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Echo Sounding and Fish Data from Selected Sites in the Lower Mackenzie River, Northwest Territories

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ABSTRACT

Jessop, E.F., and K.T.J. Chang-Kue. 1993. Echo sounding and fish data from selected sites in the lower Mackenzie River, Northwest Territories. Can. Manuscr. Rep. Fish. Aquat. Sci. 2193: v + 34 p.

Suspected coregonid pre-spawning aggregation sites in the Mackenzie Delta's Middle Channel near Horseshoe Bend, in the upper East Channel, and in the Mackenzie River near Arctic Red River were investigated with echo sounding and gillnet gear in September and October 1981. Numerous targets were recorded on transect echograms at Horseshoe Bend and Arctic Red River; the greatest numbers occurred in the prominent west bank backeddy below Horseshoe Bend. Total targets in some reaches increased by 51 to 1 144% over initial readings as the fall season progressed. Stationary echo sounding over a 24-hour period at selected sites showed highest target densities in the 3-6 m depth stratum in both areas; by October highest densities occurred in the 0-3 m stratum at Arctic Red River. Concurrent fish catches also increased as the season progressed. The total catch (N = 769) was dominated by five migratory coregonid species (91.4%). Least cisco (42.3%), lake whitefish (36.3%) and broad whitefish (7.7%) were the main species. Ninety-two percent of the coregonids were mature. The preponderance of largest size classes in the length-frequency distribution for each species reflected the presence of mature fish on spawning migrations.

Key words: Echo sounding; hydroacoustics; fishery surveys; migrations; lake whitefish; *Coregonus clupeaformis*; broad whitefish; *Coregonus nasus*; least cisco; *Coregonus sardinella*; Arctic cisco; *Coregonus autumnalis*; inconnu; *Stenodus leucichthys*; Mackenzie River; Mackenzie Delta; Arctic Red River.

RÉSUMÉ

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Les lieux présumés d'agrégation avant le frai des corégonidés dans la chenal du Milieu du delta du Mackenzie, prés du coude Horseshoe, dans le partie amont du chenal de l'Est et dans le fleuve Mackenzie prés d'Arctic Red River ont été étudiés par échosondage et capture au filet maillant en septembre et octobre 1981. De nombreuses cibles ont été enregistrées sur les échogrammes par transects au coude Horseshoe et à Arctic Red River; le nombre le plus élevé de cibles a été enregistré dans le tourbillon en retour remarquable de la rive ouest, en aval du coude Horseshoe. Le nombre total de cibles dans certains troncons a augmenté de 51 à 1 144 p. 100 par rapport aux lectures initiales au fur et à mesure que l'automne a progressé. L'échosondage stationnaire sur une période de 24 heures à certains endroits choisis a révélé que les densités les plus élevées de cibles étaient observées dans la strate de profondeur de 3-6 m aux deux endroits; en octobre, les densités les plus fortes ont été observées dans la strate de 0-3 m à Arctic Red River. Les prises de poissons réalisées en même temps ont également augmenté avec la progression de l'automne. Les prises totales (N = 769) ont été dominées par cinq espèces de corégonidés migrateurs (91,4%). Le cisco sardinelle (42,3%), le grand corégone (36,3%) et le corégone tschir (7,7%) ont constitué les principales espéces capturées. Des corégonidés capturés, 92% étaient à maturité. La prépondérance des classes de taille plus grande dans la distribution de fréquence de longueurs pour chaque espéce est indicative de la présence de poissons matures en migration de frai.

Mots clés: Échosondage;hydroacoustique; relevés de poissons; migration; grand corégone; *Coregonus clupeaformis*; corégone tschir; *Coregonus nasus*; cisco sardinelle; *Coregonus sardinella*; cisco arctique; *Coregonus autumnalis*; inconnu; *Stenodus leucichthys*; fleuve Mackenzie; delta du Mackenzie; Arctic Red River.

INTRODUCTION

Major spawning migrations of broad whitefish (*Coregonus nasus*), lake whitefish (*Coregonus clupeaformis*), Arctic cisco (*Coregonus autumnalis*), least cisco (*Coregonus sardinella*) and inconnu (*Stenodus leucichthys*) are important features of the fish populations in the lower Mackenzie River. These coregonid species are taken in the subsistence fishery in most settlements and traditional fishing camps. Initial details on coregonid migrations were documented when Department of Fisheries and Oceans (DFO), Central and Arctic Region, investigated fish resources of the Mackenzie Basin between 1971 and 1976 in the Fort Simpson, Norman Wells, Arctic Red River and the Mackenzie Delta regions (Hatfield et al. 1972a, 1972b; Stein et al. 1973a, 1973b; Jessop et al. 1974; Jessop and Lilley 1975; Percy 1975).

Increased hydrocarbon exploration activities in the southern Beaufort Sea prompted DFO to initiate another series of studies, during 1978-1981, to collect life history information on the coastal fish populations in the southeastern Beaufort coastal region and outer Mackenzie Delta (Bond 1982; Lawrence et al. 1984; Bond and Erickson 1982, 1985; Hopky and Ratynski 1983; Chang-Kue and Jessop 1992). Results from these studies showed that coastal watersheds on the Tuktoyaktuk peninsula were used extensively by populations of immature broad whitefish, lake whitefish and least cisco for summer foraging and overwintering. In addition, these drainages provided major nursery areas for young-of-year broad whitefish. Mark and recapture data also showed that broad whitefish from a representative drainage, Kukjuktuk Creek, were recaptured in subsequent years in the Mackenzie Delta during fall spawning migrations (Chang-Kue and Jessop 1992).

In 1980, we returned to the Delta to examine the seasonal abundance and maturity state of fishes migrating through or into the East Channel between Tununuk Point and Kugmallit Bay. Our investigations moved to the upper Delta in 1981 to document size distributions and maturity states of migratory coregonids at suspected prespawning aggregation sites.

Echo sounding was an important tool in our 1981 study program. Hydroacoustic fish detection has evolved to a stage where it has become an important technique for use with conventional fishing methods for life history and fishery management studies. Basic echo sounding techniques, enhanced by computerized data acquisition and processing systems, can be used to determine biomass and density of fish stocks (Mathisen 1980; Burczynski 1982). This latter approach, however, was beyond our scope and our echo sounder was used only as a means to investigate areas of the Delta suspected to be major prespawning aggregation sites. Our objective was to obtain preliminary echograms to provide visual information on location of fish aggregations, relative fish density and distribution in the water column. This report provides an interpretation of echograms obtained in two areas in the Mackenzie Delta and at the Arctic Red River confluence. Data on fish collected concurrently are also summarized.

DESCRIPTION OF THE STUDY AREA

The Mackenzie Delta is made up of a complex system of lakes, channels, levees and alluvial flats occupying an area of 12 700 km^2 (Brunskill 1986). Channel systems cover 15-20% of the area while lakes and ponds cover 40-50% (Marsh and Hey 1989). The Middle Channel carries the largest percentage of the total flow, varying from 85% of the monthly flow in summer to 94% of the monthly flow in winter (Davies 1975). A major portion of this flow diverts to the East Channel through Neklek Channel, resulting in an estimated 25 to 35% of the total Mackenzie River's flow going to Kugmallit Bay (Anderson and Anderson 1974). Channel depths reach 30 m in this lower section of the East Channel. In contrast, there is less flow in the upper East Channel where relatively shallow maximum channel depths of 1-5 m occur, especially in the narrow section above Inuvik. A maximum depth of 9.5 m for the upper East Channel is shown in Canadian Hydrographic Service navigation charts (1983 edition).

There is evidence that the Mackenzie Delta has undergone two cycles of postglacial submergence and it is believed that delta sediments lie 30 to 76 m deep over much of the delta. The main channels have cut into these sediments to a depth of 30 m in local areas in West Channel, Middle Channel and an unnamed channel 11.3 km west of Tununuk (Mackay 1963). Navigation charts show a maximum depth of 41 m at the Horseshoe Bend area of Middle Channel. The unique channel characteristics in the reach below Horseshoe Bend have resulted in the formation of a large eddy that has become a major subsistence fishing site (Fig. 1). This area is itself often referred to as "Horseshoe Bend" by local residents and this name will be used likewise in this report.

The Arctic Red River, flowing from the Mackenzie Mountains, is the first major tributary upstream from the Delta. The community of Arctic Red River, located at its confluence with the main stem of the Mackenzie River, is the centre of a major subsistence fishery in the lower Mackenzie River region. The area at the confluence has channel depths reaching 15 m and is reported to be a major prespawning aggregation and possible spawning site for lake and broad whitefish (Jessop et al. 1974).

MATERIALS AND METHODS

ECHO SOUNDING LOCATIONS

Echo sounding was conducted in three areas between 6 September and 17 October 1981. These areas and associated names used in this report are (Fig. 1):

Area A: Horseshoe Bend,
Area B: East Channel, and
Area C: Arctic Red River.

Traditional fishing camps are located at each area. Echo sounding transects at Area A covered the major west bank backeddy located 4 km downstream from Horseshoe Bend (Fig. 2). Groups of transects were made in the upper East Channel, at sites B1, B2, B3 and B4, located 18.5, 33, 34, and 45 km upstream, respectively, from Inuvik (Fig. 3). Echo soundings at Arctic Red River (Fig. 4) were done in the Arctic Red River itself (transects 1-20), in the Mackenzie River below the confluence (transects 21-28), and above the confluence (transects 33-41).

ECHO SOUNDING

A 50 kHz Honda Sitex (Model HE 106) echo sounder was used in this study. The transducer had an elliptical beam pattern with length and breadth beam angles of 20° and 40° respectively. Echoes were not recorded within 1.5 m of the transducer which was positioned 20-30 cm below the water surface and side-mounted on a 6.5 m Boston Whaler boat for downward scanning. Echograms were recorded on 15 cm wide electrosensitive paper. In the sample echogram (Fig. 5), the upper horizontal band represented the transducer position. Targets show up as echo traces which varied from dots to an inverted "v", depending on the size and position of the target in the beam. The bottom contour of the river was emphasized by the unit's "whiteline" feature which underscored the bottom with a white band to aid recognition of echoes from fish lying on or near bottom. Sensitivity and time varied gain controls were set at 7.0 and 7.2, respectively. These settings gave consistent echo traces at all depths encountered in the river channels. Settings were established by calibrating the echo sounder on specimens of dead whitefish and least cisco suspended in the water column on an anchored line. These dummy targets were placed at various depths up to 40 m during calibrations. Transects were run on parallel courses on both sides of the targets and echo trace configurations were noted on the echograms. This exercise also served to test the therortical beam pattern of the transducer.

A complete set of transects was collected in each study area on each of two or three visits during September and October 1981. Transect coverage in each area varied with the density of echo traces seen on preliminary echograms. In areas of high target densities, additional transects were made to define target aggregation limits. We intended to run transects at the same speed throughout the study; however, strong river flows and eddies created difficulties in achieving constant speed especially in the main stem river at Horseshoe Bend and at Arctic Red River.

After transects were completed in an area, continuous sounding at a selected site was conducted. The sounder was operated for 24 hours while the boat was anchored at the site. This stationary echo sounding was done at Horseshoe Bend's location HB 002 (maximum depth: 12 m) on 12 September (Fig. 2), and at location AR 101 at Arctic Red River, where a shallow site (6 m) and a deep site (15 m) were selected for echo sounding on 17-18 September and 13-14 October (Fig. 4).

ECHOGRAM NUMERICAL ANALYSIS

Echograms do not necessarily provide exact numbers of fish or allow identification to species. Because echogram traces may also represent other objects in the water column, they are usually referred to as targets or echo traces rather than fish traces. While calibration with dummy targets or fish specimens is an important step, verification by a concurrent fish sampling program is required to apportion echo traces with fish species and size composition.

Echo traces in transect echograms were counted directly to give an estimate of relative target numbers along each individual transect made on different dates. We made an assumption that the same volume of water was scanned, at the same speed, along the same transect each time so that simple target counts from different dates can be compared. Such counts were expressed as numbers of targets or echo traces per transect. No further numerical analyses were attempted because of the limitations of the echo sounding equipment.

Echo traces for the stationary 24-hour echograms were interpreted in more detail. To calculate relative densities at different depths, it was assumed that the transducer had a beam pattern shaped like an elliptical cone with a length and breadth beam angle of 20° and 40° respectively. Counts of individual targets were taken from transect echograms for each 3 m depth stratum for each hour. The appropriate depth correction factor was then applied to each of these counts. Using the area of the plane at the mid-point of the deepest stratum as unity, the mid-point area for each upper level stratum was prorated to give the required correction factor. The resulting count per stratum expressed the number of targets entering or passing through an approximate cylindrical stratum of water with a diameter equal to the mid-depth of the deepest stratum and a height of 3 m. Target density for each 3 m stratum was expressed as targets per m^3.

FISH SAMPLING

After running a set of echo sounding transects in each area, a survey gillnet (35 m long, 1.8 m deep) was set for 24 hours at 1-3 locations to sample the fishes present on that particular date. Each gillnet gang consisted of 5 m lengths each of 38, 64, 76, 89, 102, 114 and 127 mm (stretched measure) multi-filament nylon mesh. Nets were anchored from the shoreline except at Horseshoe Bend's location HB 002 where the net was set on bottom. The total catch was identified to species and data on fork length (± 1 mm), weight (± 1 g) were collected. Scales were used for ageing most fish species while otoliths were used for ageing burbot and chum salmon. Longnose suckers were not aged. Sex was determined by examining gonads of dissected fish and the maturity, based on degree of gonad development, was rated according to the following scale:

Female	Male	
1	6	Immature
2	7	Maturing
3	8	Mature
4	9	Ripe
5	10	Spent
0		Sex indistinguishable

RESULTS

TRANSECT ECHOGRAMS

Channel depths

Echograms at Horseshoe Bend (Area A) showed that maximum channel depths ranged from 21 to 45 m in the reach scanned with transects 1-11. Figure 5, a sample echogram from this area, showed that a depth of 44 m was measured in the vicinity of transect 6. The major backeddy is located on the west bank in the reach between transect 7d and 7f (Fig. 2). In the East Channel (Area B; Fig. 3), maximum channel depths were in the 4-6 m range at site B1, 6-8 m at site B2, 6-9 m at site B3, and 3-7 m at site B4. In the Arctic Red River area (Area C; Fig.4), the lower reach of the Arctic Red River (transects 1-13) had maximum channel depths between 5 and 9 m. The channel was shallower upstream as depths of 3-4 m were recorded in transects 14-20. Maximum depth ranges measured in the main-stem Mackenzie River channel were 10-30 m along transects 21-28 and 15-22 m along transects 30-41.

Channel target distribution

Transect echograms across river or delta channels revealed that target distribution in a channel cross section were more concentrated in areas of relatively low velocities, such as the inside bank of a river bend or in backeddies. Transect 7d at Horseshoe Bend, shown in Figure 6, provides an example of how target density was highest in the backeddy located on the west side of the channel. The deepest portion of the river channel reflected the path of the main discharge along the east bank and was the area where target numbers were smallest.

This observation was also evident along transect 7 (Fig. 7) which was run at an oblique angle starting from the west bank, along the backeddy and main channel interface, across the west bank sandbar, and finally across the main channel to the east bank. This visual depiction of high target concentrations in the lower velocity section of a channel cross section was generally consistent in transects in all three study areas.

Target counts

Identical sets of transects were run at Area B, East Channel (Fig. 3) on 7 and 22 September 1981. Results showed that the echo traces at site B1 decreased from a total of 23 targets on 7 September to only 9 targets two weeks later (Fig. 8). The trend, however, was an increase as observed at site B2, B3 and B4 which showed a 51% to 67% increase in targets by 22 September.

Echograms at Area A, Horseshoe Bend (Fig. 2), showed the largest number of targets, especially along transects 1-11 (Fig. 9). Target numbers generally increased between early September to mid-October. The total for transects 1 to 6 showed 206, 296 and 464 targets for 10 September, 25 September and 8 October, respectively. Transect 7, which crossed Horseshoe Bend's major west bank backeddy, showed that the total count of 257 targets on 10 September had more than doubled to 550 by 25 September. Because target counts at transect 7 had increased by 114 % by 25 September, greater than any other transect, a series of supplemental transects, 7b to 7f (Fig. 3), were run across the eddy and main channel. The total number of targets counted for 7b to 7f on 25 September was 698. This total increased to 1 252 by

8 October, a 79% increase (Fig. 9).

Echo sounding in Area C, Arctic Red River (Fig. 4), showed that targets were most evident in the reach closest to the river mouth (transects 1-11). The highest total number of echo traces for transects 1-11 occurred on 29 September (Fig. 10). Transects done further upstream (12-20) on 16 and 29 September revealed virtually no targets; furthermore, this reach was not scanned in October due to low water levels. The counts in the main stem Mackenzie River increased significantly between 16 September and 12 October (Fig. 10) when the total target count increased from 30 to 184 (513% increase) in the reach below the confluence (transects 21-28), and from 16 to 199 (1 144% increase) in the reach above the confluence (transects 30-41).

The transect echograms for all three study areas showed an overall increase in targets in the insonified water column as the fall season progressed. If we assume that these data represent an increase in fish numbers over this time period, then the results would seem to be consistent with previous observations made by Hatfield et al. (1972a) and Stein et al. (1973b) who reported significant increases in the catch-per-unit-of-effort for coregonids taken in survey gillnets at Horseshoe Bend and Arctic Red River each fall.

FISH CATCHES

Survey gillnets, fished for a 24-hour timespan at all locations, captured ten species of fish, five of which were coregonids (Table 1). Least cisco (42.3%) and lake whitefish (36.3%) dominated the total fish catch (N = 769) while broad whitefish, Arctic cisco and inconnu comprised 7.7%, 3.0% and 2.1%, respectively. The remaining 8.6% of the total catch was represented by northern pike, burbot, longnose sucker and single specimens of walleye and chum salmon.

The total fish catch at the representative fish sampling location in the East Channel (Fig. 3; Location EC 003) was small. Thirteen fish were taken over a 24-hour set on 6 September and only nine were taken on 23 September (Table 1). While traditional campsites are located in this area, this upper section of the East Channel above Inuvik is not regarded by local residents as a major fishing area for migratory coregonids. Although this area was not known as a major spawning migration route like the Middle Channel, mature broad whitefish and least cisco were indeed present (Table A1.1).

Gillnetting data at the other two areas generally indicated an increase in fish catches as the autumn season progressed, just as the target traces had increased in concurrent transect echo soundings. Gillnets set from the shoreline at locations HB 001 and HB 003 at Horseshoe Bend showed a 24% to 231% increase in the total catch (per 24-hour period) in October when compared to earlier sets in September (Table 1). The bulk of the catch at these two sites was comprised of coregonid species, i.e. least cisco (50%), lake whitefish (25.7%) and broad whitefish (9.6%). Northern pike, the main predator species, made up 12.1% of the total catch. Gillnetting at location HB 002 showed the opposite trend as the total of 50 fish captured on 13 September was down to only 13 fish on 25 September, mainly as a result of a reduction of lake whitefish.

The total gillnet catch on 13 October at location AR 100 increased by 163% when compared to the 17 September catch (Table 1). Similarly, the total catch at the Arctic Red River confluence (location AR 101) was 600 to 1067% higher than the three previous sampling occasions in September (Table 1).

The length-frequency distributions for major fish species taken from all fishing locations are shown in Fig. 11 (lake whitefish and broad whitefish), Fig. 12 (least cisco and Arctic cisco) and Fig. 13 (inconnu and northern pike). For the coregonid species, the most apparent feature was the relative lack of smaller size classes taken at these specific sites in September and October. Over 86% of lake whitefish were larger than 401 mm fork length, while 95% of broad whitefish were larger than 451 mm. All Arctic cisco were between 301-425 mm while 95.7% of least cisco were between 251-325 mm. Seventy percent of the sample of inconnu were larger than 801 mm fork length. The preponderance of the larger size ranges for each coregonid species reflected the presence of mature fish on spawning migrations. The percentages of mature fish of each species, estimated from fish with mature, ripe or spent gonads, are included in Appendix A where species fork length, weight and age data from each survey gillnet catch are summarized. For the season's total catch of lake whitefish, broad whitefish, least cisco, Arctic cisco and inconnu, the percentage of mature fish were 90.3, 93.2, 99.4, 95.7 and 87.5%, respectively.

We made no detailed effort to determine the distribution of species in the water column. The data indicated, however, that shoreline based nets, which were sampling mainly at the 3-6 m depth at locations HB 001 and HB 003, caught large numbers of least cisco and broad whitefish. Both of these species were less abundant at location HB 002 where the gillnet, set along the bottom at 15 m, caught mainly lake whitefish. Other back-eddies just downstream from Horseshoe Bend contribute to a major subsistence fishery where the preferred target species, broad whitefish, is taken every autumn with large mesh (127 mm stretch measure), shoreline-based gillnets.

Fish catches showed a seasonal change in relative species numbers. Data from the gillnetting station at the confluence of the Arctic Red River (Fig.4, loc. AR 101) showed that greater numbers of least cisco and Arctic cisco contributed to the increase in the gillnet catch on 13 October (N = 105) when compared to the 30 September (N = 11), 18 September (N = 9) and 17 September (N = 15) catches (Table 1 and A1.6). Inconnu dominated the catch in late September while lake and broad whitefish had been prominent two weeks earlier. The catch composition on 13 October was dominated by least cisco (60.0%), followed by Arctic cisco (18.1%), broad whitefish (11.4%) lake whitefish (8.6%) and inconnu (1.0%). Except for a few immature lake whitefish and northern pike, almost all of the fishes taken in this area with our gillnets were mature (Table A1.5, A1.6, A1.7 and A1.8).

In their interpretion of catch-per-unit-of effort data obtained in 1971, Hatfield et al. (1972a) found that migratory coregonids in the main stem Mackenzie River moved past the Arctic Red River area throughout the summer and fall period. Inconnu peaked in early July, followed by Arctic cisco in late August, broad whitefish and lake whitefish in mid-September, and finally, least cisco in late September. A similar pattern of migration pulses was also observed in the Delta in 1972 (Stein et al. 1973b). Extensive fishing occurs at traditional sites at Arctic Red River mouth and in back-eddies on the east side of the Mackenzie River across from the community. Subsistence fishing activity upstream on the Arctic Red River is less intense. This may be more a reflection of the greater opportunity to catch the different waves of migratory coregonid species on the main stem Mackenzie River as they reach or proceed past the confluence. Tagged coregonids from the coast and Delta have been recaptured in the Mackenzie River upstream from the Arctic Red River confluence (Stein et al. 1973b; Jessop et al. 1974; Jessop and Lilley 1975; Chang-Kue and Jessop 1992). The extent, however, of any specific migrations up the Arctic Red River is unknown.

STATIONARY ECHO SOUNDING

Results from the 24-hour echo soundings are presented in Fig. 14-16 where the density of targets every 60 minutes for each 3 m depth stratum are shown. Horseshoe Bend's location HB 002, which was scanned on 12 September (Fig. 14), showed the highest target density readings in the 3-6 m stratum with a range of 1.0 to 5.6 targets/m^3/hr. This zone also showed a diurnal variation with peak readings occurring between 0700 and 1100 hr. Target densities decreased with depth; the range of readings at the 6-9m, 9-12 m, 12-15 m and 15-18 m strata were 0.7-2.4, 0.3-0.9, 0.2-0.7 and 0.1-0.4 targets/m³/hr, respectively. Compared to the lower strata, the 0-3 m stratum was not completely insonified because of the noise limitation within 1.5 m of the unit. There appeared to be almost no activity in this 0-3 m stratum except between 1900 and 2200 hr when 0.9-3.6 targets/m³/hr were recorded. No data were obtained between 1500-1700 hr because the echo sounder ran out of recording paper.

Stationary echo sounding was conducted at Arctic Red River location AR 101 on 17-18 September and 13-14 October, where both a shallow (6 m) and a deep site (15 m) were observed for 24 hours. No data was obtained between 1500 and 2000 hr in October. Except for 1.3 and 0.3 targets/m³/hr recorded at 1000 hr and 2100 hr, respectively, there was little activity in the 0-3 m stratum of the shallow site on 17-18 September (Fig. 15). Most targets occurred in the 3-6 m stratum, where hourly readings of 0.2 to 1.0 targets/m³/hr were recorded. Although we anchored our boat in the same location a month later on 13 October, an additional stratum of 6-9 m was recorded. More targets were detected this time in the 0-3 m stratum, ranging from 0.7 to 11.2 targets/m³/hr; zero readings occurred between 1100 to 1500 hr and at 2100 hr. Target density readings of 0.3 to 1.9 targets/m³/hr in the 3-6 m stratum were higher than comparable readings made a month earlier. The 6-9 m stratum data ranged from 0.1 to 0.5 targets/m³/hr.

Few targets were recorded in the 0-3 m stratum at location AR 101 deep site on 17 September (Fig.16) when a density of 1.6 and 0.9 targets/m³/hr were only recorded at 1600 and 1700 hr. Targets were prevalent through the rest of the water column; the range of readings were 0.1-1.0, 0.1-0.7, 0.2-0.8 and 0.0-0.3 targets/m³/hr at the 3-6, 6-9, 9-12 and 12-15 m depth strata, respectively. In contrast, target densities were noticeably higher in October in the 0-3 and 3-6 m depth strata with ranges of 0.0-15.7 and 0.6-6.4 targets/m³/hr, respectively. For the 6-9, 9-12 and 12-15 m strata, range of readings were 0.1-0.7, 0.1-0.4 and 0.1-0.3 targets/m³/hr, respectively. No data was obtained for the hour ending at 1200 hr, 1300 hr, 2100 and 2200 hr. Diurnal peaks of target densities seemed to occur at 0500 hr and at 1100 hr in the 0-3 m stratum only in October. The only other obvious peak occurred at 1100 hr in the 3-6 m stratum.

Our general conclusion from 24-hour stationary echo soundings was that target densities were highest in the 3-6 m depth strata at both Horseshoe Bend (Fig. 14) and Arctic Red River (Fig. 15); however, significant activity occurred in the 0-3 m stratum in October at Arctic Red River. The large difference in density readings between September and October at Arctic Red River area was consistent with the higher number of targets seen in the transect echogram data. Fish catch totals at locations AR 100 and AR 101 also increased concurrently. At AR 101, our survey gillnet caught 15 fish on 17 September, whereas 105 fish were taken at the same site on 13 October. The difference in migration timing and relative abundance among coregonid species contributed to these observations. A change in the fish assemblage did occur between these two dates. The least cisco catch increased from 8.6% of the total catch in September to 60% of the total catch in October (Table 1). On the other hand, the lake whitefish and broad whitefish portion of the total catch decreased from 65.7% in September to only 20% in October.

It was not possible to interpret data further in terms of movements up or down the water column. Our quantification of targets from echogram traces was subjective and lacked the precision possible with more sophisticated echosounding equipment and watercraft. The potential, however, of hydroacoustic equipment as a fishery assessment tool was apparent even at the exploratory level employed in this study. We recommend that a digital echo-integration/target strength system be used in future fish population studies. A program that involves hydroacoustic data collection with concurrent fish sampling at different depth zones through the summer and autumn would facilitate data interpretations and contribute to a greater understanding of seasonal coregonid abundance, movements and behaviour.

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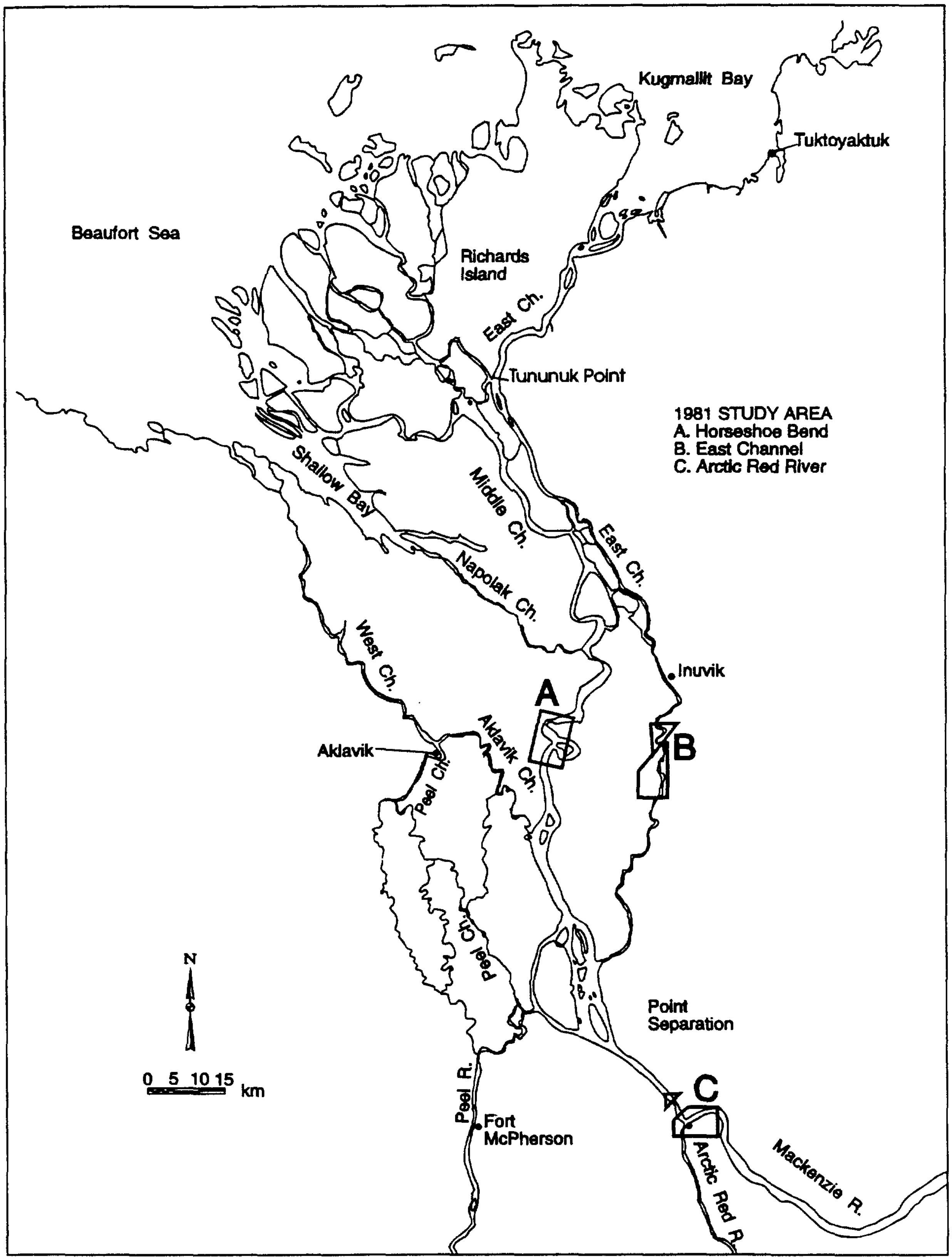


Fig. 1. Study areas A,B and C in the upper Mackenzie Delta, 1981.

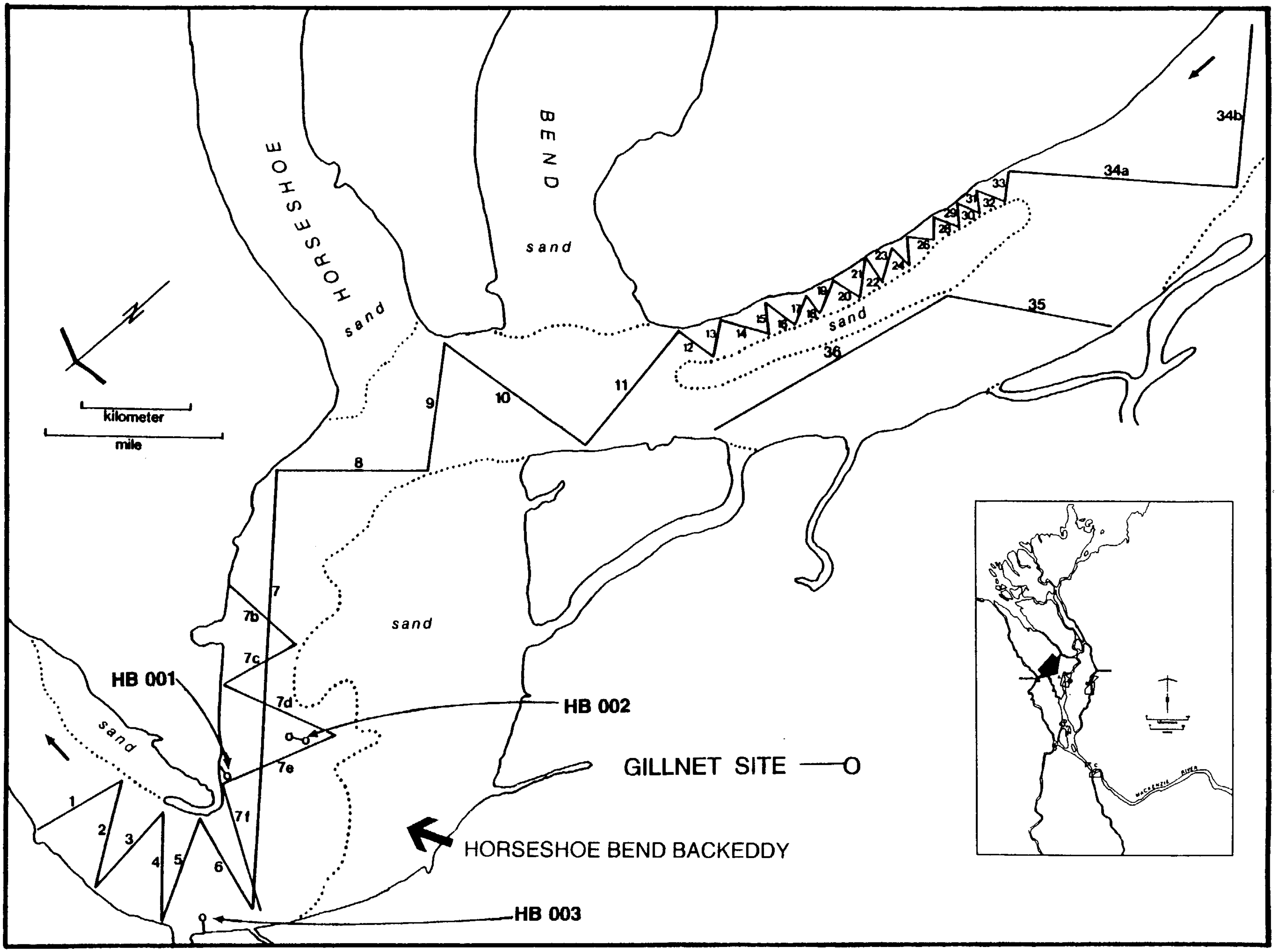


Fig. 2. Echo sounding transects and gillnetting locations in study area A, Horseshoe Bend.

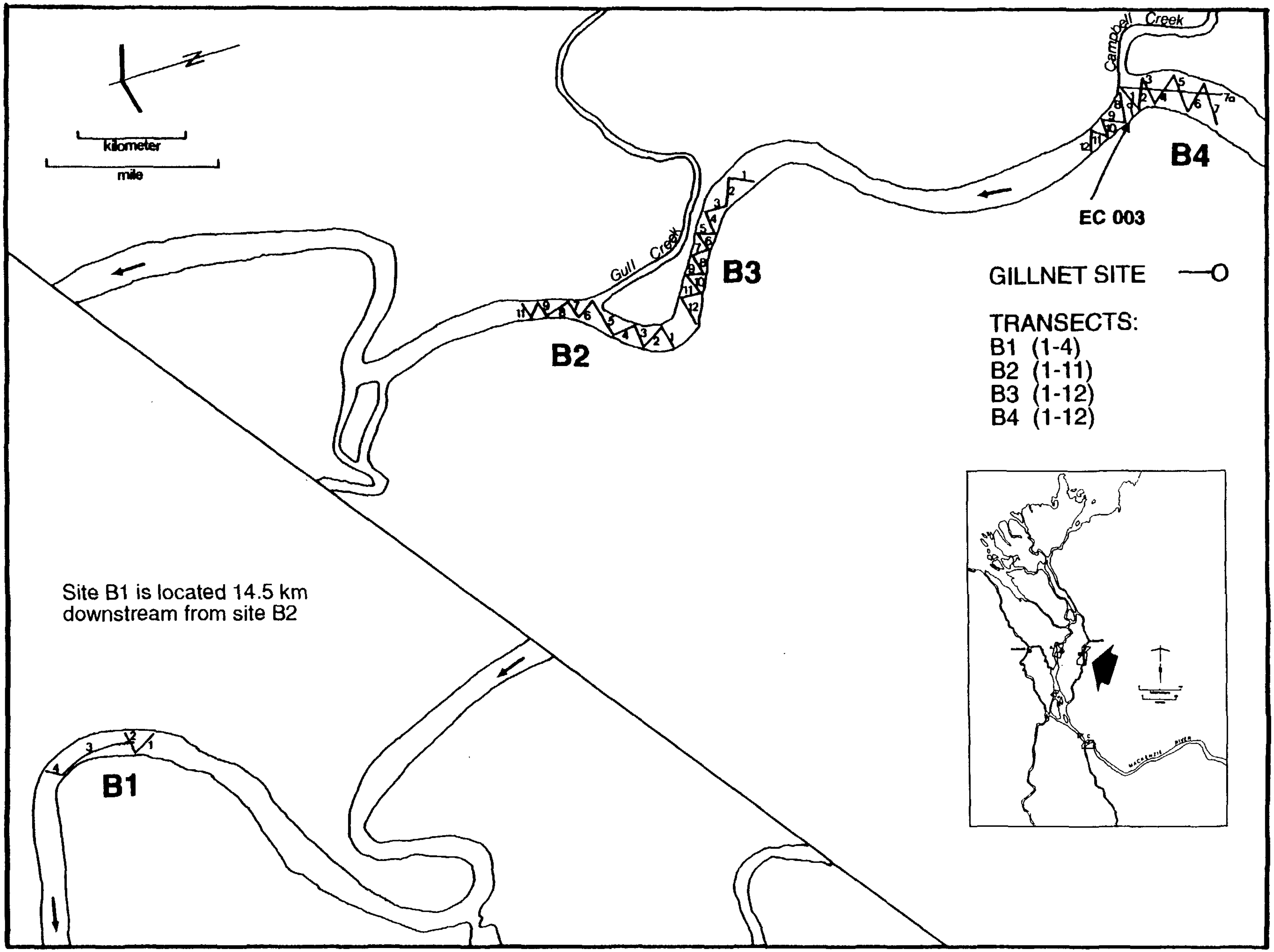


Fig. 3. Echo sounding transects and gillnetting locations in study area B, East Channel.

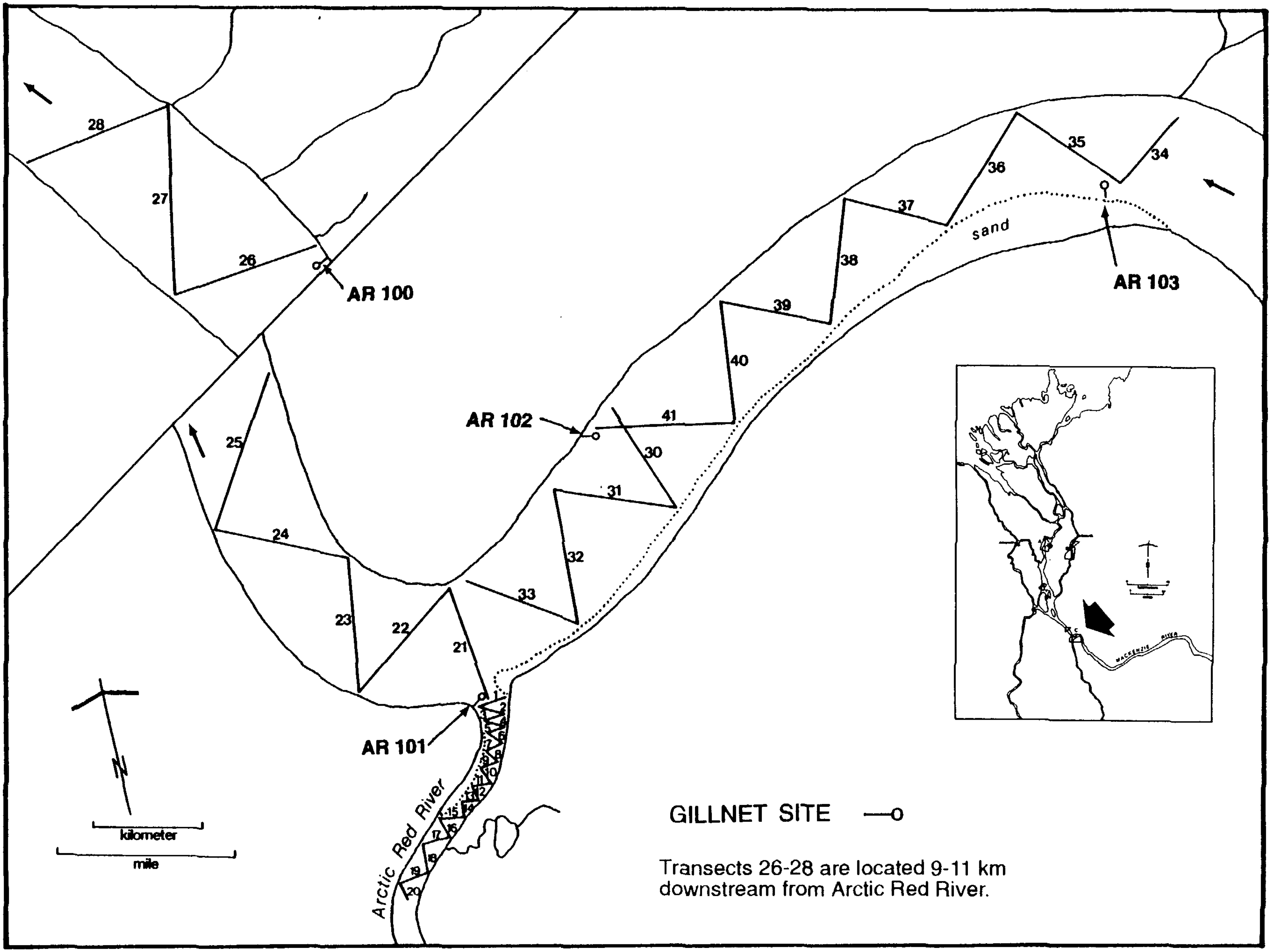


Fig. 4. Echo sounding transects and gillnetting locations in study area C, Arctic Red River.

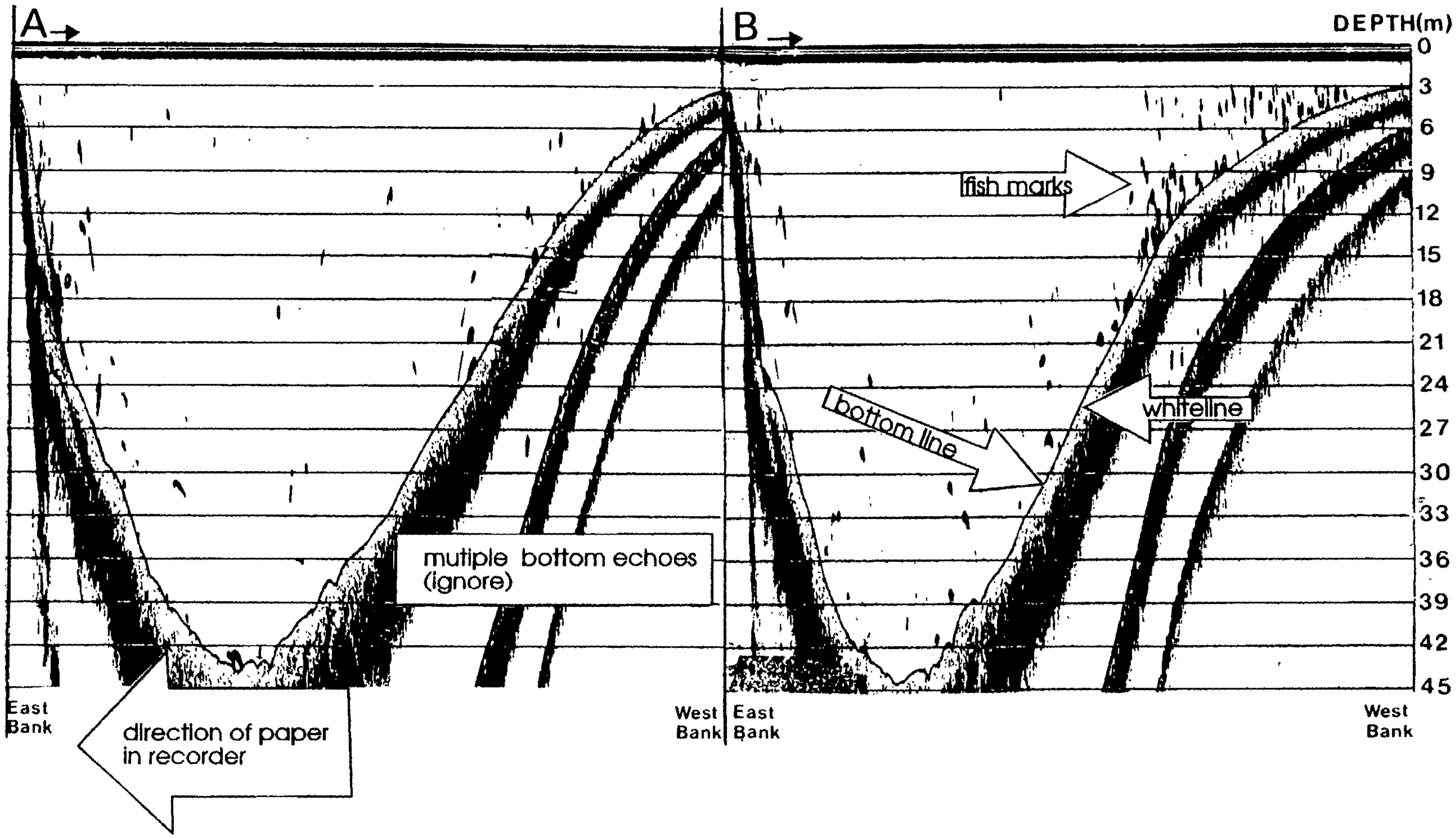


Fig. 5. Echograms of transect 6 at Horseshoe Bend on 10 September 1981 (A) and 25 September 1981 (B).

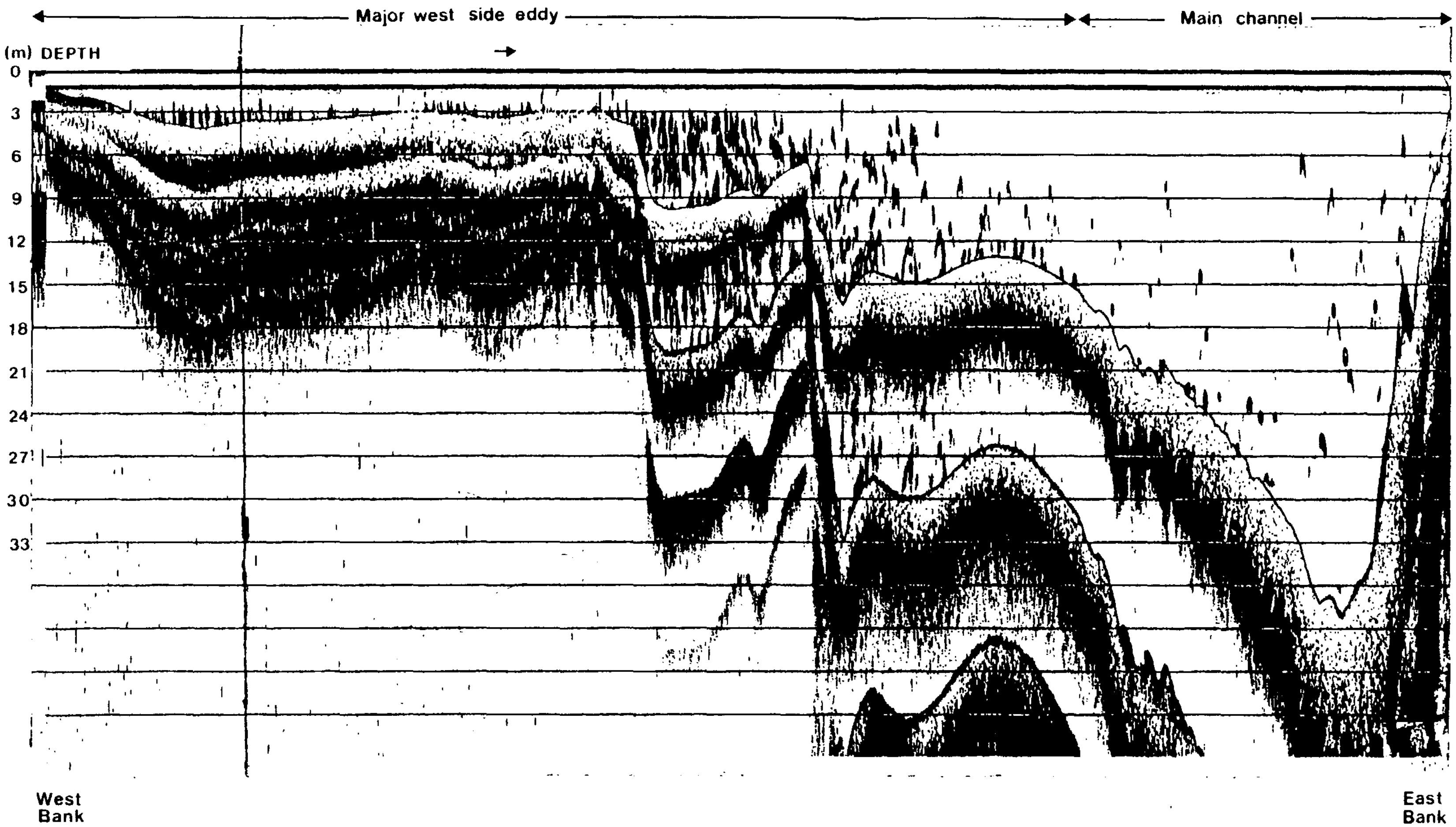


Fig. 6. Echogram of transect 7d at Horseshoe Bend on 8 October 1981.

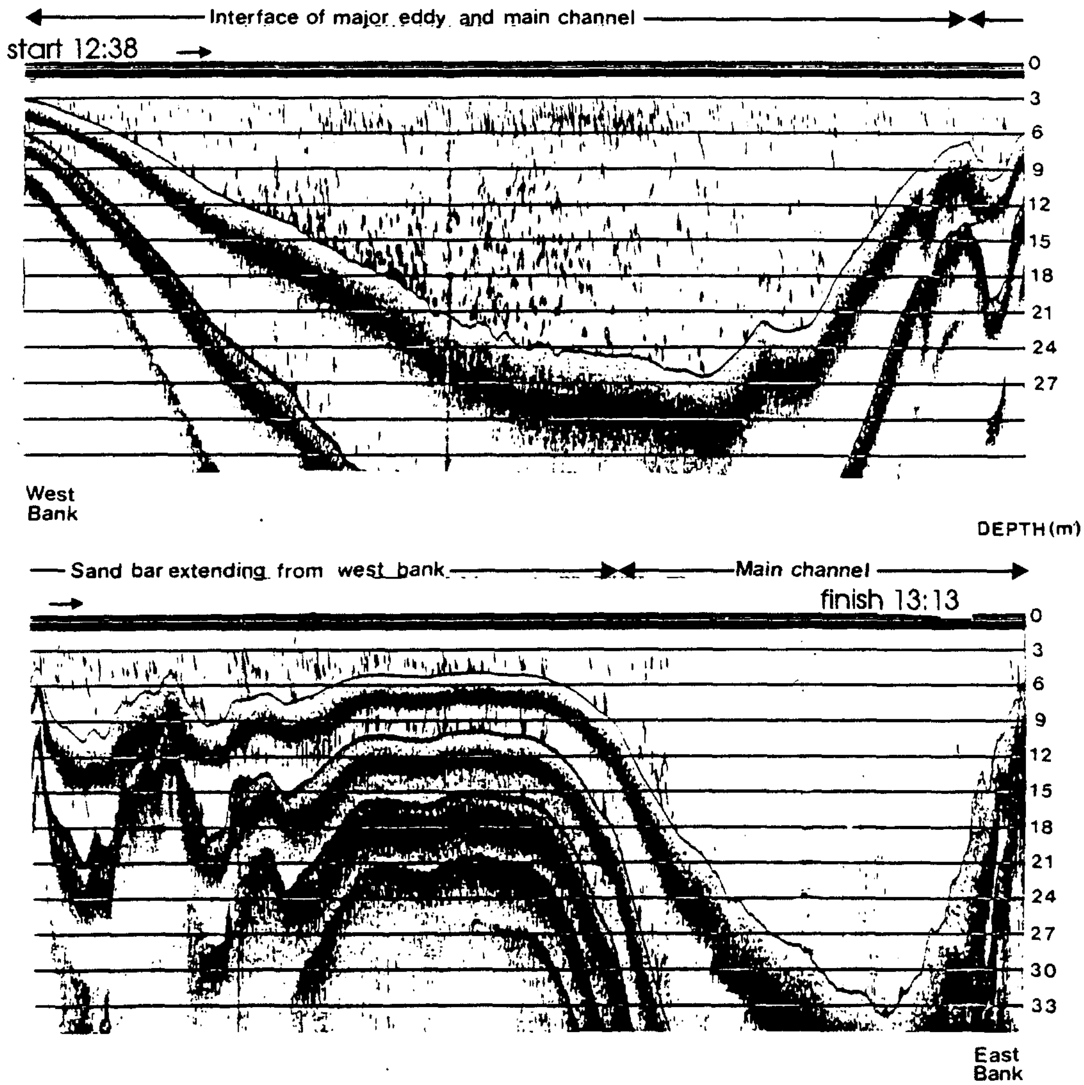


Fig. 7. Echogram of transect 7 at Horseshoe Bend on 25 September 1981.

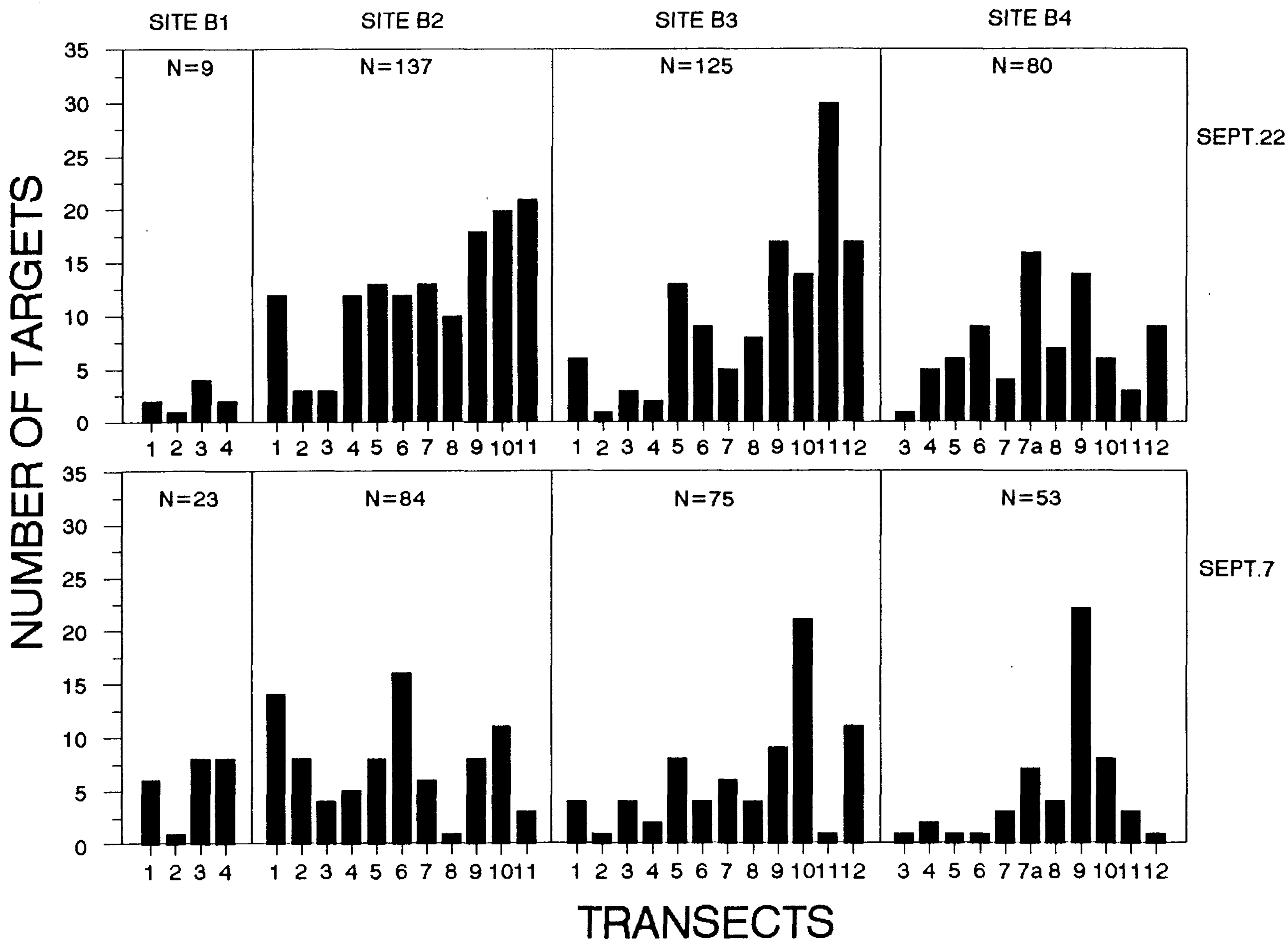


Fig. 8. Echogram target counts for transects at sites B1 to B4 in the East Channel on 7 and 22 September 1981.

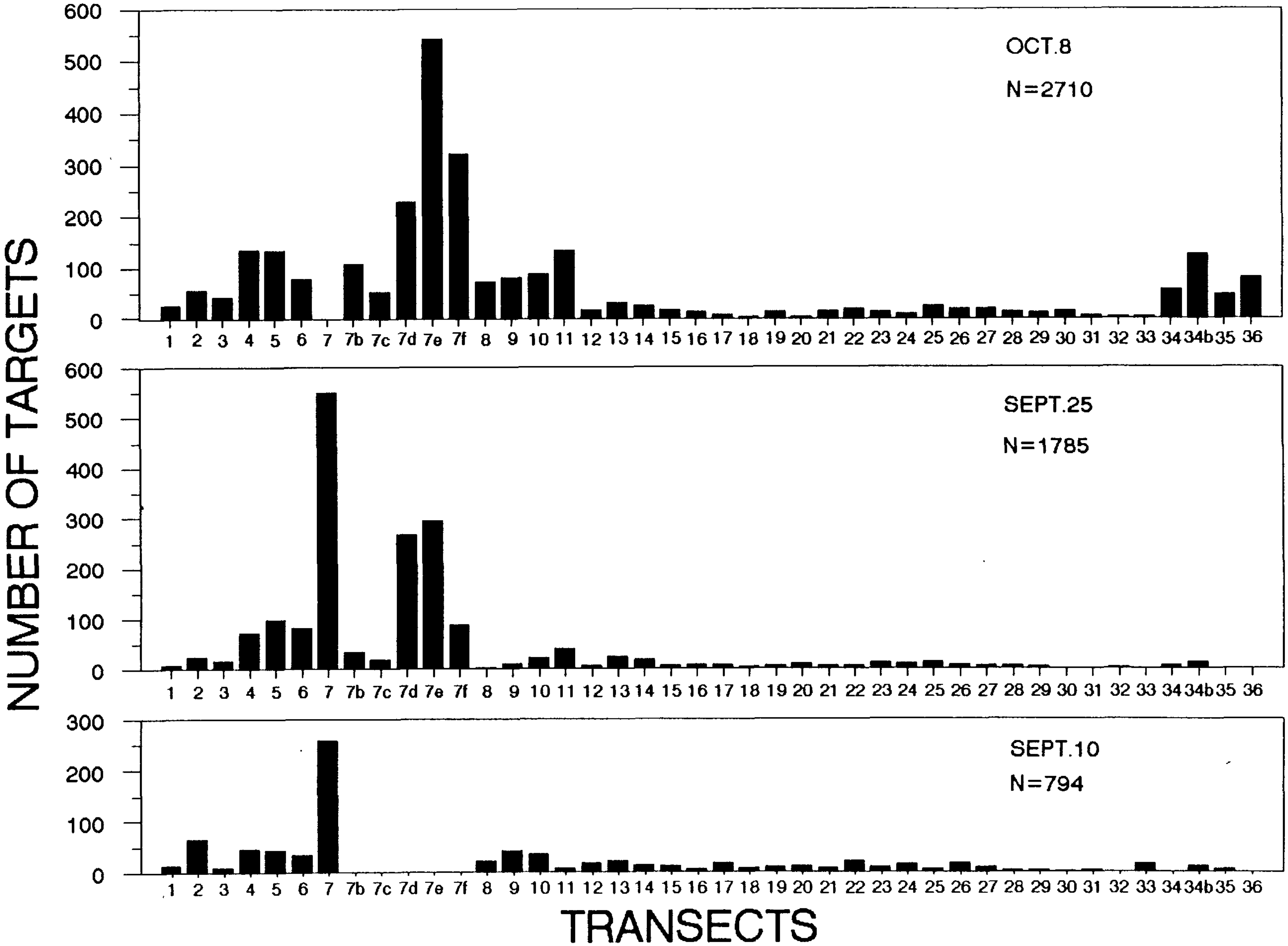


Fig. 9. Echogram target counts for transects at Horseshoe Bend on 10 September, 25 September and 8 October 1981.

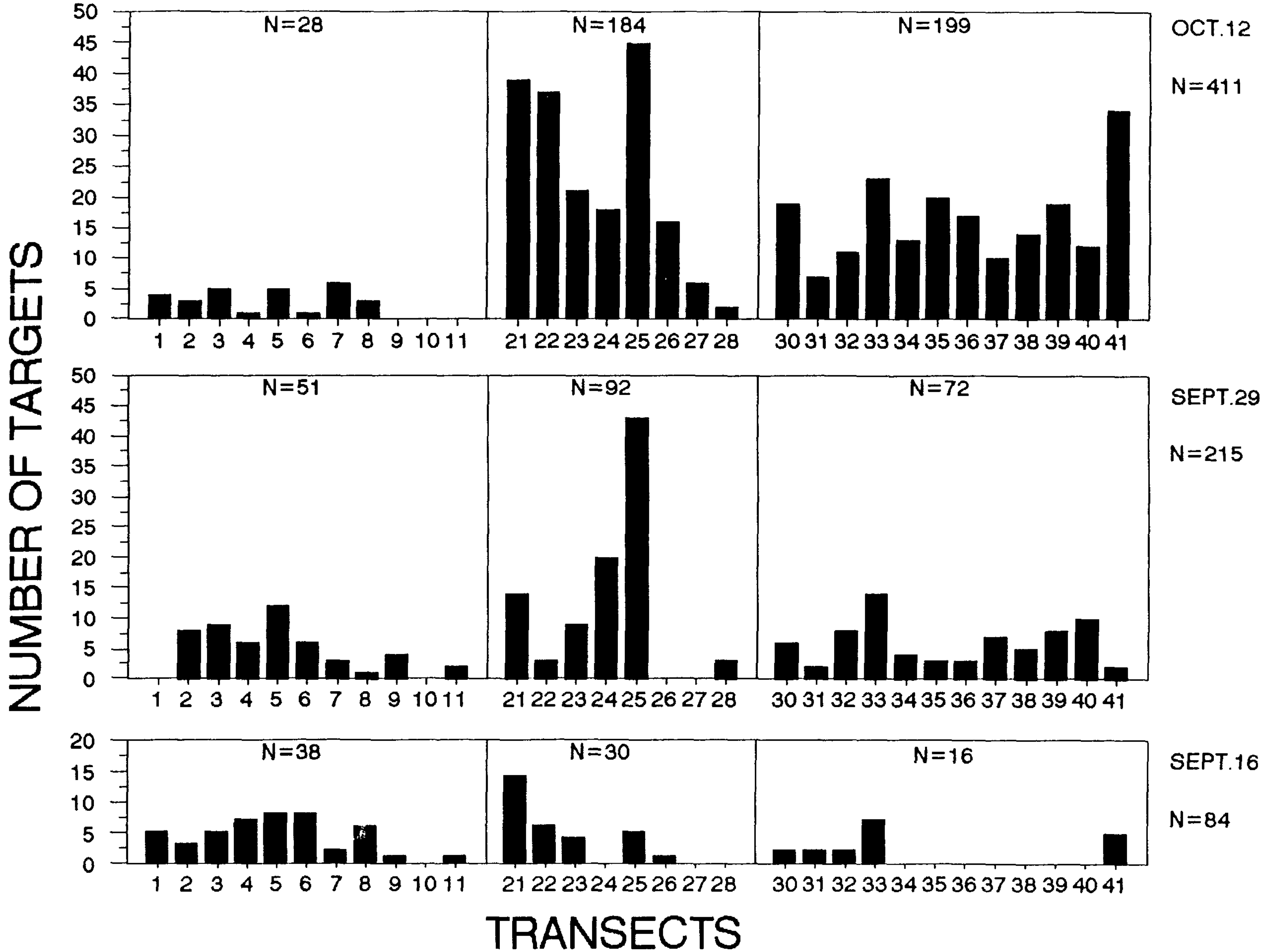


Fig. 10. Echogram target counts for transects at Arctic Red River on 16 September, 30 September and 12 October 1981.

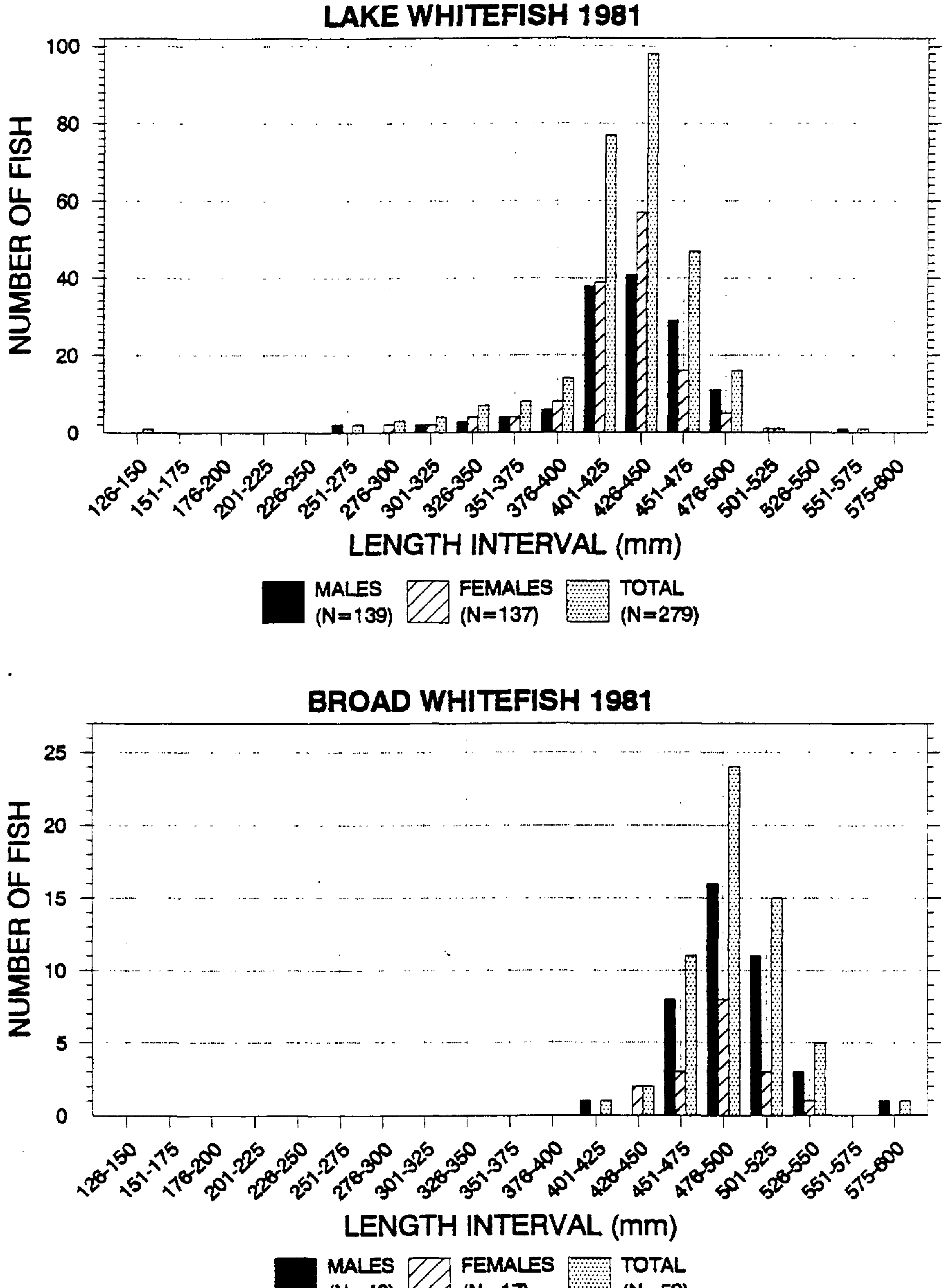


Fig. 11. Length-frequency distribution for broad whitefish and lake whitefish taken in survey gillnets, September-October, 1981.

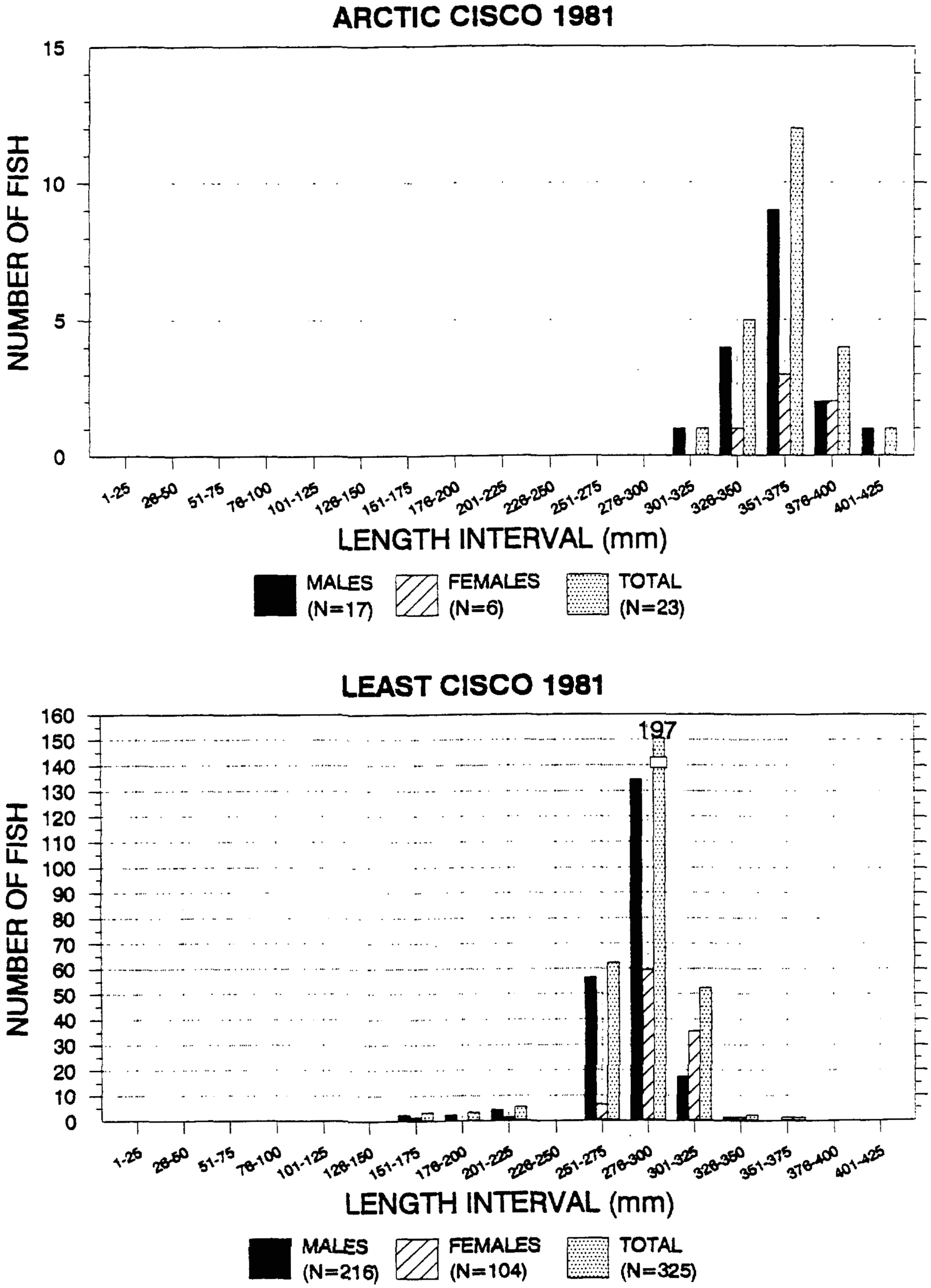
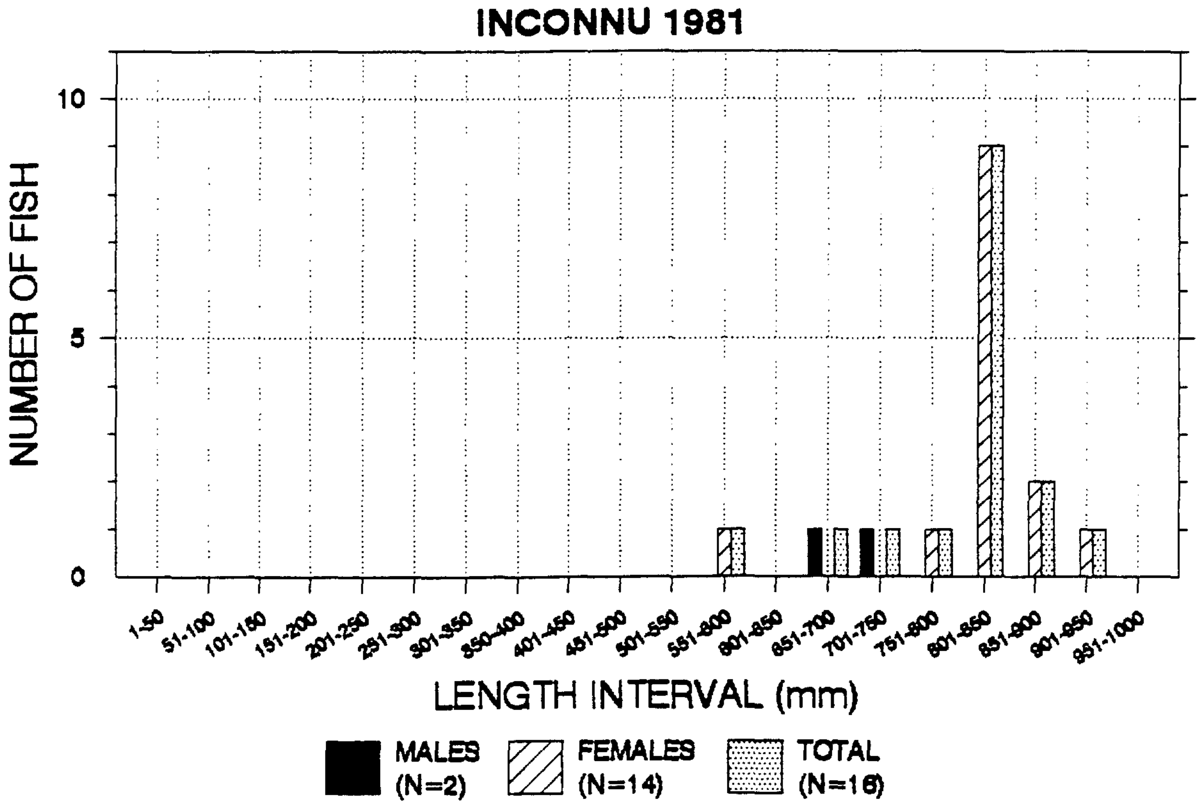


Fig. 12. Length-frequency distribution for least cisco and Arctic cisco taken in survey gillnets, September-October, 1981.



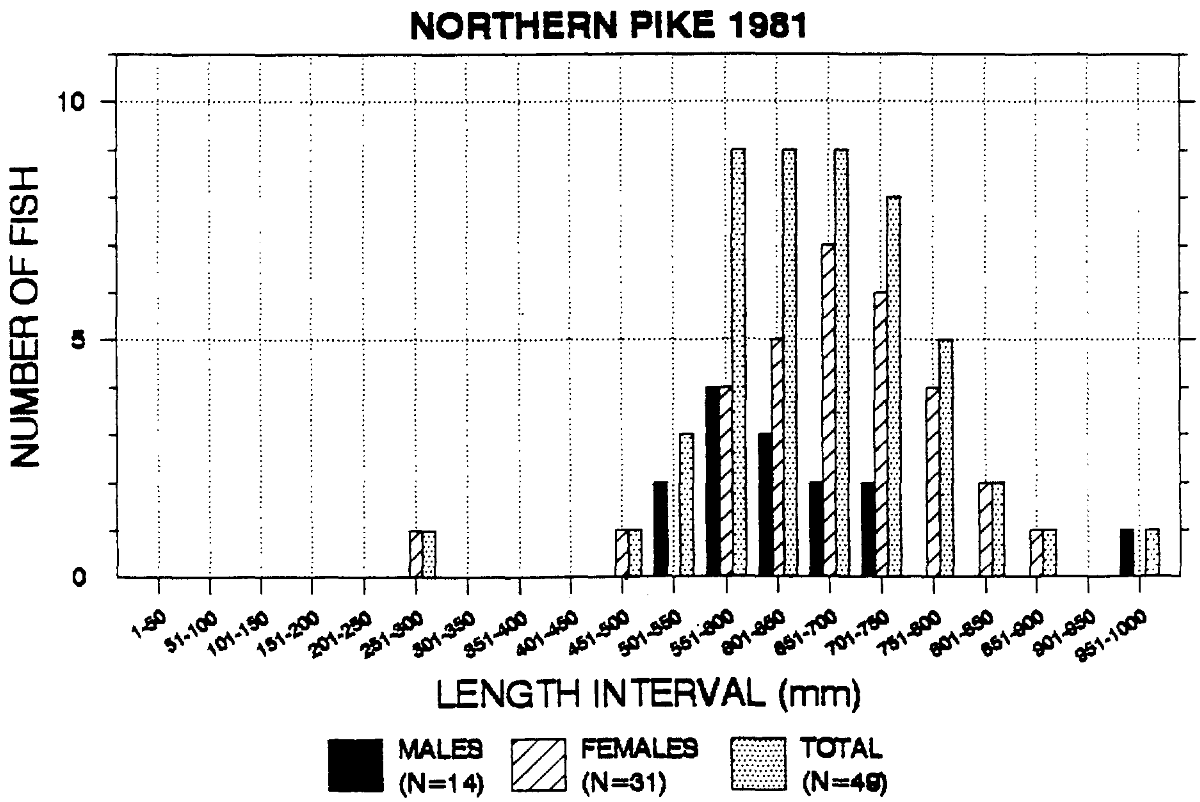


Fig. 13. Length-frequency distribution for inconnu and northern pike taken in survey gillnets, September-October, 1981.

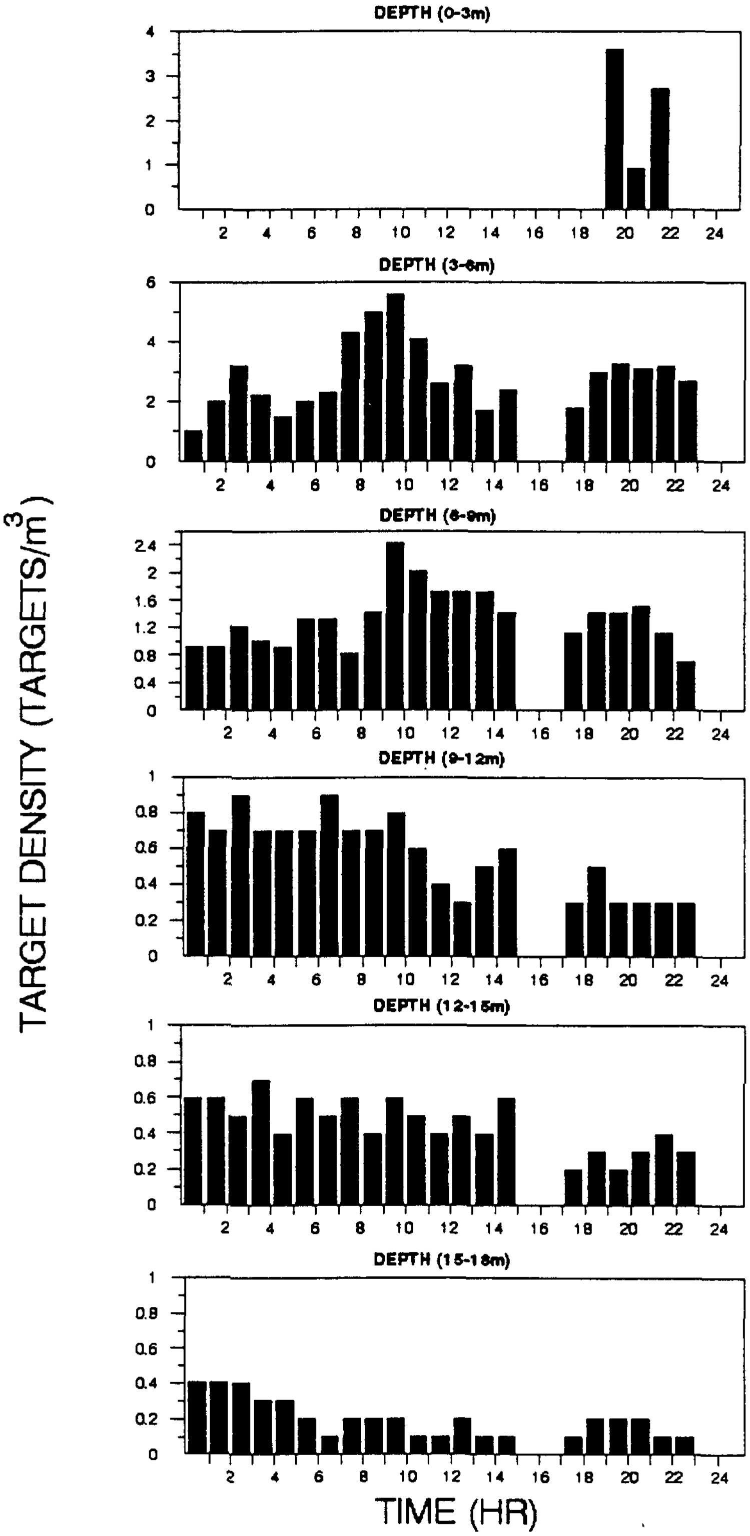


Fig. 14. Target density per hour during 24-hour stationary echo sounding at Horseshoe Bend (location HB 002) on 12 September 1981.

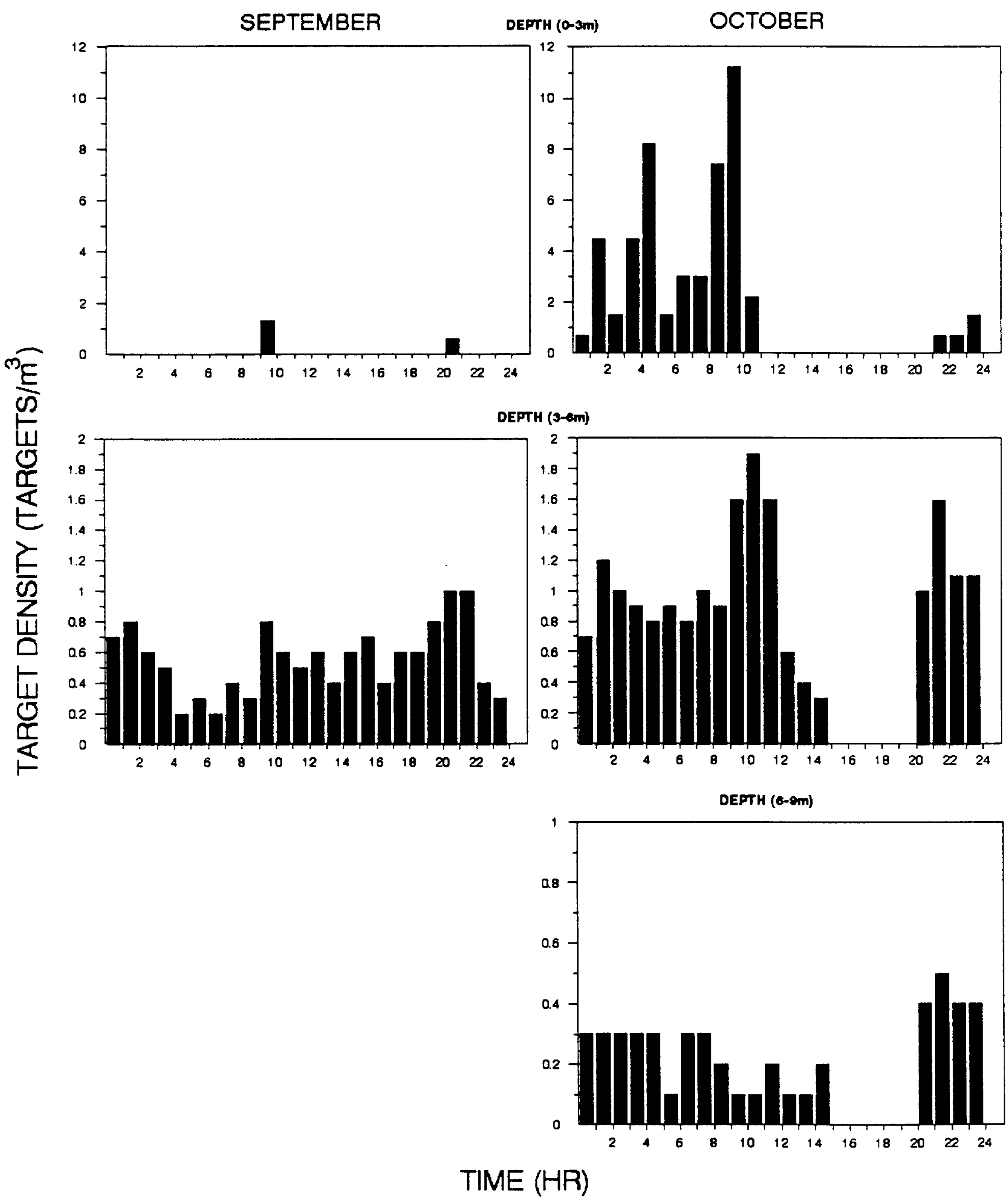


Fig. 15. Target density per hour during 24-hour stationary echo sounding at Arctic Red River (Location AR101, shallow site) on 18 September and 14 October 1981.

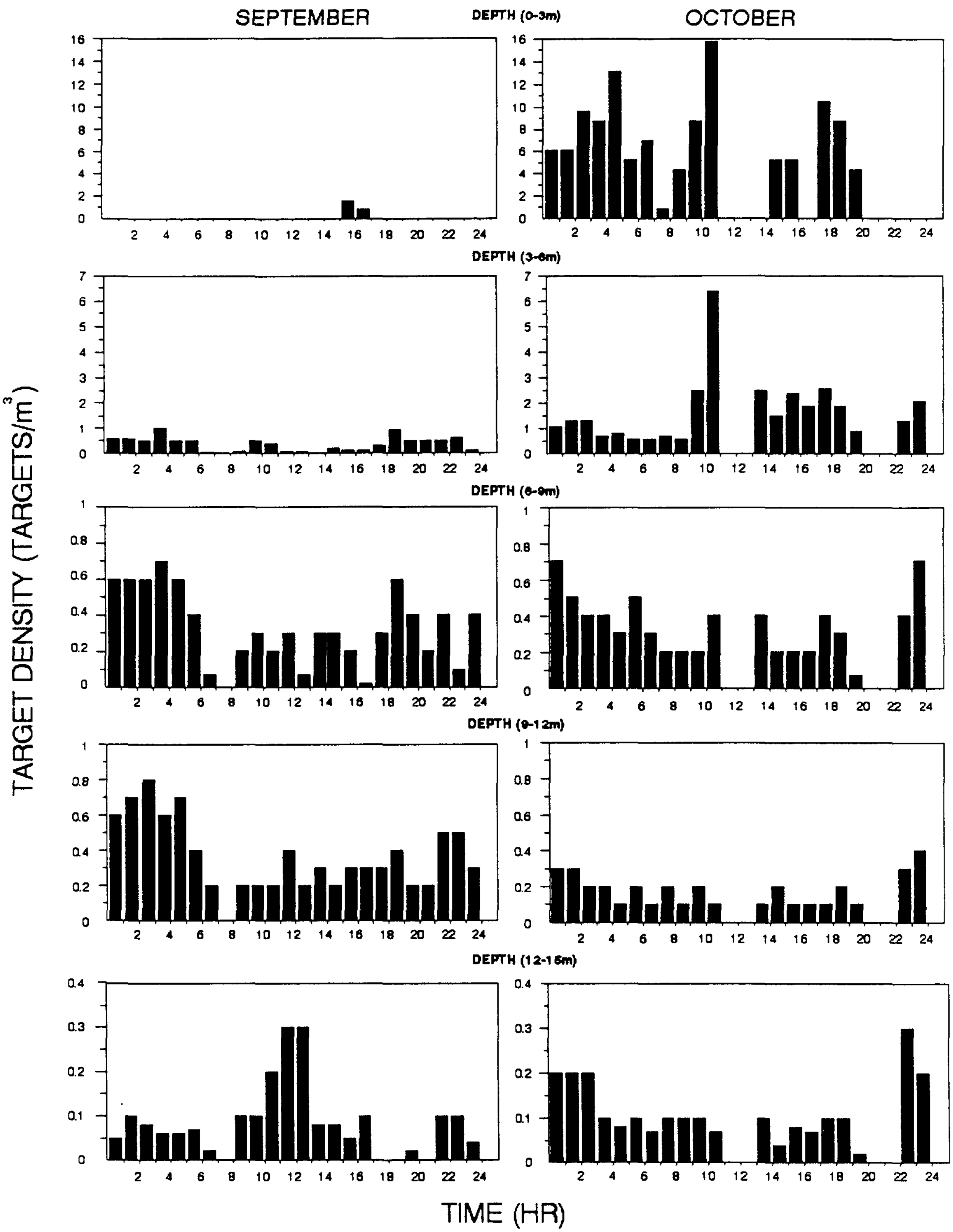


Fig. 16. Target density per hour during 24-hour stationary echo sounding at Arctic Red River (Location AR101, deep site) on 17 September and 13 October 1981.

Table 1. Summary of fishes taken in survey gillnets at sampling sites in the East Channel, Horseshoe Bend and Arctic Red River areas, September - October, 1981.

Area		Species										Total
Site:	**Date**	LKWT	BDWT	LSCS	INCO	ARCS	NRPK	BRBT	LNSK	CHSM	WALL	N
East Channel												
EC 003:	6 Sept.	0	2	7	0	-	4	0	-	-	-	13
	23 Sept.	2	1	1	2	-	2	1	-	-	-	9
Horseshoe Bend												
HB 001:	11 Sept.	7	2	16	-	-	8	0	0	-	-	33
	12 Sept.	6	2	19	-	-	0	1	1	-	-	29
	25 Sept.	21	16	1	-	-	3	0	0	-	-	41
	9 Oct.	11	2	73	-	-	10	0	0	-	-	96
HB 002:	13 Sept.	47	3	0	-	-	-	-	0	-	-	50
	25 Sept.	10	0	2	-	-	-	-	1	-	-	13
HB 003:	25 Sept.	26	5	5	-	0	0	0	1	0	-	37
	9 Oct.	1	2	26	-	2	13	1	0	1	-	46
Arctic Red River												
AR 100:	17 Sept.	11	1	6	0	0	0	0	1	-	-	19
	1 Oct.	13	0	0	6	0	4	0	0	-	-	23
	13 Oct.	24	0	21	0	2	0	3	0	-	-	50
AR 101:	17 Sept.	10	4	1	0	0	-	0	0	-	0	15
	18 Sept.	5	2	0	1	0	-	1	0	-	0	9
	30 Sept.	2	0	2	6	0	-	0	1	-	0	11
	13 Oct.	9	12	63	1	19	-	0	0	-	1	105
AR 102:	18 Sept.	2	0	7	-	-	0	0	2	-	-	11
	19 Sept.	4	5	10	-	-	2	1	0	-	-	22
	30 Sept.	19	0	0	-	-	3	0	1	-	-	23
AR 103:	13 Oct.	49	-	65	-	-	-	-	-	-	-	114
TOTAL		279	59	325	16	23	49	8	8	1	1	769
(%)		(36.3)	(7.7)	(42.3)	(2.1)	(3.0)	(6.4)	(1.0)	(1.0)	(0.1)	(0.1)	(100)

Abbreviations and fish species list :

LKWT:	lake whitefish	*Coregonus clupeaformis* (Mitchell, 1818)
BDWT:	broad whitefish	*Coregonus nasus* (Pallas, 1776)
LSCS:	least cisco	*Coregonus sardinella* Valenciennes, 1848
INCO:	inconnu	*Stenodus leucichthys* (Güldenstadt, 1772)
ARCS:	Arctic cisco	*Coregonus autumnalis* (Pallas, 1776)
NRPK:	northern pike	*Esox lucius* Linnaeus, 1758
LNSK:	longnose sucker	*Catostomus catostomus* (Forster, 1773)
BRBT:	burbot	*Lota lota* (Linnaeus, 1758)
WALL:	walleye	*Stizostedion vitreum* (Mitchill, 1818)
CHSM:	chum salmon	*Oncorhynchus keta* (Walbaum, 1792)

Common and scientific names from Robins et al. (1991).

Table A1.1. Summary of length, weight, age and maturity data for fishes taken in survey gillnets at location EC 003 in 1981.

EC 003, 6 September 1981

Species	Number	Fish Data			
		$\bar{x}$ Length (Range) mm	$\bar{x}$ Weight (Range) g	$\bar{x}$ Age (Range) yr	% Mature
Lake whitefish	0	-	-	-	-
Broad whitefish	2	483 (476-490)	2000 (1950-2050)	10	100
Least cisco	7	208 (155-285)	93 (50-200)	5.4 (3-8)	86
Inconnu	0	-	-	-	-
Northern pike	4	679 (575-980)	3300 (1500-8500)	(8-14)	75
Burbot	0	-	-	-	-
All Species	13				

EC 003, 23 September 1981

Species	Number	Fish Data			
		$\bar{x}$ Length (Range) mm	$\bar{x}$ Weight (Range) g	$\bar{x}$ Age (Range) yr	% Mature
Lake whitefish	2	- (145-365)	- (15-650)	- (2-9)	0
Broad whitefish	1	420	950	6	0
Least cisco	1	273	195	6	100
Inconnu	2	617 (563-670)	2175 (1550-2800)	8.5 (8-9)	0
Northern pike	2	601 (572-630)	1500 (1300-1700)	9.0 (8-10)	50
Burbot	1	670	1700	10	100
All Species	9				

Table A1.2. Summary of length, weight, age and maturity data for fishes taken in survey gillnets at location HB 001 in 1981.

HB 001 11 September 1981

Species	Number	Fish Data			
		x̄ Length (Range) mm	x̄ Weight (Range) g	x̄ Age (Range) yr	% Mature
Lake whitefish	7	435 (423 - 460)	1193 (1050-1350)	12.7 (11-14)	100
Broad whitefish	2	475 (465 - 485)	1625 (1400-1850)	8.0 (7-9)	100
Least cisco	16	282 (175 - 315)	235 (35-300)	6.9 (2-9)	93
Northern pike	8	612 (530 - 820)	1838 (1050-3800)	10.0 (7-13)	88
All species	33				

HB 001 12 September 1981

Species	Number	Fish Data			
		x̄ Length (Range) mm	x̄ Weight (Range) g	x̄ Age (Range) yr	% Mature
Lake whitefish	6	430 (415-450)	1175 (950-1450)	12.2 (10-14)	100
Broad whitefish	2	503 (490-515)	2150 (2000-2300)	8.5 (8-9)	50
Least cisco	19	296 (266-325)	267 (175-335)	7.7 (5-10)	100
Northern pike	0	-	-	-	-
Burbot	1	775	2450	14	100
Longnose sucker	1	525	1700	-	-
All species	29				

HB 001 25 September 1981

Species	Number	Fish Data			
		x̄ Length (Range) mm	x̄ Weight (Range) g	x̄ Age (Range) yr	% Mature
Lake whitefish	21	429 (295-555)	1138 (300-2400)	11.8 (7-19)	81
Broad whitefish	16	498 (452-550)	1997 (1250-3150)	9.3 (6-13)	100
Least cisco	1	295	230	8	100
Northern pike	3	679 (658-698)	2550 (2150-3000)	16.0 (12-19)	100
All species	41				

HB 001 9 October 1981

Species	Number	Fish Data			
		x̄ Length (Range) mm	x̄ Weight (Range) g	x̄ Age (Range) yr	% Mature
Lake whitefish	11	425 (365-460)	1127 (700-1650)	12.0 (8-14)	100
Broad whitefish	2	500 (490-510)	2350 (1950-2750)	8.5 (8-9)	100
Least cisco	73	289 (225-342)	248 (80-430)	7.6 (5-11)	100
Northern pike	10	684 (600-785)	2825 (1950-3900)	13.0 (11-16)	90
All species	96				

Table A1.3. Summary of length, weight, age and maturity data for fishes taken in survey gillnets at location HB 002 in 1981.

HB 002 13 September 1981

Species	Number	Fish Data			
		$\bar{x}$ Length (Range) mm	$\bar{x}$ Weight (Range) g	$\bar{x}$ Age (Range) yr	% Mature
Lake whitefish	47	420 (260 - 485)	1172 (215-2000)	10.7 (3-13)	87
Broad whitefish	3	495 (480 - 525)	1967 (1750-2400)	8.5 (7-10)	100
Least cisco	0	-			-
Longnose sucker	0	-			
All species	50				

HB 002 25 September 1981

Species	Number	Fish Data			
		$\bar{x}$ Length (Range) mm	$\bar{x}$ Weight (Range) g	$\bar{x}$ Age (Range) yr	% Mature
Lake whitefish	10	417 (282-455)	1130 (300-1400)	10.0 (2-14)	90
Broad whitefish	0	-	-	-	-
Least cisco	2	299 (287-310)	280 (235-325)	8.5 (8-9)	100
Longnose sucker	1	450	1050	-	-
All species	13				

Table A1.4. Summary of length, weight, age and maturity data for fishes taken in survey gillnets at location HB 003 in 1981.

HB 003 25 September 1981

Species	Number	Fish Data			
		$\bar{x}$ Length (Range) mm	$\bar{x}$ Weight (Range) g	$\bar{x}$ Age (Range) yr	% Mature
Lake whitefish	26	422 (336-510)	1140 (500-2100)	10.2 (4-14)	73
Broad whitefish	5	496 (443-520)	1910 (1150-2250)	8.8 (5-12)	60
Least cisco	5	286 (273-300)	236 (190-280)	7.2 (6-9)	100
Arctic cisco	0	-	-	-	-
Northern pike	0	-	-	-	-
Burbot	0	-	-	-	-
Longnose sucker	1	445	1100	-	-
Chum salmon	0	-	-	-	-
All species	37				

HB 003 9 October 1981

Species	Number	Fish Data			
		$\bar{x}$ Length (Range) mm	$\bar{x}$ Weight (Range) g	$\bar{x}$ Age (Range) yr	% Mature
Lake whitefish	1	450	1600	9	100
Broad whitefish	2	510 (490-530)	2050 (1700-2400)	11.0 (10-12)	100
Least cisco	26	288 (253-355)	242 (150-550)	7.8 (6-11)	100
Arctic cisco	2	393 (390-395)	550 (450-650)	9.5 (9-10)	100
Northern pike	13	664 (550-755)	2739 (1350-3750)	11.9 (4-14)	100
Burbot	1	890	4600	-	100
Chum salmon	1	590	2600	4	100
All species	46				

Table A1.5. Summary of length, weight, age and maturity data for fishes taken in survey gillnets at location AR 100 in 1981.

AR 100 17 September 1981

Species	Number	Fish Data			
		x̄ Length (Range) mm	x̄ Weight (Range) g	x̄ Age (Range) yr	% Mature
Lake whitefish	11	431 (403-465)	1232 (900-1700)	13.0 (11-15)	100
Broad whitefish	1	475	1800	10	100
Least cisco	6	274 (253-290)	204 (150-250)	4.7 (5-7)	100
Arctic cisco	0	-	-	-	-
Inconnu	0	-	-	-	-
Northern pike	0	-	-	-	-
Burbot	0	-	-	-	-
Longnose sucker	1	385	600	-	-
All species	19				

AR 100 1 October 1981

Species	Number	Fish Data			
		x̄ Length (Range) mm	x̄ Weight (Range) g	x̄ Age (Range) yr	% Mature
Lake whitefish	13	445 (402 - 483)	1300 (1000-1950)	13.3 (10-15)	100
Broad whitefish	0	-	-	-	-
Least cisco	0	-	-	-	-
Arctic cisco	0	-	-	-	-
Inconnu	6	812 (752 - 840)	5092 (3600-5750)	13.2 (11-15)	100
Northern pike	4	682 (460 - 845)	2700 (700-4250)	10.8 (6-15)	75
Burbot	0	-	-	-	-
Longnose sucker	0	-	-	-	-
All species	23				

AR 100 13 October 1981

Species	Number	Fish Data			
		x̄ Length (Range) mm	x̄ Weight (Range) g	x̄ Age (Range) yr	% Mature
Lake whitefish	24	430 (388-463)	1265 (850-1750)	12.5 (9-17)	100
Broad whitefish	0	-	-	-	-
Least cisco	21	290 (266-323)	233 (170-430)	8.2 (6-10)	100
Arctic cisco	2	365 (355-375)	550 (450-650)	9*	100
Inconnu	0	-	-	-	-
Northern pike	0	-	-	-	-
Burbot	3	806 (775-850)	3717 (3100-4500)	11.5 (10-13)	100
Longnose sucker	0	-	-	-	-
All species	50				

* = Age of 1 fish (FL = 375 mm)

Table A1.6. Summary of length, weight, age and maturity data for fishes taken in survey gillnets at location AR 101 in 1981.

AR 101 17 September 1981

Species	Number	Fish Data			
		x̄ Length (Range) mm	x̄ Weight (Range) g	x̄ Age (Range) yr	% Mature
Lake whitefish	10	430 (361 - 450)	1155 (600-1450)	13.1 (8-17)	100
Broad whitefish	4	505 (500 - 510)	2038 (1850-2150)	8.3 (8-9)	100
Least cisco	1	320	320	-	100
All species	15				

AR 101 18 September 1981

Species	Number	Fish Data			
		x̄ Length (Range) mm	x̄ Weight (Range) g	x̄ Age (Range) yr	% Mature
Lake whitefish	5	435 (423-450)	1250 (1100-1450)	11.8 (10-14)	100
Broad whitefish	2	502 (474-530)	2250 (1800-2700)	11.5 (10-13)	100
Least cisco	0	-	-	-	-
Arctic cisco	0	-	-	-	-
Inconnu	1	862	5600	16	100
Burbot	1	775	2800	9	100
All species	9				

AR 101 30 September 1981

Species	Number	Fish Data			
		x̄ Length (Range) mm	x̄ Weight (Range) g	x̄ Age (Range) yr	% Mature
Lake whitefish	2	458 (425-490)	1300 (1050-1550)	-	100
Broad whitefish	0	-	-	-	-
Least cisco	2	303 (300-305)	263 (260-265)	9.5 (9-10)	100
Arctic cisco	0	-	-	-	-
Inconnu	6	850 (815-920)	5725 (4700-7000)	14.0 (12-16)	100
Burbot	0	-	-	-	-
Longnose sucker	1	417	850	-	-
All species	11				

AR 101 13 October 1981

Species	Number	Fish Data			
		x̄ Length (Range) mm	x̄ Weight (Range) g	x̄ Age (Range) yr	% Mature
Lake whitefish	9	354 (283-450)	593 (290-1350)	9.3 (6-13)	22
Broad whitefish	12	498 (450-600)	2046 (1400-4000)	9.6 (8-12)	100
Least cisco	63	290 (256-325)	237 (145-380)	8.0 (6-10)	100
Arctic cisco	19	362 (323-415)	474 (350-650)	7.7 (6-12)	95
Inconnu	1	735	3500	11	100
Burbot	0	-	-	-	-
Longnose sucker	0	-	-	-	-
Yellow walleye	1	360	550	11	100
All species	105				

Table A1.7. Summary of length, weight, age and maturity data for fishes taken in survey gillnets at location AR 102 in 1981.

AR 102 18 September 1981

Species	Number	Fish Data			
		$\bar{x}$ Length (Range) mm	$\bar{x}$ Weight (Range) g	$\bar{x}$ Age (Range) yr	% Mature
Lake whitefish	2	473 (465-480)	1625 (1550-1700)	14 (13-15)	100
Broad whitefish	0	-	-	-	-
Least cisco	7	256 (198-305)	159 (50-250)	6.4 (4-9)	100
Northern pike	0	-	-	-	-
Burbot	0	-	-	-	-
Longnose sucker	2	479 (470-488)	1350 (1200-1500)	-	-
All species	11				

AR 102 19 September 1981

Species	Number	Fish Data			
		$\bar{x}$ Length (Range) mm	$\bar{x}$ Weight (Range) g	$\bar{x}$ Age (Range) yr	% Mature
Lake whitefish	4	438 (415-475)	1350 (1100-1800)	11.3 (9-15)	100
Broad whitefish	5	486 (465-500)	1900 (1600-2250)	9.0 (7-10)	100
Least cisco	10	282 (253-300)	211 (130-270)	7.5 (6-10)	100
Northern pike	2	- (268-800)	- (140-2550)	- (4-16)	-
Burbot	1	692	1600	9	100
Longnose sucker	0	-	-	-	-
All species	22				

AR 102 30 September 1981

Species	Number	Fish Data			
		$\bar{x}$ Length (Range) mm	$\bar{x}$ Weight (Range) g	$\bar{x}$ Age (Range) yr	% Mature
Lake whitefish	19	447 (403-490)	1340 (800-2000)	12.0 (10-14)	100
Broad whitefish	0	-	-	-	-
Least cisco	0	-	-	-	-
Northern pike	3	807 (750-900)	4433 (3500-5900)	15.0 (12-17)	100
Burbot	0	-	-	-	-
Longnose sucker	1	490	1500	-	-
All species	23				

Table A1.8. Summary of length, weight, age and maturity data for fishes taken in survey gillnets at location AR 103 in 1981.

AR 103 13 October 1981

Species	Number	Fish Data			
		$\bar{x}$ Length (Range) mm	$\bar{x}$ Weight (Range) g	$\bar{x}$ Age (Range) yr	% Mature
Lake whitefish	49	440 (390-490)	1358 (750-2500)	12.0 (7-16)	100
Least cisco	65	286 (254-335)	227 (140-430)	7.7 (6-10)	100
All species	114				