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Otolith Shape Analysis of Irminger Sea Redfish (*Sebastes mentella*): Preliminary Results

by

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Abstract

This paper represents a preliminary otolith shape analysis of pelagic redfish (*Sebastes mentella*) in the Irminger Sea, comparing NAFO and NEAFC convention areas and depth layers (shallower and deeper than 500 m). Elliptical Fourier Analysis (EFA) was applied to describe digitised otolith outlines. The resulting Fourier descriptors were used as the basis for discriminant analysis to investigate separation success between area/depth groups. In general, differences in univariate measurements (otolith length, breadth and weight) and otolith shapes between area/depth groups were marginal and subject to high variation. Discriminant analysis indicated poor separation between area/depth groups. Differences in average shapes between the area/depth groups were relatively low. Based on this morphometric study, the existence of separate stocks of *S. mentella* in the Irminger Sea seems to be unlikely, neither on a vertical (depth) nor horizontal scale (NAFO/NEAFC areas).

Keywords: Otolith shape analysis, Fourier analysis; redfish, pelagic redfish, *Sebastes mentella*; North Atlantic, Irminger Sea.

Introduction

Morphometric measurements of fish are commonly used to investigate phenotypic differences between species (e.g. Power and Ni, 1985; Creech, 1992) and stocks (Ihssen *et al*., 1981; ICES, 1996 and 1999; Murta, 2000). In addition to body morphometrics and meristic features, otolith shape analysis has become a popular tool for species and stock identification purposes. In numerous studies, otolith shapes were shown to be species-specific (Hecht & Appelbaum 1982; Gaemers, 1984; L'Abée-Lund, 1988) and also population-specific (Messieh, 1972; McKern, *et al*., 1974; Neilson *et al*., 1985). In many cases, geographic variations in otolith shapes could be related to stock differences (Bird *et al*., 1986; Castonguay *et al*., 1991; Campana and Casselman, 1993; Friedland and Reddin, 1994; Begg and Brown, 2000; Turan, 2000).

Since the stock identification for North Atlantic redfish, particularly for *Sebastes mentella*, is still uncertain (e.g. ICES, 1998), a multidisciplinary approach to investigate the stock structure of *Sebastes* species was implemented in the research project "Population structure, reproductive strategies and demography of redfish (Genus *Sebastes*) in the Irminger Sea and adjacent waters (ICES V, XII and XIV; NAFO 1)", funded by the European Union (QLK5-CT1999-01222). Apart from genetic studies and the investigation of morphometric and meristic characters of the fish body, the otolith shapes of redfish, focusing on *S. mentella*, are analysed with regard to stock-specific differences.

This paper represents a preliminary shape analysis of pelagic *S. mentella* otoliths, collected during the international hydroacoustic survey on redfish in summer 1999 (Sigurdsson *et al*., 1999). Differences in otolith shapes and univariate otolith measurements between areas (NAFO/NEAFC) and depth layers (<500m; >500m) are investigated.

Materials and Methods

Data sets

S. mentella otoliths, sampled during the international hydroacoustic survey on redfish in the Irminger Sea in June/July 1999, were chosen for a comparison of redfish otolith shapes between areas and depth layers (Table 1, Fig. 1). These samples were divided by (total fish) length groups of 26.5-31.5 cm, 32.5-37.5 cm and 38.5-43.5 cm to minimise (allometric) size effects in the shape analysis.

Image and shape analysis

The otolith outlines were digitised using an image analysis system consisting of a high resolution monochrome CCD video camera, mounted on a microscope and connected to a PC framegrabber card via BNC video cable. The microscope magnification was adjusted to the size of the otoliths to ensure as high resolution as possible, varying between 20x and 40x. The image analysis system was calibrated in horizontal and vertical direction separately to avoid possible distortion effects of the lens system. The otoliths were positioned onto a microscope slide with the sulcus down and the rostrum to the left in horizontal line to minimise distortion errors within the normalisation process. High-contrast video images were produced using transmitted light, delivering dark two-dimensional objects with bright background.

The video signal was analysed using Optimas 6.51 (Media Cybernetics, 1999) image analysis software. Images of right otoliths were mirrored vertically to allow pooling of right and left otoliths in the shape analysis. Shape digitalisation was performed by sampling 1000 equidistant points on each outline, representing the resolution of the video camera.

For the export of outline coordinates and univariate shape descriptors (otolith length, breadth, etc.), Optimas macros were applied. Elliptical Fourier Analysis (EFA) (Kuhl and Giardina, 1982; Rohlf and Archie, 1984) was performed using C++ modules based on algorithms proposed by Ferson *et al.*, 1985. The EFA represents a fitting of harmonic functions to the original otolith outlines with an ellipse as the first approximation step. The algorithm for normalising the rotation and starting angle of the outline was modified to account for deviations from the horizontal axis resulting from the positioning of the otolith on the microscope slide. During the EFA, the size, location and starting point of the object outlines within the two-dimensional space were normalised. The first 10 harmonics were used for multivariate analysis since these were responsible for 95-99% of the shape variation.

The graphical representation of average otolith shapes, characterising groups of samples (areas, species), was based on the reproduced outlines for the mean Fourier descriptors of each group.

Multivariate analysis of Fourier descriptors

Discriminant analysis, based on the Fourier descriptor matrix, was used to quantify separation success between area/depth groups.

Otolith weights

After removal of adhering tissue and blood remains from the otolith surface and a minimum of one-day air drying at room temperature, otolith weights were recorded with a precision of 0.1 mg.

Results

Univariate measurements

For each fish length interval, the mean otolith length, width and weight were compared between area/depth groups (Table 2). Significant differences between groups were only detected for the “medium” length interval 32.5-37.5 cm.

Shape analysis

The classification success of the discriminant analysis (Table 3) indicates poor separation between area/depth groups. In the “small” (26.5-31.5 cm) and “medium” (32.5-37.5 cm) length groups, less than one third of the samples are allocated correctly, and 55% of the samples within the “large” (38.5-43.5 cm) length group are classified into the correct category.

This result is in general supported by the comparison of the mean shapes of otoliths from the area/depth groups within length intervals (Fig. 2). Shape differences between the area/depth groups are relatively low, being slightly higher in the “large” length group than in the “small” and “medium” length groups.

Discussion

In general, differences in univariate measurements and otolith shapes between area/depth groups were marginal and subject to high variation. *S. mentella* of the “medium” length range (32.5-37.5 cm) from shallower depths in NAFO Div. 1F appeared to be relatively fast-growing, expressed in significantly higher mean otolith length, width and weight. Discriminant analysis and the comparison of the mean shapes within this length range, however, did not show any clear differences between area/depth groups.

The existence of separate stocks of *S. mentella* in the Irminger Sea has been raised several times over the past (*e.g.* ICES 1998). Based on this morphometric study, the existence of more than one stock of *S. mentella* in the Irminger Sea seems to be unlikely, neither on a vertical (depth) nor horizontal scale (NAFO/NEAFC areas).

Although redfish otolith shapes were found to differentiate between species with some overlap (Stransky, 2001), the use of otolith shape analysis for stock discrimination of *S. mentella* has not fully been evaluated yet. A comprehensive study in this respect is currently carried out, encompassing samples from the entire distribution area of this species, from the Baffin Bay to the Barents Sea (Stransky, unpublished data). This investigation will be of particular interest, since recently published work by Roques *et al.* (2002) showed low genetic differences within a large “Pan-oceanic” cluster of *S. mentella*, stretching from the Grand Banks to the Faroe Islands.

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Table 1: Otolith samples of pelagic *S. mentella* used for shape analysis.

Area (ICES Sub-area; NAFO Div.)	**Vessel (Nation)**	**Gear (Type)**	**Mean fishing depth**	**Date**	**No. of samples**
Irminger Sea (XII; 1F)	Walther Herwig III (GER)	pelagic (Gloria)	200-650 m	June/July 1999	421
Irminger Sea (Va, XII, XIV)	Bjarni Sæmundsson (ISL)	pelagic (Gloria)	270-720 m	June/July 1999	158

Table 2: Comparison of univariate measurements between area/depth groups by (fish total) length intervals. ** indicates significance on the level $p<0.01$ (Kruskal-Wallis test).

26.5-31.5 cm:	NAFO <500m	NAFO >500m	NEAFC <500m	NEAFC >500m	Total
Number of samples	34	30	17	16	97
Mean otolith length (mm)	11.55	11.74	11.87	11.64	11.68
Mean otolith width (mm)	7.09	7.11	7.26	7.16	7.14
Mean otolith weight (mg)	163.7	167.5	174.7	170.5	167.9
32.5-37.5 cm:					
Number of samples	86	67	56	55	264
Mean otolith length (mm) **	14.75	14.47	14.36	14.01	14.44
Mean otolith width (mm) **	8.80	8.52	8.61	8.38	8.60
Mean otolith weight (mg) **	312.3	287.3	289.7	272.7	292.9
38.5-43.5 cm:					
Number of samples	21	31	24	142	218
Mean otolith length (mm)	15.45	15.84	15.66	15.88	15.81
Mean otolith width (mm)	9.18	9.37	9.16	9.08	9.14
Mean otolith weight (mg)	358.6	379.0	368.1	374.1	372.6

Table 3: Jackknifed classification matrix of the discriminant analysis for area/depth groups by (fish total) length intervals.

26.5-31.5 cm	NAFO <500m	NAFO >500m	NEAFC <500m	NEAFC >500m	**%correct**
NAFO <500m	10	9	11	4	**29**
NAFO >500m	12	8	5	5	**27**
NEAFC <500m	6	6	4	1	**24**
NEAFC >500m	3	2	4	7	**44**
Total	**31**	**25**	**24**	**17**	**30**

32.5-37.5 cm	NAFO <500m	NAFO >500m	NEAFC <500m	NEAFC >500m	**%correct**
NAFO <500m	31	13	26	16	**36**
NAFO >500m	21	20	11	15	**30**
NEAFC <500m	18	19	6	13	**11**
NEAFC >500m	9	15	13	16	**30**
Total	**79**	**67**	**56**	**60**	**28**

38.5-43.5 cm	NAFO <500m	NAFO >500m	NEAFC <500m	NEAFC >500m	**%correct**
NAFO <500m	8	7	4	2	**38**
NAFO >500m	6	10	14	1	**32**
NEAFC <500m	5	7	6	6	**25**
NEAFC >500m	11	19	16	96	**68**
Total	**30**	**43**	**40**	**105**	**55**

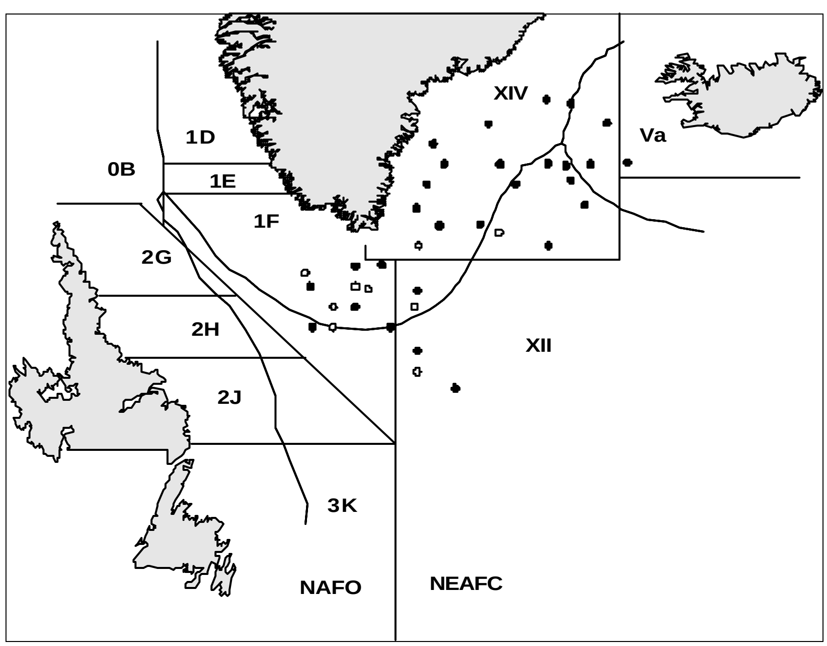

Fig. 1: Stations where otolith samples of pelagic *S. mentella* were collected in the Irminger Sea in June/July 1999 (Open circles: station shallower than 500 m; filled circles: station deeper than 500 m).

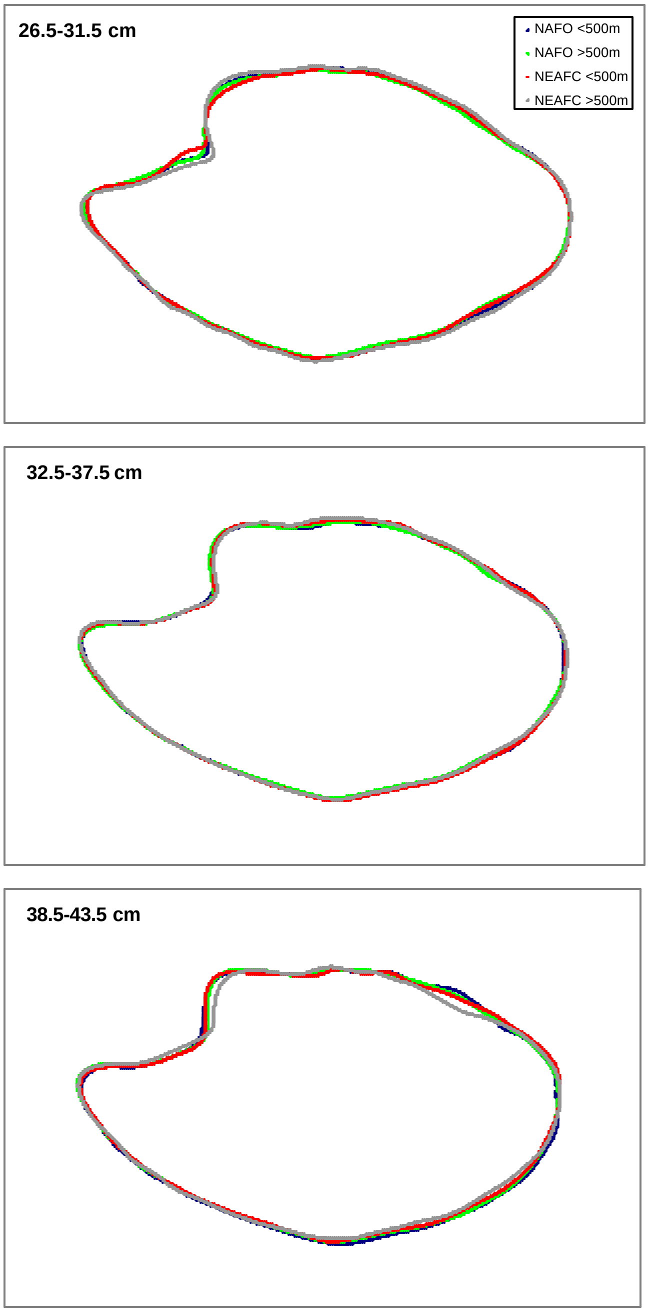

Fig. 2: Average shapes of *S. mentella* otoliths, by (fish total) length group and area/depth group. Otolith outlines were normalised for size, rotation, location and starting position.