Temperature-dependent otolith growth responses in cod larvae – pitfalls and potentials

Arild Folkvord
Department of Biology, University of Bergen
5020 Bergen, Norway



Cod larvae at 0, 24 & 42 dph (at 8°C).

Photos by E. Otterlei

Introduction

Construction of valid hatch-date distributions and growth curves depend on accurate ageing (Panfili *et al.* 2002). Recent laboratory experiments with larval Atlantic cod (*Gadus morhua*) indicate that somatic (and otolith) growth may be very low at temperatures below 6°C, and that the rate of apparent otolith increment formation using light microscopy is significantly below one per day (Otterlei *et al.* 2002). Validation of increment deposition rate is typically not undertaken at a wide range of ambient temperatures and larval feeding conditions. This may result in incorrect growth and hatch-date estimations from field studies when individuals from different time periods and regions are assumed to exhibit the same apparent increment deposition rate using routine otolith microstructure analysis. Here I include an example from a field study on Atlantic cod where alternative conclusions can be reached when incorporating temperature-dependent increment deposition rates.

Materials and methods

Models were generated based on data from controlled laboratory rearings with Norwegian coastal cod in the temperature range of 4-14°C. The larvae were fed in excess with live natural zooplankton, and reared under a light regime simulated for 60°N. Larval cod were sampled weekly from replicate tanks until day 56. The lapilli were extracted, mounted and measured from the centre of the core along the longest radius (Figure 1, Otterlei *et al.* 2002). Increments narrower than 0.8 µm could neither reliably be measured nor counted using routine light microscopy analysis. Using 0.8 µm as the smallest increment width, the number of unaccounted (or missing) increments from the lab study was simulated by assuming increment widths of 0.8 µm in the area of daily otolith growth less than 0.8 µm and subtracting the estimated increment number from the actual larval age.

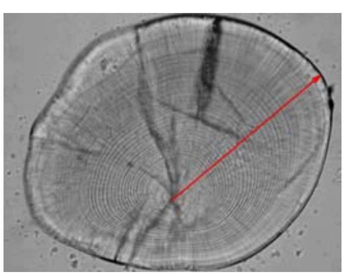

Figure 1. Lapillus from a 56 day old cod larvae reared at 14°C. Arrow depicts radius measured in this study.

Results

The growth data revealed strongly temperature-dependent otolith growth. An age-dependent otolith growth model was estimated as : ln Radius = 2.58 + 0.0059*Temp*Age + (0.00020 - 0.000042*Temp)*Age^2 with R^2 = 0.953, n = 1112 (Figure 2). The daily otolith growth (presumed increment width) was estimated by differentiation of the model above (Figure 3).

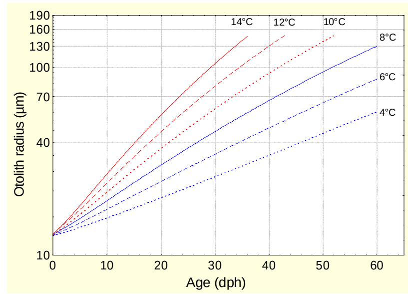

Figure 2. Temperature-dependent otolith size-at-age in larval cod (note log scale on y-axis).

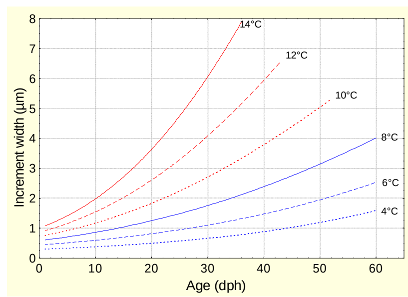

Figure 3. Temperature- and age-dependent daily otolith growth (increment width) in larval cod. Obtained by differentiation of the equation used in Figure 2.

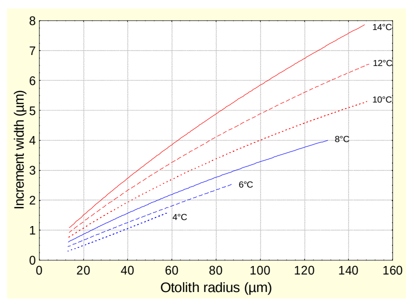

Figure 4. Temperature- and otolith size-dependent daily otolith growth (increment width) in larval cod.

An otolith size-based model was developed using the output of the age-based model and was parameter-ized as: Increment width = 0.0054*Temp*Radius - 0.000012*Temp*Radius^2, with R^2 = 0.993, n = 311 (Figure 4). From Figure 3 & 4 it can be seen that the daily otolith growth (and thus an eventual daily increment width) will be below the practical resolution limit in a routine light microscopy otolith microstructure analysis. The estimated number of unaccounted (or missing) increments increased sharply with decreasing temperature below 6-8°C (Figure 5), contrasting the validation of daily increment deposition at low temperatures reported by Suthers & Sundby (1983).

Daily ambient temperatures, estimated average hatch-dates and ages of cod larvae and juveniles were available from a field study off Iceland (Begg & Marteinsdottir, 2000). The daily otolith growth was estimated using the temperature and otolith size-dependent relation from Figure 4 and using 12.5 µm as initial lapillus radius at hatching and the daily temperatures at inputs. The average number of unaccounted (or missing) increments using the approach above was 3.6 and 16.7 for the Southern and Northern regions (Figure 6). A systematic regional bias in the hatch date estimations may therefore have occurred due to temperature-dependent otolith growth. In addition, significant correlations were found

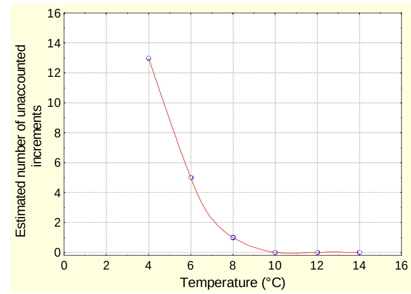

Figure 5. Estimated number of unaccounted (or missing) increments based on modelled temperature-dependent otolith growth and a minimum increment width of 0.8 µm.

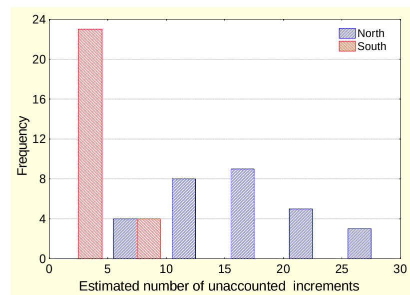

Figure 6. Frequency of estimated number of unaccounted (or missing) increments in aged cod larvae from Northern and Southern regions off Iceland in years 1970-1998 (based on data from Begg & Marteinsdottir, 2000). One average value per year and region.

within regions between average estimated yearly hatch-date and average estimated number of unaccounted (or missing) increments the corresponding year (r < -0.38, P<0.05). This may have a significant impact on the interpretation of spawning dynamics and stock structure in the area.

Summary and conclusions

A temperature and size-dependent otolith growth model of cod larvae (*Gadus morhua*) derived from controlled laboratory studies is used to evaluate estimated age and hatch-date distributions of cod populations from the field. Slow initial otolith growth, especially at temperatures below 6°C, is expected to lead to underestimation of actual age with a subsequent overestimation of growth and erroneously delayed hatch-date estimates. A temperature-dependent correction of initial increment numbers is suggested, and stringent validations covering the whole range of common ambient temperatures are strongly recommended.

References

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