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Age and growth parameters of *Siganus sutor* in Kenyan marine inshore water, derived from numbers of otolith microbands and fish lengths

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Siganus sutor (Valenciennes, 1835) is, together with the Lethrinidae, commercially the most important fish of Kenyan waters. Age and growth parameters of this fish have been estimated for stock assessment purposes, using the von Bertalanffy growth model while taking into account the initial small but finite length of fish, L_0. Microbands on the otoliths were used as a measure of age in days. Data of fish length against numbers of microbands were fitted to the growth formula by a least squares procedure applied to a non-linear fit. This gave an L_∞ of 36·2 cm S.L. and a K of 0·87 on an annual basis. Independently, a curve was fitted by eye to the same data, and values were read off the curve and used in a standard Ford–Walford plot. This gave an L_∞ of 35 cm and a K of 0·9. The close agreement of the values obtained by the two methods, and of these with values in the literature, demonstrates the value of using microbands for determining growth parameters in a tropical fish.

I. INTRODUCTION

The *Yearbook of Fishery Statistics 1985* (F.A.O., 1987) lists *Siganus* spp. along with the Lethrinidae as the most important marine fish in Kenya during the last several years. In a survey of the composition of the artisanal catch, Nzioka (1984) found that siganids made up about 50% of the total. Of this, *Siganus sutor* constitutes over 95% (our unpubl. results). In spite of this, very little work has been done on this species in Kenya. As part of a programme of study on the biology of this species carried out on the reefs round Mombasa from January to December 1985, this paper presents information on age and growth parameters, with a view to using them for stock assessment.

Age and growth parameters of fish have been most commonly estimated from length–frequency data, from annual growth marks on the otoliths or other hard structures, and from tagging release and recapture methods. Methods based on length–frequency distributions and annual or seasonal growth rings are, however, difficult to apply in tropical climates (Bagenal & Tesch, 1978). The most promising method in the tropics is based on the interpretation of microbands on the otoliths (Pannella, 1971, 1974; Brothers, 1979; Gjøsaeter *et al.*, 1984). If possible, one should verify the daily periodicity for each species. In the present work a daily periodicity of microband deposition had to be assumed. The decision to proceed on this assumption was based on the fact that microbands have been shown to have a daily periodicity in several other tropical species (Gjøsaeter *et al.*, 1984), including another *Siganus* sp. in Palau (D. Pauly, pers. commun.). The reliability of the derived parameters was checked against relevant data given in the literature (Pauly, 1980).

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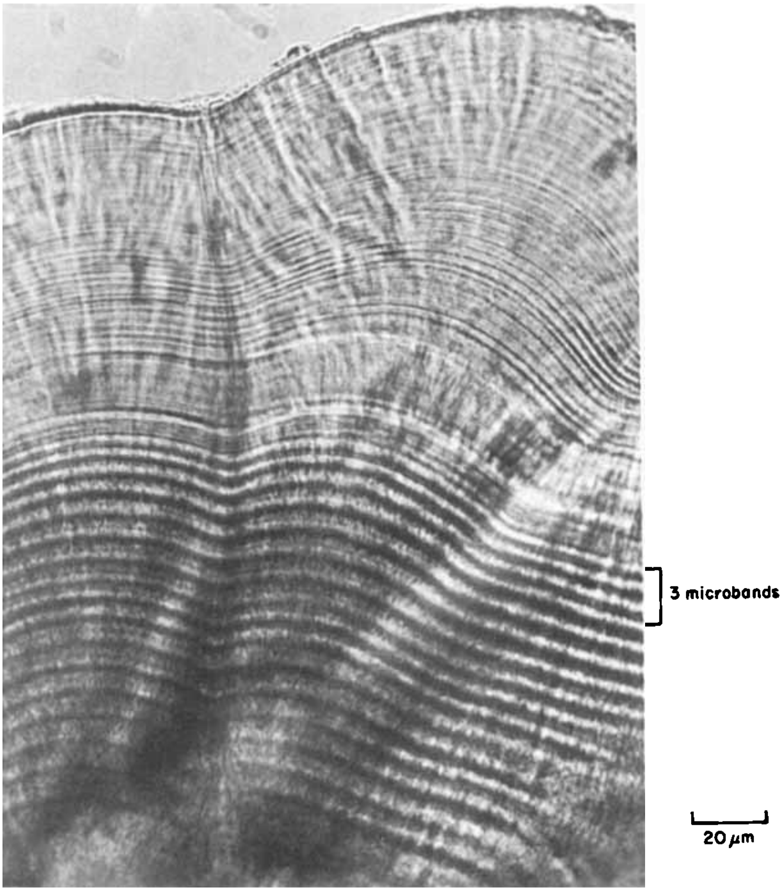

FIG. 1. An area of the anterostrum of the sagitta of *S. sutor* from the nucleus to the anterior edge. The brace on the side includes three microbands, each made up of one opaque and one translucent layer as seen by transmitted light. Whole mount; scale bar = 20 μm.

II. MATERIAL AND METHODS

Adult *S. sutor* were caught by baited bottom traps used by artisanal fishermen; juveniles were caught by beach seines (4 mm mesh). Fishing was done in the vicinity of Mombasa Island, Kenya over a period of one year (1985). The standard length of each fish was measured to the nearest millimetre. The otoliths were dissected out from 45 fish and their sexual status recorded as males, females, or unsexed juveniles. The sagittae and lapilli were stored in 80% ethanol. Before counting the microbands, the membranes surrounding the otoliths were removed and the otoliths placed on microscope slides and dried for 1–2 h at 60° C. They were then mounted in glycerine or immersion oil under a coverslip and examined under a standard microscope by bright field illumination. For permanent preparations, DPX was used as the mounting medium. Otoliths from very large fish had their surface ground slightly, using very fine grade metallurgical paper. Radii were measured from the nucleus of the sagitta posteriorly and anteriorly, using a calibrated eyepiece graticule on a standard microscope at a total magnification of × 40. The structure that was counted as a primary ring or microband was a concentric unit composed of one narrow hyaline and one broad opaque band as seen by transmitted light (Fig. 1). The number of microbands was taken to represent the age of the fish in days.

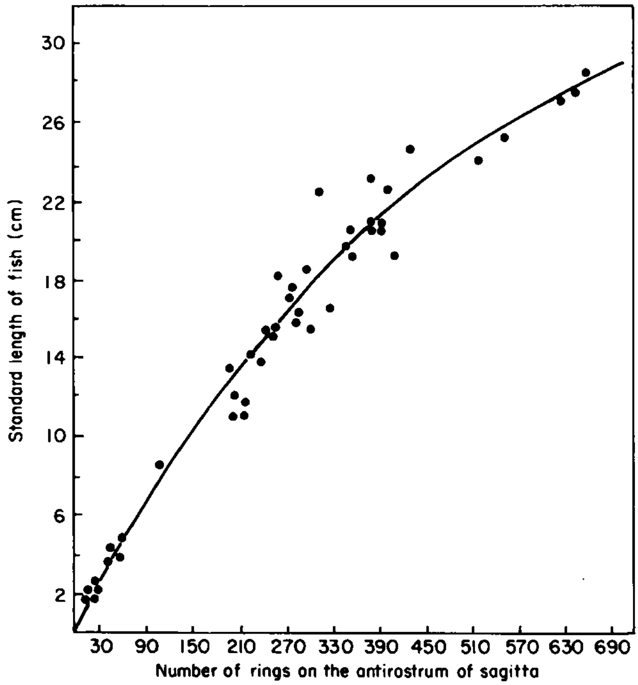

FIG. 2. Fish length against number of microbands (rings) on the anterostrum of the sagitta of *S. sutor*. Curve fitted by eye.

Data on fish length against number of microbands were fitted into a von Bertalanffy growth model specifying a method of least squares applied to a non-linear fit. The formula used was

$$L_t = L_0 + a\{1 - \exp[-(K/365)(n_t - n_0)]\} \quad (1)$$

where L_0 is the initial length of fish, n_t is the number of rings at a given length L_t, n_0 is the number of rings at initial length L_0 and a and K are parameters.

The mathematical asymptote of the curve is L_∞ and is equal to $L_0 + a$. L_0 was specified as 0·1 cm. The value chosen was derived from the dimension of the diameter of the fully grown oocyte which was approximately 0·06 cm (Ntiba, unpubl. data). From general observations of early fish development one can conclude that the length of fish about to hatch must be about twice the diameter of the fully grown oocyte. Therefore the length of *S. sutor* at this stage must be about 0·1 cm. In the standard von Bertalanffy model $L_0 = 0$.

Since computer facilities are not always available in Third World countries, a graphical method for deriving the growth parameters was also used. Fish length was plotted against number of rings and a curve fitted by eye (Fig. 2). Fish lengths were then read off the curve at equal intervals of numbers of rings and the successive lengths obtained were then used to construct a Ford–Walford plot (Fig. 3) the regression line being calculated by the least squares method and L_∞ and K determined following the method of Dickie (1978).

III. RESULTS

The primary growth increment or microbands could best be read on the anterostrum of the sagitta (Fig. 1). The microband rings were difficult to read on the rostrum and posteriorly. The relationship between the size of the anterostrum and the standard length in *S. sutor* is given by

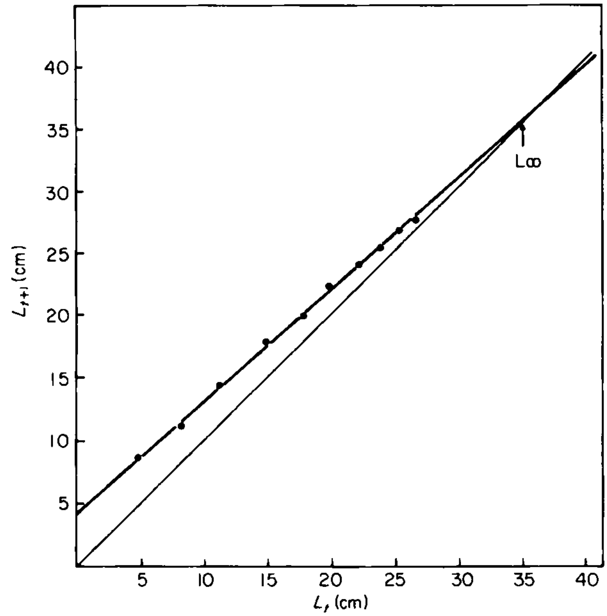

FIG. 3. Ford Walford plot for *S. sutor*; S.L. at time $t+1$ against time t, where equal intervals of time are read from equal numbers of microbands on the curve of Fig. 2. The regression line is fitted by least squares calculation. $L_\infty = 35$ cm, $K = 0{\cdot}9$ on an annual basis.

$$y = 2{\cdot}11 + 0{\cdot}12x \ (r = 0{\cdot}87, \text{d.f. } 41, P < 0{\cdot}01), \qquad (2)$$

where x is standard length of fish in cm, and y is length of anterostrum in μm (Ntiba, unpubl. results).

The least squares fit to formula (1) gave an L_∞ of 36·2 cm, a K of 0·87 on an annual basis, and an n_0 of 14, when L_0 was specified as 0·1 cm. A χ^2 test for goodness-of-fit with 5 d.f. yielded a value of 0·311. Since the 5% critical value with 5 d.f. is 11·07, it was concluded that the experimental and theoretical results come from the same population. When L_0 was specified as 0·0 cm, as in the standard von Bertalanffy model, an n_0 of 13 was obtained, but L_∞ and K remained unchanged.

Ford–Walford plot, constructed from values of fish length derived from the curve fitted by eye, resulted in an L_∞ of 35 cm and a K of 0·9 on an annual basis.

IV. DISCUSSION

If the assumption of a daily periodicity of microbands is correct, one would expect a reasonable agreement between the values of the growth parameters derived in the present work and those given in the literature. This is in fact the case. Our value of L_∞ S.L. of 36·2 cm corresponds to 45·9 cm T.L. using a conversion equation for *S. sutor* determined by De Souza (in press). This agrees very well with the value of 45 cm given by Woodland (1984) as the maximum length for *S. sutor*.

Again, the largest fish in a sample of over 900 fish analysed by us had a S.L. of 33·4 cm corresponding to 42·4 cm T.L. Pauly (1980) gives an empirical relationship whereby the value of L_∞ lies between 5 and 20% greater than the largest fish caught in a very large sample.

Considering K, the value obtained by us is consistent with that in the literature for the closely related *S. canaliculatus*. In the Philippines, *S. canaliculatus* has a T.L. of 25·2 cm and a K of 1·87 (Pauly, 1980). Pauly (1980) provides an empirical relationship between L_∞ and K in bony fish expressed by the equation

$$\log_{10}K = a - 2/3 \log_{10}L^3.$$

Substituting the values given above for *S. canaliculatus*, a in that formula is equal to 3·1, while the corresponding value for *S. sutor* is 3·3.

It must be pointed out that the L_∞ and K values reported in this work are derived from unsexed juveniles and adult males and females, and represent an overall value for the species. Preliminary analysis suggests that there are differences in the growth rates between adult males and females. However, since the juveniles could not be sexed, curves fitted separately for males and females (omitting juveniles) were too skewed away from the origin. It was thus decided to pool all the data. Unless it becomes possible by histological analysis or other means to sex the juveniles, it will not be realistic to treat males and females separately.

Since, by the time the developing egg has laid down an embryonic axis and has differentiated auditory vesicles, the fish has a small but finite size, it was decided from the start to specify an estimated initial size, L_0, in our growth model. This was felt to be biologically more realistic than the standard von Bertalanffy model which ignores such a term.

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