Journal of Plankton Research Vol.19 no.1 pp.167–169, 1997

LETTER TO THE EDITOR

Relationships between otolith and somatic growth of cod larvae (*Gadus morhua*)

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Growth increments within otoliths are often used to estimate the age of larval fishes. When the sizes of larvae are known, this information may be used to calculate the growth rates of populations (Campana and Nielson, 1985). If a strong relationship exists between somatic growth and otolith growth, then growth histories may be reconstructed on an individual basis (Campana and Jones, 1992).

In a recent contribution to the *Journal of Plankton Research*, Geffen (1995) examined the relationships between increment formation, age, otolith growth and somatic growth in cod larvae until 40 days after hatching in experimental tanks. She found that counts of increments deposited within sagittae and lapillae provided a good estimate of the true age (in days) of cod larvae throughout this period. However, the relationship between somatic and otolith growth was complex. One important finding was that, within 15 days of hatching, otolith growth and a measure of somatic growth of larvae were poorly correlated. For larvae older than 15 days after hatching, otolith growth provided a good estimate of somatic growth. Owing to this variable relationship between otolith and somatic growth rates, Geffen concluded that for cod larvae in the weeks immediately following hatching, it would be 'unlikely that backcalculation of individual growth or inferences about size-selective processes will be very accurate'.

This result will be disappointing to those workers hoping to use otoliths to examine the factors influencing year-class variability in Atlantic cod, particularly since events occurring during the weeks immediately following hatching may be an important determinant of year-class size (Bradford, 1992; Meekan and Fortier, 1996). However, the results obtained by Geffen (1995) may have been influenced by the methods used to analyze the data sets. Below, I offer some alternative interpretations of the results.

Somatic and otolith growth

In Figure 10, Geffen compared the overall otolith growth rate of the sagittae (the distance from a fluorescent mark incorporated into the otolith at hatching to the outer edge of the otolith) and larval growth rate calculated from the equation [(larval length at sampling date – 2.7 mm hatching length)/age]. From this analysis, she concluded that the sagittal growth rate was poorly correlated with the somatic growth of larvae younger than 15 days, but became strongly correlated with growth rate once larvae attained older ages.

The use of a mean to calculate somatic growth rates has some important implications. If the range of sizes at hatching of larvae is large, then the use of the difference between total size and mean hatching size will introduce an error of unknown magnitude into the calculation of overall growth rates. When the range of hatch size is large and the total size of the larvae is small, this error will be large. In a recent study of relationships between size at hatching and egg size of cod larvae from the Scotian Shelf, Miller *et al.* (1995) found that size at hatching of larvae varied by up to 275% during a single season. While this may represent an extreme case, since larvae were collected over a range of temperatures and from numerous females, the study of Miller *et al.* illustrates the point that size at hatching of cod larvae can be very variable.

In this analysis, the use of mean size at hatching to calculate growth rates may provide a simple explanation as to why growth of the sagittae might appear to be unrelated to the measure of larval growth at small larval sizes. Furthermore, as the error introduced by the use of mean size at hatching in calculations will decline as the size of the larvae increases, this could explain why there was a sudden change in the strength of the relationship between sagittal and somatic growth of older larvae.

Size selection

Geffen suggests that changes in the mean diameter of the 'hatchcheck' [a broad band of material laid down at the time of hatching; see Bergstad (1984) and Dale (1984)] of larvae with age may provide a means whereby size- or growth-selective mortality may be detected in larval populations at the time of hatching. This assumes that there is a strong relationship between larval size and otolith growth. Although the idea behind this approach is valid, size- or growth-dependent mortality will be difficult to demonstrate by comparing mean values, since these measures will change only very slowly in response to selective mortality (Mosegaard, 1990). In Figure 11, Geffen shows population means of hatchcheck and fluorescent mark diameters versus age of larvae up to 15 days after hatching. While she notes that these means were not 'significantly different', a consistent trend of increasing size of hatchcheck with age is evident. Given the conservative nature of the population mean, this implies that some size- or growth-dependent mortality occurred during the experiment. An appropriate method to analyze the data sets to investigate this phenomenon would be to construct frequency distributions of hatchcheck size of the oldest fish in the experiment and to compare these with frequency distributions of hatchchecks of fish at the start of the experiment using Kolmogorov–Smirnov tests. This comparison will show whether the frequency distributions of hatchmarks of older fish are skewed towards larger sizes, which would indicate size- and/or growth-dependent mortality favoring larger individuals at hatching. A good example of such an approach in the study of selective mortality of larval fish is given by Rice *et al.* (1993).

In summary, Geffen provides some valuable information on the correspondence between the rates of deposition of increments and their relationship to the true age of cod larvae. However, the conclusion that otolith analysis does not provide an accurate measure of individual growth of young larvae may have been influenced by the analyses used to compare otolith and somatic growth. The demonstration of selective mortality will require an individual, rather than a population-based, approach to the analysis of data sets. This is AIMS publication 854.

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