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Northwest Atlantic Fisheries Organization

Serial No. N1888 | NAFO SCR Doc. 91/16

SCIENTIFIC COUNCIL MEETING - JUNE 1991

Distribution and Abundance of the Scotian Shelf O-group Silver Hake in October-November 1978-1989

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Abstract

The results of the USSR-Canada joint inventory surveys in 1978-1989 to estimate the abundance of the Scotian Shelf O-group silver hake are presented. Special features of the temporal-spatial distributions for the youngs-of-the -year during their feeding period are determined. The effect of the spawning stock abundance on the year-class strength and the young fish survival in various age-groups are studied.

Introduction

Starting from 1978, the specialists from the USSR and Canada have been conducting the annual inventory surveys to estimate the abundance of the Scotian O-group silver hake. The objectives of this activity were to determine the trends in hake abundance at its early ontogenesis and to use these data for the hake catches forecasting in future.

Materials and Methods

Materials were obtained from the cruises of the Soviet vessels of the SRTM type onto the Scotian Shelf (Table 1). The methods used in the inventory Scotian O-group silver hake surveys were based on a principle of the stratified random sampling (Grosslein, 1969), i.e. the studies were made by stratum (Doubleday, 1981) and in every stratum predetermined number of tows were executed at the randomly specified sites. In October 1978-1980, a fry trawl "Malyok" (13.6 m) was used to count O-group hake (on a 24-hour basis and in the pre-bottom layer approximately 2-4 m above the bottom) during the trawling surveys; in the catches taken young hake of 23-70 mm in length were found together with quite a number of larvae of 10-22 mm which had not metamorphosed as yet and, thus, were not all available to the trawl. Maximum catches were taken at dawn and in the twilight, i.e. in the start and end of the vertical migrations. The studies on the young fish vertical distributions conducted in October 1980 demonstrated that the fish of this age made up significant concentrations in the pelagic layers at night and were almost absent there in the daytime (Koeller, 1981). It became evident that the methods of round-the-day trawlings in a pre-bottom layer in October to assess the young hake abundances produced some discrepancies in the abundance estimates. Since 1981 the dates of the surveys, methods and gears used have been changed to obtain more reliable data. The surveys began to be conducted two weeks earlier as compared to 1978-80, i.e. starting from mid October after all fish produced in the end of the spawning had metamorphosed and become available to trawling. The tows were made at night only (starting from 30 min after the sunset and ending 30 min before the sunrise) in three steps: pre-bottom (2-4 m above the bottom), mid-water (in the middle of the water column, as a rule) and sub-surface (3-5 m under the surface) ones. Young fish was caught at 3.5 knots of vessel speed during 30 min. Besides, to compare the data for silver hake from counting surveys to those for other gadoid fish species the fishing gear have been changed for IYGPT-trawl made from the kapron netting with a mesh size of 50-20 mm and 6.5 mm in the codend.

The materials were treated using standard methods (Grosslein, 1969; Gasyukov, 1983) to obtain the abundance estimate for 0-group fish by year. A standard unit of the young hake abundance is a mean weighted number of fish per tow calculated by weighting the catch and area against the total area of the surveyed space.

Data on spawning stock in the periods of year-class production as well as on the young hake abundances at age 1+ obtained from the July Canadian research vessels cruises (Waldron et al., 1989) were used to reveal various types of relations (e.g. between the spawning stock, on the one hand, and the abundances of fingerlings and yearlings, on the other, and between the abundances of fingerlings and yearlings).

The survival indices through a period from the egg stage to the recruitment were calculated by a formula:

$$SI = \frac{R}{N_{fm} \cdot E},$$

where SI - survival index;

R - recruitment abundance at age 0+ or 1+;

N_{fm} - total number of spawning females;

E - total fecundity of a single female (averages 395 thous. eggs; Sauskan, 1966).

The levels of abundance of the young hake year-classes were judged from comparisons of the year-class strengths to the mean long-term value. All the materials were treated according to the generally accepted statistical methods. Because of the short observational series (6-11 cases) the calculation of the correlation coefficient was made using the follow formula (Plokhinsky, 1970):

$$r = \frac{\Sigma V_1 \cdot V_2 - \frac{\Sigma V_1 \cdot \Sigma V_2}{n}}{\sqrt{C_1 \cdot C_2}} \quad ; \quad (n \geq n_{st})$$

where V_1, V_2 - values of the parameters;

C_1, C_2 - variance of parameters;

n - number of pairs compared;

n_{st} - number of paired values sufficient for the reliability of the selective correlation.

The volumetric parameter of feeding by 0-group hake at the moment of sampling and during the previous period was determined from the relative condition of every fry - the ratio of a fish's weight to the long-term mean weight of fish of the same length taken as 100% (Noskov, 1956). The amount of the materials collected and treated to study fish feeding patterns are presented in Table 1.

Water temperature measurements were made by bathy-thermograph at every station during the trawling surveys to count 0-group silver hake. The charts of the horizontal temperature distributions and those of the water temperature anomalies were drawn based on the observational data (Sigayev and Istomona, 1986). To reveal the mechanism of young hake survival during their first wintering the SST anomalies obtained from comparison of the SST monthly means to a norm (yearly mean) for 1977-1987 as well as the SST yearly anomalies in the northeast US shelf area in 1981-1986 (Wood and Tang, 1988) were used.

Results and Discussions

Spatial-temporal distributions of 0-group silver hake

A three-layer vertical water structure is formed on the Nova Scotian Shelf as a result of mixing of three water masses of different origin (Smith et al., 1978).

The analyses of the surface layer water temperatures for 1977-1989 has not revealed any regularities observed after the comparison of the temperature fields from the underlying layers. This fact is an evidence of significant effects of the atmospheric processes on the SST field formation which causes "masking" of the hydrographic regime state. There is a thermocline lying in the intermediate layers that conditions a complicated character of the temperature field with numerous cells of cold and relatively warm water and the abundant gradient zones over the entire shelf area. For this reason this layer was not taken either to compare the interyear temperature dynamics. A pre-bottom layer (lower than 100 m) is most interesting for our purpose, this layer is more weakly effected by the atmospheric processes and a thermocline is absent from it. Temperature gradient zones where main aggregations of hake fry are formed are caused by interactions of quasistationary intrusion of warm North Atlantic Slope water penetrating onto the shelf through the deepwater troughs west of the Sable Shoals with cold Labrador water.

Year-to-year fluctuations of the hydrographic conditions result in significant changes in young hake distribution patterns. Thus, in the warmest 1981, when this intrusion was extremely extensive (Fig.1; the Slope mater boundary went through the shelf itslf) the abundant concentrations of young fish (greater than 500 fish per tow) were encounted all over the area (Noskov, Sherstyukov, 1984). In 1985 the intrusion of quite ordernary intensity was registered (see Fig. 1; the Slope water boundary was located close to the continental slope) and so, dense fry concentrations were formed only in the central shelf area. In some years (e.g. 1988) poorly defined intrusions of Slope water were observed (see Fig. 1) and well defined gradient zones were formed within the limited portions of the shelf(along the shelf break and over the southern La-Have Bank) where the abundant concentrations of young hake stayed (Sherstyukov, 1990a).

Data from analysis of the young hake catches for distributions relative to the pre-bottom temperatures in different years are presented in Table 2. In warm years (e.g. 1985) young hake were caught within a wide range of pre-bottom temperatures from 6 to 12°C (89% of the total catch) and mean catches per tow were 228-362 fish. However, in cold years (e.g. 1987) young fish were mainly concentrated within a narrow range of pre-bottom temperatures from 6 to 8°C (57.8% of the total catch). In those years quite big catches (29% of the total numbers caught) were also taken from the areas where the pre-bottom temperature was 4-6°C, i.e. in the shallow portions of the shelf where the intrusion of cold Labrador water was registered. A detailed analysis of the young hake abundance distributions relative to cold (less than 5°C) water over the Scotian Shelf shoals (over the bottom shallower than 100 m) has demonstrated (Table 3) that on the Westrn Bank significant numbers of young hake (77.1% of the total 1987 catch) were caught both at thick(22%) and thin (4% of the water volume) layers as it took place in 1985 (60.1% of the total catch). Thus, it becomes evident that this is not depth of a cold water layer but the presence of the temperature gradient zones in the shallow water areas that effects the young fish distribution patterns.

Data on the young hake abundance distributions in the fry trawl catches relative to the bottom depth are presented in Table 4. It is seen from the table that during the feeding period in October-November main aggregations of the 0-group hake (54-76% of the total catch) were found not in the shallow shelf waters (depths shallower than 100 m) where spawning and larvae feeding take place but in the deeper areas (from 101 down to 200m), i.e. very close to the locations of their wintering. The exception was 1979 when major aggregations of young fish (90% of the total catch) were observed over the continental slope (deeper than 200 m).

Studies of the young hake daily vertical movements and the analysis of the data from literature on the vertical movements of planktivorous fish have made us to comprehend that the rising of young fish into the upper layers in the evening is related to their feeding on euphausiid crustaceans (Meganyctiphanes norvegica) which made up 65-100% of the total weight of food clot (Sherstyukov and Nazarova, 1987). It should be noted that the process of active movements when young hake is hunting for euphausiids the fish may form dense aggregations (up to a few thous. fish per tow) at various depths in the water column which, in its end, naturally decreases the reliability of the abundance indices obtained from the standard inventory surveys and catching the fry in three predetermined steps: near the bottom, in the moddle of the water column and near the surface.

Condition parameters of O-group hake

Variability in the young fish lengths depends first of all on their food supply, i.e. on the food quantity, quality and its availability in the pool as well as on the feeding season duration and abundance and biomass of the feeding fish. Young hake food supply was evaluated from an indirect indicator - fish condition. Comparisons of weights of the fry of the same length in 1978-1986 (Table 5) have demonstrated their condition variability between years and the corresponding plot had sinusoid form. Maximum values on the plot (110-114% of the long-term mean value) were found in 1979 and 1985 while minimum ones were registered in 1981 and 1982 (78-80% of the long-term mean value). This pattern seems to be explained by worse feeding conditions at the early ontogenetic stages. Thus, in the period 1978-1982 a decrease in mean numbers of the food zooplankton from 1010 to 740 sp./m^3 was observed which phenomenon caused a drop in the condition of O-group fish (Noskov et al., 1985). This relation is expressed in a high positive correlation (r = 0.92 $\pm$ 0.07). Besides, later dates of the spawning peak in 1982 also effected the feeding conditions for O-group silver hake.

Studies on the effects of the fry feeding conditions in the regions of their dense concentrations (more than 100 fish/tow) have shown that the concentrations formations did not influence upon fish condition. Thus, there is a high positive correlation between fish condition factors in dense aggregations and those for the whole area ($r = 0.97 \pm 0.01$):

$$y = 0.68 \cdot x + 0.01,$$ where

y - fry condition factor for areas with dense concentrations;
x - condition factor for the whole area.

It is evident that the formation of dense fry shoals and their redistribution do not effect feeding conditions for the silver hake fry. However, the increase in numbers of the feeding fish, in general, causes the worsening of the feeding conditions. Thus, in 1985 (a year of a strong year class) the hake fry of 58-73 mm in length had their absolute daily length increment 0.41 mm/day only (Sherstyukov, 1990B) while in 1988 (a middle-strength year-class) the fry of the same length had greater increment - 0.68 mm/day.

Estimation of the hake year-class strength

In 1978 and 1979, major aggregations of O-group hake inhabiting Scotian Shelf waters were found in the area between the Browns Bank and the Sable Island shoals. This region was chosen as the observation one to conduct the counting survey of O-group hake. The 1981 counting survey revealed significant concentrations (more than 100 fish/tow) of fry not only within the observation area but east and west of it too (Noskov and Sherstyukov, 1984) which made the scientists to expand the survey area. However, there was no chance to do so until 1984. Thus, in 1982 the catches of fry almost all over thearea did not exceed 55 fish/tow (caused by later dates of spawning and the undercatch of the main O-group concentrations) while in 1983 this value was low because of the long period of stormy weather. The purpose was gained only in 1984. Comparison between the hake fry abundance indices for 1981-1989 calculated for the whole expanded area and for the previously chosen one has shown (Table 6) that in some years those indices differed one from another by 36% (1984, 1985). The expansion of the survey area has allowed to get more comprehensive idea on the distribution pattern and abundance of O-group silver hake over the Scotian Shelf.

Comparison of the O-group hake abundance indices on the fry stage for 1978-1989 calculated by the researchers from Atlant-NIRO (USSR) and BIO (Canada) has revealed (Table 7) a high correlation (r = 0.98 ± 0.01) between them. Numbers of fry per tow varies among years from 44.4 (1984) to 579.0 (1981), i.e. by 13 times. The 1982 index was dropped from the comparison since it could not give the objective year-class strength estimate because of the later dates of the hake spawning in that year. For this reason a comparatively weak year-class of 1982 as determined from the inventory survey of O-group abundance appeared to be a strong one from the hake fisheries statistics in three years (in 1985).

Long-term data were used to study the effect of the spawning stock size on the year-class strengths and on the survival of young hake of various ages (Tables 8 and 9). All young hake from O-group had on the average the same survival rate (0.0051 - 0.0046%) except the 1981 strong year-class (0.0098%) which later on had great loss because of cold winter (its survival rate as determined for 1-year fish was as low as 0.0016%). Analysis of the survival statistics from egg stage up to recruitment at age 1+ has demonstrated (see Table 9) that the increase in the spawning stock size tends to result in a decrease of the survival rate from 0.0028 down to 0.0007%. The exception was a strong 1985 year-class (0.00385). The explanation of the phenomenon seems to be the favourable conditions of the fish wintering. Strong silver hake year-classes were noticed three times (Table 7) through the period of 1981-1990. They were the products of both high (1985 year-class) and low (1983) spawning stock abundances. However, in both cases strong year-classes were formed when a percent of fish survived at age 1+ was high (0.0018 and 0.0038, respectively) as of the total number of eggs spawned. But even at average abundance of the hake spawning stock (26.8×10^6 fish) and at low survival rate (0.0009) some year-classes appeared to be weak (as, for example, in 1980). A percent of fish survived seems to be regarded as an integrated index of the living conditions for hake survival at early ontogenesis. A few cases, however, were recorded, as in 1977, when low spawning stock abundance (2.4×10^6 fish) and a relatively high survival index (0.0028) still produced weak year-classes.

When analysing the relations between the abundance of a parent stock and the recruitment abundance of young fish at age 0+ and 1+ for 1978-1988 the correlation coefficients were calculated which appeared to be under the critical value (Table 10) although those coefficients became reliable when a series of years were dismissed for various reasons (1981 - as a result of death of significant fry numbers in winter, 1982 - because of late spawning of hake and the undercatch of young fish, and 1978-1980 - as the sampling methods were not standard). One of the main reasons causing a discrepancy between the abundance indices of fish at age 0+ and 1+ are the conditions of fish wintering joining their first and second year of life. An attempt to relate the mortality rates of young hake (ratio of fingerling and yearling abundances) to the temperature conditions (sum of SST anomalies in January-March) during its first winter appeared to be successful ($r = -0.71 \pm 0.19$; $\beta < 0.95$). This relationship became even stronger ($r = 0.88 \pm 0.08$) when the yearly SST anomalies were used (Wood and Tang, 1988).

It became evident that a strong year-class of 1981 hake during the severe winter of 1982 seemed to have great loss and was finally formed after wintering. This process naturally effected the discrepancy between the abundance indices for fingerlingsand yearlings ($r = 0.52$). After extraction from a comparison of the 1981 hake year-class the extremely high reliable correlation coefficients between spawning stock and fingerling and yearling abundances were obtained (see Table 8). It should be noted that a series of the observation data was too short ($n = 6$).

The analysis presented above has revealed a relationship between spawning stock and the fingerling abundance that is still poorly defined since the process of the year-class formation is not finished at the fingerling stage. This relationship becomes more evident later when fish are 1 year old (r = 0.71 - 0.95).

A preliminary prediction of the hake year-class strengths can be made 2-3 years before a particular year-class enters the fishery using the data from the inventory survey of the O-group fish abundance. To further update a hake year-class abundance estimate the data on the 1-year-old fish abundance can be used. A definite relationship exits between the fingerling numbers (recruitment at age 0+) and the recruitment abundances at age 2+ which can be defined if two years (1981 and 1982) are dropped

from the calculations for the reasons stated above (see Table 10). It more vividly demonstrates the relations between 2- and 3-year-old fish abundances (r = 0.86 - 0.95).

Conclusion

A spatial distribution of O-group silver hake on the Scotian Shelf during its feeding season (October-November) is directly related to the oceanographic conditions. Dense fry concentrations (more than 500 fish/haul) were registered in the areas of well--defined temperature gradients resulting from the interaction of quasi-stationary inflow of warm Slope North Atlantic water and cold Labrador water. When those inflows onto the Shelf were deep and strong (as in 1981) the abundant concentrations were found everywhere and if they were weak (as in 1988) dense fry aggregations were encounted only along the shelf break. The formation of numerous gradient zones resulted from a powerful inflow of warm slope water in some years (1981, 1983 and 1985) created abundant areas favourable for spawning and O-group fish feeding and, thus, contributed to the strong year-class formations.

During their feeding season the fingerlings at night move into the upper water layers following euphausiids (Meganyctiphanes norvegica) and preying on them. The nature of these movements is not regular which results in lower accuracy of the abundance indices obtained from the O-group fish inventory surveys. The formation of dense fry concentrations did not influence upon the fish conditions. But in the years of extremely strong year-class hake productions (1981, 1985) the feeding conditions dropped severely which fact was evidenced by low condition factors and the absolute daily linear increments.

The analysis of the effect of spawning stock abundance on the year-class strength and young hake survival has shown that an increase of the spawning stock size generally results in a decrease of a survival index from 0.0028 down to 0.0007%.

It has been revealed that there is an actual relationship between the spawning stock abundance and the fingerling recruitment abundance and this relationship is still poorly defined.

The strength of the hake year-class may be forecasted 2 years before the recruitment using the data from 0-group fish inventory surveys. There is definitely a relationship between the fingerling abundance and the recruitment abundance at age 2+ (r = 0.69 - 0.78). Correlation coefficients here appeared to be lower than those between the 1-year fish abundance and the recruitment abundance at age 2+ and 3+ (r = 0.86-0.95) which phenomenon seems to be explained by the fact that the formation of the year-class abundance at fingerling stage in not finished. The inverse relationship is revealed between the young fish survival during their first winter and the thermal conditions (r = -0.71 - 0.88).

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Table 1 Amount of material obtained from surveys in October-November, 1978 - 1987

Dates	Area (stratum)	Trawl type	Trawling type	Number of hauls	Number of young fish samples	Number of fish analysed
27/9-17/10/78	47-81	Fry trawl, 13.6 m	Pre-bpttom, 24-hour	100	53	446
04/10-27/10/79	47-81	-"-	-"-	100	38	1046
28/09-18/10/80	60-78	-"-	-"-	100	95	537
09/10-06/11/81	52-78	IYGPT	3-step, at night	98	41	1157
31/10-14/11/82	60-78	-"-	-"-	62	1	31
28/10-24/11/83	60-78	-"-	-"-	64	42	523
18/10-20/11/84	43-81	-"-	-"-	136	44	732
18/10-13/11/85	48-81	-"-	-"-	113	83	681
18/10-06/11/86	53-81	-"-	-"-	99	26	594
17/10-12/11/87	53-81	-"-	-"-	109	58	-
23/10-17/11/88	53-81	-"-	-"-	111	38	-
19/10-13/11/89	53-81	-"-	-"-	110	49	-

Table 2 Distribution of young hake abundance in the catches taken by fry trawl relative to pre-bottom water temperature

Year	Temperature range C°	Total catch, fish		Range of fish numbers per haul	Average catch per haul	Number of 0 hauls		Number of hauls	
		n	%			n	%	n	%
I985	0.0-2.0	0	0	0	0	I	I00	I	I
	2.I-4.0	I0I	I	0-58	9	6	54	II	I0
	4.I-6.0	2284	8	0-I677	I76	3	23	I3	I2
	6.I-8.0	8320	30	0-427I	362	2	9	23	20
	8.I-I0.0	7752	28	0-I363	228	4	I2	34	30
	I0.I-I2.0	8936	3I	I7-I4I7	298	0	0	30	26
	I2.I-I4.0	637	2	637	637	0	0	I	I
	0.0-I4.0	28040	I00	0-427I	248	I6	I4	II3	I00
I987	0.0-2.0	0	0	0	0	3	I00	3	3
	2.I-4.0	I06	I	0-40	II	4	40	I0	9
	4.I-6.0	2737	29	0-I4I6	94	7	24	29	27
	6.I-8.0	5536	57.8	0-2393	I58	8	23	35	32
	8.I-I0.0	II24	I2	0- 245	5I	3	I4	22	20
	I0.I-I2.0	I3	0.I	0- 9	2	3	37	8	7
	I2.I-I4.0	3	0.I	3	3	0	0	I	I
	I4.I-I6.0	0	0	0	0	I	I00	I	I
	0.0-I6.0	95I9	I00	0-2393	87	26	24	I09	I00

Table 3

Distribution of young hake abundance relative to the volume of cold Labrador water

A R E A	1987				1985			
	Total vol. of water x10⁹ m³	Volume of cold water		Total number of young fish	Total vol: of warer x10⁹ m³	Volume of cold: water		Total number of young fish
		$x10^9 m^3$	%	%		$x10^9 m^3$	%	%
Southern slopes of the Sable Shoals	726	29	4	2.6	726	I22	I7	3I.9
Northern slopes of the Sable Shoals	320	32	I0	0.I	320	I3	4	5.9
Emerald Bank	I05	20	I9	2.3	I05	7	7	I.0
Western Bank	44I	97	22	77.I	44I	I8	4	60.I
La-Have Bank	90	38	42	I7.0	90	42	47	0.I
Roseway Bank	57	8	I4	0.7	57	2I	37	0.2
Baccaro	5I	I7	33	0.I	5I	0	0	0.2
Browns Bank	220	33	I5	0.I	220	0	0	0.6
Total	20I0	274	I4	I00.0	20I0	223	II	I00.0

Table 4

Distribution of young hake abundance in the catches taken by fry trawl relative to bottom depth

Year	Depth, m	Total catch, fish		Average catch per haul, fish	Number of O-hauls*		Number of hauls	
		n	%		n	%	n	%
I979	0–I00	I05	I	8	I8	54	33	33
	I0I–200	87I	9	I9	I5	33	46	46
	20I–300	909I	90	433	7	33	2I	2I
		I0067	I00	I0I	40	40	I00	I00
I98I	0–I00	8238	I6	3I7	2	8	26	27
	I0I–200	38598	76	654	2	3	59	60
	20I–300	38I3	8	293	2	I5	I3	I3
		50649	I00	5I7	6	6	98	I00
I985	0–I00	9I62	33	295	6	I9	3I	27
	I0I–200	I0095	54	243	4	6	62	55
	20I–300	3783	I3	I89	6	30	20	I8
		28040	I00	248	I6	I4	II3	I00
I987	0–I00	2330	25	73	I2	37	32	29
	I0I–200	6500	68	II4	7	I2	57	53
	20I–300	689	7	34	I0	50	20	I8
	Total	95I9	I00	87	29	27	I09	I00

* Catches where O-group silver hake were not observed.

Table 5

Length and weight of O-group silver hake on the Scotian Shelf, 1978-1986, as % of the long-term mean values

Year / Length, mm	1978	1979	1980	1981	1982	1983	1984	1985	1986	Mean weight of a fry, 1973-1986
26-30	I25	II7	I33	I08	–	I08	I00	I33	II7	0.I2
3I-35	II4	I09	II4	86	57	I05	I00	II9	II9	0.2I
36-40	II9	II3	I06	87	68	I06	I05	II3	II3	0.3I
4I-45	II7	I04	I00	79	89	I04	I02	II2	II3	0.48
46-50	II5	I07	I04	82	76	I07	I04	II3	III	0.66
5I-55	II5	I06	I0I	79	84	I00	I04	II4	I07	0.92
56-60	I00	I08	II6	77	74	I0I	I08	II9	I07	I.20
6I-65	98	II5	I07	75	–	96	98	III	I0I	I.63
26-65	I07	II0	I08	80	78	I0I	I03	II4	I07	0.69

Table 6

Abundance indices for 0-group silver hake
on the Scotian Shelf in 1981-1990

Year	Young fish abundance over the whole area, x 10^7 fish	Young fish abundance for strata 60 - 78, x 10^7 fish	Abundance difference x 10^7 fish	Abundance difference %
1981	113.6	89.8	23.8	21
1982	1.3	1.3	-	-
1983	36.1	36.1	-	-
1984	10.8	6.9	3.9	36
1985	68.4	43.7	24.7	36
1986	33.2	31.8	1.4	4
1987	20.9	20.7	0.2	1
1988	33.1	32.3	0.8	2
1989	20.9	19.4	1.5	7
1990	32.1	30.5	1.6	5

Table 7

Abundance indices for 0-group silver hake on
the Scotian Shelf in 1981 - 1990

Year	Country	Number of hauls	Mean weighted number of young fish per haul, $\bar{x}$	Variance V	Standard deviation, σ	Variance coefficient, C_V
1981	USSR	77	579.0	4977.0	70	I2
	Canada	77	579.0	4I48.2	64	II
1982	USSR	6I	8.7**	I.9	I	I6
	Canada	6I	8.8**	I.5	I	I4
1983	USSR	64	232.9	574.8	24	I0
	Canada	64	232.2	597.4	24	II
1984	USSR	70	44.4	58.3	8	I7
	Canada	7I	43.4	50.I	7	I6
1985	USSR	73	292.2	42066.4	65	22
	Canada	82*	284.8	3866.5	62	22
1986	USSR	75	205.I	I926.2	44	2I
	Canada	74	I98.0	I437.6	36	I9
1987	USSR	73	I33.5	2090.8	46	34
	Canada	73	I02.0	530.5	–	II
1988	USSR	74	208.2	I57I.2	40	I9
	Canada	74	204.8	I245.2	–	I7
1989	USSR	74	I25.I	428.0	2I	I6
	Canada	74	I3I.5	360.5	–	9
1990	USSR	7I	I96.5	234.9	I5	I3
1981–1990	USSR	–	224.I	–	–	–

* 9 repeated hauls made 1 month after

** Abundance indices not reliable due to the late dates of silver hake spawning

Table 8

Year-class strengths and survival indices for silver hake at age 0+ relative to the spawning stock abundance

Spawning stock abundance, 10^6 fish	Year-class strength	Mean weighted number of young fish per haul, $\bar{x}$	Range of young fish abundance variation 10^6 fish	Mean survival index from egg through recruitment at age 0+, %
II-20	low middle high	I46.5	43.4-232.9	0.005I
2I-30	high	579	579	0.0098
3I-40	high	292	292	0.0046

Table 9

Year-class strengths and survival indices for silver hake at age 1+ relative to the spawning stock abundance

Spawning stock abundance, 10^6 fish	Year-class strength	Mean year-class abundance, 10^6 fish	Range of variation in recruitment abundance, 10^6 fish	Mean survival index from egg through recruitment at age 1+, %
I-I0	low	57	27-87	0.0028
II-20	low middle high	I05	I5-I90	0.00I8
2I-30	low high	II2	33-I92	0.0009
3I-40	high	553	553	0.0007
4I and >	middle	II4	II4	0.0007

Table 10

Correlation factors between silver hake spawning stock abundance and recruitment at age 0+, 1+ and older, 1978 - 1988

Years of observation	Number of pairs compared	Spawning stock/ recruitment 0+	Spawning stock/ Recruitment 1+	Recruitm. 0+ : Recruitm. 1+	Recruitm. 0+ : Recruitm. 2+	Recruitm. 1+ : Recruitm. 2+	Recruitm. 1+ : Recruitm. 3+
1978-1988	11	0.46	0.52	0.52	0.44	0.93±0.04 β > 0.999	0.86±0.05 β = 0.999
1978-1980, 1983-1988	9	0.24	0.71±0.16 β > 0.95	0.76±0.14 β > 0.95	0.69±0.18 β = 0.95	0.95±0.04 β > 0.999	0.86±0.09 β > 0.99
1983-1988	6	0.79±0.17 β < 0.95	0.95±0.04 β > 0.99	0.94±0.05 β > 0.99	0.78±0.17 β < 0.95	0.94±0.05 β = 0.95	0.86±0.11 β = 0.95

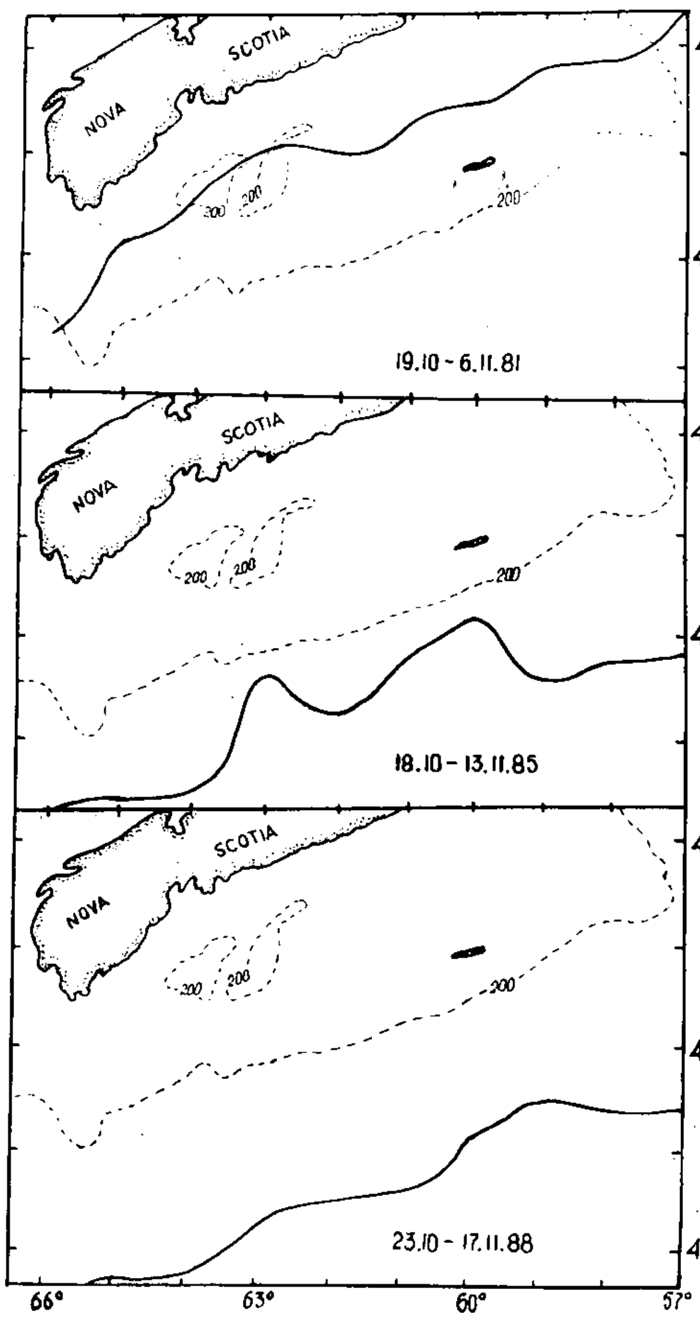

Fig. 1. Dinamics of the slope water northern boundary in October-November 1981, 1985 and 1988.