

TO LARVAE AND BEYOND:

GROWTH AND METABOLISM IN DEVELOPING FISHES

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EXTENDED ABSTRACT ONLY – DO NOT CITE

Introduction

Growth is energetically costly. For fish embryos and larvae which have growth rates that often exceed 20-30% per day, costs of growth are expected to be high. In the relationship between mass (M) and metabolic rate (VO_2), (i.e. $VO_2=aM^b$), where a is the mass coefficient and b is the mass exponent, b usually ranges between 0.69-0.80 and mass scales allometrically with metabolic rate.

Conversely, in the relationship $VO_2/M = aM^b$ where VO_2/M is the metabolic intensity or mass-specific metabolic rate, metabolic intensity decreases with increasing mass or with growth and b is negative and approximately -0.2. In contrast with these well-known physiological relationships recent studies on fish embryos and larvae found that metabolic rates scaled isometrically with mass, (i.e. mass exponents ranged from $b = 1$ to $b > 1$), and that metabolic intensities were independent of mass and absolute growth rate (Giguere et al. 1988, Weiser and Medgyesy 1990a, Rombough 1994, Weiser 1994). The majority of these studies used freshwater species which have large eggs, well developed larvae with low mortality rates which develop rapidly to juveniles. Much fewer studies have used marine species that have much smaller eggs, less developed larvae high mortality rates (>90%) and develop slowly to juveniles. For this reason few studies has investigated the effect of development and growth on metabolic-mass relationships across all early life history stages in a marine species.

The present study investigated the metabolic-mass relationships from embryonic to juvenile stages in Atlantic cod (*Gadus morhua*) and tested the premise that metabolic – mass relationships scale isometrically in all three early life history stages.

Methods and Materials

For eggs and larvae, measurements of oxygen consumption were made using a four-channel closed-system semi-flow-through respirometric system equipped with pulsed polygraphic oxygen electrodes (Type 1125, Endeco Inc., MA) housed in 250 μ l Plexiglas chambers. After each respirometry experiment eggs and larvae were removed from the chambers and dried (n= 20-30 eggs, n=10 larvae, for each mass estimate). For juveniles respirometric systems consisted of three 2.8l transparent round plastic containers with equipped with a pulsed polygraphic oxygen electrodes. For all respirometric studies, metabolic rates and metabolic intensities were calculated from regressions of oxygen concentration over time for each electrode. For each larval respirometric run swimming activity was recorded using a video camera and images were analyzed using a digital analysis program to provide estimates of swimming speeds (Hunt von Herbing and Boutilier 1996). For juveniles, fish were allowed to swim freely in the chambers and rates were compared with speeds that approximated maximal activity rates (White 2000). Estimates of swimming activity provided data, which suggested that both larvae and juveniles were swimming at routine rates.

Results and Discussion.

Metabolic rate, like tissue mass, increased rapidly in an exponential pattern during the embryonic and larval periods. Metabolic rates continued to increase throughout development and after metamorphosis to the juvenile stage and mean metabolic rates were 2 fold greater in juveniles (e.g. $0.200 \pm 0.0056 \text{ mgO}_2 \text{ h}^{-1}$) than in larvae and embryos. Metabolic expansion (i.e. the rate at which metabolic rate increases with mass) appeared to vary as a function of stage. For embryos, larvae and juveniles metabolic expansion appeared to be to be allometric. In embryos the metabolic mass exponent was $b = 0.67$, but the relationship was weak ($p=0.046$) ($SE= 0.306$; $r^2_{\text{adj}}=0.22$, $n=15$). For larvae $b= 0.84$ ($SE= 0.65$, $r^2_{\text{adj}}=0.53$, $n=65$) and for juveniles $b= 0.86$ ($SE= 0.17$; $r^2_{\text{adj}} = 0.54$, $n = 21$) and b was significantly less than unity ($p<0.0001$).

Comparisons of metabolic mass exponents (b) among all stages, showed that significant differences in slope existed (ANCOVA, $p<0.0001$). Embryonic mass exponents were significantly different from both larval and juvenile exponents. However, metabolic mass exponents between larvae and juveniles were not significantly different. For metabolic intensity, when all three stages were analyzed separately, only embryos showed a significant negative relationship

($p < 0.05$) between metabolic intensity and mass ($r^2 = 0.602$, $SE = 0.636$). For larvae and juveniles, relationships between these two variables were not significantly different ($p > 0.05$) from zero. However when stages were combined, relationships between metabolic intensity and mass were significant ($p < 0.001$) for the combined embryonic-larval-juvenile periods ($b = -0.27$, $SE = 0.02$) and for the combined larval-juvenile periods ($b = -0.29$, $SE = 0.018$) and exponents were very close to those predicted by general physiological relationships (i.e. -0.2).

References

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