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Spring vs. autumn spawners of the Baltic herring on the basis of otolith microstructure and morphology.

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INTRODUCTION

Before beginning the final discussion on how to split Baltic herring resources into manageable assessment units, some aspects of the biology and population structure of this species should be clarified to achieve common agreement on their interpretation among researchers. Thus, starting assessment calculations before or during the first SG meeting seems to be premature. First of all, the scientific basis for such divisions should be established, the practical aspects of introducing new assessment units should then be evaluated, and this could possibly be followed by an exercise on assessment calculations.

There is no need to review the current theory on Baltic herring population structure or the means used for the differentiation of population or subpopulation units. They are well known by the members of the ICES Study Group on Herring Assessment Units in the Baltic Sea. We would like to present our findings and start discussing those aspects of herring biology that, although already reported by several authors, have not yet been incorporated into the theory on Baltic herring population.

The existence of two sympatric spring and autumn spawning herring stocks over the vast majority of the Atlantic herring distributional range, including Baltic Sea, is a widely known fact. The biological background of this phenomenon was either not fully understood or misinterpreted for many years. For a long period of time, the definition of two races of Baltic herring introduced by Heincke (1898) was considered a paradigm of herring population structure. The representatives of these two groups spawning in different seasons were identified on the basis of several characters, including timing of maturity and otolith morphology. Messieh (1972), in the western North Atlantic, and Aneer (1985), in the Baltic, found that autumn spawning herring could have spring spawning herring type otoliths and vice versa. On the basis of the observed controversy between otolith type and maturity stage, Aneer (1985) speculated on the factors that determine the abundance of spring and autumn spawners and concluded that spawning time is not genetically fixed.

One year later, Smith and Jamieson (1986) proposed a new interpretation of the herring populations showing two spawning seasons. According to this concept, groups of individuals that differed by spawning seasons do not constitute separate populations but only subunits of a larger population. This idea was confirmed by McQuinn (1997) who showed that progeny of a given seasonal spawning unit may recruit to the other unit characterized by a different spawning season. This finding explains the partial lack of agreement between otolith type and maturity stage observed by Messieh (1972) and Aneer (1985). According to McQuinn (1997), the spawning season of the individual which is established at the time of its first maturity is encoded for the whole of adult life.

It is our supposition that this idea has not been fully accepted by the Baltic fishery research community. The established ICES SG appears to be a good platform to make up our minds regarding this controversial issue of herring biology, and it should be achieved well in advance of the introduction of new assessment units.

The simplest way to differentiate between spring- and autumn-spawned herring is on the basis of the diameter of the first growth zone in otoliths. Progenies of autumn spawning do not deposit a winter ring on their otoliths during their first winter as they over-winter in the larval stage. Thus, the distance from the otolith center to the first winter hyaline ring (deposited in the second year of life) is usually larger than in spring herring otoliths. Moreover, fast growing larvae of the spring herring form only a short sequence of very narrow daily increments in the otolith center followed by wide increments formed during the late larval and early juvenile stages and deposited in summer (Fig.1A). This results in the small hyaline otolith nucleus observed by age readers. Contrary to this, in the otoliths of autumn herring a long sequence of very narrow daily increments is formed due to the unfavorable living conditions of the larvae in winter and early spring (Fig. 1B). Under macroscopic examination, these otoliths are characterized by large hyaline nuclei.

The nucleus character, a feature that is very helpful in distinguishing the origin of juvenile or younger adults, is less conspicuous as the otolith thickens with age. However, the potential role of the otolith nucleus character for the identification of the season of fish birth still exists even in old specimens. This information can be achieved by means of otolith microstructure analysis. As mentioned above, the spacing of daily increments formed in the larval stage is much different in herring from spring and autumn spawn, and this difference is easily detected even in adult fish otoliths (Fig.2). To examine the character of daily increments deposited during larval age history, i.e. those located in the very center of adult herring otoliths, extensive preparatory work that cannot be performed on a routine basis is necessary.

The aim of this paper was to verify how accurately an experienced otolith reader could identify adult herring origin, i.e. spring or autumn spawning, on the basis of external otolith examination. The verification will be carried out by means of otolith microstructure analysis. The possibility of undertaking such a comparison is much greater in Baltic herring than in those from the Atlantic, as the environmental conditions which heavily impact otolith microstructure are more differentiated between the spring-summer and autumn-winter seasons in the Baltic than in the North Atlantic. The second aim of this work was to form a preliminary opinion on the origin of herring that spawn in autumn along the Polish coast, and particularly in the Vistula Lagoon.

MATERIAL and METHODS

Recently, the spring spawning population component constitutes the vast majority of the Baltic herring stocks. Therefore, if the ideas presented by Smith and Jamieson (1986) and McQuinn (1997) can also be applied to Baltic herring, it should be much easier to find spring spawning progenies within subpopulations spawning in autumn. To verify this hypothesis, the materials for examination were selected from autumn samples (Table 1 and Fig. 3). In general, all the specimens from a sample were analyzed, i.e. one otolith for microstructure and the other for age and morphological characters. However, due to the low number of fish that originated from autumn spawning that were observed and the time-consuming procedure of preparing suitable otolith sections for microscopic analysis, the otoliths from two samples (sample 4 and 5) were not chosen randomly. Instead, only individuals which could be determined on the basis of otolith morphology and maturity stages as autumn spawners were chosen for further otolith microstructure examination. Therefore, the two samples mentioned do not represent the real stock structure regarding hatching time and were only used to verify the accuracy of traditional methods of hatch cohort definition.

Table 1. List of samples examined for Baltic adult herring origin on the basis of otolith morphology and microstructure.

Sample No.	Date	Fishing ground	No. of specimens examined	Size range (cm)
1	28.11.90	Russian part of the Vistula Lagoon	35	17-26
2	5.10.99	Polish part of the Vistula Lagoon	8	17-21
3	24.09.99	Southern Baltic	8	17-20.5
4	7-17.10.99	Southern Baltic	22	13.5-24.5
5	3-7.11.99	Southern Baltic	26	14-26.5
6	10.11.99	Pomeranian Bay	43	19-29
7	17.11.99	Southern Baltic	92	15.5-29.5

The otoliths were examined by an experienced age reader, M. Wyszyński, and classified according to the spawning season on the basis of otolith characters. The sex and maturity stages were known during otolith examination, but they were not considered to be decisive features. One otolith of each pair was embedded in a microscopic medium (eukitt) and then ground and polished from both sides to achieve a transparent sagittal section thin enough to enable the examination of its central increments. The otolith sections were examined under a microscope in transmitted light at 600x magnification. Otoliths of herring larvae were mounted in eukitt on microscope slides and examined without any preparation.

Herring larvae were sampled in the 1997-1999 spring seasons with a 2 m^2 neuston trawl (500 μm mesh size) in the Vistula Lagoon during traditional spring ichthyoplankton surveys.

RESULTS

The time of sampling and the maturity of the majority of the investigated material indicated that the fish selected for the examination were from the autumn spawning. However, most of the examined specimens from random samples (excluding samples 4 and 5) constituted individuals hatched in spring, i.e. progenies of the spring spawning subpopulation (Table 2).

Table 2. Definition of hatch cohort of Baltic herring on the basis of otolith microstructure analysis and accuracy of the definition on the basis of otolith morphological characters (percentage of correct estimates to the total number of examined otoliths). Maturity and sex ratio in the analyzed samples determined during routine biological investigations of this species are included.

Sample Number	Date	Maturity stages							Sex		Origin (hatch cohort)		Accuracy (%)
		2	3	4	5	6	7	8	M	F	Spring	Autumn	
1	28.11.90					35			23	12	35	-	...
2	5.10.99			1	5			2	5	3	5	3	50,0
3	24.09.99			1	6			2	5	3	5	3	75,0
4	7-17.10.99	6		1	2	1	11	1	11	11	2	20	86,4
5	3-7.11.99			4			7	14	14	12	2	24	77,3
6	10.11.99		4	1	22	3	7	7	20	23	40	3	83,7
7	17.11.99		26	30	14	4	6	12	50	42	84	8	92,4

The most spectacular example of the recruitment of progenies from the spring spawning subpopulation to the autumn spawning one is presented by the sample from the Russian part of the Vistula Lagoon collected in 1990. In this sample, all the examined specimens collected during the autumn spawning originated from the spring spawning cohort. In a few other autumn spawning specimens collected recently (1999) in the Polish part of the Vistula Lagoon (sample 2) progenies from the spring spawning cohort also predominated however, individuals from the autumn spawning cohort, i.e. hatched in autumn, were also present among the examined fish.

The Vistula Lagoon provides researchers with a unique opportunity to study herring reproduction and recruitment. Firstly, due to the semi-enclosed character of this water body, there is no doubt that herring larvae sampled in the lagoon are progenies of the adults spawning there. Moreover, as the conditions for successful herring reproduction appeared in the Vistula Lagoon approximately a hundred year ago, i.e. increased salinity that resulted from the altered location of the Vistula mouth at the very end of the nineteenth century, the herring cohorts spawning there cannot be genetically different from fish spawning in the Gulf of Gdansk outside of the lagoon. Thus, results obtained in this basin may be applicable to a wider area of the Baltic.

Ichthyoplankton samples collected in the Polish part of the Vistula Lagoon in 1997-1999 indicated the successful reproduction of two herring subpopulations, the spring and autumn ones (Fig. 4), as the existence of two different cohorts of herring larvae were manifested in the length frequency distributions. The size and age obtained from the examination of otoliths from the larger larvae indicated their autumn spawn origin. Recently, the majority of the herring stock in the Vistula Lagoon spawns in spring, as do those in other coastal spawning grounds of the southern Baltic. The analysis of otolith microstructure in autumn spawning herring showed that a part of the larvae hatched in spring recruits to the autumn spawning subpopulation. This is characteristic not only for the Vistula Lagoon spawning grounds, but most probably also for the wider area of the Baltic proper (Table 2). However, the Vistula Lagoon, due to the semi-enclosed character of this estuary, proves that both sympatric spring and autumn spawning cohorts constitute units of the same herring population.

The contribution of each cohort to the stock might differ among years, and the Study Group should endorse the need of further investigations of the mechanism responsible for a shift between the domination of the spring and autumn spawning component in the Baltic. The explanation suggested by Aneer (1985), that the decrease of autumn spawner abundance could be the result of improved feeding conditions due to the eutrophication of the Baltic Sea, was not confirmed in the last decade of the twentieth century when high herring stock abundance was accompanied by decreased feeding conditions.

The accuracy of traditional methods of hatch cohort definition on the basis of otolith morphology seemed to be sufficient enough to be used to estimate the contribution of individuals from the spring and autumn spawning to the overall herring stock biomass in the Baltic Sea. It was generally above 75%, and only in one small sample was the accuracy achieved lower. Therefore, it is no longer necessary to engage in time-consuming otolith microstructure analysis for this purpose.

CONCLUSIONS

- The sympatric spring and autumn spawning cohorts appear to constitute units of the same herring population in the Baltic Sea. The Study Group should adopt a position on this conclusion.
- The need for further investigations of the mechanism responsible for the shift between the domination of the spring and autumn spawning component in the Baltic, and a return to the routine of recording herring otolith type during ageing should both be endorsed by the SG.
- The accuracy of traditional methods of hatch cohort definition on the basis of otolith morphology appear to be satisfactory to estimate the contribution of spring and autumn spawning progenies to the overall herring stock biomass in the Baltic Sea.

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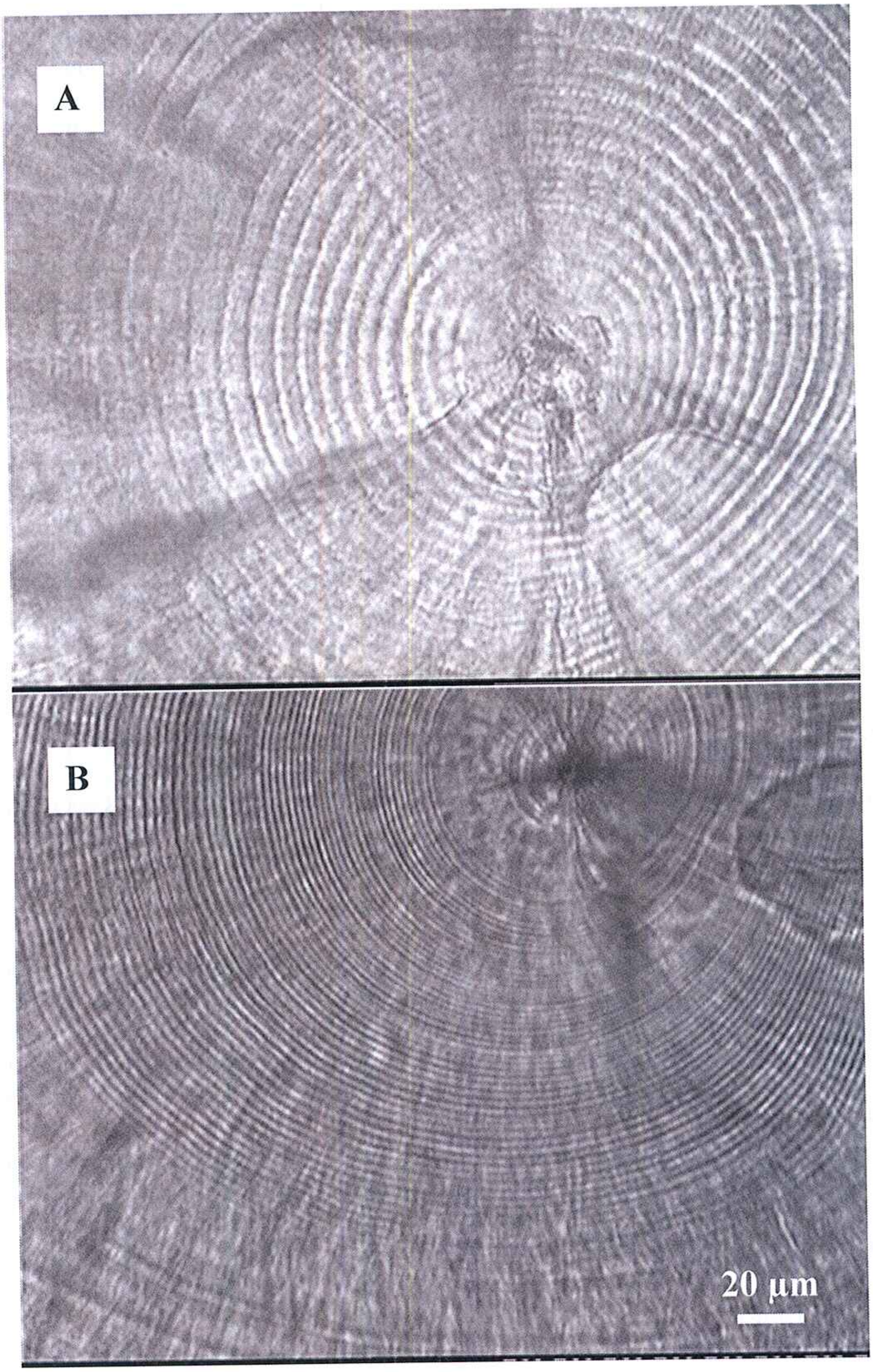
Figure captions

Fig. 1. Microscopic images of larval Baltic herring otoliths. A) spring larva; B) autumn larva (caught in spring).

Fig. 2. Microscopic images of the central part of the sagittal sections of Baltic herring otoliths. A) wide increments of spring spawning herring progeny; B) narrow increments of autumn spawning herring progeny.

Fig. 3. Location of samples analyzed for the Baltic adult herring origin on the basis of otolith morphology and microstructure.

Fig. 4. Length distribution of herring larvae in the Polish part of the Vistula Lagoon (southern Baltic) during the early spring season in 1997-1999.



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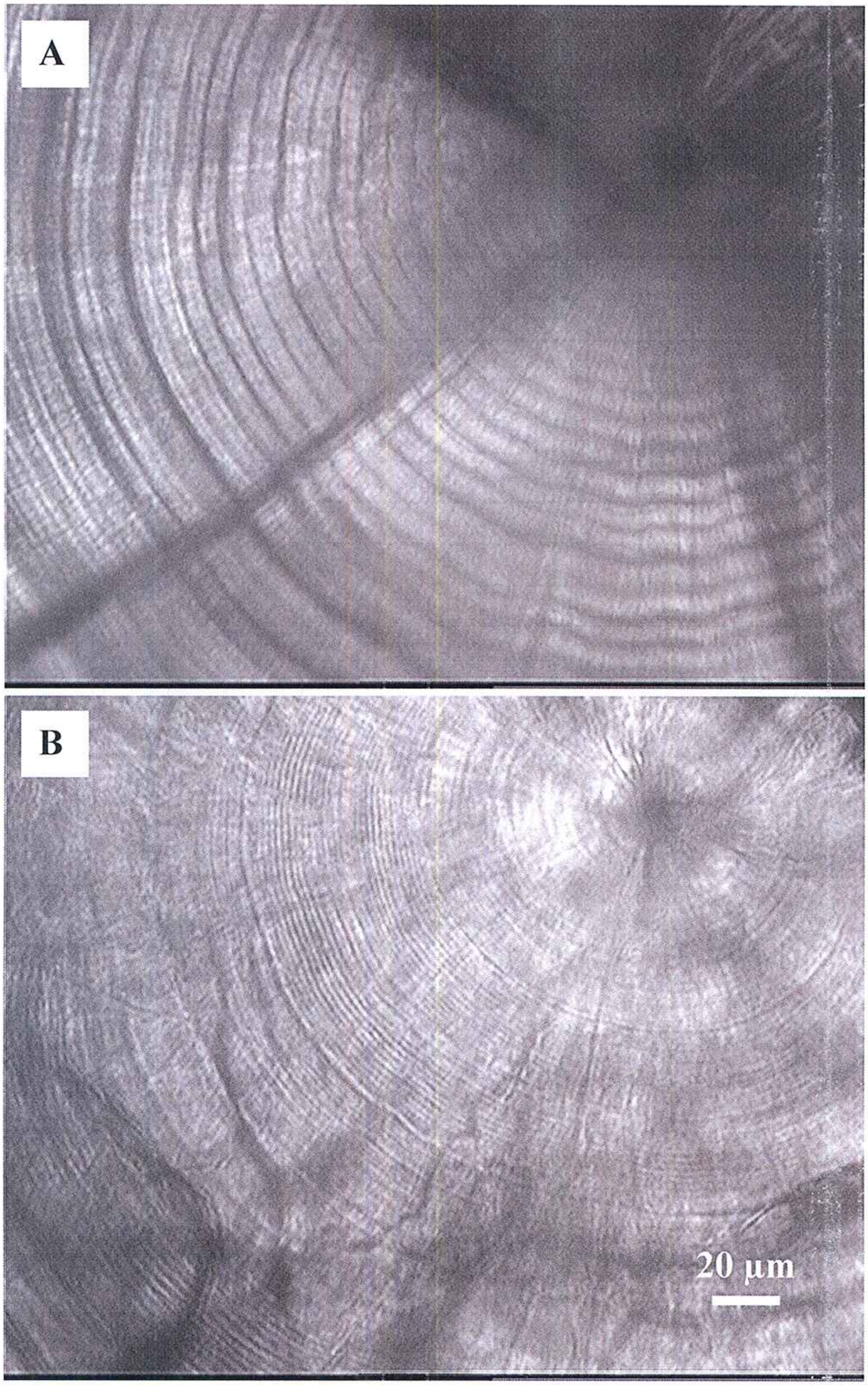

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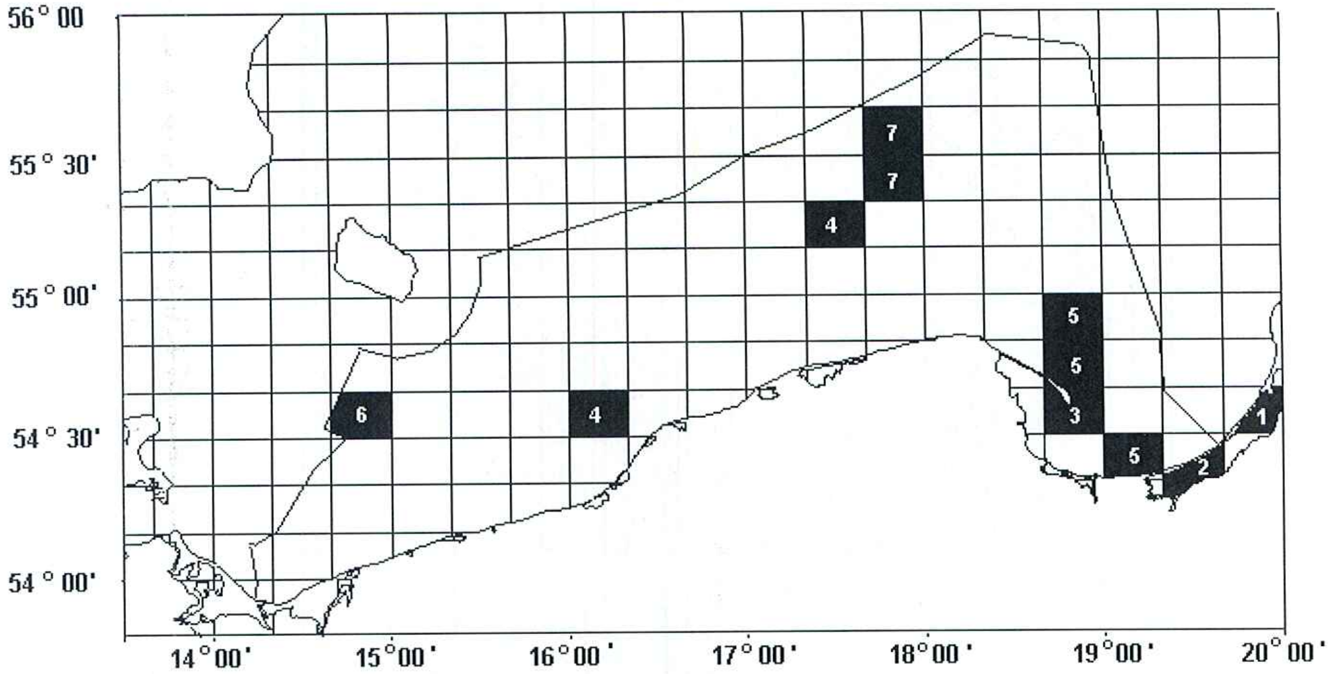

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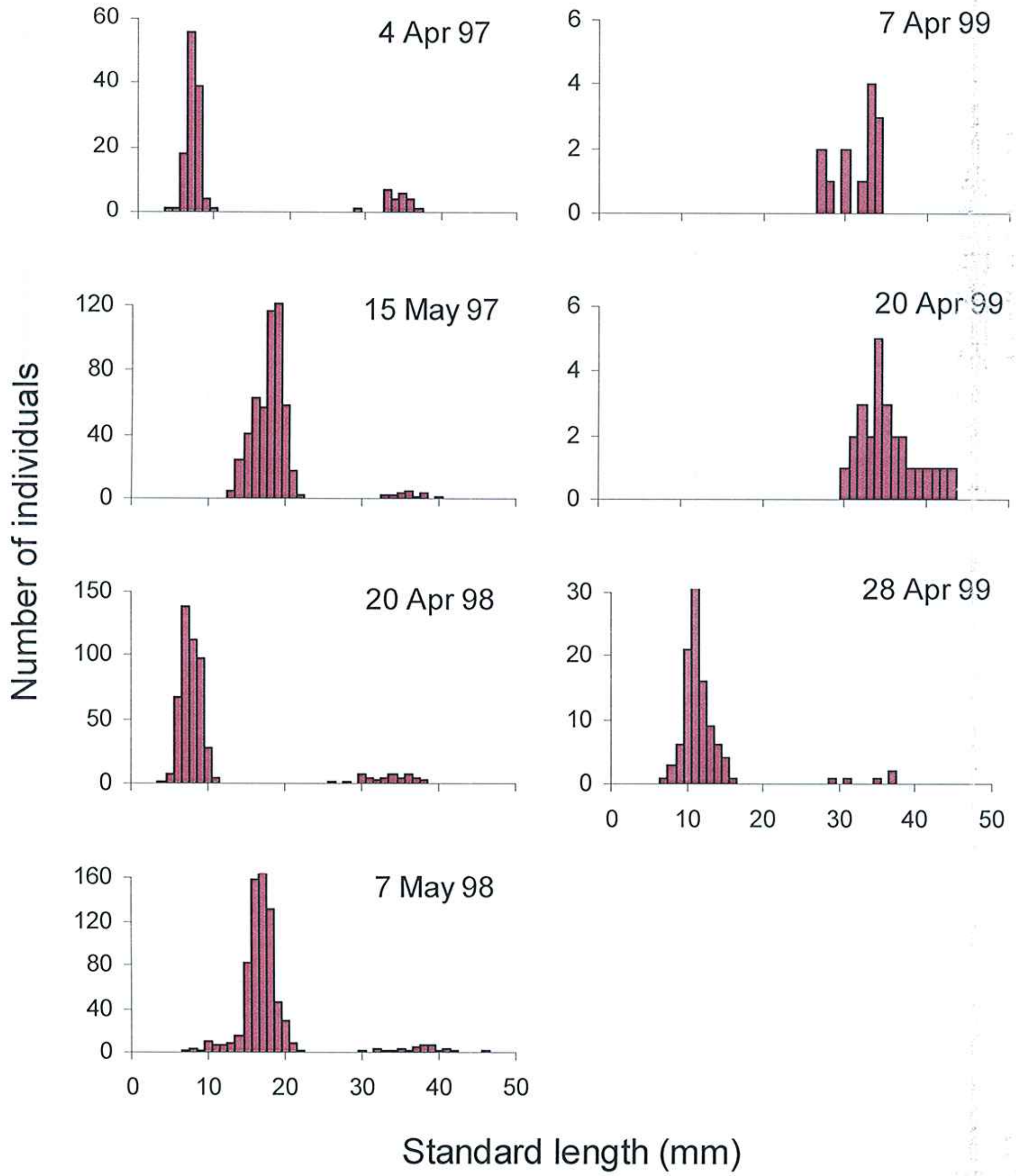

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