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Distribution and Fluctuations of the Scotian Silver Hake Abundance in Early Stages

by

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Abstract

Results of ecological surveys conducted in cooperation with the Canada scientists in August-October 1977-1982 on the Scotian Shelf are presented. Abundance of silver hake eggs and larvae and their distribution were determined. Influence of such factors as water temperatures, swelling, availability of food and feeding index values on survival and strength of silver hake year-classes is considered.

Introduction

Silver hake occurs in the Scotian waters in numbers and is an important commercial species. Regular observations on the state of silver hake stocks have been made since 1962. Abundance of separate year classes and of the stocks is subject to large fluctuations due to variable year class recruitment. At present, the abundance of fish year classes is thought to be generated at earlier stages (Nikolsky, 1974). The strength of a year class can be derived from the fry (0 group youngs) abundance, for the latter does not undergo considerable changes in the future under the influence of natural habitat. Therefore variations of the egg, larva and young fish abundance should be studied together with the environment factors that might affect survival at early developmental stages. For the purpose of studying the fac-

tors determining the abundance of silver hake year classes in the Scotian waters the scientists from the AtlantNIRO and Bedford Institute of Oceanography (Dartmouth, Canada) were engaged in a joint program of ecological surveys of the Scotian Shelf. From the results of the studies the areas and timing of spawning were specified, egg and larva distribution, composition, abundance and distribution of food organisms for larval and young silver hake, and feeding index values for larval and young silver hake were determined. Results of these studies based on the 1974, 1977-1980 data were submitted to the Regular Session of NAFO (Noskov et al., 1982).

The present paper continues a series of long-term investigations and is supplemented with the data on spawning efficiency in the Scotian waters in 1981 and 1982.

Materials and methods

Biological surveys conducted by the Soviet ships of the SRTM class on the Scotian Shelf covered a standard grid of stations (fig. 1). At each station the research work involved ichthyo- and zooplankton sampling, air temperature measurements, wind speed and cloud cover determinations, water temperature measurements, observations on the swell and sampling for feeding studies.

Ichthyoplankton was sampled using a double Bongo sampler (large model) with the opening diameter of 0.6 m with two nets of 0.333 mm mesh. The catch from one net was sampled by the Canadian scientists, and from the other by the Soviet scientists. The results of statistical processing of the data from 99 stations showed a good agreement in egg and larva counts ($r = 0.89 \pm 0.02$ and $r = 0.96 \pm 0.01$, respectively) obtained by the two scientific parties.

Zooplankton was sampled using a double Bongo sampler (small model) with the opening diameter of 0.2 m with two nets of 0.076 mm mesh. This model was attached to the same cable as the large model, one meter above the latter.

Oblique hauls were made on the 24-hour basis: at small

depths from 5 m off bottom to surface, and at deepwater stations from 200 m to the surface. The ship's speed was 2.5 m knots, the net was hauled in at 50 m/min. and back at 20 m/min. Flowmeters attached to plankton samplers were used to measure the volume of filtered water.

Hydrographic observations consisted of water temperature measurements using BT.

Hydrometeorological observations involved air temperature measurements, wind speed, air humidity, cloud cover and swell determinations.

All materials collected and processed in 1977-1982 are presented in table 1.

The method of processing zoo- and ichthyoplankton samples was described in detail in the previous paper (Noskov et al., 1982).

The number of eggs and larvae was calculated under m^2 of the sea surface. The method of squares (Aksjutin, 1968) was used to determine the minimum abundance of silver hake eggs and larvae. The obtained results of the larva abundance were not taken as absolute values, but as abundance indices, for mortality rates on the larvae were not taken into account.

The samples for feeding studies of silver hake were processed according to "Methodical manual for studying feeding and food relation of fishes in natural habitat" (1974). All examined larvae were combined for four size groups:

a) 2.0 - 5.9 mm - larvae having yolk-sacs or their residues, but already consuming zooplanktonic food (copepod eggs and nauplii);

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

c) 9.0 - 12.9 mm - larvae feeding mainly on large Copepoda;

d) 13.0 - 23.0 mm - larvae consuming large Copepoda, young Euphausiacea, Amphipoda, Decapoda and other pelagic invertebrates.

data for 1977 and 1982 were omitted, for ichthyoplankton sur-

veys had been made two weeks after the reference period in those years. No considerable difference was observed between mean lengths of larval silver hake (fig. 5), which can be related to coincidence of spawning dates. In 1981, the mean length of the larvae was approximately 3 mm greater (50%%) than in the above-mentioned years, evidently, due to earlier spawning or better feeding conditions.

Factors controlling survival of eggs and larvae

Influence of water temperatures, swell, availability of food and feeding index values on survival and strength of the silver hake year classes in the Scotian Shelf area is considered.

Oceanographic conditions. During the spawning period and development of eggs and larvae the water temperature may affect survival either directly or indirectly through the other factors (Dementjeva, 1958).

Massive spawning of the Scotian silver hake takes place at the temperatures ranging from 6 to 9°C. Eggs and larvae aggregate in the surface layer (0-50 m), where the water temperature varies from 6 to 15°C.

The thermal regime suffered considerable changes during the spawning of silver hake in 1977-1982 all over the Scotian Shelf area. Fluctuations of mean weighted temperature values in the 0-200 m layer confer this statement (table 2). The minimum temperatures (6.3°C) were recorded in August 1978, and the maximum (9.6° C) in September 1981.

On the basis of information relating the body length of the organisms to weight (Bogorov, 1939; Kanaeva, 1962), the weights of the different food organisms were determined from the actual measurements of whole organisms.

To evaluate year-to-year variation in the condition factor of the larvae, weghts of larvae by length group and year were compared with mean weights for the 1977 to 1982 period (Noskov, 1956).

Distribution of eggs and larvae

In general, massive spawning of the Scotian silver hake takes place in August - September in the shallow water regions: on Browns and Banquereau banks, and on Sable shoals (Sauskan and Serebryakov, 1968; Noskov et al., 1979).

Most dense spawning aggregations concentrate on Sable shoals at the time, when there occurs sinking of the warm surface waters (fig. 2). Due to a very slow transport of silver hake eggs and larvae from spawning grounds of Sable shoals in the south-western direction (Trites and Banks, 1958), they stay in the spawning areas till they grow into juveniles (figs. 3,4),

The data from the September survey conducted in 1977 indicate that the largest recorded larvae were from the western part of the area, where the spawning begins earlier, and the smaller ones from the eastern part, where the spawning occurs later (Noskov et al., 1978). As the spawning of silver hake is prolonged, the Bongo catches contain both newly hatched larvae (2-3 mm) and the specimens 18-23 mm in length. To compare length frequences of larval silver hake for the 1977-1982, the first ten-day period of September was taken as a reference period. The

Our first attempts were aimed at elucidation of the influence of mean weighted values of the water temperature on survival of embryos in different years (Noskov et al., 1982). The comparison between the data on survival of eggs and the mean weighted temperature values for the 0-200 m layer (table 2) showed a poor back correlation (r + -0.37). Having supplemented the data with the values for 1981-1983, we came to a conclusion that a selected factor was not reliable. The data on survival of silver hake eggs for the 1977-1980 period were compared against the swell with wind force 4 (Noskov et al., 1982). The correlation turned out to be weak (r = -0.31). Having supplemented the data with the new values for 1981-1982, we revealed that the selected factor was unreliable.

Composition and abundance of zooplanktonic food. In August - October 1977-1982 the zooplanktonic food on the Scotian Shelf

during the feeding period of larval silver hake consisted mainly of the following organisms: Oithona spp., Centropages spp., Paracalanus spp., Calanus finmarchicus, Pseudocalanus spp., etc. (table 4). The mean abundance of these organisms ranged from 710 to 1 500 sp./m^3 by year. In 1981-1982 the abundance indices were minimal, comprising 72 and 75% of the annual mean. Another peculiarity of the year 1982 was that the abundance indices of such organisms as Oithona spp., C. finmarchicus, and eggs with copepod nauplii were far below the long-term mean and constituted 21-36% of its value (table 4).

Feeding and condition factor of larval hake. The diet of the Scotian larval silver hake 2 to 9 mm in length (70 to 90% by weight) is mainly represented by planktonic animals of the lower crustaceans, namely, Clausocalanus spp., Paracalanus spp. and Pseudocalanus spp. with the mean length of 0.8-1.2 mm, and the eggs and nauplii of these zooplankters (Noskov et al., 1982). The larval silver hake 9 to 23 mm in length feed primarily on C.finmarchicus (mean length of 2.5 to 2.8 mm) and Centropages spp. (mean length of 1.4 mm).

The feeding index value of larval silver hake for September-October 1977-1982 relative to the index of food consumption is presented in table 5. It can be seen from the table that the feeding index value was below the long-term mean in 1981 (95%), especially so in 1982 (64%).

Availability of food exerts an important control on recruitment success (Nikolsky, 1974). The quantity, quality and accessibility of food, duration of the feeding season, abundance, biomass and state of the feeding fish populations are features determining availability of food for the fish. To judge of the food reserve, an indirect index - condition factor - is used.

The comparison of weights of larval silver hake of the same size in September-October 1977-1982 (table 6) showed that the condition factor was highest in 1978 for the larvae 2 to 10 mm in length (126% of the mean long-term value), and lowest in 1981 and 1982 (82 and 85% of the mean long-term value). The data on the condition factors for the young silver hake for the

1978-1984 period contained in table 7 give a similar pattern. In 1978 the condition factor of the young silver hake was very high (114% of the mean long-term value), and in 1981 it was lower (88%) and in 1982 still more lower (60%).

The analysis of condition factors of larval silver hake in the areas of their concentration (100 sp. more under m^2), of abundance of the zooplanktonic food and the temperature in the 0-200 m layer revealed some correlations. A strong direct correlation ($r = 0.79 \pm 0.13$) existed between the condition factor of larval silver hake 2 to 10 mm in length and the total abundance of zooplankters (C.finmarchicus, Paracalanus spp. and Clausocalanus spp.) in the summer-fall period of 1977-1982. The selected factor appeared to be reliable. A strong back correlation ($r = -0.73 \pm 0.19$) was also found between the mean weighted temperature values for the 0-200 m layer and the condition factor of the larvae 2 to 10 mm in length. The selected factor turned out to be reliable.

Summary

The massive spawning of the Scotian silver hake takes place in August-September in the shallow waters (Browns and Banquereau Banks, Sable shoals), and in the zone of sinking waters at the temperature ranging off bottom from 6 to 9°C.

The eggs and larvae are abundant westward of Sable Island, in the surface layer with the temperature ranging from 6 to 15°C. The abundance of eggs and larvae did not change significantly in Septemver-October of 1977-1982. The abundance of the 0-group fish considerably ranged from $110.9 \cdot 10^7$ (1981) to $1.7 \cdot 10^7$ sp. (1982), i.e. 65 times.

The feeding conditions is the major factor responsible for survival of the young silver hake, for more successful year classes have been observed in the years, when the condition factor of the youngs was the highest. So, a least numerous year class recorded was in 1982, when the feeding index value and condition factor were the lowest.

The survival of the eggs and larvae was not affected by the

water temperature and sea state.

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Table 1 Material collected in the Scotian Shelf area in 1977-1982.

Year	Date	Area of survey, sq.miles	Hauling depth, m	No. of stations, sp.	No. of processed samples		No. of processed larvae, sp.
					ichthyoplankton	zooplankton	
1977	21.09-14.10	46 240	100-0	162	157	162	1 707
1978	06.08-25.08	50 820	100-0	147	85	147	157
	29.08-15.09	50 820	100-0	149	72	148	215
1979	04.08-19.08	36 840	200-0	126	117	126	1 134
	24.08-10.09	36 840	200-0	125	110	119	1 170
1980	15.08-31.08	41 410	200-0	130	69	119	951
	04.09-22.09	41 410	200-0	126	53	113	607
1981	26.08-12.09	50 820	200-0	79	61	79	405
	22.09-09.10	50 820	200-0	99	73	99	270
1982	24.09-12.10	41 370	200-0	92	62	92	242
Total				1 235	859	1 204	6 858

Table 2 Water temperature and survival of silver hake eggs in the Scotian Shelf area in 1977-1982

Year	Date	Survival of eggs, ‰	Mean weighted water temperatures, °C
1977	21.09-14.10	39.1	8.8
1978	06.08-25.08	62.9	6.3
	29.08-15.09	23.6	7.2
1979	04.08-19.08	43.3	7.8
	24.08-10.09	49.6	8.1
1980	15.08-31.08	55.0	8.1
	04.09-22.09	46.7	9.3
1981	26.08-12.09	49.0	9.6
	22.09-09.10	42.0	9.6
1982	24.09-12.10	63.4	8.3

Table 3 Abundance of silver hake eggs and larvae in the Scotian Shelf area in 1977-1982

Year	Date	Eggs, sp. . 10^{11}	Larvae, sp. . 10^{11}
1977	21.09-14.10	10	64
1978	06.08-25.08	92	84
	29.08-15.09	41	60
1979	04.08-19.08	35	150
	24.08-10.09	13	103
1980	15.08-31.08	21	39
	04.09-22.09	12	33
1981	26.08-12.09	198	206
	22.09-09.10	22	61
1982	24.09-12.10	41	87

Table 4 Composition and abundance of food organisms (sp./m^3 and %% of mean value) in the Scotian Shelf area in September-October 1978-1982

Food organisms	Length, mm	No.	1977	1978	1979	1980	1981	1982	1977-1982
Copepod eggs and larvae	0.1-1.0	Sp./m^3	260	160	240	100	70	30	140
		%%	185	114	171	71	50	21	100
Calanus finmarchicus	2.2-5.2	sp./m^3	40	60	60	90	90	20	60
		%%	66	100	100	150	150	33	100
Paracalanus sp.	0.8-1.5	sp./m^3	50	110	50	60	70	170	85
		%%	58	129	58	70	82	200	100
Pseudocalanus sp.	1.1-1.9	sp./m^3	60	70	50	20	70	40	50
		%%	120	140	100	40	140	80	100
Clausocalanus sp.	0.9-1.7	sp./m^3	+	+	+	10	+	20	15
		%%	+	+	+	66	+	133	100
Centropages sp.	0.2-2.0	sp./m^3	380	290	100	310	140	320	260
		%%	146	111	38	119	53	123	100
Oithona sp.	0.5-1.5	sp./m^3	710	320	520	320	270	140	380
		%%	186	84	136	84	71	36	100
Total			1 500	1 010	1 020	910	710	740	980
			153	103	104	92	72	75	100

Table 5 Feeding index values (°/$_{oo}$ and % of mean value) of larval Scotian silver hake in September-October 1977-1982

Length of larvae, mm	Feeding index value	1977	1978	1979	1980	1981	1982	1977-1982
2.0-5.9	°/$_{oo}$	910	550	560	580	680	530	635
	%	143	87	88	91	107	83	100
6.0-8.9	°/$_{oo}$	360	530	420	410	360	230	385
	%	93	138	109	106	93	60	100
9.0-12.9	°/$_{oo}$	360	550	590	610	470	160	460
	%	78	120	128	133	102	35	100
13.0-17.9	°/$_{oo}$	300	270	420	440	190	160	300
	%	100	90	140	147	63	53	100
18.0-22.9	°/$_{oo}$	300	-	320	400	300	-	330
	%	91	-	97	121	91	-	100
2.0-22.9	°/$_{oo}$	450	480	440	490	400	270	420
	%	107	114	105	117	95	64	100

Table 6 Length and weight (% of mean weight) of larval Scotian silver hake in 1977-1982

Length, mm	1977	1978	1979	1980	1981	1982	Mean weight of larvae, 1977 to 1982 period	
							mg	%%
2	92	147	120	84	60	67	0.1	100
3	93	138	115	89	68	74	0.3	100
4	94	132	111	93	74	79	0.6	100
5	94	127	108	96	80	83	1.2	100
6	95	123	106	99	84	87	1.9	100
7	95	120	104	101	88	90	3.0	100
8	95	118	103	103	92	93	4.4	100
9	96	116	102	104	95	95	6.1	100
10	96	114	100	106	98	98	8.2	100
2-10	94	126	108	97	82	85		

Table 7 Length and weight (% of mean value) of juvenile Scotian silver hake in October-November 1978-1984

Length, mm	1978	1979	1980	1981	1982	1983	1984	Mean weight of juveniles, 1978 to 1984 period	
								g	%%
26-30	100	93	106	84	30	100	77	0.15	100
31-35	119	109	114	90	62	105	101	0.21	100
36-40	119	113	106	97	68	106	103	0.31	100
41-45	117	104	100	87	87	104	102	0.48	100
46-50	119	111	108	83	78	110	108	0.64	100
51-55	123	114	95	86	84	106	112	0.86	100
56-60	111	120	101	87	82	112	119	1.08	100
61-65	102	119	96	82	-	100	102	1.57	100
66-70	-	-	107	93	-	127	119	1.69	100
26-70	114	110	104	88	60	108	105		

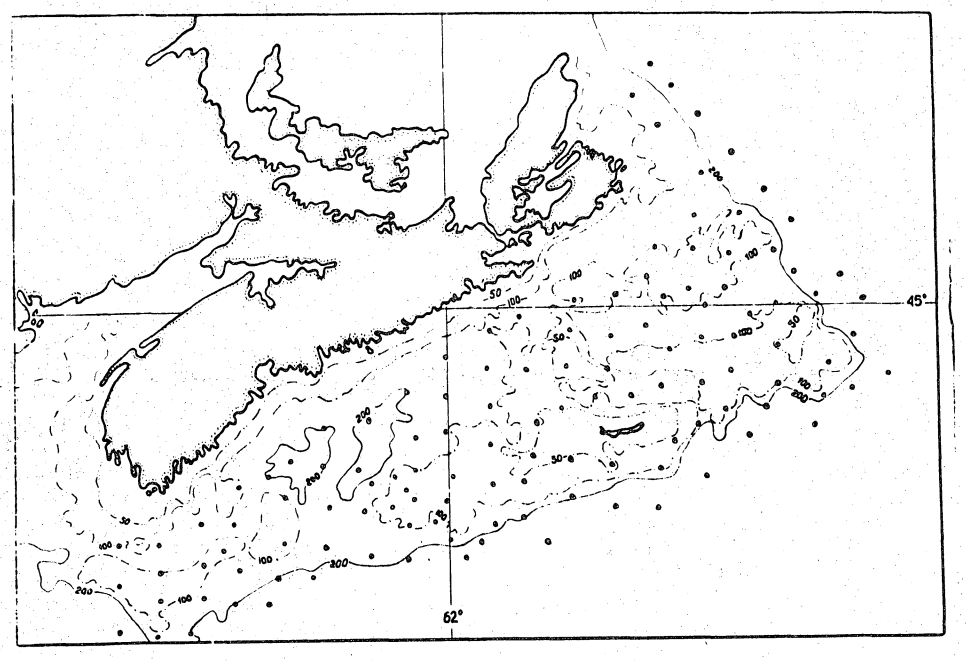

Fig. 1. Scheme of stations for ecological surveys (August - October 1977-1982).

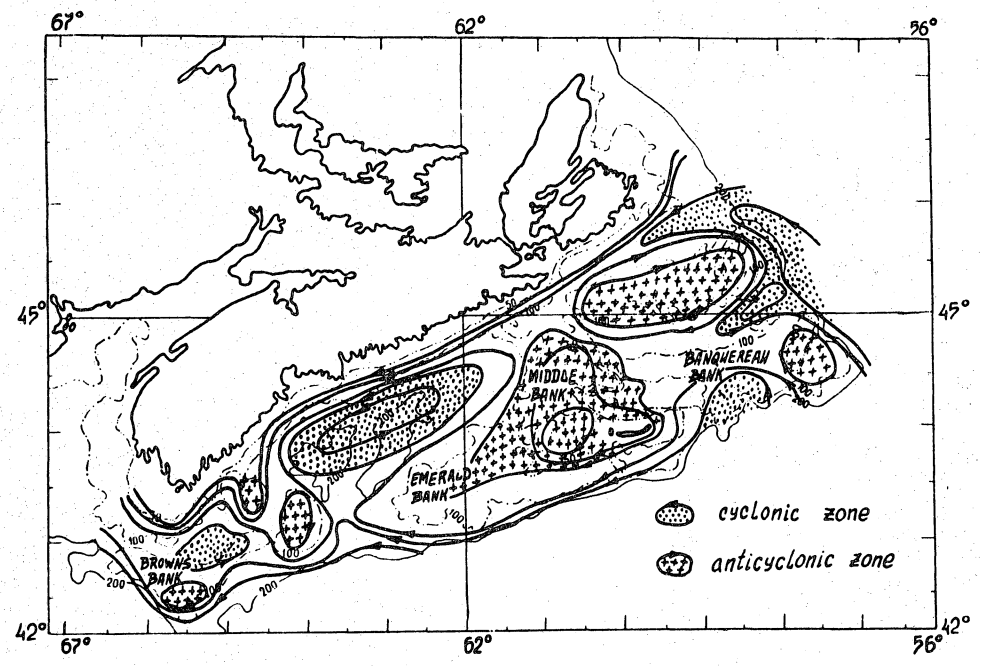

Fig. 2. Scheme of geostrophic circulation of the waters on the Scotian Shelf in August (from Sigaev, 1978).

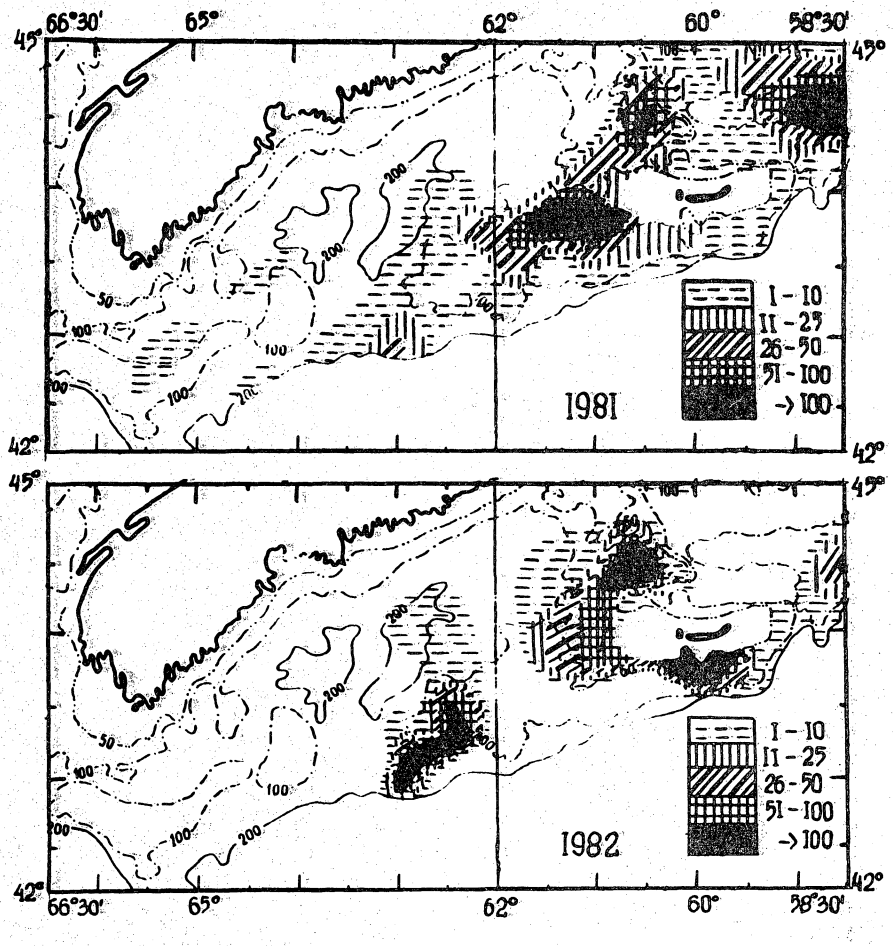

Fig. 3. Distribution of silver hake eggs, sp./m^2 (September-October 1981-1982).

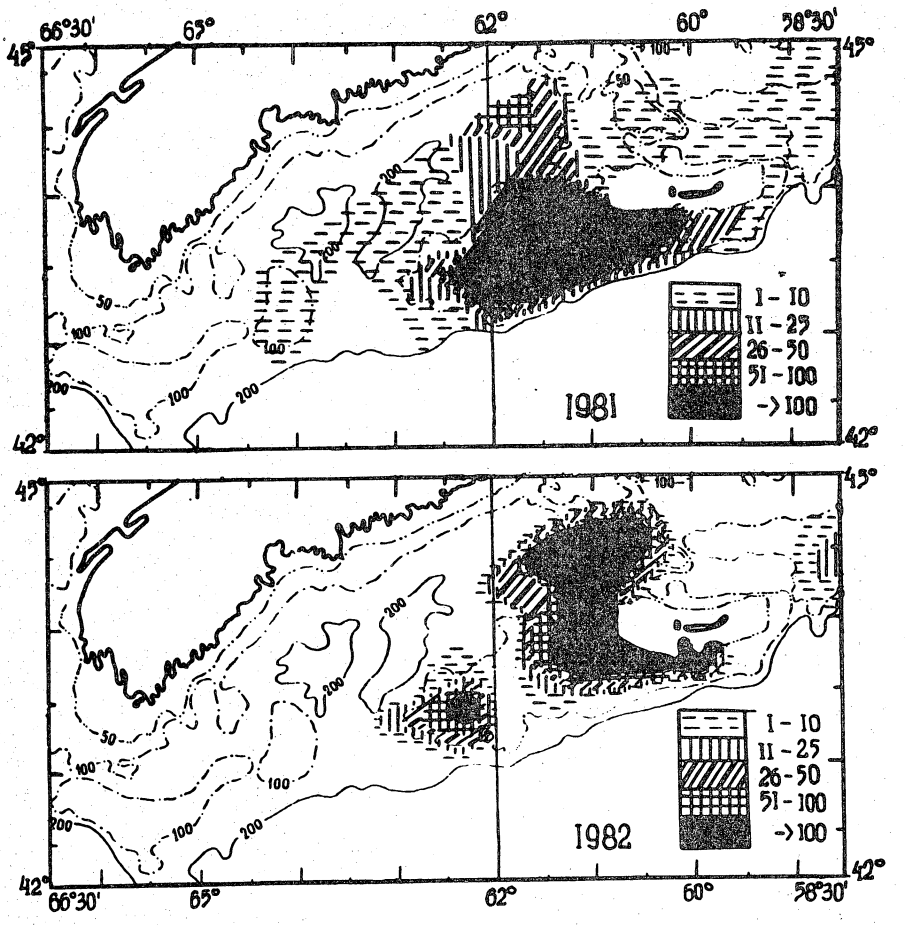

Fig. 4. Distribution of larval silver hake, sp./m^2 (September-October 1981-1982).

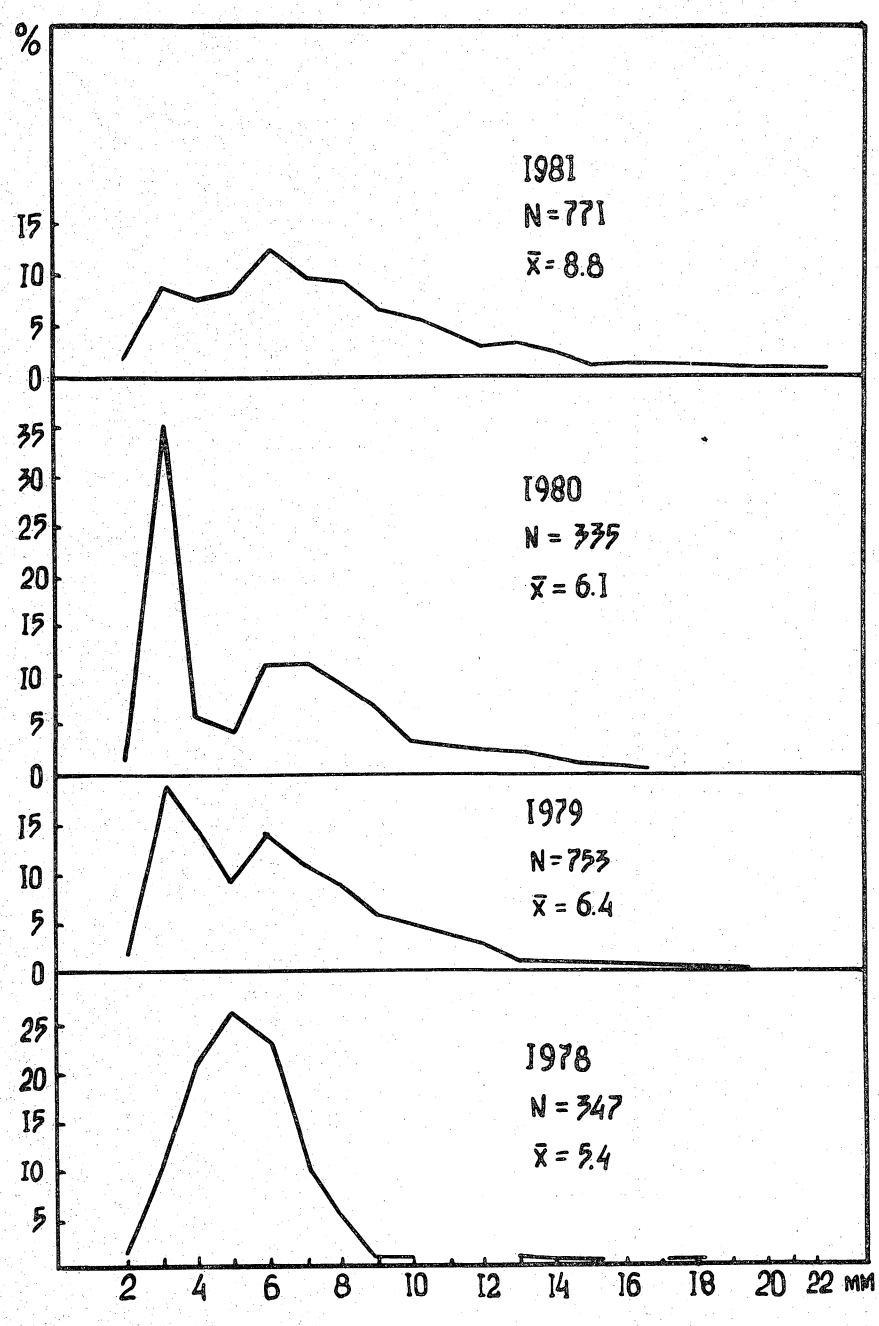

Fig. 5. Length frequency of larval silver hake on the Scotian Shelf (first ten-day period of September 1978-1981.