Optimal spawning time in cod, behavioural flexibility and physiological constraints

The match-mismatch hypothesis is the most common explanation of why fish hatch at a certain time in the seasonal cycle (Cushing 1969, 1990, Durant et al. 2007). In fact the hypothesis was largely based on observations of spawning time in the Northeast Arctic cod. The match-mismatch hypothesis essentially assumes that fish spawn at relatively fixed time each year, and that seasonal variation in the availability of food for the newly hatched offspring, is what determines the fish larvae survival, and ultimately the recruitment success of the population (Hjort 1914). However, several recent publications have suggested that the evidence for this hypothesis is quite thin (Samplonius et al. 2021), and that fish may in fact be rather flexible in when they choose to spawn (Pedersen 1984, Opdal et al. in review). However, environmental constraints such as light and temperature are still important. An obvious question thus arise: do cod know the best time to spawn, and can we find it using a simple mechanistic model?

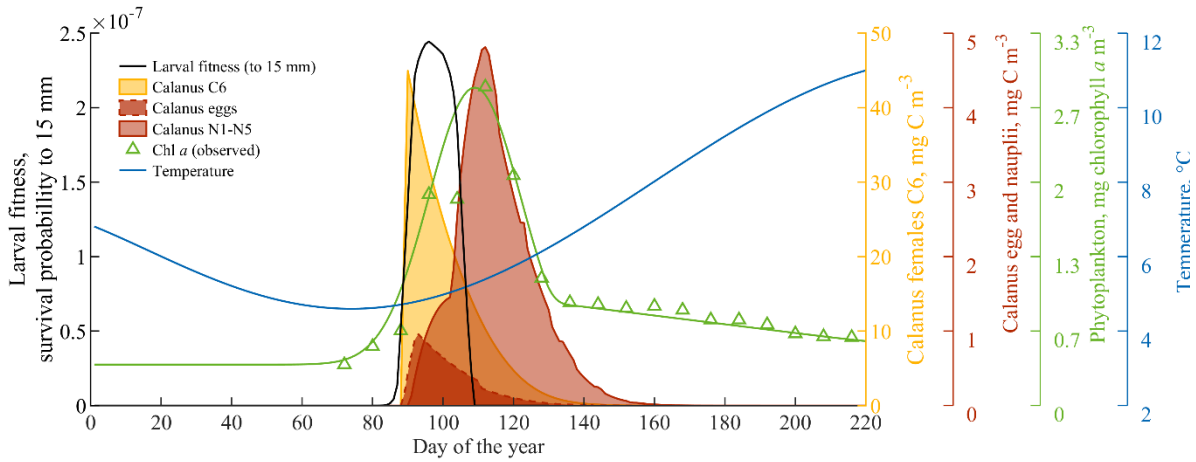

Figure 1. Example of model output. Here, the phytoplankton spring bloom is drawn from observations, and the zooplankton *Calanus finmarchicus* ends overwintering when the bloom starts. The calanus females starts spawning eggs, which hatch and develop (and die) from nauplii to copepodites. The speed of development is determined by temperature. The black line shows the survival probability of a newly hatched cod larvae (ca 5 mm) up to 15 mm. In this scenario, the highest survival occurs when cod hatch around day 95.

Method

In this project, we will use models of cod eggs and larvae and calculate the survival of eggs spawned at different times of the season. We construct environments from several variables that we think have an impact on growth and survival of larval cod: temperature, prey availability, phytoplankton, light, optical properties of the water, and predator abundance and efficiency. We have built detailed models for growth and development of cod, and applied it in other projects (Fiksen and Opdal 2015, Fouzai et al. 2015), and a previous master thesis (Sorø 2019) have constructed a working model that may be adapted as a template for further development.

Depending on how the model is parameterized, we can find different theoretically optimal spawning times, where the offspring survival is highest, in different environmental (climatic) scenarios. However, the spawning female can not choose freely when to spawn, and face opposing constraints. Ultimately, we can compare model results with real observations from the field, and try to identify the most important drivers for cod spawning time.

The student should have an interest in computers and numbers. Most of the code is available at the start, so the project is quite safe. The code is currently in Matlab, but other simulation tools are possible.

Research environment: The master student will be a member of the Theoretical Ecology Group http://bio.uib.no/te/. We supply programming tools, a computer and support.

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