The migrations of anadromous cisco (*Coregonus artedii*) and lake whitefish (*C. clupeaformis*) in estuaries of eastern James Bay

RODERICK MORIN[1]
Centre d'Etudes Nordiques, Département de Biologie, Université Laval (Qué.), Canada G1K 7P4

JULIAN J. DODSON[2]
GIROQ, Département de Biologie, Université Laval, Québec, G1K 7P4

AND

GEOFFREY POWER[3]
Centre d'Etudes Nordiques, Département de Biologie, Université Laval (Qué.), Canada G1K 7P4
Received January 26, 1981

MORIN, R., J. J. DODSON, and G. POWER. 1981. The migrations of anadromous cisco (*Coregonus artedii*) and lake whitefish (*C. clupeaformis*) in estuaries of eastern James Bay. Can. J. Zool. **59**: 1600–1607.

Experimental gill-netting and tagging programs were undertaken in the Eastmain and La Grande rivers of James Bay to determine the migratory patterns of anadromous cisco (*Coregonus artedii*) and lake whitefish (*C. clupeaformis*). Cisco and whitefish were found to differ in the distribution of juveniles during summer, in the upriver migration of mature fish, and in the selection of overwintering sites. Models are presented to illustrate the general life cycles of anadromous cisco and lake whitefish in James Bay.

MORIN, R., J. J. DODSON et G. POWER. 1981. The migrations of anadromous cisco (*Coregonus artedii*) and lake whitefish (*C. clupeaformis*) in estuaries of eastern James Bay. Can. J. Zool. **59**: 1600–1607.

Des programmes de pêche expérimentale aux filets et des programmes de marquage furent établis dans les rivières Eastmain et La Grande de la Baie de James afin de déterminer les mouvements migratoires du cisco (*Coregonus artedii*) et du grand corégone (*C. clupeaformis*). La distribution des poissons juvéniles durant l'été diffère chez ces deux espèces, de même que la migration en amont des individus à maturité et la sélection des sites d'hivernage. Les observations ont conduit à l'élaboration de modèles qui illustrent les cycles de vie du cisco et du grand corégone anadrome de la Baie James.

Introduction

Coregonine fishes are distributed over a wide range of North America and Eurasia. Several species are found in diverse habitats throughout the cooler parts of the northern hemisphere. Of 12 coregonine species described by McPhail and Lindsey (1970) from northwestern Canada and Alaska, the inconnu (*Stenodus leucichthys nelma*); lake whitefish (*Coregonus clupeaformis*); broad whitefish (*C. nasus*); least cisco (*C. sardinella*); Arctic cisco (*C. autumnalis*); Bering cisco (*C. laurettae*); and round whitefish (*Prosopium cylindraceum*) were reported as either anadromous or occurring in brackish water. In eastern Canada, it has been known that lake cisco (*C. artedii*), lake whitefish, and round whitefish enter the salt water of James Bay and Hudson Bay since the accounts of Melville (1915) and Dymond (1933).

[1]Present address: Woods Hole Oceanographic Institution, Woods Hole, MA, U.S.A. 02543.
[2]Author to whom reprint requests should be addressed.
[3]Present address: Department of Biology, University of Waterloo, Waterloo, Ont., Canada N2L 3G1.

Although coregonine species occur frequently in estuaries, little has been published on the ecology of anadromous populations in North America. In spite of the importance of coregonines to the native fisheries of James and Hudson bays (Berkes 1977) and of the concern expressed for this resource in view of current hydroelectric development (Penn 1975), few contributions have been made from studies in the James Bay area. The present study reports on field studies conducted primarily between 1973 and 1975 in the Eastmain and La Grande rivers of James Bay, Québec. Its purpose was to describe the migratory patterns of anadromous lake cisco and lake whitefish and to propose models of their life cycles.

Materials and methods

The migrations of lake cisco and lake whitefish were studied by conventional tagging programs and by recording changes in the composition of catches in specific areas of the Eastmain and La Grande rivers (Fig. 1). The estuaries of both rivers were divided into two zones corresponding to the river mouth and the saltwater zone. The river mouth was usually fresh water from surface to bottom, but was subject to frequent intrusions

0008-4301/81/081600-08$01.00/0

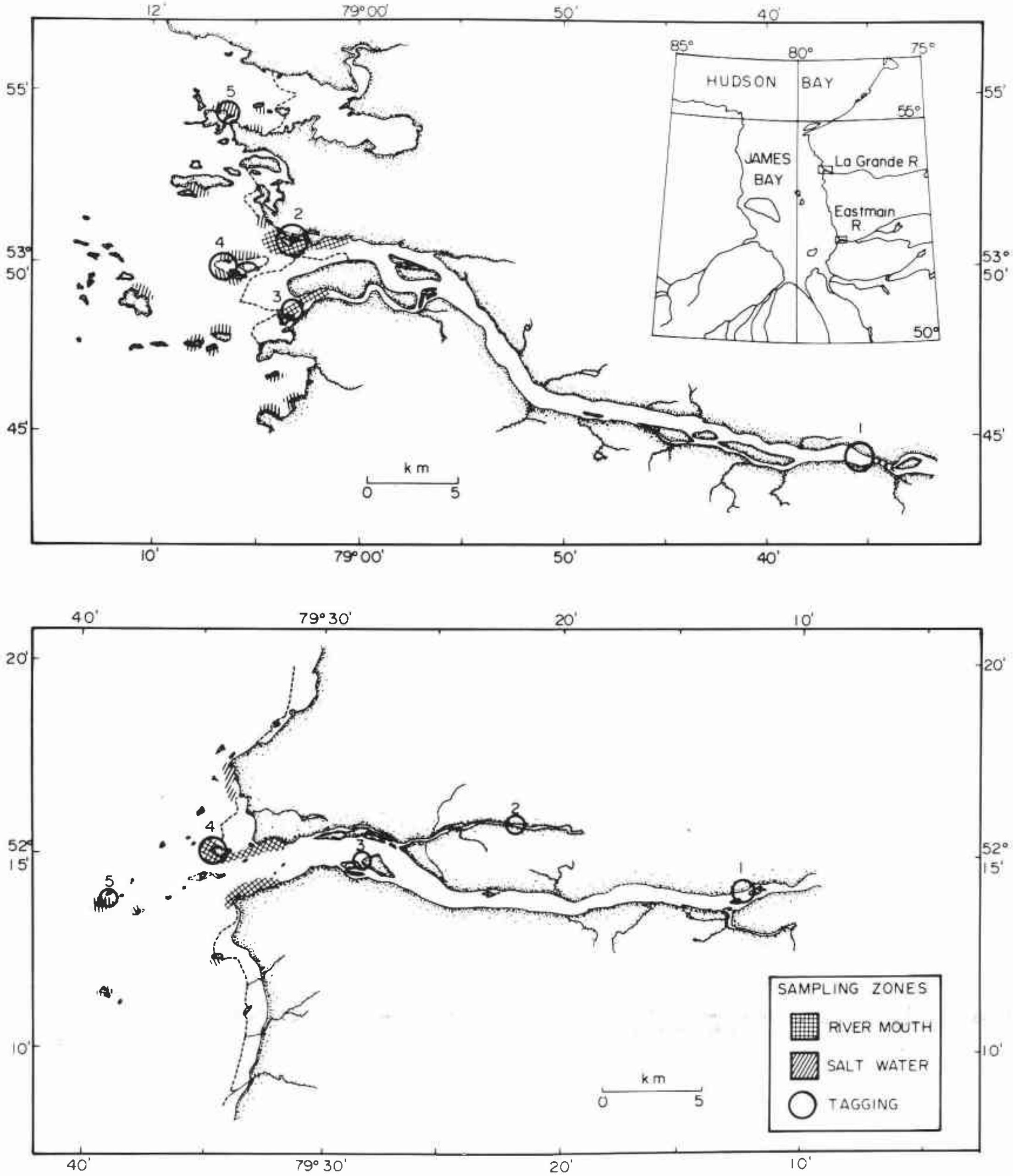

FIG. 1. Map of La Grande River (upper panel) and of the Eastmain River (lower panel) indicating sampling and tagging zones. Hatched regions at the river mouth and in salt water refer to sampling zones in the analysis of catch data.

of saline water during storms and high tides. The saltwater zone was characterized by the presence of a vertical salinity gradient. The vertical ranges of salinity varied with tide, season, and location. In the La Grande estuary during the summer months of July to September, the salinity from surface to bottom ranged from 0 to 7‰ near the mouth to 17 to 20‰ at islands located 10 km offshore of the river mouth. The outflows of La Grande and Eastmain rivers form plumes extending northwards in James Bay (Peck 1976).

Diverse methods of capture were employed, including gill nets, seines, trap nets, minnow traps, rotenone, and trawls; however, the most frequently used were gill nets and seines.

Catch was expressed as the number of cisco or whitefish captured over 24 h using a standard experimental gill net. Such gill nets measured 45.7 × 1.8 m and comprised six panels of multifilament mesh graded 25, 38, 51, 64, 76, and 102 mm (stretched measure). They were normally set over a period between 24 and 48 h. During 1974 and 1975, experimental gill nets were set at regular intervals at the mouths of the La Grande and Eastmain rivers. The purpose was to record changes in the composition of catches and to detect possible migrations of cisco and whitefish. Experimental gill nets were also set regularly in the saltwater zone of the La Grande estuary out to a distance of approximately 5 km from the river mouth. Seasonal changes in the abundance of cisco and whitefish were analyzed by comparing the mean monthly catch per 24 h in each zone. Differences were tested by a Kruskal–Wallis one-way analysis of variance (Siegel 1956).

In La Grande River, cisco and whitefish spawn near the base of the first rapids located 37 km upriver, although the exact location of the spawning beds has not been determined. Sampling was conducted at this site using the technique employed by the native Cree (Berkes 1976). A gill net was extended across small inlets in the rapids and then pulled through the water as a seine. Over 950 fish were captured in 1974 by this method, the majority of which were cisco and whitefish.

Tagging programs were initiated at La Grande River in 1973 and at the Eastmain in 1974 to determine the extent of movements of cisco and whitefish. From 1973 to 1975, a total of approximately 2500 cisco and whitefish were tagged in the lower La Grande River and estuary, and in the lower Eastmain River and estuary. Gill nets were lifted frequently, ensuring live and vigorous specimens for tagging. Carlin tags, Floy dart tags, and opercular strap tags (Ricker 1968, p. 84) were used. Fork length or total length was recorded, a scale sample taken, and the tagged fish was immediately released.

The recapture rates of tagged fish varied widely throughout the study but were frequently lower than 5% for given months and locations. One important cause of the low rates of return was that most of the tagging was concentrated in late autumn, shortly before the departure of field workers. Tagging results were also subject to recapture biases caused by reduced fishing effort in the saltwater zone during frequent autumn storms, and by the intense fishing effort of the native winter fishery concentrated at the river mouth. Therefore, recapture effort was not evenly distributed in space and time. In this paper, tagging results are used to provide limits to the movements of cisco and whitefish and, in combination with the analysis of catch, to indicate migratory patterns.

Results

Catch analysis

Table 1 presents mean monthly catches of cisco and whitefish at the mouth of La Grande River and in the saltwater zone sampled. Marine catches of cisco dropped in the months of August and September, whereas catches at the river mouth remained low throughout the spring and summer, showing a marked increase in October. Results of the Kruskal–Wallis analysis of variance for mean monthly catches of cisco in the saltwater zone indicated significant differences between means ($\chi^2 = 9.9$, df = 4, $0.01 < P < 0.05$). Differences between mean monthly catches of cisco at the mouth of the river were very significant ($\chi^2 = 15.8$, df = 4, $P < 0.01$). Table 2 shows that a similar rise in the catch of cisco occurred at the mouth of the Eastmain River. Data from experimental gill nets were insufficient in the saltwater zone of the Eastmain River to present monthly catches. On the basis of La Grande data, cisco appear to be most numerous in the saltwater zone during spring and early summer.

TABLE 1. Mean monthly catches (number of cisco or whitefish per 24 h) from experimental gill nets set at the mouth and in the saltwater zone (Fig. 1) at La Grande River, 1974 and 1975 data combined. Numbers in parenthesis represent number of gill-net sets

	Cisco		Lake whitefish	
Month	Mouth	Salt water	Mouth	Salt water
June	1.98(6)	16.62(8)	0.66(6)	4.79(8)
July	0.64(9)	19.12(6)	3.20(9)	5.95(6)
August	3.53(9)	5.20(10)	3.32(9)	1.54(10)
September	4.80(7)	1.92(6)	1.81(7)	0.17(6)
October	12.29(8)	8.38(2)	1.97(8)	0.38(2)

Samples taken at the mouth of La Grande River up to mid-September 1974 comprised mostly large cisco, with a mode of fork lengths between 270 and 320 mm (Fig. 2*a*). Samples taken in late September and in October, when the catch was highest, were of smaller cisco with a mode of fork lengths between 200 and 250 mm (Fig. 2*b*). The difference in the length–frequency distributions of cisco in the two periods was highly significant (Chi-square test, $\chi^2 = 85.6$, df = 21, $P < 0.001$). The distribution of the length–frequency of mature and spawning cisco sampled at the rapids of La Grande River (Fig. 2*c*) was not significantly different from cisco sampled at the mouth of the river up to mid-September (Fig. 2*a*) ($\chi^2 = 31.6$, df = 21, $P > 0.05$), but significantly different from cisco taken at the mouth in late September and October (Fig. 2*b*) (χ^2

TABLE 2. Mean monthly catches (number of cisco or whitefish per 24 h) from experimental gill nets set at the mouth of the Eastmain River in 1974. June data are taken from 1975. *n* = number of gill-net sets

Month	*n*	Cisco	Lake whitefish
June	4	0.12	0.38
August	3	0.72	0.79
September	4	3.04	4.01
October	3	31.08	3.67

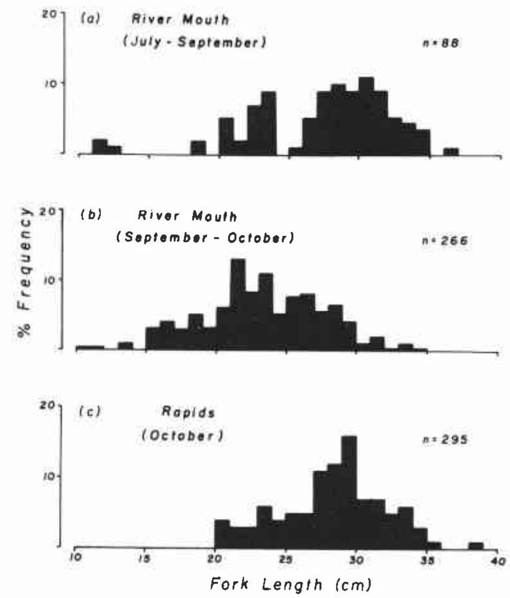

FIG. 2. Length–frequency distributions of cisco captured in La Grande River in 1974 (*a*) at the river mouth from mid-July to mid-September; (*b*) at the river mouth during late September and October; and (*c*) at the first rapids, located 37 km upriver, during October. n = numbers of fish captured.

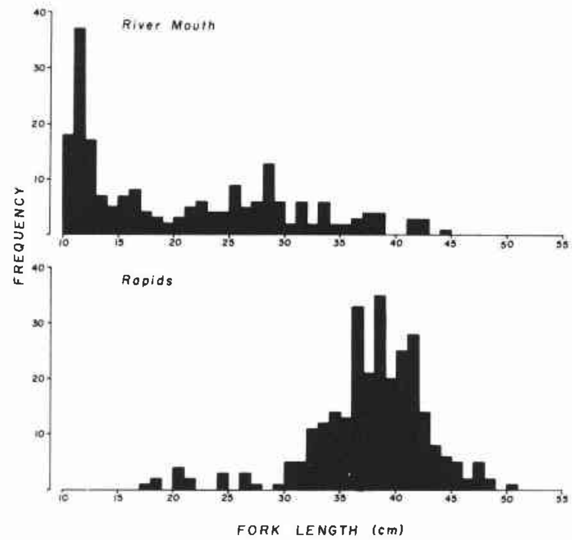

FIG. 3. Length–frequency distributions of lake whitefish captured in La Grande River in 1974 at the river mouth from July to October and at the first rapids, located 37 km upriver, during September and October.

= 177.1, df = 21, $P < 0.001$). Therefore, cisco captured at the mouth of La Grande River in summer were similar in size to cisco representative of the spawning stock. These, in turn, were composed predominantly of larger cisco than found at the river mouth in autumn.

Whitefish catches appeared generally lower throughout the sampling period than those of cisco. Changes in the catch of whitefish in the saltwater zone of La Grande River (Table 1) appear similar to those of cisco, but no significant difference was found between means (Kruskal–Wallis, $\chi^2 = 4.9$, df = 4, $P > 0.05$). Similarly, there was no significant difference between mean catches of whitefish at the mouth of the La Grande River ($\chi^2 = 9.6$, df = 4, $P = 0.05$). Mean monthly catches of lake whitefish at the mouth of the Eastmain River (Table 2) were of similar magnitude to whitefish catches at the mouth of La Grande River.

The length–frequency distributions of lake whitefish sampled at the mouth and in the estuary of La Grande River from July to October 1974 show a predominance of small individuals, whereas samples taken at the rapids of La Grande during September and October of 1974 indicate a recruitment of larger whitefish upriver (Fig. 3).

The sex composition of both cisco and whitefish varied with the sampling period and location. Up to September 15, 58% of cisco caught at the mouth of La Grande River were maturing and would spawn that year, whereas in the autumn period that followed until the end of October only 8% of the catch were maturing. Sex ratios of immature cisco remained the same over the two periods (male/female; 1/1.2 in summer; 1/1.1 in autumn). However, the sex ratio of maturing cisco at the river mouth changed notably (male/female: 1/0.9, in summer; 1/7.0 in autumn) indicating that the remaining mature cisco were dominated by late-spawning females. Lake whitefish caught at the river mouth were mostly immature. Maturing whitefish made up only 6% of the total catch at the mouth of La Grande River from July to October 1974 with little monthly variation.

At the rapids of La Grande River where cisco and whitefish spawn 93% of the cisco captured in September and October in 1973 were mature. For the same period and location, 68% of whitefish captured were mature. Therefore, in La Grande River two discrete groupings of cisco were observed in the autumn, with large mature cisco located at the rapids and smaller immature cisco remaining at the river mouth. In contrast, although larger lake whitefish predominated at the rapids, they were composed of both mature and immature whitefish.

The results of sampling at the mouth of the Eastmain River were similar to the results shown for La Grande River. Increased numbers of cisco captured at the mouth of the Eastmain in October 1974 were composed mostly of juveniles measuring up to 250 mm in fork length. As an example of the dense concentrations of juvenile cisco which form in the lower river in autumn, one 51 mm mesh gill net, most selective in the 200–250 mm range of fork lengths, was fished during 45 h in the lower Eastmain River in late October 1974. Over 800 cisco, composed entirely of juveniles, were captured. As in La Grande River, catches of lake whitefish were low at the mouth of the Eastmain River throughout the sampling period (Table 2). In 1974, mature lake whitefish formed only 9% of the total lake whitefish catch at the mouth of the Eastmain River. Insufficient data were available on the size distributions of spawning cisco and lake whitefish in the Eastmain River for comparisons with samples taken at the river mouth.

Tagging program

The majority of recaptures of both species came from autumn tagging at the rapids (area 1, Fig. 1, upper panel) and at the mouth (areas 2 and 3, Fig. 1, upper panel) of La Grande River. Of 27 cisco recaptured from tagging during September of 1974 at the rapids of La Grande River, 26 were recaptured up to 39 days after tagging at the same location. Of 20 cisco recaptured from tagging during October and November of 1973 and 1974 at the mouth of La Grande River, all were recaptured within the same region up to 34 days after tagging. Cisco displayed similar localized movements in autumn at the mouth of the Eastmain River.

Sixteen whitefish were recaptured from tagging at the rapids of La Grande River during September and October of 1974. Eight were recaptured at the same location up to 25 days after tagging and seven were recaptured the following June on the coast of James Bay. Whitefish catches at the mouth of La Grande River were low and no conclusions could be drawn from the limited tagging effort.

Cisco and whitefish undertake long-range movements between rivers and coastal James Bay. The largest displacement of cisco was of an individual tagged at the first rapids of La Grande River (area 1, Fig. 1) in October, 1974 and recaptured in June, 1975 on the coast of James Bay approximately 66 km away. A cisco tagged on the coast of James Bay (area 5, Fig. 1, upper panel) in August of 1974 was recaptured at the first rapids of La Grande River (area 1, Fig. 1, upper panel) in October, 1974, 53 km away. Seven whitefish tagged at the first rapids of La Grande River in autumn of 1974 were recaptured the following June on the coast of James Bay 43 km away. Two whitefish tagged at the mouth of the Eastmain River (area 4, Fig. 1, lower panel) were recaptured approximately 2 weeks later 16 and 20 km along the James Bay coast. Both specimens were autopsied upon recapture and found to be immatures feeding upon marine organisms. All coastal movements of cisco and whitefish were northwards, except for one La Grande cisco recaptured south of the river.

Discussion

Figures 4 and 5 present models of the life cycles of anadromous cisco and lake whitefish based on our observations and on known species characteristics. Balon (1975) classified lake whitefish as belonging to the guild of lithophils. The larvae of lithophils hatch early and are negatively phototaxic, tending to remain in the spawning gravel. Cisco were included in the guild of lithopelagophils, wherein larvae are semibuoyant and do not seek concealment on the bottom but swim immediately after hatching. The incubation period of cisco is longer at low temperatures than that of lake whitefish (Colby and Brooke 1970). Whereas the embryonic development of whitefish progresses regularly through the winter, the hatching of cisco is initiated by increased illumination and wave action at the time of breakup (John and Hasler 1956).

In the James Bay region, the hatching time of both species has not been determined, and no studies have been made on the role of water temperatures and flow rates on larval development and dispersion. However, the larvae of lake whitefish have been collected throughout the lower La Grande River, particularly at the river mouth (Turgeon 1976), whereas in the same collections few cisco were found. Small whitefish (Fig. 3), mostly of age 1+ (Morin 1980), predominate in samples taken at the mouth and in the saltwater zone of La Grande whereas cisco smaller than 150 mm fork length were poorly represented in samples taken at the river mouth (Fig. 2). Legendre and Simard (1978) reported highest concentrations of phytoplankton at the mouths of the Eastmain and La Grande rivers and highest values of chlorophyll in the river estuary of Rupert's Bay. Therefore, it appears that although lake whitefish use the lower river and inshore estuary as a nursery during early stages, the larvae of cisco are more susceptible to transport due to their pelagic nature and are carried farther into James Bay by the heavy spring runoffs.

Juvenile cisco become abundant at the mouths of La Grande and Eastmain rivers in October. On the basis of tag returns at the mouths of both rivers, their movements appear to remain localized over much of the early winter. Cisco grouping at the mouth of La Grande River are subject to a traditional native fishery (Berkes 1979) which follows freezeup from November to early January.

The causal mechanisms of the autumn movement of juvenile cisco from the saltwater zone to the river mouth are not clearly known. The distribution of coregonine fishes is frequently explained on the basis of food distribution and preferred temperature (Valtonen 1970). Juvenile cisco do not gather at the mouth of La Grande River to feed, as over 90% have empty stomachs during this period (Greendale and Hunter 1978). Juvenile cisco entered the Eastmain and La Grande rivers in 1974 when the temperature of fresh water was between 4 and 6°C. It

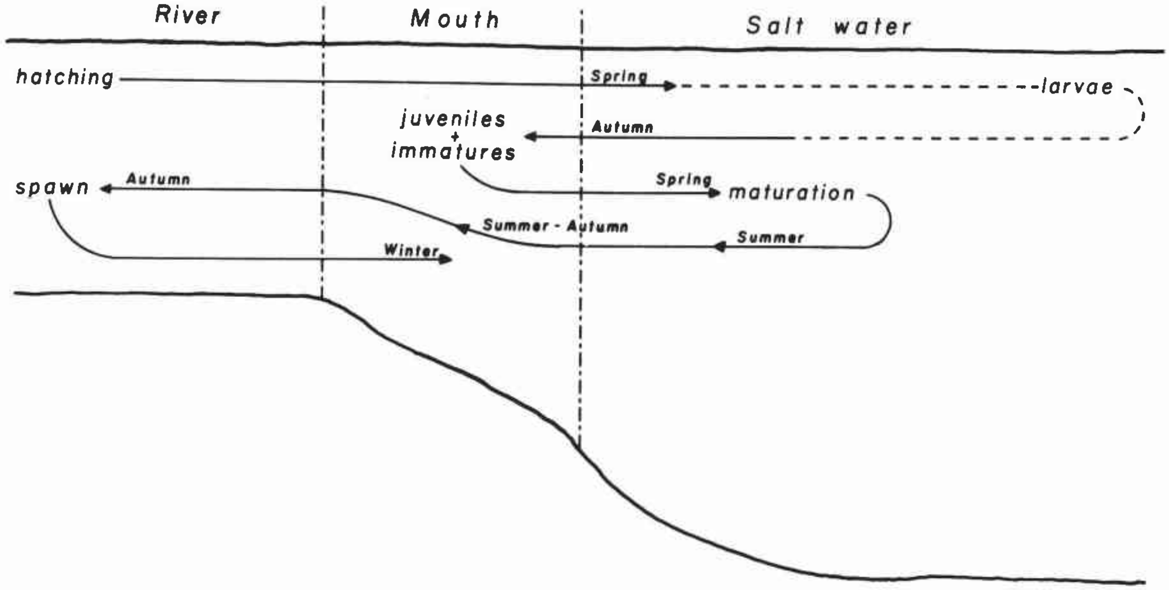

FIG. 4. The life cycle of anadromous cisco in coastal James Bay. Horizontal lines indicate the movements of cisco through the freshwater, river mouth, and saltwater zones from hatching to postspawning. Arrows indicate the direction of movements and also the location at which collections were made. Dashed lines indicate movements that are speculative. The vertical arrangement of lines bears no relation to the depth distribution of cisco.

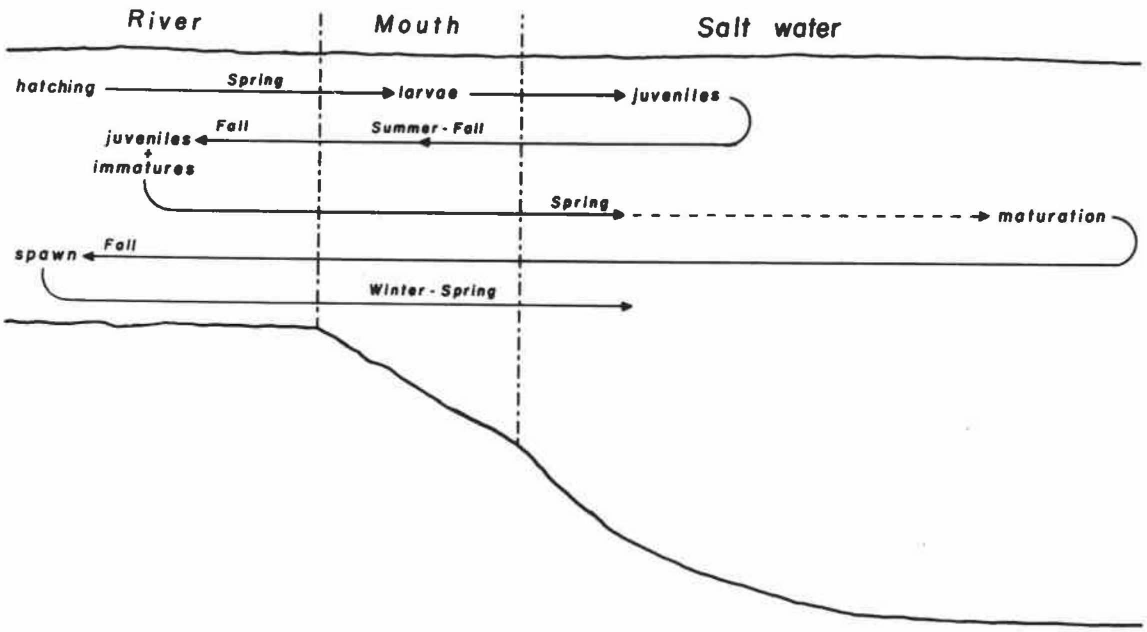

FIG. 5. The life cycle of anadromous lake whitefish in coastal James Bay. Horizontal lines indicate the movements of lake whitefish through the freshwater, river mouth, and saltwater zones from hatching to postspawning. Arrows indicate the direction of movements and also the location at which collections were made. Dashed lines indicate movements that are speculative. The vertical arrangement of lines bears no relation to the depth distribution of lake whitefish.

was not determined whether brackish water was warmer at this time, although it is possible that river water cools initially faster than saline water. The movements of juvenile cisco closely resemble the overwintering movements of the Arctic cisco (*C. autumnalis*). Burkov and Solovkina (1976) noted that in October, sexually immature Arctic cisco move from the Barents and Kara seas into rivers to overwinter, ascending no higher than the tidal zone.

Cisco are most numerous during spring and early summer in the saltwater zone, although tagging indicates that they may range much farther than the region sampled. Mature and immature cisco occur together in the estuary and not all cisco of the same age-class attain spawning condition in the same year (Morin 1980). On the basis of sampling at the river mouth, the upriver migration of cisco is gradual and prolonged, beginning in midsummer. By October, the catch at the river mouth is increased as small immature cisco move into the mouth of the river, and the remaining mature cisco are dominated by late-spawning females.

In August, a native fishery exploits maturing cisco and whitefish that congregate in the first rapids of La Grande River (Berkes 1976). Faubert (1975) reported that cisco and whitefish spawned at the base of the same rapids during middle and late October of 1974 when the water temperature was approximately 1°C. On the basis of a single recapture and from the capture of spent cisco at the mouth, cisco appear to move downriver after spawning, joining overwintering juveniles at the mouth.

The whitefish catch was dominated by juveniles at the river mouth and in most of the saltwater zone sampled. There was no indication from catch data that whitefish concentrate at the river mouth in large numbers in the autumn and winter. Catches at the mouth of La Grande River in December 1974 were mostly of cisco, with lake whitefish forming less than 5% of the total catch. However, the presence of concentrations of immature and spawning whitefish together at the rapids indicates that the overwintering of lake whitefish may occur well upstream in fresh water to the limit of the first rapids, as suggested by Moreau and Barbeau (1979) upon analysis of the mineral composition of whitefish scales in La Grande River. Vigneault and Le Jeune (1976) reported that whitefish concentrated at the rapids in June of 1974, but decreased in abundance during the summer months when whitefish had presumably moved downriver.

The summer movements of maturing whitefish are speculative. Whitefish tagged in October at the La Grande rapids were recaptured on the coast during the following May and June, but their reproductive condition was not determined. Unpublished data of the Société d'Energie de la Baie James indicate that from May to August whitefish located at the rapids of La Grande River were almost entirely immature. Maturing whitefish were also absent from the lower river and saltwater zone sampled. Berkes (1977) reported that during spring and summer the natives of Fort George, located at the mouth of La Grande River, and of Eastmain (Berkes 1979), exploit whitefish along the James Bay coast at a distance beyond 15 km from the rivers' mouths. The results from tagging indicate that this distance is within the range of the coastal movements of whitefish tagged in the Eastmain and La Grande rivers. Therefore, on the basis of the absence of mature lake whitefish from the river and saltwater zone sampled during summer and because of their concurrent abundance in more distant coastal regions, it is presently assumed that whitefish undergo maturation following lengthy migrations to coastal James Bay. The return migration of mature and overwintering whitefish is undetected by gill nets set at river mouths, suggesting that whitefish probably enter the coastal river plume and ascend the river in deep water.

Many salmonids show homing tendencies, and in the case of coregonines, taxnomic complexities have been attributed to homing to natal spawning grounds for reproduction (Behnke 1970; Todd *et al.* 1981). We know of no studies that conclusively demonstrate homing in coregonines and the question of whether cisco and lake whitefish migrating from James Bay home to their natal rivers are mature remains to be demonstrated. Similarly, the question of home-river fidelity of overwintering juvenile and immature coregonines remains unanswered.

Acknowledgements

We wish to acknowledge the Arctic Biological Station of the Canadian Department of Fisheries and Oceans and the Société d'Energie de la Baie James for their permission to use unpublished data.

BALON, E. K. 1975. Reproductive guilds of fishes: a proposal and definition. J. Fish. Res. Board Can. **32**: 821–864.

BEHNKE, R. J. 1970. The application of cytogenetic and biochemical systematics to phylogenetic problems in the family Salmonidae. Trans. Am. Fish. Soc. **99**: 237–248.

BERKES, F. 1976. James Bay: The coastal fishery of the Cree Indians. Can. Geogr. J. **93**: 60–65.

——— 1977. Fishery resource use in a subarctic Indian community. Human Ecol. **5**: 289–307.

——— 1979. An investigation of Cree Indian domestic fisheries in northern Québec. Arctic, **32**: 46–70.

BURKOV, A. I., and L. N. SOLOVKINA. 1976. The main commercial and biological indicators of the omul, *Coregonus autumnalis*, from the North European zoogeographic region, and the results of tagging. J. Ichthyol. **16**: 327–331.

COLBY, P. J., and L. T. BROOKE. 1970. Survival and development of lake herring (*Coregonus artedii*) eggs at various incubation temperatures. *In* Biology of coregonid fishes. *Edited by* C. C. Lindsey and C. S. Woods. Univ. Manitoba Press, Winnipeg, Man. pp. 417–428.

DYMOND, J. R. 1933. The coregonine fishes of Hudson and James bays. Contrib. Can. Biol. New Ser. **8**: 1–12.

FAUBERT, N. 1975. Etude spéciale du corégone anadrome des rivières Eastmain et La Grande Rivière, 1974. Rapport d'expédition 39, Société d'énergie de la Baie James, Montréal.

GREENDALE, R., and J. G. HUNTER. 1978. Feedings of freshwater fishes in estuarine and coastal waters. Fish. Mar. Serv. Tech. Rep. 777.

JOHN, K. R., and A. D. HASLER. 1956. Observations on some factors affecting the hatching of eggs and the survival of young shallowwater cisco, *Leucichthys artedii* (Le Sueur), in Lake Mendota, Wisconsin. Limnol. Oceanogr. **1**: 176–194.

LEGENDRE, L., and Y. SIMARD. 1978. Dynamique estivale du phytoplancton dans l'estuaire de la Baie de Rupert (Baie de James). Nat. Can. **105**: 243–258.

MCPHAIL, J. D., and C. C. LINDSEY. 1970. Freshwater fishes of northwestern Canada and Alaska. Bull. Fish. Res. Board Can. **173**: 1–381.

MELVILLE, C. D. 1915. Report on the east coast fisheries of James Bay. Annu. Rep. Can. Dep. Naval Serv. 1913–1914: 3–29 of appendix.

MOREAU, G., and C. BARBEAU. 1979. Différenciation de populations anadromes et dulcicoles de Grands Corégones (*Coregonus clupeaformis*) par la composition minérale de leurs écailles. J. Fish. Res. Board Can. **36**: 1439–1444.

MORIN. R. 1980. Ecology of anadromous coregonine fishes in estuaries of eastern James-Hudson Bay. M.Sc. Thesis, Department of Biology, Université Laval, Québec, Canada.

PECK, S. 1976. Nearshore oceanography of James Bay. *In* James Bay–Environment Symposium Proceedings. 19–20 May 1976. Montreal. pp. 115–145.

PENN, A. F. 1975. Development of James Bay: the role of environmental impact assessment in determining the legal right to an interlocutory injunction. J. Fish. Res. Board Can. **32**: 136–160.

RICKER, W. E. (*Editor*). 1968. Methods for assessment of fish production in fresh waters. IBP Handbook No. 3. Blackwell Scientific Publications, Oxford.

SIEGEL, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., Toronto.

TODD, T. N., G. R. SMITH, and L. E. CABLE. 1981. Environmental and genetic contributions to morphological differentiation in ciscoes (Coregoninae) of the Great Lakes. Can. J. Fish. Aquat. Sci. **38**: 59–67.

TURGEON, M. 1976. Etude des poissons anadromes des rivières Eastmain et La Grande Rivière. Rapport d'expédition 64, Société d'énergie de la Baie James, Montréal.

VALTONEN, T. 1970. The selected temperature of *Coregonus nasus* (Pallas), *sensu* Svärdson, in natural waters compared with some other fish. *In* Biology of coregonid fishes. *Edited by* C. C. Lindsey and C. S. Woods. Univ. Manitoba Press, Winnipeg, Man. pp. 347–362.

VIGNEAULT, Y., and R. LE JEUNE. 1976. Etude du corégone du fleuve Grande-Rivière. Manuscript of Centre d'Etudes nordiques, Université Laval pour la Société d'énergie de la Baie James.