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COMMENT

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Comment on "Early arrival of spring-spawning Atlantic herring *Clupea harengus* at their spawning ground in the Kiel Fjord, western Baltic, relates to increasing winter seawater temperature" by Ory et al. (2024)

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In their recent paper, Ory et al. (2024) used a unique set of multidecadal commercial catch data from Kiel Fjord (western Baltic Sea) to investigate the effects of a changing temperature regime on the timing of herring spawning migration. Using a subset from the past 13 years (2008–2020) with detailed information (weekly catches in the Kiel Fjord), they derived a normal function to describe the seasonal course of immigration intensity as a bell-shaped curve with a single peak in the middle of the season. Using this function, they then estimated the seasonal immigration patterns of herring for all 37 previous years (1971–2007), for which only the total, initial, and terminal catch was available along the season. We perceive that the authors have not considered the behavioral changes and fluctuations that are likely to occur given the large time span of the data series. We believe that the use of actual recorded data (start and end of catches in each season) would provide a better basis for investigating temporal shifts in migration patterns than using seasonal curves estimated in this way.

Nevertheless, the results in this article are consistent with previous studies on spring-spawning herring in the western Baltic. Polte et al. (2021), for example, have already documented an earlier spawning activity in the main spawning area of this metapopulation, Greifswald Bay (Bekkevold et al., 2023), due to increasingly mild winters. Thus, the findings of Ory et al. are a valuable addition, which also supports the notion that climate change effects on important fish species are a current problem and not an abstract future scenario.

Based on two commercial samples from the last decade of their time series (2018 and 2020) and from the period thereafter (2021), the authors postulate that the start of herring spawning activity is exclusively determined by the temperature-controlled gonad development in the preceding weeks and not by a triggering temperature threshold, as demonstrated earlier by Klinkhardt (1996) and Polte et al. (2021). In view of the underlying data, we consider this exclusionary conclusion to be too extensive because:

i. Since 2018, sampling has been carried out in Kiel Canal (KC), an artificial waterway (thus all maturity samples were taken in the canal) and not, as in previous decades, in the adjacent fjord. Unfortunately, the authors did not discuss that the contribution of the KC spawning component to the herring metapopulation in the western Baltic must be considered marginal based on the state of knowledge (Bekkevold et al., 2023), which limits the transferability of the results to the rest of the metapopulation. It can further be assumed that there are significant differences between the fjord and the canal, which are probably reflected in their different utilization as spawning beds. Observations in other areas (such as the most important spawning grounds around Rügen Island) suggest that the animals first aggregate near the spawning area and only then migrate to their actual spawning beds when both conditions are met: the temperature on the spawning ground has raised above a certain temperature, and the fishes have reached spawning maturity. Therefore, we consider it questionable to extrapolate few observations of herring maturity from the canal to the long-term catches in the fjord or even beyond.
ii. The years used for the maturity studies (2000, 2018, 2020, and 2021) were among the warmest in terms of winter water temperatures (especially in the context of the entire time series). These years were significantly above the long-term means of winter

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temperatures, thus representing "weak" or "moderate" winters according to the classification of the Federal Maritime and Hydrographic Agency (BSH, Aldenhoff, 2022). Ory et al. themselves show with fig. 4a that at least in 2 years (2018 and 2020), in which the maturity of the migrating herring was measured, the water temperatures in Kiel Bight in calendar week 4 had already exceeded the threshold value of 3.5°C described by Polte et al. (2021), even if the temperature may have temporarily dropped again in later weeks of 2018. Regarding the maturity, we consider it essential to include years with cold winters in the analysis to enable a transfer of the findings to earlier years in the data series.

In summary, long-term data series, such as those used by Ory et al., offer great potential for analysing effects of climate change on commercial fish species. However, we believe that the conclusions drawn by the authors of this study (e.g., the supposed refutation of a temperature threshold) do not fully consider already known and important spatiotemporal variations.

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