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Feeding of 0-group Silver Hake (*Merluccius bilinearis*) in Scotian Shelf Area

by

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Abstract

The results of hake young-of-the-years feeding research in the Scotian Shelf Area based on long-term data (1982-91) are presented. Feeding peculiarities in relation to fish growth, inter-annual variations of food composition and feeding rate for fall-winter are shown. The attempt has been made to assess food supply by years. Cannibalism and abundance formation conditions of year-classes entering fishery are considered.

Introduction

Complex research carried out jointly with Canadian scientists in the Scotian Shelf Area since 1977 were aimed at the assessment of spawning efficiency and hake population recruitment. During long-term research of the causes of recruitment year-class strength fluctuations, we collected and processed samples of juvenile hake food items.

The inflow of the Atlantic water masses into Scotian Shelf and fluctuations of Gulf Stream front significantly affect the temperature regime of the area (Lausier, 1965; Ingham and MacLain, 1983; Trites and Drinkwater, MS 1984; Sigaev, MS 1985, MS 1988, MS 1991).

Temperature conditions determine abundance and biomass, spawning period and rate of zooplankton development. On the basis of long-term observations by Degtiaryova (1973), a positive relation was revealed between *Calanus finmarchicus* abundance and plankton biomass and the Barents Sea temperature, i.e. the higher temperature the larger plankton biomass and Calanus abundance which seems true also in the Scotian Shelf Area (Sameoto, 1982, 1984; Vinogradov, MS 1993b).

Juvenile hake feeding was researched by Canadian scientists (Koeller *et al*., 1989). It was stated that in October 1980 and 1981 copepodite stages of Copepoda and later small gammarides and euphausiids predominated in larvae and small fry (19-57 mm in length) feeding. In November 1985 (Sherstyukov and Nazarova, MS 1987) larvae and small fry (20-40 mm) consumed copepodites (35-59% by weight) and euphausiids (40-65% by weight). The larger fry (50-110 mm) consumed mainly euphausiids (60-100% by weight) both in homothermal and stratified water layers. In January 1981, as Koeller *et al*. (1989) found, hake fry (40-90 mm) consumed only euphausiids *(M. norvegica*). While some peculiarities of juvenile and adult hake feeding had been revealed earlier jointly with our co-authors (Noskov et al., MS 1985; Sherstyukov and Vinogradov, MS 1991; Rikhter and Vinogradov, MS 1992), the long-term data on 0-group feeding allowed to update such features as feeding rate, food supply and condition of larvae and fry by length groups and years, and conditions of cannibalism increase.

The purpose of this work is to assess peculiarities of juvenile hake feeding in reference to growth on the basis of long-term author's data, to show inter-annual variability of food composition and feeding rate during fall-winter, to determine food supply of juvenile hake by years, to consider cannibalism phenomenon and to specify the conditions of abundance formation in year-classes entering fishery.

Materials and Methods

Sampling of juvenile hake food was carried out mainly during trawling surveys in October-January 1982-1991 in the Scotian Shelf Area. To assess juvenile hake abundance standard pelagic trawl for juvenile gadoids fishery (IGYPT) with small mesh (5-6.5 mm) netting "insert" in the cod-end was used. Trawlings were carried out by layers only at night in 3 stages: near the bottom (2-4 m from the ground), in pelagic layer and near the surface (3-5 m from the surface) (Doubleday, 1981). Juvenile fish feeding conditions during sampling and in the previous period were assessed on the basis of fish condition, i.e. the ratio of fish weight to the long-term average fish weight of respective length, assumed to be 100% (Noskov, 1956). For positive weight deviation fish condition is assumed to be above 100%, for the negative one – below 100%. The amount of material sampled is presented in Table 1. Totally 7 186 individuals were processed.

Larvae and fry were measured from the mouth tip to the chord end or to the beginning of tail fin rays to the nearest 1 mm. To estimate the average weight, all fish of similar length were divided into groups of 10 ind. or less and weighted on analytical balance after drying with filter paper. Then their abdominal cavity was opened with preparation needles under a binocular. Organisms contained in a stomach were separated and identified. All food items were measured. The number of food items by species and groups was estimated. Their reconstructed weight was estimated using tables (Bogorov and Preobrazhenskaya, 1934; Bogorov, 1939; Kanayeva, 1962; Shmelyova, 1963).

Feeding rate was estimated on the basis of proportion of larvae and fry with food in stomachs and consumption indices. Consumption index is the ratio of food items average weight and weight of larvae and fry containing food items of particular length groups.

Hake larvae and fry are subdivided into 10 mm interval groups. The first group (18-25 mm) includes larvae transferred into exogenous feeding consuming mainly Calanoids, then fry of 26-35 mm in length with scale cover and all features of adult fish (Lange and Dimitrieva, 1981; Moiseev *et al*., 1981), and soon. The last group is represented by fish of 156-165 mm in length. For the purpose of food composition and feeding rate assessment hake fry (young-of-the-year) were subdivided into 3 groups by length: small (18-55 mm), middle (56-85 mm) and large (86-115 mm).

Observation Results

Food composition. Above 50 organisms were found in hake young-of-the-year food. All food items may be grouped as follows: calanoids, euphausiids, amphipods, decapods, pteropods, hake larvae and fry. As a result of rare occurrence all eggs and copepodite stages of copepods, furcilia and zoea of crustacea, juvenile squids, polychaeta larvae were included into respective groups. Some organisms such as polychaeta, mysides, cumaceas, sagitta, squids are represented separately due to their significant occurrence in some years.

It is noted that in larvae of 18-25 mm in length, the bulk of food is represented by calanoids, their eggs and copepodite stages of 0.05-4 mm in length, while in some years (1984, 1985, 1987) euphausiids, amphipods and decapods (with body length not exceeding the consumers) constituted from one half to three-thirds of the food by weight. For large fry 96-105 mm) most abundant in samples the bulk of food was represented by 3 groups of crustacea: euphausiids, amphipods, decapods and sometimes hake fry (1987). Between these extreme lengths of hake larvae and fry, different ratio of food item groups were observed in their food composition, however, if fry of 26-35 mm in length above 30% of food content consisted of euphausiids, amphipods, decapods, i.e. rather large food items.

The analysis of food composition in October-November by years revealed that it was a diverse one in 1982-85 (Copepods, amphipods, decapods, sagitta). From 1986 to 1991 the bulk of hake food (all length groups) consisted of euphausiids. During the first period in October food of hake fry was characterized by a variety of crustacea and other small organisms (Copepods, pteropods, small sagitta, larvae and fry of hake and other fishes) (Fig. 1A), while in November (Fig. 1B) the grown-up juvenile hake consumed larger food items (amphipods, decapods, mysides, polychaets). During the second period (1986-91) juvenile hake mainly consumed euphausiids both in October and November. Similarly, in December and January the bulk of hake food consisted of large euphausiids, while decapods were observed rarely and hake fry and copepods – very rarely.

Feeding rate. Food items proportions (Fig. 2) in hake fry predominated food (Table 2) have no large differences, however, the long-term observations of food items number per 1 feeding fry (Table 3) and average index of food composition (Fig. 2) decreased significantly from small fry (26-55 mm) to large ones (86-115 mm). These indices decreased by 2-4 times from October to January, which is most probably related to food resources depletion at the beginning of fry "descending" into the near-bottom large for "over-wintering".

Juvenile hake feeding rate in October (Fig. 3A) and November (Fig. 3B) in 1982-85 revealed no trends while indices varied significantly depending on availability of more or less accessible food. It is most evident in small fry (26-55 mm). October-November 1986-91 was characterized by more active food consumption in October as compared to November. Similarly, in October long-term indices of food consumption by all length groups were higher than in November. Analysis of average long-term feeding rate by months showed the decrease from October to January by about 2.5 times (Fig. 3A, B, C, D). Another pattern of feeding rate may be seen by juvenile hake length groups (small, middle, large). In small fry the trend towards feeding rate decrease by 4.7 times was observed from October to January. Feeding rate of middle fry decreased only from October to December, while in January feeding rate was even higher than in November. Feeding rate of large fry decreased only from October to November, while in December and January it was higher than in November (Fig. 3C, D). The trends toward feeding rate decrease by months from small to large fry was raced from October to December, excluding January, when the decrease was more evident in small fry feeding and less evident in large fry since at that period food is less available to small fry.

Juvenile hake food composition and feeding rate are interrelated and consumption of any other food items, except euphausiids, affected the feeding rate depending on availability and caloric content of food items. Only consumption of euphausiids was stable when stomachs fullness index was average.

Thus, during the years when "forced" food items predominated in juvenile fish feeding, recruitment had its peculiarities in mortality rate, survival proportion, etc. (Rikhter and Vinogradov, MS 1992).

Cannibalism in juvenile hake. Predation and cannibalism in adult and juvenile hake have been noted by many scientists, such as Schaefer (1960), Jensen and Fritz (1960), Fritz (1962), Dexter (1969), Vinogradov (1972, MS 1993a), Bowman (1980a and b), Bowman and Bowman (1980), Noskov *et al*. (MS 1982), Clay *et al*. (MS 1984), Vinogradov (1988), Koeller *et al*. (1989). Our observations showed that cannibalism is inherent to hake individuals from small (26 mm – 1-2% by weight) to large ones (105 mm – 100% by weight) (November 1987) (Table 2). The length of prey consumed constituted from 50 to 100% of the predator's length (fishes in the stomach were in the rolled form) in the "small" group and not more than 50% in the "large" group. The analysis of young hake feeding by years showed that cannibalism occurred most frequently in October 1983-1984 (Table 2), as well as in November 1987-1988, while in 1983 and especially in 1994 individuals of the own species predominated in stomachs of small and medium-size fry, and in 1987-88 in stomachs of large fry.

Analysis of prey size variations with juvenile hake length increase revealed the trend of prey size increase with juvenile hake length increasing (Fig. 4), while the increase of prey size in small and large fry was higher than in medium-size ones.

Cannibalism in adult hake was more evident and constituted significant food proportion. According to our data (Vinogradov, MS 1993a) in 1988 hake population consumed 46.4% of own species (mainly at age of 1+, 2+), and in 1990 – 27.6%. In the absolute value these estimates are of the same order. Only in 1990, the food consisted mainly of 2 groups – juvenile hake and squid, in addition to euphausiids, while in 1988 only juvenile hake predominated.

Similar results are supported with the data by other authors (Schaefer, 1960; Vinogradov, 1972; Maurer, MS 1975; Koeller *et al*., 1989), stating that not more than 30% of food by weight consisted of the own species, while fry stomachs were sometimes filled with smaller organisms. However, such periods were observed only in the absence of other food components (winter, spring) or when smaller fry were available to larger ones (autumn) (Koeller *et al*., 1989).

Discussion of Results

It is important to study all fish life cycle stages, especially that of fry and juvenile fish, since the latter determine recruitment of the adult population. During mass reproduction, hake larvae and fry constitute considerable proportion of the total plankton biomass, creating a trophic link in hake and other species feeding.

Nickolskiy (1974) thinks that the maximum possible level of population biomass is determined by food supply, i.e. availability of specific food quantity being used by fish to gain body weight and reproduction.

Our observations showed that the main food of fry of all size groups consisted of euphausiids, and to the lesser extent, of amphipods and decapods. However, in some years (1982) copepods predominated in food of fry and even adult hake (Vinogradov, 1988). More intensive food consumption by small fish (26-55 mm) was observed in October and November, while it sharply decreased in larger fish (86-115 mm) by January.

In the decade series of our observations, two years (1984 and 1985) have been distinguished when the lowest food consumption indices varied from 200 to 1 000% with copepods, decapods and euphausiids being the major food items. Similar values were obtained by Sherstyukov and Nazarova (MS 1987) for feeding of pelagic young hake in November 1985, when euphausiids (*M. norvegica*) with diurnal vertical migrations constituted the bulk of food (65-1 005 by weight) (Mauchline and Fischer, 1969). According to Sherstyukov (MS 1991a) the young-of-the-year had the highest abundance in 1985 amounting to 68.4×10^7 individuals in the Scotian Shelf Area. The data analysis presented in the article mentioned and our observations evidenced that the highest condition of fry of different size from 26 to 65 mm was in 1983, 1985 and 1986, when they had the highest abundance. This confirmed good food supply of fry during these years. In other years, euphausiids predominated in fry food with consumption index 1 000-8 000% (Sherstyukov and Vinogradov, MS 1991). The highest consumption indices were recorded in October 1983 in all groups feeding upon copepods and in November in small groups feeding upon euphausiids. It should be noted that in April-August 1984-1985 fish of 2-4 years old (26-35 cm) were intensively feeding and this was confirmed by their high relative condition. Such food items as calanoids (1984) and fish (mainly young hake) (1985) predominated in their food (Rikhter and Vinogradov, MS 1992).

It is likely that in some seasons of the observation period with scarce euphausiids, some groups of fry consumed more available decapods, amphipods, hyperiids and copepods. This list was occasionally supplemented with pteropodes and young hake of smaller size.

Since feeding rate and food composition are interrelated, in the case of "forced" food consumption may occur in individuals with poor growth rate resulted in scarce recruitment (Duka, 1988).

The earlier research (Noskov *et al*., MS 1982; Koeller *et al*., 1989) noted that starting from October hake of 30 mm in length consumed its "relatives", while by January the own species individuals constituted considerable proportion of food in stomachs of fry of 76-115 mm in length. Among hake larvae and fry found in larger fry stomachs there were some specimen of the length equal to 100% of the predator length, however major preys were up to 25% of the predator length.

Our observation showed that during some years in the period from October to January when the preferred food (euphausiids) was scare, cannibalism could have significant extent (in some individuals – up to 100% of the food content).

Consumption of own young fish by silver hake may became of overall nature only in the years of its high abundance being the factors of the latter regulation and reduction of competition of food. The same has been noted for cod of the Barents Sea (Orlova and Matishov, 1993). Besides, some authors (Marti, 1980) sated that such way of energy transfer is disadvantageous in the sense of energy spending to prey capture at the latter concentration reduction.

Conclusion

To summarize the above said and earlier published data, it may be concluded as follows:

The research show that euphausiids are the most common food items of cod in the Barents Sea, while in the Scotian Shelf Area the abundance of euphausiids determines the success of fish individual left stages, winter feeding and survival of "bottom" young hake, adult hake condition in spring, summer and autumn.

Like cod, hake pelagic young-of-the-years survival is closely related to the feeding conditions and water temperature, while further survival of "bottom" cod and hake young-of-the-years also depends on feeding conditions and water temperature in the period of thermal minimum.

In August-September planktophages mainly graze zooplankton, therefore, the reverse relation between plankton abundance and hake larvae condition and abundance is observed.

The abundance of pelagic young hake in October-November does not depend on eggs and larvae abundance in July-August and is determined by their survival from July-August to October-November.

The young hake survival from July-August to October-November is affected by feeding conditions as indicated with food consumption and condition indices. According to Fanning *et al*. (MS 1987) comparative analysis of 0-group and one year group abundance indices shows that these indices are comparative, however, in some years the 0-group abundance estimate does not reflect the actual picture of older year-classes abundance.

Cannibalism of pelagic young hake seems to increase in the years with unfavourable food conditions, as well as in the case of strong year-classes appearance (as observed in 1981).

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TABLE 1. Materials sampled during juvenile trawling surveys in October-November 1982-1991.

Year	Month	Depth layer, m		Number of samples	Number of fry (ind.)	R/V
		min.	max.			
1982	October	120-0	220-0	25	242	SRTM "Ekliptika"
1983	October November	118-0 108-01	223-0 161-0	33 7	616 116	SRTM-K "1500 years of Kiev"
1984	October November	55-0 37-0	125-0 185-0	21 23	323 408	
1985	October November	42-0 62-0	170-0 240-0	29 14	467212	SRTM-K "Tava"
1986	October November	45-0 50-0	295-0 140-0	21 5	546 79	SRTM-K "Torok"
1987	October November	105-0 35-0	235-0 202-0	28 30	411 390	SRTM-K "Maltsevo"
1988	October November	115-0 100-0	225-0 245-0	5 33	68 690	SRTM-K "Soulkrasty"
1989	November December	35-0 100-0	100-0 141-0	12 8	133 70	SRTM-K "Maltsevo"
1990	January October November December	100-0 73-0 40-0 93-0	145-0 240-0 248-0 230-0	12 44 49 13	108 645 699 135	
1991	January November December	90-0 72-0 80-0	268-0 200-0 200-0	36 25 3	408 375 45	
All years	January October November December	100-90-0 120-42-0 108-35-0 100-80-0	268-145-0 295-125-0 248-100-0 230-141-0	48 206 198 24	516 3318 3102 250	7186

TABLE 2. Predominated food items of hake larvae and fry in Scotian Shelf Area during October-November (1982-1991).

Length, mm	Month	Year									
		1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	2	3	4	5	6	7	8	9	10	11	12
18-25	X	cop.1	cop.	cop.	euph. cop.	-	euph.	-	-	-	-
	XI	-	-	cop.	cop.	-	cop. amph.	-	-	cop.	-
26-35	X	euph. 2 cop.3	cop.	dec. silv. hak.	euph.	euph.	euph.	-	-	euph	-
	XI	-	euph.	dec.	euph.	-	euph.	euph.	-	euph	euph
36-45	X	euph.	cop.	euph. dec.	euph. cop.	euph.	euph.	euph.	-	euph	-
	XI	-	euph.	dec.	euph.	cop.	euph.	euph.	amph. euph.	euph	euph
46-55	X	euph.	euph.	silv. hak euph.	euph.	euph.	euph.	euph.	-	euph	-
	XI	-	euph.	dec.	euph.	euph cop.	euph.	euph.	euph.	euph	euph
56-65	X	cop.4	euph.	silv. hak euph.	euph.	euph.	euph.	euph.	-	euph	-
	XI	-	euph. 4	dec.	euph. dec.	amph.	euph.	euph.	euph.	euph	euph
66-75	X	cop.4	euph.	silv. hak euph.	euph.	euph.	euph. 4	euph.	-	euph	-
	XI	-	euph. 4	dec.	euph. dec.	dec. euph.	euph.	euph.	euph.	euph	euph
76-85	X	cop.4	silv. hak.	silv. hak.	euph.	euph.	-	euph.	-	euph	-
	XI	-	dec.	euph. dec.	euph. 4	euph. 4	euph. silv. hak.	euph.	euph.	euph	euph
86-95	X	cop.4	silv. hak. euph.	dec.4	euph. 4	euph.	-	euph.	-	euph	-
	XI	-	silv. hak.. euph.	dec.	euph.	cop.4	euph.	euph.	euph. 4	euph	euph .4

TABLE 2. (continued).

1	2	3	4	5	6	7	8	9	10	11	12
96-105	X	cop.4	uph.4	-	-	-	-	-	-	euph 4	-
	XI	-	-	dec.po -lych.	dec.4	-	silv. hak.4	euph. dec.	euph.	euph	euph . 4
106-115	X	cop. 4	-	-	-	-	-	dec.4	-	euph .4	-
	XI	-	-	-	-	-	-	silv. hak	cop. amph.	euph	euph
All lengths	X	cop.	euph. cop.	silv. hak. dec.	euph.	euph.	euph.	euph.	-	euph	-
	XI	-	euph.	dec.	euph. dec.	euph. cop.	euph.	euph.	euph.	euph	euph

Note: 1 - food item constitutes above 75% by weight
2 - from 50 to 75%
3 - from 25 to 50%
4 - 100%
cop. - copepoda; amph. - amphipoda; euph. - euphausiacca; dec. - decapoda; polych. - polychacta; silv. hak - silver hake

TABLE 3. Number of food items (ind.) per one feeding fry in Scotian Shelf Area by months (1982-1991).

Length, mm	1982	1983		1984		1985		1986		1987		1988		1989	
	X	X	XI	X	XI	X	XI	X	XI	X	XI	X	XI	X	XI
18-25	3.3	33.5		8.9	64.0	92	5.5			6.4	8.0				
26-35	3.5	50.6	4.3	21.6	16.2	9.5	1.4	11.4		6.6	13.6		7.5		7.0
36-45	4.0	58.7	42.3	22.7	39.6	12.3	3.5	17.0	13.0	6.1	10.3	5.4	62	92	2.9
46-55	1.7	71.3	36.9	11.7	22.0	11.9	3.6	33.3	11.3	2.5	93	5.1	16.7	3.7	4.1
56-65		35.9	41.8	2.8	12.9	11.4	2.9	17.1	36.0	2.8	8.6	3.9	21.8	2.8	3.5
66-75		33.0	1.2	2.5	8.1	11.5	2.4	4.1	52	4.0	6.0	7.4	9.6	6.0	1.8
76-85		3.8	2.4	1.2	5.4	2.2	1.8	1.9	4.0		6.4	6.5	6.8	52	43
86-95		22.0	1.2	6.0	3.0	1.0	3.6	2.6	103.0		3.3	1.5	7.4	2.0	2.2
96-105		1.0		3.4		2.0					2.0		3.3	0.5	12.0
106-115												2.0	4.5	3.0	
116-125															
126-135															
136-145															
156-165	1.0														
226-235															
226-235															
In average per month	3.1	50.2	26.6	15.2	19.3	11.0	2.9	20.5	20.0	5.6	9.8	4.8	12.8	5.4	3.6

Length, mm	1990				1991			Average number per one fry				Long-term average by groups			
	I	X	XI	XII	I	XI	XII	X	XI	XII	I	X	XI	XII	I
18-25			6.0					12.3	20.9						
26-35	2.0	3.2	4.6	5.8	4.4	3.4		15.2	8.5	6.4	3.2	16.5	11.8	3.9	3.9
36-45	4.5	5.1	5.1	2.8	4.4	2.8	2.0	16.4	14.7	2.6	4.4				
46-55	3.7	5.2	4.7	2.1	4.6	2.4	1.6	17.8	12.3	2.6	4.2				
56-65	4.1	4.0	6.1	1.8	3.7	2.8	1.2	11.1	15.1	2.2	3.9	7.9	8.1	2.5	4.7
66-75	8.4	4.5	4.0	2.9	5.9	2.9	1.9	9.6	5.0	2.2	7.2				
76-85	3.4	3.0	3.3	1.8	2.5	2.5	3.5	3.1	4.2	3.2	3.0				
86-95	4.2	4.0	3.2	2.8	2.9	1.5	3.0	6.2	14.2	2.7	3.6	3.3	6.5	4.9	3.4
96-105	4.4	3.7	3.2	6.7	2.9	0.8	2.5	2.4	2.2	7.1	3.6				
106-115	3.0	0.5	2.2		3.2	2.7		1.2	3.1		3.1				
116-125	24.0	4.0	0		3.1			4.0	0		13.6				
126-135		1.0			1.6			1.0			1.6				
136-145			1.0		0			1.0			0				
156-165								1.0							
226-235					1.0						1.0				
In average per month	4.7	4.3	4.6	2.6	3.4	2.6	1.8	8.4	8.4	3.6	4.0				

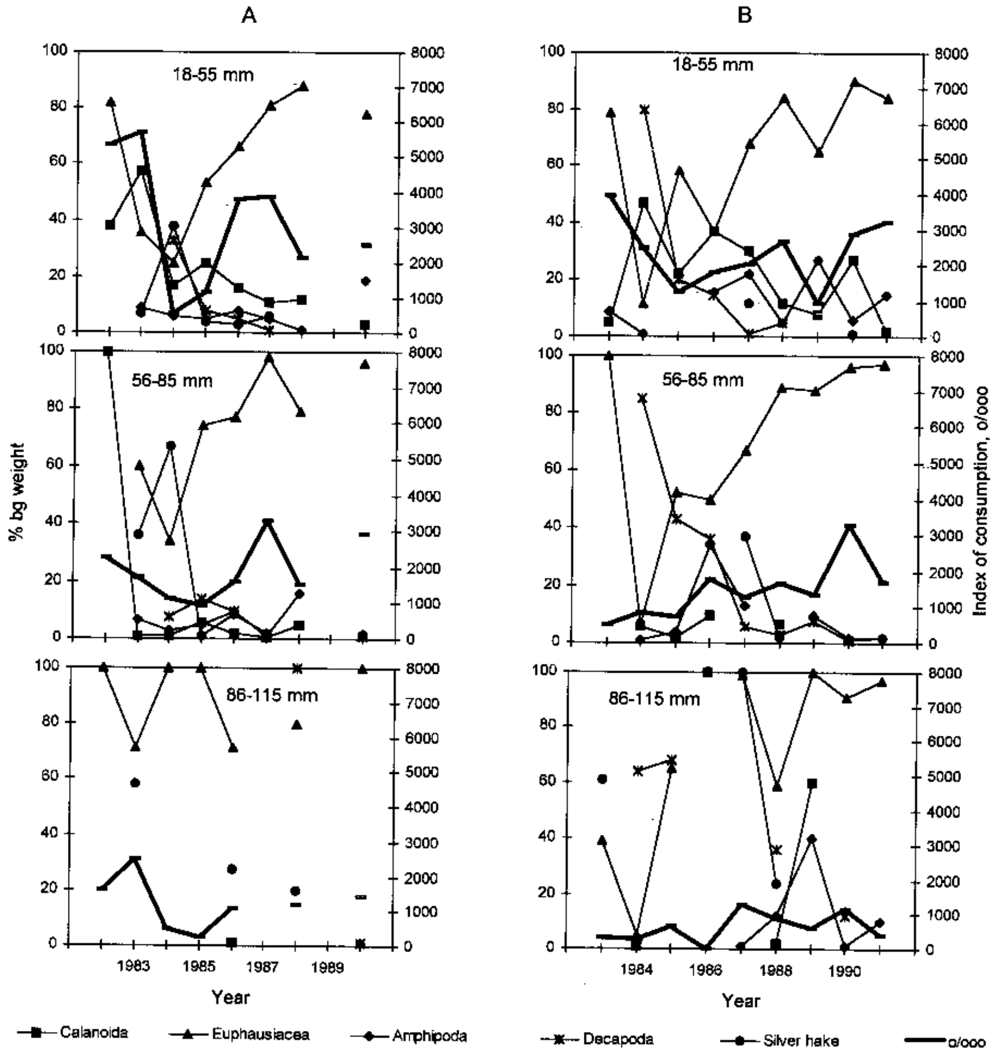

Fig. 1. Inter-annual variability of food composition (occurrence by weight, %) feeding rate (consumption index, ‰o) in small, mid-size and large juvenile hake in the Scotian Shelf Area during October (A)and November (B).

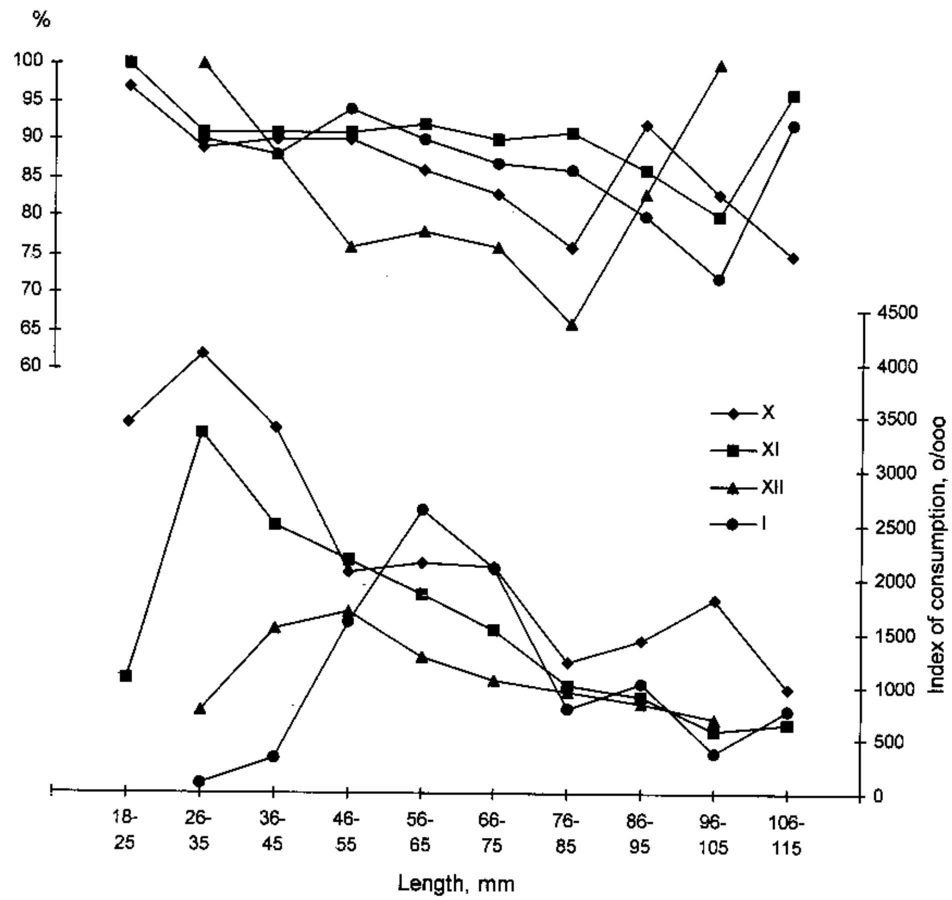

Fig. 2. Variability of average long-term consumption index (‱) and long-term proportion for feeding juvenile hake (%) by length groups and by months in the Scotian Shelf Area.

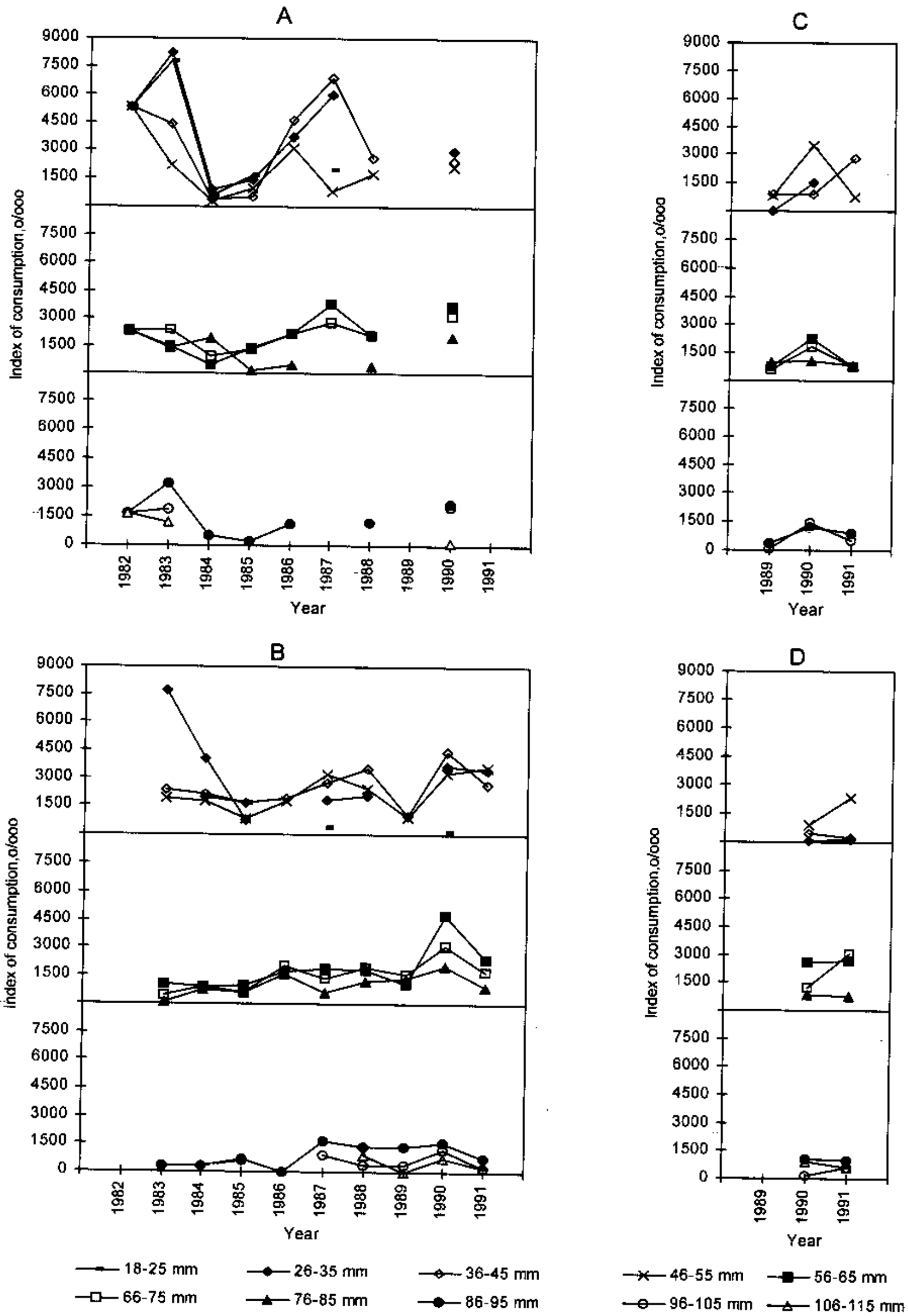

Fig. 3. Inter-annual variations of food composition (‰o) in different groups of juvenile hake in Scotian Shelf Area during October (A), November (B), December (C) and January (D).

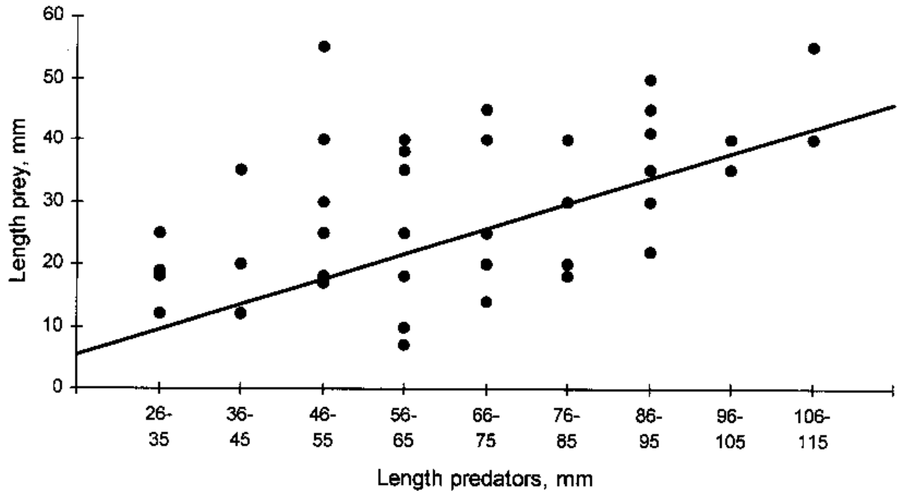

Fig. 4. Ratio of predator and prey length in juvenile hake in the case of cannibalism.