Project brief

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Climate change and herring recruitment in the North Sea: current trends and future risks

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- **A combination of field observations and physiological modeling was used to investigate feeding conditions of herring larvae in the North Sea in winter and autumn**
- **The community composition and size structure of zooplankton prey were similar between herring spawning areas, but total abundance was much lower in winter than in autumn**
- **Autumn herring larvae were strongly affected by starvation only during the onset of exogenous feeding, while suitable zooplankton prey was sufficient to support the growth of larger larvae. In contrast, winter larvae experienced a prolonged period of food limitation, affecting larval growth and survival**
- **Our physiological model predicts that, in the future, herring larvae will require 28% (autumn) and 35% (winter) more prey biomass to sustain their growth and survival in the rapidly warming North Sea.**

Background and aims

Recruitment of marine fishes is influenced by various processes, with feeding conditions during early life stages often playing a crucial role. Particularly the larval stage is sensitive to any natural or anthropogenic changes in marine ecosystems, including climate change. Recruitment of several commercially important fish species in the North Sea recently became very low partially due to unfavorable conditions for their larvae. One of the affected fish stocks is North Sea herring that spawns in autumn and winter along the British coast and in the southern North Sea.

Like most fish larvae, herring larvae feed on plankton. However, there is a significant knowledge gap regarding plankton dynamics during autumn and winter, i.e., outside the bloom period. The aim of the project THRESHOLDS was to investigate plankton abundance and community composition at the spawning grounds of North Sea herring, evaluate the feeding conditions of young herring larvae, and estimate their growth and survival during their first month of life, a period considered critical for herring recruitment success.

Approach

We extended the observational program of the International Herring Larvae Survey (IHLS) to include simultaneous sampling on plankton and herring larvae in the main herring spawning areas: Buchan and Banks in autumn and Downs in winter (Fig. 1). In total, ten surveys were conducted between 2013 and 2019. We employed a dual sampling approach, using two plankton nets (GULF-VII and PUP samplers) to collect herring larvae and to properly sample a wide size range of planktonic organisms from micro- to mesoplankton (from 55 to 2000 µm). In the laboratory, herring larvae were staged and their length was measured. Collected zooplankton samples were processed using imaging systems FlowCam (for microplankton) and Zooscan (for mesozooplankton) to measure size and abundance of organisms. A novel deep neural network-based tool was developed to streamline sampling analysis and identify taxonomic groups of the sampled plankton. The obtained data were used to investigate the spatiotemporal variability of zooplankton, its community composition and size structure. Furthermore, we identified zooplankton organisms suitable for larval foraging and estimated their abundance. The collected data on larvae, their suitable planktonic prey and temperature were integrated in an individual-based physiological model of herring larvae. This model incorporated key processes such as food intake, energy expenditure, and growth, which are influenced by factors like larval size/age, prey abundance, and temperature. Model simulations enabled us to evaluate whether the available prey was sufficient to meet the energy demands of herring larvae and to support their growth and survival.

Key findings

Zooplankton community diversity in both spawning areas was similar across the years, with no significant trend in total abundance. Diatoms and dinoflagellates taxonomical groups dominated the microplankton community and gastropods and copepods the mesozooplankton one. While community composition was similar, zooplankton abundance and size structure differed significantly, with notably lower abundance of larger mesozooplankton in the Downs region, especially in the English Channel, compared to Buchan. Beyond this general pattern, our findings revealed that temporal and special variability in zooplankton community composition and size structure was closely related to the dynamics of major water masses in both regions, such as Atlantic Inflow Water, proper North Sea Water, and river outflow.

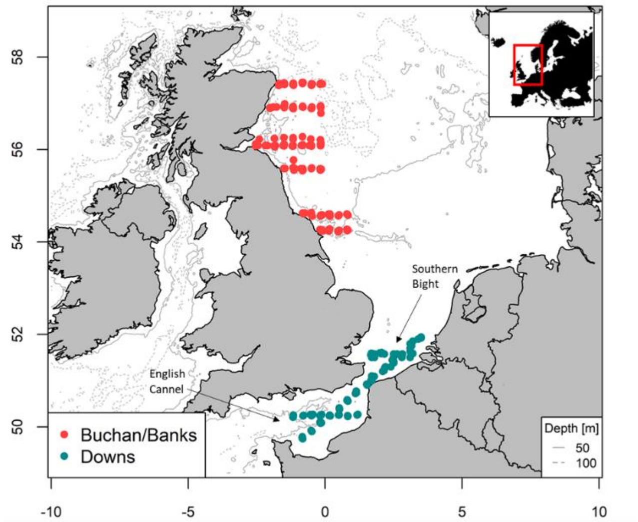

Figure 1: Sampled stations in the Buchan/Banks (September; red dots) and Downs (December; cyan dots) spawning grounds of North Sea herring (Source: Börner et al., 2025).

The comparizon between our model and observations revealed that the size structure of the observed zooplankton closely aligns with the optimal feeding requirements of herring larvae. Furthermore, we demonstrated that herring larvae can grow up to 40% faster when they incorporate a wider variety of zooplankton into their diet, rather than consuming only copepods. This effect was especially pronounced in young, first-feeding larvae, where a strict copepod diet was predicted to result in increased starvation and higher mortality rates. Even when herring larvae include various planktonic prey in their diet, they were predicted to experience significant mortality during the first-feeding phase (size <10 mm). In autumn, mortality rates declined rapidly as larvae grew larger, with those exceeding 14 mm exhibiting robust growth and no risk of starvation (Fig 2). In contrast, the low zooplankton biomass during winter in Downs posed challenges even for larger larvae, leading to predicted starvation mortality rates exceeding 40%, even for largest larvae tested in this study (>20 mm).

The physiological model used in our study predicts how future warming of the North Sea will impact herring larvae. Under the anticipated 2 °C warming of the North Sea by the end of the 21st century, herring larvae are expected to require between 28% (in autumn) and 35% (in winter) more food to meet their higher metabolic demands and sustain growth and survival. Further research is required to understand whether the North Sea's productivity will rise to this level in the future, or if Atlantic herring will need to adjust their spawning strategy, such as altering the spawning season or location, to ensure larval survival.

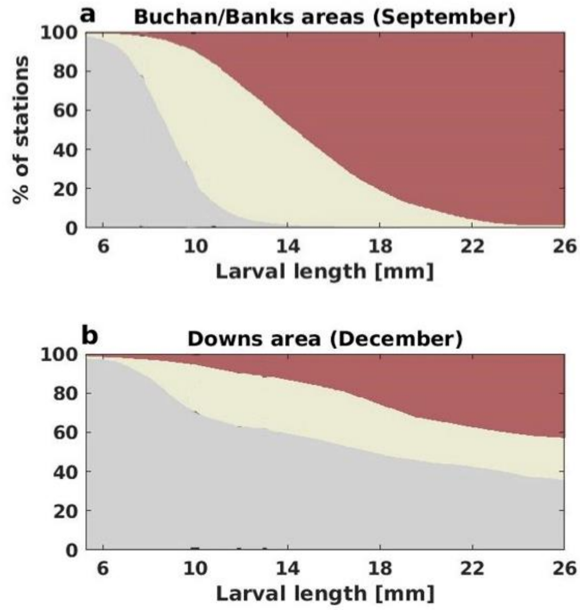

Figure 2: The fraction of stations (in %) where the modeled larvae of different length were predicted to experience starvation (gray), food-limitation (beige) or to grow at their maximal growth capacity (brown). (a) Buchan/Banks areas in autumn, (b) Downs area in winter (Source: Akimova et al., 2023).

Further Information

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Partners

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Publications

Akimova, A., Peck, M.A., Börner, G., van Damme, C. and Moyano, M. (2023), Combining modeling with novel field observations yields new insights into wintertime food limitation of larval fish. Limnol Oceanogr, 68: 1865-1879. https://doi.org/10.1002/lno.12391

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