

Abstract

Atlantic cod, *Gadus morhua* Linnaeus 1758, is a widespread species, occurring in the North Atlantic region, and through the North Sea have reached the Baltic. Cod is a generalist species, playing the role of an important predator in every ecosystem it inhabits. The specific hydrological conditions in the Baltic Sea make it a very unique habitat for this species compared to other seas. In the Baltic, two stocks can be distinguished: western and eastern, which not only inhabit different areas geographically, but also slightly differ in biological terms. Until recently, cod was widely caught for commercial purposes in the Baltic Sea, but the poor condition of the eastern stock resulted in a ban on catching it from 2019. Deteriorating conditions for cod reproduction in the Baltic Sea, combined with the lack of appropriate food resources, resulted into slower growth rates and high natural mortality of this species. It can be assumed that a number of unfavorable factors influence the early development of this species. It is evidenced by the fact that since 2012, the recruitment to the stock of adult fish has been decreasing. This situation highlights the importance of studies on processes occurring during the larval and early juvenile period. The studies, that falls within the scope of the ecology of early stages of fish development, which in natural conditions is usually carried out on the basis of ichthyoplankton cruises. An important element of such research is the use of analysis of the microstructure (daily growth) of otoliths in order to determine the age and then the growth rate and hatching dates of the larvae.

This doctoral thesis consists of three articles published in peer-reviewed scientific journals. The research material was collected during Polish plankton cruises on board the RV *BALTICA* between 2006 and 2014. The cruises took place every year in spring and summer in three areas of the Baltic Sea: Bornholm Basin, Słupsk Furrow, and Gdańsk Basin. Three types of samples were collected at the same stations (approx. 90 stations) i.e.: ichthyoplankton, zooplankton, and hydrological parameters were recorded.

After extracting otoliths (a total of 1,674 sagittae and lapilli) from cod larvae and juveniles (4.1-39.2 mm SL), a microscopic analysis of their structure was performed. Since the microstructure of cod otoliths, compared to other species, is one of the most difficult to read, the influence of the experience level of the person determining age on the analyzes results of growth rate and hatching dates was examined. It turned out that the experience of the person taking the readings has a positive effect on the precision (repeatability) of the readings, but does not guarantee their correctness and prior calibration work with the participation of an expert in age readings of this species is necessary. Especially since incorrect readings may result in severe errors in the following analyzes of growth rates and larval hatching dates (article no. 1, Spich and Fey 2020). The methodological results from the first publication were used in further research on the ecology of early development stages of cod. These

studies have shown that both the biomass and species composition of zooplankton influence the differences observed between years and seasons in the growth rate of cod larvae and juveniles. Moreover, the water surface temperature had a significant impact on the biomass and taxonomic structure of the zooplankton community. This relationship was particularly visible in spring. During the analyzed period of 2006-2014, two different average values of the cod growth rate were observed, i.e. 2006-2011 and 2012-2014. Lower growth rate values have appeared since 2012, which, according to ICES data, coincides with lower recruitment, i.e. weaker year-class joining the adult eastern cod stock every year (article no. 2, Spich and Fey 2023). The last stage of this doctoral thesis was a review of the available literature, which was carried out to determine the intensity and the purpose of the otoliths size and microstructure analysis of Atlantic cod larvae and juveniles, divided into works concerning larvae or juveniles and those using sagittae or lapilli. The literature search covers the period from the first 'otolith' article appearance in 1980 until 2021. The goal of the analyzes of otoliths microstructure of larval and juvenile cod has not changed significantly over the years in relation to the main thematic categories of research. 41 years of research in this area can be summarized by the statement that otoliths are a valuable source of information on the ecology of the early development stages of cod *Gadus morhua* L. and are most often used in studies of the growth rate and hatching dates of larvae, and the otolith used in research is most often a lapillus (article no. 3, Spich and Fey 2022).