Morphological abnormalities in gonads of the Baltic herring (*Clupea harengus membras*) in the northern Baltic Sea

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Introduction

Reproductive disorders are a major environmental concern in the Baltic Sea, due to heavy anthropogenic influence and long- and short-term variations taking place in the natural environment. We report here an increasing prevalence of gonadal malformations in the Baltic herring (*Clupea harengus membras*),a key species of the Baltic ecosystem and important in commercial fishery.

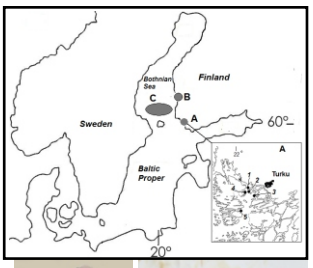

Fig 1. Sampling areas

Materials and methods

During 1987-2014, spawning herring were collected annually from commercial trap nets in the Airisto Inlet, which is one of the most important spawning areas of herring in the Archipelago Sea (Fig. 1) In the Bothnian Sea, samples were taken in 2013 from the catches of commercial trawlers operating in the open sea and from gill nets catching spawning herring on the coast (Fig. 1). The total number of fish examined was 38 284 in the Airisto Inlet (1987-2014) and 541 in the Bothnian Sea (2013). Gonad samples were examined histologically for signs of morphological and structural changes in fully mature gonads, using an optical light microscope. The annual trend of the gonadal malformations in 1987-2014 was studied with logistic regression modelling (Generalized Linear Models, GLIMMIX procedure). Differences in prevalence of gonadal malformations between the Archipelago Sea and the Gulf of Bothnia were examined using χ^2-test.

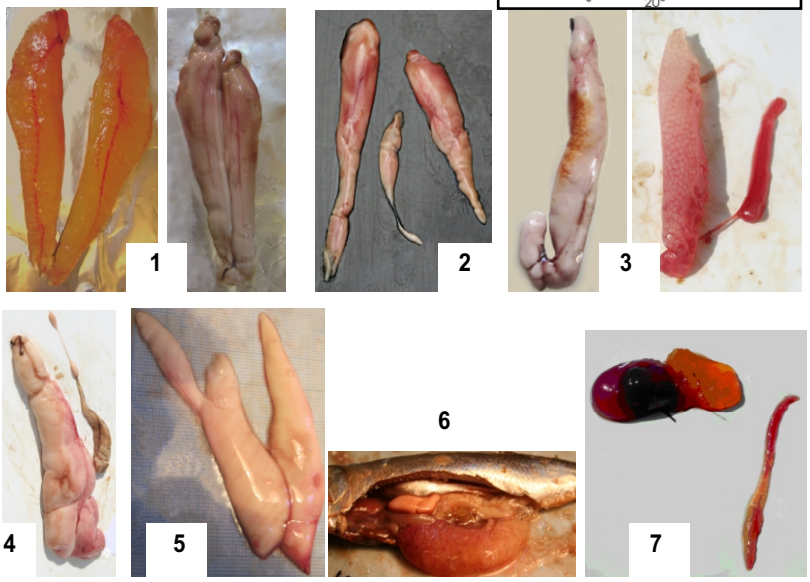

Fig. 2. Morphological gonad types found in the Baltic herring collected from the Archipelago Sea and the Bothnian Sea. The numbers refer to different gonad types

Gonad types and their prevalence

The gonad types found were divided into seven different categories by gross morphological characteristics with type 1 being the normal gonad (Fig. 2).The other types were **asymmetric** (type 2), **rudimentary** (type 3), **segmented** (type 4) and **branched** gonads (type 5). In addition, **hermafroditism** (type 6) and **miscellaneous abnormalities** (type 7) were found. During the study period when all different types were considered, gonad abnormalities increased significantly(Fig 3) in the Airisto Inlet ($F=32.65$; $p<0.001$; $df= 1$.In the Bothnian Sea, abnormal gonads were significantly more frequent than in the Airisto Inlet in 2013 ($\chi2 =6.24$; $df=1$; $p<0.05$), with the average prevalence being 2.8 % in the samples (n=541). In some samples of this area, even 4-5 % of the fish had abnormal gonads.

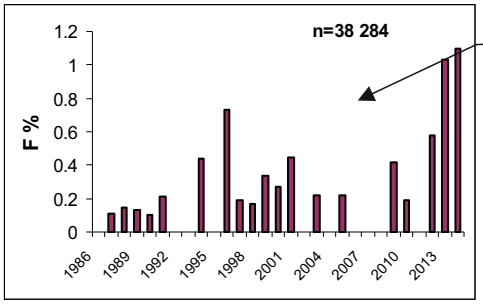

Fig 3. Frequency of gonad abnormalities in the Baltic herring in Airisto 1987-2014.

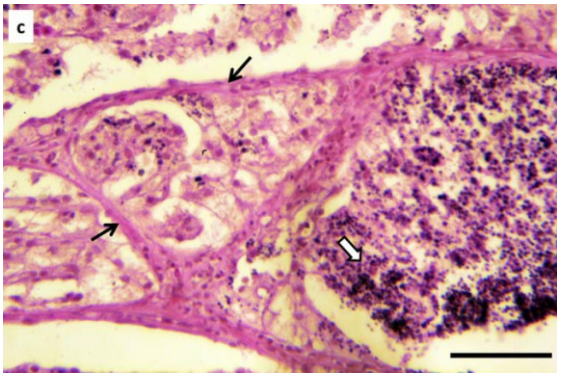

Fig. 4. Histological structure of a partly atrophic testis. Sperm cells are found in some tubules (open arrow) whereas tubules on the left hand side are atrophic Bar length=50 µm.

Conclusions

Our study revealed a new type of reproductive disorders in the Baltic herring, but clearly further studies are needed on their anatomy and histology, to understand the reasons behind this condition. Most likely, the gonad anomalies have a complex background and several different origins: chemicals of municipal, industrial or agricultural origin, but some of them can be related to the changes of the Baltic ecosystem in one way or another. At present, gonad abnormalities may have little or no influence on the reproductive capacity of the herring population, but monitoring of gonad health is necessary in herring and presumably also in other fish species. Future scenarios predicting the development of the Baltic Sea suggest an increase of rainfall and fresh water input into the Baltic, which would increase the air-borne fall of pollutants and discharges of nutrients, biocides, and other environmental contaminants from the catchment area. Especially in commercially exploited species also the reproductive health of the parental stock should be examined and monitored, so as to find out the reasons for the reduced recruitment and stock size, if such emerge.

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