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A revision of coregonine fish distribution and abundance in eastern James-Hudson Bay[1]

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Synopsis

Recent sampling programs conducted in the estuaries of the Eastmain and La Grande rivers (James Bay) and the Great Whale, Little Whale, Innuksuac and Povungnituk rivers (Hudson Bay) revealed patterns of coregonine fish distribution that differ from previous observations. The relative abundance of cisco, *Coregonus artedii*, and lake whitefish, *C. clupeaformis*, varied among rivers but did not reveal a latitudinal cline. Previous sampling programs underestimated the abundance of cisco in the Little Whale River. In addition, cisco was the third most abundant species captured in the Povungnituk River, situated 200 km to the north of the previously proposed northern limit at Innuksuac River. As such, the low abundances of cisco in the Great Whale and Innuksuac rivers cannot be attributed to a physiological inability to cope with a reduced growing season. Immature cisco were almost totally absent from the estuaries of the Hudson Bay rivers following spring breakup whereas immature lake whitefish made up 100% of the catch in the Innuksuac River at the same time of year. Species-specific migration patterns in Hudson Bay that differ from those observed in James Bay and the existence of unique juvenile overwintering rivers are 2 hypotheses proposed to explain the discontinuous age-class distribution of cisco and lake whitefish observed in Hudson Bay.

Introduction

The estuarine and coastal fish communities of eastern James-Hudson Bay are dominated by Salmonidae, Catostomidae and Cottidae (Morin et al. 1980, Morin & Dodson 1986). The number of marine fish species increases northward from James to Hudson Bay whereas the number of freshwater species declines. Along the same gradient, freshwater assemblages are characterized by an increasing proportion of euryhaline, diadromous species that migrate into brackish water seasonally, daily or periodically to feed (reviewed by Morin & Dodson 1986).

A major faunal component of the majority of the estuarine and coastal communities of this area is represented by 2 anadromous coregonines, the cisco, *Coregonus artedii,* and the lake whitefish, *C. clupeaformis*. The relative abundance of these 2 species varies according to latitude with cisco dominant in the Eastmain and La Grande estuaries (Fig. 1) and lake whitefish dominant in Hudson Bay estuaries. Cisco apparently approach their northern limit in the Innuksuac River (Morin et al. 1980). These observations in combination with latitudinal variations in life history parameters (Morin et al. 1982) led to the hypothesis that the reduction in cisco's abundance, growth and age-specific

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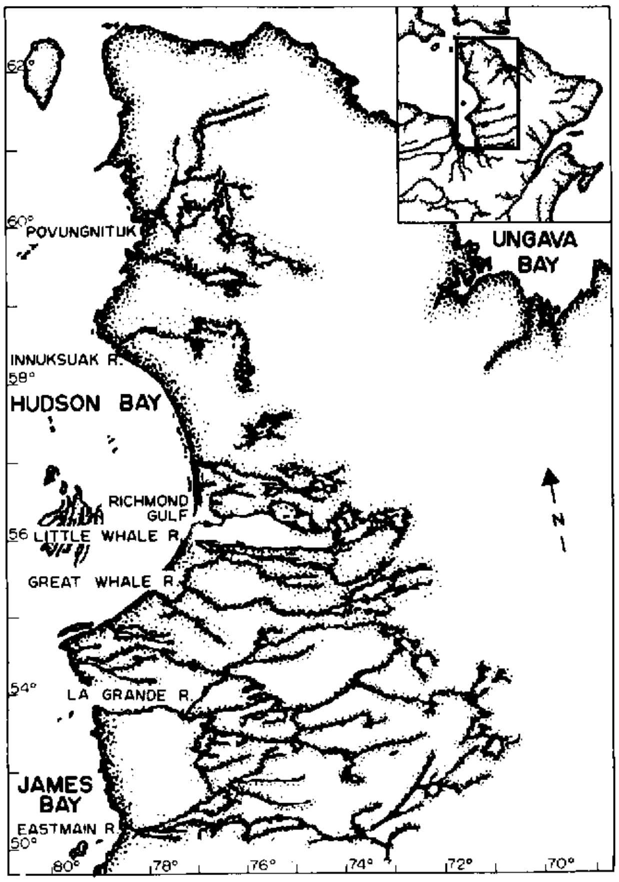

Fig. 1. James and Hudson Bay. The rivers and estuaries sampled on the east coast were the Eastmain River, La Grande River, Little Whale River, Great Whale River, Innuksuac and Povungnituk River.

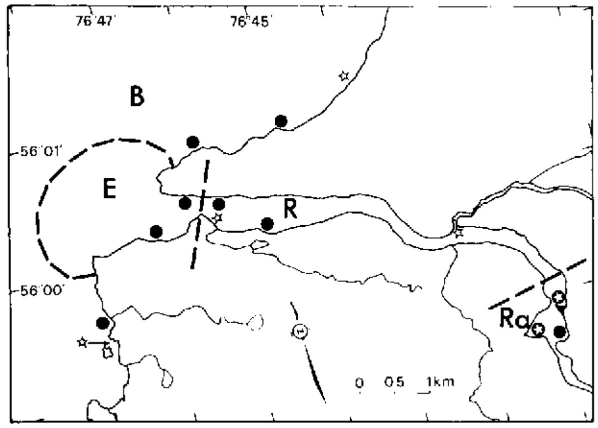

Fig. 2. Map of Little Whale River showing boundaries of sampling zones. Rapids = Ra; River = R; Estuary = E and Bay = B. Localisation of gill-net sampling stations are also indicated; this study (●); Auger & Power (1978) (☆), sampling stations common to both studies (◉).

reproductive maturation rates in Hudson Bay represent a physiological response to a decreasing energy budget. In contrast, the observation that lake whitefish maintain abundance and age-specific maturation rates in Hudson Bay while reducing fecundity independent of variations in growth constitute limited evidence for an adaptive strategy.

Recent sampling programs conducted by the present authors in the estuaries of the Eastmain and La Grande rivers (James Bay) and the Great Whale, Little Whale, Innuksuac and Povungnituk rivers (Hudson Bay: Fig. 1) have revealed patterns of coregonine distribution and relative abundance that differ from previous observations and cast doubt on the existence of a latitudinal cline in the relative abundances of cisco and lake whitefish. The purpose of this paper is to revise our description of the geographic distribution of the Coregoninae in Eastern James-Hudson Bay and to identify variables related to the sampling programs and the migration patterns of the species that are most likely responsible for producing the contradictory observations.

Material and methods

The data presented here were obtained from 2 independent studies conducted between 1985 and 1987. The first study concerned the migration and reproductive patterns of sympatric populations of anadromous cisco and lake whitefish sampled in the Little Whale River (Fig. 2, Table 1) in 1985 and 1986. Fish were sampled in 4 physically distinct zones of the river (Ingram 1979). The rapids zone was located immediately below the first waterfalls and represents the major salmonid spawning area in the lower part of the river. The river zone extends 6 km between the rapids and the estuary. The estuarine zone extends another 2 km where salinity fluctuates between 0 and 20 g kg^{-1}. The bay zone represents the open waters of Hudson Bay where salinity remained constant at about 24 g kg^{-1}.

Sampling was conducted with 2 types of multifilament experimental gill nets and a trap net. The experimental gill nets most commonly used were 45 m long and 2.4 m high composed of 6 panels of 25, 37, 50, 62, 75 and 100 mm mesh size (stretched measure). Other gill nets were composed of three 15–m panels of 50, 62 and 75 mm mesh size. Dimensions of the trap net house were 2.4 × 2.4 × 7.2 m. The leader measured 60 m in length and 2.4 m in depth.

Table 2 presents the gear used at different times and at different stations (Fig. 2). Sampling effort was not constant in the different zones for each month because the sampling program was designed according to the migratory movements of cisco and lake whitefish. As data from all fishing gear could not be standardized, catch per unit effort (CPUE) and relative abundance were calculated using only the data obtained with the 6 panel experimental gill nets. CPUE corresponds to the number of fish captured by one gill net during 24 h of fishing. CPUE and the relative abundance for each species were calculated for each month and zone as well as for pooled samples. Fork length, sex and maturity stage according to Nikolsky (Lagler 1978) were noted for cisco and lake whitefish. Although only data concerning the Salmonidae are presented here, relative abundances were calculated relative to the total catch of fish. Thousands of capelin, *Mallotus villosus*, caught in the bay on one night in July 1985 were omitted from the calculations of relative abundance.

A second more extensive sampling program, conducted to obtain tissue samples for genetic and physiological studies of northern coregonine populations, was conducted at the mouths of the Eastmain and La Grande rivers from May 26 to 31, 1987 and at the mouths of the Great Whale, Innuksuac and Povungnituk rivers from June 25 to 30, 1987 (Fig. 1). All sampling was conducted immediately following spring breakup at the rivers' mouths.

Table 1. The major physical characteristics of the rivers studied. Growing season refers to the number of degree-days > 5.0° C; they are taken from Environment Canada (1982). Drainage area and mean annual flow are taken from Société d'Energie de la Baie James (1978) and Hydro-Québec (G. Drouin and A. Lacroix pers. comm.). Data in parentheses represent conditions that existed in the Eastmain R. prior to diversion and in the La Grande R. prior to flow regulation completed in 1982. Mean breakup date is taken from Wilson (1971).

River	Latitude	Growing season	Drainage area (1000 km^2)	Mean annual flow (m^3 s^{-1})	Mean date of breakup
Eastmain	52° 15′	886	28.9 (46.4)	121 (603)	May 10
La Grande	53° 50′	680	151.4 (97.6)	3105 (1700)	May 20
Great Whale	55° 17′	548	42.1	672	May 20
Little Whale	56° 00′	548	15.0	212	June 1
Innuksuac	58° 26′	340	10.3	102	June 20
Povungnituk	60′ 01°	200	28.5	399	June 25

Table 2. Sampling conducted in the Little Whale R., 1985 and 1986. Rapids = Ra, River = R, Estuary = E, Bay = B.

Date	Zone sampled	Exp. gill net (6 panel)		Exp. gill net (3 panel)		Trapnet	
		Nets	effort (h)	Nets	effort (h)	Nets	effort (h)
July '85 (19 to 25)	R, E, B	3	325				
September '85 (23 to 30)	Ra, R	3	307	2	279		
June '86 (2 to 9)	E	3	325				
August '86 (25 to 31)	Ra, R, E	5	347			1	95
October '86 (6 to 12)	Ra	4	622	2	45	1	126

Physical descriptions of these rivers are presented in Table 1.

Fish were sampled with 45 m multifilament gill nets composed of four 11.25 m panels of 50, 62, 75 and 87 mm mesh size (stretched measure). In addition, 6 panel experimental gill nets, as previously described, were used in the Great Whale River. CPUE was not calculated, as catch data could not be standardized among sampling localities. Only the relative abundances of salmonid species are presented, although they were calculated relative to total fish catch. Fork length, sex and maturity stage were noted for cisco and lake whitefish.

Results

Little Whale River

A total of 17 species representing 8 families were caught in the Little Whale River. Salmonidae was the most abundant family with 7 species and a relative abundance of 76.5%. Mean CPUE was 14.9 fish per net set.

Considerable variability in CPUE and relative abundance was observed among sampling zones and dates (Tables 3, 4). In the rapids zone, mean salmonid CPUE was low compared to all other sampling zones. Catches were dominated by round whitefish, *Prosopium cylindraceum*, and brook charr, *Salvelinus fontinalis*, followed by lake whitefish. For all sampling periods, the relative abundance of cisco was low (Table 4). The river zone was characterized by dramatic shifts in CPUE which declined from a high of 66.1 in July to a low of 8.4 in August (Table 3). The zone was dominated by brook charr with few coregonines (Table 4). In contrast, cisco dominated catches in the estuary and bay for all sampling periods with the exception of August when brook charr was the most abundant species in the estuary (Table 4).

Examination of the length class frequency distri-

Table 3. Catch per unit effort (CPUE) in Little Whale R., 1985 and 1986, by month and sampling zone. Not sampled = n.s.

Month	Rapids	River	Estuary	Bay	Mean per month
June	n.s.	n.s.	21.9	n.s.	21.9
July	n.s.	66.1	32.4	15.3	29.5
August	6.7	8.4	31.2	n.s.	13.3
September	10.6	13.2	n.s.	n.s.	11.3
October	6.4	n.s.	n.s.	n.s.	6.4
Mean per zone	7.3	31.1	25.0	15.3	14.9

Table 4. Relative abundance (%) for Salmonidae captured in Little Whale R., 1985 and 1986, by month and sampling zone.

Species	Rapids			River			Estuary			Bay	L. Whale
	Aug.	Sept.	Oct.	July	Aug.	Sept.	June	July	Aug.	July	mean
Coregonus clupeaformis	23.3	10.0	19.1	8.4	0.0	2.2	18.2	1.1	3.4	3.3	11.2
Coregonus artedii	3.3	5.0	5.6	2.1	0.0	6.8	41.7	69.7	11.1	45.5	23.2
Prosopium cylindraceum	25.0	23.0	35.8	4.2	0.0	4.5	12.1	1.1	6.9	2.5	12.9
Coregonus sp.	1.7	0.0	0.0	3.2	0.0	0.0	0.7	5.6	0.0	2.5	1.4
Salvelinus fontinalis	23.3	33.0	20.4	56.3	40.0	11.7	14.8	3.4	59.8	9.1	27.3
Salvelinus alpinus	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Salvelinus namaycush	1.7	1.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Salmonidae (total)	78.3	73.2	82.1	74.2	40.0	25.2	87.5	80.9	81.2	62.9	76.5

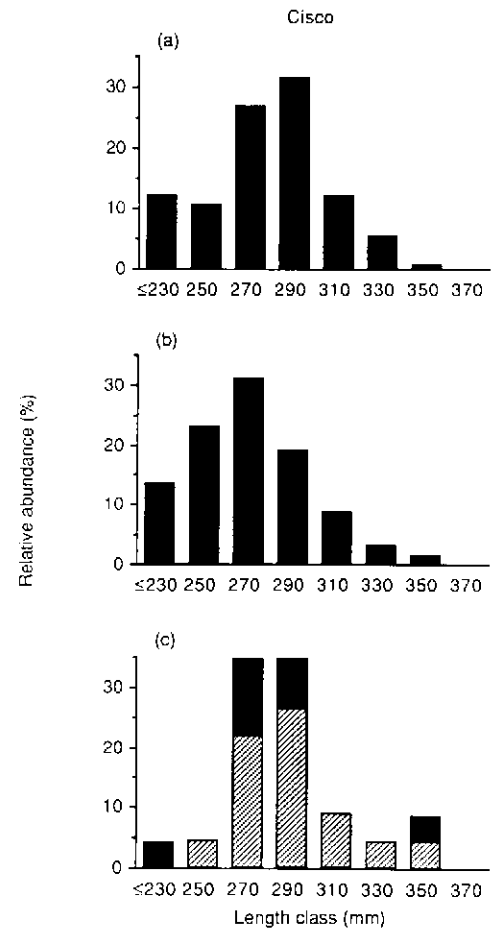

Fig. 3. Length frequency distributions of cisco (length classes of 20 mm indicated by median) for Little Whale R.; (a) estuary, June 1986 (n = 130), (b) salt and brackish water (estuary and bay), July 1985 and August 1986 (n = 125) and (c) freshwater (rapids and river), September 1985 and October 1986 (n = 23). Diagonal lines in histogram (c) indicate the proportion of mature fish by length class.

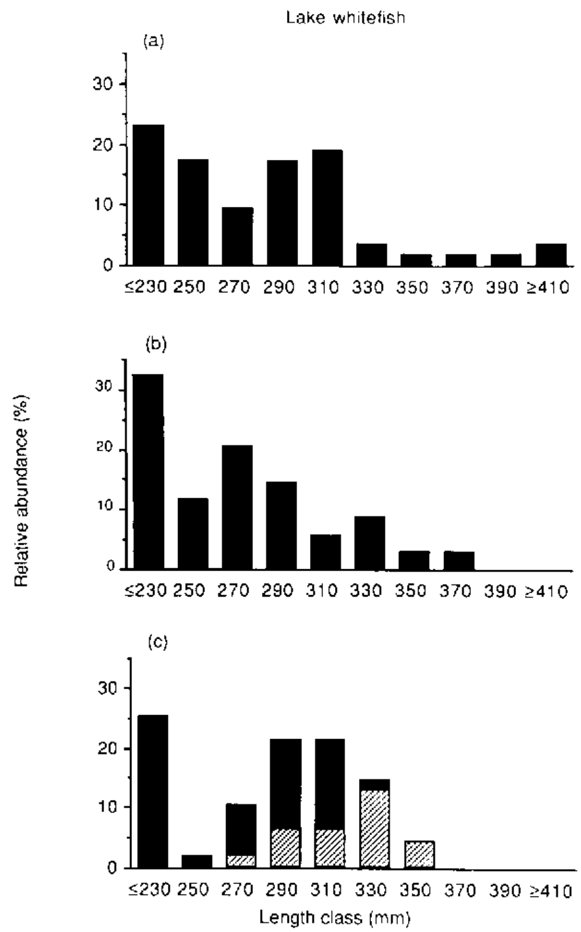

Fig. 4. Length frequency distributions of lake whitefish (length classes of 20 mm indicated by median) for Little Whale R.; (a) estuary, June 1986 (n = 52), (b) freshwater (rapids and river), July 1985 and August 1986 (n = 34) and (c) freshwater, September 1985 and October 1986 (n = 47). Diagonal lines in histogram (c) indicate proportion of mature fish by length class.

butions of cisco revealed that juvenile fish (measuring less than 260 mm) were relatively scarce in the estuary following spring breakup (Fig. 3a) and continued to be so in salt and brackish water throughout the summer months (Fig. 3b). Length at maturity of cisco in the Little Whale River is 260 mm (Kemp, unpublished data). In the fall, 87% of cisco caught in fresh water were adult (≥ 260 mm) of which 73% were in a reproductive state (Fig. 3c). In contrast, small lake whitefish were relatively abundant in spring and summer (40% and 44%, respectively, measured less then 260 mm) (Fig. 4a, b). Although catches of mature lake whitefish in the Little Whale River were too few to estimate length at maturity, no lake whitefish measuring less than 260 mm were observed to be undergoing sexual maturation (Kemp, unpublished data). In the fall, lake whitefish of all ages, size classes and reproductive states were captured in the rapids contrary to cisco (Fig. 4c).

Other rivers

Spring sampling of the Eastmain, La Grande, Great Whale, Innuksuac and Povungnituk rivers revealed that salmonids were the most important family in terms of relative abundance and numbers of species (Table 5). The 3 coregonine species are present in all rivers except the Eastmain River where round whitefish were absent. The relative abundance of cisco and lake whitefish varied among rivers (Table 5) but did not reveal a latitudinal cline. In addition, 42 of 44 cisco sampled at the mouths of the Great Whale, Innuksuac and Povungnituk rivers were adults undergoing sexual maturation for fall spawning. In contrast, catches of lake whitefish in all rivers, with the exception of the Innuksuac River, were composed of both immature and adult fish undergoing sexual maturation. In the Innuksuac River, 101 of 102 lake whitefish captured were sexually immature fish.

Discussion

Present results do not conform to observations recorded by Morin et al. (1980) and Morin & Dodson (1986). The abundance of cisco relative to that of lake whitefish does not decline with increasing latitude. Although apparently less abundant than lake whitefish in the Great Whale, Innuksuac and Povungnituk rivers, cisco are 2.1 times more abundant than lake whitefish in the Little Whale River. In addition, cisco were reported to be the most abundant species in Richmond Gulf located 20 km to the north of the Little Whale River (Boivin & Power 1985). Cisco was the third most abundant salmonid captured in the Povungnituk River situated 200 km to the north of their proposed northern limit at Innuksuac, the northern most sampling station reported by Morin et al. (1980).

The differences in the relative abundances of cisco and lake whitefish in the Little Whale River reported by Morin et al. (1980) (lake whitefish 3.9 times more abundant than cisco) and in the present study (cisco 2.1 times more abundant than lake whitefish) appear mainly due to the different sampling strategies used in the 2 studies. Data presented by Morin et al. (1980) were obtained from a report by Auger & Power (1978) who sampled the rapids, river and bay zones of the Little Whale River in late July and August of 1977 (Fig. 2). Mean relative abundances reported by Auger & Power (1978; Table 6) for cisco (5.2%) and round whitefish (3.2%) are low compared to observations reported here (cisco, 23.2%; round whitefish, 12.9%; Table 4) whereas that of lake whitefish (19.8%) is high compared to our observation (11.2%, Table 3). Such differences appear mainly

Table 5. Number of catches and relative abundance (%) of salmonidae in the Eastmain, La Grande, Great Whale, Innuksuac and Povungnituk rivers, May and June, 1987.

Species	Eastmain		La Grande		Great Whale		Innuksuac		Povungnituk	
	Number	%	Number	%	Number	%	Number	%	Number	%
Coregonus clupeaformis	103	47.0	67	11.1	9	4.9	102	41.6	68	27.0
Coregonus artedii	95	43.4	291	48.1	4	2.2	6	2.4	34	13.5
Prosopium cylindraceum	0	0.0	5	0.8	23	12.5	17	6.9	77	30.6
Salvelinus fontinalis	10	4.6	3	<0.5	20	10.9	65	26.5	20	7.9
Salvelinus alpinus	0	0.0	0	0.0	0	0.0	14	5.7	34	13.5
Salvelinus namaycush	0	0.0	0	0.0	1	0.5	4	1.6	8	3.2
Total Salmonidae	208	95.0	366	60.5	57	31.0	208	84.8	241	95.6
Total (all species)	219	100.0	605	100.0	184	100.0	245	100.0	252	100.0
Total number of species	6		9		10		10		7	
Sampling effort (net hour)	56		63		209		175		36	

due to the fact that Auger & Power (1978) did not sample the estuary zone where cisco is the most abundant species in July and August (Fig. 2; Table 4). However, we observed that lake and round whitefish were more abundant in the rapids and river zones during the same period which is in agreement with the observations of Auger & Power (1978). Thus, apparent contradictions in observations of community structure and relative abundances are largely due to the heterogeneous distribution of cisco and lake whitefish in time and space.

The migratory movements of cisco and lake whitefish are responsible for their heterogeneous spatial and temporal distributions. During the summer months, mature and immature cisco gather in estuarine zones for feeding (Morin et al. 1981). Similar behavior has been reported for *C. autumnalis* and *C. sardinella* in the Beaufort Sea (Craig 1984) and for *C. lavaretus* (L.) in the Gulf of Finland (Ikonen 1982). In the fall, juveniles and non-reproductive adults remain associated with estuaries whereas reproductive fish move upstream to spawning areas generally located below the first waterfalls encountered. All fish overwinter in freshwater (Morin et al. 1981). In the Little Whale River, cisco were caught almost uniquely in the estuary during the summer months. In the fall, 70% of cisco caught in freshwater were in a reproductive state (Fig. 3). However, juvenile cisco were relatively scarce throughout the entire sampling period.

Our observations of lake whitefish in the Little Whale River suggest that juveniles are more closely associated with freshwater than are reproductive adults, as reported by Morin et al. (1981). Similar results were obtained by Auger & Power (1978). As reproductive lake whitefish appear to undertake extensive feeding migrations many kilometers from the estuarine zone (Morin et al. 1981), the low number of reproductive adults caught in the present study is probably due to the fact that sampling did not extend further than 4 km from the river's mouth.

Cisco and lake whitefish of all ages and maturity states aggregate in the estuaries of James Bay waiting for the retreat of the ice pack on the bay in order to migrate to feeding grounds (Morin et al. 1981). This does not appear to be the case in Hudson Bay. The almost total absence of immature cisco from the estuaries of the Hudson Bay rivers may be due to 2 possibilities: (1) they overwinter in different rivers than those used by reproductive adults, or (2) they migrate very early into the bay under the ice pack before reproductive adults leave the estuary. We are at present unable to evaluate the validity of these hypotheses.

Contrary to cisco, immature lake whitefish made up 100% of the catch in the Innuksuac River suggesting that it is used only as an overwintering ground by juveniles. A similar phenomenon has been noted by Gallaway et al. (1983) for the arctic cisco, *C. autumnalis*. Catches of lake whitefish af-

Table 6. Catch per unit effort (CPUE) and relative abundance (%) of Salmonidae in Little Whale R., for July and August 1977. Modified from Auger & Power 1978; data concerning *Mallotus villosus* have been omitted for calculation of total CPUE.

Species	Rapids		River		Bay		Mean %
	CPUE	%	CPUE	%	CPUE	%	
Coregonus clupeaformis	9.1	44.8	2.3	8.1	0.0	0.0	19.8
Coregonus artedii	0.8	3.7	1.5	5.4	0.6	8.2	5.2
Prosopium cylindraceum	1.1	5.5	0.8	2.7	0.0	0.0	3.2
Salvelinus fontinalis	4.3	20.9	15.0	54.0	0.8	10.9	34.8
Salvelinus alpinus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Salvelinus namaycush	0.1	0.6	0.1	0.5	0.0	0.0	0.4
Total Salmonidae	15.4	75.5	19.7	70.7	1.4	19.1	63.4
Total (all species)	20.4	100.0	27.8	100.0	7.4	100.0	100.0

ter spring breakup in all other rivers sampled revealed that both immature and adult fish gather in the estuary as suggested by Morin et al. (1981). As in the case of cisco, hypotheses concerning lake whitefish juvenile overwintering areas remain to be tested.

Relative abundances of coregonines measured shortly after spring breakup are probably most representative as the majority of cisco and lake whitefish aggregate in the estuary waiting for the retreat of the ice pack on the bay in order to migrate to feeding grounds. However, even these may provide biased estimates, particularly if juveniles do not overwinter in the same rivers as adults. Although the relative abundances of coregonine fish observed in the La Grande, Great Whale and Innuksuac rivers resemble those reported by Morin et al. (1980), the observations of Morin et al. (1980) and Lambert (1987) in the Eastmain River suggest that cisco are 3 times more abundant than lake whitefish while present results indicate they are equally abundant. The data of Lambert (1987) summarizes 3 years of exhaustive sampling and thus are the most reliable. Such discrepencies between the observations of different studies clearly illustrate that measures of relative abundances based on spatially and temporally limited sampling may lead to considerable error in evaluating community structure. This is of particular importance in assessing the environmental impact of the diversion of the Eastmain River in 1980 and regulation of the La Grande River for hydroelectric development in the late 1970's. Although tempting to suggest that the differences between present observations at Eastmain River and those of Lambert (1987) are due to the effects of diversion, only extensive sampling in the area will provide an unbiased estimate of community structure and species abundance.

Present results suggest that low abundances of cisco in the Great Whale and Innuksuac rivers cannot be attributed to a physiological inability to cope with a reduced growing season in the north of their range as hypothesized by Morin et al. (1982). The greater abundance of cisco relative to lake whitefish in Little Whale River, their greater absolute abundance in the Povungnituk River and the apparent differential distribution of juvenile and adult cisco and lake whitefish in the rivers of Hudson Bay all suggest that the abundance of these species is not only governed by growing season but by other abiotic (e.g. substrate, river flow) and biotic variables (e.g. migration, competition). Evidence exists to demonstrate the effect of such variables on the abundance, diversity and distribution of estuarine fish communities (McErlean et al. 1973, Oviatt & Nixon 1973, Haedrich & Haedrich 1974, Copeland & Bechtel 1974, Livingston et al. 1976, Lambert & Dodson 1982). Species-specific migration patterns that may change in the northern part of the range and the possibility of unique juvenile overwintering areas are 2 such variables that may be responsible for the discontinuities observed in the age-class distribution of cisco and lake whitefish along the east coast of Hudson Bay. These observations also suggest that the scale of the spatial extent of community structure and coregonine population dynamics in Hudson Bay may be underestimated by spatially and temporally limited sampling programs.

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