Age and growth of *Sandelia bainsii* Castelnau (Pisces: Anabantidae) in the Tyume River, Eastern Cape (South Africa)

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Otoliths and scales were used for age and growth determination of *Sandelia bainsii*. There was a linear relationship between fish length and both scale and otolith radii. Growth rings were deposited annually in spring. Otoliths provide a more reliable estimate of age and growth than scales. Males grow faster, reach a larger size and have a longer lifespan than females. Based on otoliths the growth of males is described by $L_t = 287(1-e^{-0,186(t-0,15)})$ mm SL and that of females by $L_t = 214(1-e^{-0,223(t-0,18)})$ mm SL.

Otoliete en skubbe is gebruik vir ouderdoms- en groeibepalings in *Sandelia bainsii*. Daar was 'n direkte verband tussen vislengte en die radiusse van beide skubbe en otoliete. Groeiringe is jaarliks in die lente vasgelê. Otoliete verskaf 'n meer betroubare skatting van die ouderdom en groei as die skubbe. Die mannetjies groei vinniger, word groter en het 'n langer lewensduur as die wyfies. Gebaseer op otoliete kan die groei van mannetjies beskryf word deur $L_t = 287(1-e^{-0,186(t-0,15)})$ mm SL en die van wyfies deur $L_t = 214(1-e^{-0,223(t-0,18)})$ mm SL.

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The Anabantidae is a small Afro-Asian family of fishes with three genera. The two species of the genus *Sandelia* are restricted to the Cape Province of South Africa, while the genus *Ctenopoma* with some 26 species (Gosse 1986) occurs in West central, Central and South-eastern Africa. The Asian genus *Anabas* is monotypic and is restricted to south-east Asia (Liem 1963). The eastern Cape rocky, *Sandelia bainsii* is endemic to the eastern Cape occurring only in the Kowie, Great Fish, Keiskamma, Buffalo and Nahoon River systems. *Sandelia capensis* occurs in south-west Cape rivers from the Sundays River near Port Elizabeth to the Berg River in the western Cape (Harrison 1952).

A study of age and growth of *S. bainsii* was included in a general investigation of the biology of the species (Mayekiso 1986). The present study is the first detailed investigation of age and growth of an anabantid species. An understanding of age and growth of this species was required to determine the age structure of the population and as an aid for the calculation of natural mortality and to determine the age at sexual maturity. In turn, these parameters were required to formulate a conservation strategy for the species.

Methods

Several hard tissues were examined for growth checks. However, only the scales and otoliths were found to be suitable.

Removal and preparation of scales and otoliths

Six ctenoid scales were removed from the pectoral region below the lateral line. These scales were selected because of their large uniform size, better symmetry and legibility. They were cleaned, dried and mounted on microscope slides and then examined on a microfiche reader at 30× magnification.

Sagittal otoliths were removed by dissection of the cranium, immersed in xylol in a black dish and examined whole under a stereomicroscope at 40× magnification using reflected light.

Growth estimations from scales and otoliths

The choice of the formula for back-calculations of length-at-age is determined by the relationship between fish length and scale or otolith radii.

The standard length (SL) of 367 *S. bainsii* of all size groups was plotted against their corresponding scale radii (scale radius = distance from focus to the midpoint of the anterior scale edge). For scales the relationship was found to be linear and directly proportional (scale radius = 0,03 SL, $r^2 = 0,94$; $p < 0,005$). According to Tesch (1968) such a relationship is described by Lea's formula:

$$L_n = \frac{S_n \times L}{S}$$

where L_n = standard length (SL) when annulus 'n' was formed, L = SL when fish was sampled, S_n = radius of annulus 'n' (at length L_n), S = total scale radius.

The standard length of 224 *S. bainsii* of all size groups was plotted against their corresponding otolith radii (otolith radius = distance from the otolith nucleus to the midpoint of the anterior edge in the longitudinal axis). The relationship was linear but not directly proportional (otolith radius = 0,022 SL + 0,6365; $r^2 = 0,89$; $p < 0,005$). Such a relationship is described by the formula of Frazer and Lee (Frazer 1916; Lee 1920):

$$L_n - c = \frac{S_n (L - S)}{S}$$

where L_n = standard length (SL) when annulus 'n' was formed, c = intercept on abscissa, S_n = radius of annulus 'n' (at length L_n), S = total otolith radius, L = SL when fish was sampled.

The back-calculated length-at-age data determined from scales and otoliths were fitted to the von Bertalanffy growth model using Beverton's method of least squares (Ricker 1975). The length-at-age data based on scales and otoliths were compared by analysis of variance (ANOVA) and Student-Newman-Keuls (SNK) procedure. In order to test for sampling bias and selective mortality the radii of the first annulus of the 1+, 2+ and 3+ fish were also compared using the ANOVA and SNK procedure.

Results

Description of scale and otolith rings

Regular concentric rings occur on the anterior and lateral fields of the scale of *S. bainsii*. In the posterior field the circuli are replaced by rows of ctenii. A ring is formed when a zone of closely spaced circuli is followed by a zone of widely spaced circuli. Widely spaced circuli are indicative of rapid growth which for most fishes occurs during the warm summer season, while closely spaced circuli are indicative of slow growth during the cold winter season (Bilton 1974). The distance from the most recent ring to the anterior edge of the scale is the marginal increment. The number of circuli in the marginal increment of a scale depends on the time of sampling. In fishes sampled immediately, or shortly after a ring has been formed, the ring is on the anterior margin of the scale and there are no, or few, circuli in the marginal increment. If a large sample of scales is taken throughout the year, and the number of circuli in the marginal increment is determined, the time of ring formation can be established (Bruton & Allanson 1974). The mean number of circuli in the marginal increment of scales of 183 *S. bainsii* falling in the size range 35–80 mm SL caught monthly from March 1983 to August 1984 is presented in Figure 1. There is a decrease in the mean number of circuli in the marginal increment in October/November indicating that one ring (annulus) was formed during these months.

The otolith of *S. bainsii* consists of a nucleus surrounded by alternating wide opaque and narrow translucent zones. If one opaque and one translucent zone are deposited per year then they collectively constitute an annulus (Hecht & Smale 1986). The marginal increment of an otolith is the distance from the most recent translucent zone to the edge of the otolith in the anterior longitudinal axis. As with scales, the size of the marginal increment depends on the time of sampling. If a large number of otoliths is taken at different times of the year, and the size of the marginal increment measured, the time of formation of each zone can be established. The mean size of the marginal increment of otoliths of 118 *S. bainsii* in the size range 35–80 mm SL caught monthly from March 1983 to August 1984 is presented in Figure 2. The mean size of the marginal increment decreases in October indicating the beginning of the deposition of the new opaque zone.

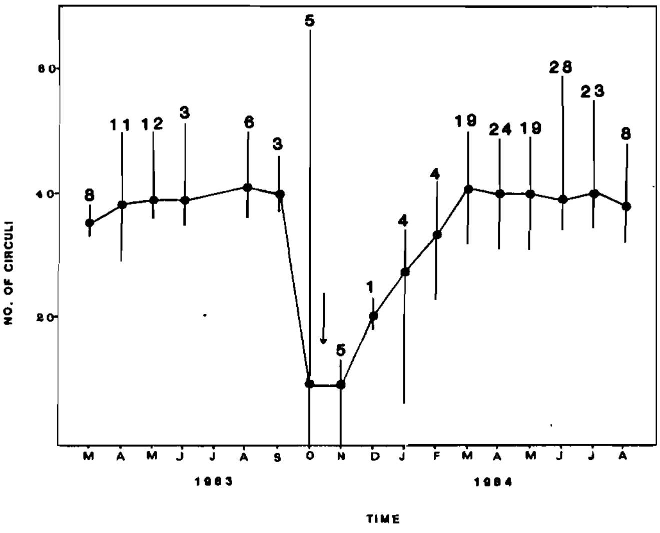

Figure 1 Monthly changes in the mean number of circuli in the marginal increment of 183 *S. bainsii* scales (●). The vertical lines show the range, the numbers the sample size, and the arrow the time of annulus formation.

Age and growth

The calculated von Bertalanffy lengths-at-age and observed mean lengths-at-age data of male *S. bainsii* obtained from scale and otolith readings are shown in Table 1 and those of females in Table 2. The lengths-at-age based on scales and otoliths were significantly different ($p < 0,05$) only in the 1+ fish. In both sexes the growth rate was fastest in the first year and decreased thereafter. There were some discrepancies, however, with some older age classes showing faster growth than younger age classes in both back-calculated and observed data. There was a significant difference between the back-calculated length-at-age data and the observed length-at-age data ($p < 0,01$; *t* test). No significant difference was found among the first annulus radii of 1+, 2+ and 3+ fish in both scale and otolith data suggesting that the Rosa Lee phenomenon (Ricker 1975) was not pronounced. The values of the constants in the von Bertalanffy growth model based on scales and otoliths are shown in Table 3 and growth is illustrated in Figures 3 and 4. Although males showed a faster growth rate ($p < 0,05$), females had a higher growth coefficient (K) but a lower L_∞.

The population age structure of *S. bainsii* in the Tyume River based on values calculated from age–length keys (Ricker 1975) is unimodal with about 52% of the population falling in the 1+ age class (Figure 5). Considering that recruitment takes place virtually throughout the year (Mayekiso 1986) the high percentage of the 1+ fish was not unexpected. The

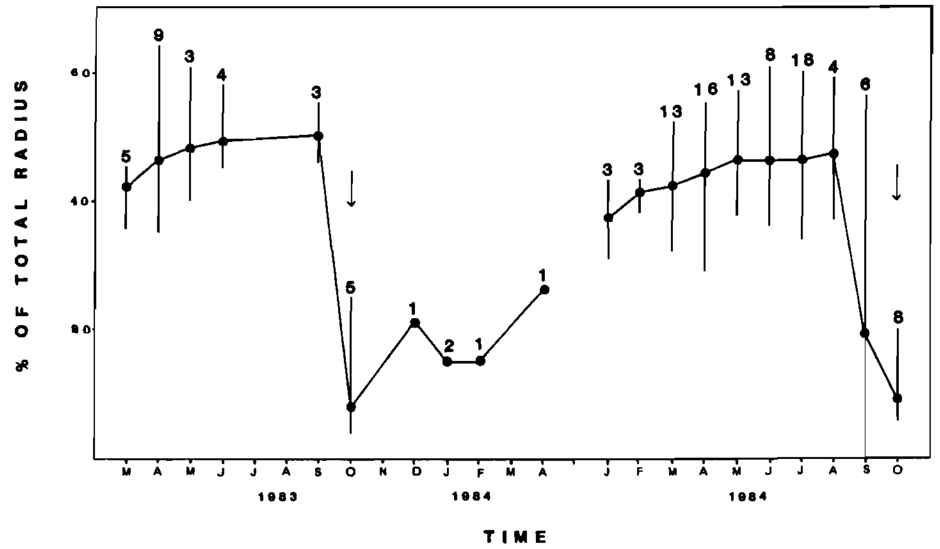

Figure 2 Monthly changes in the mean size of the marginal increment of 118 *S. bainsii* otoliths (●). The vertical lines show the range, the numbers the sample size and the arrow the beginning of deposition of the opaque zone on the otoliths.

Table 1 The calculated von Bertalanffy and the observed mean lengths-at-age (SL), standard errors (SE) and annual length increments (ΔSL) of male *S. bainsii* based on scales and otoliths

	Calculated								Observed							
	Scales				Otoliths				Scales				Otoliths			
Age	SL	ΔSL	SE	*N*	SL	ΔSL	SE	*N*	SL	ΔSL	SE	*N*	SL	ΔSL	SE	*N*
1	42	42	0,9	118	47	47	1,1	101	84	84	1,2	80	85	85	1,2	70
2	77	35	2,6	35	88	41	2,6	41	112	28	3,6	23	117	32	3,7	19
3	114	37	4,8	15	122	34	3,4	13	143	31	4,7	10	141	24	4,6	9
4	149	35	7,1	6	150	28	1,7	4	163	20	6,7	6	168	27	1,4	4

Table 2 The calculated von Bertalanffy and observed mean lengths-at-age (SL), standard errors (SE) and annual length increments (ΔSL) of female *S. bainsii* based on scales and otoliths

	Calculated								Observed							
	Scales				Otoliths				Scales				Otoliths			
Age	SL	ΔSL	SE	*N*	SL	ΔSL	SE	*N*	SL	ΔSL	SE	*N*	SL	ΔSL	SE	*N*
1	33	33	0,7	146	41	41	0,9	112	73	73	1,1	95	76	76	1,2	63
2	71	38	1,5	48	76	35	1,4	38	98	25	2,3	32	102	26	2,2	31
3	99	28	3,7	16	103	27	2,1	16	117	19	2,0	16	116	14	2,2	16
4	124	25	–	1	126	23	–	1	136	19	–	1	136	20	–	1

figure includes an underestimate of juvenile fish (0+) as no attempt was made to catch all these fish during sampling. The oldest male *S. bainsii* caught in the Tyume River was five years old and the oldest female was four years old.

Discussion

The formation of the annulus on the scale and the opaque zone deposition on the otolith in October coincide with increased water temperature, the beginning of the rainy season, the beginning of the breeding season and increased stomach fullness indices (Mayekiso 1986). It seems that the scale annulus formation and opaque zone deposition on the otolith occur when the fish grow rapidly in response to increased food availability brought about by factors such as increased temperatures and rainfall.

Growth in size of *S. bainsii* has been estimated as the difference between lengths at successive ages as

Table 3 The values of the constants in the von Bertalanffy growth model and correlation coefficients from Ford–Walford plots as fitted to the length-at-age data of *S. bainsii*

	Sex	L_∞	K	r^2	t_0
Scales	Males	603	0,073	0,99	1,14
	Females	236	0,198	0,99	1,26
Otoliths	Males	287	0,186	0,99	0,15
	Females	214	0,223	0,99	0,18

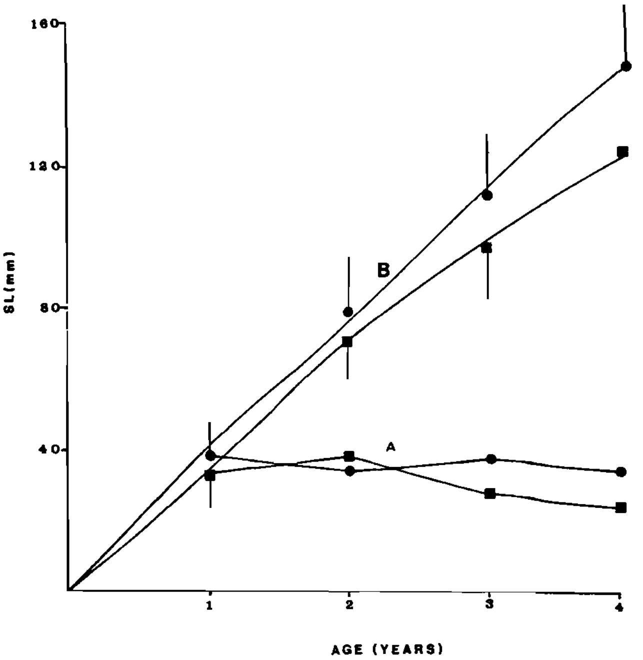

Figure 3 Von Bertalanffy growth in length (B) of 174 male (●) and 211 female (■) *S. bainsii* based on scales. The data are given as means and half standard deviation (vertical lines). The annual length increments are also shown (A).

determined from scale and otolith annuli. Young fish typically grow faster than older fish (Ricker 1975). This pattern was shown by some age classes but there were discrepancies with other age classes in both back-calculated and observed data. This is attributable to the near continuous recruitment in this species (Mayekiso 1986), which results in great variation in lengths-at-age. For example, 1+ fish range in length from 35 mm to 95 mm suggesting that the fish form a ring (annulus?) in spring irrespective of age in months. Isely & Noble (1987), using daily otolith growth rings suggested that fish length may be determined by individual age, that is, individual hatching time within an age class. Fish spawned at different times have been observed to have different growth rates (Millar & Storch 1984). We propose that the variation in growth rates of *S. bainsii* is due to the failure of the 'annual growth method' to account for different spawning dates and hence the different growth starting times and possible differential growth. The size variation within an age class is probably also responsible for the large difference between back-calculated and observed data.

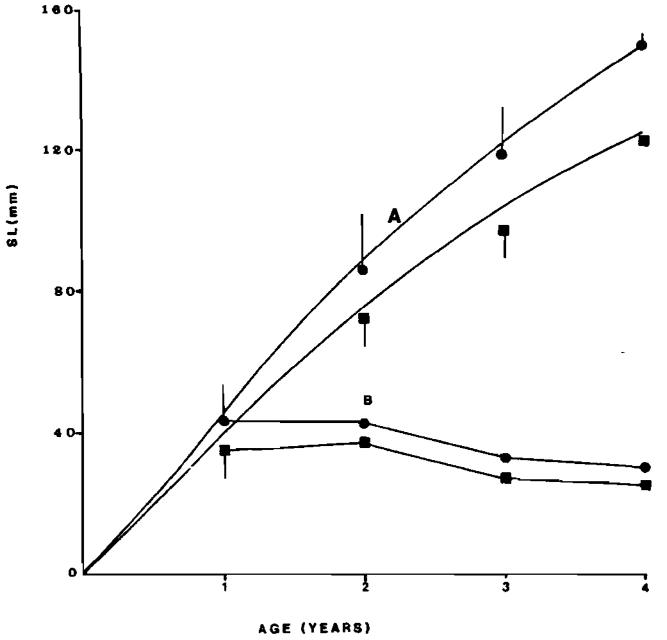

Figure 4 Von Bertalanffy growth in length (A) of 159 male (●) and 167 female (■) *S. bainsii* based on otoliths. The data are given as means and half standard deviation (vertical lines). The annual length increments are shown (B).

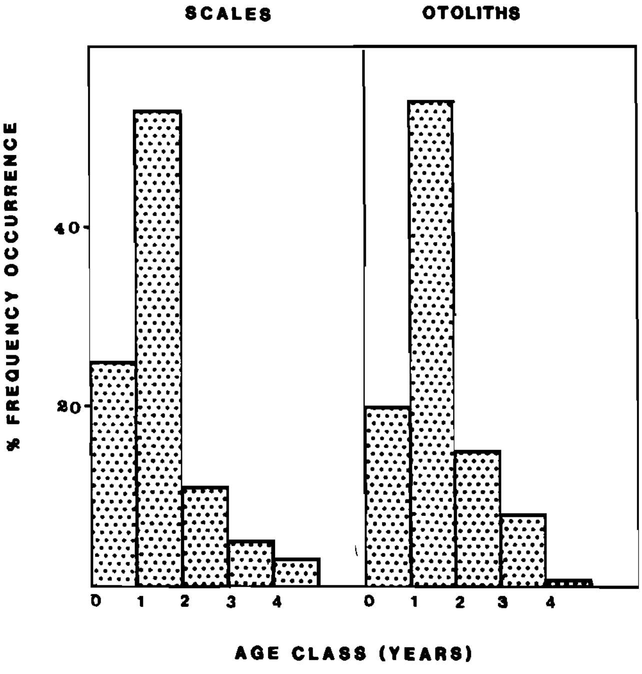

Figure 5 The population age structure of *S. bainsii* based on 269 scales and 205 otoliths. The values were calculated using length-age keys (Ricker 1975).

On closer examination of both scale and otoliths of *S. bainsii* and the data presented in Tables 1 & 2 and Figures 3 & 4, a number of points emerge that show that otoliths are more suitable than scales for age determination in this species viz:

(i) the greater difficulty of reading scales of three- and four-year-old fish as the rings become crowded in the anterior and lateral fields;

(ii) the von Bertalanffy parameter L_∞ of 603 and 236 mm for males and females, respectively, calculated on the data from scales is improbable when compared with the observed maximum length of 190 mm and 136 mm attained by males and females, respectively. The L_∞ of 287 mm and 214 mm for males and females, respectively, calculated on the data from otoliths are a better estimate considering that the species reaches a length of 325 mm in Staples Dam near Grahamstown (Cambray 1981);

(iii) the erratic nature of the growth in length based on scales, shown in Figure 3, compared to the more uniform growth pattern which conforms to expected norm shown in Figure 4.

The faster growth of males compared to females is common in other fish families, e.g. cichlids (Fryer & Iles 1972; Bruton & Allanson 1974; Hecht 1980). The higher growth coefficient (K) accompanied by a lower L_∞ of the females is, according to Kingsley (1980), characteristic of the sex that matures earlier and at a smaller size. Although male and female *S. bainsii* mature during their second year of growth (Mayekiso & Hecht 1988), males mature at a larger size than females.

The maximum observed length of *S. bainsii* in the Tyume River was 190 mm SL (total length (TL) = 246 mm) which approximates that of the larger anabantids. The maximum length reached by *Anabas testudineus* is 250 mm TL (Forselius 1957) whereas the *Ctenopoma* spp. reach 155 mm SL (Daget 1961) and *S. capensis* reaches 220 mm TL (Bruton, Jackson & Skelton 1982).

The *S. bainsii* population in the Tyume river is relatively small and is considered vulnerable to local extinction (Mayekiso & Hecht 1988). Over 70% of the fish fall in the 0+ and 1+ age classes and considering that the 0+ fish have been underestimated, it seems that the population is dominated by young fish. These data suggest that the species is heavily dependent on recruitment to maintain its population.

The data on life-history characteristics of *S. bainsii,* such as late maturity (2nd year), large body size and iteroparity suggest that the species is K-selected (Pianka 1970) and has a precocial lifestyle (Balon 1981). This finding is not consistent with expectations since the environment of the species in the eastern Cape is harsh and unpredictable because of the erratic river flow resulting from frequent droughts.

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References

BALON, E.K. 1981. Additions and amendments to the classification of the reproductive styles in fishes. *Env. Biol. Fish.* 6(3/4): 377–389.

BILTON, H.T. 1974. Effects of starvation and feeding on circulus formation on scales of young sockeye salmon of four races, and one race of young kokanee, coho and chinook salmon. In: Ageing of fish (ed. Bagenal, T.B.). Proceedings of an International Symposium. Unwin Brothers Limited.

BRUTON, M.N. & ALLANSON, B.R. 1974. The growth of *Tilapia mossambica* Peters (Pisces : Cichlidae) in Lake Sibaya, South Africa. *J. Fish Biol.* 6: 701–715.

BRUTON, M.N., JACKSON, P.B.N. & SKELTON, P.H. 1982. Freshwater fishes of southern Africa. Centaur Publishers, Cape Town.

CAMBRAY, J.A. 1981. The eastern Cape Rocky (*Sandelia bainsii*). *The Naturalist* 25(1): 28–30.

DAGET, P. 1961. Poissons. *Mem. Inst. Fr. Noire* 62(2): 325–362.

FORSELIUS, S. 1957. Studies in Anabantid fishes. *Zoologista Bidrag Uppsala* 31–32: 97–597.

FRAZER, C. McL. 1916. Growth of the spring salmon. *Trans. Pacif. Fish. Soc. Seattle*: 29–39.

FRYER, G. & ILES, T.D. 1972. The cichlid fishes of the great lakes of Africa. Oliver and Boyd, Edinburgh. 641 pp.

HARRISON, A.C. 1952. The Cape Kurper. *Piscator* No. 23: 82–91.

HECHT, T. 1980. A comparison between the scale and otolith methods of ageing, and growth of *Sarotherodon mossambicus* (Pisces: Cichlidae) in a Venda impoundment (Southern Africa). *S. Afr. J. Zool.* 15(4): 222–228.

HECHT, T. & SMALE, M.J. (eds.) 1986. Proceedings of a workshop on age determination and growth modelling of South African marine line fish. *J.L.B. Smith Institute of Ichthyology Investigational Report* No. 21.

ISELY, J.J. & NOBLE, R.L. 1987. Use of daily otolith rings to interpret development of length distributions of young largemouth bass. In: Age and growth of fish (eds. Summerfelt, R.C. & Hall, G.E.). Iowa State University Press, Ames.

KINGSLEY, M.C.S. 1980. Von Bertalanffy growth parameters. *Trans. Am. Fish. Soc.* 109: 252–253.

LEA, E. 1910. On the methods used in herring investigations. *Publs. Circonst. ons. prem. int. Explor. Mer.* No. 53.

LEE, R.M. 1920. A review of the methods of age and growth determination in fishes by means of scales. *Fishery Invest. Lond. Ser.* II 4, 32 pp.

LIEM, K.F. 1963. The comparative osteology and phylogeny of the Anabantoidei (Teleostei: Pisces). *Illinois Biological Monographs,* No. 30, Urbana. 149 pp.

MAYEKISO, M. 1986. Some aspects of the ecology of the eastern Cape Rocky, *Sandelia bainsii* (Pisces: Anabantidae) in the Tyume River, eastern Cape, South Africa. M.Sc. thesis, Rhodes University, Grahamstown. 130 pp.

MAYEKISO, M. & HECHT, T. 1988. Conservation status of the anabantid fish *Sandelia bainsii* in the Tyume River, South Africa. *S. Afr. J. Wildl. Res.* 18: 101–108.

MILLAR, S.J. & STORCH, T. 1984. Temporal spawning distribution of largemouth bass and young-of-year growth, determined from daily otolith rings. *Trans. Am. Fish. Soc.* 13: 371–578.

PIANKA, E.R. 1970. On r- and K- selection. *The American Naturalist* 104: 592–597.

RICKER, W.E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. *Fish. Res. Can. Bull.* 191: 382 pp.

TESCH, F.W. 1968. Age and growth. In: Methods for Assessment of Fish Production in Fresh Waters, (ed. Ricker, W.E.). Blackwell, Oxford.