REDUCED GROWTH OF ATLANTIC COD (*GADUS MORHUA*)

IN CHRONIC HYPOXIA:

THE EFFECT OF VARYING MEAL FREQUENCY

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Introduction

In the Gulf of St. Lawrence, Atlantic cod frequently spend time in waters with low levels of dissolved oxygen (hypoxia). In a previous experiment (Chabot and Dutil 1999), we showed that growth rate of Atlantic cod declined when dissolved oxygen fell below 73% saturation. At 45% saturation, growth in length and mass was reduced by 35 and 56%, respectively, relative to growth in normoxic water. Hypoxia-induced reductions in growth rate were due to decreased ingestion rates. It is not clear if a post-prandial peak in oxygen consumption limits food intake in hypoxia, or if cod digest meals at a slower rate, and as a result reduce their food intake. If the former was true, cod should be able to increase food intake in hypoxia by taking more frequent, smaller meals. To verify this hypothesis, we compared growth in cod exposed to 3 different meal frequencies, in hypoxia and normoxia.

Methods

We varied meal frequency (1, 3, and 7 meals per week) for cod held at two regimes of dissolved oxygen (40 and 90% saturation). Two replicate tanks with 9 or 10 fish each were used for each combination of oxygen level and meal frequency. For each meal, cod were fed capelin ad lib for one hour. Temperature and salinity were held constant (10°C and 28‰). Fish were tagged to allow determination of individual growth rates in mass (g/d and specific growth, 100 x (ln(final mass) – ln(initial mass))/56 days), length (mm/d) and condition (Fulton K) at the end of the experiment. In addition, food consumption was measured for each tank.

Results and Discussion

In general, growth increased with feeding frequency in normoxia, but was little affected by feeding frequency in hypoxia (Figure 1). We noted marked differences between replicates at 3 meals per week, for both oxygen levels. The reasons for this are not clear, but could be related to small sample size in each

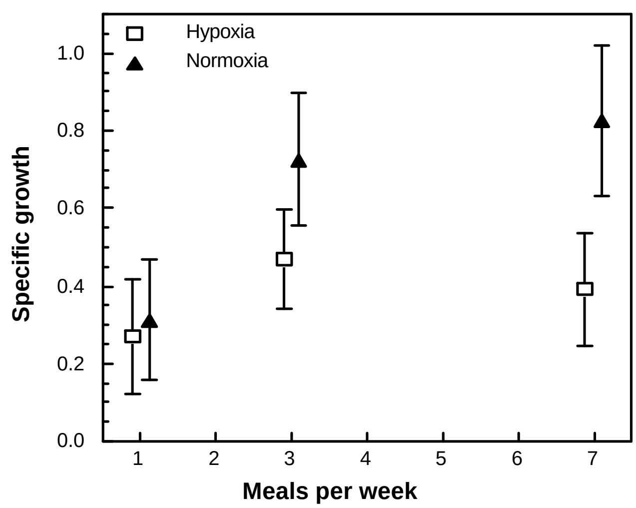

Figure 1.Growth rate of cod according to oxygen level and meal frequency (mean of fish in two tanks, with 95% CI).

tank, and to differences in initial size of fish between tanks, despite random allocation of the fish. However, a 2-way Anova with replicates as a nested factor showed that overall, replicates for each treatment did not differ significantly ($F_{[6,102]}$=1.03, p=0.4). Replicates were therefore pooled to increase the power of the Anova.

The interaction was significant ($F_{[2,108]}$=3.48, p=0.034), indicating that changes in meal frequency did not affect growth in the same manner for both oxygen levels. Multiple comparisons of means showed that in normoxia, growth was significantly reduced at 1 meal per week compared to 3 and 7 meals. In hypoxia, however, there was no difference in growth between the 3 feeding frequencies. At 1 meal per week, growth was equally poor at both oxygen levels. At 3 and 7 meals per week, growth was faster in normoxia than in hypoxia, although this was significant only at the highest feeding frequency. In our previous experiment (Chabot and Dutil 1999), growth was significantly greater in normoxia than at 45% oxygen saturation, at a feeding frequency of 3 meals per week. Possibly the larger range of fish sizes and the lower density of fish in each tank allowed aggressive interactions which increased variability in the present experiment.

The same conclusions were reached when growth in length and changes in condition were compared for the 2 levels of dissolved oxygen and the 3 meal frequencies.

As in Chabot & Dutil (1999), differences in growth between the different treatments were entirely mediated by differences in food ingestion (Figure 2), and a single relationship fitted all the data, irrelevant of whether reductions in food ingestion were caused by hypoxia or feeding frequency.

Furthermore, this relationship was almost identical to the one reported by Chabot and Dutil (1999). The slope was slightly but significantly lower in the latter (0.285 vs 0.347, $F_{[1,14]}$=8.02, p=0.013), but this difference disappears after removing the surprisingly low growth observed at 93% O_2 saturation in 1995. Excluding this point and pooling data from both experiments leads to the following relationship:

Growth rate (in g/d) = -1.398 + 0.338 · ingestion rate (in g/d), r^2 = 0.99

Assimilation efficiency varied between treatments, but was very highly correlated with food ingestion, and had little impact on growth rate compared with food ingestion.

It appears that hypoxia and low feeding frequencies result in lower food intake, which in turn reduces growth rate. Our results also suggest that cod digest food so slowly in hypoxia that growth rates are the same whether they have access to food 1, 3 or 7 times per week. Cod cannot reduce the negative impact of

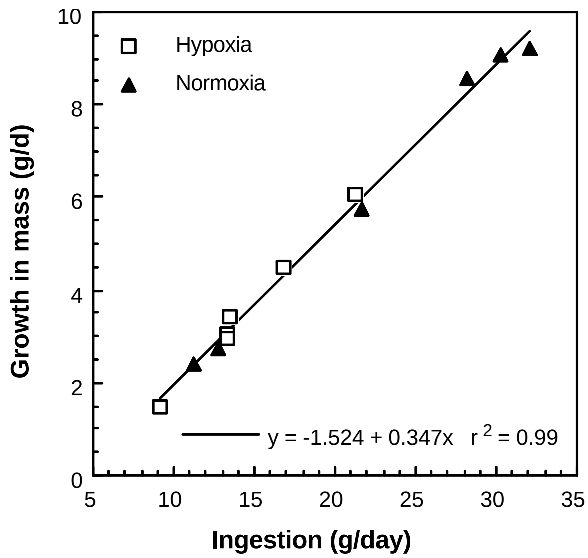

Figure 2.Relationship between growth and food ingestion.

hypoxia on growth by taking more frequent meals.

Reference

Chabot, D., and J.-D. Dutil. 1999. Reduced growth of Atlantic cod in non-lethal hypoxic conditions. J. Fish Biol. 55:472-491

Acknowledgments

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