

Elsevier Oceanography Series, 44

CANADIAN INLAND SEAS

Edited by

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GC
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1986



ELSEVIER

Amsterdam – Oxford – New York – Tokyo 1986





Inuit print. (From Inuktitut Magazine, Indian and Northern Affairs; chosen by F. Berkes)

Chapter 15

THE ECOLOGY OF FISHES IN JAMES BAY, HUDSON BAY AND HUDSON STRAIT.

R. MORIN AND J. J. DODSON

INTRODUCTION

Hudson Bay remains today one of the world's last great inland seas for which the marine fauna has yet to be completely explored. Prior to this last decade, interest in the ichthyofauna of Hudson Bay centered on speculation about its potential for commercial exploitation. Melville (1915) and Lower (1915) surveyed the fish resources of the eastern and western shores of James Bay during 1914 and suggested, on the basis of gill net catches and reported harvests, that salmonid species could be exploited if the resource was made accessible to southern markets. The Loubyrne expedition of 1930 undertook a more rigorous evaluation of the potential for a deep-sea fishery in Hudson Bay, including a description of its physical, chemical and biological oceanography (Hachey, 1931a,b). The results of this expedition dispelled any hopes of establishing a fishery in Hudson Bay. Oceanographic research did not resume in the region until the M/V Calanus occupied stations in Hudson Strait and Ungava Bay 20 years later (Dunbar, 1982). Comprehensive oceanographic research involving fishes was never resumed in Hudson Bay after 1930 and has never been conducted in the offshore waters of James Bay.

In this chapter we describe our current knowledge of fishes in James Bay, Hudson Bay and Hudson Strait. Foxe Basin has been excluded due to insufficient sampling of the fish fauna. Since the development of the hydroelectric potential of Quebec rivers during the 1970s, considerable attention has been given to the ecology of fish in coastal regions of eastern James-Hudson Bay. This chapter reflects the disparity that has developed between our understanding of marine fishes and that of the important coastal and anadromous fishes. The first part of this chapter describes the role of water masses in determining the number and type of marine species occurring in the area and the role that geological events have played in post-glacial colonization by freshwater and euryhaline fishes. The second part discusses the structure of fish assemblages in marine waters based on recent trawling

surveys in Hudson and Davis straits, and in coastal waters based on extensive sampling of estuaries in eastern James-Hudson Bay. The dominant feeding patterns of fish that appear throughout the region are also discussed. In the third part of this chapter we present life cycles of representative marine and coastal fishes in James-Hudson Bay. In the concluding section we propose further research on fish inhabiting Canada's northern inland seas.

BIOGEOGRAPHY

The occurrence of fish species in James Bay, Hudson Bay and Hudson Strait is considered first for marine species and secondly for euryhaline and freshwater species, due to differences in the physical processes influencing their biogeography in three zones (Fig. 15.1). These zones include James Bay, due to the importance of freshwater input (Prinsenber, 1980, 1982) and its proximity to the species-rich St. Lawrence-Great Lakes system; Hudson Bay, dominated by Arctic waters and marginally influenced by the Atlantic

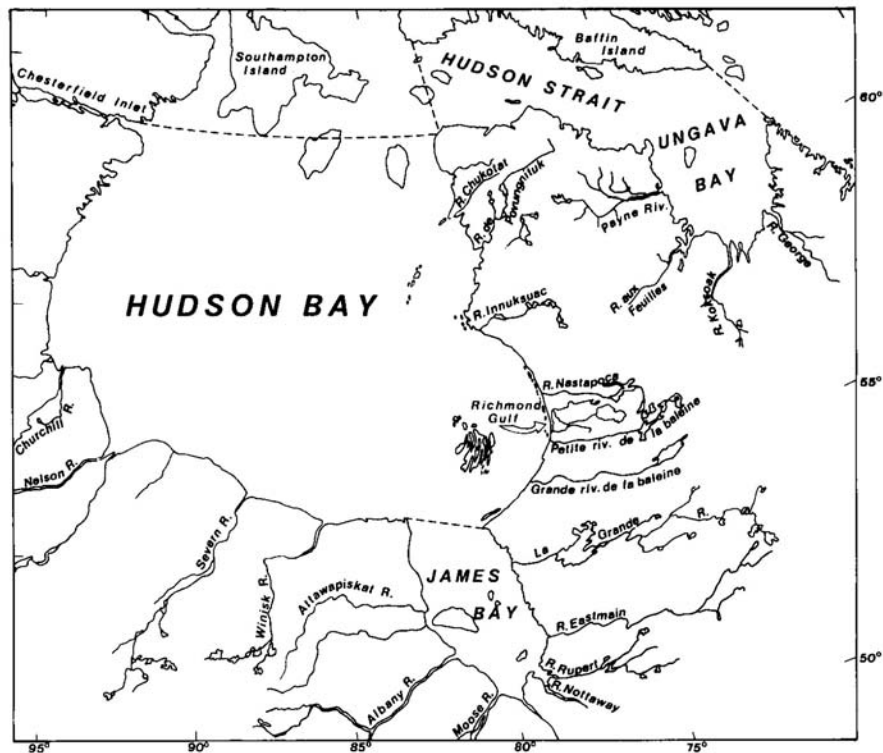


Figure 15.1. The major rivers and study sites of James-Hudson Bay and Ungava Bay. Dashed lines define the boundaries of the three biogeographic zones of Table 15.1.

(Dunbar, 1958); and Hudson Strait, including Ungava Bay, where Arctic and Atlantic waters have combined influence (Drinkwater, 1986).

A total of 19 families and 55 species of marine fishes are recorded throughout the three zones (Tables 15.1, 15.2). Hudson Strait is the most species-rich zone with 51 species as compared to Hudson Bay with 34 and James Bay with 22 species. Hudson Bay is dominated by Arctic marine fishes (68% of 34 species), whereas James Bay, probably due to shallow water, low salinity and possibly warmer conditions, contains proportionately fewer Arctic species (59% of 22 species, Table 15.2). Hudson Strait is closer to the center of

TABLE 15.1

Arctic marine fishes of James Bay, Hudson Bay and Hudson Strait. Arctic species are defined as species with their center of distribution in the Arctic Ocean and as species withstanding extreme low temperatures (Backus, 1957). Biological notes on Arctic fishes are taken from Bigelow and Schroeder (1953), Backus (1957), Andriyashev (1954), Leim and Scott (1966), Marshall (1973) and Able and McAllister (1980). Sources on fish distributions: Vladykov (1933), Dunbar and Hildebrand (1952), Hunter (1968), Edwards (1961), McAllister (1964, pers. comm.), Able and McAllister (1980), Morin et al. (1980), McAllister et al. (1981), Anderson (1982), Ochman and Dodson (1982).

Family & species	James Bay	Hudson Bay	Hudson Strait
<u>Rajidae</u>			
<u>Raja hyperborea</u>			X
<u>Gadidae</u>			
<u>Boreogadus saida</u>	X	X	X
<u>Gadus ogac</u>	X	X	X
<u>Zoarcidae</u>			
<u>Gymnelus viridis</u>		X	X
<u>Lycodes mucosus</u>			X
<u>L. reticulatus</u>	X	X	X
<u>L. pallidus</u>	X	X	
<u>Stichaeidae</u>			
<u>Eumesogrammus praecisus</u>		X	X
<u>Stichaeus punctatus</u>		X	X
<u>Lumpenidae</u>			
<u>Anisarchus medius</u>	X	X	X
<u>Leptoclinus maculatus</u>		X	X
<u>Pholididae</u>			
<u>Pholis fasciata</u>	X	X	
<u>Cottidae</u>			
<u>Artediellus uncinatus</u>			X
<u>Cottunculus microps</u>			X
<u>Gymnocanthus tricuspis</u>		X	X
<u>Icelus bicornis</u>		X	X
<u>I. spatula</u>		X	X
<u>Myoxocephalus quadricornis</u>	X	X	X
<u>M. scorpioides</u>	X	X	X
<u>Triglops nybelini</u>			X
<u>T. pingeli</u>		X	X
<u>Liparididae</u>			
<u>Careproctus reinhardti</u>		X	
<u>Liparis fabricii</u>	X	X	X
<u>L. tunicatus</u>	X	X	X

TABLE 15.2
 Non-Arctic marine fishes of James Bay, Hudson Bay and Hudson Strait.
 Definitions and data sources as in Table 15.1

Family & species	James Bay	Hudson Bay	Hudson Strait
<u>Dalatiidae</u>			
<u>Somniosus microcephalus</u>			X
<u>Rajidae</u>			
<u>Raja radiata</u>	X	X	X
<u>R. spinacauda</u>			X
<u>Clupeidae</u>			
<u>Clupea harengus</u>		X	
<u>Osmeridae</u>			
<u>Mallotus villosus</u>	X	X	X
<u>Myctophidae</u>			
<u>Benthoosema glaciale</u>			X
<u>Notoscepepus elongatus</u>			X
<u>Gadidae</u>			
<u>Gadus morhua</u>			X
<u>Gaidropsarus ensis</u>			X
<u>Urophycis chesteri</u>			X
<u>Macrouridae</u>			
<u>Macrourus berglax</u>			X
<u>Zoarcidae</u>			
<u>Lycodes esmarki</u>			X
<u>L. vahlii</u>			X
<u>Anarhichadidae</u>			
<u>Anarhichus minor</u>			X
<u>Lumpenidae</u>			
<u>Lumpenus fabricii</u>	X	X	X
<u>Ammodytidae</u>			
<u>Ammodytes dubius</u>	X	X	X
<u>A. hexapterus</u>	X	X	X
<u>Scorpaenidae</u>			
<u>Sebastes marinus</u>			X
<u>S. mentello</u>			X
<u>Cottidae</u>			
<u>Myoxocephalus scorpius</u>	X	X	X
<u>Triglops murrayi</u>	X	X	X
<u>Agonidae</u>			
<u>Aspidophoroides olriki</u>	X	X	X
<u>Leptagonus decagonus</u>		X	X
<u>Cyclopteridae</u>			
<u>Cyclopteropsis jordani</u>			X
<u>Cyclopterus lumpus</u>	X	X	X
<u>Eumicrotremus derjugini</u>	X	X	X
<u>E. spinosus</u>	X	X	X
<u>Liparididae</u>			
<u>Liparis atlanticus</u>			X
<u>L. gibbus</u>	X	X	X
<u>Pleuronectidae</u>			
<u>Hippoglossoides platessoides</u>		X	X
<u>Reinhardtius hippoglossoides</u>			X

distribution of species associated with subarctic and Atlantic waters and as a result contains the smallest proportion of Arctic fishes (49% of 51 species).

The distribution of freshwater species (Table 15.3) has been largely determined by post-glacial geological events (McPhail and Lindsey, 1970; Crossman and McAllister, 1985). Most of the species of Table 15.3 have post-glacial origins in the Mississippi and Atlantic refugia. Nine species may also have survived glaciation in the Bering refuge (Table 15.3). As the last Wisconsinian ice sheet retracted northward, numerous large glacial lakes and waterways formed which drained to the south and east permitting the northward dispersion of fishes from southern refugia. Dadswell (1972) has demonstrated that the distributions of spoonhead sculpin (Cottus ricei), fourhorn sculpin (Myoxocephalus quadricornis), trout-perch (Percopsis omiscomaycus) and ninespine stickleback (Pungitius pungitius) in eastern Ontario and western Quebec are associated with the maximum extent of these large, interconnected glacial lakes. Further dispersal may have occurred as drainage systems adjusted to post-glacial rebound and numerous connections formed between different hydrographic basins (Legendre and Legendre, 1984). In addition, colonization by euryhaline species may have occurred by coastal routes as sea waters entered Hudson-James Bay forming the post-glacial Tyrell Sea approximately 7000-8000 years ago (Lee, 1960; Shilts, 1986).

A unique characteristic of the James-Hudson Bay fish fauna is the relative importance of freshwater species exploiting the extensive coastal brackish zone. Of the 42 species identified in Table 15.3, 22 (52%) seasonally inhabit brackish waters of salinities up to 15 ppt. Some of these species, including walleye (Stizostedion vitreum) and the Catostomidae, are rarely associated with such habitats elsewhere in their North American ranges. The relative importance of euryhaline species is greater in northern coastal regions. In James Bay, 56% (22 species) of 39 freshwater species occupy brackish waters whereas 70% (21 species) of 30 freshwater species occupy similar zones in Hudson Bay. In Ungava Bay, 94% (16 species) of 17 freshwater species occupy brackish waters.

The reduction in the number of freshwater species and the increased proportion of euryhaline species northward may be due to the patterns of post-glacial dispersion, although more proximal factors may be involved as discussed in the next section. Freshwater species which re-entered the territory by inland routes from southern refugia may have been delayed by the slow retreat of the ice sheet and restricted to the James Bay lowlands and adjacent areas. Euryhaline species may have had a more rapid and extensive colonization of northern estuaries, rivers and coastal zones because of coastal routes of dispersion.

Coastal brackish water zones also appear to be important in the life cycles of some marine species. Five of the 55 marine species of Tables 15.1

TABLE 15.3

Habitat and occurrence of freshwater fish in James Bay, Hudson Bay and Ungava Bay. Brackish water habitat applies to fish found in water of salinity less than 15 ppt. Asterisks indicate species that may have survived glaciation in the Bering refuge. Sources: McPhail and Lindsey (1970), Scott and Crossman (1973), Morin et al. (1980), Zalewski and Weir (1981).

Family and Species	Habitat		Location		
	Brackish	Fresh	James	Hudson	Ungava
Petromyzontidae					
<u>Ichthyomyzon unicuspis</u>		X		X	
Acipenseridae					
<u>Acipenser fulvescens</u>	X	X	X	X	
Hiodontidae					
<u>Hiodon alosoides</u>		X	X		
<u>H. tergisus</u>		X	X		
Salmonidae					
<u>Coregonus artedii</u>	X	X	X	X	X
<u>C. clupeaformis</u>	X	X	X	X	X
* <u>Prosopium cylindraceum</u>	X	X	X	X	X
<u>Salmo salar</u>	X	X		X	X
* <u>Salvelinus alpinus</u>	X	X	X	X	X
<u>S. fontinalis</u>	X	X	X	X	X
* <u>S. namaycush</u>	X	X	X	X	X
* <u>Thymallus arcticus</u>		X		X	
Esocidae					
* <u>Esox lucius</u>	X	X	X	X	X
Cyprinidae					
<u>Couesius plumbeus</u>	X	X	X	X	X
<u>Notropis atherinoides</u>		X	X		
<u>N. cornutus</u>		X	X		
<u>N. heterolepis</u>		X	X		
<u>N. hudsonius</u>		X	X		
<u>Phoxinus eos</u>	X	X	X	X	
<u>P. neogaeus</u>		X	X	X	
Pimephales promelas		X	X	X	
<u>Rhinichthys cataractae</u>		X	X	X	X
<u>Semotilus atromaculatus</u>		X	X		
<u>S. corporalis</u>		X	X		
<u>S. margarita</u>		X	X	X	
Catostomidae					
* <u>Catostomus catostomus</u>	X	X	X	X	X
<u>C. commersoni</u>	X	X	X	X	X
<u>Moxostoma macrolepidotum</u>	X	X	X	X	
Percopsidae					
<u>Percopsis omiscomaycus</u>		X	X	X	
Gadidae					
* <u>Lota lota</u>	X	X	X	X	X
Gasterosteidae					
<u>Culaea inconstans</u>	X	X	X	X	
<u>Gasterosteus aculeatus</u>	X	X	X	X	X
* <u>Pungitius pungitius</u>	X	X	X	X	X
Percidae					
<u>Perca flavescens</u>		X	X		
<u>Stizostedion canadense</u>	X	X	X		
<u>S. vitreum</u>	X	X	X	X	
<u>Etheostoma exile</u>		X	X		

Family and Species	Habitat		Location		
	Brackish	Fresh	James	Hudson	Ungava
<u>E. nigrum</u>		X	X	X	
<u>Percina caprodes</u>		X	X	X	
Cottidae					
<u>Cottus bairdi</u>		X	X	X	X
* <u>C. cognatus</u>	X	X	X	X	X
<u>C. ricei</u>	X	X	X	X	

and 15.2 (capelin, Mallotus villosus; the sand lances, Ammodytes dubius and A. hexapterus.; ogac, Gadus ogac; fourhorn sculpin) regularly inhabit brackish coastal waters of James, Hudson and Ungava bays. Other marine species may exploit brackish waters, particularly in James Bay, but as most sampling in coastal zones has been by gill nets and beach seines, the extent of such a phenomenon must be a subject of future research.

The total number of fish species inhabiting James Bay and Hudson Bay is 56, comprising marine and coastal euryhaline species. The lack of a diverse fish fauna in James-Hudson Bay has been associated with low biotic production of its marine waters. Hunter (1968) illustrated the point by comparing the species richness of Hudson Bay with that of adjoining parts of the Arctic, Atlantic and Pacific oceans. Such comparisons fail to account for the widely divergent ecology and geology of enclosed seas and open oceans, nor is species richness a reliable indicator of productivity.

A comparison of fish faunas in James-Hudson Bay and other northern seas (Table 15.4) is more appropriate, but also presents difficulties of

TABLE 15.4

A comparison of the dimensions of some northern enclosed seas and the number of marine and euryhaline fish species found. Physical data on Baltic and Barents seas are taken from Zenkevitch (1983); the remaining seas are based on Sverdrup et al. (1942). Sources for number of fish species: 1: Srivastava (1971); 2: Ojaveer et al. (1981); 3: Ross et al. (1949); 4: approximate number (Wilimovsky, 1974).

	Area (10^6 km^2)	Mean Depth (m)	Volume (10^6 km^3)	Fish Species
Gulf of St. Lawrence	0.226	152	0.035	151 ¹
Baltic Sea	0.386	86	0.033	71 ²
Hudson Bay	1.232	128	0.158	56
Barents Sea	1.405	229	0.322	130 ³
Bering Sea	2.304	1598	3.683	300 ⁴

interpretation. Some variation in species richness occurring between inland seas is due to the presence of endemic species and to the richness of faunas in adjacent water bodies. For example, the Bering Sea was not glaciated and as a result contains some endemic species. It is also broadly linked to the northern Pacific fish fauna. Most inland seas lack an endemic fauna, being colonized by fish from adjacent oceans and freshwater. Colonizing fish species are thus limited by the variety of ecological niches available within an enclosed sea. Species such as the mesopelagic Myctophidae and Sebastes, which are present in Hudson Strait but absent in Hudson Bay, are likely restricted by the shallow depths of Hudson Bay. The absence of some Arctic marine fishes in Hudson Bay that are found in Hudson Strait may also reflect the absence of appropriate habitat rather than limited productivity.

Summary

Freshwater inputs to James Bay exert an influence on the composition of the fish fauna that is as great as that of the presence of Arctic and Atlantic water masses. The number of marine fish species increases northward from James Bay to Hudson Bay and then Hudson Strait. Along the same gradient, freshwater assemblages are characterized by an increasing proportion of euryhaline species. Of the 42 freshwater species reported in Table 15.3, over one half are diadromous, moving into brackish water seasonally, daily, or periodically to prey upon fish, crustacea and molluscs. The ability of freshwater species to withstand saltwater is probably an important ecological adaptation in James-Hudson Bay.

COMMUNITY STRUCTURE

Marine

The relative abundance of species composing the marine communities of these areas is the most poorly studied aspect of the ecology of Hudson Bay fishes. The only quantitative data available is provided by recent trawling surveys conducted in Hudson and Davis straits to evaluate the commercial potential of groundfish and shrimp. Sampling was conducted aboard the vessels Canso Condor from July to September 1978 in eastern Hudson Strait, Ungava Bay and Davis Strait (MacLaren Marex Inc., 1978); the F/V Torsbugvin from August to October 1979 in eastern Hudson Strait and Ungava Bay (Imaqpiq Fisheries Inc., 1981); and the Lumaaq during October 1980 in western Hudson Strait (D. Gillis, unpublished data). All these expeditions used similar small-meshed bottom trawls appropriate for the capture of shrimp. Fish captured in trawls were identified, weighed and either counted in whole or as a subsample. Not all taxa were identified to species. Lanternfish (Myctophidae), pricklebacks (Stichaeidae), eelpouts (Zoarcidae), redfish

(Scorpaenidae), and seasnails (Liparididae) were identified only to family.

The trawling surveys indicate a decline in biomass (weight of catch per unit effort, Table 15.5) towards western Hudson Strait. Davis Strait catches averaged several times the biomass of catches in Hudson Strait and Ungava

TABLE 15.5

Summary of fishing activities in the four regions of Figure 15.2. Catch per unit of effort refers to number or weight of fish captured per hour of trawling. Trawls were set for one hour in all regions other than Davis Strait (0.5 h).

	Hudson Strait		Ungava Bay	Davis Strait
	West	East		
Number of stations	16	34	50	75
Mean depth (m)	259	358	281	388
Number captured	9884	23131	30858	74672
Catch per unit effort (number)	618	680	617	1991
Weight of catch (kg)	320	1030	1594	5164
Catch per unit effort (weight)	20	30	32	138

Bay. A decline in density (number per unit effort, Table 15.5) also occurs towards Ungava Bay and western Hudson Strait. The reduction in biomass and density observed in western Hudson Strait may be accentuated in Hudson Bay. Vladykov's (1933) analysis of the results of the 1930 Loubyrne bottom trawl survey of Hudson Bay revealed that no fish were captured at 65% of the 30 stations sampled at depths greater than 100 m. Fish were absent from 22% of the 18 stations located in depths less than 100 m. Abundance data from the survey were not reported, therefore a direct comparison with the Hudson Strait data cannot be made.

The decline in biomass that occurs towards western Hudson Strait is accompanied by a change in the relative abundance of species (Fig. 15.2). Although Arctic cod (Boreogadus saida) is pelagic, it dominates bottom trawl catches by numbers in Davis Strait and eastern Hudson Strait. In terms of weight, Greenland halibut (Reinhardtius hippoglossoides) dominate catches in these same areas. In west Hudson Strait, Arctic cod and Greenland halibut are replaced in dominance by the lumpfish (Cyclopterus lumpus) and seasnails. Lumpfish appear throughout coastal Hudson Bay and James Bay, although its abundance relative to other marine species is unknown.

The fish fauna of Hudson Strait exhibits a greater diversity of feeding modes than that of Hudson Bay. The large majority of species occurring in Hudson Bay and Hudson Strait are benthic non-specialists, a characteristic of fish in Arctic waters (Nikolskii and Radakov, 1968; McAllister, 1975). For

example, a common Hudson Bay marine piscivore such as ogac also consumes large amounts of invertebrates. However, exceptions to this pattern occur in Hudson Strait. Cryopelagic forms, meaning midwater fish that are associated at some time in their life cycle with drifting or fast ice, are represented by Arctic cod, a species that dominates fish assemblages throughout Hudson Strait. Other examples of pelagic species that are present only in Hudson Strait are the mesopelagic forms such as lanternfishes and redfish (*Sebastes mentella*). In addition, the only true top predator reported in the region is the Greenland shark (*Somniosus microcephalus*), a species that feeds uniquely on fish and marine mammals. Greenland shark occurs throughout Hudson Strait but has not been reported in Hudson Bay (Dunbar and Hildebrand, 1952).

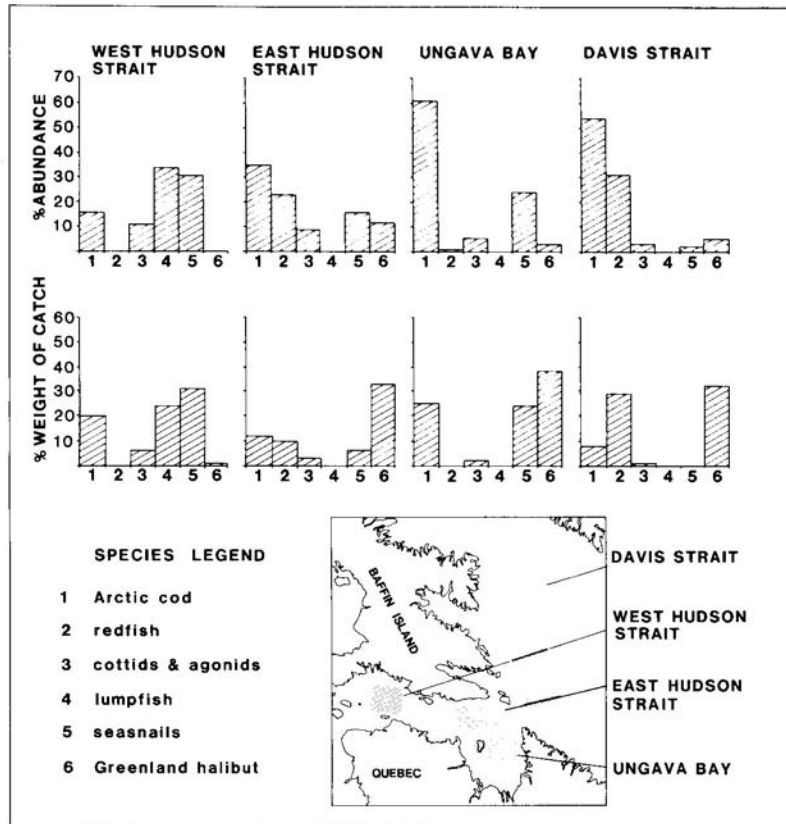


Figure 15.2. Catch composition by bottom trawls of dominant fish species and taxa in Davis Strait, East and West Hudson Strait and Ungava Bay. Upper set of histograms shows composition of catch of major species and fish taxa based on their portion of the total number of fish caught (% abundance). Lower set of histograms shows composition based on the weight of each species or taxon in relation to the total weight of catch (% weight of catch).

The reduction in diversification of feeding modes and the concomitant change in species composition and reduction in species richness and biomass occurring in western Hudson Strait and Hudson Bay may be related to the colder and more shallow conditions that prevail in Hudson Bay. Dunbar (1958) reported that the upper 100 m of water along the northern shore of Hudson Strait receives very cold water in July (-1.5°C). At depths below 100 m, Hudson Strait and Ungava Bay receive warmer, more saline water; however, this warmer water dissipates in western Hudson Strait and is absent from Hudson Bay where the depth is insufficient for it to penetrate further westward.

Estuarine and Coastal

Fish communities in six estuaries located along approximately 900 km of eastern James and Hudson Bay are dominated by Salmonidae, Catostomidae, and Cottidae (Table 15.6). The number of freshwater species is reduced towards the north. Such a pattern may be due, in part, to the nature and extent of post-glacial dispersion into the region as discussed in the previous section. However, in the smaller rivers of the Hudson Bay where the distance from the river mouth to the first impassable barrier is less than in rivers of James Bay, stenohaline freshwater species may be absent because of lack of adequate habitat or competition with euryhaline species. The shorter and more variable growing seasons of Hudson Bay may also limit certain freshwater species.

Factors such as temperature and salinity that influence latitudinal variations in community structure also influence the structure of estuarine communities on a seasonal basis (Lambert and Dodson, 1982a). The brackish zone of the Eastmain River, situated in a radius of several kilometers around the river mouth, varied in temperature from 6.5° to 16°C and in salinity from 1 to 17 ppt throughout the 1979 sampling season. This zone was dominated by anadromous cisco (Coregonus artedii) and fourhorn sculpin (Myoxocephalus quadricornis) throughout the entire season. Ogac and shorthorn sculpin (M. scorpius), present in this zone principally in the spring, disperse offshore in the colder waters of James Bay as coastal temperatures increase. Inversely, anadromous brook trout become more abundant in the brackish zone as temperatures increase and as their fall spawning period approaches. Capelin (Mallotus villosus) are present in the brackish zone at the end of June while spawning inshore. The freshwater zone, including the river mouth and the first 5 km of river, varied in temperature from 8° to 18°C with salinity rarely exceeding 1 ppt. This zone is dominated by longnose sucker (Catostomus catostomus) throughout the entire season. Walleye (Stizostedion vitreum) are abundant at the river mouth in June and July. The large majority of walleye are immatures of two to five years of age and their

TABLE 15.6

Species composition and relative abundance in six rivers and estuaries of eastern James-Hudson Bay. The relative abundance of fish in each estuary is based on the percentage of total catch from gill nets. Asterisks indicate the presence of species only, as revealed by all other sampling methods. (adapted from Morin et al., 1980).

Species	Estuary					
	Rupert's Bay	Eastmain	La Grande	Great Whale	Little Whale	Innuksuac
Acipenseridae						
<i>Acipenser fulvescens</i>	<1.0	<1.0	<1.0			
Clupeidae						
<i>Clupea harengus</i>						<1.0
Salmonidae						
<i>Salmo salar</i>						<1.0
<i>Salvelinus alpinus</i>						2.7
<i>S. fontinalis</i>	<1.0	2.4	1.8	20.2	28.0	10.2
<i>S. namaycush</i>					<1.0	2.4
<i>Coregonus artedii</i>	6.3	42.1	25.1	6.7	4.1	<1.0
<i>C. clupeaformis</i>	7.1	15.8	8.4	6.3	15.9	34.1
<i>Prosopium cylindraceum</i>		*	6.4	3.9	2.6	3.0
Osmeridae						
<i>Mallotus villosus</i>	*	<1.0	17.2	1.3	19.7	3.3
Ammodytidae						
<i>Ammodytes hexapterus</i>	*	*	*	*	*	*
<i>A. dubius</i>				<1.0	<1.0	
Stichaeidae						
<i>Lumpenus fabricii</i>			*	*	*	
Hiodontidae						
<i>Hiodon tergisus</i>	<1.0					
Esocidae						
<i>Esox lucius</i>	<1.0	4.2	<1.0	<1.0	<1.0	
Cyprinidae						
<i>Couesius plumbeus</i>	*	<1.0	<1.0	3.2	1.2	
<i>Notropis atherinoides</i>			*			
<i>N. hudsonius</i>	*	*	*			
<i>Rhinichthys cataractae</i>		*	*			
<i>Semotilus corporalis</i>	*	<1.0				
<i>S. margarita</i>			*			
Catostomidae						
<i>Catostomus catostomus</i>	52.6	12.6	27.4	30.6	15.4	
<i>C. commersoni</i>	6.0	1.4	1.0	<1.0		1.5
Gadidae						
<i>Gadus ogac</i>		<1.0	<1.0	5.2	1.2	25.4
<i>Lota lota</i>	*	<1.0	<1.0	<1.0	<1.0	1.4
Gasterosteidae						
<i>Culaea inconstans</i>			*			
<i>Gasterosteus aculeatus</i>	<1.0	*	*	*	*	*
<i>Pungitius pungitius</i>		*	*			
Percopsidae						
<i>Percopsis omiscomaycus</i>	<1.0	<1.0	<1.0	*	*	*
Percidae						
<i>Perca flavescens</i>		<1.0				
<i>Stizostedion canadense</i>	*					
<i>S. vitreum</i>	24.8	10.4	<1.0			
Cottidae						
<i>Cottus bairdi</i>		*				

Species	Rupert's Bay	Eastmain	La Grande	Great Whale	Little Whale	Innuksuac
<u>C. cognatus</u>		*	*			*
<u>C. ricei</u>	<1.0					
<u>Myoxocephalus quadricornis</u>	1.2	7.0	8.2	18.4	3.3	11.4
<u>M. scorpioides</u>		<1.0	<1.0		<1.0	
<u>M. scorpius</u>		<1.0	1.5	2.8	6.4	3.5

presence along the upstream limit of salt intrusion is clearly associated with feeding on threespine and ninespine sticklebacks (Gasterosteus aculeatus and Pungitius pungitius, respectively) both of which are abundant in the estuary throughout the season. Colder temperatures in early spring and fall and localized variations in the intrusion of saltwater limit the extent and duration to which walleye exploit estuarine food resources (Belzile and Dodson, 1984).

Of equal importance to physiological constraints in determining community structure is the role that large rivers play in shaping trophic dynamics, an aspect that has not been elaborated in coastal and marine studies of James Bay. Organic carbon originating from allochthonous sources may influence fish production in estuaries (deSilva, 1975, Sibert et al., 1978). This may apply to estuaries of James Bay where forested watersheds provide seasonal input of large woody debris and particulate organic matter. The same trophic process may not occur in the tundra regions of Hudson Bay and Hudson Strait, based on comparison with trophic processes in Simpson Lagoon of the Alaska Beaufort Sea. Although terrestrial organic carbon from peat exceeds primary production in inshore waters of the lagoon (<10 km from shore), isotopic analyses indicate that peat carbon is not efficiently utilized in the marine food web and does not contribute to marine fish production. However, peat carbon is important in the freshwater food web, forming the basis for the production of obligate freshwater and anadromous fishes in streams flowing into Simpson Lagoon (Schell, 1983; Craig et al., 1984).

Some evidence suggests that terrestrial carbon sources may be important in the nearshore marine environment of James Bay. The dominant marine species in estuaries of James Bay, fourhorn sculpin (Myoxocephalus quadricornis), is a benthic fish that consumes mainly amphipods and molluscs, organisms that may process organic matter directly or through bacterial action. Of 74 fourhorn sculpin sampled in the estuary of the Eastmain River in 1979, 69 (93%) had ingested amphipods (Gammarus oceanicus, Gammarus sp.,

Onisimus litoralis, Gammaracanthus loricatus, Atylus carinalus, Ischyrocerus anguipes, Pontoporeia femorata) (Y. Lambert, unpublished data). Amphipods appeared alone in the diets of the sampled sculpin in 54 cases (73%) and plant material appeared in 11 stomachs (15%). The remaining prey, consisting of molluscs, insects, mysids, polychaetes and fish, appeared in less than 10% of the sculpins sampled.

Summary

The physical processes that shape the marine environment and its biotic processes also influence fish community structure. For example, the freshwater mass of James Bay limits the presence of marine species due to the physiological stress of low salinity and elevated water temperature in summer. As a result, predatory niches in estuaries of southern James Bay are occupied by freshwater species such as walleye, whereas similar niches in Hudson Bay are filled by marine and more euryhaline species such as ogac and brook trout (Morin et al., 1980).

At present we lack knowledge of the food chains leading to fish production in offshore waters of Hudson Bay. Phytoplankton biomass and primary production are low in central Hudson Bay. This is mainly caused by persistent vertical stability of the water column which restricts nutrient cycling (Roff and Legendre, 1986). It may be assumed that primary production forms the basis for fish production in this region. In estuaries and in coastal regions, particularly along the forested watersheds of James Bay, allochthonous organic matter may contribute significantly as a source of organic carbon. Considerable research is required to understand the mechanisms of trophic processes and to provide reasonable measures of biomass and production of the main components of the food chain.

REPRESENTATIVE LIFE CYCLES

James Bay and Hudson Bay have been the site of studies on the biology of individual fish species only since the 1970s, coincident with the development of the hydroelectric potential of the area's rivers. Our knowledge of the life cycles of marine fishes is still poor, although some progress is reported here for ogac. In the case of the euryhaline fishes of coastal waters, we are able to describe in detail the life cycles and ecology of the coregonines represented here by two species that are prominent in estuarine fish communities throughout eastern and western James-Hudson Bay. Other sources of information are available for anadromous salmonids in the region. Dutil and Power (1980) studied the biology of anadromous brook trout in Richmond Gulf (Lac Guillaume-Delisle) and Gaboury (1980) documented the biology of anadromous and non-migratory brook trout in the lower Nelson River

area, Manitoba. Greendale and Hunter (1978) described their feeding in the lower La Grande River and estuary, James Bay. Information on the Arctic charr and Atlantic salmon of Ungava Bay is reported by Jessop et al. (1970), Power (1969), Lee (1969) and Gillis et al. (1982). Sprules (1952) described the ecology of Arctic charr in coastal and land-locked populations near Tern Point in northwestern Hudson Bay. More detailed information on the life cycle of anadromous Arctic charr is reported from northern Labrador (Dempson and Green, 1985), from the literature review by Johnson (1980) and in the recent volume edited by Johnson and Burns (1984).

Ogac

Ogac (Gadus ogac) are physiologically adapted to Arctic conditions. Their blood-serum freezing point has been recorded as low as -2.17°C and is attributed to the presence of glycoproteins that act as a biological antifreeze (Van Voorhies et al., 1978). Ogac do not move to warmer offshore waters in winter as do Atlantic cod (G. morhua) due to their capacity to tolerate cold water. They are found among the southerly islands of the Canadian Arctic Ocean and from Point Barrow in the west to west Greenland waters in the east (Hunter et al., 1984; Leim and Scott, 1966). Ogac are also tolerant of low salinities and moderate temperatures enabling them to penetrate into southern James Bay where they are found throughout coastal waters as far south as islands below the mouth of the Eastmain River (Melville, 1915; Lower, 1915). Ogac are also present along the coast of Labrador, in the northern Gulf of St. Lawrence and occasionally further south (Scott, 1952).

Ogac in Greenland waters mature after three to four years of age and attain a maximum age of 11 years (Jensen, 1948). Collections from James Bay in 1974 indicate that ogac can attain 21 years of age (Morin, unpublished data). Jensen (1948) reported that spawning occurs during February and March in Greenland waters. Ochman (1982) found yolk-sac ogac larvae in July in the vicinity of the Eastman River, which suggests that spawning occurs later than reported by Jensen. The maximum size of ogac is 5 kg in the central Arctic (Cambridge Bay) and 1.5 kg in James Bay.

Ogac were sampled within 2 km of the mouth of the Innuksuac River in Hudson Bay from July to late September, 1977 (Morin et al., 1980). Ogac were captured at most stations in the Innuksuac estuary and formed over 25% of the catch from gill nets. Although it was the dominant marine species in gill-net collections, the abundance of ogac in the Innuksuac estuary diminished throughout the summer. Lambert and Dodson (1982a) observed the same seasonal pattern in the estuary of the Eastmain River in James Bay. They attributed the decline in abundance of cod during the summer to a

response to the progressive warming of the coastal waters.

Ogac are opportunistic feeders, consuming a range of organisms including fish, crustaceans, echinoderms, molluscs and polychaetes (Jensen, 1948). The stomachs of 126 ogac were examined from the Innuksuac estuary in 1977. Fish and amphipods were the main components of the diet. Fish appeared in 64 (51%) of the stomachs examined and amphipods appeared in 50 stomachs (40%). The fish species preyed upon included mostly marine species such as capelin, sand lance, sculpin (Myoxocephalus sp.) and small ogac; however, brackish-water species were also found, such as white sucker (Catostomus commersoni) and lake whitefish (Coregonus clupeaformis). Other groups of organisms consumed included zooplankton (appearing in 13% of all stomachs), polychaetes (8%) and molluscs (4%). Plant detritus appeared in 4% of the stomachs examined. A more detailed examination of diet was made of 14 ogac taken in the outer estuary of the Eastmain River during 1979 and 1980 (Y. Lambert, pers. comm.). The main components of the diet were also fish, amphipods and zooplankton. Among the fish consumed were capelin (Mallotus villosus), sand lance (Ammodytes spp.), fourhorn sculpin (M. quadricornis), threespine stickleback (Gasterosteus aculeatus) and ninespine stickleback (Pungitius pungitius). Amphipods included Gammarus oceanicus and Gammaracanthus loricatus. Mysis mixta was the only zooplankter recorded. Three species of marine molluscs were found: Mytilus edulis, Macoma balthica and Astarte sp.

The analysis of the stomach contents of ogac in James Bay and Hudson Bay suggest a fairly consistent diet of benthic invertebrates and fish, although more data are required to confirm this. Chaput (1981) analyzed the diets of ogac at two sites on the coast of southern Labrador. Ogac sampled at depths similar to sampling locations in James-Hudson Bay displayed similar feeding habits. Shrimp and polychaetes appeared most frequently in the stomachs at two sites along southern Labrador, followed by fish and gammarid amphipods. At both locations fish, mostly sculpins and seasnails, constituted most of the weight and volume of consumed prey.

The widespread occurrence of ogac throughout the region led us to predict enhanced growth and abundance of ogac populations in James Bay where the water is warmer and marine competitors fewer than in the Arctic Ocean. Available data does not support such a pattern. It appears that ogac are less abundant in southern estuaries than in northern Hudson Bay (Table 15.6), although sampling has not been extensive. A comparison of the body growth of **ogac in James Bay (Eastmain River estuary, latitude 52°15')**, **Hudson Bay (Innuksuac River estuary, latitude 58°26')** and the central Arctic (Coronation Gulf, latitude 68°) shows that the growth of ogac is remarkably similar at

the three locations (Fig. 15.3). However, ogac attain larger sizes at each age class in west Greenland waters (Fig. 15.3; Hansen, 1943).

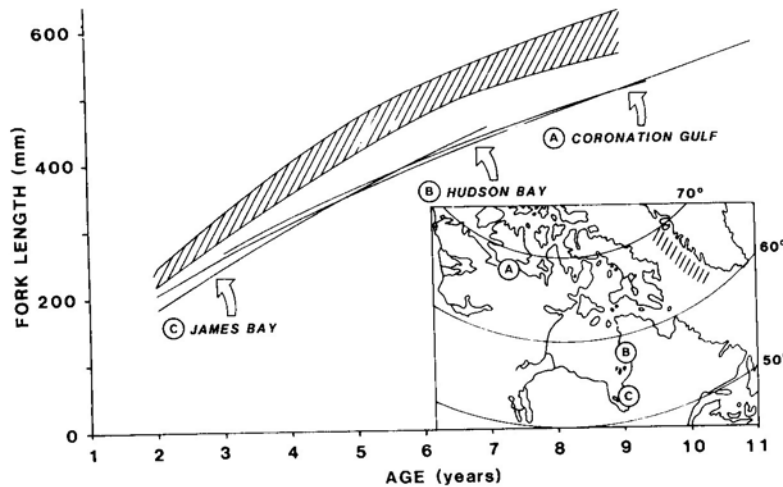


Figure 15.3. A comparison of the growth of ogac (*Gadus ogac*) at four sites: central Arctic (Coronation Gulf), Hudson Bay (Innuksuac River estuary), James Bay (Eastmain River estuary) and west Greenland. Growth curves are based on regressions of the form $\log FL = a + b \log \text{Age}$. For Arctic sample, $a = 2.1518$; $b = 0.5775$; $n = 78$ and r (correlation coefficient) = 0.79. For Hudson Bay sample, $a = 2.1345$; $b = 0.5973$; $n = 88$; $r = 0.90$. For James Bay, $a = 2.0405$; $b = 0.7302$; $n = 21$; $r = 0.95$.

The relative constancy of the feeding, growth and longevity of ogac within the inland seas is in contrast to the highly variable life-history patterns of the coastal whitefish species, described in the following section. At present there is no explanation for this apparent difference between widespread marine and euryhaline species.

The Anadromous Coregonines

A major faunal component of most of the estuarine fish communities presented in Table 15.6 is represented by two anadromous coregonines, the cisco (*Coregonus artedii*) and the lake whitefish (*Coregonus clupeaformis*). The relative abundance of the two species changes along the coastline, with cisco dominant in the Eastmain and La Grande estuaries and whitefish dominant in the north of the range (Table 15.6). Neither species is very abundant in Rupert Bay, a large and shallow tidal basin in which the freshwater plumes of three rivers (Nottaway, Broadback and Rupert) blend with the offshore water mass. Rupert Bay is dominated by longnose sucker (*Catostomus*

catostomus) that alone represents 53% of gill net collections (Table 15.6). Cisco approach their northern limit in the Innuksuac River. The gradient in relative abundance is associated with a change in climate along the coastline. The growing season (mean daily temperature $>5.6^{\circ}\text{C}$) ranges from 140 days at Rupert Bay to 80 days at the Innuksuac River (Wilson, 1971).

In the La Grande and Eastmain rivers lake whitefish spawn near the base of rapids located approximately 30 km upriver in mid-October as temperatures decline below 5°C (Morin et al., 1981; Levesque and Cossette, 1983). Cisco spawn in the same areas in early November as the rivers freeze. The spring hatching period of both species coincides with spring thaw and larvae are flushed from the rivers into James Bay. The peak of the passive migration of coregonine larvae through the Eastmain estuary in 1980 occurred during the first two weeks after ice break-up and was associated with the passive migration of burbot Lota lota (Ochman and Dodson, 1982). The spring transport of fish larvae to James Bay appears to be a mechanism to exploit the greater availability of food in the bay than in the river. No coregonine larvae captured in the river possessed gut contents. In ice-covered seas, the diatoms present under the ice and released during spring melt are a potential food source for larvae arriving early in the spring. The subsequent absence of larvae in shallow coastal areas of James Bay and at the mouth of the Eastmain River suggests that larvae are transported far offshore, probably in conjunction with the melting pack ice that remains in the bay until late June. In July, coregonine fry are taken at the river mouth and in shallow inshore areas (Ochman and Dodson, 1982).

During September and October, juveniles and non-reproductive adults of both species enter the lower reaches of the rivers where they pass the winter (Morin et al., 1981; Roy, 1982). Such movements closely resemble the overwintering movements of the Arctic cisco (C. autumnalis) in the Barents and Kara seas (Burkov and Solovkina, 1976) and those of the migratory whitefish (C. lavaretus) in the Gulf of Finland (Ikonen, 1982). Cisco that overwinter in the La Grande and Eastmain rivers tend to concentrate near the river mouths whereas overwintering lake whitefish are found throughout the rivers up to and including the spawning grounds. During the following spring, both species migrate from the rivers to feed in James Bay.

The upstream migration of mature fish, beginning between mid-July and mid-August, is prolonged and meandering. Gill nets set in the upper estuary of the Eastmain River during 1983 revealed several peaks in cisco and whitefish catches as schools of fish migrated upriver to spawning sites. The time elapsed between the passage of these peaks at two locations revealed an average rate of upstream displacement in the river estuary of 1.9 km per day in the case of cisco and 0.7 km per day in the case of lake whitefish (Dodson

et al., 1986). As over 50% of the whitefish captured at the first rapids had full stomachs, the meandering nature of the whitefish migration may be due in part to feeding. Cisco do not feed while migrating in freshwater.

Although cisco do not spawn until the beginning of November, they migrate to rapids located below spawning sites in the Eastmain River in early September. They subsequently wait at least two months on the spawning grounds without feeding (Dodson et al., 1986). Lake whitefish, however, traverse the rapids throughout early September for spawning in October. Low temperatures lead to poor swimming capacity in coregonines by diminishing their oxygen uptake and metabolic scope for activity, thus reducing their swimming endurance and performance (Bernatchez and Dodson, 1985). Therefore low temperatures and high water velocities encountered in rapids downstream of spawning sites may be more important factors than spawning temperature in controlling the early upstream migration of coregonines. In the case of the smaller cisco, current speeds in the rapids may exceed maximum theoretical swimming speeds as temperatures decline to 7°C (Dodson et al., 1986).

The summer movements and distribution of anadromous coregonines in James and Hudson Bay are poorly documented. Summer catches of adult cisco are low but increase in abundance at the mouth of the Eastmain River and along the coast north of the river in late July as mature fish begin their reproductive migrations (Lambert and Dodson, 1982b). Tagging studies conducted in the Eastmain and La Grande rivers revealed far-ranging summer movements, predominantly northwards along the coast (Morin et al., 1981). The longest displacement of cisco recorded by tagging was 66 km from the first rapids of La Grande River to the coast of James Bay. Similarly, lake whitefish catches along the coast north of the Eastmain and La Grande rivers during summer indicate lengthy feeding migrations to coastal James Bay. Berkes (1977, 1979) reported that during spring and summer, native Cree exploit the La Grande whitefish stock along James Bay at distances up to 15 km from the river mouth.

Growth and Reproduction. Cisco and lake whitefish exhibit different growth patterns over their range in eastern James-Hudson Bay range (Fig.15.4). In most rivers for which adequate data are available, length at age of whitefish is approximately twice as variable as it is for cisco. Within rivers, growth rates of cisco and whitefish are generally similar during the first five to seven years of life. The growth of cisco subsequently declines and whitefish attain the greatest maximum length and age. For example, whitefish sampled in the La Grande River during 1974 had a maximum age of 17 years and a maximum fork length of 446 mm compared to 13 years and 367 mm for cisco (Morin et al., 1982).

The growth of cisco diminishes in the north of its James-Hudson Bay range. Cisco are significantly smaller in Richmond Gulf than in more southern estuaries over four of the first five year classes, and limited data from the Innuksuac population indicates further reductions in growth north of Richmond Gulf (Fig. 15.4; Morin et al., 1982). A similar analysis of lake whitefish indicated significant differences in length between rivers in five of the first eight year classes tested, but such variations did not appear to reflect a latitudinal trend.

Our knowledge of the environmental control and adaptive significance of coregonine growth patterns remains sketchy despite the existence of numerous manuscript reports describing their growth in the north. One major problem in the interpretation of published growth rates is that age determination by the scale method frequently underestimates the age of older fish, a problem that is particularly acute in the case of long-lived northern species

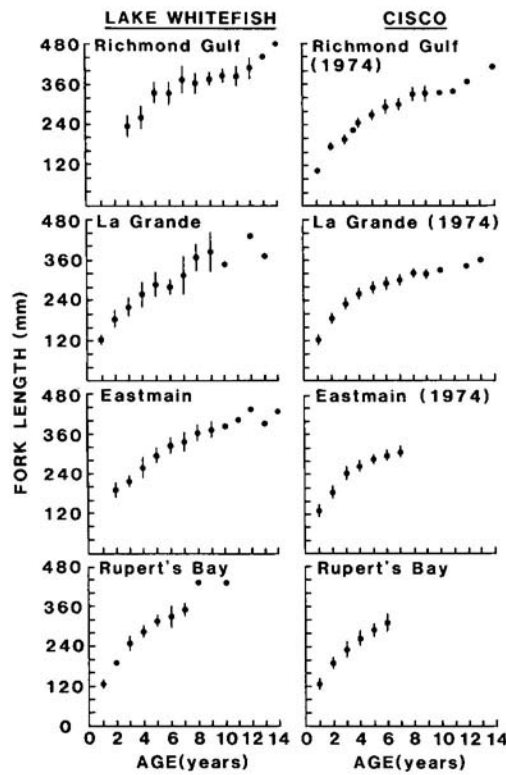


Figure 15.4. A comparison of the growth of the anadromous lake whitefish (*Coregonus clupeaformis*) and cisco (*C. artedii*) at sites in eastern James-Hudson Bay. The mean fork length and standard deviation of each age class is shown. Standard deviations were calculated for sample sizes greater than five.

(Power, 1978; Morin, 1980). This problem is resolved, in the case of northern salmonid species, by the use of otoliths for age determination. A second problem in the interpretation of length at age data of anadromous coregonines is associated with fishing effort and the heterogeneous distribution of length classes. Lake whitefish captured at the rapids of La Grande River in 1974 were significantly longer than whitefish captured at the river mouth in the same year for fish five years of age and older (Morin et al., 1982). This was attributed to the upstream migration of larger and more mature individuals for autumn spawning. Thus, fishing effort that is localized in time and space may lead to considerable bias in calculating growth.

The reproductive efforts of cisco and lake whitefish are also variable over the James Bay and Hudson Bay range. There is no simple criterion for identifying the age of maturity because coregonines, like many other northern fish species, do not spawn yearly. The percentage of maturing fish usually increases as the fish grow older until it peaks at an age and maximum percentage determined by the age of first maturity and the frequency of spawning. Using these criteria, it is evident that cisco mature earlier than lake whitefish because within rivers cisco exhibit a greater percentage of maturing females for year classes 3 to 7 than do lake whitefish (Fig. 15.5). In 1973, the most abundant year class for female cisco on the La Grande spawning grounds was five years, while six and seven-year-old females were most abundant among lake whitefish (Morin et al., 1982). Such differences in age are also reflected in length differences. In the Eastmain River, the minimum length at which cisco mature is 26 cm compared to 32 cm for lake whitefish (Lambert and Dodson, 1982b).

The age-specific reproductive effort of cisco diminishes in the north of its range, with fewer mature females in all age groups from La Grande and Richmond Gulf than from the Eastmain River (Fig. 15.5). In the case of whitefish, percent maturity in the older age groups remained more or less constant for all populations. There were, however, more young mature females in the Eastmain population and fewer northwards.

In James Bay rivers where the two species cohabit, cisco exhibit a more intense reproductive effort than lake whitefish. This is supported by analyses of the relationship between fecundity and net body weight (Morin et al., 1982; Dodson et al., 1986). In the La Grande and Eastmain rivers, cisco were significantly more fecund than lake whitefish sampled in the same years. Interpopulation comparisons have been more difficult to interpret, particularly for cisco which exhibit highly variable fecundity between years in the same population. At present, there is no evidence of a latitudinal trend in cisco fecundity. In the case of lake whitefish, fecundity in Richmond Gulf was lower than in La Grande and Eastmain populations which

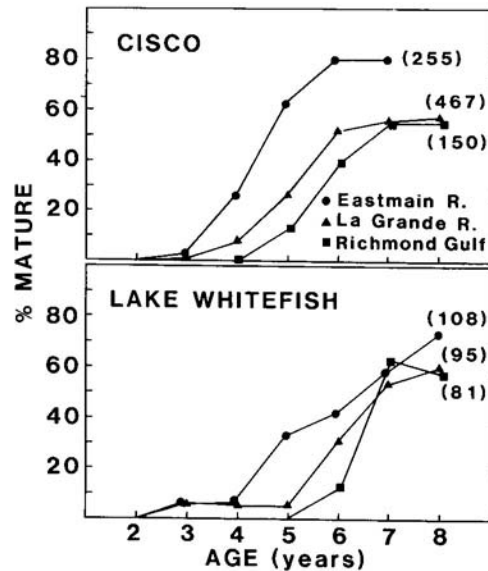


Figure 15.5. The percentage of mature females of anadromous cisco (*Coregonus artedii*) and lake whitefish (*C. clupeaformis*) in rivers along eastern James-Hudson Bay.

suggests a northward decline in fecundity.

The combined observations of growth and reproduction illustrate that cisco and lake whitefish exhibit different life-history strategies in response to identical sets of environmental conditions (rivers) encountered over their range in eastern James-Hudson Bay. Although the growth of both species diminishes following the approximate age of first reproduction, cisco mature at a smaller size, exhibit a greater percentage of mature females per age class, exhibit greater fecundity and a shorter life span than lake whitefish. Although lake whitefish mature at a greater size and exhibit a lower percentage of mature females per age class, their longevity may permit more potential lifetime maturation cycles. As cisco approach the northern limit of their distribution in Hudson Bay, reduced growth may occur because of shorter growing seasons and age-specific reproductive maturation may be reduced due to diminished growth. Data concerning egg production and the longevity of cisco in Hudson Bay are insufficient to evaluate whether fecundity and life-time reproductive effort are also reduced. The observed changes in cisco's growth and reproduction thus may not represent an adaptive strategy (*sensu* Wootton, 1984) but physiological responses to a decreasing energy budget. In contrast, lake whitefish apparently reduce fecundity in the north independent of variations in growth and maintain the percentage of reproductive maturation within those age classes comprising the majority of

the population's reproductive females. These observations constitute limited evidence for an adaptive strategy, a conclusion supported by the observation that lake whitefish maintain their abundance along the coast of Hudson Bay (Table 15.6).

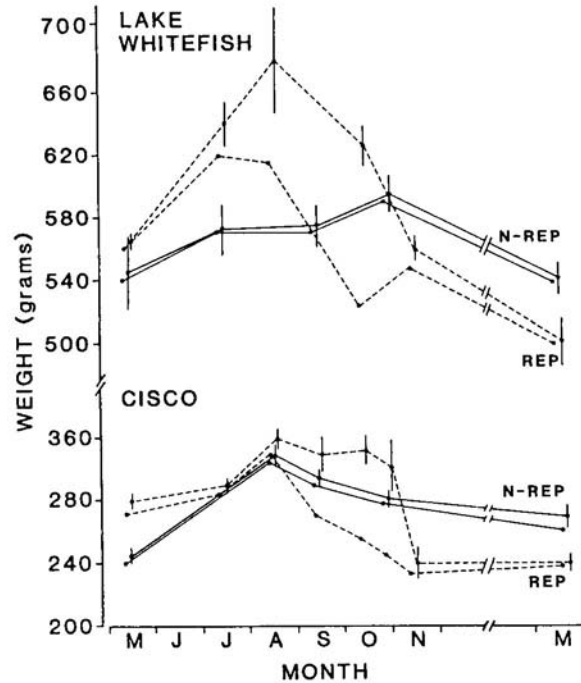


Figure 15.6. Total and net weight of standard reproductive (REP, dashed lines) and non-reproductive (N-Rep, solid lines) female cisco (*Coregonus artedii*) and female lake whitefish (*C. clupeaformis*) sampled during 1982 and 1983 along their migratory route. The standard fork length for cisco is 29 cm and for lake whitefish 36 cm. In the case of both REP and N-REP fish, upper line indicates total weight, lower line indicates net weight (total weight - weight of gonadal tissues). Vertical bars indicate standard deviations of total weight. (from Dodson et al. 1986).

The bioenergetic mechanism underlying the contrasting patterns of growth and reproduction exhibited by the anadromous coregonines is reflected in the dynamics of weight gain and loss associated with reproduction and migration. Non-reproductive cisco accumulate somatic weight during the growing season. This accumulated reserve is subsequently invested by reproductive individuals in gonads and other reproductive activities (Fig. 15.6; Dodson et al., 1986). This reserve represents 15.7% of the total dry weight of reproductive individuals. Female cisco invest 25.6% of their total dry weight in gonads.

The reduction in total weight of reproductive cisco due to spawning and overwintering suggests that spent fish surviving to the next spring must accumulate somatic weight during at least one summer, assuming that length increase is minimal, before adequate reserves are available for repeat spawning. In addition, spawning appears to contribute to mortality related to overwintering. Whereas surviving non-reproductive female cisco lose 5% of their somatic weight during the winter, surviving spent fish apparently lose no weight. Although observed weight loss over winter is a biased estimate of the absolute cost of overwintering because of selective mortality, the apparent lack of weight loss for spent fish relative to non-reproductive fish suggests that overwintering mortality is greatest among spent fish with only those in the best condition surviving.

Lake whitefish exhibit a pattern similar to that of cisco whereby non-reproductive individuals accumulate somatic weight and subsequently invest it in gonads and other reproductive activities. However, the accumulated reserve, which represents 11.8% of the total dry weight of reproductive females, appears to be less important for lake whitefish than for cisco because of the greater minimum body size that lake whitefish attain before maturation. The lower fecundity of lake whitefish relative to cisco is reflected in the slightly lower proportion of total resources invested in gonads (22% dry weight). After spawning, lake whitefish lose proportionately less weight than cisco (Fig. 15.6). Spent female lake whitefish sampled in the Eastmain River during the spring of 1982 had somatic reserves similar to females that had not spawned, although a difference between the two groups was observed one year later. Furthermore, weight losses of surviving spent and non-reproductive female lake whitefish are similar, indicating that winter mortality is similar for the two groups.

Evidence in support of the hypothesis that cisco suffer greater mortality than lake whitefish is provided by the analysis of catch curves (Fig. 15.7). In the case of lake whitefish, the interpretation of the catch curve (Ricker, 1975) indicates a low mortality rate in combination with a diminishing growth rate that causes the piling up and apparent increased abundance of reproductive fish (>32 cm) relative to smaller length classes. The cisco catch curve indicates a high mortality rate after maturity (26 cm) in combination with a diminishing growth rate that causes a steeply descending right limb of the curve. As the native fishing effort in the vicinity of the Eastmain River is light, these differences are not due to differential fishing effort on cisco but reflect the higher post-spawning mortality of cisco relative to whitefish.

The major conclusion to be drawn from this consideration of growth and reproduction is that the later age and greater size at maturity exhibited by

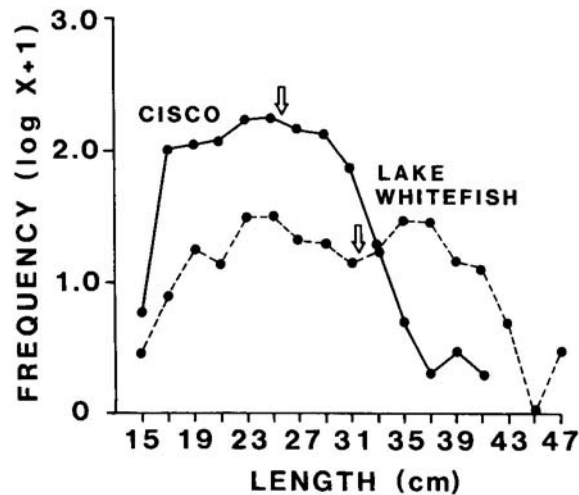


Figure 15.7. Logarithms of the number of cisco (solid line) and lake whitefish (dashed line) in 2-cm length classes from gill net collections in the Eastmain River and estuary in 1980. Vertical arrows indicate length of fish at onset of maturity. The ascending left limb of the curves represents length classes incompletely sampled by gill nets.

Lake whitefish appear to be associated with lower mortality and the spreading out of total reproductive effort over a longer life span. This strategy is associated with greater abundance relative to cisco in Hudson Bay. Several authors have noted a general trend among northern fishes to reduce fecundity and increase the life-time frequency of spawning (Nikolskii, 1970; Leggett and Carscadden, 1978), yet the mechanism underlying such adaptations has not been clearly defined. Protopopov (1982) documented a pattern of growth and reproduction for the semimigratory Volkhov whitefish (*Coregonus lavaretus pidschian*) that is strikingly similar to that of anadromous lake whitefish. The majority of Volkhov whitefish start spawning at a length of 31 to 36 cm and a weight of 400 to 700 g. As growth is variable, age at maturity extends from five to ten years of age. Protopopov (1982) suggested that the range of length and weight in first spawners is due to the interaction between growth, fat accumulation and maturation, with the most rapidly growing fish attaining maturity first. Nikolskii (1969) has noted that conditions permitting rapid growth result in early maturation and increased fecundity. Thorpe et al. (1984) demonstrated that young Atlantic salmon (*Salmo salar*) which have developed more rapidly in freshwater produced more eggs at any given body size than slower developers and cited two studies reporting similar results for brook trout (*Salvelinus fontinalis*) and rainbow

trout (Salmo gairdneri). Taken together, these observations lead to the speculation that highly variable growth rates, as exhibited particularly by lake whitefish, may generate a variety of life-history pathways characterized by different age-specific schedules of maturation, fecundity and longevity. Such multiple life-history pathways within a population would represent an important source of stability in the face of variable or unpredictable environments. Good years or habitats may favor rapid growth and early reproduction of many young whereas poor years or habitats may lead to diminished growth, delayed maturation and smaller reproductive effort permitting proportionately greater investment of resources in maintenance, growth and future fecundity. The problem of the environmental and physiological control of growth and its relation to reproduction remains largely unsolved and of major interest in the biology of anadromous coregonines and many other northern fish species.

RESEARCH AND MANAGEMENT

In this chapter we have referred to areas of research in which information is lacking on the fishes of Canada's northern inland seas. We outline here three primary objectives for future research and then relate these to developing issues in research and management.

1. Systematic and thorough sampling of the marine fish fauna is required, particularly in Foxe Basin, Hudson Bay and James Bay. The objective is to determine what marine species are present and how they occur together as assemblages.
2. The life cycles of the Arctic fishes are poorly understood, particularly for marine species. Consequently, the effects of environmental perturbations and exploitation can rarely be ascertained. It is important to know the general life cycles of the dominant species, including their seasonal movements, reproductive schedules, salinity and temperature preferences, growth, population age structure and feeding habits.
3. An integrated approach is required to understand the processes controlling fish production in different regions of the northern inland seas. This approach requires the consideration of fish as components of ecosystem processes. The objective of this research is to describe the food chains leading to fish production, thereby determining the trophic basis for fish production.

Measures of abundance, biomass and production are difficult to attain for fish in the northern inland seas, even for the locally abundant coastal fish stocks. This is mainly due to the dispersed seasonal occurrence of fish, and in the case of marine species, the absence of any substantial

exploitation from which to measure population parameters. The research objectives outlined above provide a basis for obtaining such information.

Mills (1984) has listed 15 marine conservation issues relating to non-renewable resource development in the Arctic. The growing diversity and complexity of environmental issues in the Arctic are increasingly relevant to Canada's northern inland seas. It is important to foresee the development of a reasonable database on the fish resources of the northern seas and the theoretical tools to interpret and predict trends.

The fisheries potential of James-Hudson Bay was a subject of speculation until the earlier part of this century, but the prospects for commercial exploitation have since been rightfully laid to rest (Hunter, 1968; Dunbar, 1970). However, in doing so we have overlooked the importance of the fishery that has always existed in this region. During the 1970s detailed inventories were made of the harvests of Cree and Inuit in communities encompassed by the James Bay and Northern Québec Agreement. Within the same region, Berkes (1977, 1979) described the methods that Cree have developed to exploit fish in eastern James Bay. Cree and Inuit throughout the north have developed an efficient and complex set of practices for exploiting the fish resources (Berkes and Freeman, 1986).

In spite of the many cultural changes that have occurred in northern native communities over the past 40 years, the dietary habits of Cree and Inuit continue to include the local fish and game as the primary source of protein and fat. Figure 15.8 shows the pattern of exploitation of major coastal and marine fishes in communities throughout eastern James-Hudson Bay and Ungava Bay. The composition of the domestic fishery indicates a shifting pattern of exploitation based principally on the anadromous species, being whitefishes in James Bay and southern Hudson Bay, Arctic charr in northern Hudson Bay, and Atlantic salmon and Arctic charr in Ungava Bay. This pattern partly reflects the makeup of fish communities, with the most concentrated biomass probably in the coastal anadromous stocks. It reflects, in part, a dependence on dominant species in coastal waters. However, abundant catostomids and cottids, for example, are avoided, while anadromous brook trout is actively sought in the La Grande estuary where it is not an abundant species (Table 15.6; Berkes, 1979). Although the fishery has never been known to fail, Berkes (1977) characterized the Cree fishery of Chisasibi (La Grande River) as large and successful, with the potential to modify fish populations.

Several factors suggest that native fisheries will acquire growing importance and necessitate a considerable research effort. The population of natives is growing and will likely double within the next 25 years. Given the difficult economic conditions of life in the north, high unemployment and

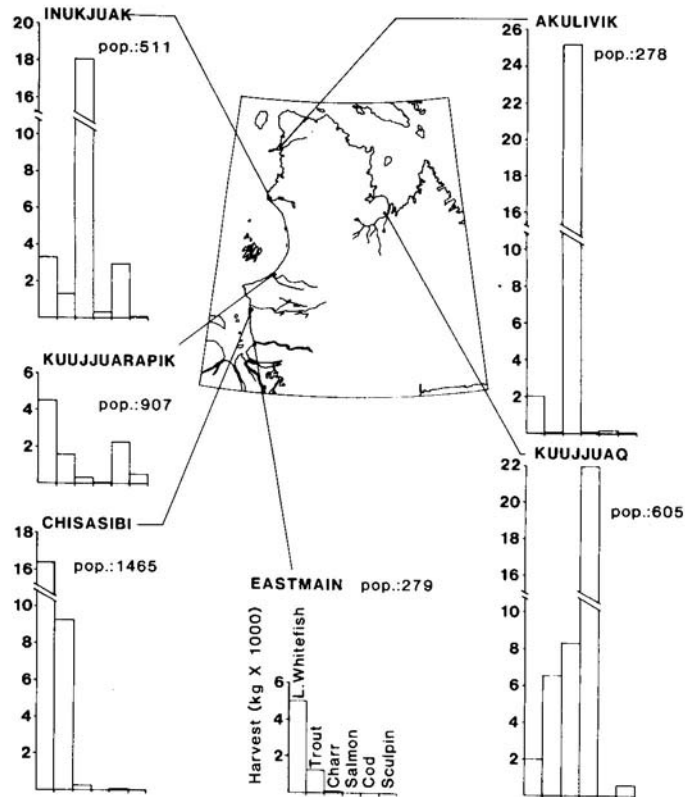


Figure 15.8. The exploitation of major anadromous and marine fish species by native subsistence fisheries in eastern James-Hudson Bay and Ungava Bay. The location of the communities is shown on centre map. The native population size is indicated, based on 1973 census for all communities but Akulivik (1982). Annual harvested weight of fish are the means of five or six years, based on surveys of Cree and Inuit fisheries in regions close to the community settlements.

the lack of diverse career opportunities, it is likely that traditional hunting and fishing patterns will continue. It will become increasingly necessary to seek management policies that are consistent with native fishing practices, to ensure the continuation of their traditions as the levels of exploitation increase. At present we lack vital population parameters on exploited fish stocks, including size, mortality and recruitment. Knowledge of the habitat requirements of important species is necessary. Combined with considerations of the adaptive characteristics of species in the region, it is possible to consider population enhancement programs, including habitat improvements and the extension of the range of appropriate species.

ACKNOWLEDGEMENTS

We wish to thank David Gillis (Makivik Corp.), Yvan Lambert (Université Laval) and Don E. McAllister (National Museums, Ottawa) for providing unpublished data for this chapter. Shirley Leach and Serge Higgins assisted in data analyses. Critical reviews were provided by Drs. F. Berkes, E.D. Crossman, E.H. Grainger, D.E. McAllister, G. Power and D. Barton, to whom we are sincerely grateful.

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