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A PRELIMINARY STUDY OF MICROSTRUCTURE IN OTOLITHS OF SEA-CAUGHT MACKEREL (*Scomber scombrus* L.) LARVAE

by

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ABSTRACT

Mackerel larvae have been sampled during two cruises south of Irland, in May and June 1989 and preserved in ethanol. The microstructure of the otoliths (sagittae) from the mackerel larvae have been examined. There is a linear relationship between length (3.6 - 11.6 mm) of the larvae and the radius of the otolith and there is an exponential relationship between the dry weight of the same larvae and the radius of the otolith. Although the mackerel larvae initially have a high specific growth rate (~ 12 % d^{-1}), the corresponding otolith increment size is rather small (< 1 µm). From an estimated age of 20 days till an age of 35 days the specific growth rate increased three times (~ 30 % d^{-1}), while the increment size doubled (~ 1.5 µm).

The average hatching date for the sampled mackerel larvae in May were estimated to 16. April 1989, and the average spawning date was calculated to 10. April 1989. For the larvae sampled in June the average hatching date were estimated to 21. May 1989, and the average spawning date was calculated to 16. May 1989.

INTRODUCTION

There are two spawning stocks of mackerel (Iversen, 1981), the western stock which spawn west and soutwest of Ireland and the the North Sea stock which spawn in the North Sea. The western stock starts spawning in March and with a peak spawning in May/June. The North Sea stock starts to spawn in May and have a peak spawning in June/July. Mackerel egg surveys have been carried out since 1968 in the North Sea and since 1977 in the Western area. Since 1977, these surveys have mainly been carried out for stock assessment purposes (Anon., 1990a). In addition to mackerel eggs, also mackerel larvae have been collected during these surveys.

Otolith microstructure has earlier been used to study growth rate of western Atlantic mackerel (Kendall and Gordon, 1981). D´Amours et al. (1990) concluded from a laboratory experiment that on western Atlantic mackerel the increments are formed on daily basis and the increment widths reflects the growth rate of the larvae. A similar relationship are to be expected for the mackerel in the eastern Atlantic. This indicate that by reading the otolith microstructure, the growth rate and birthdate of each individual mackerel larvae can be obtained. This will eventually give the growth rate and birthdate distribution of the recruiters in a yearclass and in addition give the backcalculated time of spawning for the recruiters. This will indicate if any parts of the spawning season is better for larval survival than others. In addition, there might be differences in the otolith microstructure between the two spawning populations, due to differences in spawning periods and environmental conditions, as temperature and prey densities. Since the two spawning stocks mix during the second half year in the North Sea, eventually differences in microstructure of the otoliths might be a useful tool to separate the two stocks in the mixing area. From these points of view, the otolith microstructure might be an interesting toll in the future study of mackerel.

This paper gives results of some preliminary investigations of the otolith microstructure from mackerel larvae belonging to the western spawning stock. For this study, mackerel larvae were collected both in the western spawning area and in the North Sea during the egg surveys in 1989. Unfortunately, the larvae from the North Sea were not handled successfully, and therefore no otoliths were available from this area.

MATERIAL AND METHOD

Mackerel egg surveys have been carried out every third year since 1977 in the spawning area west and southwest of Ireland for stock assessment purposes. In 1989 the surveys were carried out on a multi national basis in the period 1. April - 19. July (Anon. 1990b). The sampling strategy and timing of the different surveys are given in Anon. (1988, 1990b).

The mackerel larvae were preserved in 96% ethanol onbord the Scottish RV "Scotia" in the period 9.-12. May 1989 and onbord the RV "Tridens" from the Netherlands on the 7. June 1989. The sampled larvae ranged from 3.6 mm to 11.6 mm in standard length and from 0.019 to 2.263 mg in dry weight. None of the measurements have been converted to live length or weight. The area of sampling for both ships are given in Fig. 1. The plankton sampler used was a modified Gulf III. In areas without thermocline the sampler was towed in oblique hauls from 200m to the surface. Otherwise the sampler was towed from 20 m below the thermocline to the surface (Anon. 1985). The temperature in the sampling area was approximately 12.5 °C during the May cruise and approximately 14.0 °C during the June cruise.

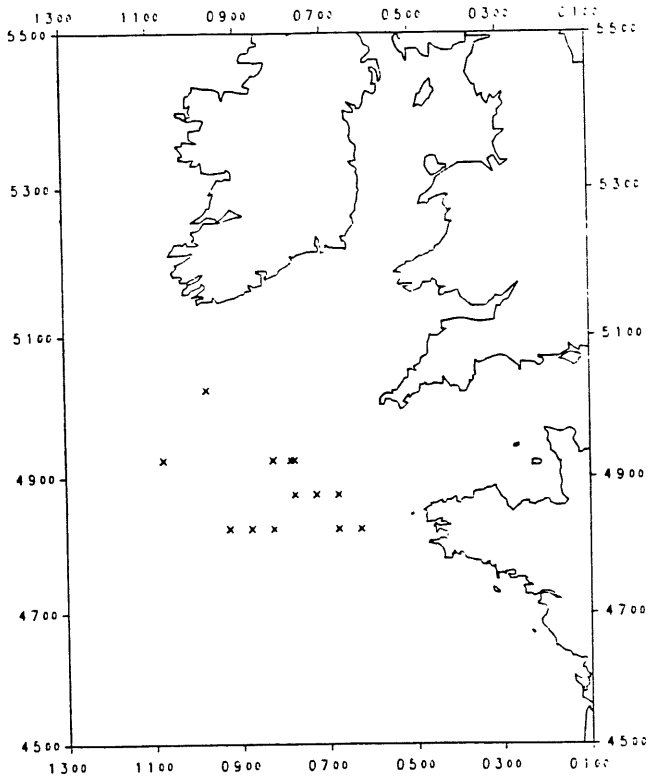

Figure 1. The sampling area of the studied mackerel larvae.

At the Flødevigen Marine Research Station, otoliths from 101 mackerel larvae caught in the western area were dissected, mounted on glass slides, daily increments read and growth rate backcalculated (Moksness and Wespestad, 1989). Five days was added to the estimated age in days to compensate for the yolk sac period, which is two more days compared to the end of yolk-sac stage of Pacific mackerel at 19 °C (Hunter and Kimbrell, 1980). To backcalculate the spawning date of the sampled larvae, respectively 6 and 5 days was added to the estimated age of the larvae, using the formulae for the egg development rate (Lockwood et al., 1981) at average temperature of 12.5 and 14.0 °C:

Ln (h) = -1.76 Ln (T) + 9.38; where h = hours and T = temperature in °C.

Specific growth rate, SGR, (Houde and Schekter, 1981) was calculated according to the formulae:

SGR = (exp((Ln W_{t2} - Ln W_{t1}) / (t_2-t_1))-1)*100, where W_{t1} and W_{t2} are the dry weight of the fish at day t_1 and t_2.

RESULTS AND DISCUSSION

Microstructure

The sagittae in mackerel is known to be small compared to the size of herring and cod of same age. The average increment size with standard deviation is given in Figure 2. The number of increments counted ranged from 2 to 31. The initial increment size was less then 1 µm, which is a similar size as observed for autumn spawned North Sea herring. The maximum number of increments counted in the otoliths were 31, which is approximately the double of the number of increments counted by Kendall and Gordon (1981) in same size mackerel larvae (15 increment in a 13.7 mm mackerel larvae) in the western Atlantic. There is two possible explanations for this difference. The counting might include subdaily increments and mackerel in the western Atlantic might have a much higher growth and thereby wider increment size. The mean distance from the nucleus to the hatch check was 9.8 µm (Standard deviation = 0.6) which is 1.6 µm longer than measured in the otoliths of western Atlantic mackerel (D´Amours et al., 1990).

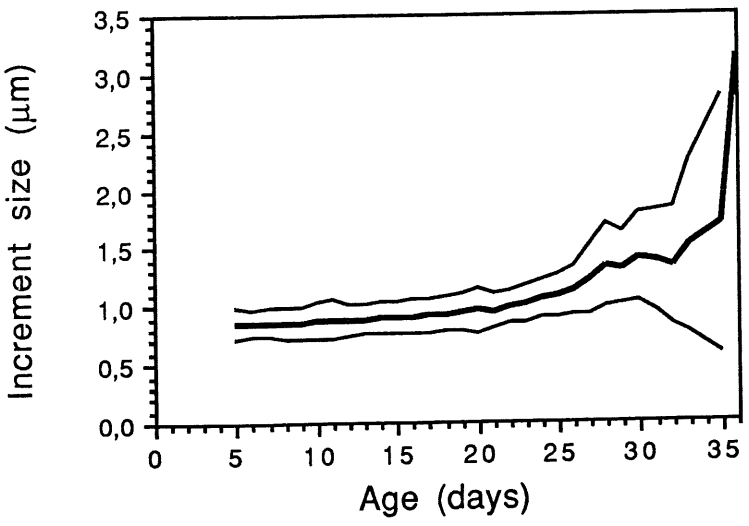

Figure 2. The observed average increment size (µm) with standard deviation from the otoliths of the mackerel larvae.

To backcalculate the growth rate, both in length and dry weight, a relationship between length/dry weight and otolith radius has to be established. These relationships based on the collected material (3.6 - 11.6 mm larvae) are given in the figure 3 and 4, respectively. As shown in Figure 3, there is a linear relationship between the standard length of the larvae and the radius of the otoliths. A similar relationship is given when using the total length instead of the standard length. The relationship between dry weight and otolith radius (Figure 4) is exponential. The equations for standard length and dry weight were later used in the estimation of daily growth rate.

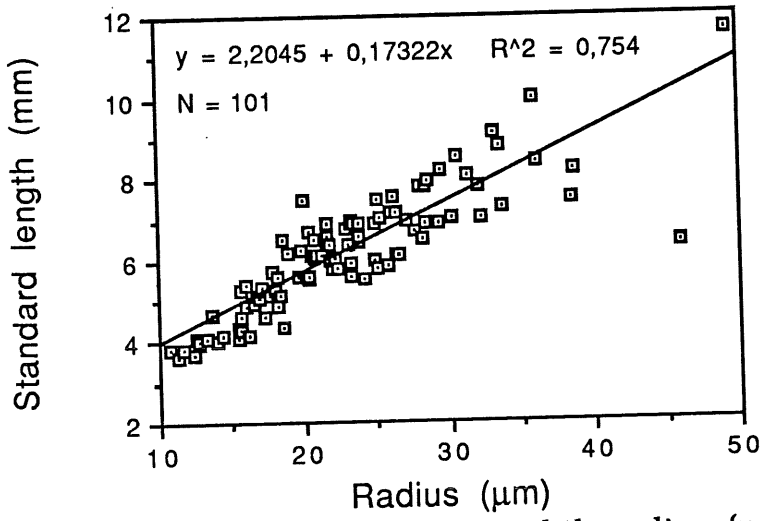

Figure 3. The relationship between otolith radius (µm) and the standard length (mm) of the mackerel larvae. When using total length, the relationship is: y=1.9292 + 0.19437x, r^2=0.768.

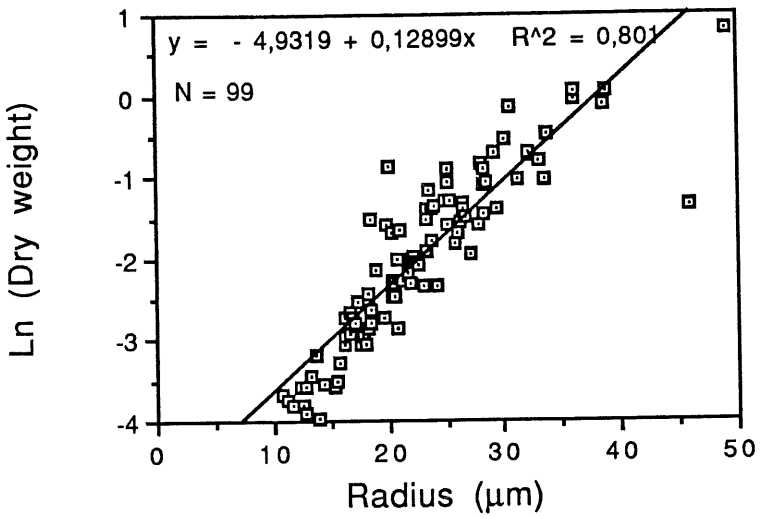

Figure 4. The relationship between otolith radius (µm) and the dry weight (mg) of the mackerel larvae.

Growth rate

The average dry weight and specific growth rate is shown in Figure 5. The average dry weight had an exponentially pattern from 0.019 mg at hatching to 2.263 mg at age 35 days. The initial specific growth rate was 12 $\%d^{-1}$, which is rather high compared to growth rate other important commercial species like herring (4-8 $\%d^{-1}$; Moksness, unpubl. data) and cod (2-5 $\%d^{-1}$; Moksness, unpubl. data). From age 20 days and onwards, the specific growth rate increased and was calculated as high as 35 $\%d^{-1}$ at age 31 days. In Table 1 an overview of reported specific growth rates for mackerel is given. An average specific growth rate was calculated at 14.6$\%d^{-1}$ for the first 35 days after hatching. In a recent study, D´Amours et al. (1990) fitted a Gompertz curve to length at age data and estimated that at an age of approximately 38 days from hatching, the mackerel will have its maximum growth rate. The growth rate pattern of the early larvae in their study, as in the study by Ware and Lambert (1985), was much higher compared to the observations in the present study. However, in a laboratory experiment with mackerel larvae of known age, similar growth rates as in the present study, have been observed by Buckley et al. (1987).

Table 1. Comparation of specific growth rate (% d^{-1}) during the early life history of mackerel larvae.

SGR (% d^{-1})	Temperature (°C)	Age range (days)	Reference
40.0	15.0-15.7	0-11	Ware and Lambert (1985)[a]
45.0	14.5-16.1	0-8	Ware and Lambert (1985)[b]
55.3	16.4-18.7	0-7	Ware and Lambert (1985)[c]
10.4-17.7	15.0	3-24	Buckley et al. (1987)
12.0	12.0-14.0	0-20	This study
19.7	12.0-14.0	20-35	This study

a: Calculated from their Table A2
b: Calculated from their Table A4
c: Calculated from their Table A3

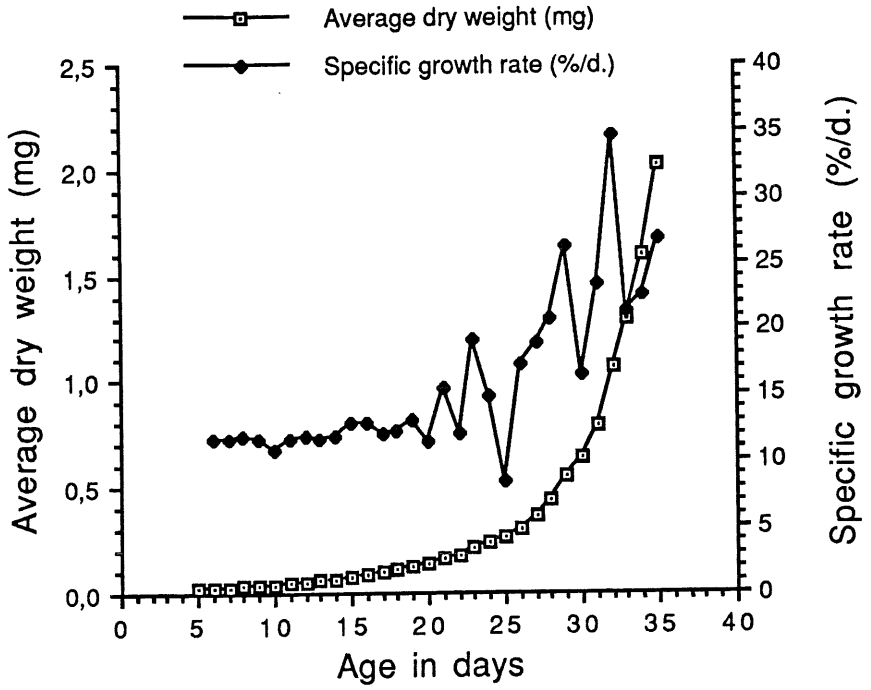

Figure 5. The backcalculated average dry weight (mg) and specific growth rate (% d^{-1}) of all the mackerel larvae (N = 101).

Initial the mackerel larvae had length increments of 0.16 mm d^{-1}, exceeding 0.20 mm d^{-1} at age 28 days. The overall average length increment was 0.19 mm d^{-1} for the first 35 days. This backcalculated growth rate is far below that backcalculated for western Atlantic mackerel (Kendall and Gordon, 1981; D'Amours et al., 1990). They calculated the growth rate to be in the range from 0.75 to 1.38 mm d^{-1} the first 20 days from hatching, increasing to 2.1 - 2.5 mm d^{-1} the next 15 days (see Table 2). However, similar growth rates as found in the present study have been reported from laboratory experiments both with western Atlantic mackerel (Buckley et al., 1987; Migoya, 1989) and Pacific mackerel

(Hunter and Kimbrell, 1980). The lower temperature in the study area indicates a lower growth rate of the Celtic Sea mackerel. Calculations based on data in Sette (1943), the growth rate of eastern Atlantic mackerel is 0.2 mm d^{-1} the first 20 days, increasing to 0.33 mm d^{-1} the next 15 days, which is similar to the calculated values in this study (see Table 2).

Table 2. Comparation of growth rates in length (mm d^{-1}) during the early life history of mackerel larvae.

Growth rate (mm d^{-1})	Temperature (°C)	Age range (days)	Size range (mm)	Reference
0.16	12.0-14.0	5-20	3-6	This study
0.20		0-20		Sette (1943)
0.16	16.8	1-6		Hunter and Kimbrell (1980)[a]
0.57	16.8	1-25		Hunter and Kimbrell (1980)[a]
0.75	~ 20	0-20		Kendall and Gordon (1981)[b]
0.15-0.31	15.0	3-24		Buckley et al. (1987)
0.53-0.62	15.3-16.7		3-6	Ware and Lambert (1985)
0.63-0.81	15.5-17.8		6-8	Ware and Lambert (1985)
1.02-1.38		10-20		D´Amours et al. (1990)
2.07-2.30		20-30		D´Amours et al. (1990)
2.69-2.79		30-40		D´Amours et al. (1990)
0.24	12.0-14.0	20-35	6-12	This study
0.33		20-35		Sette (1943)[c]
2.10	~ 20	20-35		Kendall and Gordon (1981)[b]
0.73	15-17		3-15	Ware and Lambert (1985)

a: Calculated from their Table 1
b: Calculated from their Figure 2
c: Calculated form his Figure 8

Spawning and hatching dates

The estimated hatching and spawning time of the sampled mackerel larvae are given Table 3. The table shows that the average hatching date for the sampled mackerel larvae in May were estimated to 16. April 1989, and the average spawning date was calculated to 10. April 1989. For the larvae sampled in June the average hatching date were estimated to 21. May 1989, and the average spawning date was calculated to 16. May 1989. The Gulf III is probably not sampling the larger mackerel larvae as well as the smaller ones. Therefore the hatching data presented in Table 3 is probably not quit real, but is given here as an example of the possibilities of microstructure studies. The spawning time given in Table 3 are based upon the hatching time given in Table 3 and an average temperature of 12.5 °C (May cruise) and 14.0 °C (June cruise) during incubation of the eggs. In addition to the source of error caused by the temperature, this curve has the same bias as the hatching curve.

Table 3. Estimated mean hatching and spawning date of the mackerel larvae caught during the May and June 1989 cruises.

Sampling date	Mean Hatching date	Mean Spawning date	Standard deviation (days)	Number
9.-10. May	16. April	10. April	6	38
7. June	21. May	16. May	6	63

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