Comparison of size-at-age of larval cod (*Gadus morhua* L.) from different populations based on size- and temperature-dependent growth models

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Background

Previously developed age-based growth models for cod larvae that are appropriate for constant temperature conditions, e.g. (Campana and Hurley 1989; Otterlei *et al.* 1999), lack the flexibility needed when comparing size-at-age of offspring from variable temperature conditions. The purpose of this study is therefore to provide general size-based growth models for larval and early juvenile cod that incorporates temperature and size as input variables so that comparisons can be made across different experimental scales, environments and regions. The model outputs can then be compared against growth estimates from the field obtained through otolith microstructure analysis. To my knowledge this is the first attempt to evaluate the growth performance of surviving fish larvae from several field locations and environments relative to their size- and temperature-dependent growth potential. Based on the importance of size-dependent predation mortality in marine fish larvae, e.g. (Bailey and Houde 1989), it is hypothesized that surviving cod larvae are generally characterized by relatively high growth rates.

Materials and methods

Size and temperature dependent growth (STDG) models for Norwegian coastal cod and Northeast Arctic cod were made based on growth data obtained from temperature constant experiments in the lab (Figure 1, Otterlei et al. 1999). Model outputs were contrasted against other studies from the lab, mesocosm (not shown here), and field. Growth performance was calculated as the ratio of average observed growth rate versus the average predicted growth rate.

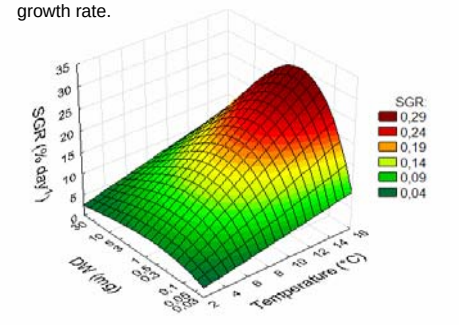

*Figure 1. Plot of STGD model for Norwegian coastal cod: SGR = 1.20 + 1.80*Temp – 0.078*Temp*Ln DW – 0.0946*Temp*(Ln DW)^2 + 0.0105*Temp*(Ln DW)^3*

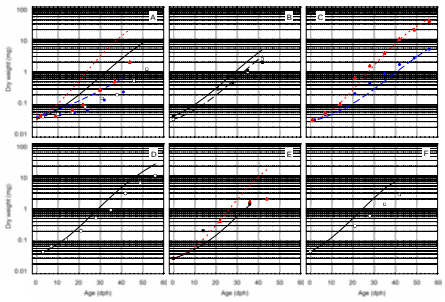

Figure 2. Observed (points) and estimated (lines) sizes-at-ages from different laboratory studies. A) Laurence 1978, B) Laurence et al. 1981 (solid line) and Buckley et al. 1993 (dashed line), C) Otterlei et al. 1999 (10°C dotted line and 6°C dashed line), D) Folkvord et al. 1999, E) Baskerville-Bridges & Kling 2000 (dotted line Exp. I, and solid line Exp II), and F) Puvanendran & Brown 2002.

Results

The STDG model is based on some of the best performing lab groups in the literature, i.e. the predicted size-at-age is generally higher than the observed size-at-age (Figure 2). At the same time the observed size-at-age from field studies is higher than predicted, i.e. the surviving larvae are growing better than predicted (Figure 3). The lab data from (Laurence 1978), which have been used in several modeling studies, obtained less than 70% of the average daily growth rate of the better performing groups (Figure 4). Higher growth ratios are seen in the enclosure data series which generally confirm the high growth rates experienced in these systems (Figure 4). Summarizing the results from the field investigations it becomes clear that the surviving larvae in general have been growing at rates close to their maximum rates (Figure 4). The only exception to the rule seems to be the output from the Campana & Hurley model, which clearly predicts a lower average growth than the original data by (Bolz and Lough 1988). The two instances of very high growth rates in the field are both based on data from cold water environments.

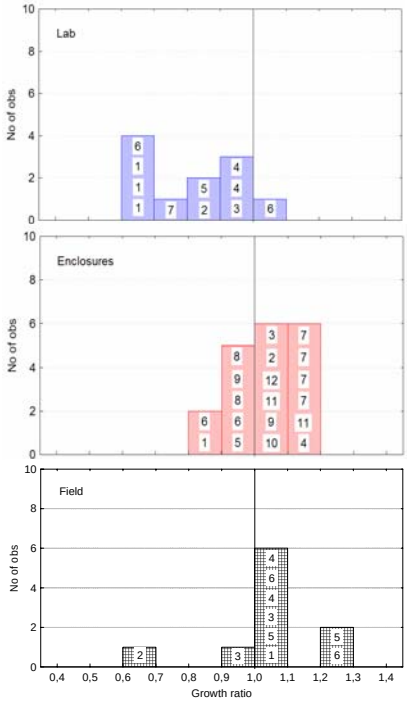

Figure 4. Growth ratios from lab (upper), enclosure (middle) and field (lower) studies. Vertical line at 1.0 refers to ratio where observed average growth rate equals predicted average growth rate. Numbers in bars refer to respective studies

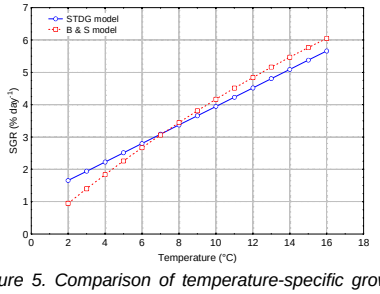

Figure 5. Comparison of temperature-specific growth predictions for Northeast Arctic cod of 450 mg DW using the STDG model and model presented by Björnsson and Steinarsson (2000) (B & S model).

The model growth prediction at the outer size range of the model are also seem robust and are in accordance with other model predictions (Figure 5).

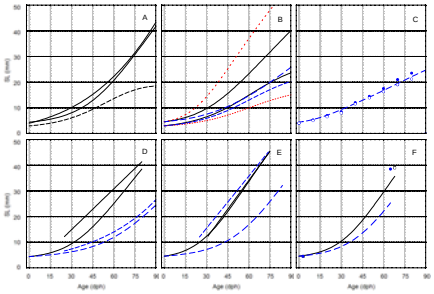

Figure 3. Observed and predicted size-at-age. Thicker lines indicate own model predictions and regular thickness are original predictions from respective paper. A) Bolz and Lough 1988 (solid line) and Campana & Hurley 1989 (dashed line), B) Campana & Hurley 1989 (dotted 9°C, solid 6°C and dashed 4 °C), C) Meekan & Fortier 1996 (filled symbol from warmer 1992/93 and open symbol for colder 1991/92 season), D) Suthers & Sundby 1996 (solid line from Norwegian coast, dashed line from Canadian coast), E) Begg & Marteinsdottir 2000 (solid line from southern Iceland, dashed line from northern Iceland), and F) Anderson & Dalley 2000 (solid line from warmer 1996 and dashed line from colder 1997 season).

Conclusions

This study presents the first intra-specific evaluation of larval growth performance across several different experimental scales, environments and regions of a marine fish species. Comparisons with results from other laboratory experiments reveal that the model predictions represent relatively high growth rates. Results from enclosure experiments under controlled semi-natural conditions generally provide similar growth rates as predicted from the models. The models are therefore considered suitable as reference growth relations which field based growth estimates can be compared against. These comparisons generally confirm that surviving cod larvae in the field typically grow at rates close to their size- and temperature-dependent capacity. This suggests that climatic influence will strongly affect the year-to-year variations in growth of cod during their early life history due to their markedly temperature-dependent growth potential.

References

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- (and many more….)

Acknowledgements

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