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Age and changes in growth of the king weakfish *Macrodon atricauda* (Günther, 1880) between 1977 and 2009 in southern Brazil

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ABSTRACT

The coastal demersal sciaenid *Macrodon atricauda* (Günther, 1880), formerly *M. ancylodon* (Bloch and Schneider, 1801) was sampled for ageing during four periods (1977–1979, 1984–1986, 1997–1998 and 2006–2009) in commercial fishing and scientific surveys along southern Brazil (Lat. 30°S–34°40′S). Maximum observed age was seven years, but no fish over five years old was sampled in the last period. Marginal increment analysis of thin sections validated ageing and showed that opaque and translucent bands were laid down at all ages in spring–summer and autumn–winter, respectively. Ageing *M. atricauda* based on sectioned otoliths is highly recommended because comparisons with readings on whole otoliths showed that ages based on whole otoliths exceeded those based on sectioned otoliths for 56.5% of the aged specimens. The growth of *M. atricauda* has increased in the last four decades, most noticeably in the case of adult males over two years old and females over three years old. A threefold decrease in its density and the demersal fish community as a whole are the most likely causes of the growth increase.

1. Introduction

The king weakfish *Macrodon atricauda* (Günther, 1880) had its taxonomical status reviewed by Carvalho-Filho et al. (2010). Until recently, the accepted scientific name for king weakfish from southern Brazil was *Macrodon ancylodon* (Bloch and Schneider, 1801), with a distribution range in the western Atlantic from northern Patagonia (Lat. 43°S) in Argentina (Cousseau and Perrota, 1998) to Venezuela (Menezes et al., 2003). More recently, Santos et al. (2006) and Carvalho-Filho et al. (2010), based on genetic, meristic and morphological evidences, concluded that two distinct species occur in this geographic range: the subtropical *M. atricauda* from Espirito Santo, Brazil (Lat. 20°S) to the south and the tropical *M. ancylodon*, to the north.

In southern and southeastern Brazil, *M. atricauda* has been a major target of the bottom trawl fishery since the late 1950s (Yamaguti and Moraes, 1965; Yesaki and Bager, 1975; Valentini et al., 1991; Haimovici, 1998; Carneiro and Castro, 2005). It has also been fished in Uruguay and Argentina (Cousseau and Perrota, 1998). Because of its importance as a fishing resource, several aspects of its biology and population dynamics have been studied, including reproduction (Yamaguti, 1967; Juras and Yamaguti, 1989; Militelli and Macchi, 2004), feeding (Juras and Yamaguti, 1985), migration (Santos and Yamaguti, 1965), mortality (Yamaguti, 1968) and the age and growth of sub-adults and adults (Yamaguti and dos Santos, 1966; Haimovici, 1988).

Age determination is an important tool in fishery biology which, along with length and weight measurements, provides information on growth, age at maturity, longevity and mortality (Bagenal and Tesch, 1978). Several structures are used to age bony fishes, but otoliths are the most frequently used because they are easy to collect and preserve. Besides, information on the whole life span of the fish is recorded in this structure (Casselman, 1990; Green et al., 2009). Depending on its size and shape, the entire otolith can be read, but it can also be cut through the nucleus or in thin sections (Chilton and Beamish, 1982)

The king weakfish otolith is laterally compressed and relatively large; on its outer surface, opaque and translucent bands can be distinguished. These bands have been interpreted to be annuli in previous age and growth studies of the king weakfish in southern Brazil (Yamaguti and dos Santos, 1966; Haimovici, 1988). Although ageing has been validated through marginal increment analysis, it is difficult to identify the translucent bands on the outer edge of otoliths. Therefore, the first translucent band can easily be confused with false or juvenile rings (Haimovici, 1988). Errors in ageing influence both growth and mortality estimates. For this reason, whole otoliths, previously read from 1984 to1986, were sectioned and the readings were compared.

Changes in growth of heavily exploited fishes are common (Law, 2000) and can be attributed to density dependent causes (Bromley, 1989; Millner and Whiting, 1996; Jennings et al., 1999) or

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density independent causes, such as eutrophication (Rijnsdorp and van Leeuwen, 1996) and temperature (Thresher et al., 2007). Since the beginning of industrial fishing between Chui and Santa Marta Grande Cape (Lat. 28°S–34°40′S) in the 1950s, the king weakfish, as well as most demersal fishes, has been intensely exploited (Yesaki and Bager, 1975; Haimovici, 1998; Haimovici et al., 2006b). The availability of otoliths collected between 1976 and 2009 made it possible to evaluate changes in the growth of *M. atricauda* in southern Brazil.

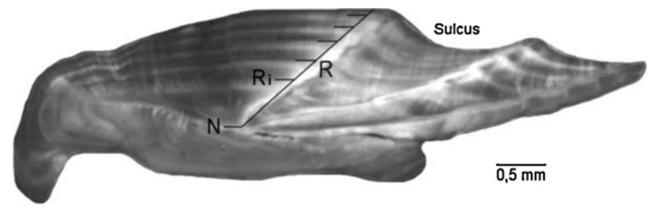

Fig. 1. Thin section examined with reflected light of a five-year-old female (*L*: 368 mm) *Macrodon atricauda* from southern Brazil. Black bars indicate the end of each opaque band. N: nucleus, R_i: the distance from the nucleus to the end of each opaque band; *R*: the distance from the nucleus to the inner edge. Opaque bands can be seen as white bands whereas translucent ones can be seen as dark bands.

2. Material and methods

Specimens sampled for ageing were landed by commercial bottom trawler in Rio Grande from 1976 to 2009 (Haimovici, 1987) and from bottom trawl surveys along southern Brazil between latitudes 30°S and 34°40′S (Haimovici et al., 1996, 2005). Samplings comprised measurements of total length (*L*, mm) and total weight (*W*, g), sex determination and extraction of *sagittae* otoliths. Otoliths of specimens that represent the whole size range and all months of the year (whenever samples were available) were selected in each one of the four periods: 1977–1979, 1984–1986, 1997–1998 and 2006–2009.

Thin transverse sections (0.20–0.25 mm) through the nucleus were made in otoliths embedded in a polyester resin with a single high concentration diamond blade of a Buehler–Isomet low-speed saw. All sections were mounted on glass slides with xylol base mounting media (ENTELAN Merck®).

Sections were examined with transmitted light under a compound microscope (35×). The opaque (clear) bands were counted, the distances from the nucleus to the end of each opaque band (R_i) and to the inner edge (*R*) were measured (in micrometric units) along the dorsal border of the sulcus and the opacity of the inner edge was recorded (Fig. 1). After several preliminary readings, the opaque bands were counted independently by two readers. A third joint reading was carried out and, in cases of disagreement, results were discarded.

The mean coefficient of variation (CV) was used to evaluate the precision of the annual increment counted between readings (Campana and Jones, 1992):

$$CV_j = 100\% \times \frac{\sqrt{\sum_{i=1}^{R}(X_{ij} - X_j)^2/(R-1)}}{X_j}$$

where CV_j is the age precision estimate for the *j*th fish; X_{ij} is the age determination of the *j*th fish by the *i*th reader; X_j is the mean age of the *j*th fish and *R* is the number of readings.

Ages read in the sectioned otoliths of 238 specimens sampled from 1984 to 1986 were compared with those read in the same whole otoliths by Haimovici (1988), who examined the outer surface of the otoliths with reflected light over a black background.

The periodicity of the formation of opaque and translucent bands on the edge of the otoliths was evaluated. It was based on the analysis of the type of edge and marginal increment (MI). The translucent and opaque bands on the edge of the otolith section were counted monthly and displayed as relative frequencies (%). The monthly mean width of the translucent bands formed on the edge of the sections was calculated for each specimen and grouped monthly for each age class. The MI was calculated as the quotient between the distance from the nucleus to the end of the last opaque

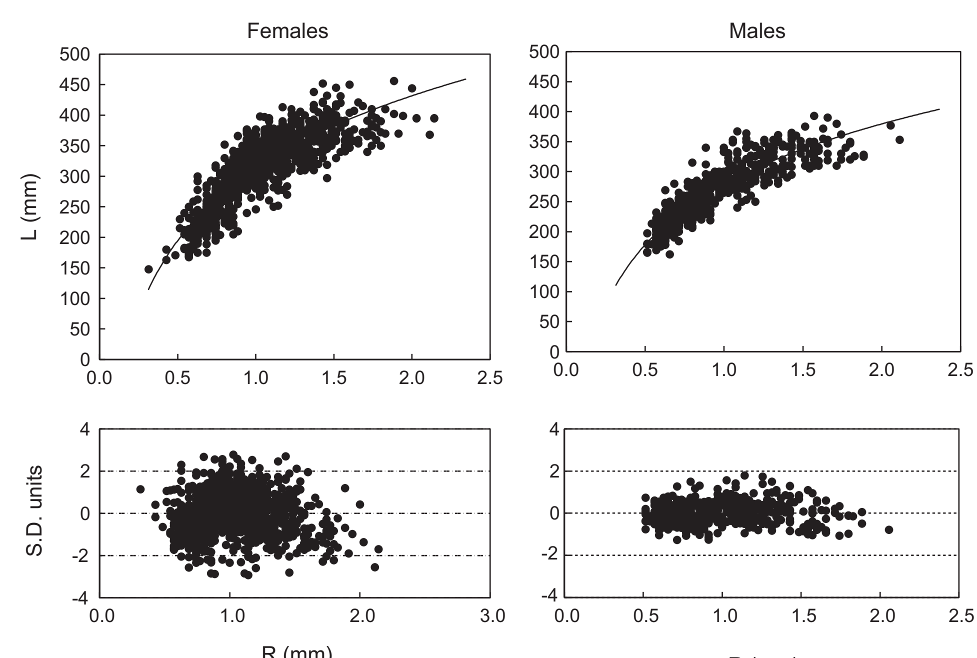

Fig. 2. Relationship between total length *L* (mm) and the distance from the nucleus to the inner surface of the otoliths *R* (mm) of Macrodon *atricauda*. Lower panels: error distributions in standard deviation units.