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COMPOSITION AND STRUCTURE OF THE LARVAL AND JUVENILE FISH COMMUNITY OF THE EASTMAIN RIVER AND ESTUARY, JAMES BAY[1]

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Résumé

La communauté de poissons d'âge 0 de l'estuaire de la rivière Eastmain (baie James) est hautement structurée, selon les dates d'éclosion des larves et, au plan spatial, selon la salinité. La structure de cette communauté durant la période mai-septembre est expliquée par le comportement pélagique ou démersal des larves, leur transport par les courants et le degré de tolérance à l'eau saumâtre des différentes espèces. L'effet à court terme du détournement de la rivière Eastmain fut le transport de larves caractéristiques de la baie James dans les parages de la rivière.

Abstract

The larval and juvenile fish community of the lower Eastmain river and estuary (James Bay) was highly structured both temporally by date of hatching and spatially by salinity. Community structure throughout the ice-free period is discussed as a function of the pelagic and/or demersal behaviour of larvae after hatching, their transport by currents and the degree to which each species is euryhaline. The major short term effect of the diversion of the Eastmain River was a transport of larvae characteristic of the bay into the river zone.

Introduction

James Bay is the largest inshore estuary in North America (McHugh, 1967), where surface water, derived mostly from local rivers, is warm and of low salinity in summer and bottom water from Hudson Bay is cold and more saline (Barber, 1972; Grainger & McSween, 1976). Low temperatures and low light availability during the ice-covered period from November to May (Larnder, 1968) create a physically stressed ecosystem.

The site of the present study was the Eastmain River which flows into a relatively shallow (less than 10 m) coastal area of James Bay with a low mean tidal amplitude (1 to 2 m). The discharge of the Eastmain River was reduced by approximately 85% in July 1980 as part of the James Bay hydroelectric development scheme. This caused an inflow of salt water from James Bay into the river giving rise to a partially mixed estuary (Ingram, 1982).

Although there are several studies dealing with adult fish in James and Hudson Bays (Dymond, 1933; Vladykov, 1933; Hunter *et al.*, 1976; Morin *et al.*, 1980), knowledge concerning the ecology of larval and juvenile fish in these areas is non-existent. The objectives of this study were to describe the species composition, abundance and seasonal sequence of larval and juvenile fish in the lower reaches and estuary of the Eastmain River. Potential effects of the river's diversion on the structure of the juvenile fish community are discussed.

Materials and methods

Fish larvae and juveniles were sampled from May to September in 1979 and in 1980 in three zones of the Eastmain River and adjacent areas (Fig. 1). The 1979 sampling program was preliminary and exploratory in nature. Sampling began in late May using 0.5 m conical plankton nets mounted on

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Cuban trapezes (Guitart, 1971) and fitted with a no. 0 (0.51 mm) or a no. 10 (0.15 mm) mesh net towed from an inflatible boat. Oblique and surface tows were made with both nets. The plankton nets yielded very few larvae in the river and river mouth. Sampling began after the period of early spring larval drift contributing to the apparent scarcity of larvae. Furthermore, summer-hatching riverine larvae were discovered to be mainly benthic and to occupy shallow littoral regions that were not adequately sampled by seines in 1979. Sampling in the bay was inefficient due to the extent of the sampling zone and bias due to gear avoidance. As a result of these preliminary observations, the 1980 sampling program was greatly modified and improved. Therefore, the results of the 1979 program cannot be quantitatively analyzed and compared to the 1980 program and are presented only as qualitative statements of presence or absence.

In 1980, standard plankton nets were used in May and early June but thereafter a 1.3 m^2 Tucker trawl (Davies & Barham, 1969), equipped with a no. 0 net and an opening and closing device was towed behind a 10 m catamaran. All sampling was carried out during night and twilight hours as night sampling is the most successful and simplest way to overcome bias due to gear avoidance by larvae and juveniles (Clutter & Anraku, 1968). Only samples collected at the beginning of May were collected during the day.

For every sampling period in 1980, twelve fifteen-minute tows were performed consisting of three series of four tows. Each series corresponded to a different state of the tide. In the bay (zone C, Fig. 1) where mean depth was 7 m, two surface and two oblique tows were made while at the river's mouth and in the river, where depths did not exceed 3 m, two surface and two bottom tows were made. Salinity and temperature were recorded at the surface and bottom before and after each series of tows. The Tucker trawl was lowered open but retrieved closed to avoid mangling of the larvae. Towing speed was maintained at 1.2 m/s for the standard plankton nets and 1.8 m/s for the Tucker trawl. A General Oceanics flowmeter was used to measure the volume of water filtered per tow, which varied from 180 to 270 m^3 for the standard plankton nets and from 1100 to 1900 m^3 at the mouth of the Tucker trawl. All samples were preserved in 5% buffered formalin immediately after capture (Richards & Berry, 1973).

Other capture methods included emergent traps (Collins, 1975), placed at the foot of rapids located 7 km from the river's mouth. Two 5 mm-mesh trap nets with a 2.5 cm mesh at the entry to prevent access

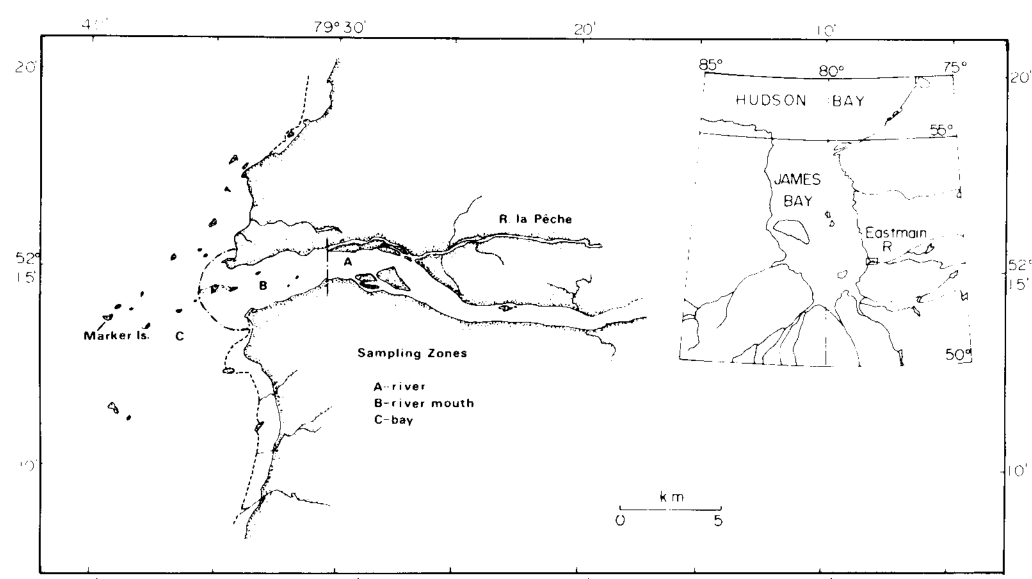

Figure 1. Location of the Eastmain River on the east coast of James Bay and the three major sampling zones.

of larger fish were placed on a protected shoreline of an island at the river's mouth. A fine-meshed (3 mm) beach seine was used during daylight along shorelines adjacent to areas sampled with the plankton nets. Two replicate tows were performed in each zone and salinity and temperature were recorded. The volume of water filtered by seines was estimated from the distance covered along the shore, the mean depth and the spreading of the wings.

All fresh water larvae were identified following Fish (1932). Identification was carried out to the species level using descriptions by Faber (1970) for *Coregonus* sp., by Fuiman (1979) and Fuiman & Witman (1979) for *Catostomus* sp. and by Heufelder & Auer (1980) for *Cottus* sp. All other larvae from the bay were identified following Lacroix & Bergeron (1964) and Khan & Faber (1974). For the genera *Gadus* and *Pholis*, identification to the species level was facilitated by the fact that only *G. ogac* and *P. fasciata* are known to occur in James and Hudson Bay (Hunter, 1968).

Larvae smaller than 20 mm were measured with an ocular micrometer, while the larger specimens were measured with a dial caliper. Precision was to the nearest 0.1 mm in both cases. Standard length was measured for specimens possessing fin folds and also for larger individuals (Berry & Richards, 1973). The term larvae designates the period from hatching to the time when fins are fully differentiated. Thereafter, the term juvenile applies to young of the year fish.

The 1980 plankton net samples were analyzed to detect larval groupings and to determine those environmental variables associated with observed groupings. The Bray & Curtis dissimilarity coefficient (Odum, 1950; Bray & Curtis, 1957), a measure of association appropriate for quantitative abundance data (Legendre & Legendre, 1979), was used to cluster samples; nearest neighbour clustering (Lukaszewicz, 1951; Sneath, 1957) was used to define the larval groups and discriminant analysis of these groups by environmental variables was performed as recommended by Green & Vascotto (1978).

Results

Plankton nets and beach seines permitted the sampling of both the pelagic and littoral areas of the three sampling zones. The species composing the catches of both types of gear and their abundance in the three sampling zones are presented in Figure 2.

PLANKTON NET CATCHES

The twelve species of fish larvae taken by plankton nets cluster into five distinctive groups (Table I). The high degree at which these groups fuse ($D < 0.998$, a Bray-Curtis value of 1 indicating completely dissimilar groups) reveals a very small overlap in species composition and abundance. The separation of these five groups on the first two discriminant functions explains 69% and 23% of the intergroup variance. Date of sampling appears on both axes. The importance of date in the discriminant analysis is explained by the obvious sequence of the appearance of larvae with yolk sacs (Fig. 3). Salinity and temperature are the next most important variables influencing group separation along the first and second discriminant axes respectively. Temperature is closely related to the sampling date and salinity is related to the zone from which a particular group of larvae were taken. These physical data are presented in Table I.

Group 1 is represented by larvae of burbot, *Lota lota* and of *Coregonus* spp. These larvae occurred early in the season when water temperatures were lower than 8°C (Table I). They were most abundant in the river (Fig. 2) and present only in surface waters of the bay. At this time, surface salinities never exceeded 4‰ (Table I). Spring break-up on the Eastmain River took place during the first days of May with ice flows continuing well into the second week of May. All burbot larvae and 86% of *Coregonus* spp. larvae were collected between May 5 and May 12. On May 19, the last *Coregonus* spp. larvae were taken at the river mouth. In 1979, no burbot larvae were present in the samples and only 7 *Coregonus* spp. larvae were taken in zone C. Sampling that year did not start until May 27, about 2 weeks after break-up. All burbot specimens had large yolk sacs and measured 4.8 to 6.0 mm. Among the *Coregonus* spp. larvae captured, 27% were *C. clupeaformis*, 43% were *C. artedii* and 30% were not identifiable because of pigmentation loss. The smallest whitefish measured 11 mm and the largest 15.2 mm. The size range for cisco was from 9.5 to 14 mm. Most undamaged larvae still had a yolk sac which diminished in proportion to increasing size, with whitefish larvae greater than 15 mm possessing only a faintly

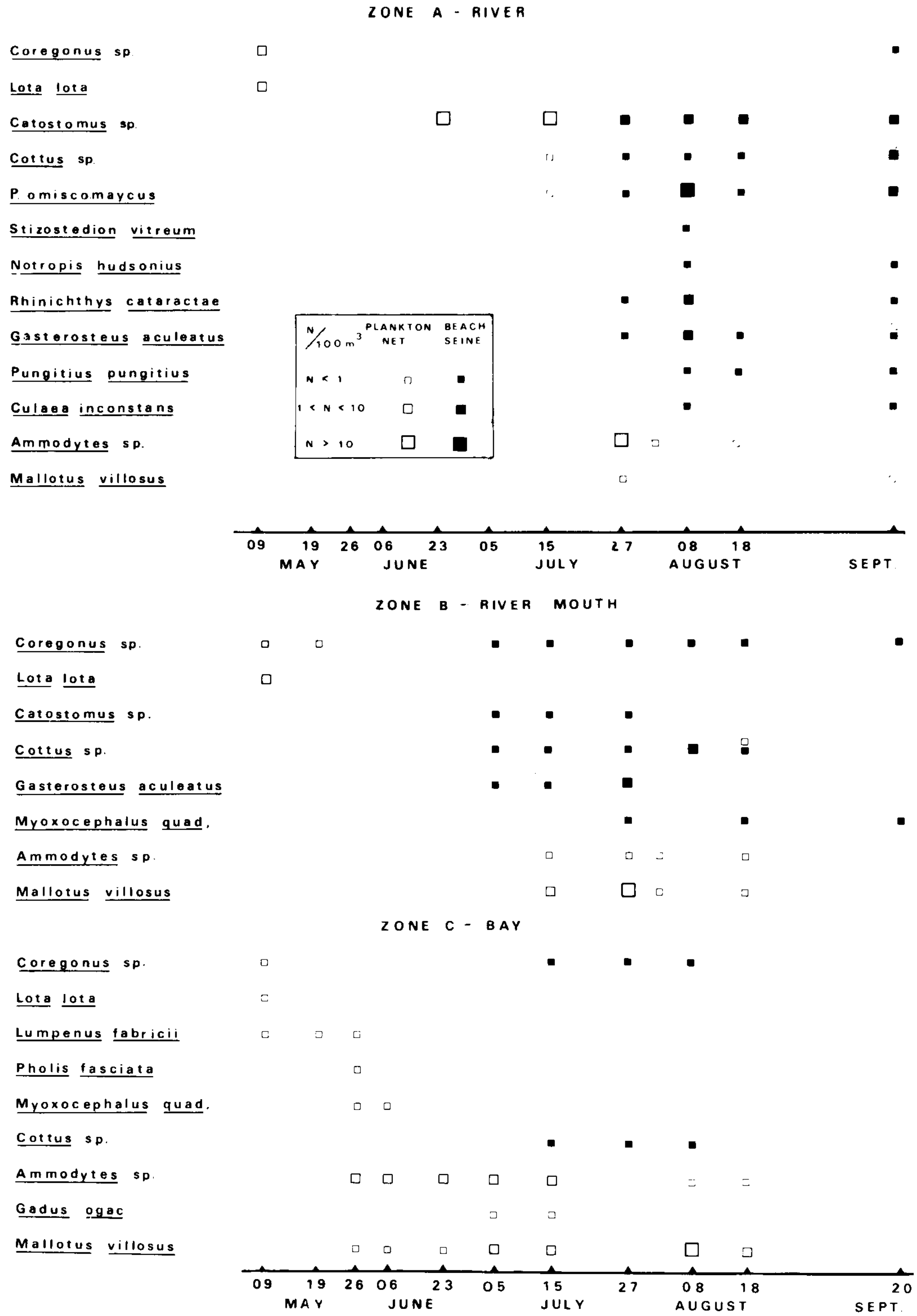

Figure 2. Abundance of young-of-the-year fish during the 1980 field season. The numbers (N) represent the mean values for 12 tows with the plankton nets and 2 tows with the beach seine. No seining was performed in the river on July 5 and 15 and in September, the Tucker trawl was only used in zone A. *M. villosus* taken in the bay in May and June were larger than 42 mm.

TABLE I

Groups of larval and juvenile fish as revealed by cluster analysis with corresponding physical data (medians) of waters from which they were taken (Numbers in brackets are ranges of the indicated physical variable)

Species		Temperature (°C)	Salinity (‰)
Group 1	*Lota lota*	5.5	2.0
	Coregonus spp.	(3.0-8.0)	(0-4.0)
Group 2	*L. fabricii*		
	P. fasciata	2.5	10.5
	M. quadricornis	(−1.0-6.0)	(4.0-17.0)
Group 3	*C. catostomus*		
	P. omiscomaycus	16	2.0
	Cottus sp.	(14.0-18.0)	(0-4.0)
Group 4	*Ammodytes* sp.		
	G. ogac	10	12.0
	M. villosus	(5.0-15.0)	(4.0-20.0)
Group 5	*M. villosus*		
	Cottus sp.	10	6
	G. aculeatus		(5.0-7.0)

visible yolk sac. In May, the mean length for whitefish was 12.7 mm while for cisco it was 11.5 mm. By August, juvenile whitefish and cisco had grown to an average length of slightly below 60 mm (Fig. 4).

Group 2 is composed of larvae of the Greenland blenny *(Lumpenus fabricii)*, the banded gunnel *(Pholis fasciata)* and the fourhorn sculpin *(Myoxocephalus quadricornis)*. Larval capelin *(Mallotus villosus)* which overwintered in the bay and measured more than 42 mm in the spring, were not included in the analysis but can be considered a part of this group. The larvae of group 2 were taken early in the season (May – early June) in oblique tows in the bay. Temperature of these waters ranged from −1 to 6°C and salinity from 4 to 17‰ (Table I). The first larvae present in the bay were Greenland blenny (Fig. 2). The smallest yolk sac specimens measuring 10 mm were captured at the end of May when the largest larvae were already 20 mm long. In 1979, Greenland blenny larvae, measuring 15 to 25 mm, were captured throughout June in the bay. They were never very abundant. Only 5 banded gunnel larvae, measuring between 12 and 16 mm, were taken at the end of May. Fourhorn sculpin larvae, measuring between 11 and 14 mm, were taken for the first time in mid-May. The largest fourhorn sculpin larvae measured 15 mm and was taken at the beginning of June. After this, none were caught until the end of July at the river mouth, in the trap nets and by seining.

The third group is made up of larvae of the longnose sucker *(Catostomus catostomus)*, the trout-perch *(Percopsis omiscomaycus)* and of cottids *(Cottus* sp.). This group was captured in the river starting in late June (Fig. 3). By then water temperatures had increased to 14°C (Table I). Mass hatching of longnose sucker larvae started in late June and lasted about two weeks. In 1979, hatching of longnose suckers started around June 19. Water temperatures had already reached 14°C by this date. Longnose sucker larvae were even caught in surface waters of the bay at low tide, salinity not exceeding 4‰. Trout-perch larvae were taken by the Tucker trawl in mid-July. The smallest measured 9.5 mm indicating a recent hatching (Norden, pers. comm.), probably some time at the beginning of July or end of June. *Cottus* sp. larvae hatched at the end of June. The smallest ones measured 9 mm. At this time, they were taken in emergent traps, but by mid-July *Cottus* sp. young were caught by the Tucker trawl indicating downstream transport. Although *C. cognatus* was identified, *C. bairdii* must not be excluded as a possibility. Larval *C. ricei*, their entire bodies covered with small prickles, were also captured in July and August. A description of this cottid is in preparation.

Group 4 is composed of larvae of sandlance (*Ammodytes* sp.), ogac *(Gadus ogac)* and capelin *(Mallotus villosus)*. They were taken in surface and oblique tows in the bay where salinities ranged from 4 to 20‰

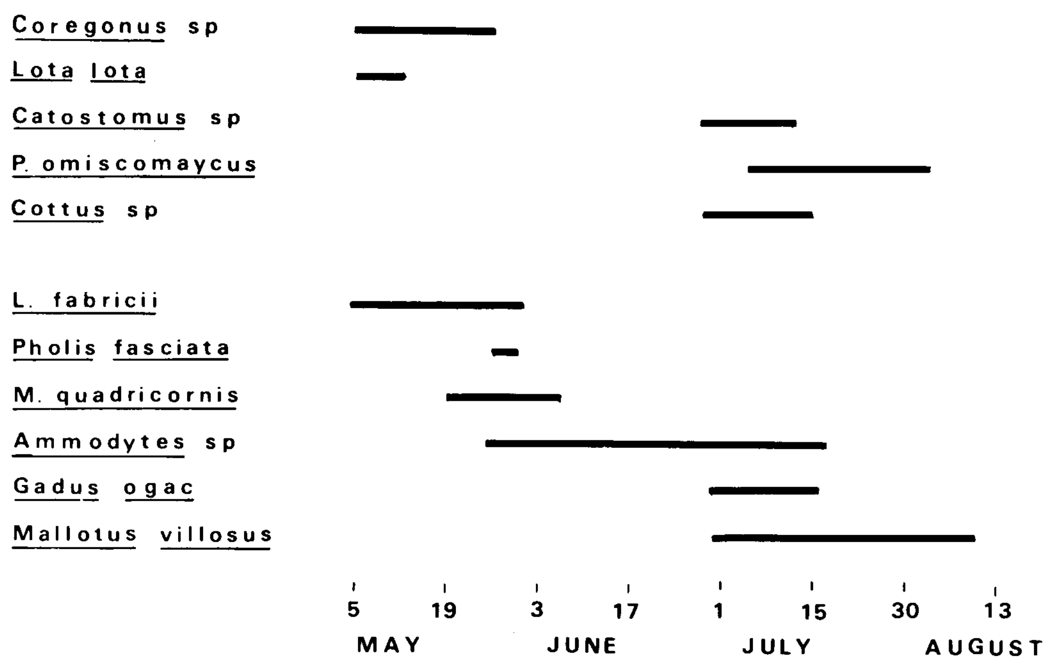

Figure 3. Dates representing time when yolk sac larvae were captured. The first five species were taken mainly in the river, while the six others were taken in the bay. *Cottus* sp. and *P. omiscomaycus* larvae were not yolk sac but were smaller than 12 mm indicating a recent hatching.

(Table I). Sand lance larvae appeared at the lower temperature limit of group 4 (5°C) at the end of May. They were taken only in two samples with larvae of group 2. Larvae with yolk sacs were caught until mid-July (Fig. 3). The beginning of July marked the arrival of larvae of capelin and ogac. By mid-July, ogac larvae were no longer captured, while yolk sac larvae of capelin were taken until the first week of August. The presence of sand lance and capelin larvae in zones A and B (Fig. 2) was associated with the intrusion of saltwater following the diversion of the Eastmain River in July, as these larvae were not captured in zones A and B in 1979.

Large capelin larvae, juveniles of threespine stickleback, *Gasterosteus aculeatus*, and cottids are characteristic of group 5. They were taken in September in zone A (Fig. 2), when temperatures were 10°C and salinity averaged 6‰ (Table I).

BEACH SEINE CATCHES

The young of some species of fish from zone A were only caught by seines (Fig. 2). The littoral distribution of walleyes *(Stizostedion vitreum)*, spottail shiners *(Notropis hudsonius)*, longnose dace *(Rhinichthyes cataractae)*, threespine sticklebacks *(Gasterosteus aculeatus)*, ninespine sticklebacks *(Pungitius pungitius)* and brook sticklebacks *(Culaea inconstans)* explains the absence of the young of these species from plankton net catches. These species are associated with the larvae and juveniles of species belonging to group 3 (Table I). Furthermore, juveniles of longnose sucker, trout perch and *Cottus* sp. were also taken by seines in shallow littoral areas. At the end of July and in August, these species were taken from waters for which the mean temperature was 20°C and the mean salinity was 3.5‰. In September, temperature had dropped to 13°C with salinity remaining around 4‰.

In zone B, juvenile whitefish and ciscos were taken starting in early July. They were most abundant at the river mouth along with juvenile fourhorn sculpin, which were taken exclusively in this zone. Larvae and juveniles of longnose suckers and juveniles of threespine sticklebacks were also taken in this zone. Fresh water was typical of shoreline areas at the river mouth before the river's diversion but thereafter salinities of up to 12‰ were recorded. In zone C, *Coregonus* sp. and *Cottus* sp. juveniles were taken in areas along island shores where salinities did not exceed 16‰.

Discussion

The larval fish community of the Eastmain river and estuary was observed to be highly structured both temporally and spatially. Hatching of fish species at this northern latitude was spread over three months with larvae of groups 1 and 2 hatching in May and larvae of groups 3 and 4 hatching in June and July. The temporal and spatial separation between larval groupings, related to water temperature (date) and salinity, has the obvious advantage of spreading predation on the available food supply over the ice-free period and thus may serve the purpose of reducing interspecific competition. Although the time and location of adult spawning is of prime importance in governing the initial structure of any larval fish community (Balon, 1975a), the maintenance of that structure and the subsequent distribution of young-of-the-year throughout the system is a function of the behaviour and mode of life of larvae after hatching, the role of river and tidal currents in transporting larvae to or maintaining them in nursery areas and the physiological capacity of each species to inhabit brackish waters. The following discussion deals with the role of these factors in contributing to the community structure observed in the Eastmain estuary and lower river.

Larvae of burbot, whitefish and cisco hatched in May in the river and were captured in all three zones. The peak of the passive migration of these larvae in the river, through the estuary and into the bay occurred during the first two weeks after spring break-up. The 4.8-6.0 mm-long specimens of burbot were not yet able to feed due to the presence of their enormous yolk sac that rendered prey capture unlikely. Thus, they may be called burbot eleutheroembryos (Balon, 1975b). Observation of burbot eleutheroembryos in aquaria showed that they swim relentlessly but start to sink as soon as they stop swimming. A pelagic life after hatching is typical of all common gadoids (Faber, 1967). In the case of burbot, such behaviour at the time of spring runoff explains their capture in the surface waters of James Bay. At this size, they were probably carried for a considerable distance into the bay.

Most downstream movement of *Coregonus* sp. larvae may occur at night when they lose their orientation and even slow currents displace them (Lindroth, 1957). Lindroth calculated that under the most favorable conditions whitefish larvae could travel some 80 km in one day. Although Hoagman (1973) and John & Hasler (1956) demonstrated that feeding for both whitefish and cisco started long before yolk sac absorption, they found that larvae of both species can survive up to one month on their yolk sacs. In the present study, the examination of 30 *Coregonus* spp. larvae caught in the river revealed no visible gut contents. It is therefore probable that *Coregonus* spp. larvae do not start feeding until they reach the bay.

The transport of group 1 larvae into the bay is probably a mechanism to exploit the greater availability of food in the bay than in the river at this time of year. In ice-covered seas, algae released from the ice adds to the phytoplankton bloom and results in the observed algal increase under melting ice (Legendre *et al.*, 1981). In the Arctic, the ice-algal bloom and the spring phytoplankton bloom are clearly separated in time (Apollonio, 1965). The diatoms present under the ice are a potential food source for fish larvae arriving early in the spring before phyto- and zooplankton peaks in June as water temperatures increase. Although it is reported that young-of-the-year whitefish tend to concentrate at the surface in shallow inshore areas for the first two months of their life (Hart, 1930; Reckahn, 1970), sampling in shallow coastal areas of James Bay, along foreshore flats and at the river mouth in May and June revealed that this was not the case for Eastmain *Coregonus* spp. larvae. The absence of larvae in these inshore areas and in the river supports the idea that larvae are transported far into the bay (Morin *et al.*, 1981), probably in conjunction with the melting pack ice that remains in the bay until late June. In July, however, juvenile coregonids are taken in zones B and C. The intensity of spring runoff, the action of the tides (Godin, 1974) and high northwest wind events (Godin, 1975) all play a role in timing their return to these zones. Therefore, the bay and later the river mouth, can be considered as nursery areas for larval and juvenile coregonids, even though few were captured. This apparent scarcity of juvenile coregonids has been noticed in other studies (Pritchard, 1931; Edsall, 1960; Lindström, 1970).

The first summer's growth of juvenile coregonids in the Eastmain (Fig. 4) is inferior to that noted for more southerly populations. In Lake Huron, Reckahn (1970) reported mean lengths of 120 mm for whitefish in October and Lassus (1967) reported that one-year old whitefish averaged 146 mm in the St. Lawrence River. *C. lavaretus* attain a length of 100 mm by the end of their first summer in Swedish rivers (Lindroth, 1957). However, Dumont & Fortin (1978) found one-year old whitefish in two lakes in the James Bay area averaged 90 mm, indicating a growth rate inferior to that of Eastmain whitefish. Stomach content analysis of Eastmain coregonids revealed that juveniles fed mainly on the abundant copepods in brackish waters. Thus, the faster growth of anadromous whitefish juveniles relative to the oligotrophic lake populations may be attributed to a plentiful food source whereas their generally poorer growth relative to more southerly populations may be attributed to a shorter growing season.

Larvae of Greenland blenny, banded gunnel and fourhorn sculpin (group 2), present in May and early June in zone C, probably hatched under the ice prior to and during its receeding from the bay. Larvae of group 2 live pelagically after hatching, but their absence from plankton net catches later in June may be explained by a change to the more demersal life-style typical of these species. In late May, *Ammodytes* sp. larvae appeared in the surface waters of the bay. They were small (< 7 mm) in comparison to larvae of group 2 (> 11 mm) and therefore competition between them was probably minimized.

Larvae of longnose suckers, trout perch and *Cottus* sp. (group 3) started hatching at the end of June as water temperatures increased to 14°C. This corresponds to a

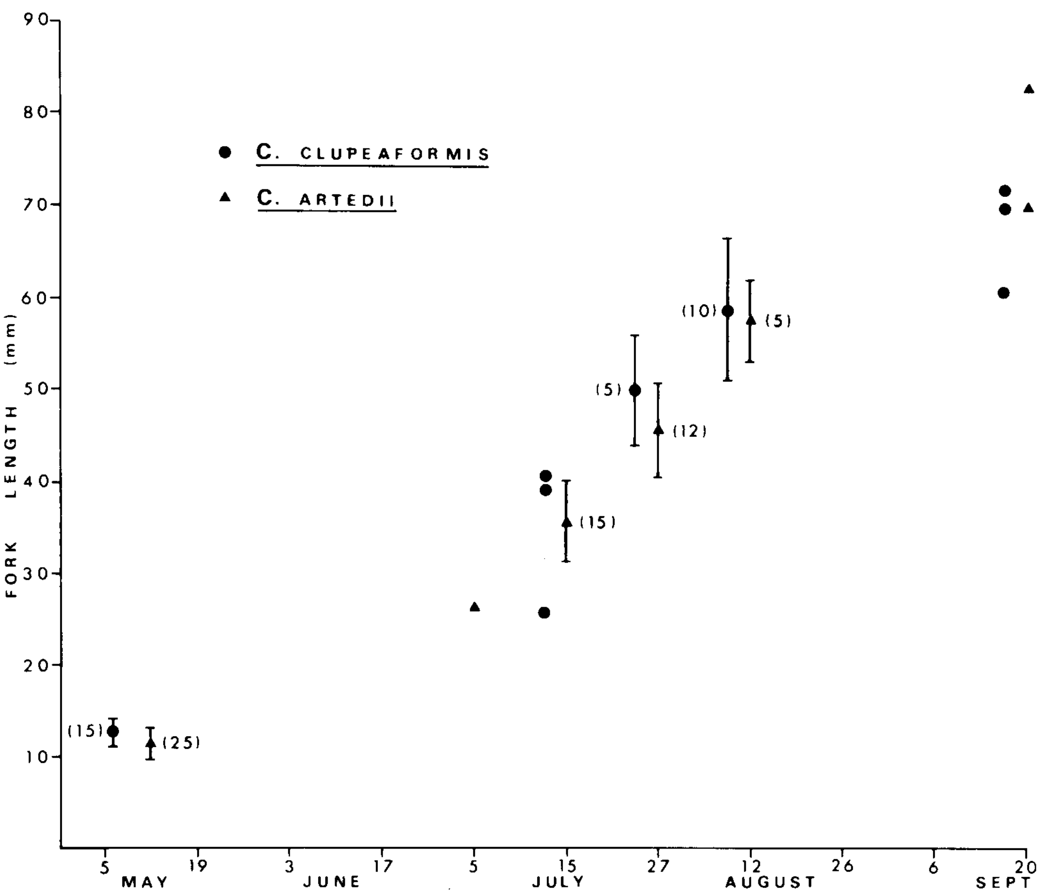

Figure 4. Growth rate of *Coregonus* sp. Standard length is given for larvae taken in May. Numbers in brackets indicate numbers of specimens measured and vertical bars represent standard deviations calculated only for samples of five fish or more. Solitary points represent the lengths of individual fish.

period when adequate quantities of food started to be available in the Eastmain River itself. As Lillelund (1965) has noted, it is advantageous for fish to hatch at a temperature greater than 10°C as plankton production in his riverine study sites did not start at temperatures less than 10°C. The capture of these species in plankton nets and seines followed by seine captures only suggests that these larvae live pelagically before changing to a more demersal way of life.

During their pelagic phase, downstream drift into brackish water was observed for the larvae of group 3. Although most downstream movement of larval suckers has been observed to occur between dusk and dawn (Geen *et al.*, 1966), longnose sucker larvae were observed drifting in the Eastmain during the day. All larval Cottidae are pelagic for a time before they settle to the bottom (Taranets, 1941) and such transport was observed in the Eastmain River. As a result of downstream transport, juvenile longnose suckers extended their habitat into the river mouth in salinities up to 12‰ and juvenile cottids extended their habitat into all three zones in salinities up to 16‰. Trout perch larvae and juveniles appeared to be the least tolerant of salinity of the group and remained in fresh water.

The juveniles of walleye, spottail shiner, longnose dace and the three species of sticklebacks occupied riverine littoral habitats with only the threespine stickleback extending into the shallow areas at the river's mouth. None of the larvae of these species were captured, most likely due to their hatching further upstream or in habitats inaccessible to our sampling methods. After diversion of the river, all these species were captured in salinities up to 4‰. Juvenile threespine sticklebacks were the most euryhaline being captured in salinities up to 12‰.

The most evident short term impact of the diversion of the Eastmain River was the entry into zone A and B at high tide of larvae of species characteristic of the bay (group 4; sand lance and capelin). The capture of capelin, *Cottus* sp. and the three-spine stickleback (group 5) in zone A in September may be indicative of the species that will inhabit this area in the future along with the more euryhaline species of other groups.

Survival of fish larvae and eggs will be determined by their ability to survive such effects of dams as conditions of low oxygen, high siltation and altered seasonal temperature patterns (Baxter & Glaude, 1980). Fish belonging to guilds of non-guarding lithophils (for example: whitefish, suckers, walleyes) will be more affected than guarding speleophils (*Cottus* sp.) and ariadnophils (sticklebacks) (Balon, 1975a). Larvae of species that present a pelagic behaviour for some time after hatching will be affected by the decrease in flow because their transport to downstream nursery areas will be compromised. They will not extend their habitat as fast and will be concentrated close to spawning grounds, increasing intraspecific competition. Furthermore, the species of young fish that will use the lower reaches of the Eastmain River as nursery areas will have to adapt their requirements to the altered physical conditions. The most euryhaline species will adapt most readily. Date of hatching will still be important in separating temporally the major groups of larvae but their spatial separation will be reduced.

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