Stock identification of Atlantic herring in the Northeast Atlantic based on otolith shape

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Summary

Otolith shape variation of seven herring stocks in the Northeast Atlantic and Canada was studied to see if otolith shape can be used to discriminate the stocks. The otolith shape was obtained using quantitative shape analysis, transformed with Wavelet and analysed with multivariate methods. Otolith shape differences were detected among the seven stocks, which could be traced to three morphological structures. These shape differences could discriminate between Icelandic summer spawners and Norwegian spring spawners, which are known to mix at feeding grounds east of Iceland. This study provides a method which can be used as a discriminating tool for stock identification of Atlantic herring and the technique can be applied to other fish species as well.

Introduction

Atlantic herring (*Clupea harengus* L.) may have the most complex stock structure of any marine fish species (Iles and Sinclair 1982) where stocks are defined based on where and when they spawn. Atlantic herring often share the same morphological body features regardless of origin, making it problematic to estimate the contribution of each stock in mixed fisheries. The aim of this study is to evaluate otolith shape differences between Atlantic herring stocks and if these differences can be used to trace herring back to their spawning stock in mixed fisheries. First, the otolith shape variation of six herring stocks from five countries in the Northeast Atlantic and one herring stock from Canada was mapped using Discrete Wavelet and quantitative shape analysis. Secondly, otolith shape differences among the Icelandic summer spawning and the Norwegian spring spawning herring stocks, which are known to mix during feeding in Icelandic waters (Anon 2013), were identified and otolith shape used to classify them back to their spawning stock. Lastly we evaluate whether the variation among stocks can be traced to the main variable characteristics of the otolith shape.

Materials and methods

Spawning Atlantic herring were sampled from seven stocks during 2009 - 2011 from five countries in the Northeast Atlantic: Iceland, Faroe Islands, Norway: Møre and Lofoten, Scotland and Ireland, and from Canada. Biological information was collected for each fish and otoliths extracted and aged. Digital images were taken of all otoliths (n=400) and outlines collected with functions written in the program R (R Core Team 2012). Otoliths were normalized and Wavelet shape coefficients obtained by conducting a Discrete Wavelet transform. The data were corrected for fish length following methods by Agüera and Brophy (2011) and Lleonart *et al.* (2000). Variation in otolith shape between stocks was analysed with CAP (Anderson and Willis 2003) and MANOVA and by applying a priori comparisons considering the main geographic regions. Hierarchical cluster analysis of pairwise distances between samples was performed and the reliability estimated by bootstrap resampling. Classifiers for stocks I and M were developed with Linear Discriminant Analysis and the success rate estimated with jackknife cross-validation. Average otolith shapes where plotted for each stock by using means of the reconstructed outlines of the averaged normalized Wavelet coefficients.

Results and discussion

Differences in otolith shape were observed between all stocks (p=0.001) and for all a priori comparisons (C vs. IMLFSR, SR vs. IMLF, I vs MLF, MLF, p<0.05). For the stocks found in mixed fisheries, I and M, otolith shape differed significantly (p=0.001) and LDA classifiers were able to classify individuals back to their spawning stock with a success rate of 75.0% (0.03% SE), 75.0% out of 88 individuals from I were classified correctly and 74.7% out of 83 individuals from M. The hierarchical cluster analysis suggests two main clusters, one with the two stocks from the British Isles (R and S) and the second one with two clusters, one with F and M and second with C, I and L (Figure 1A). The average shape of otoliths differed when compared among the seven stocks (Figure 1B). There were modifications in the shape of otoliths mainly at the excisura major but also at the postrostrum and pararostrum between stocks.

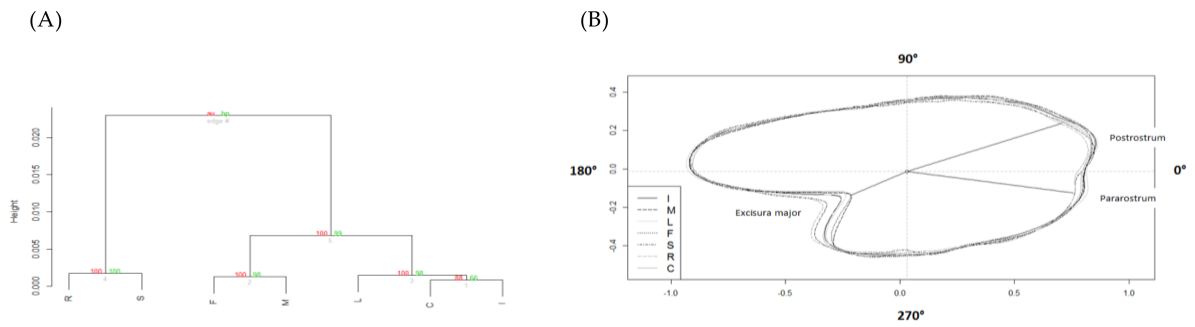

Figure. 1 (A) Hierarchical cluster analysis of shape coefficients for the seven herring stocks (I: Iceland, M: Norway Møre, L: Norway Lofoten, F: Faroe Islands, S: Scotland, R: Ireland, C: Canada). The values on each branch represent percentages on how well the clusters are supported by the data, obtained by bootstrap (approximate unbiased values (au) in red, regular bootstrap values (bp) in green). (B) Average shape of otoliths in the seven herring stocks. Lines inside the otolith represent the three radii and most variable areas among stocks: excisura major, post- and pararostrum.

Otolith shape in Atlantic herring differ between populations spawning at different locations in the Northeast Atlantic and Canada. The variation in shape can be used to trace the origin of samples which mix at feeding ground as for the Icelandic summer spawners and the Norwegian spring spawners. Three main shape features were identified on the otolith that can be used to identify herring populations from different geographic regions. Natal homing in this species (Ruzzante *et al.* 2005) appears to maintain the diversity between stocks despite seasonal mixing.

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