta. Over 15 percent of the 4,207 specimens tagged within the Delta have been recaptured by the domestic fishery.

In the present study, broad whitefish comprised four percent of the gillnet catch along the coast, seven percent of the lake catch and 17 percent of the stream catch within the outer Delta (Table 2). They venture into brackish water but remain nearshore (Fig. 43). A single broad whitefish was captured in the outer Mackenzie Delta during the winter surveys in 1974 and 1975. Overwintering whitefish were also netted in several lakes in the inner Delta (Jessop and Lilley, 1975).

The 354 gillnetted fish ranged from 141 to 655 mm fork length. The length frequency for broad whitefish, given in Figure 10 shows the majority of the catch in the 350 to 530 mm length range. The length-weight relationships for this species by sex and maturity are summarized in Table 12.

The maximum age for 143 broad whitefish netted from the study area was 15 years (Table 10; Fig. 22); 88 percent were between 3 and 11 years of age. The maximum scale-based age for broad whitefish in the Mackenzie River is consistent with values in the literature (Muth, 1969; Stein *et al.*, 1973). A larger proportion of the catch was composed of young fish (less than age 4) than that reported from the Aklavik and Arctic Red River areas in the inner Delta (Stein *et al.*, 1973).

The lengths, weights and age distribution of a subsample of broad whitefish (N = 149) taken by the Holmes Creek commercial fishery within the study area during 1973 is given in Table 11. Ninety-one percent of these fish, caught in 14 cm (5.5 inch) mesh gillnet, were between 8 and 11 years old.

The growth of fish captured in the study area (Fig. 22) was considerably faster than broad whitefish populations in the Coppermine River and only slightly faster than upper Mackenzie River whitefish (Muth, 1969).

Females outnumbered males in the outer Delta (Table 4) but did not approach the high 12:1 or 15:1 ratios indicated for the inner Delta (Wynne-Edwards, 1952).

Fish that were 301 to 350 mm fork length (3 and 4 year age classes) were the smallest individuals capable of spawning in the fall of 1974 (Table 10).

Index gillnetting indicated increasing numbers of whitefish at channel locations (Figs. 14 to 17) throughout early summer. The decrease shown at location 70 on the East Channel (Fig. 15) is unrepresentative since the sampling location was moved to the opposite side of the channel between July 10 and August 8.

An annual upstream spawning migration, peaking during September and October in the inner Delta, has been documented in the Mackenzie River (Stein *et al.*, 1973; Jessop *et al.*, 1974; Jessop and Lilley, 1975). Ripe and spent whitefish have been simultaneously captured in backeddies in late October at the mouth of Arctic Red River and at Horseshoe Bend on the Main Channel (Jessop *et al.*, 1974). Other stretches of the Mackenzie below the confluence of the Arctic Red River probably also serve as spawning grounds. Tag return data indicate that the downstream run of spent fish occurs during the first two weeks of November (Jessop *et al.*, 1974).

Stomach analysis of 136 broad whitefish (399 to 516 mm fork length) revealed that 130 were empty; the remainder included gastropods, trichopterans and plant remains.

Whitefish fry and juveniles were captured by seine within delta lakes as well as in the estuary (Fig. 43). Only 3 of 102 were definitely identified as broad whitefish and 7 as humpback whitefish. Stomach contents of fry caught along the coast, in streams and in delta lakes are summarized in Figure 27. There is a distinct difference in the diets of these three groups. Coastal fry were principally feeding on chironomids and copepods, stream specimens on plecopterans, crustaceans and oligochaetes, and lake specimens on mysids.

6.2.4 Humpback Whitefish

Humpback whitefish, *Coregonus clupeaformis* (Mitchill) complex, are more abundant than broad whitefish in the study area. Both appear to have similar distribution patterns (compare Fig. 42 to Fig. 43). Generally tag returns indicated that humpback whitefish have similar migration routes and spawning areas as the broad whitefish, although spawning migrations are several weeks earlier for the former species. Approximately 12 percent of the total gillnet catch in the present study comprised of humpback whitefish (Table 2). In winter surveys this species was caught at two channel locations and one coastal location (Fig. 8; loc. 3, 12 and 11 respectively). Overwintering broad whitefish but not humpback whitefish were captured in inner Delta lakes (Jessop and Lilley, 1975).

Fish caught by gillnet ranged from 151 to 590 mm fork length (Fig. 10); a single one large individual (800 mm fork length) was taken from the East Channel. Forty-one percent of those sexed (N = 312) were males. The minimum age at sexual maturity in the outer Delta was 7. For comparison, Alaskan fish matured at age 8 (Alt and Kogl, 1973) and age 9 to 13 (Craig and Wells, 1975). The latter range are otolith-based ages; there is evidence to suggest that scale age underestimates otolith age by several years in this species (Craig and Wells, 1975). Fish from Great Bear Lake first reached sexual maturity at a scale age of 7 years (Kennedy, 1949).

The majority of specimens caught in delta lakes and channels during winter 1974 were immature (Mann, 1975).

Sixty-five percent of the humpback whitefish aged (N = 211) were between 5 and 12 years old (Table 10; Fig. 23). The maximum age for fish in the outer Delta was 18 years. This is two years older than previously reported for the Mackenzie (Stein *et al.*, 1973) and three years younger than reported in Great Bear Lake. Whitefish from Great Bear Lake grow faster than those from the outer Delta.

The index gillnet catches of humpback whitefish throughout the 1974 open-water season are compared in Figures 14 to 17. They were most abundant in the East Channel of the Mackenzie River.

Seined specimens ranged from 101 to 220 mm fork length (Table 6) and 1 to 3 years in age.

Meristic characters for a small sample of broad and humpback whitefish are presented in Table 13. Modal gill raker counts of 21 for the former and 24 for the latter are consistent with those reported for these species in the literature (Lindsey and Woods, 1970; McPhail and Lindsey, 1970). Lateral line scale counts for both were also within the ranges previously reported. However, pyloric caeca counts for broad whitefish were higher than values in other segments of their range.

The contents of the 265 stomachs analyzed are summarized in Figure 26. Humpback whitefish were feeding on isopods and pelecypods; in the channels they fed mostly on isopods and gastropods whereas in delta lakes, plant material and gastropods were important components of their diet. Over-wintering humpbacks taken in outer Delta lakes and channels had fed on *mysis sp.*, filamentous algae, isopods, sphaeriid clams and trichopteran larvae (Mann, 1975).

6.2.5 Arctic Cisco

The Arctic cisco, *Coregonus autumnalis* (Pallas), is an anadromous cold-water species found along much of the Beaufort Sea coast. Generally local populations do not ascend far up-river. However, in the Mackenzie River Arctic cisco have been netted as far south as Fort Simpson; they are not abundant past the Normal Wells area (Stein *et al.*, 1973). In the outer Delta this species was taken from coastal and channel locations (Fig. 44) but not from the lakes. Cisco are adapted to feeding in shallows up to about the 10 m isobath (Berg, 1948-49), although specimens have been captured offshore in mid-water trawls 27 km northeast of Herschel Island (Galbraith and Hunter, 1976).

Arctic cisco comprised over 4 percent of the coastal gillnet catch in summer 1974 (Table 2). Along the Yukon coast they comprised 29 percent of the gillnet catch; juvenile fish were also abundant in the region (Kendel *et al.*, 1976).

Gillnetted specimens ranged from 180 to 480 mm fork length with the majority in the 320 to 420 mm size range (Fig. 9). The maximum recorded age for 126 ciscoes was 11 years (Table 10), although the majority (90 percent) were age 4 to 10 years.

Berg (1957) reports that fish in the Lena River of Russia are usually 11 to 16 years old up to a maximum of 20 years. Sexual maturity in that population was reached age 6 to 8. The youngest mature cisco in the outer Delta were 7 years (over 370 mm fork length). This is comparable with results for the upper reaches of the Mackenzie River (Stein *et al.*, 1973). Within the study area 59 percent of fish sexed (N = 143) were males. Sex and maturity by length interval are presented in Table 4.

In the inner Delta at Aklavik, 7 and 8 year old fish comprised about 80 percent of the catch (Stein *et al.*, 1973), no fish below age 7 was caught there. Apparently Arctic cisco do not spawn every year (Berg, 1957; Griffiths *et al.*, 1975). Both juvenile and mature non-spawning fish appear to remain along the coast throughout the summer and fall. These were caught in embayments in the outer Delta especially along the northeast coast of Richards Island. Arctic cisco have also been taken along the Yukon coast during the summer (Kendel *et al.*, 1976; Griffiths *et al.*, 1975).

Only three percent of the 4,639 fish tagged within the Delta have been recovered (Table 7). Most of these were tagged along the coast near Shingle Point and recaptured in the inner Delta near Aklavik and Arctic Red River. One specimen tagged in Stokes Point Lagoon, farther along the Yukon coast in July was recaptured at the mouth of the Peel River 110 days after its release. Arctic cisco commence a spawning migration in the Mackenzie system in late June and July; there is a general decline in numbers in channel catches in late July and August (Figs. 14 to 17) in the outer Delta. Concurrently, a significant increase in abundance occurs in the Arctic Red River area (Stein *et al.*, 1973).

Possible spawning areas in the Mackenzie system include the tributaries of the Peel, Arctic Red and Great Bear Rivers (Stein *et al.*, 1973). Spawning takes place from late September to early October; a definite post-spawning run occurs during October. Young-of-the-year migrate to the mouth of the Mackenzie and the immediate coastal area.

A large number of unidentified cisco fry were caught along the coast (Fig. 44) representing 41 percent of the seine catch in brackish water and 29 percent of the overall fry catch (Fig. 3). Seined fish ranged in length from 21 to 150 mm (Table 6). The lower reaches of the Colville River in Alaska may also be a spawning area along the Beaufort Sea Coast (Craig and Mann, 1974).

Growth rates of Arctic cisco of the outer Delta were slower than those of Siberian populations (Berg, 1948-49). Ponderal indices (Table 12), as expected, are highest for mature females.

A total of 121 stomachs were analyzed; all but 6 from coastal specimens were empty. These contained pelecypods and plant material (Fig. 27). All fish caught at the channel sites were empty. Migrant fish in the inner Delta are usually not feeding (Stein *et al.*, 1973). In Yukon coastal waters, 97 percent of the fish examined had been feeding; amphipods, copepods and mysids were the most common prey organisms (Craig and Mann, 1974).

Within the study area 122 least and Arctic cisco caught in seines (29 to 146 mm fork length) were analyzed for feeding habits. The diets of coastal, lake and stream specimens are compared in Figure 33; fewer empty stomachs were recorded in fish in this size range than in adults. Copepods, mysids and chironomids were the principal food items.

Arctic cisco were absent from the overwinter catch in the inner Delta (Jessop and Lilley, 1975). In this study a specimen was taken through the ice in Mallik Bay in March 1975 (Table 8), suggesting that the outer Delta is a potential overwintering site for this species. Arctic cisco were present at Shingle Point at break-up in 1973 (June 27-29) (R. Percy - unpublished data) and again in April 1974 (Kendel *et al.*, 1976). Siberian populations are reported to overwinter in coastal bays and partly in river deltas (Berg, 1957).

Hybridization between ciscoes and whitefish has been documented by Berg (1948-49). A cisco population in a lake-creek system on Tuktoyaktuk Peninsula also appears to contain hybrids (Lawrence *et al.*, 1975 - in press).

6.2.6 Least Cisco

The least cisco, *Coregonus sardinella* (Valenciennes) is present in two forms; a large migratory form and a smaller non-migratory lake resident form (McPhail and Lindsey, 1970). In the outer Delta they comprised 34 percent of the total gillnet catch (Table 2). This species is common in most Beaufort Sea coastal waters throughout Alaska, the Yukon and Northwest Territories. Along the Yukon coast they are more abundant near the Mackenzie Delta (Kendel *et al.*, 1976); the limit of distribution for this Mackenzie River stock is the Herschel Island area (Griffiths *et al.*, 1975).

No differentiation between the two has been attempted in this study.

From late June to mid-September 1974, ciscoes were abundant nearshore around Kendall, Garry and Pelly Islands, along the west coast of Tuktoyaktuk Peninsula and the northeast coast of Richards Island (Fig. 45). Cisco (N = 25) were caught under ice cover in Mallik Bay and in Kugmallit Bay near Hendrickson Island in March 1975 (Table 8). Immediately following Mackenzie River break-up, June 27 to 29, 1973, while coastal waters were still ice infested, ciscoes were abundant at Shingle Point west of the delta (unpublished data). This species has also been netted 3 km off Tuktoyaktuk Peninsula at Tibjak Point in December (Galbraith and Hunter, 1976). Ciscoes have also been recorded in inner Delta winter collections (Jessop and Lilley, 1975).

Ciscoes were captured in lakes in the outer Delta (Fig. 7; loc. 30, 31) in early spring shortly after break-up (June 21-25). In 1974 least cisco were absent from Mallik Bay during June and July but were abundant in late summer collections.

Based on the available data the outer Delta including coastal waters along Tuktoyaktuk Peninsula should be considered an important overwintering area for this species.

The length frequency for 830 gillnetted fish from the overall study area is given in Figure 9. These fish ranges from 170 to 340 nm in fork length.

Fry and juvenile least cisco comprised 4 percent of the seine catch; however, an additional 29 percent were ciscoes unidentified to species (Table 3). Cisco fry were generally caught in the same areas as described previously for adults (Fig. 45). In the Nunaluk lagoon area, western Yukon coast, most ciscoes exceed 250 mm fork length (Griffiths *et al.*, 1975) whereas along the eastern portion of the Yukon coast (Kendel *et al.*, 1976) and in the outer Delta (Percy *et al.*, 1974) smaller ciscoes in the 40 to 200 mm size range are abundant.

A total of 165 seined and gillnetted fish were aged (Table 10; Fig. 25). The maximum age measured was 11 years and 84 percent were in the 3 to 8 year age classes. Seined specimens ranged from 61 to 210 mm fork length (Table 6) and from age 0+ to 4 years (Fig. 25). No fish less than 5 was mature. Fifty-two percent of the fish sexed from the outer Delta (N = 520) were males; sex and maturity by length interval is presented in Table 4.

A total of 338 least cisco caught along the coast, 68 in lakes and 75 in streams were examined for stomach contents (Fig. 28). Most stomachs were empty (86, 84 and 95 percent, respectively). The most common food items were amphipods, insects and mysids. Only two overwintering fish were analyzed for food contents; one was empty and the other had fed exclusively on amphipods. Very few marked least cisco (22 of 2,151) have been recaptured; most of these have been taken by Fisheries Service crews using variable mesh gill-nets. Tag mortality as well as the fact that domestic fish-ermen are using larger mesh nets probably accounts for the very poor return of this species. Commencing August 12 to 26, 1974 there was a dramatic increase in the fishing success for least cisco at all 4 channel monitoring sites (Figs. 14 to 17). This corresponds to an upstream spawning migration which continued until freeze-up. The majority of fish caught at these sites (95 percent) were in the 230 to 330 mm size range. A subsample of migrants was sexed (N = 64) of which 62.5 per-cent were males. All females caught at this time exhibited either moderate or advanced sexual development while only 27.5 percent of the males had well developed reproductive organs. All of the fish sampled had not recently fed. Migratory least cisco were also reported in early October 1974 from Moose Channel and West-twin Channel (Mann, 1975). Freshwater least cisco follow seasonal migrations within lake systems along the Beaufort Sea Coast much as anadromous fish do (Lawrence *et al.*, 1975 - in press).

Only potential spawners move up to spawning grounds in the inner Delta based on a comparison of length-frequency data from the outer Delta (Fig. 9) and from the catch per unit-effort sampling sites between mid-August and freeze-up (Fig. 13).

6.3 Freshwater Species

6.3.1 Pond Smelt

The pond smelt, *Hypomesus olidus* (Pallas), is reported to be an anadromous species (Wynne-Edwards, 1952). Three specimens ranging from 39 to 53 mm fork length (Table 6) were caught in seines in Shallow Bay near the mouth of West Channel (Fig. 7, loc. 2). None, however, were caught along the coast away from the influence of the Mackenzie River.

In a Yukon tundra lake, first spawning took place at age 4 (50 to 65 mm fork length) and the fish appeared to spawn every spring thereafter (de Graaf, 1974). Three years (80 mm, mean length) is the maximum age reported for this species in Alaska (McPhail and Lindsey, 1970); however, de Graaf reports 8 and 9 year old fish.

The stomachs of two smelt from the outer Delta were examined. One was empty, the other contained 27 copepods, one mysid and one chironomid.

6.3.2 Spoonhead Sculpin

A total of 67 spoonhead sculpin, *Cottus ricei* (Nelson), were caught in seines. All were obtained from turbid lakes and streams rather than coastal waters (Fig. 37). This species is also common in seine catches in the upper Delta (Stein *et al.*, 1973).

Fork lengths ranged from 21 to 70 mm (Table 6). The 22 specimens ages ranged from 0+ to 3 years (Table 10). Spawning may occur in the fall (Scott and Crossman, 1973) but the actual place and time are still unknown.

Spoonhead sculpins caught in the outer Delta were feeding principally on plecopterans, mysids, chironomids and ostracods (Fig. 35). Only 3 of the 25 specimens examined had empty stomachs.

6.3.3 Burbot

Burbot, *Lota lota* (Linnaeus), have a circumpolar distribution and are found throughout the study area (Fig. 40). This species frequents brackish waters, especially in the Kendall Island area where large numbers were taken by trap net in 1974. Burbot were absent from collections along the northeast coast of Richards Island where surface salinities commonly exceed 5 ppt.

The 76 specimens taken by gillnet and trap net ranged from 210 to 740 mm fork length (Fig. 2). A small subsample (N = 12) of these fish were from 4 to 14 years of age (Table 10). Mackenzie Delta burbot appear to grow faster than those of interior Alaska (Chen, 1969) but at a slower rate than burbot of temperate climates (Clemens, 1950). Forty-six percent of the fish sexed (N = 37) were males. Approximately 748 burbot have been tagged and released within the Delta in the past three years. Of this number, 107 have been recaptured. Returns indicate that burbot move relatively short distances from their point of release. They reside in lakes and small streams throughout the Delta during summer then move to stream mouths in fall to feed and finally to channel locations for spawning in mid-winter. There is an important local winter domestic fishery for burbot near Aklavik, Arctic Red River and Inuvik.

Lake Erie burbot mature in the third to fifth year when they are 300 to 480 mm fork length (Clemens, 1950), whereas Alaskan fish (Chen, 1969) reach sexual maturity at 6 or 7 years of age (400 to 500 mm fork length). In this study, outer Delta burbot appear to be capable of spawning at about 550 mm fork length (Table 12) and 7 to 8 years old, based on age estimates of few specimens.

The outer Delta does not appear to be a nursery area for burbot since only one juvenile individual (150 mm length) was taken by seine.

From two years of winter-sampling within the study area, only two specimens were taken; one in Mallik Bay, the other in the East Channel (Fig. 8; loc. 9 and 12 respectively). Catch per unit-effort (Fig. 14, 15 and 16) within the channels was low in the summer; none were taken in Reindeer Channel.

Burbot are bottom feeding predators. Fish captured along the coast were principally feeding on fish such as sculpins, other burbot and smelt, and on isopods. However, mysids, nematodes and amphipods also appeared as food items in the stomach contents (Fig. 29). Burbot caught within delta lakes and channels were feeding upon isopods, fish and to a lesser extent nematodes, parasitic cestodes were found in many of the stomachs. In winter they had only eaten fish. The literature suggests that a seasonal variance exists in the food habits of this species (Lawler, 1963). However, in this study a larger sample size, netted in winter, is required to determine if this trend also applies in the outer Delta. Two burbot have appeared in winter collections from the outer Delta; one in East Channel, the other in Middle Channel (Mann, 1975).

6.3.4 Ninespine Stickleback

The ninespine stickleback, *Pungitius pungitius* (Linnaeus), is a euryhaline species exhibiting a wide geographic distribution. It is an important forage species which is also present throughout the Mackenzie system (Stein *et al.*, 1973). They were caught within the study area at seining locations in Shallow Bay, Kendall Island, Swan Channel and the East Channel (Fig. 39). Specimens were collected off Rae Island in Mackenzie Bay (F. Slaney, 1973).

A total of 64 specimens ranging in length from 11 to 50 mm (Table 6) were caught; all of the specimens aged by otoliths were 0+ years old (Table 10). Ninespine sticklebacks 48 to 70 mm long have been caught in Alaskan streams flowing into the Beaufort Sea (Roguski *et al.*, 1971).

Spawning occurs in spring and summer; in temperate areas stickleback reach sexual maturity after one year and may live for three years (McPhail and Lindsey, 1970).

Sixty-eight percent of the sticklebacks examined had empty stomachs; the principal food items identified in the remainder were chironomids, mysids and ostracods (Fig. 34).

6.3.5 Trout-perch

Trout-perch, *Percopsis omiscomaycus* (Walbaum), were principally caught in turbid lakes on Richards Island; they represented 10 percent of the total seine catch (Table 3). Trout-perch from the outer Delta ranged in length from 11 to 80 mm (Table 6) and were a maximum of three years old (Table 10). In Lake Michigan trout-perch live for eight years

(House and Wells, 1973) and are sexually mature by their third year. Outer Delta specimens have a slower growth rate than temperate forms (Magnuson and Smith, 1963) and spawn in summer. Fifty-six percent of the fish examined had empty stomachs; chironomids, mysids, ceratopogonids and amphipods were present in full stomachs (Fig. 34).

6.3.6 Northern Pike

Northern pike, *Esox lucius* (Linnaeus), is a stenohaline species (i.e. unable to survive long at sea); this is evident from their distribution within the outer Delta (Fig. 39). Only seven of 186 fish caught were from the immediate coastal zone and these were in the vicinity of channel mouths where salinities are low.

Gillnetted pike ranged from 231 mm to 960 mm in fork length (Fig. 11). Approximately 100 fish were aged (Fig. 20); these were from 1 to 13 years old. The 7 to 10 year age classes represented 71 percent of the catch. Older pike (19 years) have previously been reported from the Mackenzie Delta (Stein *et al.*, 1973).

Pike from the outer Mackenzie Delta appear to have a considerably faster growth rate than fish from the Chandalar River system of Alaska (Craig and Wells, 1975). They also grow slightly faster than fish from the Tanana River drainage up to age 5; thereafter the Alaskan fish outgrow them (Cheney, 1972). Similarly in Great Bear and Great Slave Lakes, pike (Miller and Kennedy, 1948) exhibit slower growth than those from the Delta.

The upper Delta south of Richards Island appears to be a more important nursery area for pike than the outer Delta. Pike comprise a greater percentage of the total fish catch upstream from the mouth of the Mackenzie River (Stein *et al.*, 1973). A total of 4,092 pike have been tagged and released in the Delta area and 532 recaptures recorded. Tag returns over the three years indicate that the range of movement of pike within the Delta is restricted and that they normally return to the same lake or creek system each summer.

Although only a single juvenile pike (95 mm) was caught in this study (Fig. 39), the outer Delta contains many areas suitable for spawning. Flooded vegetation typical of the Delta is considered essential habitat for successful spawning (Hassler, 1970).

No fish younger than 7 years old was found to be sexually mature, however, few specimens in the gillnetted catch were young fish. Many small pike were tagged and released rather than being sampled. Fifty-five percent of the fish sexed (N = 132) were males. Pike of both sexes reach sexual maturity by age 6 in the Tanana River drainage (Cheney, 1972).

The minimum age at sexual maturity for pike captured in the upper Delta was three years for males and four years for females (Stein *et al.*, 1973).

'Catch per unit-effort' at channel locations declined throughout early summer (Figs. 14 to 17). Pike were again abundant at these sites late in August. This is consistent with earlier findings that pike move into lakes and smaller tributaries of the Delta to spawn from break-up to mid-June and that prior to freeze-up they return to the deeper channels (Jessop *et al.*, 1974). In the upper Delta between February 20 and May 13, 1974 a total of 14 pike (440 to 808 mm fork length, 5 to 14 years of age) were captured at a single netting location in the Peel Channel; an additional 26 fish (440 to 672 mm fork length, 5 to 10 years of age) were caught in a nearby lake from April 3 to May 15 (Jessop and Lilley, 1975).

A single pike was netted through the ice during the winter surveys of 1974 and 1975 in the outer Delta. This specimen, caught in Harry Channel (Fig. 8), had not recently fed. Six specimens were captured in outer Delta lakes and channels in October and November (Mann, 1975). Two of these fish had fed on whitefish and ninespine sticklebacks.

Pike captured during the open water season at channel locations were feeding almost exclusively on humpback whitefish, burbot and ciscoes whereas pike resident in Delta lakes also included invertebrates such as isopods, odonata, nematodes (Fig. 27) in their diet. Parasitic cestodes were also present in many stomachs.

6.3.7 Longnose Sucker

The distribution of the longnose sucker, *Catostomus catostomus* (Forster), essentially parallels that of pike. They were caught primarily at channel fishing sites and did not appear to range far offshore (Fig. 40).

Fork lengths of fish caught by gillnet in the outer Delta ranged from 191 to 880 mm; 78 percent of these fell in the 331 to 510 mm length intervals (Table 10). Longnose suckers of the Mackenzie system are more abundant but smaller in size south of the Delta (Stein *et al.*, 1973). Within the study area, males and females were equally abundant.

Females tend to live longer and grow heavier than males; fish attaining 20 years of age have been netted in the Delta (Stein *et al.*, 1973). Length-weight relationships for suckers caught in the present study are presented in Table 12. In the three years since tagging was initiated, only 8 of the 386 fish marked in the Delta have been recaptured.

Age and growth data for suckers of the Mackenzie and its tributaries have been previously described (Hatfield *et al.*, 1972; Stein *et al.*, 1973; Tripp and McCart, 1974).

Sexual maturity in Great Slave Lake is reached by age 7; however, only fish 9 years and older participate in spawning migrations (Harris, 1962). In the Donnelly River, the youngest mature males were age 9 and the youngest mature females age 12 (Tripp and McCart, 1974).

These fish probably spawned every year after maturation. Suckers spawn in streams or lake shallows immediately following break-up (McPhail and Lindsey, 1970).

A single overwintering longnose sucker has been caught in the outer Delta; this was taken in the East Channel in November (Mann, 1975).

Seined fish (Table 6) were 21 to 120 mm fork length; these were principally taken in river mouth and upstream locations but not offshore (Fig. 40). Stomachs of nine juvenile contained chironomids, crustacean and insect remains.

6.3.8 Lake Trout

Lake trout, *Salvelinus namaycush* (Walbaum), were commonly captured in clear Delta lakes. However, they were occasionally taken in channels of the Mackenzie in late June and early July, 1974 (Fig. 39). Few specimens have been tagged. Returns indicated that some lake trout move considerable distances. A fish marked and released in Ya-Ya Lake, for instance, was recaptured later in the same summer (1974) in the East Channel at the mouth of Holmes Creek. A number were netted in Mallik Bay and at Rae Island on the coast, indicating that this species sometimes ventures into brackish water. A total of 22 lake trout were captured; most of these were tagged and released. Fifty percent of the fish sexed were males; the 11 specimens aged were from 8 to 24+ years old (422 to 913 mm fork length). The minimum age at maturity for Alaskan lake trout is 10 to 15 years (Craig and Wells, 1975; McCart *et al.*, 1972). Only the three fish older than 24 years in the outer Delta appeared capable of spawning in the late summer 1974. Lake trout probably spawn every second or third year in cold waters of northern regions (McPhail and Lindsey, 1970).

The contents of 13 lake trout stomachs were examined; eight were empty but the remainder contained gastropods, nematodes, amphipods, mammal fur and fish remains (Fig. 29). Lake trout have not been captured overwintering in the outer Delta though they probably exist there during ice cover.

6.4 Other Species

The Arctic char, *Salvelinus alpinus* (Linnaeus), is a fall spawning species. Char are found in north slope drainages and within the Mackenzie system. Upstream migrations pass through the western portion of the Delta, principally along the West, Peel and Husky Channels. Two anadromous spawning populations have been observed in the Mackenzie Delta. One of these utilizes Fish Creek, a tributary of the Rat River, while the other population spawns in Cache Creek, a tributary of the Big Fish River. Approximately 460 tags have been returned by the domestic fishery from a total of 1,365 char tagged in the Delta during 1972 and 1973. These returns indicate that char annually migrate from the Beaufort Sea coastal zone to the upstream spawning areas where they overwinter. Generally, but not always, the fish return to their natal streams.

The upstream migrations through the lower Big Fish River occur during August and early September with spawning occurring in late September and early October (Jessop *et al.*, 1974). The population moving up the Rat River shows a similar pattern, although the migration is several weeks later. The Rat River char spawn about a month earlier than those in the Big Fish River (Jessop *et al.*, 1974).

A non-migratory population of char, composed of smaller and darker individuals, has also been reported in Cache Creek (McCart and Bain, 1974).

The Arctic grayling, *Thymallus arcticus* (Pallas), is a spring spawning species common to many clear, fast-flowing tributaries in the Mackenzie system. They are present in the headwaters of streams flowing into the outer Delta, from the Caribou Hills on the east to the Richardson Mountains on the west; two mature males were captured in Moose Channel (Mann, 1973). Only fry (N = 8, 51 to 80 mm fork length) were captured in this study in the East Channel at the mouth of Holmes Creek (Fig. 43). Stomachs contained plecopteran and crustacean remains.

Detailed reviews of the general biology and life history of Arctic grayling in the Mackenzie system (Stein *et al.*, 1973; Jessop *et al.*, 1974; Tripp and McCart, 1974; Jessop and Lilley, 1975; Chang-Kue and Cameron, 1975 - in press) and in drainages along the Beaufort Sea coast (de Bruyn and McCart, 1974; Kendel *et al.*, 1976) have been recently published.

The Arctic lamprey, *Lampetra japonica* (Martens) is an anadromous species spawning over gravel in fast-flowing tributaries within the Mackenzie system. The juvenile stages, known as ammocoetes, are swept downstream where they settle out and burrow into soft mud, they live as filter-feeders for a number of years before transforming into parasitic adults and swimming out to sea.

Many of the lamprey ammocoetes (N = 64) taken by electroshocking at channel mouths (Fig. 7; loc. 41) were in advanced stages of transformation. Inconnu caught at the same site were feeding heavily on them.

Adult lamprey (300 to 400 mm standard length) were found attached to Pacific herring captured by gillnet near Tuktoyaktuk (Riske, 1960). Many least and Arctic cisco caught in the same nets had lamprey scars. Similarly, a high incidence of scars attributable to lamprey attack were observed during tagging on the upstream run of Arctic char in Husky Channel in 1973

The round whitefish, *Prosopium cylindraceum* (Pallas), is widely distributed in the Arctic and sub-Arctic. It is a fall-spawning species common to clear fast-flowing streams, although able to tolerate brackish waters. Two specimens were captured within the study area, one at Kendall Island and the other in a lagoon southwest of Tuktoyaktuk (Fig. 41). Both fish were feeding on chironomids; however, ostracods, copepods and insect remains were also present. Round whitefish are slow-growing and long-lived. Fish to 15 years of age have been caught in the Mackenzie River (Stein *et al.*, 1973) and fish to 22 years of age have been reported from the Yukon River in Alaska (Craig and Wells, 1975). The latter reach sexual maturity at 7 to 8 years of age.

A single lake chub, *Couesius plumbeus* (Agassiz), was captured in the East Channel (Fig. 37). This cyprinid is a spring spawner and is abundant in the upper Delta where it feeds principally on insects (Stein *et al.*, 1973). The specimen captured was 124 mm fork length and had an empty stomach. The biology of lake chub is reviewed by McPhail and Lindsey (1970).

6.5 General Discussion

A number of the Beaufort Sea studies attempt to assess the fate of contaminants spilt into the Arctic aquatic environment. Current knowledge suggests that long-term pollution is a distinct possibility. Low evaporation and biodegradation rates for petroleum compounds probably occur in cold northern seas. Moreover, recent evidence suggests that oil can be incorporated into newly forming ice thus rendering the weathering and biodegradative processes inoperative for extended periods.

Food chains in the Arctic tend to be short and are therefore very susceptible to disruption. The reproductive potential is generally low because of the short reproductive season, slow rate of growth and because individuals mature later and live longer. These factors combined with the knowledge that many of the species do not spawn annually after reaching sexual maturity suggests that repopulation of depleted areas would be a slow process.

Our present knowledge of the life history of major fish species utilizing the outer Mackenzie Delta, though incomplete, is summarized in Table 1. In the present investigation, approximately 58 percent of the total gillnet catch was taken along the Beaufort Sea coast, 34 percent in Mackenzie River channel locations and the remainder within Mackenzie Delta lakes. Similarly, fry were

Table 1. Summary of information presently available on the life

Species	Habitat Preference	Relative Abundance in Study Area	Maximum Age in Outer Delta	Age at Maturity	Spawning Season
Arctic cisco	anadromous	+++	11 (11^{Δ})	7	late Fall
Arctic char	anadromous (also landlocked)	++		4 - 5*	late Fall
Arctic flounder	marine and brackish water	++	12*	5*	Winter
Arctic grayling	freshwater	+	(8^{Δ})	4 - 7	Spring
Arctic lamprey	anadromous	adults(+) ammocoetes(++)	unknown	unknown	probably Spring
Boreal smelt	anadromous	+++	8*	6*	early Spring
Broad whitefish	anadromous	+++	15	3 - 4	Fall
Burbot	freshwater	++	14*	7 - 8*	mid-Winter
Fourhorn sculpin	euryhaline	++	14*	3*	Winter
Humpback whitefish	anadromous	+++	18	7	Fall
Lake trout	freshwater	++	>24*	5 - 11* (upper Mackenzie R.)	Fall
Least cisco	anadromous (also non-migratory forms)	+++	11	5	late Fall
Longnose sucker	freshwater	++	(20*Δ)	7 - 9*	early Spring

history of major fish species utilizing the outer Mackenzie Delta.

Spawning Grounds Known (K) and Suspected (S)	Spawning Habitat	Prespawning Migration	Postspawning Migration	Overwintering in Outer Delta
tributaries Arctic Red and Peel R. (K)	over gravel	throughout summer	early October	yes
Cache and Fish Ck. (K)	pools or riffles over gravel	mid-August until late September	at breakup	mountain streams not delta
Mallik Bay & northeast coast Richards Is. (S)	probably silt substrate	localized	-	yes
Fish R., Holmes Ck., tributaries of upper Mackenzie (S)	clear fast-flowing streams	breakup	variable; some spend summer in spawning streams	unknown
Mackenzie R. tributaries (S)	gravel substrate	unknown	unknown	ammocoetes only
Arctic Red R. area & Holmes Ck. (S)	gravel substrate	prior to breakup	June - early July	along coast
Arctic Red R. and main Mackenzie R. (K)	small lakes and Mackenzie back-eddies	early Fall	November	yes
upper delta channels (K)	clear streams & lake shallows	relatively localized	-	yes
Mason & Mallik Bays (S)	probably sand substrate	relatively localized	-	yes
Arctic Red R., main Mackenzie & tributaries (K)	stone or hard silt substrate	late summer	October-November	yes
lakes throughout Richards Is. (S)	lakes	localized	-	suspected
upper Mackenzie R. tributaries (S)	sand or gravel substrate	mid-August until after freeze-up	unknown	yes
Mackenzie R. tributaries (K)	stream & lake shallows over gravel	early Spring	Spring	unknown

Table 1.

Species	Habitat Preference	Relative Abundance in Study Area	Maximum Age in Outer Delta	Age at Maturity	Spawning Season
Inconnu	anadromous	+++	16 (22^{Δ})	6	Fall
Ninespine stickleback	freshwater	++	probably 3	unknown	Spring & Summer
Northern pike	freshwater	++	13 (19^{Δ})	4 - 7	early Spring
Pacific herring	marine and brackish water	++	(14^{Δ})	(6^{Δ})	Spring
Saffron cod	marine and brackish water	++	16*	unknown	unknown
Starry flounder	euryhaline	+	15*	unknown	Winter

+ not abundant within study area

++ abundant but restricted in distribution

+++ abundant throughout study area

continued

Spawning Grounds Known (K) and Suspected (S)	Spawning Habitat	Prespawning Migration	Postspawning Migration	Overwintering in Outer Delta
tribs. of Peel, Arctic Red & Mackenzie R. (S)	swift water over coarse gravel	summer	October	yes
lakes throughout Delta (K)	unknown	localized	-	suspected
lakes & tributaries in upper Mackenzie (K)	flooded vegetation; shallows	localized	-	yes
Northeast coast Richards Is. (S)	nearshore in shallows	unknown	-	yes
none	breed at sea	unknown	-	no
none	shallows at river mouths	localized	-	yes

* otolith based ages

Δ ages reported from elsewhere in Delta

captured principally in coastal areas (61 percent). Least cisco and Arctic cisco were the most abundant species taken in seines. These numbers obviously reflect to a certain degree the fishing effort expended even though an attempt was made to standardize the effort.

Index netting suggests that Arctic cisco, least cisco, burbot, inconnu, broad whitefish and humpback whitefish are tolerant of brackish water in protected coastal lagoons. Least cisco are especially abundant here, although the entire Beaufort Sea coast may be an important nursery area for many of these species.

Boreal smelt return to offshore areas of the outer Delta during the summer, having completed spring spawning in tributaries of the Mackenzie River. The fry spend their first years feeding in near-shore areas along the coast.

Saffron cod and Pacific herring are pelagic species which remain in brackish or saline waters throughout the summer, especially along the northeast coast of Richards Island. No nursery areas were identified for these fish, however.

Fourhorn sculpin and Arctic flounder, both adult fish and fry, are widely distributed in brackish water of the outer Delta year round.

Northern pike and longnose suckers had similar ranges, invading the coastal area only to the mouths of rivers. Longnose sucker fry are restricted to fresh waters throughout the Delta.

Arctic and least cisco comprised 44 percent of the coastal catch, 35 percent of channel catches and 22 percent of lake catches. Offshore species, including boreal smelt, fourhorn sculpin, Pacific herring, saffron cod, starry flounder and Arctic flounder accounted for approximately 24 percent of the coastal catch and one percent each in the outer areas. Broad whitefish, humpback whitefish and inconnu made up 25 percent of the coastal sample, 48 percent of stream samples and 55 percent of lake samples.

Anadromous and, to a lesser extent, marine fishes are commonly encountered along the coastal fringe of the Delta, particularly in protected lagoons and bays. Many of the anadromous fish caught along the Yukon coast as far away as Herschel Island and along the Tuktoyaktuk Peninsula are members of the Mackenzie breeding stock. Fish populations of the Beaufort Sea coastline are therefore concentrated in the delta area during spawning migrations primarily in the late summer and early fall. At these times, they are susceptible to any large scale polluting event.

Not only is the outer Delta an important migration corridor for anadromous fish moving to spawning grounds on the inner Delta, it is also critical for overwintering. Lakes with sufficient depth are utilized by whitefish and least cisco. Least cisco, Arctic cisco, Arctic flounder, burbot, boreal smelt, inconnu and fourhorn sculpins overwinter in Mallik Bay. Areas suitable for overwintering are also plentiful along the northeast coast of Richards Island. In contrast, relatively small numbers of boreal smelt, humpback whitefish and least cisco have been netted through the ice in Kugmallit Bay. Inconnu and fourhorn sculpins have been captured in the Shingle Point area, to the west of the delta, in winter.

Both fresh and brackish water species of invertebrates were encountered in fish stomach contents during this investigation. The Copepoda (Cyclopoids), Trichoptera, Gastropoda and Coleoptera were all identified as freshwater forms. The mysids were represented by *Neomysis* sp. (freshwater) and *Mysis relicta* (both fresh and brackish water). *Onisimus affinis* was the most common amphipod in fish stomachs and in seine hauls from the coastal area, particularly in Mason Bay and along the northeast coast of Richards Island. The isopod, *Mesidotea entomon* was common in brackish water especially along the west coast of Tuktoyaktuk Peninsula. This species was also the most common invertebrate taken in seine hauls throughout the outer Delta (Fig. 46). *Yoldiella intermedia* is a brackish water pelecypoda commonly found in stomachs of fish caught in the coastal zone. Nematoda and Ostracoda, which were not identified to species, are important in the diet of fish captured in both lake and coastal habitats.

Stomach contents from anadromous species are reported separately from coastal, lake and channel locations in order to emphasize differences in feeding behaviour. Stomach content analyses suggest that most fish in the outer Delta are opportunistic feeders. For example, inconnu, at some sites in early spring were engorged with lamprey ammocoetes; in winter they were feeding almost exclusively on least cisco and throughout the rest of the year had fed on a varied diet of fish and invertebrates.

Many migrating fish such as the Coregonids cease feeding and would be susceptible to additional stresses caused by any disturbance which delays or blocks normal migration.

Fry of all species appeared to feed almost exclusively on invertebrates.

Large turbid lakes in the lower Delta contain substantial fish populations throughout the summer. Broad whitefish, humpback whitefish, inconnu, least cisco and northern pike utilize this type of lake extensively for feeding. Clear, deep delta lakes, on the other hand, are primarily used by lake trout and least cisco.

Areas offshore in Kugmallit and Mackenzie Bay contain few concentrations of fish other than boreal smelt and fourhorn sculpins. A heterogeneous fish population is found in nearshore areas around Kendall and Garry Islands; the predominant species are least cisco, inconnu and burbot. Few resident fish or fry populations were encountered in Shallow Bay or along the shore between Shallow Bay and Garry Island.

The region between Hendrickson and Pullen Islands on the northeast coast of Richards Island (Fig. 7) is a complex area worth examining in more detail. It is largely isolated from the direct influence of the Mackenzie River and subject to impressive wind tides bringing in and entrapping saline Beaufort Sea water. In Mason Bay, for instance, salinity readings exceeded 5 ppt in surface water and 18 ppt at depths of 20 m (Table 9). Marine fish species penetrate the near-shore zone in such areas of increased salinity. This area, similar to other lagoons along the west coast of Tuktoyaktuk Peninsula would appear to be extremely vulnerable to oil slicks originating in the offshore zone.

Index sampling carried out in spring, mid-summer and late fall demonstrated an interesting pattern of distribution of anadromous and marine fish in this area. Along the coast northwest of Mason Bay (Fig. 7) boreal smelt were netted at the mouths of lagoons but infrequently within the lagoons. Least cisco, fourhorn sculpin, Arctic flounder and inconnu were the most abundant species within the outer lagoons; however, humpback whitefish, broad whitefish and Arctic cisco were also caught there. In the innermost lagoon areas, Pacific herring were frequently the only species captured. Clear, fresh lakes draining into those lagoons appeared to contain only lake trout and least cisco.

In Mason Bay and an adjacent unnamed bay (Fig. 7), Pacific herring and saffron cod, both true marine species, were caught in deep water. Closer to shore, Arctic flounder and fourhorn sculpins predominated. In shallower and more protected areas of the bays (Fig. 7; loc. 57) relatively large numbers of inconnu and fourhorn sculpin were encountered. This diverse fish fauna was feeding largely on amphipods. Amphipods were also taken in large numbers by seine throughout the area.

Seine catches indicated that the northeast coast of Richards Island is an important nursery for Arctic flounder, boreal smelt, broad whitefish, ciscoes and fourhorn sculpins. Only Arctic flounder and fourhorn sculpins were captured in the deep, saline tidepools that are found throughout this same region.

Between Kittigazuit and Tuktoyaktuk (Fig. 7; loc. 68 to Tuk) the coast is characterized by numerous inter-connecting, low-salinity lagoons subject to tidal influences. Here large fish populations are resident throughout the summer months, predominantly least cisco, humpback whitefish, broad whitefish and inconnu. These species are abundant in the innermost extensions of these lagoons whereas boreal smelt are common near the outlets and further offshore. Such lagoons appear to be important nursery areas for anadromous species which have moved down from spawning grounds in the Mackenzie River system.

Mallik Bay on the northern shore of Richards Island is subject to storm tides and low rates of exchange. Concentrations of least cisco and inconnu are present here throughout the year. Humpback whitefish, fourhorn sculpin and Arctic flounder are also present during summer. Mallik Bay is a nursery area for whitefish, ciscoes and, to a lesser extent, fourhorn sculpins.

It must be borne in mind that, although adult fish are not found in large concentrations offshore in the Beaufort Sea, those present will probably orient to floating structures or to newly created artificial islands where invertebrate fauna colonize. There could therefore be a greater local impact from a spill of toxic contaminants than initially suspected.

7. CONCLUSIONS

The outer Mackenzie River Delta provides an essential habitat for the maintenance of the freshwater, coastal marine and anadromous fish resources in much of the southern Beaufort Sea area. The inshore zone is an important nursery, feeding and overwintering site for both nearshore and offshore organisms. It is especially important to those anadromous species which form the basis of the domestic and commercial fishery in the Delta (broad whitefish, Arctic char, Arctic cisco and inconnu). Standing stocks of fish are greatest nearshore since the anadromous species tend to frequent shallow coastal waters during the summer months rather than moving far offshore.

The seasonal fluctuations in Mackenzie discharge play an important role in determining species distribution and abundance within the outer Delta. The marine fish fauna normally present in waters beyond the barrier islands in Mackenzie Bay move nearer shore with the encroachment of brackish water in the fall; marine species are also found in the brackish waters of Mason and Mallik Bays throughout the year.

Any large scale reduction in the aquatic invertebrate fauna would have a profound effect on the fishery. Stomach analyses indicate that fish utilizing the area are largely dependent on this food source. Many of the fish species present tend to be opportunists in their feeding habits and could therefore probably compensate for minor changes. It should be noted that all species are important to the stability of an ecosystem since the more diverse the biological community the greater its ability to compensate for changes in the environment.

The outer Delta is an important migration corridor for anadromous species moving from the sea to spawning grounds in the inner Delta. The juveniles of many species as well as those fish which spawn in alternate years remain in the outer Delta.

Boreal smelt principally migrate through channels in the eastern Delta in early spring. Arctic char tend to utilize the western Delta channels for prespawning migrations in the fall and again in the early spring when moving back to sea. Arctic cisco, least cisco, inconnu, broad whitefish and humpback whitefish migrate through most delta channels during the late summer and early fall, when moving to upstream areas, and again during downstream runs in late fall.

Offshore areas within the study zone are flushed by the Mackenzie River on a continuous basis and contain fewer concentrations of adult fish than does the coastal zone; however, pelagic larval forms are abundant further offshore and therefore neither area can be considered insensitive to exploration activities. The long-term impact could be considerable if oil becomes entrained in the sediments.

Several broad coastal areas near the Mackenzie Delta contain significant fish populations which may be sensitive to contaminants originating offshore. ERTS (earth resource technology satellite) imagery shows that many of these lagoons and embayments are not normally flushed by the Mackenzie. Low rates of exchange of water and the occurrence of storm tides render these areas highly susceptible to pollutant contamination from routine exploration activities or to oil from an uncontrolled well blowout. Repopulation of depleted areas would be a slow process.

Areas sensitive to disruption are found along the west coast of Tuktoyaktuk Peninsula, at least as far as Tuktoyaktuk, the irregular northeast shoreline of Richards Island between Pullen and Hendrickson Islands, and the Mallik Bay area on the north shore. All contain large resident populations of adults and fry throughout the summer months (primarily whitefish, ciscoes and inconnu). These habitats provide a haven within the Delta area for marine fish species such as flounders, sculpins, Pacific herring and saffron cod, important forage species for Beaufort Sea birds and mammals. Fish also concentrate near Kendall Island (least cisco and burbot) and Garry Island (boreal smelt and ciscoes) during the summer; these areas become even more sensitive in fall, at which time inconnu congregate for overwintering in nearby channels and in Mallik Bay. With the exception of the western and northwestern portion of Shallow Bay, which is a critically sensitive migration corridor for char, inconnu and ciscoes, no significant fish populations were found in the region between Shallow Bay and Garry Island during this investigation.

Many of the questions asked of the Beaufort Sea Project cannot be adequately answered in an 18 month crash program. However, it has provided valuable baseline information which can be used to help minimize social and environmental disruption during exploratory offshore drilling.

8. IMPLICATIONS AND RECOMMENDATIONS

The fish resource of the outer Mackenzie Delta is sensitive to a number of disturbance factors associated with offshore exploration. The most obvious potential threat is a massive oil spill. A film of free oil prevents gas exchange at the surface of water bodies; this can result in death by suffocation for fish and fry in smaller tidepools along the coast but is probably not a significant factor offshore. A more serious threat to the coastal and offshore fishery comes from oil in emulsion and from the toxic effects of oil. Emulsions prevent respiratory and ion exchange by coating fish gills. In sea water, low oil concentrations can produce disagreeable flavours and odours in fish; this potentially poses a serious threat to the local fishery, anadromous species in particular.

Mechanical clean-up techniques alone should be used in combating oil spills until we have gained a greater insight into the fate and effects of dispersants and of dispersed oil in the biotic and abiotic marine environment in the Arctic. Often the emulsifiers that are used in temperate waters prove to be more lethal than the oil being mopped up. Similarly, sinking agents merely transfer the problem from the surface to the bottom where it becomes virtually impossible to deal with. Mechanical clean-up equipment now in use must be radically improved to cope with oil spills at sea (not only in placid lagoons!) and new approaches devised to recover oil on and under ice. It is recommended that during any polluting incident first priority be given to preventing oil or other pollutants from moving into the nearshore zone where contact with estuarine waters will lead to its sedimentation and retention for extended periods of time. Sedimentation of oils and tars along the coast could destroy nursery and spawning areas and may kill essential benthic food organisms or force them to emigrate from the area. Embayments and lagoons throughout the outer Delta are important in the life history of many fish species; not only the coastal fishes but also those utilizing the whole Mackenzie Delta region.

If approval is granted for offshore exploration, an essential requirement is a program of effective resource monitoring studies that will facilitate the identification and resolution of potentially dangerous environmental problems at the earliest possible stage. It is important that studies be carried out prior to development, during the period of disturbance and during an assessment phase. It is critical to monitor control areas along-side impacted areas in order to clarify natural environmental trends. The rate of exploitation will have to be governed by the overall extent of the impact expected. Now that an inventory of baseline data for all the environmental components in the Beaufort Sea has been compiled, adequate oil clean-up contingency plans can be developed. These must not be imported from other less hazardous areas in the south, but developed with the specific environmental problems of the area as a focus.

Baseline petroleum hydrocarbon levels have been determined for a few species of plankton, invertebrates and fish as well as for Beaufort Sea water. This program should be expanded to provide reference material for comparison with hydrocarbons found in tissues and water at later dates. This will be particularly useful in determining the persistence of oil in the Arctic marine environment and its passage through the food chain. Industry should provide samples of oil discovered in the Beaufort Sea area to allow meaningful site-specific toxicity and behavioural studies to be carried out. Chromatographic "fingerprints" of this oil should also be made available in order to effectively trace the fate of any spills that do occur.

Discharge of drilling muds and other "housekeeping" wastes at offshore sites could have similar short and long-term impacts to those of an oil spill. The synergistic and antagonistic effects of all of these potential pollutants in Beaufort Sea water cannot at present be fully appreciated and therefore stringent implimentation of waste water and drilling fluid disposal regulations must be assured.

9. NEEDS FOR FURTHER STUDY

Although there is considerable baseline information on the effects of oil on fish in temperate waters (both lethal and sublethal doses) there is virtually no comparable work in the Arctic. The applicability of these toxicity studies to the Arctic ecosystem is suspect, especially since there are the added complications (at least in the Beaufort Sea area) of clear-turbid, fresh-saltwater interfaces and prolonged periods of ice cover and darkness.

Most toxicity studies are of the static bioassay type which measure only short-term lethal effects. The longer-term, more subtle effects of pollutants on behaviour, growth and reproduction must receive closer attention in the future. Similarly, synergistic and antagonistic interactions of pollutants that are likely to be released into the Beaufort Sea are even more poorly understood. Such studies must be of an "ecotoxicological" nature rather than being restricted to the single species case.

In an 18 month study such as this, it is obviously impossible to ascertain seasonal and annual variations in distribution and abundance. Virtually nothing is known yet about the habits and habitats of overwintering fish. The fish resource must be monitored on a much longer, though less intense, basis in order to gather other than baseline information. Monitoring of the Beaufort Sea and adjacent coastal waters is essential throughout the exploratory drilling phase. The data obtained will help to determine the "real" effects as opposed to the predicted effects.

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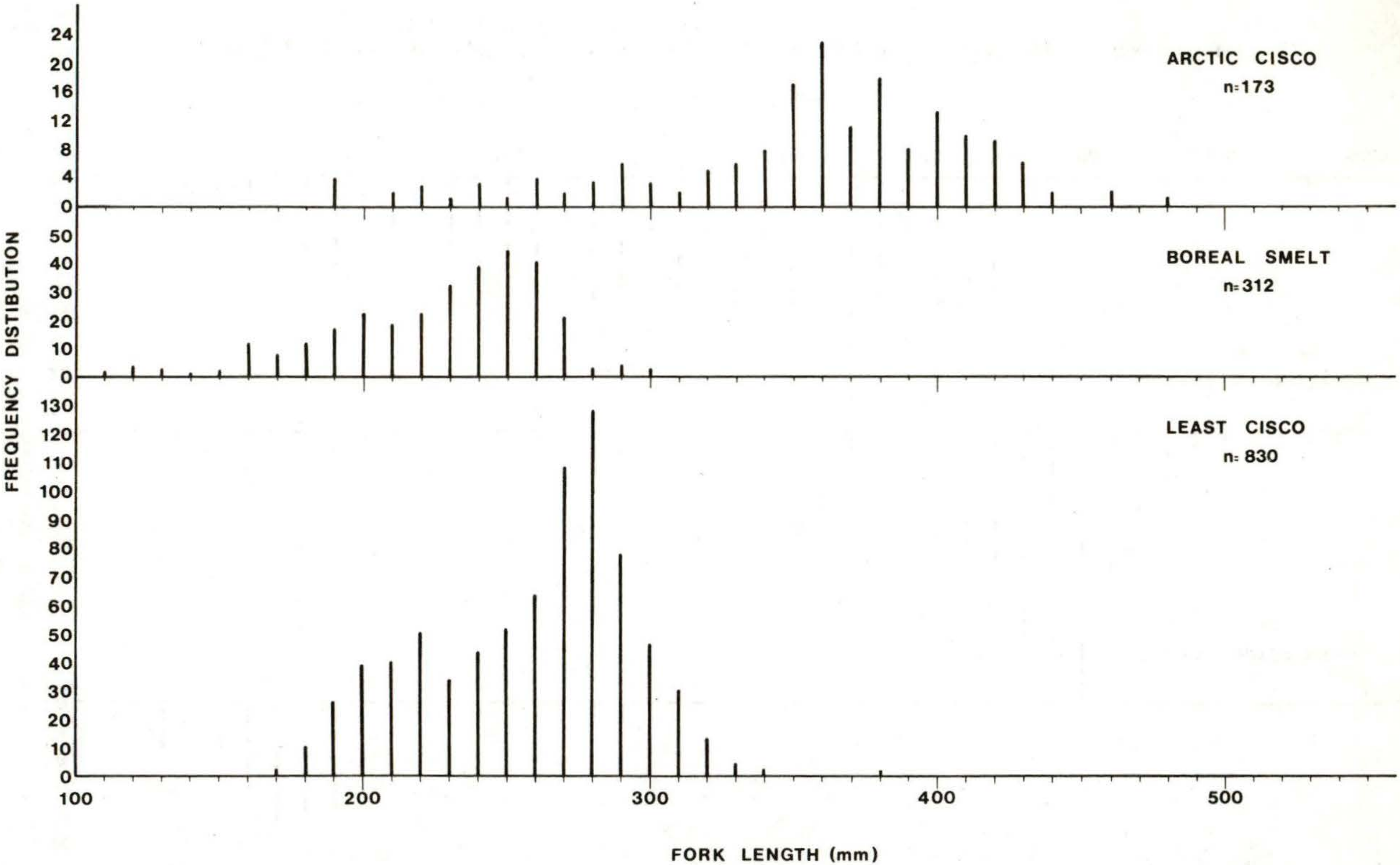

Figure 9. Length-frequency of Arctic cisco, boreal smelt and least cisco gillnetted in the outer Mackenzie Delta.

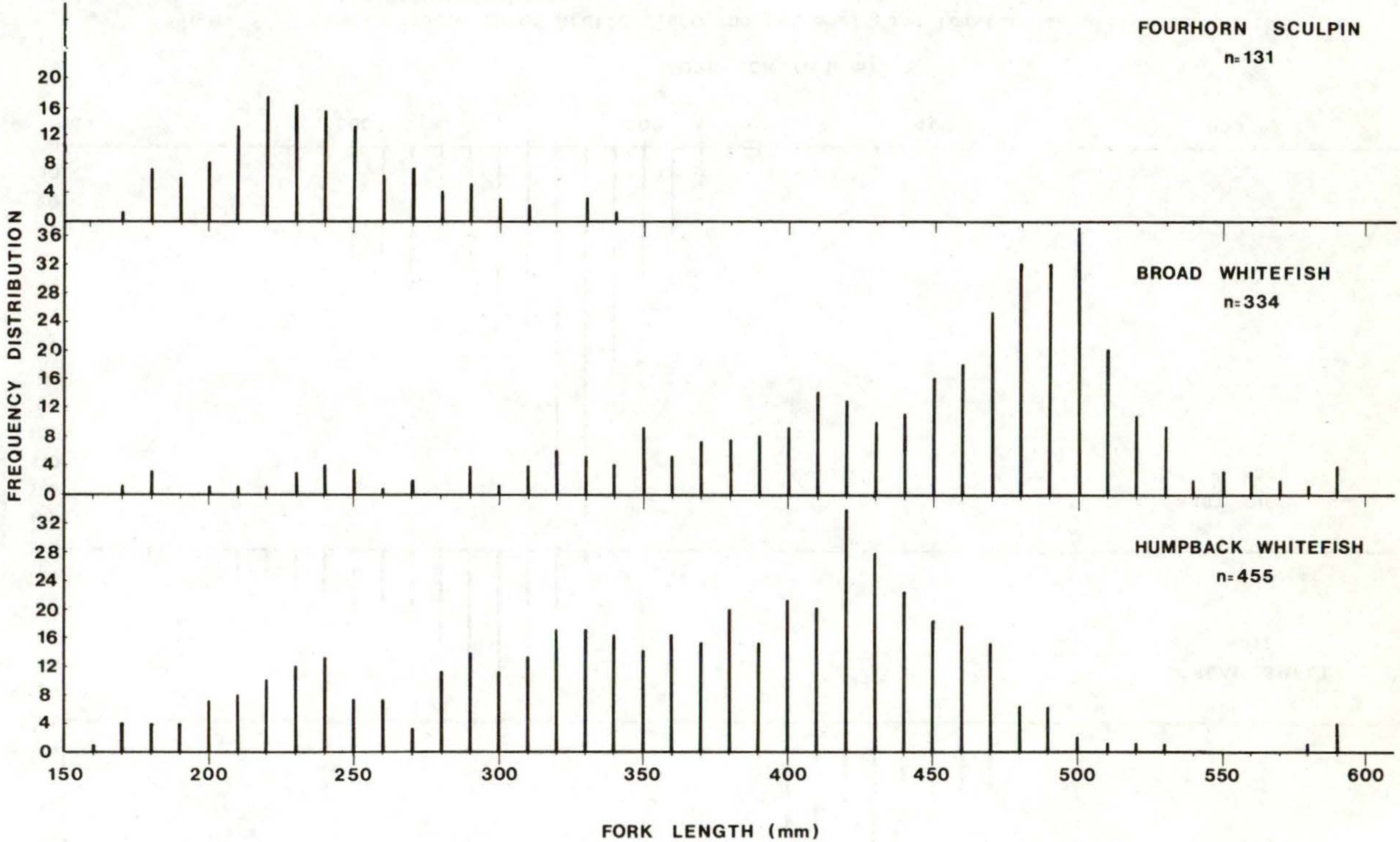

Figure 10. Length-frequency of fourhorn sculpin, broad whitefish and humpback whitefish gillnetted in the outer Mackenzie Delta.

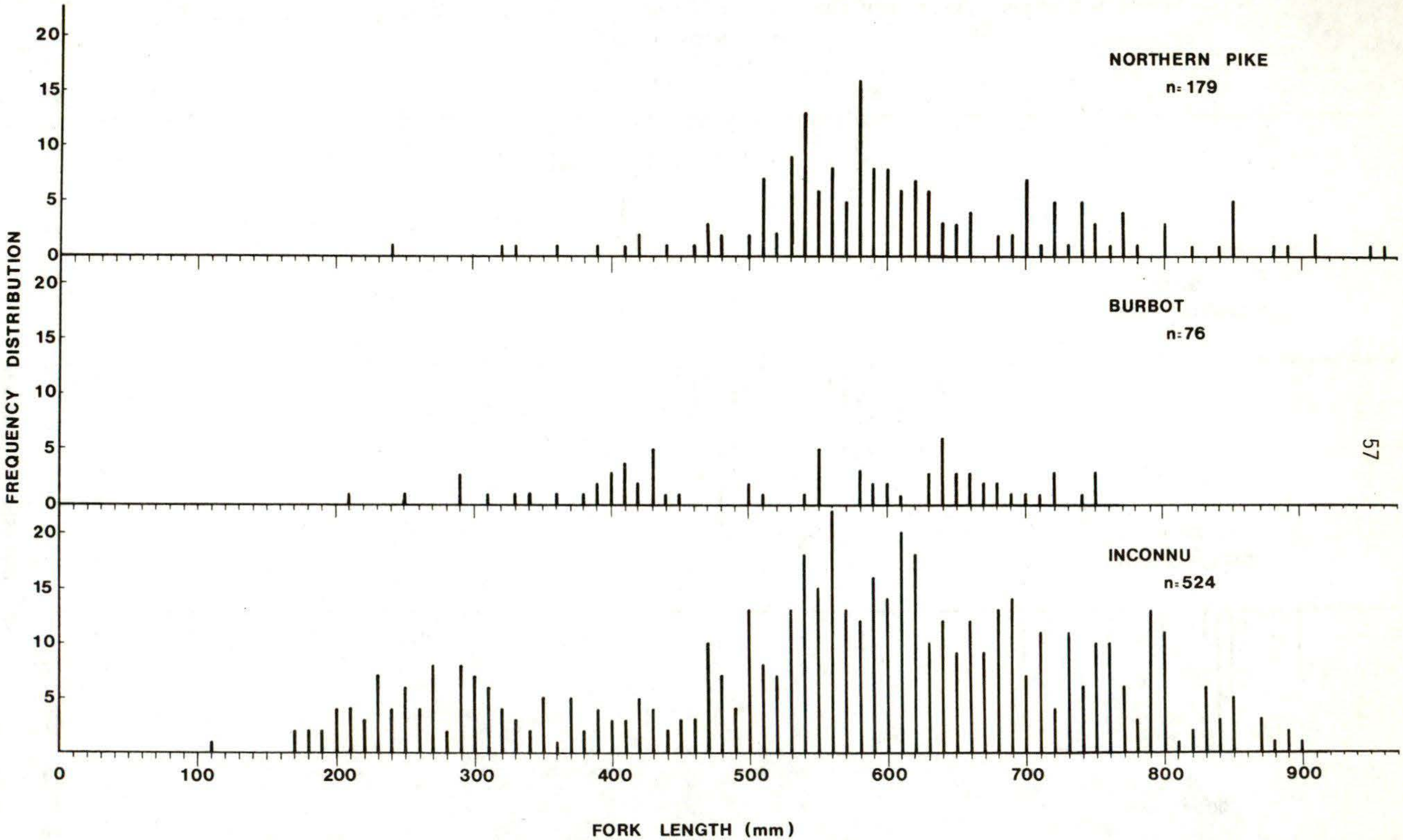

Figure 11. Length-frequency of northern pike, burbot and inconnu gillnetted in the outer Mackenzie Delta.

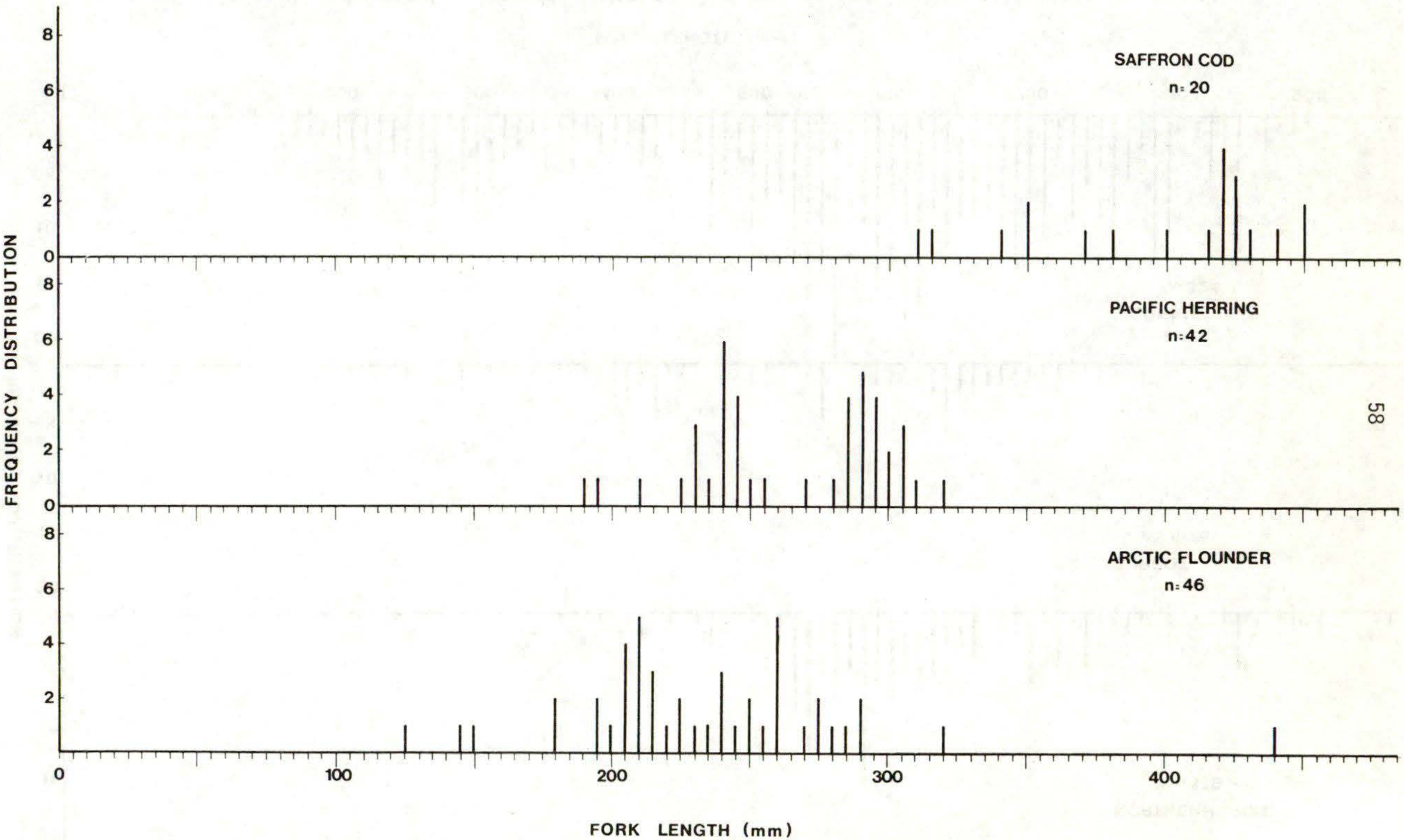

Figure 12. Length-frequency of Arctic flounder, saffron cod and Pacific herring gillnetted in the outer Mackenzie Delta.

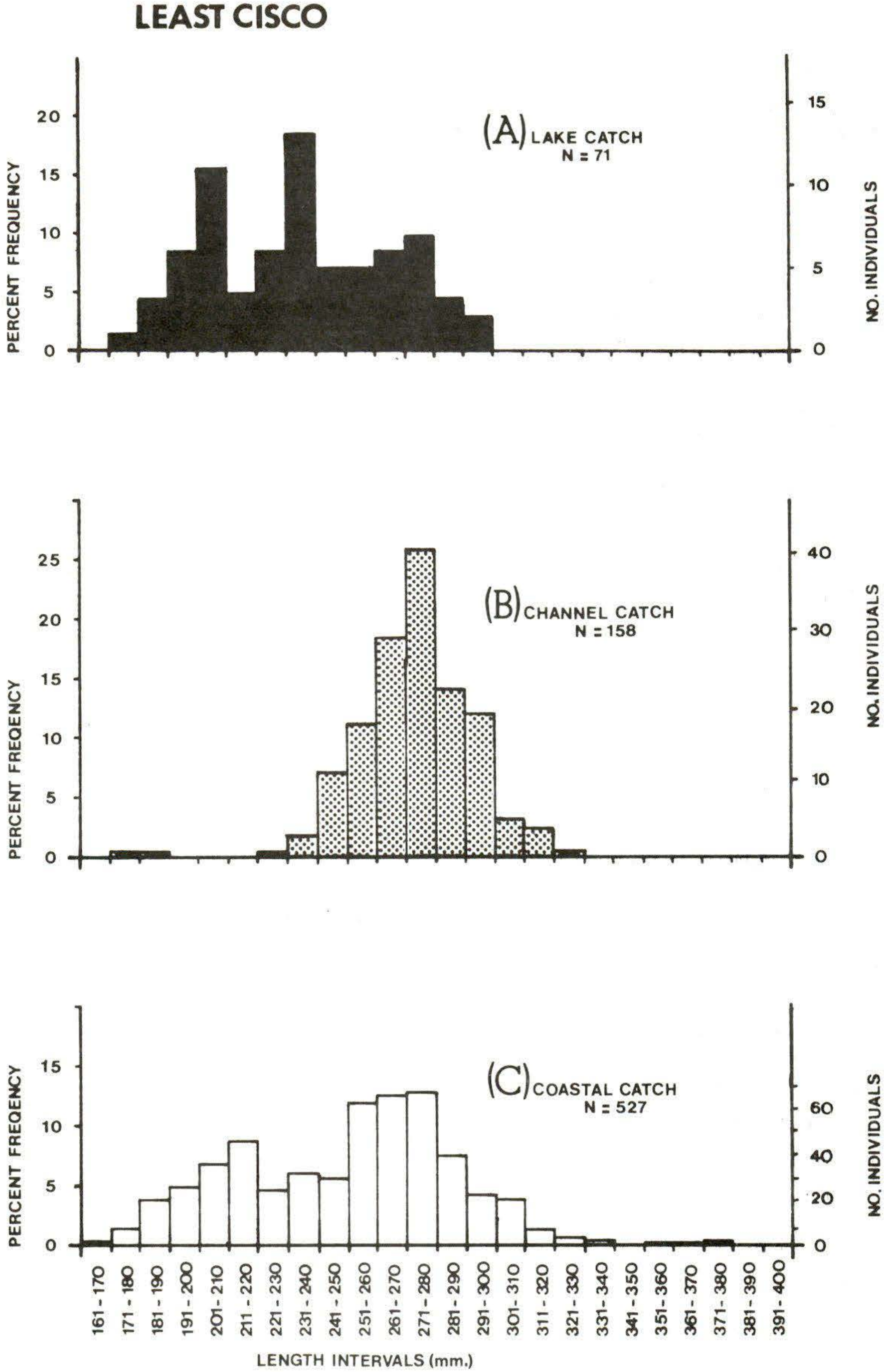

Figure 13. Length-frequency of least cisco gillnetted in lakes, streams and coastal waters of the outer Mackenzie Delta. The channel catch represents mostly upstream spawning migrants.

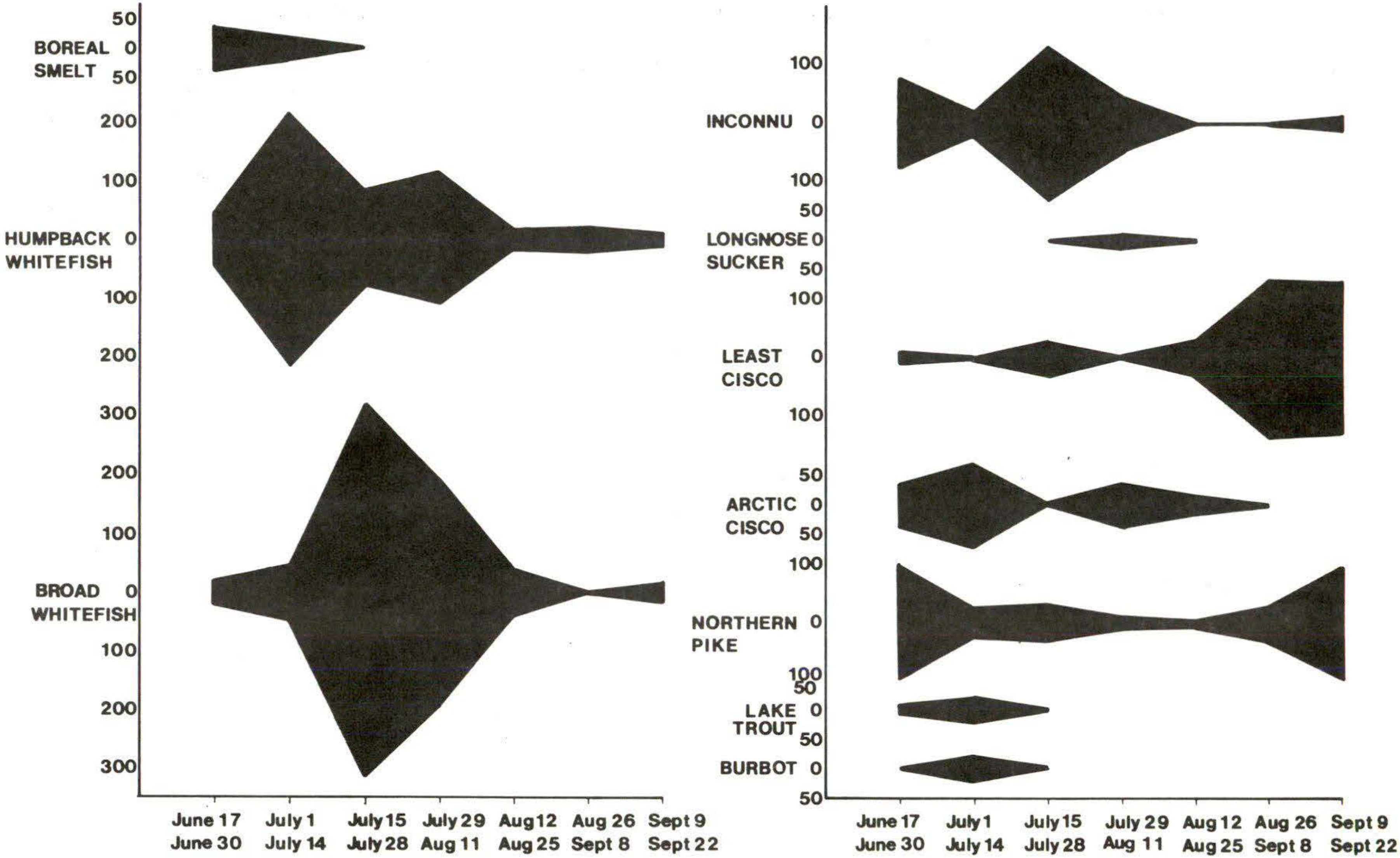

Figure 14. Seasonal change in index gillnet catches (catch per unit-effort X 1000) at location 33, Harry Channel (Fig. 7).

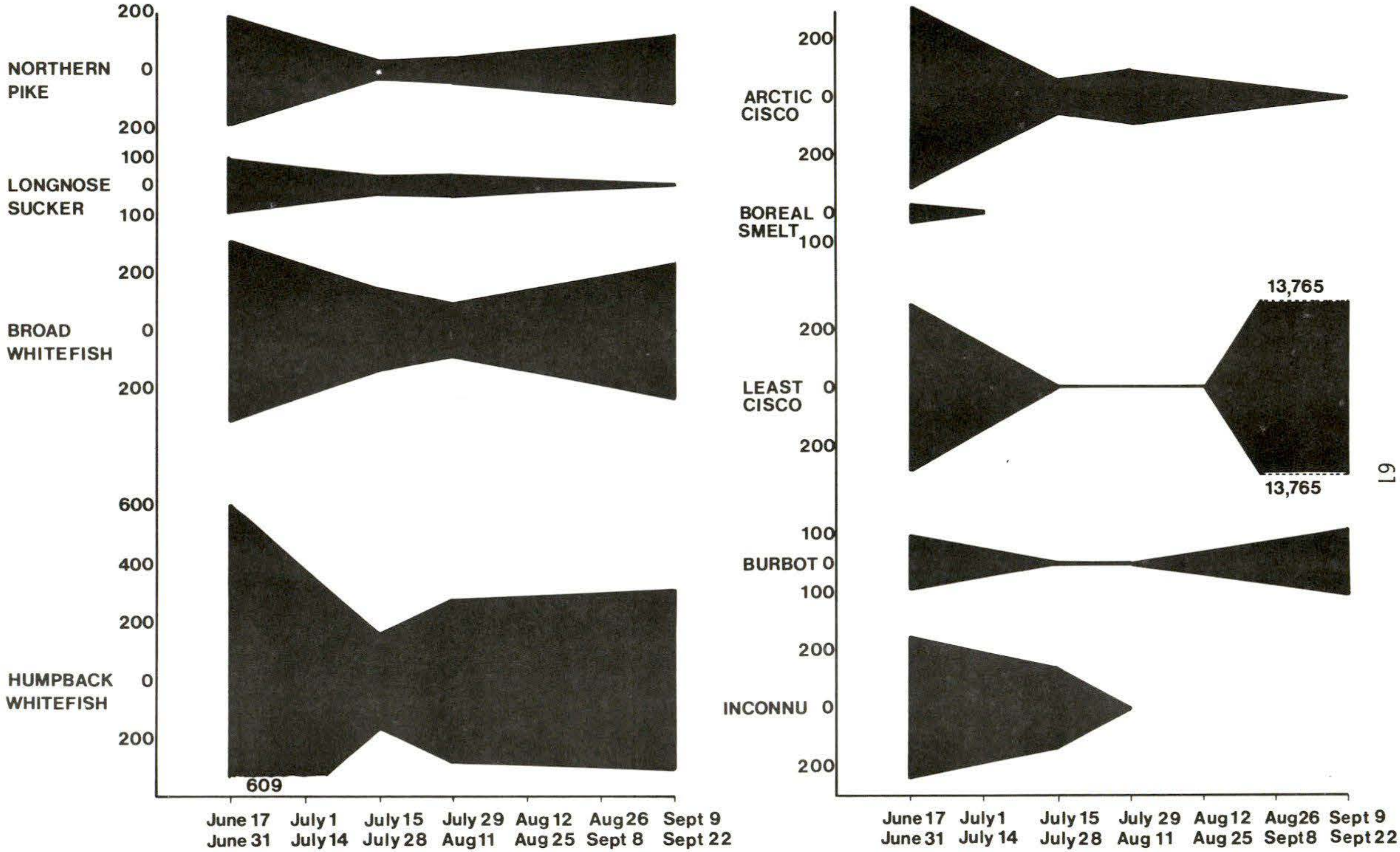

Figure 15. Seasonal change in index gillnet catches (catch per unit-effort X 1000) at location 70, East Channel (Fig. 7).

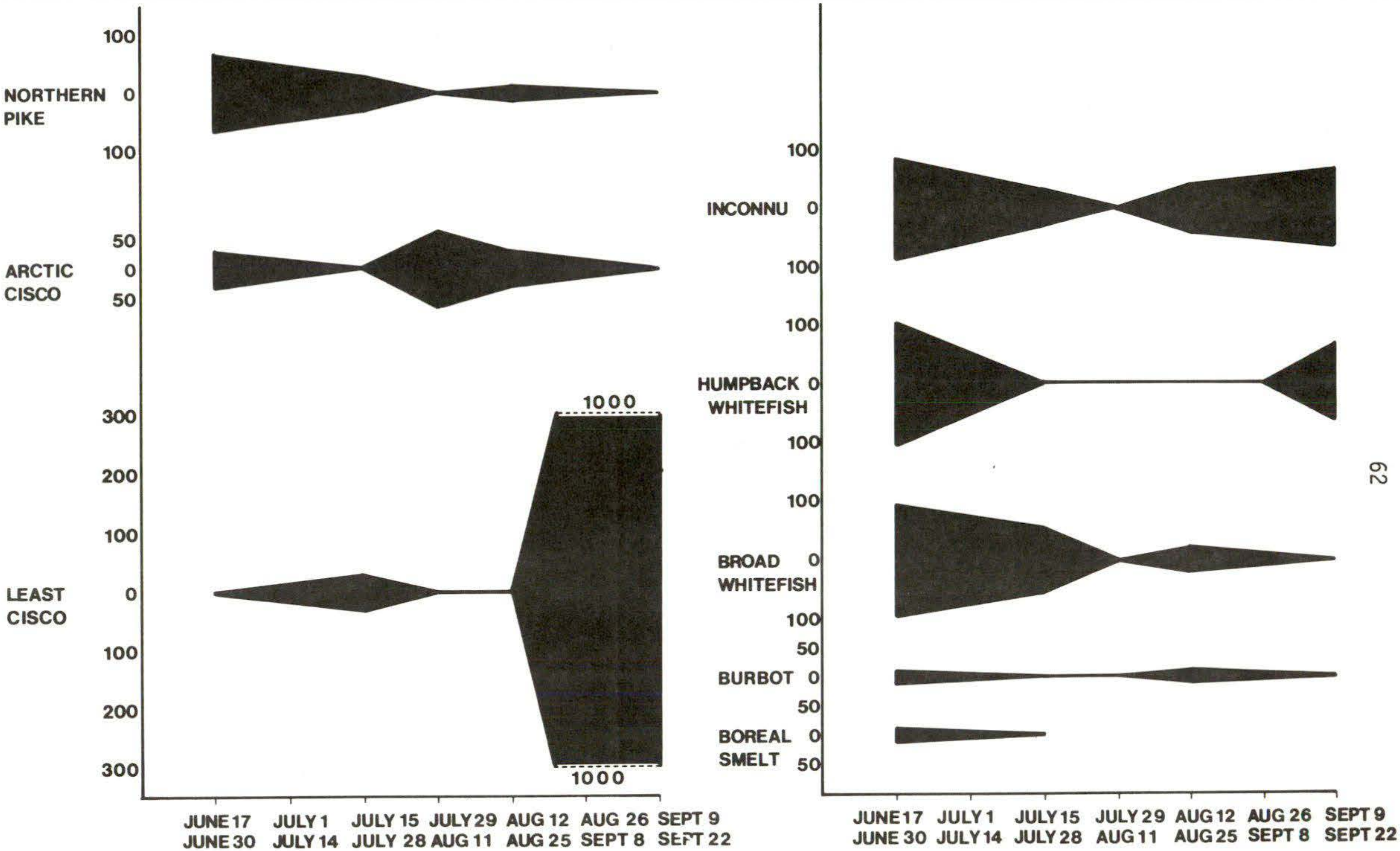

Figure 16. Seasonal change in index gillnet catches (catch per unit-effort X 1000) at location 32, Main Channel (Fig. 7).

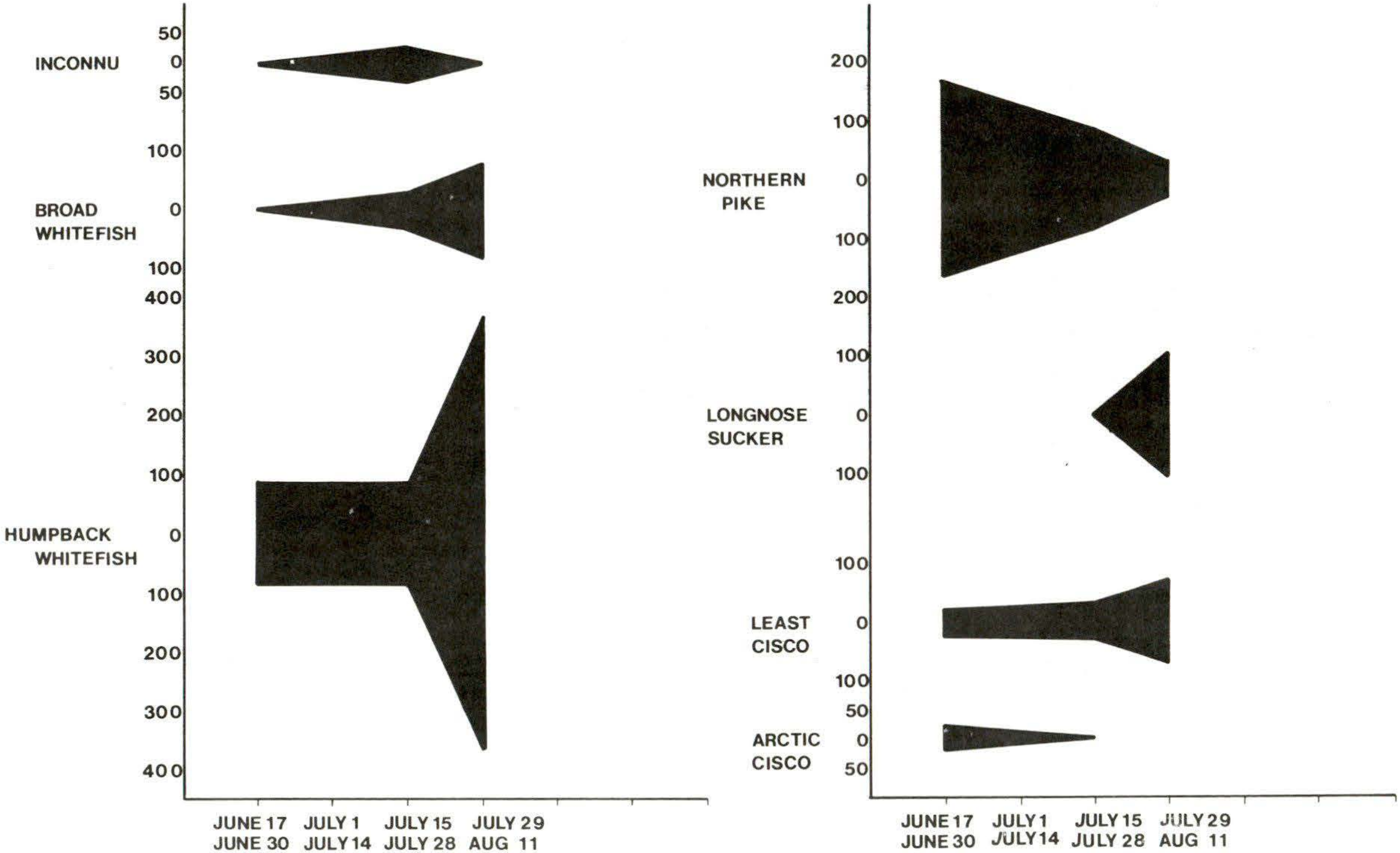

Figure 17. Seasonal change in index gillnet catches (catch per unit-effort X 1000) at location 5, Reindeer Channel (Fig. 7).

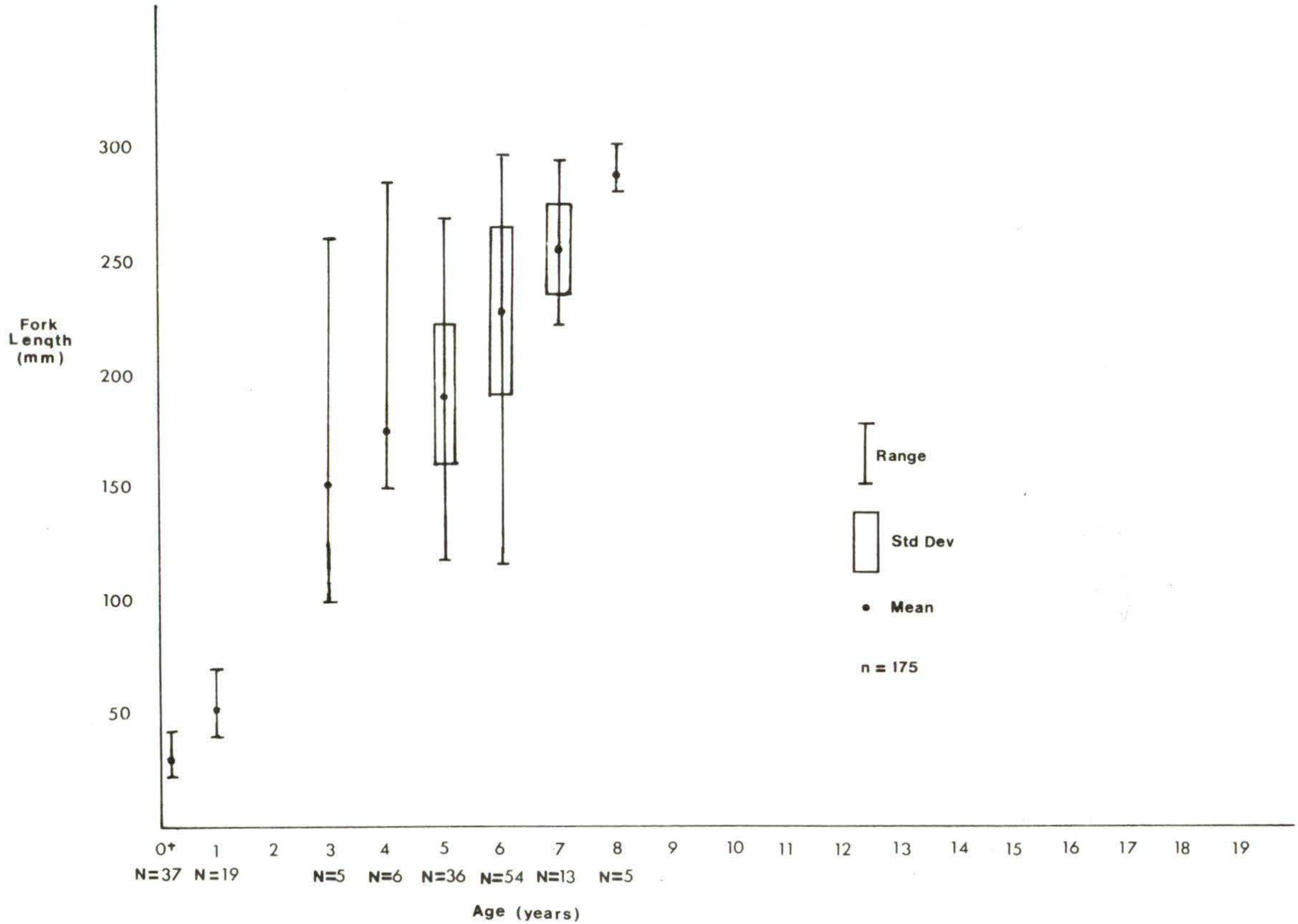

Figure 18. Age-length relationship of boreal smelt caught in the outer Mackenzie Delta in summers 1974 and 1975.

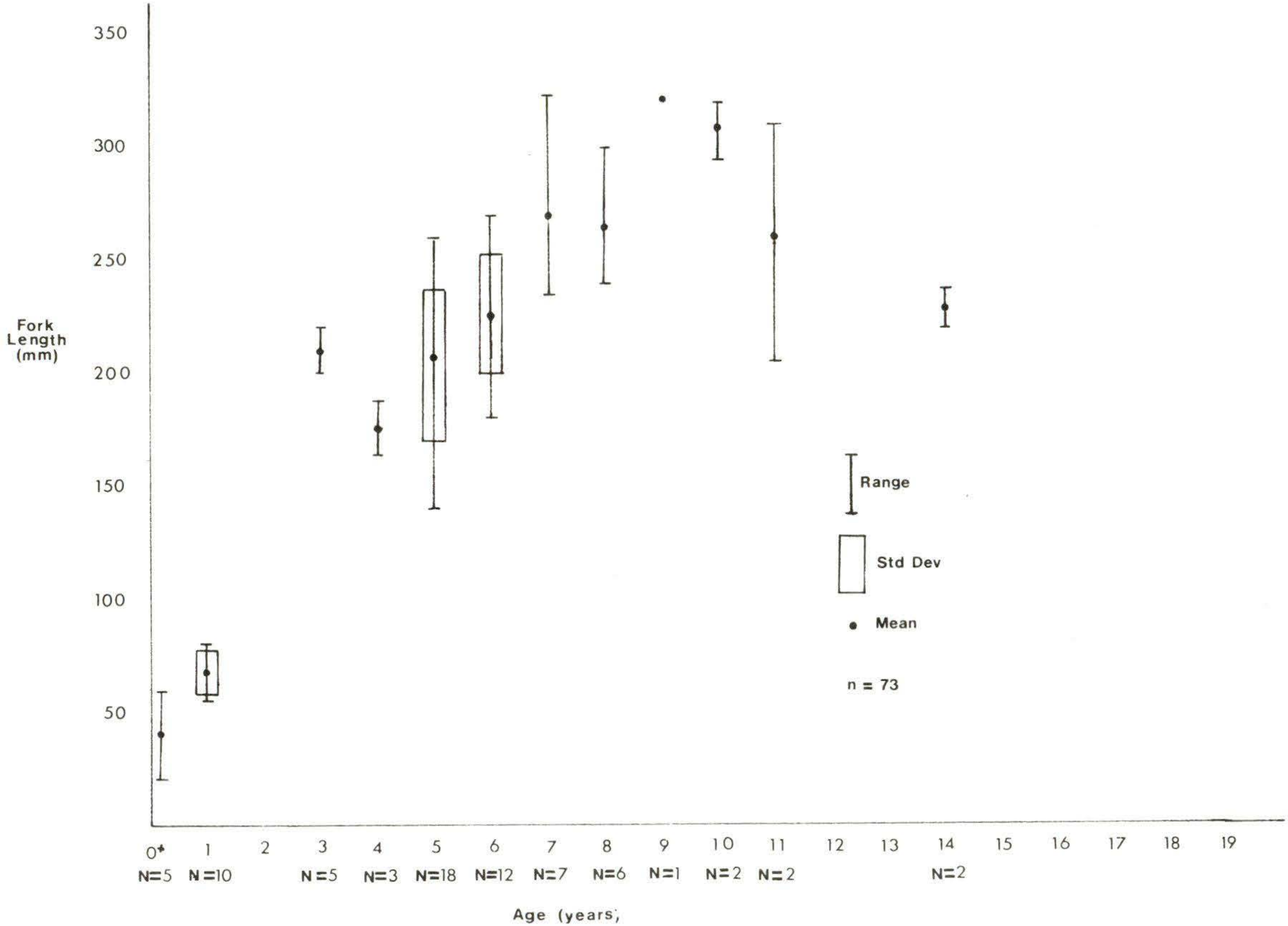

Figure 19. Age-length relationship of fourhorn sculpin caught in the outer Mackenzie Delta in summers 1974 and 1975.

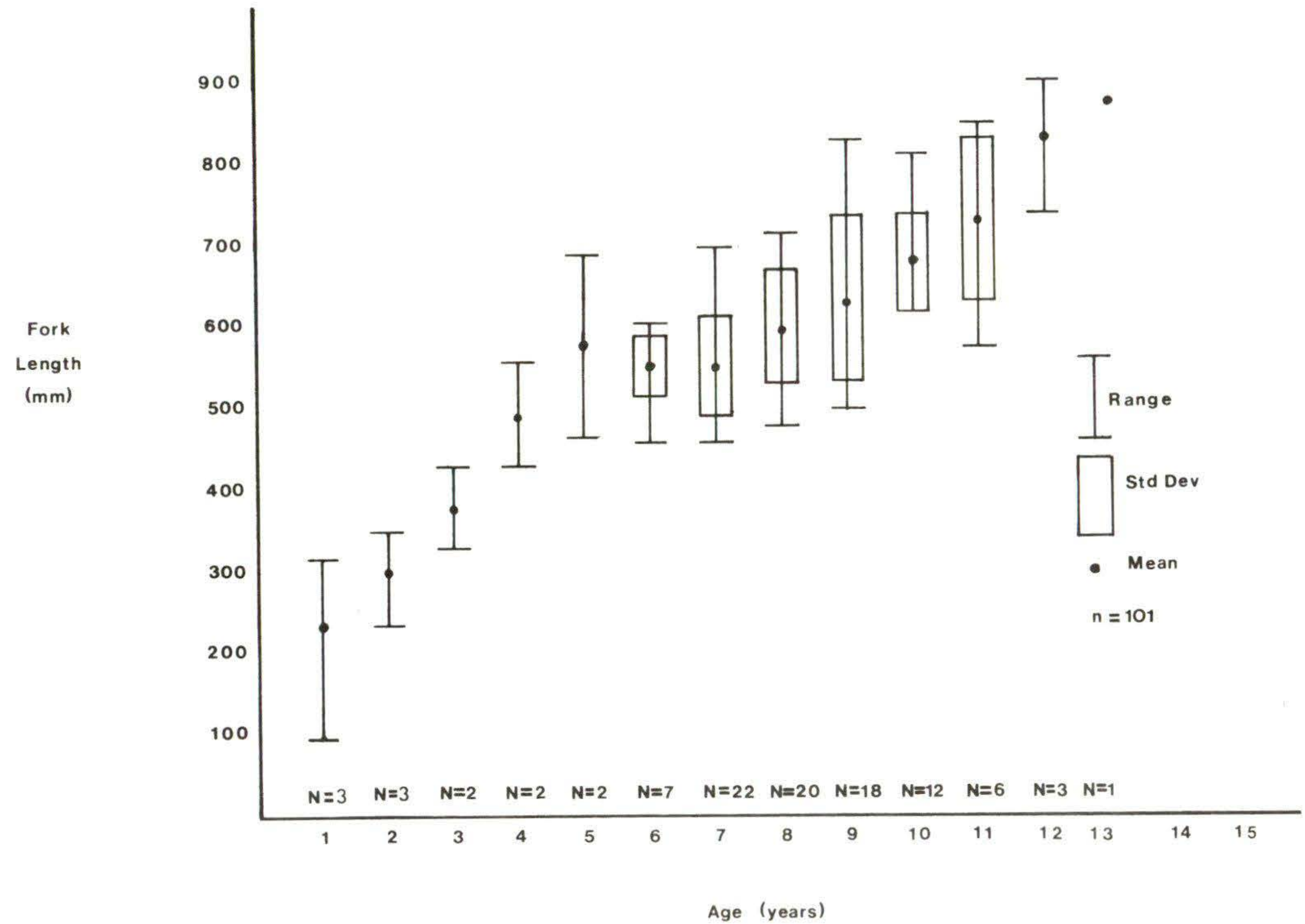

Figure 20. Age-length relationship of northern pike caught in the outer Mackenzie Delta in summers 1974 and 1975.

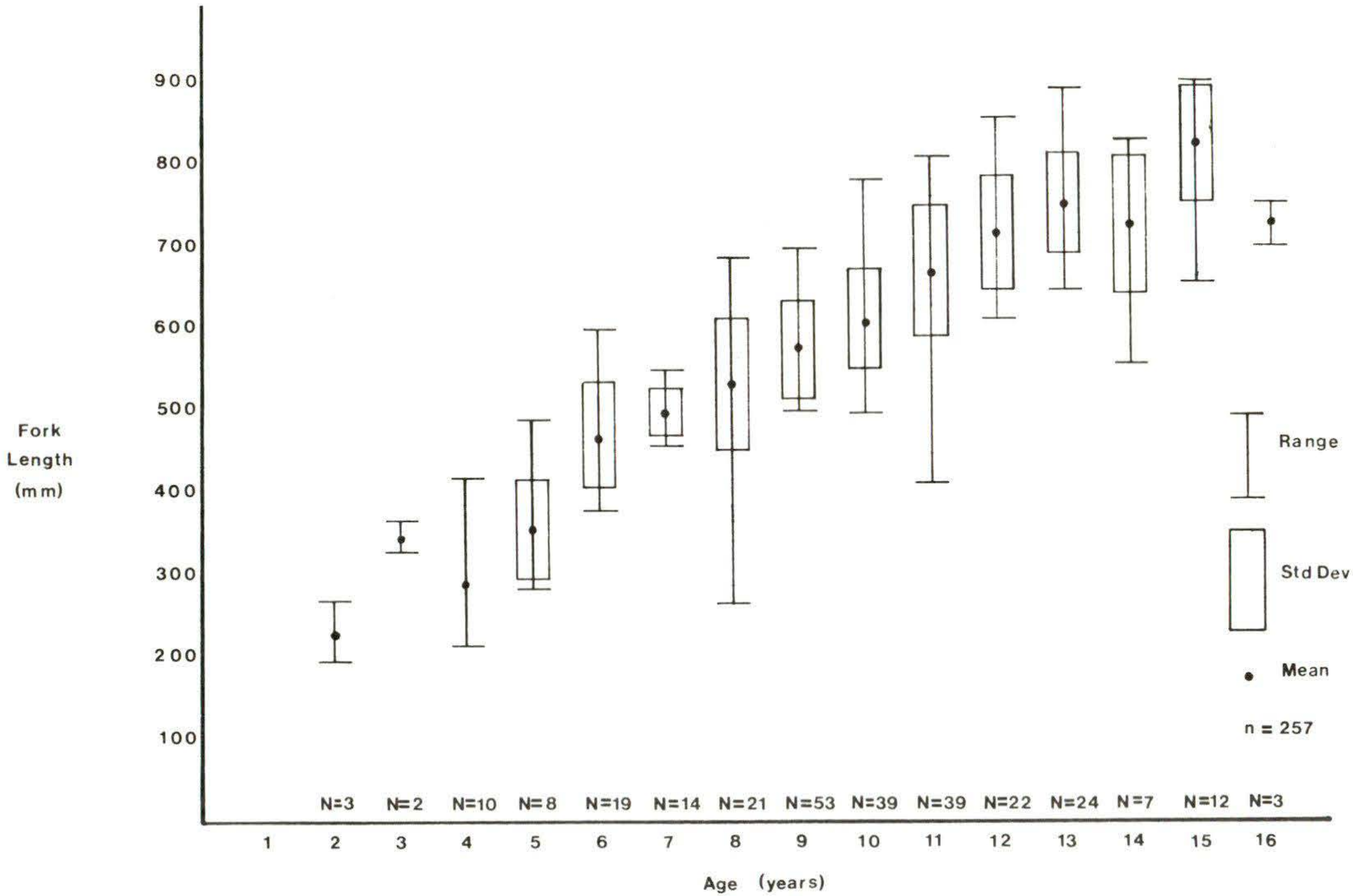

Figure 21. Age-length relationship of inconnu caught in the outer Mackenzie Delta in summers 1974 and 1975.

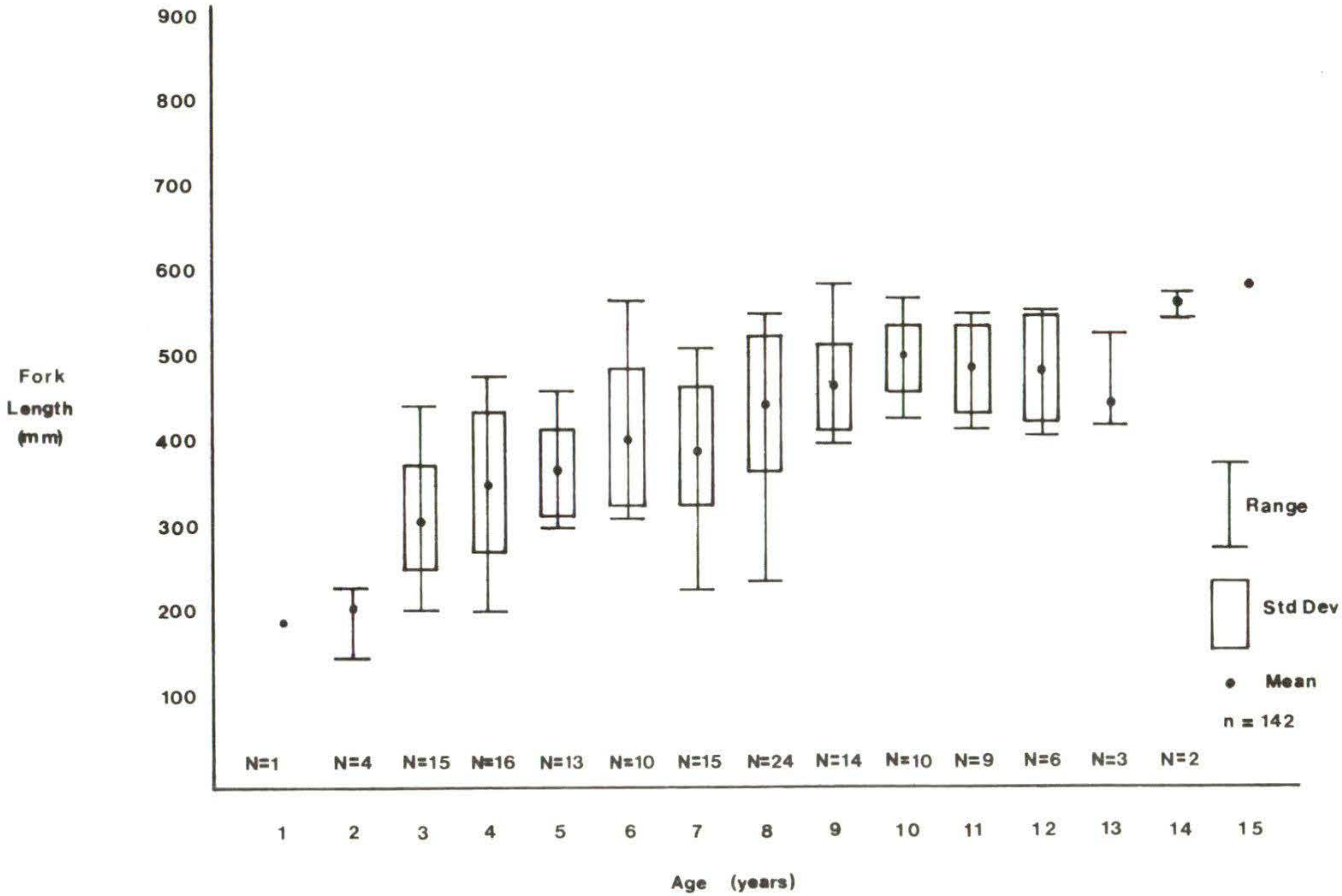

Figure 22. Age-length relationship of broad whitefish caught in the outer Mackenzie Delta in summers 1974 and 1975

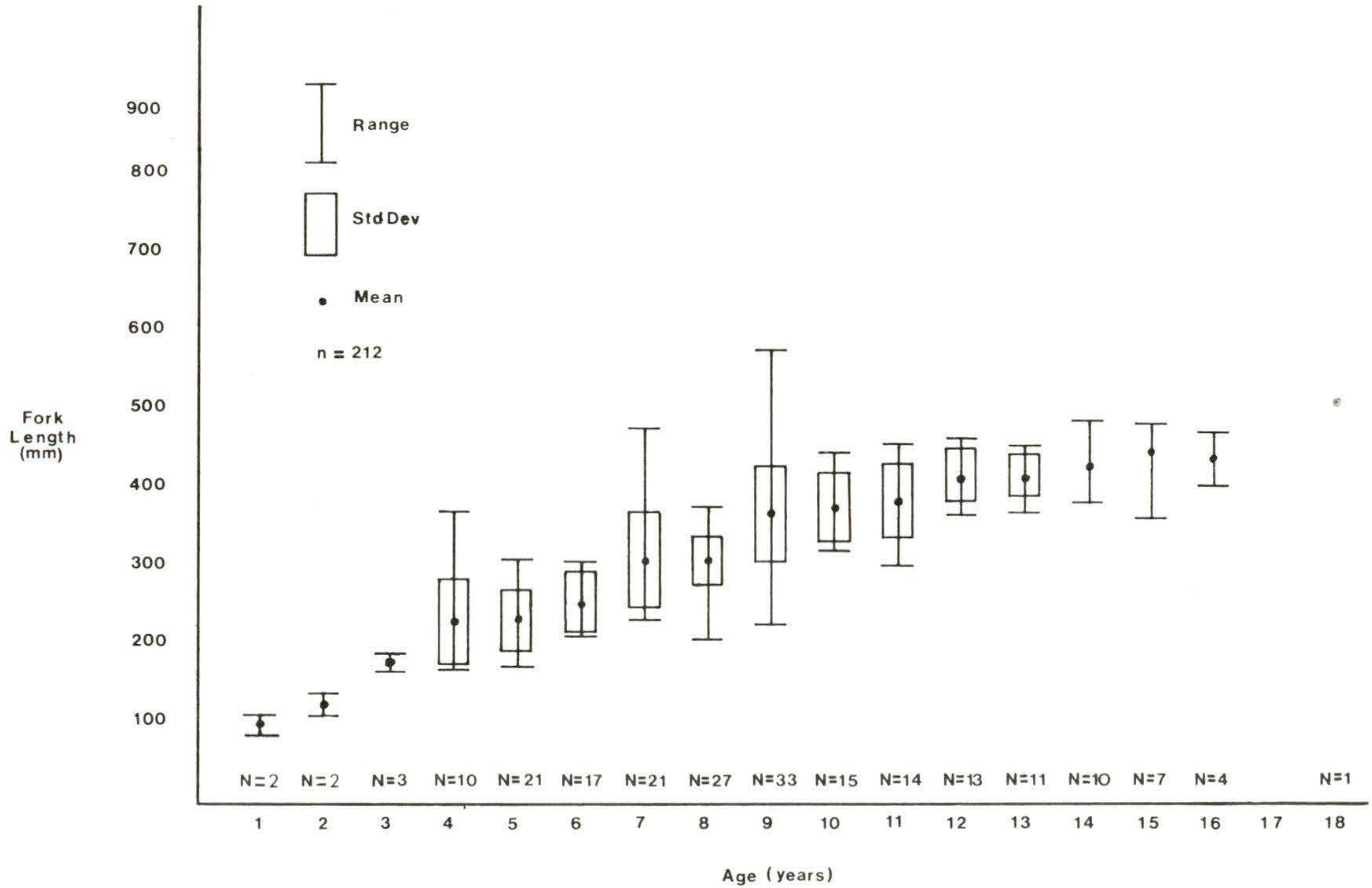

Figure 23. Age-length relationship of humpback whitefish caught in the outer Mackenzie Delta in summers 1974 and 1975.

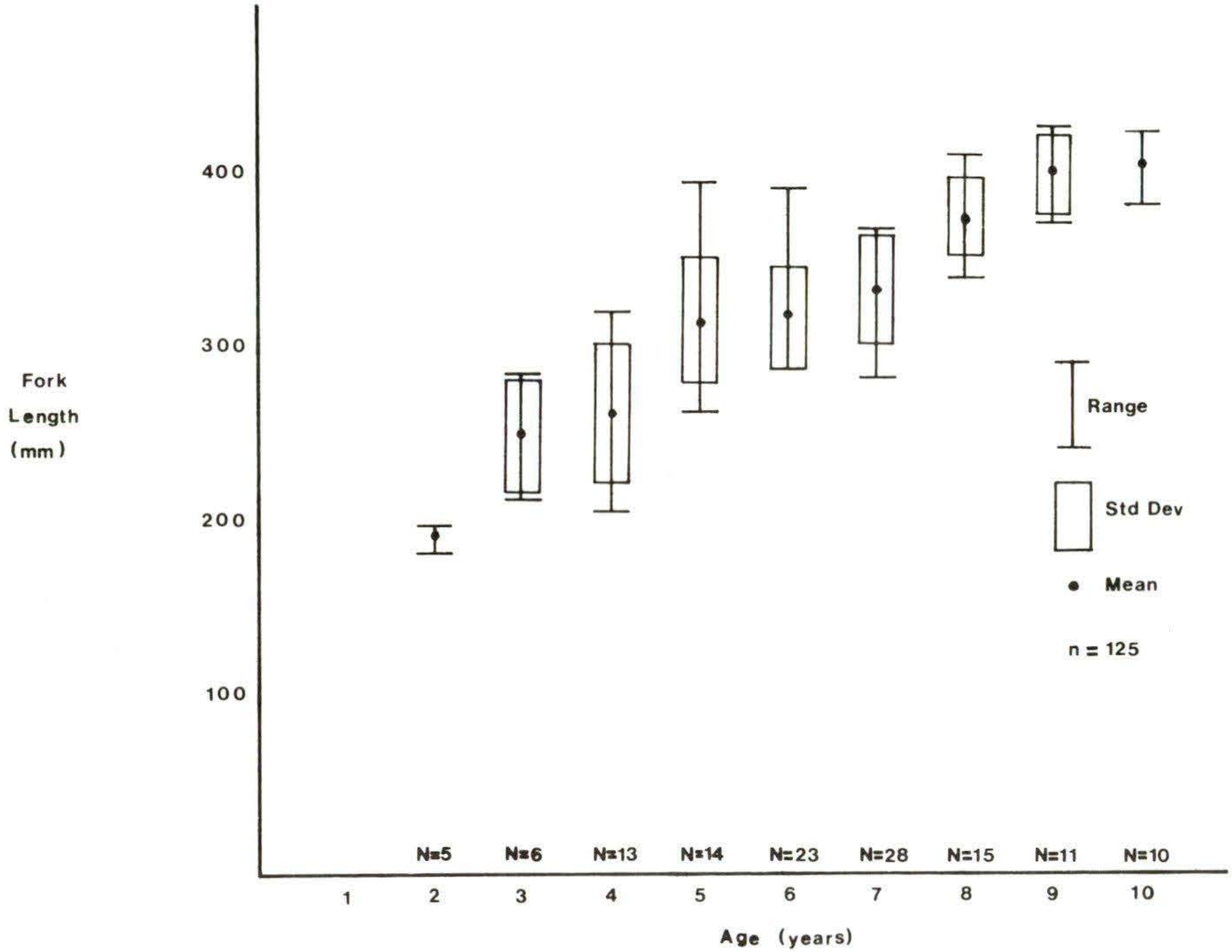

Figure 24. Age length relationship of Arctic cisco caught in the outer Mackenzie Delta in summers 1974 and 1975.

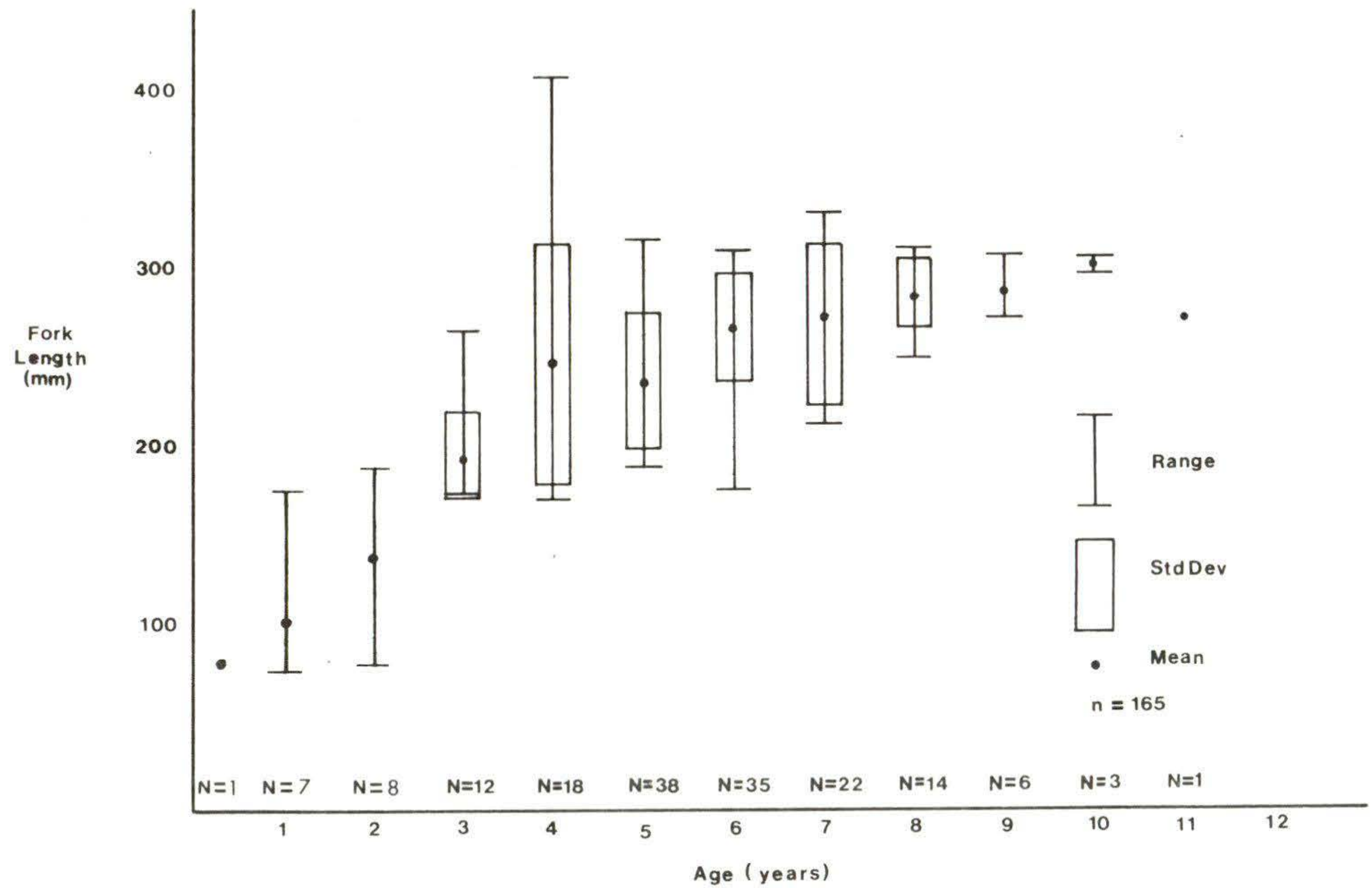

Figure 25. Age-length relationship of least cisco caught in the outer Mackenzie Delta in summers 1974 and 1975.

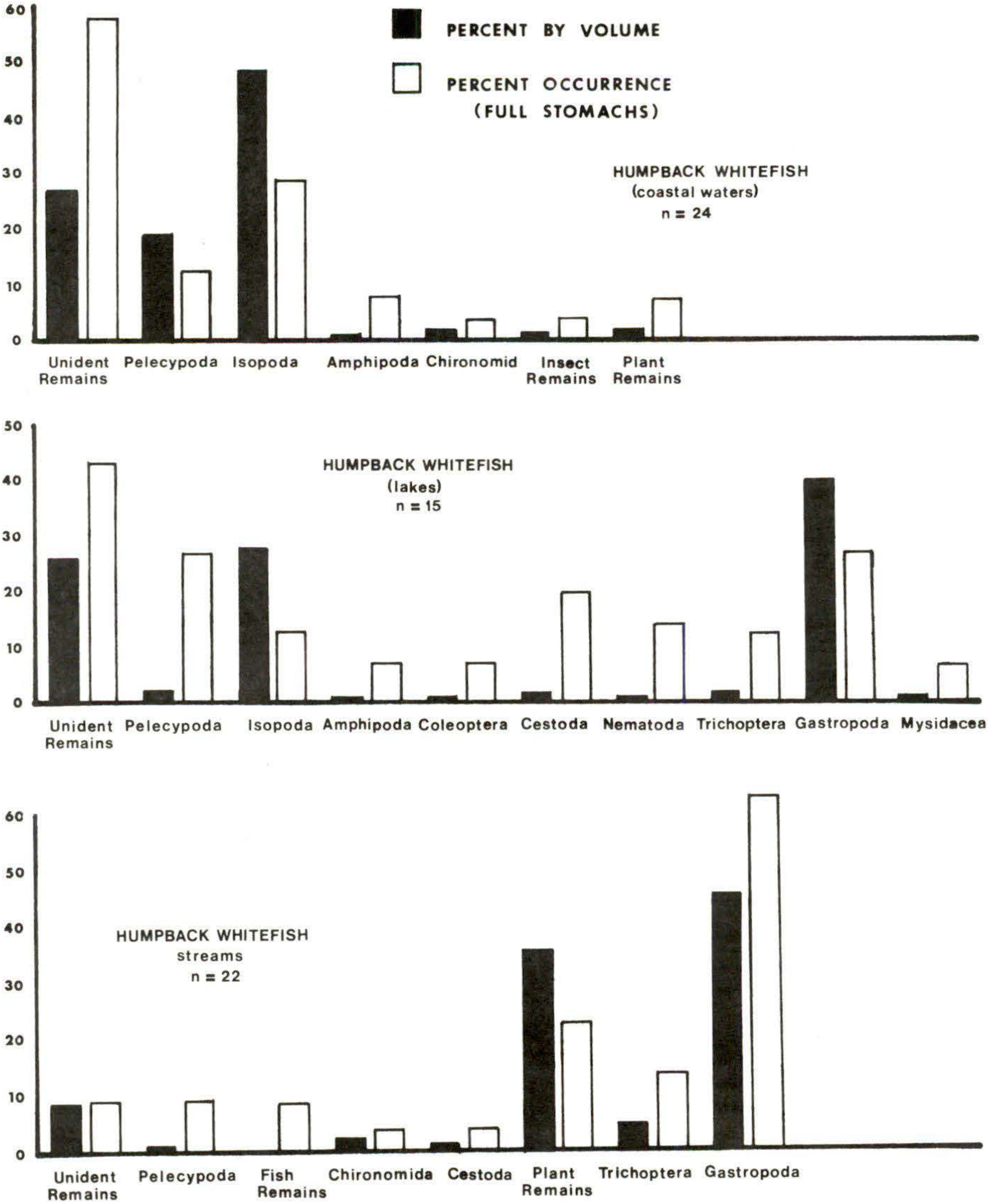

Figure 26. Stomach contents of gillnetted humpback whitefish from the outer Mackenzie Delta: 92 coastal specimens (68 empty), 32 lake specimens (17 empty) and 141 stream caught fish (119 empty).

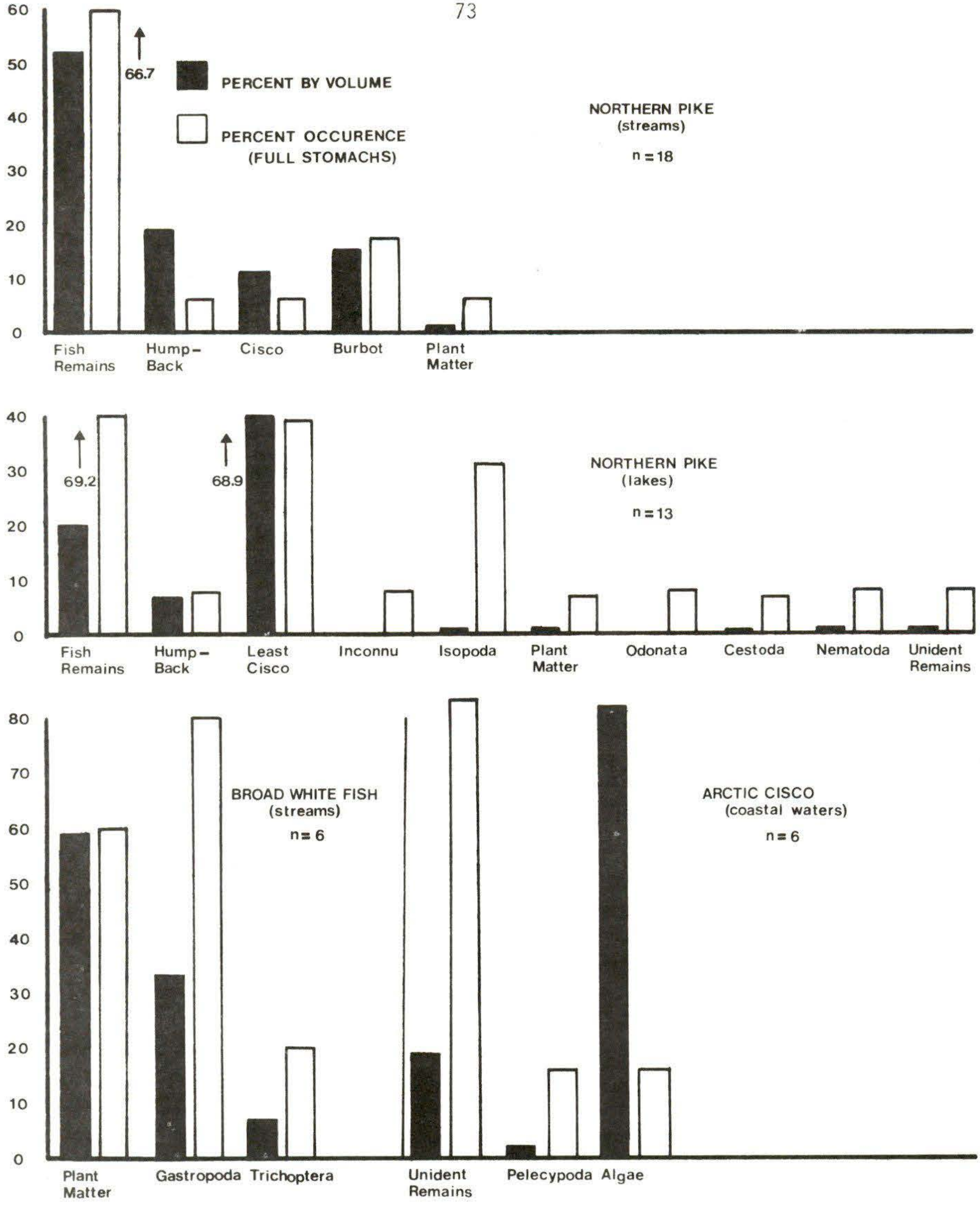

Figure 27. Stomach contents of gillnetted fish from the outer Mackenzie Delta: 83 northern pike caught in streams (65 empty), 35 northern pike caught in lakes (22 empty), 136 broad whitefish (130 empty) and 121 Arctic cisco (115 empty).

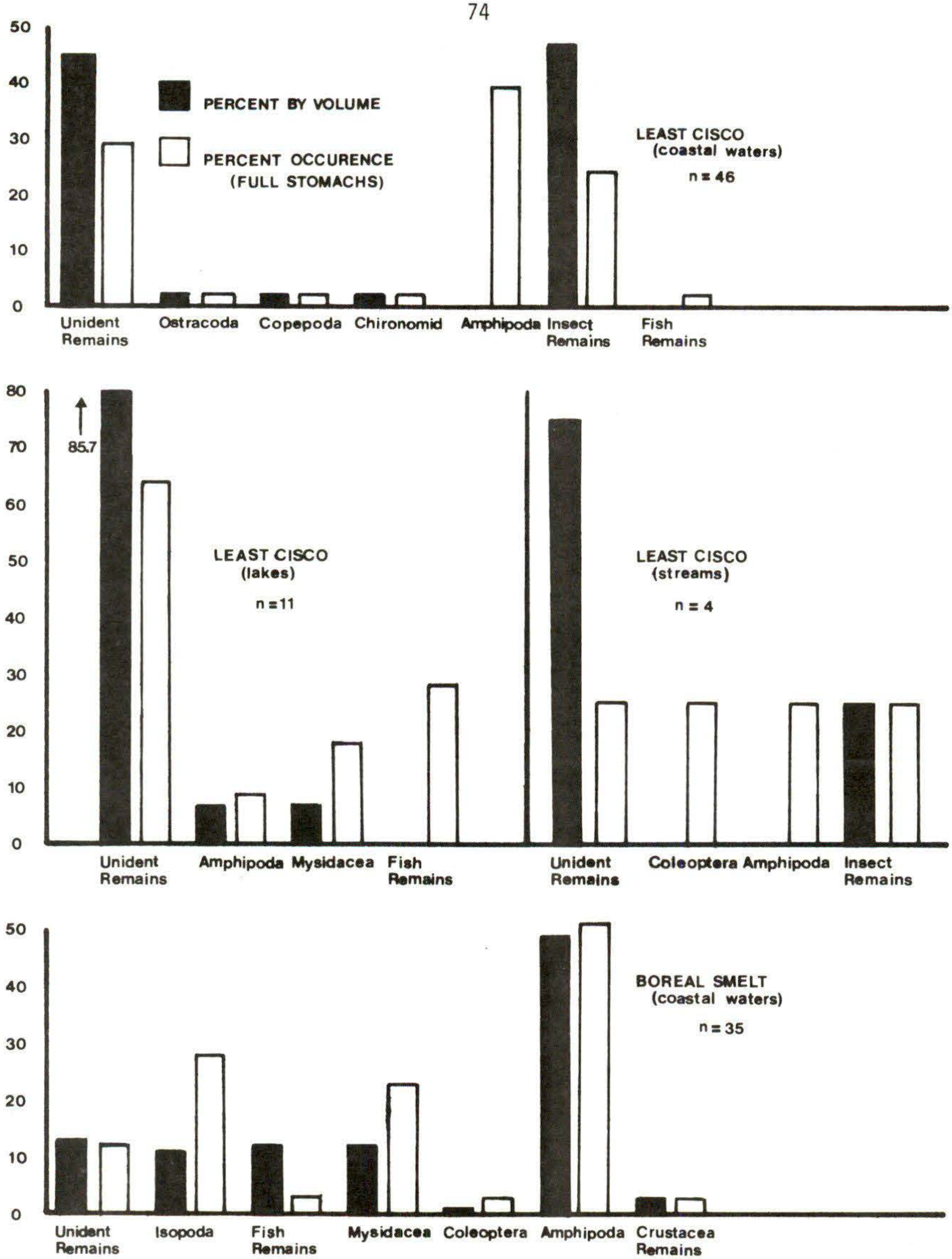

Figure 28. Stomach contents of gillnetted fish from the outer Mackenzie Delta: 338 coastal least cisco (292 empty), 68 least cisco caught in lakes (57 empty), 75 least cisco caught in streams (71 empty) and 311 boreal smelt (276 empty).

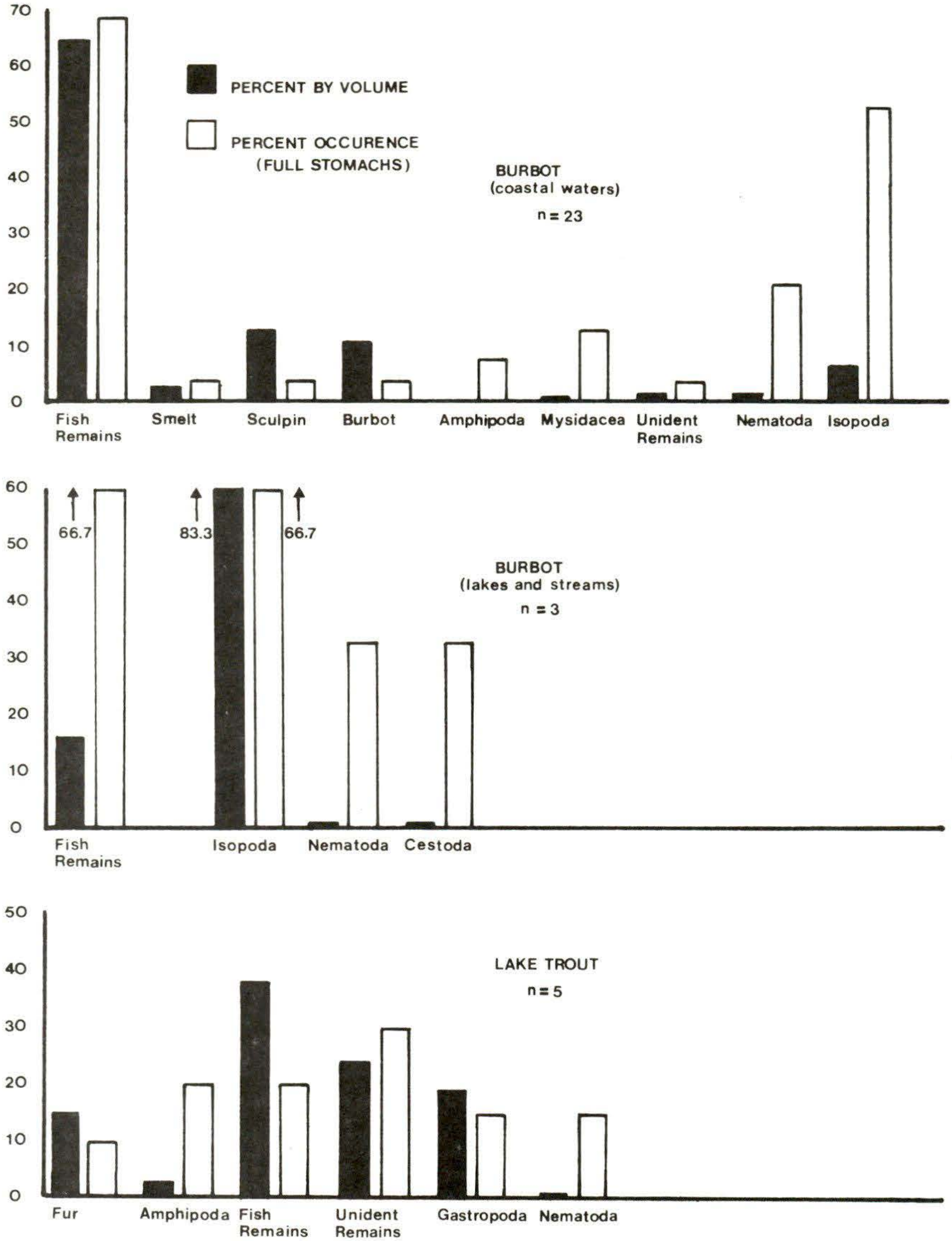

Figure 29. Stomach contents of gillnetted fish from the outer Mackenzie Delta: 32 coastal burbot (9 empty), 8 burbot caught in lakes and streams (5 empty) and 13 laketrout (8 empty).

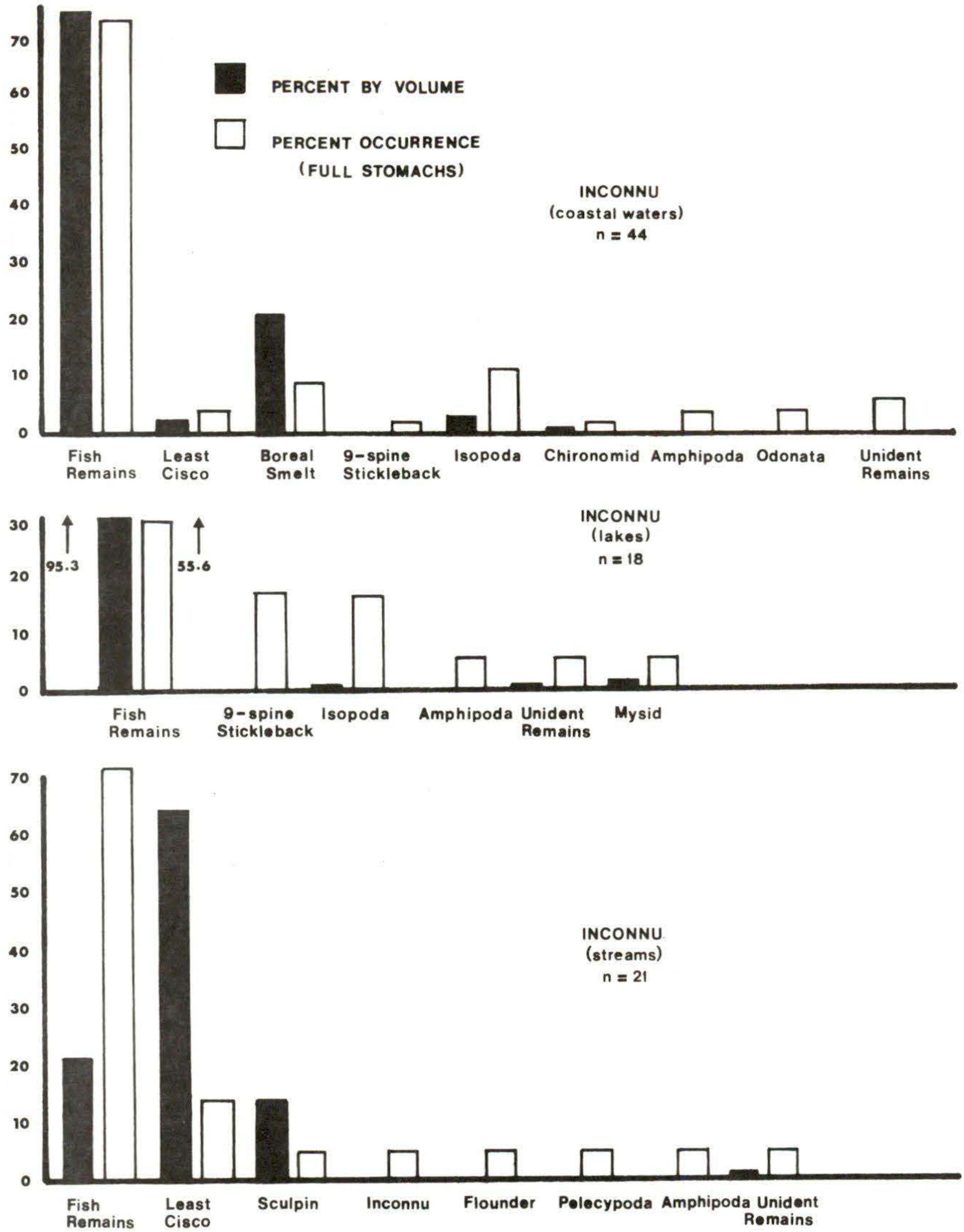

Figure 30. Stomach contents of gillnetted inconnu from the outer Mackenzie Delta: 184 coastal specimens (139 empty), 67 lake caught fish (49 empty) and 129 caught in streams (108 empty).

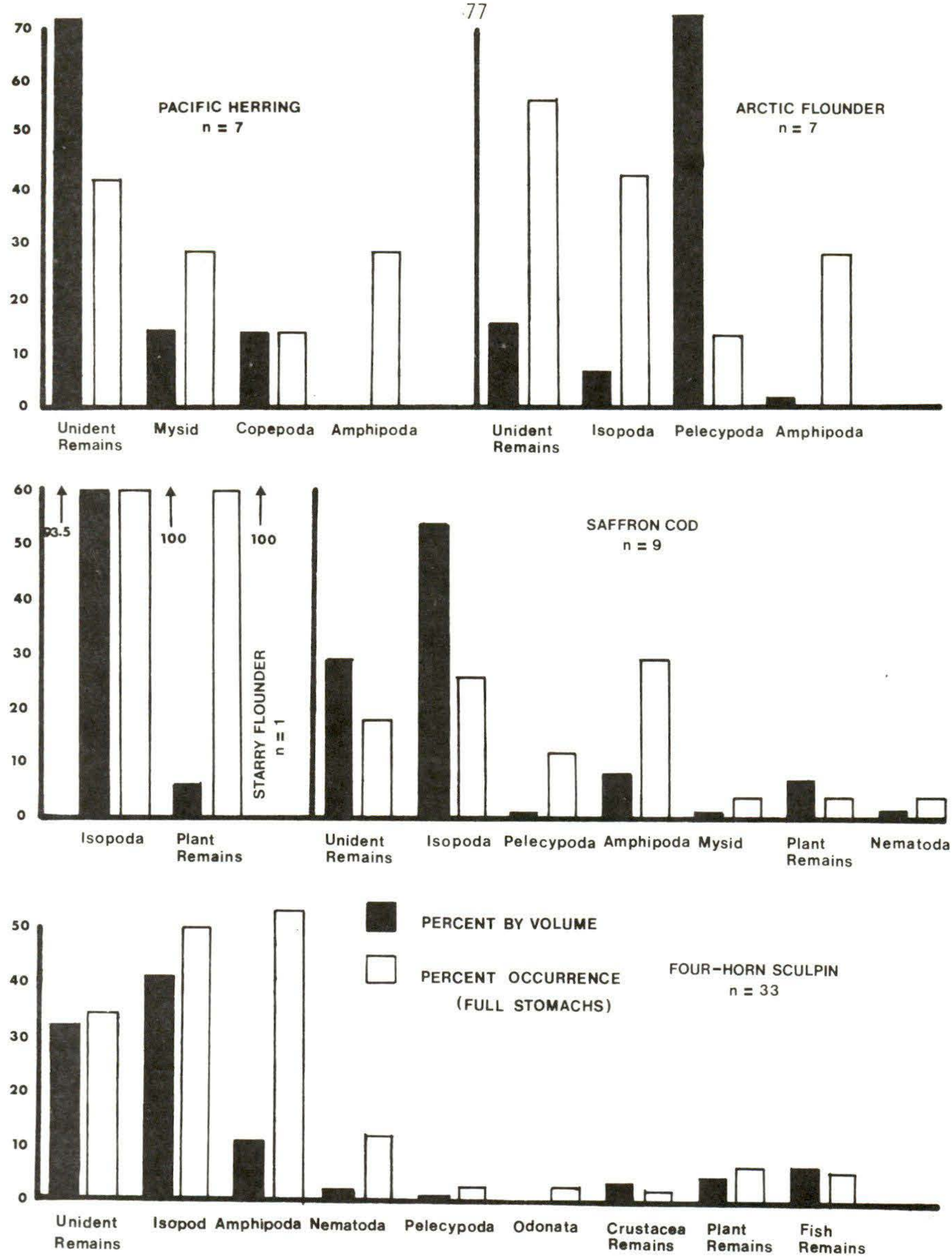

Figure 31. Stomach contents of fish caught by gillnet in coastal waters of the outer Mackenzie Delta: 20 Pacific herring (13 empty), 21 Arctic flounder (14 empty), 2 starry flounder (1 empty), 10 saffron cod (1 empty) and 81 fourhorn sculpins (48 empty).

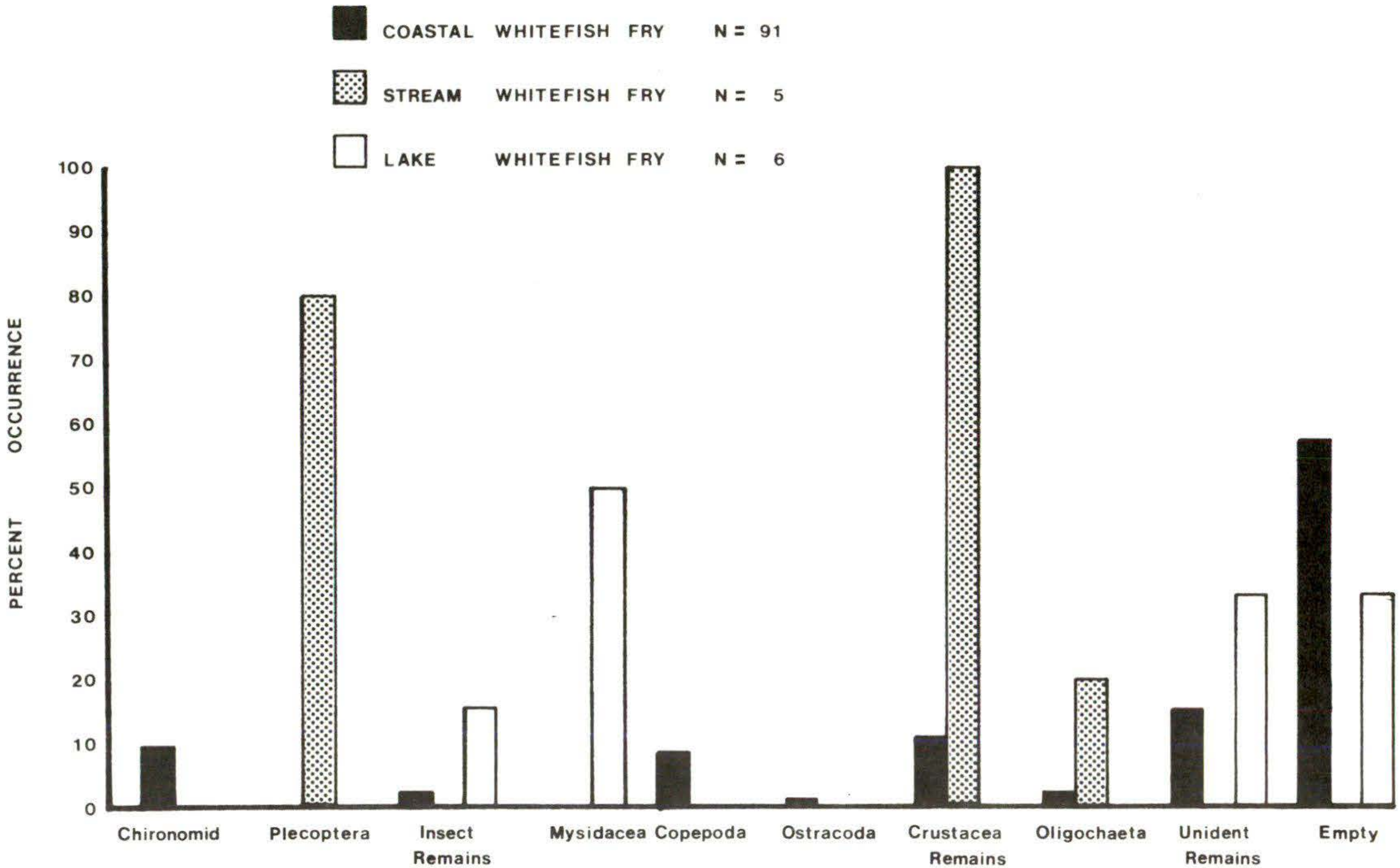

Figure 32. Stomach contents of 102 whitefish seined in the outer Mackenzie Delta; 91 from coastal waters (29-132 mm), 5 caught in streams (72-95 mm) and 6 lake caught specimens (28-93 mm).

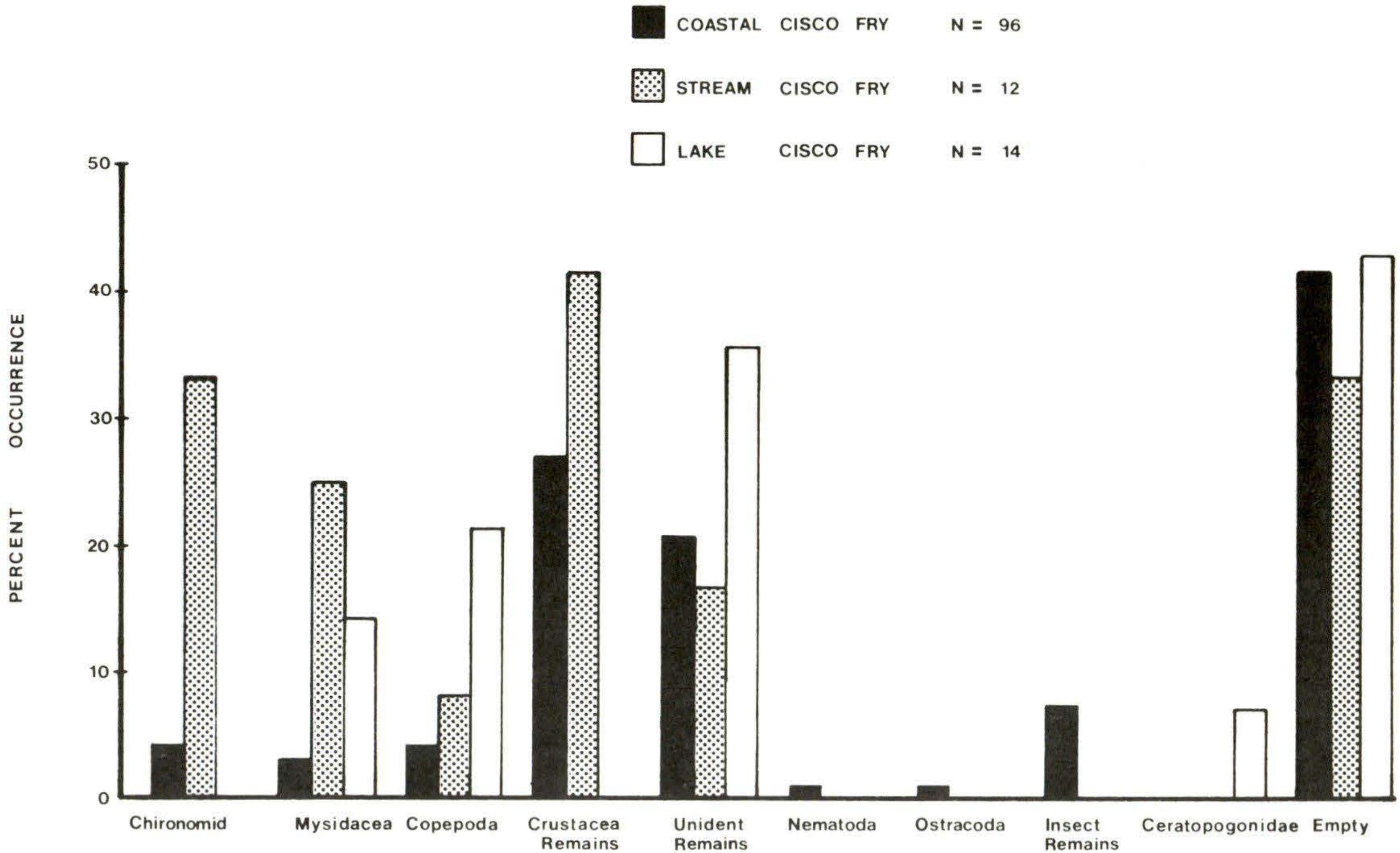

Figure 33. Stomach contents of 122 cisco seined in the outer Mackenzie Delta; 96 coastal fish (29-146 mm) 12 caught in streams (39-124 mm) and 14 lake-caught specimens (30-98 mm).

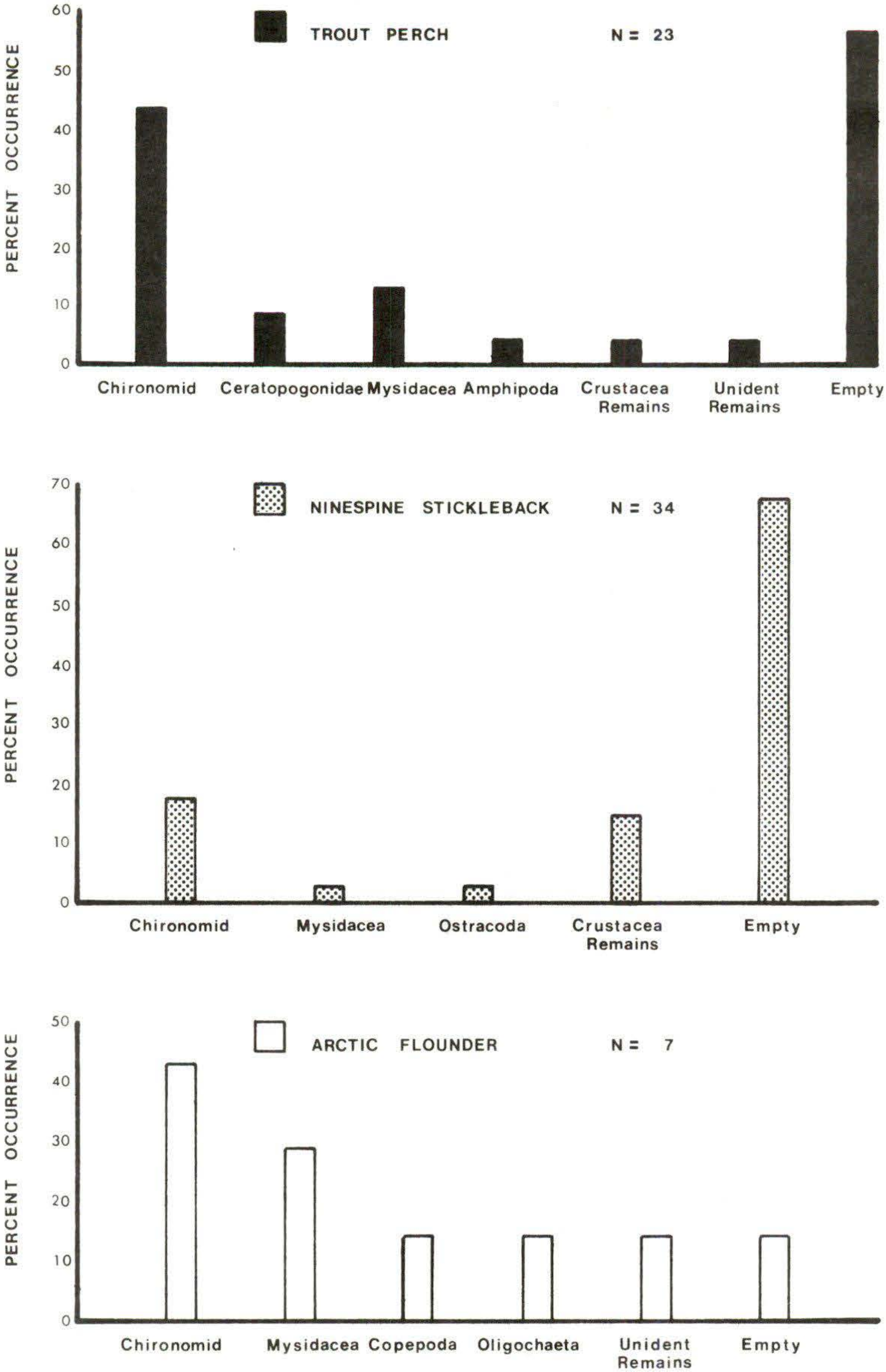

Figure 34. Stomach contents of trout-perch (26-75 mm), ninespine stickleback (19-46 mm) and Arctic flounder (46-58 mm) seined in the outer Mackenzie Delta.

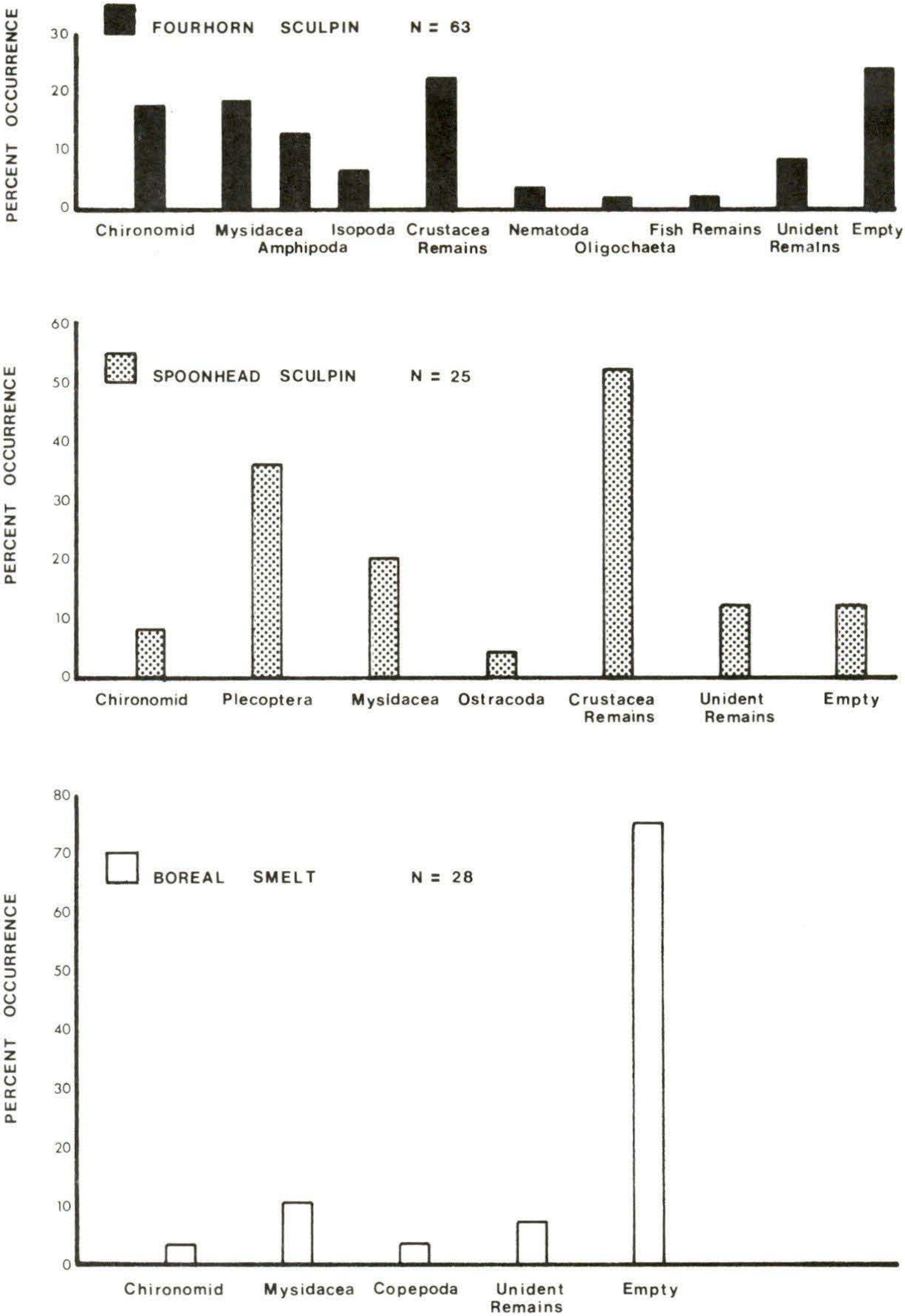

Figure 35. Stomach contents of fourhorn sculpins (19-215 mm), spoonhead sculpins (28-57 mm) and boreal smelt (25-70 mm) seined in the outer Mackenzie Delta.

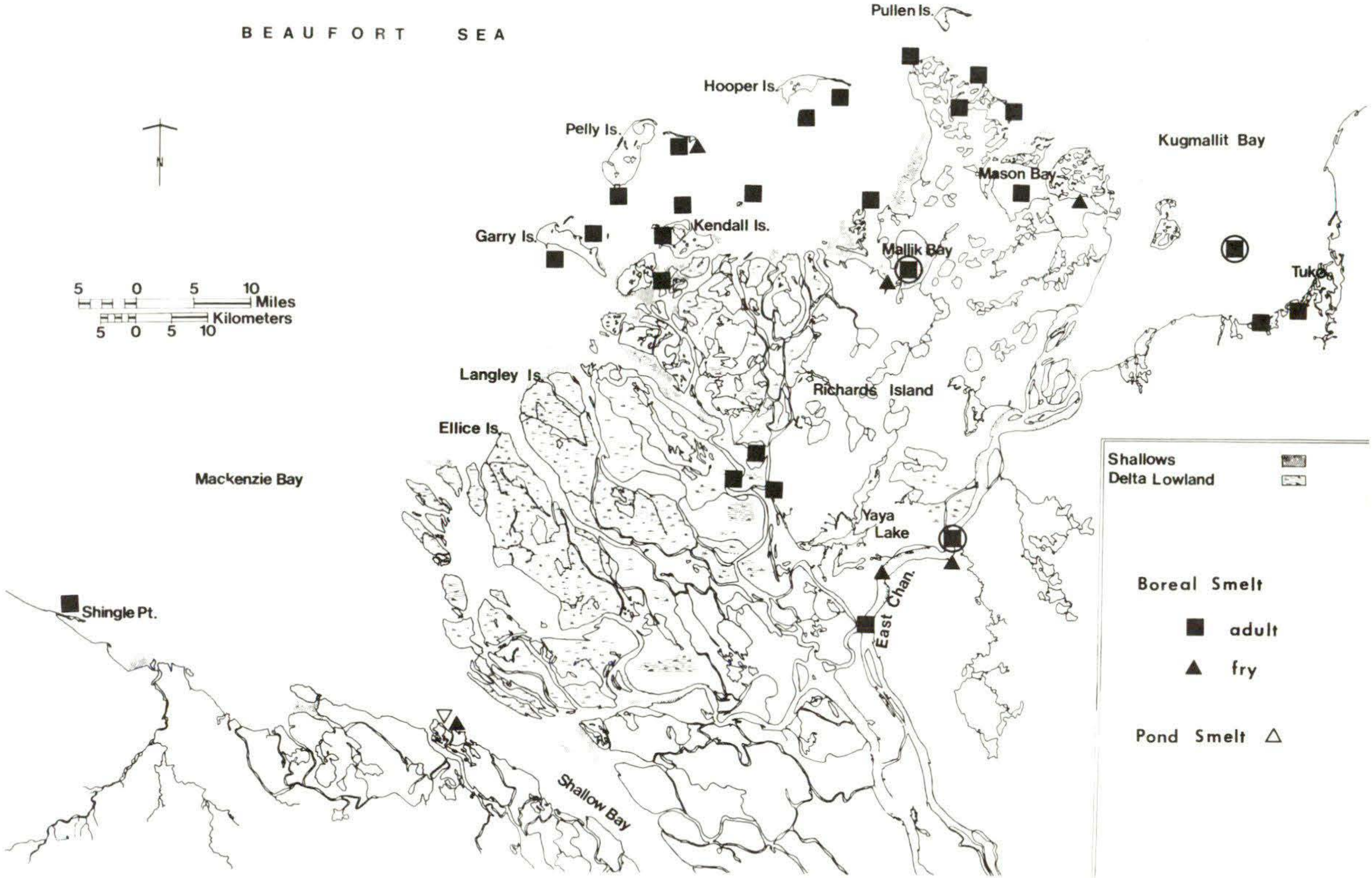

Figure 36. Distribution of boreal smelt and pond smelt in the outer Mackenzie Delta. Encircled symbols represent both summer and winter distributions.

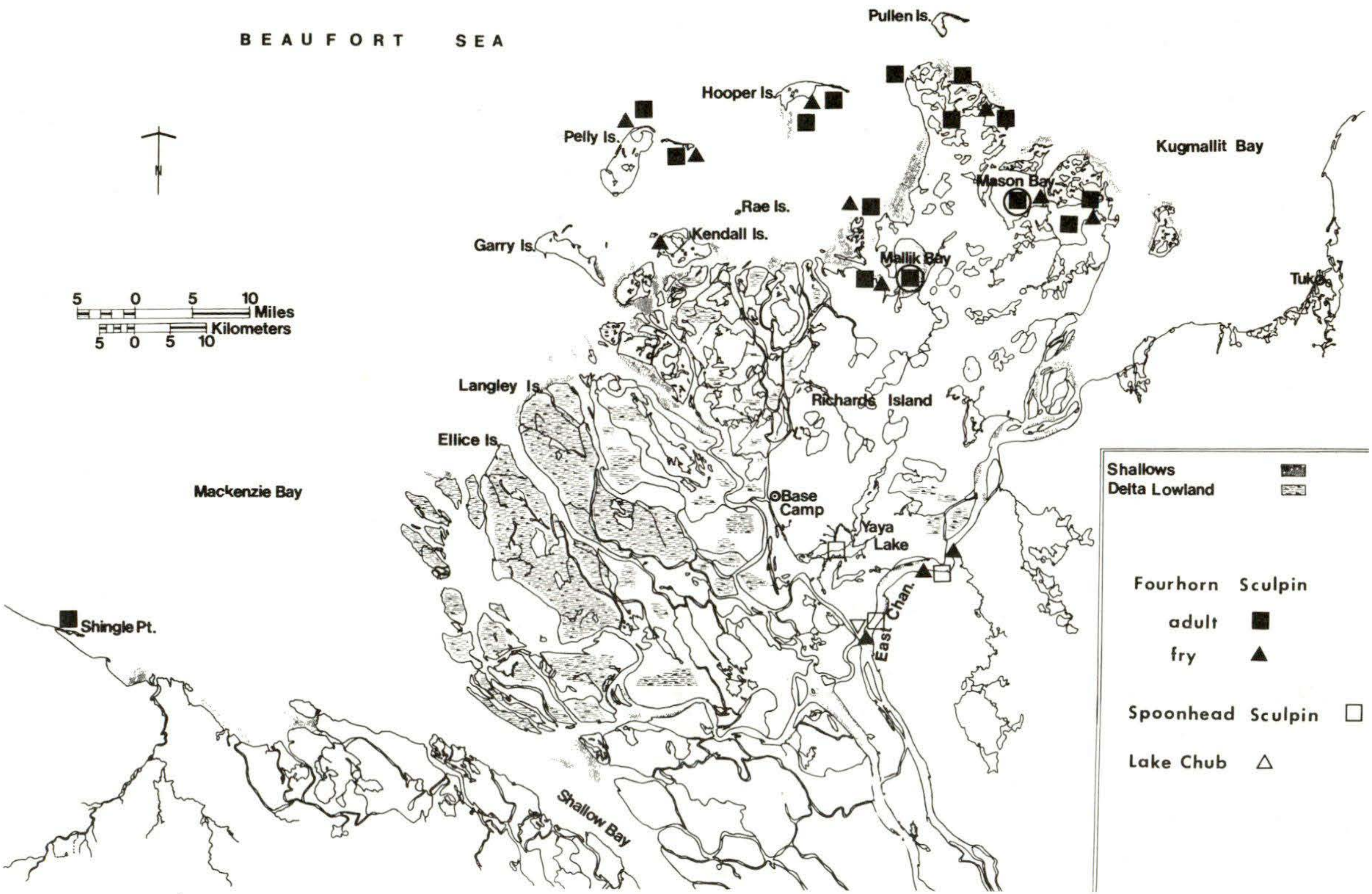

Figure 37. Distribution of fourhorn sculpin, spoonhead sculpin and lake chub in the outer Mackenzie Delta. Encircled symbols represent both summer and winter distributions.

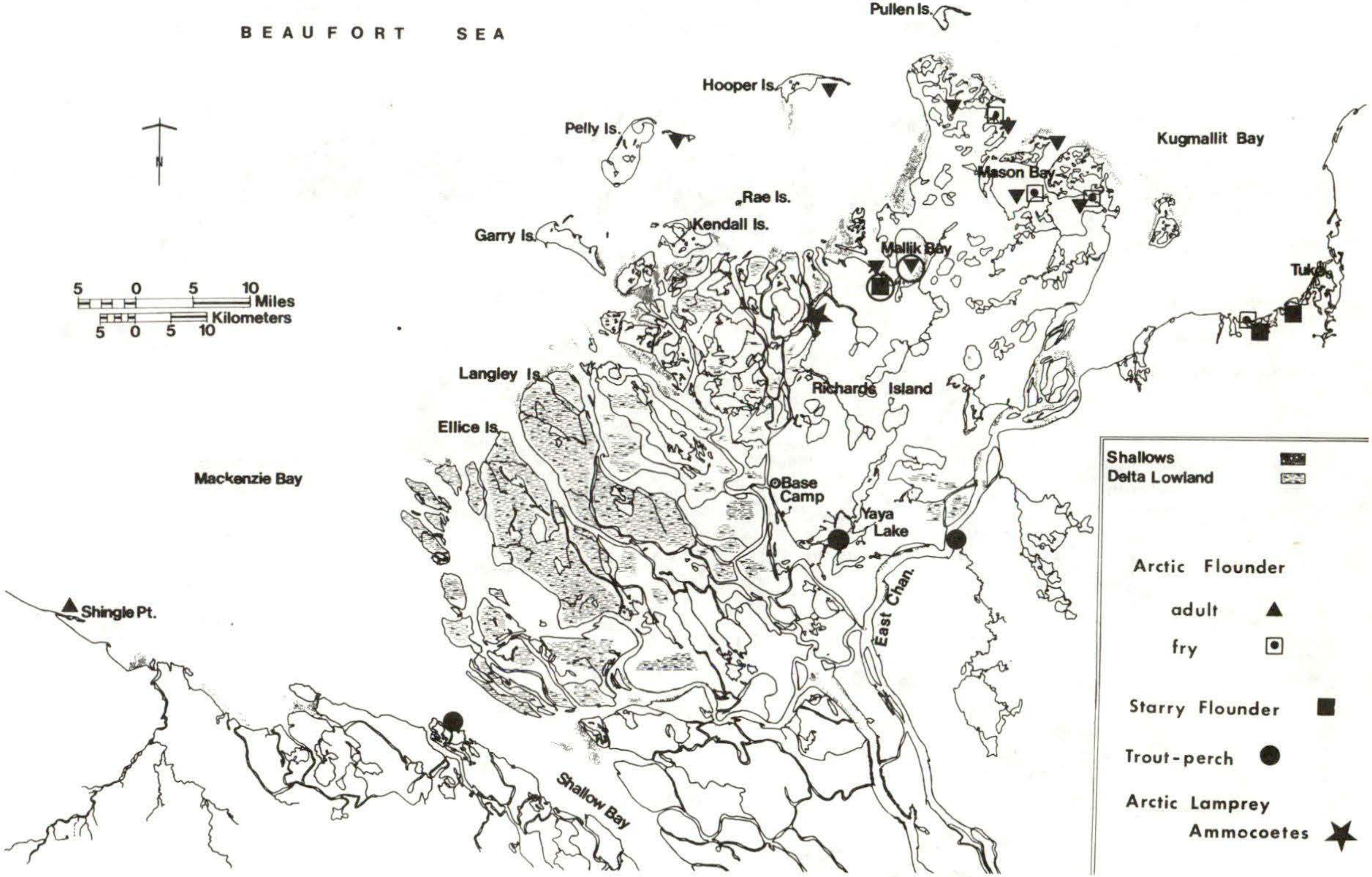

Figure 38. Distribution of Arctic flounder, starry flounder, trout-perch and Arctic lamprey in the outer Mackenzie Delta. Encircled symbols represent both summer and winter distributions.

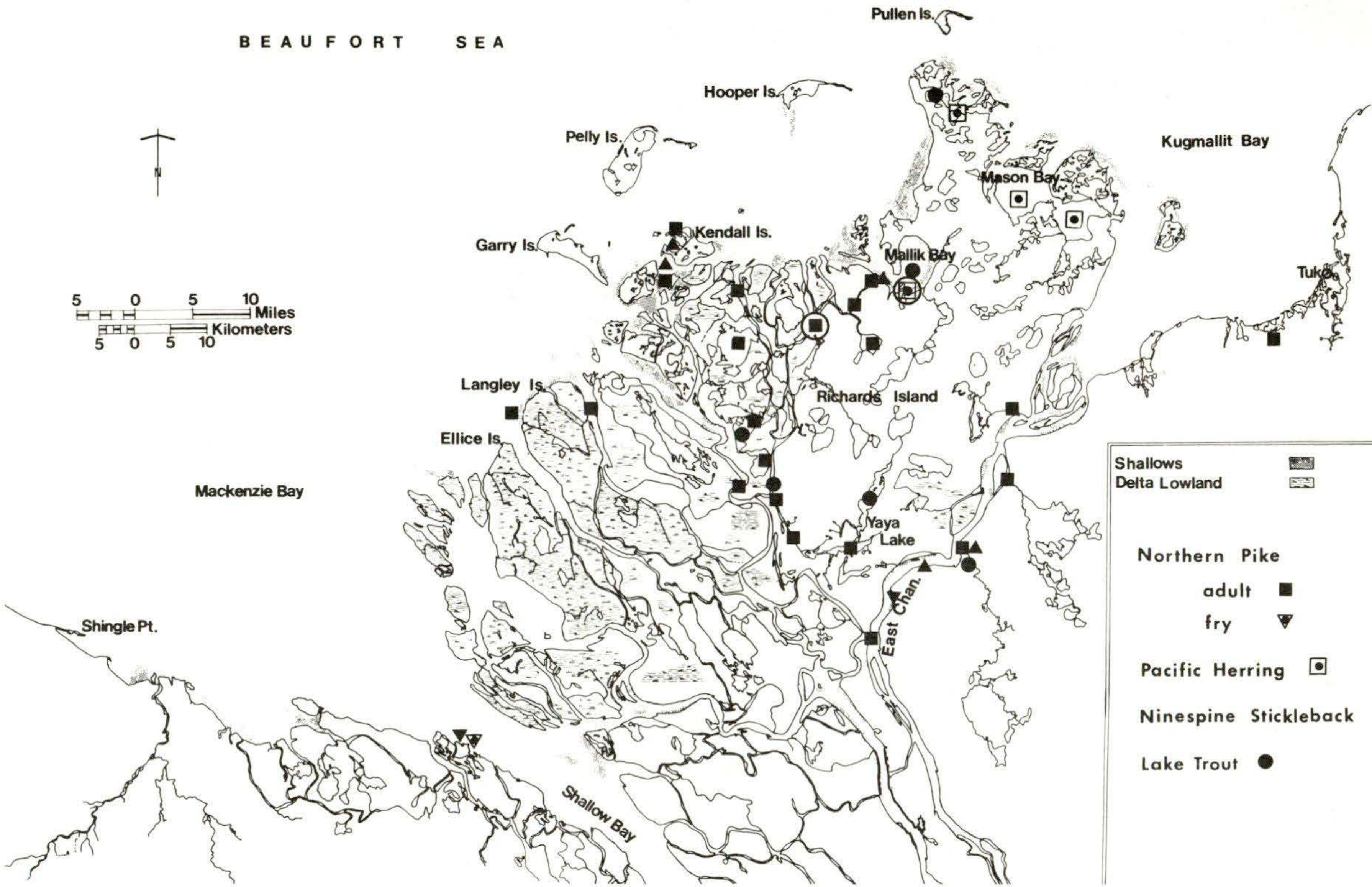

Figure 39. Distribution of northern pike, pacific herring, ninespine stickleback and lake trout in the outer Mackenzie Delta. Encircled symbols represent both summer and winter distributions.

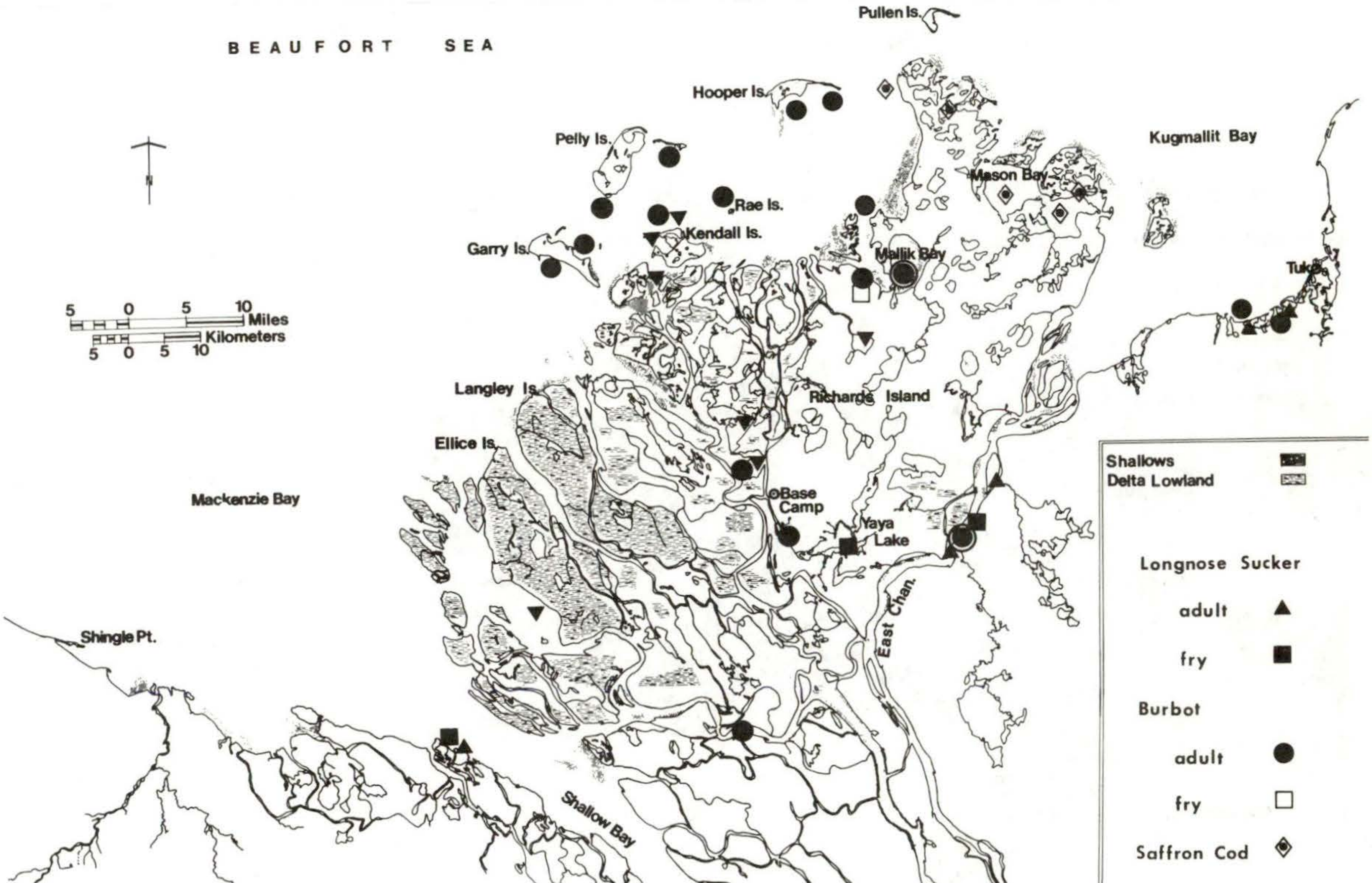

Figure 40. Distribution of longnose sucker, burbot and saffron cod in the outer Mackenzie Delta. Encircled symbols represent both summer and winter distributions.

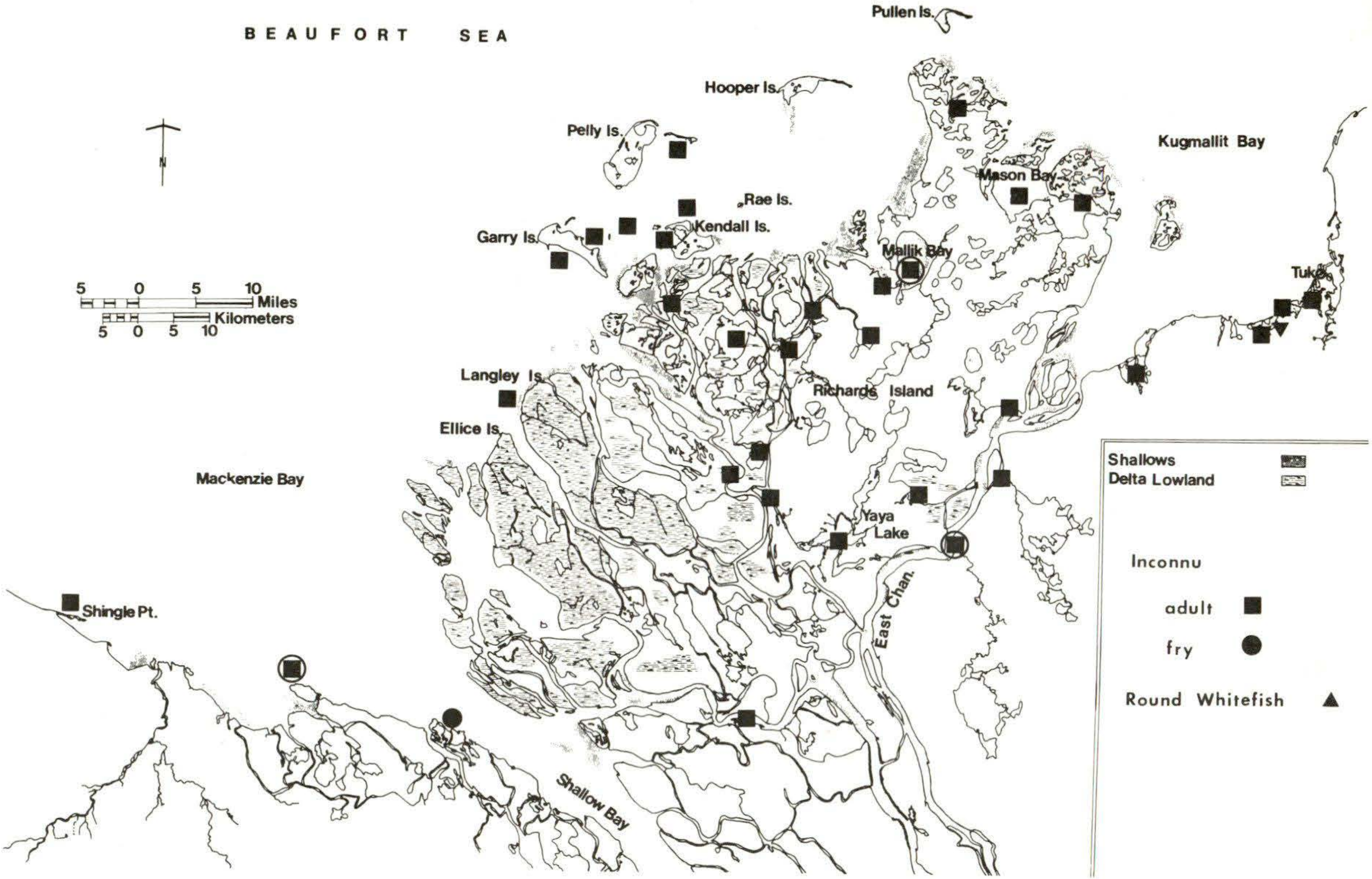

Figure 41. Distribution of inconnu and round whitefish in the outer Mackenzie Delta. Encircled symbol represents both summer and winter distributions.

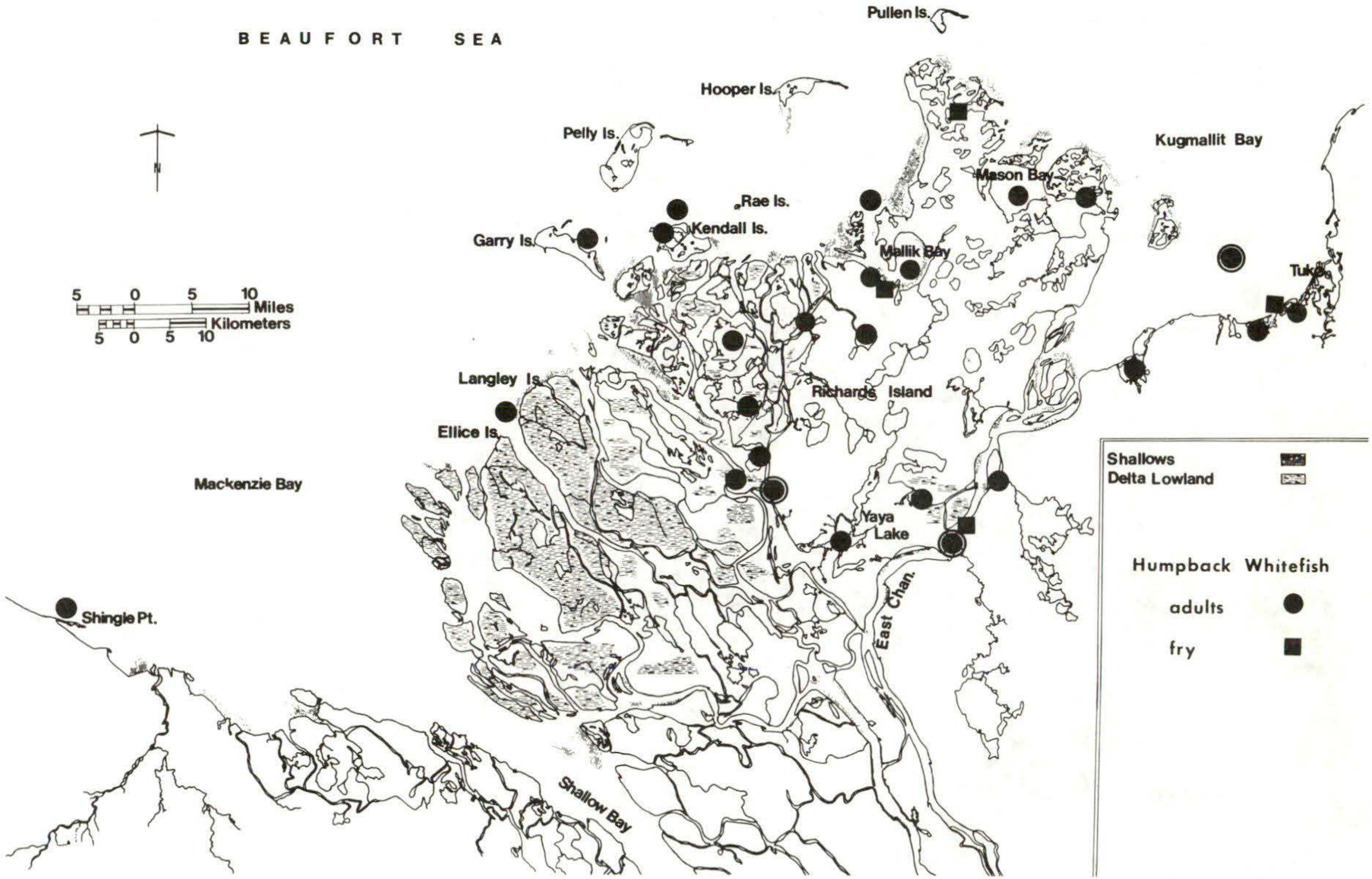

Figure 42. Distribution of humpback whitefish in the outer Mackenzie Delta. Encircled symbols represent both summer and winter distributions.

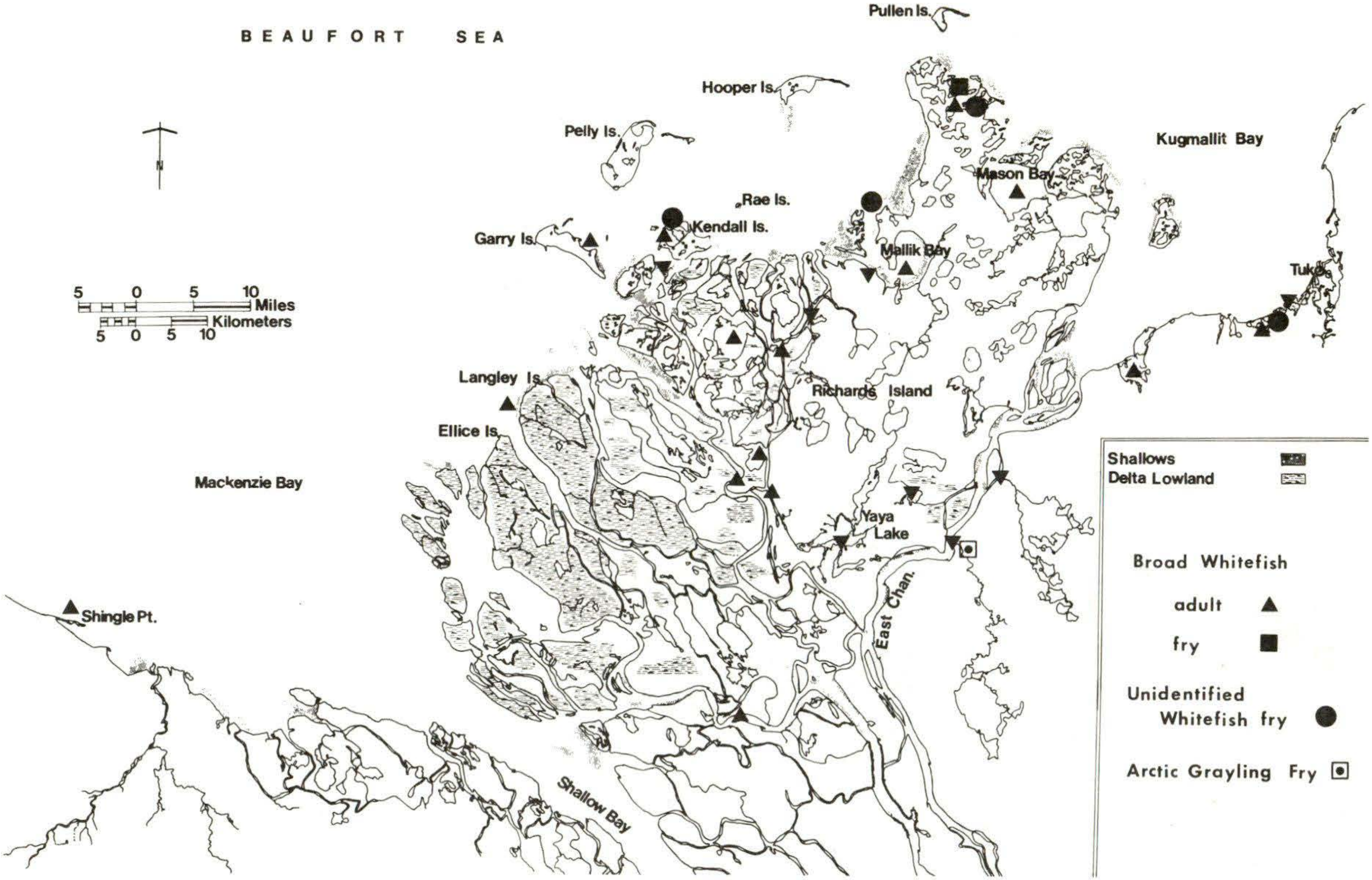

Figure 43. Distribution of broad whitefish, Arctic grayling fry and unidentified whitefish fry in the outer Mackenzie Delta.

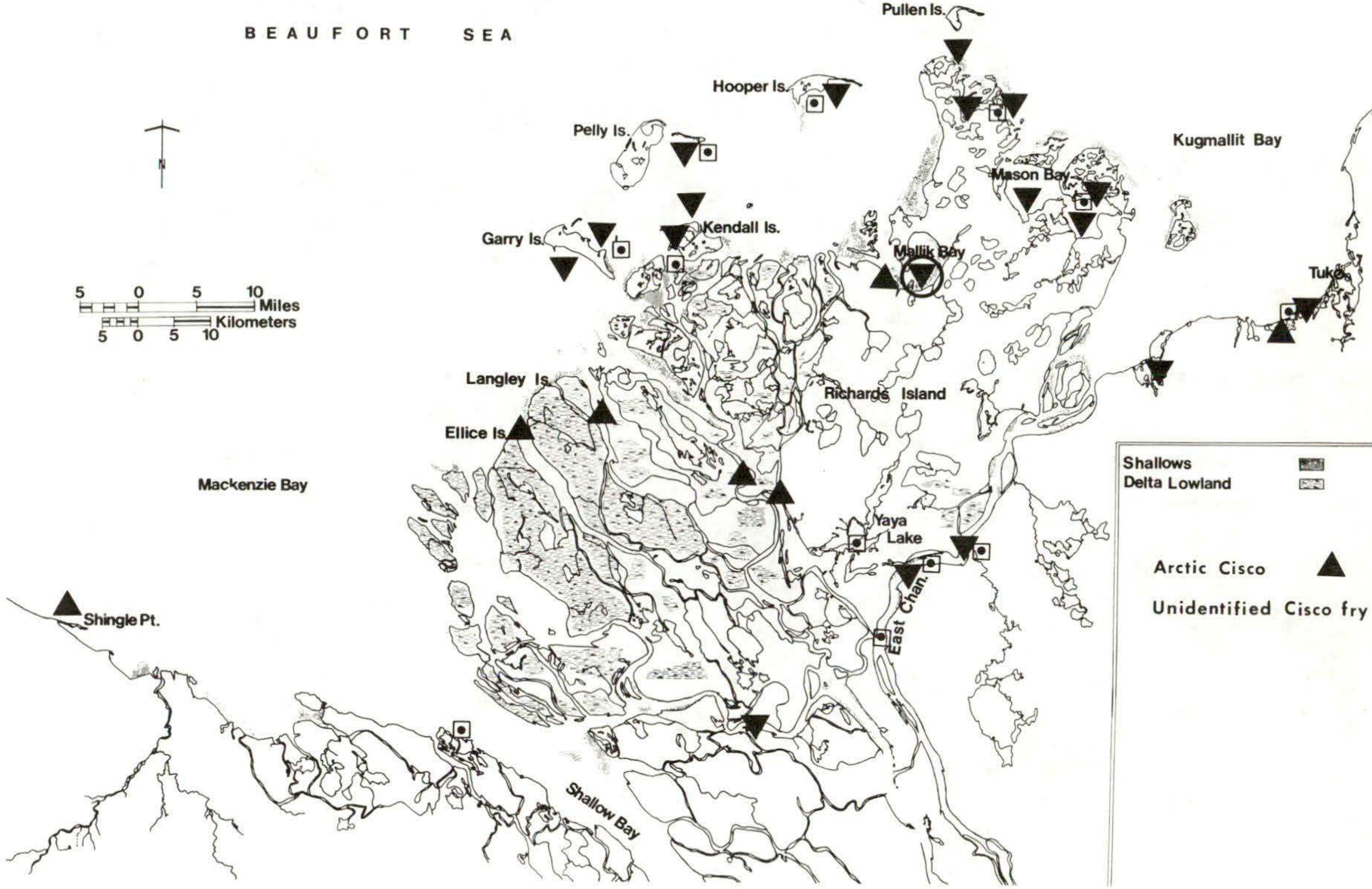

Figure 44. Distribution of Arctic cisco and unidentified cisco fry in the outer Mackenzie Delta. Encircled symbol represents both summer and winter distributions.

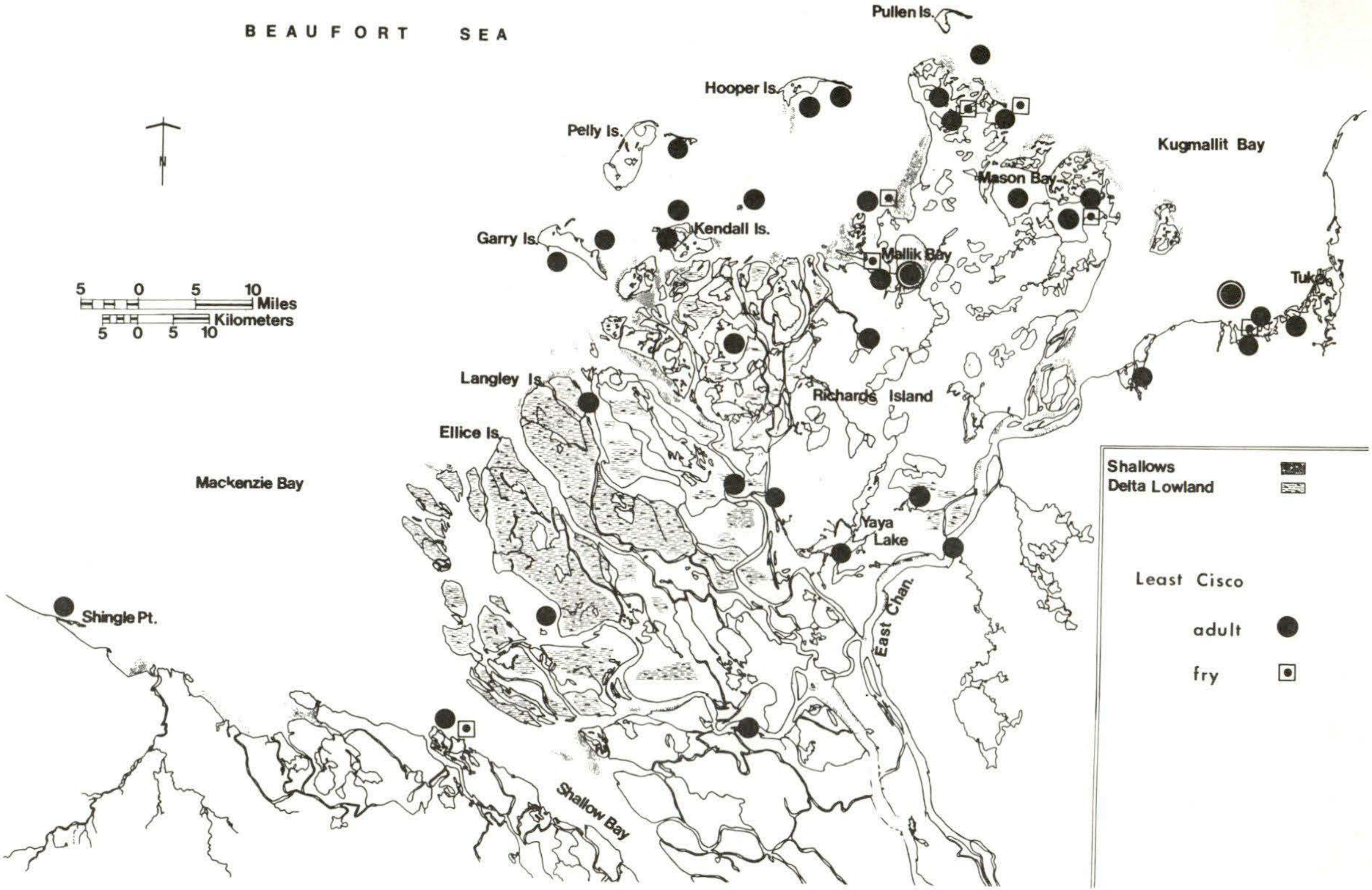

Figure 45. Distribution of least cisco in the outer Mackenzie Delta. Encircled symbols represent both summer and winter distributions.

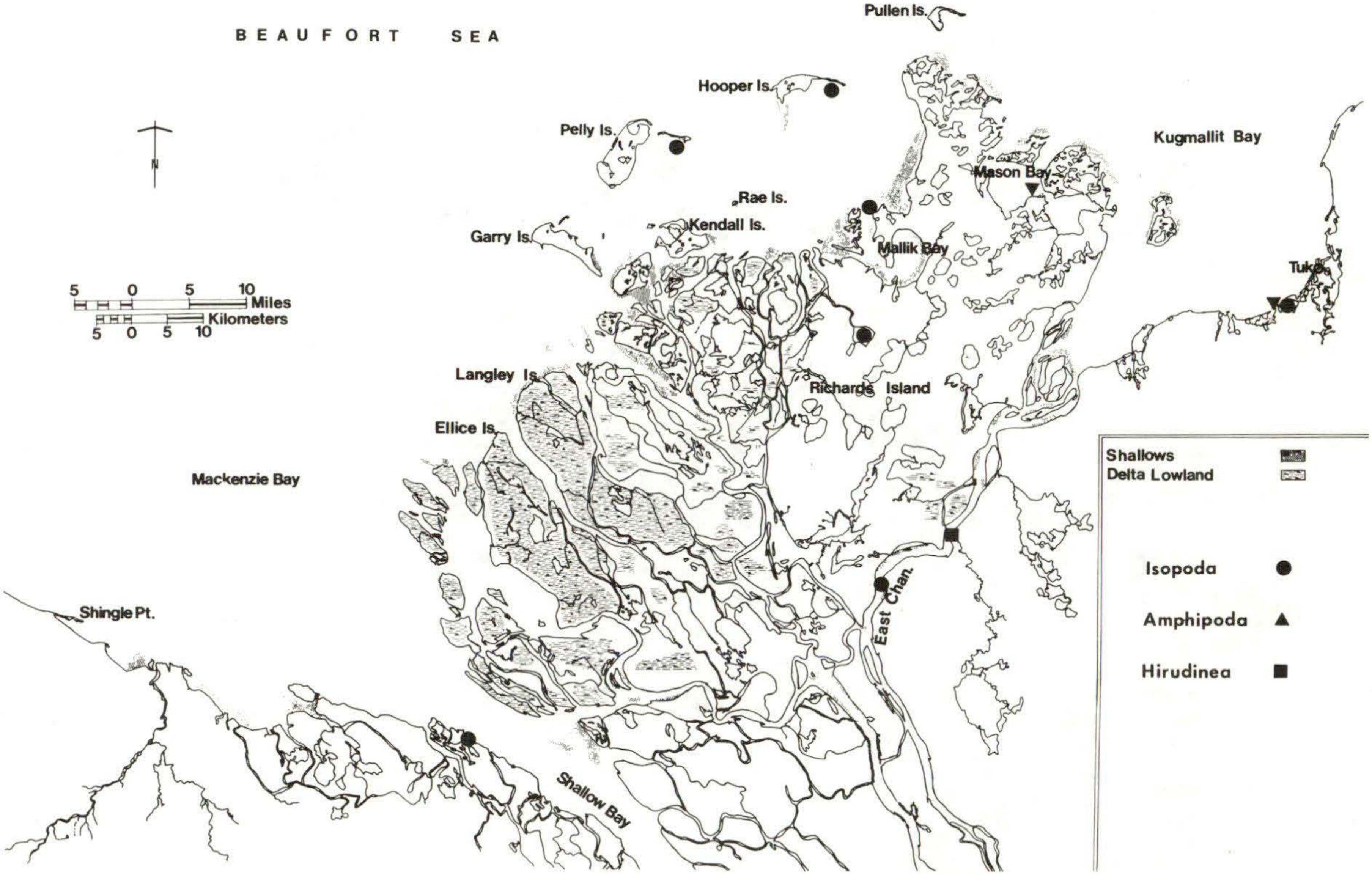

Figure 46. Distribution of invertebrates seined in the outer Mackenzie Delta. Isopods were of the species *Mesidotea entomon* and amphipods principally *Onisimus affinis*.

Table 2. Relative abundance of anadromous, freshwater and marine fishes caught in gillnets, sweep nets and trap nets in the outer Mackenzie Delta in 1974 and 1975.

Species	Coastal Waters		Streams		Lakes		Total Catch	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Arctic cisco	107	(4.4)	83	(6.0)	0		190	(4.5)
Arctic flounder	55	(2.2)	0		0		55	(1.3)
Arctic lamprey	0		64	(4.6)	0		64	(1.5)
Boreal smelt	335	(13.6)	18	(1.3)	4	(1.1)	357	(8.5)
Broad whitefish	90	(3.7)	240	(17.2)	24	(6.6)	354	(8.4)
Burbot	59	(2.4)	15	(1.1)	1	(0.3)	75	(1.8)
Fourhorn sculpin	214	(8.7)	2	(0.1)	0		216	(5.1)
Humpback whitefish	132	(5.4)	271	(19.5)	78	(21.3)	481	(11.4)
Inconnu	395	(16.1)	153	(11.0)	97	(26.5)	645	(15.3)
Lake trout	4	(0.2)	2	(0.1)	16	(4.4)	22	(0.5)
Least cisco	951	(38.7)	396	(28.4)	80	(21.9)	1427	(33.8)
Longnose sucker	20	(0.8)	20	(1.4)	6	(1.6)	46	(1.1)
Northern pike	7	(0.3)	122	(8.8)	57	(15.6)	186	(4.4)
Pacific herring	48	(2.0)	0		0		48	(1.1)
Saffron cod	21	(0.9)	0		0		21	(0.5)
Starry flounder	6	(0.2)	0		0		6	(0.1)
Whitefish (unidentified)	15	(0.6)	8	(0.6)	3	(0.8)	26	(0.6)
Total catch	2459	(100)	1394	(100)	366	(100)	4219	(100)

Table 3. Relative abundance of fish fry caught in seines in the outer Mackenzie Delta in 1974.

Species	Coastal Waters		Streams		Lakes		Total Catch	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Arctic flounder	8	(1.9)	0		0		8	(1.1)
Arctic grayling	0		8	(6.5)	0		8	(1.1)
Boreal smelt	39	(9.1)	17	(13.8)	0		56	(8.0)
Broad whitefish	3	(0.7)	0		0		3	(0.4)
Burbot	2	(0.5)	0		0		2	(0.3)
Cisco (unidentified)	175	(40.9)	14	(11.4)	14	(9.4)	203	(29.0)
Fourhorn sculpin	75	(17.5)	11	(8.9)	0		86	(12.3)
Humpback whitefish	7	(1.6)	0		0		7	(1.0)
Inconnu	1	(0.2)	0		0		1	(0.1)
Lake chub	0		1	(0.8)	0		1	(0.1)
Least cisco	25	(5.8)	0		0		25	(3.6)
Longnose suckers	10	(2.3)	12	(9.8)	1	(0.7)	23	(3.3)
Ninespine stickleback	26	(6.1)	38	(30.9)	0		64	(9.1)
Northern pike	1	(0.2)	0		0		1	(0.1)
Pond smelt	3	(0.7)	0		0		3	(0.4)
Round whitefish	1	(0.2)	0		0		1	(0.1)
Spoonhead sculpin	0		10	(8.1)	57	(38.3)	67	(9.6)
Trout perch	1	(0.2)	4	(3.3)	71	(47.7)	76	(10.9)
Whitefish (unidentified)	40	(9.4)	5	(4.1)	6	(4.0)	51	(7.3)
Other	11	(2.6)	3	(2.4)	0		14	(2.0)
Total catch	428	(100)	123	(100)	149	(100)	700	(100)

Table 4. Sex and maturity ratios, by size class, for commonly captured species in the outer Mackenzie Delta. Maturity includes fish of both sexes.

Fork Length (mm)	Broad Whitefish					Humpback Whitefish				
	Percent Males	Maturity (Percent)			Sample Size	Percent Males	Maturity (Percent)			Sample Size
		Immature	Minor	Mature			Immature	Minor	Mature	
0-50	-	-	-	-	-	-	-	-	-	-
51-100	-	-	-	-	-	-	-	-	-	-
101-150	-	100	-	-	1	-	100	-	-	4
151-200	-	100	-	-	2	27	73	27	-	15
201-250	22	78	22	-	9	24	68	29	-	34
251-300	25	75	25	-	4	41	52	48	-	29
301-350	46	23	69	8	13	50	11	89	-	54
351-400	71	-	100	-	14	41	4	93	4	54
401-450	45	3	86	10	29	44	2	77	21	86
451-500	50	-	76	24	66	43	-	70	30	30
501-550	36	-	52	48	25	-	-	50	50	2
551-600	20	-	20	80	5	75	25	75	-	4
601-650	-	-	-	100	1	-	-	-	-	-
651-700	-	-	-	-	-	-	-	-	-	-

Table 4. (Cont'd)

Fork Length (mm)	Burbot					Fourhorn Sculpin				
	Percent Males	Maturity (Percent)			Sample Size	Percent Males	Maturity (Percent)			Sample Size
		Immature	Minor	Mature			Immature	Minor	Mature	
0-50	-	-	-	-	-	-	100	-	-	48
51-100	-	-	-	-	-	-	100	-	-	30
101-150	-	-	-	-	-	-	50	-	50	2
151-200	-	-	-	-	-	31	6	63	31	16
201-250	-	-	-	-	-	25	-	35	65	49
251-300	33	67	33	-	3	5	-	10	90	19
301-350	33	33	67	-	3	-	-	-	100	6
351-400	-	-	-	-	-	-	-	-	-	-
401-450	29	57	43	-	7	-	-	-	-	-
451-500	100	-	100	-	1	-	-	-	-	-
501-550	50	-	100	-	4	-	-	-	-	-
551-600	33	-	83	14	6	-	-	-	-	-
601-650	50	-	100	-	2					
651-700	67	2	83	-	6					
701-750	50	-	75	25	4					
751-800	-	-	-	-	-					
801-850	-	-	-	-	-					
851-900	100	-	100	-	1					

Table 4. (Cont'd)

Fork Length (mm)	Inconnu					Northern Pike				
	Percent Males	Maturity (Percent)			Sample Size	Percent Males	Maturity (Percent)			Sample Size
		Immature	Minor	Mature			Immature	Minor	Mature	
0-50	-	-	-	-	-	-	-	-	-	-
51-100	-	100	-	-	1	-	100	-	-	1
101-150	100	-	100	-	1	-	-	-	-	-
151-200	33	67	33	-	6	-	-	-	-	-
201-250	12	65	35	-	17	-	100	-	-	1
251-300	40	35	76	-	25	100	-	100	-	1
301-350	56	13	81	6	16	67	33	67	-	3
351-400	92	-	100	-	12	100	-	100	-	1
401-450	75	8	92	-	12	75	25	75	-	4
451-500	62	5	95	-	21	25	-	100	-	4
501-550	49	9	91	-	43	77	-	100	-	22
551-600	65	-	100	-	53	46	-	94	6	35
601-650	61	-	100	-	61	47	-	100	-	19
651-700	68	-	96	2	44	57	-	100	-	14
701-750	45	-	100	-	31	58	-	83	17	12
751-800	10	-	100	-	31	20	-	100	-	5
801-850	8	-	100	-	13	80	-	80	20	5
851-900	-	-	60	40	5	100	-	100	-	1
901-950	-	-	-	-	-	33	-	100	-	3
951-1000	-	-	-	-	-	100	-	100	-	1

Table 4. (Cont'd)

Fork Length (mm)	Least Cisco					Arctic Cisco				
	Percent Males	Maturity (Percent)			Sample Size	Percent Males	Maturity (Percent)			Sample Size
		Immature	Minor	Mature			Immature	Minor	Mature	
0-50	-	-	-	-	-	-	-	-	-	-
51-100	-	100	-	-	3	-	-	-	-	-
101-150	-	100	-	-	11	-	-	-	-	-
151-200	53	28	73	-	60	67	33	67	-	3
201-250	54	9	81	9	172	44	22	78	-	9
251-300	58	2	56	30	247	69	6	94	-	16
301-350	13	-	71	29	24	19	-	100	-	33
351-400	-	-	100	-	2	48	-	72	24	58
401-450	100	-	100	-	1	9	-	41	59	22
451-500	-	-	-	-	-	100	-	50	50	2
501-550	-	-	-	-	-	-	-	-	-	-

Table 4. (Cont'd)

Fork Length (mm)	Boreal Smelt					Pacific Herring				
	Percent Males	Maturity (Percent)			Sample Size	Percent Males	Maturity (Percent)			Sample Size
		Immature	Minor	Mature			Immature	Minor	Mature	
0-50	-	100	-	-	47	-	-	-	-	-
51-100	11	89	-	-	9	-	-	-	-	-
101-150	2	78	22	-	9	-	-	-	-	-
151-200	26	50	49	-	70	50	-	50	50	2
201-250	68	4	83	15	145	64	-	71	29	14
251-300	52	-	55	45	67	50	-	29	71	14
301-350	50	-	50	50	40	80	-	80	20	5
351-400	-	-	-	-	-	-	-	-	-	-

Table 5. Sex and maturity ratios for less commonly captured species within the outer Delta.

Species	Fork Length Range (mm)	Percent Males	Maturity (Percent)			Sample Size
			Immature	Minor	Mature	
Arctic flounder	125-323	44	33	33	33	9
Lake trout	360-913	50	8	75	17	12
Longnose sucker	197-583	50	19	69	12	16
Saffron cod	310-450	76	-	100	-	17

Table 6. Length-frequency for seined fish caught in the outer Mackenzie Delta in 1974.

Species	Fork Length Intervals (mm)																				
	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 to 120	121 to 130	131 to 140	141 to 150	151 to 160	161 to 170	171 to 180	181 to 190	191 to 200	201 to 210	211 to 220
Arctic flounder				3	4							1		1							
Arctic grayling					1	4	3														
Boreal smelt		16	20	11	4	3	1														
Burbot															1						
Cisco		2	15	35	23	26	30	41	24	3	3	1	2	1							
Fourhorn sculpin	3	25	14	6	16	10	3	1								1	1	1	1		1
Humpback whitefish										1	1		2			1	1				1
Inconnu															1						
Lake chub												1									
Least cisco							1	2				3	3	1	5	1	1			2	
Longnose sucker		7	3	4	2	1	2		2		1										
Ninespine stickleback	2	50	19	2																	
Northern pike									1												
Pond smelt			1	1	1																
Round whitefish									1												
Spoonhead sculpin		3	44	13	8	1															
Trout-perch		11	11	22	16	12	4														
Whitefish		2	4	10	7	7	11	6	3			1									

Table 7. Summary of the major fish species tagged and the number recaptured in the Mackenzie Delta during the period 1972 to 1975.

Species	Number Tagged	Number Recaptured	Percent Recaptured
Arctic cisco	4639	148	3.2
Arctic char	1365	458	33.6
Broad whitefish	4207	645	15.3
Burbot	748	107	14.3
Humpback whitefish	3789	356	9.4
Inconnu	1114	170	15.3
Least cisco	2151	22	1.0
Longnose sucker	386	8	2.1
Northern pike	4092	532	13.0
Total	22,491	2,446	10.9

Table 8. Catch analysis and chemical and physical parameters of winter fishing locations in the outer Delta (Location numbers refer to Fig. 8).

Date	Location (#)	Fish Catch Data: Set Duration (hr)	Species	No. Caught	Fork Length (mm)	Physical and Chemical Data: Water Depth (m)	Sal. (ppt)	Cond.	pH	Hardness
15.02.74	Tent Island (1)	120	Inconnu	1	494	2.0	-	-	-	-
21.03.74	Hooper Is. (7)	no net	-	-	-	1.5	1.1	0.7	-	-
22.03.74	Kendall Is. (5)	no net	-	-	-	8.0	0.3	0.3	-	-
22.03.74	Immerk (6)	24	no fish	-	-	3.0	0.3	0.3	8.5	-
24.03.74	Swimming Point (12)	92	Inconnu	1	435	-	-	-	8.5	-
			Burbot	1	540					
			Boreal smelt	4	250-300					
08.03.75	Harry Channel (3)	96	Humpback whitefish	1	-	1.5	-	-	8.0	9.0
09.03.75	Big Horn Pt. (8)	38	Northern pike	1	798	1.8	-	-	8.5	8.0
10.03.75	Mallik Bay (9)		Inconnu	16	580-850					
			Fourhorn sculpin	12	195-235					
			Least cisco	25	-					
			Boreal smelt	2	250					
		101	Arctic cisco	1	-	4.2	4.9	-	8.5	-
			Burbot	1	560		7.9*		9.0*	
			Pacific herring	4	260-295					
			Arctic flounder	4	185-300					
			Starry flounder	1	300					
			Broad whitefish	1	235					
11.03.75	Mason Bay (10)	48	Fourhorn sculpin	3**	-	4.2	9.6	6.7	8.5	-

Table 8. Cont'd

Date	Location (#)	Fish Catch Data: Set Duration (hr)	Species	No. Caught	Fork Length (mm)	Physical and Chemical Data: Water Depth (m)	Sal. (ppm)	Cond.	pH	Hardness
12.03.75	Kendall Is. (5)	no net	-	-	-	2.6	0.2	0.2	9.0	11.0
12.03.75	Ya-Ya Lake (2)	48	no fish	-	-	1.0	-	-	-	-
14.03.75	Hendrickson Is. (11)	72	Least cisco Boreal smelt Humpback whitefish	1 1 1	- - -	1.0	0.2	0.1	7.7	9.0
18.03.75	Swimming Point (12)	22	Humpback whitefish Boreal smelt	1 1	432 259	-	-	-	7.5	6.0

* These are near bottom measurements.

** Not representative since only 3 meters of a 36 meter net recovered.

Table 9. Water chemistry data collected within the outer Delta during the 1974 and 1975 surveys. Locations refer to Figure 7.

Location	Date	Depth* (m)	Temp. (°C)	D.O. (ppm)	pH	Hardness	Alkalinity	Salinity (ppt)	Secchi depth (cm)
6	25/8/74	Surface	-	10.0	8.5	9.0	-	>1	-
11	10/7/74	Surface	8.9	-	-	-	-	>1	-
14	13/8/74	Surface	10.0	11.0	8.5	9.0	7.0	<1	-
18	25/3/74	Surface	0.0	-	8.5	-	-	0.3	-
19	11/7/74	Surface	-	-	-	-	-	>1	-
	26/7/74	Surface	1.1	-	-	-	-	>1	-
	13/8/74	Surface	10.0	10.0	8.5	10.0	5.0	-	-
	24/3/74	Surface	0.0	-	-	-	-	0.3	-
22	26/7/74	Surface	16.1	-	-	-	-	-	16
	12/3/75	Surface	0.0	-	9.0	11.0	8.0	0.2	-
24	9/7/74	Surface	7.8	-	7.5	7.0	-	>1	-
	17/7/74	Surface	6.0	-	-	-	-	-	-
	7/8/74	Surface	14.4	-	-	-	-	-	-
29	25/7/74	Surface	8.3	-	-	-	-	-	-
	15/9/74	Surface	3.8	-	-	-	-	-	-
30	25/6/74	Surface	5.0	13.0	8.5	9.0	-	-	63
	23/7/74	Surface	10.0	-	-	-	-	-	-
	15/9/74	Surface	4.4	-	-	-	-	-	-
31	21/6/74	Surface	4.0	11.0	9.5	6.0	-	-	16
	25/6/74	Surface	8.0	-	-	-	-	-	-
	22/8/74	Surface	-	11.0	8.5	9.0	7.0	<1	12
34	5/8/74	Surface	13.9	-	-	-	-	-	-
	20/8/74	Surface	7.1	-	-	-	-	-	-
39	15/8/74	Surface	-	11.0	8.5	16.0	6.0	3.0	-
41	9/3/75	Surface	0.0	-	8.5	8.0	7.0	-	107
42	21/6/74	Surface	3.5	11.0	8.5	9.0	-	-	44
	5/8/74	Surface	13.3	-	-	-	-	-	-
44	29/6/74	Surface	9.5	-	-	-	-	1.0	-
46	8/9/74	Surface	-	-	-	-	-	4.0	-
		5.5	-	-	-	-	-	4.0	-
	10/3/75	Surface	-	-	9.0	-	4	4.9	-
		4.2	-	-	8.5	-	10	7.9	-

Table 9. Cont'd

Location	Date	Depth* (m)	Temp. (°C)	D.O. (ppm)	pH	Hardness	Alkalinity	Salinity (ppt)	Secchi depth (cm)
47	14/8/74	Surface	9.4	-	-	-	-	2.0	-
48	21/3/74	Surface	0.0	-	-	-	-	1.1	-
	15/8/74	2.9	7.8	11.0	8.5	11.0	11.0	<1	-
49	29/8/74	Surface	10.0	-	-	-	-	3	12
50	28/8/74	Surface	-	11.0	8.5	6.0	-	-	<120
54	27/7/74	Surface	10.0	-	-	-	-	6.0	-
	20/9/74	Surface	3.3	12.0	-	-	2.0	8.0	-
		20m	4.7	2.0	-	-	9.0	18.0	-
	11/3/75	Surface	0.0	-	8.5	-	-	9.6	-
57	28/7/74	Surface	13.3	-	-	-	-	2.0	-
58	19/7/74	Surface	15.6	-	-	-	-	>1	20
	15/3/75	Surface	0.0	-	7.7	9.0	1.0	0.2	-
62	17/7/74	Surface	14.4	-	-	-	-	-	16
	7/9/74	Surface	6.1	-	-	-	-	>1	-
64	18/7/74	Surface	16.7	-	-	-	-	-	-

*Depth at which water sample was obtained.

Table 9a. Water temperature readings at the four catch per unit effort fishing locations (Fig. 7) throughout the 1974 field season.

Date	Water Temperature (°C)			
	Reindeer Channel (5)	Main Channel (32)	Harry Channel (33)	East Channel (70)
June 15 - June 21	-	-	7.8	11.1
June 22 - June 28	11.1	11.1	11.1	15.0
June 29 - July 5	-	-	10.0	-
July 6 - July 12	14.1	-	-	13.3
July 13 - July 19	16.7	15.6	15.6	17.7
July 20 - July 26	-	15.6	13.3	16.7
July 27 - Aug. 2	15.6	15.6	16.7	-
Aug. 3 - Aug. 9	-	16.7	-	15.6
Aug. 10 - Aug. 16	-	13.3	13.3	-
Aug. 17 - Aug. 23	-	9.4	8.9	-
Aug. 24 - Aug. 30	-	-	-	-
Aug. 31 - Sept. 6	8.9	-	-	-
Sept. 7 - Sept. 13	-	8.9	7.1	9.4
Sept. 14 - Sept. 20	-	8.9	8.9	7.8

Table 10. Number (N), mean fork length (X) and size range (R) by age class of anadromous, freshwater and marine fishes caught in the outer Mackenzie Delta in 1974 and 1975.

Age		0+	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Arctic	N	-	-	5	6	13	14	23	28	15	11	10	1	-	-	-	-	-	-	-	-
cisco	$\bar{X}$	-	-	191	254	264	337	340	374	376	403	409	376	-	-	-	-	-	-	-	-
	R	-	-	185	215	209	265	290	285	342	374	385	376	-	-	-	-	-	-	-	-
		-	-	203	287	322	396	393	472	425	430	428	-	-	-	-	-	-	-	-	-
Arctic	N	7	-	-	1	1	7	6	4	2	-	-	1	1	-	-	-	-	-	-	-
flounder*	$\bar{X}$	52	-	-	125	148	250	237	247	233	-	-	280	291	-	-	-	-	-	-	-
	R	46	-	-	125	148	153	197	206	205	-	-	280	291	-	-	-	-	-	-	-
		58	-	-	-	-	276	323	293	261	-	-	-	-	-	-	-	-	-	-	-
Boreal	N	37	19	-	5	6	36	54	13	5	-	-	-	-	-	-	-	-	-	-	-
smelt*	$\bar{X}$	31	51	-	151	194	189	230	250	284	-	-	-	-	-	-	-	-	-	-	-
	R	24	40	-	100	150	118	118	223	255	-	-	-	-	-	-	-	-	-	-	-
		42	70	-	260	286	267	295	294	305	-	-	-	-	-	-	-	-	-	-	-
Broad	N	-	1	4	15	16	13	10	15	24	14	10	9	6	3	2	1	-	-	-	-
whitefish	$\bar{X}$	-	175	211	315	359	372	407	399	446	468	481	482	490	459	620	585	-	-	-	-
	R	-	175	149	203	180	305	261	235	241	380	440	420	409	425	584	585	-	-	-	-
		-	-	236	444	483	463	568	495	555	588	573	525	558	514	655	-	-	-	-	-
Burbot*	N	-	-	-	-	2	1	-	1	1	2	2	2	-	-	1	-	-	-	-	-
	$\bar{X}$	-	-	-	-	318	450	-	425	571	624	653	725	-	-	720	-	-	-	-	-
	R	-	-	-	-	310	450	-	425	571	575	603	714	-	-	720	-	-	-	-	-
		-	-	-	-	325	-	-	-	-	673	703	736	-	-	-	-	-	-	-	-
Fourhorn	N	5	10	-	5	3	18	13	7	6	1	2	2	-	-	2	-	-	-	-	-
sculpin*	$\bar{X}$	40	68	-	210	176	208	226	271	264	322	308	258	-	-	228	-	-	-	-	-
	R	20	56	-	199	164	140	181	235	240	322	295	205	-	-	220	-	-	-	-	-
		59	80	-	221	186	260	270	324	300	-	321	310	-	-	235	-	-	-	-	-

Table 10. (Cont'd)

Age		0+	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Humpback	N	-	2	2	3	10	21	17	21	27	33	15	14	13	11	10	7	4	-	1	-
whitefish	X̄	-	106	125	181	213	234	258	310	308	374	379	385	417	417	431	448	442	-	514	-
	R	-	95	110	173	170	178	214	227	208	230	323	302	371	377	385	375	409	-	514	-
		-	116	140	185	368	316	300	483	380	588	448	466	475	460	489	485	477	-	-	-
Inconnu	N	-	-	3	2	10	8	19	14	21	53	39	34	22	24	7	12	3	-	-	-
	X̄	-	-	231	348	291	359	468	502	538	584	616	666	716	757	733	830	730	-	-	-
	R	-	-	197	330	213	238	380	460	265	503	492	414	614	650	560	663	700	-	-	-
		-	-	268	365	421	488	604	551	690	702	785	815	863	890	834	900	752	-	-	-
Least	N	1	7	8	12	18	38	35	22	14	6	3	1	-	-	-	-	-	-	-	-
cisco	X̄	75	104	136	196	251	238	267	265	287	291	304	273	-	-	-	-	-	-	-	-
	R	75	80	85	178	175	192	180	217	256	275	300	273	-	-	-	-	-	-	-	-
		-	184	192	267	413	319	313	335	315	311	309	-	-	-	-	-	-	-	-	-
Northern	N	-	3	3	2	2	2	7	22	20	18	12	6	3	1	-	-	-	-	-	-
pike	X̄	-	233	304	380	489	580	566	549	598	630	684	729	832	878	-	-	-	-	-	-
	R	-	95	236	328	418	465	463	463	479	505	613	576	742	878	-	-	-	-	-	-
		-	314	355	431	560	694	604	696	713	850	812	850	905	-	-	-	-	-	-	-
Saffron	N	-	-	-	-	-	1	4	-	-	-	-	-	-	-	-	4	2	-	-	-
cod*	X̄	-	-	-	-	-	370	357	-	-	-	-	-	-	-	-	424	373	-	-	-
	R	-	-	-	-	-	370	310	-	-	-	-	-	-	-	-	403	316	-	-	-
		-	-	-	-	-	-	424	-	-	-	-	-	-	-	-	450	430	-	-	-
Starry	N	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	1	-	-	-	-
flounder*	X̄	-	-	-	-	-	225	-	-	-	-	-	-	-	337	-	245	-	-	-	-
	R	-	-	-	-	-	225	-	-	-	-	-	-	-	337	-	245	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 10. (Cont'd)

Age		0+	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Spoonhead	N	1	7	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
sculpin*	X̄	23	35	46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	R	23	32	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	38	57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trout	N	8	7	13	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
perch	X̄	26	42	56	67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	R	24	33	47	55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		34	50	72	78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

- 17 Ninespine sticklebacks (25-35 mm) were all age 0+.
- 11 Lake trout* (422-913 mm) ranged in age from 8 to 24 years.

*ages determined from otoliths

Table 11. Lengths, weights and age classes for 146 broad whitefish caught by the Holmes Creek commercial fishery, 1973.

Age Class	N	Length (mm)		Weight (g)	
		Range	Mean	Range	Mean
6	1	462	462	1588	1588
7	9	405-484	456	1134-2126	1578
8	30	405-519	471	1276-2495	1818
9	49	440-558	487	1446-2948	1932
10	30	458-545	499	1503-2605	2080
11	24	464-570	514	1701-2892	2278
12	2	520-555	538	2495-2552	2524
13	1	553	553	3147	3147

Table 12. Length-weight relationship by sex and maturity for major species of fish in the outer Mackenzie Delta (log weight = log A + B. Log length).

N = sample size
A = intercept
B = ponderal index (slope)
SE = standard error of estimate

Species	Maturity	Sex	N	A	B	SE
Arctic cisco	Immature	M/F	111	-0.6133	1.2643	0.2384
	Mature	F	25	-4.0208	2.6563	0.0425
	Mature	M/F	27	-0.3158	1.2289	0.0785
	All	M/F	138	-1.1496	1.4914	0.2298
Boreal smelt	Immature	M/F	245	-4.0395	2.5306	0.1525
	Mature	M	29	-3.6896	2.4091	0.0384
	Mature	F	25	-2.7657	2.0235	0.0895
	Mature	M/F	54	-3.0980	2.1619	0.0659
	All	M/F	299	-4.2006	2.6037	0.1423
Broad whitefish	Immature	M/F	134	-4.4912	2.8620	0.1199
	Mature	F	35	-5.5607	3.2739	0.0696
	Mature	M/F	36	-5.5317	3.2633	0.0686
	All	M/F	170	-4.6572	2.9285	0.1121
Burbot	Immature	M/F	37	-4.1738	2.6154	0.0870
	All	M/F	39	-4.1951	2.6236	0.0848
Humpback whitefish	Immature	M/F	266	-4.3593	2.7910	0.1024
	Mature	M	4	-5.2817	3.1740	0.0250
	Mature	F	24	-5.7177	3.3421	0.0509
	Mature	M/F	28	-5.6924	3.3321	0.0474
	All	M/F	294	-4.5271	2.8607	0.1021

Table 12. Cont'd.

Species	Maturity	Sex	N	A	B	SE
Inconnu	Immature	M/F	384	-4.7074	2.8804	0.0940
	Mature	F	4	-4.7641	2.9234	0.0901
	Mature	M/F	4	-4.7641	2.9234	0.0901
	All	M/F	388	-4.7147	2.8833	0.0940
Lake trout	Immature	M/F	13	1.0212	0.8114	0.3173
	Mature	M/F	3	-5.6619	3.2604	0.0620
	All	M/F	16	-1.9880	1.9381	0.3035
Least cisco	Immature	M/F	416	-4.7041	2.8551	0.1143
	Mature	M	32	2.2777	-0.0171	0.1157
	Mature	F	65	-1.5650	1.6040	0.0773
	Mature	M/F	97	2.1787	0.0527	0.1180
	All	M/F	514	-1.6952	1.6005	0.1695
Longnose sucker	Immature	M/F	10	-5.1615	3.1094	0.0468
	All	M/F	12	-4.8751	2.9929	0.0487
Northern pike	Immature	M/F	126	-4.7324	2.8539	0.0715
	Mature	M/F	4	-4.8308	2.9122	0.0377
	All	M/F	131	-4.7835	2.8733	0.0718

Table 13. Meristic characters of humpback and broad whitefish from the outer Mackenzie Delta. Gill raker measurements are presented as upper limb and lower limb counts.

Humpback Whitefish				Broad Whitefish			
Fish No.	Gill Raker Counts	Lateral Line Scale Counts	Pyloric Caeca Counts	Fish No.	Gill Raker Counts	Lateral Line Scale Counts	Pyloric Caeca Counts
1	15 + 7	84	173	1	14 + 8	87	170
2	15 + 8	87	101*	2	12 + 8	88	164
3	15 + 8	86	188	3	14 + 8	84	178
4	15 + 9	87	163				
5	15 + 9	83	135				
6	16 + 9	82	163				
7	15 + 9	78	169				
8	15 + 11	89	187				
9	16 + 9	84	178				
10	15 + 10	78	123*				
11	17 + 12	76	176				
12	15 + 9	80	140				
13	14 + 9	83	174				
14	16 + 7	84	156				
15	15 + 8	78	160				
16	17 + 10	-	-				
Range	15-17+7-12	78-89	135-188		12-14+8	84-88	164-178
Mean	15 + 9	83	163		13 + 8	86	173

*Unreliable counts.

Table 14. Alphabetical list of common names and associated generic names for fish caught in the Beaufort Sea Study.

Arctic cisco - *Coregonus autumnalis* (Pallas)

Arctic flounder - *Liopsetta glacialis* (Pallas)

Arctic grayling - *Thymallus arcticus* (Pallas)

Arctic lamprey - *Lampetra japonica* (Martens)

Boreal smelt - *Osmerus eperlanus* (Linnaeus)

Broad whitefish - *Coregonus nasus* (Pallas)

Burbot - *Lota lota* (Linnaeus)

Fourhorn sculpin - *Myoxocephalus quadricornis quadricornis* (Linnaeus)

Humpback whitefish - *Coregonus clupeaformis* (Mitchill)

Inconnu - *Stenodus leucichthys nelma* (Pallas)

Lake chub - *Couesius plumbeus* (Agassiz)

Lake trout - *Salvelinus namaycush* (Walbaum)

Least cisco - *Coregonus sardinella* (Valenciennes)

Longnose sucker - *Catostomus catostomus* (Forster)

Ninespine stickleback - *Pungitius pungitius* (Linnaeus)

Northern pike - *Esox lucius* (Linnaeus)

Pacific herring - *Clupeaharengus pallasi* (Valenciennes)

Pond smelt - *Hypomesus olidus* (Pallas)

Round whitefish - *Prosopium cylindraceum* (Pallas)

Saffron cod - *Eleginus navaga* (Pallas)

Spoonhead sculpin - *Cottus ricei* (Nelson)

Starry flounder - *Platichthys stellatus* (Pallas)

Trout-perch - *Percopsis omiscomaycus* (Walbaum)