Northwest Atlantic Fisheries Organization

Serial No. N1893 NAFO SCR Doc. 91/19

SCIENTIFIC COUNCIL MEETING - JUNE 1991

On Reproduction and Formation of Silver Hake (*Merluccius bilinearis* Mitchill) Year-class Strengths at Early Ontogenesis on the Scotian Shelf

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ABSTRACT

Various stages of the silver hake life cycle related to its reproduction and year-class formation at early ontogenesis have been studied. The features of year-to-year variability in the silver hake maturation and spawning on the Scotian Shelf in 1977-1989 have been revealed. The regularities in spatial and temporal distributions of eggs and larvae relative to the various environmental factors have been described. The reliable correlations have been found between the mean weights of the silver hake larvae and the mean densities of their main feeding organisms concentrations.

INTRODUCTION

The development of the trawl fisheries for silver hake on the Scotian Shelf since 1962 has demonstrated that the species is among those fishes which are characterized by strong fluctuations in some year-class abundances. It is obvious that the studies of the reasons determining the year-class abundance at the earlier life stages - the embryo and larva - are necessary. To meet this purpose in 1977-1982, the scientists from the AtlantNIRO and the BIO (Dartmouth, Canada) had conducted the comprehensive ecological surveys on the Scotian Shelf within the framework of their joint program. The data from those researches have been published in papers (Noskov et al., 1982; Noskov et al., 1985).

This paper is a continuation of summarizing the above mentioned multi-year studies.

MATERIALS AND METHODS

The methods of the data collection and treatment have been presented earlier in detail (Noskov et al., 1982; Noskov et al., 1985). Silver hake eggs and larvae numbers caught by the fishing gear were converted into the numbers per surface square meter (sp./m^2). Minimum abundances of eggs and larvae in the survey area were calculated by the methods of squares (Aksyutin, 1968). Index of the mean-weighted larvae numbers per towing was used as well calculated by weighing the catch and square against the total area of the survey region.

To determine the dates of the hake spawning peak start the additional information on egg distribution was used obtained from the Canadian R/V E.E.PRINCE (P-276) trip, July 15 - August 5, 1982.

The dates of the start, peak and finish of the hake massive spawning and,thus, the start of the embryo period, were specified from the analysis of the annual changes in the maturity stage ratio for the mature fish (broken down by 5-day period) being in pre-spawning and spawning conditions. The maturities of the hake gonads were classified based on a scale proposed by Sauskan (Sauskan and Serebryakov, 1968). The 1977-1982 spawning efficiency of hake was analysed using the data on a near-bottom temperature obtained from the cruises by the Canadian vessels in July 1977-1987 and kindly presented to the author.

The material obtained was treated by the generally accepted statistical methods. The correlation coefficients due to the short observational series were calculated by the formulas (Plokhinsky, 1970).

Basing on the results from the comprehensive studies carried out over the Scotian Shelf in the summer-fall period of 1977-1982 (Noskov et al., 1982; Noskov et al., 1985) the study area was chosen (Fig. 1) to find out the life conditions which at the earlier life cycle stages predetermine the fate of a silver hake year-class.

Hake egg and larvae mortality rates were calculated according to the formula (Zasosov, 1970):

$$M = \frac{l_n N_o - l_n N_1}{t},$$

where:

M - mortality rate;

N_o, N_1 - number of eggs (larvae) in the start and the end of a period t;

t - period of time between the surveys.

RESULTS AND DISCUSSION

Comparative description of the silver hake maturation and spawning

Main concentrations of the Scotian silver hake during the pre-spawning period (April-June) are located along the oceanic slope over the depths of 140-280 m with a temperature range of 7-10°C (Karasyov, 1975; Scott, 1982). Its distribution patterns and the concentrations longivities in this area are determined by the extent of effect of the warm slope water. Generally in late June - early July as the shallow water around the Sable Island and on the Emerald Bank gets warmer and the warm slope water begins to penetrate into the area the spawning concentrations of silver hake leave the slope area for the shoals and the females spawn their first batches of eggs (start of the massive spawning). The concentrations disperse for some time but later, by the end of July, they are formed again and another portion of eggs is spawned (peak of the massive spawning). The third portion (end of the massive spawning) is usually recorded in mid-September. This is supported by the temporal-spatial distribution of the silver hake eggs (Fig. 2). If the environmental conditions are favourable for the hake spawning in the later dates some fish may proceed with the process. Thus, hake egg collections obtained during the first decade of November, 1989, in the shallow waters of the Sable Shoals with a pre-bottom temperature being 9-10°C served as an evidence that the spawning was still in the process. Besides the usual penetration of the warm slope water onto the Shelf shoals as it took place in 1981 and 1986 (Fig. 3), in some years (1982, 1987) cold Cabot water moves along the slope, south of the Sable Island, isolating the Island from the slope water influence. Main aggregations of hake remain in the area along the slope till September, i.e. until the cessation of the cold water intrusion south of the Sable Island. This is the reason why the massive spawning takes place later than usually, in September.

A rather rapid maturation of the gonads from the third through the fifth stage as a rule takes place during the pre-spawning period (June-July). This process is evidenced by a sharp increase in mean maturity index for females in time as it was observed in 1981 and 1985 (Fig. 4). In cold years (1982 and 1987) the above mentioned index starts to go up two weeks later than usually (Fig. 4) because of the later dates of the massive spawning.

The analysis of changes in the ratio between the gonad maturity stages in silver hake conducted by 5-day period for 1977-1989 has shown that on the Scotian Shelf the spawning period of this fish is a very extended one - from late June to September (Table 1). With the establishment of the Canadian Fishing Zone quatas for silver hake catches fishing for this fish starting from 1978, generally stopped in the end of July - beginning of August (before the spawning peak) and the vessels left the area. For this reason the data from the biological analyses used to determine the dates of the massive spawning are limited.

However, the best indicator to determine the dates of the fish spawning is considered to be the abundant egg concentrations in the water column which can be found by a series of consecutive ichthyoplankton surveys. The surveys of this kind had been conducted over the Scotian Shelf in the summer-fall periods, 1977-1982, within the framework of the joint Soviet-Canadian project (Noskov et al., 1982; Noskov et al., 1985). It had been revealed that the major hake spawning takes place on the Sable Island and Emerald Bank shoals although some portion of fish spawns in the other shallow areas as well (Middle, Browns and Banquereau Banks). The numbers of eggs were not always high as, for example, in August, 1978 - 92 x 10^{11} eggs (Noskov et al., 1985). In most cases numbers of eggs ranged between 10 $\cdot$ 10^{11} and 41 $\cdot$ 10^{11} eggs while the abundance indices of the larvae were noticably higher: from

$33 \cdot 10^{11}$ to $150 \cdot 10^{11}$ fish. This phenomenon is quite understandable since the duration of the hake embryo development is not long and reaches 2-5 days (Nichols and Breder, 1927; Coombs and Mitchell, 1982). Despite all the above said the dates of the massive spawning can be determined from the quantitative parameters of the silver hake larvae (their mean lengths in the areas of their main concentrations and the absolute daily increments). It has been found that the absolute daily increment in the silver hake larvae is 0.2 mm/day (Sherstyukov, 1990). From the calculations new dates of the massive spawning in 1977-1982 were determined which agreed well with the previously obtained ones (the analyses of the ratio of the gonad maturity stages in time) and supplemented the lacking information (Table 2).

It is evident that different hydrographic conditions in different years effect the dates of spawning of the egg portions as well as the intervals between them. The spawning period of every portion is also quite extended because of the non-simultaneous maturation of the ovocytes in large and small hake females (Sauskan, 1966).

Spatial and temporal distributions of silver hake eggs and larvae

Dannevig (Dannevig, 1919) was the first to report the presence of the silver hake eggs in the Scotian Shelf area. Sauskan and Serebryakov (1968) have described the distribution patterns of eggs and larvae over the various portions of the Nova Scotia Shelf during the spring-summer season, 1959-1962. In 1977-1982, when exercizing the ecological survey according to the joint Soviet-Canadian program on the Scotian Shelf the drift and dispersal of the Scotian silver hake eggs and larvae had been studied in more detail (Noskov et al., 1982, 1985; Koeller et al., 1986).

Main concentrations of eggs and larvae (ref. Fig. 2) are annually observed over the Sable Island and Emerald Bank shoals. In some years silver hake spawns over the Scotian Shelf break as it took place, for example, in 1977, close to 63°W in which case the possibility of the eggs and larvae sweeping out from the shelf by water advection increases. However, the persistent wide distribution of hake larvae and their high density seem to decrease the possibility of high mortalities because of the environmental factors. The favourable conditions for spawning and distributionsoof hake eggs and larvae and their feeding organisms west of the Sable Island seem to be explained by the formations of the zones where the waters move up and down (Sigaev, 1978). The penetration of the warm (10-14°C) oceanic slope water onto the Shelf shallows and their interaction with cold (2-5°C) Labrador water results in the formation of numerous gradient zones where hake eggs, zooplanteurs and small hake larvae 4-5 mm in length (Fig. 5) are concentrated and kept. Drift and dispersal of eggs and larvae from the spawning beds, namely to the south-west (Trites and Banks, 1958) from the Sable Island are usually very slow and the larvae, therefore, remain over the shallows till the fry stage. Such a slow movement of larvae and post-larvae seems to be explained by their daily vertical migrations relative to the tidal streams observed in this area. This supposition is similar to that made from the observations on the Atlantic herring larvae dispersal in the Northwest Atlantic (Sinclair M. and T. D. Iles, 1985).

Factors determining year-class abundance on the larval stage

The ichthyoplankton surveys on the Scotian Shelf were coducted in August-September (period of the massive silver hake spawning), 1977-1988, to use the obtained data on the numbers of eggs and larvae to forcast the recruitment abundance 2-3 years in advance. The determination of the eggs and larvae mortalities in their natural environment is of major importance when solving the problem. Earlier the mortality of the eggs has been estimated from the ratio of the dead ones in the samples (Noskov et al., 1982) using the methods developped by T. F. Dementyeva (1958). Data on the dead eggs were related to the various abiotic factors but the selected coefficients appeared to be unreliable. It was the thing one had to expect since the methods of estimation of the "dead" eggs was erroneous and could not be used to estimate mortality as the number of dead eggs in the samples was a result of their damage during the sampler towing (Ciechomski, Capezzani, 1973). Another attempt to use different method for egg and larvae mortality estimation (Zasosov, 1970) was not a success as well because of the impossibility to discriminate between the first and second portions of eggs as well as the larvae in hake with a portional spawning in the whole sample mass. The problem was difficult to solve because of other seasons as well (a long distance to the area of observations, a short series of observations, etc.). Generally the abundance indices for hake larvae ranged from 7.5 sp./tow (22.09-9.10.1981) up to 104.6 sp./tow (06-25.08.1978) i.e. by 14 times (Table 3). However, the trends in the larvae abundances in 1977-1982 became distorted since in some years not all of the larvae were accessible to the sampler because of the changes in the dates of the massive hake spawning. For example, in 1981, the spawning peak was recorded earlier than usually (ref. Tables 1, 2) and, therefore, quite a portion of fries of 23-40 mm in length (10%) and insignificant numbers of larvae were registered in the samples. It means that by the moment of the surveys great number of young fish that are more mobile than the larvae were dispersed.in the water column. The 1981 abundance index for the hake fries calculated from the data of the trawling counting survey was the highest for the period 1978-1983 (Noskov, Sherstyukov, 1984).

The data on the marine fish egg and larvae survival in the process of development presented in the literature show that the highest mortality is observed not only in the period of the embryo development but in the "critical period" of life as well (Hjort, 1914) corresponding to the shift of the larvae to the exogenous feeding. Earlier it has been found that the Scotian silver hake larvae of 2.0-5.9 mm with the yalk sac already feed on the copepod eggs and nauplii and small copepods while having attained the length of 6 mm they feed on large copepods (Noskov et al., 1982). The main diet components of the hake larvae with the yalk sac remnants were Paracalonus parrus (28.2% of the total stomack content) and Pseudocalanus elongatus (11.7%) (Noskov et al.,1979). The larger larvae (of 6-22 mm in length) fed mainly on Calanus *finmarchicus* (22-51%) and *Centropages typicus* (10-100%) while the importance of other zooplankters was insignificant (Noskov et al., 1982). The observations on the distributions of the main hake larvae and their food organisms concentrations on the Scotian Shelf made in 1977-1982 have demonstrated that the areas of their distributions within the selected distributional region (ref. Fig. 1) overlap. Studies of the effects of the feeding conditions in the observational region in the areas of dense hake larvae concentrations (more than 100 sp./m^2) and all over the region have demonstrated that the formation of dense concentrations does not effect larvae condition. Thus, a strong positive correlation ($r = 0.98 \pm 0.01$) has been revealed between the corresponding indices. It becomes evident that feeding conditions for silver hake larvae are not influencdd by larvae re-distribution and dense concentration (more than 100 sp./m^2) formations, while year-to-year changes in the volumes of the feeding zooplankton result in aggrevation or improvement of the hake larvae feeding conditions. Mean volume of the feeding zooplankton on the Scotian Shelf decreased during the observational period from 1010 sp./m^3 (1978) down to 740 sp./m^3 (1983). Comparison between the weights of larvae of the same size (length group 2-11 mm) found in great numbers in the sampler catches has shown the highest condition factor in 1978 and the lowest one in 1982. The indices of correlation between the mean weights of those larvae and the mean densities of the various feeding organisms concentrations appeared to be high and reliable ($r = 0.84 - 0.98$) (Table 4) on the Scotian Shelf in August-September, 1977-1982. The temperature factor had but insignificant ($r = 0.67$) effect on the feeding of larvae.

Due to the short observational series the effect of the spawning stock abundance on the year-class strength and hake larvae survival has not been studied. The corresponding analyses for the youngs-of-the-year has given similar survival rates (0.0051 ÷ 0.0046%) with the exception of a strong year-class of 1981 which suffered great losses because of the severe winter (survival rate in the 1-year-old fish was as low as 0.0016% (Sherstyukov, 1991, in press). The explanation of the phenomenon seems to be the low condition factors of the hake fry from 1981 year-class. It is worthy noting that the conditions of larvae of that year-class was at a minimum level as well.

CONCLUSION

Silver hake is characterized by a protruded spawning period (late June-September) and its eggs and larvae are widely distributed over the Scotian Shelf which seems to decrease a possibility of high mortality resulted from the unfavourable environmental conditions. Spawning peak is generally observed in late July - early August. In cold years (e.g. 1982) it can be registered later - in September.

The location of the spawning beds and the dispersal of hake eggs and larvae are influenced by the water circulation patern formed by the interactions between the warm oceanic slope water and cold Labrador water.

The areas of distribution of the silver hake larvae and the areas of their feeding organisms distributions (copepods: Centropages typicus, Paracalanus parvus, Calanus finmarchicus, Pseudocalanus elongatus) coincided in the summer-fall period, 1977-1982. The indices of correlation between the mean weights of hake larvae and the mean densities of the various feeding organisms concentrations appeared to be high ($r = 0.84 - 0.98$) and reliable. Temperature factor also had some influence on larvae during their feeding period ($r = 0.67$).

Due to various reasons (short series of observations, the impossibility of determinating the mortality rates in eggs and larvae in situ etc.) the researchers were not at a position to estimate the strength of the silver hake year-classes on the egg and larvae levels. However, it has been established that the process of formation of the year-class strength is not stopped on the stage of larvae or youngs-of-the-year. Thus, the strong 1981 year-class suffered great losses during the severe winter of 1981-1982 because of low densities of the feeding organisms and, hence, the unsatisfactory conditions of larvae and youngs-of-the-year (low condition factors).

REFERENCES

1. Aksyutina Z.M., 1968. Elements of the mathematical estimation of the observational results in biological and fisheries studies. M., Pishchevaya promyshlennost, pp. 242-247. (In Russian).

2. Ciechomski J.Dz.,D.A.Capezzani, 1973. Studies on evaluation of the spawning stocks of the Argentinean anchovy, Engraulis anchoita, on the basis of eggs surveys.-Rapp.P.-v.Reun. Cons.perm.int.Explor.Mer.v.164,293-301.

3. Coombs S.H. C.E.Mitchell, 1982. The development rate of eggs and larvae of the hake Merluccius merluccius (L.) and their distribution to the west of the British Isles.J.Cons.int.explor. mer. 40, n 2,pp.119-126.

4. Dannevig, 1919.Canadian fish eggs and larvae.Canad.Fish.Exped. 1914-1915.Ottawa.

5. Dementjeva T.F., 1958. Studying methods of the effect of natural factors on the Azov anchovy abundance. Trudy of VNII of Marine Fisheries and Oceanography, Vol.34,pp.30-62 (In Russian).

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

7. Karasyov B.E., 1975. Methods of short-term forecasting of distribution and behaviour of silver hake from the Northwest Atlantic "Zaprybpromrazvedka". Kaliningrad, pp.45 (In Russian).

8. Koeller P.A., P.C.F.Hurley, P.Perley and J.D.Neilson, 1986. Juvenile fish surveys on the Scotian Shelf:Implications for year-class size assessments J.Cons.int.Explor.Mer.43,pp.59-76.

9. Nichols J.T. and C.M.Breder, 1927. The marine fishes of New York and Southern New England. Zoologica, 9(1), 1-192.

10. Noskov A.S., V.I.Vinogradov and A.I.Sherstyukov, 1982. Results of Ecological Surveys Conducted on the Nova Scotia Shelf in 1974 and 1977-1980 to Study the Spawning Efficiency of Silver Hake. NAFO SCR Doc.N33, Serial N521, 28p.

11. Noskov A.S. A.I.Sherstyukov and V.I.Vinogradov, 1985. Distribution and Fluctuations of the Scotian Silver Hake Abundance in Early Stages. NAFO SCR Doc. N114, Serial N1091, 16p.

12.Plokhinsky N.A., 1970. The Biometry. MGU, M.,pp.367, (In Russian).

13. Sauskan V.I., 1966. Biological basis for silver hake, Merluccius bilinearis (M) fisheries and systematics of species from genus Merluccius. Summary of dissertation for a doctorate in biology. Kaliningrad, pp.21. (In Russian).

14. Sauskan V,I. and Serebryakov V.P., 1968. Reproduction and development of silver hake (Merluccius bilinearis). Voprosy Ichthyologii, Vol.8N3/50/,pp.500-521.(In Russian).

15. Scott J.S., 1982. Depth, Temperature and Salinity Preferences of Common Fishes of the Scotian Shelf. J.Northw.Atl. Fish.Sci.v.3,pp.29-39.

16. Sherstyukov A.I., 1990. The Young Silver Hake Growth in the Scotian Area, 1977-1988.NAFO SCR Doc.N 2, Serial N 1702, 11p.

17. Sherstyukov A.I., 1991. Distribution and Abundance of the Scotian Shelf 0-group Silver Hake in October-November 1978-1989. NAFO SCR Doc., in press.

18. Sigaev I.K., 1978. Intra-year Variability of Geostrophic Circulation on the Continental Shelf off New England and Nova Scotia. ICNAF Selected Papers, N3, pp.97-107.

19. Sinclair M. and T.D.Iles, 1985. Atlantic herring (Clupea harengus) distributions in the Gulf of Maine-Scotian Shelf area in relation to oceanographic features. Can.J.Fish.Aquat.Sci., 42,pp.880-887.

20. Trites R.W. and R.E.Banks, 1958. Circulation on the Scotian Shelf as indicated by drift bottles.S.Fish.Res.Bd. Canada, 15(1).

21. Zasosov A.B., 1970. Theoretical basis for fisheries. M., "Pishchevaya promyshlennost", pp. 292. (In Russian).

Table 1

Approximate dates and stages of the massive silver hake spawning on the Scotian Shelf as determined from the biological analyses

Spawning stage / Year	Start	Peak	Finish	Note
1977	July 1-5	July 26-31	September 6-10	
1978	July 21-25	August 16-20	-	
1979	-	-	-	Data scarce and not reliable
1980	July 15-20	August 11-15	-	
1981	July 6-10	-	-	
1982	July 21-25	-	-	
1983	June 26-30	-	-	
1984	July 1-5	-	-	
1985	July 1-5	July 26-31	August 11-15	
1986	July 11-15	-	-	
1987	July 21-25	-	-	
1988	July 1-5	-	-	
1989	July 6-10	-	-	

Table 2

Approximate dates and stages of the massive silver hake spawning on the Scotian Shelf as determined from ichthyoplankton surveys

Spawning stage / Year	Start	Peak	Finish	Note
1977	-	-	September 10	
1978	July 25	August 20	-	
1979	July 23	-	September 10	
1980	-	August 10-20	-	
1981	-	August 1	September 10	
1982	-	September 20	-	

Table 3

Comparison of abundance indices of the silver hake larvae, 1977- 1982

Date	Mean weighted number of larvae per tow, $\overline{X}$	Variance, V	Standard deviation, σ	Coefficient of variation, C_v
21.09 - 14.10.77	31.2	11	3	11
06.08 - 25.08.78	104.6	294	17	16
29.08 - 15.09.78	68.6	81	9	13
04.08 - 19.08.79	65.9	238	15	23
24.08 - 10.09.79	83.8	202	14	17
15.08 - 31.08.80	57.6	23	5	8
04.09 - 22.09.80	33.5	13	4	11
26.08 - 12.09.81	59.9	480	222	36
22.09 - 09.10.81	7.5	6	1	10
24.09 - 12.10.82	15.7	7	1	5

Table 4

Indices of correlation between mean weights of hake larvae (2 - 11 mm) and mean densities of various feeding organisms concentrations over the Scotian Shelf in August-September, 1977-1981

Parameter	Mean larva weight/mean concentration density of *Pseudocalanus elongatus*	Mean larva weight/mean concentration density of *Paracalanus parvus*	Mean larva weight/mean concentration density of *Calanus finmarchicus*	Mean larva weight/mean concentration density of *Centropages typicus*
Intersection	2.011	1.839	1.411	2.014
Slope	0.072	0.077	0.115	0.022
r	0.98	0.96	0.97	0.84
β	0.99	0.95	0.99	0.95

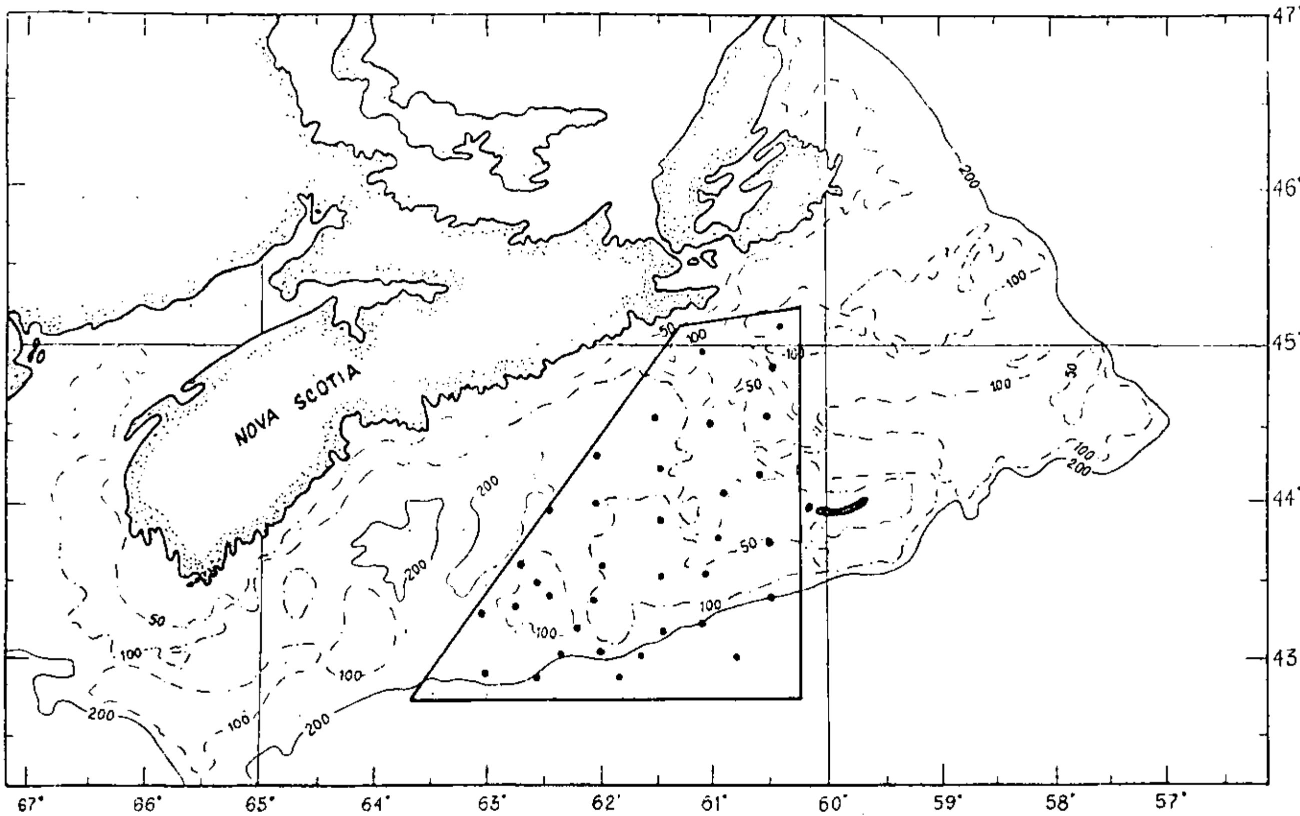

Fig. 1. Grid of stations in the conventionally selected area of observations.

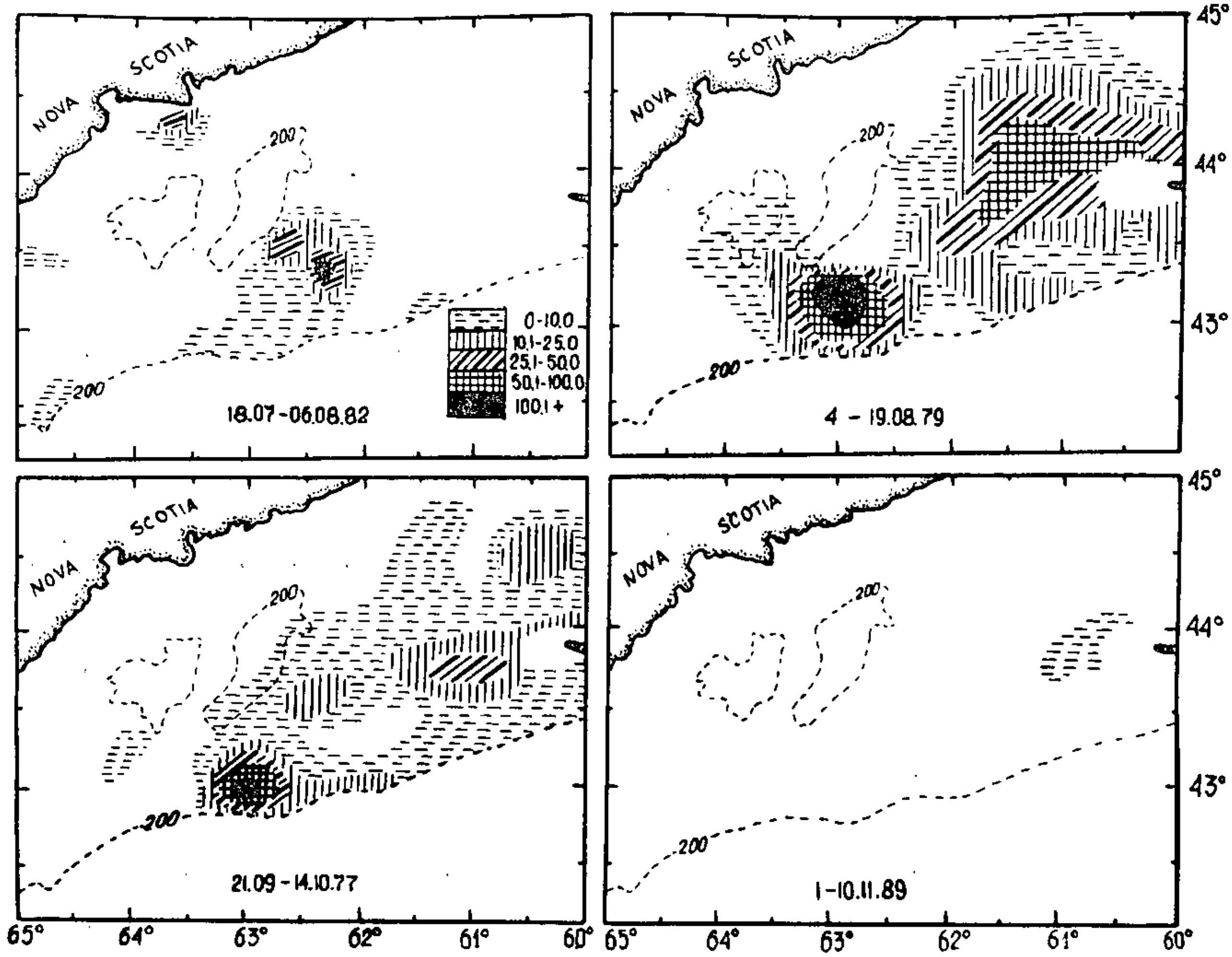

Fig. 2. Spatial and temporal distribution of the Scotian silver hake eggs.

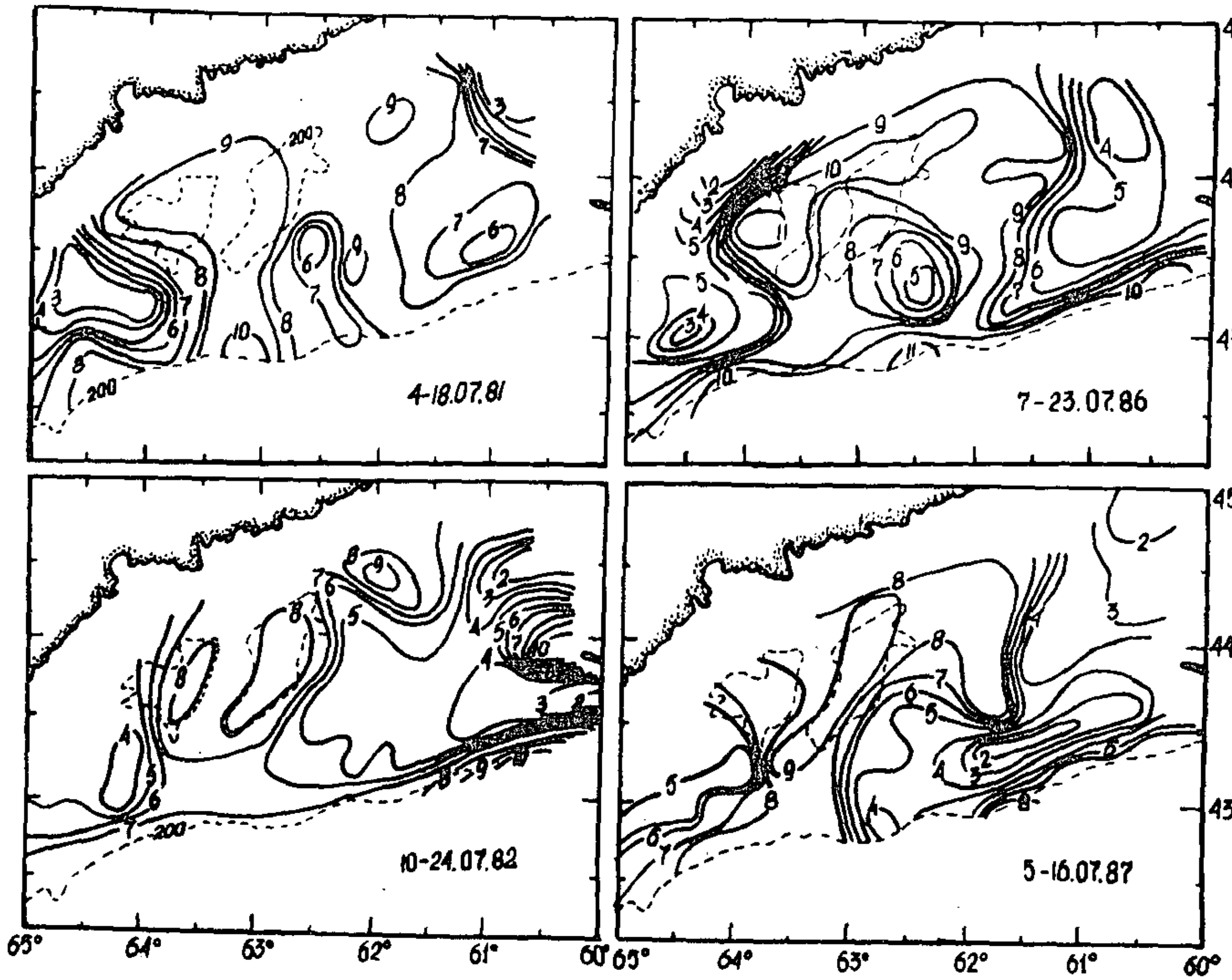

Fig. 3. Distribution of near-bottom temperature in July, 1981-1987.

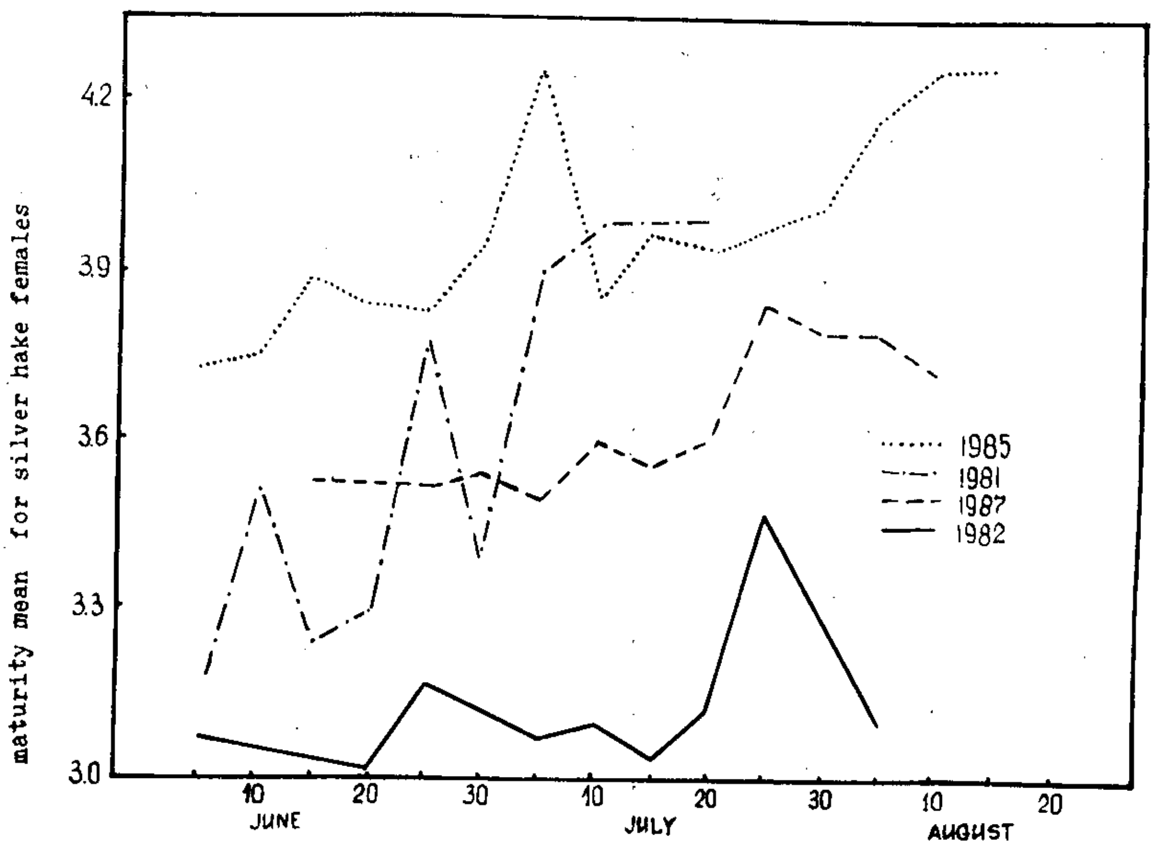

Fig. 4. Temporal dynamics of the mean maturity stage index for gonads in hake mature females.

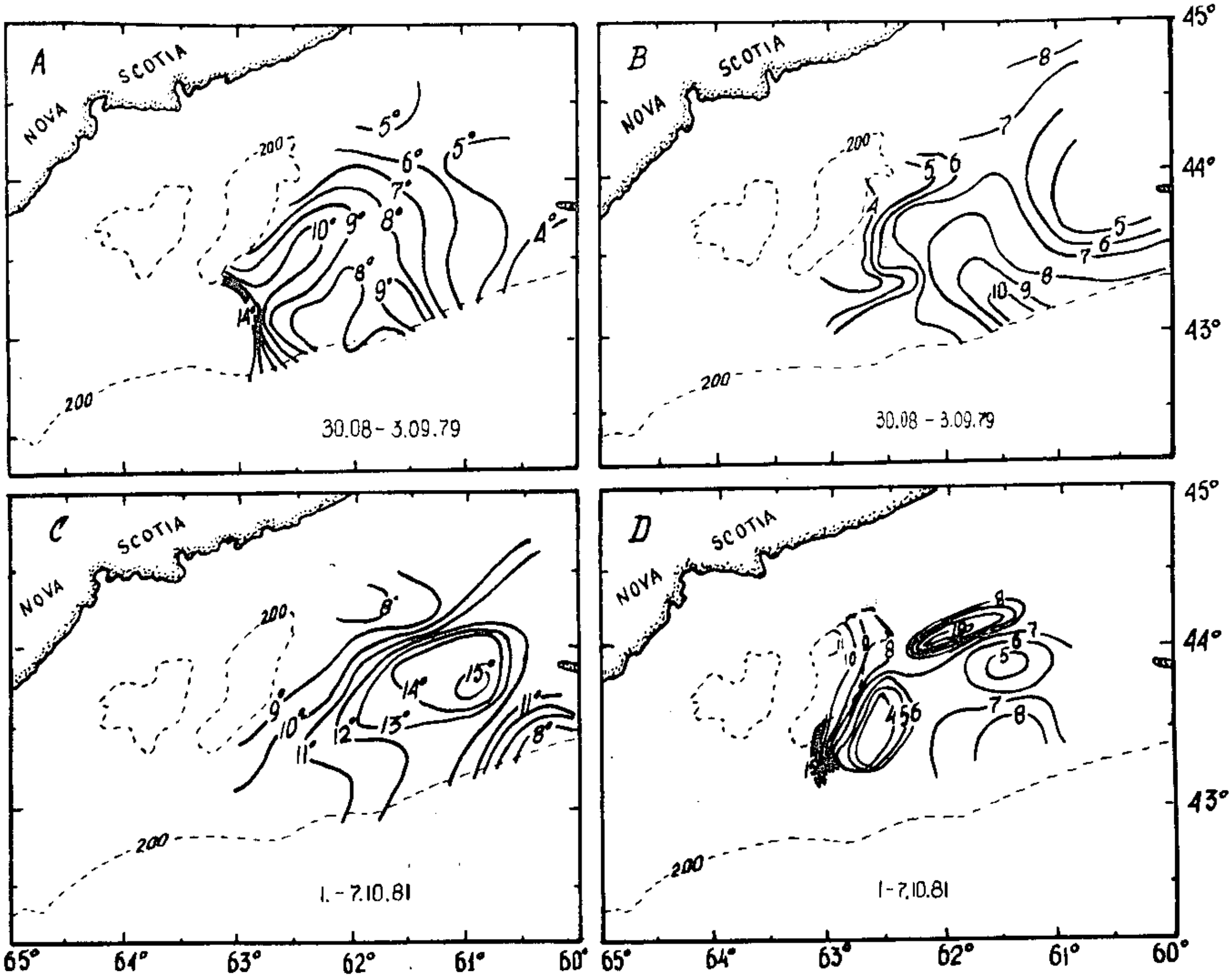

Fig. 5. Distributions of near-bottom temperature (A,C) and silver hake larvae, mean length, mm (B,D).