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The Effect of Patchiness in Prey on the Growth of Larval Lesser Sandeel in the North Sea: An Examination using Individual-Based Modelling

Zeren Gurkan[§*], Asbjorn Christensen[*] and Henrik Mosegaard[*]

[*]*DTU Aqua - National Institute of Aquatic Resources, Charlottenlund Slot, Jaegersborg Alle 1 DK-2920 Charlottenlund, Denmark*

Abstract

It has been stated that global climate change will challenge fisheries and ecosystem management in the North Sea. SUNFISH, "Sustainable fisheries, climate change and the North Sea ecosystem" (SUNFISH, 2007), is an international project aiming to improve the scientific basis of understanding and predictions of the effects of climate change on the North Sea ecosystem and the sustainable fisheries management in the North Sea by providing an integrated modelling framework for developing optimal and sustainable fisheries management strategies with focus on Atlantic Cod (*Gadus morhua*) and Lesser Sandeel (*Ammodytes marinus*), which are key species in the North Sea ecosystem and economically important to the Danish fishery.

The influence of prey/food availability on the growth of Lesser Sandeel at its larval stage in the North Sea is studied under this scope, using a generic individual-based model (IBM), where prey encounter and physiological processes are parameterized explicitly. The bioenergetic IBM for the

larval sandeel is formulated with particular emphasis on the response to the local feeding conditions, which are obtained by using the Continuous Plankton Recorder (CPR) survey time series data (Johns, 2009). The IBM is based on the nominal model described by Letcher et al. (1996) and has been implemented in MATLAB® (2008). It includes processes of *prey encounter, foraging* and *growth.* Growth is formulated in daily steps as the biomass surplus of ingestion after the total energetic costs and egestion. Encounter with prey is dependent on the larval and prey sizes/lengths. The encountered prey is considered in the foraging routine by the application of optimal foraging strategy and the actual number of prey items ingested in a day is calculated from the binomial distribution with number of trials equal to the daily encounter rates with probability of successes of calculated capture successes. Daily ingestion has been set to the minimum of realized number of prey eaten and maximum consumption, which is described as a power law based on the larval weight.

Jensen et al. (2003) describes sandeel larvae as visual feeders and feeding only during the day. This is considered in the described individual-based model by confining the larval activity to 13 hours in a day. They state that the food preference of larvae changes with increasing larval size towards larger prey (from eggs to nauplii, to copepodites and finally to larger copepodites and adult copepods), which has been incorporated into the model formulation by defining four prey types of different size-classes. It has been observed in Jensen at al.'s study in the North Sea that Lesser Sandeel larvae congregate where there is a peak abundance of zooplankton in the water column and it has been showed that the patchy distribution of prey of larvae has influence on the larvae as larvae are distributed patchily in accordance with their prey vertically along the water column, which may significantly influence the horizontal transport of larvae as well. Patches can be described as the regions of higher abundance of zooplankton as zooplankton is sparse in the water column with few high-density aggregations of up to 10^3 times the median abundance (Folt and

Burns, 1999). Mackas and Boyd (1979) indicates the importance of aggregation of zooplankton as fish in their early life history must encounter perhaps much greater than average food concentrations for sufficient survival and states that the near-surface zooplankton patchiness in the North Sea is very intense (peak abundance of $10^5/m^3$ and abundance contrast of 4-5-fold). Steele and Henderson (1992) show similar concentrations of zooplankton as by Mackas and Boyd (1979) in the surface seawater in the North Sea.

In the study presented here, we have examined the growth of a larva representing one of Lesser Sandeel located inside a food patch and gradually outside of the food patch by using the described IBM. The simulations were run for 70 days as it is stated by Jensen et al. (2003) that the larval phase lasts for 33 - 90 days. Growth data for Lesser Sandeel in the North Sea have been used to validate the model simulations (Jensen, 2001). The patch concentration of each prey type is determined by using the CPR data for total copepods and the factors from Letcher et al. (1996) between prey size-classes for copepodites, copepod nauplii and copepod eggs. CPR data showed on the months and years that the sandeel growth data are from densities of total copepods are close to what is nominal in the Letcher et al.'s (1996) model while they are lower for copepod nauplii and eggs than the nominal densities throughout the years. Figure 1 shows the growth of sandeel larva under food density derived from the CPR data from central eastern North Sea. The length-weight allometric-scaling relationship used is as in Christensen et al. (2008b) and the age-length data shown is for the years 1995 and 1996 (Christensen et al., 2008a). These conditions represent the observed growth of sandeel successfully as shown by the model output. A reduced prey density input to the model would mean the larva is lying outside the zooplankton patch therefore, exposed to unfavourable feeding conditions for growth. The results for this type of situation are shown in Figures 2 and 3, where first the prey densities have been reduced to half and then to 40 %. It is clearly seen in the figures that the growth of larva is reduced consequently in both cases and more severely under the lower prey densities (Figure 3).

Keywords: Individual-based model, bioenergetic, growth, Lesser Sandeel, larva, climate change

[§]***Contact author:*** *PhD student, DTU Aqua - National Institute of Aquatic Resources, Charlottenlund Slot, Jaegersborg Alle 1 DK-2920 Charlottenlund, Denmark, Tel.: +45 21456985, E-mail: zegy@aqua.dtu.dk*

Figures

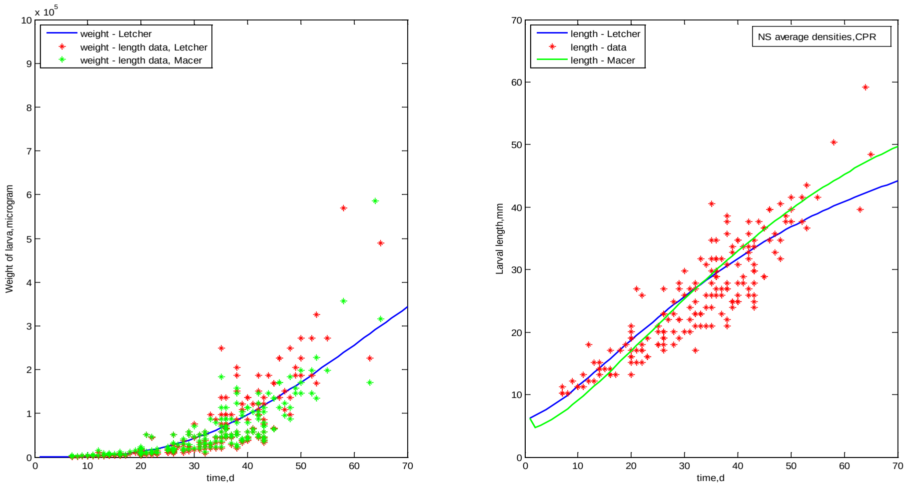

Fig. 1: IBM simulations of weight and length of sandeel larva with prey densities derived from CPR data. Sandeel age-length data from the North Sea are shown on the second plot.

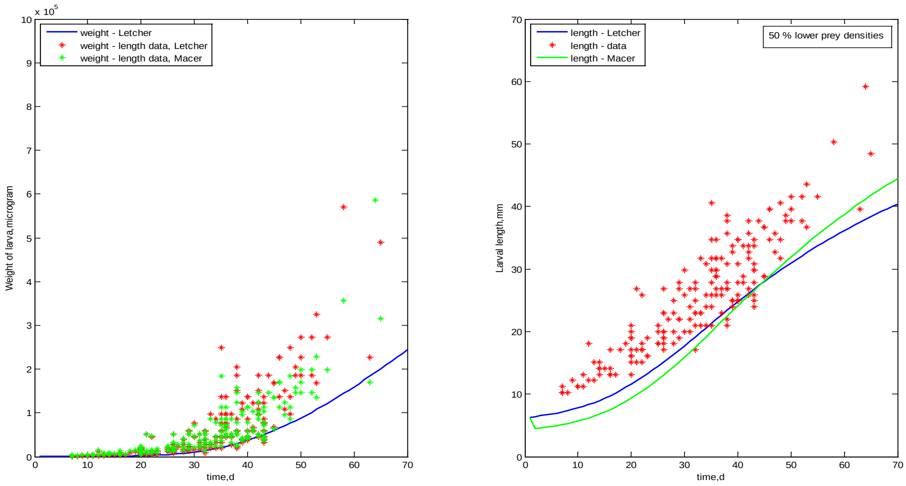

Fig. 2: Weight and corresponding length simulations with prey densities reduced to 50 % of the initial.

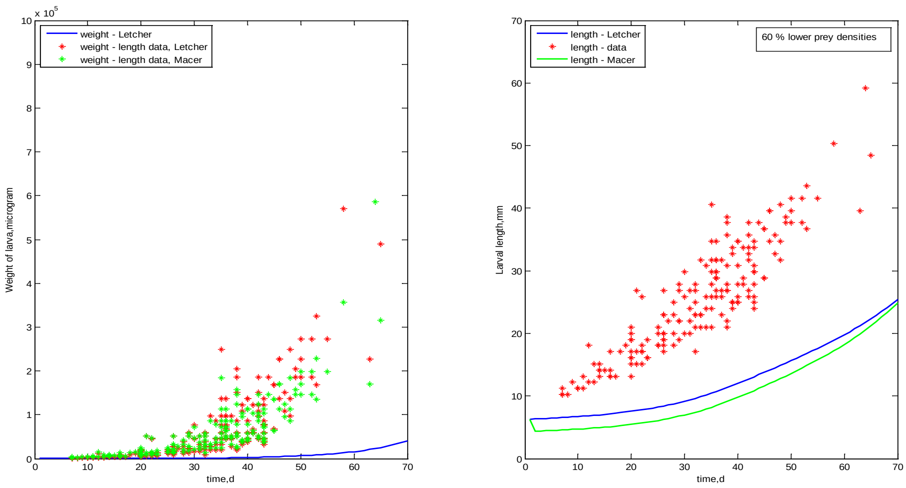

Fig. 3: Weight and length simulations with prey densities reduced by 60 % of the initial.

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