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Results of Ecological Surveys Conducted on the Nova Scotia Shelf in 1974 and 1977-1980 to Study the Spawning Efficiency of Silver Hake

by

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Abstract

Results of the studies on spawning efficiency of the silver hake on the Nova Scotia Shelf are presented. The abundance and distribution of silver hake eggs, larvae and fry and their food zooplankton is determined. The egg survival, composition of larvae and fry and their feeding intensity are estimated. A correlation between the year class strength and feeding conditions at early development stages is presumed.

Introduction

The silver hake is an abundant species in the ichthyocenosis of the Nova Scotia Shelf ecosystem. Its stocks are subject to considerable fluctuations due to variable recruitment. In order to study the reasons determining the fluctuations of abundance of some silver hake year classes Dr. A.S. Noskov, the Chief of the Northwest Atlantic Laboratory, AtlantNIRO, in 1974 proposed to Canadian scientists a scheme of program for studying of spawning efficiency of the Nova Scotia silver hake. Canadian scientists agreed to this proposition, and the program of joint research was elaborated involving the following aspects:

1. Determination of spawning areas and times of the silver hake;
2. Abundance and distribution of eggs, larvae and fry;
3. Feeding of silver hake larvae and fry;
4. Distribution, abundance and biomass of food zooplankton;

5. Mortality of eggs and larvae induced by abiotic and biotic factors;

6. Oceanographic conditions (thermal regime, currents, state of the sea).

Materials and Methods

The investigations involved the conduction of complex ichthyoplankton surveys. The preliminary research was made in August 1974 according to the AtlantNIRO program, and the joint USSR-Canada program was implemented over 1977-1980. During the research the water temperature determinations, ichthyo-and zooplankton sampling and standard meteorological observations were made.

The ichthyoplankton was sampled with the large Bongo model; it had an opening diameter of 0.6 m and was fitted with the 0.333 m mesh gauze. Firstly the layer of 0-50 m (1974) was sampled, for according to the previous investigations the larvae occurred in the surface layers where the zooplankton biomass was very high (Sigaev, Sushin, 1973). Then, in 1977-1978, the sampling was made in the layers of 0-100 m and 0-200 m respectively as suggested by Canadian scientists. Over the depths of 200 m or less the plankton was collected 5 m off the bottom. The towing speed was 2.5 knots, and pay out and haulback rates of the fishing gears were 50m/min and 20 m/min. The amount of filtered water was recorded by the flow meters. Fig.1 shows a grid of stations of the complex ichthyoplankton survey.

To obtain the zooplankton samples a small Bongo model with the opening diameter of 0.2 m, fitted with 0.076 mm mesh gauze was used.

In October 1978-1980 trawl surveys of the silver hake fry were carried out (Fig.2). A 13.6 m fry trawl with a small-meshed netting (5 mm mesh size) inserted in the cod-end was used. This trawl was proposed by the AtlantNIRO scientists A.S.Noskov and B.K.Motuzenko. Hauls of 30 minute duration were made at a vessel speed of 3.5 knots. The echosounding cable depth meter (IGEK) was used. Catch data were entered on the trawl logs. According to Sauskan and Serebryakov (1968) the body length of the developed silver hake fry is 23 mm. So, the specimens below 23 mm were taken as the larvae, and those of 24 mm and more as the fry.

The chamber processing of the ichthyoplankton samples was made in the laboratory:

1. The eggs and larvae were carefully collected from the total amount of the plankton;

2. The total number of fish eggs and larvae was counted in the whole sample and under m^2;

3. According to the scale suggested by Rass and Kazanova (1966) the development stages of 20 eggs were determined;

4. The proportion of live and dead eggs was calculated by the method of Dementjeva (1958);

5. The body length of 50 larval fish was measured from the top of the snout to the end of the chorda.

The zooplankton samples were analysed under the binocular. A portion of about 500 zooplankters was taken from the total sample in the Falsom's chamber. Then, the organisms were counted in the random-chamber, and the species and genera identified. Large organisms were counted in all 100 squares of the chamber and small specimens only in 10 squares selected by the table of random numbers. After all the sampled organisms were counted their numbers were converted to the whole sample and the abundance under m^2 was computed.

The catch taken with a fry trawl was sorted out by species, the fish were measured from the tip of the snout to the end of middle rays of caudal fin and the fry preserved in 4% formalin for feeding studies.

The counts of zoo-and ichthyoplankton and fry were recorded in the logs, the squares of regions with equal density of organisms were determined using the planimeter, and then their total abundance was calculated.

Table 1 presents the materials collected during the surveys conducted in August-September 1974 and in 1977-1980.

For feeding studies 10 specimens of larvae. or all the specimens if less, were taken by the following length groups:

a) 2.0-5.9 mm - the larvae with the yolk sac or its remnants, but already feeding on the food zooplankton (Copepoda eggs and nauplii);

b) 6.0-8.9 mm - the larvae feeding on small organisms, mainly on copepodites;

c) 9.0-12.9 mm - the larvae feeding predominantly on larger copepods;

d) 13.0-23.0 mm - the larvae and fry of 24 to 86 mm, larger Copepods, young Euphausiacea, Amphipoda, Decapoda and other pelagic invertebrates predominating in their food.

Each group of larval hake was weighed to find the mean weight. The bodies were dissected and stomach contents analysed under the binocular. The number of food organisms was counted by species and groups. Their initial weight was determined using the tables of weights for the North Atlantic and Meditteranean zooplankters (Bogorov, 1939; Bogorov, Preobrazhenskaya, 1934; Kanaeva, Shmeleva, 1963).

Feeding intensity was estimated based on the proportion of larvae with the food in the stomach and using the index of consumption in ‰o.

The condition factor was determined by comparison of mean weights of the larvae of the same size with the mean values for 1974, 1977-1980 (Noskov, 1956).

Results

Distribution and abundance of silver hake eggs and larvae

Usually, massive spawning of silver hake occurs in August in the shallow water areas: Browns, Sable and Banquereau Banks (Noskov et al.,1978,1979). The most dense spawning aggregations were observed both on the western slopes of Sable Bank and south and west of this Bank. The favourable conditions for silver hake spawning west of Sable Island can be related to peculiarities of the water circulation (Sigaev, 1978) owing to which the warm oceanic waters penetrate into the shallow water areas through the Nova Scotia Trough, and the intermediate layer of cold Labrador waters with the temperature of 2-5° is always observed on the shelf slopes. The ecological survey made in September 1977 showed that the dense concentrations of larval silver hake and eggs were observed along the boundaries of the zones of upwelling and downwelling at the temperature of 14-15° at the surface, of 6-7° in the 50 m layer and of 10° near the bottom at the vertical thermocline of 7-14° in the layer of 40-50 m.

The eggs were observed throughout the shelf area, excluding the northern Banquereau Bank and the largest number was recorded west of Sable Island. The larvae were found in the same areas but the largest numbers were observed more westward than the eggs. This may be explained by the fact that the eggs and larvae drifted in the south-western direction due to the current. The data of the survey conducted in September 1980 show a typical distribution of the eggs and larvae (fig. 3 and 4). A similar distribution of the ichthyoplankton in August-September was observed in the previous years (Noskov et al., 1978, 1979). Massive drift of the eggs and larvae from the shelf area was not observed over the entire investigation period.

In September 1977, in the Banquereau Bank area, the length of the larvae ranged between 2 and 16 mm, 5.4 mm on the average (fig. 5), between 2 to 23 mm (6.4 mm on the average) in the Sable Shoal area, and between 2 to 23 cm (10.1 mm on the average) in the Browns Bank area. Thus, the largest larvae were observed in the western part of the area, where the spawning commenced earlier, and the smallest larvae were found in the eastern part where the spawning occurred later. Judging from the length of the larvae the spawning is extended, for both the specimens of 18-23 mm in length and newly hatched larvae (2-3 mm) were found.

Fig. 6 shows the average distribution of the larval silver hake by length throughout the area in September 1977-1980. The smallest larvae of 5.5 mm mean length and the largest ones were observed in 1978 and 1977 respectively. This means that in 1977 the massive spawning occurred earlier and in 1978 later.

Total abundance of the silver hake eggs varied by year between 10 and $93 \cdot 10^{11}$ during the survey period, i.e. by about 10 times, the number of the larvae by 4, and the number of the fry by 5 times (table 2).

Distribution and abundance of the silver hake fry

The results of the trawl surveys conducted in October 1978-1980 showed that significant aggregations of the hake fry (100 and more sp.per catch) were recorded in the Nova Scotia Trough (Fig.7). Thus, in October, a cyclonic gyre (upwelling) was observed above the Emerald Bank and an anticyclonic gyre above the shoals of Sable Island and Middle Bank (Sigaev, 1978). Massive aggregations of the fry were found in the Emerald Bank area in October 1980.

In October 1980, a vertical distribution of the hake fry was studied west of Sable Island. Based on the oblique three-step hauls (near the bottom in the pelagial and at the surface) it can be concluded that the catches of the hake fry at night were equally distributed by all these depth layers in the temperature range of 7-15°, and in the daylight the fry occurred in the catches individually. Total abundance of the fry by year varied between 47 and $258 \cdot 10^6$ sp. (table 2).

In October, the larvae of 10mm occurred in the catches taken by the fry trawl among the hake fry, their numbers being higher in the Browns Bank area (4X), where the spawning takes place earlier than in the Emerald Bank area (4W) (Fig. 8).

Composition, Abundance and Distribution of Food Zooplankton

Oithona spp., Centropages spp, Calanus finmarchicus, eggs and nauplii of copepods were the main food organisms (80%) in the diet of the silver hake larvae and fry (table 3). The abundance of zooplankters by year fluctuated between 917 sp./m^3 in 1980 and 1533 sp./m^3 in 1977. The highest abundance of Oithona spp., which is the principal food organism for the larval hake, was recorded in 1977 (710 sp/m^3) and in 1979 (520 sp/m^3). The proportion of eggs and nauplii of copepods was also large in these years (260 and 240 sp/m^3 respectively). The abundance of Centropages spp. was high in 1977 and 1980, of Calanus finmarchicus in 1980, and of Paracalanus spp. in 1978.

Typical distributions of the food zooplankton biomass on the Nova Scotia shelf in August and September 1980 are shown in Figs. 9 and 10. As is evident from the figures, the biomass is uniformly distributed all over the shelf, and can be estimated at 10 g under m^2 on the average. More dense aggregations (11-40 g under m^2) were found west of Sable Island in the Emerald Bank area, and on the Browns Bank. The distribution of predominating food organism, Oithona spp., in August and September is shown in figs. 11 and 13. It is worth noting that the areas of the larval hake concentrations (Fig. 4) north-west and west of Sable Island coincide with the Oithona spp. aggregations, particularly in September, the abundance of which fluctuated between 26 and 100 thous. sp. under m^2.

Feeding of the silver hake larvae and fry, condition factor of the fish

In August and September 1974, 1977-1980, Clausocalanus spp., Paracalanus spp. and Pseudocalanus spp. with the body length of 0.8-1.2 mm were prevailing (35 to 50% by weight) in the food mass of the larval hake 2 to 9 mm in length (table 4). In 1980, the proportion of Clausocalanus spp. in the feeding of this group ranged between 30 and 40% and that of Oithona spp. between 20 and 50% by weight. The larval hake 9 to 23 mm in length fed mainly on Calanus finmarchicus (20 to 100% by weight) and on Centropages spp. (15 to 100% by weight). Sometimes, in August, the proportion of Euphausiacea or larvae of decapods was significant in the diet of very large larvae of the hake-40% and 20% respectively.

As is evident from the number of feeding specimens (table 5) and from the number of consumed organisms and consumption index (table 6), the feeding intensity of larval hake in August and September increased with the growth of the larvae in length. Taking into account that the food zooplankton abundance was very low, the fact of a relatively high feeding intensity can be attributed to patchy distribution of the plankton.

The comparison between the weights of the larvae of the same size for 1974 and 1977-1980 (table 7) demonstrated that the condition factor for the small larvae (2-9 mm) was the highest in 1978 and 1974, and very low in 1977 and 1980. The condition factor for the hake 10-23 mm in length exceeded the mean long-term value in 1974 and 1980 and was below that value in 1979. A similar feeding pattern and condition factor were observed in the Georges Bank area (Noskov et al., 1979).

In October 1979, Parathemisto spp., euphausiids, amphipods were prevailing in the diet of the hake fry, and in October 1980 Parathemisto spp., Centropages spp. and polychaets amounted to 30-100% by weight in the food mass (table 8). The proportion of euphausiids and Parathemisto spp., sometimes of polychaets and sagittas, increased with the growth of the fry.

The condition factor over the period from 1978 to 1980 was the highest in 1978 for the hake fry of all the size classes (24 to 70 mm) and fluctuated within the 100-104% range compared with the mean long-term value (table 9). In 1980 the condition factor was also high for the fry 24 to 37 mm in length, however, it decreased to 90% with their growth.

Survival of eggs, larvae and fry of the hake

For all the fish species, like for majority of other vertebrates, the early development stages are mostly subject to mortality (Nickolsky, 1965; Dementjeva,1976; Cushing, 1979). Revealing and understanding of the factors controlling the appearance of strong or poor year classes and of mechanisms influencing the life of the hake year classes at early development stages is an integral part of the research, which is very important for a long-term forecasting of the catches.

The results of the survey on the hake egg abundance conducted in August and September 1977-1980 on the Nova Scotia shelf are given in table 10 by development stages. The mortality is very high (approximately 90%) in the period of embryonic growth. The highest loss of the hake eggs is observed at their early development stages (fractionation and gastrulation period) and is not actually observed at the stage of shaped embryo.

The major factors provoking the egg loss at early ontogenesis are unfavourable abiotic conditions, namely the water temperature and sea state (Cushing, 1979). Usually, the hake start spawning at the temperature exceeding 5.5° and keep to the regions with the 7 to 13° temperature range for the spawning period (Bigelow et Schroeder, 1953), although the temperatures of 13-15° are considered to be the most favourable for egg incubation (Sauskan and Serebriakov, 1968). The water temperatures below 10° and over 18.3° are considered to be unfavourable for egg development (Bigelow et Schroeder, 1953). As to thermal regime of the Nova Scotia shelf, it was subject to considerable variations in August and September of 1977-1980. In August cold Labrador waters moved westward along the Nova Scotia Peniusula forming a rather stationary branch directed to the continental shelf in the Emerald and Banquereau Banks area (Noskov et al., 1979). The influx of warm (5-10°) waters of oceanic origin related to the Gulf Stream to the Nova Scotia trough occured through the deepsea canyons and depressions. In September the heating of the waters still continued, their temperature ranging between 11 and 15°, and the influence of cold Labrador waters decreased.

In order to define the influence of the water temperature on the viability of the embryos the data on the egg survival for different years were compared with the mean weighted temperature values for the Nova Scotia shelf for the 0-200 m horizon (Fig. 13). A weak inverse dependence of the egg survival on the water temperature was observed in August and September (correlation factor 0.37): the per cent of live eggs decreased with the increase of the water temperature.

The sea state plays an important role in the egg survival (Nikolsky, 1965; Dekhnik, 1973; Cushing, 1979). Even moderate state of the sea (over 4, Beaufort Scale number) entails the massive loss of the pelagic eggs of the marine fishes.

In August and September of 1977-1980 the investigation area was under the influence of cyclons moving in the north-eastern and eastern directions and anticyclons travelling from the continent eastwardly and south-eastwardly. The moving of these baric formations was responsible for predominant western, south-western and north-western winds (3-4, Beaufort Scale number) with the

32-66% recurrence (table 11). The ripples in the above-mentioned directions prevailed with the 27-69% recurrence (table 11). The increased proportion of winds of 5-6 (Beaufort Scale number) in September (17-37%) compared with August (11-12%) resulted in increased roughness. The roughness of 5-6 (Beaufort Scale number) increased from 1-9% in August to 7-33% in September (Table 12). The roughness of 7 and more was observed in September 1978 comprising only 1%.

Taking into account great susceptibility of pelagic eggs to mechanic influence the effect of the moderate state of the sea (4, Beaufort Scale number) on the survival of the silver hake eggs on the Nova Scotia shelf was considered. A weak inverse dependence (correlation factor 0.31) was observed of the silver hake egg survival on the stormy regime: the per cent of live eggs decreases with the increase of the number of stormy days (Fig. 14).

Other environmental factors (salinity, dissolved oxygen content, etc.) in the spawning areas of silver hake are relatively stable and cannot be regarded as limiting factors for egg development.

Transition of the larvae to active feeding is a very important period in their life, during which the highest mortality occurs (Hjort, 1914; Hunter, 1975; Cushing, 1979; Dementjeva, 1958). Transition of the silver hake larvae to active feeding on the Nova Scotia shelf and on Georges Bank takes place at the body length of 2.5 to 5.9 mm (Samyshev, Ptitsyna, 1976). The comparison between the proportion of feeding larvae, the mean consumption and condition factors of the fry showed that the feeding conditions in 1978 were more favourable than in 1980. It is worth noting that the abundance of the 1978 year class (at the age of 3) was higher than that of the 1975, 1976 and 1977 year classes (Noskov, in press). Evidently, the strength of the silver hake year classes in the Nova Scotia area is determined by the feeding conditions for the larvae and fry. This suggestion can be controlled, however, by the appearance of a poor year class. Therefore it is desirable to continue ecological investigations at least in the main spawning ground of the silver hake west of Sable Island.

Conclusions

1. Massive spawning of the silver hake on the Nova Scotia shelf takes place west of Sable Island in the zone of cyclonic gyre. In general, the eggs and larvae drift to the south-west, but stay within the shelf boundaries.

2. The main abundance of the eggs in 1977-80 fluctuated 10 times, of the larvae 4 times and of the fry 5 times.

3. In August and September the larvae mainly fed on Oithona spp., Centropages spp., Calanus finmarchicus and on the eggs and nauplii of copepods.

4. The mean biomass of the food zooplankton was 10 g under m^2; more dense aggregations (to 40g under m^2) were observed west of Sable Island in the area of massive concentration of the larvae.

5. Most favourable feeding conditions for the silver hake larvae and fry were observed in 1978. The abundance of the 1978 year class appeared to be higher than the average, which makes it possible to suggest that the year class strength is determined by the feeding conditions for the larvae and fry.

References

1. Bigelow H.B., Schroeder W.C. Fishes of the Gulf of Maine. U.S.Fish.Bull., 74, vol.53, pp. 173-182.
2. Bogorov V.G. Weights and ecological peculiarities of macroplankters from the Barents Sea. Trudy VNIRO, v.4, 1939, p. 251-255.
3. Bogorov V.G., Preobrazhenskaya E.N. Weight characteristics of the Barents Sea plankters, 2, Copepoda.Bull. No.2, VNIRO, 1934, p. 1-21.
4. Dementjeva T.F. Methods for studying of the influence of natural factors on the abundance of the Azov anchory. Trudy VNIRO, v. 34, 1958, p.42-57.

5. Dementjeva T.F. Biological substantation of the fishing forecasts. M., 1976, 236p.

6. Dekhnik T.V. The Black Sea ichthyoplankton. "Naukova dumka". Kiev, 1973, p. 9-12,

7. Hjort J. Fluctuations in the great fisheries of northern Europe viewed in the light of biological research.Rapp.P.-V.Reun.Cons.Perm.Int.Explor. Mer., 1914, 20:1-228.

8. Hunter J.R. Report of a Colloquium on larval fish mortality studies and their relation to fishery research, January 1975. NOAA Technical Report NMFS CIRC-395, Seattle, WA, May 1976, pp. 1-15.

9. Kanaeva I.P. Mean weight of Copepoda from the Central and North Atlantic, Norwegian and Greenland Seas. Trudy VNIRO, v. 46, col.1, 1962, p. 253-265.

10. Cushing D.H. Marine ecology and fishery. M, 1979, 288p.

11. Nikolsky G.V. Theory of dynamics of fish schools as biological basis for rational exploitation and reproduction of the fish resources. "Nauka", M., 1965, 447p.

12. Noskov A.S. On the evaluation of the fish condition factor. Trudy BaltNIRO, vyp. 2, 1956, p. 90-94.

13. Noskov A.S., Karaulovsky V.P., Romanchenko A.N., Sherstiukov A.I. Distribution and abundance of silver hake eggs and larvae and environmental conditions off Nova Scotia in September-October 1977. ICNAF Res.Doc.VI/32, 1978, pp. 1-10.

14. Noskov A.S., Sherstiukov A.I., Romanchenko A.N. Distribution and abundance of silver hake eggs, larvae and juveniles and environmental conditions off the Nova Scotia shelf in August-October 1978. ICNAF Res.Doc.VI/100.1979, pp. 1-10.

15. Noskov A.S., Vinogradov V.I., Ptitsyna L.G., Romanchenko A.N. Feeding of the larval silver and red hakes on the Georges Bank in 1965-1976. Trudy AtlantNIRO, v. 81, 1979, p. 44-60.

16. Noskov A.S. Stock assessment and admissible catch of silver hake (Merluccius bilinearis) on Nova Scotia Shelf. (in press).

17. Rass T.S., Kazanova I.I. Methodic manual on sampling of fish eggs, larvae and fry. "Pishchevaya promyshlennost", 1966, p. 30-34.

18. Samyshev E.Z., Ptitsyna L.G. Feeding of larval herring, silver and red hakes in the Georges Bank area. Trudy AtlantNIRO, v.60, 1976, p. 138-142.

19. Sauskan V.I., Serebryakov V.P. Reproduction and growth of silver hake (Merluccius bilinearis). Voprosy ikhtiologii, v.8, vyp.3(50), 1968, p.500-521.

20. Sigaev I.K., Sushin V.A. Some results of investigation into the water temperature and zooplankton in the Georges Bank area during 1965-1970. Trudy AtlantNIRO, v.51, 1973, p.60-68.

21. Sigaev I.K. Intra-year variability of Geostrophic Circulation on the Continental Shelf off New England and Nova Scotia.ICNAF.Sel.pap.No3, 1978, pp.97-107.

22. Shmeleva A.A. Weight characteristics of the massive zooplankton forms in the Adriatic Sea. Report 2.Trudy of the Sebastopol biol.station, v.16, 1963, p. 56-68.

23. Vladimirskaya E.V. Distribution and seasonal changes of the zooplankton biomass in the northwestern Atlantic. Trudy VNIRO, v.77, 1972, p. 38-70.

24. Vladimirskaya E.V., Elizarov A.A., Movchan O.L. Seasonal changes in the marine ecosystem in the Newfoundland area. Biology of the sea, v.5, 1976, p. 38-47.

TABLE 1. Materials collected during the surveys conducted in August-October 1974, 1977-1980.

Year	Month	Layer of fishing, m	No.of ichthyoplankton samples	No. of zooplankton samples	No. of fry samples	No. of analysed larvae, sp.	No. of analysed fry, sp.
1974	August	50-0	102	102	-	467	-
1977	September	100-0	162	162	-	1707	-
1978	August	100-0	147	147	-	157	-
	September	100-0	148	148	15	215	79
	October	200-0	-	-	38	-	367
	August	200-0	122	130	-	1134	-
1979	September	200-0	106	119	-	1170	-
	October	200-0	-	-	38	-	1046
	August	200-0	69	119	-	951	-
1980	September	200-0	53	113	-	607	-
	October	200-0	-	-	95	-	537
	Total:		909	1040	186	6408	2029

TABLE 2. Total abundance of silver hake eggs, larvae and fry in August, September, October 1977-80.

Year	Month	eggs, 10^{11}	larvae., 10^{11}	fry., 10^{6}
1977	September	10	64	-
	August	92	84	-
1978	September	41	60	-
	October	-	-	258
1979	August	35	150	-
	September	13	103	-
	October	-	-	49
1980	August	21	39	-
	September	12	33	-
	October	-	-	47

TABLE 3. Composition and abundance of massive zooplankters (sp./m^3) on the Nova Scotian Shelf, September 1977-1980.

	Length, mm	1977	1978	1979	1980
Ova+Nauplii Copepoda	0.1-1.0	260	160	240	100
Calanus finmarchicus	2.2-5.2	40	60	60	90
Paracalanus spp.	0.8-1.5	50	110	50	60
Pseudocalanus spp.	1.1-1.9	60	70	50	20
Clausocalanus spp.	0.9- 1.7	+	+	+	10
Centropages spp.	0.2-2.0	380	290	100	310
Oithona spp.	0.5-1.5	710	320	520	320
Sagitta spp.	3.5-9.6	8	4	1	1
Euphausiacea	4.6-11.2	1	2	2	5
Bivalvia larvae	0.2-2.0	24	7	10	1
Polychaeta spp.	2.1-3.4	-	-	+	+
TOTAL:		1533	1023	1033	0917

TABLE 4. Food composition for larval silver hake of different length (mm) in August, September 1974, 1977-1980, % by weight.

Food organisms	2.0 - 5.9 mm			6.0 - 8.9 mm			9.0 - 12.9 mm			13.0 - 17.9 mm			18.0 - 22.9 mm			2.0 - 22.9 mm		
	mm	VIII	IX	mm	VIII	IX	mm	VIII	IX	mm	VIII	IX	mm	VIII	IX	mm	VIII	IX
Ova copepoda	0.1	1	1	0.1	1	+	0.1	+	+	0.1	-	+	0.1	-	+	0.1	1	+
Nauplii Copepoda	0.2 -0.3	6	7	0.3	1	1	0.3	-	+	-	-	-	-	-	-	0.2-0.3	1	2
Calanus finmarchicus	-	-	-	1.8	7	13	2.2-2.5	43	51	2.0-2.4	22	31	2.4	-	47	1.8-2.5	14	28
Paracalanus spp.	0.8	7	23	0.9	15	18	0.8-0.9	9	3	0.8	-	3	0.8	-	4	0.8-0.9	6	10
Pseudocalanus spp.	1.1-1.2	10	5	1.1	9	8	1.1	-	1	1.2	-	1	1.2	-	1	1.1-1.2	4	3
Clausocalanus spp.	0.9-1.1	27	20	1.1	12	17	1.2	6	2	1.2	1	1	1.2	-	3	0.9-1.2	9	9
Aetideus spp.	-	-	-	1.0	-	+	1.9	-	1	1.8-2.5	-	4	1.8	-	3	1.8-2.5	-	2
Centropages spp.	0.4	1	2	1.0-1.2	4	8	1.2-2.0	14	22	1.4-2.0	10	23	1.5	100	18	0.4-2.0	26	15
Candacia spp.	-	-	-	0.6	-	+	0.8	-	+	2.0	-	1	2.0	-	1	0.6-2.0	-	1
Oithona spp.	0.6	5	8	0.6	3	4	0.6	1	+	0.6	-	+	0.6	-	+	0.6	2	2
Nonidentified and digested Copepoda	0.7-0.9	43	34	0.8-1.3	48	31	1.0-1.8	27	20	1.6-1.8	3	35	2.0	-	13	0.7-2.0	24	26
Euphausiacea	-	-	-	-	-	-	-	-	-	1.5	40	1	1.5	-	10	1.5	8	2
Decapoda larvae	-	-	-	-	-	-	-	-	-	1.5-1.8	24	-	-	-	-	1.5-1.8	5	-
TOTAL:	-	100	100	-	100	100	-	100	100	-	100	100	-	100	100	-	100	100

TABLE 5. Proportion of feeding larval silver hake on the Nova Scotia Shelf in August-September 1974, 1977-1980.

Larval length, mm	Indices	1974	1977	1978		1979		1980		1974, 1977-1980	
		VIII	IX	VIII	IX	VIII	IX	VIII	IX	VIII	IX
1	2	3	4	5	6	7	8	9	10	11	12
2.0-5.9	Total number of larvae, sp.	354	455	144	130	647	559	565	195	1710	1339
	Proportion of feeding larvae, %	71	81	83	74	80	75	45	62	70	73
6.0-8.9	Total number of larvae, sp.	65	632	12	72	398	496	328	223	803	1423
	Proportion of feeding larvae,%	80	82	67	75	74	77	59	67	70	75
9.0-1 2.9	Total number of larvae, sp.	41	468	1	9	82	98	52	128	176	703
	Proportion of feeding larvae, %	95	88	100	100	82	83	76	73	88	86
13.0-17.9	Total number of larvae, sp.	7	130	-	4	6	15	5	54	18	203
	Proportion of feeding larvae,%	100	87	-	100	83	73	80	83	88	86
18.0-22.9	Total number of larvae,sp.	-	22	-	-	1	2	1	6	2	30
	Proportion of feeding larvae,%	-	87	-	-	100	100	100	100	100	87
2.0-22.9	Total number of larvae, sp.	467	1707	157	215	1134	1170	951	606	2709	3698
	Proportion of feeding, %	75	84	81	70	78	47	72	77	77	69

TABLE 6. Feeding intensity (%oo) and number of consumed organisms per feeding larval silver hake in August and September.

Length of larvae, mm	Indices	1974 VIII	1977 IX	1978 VIII	1978 IX	1979 VIII	1979 IX	1980 VIII	1980 IX	1974, 1977-80 VIII	1974, 1977-80 IX
2.0-5.9	No.of organisms, sp.	3	5	3	3	3	3	2	3	3	4
	Mean index of consumption, %oo	920	910	640	550	690	560	700	580	740	650
6.0-8.9	No.of organisms, sp.	3	6	5	5	4	4	2	4	4	5
	Mean index of consumption, %oo	410	360	260	530	290	420	310	410	320	400
9.0-12.9	No.of organisms, sp.	2	4	1	3	3	5	2	3	2	4
	Mean index of consumption, %oo	380	360	360	550	230	590	300	610	320	530
13.0-17.9	No.of organisms, sp.	2	7	-	4	5	9	6	4	4	6
	Mean index of consumption, %oo	110	300	-	270	610	420	630	440	450	360
18.0-22.9	No.of organisms, sp.	-	8	-	-	6	6	5	7	6	7
	Mean index of consumption, %oo	-	300	-	-	140	320	200	400	170	340
2.0-22.9	No.of organisms, sp.	3	6	3	4	4	5	3	4	3	5
	Mean index of consumption, %oo	450	450	420	480	390	440	430	490	420	460

TABLE 7. Length and weight of larval hake on the Nova Scotia Shelf in 1974, 1977-1980, % of mean value.

Length, mm	1974	1977	1978	1979	1980	Mean weight of larvae in 1974,1977-80 mg
2	101	80	131	108	74	0.1
3	105	82	124	104	80	0.3
4	107	84	120	101	84	0.7
5	109	86	116	99	88	1.3
6	110	87	114	98	91	2.1
7	112	88	111	97	93	3.2
8	113	89	109	96	96	4.7
9	114	90	108	94	98	6.5
10	115	91	106	94	99	8.8
11	116	91	105	93	101	11.4
12	116	92	104	92	103	14.6
13	117	92	103	91	104	18.2
14	118	93	102	91	106	22.4
15	118	94	101	90	107	27.2
16	119	94	100	90	108	32.6
17	120	94	99	89	110	38.6
18	120	95	99	89	111	45.2
19	121	95	98	88	112	52.6
20	121	96	97	88	113	60.7
21	121	96	97	87	114	69.6
22	122	96	96	87	115	79.2
23	122	97	96	87	116	89.7

TABLE 8. Food composition for silver hake fry of different length (mm) in October 1979-1980, % by weight.

Food organisms	Fry length, mm: 30.0-39.9 mm	X	40.0-49.9 mm	X	50.0-59.9 mm	X	60.0-69.9 mm	X	70.0-79.9 mm	X	80.0-89.9 mm	X	30.0-89.9 mm	X
Calanus finmarchicus	1.8-3.0 / 2.2	+	-	-	3.8	+	-	-	-	-	-	-	1.8-3.8 / 2.0	+
Undinula spp.	1.8-3.0 / 2.2	1	3.0	+	3.0	+	-	-	-	-	-	-	1.8-3.0 / 2.2	+
Paracalanus spp.	0.8	8	0.8	+	-	-	-	-	-	-	-	-	0.8	4
Pseudocalanus spp.	1.2	+	1.2	2	-	-	-	-	-	-	-	-	1.2	+
Clausecalanus spp.	-	-	-	-	1.0	4	-	-	-	-	-	-	1.0	+
Matridia spp.	1.3-3.4 / 2.2	4	1.8-2.9 / 2.5	8	2.5-6.0 / 3.0	+	-	-	-	-	-	-	1.3-6.0 / 2.7	4
Aetideus spp.	-	-	2.8	+	-	-	-	-	-	-	-	-	2.8	+
Centropages spp.	0.8-2.8 / 1.2	21	1.1-1.5 / 1.2	8	1.2-1.5 / 1.3	4	1.5	+	-	-	-	-	0.8-2.8 / 1.2	8
Candacia spp.	1.3-3.1 / 2.6	1	2.5-3.0 / 2.8	6	3.0	+	-	-	-	-	3.0	12	1.3-3.1 / 2.8	4
Temora spp.	-	-	2.3	+	-	-	-	-	-	-	-	-	2.3	+
Scolecithrix spp.	2.1-2.6 / 2.4	+	1.3-2.1 / 1.3	10	-	-	-	-	-	-	-	-	1.3-2.6 / 2.2	3
Nonidentified and digested Copepoda	1.2-3.0 / 2.1	+	2.0	+	-	-	-	-	-	-	-	-	1.2-3.0 / 2.1	+
Mysidacea	7.0-11.0 / 8.5	1	7.0-10.0 / 7.8	2	8.0	1	-	-	-	-	-	-	7.0-11.0 / 8.3	1
Cumacea	5.0-6.0 / 5.4	+	6.0	+	-	-	-	-	-	-	-	-	5.0-6.0 / 5.4	+
Gammarida	4.0-7.3 / 6.0	1	5.0-10.2 / 8.8	1	5.0-13.3 / 10.0	8	-	-	-	-	-	-	4.0-13.3 / 9.0	3
Hyperida	3.5-4.2 / 3.8	+	-	-	-	-	-	-	-	-	-	-	3.5-4.2 / 3.8	+
Amphipoda	2.0-6.0 / 4.0	9	3.0-7.0 / 4.7	5	3.5-6.0 / 4.9	3	4.0	1	-	-	-	-	2.0-7.0 / 4.8	4
Euphausiidae	4.0-15.0 / 8.8	16	1.6-20.0 / 10.1	15	7.0-16.0 / 10.3	25	14.0-19.0 / 14.9	48	9.0	100	-	-	1.6-19.0 / 10.5	20
Parathemisto spp.	2.0-14.4 / 6.8	30	2.8-13.2 / 6.5	30	1.8-13.4 / 6.5	41	7.0-12.3 / 9.8	35	-	-	5.0	31	1.8-14.4 / 8.0	35
Decapoda zoea	3.0-5.0 / 4.3	+	4.0-5.5 / 4.6	+	5.0-18.0 / 7.8	2	5.0	1	-	-	-	-	3.0-18.0 / 5.6	1
Polychaeta	2.1-2.4 / 2.2	1	2.0-3.2 / 2.7	6	2.8-3.2 / 3.0	10	2.7-3.4 / 3.0	15	-	-	-	-	2.0-3.4 / 3.0	8
Nemertini	3.0-4.3 / 3.8	+	3.7-4.3 / 3.9	2	-	-	-	-	-	-	-	-	3.0-4.3 / 3.9	+
Sagitta spp.	15.0-19.0 / 17.5	+	10.5-15.0 / 12.5	+	4.0-15.0 / 9.5	+	-	-	-	-	11.0	57	10.5-19.0 / 13.4	+
Bivalvia	1.0	+	10.0	+	-	-	-	-	-	-	-	-	1.0-10.0	+
Larval fish	7.8-19.3 / 11.2	3	5.8-20.4 / 13.7	5	7.8-23.0 / 12.3	3	-	-	-	-	-	-	5.8-23.0 / 13.5	4
Larval hake	8.0-15.0 / 10.9	4	-	-	-	-	-	-	-	-	-	-	8.0-15.0 / 10.9	1
TOTAL:		100		100		100		100		100		100		100

Note: Extreme sizes of food organisms are given in numerator and mean values of consumed organisms in denominator

TABLE 9. Length and weight of the hake fry on the Nova Scotia Shelf in 1978-1980, % of the mean value.

Length, mm	1978	1979	1980	Mean weight (g) of fry for 1978-1980
24-25	104	94	107	0.10
26-30	104	95	104	0.15
31-35	103	96	102	0.24
36-40	102	97	99	0.37
41-45	102	97	97	0.53
46-50	101	98	95	0.74
51-55	101	98	94	1.00
56-60	101	99	93	1.31
61-65	100	99	92	1.66
66-70	100	100	90	2.30
71-75	-	-	-	-
76-80	-	-	-	-
81-85	-	-	-	-
86-90	99	101	87	4.28

TABLE 10. Occurrence of live (l) and dead (d) silver hake eggs at varying developmental stages on the Nova Scotia Shelf in August-September 1977-1980.

Survey time		No. of analysed eggs		Developmental stages of eggs											
				I			II			III			IV		
Year	Month			Total	l	d	Total	l	d	Total	l	d	Total	l	d
1977	September	No.	847	456	10	446	126	86	40	209	179	30	56	56	–
		%	100	54*	2**	98	15	68	32	25	86	14	6	100	0
1978	August	No.	366	105	9	96	58	31	27	148	135	13	55	55	–
		%	100	29	8	92	16	53	47	40	92	8	15	100	0
	September	No.	259	115	1	114	78	16	62	56	34	22	10	10	–
		%	100	44	1	99	30	20	80	22	61	39	4	100	0
	August	No.	531	255	3	252	96	53	43	122	116	6	58	58	–
1979		%	100	48	1	99	18	55	45	23	95	5	11	100	0
	September	No.	549	216	7	209	116	58	58	165	155	10	52	52	–
		%	100	39	3	97	21	50	50	90	94	6	10	100	0
	August	No.	599	232	9	223	81	54	27	213	195	18	73	73	–
		%	100	38	4	96	14	67	33	36	92	8	12	100	0
1980	September	No.	428	185	3	182	58	28	30	147	133	14	38	38	–
		%	100	43	2	98	14	48	52	34	91	9	9	100	0

* Number of live and dead eggs (%) of total analysed number

** Number of live eggs (%) of total number of eggs

TABLE 11. Recurrence of winds (%%) in August and September of 1977-1980.

Wind force	1977	1978		1979		1980	
	Sept.	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.
3-4	32	53	66	66	45	43	40
5-6	37	12	30	12	-	1	17
7 and >	7	3	4	-	-	-	-

TABLE 12. Recurrence of rough sea (%%) in August and September of 1977-1980.

Roughness	1977	1978		1979		1980	
	Sept.	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.
3-4	27	52	66	44	69	32	55
5-6	28	9	14	6	7	1	33
7 and >	-	-	1	-	-	-	-

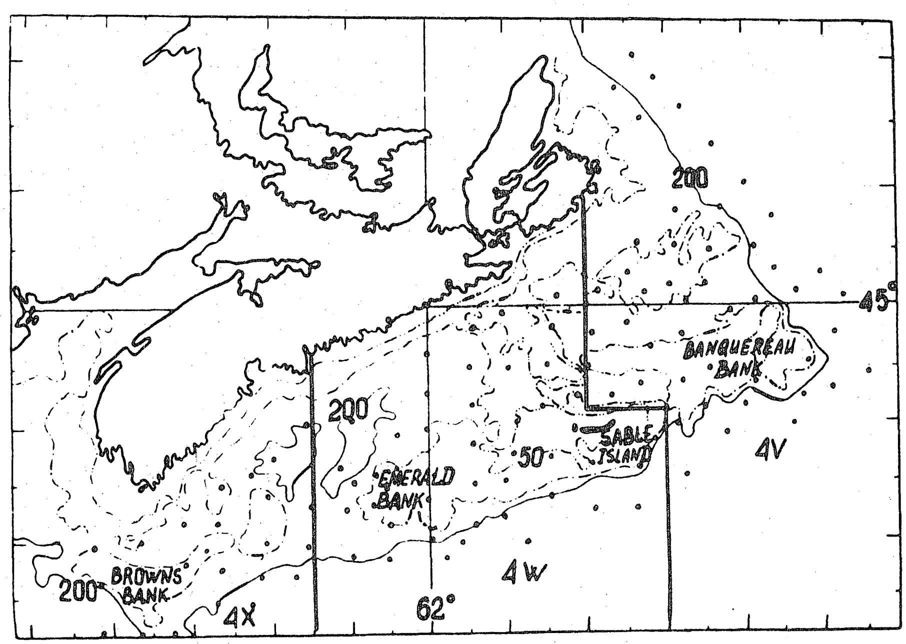

Fig. 1. Scheme of stations of the ichthyoplankton survey in August-September 1977-1980.

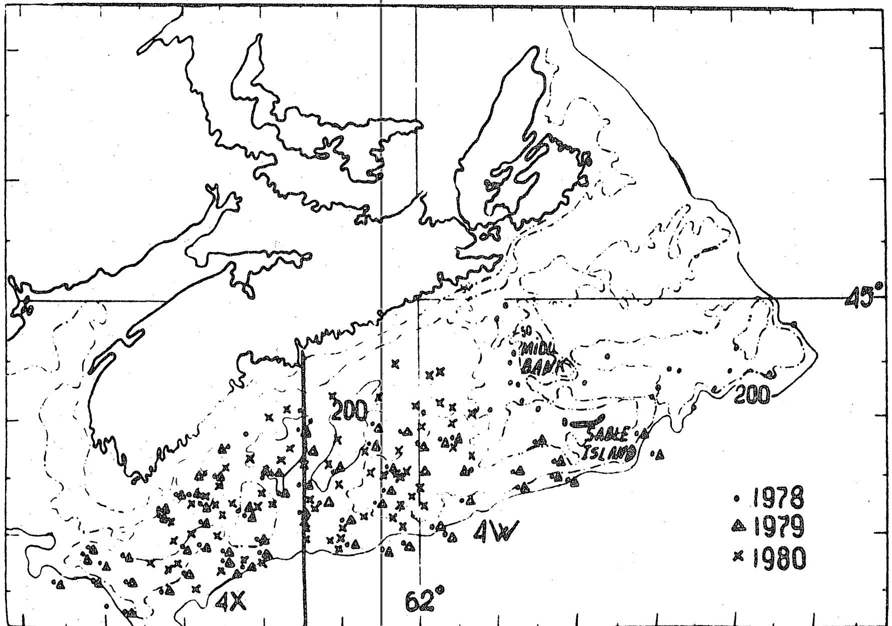

Fig. 2. Scheme of stations of the trawl fry survey in October 1978-1980.

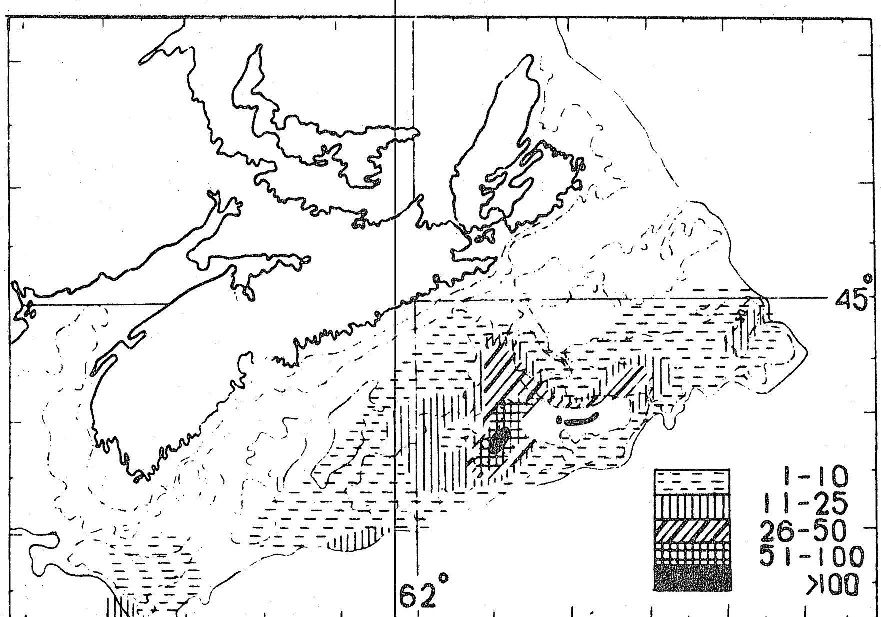

Fig. 3. Distribution of silver hake eggs, sp./m^2 (September 1980).

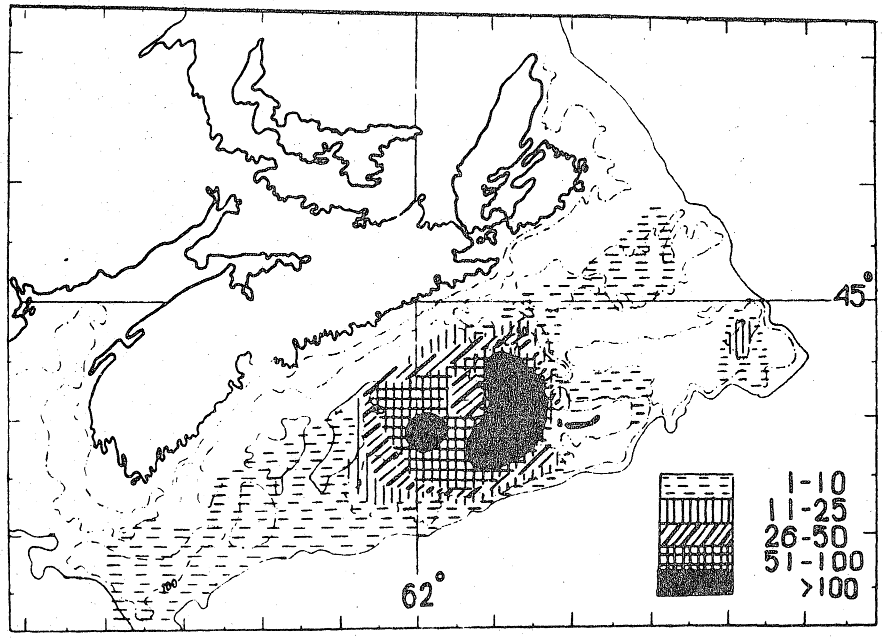

Fig. 4. Distribution of larval silver hake, sp./m^2 (September 1980).

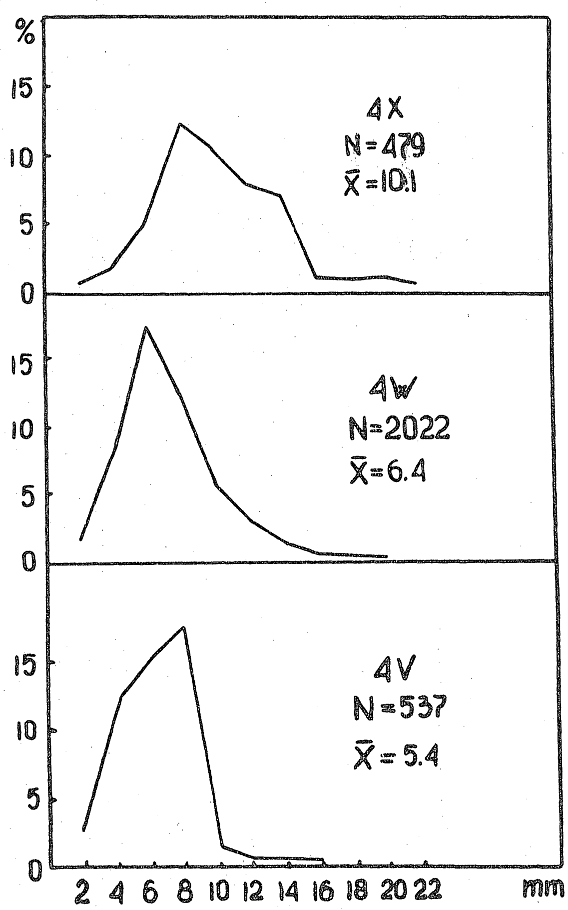

Fig. 5. Distribution of larval silver hake by body length (September 1977).

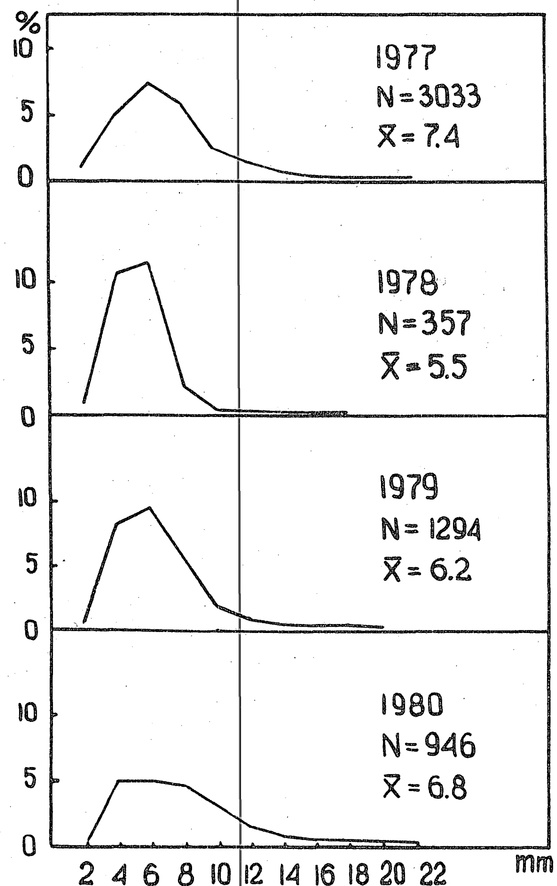

Fig. 6. Distribution of larval silver hake by body length (September 1977-1980.

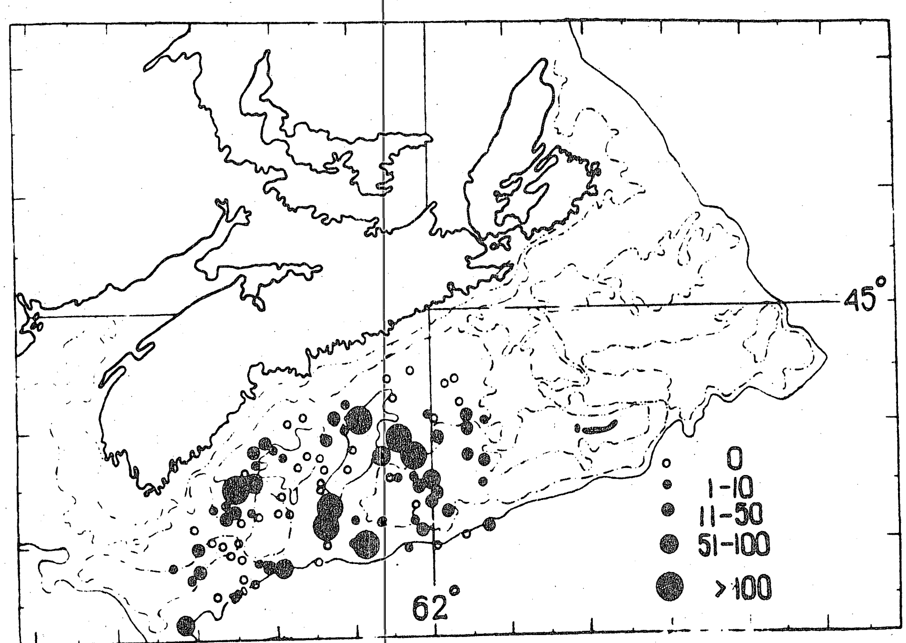

Fig. 7. Distribution of silver hake fry, sp. (October 1980).

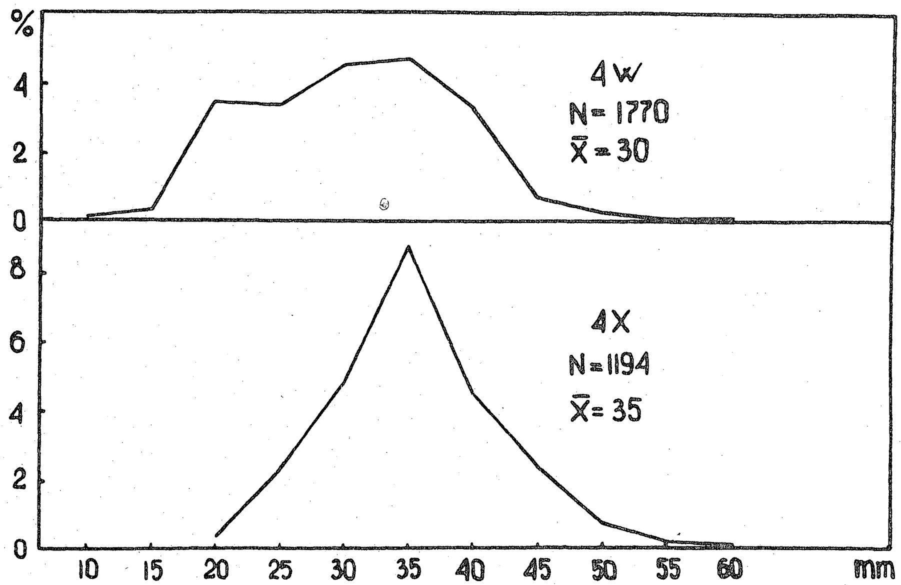

Fig. 8. Distribution of silver hake by body length (October 1980).

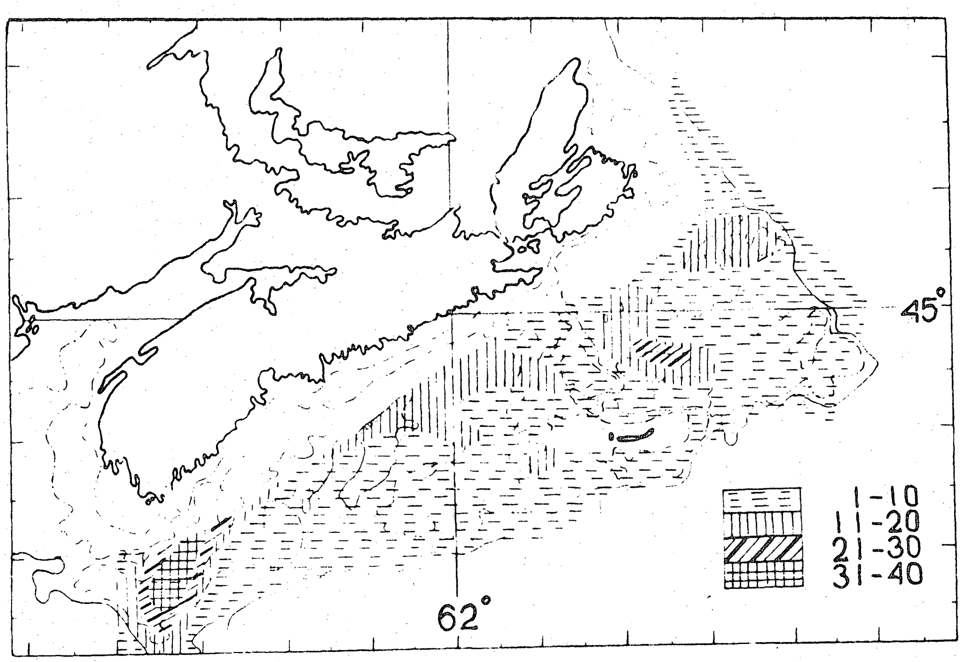

Fig. 9. Distribution of food zooplankton biomass, g/m^2 (August 1980).

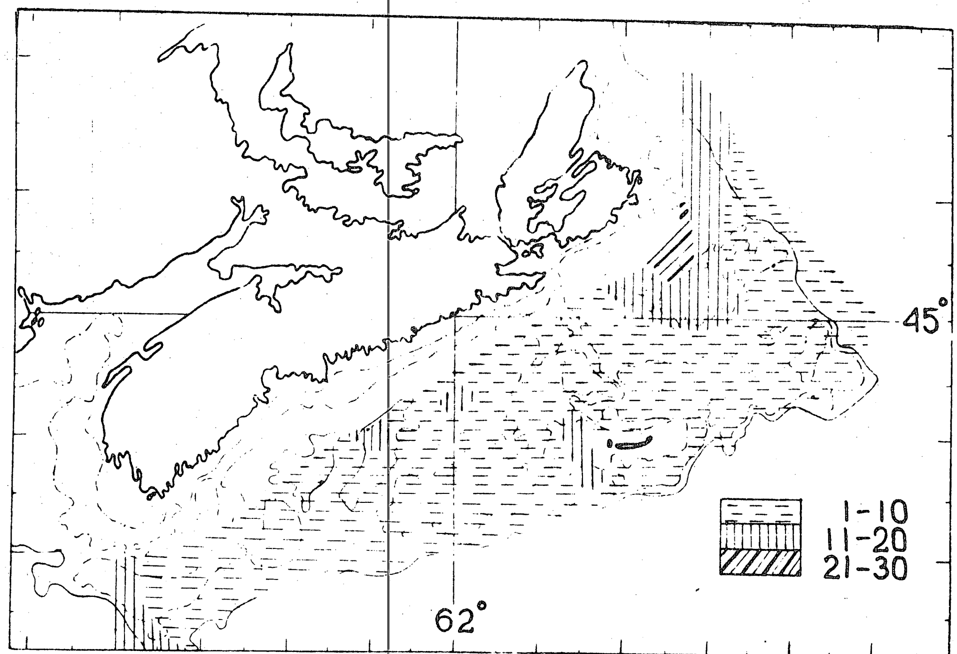

Fig. 10. Distribution of food zooplankton biomass, g/m^2 (September 1980).

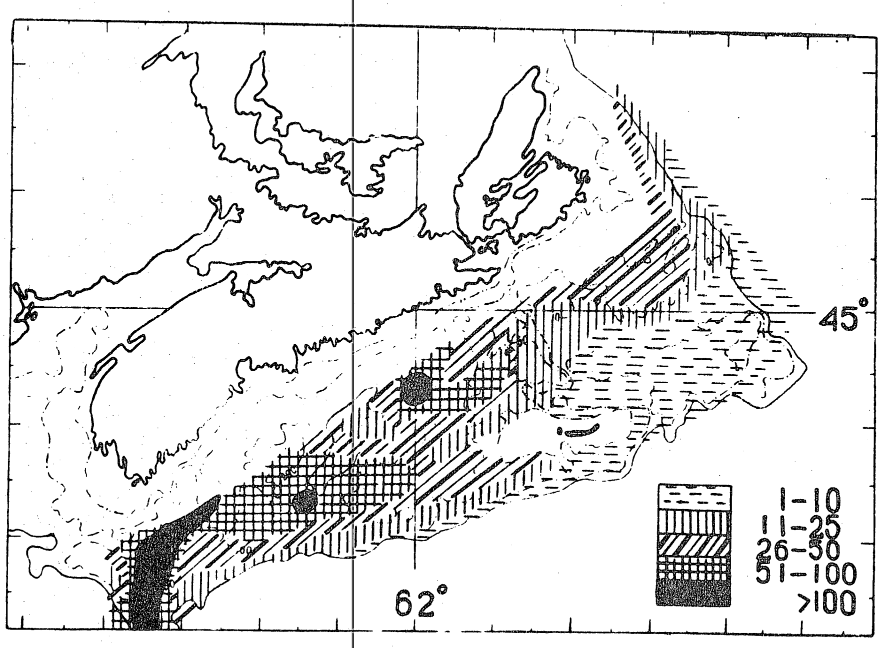

Fig. 11. Distribution of zooplankters Oithona spp., thous.sp./m^2 (August 1980).

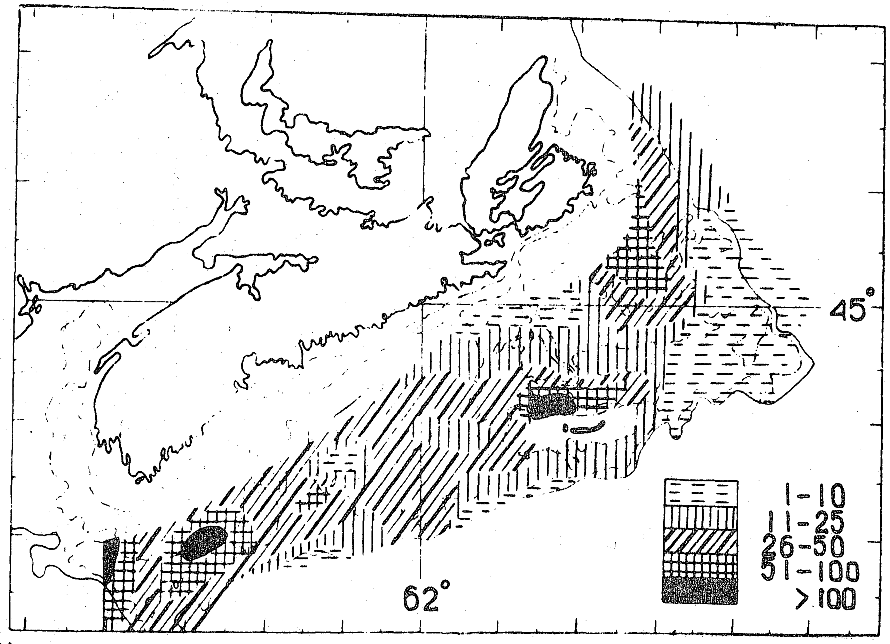

Fig. 12. Distribution of zooplankters Oithona spp., thous.sp./m^2 (September 1980).

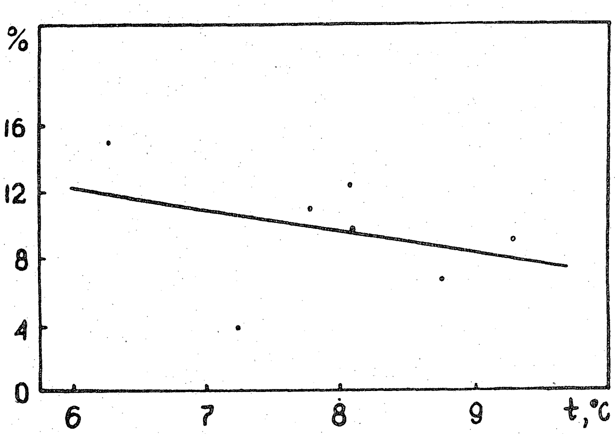

Fig. 13. Dependence of the hake egg survival on the weighted mean water temperature in the 0-200 m layer.

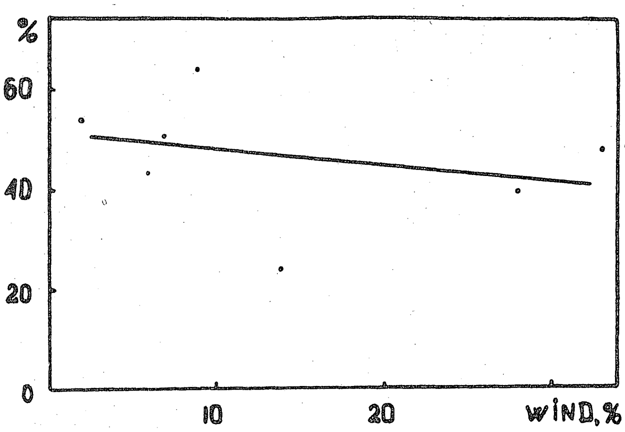

Fig. 14. Dependence of the hake egg survival on the sea state (4, in Beaufort scale number).