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Loops of near shore habitat use by early herring (*Clupea harengus*, L.) life stages in the Western Baltic Sea

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Summary

Hypothesizing that larval herring hatched in shallow lagoons of the Baltic Sea develop in a quite different suite of coastal habitats than their counterparts in the neighboring North Sea, we sampled pelagic and littoral sites in a major spawning ground of Western Baltic spring spawning herring. Additionally we investigated the vertical distribution of larvae based on the hypotheses that in the well mixed waters of the lagoon early larval herring is distributed accordingly and not stratified as documented from the open ocean. The results of this study revealed an unexpected loop of habitat use where larvae moved from spawning grounds in shallow littoral habitats to pelagic areas during the first development stages but returned to this habitat in at later stages previous to metamorphosis. Vertical distribution of early larval herring was surprisingly distinct but varied with extension of the water column and larval body length. In general our results demonstrate a quite patterned habitat utilization of early herring life stages in calm, inshore systems. This study implicates that fishery assessment and management of fish resources should take into account potential ecological functions of littoral habitats and behavioral distribution mechanisms for dispersal and survival of larval fish.

Introduction

The relevance of transitional waters as nursery area for ocean going fish species is generally acknowledged (e.g. Beck et al. 2001). Although this includes key stone species, such as herring (*Clupea spp.*), particular habitat use of juvenile stages hatched in those inshore systems is not well understood. Western Baltic spring spawning herring enters shallow lagoons and estuaries, spawning on vegetated sea beds in the littoral zone (Klinkhardt 1996). These semi-enclosed waters are considered not only spawning areas but important retention areas for larvae prior to metamorphosis. Research on early herring life stages in inshore systems is widely underrepresented since most ichthyoplankton surveys are traditionally focused on outer coastal shelf ecosystems. Results on temperature driven survival of larval herring in coastal ocean systems (e.g. Fässler et al. 2011) potentially contradict the suitability of shallow inshore systems for larval herring retention. Not only are seasonal temperature gradients highly variable but diurnal water temperatures also fluctuate extensively in waters shallower than 5 m. According to current understanding we assume that sensitive pelagic fish larvae such as herring would avoid fluctuating environments such as the littoral zone. Additionally we hypothesize a rather homogenous distribution of larval stages in the pelagic zone of the lagoon since the shallow water body is considered to be well mixed by forcing winds. Combining ichthyoplankton monitoring data with case studies on larval abundance in the littoral-and pelagic zone, we investigated patterns of habitat use of *Clupea harengus* larvae addressing a critical knowledge gap of recent fisheries management.

Materials and Methods

Greifswald Bay located in the South Western Baltic Sea is considered a major spawning area for Western Baltic spring spawning herring (Oeberst et al. 2009). When the ice has retreated and herring

enters the system for spawning in March, temperatures range around 4 °C. At the end of the spawning period in early May, water temperatures are approaching 20°C. Larval abundance per size class was studied on a site characterized by a vegetated sand shoal, sloping along shallow water areas of 1 to 3m depth and compared to reference sites of pelagic stations. Of those pelagic stations three sites were chosen according to differing water depth (5m, 8m. 10m). These sites were sampled in a stratified pattern to investigate vertical distribution of larval herring stages. Environmental variables such as temperatures, salinity, and dissolved oxygen were simultaneously recorded in different habitats.

Results and Discussion

Along the early herring ontogeny our results indicate a certain loop of larval distribution including littoral and pelagic habitats of the bay. After hatching, yolk sac stages left the shore zone and moved towards pelagic habitats of the basin. However, they were still aggregated in the vicinity of the spawning beds. From a total length (TL) of 10 mm on, larvae were found to be increasingly dispersed throughout the pelagic zone of the bay. Although even the outer bay is quite shallow (avg. 5.6, max. 13.6) and, during spring, characterized by a well-mixed water body without stratification of the physical environment, herring larvae were not distributed homogenously but showed a quite distinct vertical distribution indicating active positioning within the water column. Larvae > 30 mm TL were found frequenting the near shore zone including the particular spawning beds where larvae hatched. Exceptionally full stomachs of post-flexion-larvae caught in the littoral zone of the bay indicated a rich food supply of plankton prey occurring in vegetated shore zones. Although potential predators, such as sticklebacks (*Gasterosteus aculeatus*) and juvenile perch (*Perca fluviatilis*) were quite abundant in those habitats, pelagic herring larvae might experience advantages in littoral habitats. Those are subject of further research but might include an enriched food supply and shelter from predation by increased habitat complexity due to macrophyte cover. In the absence of significant tides and major ocean current regimes, the distribution of all studied larval stages hints on active behavioral mechanisms of habitat selection. In general transitional waters seem to represent important retention areas for the early herring ontogeny until metamorphosis to the juvenile fish.

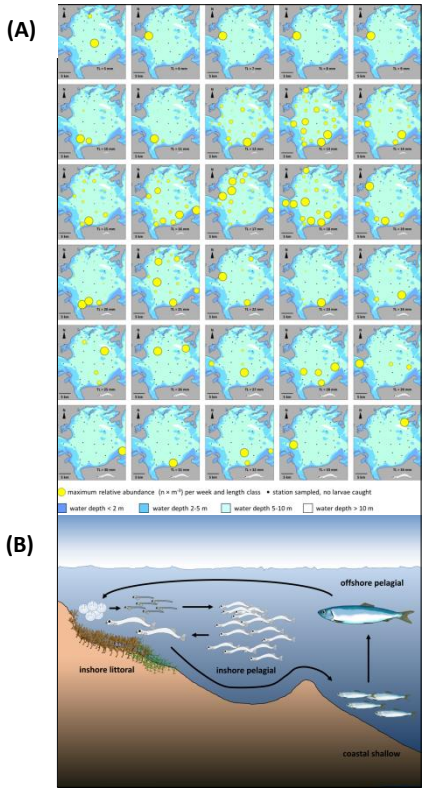

Figure 1: (A) Distribution of larval herring size classes (mm total length, TL) in weeks of maximum abundance, based on the number of larvae m^{-3} sampled during the weekly Rügen herring larvae survey in 2011. Source of bathymetry data: Federal Maritime and Hydrographic Agency (BSH), Germany.**(B)** Schematic habitat use along the life cycle of herring

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