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A Preliminary Investigation of Age and Growth of *Otolithes ruber* from KwaZulu-Natal, South Africa

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Abstract—This study investigated age and growth of *Otolithes ruber*, found in KwaZulu-Natal, South Africa. The specimens were collected from prawn trawlers that operate off the shallow water Tugela Bank and from a recreational boat fishery in Durban. Estimates of age and growth parameters were based on the examination of sectioned sagittal otoliths.

There was difficulty in estimating growth parameters for separate sexes because the small fish were not sexed and the numbers of males was low. Periodicity of growth zone formation was assumed to be annual although periodicity of growth zone deposition could not be established by marginal zone analysis. The von Bertalanffy growth curve was used to describe the combined male and female growth of *O. ruber*:

$L_t = 419\text{mm TL } (1\text{-e}^{-0.31\,(t+0.96)})$

The maximum age estimated was eight years. The repeatability of the age estimates was relatively high (Average Percentage Error: 12.5%). The information gathered from this study will be used in a subsequent stock assessment.

INTRODUCTION

Otolithes ruber (Schneider, 1801) is a species from the family Sciaenidae, and is known as the snapper kob in South Africa, corvina dentuça in Mozambique, jew fish in India and the Malindi herring in Kenya. The family Sciaenidae is widely distributed in shelf waters of tropical and subtropical Indian, Pacific and Atlantic oceans (Lowe-McConnell, 1962; Druzhinin, 1974; Trewavas, 1977; Longhurst & Pauly, 1987; Sasaki, 1996). *O. ruber* is widely distributed in the Indo-West Pacific (Smith & Heemstra, 1986) and along the east coast of Africa where it occurs in tropical and subtropical shelf waters, south to at least Durban, South Africa (29°51'S; 31°02'E) (Smith & Heemstra, 1986) and north to the Red Sea (43°38'N; 12°57'E) (van der Elst, 1988).

In South Africa, Mozambique, Tanzania and Kenya, *O. ruber* is caught as a bycatch on penaeid prawn trawlers (Schultz, 1992; Fennessy, 1994a; Alverson *et al.*, 1994; Mwatha, 2002). *O. ruber* is also caught by recreational hook and line fishing in South Africa (Beckley & Fennessy, 1996), and by subsistence gill-nets, beach-seines and line fishing in Mozambique (Baloi *et al.*, 2000; Claudia, 2001; Santana Afonso & Mafuca, 2001). In Tanzania and Kenya *O. ruber* is caught by means of gill-nets and hand lines (Fischer & Bianchi, 1984; Mwatha, 2002).

Aspects of the biology of this species have been investigated by several authors. *O. ruber* are sluggish carnivores (van der Elst, 1988), that are found over sandy and muddy substrata but do not inhabit rocky areas (Navaluna, 1982). They mature at a size of between 220mm and 240mm total

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length in India (Vaidya, 1960) and 237mm (females) total length on the KwaZulu-Natal coast (Fennessy, 2000). The spawning season is extended and occurs in summer (Wallace & van der Elst, 1975; Fennessy, 2000; Vaidya, 1960; Wallace, 1975). Schultz (1992) and Navaluna (1982) have undertaken studies of growth rate based on modal length analysis in Mozambique and the Philippines respectively. However, this species has not been aged, and growth rate, which is an important indicator of how heavily a species can be harvested, has not yet been established for the South African stock. The aim of this study was therefore to estimate the age of *O. ruber* from KwaZulu-Natal, South Africa, using sectioned otoliths and to determine longevity, growth rate and age at maturity. The information will subsequently be used to undertake a stock assessment, which will assist in the management of this species.

MATERIALS AND METHODS

Data collection

From 1989 to 1992 an onboard observer collected bycatch data from Tugela Bank prawn trawlers in KwaZulu-Natal (Figure 1; Fennessy, 2000). From each trawl, a 20kg random sub-sample of the bycatch was collected and sorted. Sagittal otoliths from *O. ruber* were collected on an ad hoc and irregular basis from these trawl samples from June 1989 to September 1992. Although no formal protocol was employed for the collection of otoliths, attempts were made to obtain otoliths in each month and over the full size range caught by the trawlers. The fish from which otoliths were collected were measured (total length, TL) in mm and sexed macroscopically. In addition, otoliths were also collected on an ad hoc and irregular basis from *O. ruber* caught by recreational boat anglers in Durban from September 1993 to February 1994. All data (including otoliths) are housed at the Oceanographic Research Institute and can be made available on request.

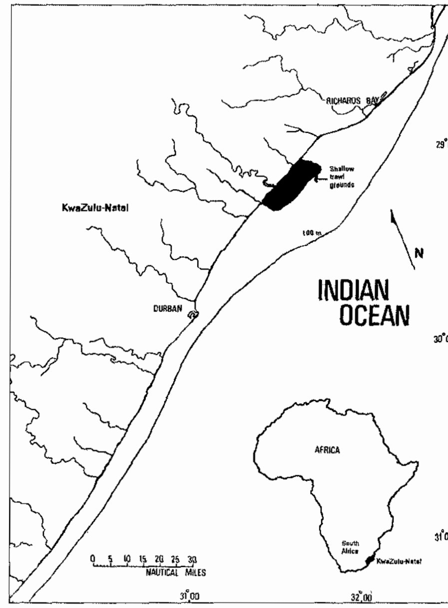

Fig. 1. Trawling grounds on the Tugela Bank in KwaZulu-Natal, South Africa

Age estimation

One otolith from each pair was selected at random, and ground along its longitudinal axis using a grinding stone to expose the nucleus. The otolith was then attached to a glass slide using a clear adhesive and the opposite side was ground until alternating dark and light zones were visible. The otoliths were then viewed under transmitted light on a dissecting microscope at 10-12x magnification. One light (hyaline) and one dark (opaque) zone were collectively interpreted as one year's growth. The age estimates were obtained by reading each otolith at least twice. If the two age estimates did not coincide, a third reading was taken. When the three readings differed by one year, the median age of the three readings was used. However, when all three readings differed by more than one year, that otolith was discarded. Otoliths were read with no reference to the length or weight of the fish. The average percentage error method (APE; Beamish & Fournier, 1981) was used to assess the repeatability of the age estimates. All age estimates were used to obtain the APE.

The APE is described by:

$$APE = 100\left[\frac{1}{n}\sum^{n}\left(\frac{1}{R}\sum_{i=1}^{R}\frac{|Xij - Xj|}{Xj}\right)\right] \quad (1)$$

Where:
n = number of fish aged
R = number of age counts per fish
Xij = ith age determination of the jth fish, and
Xj = average age calculated for the jth fish

Age validation

Numerous factors influence the growth of a fish and therefore there is a need to determine the periodicity of zone formation (Beamish & McFarlane, 1983; Fletcher and Blight, 1996; Newman *et al.*, 1996). In order to establish this, the occurrence on a monthly basis of an opaque or a hyaline zone on each otolith margin was recorded. A maximum of 20 otolith margins was examined each month. The percentage frequencies of hyaline and opaque zones were plotted on a monthly basis to determine seasonality of zone deposition (marginal zone analysis). Monthly data were pooled across all years for the period 1989 to 1994.

Growth determination

The von Bertalanffy growth model (von Bertalanffy, 1957) was fitted to the observed length-at-age data for males, females and both sexes combined.

The von Bertalanffy growth curve is:

$$L_t = L\infty\ (1-e^{-k(t-t_0)}) \quad (2)$$

Where:

L_t = mean length at age t
k = growth constant
t_0 = theoretical age at zero length
$L\infty$ = theoretical maximum length according to the equation.

The estimates of the growth parameters $L\infty$, k and t0 were obtained by minimising the sum of the squared differences between observed and predicted lengths-at-age using the solver routine in Microsoft® Excel®.

RESULTS

Data Collection

Pooled numbers of fish sampled from trawler bycatch and recreational boat angler catches are shown in Table 1.

Age estimation

Of the 288 otoliths examined 25 (8.7%) were discarded either because they were unreadable (n=3; 1%) or because the three age estimates differed by more than one year (n=22; 8%). A total of 107 (37%) otoliths had three readings that differed by less than one year and 156 (54%) had two readings that coincided. The maximum age estimated was eight years and only three fish had an age estimate of less than one year. Aged fish ranged in length from 84mm TL to 485mm TL. A relatively high APE of 12.5% was calculated, which indicated a moderate to poor reproducibility of age estimates.

Sectioned otoliths showed reasonably clear growth zones, with each zone consisting of a wide, clear, hyaline zone and a narrow, dark, opaque zone (Fig. 2). However, the zonation pattern was not always very distinct and age estimation was difficult.

Table 1. Pooled monthly numbers of *O. ruber* otoliths collected during the period 1989 to 1994 (n=288)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
20	5	7	0	13	15	106	19	19	9	56	18

Age validation

Marginal zone analysis showed no clear seasonal pattern (Fig. 3). Periodicity of zone formation was therefore inconclusive and could not be used to determine whether one hyaline and one opaque growth zone are deposited per annum. However, periodicity was assumed to be annual, since the growth rate parameters obtained below were similar to those obtained for this species in other studies (Schultz, 1992; Gislason, 1985).

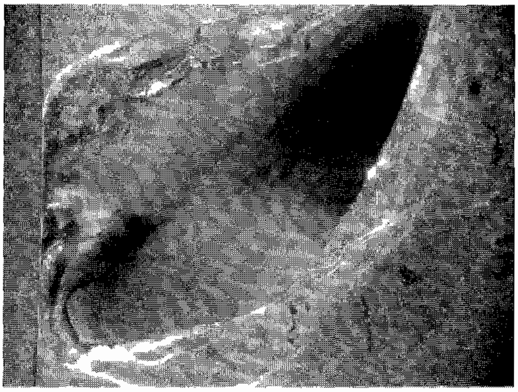

Fig. 2. Sectioned otolith from eight-year-old *O.ruber*

Growth determination

The von Bertalanffy growth equation fitted to the observed data for males and females combined was $L_t = 419\text{mmTL}(1\text{-}e^{-0.31\ (t+0.96\ )})$ (Fig. 4). Separate growth curves for males and females were not plotted because the L_∞ estimate obtained for males was substantially larger than the range of observed lengths (Table 2), and the solver routine produced inconsistent results, probably due to the small number of data points (n = 66). In addition, there was no sex information for fish smaller than 143mm TL. Therefore, a von Bertalanffy growth curve was fitted to the combined data without reference to sex. The parameters obtained are summarised in Table 2.

DISCUSSION AND CONCLUSION

Otoliths were sectioned, as they were too opaque to read in a whole state. This study found that sectioned otoliths viewed under transmitted light produced the greatest clarity of growth zones. The growth zones in otoliths generally consist of wide, hyaline zones formed during normal somatic growth and narrow, opaque zones formed during slower somatic growth (Campana & Neilson, 1985). Precision of age estimates was fairly poor, as according to Beamish and Fournier (1981), an APE value of 12.5% indicates relatively high variability and low reproducibility. A possible reason for this may be that the ground otolith sections were fairly thick (>0.5mm) and the zoning was not very clear. Difficulty may be experienced in tropical fish species where differences in temperature and thus growth are less marked seasonally (Pauly, 1984). There is no target level in APE value for ageing studies (Campana, 2001) as the precision is influenced by the species, the nature of the otolith structure and the age reader. However, studies have indicated that an APE of 5.5% is satisfactory (Beamish and Fournier, 1981).

Unfortunately there was no consistency in the timing of otolith collection, which confounded interpretation of trends in marginal zone deposition due to a lack of samples in all months of the year. Despite the lack of support from the marginal zone

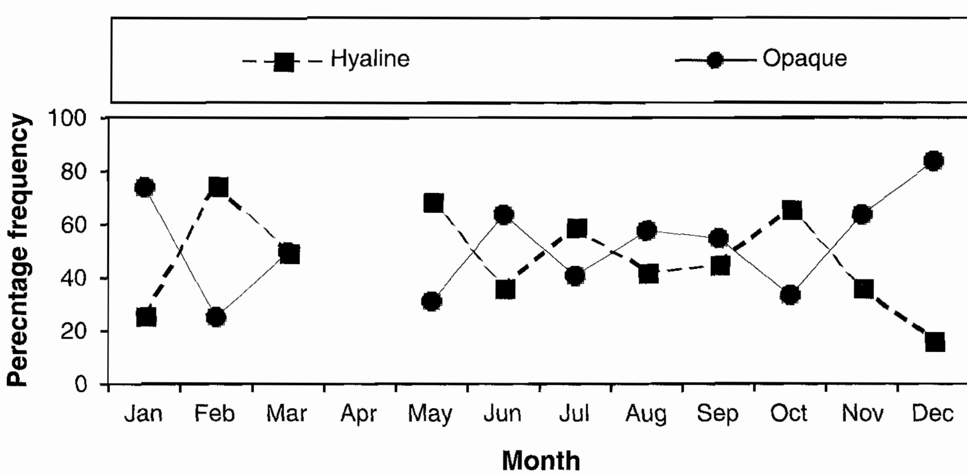

Fig. 3. Temporal changes in the proportion of opaque and hyaline zones on the margin of *O. ruber* otoliths (n=155)

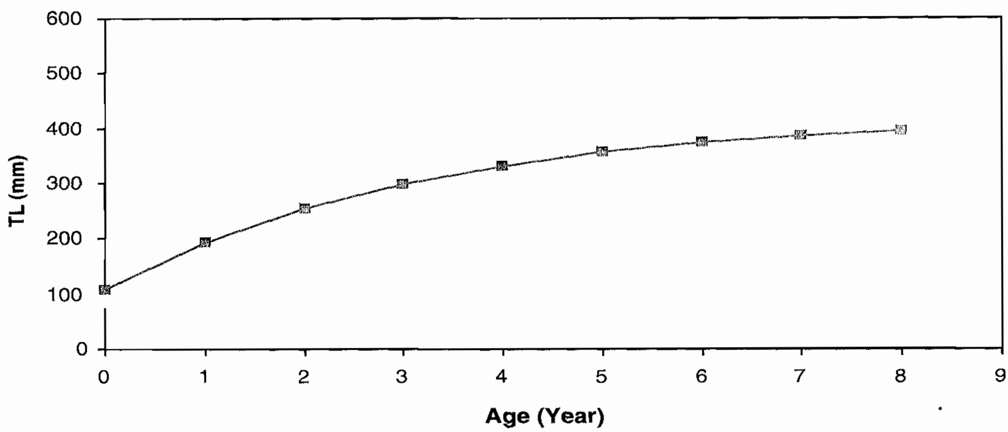

Fig. 4. The (combined sexes) age-length relationship of *O. ruber* from South Africa (n = 263)

Table 2. von Bertalanffy growth parameters for *O. ruber* from South Africa

	n	L∞	k	t_0	Min Length (mm)	Max Length (mm)
Male	66	571	0.1	-2.1	158	380
Female	164	478	0.2	-2.5	143	485
Combined	263	419	0.31	-0.96	84	485

analysis, we assumed that *O. ruber* lays down one hyaline and opaque growth zone per annum. This assumption is justified by two other studies which reported growth parameters for *O. ruber* similar to those obtained in this study, albeit based on lengths rather than otoliths (Gislason (1985) and Schultz (1992); Table 3). To further test the validity of the assumption, we then assumed that two growth zones are deposited annually (i.e. we halved our age estimates), and ran the solver routine again. This produced a k estimate of 0.66 per year, which is more than double that obtained in the studies by Gislason (1985) and Schultz (1992). Furthermore other studies that have been done on this family have also shown that growth zones are deposited annually e.g. *Pseudotolithus elongates* in Nigeria, (Nawa, 1987); *P. elongates* in Nigeria, (Etim *et al*., 1994); *P. diacanthus* in India, (Roa, 1968); *Argyrosomus japonicus* in South Africa, (Griffiths and Hecht, 1995a); *A. inodorus* in South Africa, (Griffiths, 1996); *Atractoscion aequidens* in South Africa, (Griffiths and Hecht 1995b); *Cynoscion analis* in Peru, (Samané & Okado, 1973); *C. macdonaldi* in Venezuela, (Beverton & Holt, 1959); *C. nobilis* in Florida, (Thomas, 1968), (Table 3). However, we suggest that the validation of periodicity be further investigated in subsequent studies. In order to do this, larger sample sizes for each month of the year need to be collected and examined. Another method for validating periodicity is by chemical marking or labelling of otoliths, known as fluorochrome marking (Lang and Buxton, 1993). In order to achieve this, the fish need to be kept in captivity for a period greater than one year. This method of validation should also be attempted for *O. ruber.*

The von Bertalanffy growth model was chosen to fit the age-length data as this is the most commonly used model to express fish growth (Griffiths, 1996). The parameters from the von Bertalanffy growth model can also be directly incorporated into stock assessment models (Ricker, 1975; Vaughan and Kanciruk, 1982) and are used in estimating natural mortality (Pauly, 1980). Furthermore, because von Bertalanffy parameters have been so commonly used in ageing studies, they permit comparisons of the life history styles of fish. The use of this model has been criticised because of the use of parameters such as t_0, which has little biological meaning (Schnute, 1981), and the absence of parameters that consider seasonality and growth rate. (Pauly, 1980; Moreau, 1987). Nevertheless, the von Bertalanffy growth model has been successfully used for a number of sciaenids (Griffiths & Hecht, (1995a); Griffiths,

Table 3. Comparison of von Bertalanffy growth parameters for *O. ruber* and other sciaenid species

Species	L∞ (mm)	k (per year)	Source
Otolithes ruber	419	0.31	This study
O. ruber	429	0.14	Gislason (1985)
O. ruber	459	0.32	Schultz (1992)
Pseudotolithus elongatus	480	0.28	Nawa (1987)
P. elongates	600	0.38	Etim *et al.* (1994)
P. diacanthus	1220	0.32	Roa (1968)
Atractoscion aequidens	1124	0.27	Griffiths & Hecht (1995b)
Argyrosomus inodorus	1086	0.41	Griffiths (1996)
A. japonicus	1372	0.26	Griffiths & Hecht (1995a)
A. thorpei	518	0.29	van der Elst *et al.* (1990)
Johnius dorsalis	195	0.90	Fennessy, unpublished data
Cynoscion analis	620	0.12	Samané & Okado (1973)
C. macdonaldi	1280	0.30	Beverton & Holt (1959)
C. nobilis	1460	0.13	Thomas (1968)

(1996); Navaluna, (1982); Barger, (1985); Beverton & Holt, (1959); Le Guen, (1971); Roa, (1968); Samané & Okado, (1973); Thomas, (1968)). The values of k presented in Table 3, indicate that most members of this family, including *O. ruber,* are generally slow-growing and long-lived.

According to Navaluna (1982) and Schultz (1992) *O. ruber* has been over-fished by trawlers in the Philippines and Mozambique. Substantial numbers of this species are being caught by prawn trawlers in South Africa, Fennessy (2000); Fennessy (1994a); Fennessy (1994b), so a stock assessment needs to be carried out in order to determine whether the South African stock of *O. ruber* is being over-fished.

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