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STUDY OF THE GROWTH PATTERN OF JUVENILE EUROPEAN HAKE (*Merluccius merluccius L.*) USING WHOLE OTOLITHS AND LENGTH FREQUENCY DISTRIBUTIONS FROM COMMERCIAL CATCHES AND GROUNDFISH SURVEYS.

BY

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ABSTRACT

A review of length distributions of commercial landings from bottom trawls, small gillnetters and groundfish surveys in Galicia has led to a new hypothesis about the individual growth of young hake from the Southern Stock (ICES Divisions VIIIc and IXa). According to this new hypothesis, hake grow to about 20 cm in the first year of life and up to 35–40 cm during the second. This is in contrast with the more widespread belief that hake grow to about 15 cm and 24 during the first and second years of life respectively. Consequences of the new hypothesis are that landings of hake from trawls and small gillnetters would be mainly composed of 1 year old hake and that they would reach first maturity at age 3. An interpretation of the pattern of otolith rings consistent with this hypothesis is that 6 months after birth a first hyaline ring is formed, probably associated with the change from pelagic to demersal life and that another hyaline zone with opaque rings evbedded in it is formed during the first winter. Although this study refers to hake from the Southern stock, it is possible that these conclusions are applicable also to hake from the Northern stock (ICES Divisions VIIIa,b, Sub–areas VI,VII and IV).

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INTRODUCTION

The growth pattern of European hake (*Merluccius merluccius*) inhabiting Iberian waters (Divisions VIIIc and IXa) is not well understood in spite of the many studies devoted to it. Most of the work has been based on otolith readings (Iglesias and Dery, 1981; Goñi and Piñeiro, 1988; Piñeiro and Hunt, 1989) and, although several techniques for making otolith easier to examine have been employed, all the researchers encountered difficulties in interpreting the pattern of ring formation. This problem has also been encountered in studies of the growth of hake from the Northern stock (ICES Subareas VI,VII and Divisions VIIIab) (Hickling, 1930; Bagenal, 1954; Meriel Bussy 1966; Decamps and Labastie, 1978; Anon., 1983; Anon.,1984; Anon., 1986; Guichet, 1988).

Some attention has also been devoted to the analysis of length frequency distributions of catches, mainly from surveys (Piñeiro et al., 1989). Survey data were generally preferred over commercial data because of the reduced bias due to full selection of the survey gear (very small mesh size) and the use of a statistical sampling design. Studies carried out on hake from Iberian waters resulted in unimodal distributions composed by very young hake from which it was difficult to draw any conclusion (Pereiro et al., 1991). Commercial length distributions from bottom trawlers and gillnet vessels fishing in the area are also available and in spite of their limitations, they can provide information on the age groups that make up the bulk of the catch, their modal sizes, and progression. However, they have not been used in the past for growth research purposes.

This study is an attempt to derive a model of the early growth of European hake of the Southern stock by combining all the available information from both otolith age readings and length composition of commercial and survey catches.

MATERIALS AND METHODS

All the material employed in this paper was collected from ICES Divisions VIIIc and IXa. The following information was employed in the study:

1.- Length distributions of:

a - Landings of "bakas" (bottom trawlers) from the ports of Muros and Ribeira where, the sampling coverage is highest. Quarterly samples are available from 1985 to 1991 (except 1988). This fleet consist of small vessels which fish mainly hake and blue whiting (*Micromesistus poutassou*) and use 40 mm meshes nets and they operate in coastal areas, often on a daily basis.

b - Landings of small gillnetters (ports of Muros and Ribeira) which use nets with 45 mm meshes and fish hake seasonally. This fleet is artisanal, vessels are small and fishing takes place very close to the coast. The size composition of hake caught is narrow and ranges between 20 and 40 cm.

c – Annual bottom trawl surveys carried out in the autumn (September–October) from 1985 to 1991 (exception 1987) employing a standardized stratified random sampling design (see Pereiro et al., 1991).

d – Two spring surveys carried out with the same statistical sampling desing in March 1983 (Fariña, 1984) and May 1984 (an Ichthyoplankton survey, data unpublished).

e – Monthly surveys carried out in areas closed to hake fishing conducted between October 1989 and July 1990 (Piñeiro et al. ,1992).

2.- Otoliths:

An otolith data base was created in the Vigo Oceanographic Center of the Instituto Español de Oceanografia (IEO) during 1992 for the growth study purpose . This data base contains information of hake otoliths from 1983 to 1990 and includes the following variables: otolith size (length, width..), number of rings observed, distances from otolith nucleus to all hyaline rings on every otolith, edge type, whole otolith or sectioned, catch location , fish size, sex, date of capture, age, etc.

In this study, a sample of 1450 whole otoliths from fish 7–35 cm. collected between September 1989 to September 1990 was examined. To ensure the geographical homogeneity of the samples, the otoliths were estracted from hake caught in the same areas were the commercial and surveys fishing operations take place regularly. Sex differenccs in growth were no considered in this study.

METHODS:

Length distributions from commercial gear were plotted on a quarterly basis. Those derived from the spring surveys were plotted together with the quarterly length distributions of the commercial fleet, and those from the autumn survey were included in the third quarter plots. Every plot was examined by eye, to locate modes and modal progressions. MIX was tried (Macdonald and Pitcher, 1979) to split length distributions into theoretical components, mainly for the surveys made during the closed fishing season and, in some cases, on the distributions from commercial landings. However, MIX results were not used.

It was found that this program (MIX) can be very useful to define age groups from a length distribution when one knows how individuals grow, and one can define how and where the search must work. But in other cases it can lead to misleading results, mainly if one does not know how many components to look for, or what the growth rate is. For example, an age group generated over a wide time interval could be split into several theoretical groups by the program. The fit of a single age group to a theoretical distribution can be rejected as well.

Otoliths were stored in vials with sea water and approximately 0.5% thymol for avoid fungus development. Whole otoliths were viewed on a black background under reflected light through stereomicroscope. Otolith interpretation commences at the nucleus and proceeds to the edge. A systematic recording of the measurements from each otolith was collected with the Optical Pattern Recognition System (OPRS) software Biosonics.

A specific interactive program application was developed to manage the data base and plot the increments between hyaline rings of each otolith. The program is written in the ACTOR programming language in a windows environment and makes use of the information collected by the Image Analyser (BIOSONICS). A set of otoliths can be selected through conditions imposed by the user as follows : fish size, otolith size, number of rings, edge type, catch location, catch date, etc.

The otolith data base was mainly used to analyse the modal size of hake at which rings are formed. The analysis was made as follows:

a) For each length distribution for which otolith readings were made, a sample of otoliths from individuals with size corresponding to the modal length or close to the mode was chosen.

b) Then the otoliths corresponding to those individuals were examined, and otoliths showing the most frequent pattern were chosen.

c) From otoliths chosen in b), the size corresponding to the formation of each ring was estimated by a linear relationship (Piñeiro, unpublished)

RESULTS AND DISCUSSION

The interpretation of length distribution data becames more difficult through time due to changes in this fishery. Figure 1a shows the length distribution of the yearly landings of the bottom trawlers, 1985–1987 and 1989–1991. It can be seen that the landings decreased abruptly, mainly for smaller individuals. This decrease mainly took place after 1987, both total landings and the exploitation pattern changed. These changes are partly due to a better enforcement of minimum size rules, which that presumably transformed landings of very small hake into discards, but also to decreased recruitment. In support of this statement, Figure 1b shows the length distribution of yearly catches of small gillnetters for the same period. Here there is no change in exploitation pattern. However, catches decreased during the period, indicating reduced recruitment. There was a simultaneous change in seasonality. In the earlier years, most fish were caught in the first half of the year (Fig. 2). In later years the seasonality is not so well defined due to an important decrease of catches in the first half of the year. In spite of it, a similar pattern of modal progression for the whole period can be identified. The information available to us seems to indicate a decline in recruitment in the last years.

We recall that the size range of hake caught by small gillneters is very constant, due to the selectivity of this gear. Individuals of only 20–40 cm are normally caught.

The scale of length distributions from surveys and small gillnetters has been magnified for the porpuse of comparing them with the much larger commercial trawl catches. Because the catch of autumn surveys is bigger than spring surveys, the last have also been magnified. Length distributions of the catch in the spring and autumn surveys at the same scale, are shown in Figure 3.

Quarterly length distributions from 1985 to 1991 (except 1988) shown in Figures 4 and 5. They indicate that hake grows more quickly than previously thought. In 1985, 1986 and 1987 (Figure 4) hake landed by bottom trawlers have a modal length of about 20 cm in the fourth quarter, consistent with the modal length appeared in the autumn survey. In the first quarter, fish of about 20 cm continue to be available to bottom trawlers, so that the length distribution ranges go from about 10 (the recruits) to 20 cm, those already present in autumn during the survey. In the second quarter the mode lies between 20 and 30 cm, and the length distribution from small gillnetters is similar to that of the trawl. In some years, recruitment to bottom trawl gear also occurring during this quarter. In the third quarter the main mode lies between 30 and 40 cm, the concrete position varies with the year, and this displacement happens for both gears. Finally, there is a mode between 35–45 cm in the fourth quarter, with a new wave of recruits also appears in the commercial landings.

In 1989, 1990 and 1991 (Fig. 5) the pattern changes for the smallest individuals. That is due to the fact that the strong recruitment peak is not now appearing and a small number of recruits are continuosly being recruited for bottom–trawlers. However, it is possible to track the modes through successive quarters, as indicated on the Figure. Small individual landed by bottom trawlers in the 4–th quarter are the same as caught during the autumn survey. The mode at 22–23 cm in the first quarter of 1989 reaches 30 cm during the second quarter and about 34 cm during the third, and the mode at about 25 cm during the third quarter reaches 30 cm during the fourth.

In 1989, the recruitment index from the autumn survey (based on number of individuals caught less than 17 cm long, see Anon., 1992) was the highest in the series. They were very small individuals, with a mode at 10–11 cm. They are probably the same group fished by small trawlers and small gillnetters during the second quarter of 1990, when a large catch was made by bottom trawlers of individuals with a modal length of 24 cm. That mode moved in the third quarter to about 30 cm. Consistency between the catch of small individuals during the autumn survey and landings of bottom trawlers in the 4–th quarter is maintained.

Landings by bottom trawlers and the catch of small gillnetters decresed even more in 1991. However, the same modal progression is evident, though it is not shown so clearly due to the poor catches.

Length distributions from the Sisargas and "closed areas" surveys (Fig. 3 and 6) are coincident to those just mentioned.

We conclude that hake reached one year of age with an average length of about 20 cm, and two years at about 35–40 cm.

If hake growth to 20 cm in the first year of life and several rings appear in otoliths of one year old hake. What is the biological meaning of this rings. To interpret the pattern of ring formation, it was assumed that hake were one year old on reaching 20 cm, and that they grew linearly from the fourth month of life (assumed length 4 cm) to the 14th month (24 cm). We then estimated hake size at the moment when each ring was formed by a linear relationship (Piñeiro, unpublised); size was converted to age (months) by the means of this relationship. Results are shown in Figure 7a.

Approximately six months after birth, a characteristic "hyaline zone" is formed in the otolith. This zone or ring has been described by different authors studying hake growth, but with no agreement with regard to its location in the otolith (Decamps and Labastie, 1978; Iglesias and Dery, 1981; Goñi and Piñeiro, 1988; Piñeiro and Hunt, 1989). The available literature appears to indicate that the formation of this early "hyaline zone" is not related with environmental changes (as is commonly believed for most well marked rings in fish otoliths), but with internal biological processes (Iglesias and Dery, 198; Orsi-Relini et al., 1987). The apparent constancy in the time of formation of this "hyaline zone" regardless of the season supports this conclusion. The biological process responsible for the formation of this zone seem associated with the change from pelagic to demersal life during the juvenile stage of hake. This is why this ring is known as "demersal ring". Most of the other hyaline rings or zones that can be seen in the otolith are formed during the winter and, as shown in Figure 7a, more than one ring appears to be formed each winter.

The birth date has been estimated on the basis of the relationship between the size of the fish and the size of the otolith (Piñeiro, unpublished), which is considered linear during the first few years. According to the otoliths, most hake are born during the first quarter of the year and the rest during the summer. This is an agreement with the extended (December to May) spawning period of hake from this stock (Pérez y Pereiro, 1985). The time of birth within this extended period will determine the distance between the "demersal ring" and the first winter hyaline rings or zones (Piñeiro and Hunt, 1989).

According to this, the high number of hyaline rings formed during the first year of life in hake otoliths is accounted for by an early characteristic "demersal ring", formed when fish are 7–10 cm. and several hyaline zones formed during the first winter. In otolith samples of 1 year old hake (<24 cm), with the exception of the clearly marked "demersal ring", the rest of the hyaline rings are poorly defined and can be grouped in a band of "intermittent hyaline zones". This appears to indicate that during the first winter of life hake growth undergoes a series of interruptions or that growth at that time is "intermittent" (see sample 7 in Figure 7a for an example).

This interpretation of the pattern of otolith ring formation according to the hypothesis of "fast growth" is supported by the results of the study of length distributions of the catches presented earlier.

The same process but now with the hypothesis of "slow growth" (by which hake grow to about 15 cm. in the first year and to about 24 cm. in the second) in mind, is repeated in Figure 7b. As can be seen in Figure 7b, if the pattern of ring formation is interpreted according to this hypothesis the time of formation of the second hayline zone or set of hyaline zones would not always coincide with the winter or any one given season. In this case, the winter rings can be formed at any time of the year. If this were the case, due to the extended spawning period, the juveniles recruiting to the fishery at any time of the year can generate several modal classes close to each other which can be interpreted as different age groups. On the other hand, when recruitment to the fishery occurs mostly during the fourth quarter, the spawning peak has taken place most likey during the fist quarter.

According to this hypothesis, age at first maturity is reached in the third year of life, and fish caught are mostly age class 1. K, the parameter of the V. Bertalanffy equation, probably has a higher value than previously believed, and the number of age classes contributing significantly to the catch is much smaller.

Data from the commercial fishery seem to support that Southern hake grows at a quicker rate than previously believed. However, that is not backed by the information from research surveys. This information is difficult to interpret, because length distributions from surveys are almost exclusively composed by individuals that have not reached 20 cm length, while most of hake from the commercial fleet is longer than 20 cm. That can be very clearly seen in Figures 4 and 5, third quarter, for the years 1985, 1986 and 1989–91. These Figures show that the length distributions from the surveys are completely different of those from the commercial fleet, and even they do not overlap in some cases.

From our point of view, it is impossible to explain these differences between the length distributions from research surveys and the commercial fleet by the different selectivity of gears used. We think that it could explain why the number of hake less than 20 cm long is so small in the commercial fleet, but it could not explain the almost absolute lack of hake longer than 20 cm in the research survey.

A possible reason to explain that difference is a loss of availability in research surveys for hakes more than 20 cm long. This fact could be caused by the concentration of that hake closer to the coast, where rough grounds are very abundant, and the research vessel has a lot of problems to work in adequate way; i.e., while hake less than 20 cm long is distributed all over the shelf, individuals more than 20 cm long would be distributed closer to the coast, so that the commercial trawl fleet could concentrate on this age class working with gears especially adapted to rough grounds.

This explanation is supported by the catch made by gillnetters, exclusively composed by hake more than 20 cm long. The high season is the first and second quarter, i.e., when the research vessel is making very low catches of hake (see on Fig. 3 the length distribution in the catch of the spring and autumn surveys, –absolute numbers–, and on Fig. 4 and 5 the length distribution in the spring survey and gillnets); and, in fact, gillnets fish very close to the coast.

We recognize that the series of commercial data available is too short, and this work should be redone as the series becomes longer; the conclusions in this paper should be confirmed in future.

Finally, although this paper is not addressed to the Northern stock of hake, it is evident that a similar reinterpretation can be tried for that stock.

We expect this paper will be useful mainly to reopen discussion on the dynamics of hake. Our main objetive has been to remove "assumed dogmas" in order to look for a new way leading towards a better knowledge of European hake biology and its dynamics.

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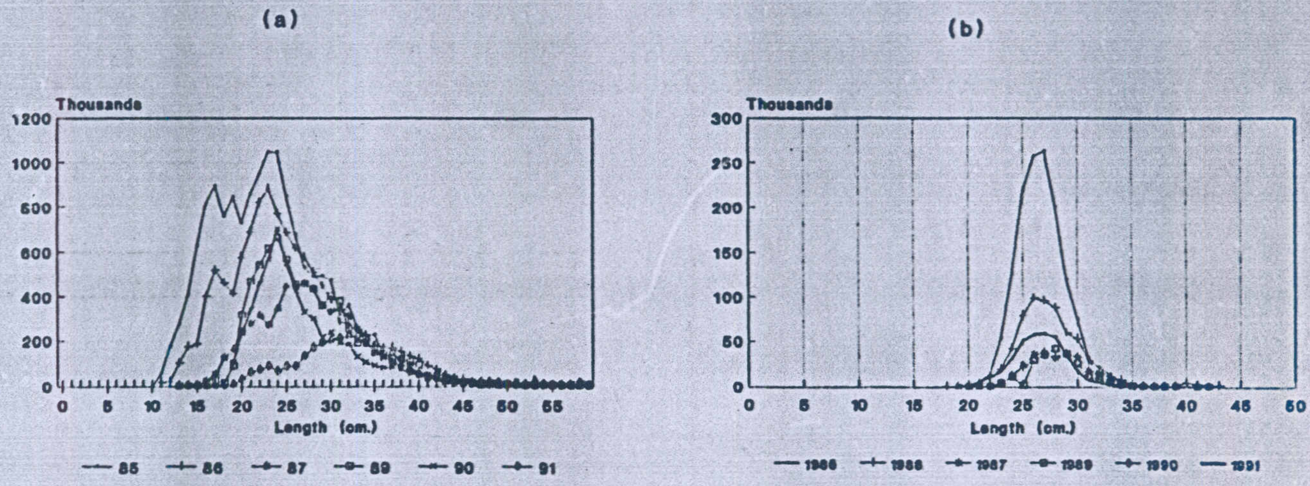


Fig. 1. Length distributions of commercial catches from bottom trawl (a) and small gillnets (b) for the period 1985–1991.

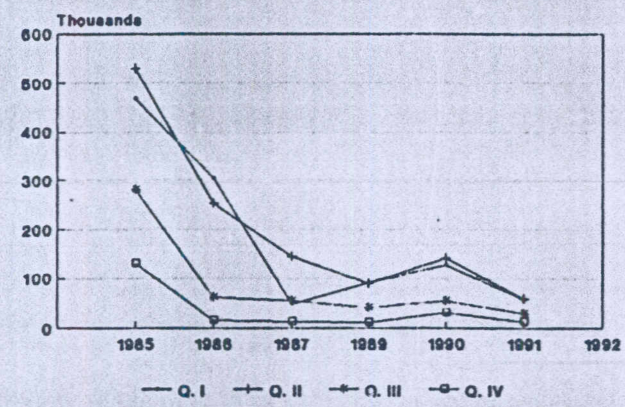


Fig. 2. Abundance in number of small gillnets catches by quarter for the period 1985–1991.

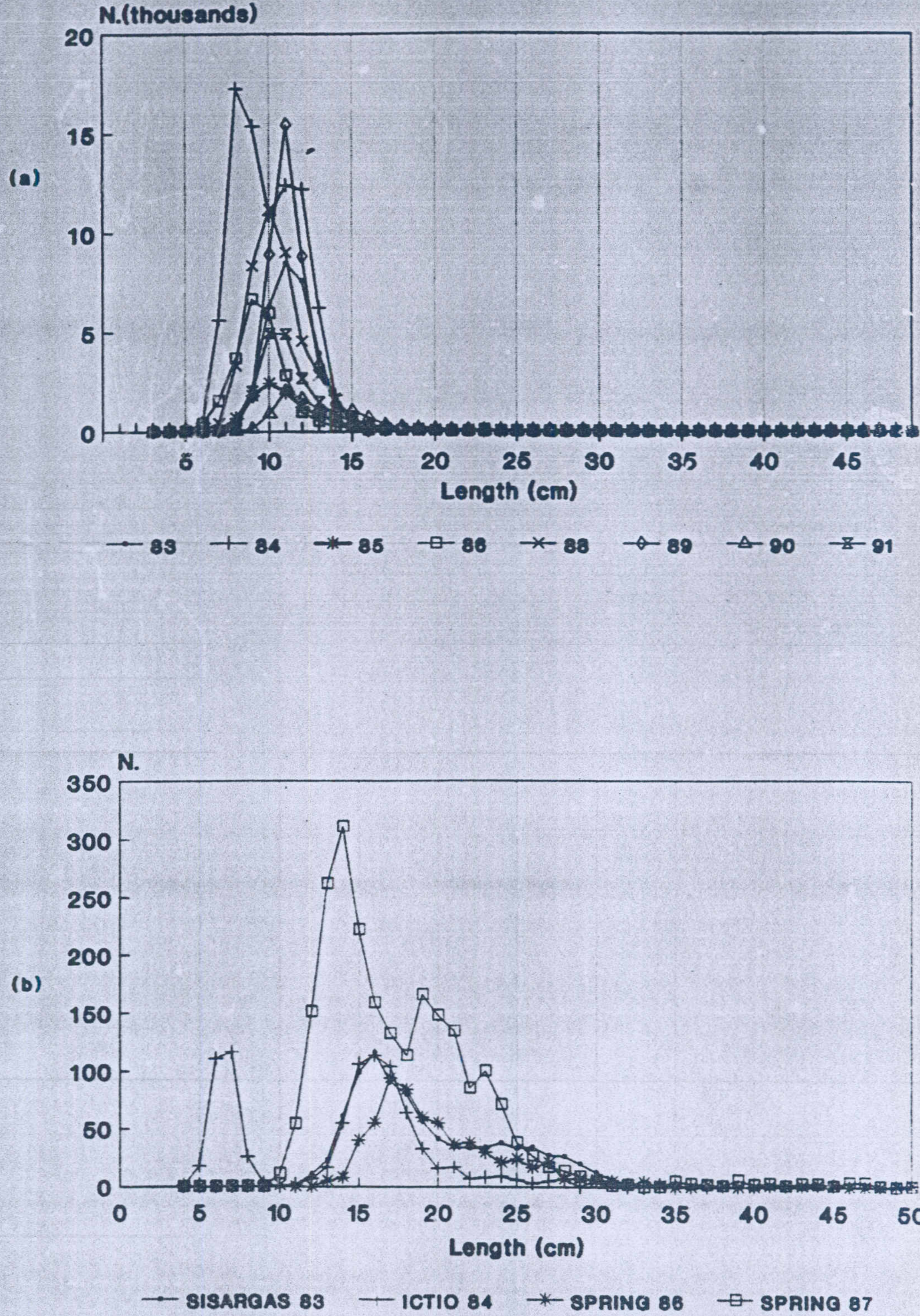


Fig. 3. Length distributions from surveys carried out in autumn (a) and spring (b). *N, number of individuals.*

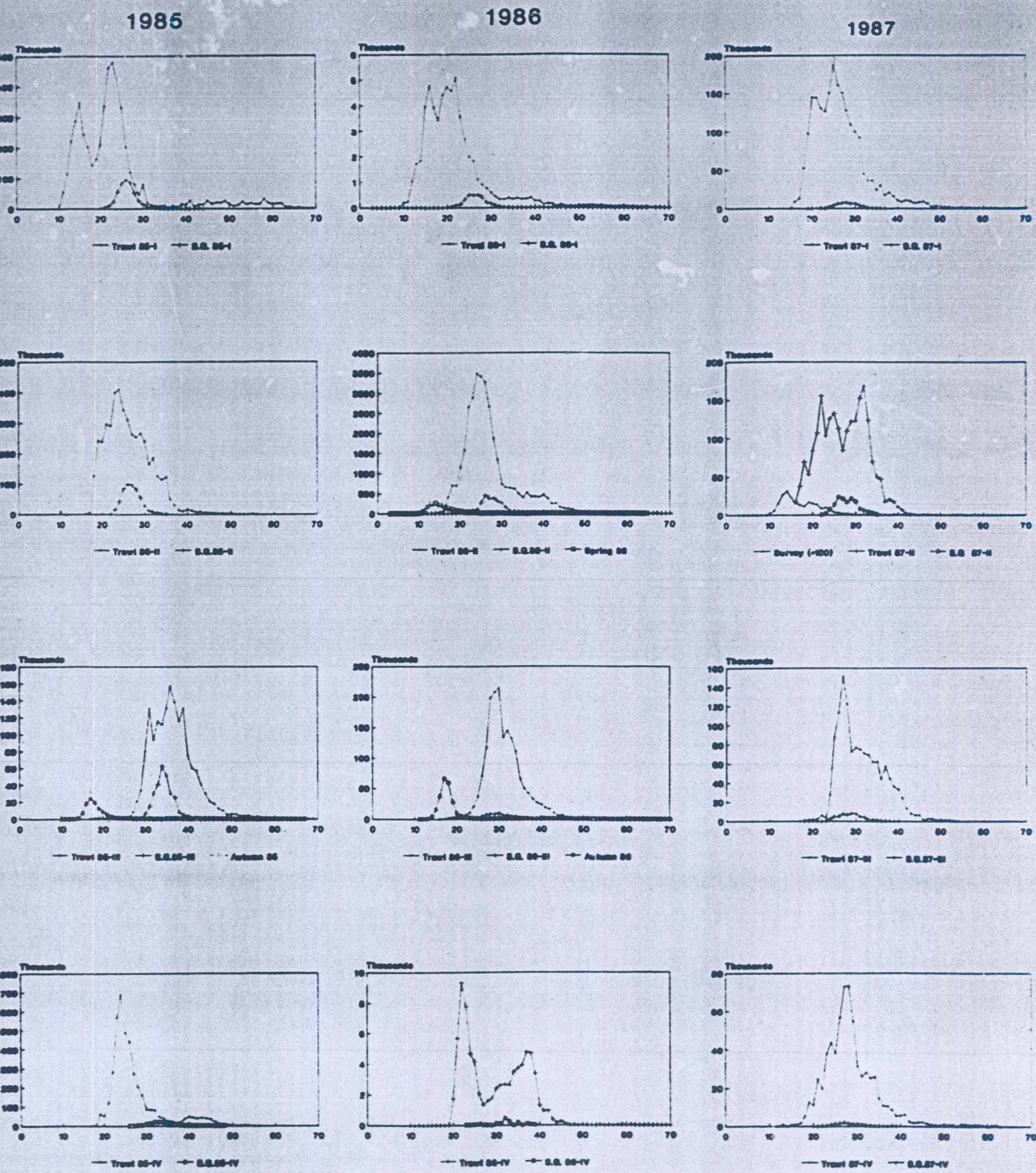


Fig. 4. Length distributions from commercial catches and bottom trawl surveys (in number) by quarter (expressed by I,II,III,IV) for the period 1985–1987.

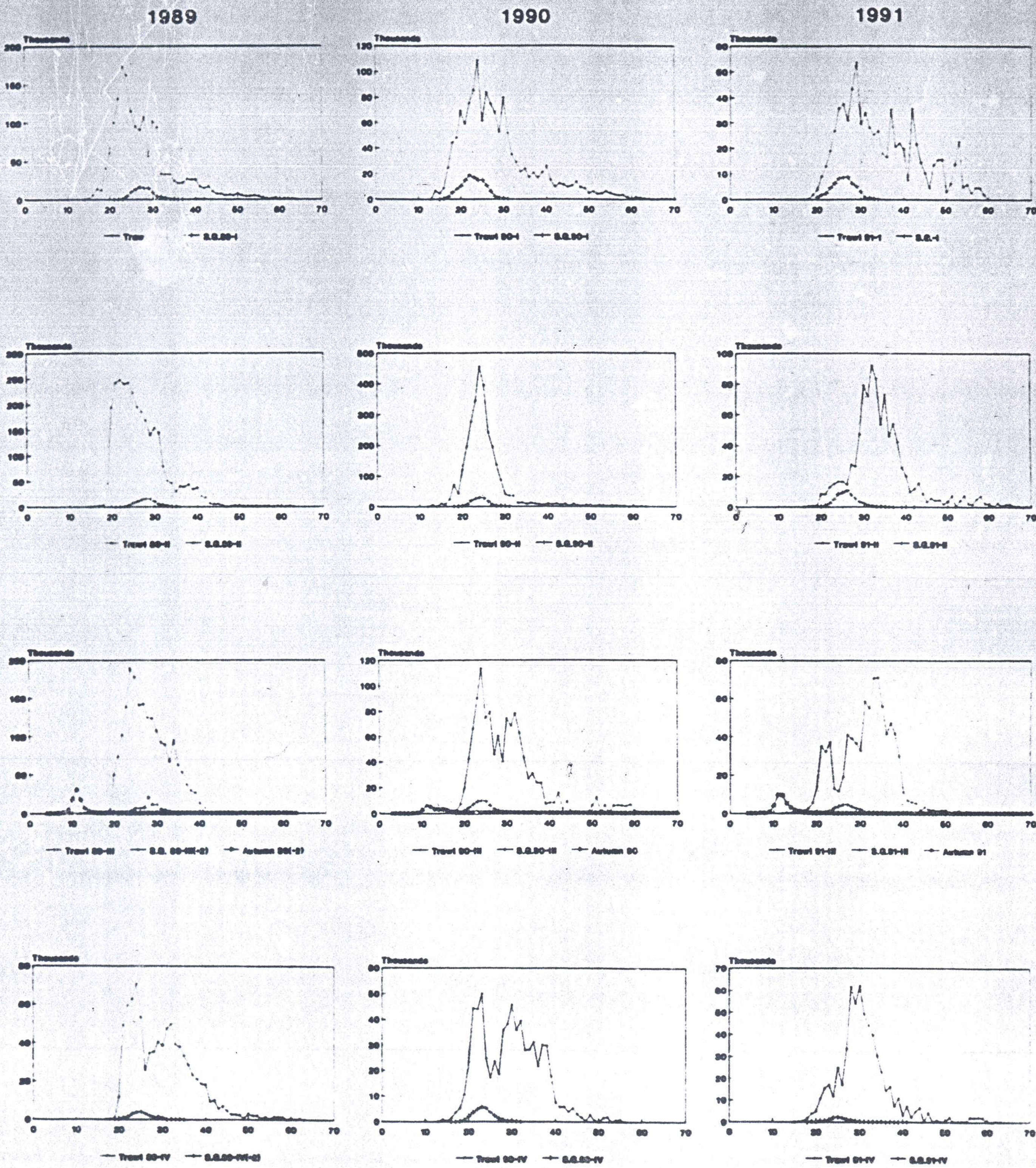


Fig. 5. Length distributions from commercial catches and bottom trawl surveys (in number) by quarter (expressed by I,II,III,IV) for the period 1989–1991.

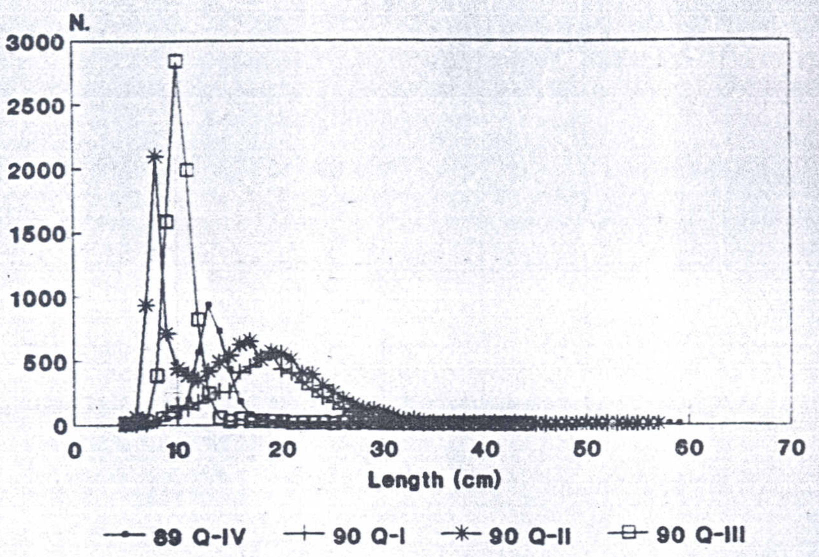
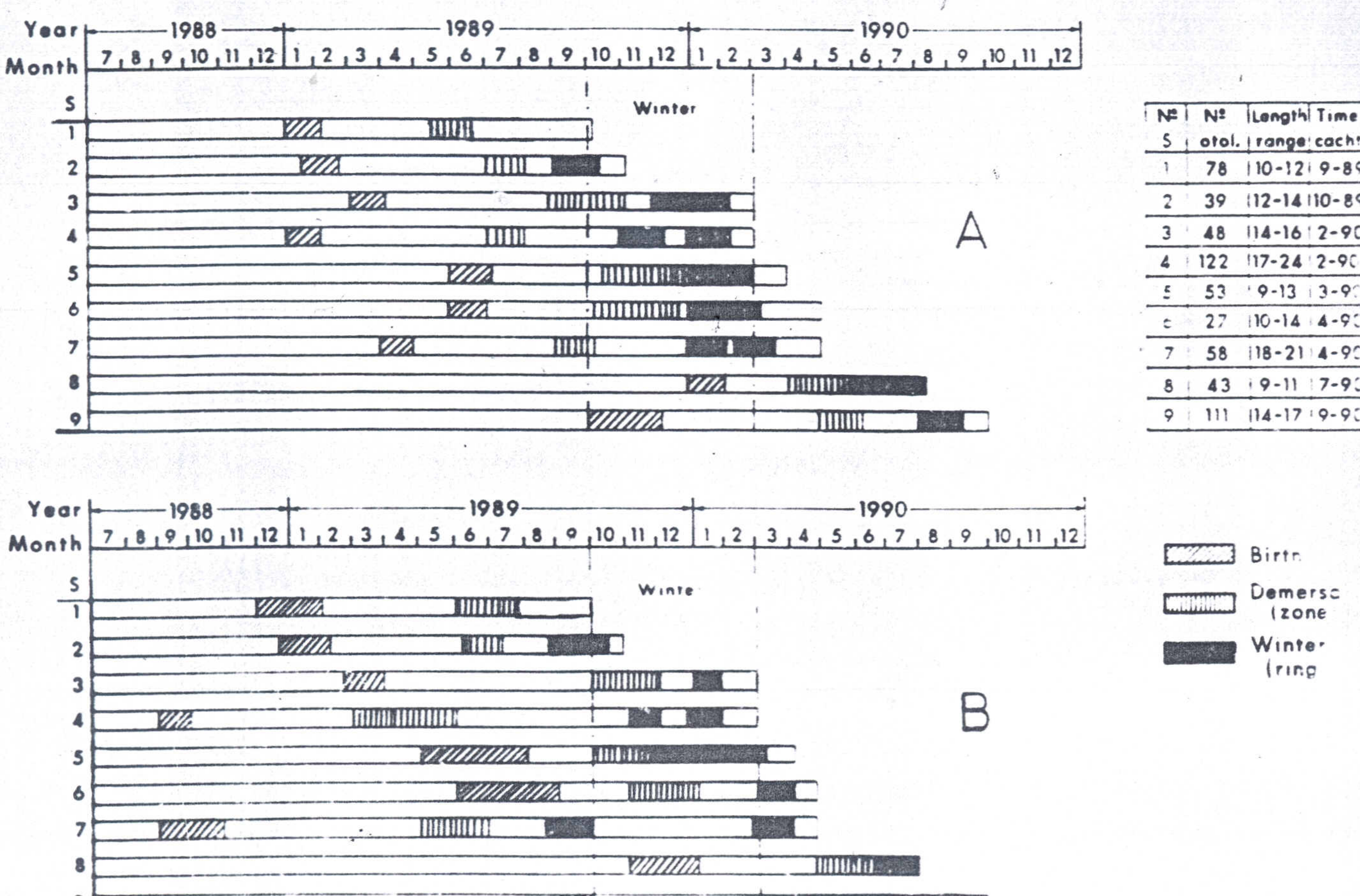


Fig. 6. Quarterly length distribution (expressed by Q: I,II,III,IV) from bottom trawl survey (in number) conducted in "closed areas" during the period 1989–1990.



Nº S	Nº otol.	Length range	Time cacht
1	78	10-12	9-89
2	39	12-14	10-89
3	48	14-16	2-90
4	122	17-24	2-90
5	53	9-13	3-90
6	27	10-14	4-90
7	58	18-21	4-90
8	43	9-11	7-90
9	111	14-17	9-90

Fig. 7. Retrospective analysis of the time estimated from rings formation on tipical otoliths deppending on two hypothetical growth: **quick (A)** and **slow (B)**. The period studied is 1989–1990. On each bar, birth time and rings formation of the most frequent otolith pattern in the sample studied are represented. *S, otoliths sample.*