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"GROWTH PATTERNS IN OTOLITHS AS AN INDICATION OF DAILY GROWTH
VARIATIONS OF LARVAL HERRING (CLUPEA HARENGUS) FROM AN EXPERI-
MENTAL ECOSYSTEM"

by

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ABSTRACT

Larval herring were released in a large outdoor basin four days after hatching and the mean growth in length and weight of the herring larvae and fry was monitored for 100 days. The food supply was estimated from weekly sampling of zooplankton. At termination of the experiment herring fry were collected and the width of the daily growth zones were measured in the otoliths of some of the herring fry. The mean zone width on a day to day basis mimiced the mean larval growth rate. As the variation in food supply determined the growth rate, there was also a close relation between mean zone width and the food supply. A method for measuring the zone widths by means of a digitizing board is described.

INTRODUCTION

Primary growth zones, which are found in the otoliths of a variety of fish species, are in many cases shown to be formed daily. If there exists a relationship between growth of the fish and its otoliths, then the width of these daily growth zones should reflect the growth of the fish on a day to day basis.

Analysing the growth pattern of the otoliths would then be a useful method of studying the growth characteristics of individual fish and populations.

Some workers have used the method of reading daily growth zones in ageing some larval fish, e.g. Barkman (1978), Brothers, Mathews and Lasker (1976), Lough et al. (1980), Methot (1979), Radtke (1980), Radtke and Waiwood (1980) and Taubert and Coble (1977).

In this paper the daily growth zone method has been applied to describe the growth of herring larvae from an enclosure experiment, where food supply and growth rate of the herring was known, and has earlier been described by Øiestad and Moksness (1979).

MATERIALS AND METHODS

Eggs of Norwegian spring spawning herring were incubated in the laboratory at Statens Biologiske Stasjon Flødevigen at 5 March 1979. Hatching occurred at 4 April. The larvae were released in a large outdoor basin four days later. The experiment was terminated at July 12-13, when the larvae were 99-100 days old, calculated from the day of 50% hatching.

Samples of the zooplankton in the basin were taken at weekly intervals and samples of herring larvae two times per week to start of schooling and later weekly. The growth of the herring larvae and fry has been indicated both as specific growth rate (SGR) based on larval dry weight and as daily length increment (DLI).

The feeding conditions are expressed both as number of organisms

per litre and as cal per litre.

At termination of the experiment a sample of herring larvae was frozen and brought to the Institute of Fishery Biology at the University of Bergen for examination of the otoliths.

From this sample a subsample containing 20 larvae was later on taken and treated as follows:

The standard length was measured to the nearest mm below and the two sagittae were removed. They were positioned on glass slides, one with convex, the other with concave side up, in a drop of syntetic mounting medium Protexx. They were left to dry for about 24 hours, and then inspected in a compound microscope. In the smallest otoliths laying concave side up, the primary growth zones were discernable without further treatment. The others were grinded using 800 grit silicon carbide paper immersed in water in a large petri dish. The otoliths were frequently inspected in the microscope, and the grinding process was terminated as the zones became visible from center to edge. The otoliths were then photographed on a 400 ASA black & white film, using photographic equipment attached to the microscope. The magnification used was 100 to 250 X. After developing the film, the negatives were mounted in slide frames and projected on a digitizing board with a slide projector installed in a vertical position above the table. To ensure that the zone width should be comparable, an identical radius was photographed for all otoliths, viz. the radius to the dorsal edge perpendicular to the radius through rostrum. A white sheet of paper was positioned on the digitizing board, a straight line representing the radius along which the measurement was to be done. The zones along this radius were then digitized by means of a cursor moved along the line pushing a button for each zone, thus making the coordinates of each point to be stored in a computer. The measurement of the board was scaled to real size by comparing the length of the whole radius measured on the board with measurements of the same radius in the microscope. The width of the zones were then computed and the data obtained as zone number and zone width in micrometer.

RESULTS

Food supply and growth respons. The amount of food organisms expressed as number per litre, increased to day 50 when a sudden collapse in the population of holopelagic zooplankton populations took place, Fig.1. The number of cal per litre continued, however, to increase beyond day 50 due to an inclusion of semipelagic food organisms in the diet, mainly juvenil amphipods, but these semipelagic organisms were far less available than the holopelagic organisms as food for the herring fry.

The specific growth rate increased with increasing food supply and decreased at the time of collapse in the holopelagic zooplankton populations, Fig.2. The daily length increment increased also with increasing food supply, but did not decrease at the time of collapse in the holopelagic zooplankton. However, when also the semipelagic zooplankton was heavily reduced from day 70 the DLI decreased sharply.

Zone width. Although the zones could be counted in one or both otoliths from the majority of larvae, only otoliths from ten specimens were used in the measuring of zone widths. Only those otoliths considered to have the highest quality were used. The reason for this truncation of data was that in some otolith pictures it was impossible to see all the zones along the particular chosen radius. This was partially caused by some otoliths laying with their grinded surface (or the plane where the zones best could be seen) at an angle to the microscope slide. As the focusing depth of the microscope is limited, it was sometimes impossible to get a sharp image of the entire radius on one photo.

The width of each zone averaged over the ten specimens is plotted against age in Fig.3. The standard deviation is given for every 5. day.

It has been shown earlier (Gjørseter, 1981) that the first zone for this group was laid down in the otoliths when the larvae were about 4-5 days old or at first feeding opportunity. The first zone is in this study assumed to correspond to a larval age of five days. This gives a mean age of the ten larvae of 97 days,

which is fairly close to the real age of 99 days for the sample. This mean age has a standard deviation of 3.4 days.

The mean zone width increases from about 3 μm near the nucleus to a peak of 7-8 μm on day 40 - 50 (Fig.3). Then the zone width decreases during the next 15 days to 4 μm , whereafter there is a further slight decrease to 3 μm until termination of the experiment.

DISCUSSION

Two assumptions underlie the interpretation of the zone width as a measure of fish growth. The first is that the zones are deposited on the otolith with a regular periodicity. If the zone width is used in backcalculation of fish growth, this periodicity must be known. Secondly, a functional relationship between fish size and otolith size must exist and be known.

Using herring larvae from this and other basin experiments in Flødevigen it has been shown that the primary growth zones are laid down with a daily periodicity for at least 135 days (Gjørøster, 1981). As to the second assumption the data are somewhat sparse, but they indicate a linear relationship between the measured otolith radius and the fish length.

This implies that there is a direct proportionality between growth zone width and fish growth in length of herring larvae up to about 50 mm SL.

The reduction in width started at about the same time as the reduction in SGR, and the width made a new decline when also the DLI went down.

A comparison of the variations of zooplankton (Fig.1) and mean zone width (Fig.3) with age reveals a high degree of covariation.

Thus we have obtained two independent measures of the mean growth rate of the herring larvae and fry: the SGR and DLI as calculated from frequent sampling of the population, which is a direct method of measuring growth, and the otolith zone width, as measured in the otoliths from the larvae alive at termination of the experiment.

The last method being indirect is seemingly able to detect the variations in mean growth rate with time. This variation is determined by the amount of available food. This method can also be used to demonstrate individual growth variations, and from an ecological point of view the individual growth of a larva is of great interest.

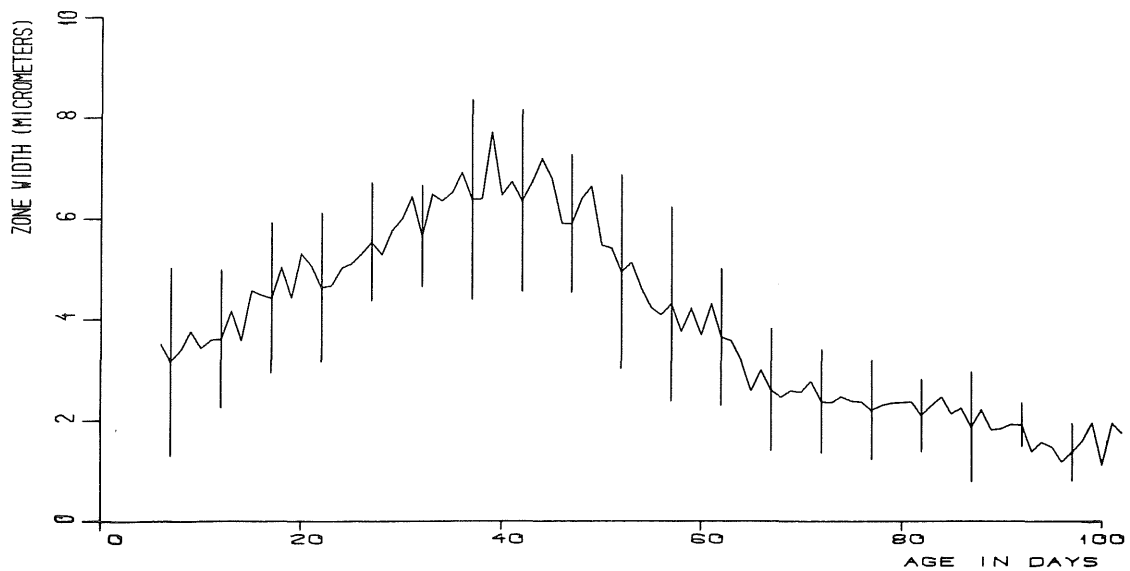
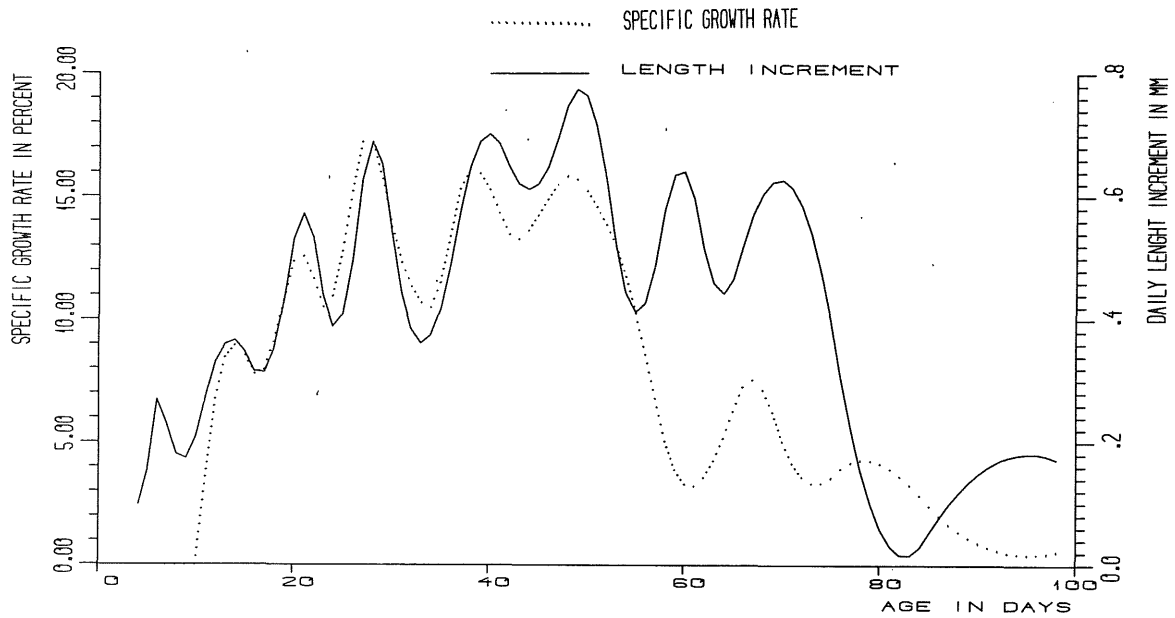
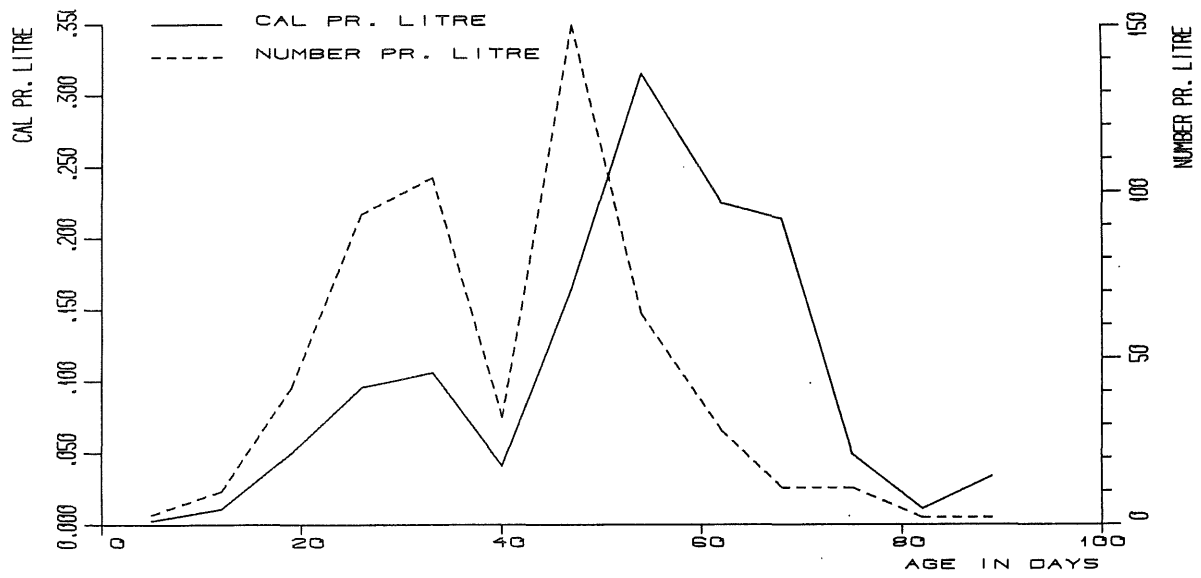
CONCLUSION

If a functional relationship between a measure of otolith size and fish size can be established, the measuring of daily growth zone width can be used to backcalculate the growth of individual larvae from first feeding to the time of sampling, and should therefore be of great applicability in studies on larval biology and ecology.

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Figs. 1, 2 and 3. Number of potential food organisms per litre for herring larvae and fry, and cal per litre of suitable food organisms (1); specific growth rate and daily length increment of the herring larvae and fry (2); and zone width of the daily growth zone in the otoliths with standard deviation for every five day indicated (vertical bars) (3).



Fig.4. A section of a otolith from a 100 days old herring fry, which illustrates different width of the growth zones.

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