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Otolith sectioning reveals higher maximum age in greater weever (*Trachinus draco*)

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Abstract

Growth and maximum age are two key parameters that inform resilience of fish populations to exploitation. Existing information on those for greater weever inhabiting the eastern North Sea is based on the analysis of whole otoliths. Here, we present a reanalysis using sectioned otoliths. The results reveal a different growth pattern and a higher maximum age than that previously reported. The higher maximum age makes greater weever populations more vulnerable to exploitation. Such information can serve as a basis for the estimation of the growth curve that can be used for future assessment of the species.

KEYWORDS

ageing, growth, maximum age, North Sea, otolith sectioning

The greater weever (*Trachinus draco*, Linnaeus 1758) is a demersal marine fish of the family Trachinidae distributed along the eastern Atlantic coastline from Norway to Morocco, and into the Mediterranean, Aegean, B10 and Black Seas (Čustović et al., 2015). The species occurs at depths ranging from shallow water to 150 m. It inhabits mostly muddy or sandy grounds, and it is notoriously known for its venomous spines that can inflict serious injuries on humans through accidental stinging (Tortonese, 1986). In the north-eastern Atlantic, the species is common in the Kattegat and along the coasts of the Skagerrak, where a fishery has existed since the 1950s, mainly conducted by Denmark and Sweden (Bagge, 2014).

Due to its minor commercial importance, the species in the Kattegat-Skagerrak region is not designated as a priority species either by the E.U. data collection framework (DCF) or by the International Council for the Exploration of the Sea (ICES). Consequently, only a modest amount of data is collected annually, and no assessments are currently being conducted. The greater weever is primarily captured in trawl fisheries in the Kattegat, with smaller quantities also taken in the Skagerrak (https://fiskeristyrelsen.dk/fiskeristatistik/dynamiske-tabeller; https://www.havochvatten.se/fiske-och-handel/statistik-och-fakta/statistik/fangststatistik-yrkesfisket.html). Fishing for greater weever occurs for both human consumption and industrial purposes, with no E.U.-regulated quota in the Kattegat-Skagerrak. Landings of greater weever occur throughout the year, mainly as by-catch in trawl fisheries targeting Norway lobster. Historically, annual catches of greater weever ranged between 100 and 200 t, except for a few years in the 1980s when they nearly reached 600 t. Since 2006, catches have shown an increasing trend, reaching their peak in 2014, with Danish and Swedish fisher landing 1226 and 897 t, respectively, in the Kattegat.

Current knowledge on key biological characteristics of greater weever in the Kattegat-Skagerrak, such as length-weight relationship, sex ratio, growth, maturity, length, and age distribution, is only based on the work of Bagge (2014), which relied on the traditional ageing method using the whole otolith (Figure 1a, right). Here, we present a reanalysis of growth of the species using sectioned otoliths (Figure 1a, left). The results reveal a different growth pattern and higher maximum age than that previously reported. The higher maximum age makes greater weever populations more vulnerable to exploitation.

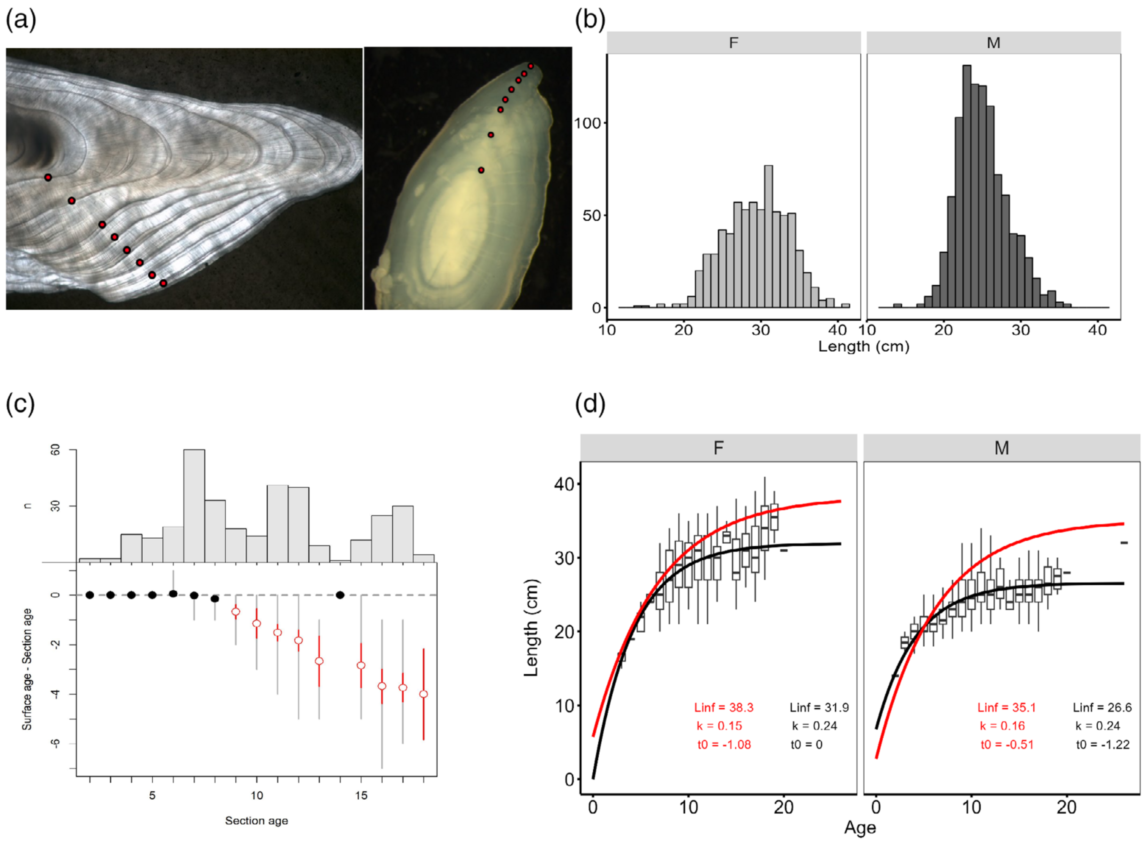

FIGURE 1 (a) Comparison between a sectioned otolith (left) and a whole otolith of greater weever (right). (b) Length frequency distribution of females and males of greater weever. (c) Age-bias plots are used to compare the mean estimated ages from the whole otolith method to the ages estimated by the sections of otoliths from a subsample of 338 individuals. The horizontal dashed line represents the agreement line where no difference can be found between the two age reading methods. Points represent the mean difference between the age obtained by reading the whole otolith compared to the age obtained by sectioning it. Means shown with an open dot are mean age differences that are significantly different from zero. Red vertical lines represent the confidence intervals for difference in ages, whereas gray vertical lines represent the ranges of values. A histogram of the number of individuals per age, using the otolith sectioning method, is shown at the top of the graph. (d) von Bertalanffy's growth curve estimated using sectioned otolith (in black) compared to Bagge's (2014) estimation using whole otoliths (in red).

Such information can serve as a basis for estimating the growth curve to be used for future assessment of the species.

Greater weever were sampled during the International Bottom Trawl Survey (IBTS) carried out on the third quarter of 2014 on board of the Danish R/V Dana in the Kattegat and Skagerrak area, in the eastern part of the North Sea. Additional samples were collected through commercial samplings in June 2015 in the same area. Samples belonging to the scientific survey were stored in a freezer (−20°C) until the analyses were performed in the laboratory, whereas the commercial samples were processed immediately after landing.

A total of 1670 specimens were collected, and the biological parameters measured were total fish length (LT, to the nearest 0.5 cm) and total weight (W, to the nearest 0.1 g). Pairs of sagittal otoliths were removed and stored dry in paper envelopes. The left of each pair of unpolished otoliths was embedded in black polyester resin and sectioned through the center of the nucleus in the dorsal–ventral direction, with a thickness of 500 μm (Beamish, 1979). Sections were cut using a Struers model Accustom-50 thin-sectioning machine. The sectioned otoliths were covered with glycerol to highlight the growth increments (Abecasis et al., 2008; Cengiz et al., 2013) and observed under a binocular microscope with reflected light at 10× to 40× magnification. A few otoliths, accounting for 12% of the sample, were deemed unreadable due to physical damage incurred during handling and processing. This damage posed challenges in accurately discerning the growth rings crucial for age determination, resulting in their exclusion from the analysis.

To assess the comparison between different ageing techniques for a subsample of 338 individuals, the right otolith was studied as a whole (i.e., without sectioning) following Bagge (2014). The annular pattern in whole otoliths was observed under reflected light against a dark background at 8–25× magnification, with the *sulcus acusticus* faced down and immersed in ethanol (70%), which made the translucent bands more distinct. In this study, each year of age (annulus) was assigned by counting pairs of opaque and translucent zones. The first year was assigned to the central opaque nucleus and the first translucent zone immediately adjacent to it, and thereafter only opaque–translucent pairs that grew completely around the otolith were counted as annuli (Gettel et al., 1997).

The age estimations obtained from sectioned otoliths were compared with those determined from the whole otoliths with a t-test for paired samples followed by McNemar's test of symmetry (Baudouin et al., 2016; Evans & Hoenig, 1998). To compare the ages of sectioned otoliths with those detected by the otolith analysed as a whole, we also subtracted the age obtained by the sectioned otolith from the mean age obtained by the whole otolith for each age class following Beamish (1979). To ensure precision, the age of a subsample of 100 individuals was independently estimated by two scientists using the sectioned otolith method. The precision of estimates between readers (same method, different readers) was measured by the mean c.v. (Campana, 2001) defined as:

$$\text{c.v.} = 100 \times \left[\left(\sum_{j=1}^{n} \frac{s_j}{x_j} \right) / n \right]$$

where x_j is the mean age for the j-fish; n is the number of aged fish in the sample; and s_j is the standard deviation of the age estimates for the j-fish.

The von Bertalanffy growth equation (von Bertalanffy, 1938) was fitted using the estimated ages from sectioned otoliths according to the following formula:

$$\text{LT} = L_\infty \left(1 - e^{-k(t - t_0)} \right)$$

where LT is the total length at age t; k is the growth rate; L_∞ is the asymptotic LT at which growth is 0; t is the age of the fish; and t_0 is the theoretical age at zero size. We compared the von Bertalanffy growth curve obtained from sectioned otoliths with that published by Bagge (2014) from the whole otoliths for the Kattegat area.

Collected individuals varied in LT from 12 to 41 cm (Figure 1b). The mean ranges and standard error for LT and weight of male and female are presented in Table 1. The overall sex ratio was dominated by males (58.3%), especially in smaller size classes (12–28 cm), whereas females mostly belonged to larger length classes (29–42 cm), as shown in Figure 1b.

Ages determined with the whole otoliths method were significantly different ($p < 0.01$) from ages detected through the sectioning method. The plot of the mean deviation of the whole otoliths ages against the sectioned otolith ages (Figure 1c) shows that the estimates by using the whole otoliths were similar to the sectioned otolith ages up to 8, whereas there is an underestimation that increased with an increase in sectioned otolith age (Figure 1c) as detected by McNemar's symmetry test ($p < 0.05$). The precision of estimates between readers for the sectioned otoliths has a mean c.v. of 6.38%.

Growth curves for males and females estimated using sectioned otolith show similar annual growth up to age 5 (black line) when compared to Bagge (2014) (red line), after which mean lengths for females are significantly larger (t-test $p > 0.05$) (Figure 1d). The estimated parameters of von Bertalanffy's growth curve, both L_∞ and k, obtained from sectioned otoliths were significantly different from those of Bagge (2014) (t-test $p > 0.05$). Using sectioned otoliths, both sexes grew faster than previously estimated until age 8 and slowed down thereafter when approaching L_∞, which was estimated to be smaller compared to Bagge (2014). The estimated maximum age using the whole otolith was 18, whereas it was 26 when sectioned otolith was used, with a maximum difference of 7 years for the same individuals when analysed using both methods.

Reanalysis of the growth of greater weever in the Kattegat-Skagerrak, eastern North Sea, using otolith sectioning revealed a higher maximum age than previously known by studying the whole otolith. The use of thin sections of otoliths mounted in black resin offers several advantages over the traditional methods of ageing (Easey & Millner, 2008), and it greatly improves the contrast between opaque and translucent zones. This enhancement enables precise identification of the ring structure on any part of the otolith using reflected light (Easey & Millner, 2008). This advantage holds true for the otoliths of greater weever collected in the Kattegat-Skagerrak region as well. Despite the additional time required for the preparation of thin sections compared to whole otoliths, the benefits are significant. Once produced, an experienced reader of otoliths can age a larger number of otoliths than previously feasible. This increased efficiency is coupled with enhanced confidence in the age determination due to the improved clarity of the zones observed in the thin sections. This allows a greater accuracy in the age determination, particularly of older individuals, for which recently deposited translucent rings are difficult to count (Vitale et al., 2019). The life-history traits described here (i.e., higher maximum age) for greater weever populations contribute to their increased vulnerability to exploitation (Cailliet & Andrews, 2008). This novel finding in conjunction with the lack of assessment and management measures for the stock in the Kattegat-Skagerrak area puts the species at risk of overexploitation in an area with the highest fishing effort by square kilometers in Europe (Eigaard et al., 2017). Therefore, considering the species' biology, it would be highly advisable to conduct an assessment and implement management strategies for greater weever in the Kattegat-Skagerrak region.

TABLE 1 Descriptive statistics for females and males of greater weever collected in the Kattegat-Skagerrak.

Sex	N	Minimum LT (cm)	Maximum LT (cm)	Mean LT ± s.e. (cm)	Minimum W (g)	Maximum W (g)	Mean W ± s.e. (g)
Female	696	14	41	29.41 ± 0.16	19	435	189.11 ± 2.81
Male	974	12	36	24.99 ± 0.14	9	302	111.35 ± 2.33
All fish	1670	12	41	26.83 ± 0.11	9	435	143.73 ± 1.78

Abbreviations: LT, total length; W, total weight.

AUTHOR CONTRIBUTIONS

MM and AO contributes to writing and statistical analysis, JL, FV and MC contributes to writing.

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