Age and growth of the estuarine-dependent sparid *Acanthopagrus berda* in northern KwaZulu-Natal, South Africa

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Ages were estimated for the tropical sparid, *Acanthopagrus berda,* caught in northern KwaZulu-Natal estuaries. Whole otoliths were used in the age determination. Age estimates were validated by marginal increment analysis and oxytetracycline labelling, which indicated that opaque deposition occurs primarily from September to November each year. The reproducibility of age estimates was described by a coefficient of variation of 10%. The von Bertalanffy growth curve was found to best describe the growth of *A. berda*. The parameters of the von Bertalanffy growth curve indicated that *A. berda* in northern KwaZulu-Natal is a slow-growing species, capable of reaching at least 16 years of age. Longevity of the species, coupled with sex change, late maturation and estuarine dependency, give cause for concern for the continued sustainable utilization of this species.

Key words: whole otoliths, von Bertalanffy growth curve, slow growing, long-lived.

INTRODUCTION

The riverbream or perch, *Acanthopagrus berda* (family Sparidae), is widespread in the tropical Indo-Pacific region, occurring from South Africa to India, northern Australia and Japan (Smith & Heemstra 1986; Garratt 1993). In South Africa it is found along the east coast, where its range extends southwards to Port Elizabeth (33°58′S, 25°36′E). It is one of 22 species of fishes found in South Africa that are dependent on estuaries in the juvenile phase of their life cycles (Wallace *et al.* 1984). Adult *A. berda* are also estuarine dependent, rarely being found in the marine environment. Like many other members of the sparid family, *A. berda* changes sex and is one of several known protandrous sparids in South Africa (Garratt 1993). *A. berda* is a fairly small sparid, and although the maximum length recorded for the species is 750 mm TL, the majority caught in South African waters are <400 mm TL (Smith & Heemstra 1986). Length at 50% maturity has been established at 220 mm TL (Wallace 1975).

In South African estuaries, *A. berda* is harvested by a variety of methods, which include hook and line, gill nets and traditional fish traps. It is a particularly important component of the recreational and subsistence catch taken in the three large northern KwaZulu-Natal estuaries, namely Kosi Bay (26°54′S, 32°53′E), St Lucia (28°23′S, 32°25′E) and Richards Bay (28°48′S, 32°05′E) (James 2001, James *et al.* 2001; Mann *et al.* 2002).

The reproductive and feeding biology of *A. berda* have been studied in South Africa (Wallace 1975; Wallace & van der Elst 1975; Harrison 1991; Garratt 1993). Though age and growth of *A. berda* has been studied in Kuwait (Samuel & Mathews 1987) no work has been published on age and growth of the species in South Africa. The aim of this study was to investigate the age and growth of *A. berda* in northern KwaZulu-Natal estuaries to provide a basis for assessing the sustainability of this fishery.

METHODS

Fish were sampled primarily by seine netting in Richards Bay between 1987 and 1991. Additional opportunistic samples were collected by spearing in Kosi Bay and rod and line in Durban harbour (29°52′S, 31°03′E) during the period 1998–2000. The fork length (FL) of each fish was measured (mm), and, where possible, sex was macroscopically determined. Sagittal otoliths were removed from the auditory bullae, cleaned, dried and stored in paper envelopes prior to ageing.

A total of 403 otolith pairs was collected in this study. Age estimates were obtained by counting the number of opaque increments in whole otoliths. The otoliths were placed in a solution of glycerine, as this was found to enhance the

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visibility of growth increments, and read under reflected light, against a black background, using a low-power dissecting microscope. One otolith from each pair was read twice by a primary reader and once by a second reader. Readings were made at least two weeks apart, with no reference to previous readings or fish length. Age estimates were only used if two or more of the readings coincided.

To ensure that age estimates from whole otoliths were reliable, otoliths from a sub-sample of 60 *A. berda* were sectioned and age estimates compared with those obtained from the whole otoliths. The sub-sample was selected based on the ages estimated (approximately 10 otoliths were selected from each age class (0–2; 3–5 etc.). Otoliths were sectioned using the methods described by Mann & Buxton (1997), examined under transmitted light using a low-power dissecting microscope and dark opaque zones counted. The difference between age estimates from whole and sectioned otoliths was plotted against the age estimates obtained from the sectioned otoliths. Thereafter, linear regression techniques as described by Newman *et al.* (2000) were used to determine if significant relationships existed between the readings obtained from the whole and sectioned otoliths.

Precision of age estimates was determined by estimating the coefficient of variation (CV), which expresses, as a percentage, the standard deviation of replicated age counts per fish as a fraction of the mean (Chang 1982). The CV is given by the equation:

$$CV = 100 \times \left[\frac{1}{N} \sum_{j=1}^{N} \left[\sqrt{\sum \frac{\frac{(X_{ij} - X_j)^2}{R-1}}{X_j}} \right] \right],$$

where N = the total number of fish aged, R = the number of times each fish was aged, X_{ij} = ith age determination of the jth fish, and X_j = average age calculation for the jth fish

In order to validate whether single opaque increments were deposited annually, marginal increment analysis and oxytetracycline labelling was performed. Marginal increment analysis required examining the optical nature of the outer margin of the otoliths on a monthly basis for the presence of opaque increments on the edge. In order to avoid biasing the results, the margins of the otoliths were examined with no knowledge of the time of year when the otoliths were collected.

To undertake an oxytetracycline (OTC) labelling experiment to validate annual deposition of growth zones (Beamish & McFarlane 1987), a sample of eight *A. berda*, ranging in size from 131 mm FL to 204 mm FL, was caught in the Umgeni Estuary (29°49′S, 31°02′E), using hook and line in July 2000. The fish were transported to an aerated flow-through pool (6000 litres) located nearby at Sea World, Durban, and allowed to acclimate for a period of 2 weeks. Thereafter the fish were caught, measured and tagged by inserting an IDENTIPET passive transponder (microchip) below the left pectoral fin. Each fish was injected intramuscularly between the dorsal fin and the pectoral fin with a 0.5 mg/kg fish dosage of Terramycin (1 ml contains 100 mg of oxytetracycline hydrochloride), as recommended by Lang & Buxton (1993). The fish were then returned to the pool and fed daily. Unfortunately, as a result of fungal infection, the injected fish died after 11 months in captivity. However, all fish were re-measured and the otoliths removed and stored in the dark until viewing. The otoliths were examined whole under low magnification using reflected ultra-violet light. The position of the fluorescent OTC band was marked on the otoliths and the number of opaque and translucent increments distal to the fluorescent band counted.

A single birth date of June was assigned to *A. berda* (after Williams & Bedford 1974), as peak spawning occurs in June (Garratt 1993). Age-at-length data for males, females and both sexes combined were then fitted to the von Bertalanffy, generalized von Bertalanffy, as well as the Richards and Schnute growth models using an iterative, non-linear minimization procedure. The runs and homoscedasticity tests (Punt 1992) were used to determine the goodness of fit of the growth models and an *F*-test (Draper & Smith 1981) was used to determine whether the models were significantly different from each other. Five hundred conditioned parametric bootstraps, were run to calculate standard errors and confidence intervals of the parameters for the different growth models. The software PC-YIELD (Punt 1992) was used for the above analyses.

RESULTS

The 403 fish sampled ranged in length from 70 mm FL to 470 mm FL (Fig. 1). Males and juveniles dominated the smaller size classes and females

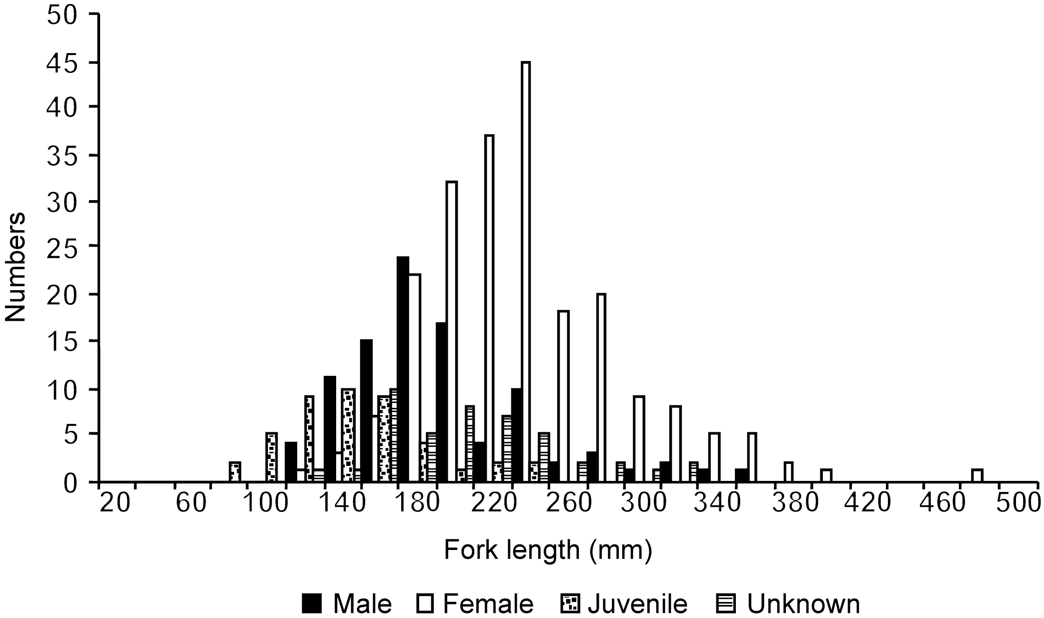

Fig. 1. Length frequency and sex of the 403 *Acanthopagrus berda* caught for ageing purposes in northern KwaZulu-Natal estuaries between 1987 and 2001.

the larger size classes. Despite a predominance of females, some males were also recorded in the larger size classes.

Age estimates from whole otoliths were not significantly different from ages estimated from sectioned otoliths ($P_{slope} = 0.120$; $P_{intercept} = 0.626$). The age estimates derived from the whole otoliths were neither consistently higher or lower than those estimated from the sectioned otoliths (Fig. 2), so all the otoliths were read whole.

Of the 403 otoliths read, 57% of readings coincided on all three occasions, while 40% coincided twice. The remaining 3% yielded conflicting ages and were excluded from the analysis. A CV of 10% was recorded for the three sets of age readings, indicating good agreement between readings. Marginal increment analysis (Fig. 3) indicated that opaque increment deposition occurred primarily

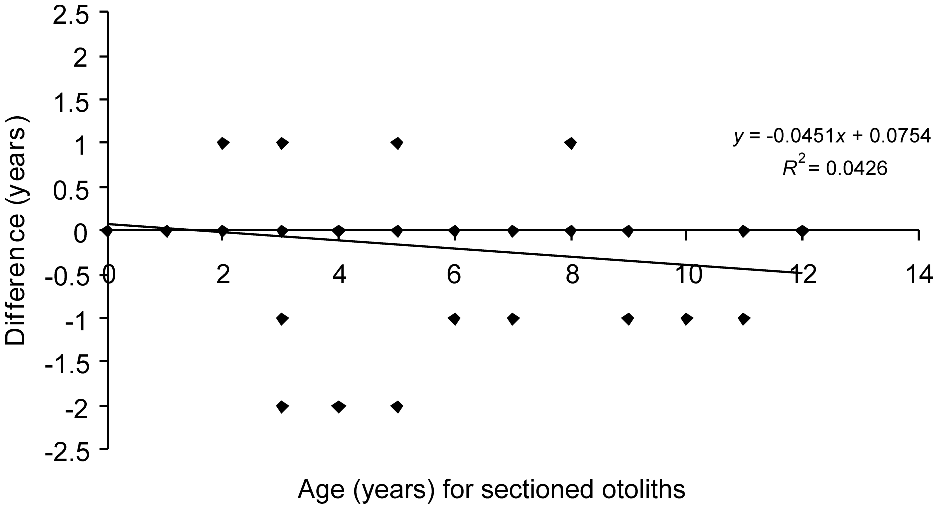

Fig. 2. Difference between age estimates obtained from whole and sectioned otoliths plotted against age estimates from sectioned otoliths of *Acanthopagrus berda.*

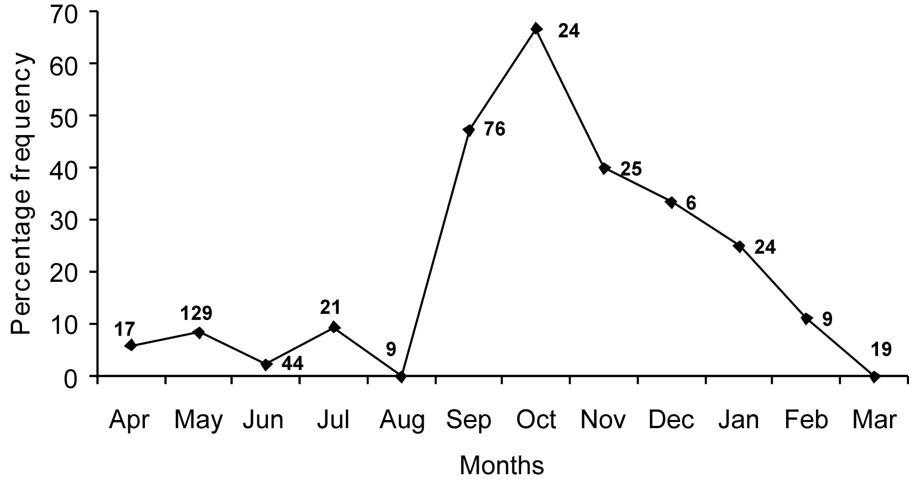

Fig. 3. Monthly changes in the percentage frequency of otoliths with opaque increments on their margins (numbers in the graph refer to the number of fish sampled in each month).

from September to November each year.

Oxytetracycline labelling provided an additional method of validation. A fluorescent OTC band could be seen on all the otoliths of the fish used in the experiment. One translucent increment and the beginning of an opaque increment, on the margin, could be discerned distal to the OTC mark on each otolith. These results provide strong evidence that one opaque and one hyaline increment are deposited annually.

The maximum age recorded was 16 years, with most *A. berda* sampled falling in age classes between one to seven years. Observed lengths were highly variable within age groups (Fig. 4).

Growth

Both the Schnute and von Bertalanffy models passed the runs test, which indicates that the residuals were randomly distributed at the 5% level of significance. However, both models failed the test for homoscedasticity at the 5% level. This can be expected as the data have been split into fractions of years based on birth date that can lead to high within-group estimates of variance when compared to the total variance in the sample. An F-test revealed that the von Bertalanffy model, assuming an absolute error structure, was statistically superior (F = 0.0036, d.f. = 1, 381) to the Schnute growth model.

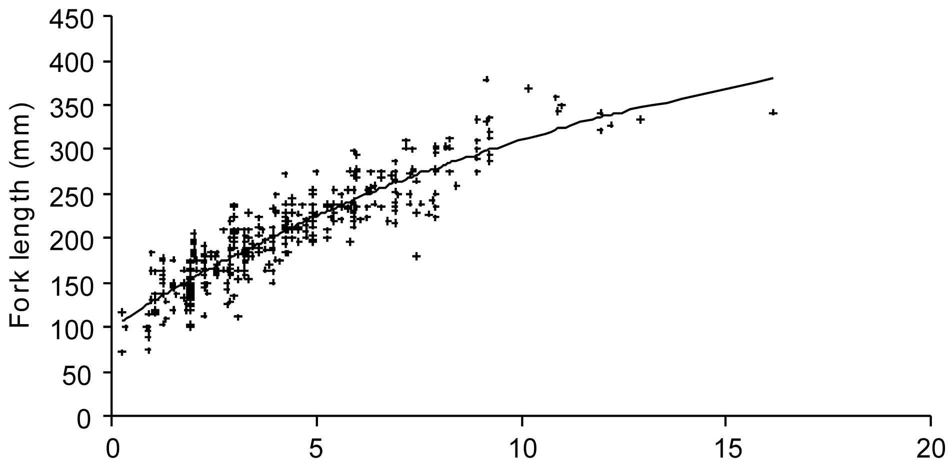

Fig. 4. A von Bertalanffy growth curve fitted to the age–length data for *Acanthopagrus berda* (males and females combined) caught in northern KwaZulu-Natal estuaries between 1987 and 2001.

Table 1. Estimates of the parameters of the von Bertalanffy growth model for *Acanthopagrus berda*, their estimated standard errors and 95% confidence intervals (CI).

Parameter	Value	S.E.	Left 95% CI	Right 95% CI
L_∞ (mm FL)	499.914	68.840	418.780	683.040
K (per year)	0.075	0.016	0.044	0.106
t_0	–2.995	0.426	–3.997	–2.278

Attempts were made to fit the von Bertalanffy growth model separately to the male and female data sets. However, the female data set failed the runs test and displayed a linear fit with no curvature. This was probably due to the small number of females in the lower length classes (Fig. 1). There were also many juveniles and fish that were not sexed in the data set, which made sex-specific analyses problematic. As a result, the growth models were fitted to the full data set. Estimates of the parameters of the von Bertalanffy model, their standard errors and their 95% confidence intervals are shown in Table 1, while the von Bertalanffy growth curve is depicted graphically in Fig. 4.

DISCUSSION

Most of the fish caught by seine netting were between 160 and 300 mm FL. Subsequent spearing and hook and line fishing succeeded in obtaining larger specimens necessary for the completion of the growth curve. *Acanthopagrus berda* is a protandrous hermaphrodite, which changes sex from male to female. However, not all males change sex (Tobin & Sheaves 1997) and the results of this study confirm this as a few males were present in most of the larger size classes. As few fish <160 mm FL were sampled, most of the *A. berda* used in this study were female. Tobin & Sheaves (1997), working on *A. berda* in northeastern Australia, found that most fish <160 mm were males.

Growth increments in otoliths of *A. berda* were found to be reasonably clear, suitable for ageing whole and there was good agreement between age readings. Sarre & Potter (2000), in a similar study on *Acanthopagrus butcheri,* found that fish age was consistently underestimated when using whole otoliths. This was not the case in this study. Stacking of growth increments in older fish, which reduces readability and is often apparent in the otoliths of many other sparid species (Smale & Punt 1991; Buxton & Clarke 1992; Bennett 1993; Mann & Buxton 1997; Chale-Matsau *et al.* 2001), was not found to be a problem in *A. berda.*

There was a great deal of size variability within age groups. This has also been observed in *A. butcheri* from the Gippsland Lakes of southeastern Australia (Morison *et al.* 1998). Sarre & Potter (2000), in a study of *A. butcheri* in southwestern Australia, found that low salinities and quality of food can affect the rate at which the fish increase in length, suggesting that seasonal changes in environmental factors may explain the variation in length-at-age observed from fish which are sampled over a wide time frame.

It is imperative that age estimates be validated as changes in behaviour, food availability and environmental factors can alter the deposition rates of different materials within otoliths, resulting in the formation of 'sub-annual' rings or false checks (Beamish & McFarlane 1987; Lai *et al.* 1996). In this study, marginal increment analysis and oxytetracycline labelling were used to validate age estimates, and showed strong evidence that one opaque increment is deposited annually. These results are consistent with results from other South African sparid species, which have also been shown to deposit one opaque increment annually (Coetzee & Baird 1981; Buxton & Clarke 1986; 1989; Buxton 1993, van der Walt & Beckley 1997; Chale-Matsau *et al.* 2001).

In this study, a von Bertalanffy growth model was fitted to the length-at-age data for the combined sexes. However, as *A. berda* is known to change sex from male to female, growth differences between the sexes do need to be addressed in future studies. Sex-changing individuals may experience different somatic growth rates during their life cycle, which in turn may affect per-recruit analyses (Garratt *et al.* 1993; Punt *et al.* 1993). All growth models failed the test for homoscedasticity. Failure of this test means that application of other statistical tests have lower power. This problem has also been encountered by Smale & Punt (1991) and van der Walt & Beckley (1997) for other sparids.

The von Bertalanffy growth curve revealed that

A. berda in northern KwaZulu-Natal is a slow-growing species (K = 0.075) capable of reaching at least 16 years of age. The L_∞ of 500 mm FL was much larger than the observed lengths of the fish in the sample, but below the maximum length recorded for the species (750 mm TL).

A. berda in northern KwaZulu-Natal exhibits considerably slower growth than *A. berda* from Kuwait, which reaches a maximum age of 14 years and has a *K* value of 0.325 (Samuel & Mathews 1987). Growth was faster than that recorded for *A. butcheri* in southeastern Australia (Morison *et al.* 1998) and slower than that recorded for *A. butcheri* in southwestern Australia (Sarre & Potter 2000). *A. berda* also exhibits slower growth than a number of other South African sparid species (see Buxton 1993 for a review), although it does not appear to have the same longevity as some of the larger species, such as *Cymatoceps nasutus* which is known to reach ages of up to 45 years (Buxton & Clarke 1989).

Slow growth has important management implications for fisheries. Slow-growing species tend to mature later in life and therefore have a low production–biomass ratio and a low yield per unit stock. As a consequence, they are susceptible to overfishing (Musick 1999). Catch per unit effort for *A. berda* in the Kosi Bay recreational fishery has shown a disturbing downward trend (James *et al.* 2001), which may be indicative that total fishing effort by the various sectors operating in the system has exceeded sustainable limits. In the light of this, the age and growth parameters obtained in this study will be used to undertake yield-per-recruit analyses to assess the state of the *A. berda* stock in northern KwaZulu-Natal estuaries.

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