S. Afr. J. mar. Sci. 21: 201–209
1999

GROWTH OF NAMIBIAN SILVER KOB *AGYROSOMUS INODORUS* BASED ON OTOLITHS AND MARK-RECAPTURE DATA

C. H. KIRCHNER and S. F. VOGES**

The growth of silver kob *Argyrosomus inodorus* sampled from two regions (northern and southern) along the Namibian coast was determined using longitudinally sectioned otoliths. The special Von Bertalanffy growth model adequately described the growth of kob in both regions. Growth rate for kob in the south was validated using mark-recapture data, and similar growth rates were obtained using both methods. Growth of kob sampled in the south (maximum age 19 years) was significantly different from those in the north (maximum age 28 years). Kob from the two regions appeared to be from the same stock, and consequently length-at-age data from the regions can be pooled for management purposes. Growth of Namibian silver kob was markedly different from the South African silver kob, for which growth was best described by logistic (South-Western Cape) and Richards (Southern and South-Eastern Cape) models. The special Von Bertalanffy growth parameters were determined by the equations:

$L_t = 116\ (1 - e^{0.120\ (t + 1.47)})$ mm for the southern region,
$L_t = 112\ (1 - e^{-0.094\ (t + 2.29)})$ mm for the northern regions,
$L_t = 103\ (1 - e^{-0.136\ (t + 1.58)})$ mm for both regions combined.

Silver kob *Argyrosomus inodorus* are the most important linefish species caught in Namibian waters, on the basis of total landed catch and the degree of targeting on that species (Kirchner and Beyer 1999, Kirchner *et al*. in press). It is exploited commercially by the linefish and skiboat fishery and recreationally by shore- and skiboat-anglers. Regulations governing the capture of silver kob in Namibia have to date been based on little quantitative scientific research, and the fishery is currently limited by few regulations

Table I: Age-length key for *A. inodorus* collected along the Namibian coast during 1995 and 1996. Data are combined from the southern region (n = 338), the northern region (n = 152) and the central region (n = 30)

Total length interval (cm)	Number of fish at age (years)																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	28	Total
20.5–25.49	2																					2
25.5–30.49	8																					8
30.5–35.49	1																					1
35.5–40.49		7	3																			10
40.5–45.49		14	12	5	2																	33
45.5–50.49		7	22	11	1	5	2															48
50.5–55.49			21	14	8	11	4															58
55.5–60.49			5	5	16	18	4															48
60.5–65.49				1	7	31	4															43
65.5–70.49				2	7	41	10	4	5	4	2											75
70.5–75.49					6	30	9	2	9	2	4	1										63
75.5–80.49					2	15	17	3	3	1	7	2	1									51
80.5–85.49						3	5	3	2	3	6		1	1							1	25
85.5–90.49								2	4	6	1	2	2			1	2					20
90.5–95.49								2	0	11	1	1		2	1			1	1		1	21
95.5–100.49									3	1	2	2										8
100.5–105.49													1			1	1		2		1	6
Total	11	28	63	38	49	154	55	16	26	28	23	8	5	3	1	2	3	1	2	1	3	520

*Ministry of Fisheries and Marine Resources, P.O. Box 912, Swakopmund, Namibia. E-mail: ckirchner@mfmr.gov.na

Manuscript received: August 1998

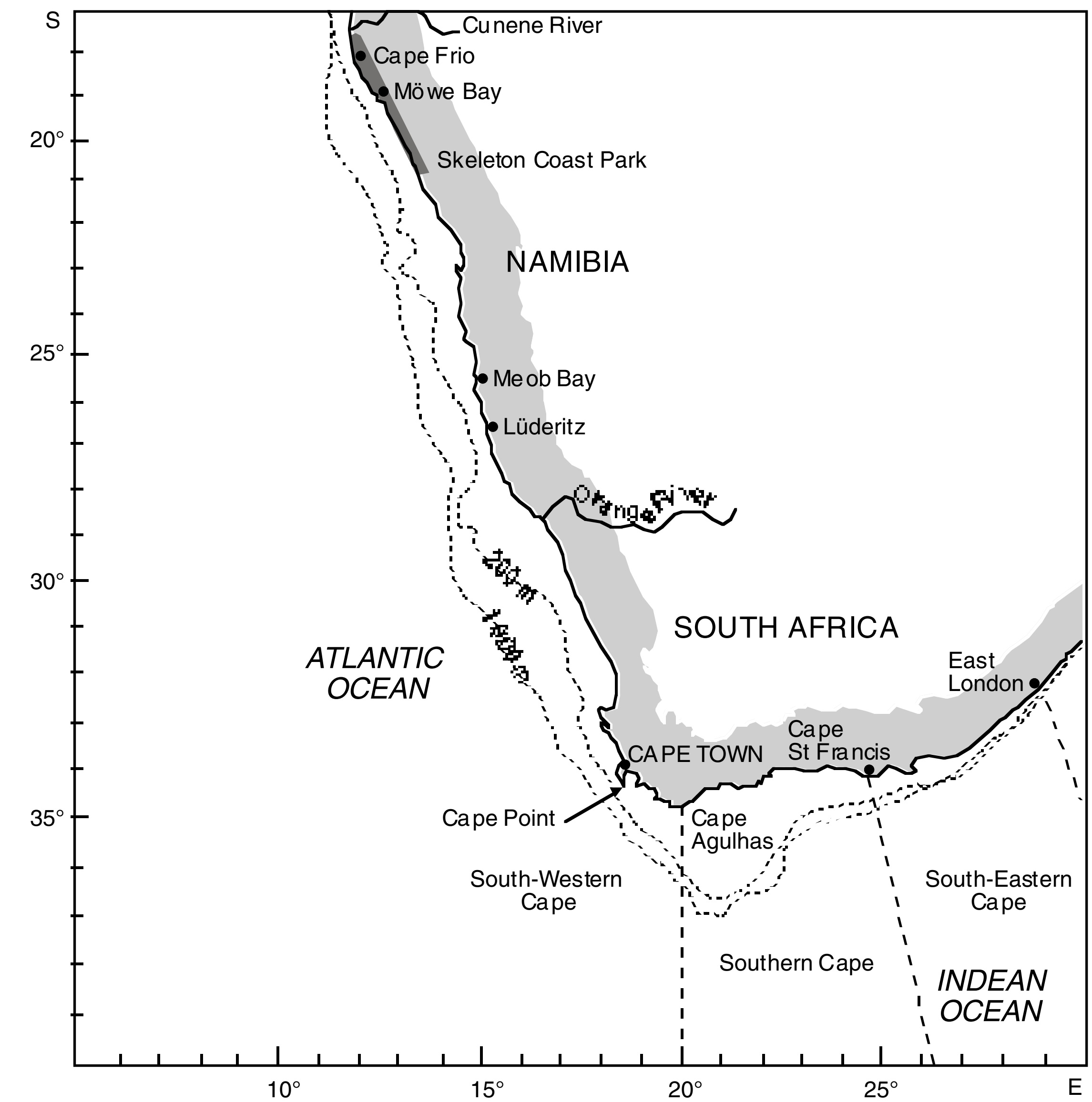

Fig. 1: Map of Namibia and South Africa showing the localities mentioned in the text

and restrictions (Anon. 1993). The recreational fishery is controlled by a daily bag limit of either 30 fish or 30 kg of filleted fish per angler. Gear is restricted to one rod with two hooks per angler. The commercial skiboat fishery is restricted to certain areas, but the commercial linefish boat-fishery has no restrictions. The Namibian silver kob stock has declined markedly in recent years, indicated by the decrease in catches with little change in exploitation patterns (Kirchner 1999). This has necessitated the need to study the

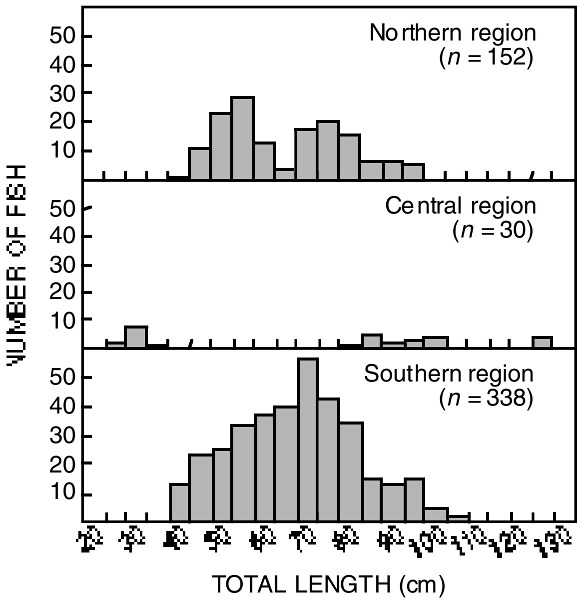

Fig. 2: Length frequencies used for the growth determination of *A. inodorus* caught off southern and northern Namibia. Rejected otoliths were not included

dynamics of the silver kob population in order to provide sound scientific advice to manage this resource.

Griffiths (1996) compared the growth of silver kob from three regions along the South African eastern seaboard. No difference was found in growth between silver kob of the Southern and South-Eastern Cape, but growth was different between those region and the South-Western Cape. Although Namibian silver kob are found along the entire 1 500 km of the Namibian coastline, they are most abundant from Meob Bay to Cape Frio (Fig. 1). South African silver kob are abundant only off the Southern and South-East Cape from Cape Point to East London (Fig 1). This suggests that there is a separation of the stocks between Cape Point and Meob Bay, possibly preventing mixing between the South African stock and the Namibian one. It is therefore likely that Namibian silver kob form a separate stock. This is supported by the fact that, from a total of some 13 000 kob (*A. inodorus* and *A. coronus*) tagged in Namibian waters, only two out of 171 recaptures were made on the west coast of South Africa (Kirchner 1999).

Given the possibility of stock separation between the Namibian and South African silver kob, the age structure and growth patterns of the Namibian kob were investigated and compared to those of the South African stock.

MATERIAL AND METHODS

Age determination

Routine biological sampling of silver kob by shore-angling was undertaken between 1994 and 1996, as part of the Namibian fish tagging programme. In Meob Bay (the southern distribution), 357 fish were collected in summer 1995 (January–April); silver kob move out of the area with the approach of winter. A total of 160 silver kob was collected in most months in 1995 and 1996 off the Skeleton Coast Park (the northern distribution). Because of the scarcity of small and large silver kob in the northern collections, an additional 33 fish of that size were collected in the central region of the Namibian coast between Meob Bay and the Skeleton Coast Park (Fig. 1). Total fish length (to the nearest cm) and fish mass (to the nearest 50 g) were recorded for both male and female kob.

Otoliths were embedded in resin and the sagittae were thinly sectioned (approx. 0.5 mm thick longitudinally with a single, diamond-tipped blade (Rauck 1976). Sections were mounted on glass microscope slides and polished to a smooth surface. The sectioned otoliths were immersed in water and viewed under a stereo microscope using reflected polarized light against a black background.

Griffiths (1996) found that one opaque and one translucent zone were deposited annually in South African *A. inodorus*. Assuming a similar pattern of growth zone deposition in the Namibian species, annuli were counted from the beginning of each opaque band to the end of the dark (translucent) ring (Fig. 2). Otoliths were read without any reference to fish length. The number of translucent zones was counted four times by one reader, at least one week apart, and only if at least three counts agreed was the count accepted as an age estimate. The Average Percentage Error (*APE*, Beamish and Fournier 1981) was used to calculate band count precision.

The four-parameter Schnute (1981) growth model was initially fitted to the age-length data in order to determine if a submodel with fewer parameters (such as the Von Bertalanffy growth model) could adequately describe the observed data. For the Schnute (1981) model, as well as its underlying submodels, two error structures were assumed: the absolute error model, which considers that the size of the residual is constant

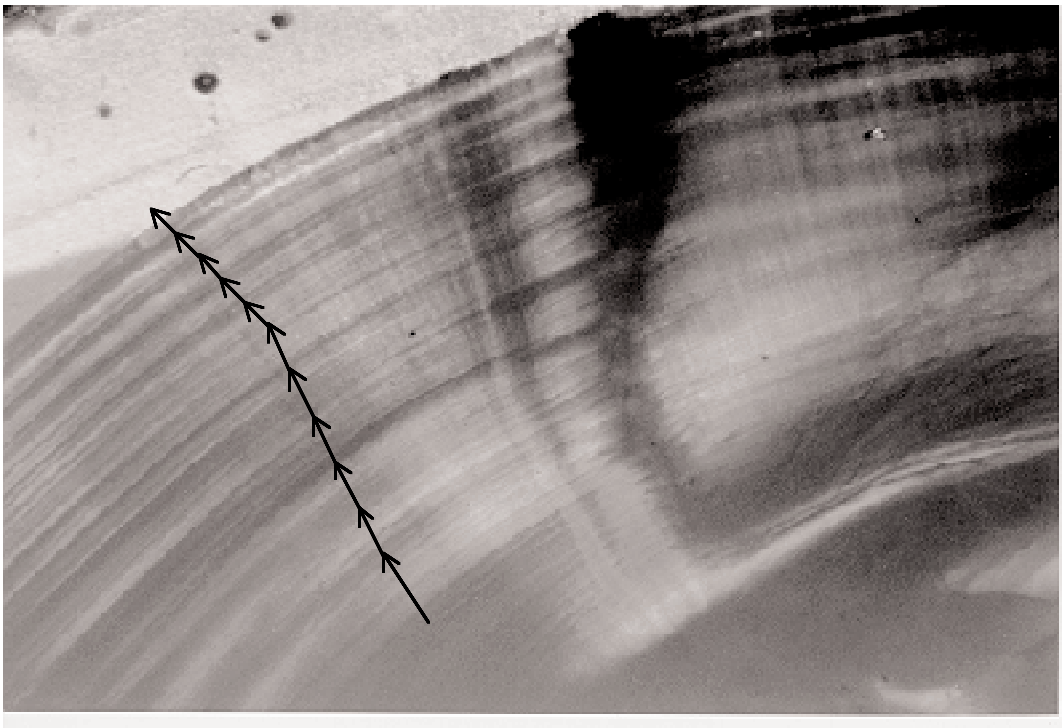

Fig. 3: Longitudinal otolith section of *A. inodorus*, from which 11 opaque rings were counted. The arrows indicate one year's growth

for all age-classes, and the relative error model, which assumes that the residual size increases with increase in age. Standard errors and 95% confidence limits for each model parameter were calculated using a parametric bootstrap technique (Efron 1982) and the percentile method (500 bootstraps) respectively. The analysis was undertaken using the computer software PC-Yield (Punt 1992). The goodness-of-fit criteria adopted were: randomness and no systematic trends in residuals (Draper and Smith 1966), credible L_∞ values (i.e. L_∞ should be close to, but lower than the observed maximum length), and lowest sum-of-squared residuals.

Growth between regions and between sexes was compared by means of likelihood-ratio tests (Draper and Smith 1966). Only four one-year-old fish were sampled from the southern region and none of that age was sampled from the northern region, because such young fish are scarce in those areas. In all, 11 one-year olds obtained from the central Namibian coast were included in the data for both regions. The remaining 19 fish sampled in the central region were combined with the northern collections: silver kob seem to move from the northern region into the central region at the onset of the spawning season during summer (Kirchner 1999).

Use of mark-recapture data to validate age estimates

Growth parameters were also calculated using mark-recapture data. Since 1991, 13 473 silver kob have been marked and released along the Namibian coast by shore-anglers. However, only 171 (1.3%) fish have been recaptured to date. Of these, only 26 were measured accurately by trained staff at recapture, and consequently only those fish were used in the present analysis. Only recaptured fish that were tagged in the southern and central regions were used in order to ensure that those examined were *A. inodorus*. In northern Namibian waters, there is a distributional overlap between *A. inodorus* and *A. coronus* (Griffiths and Heemstra 1995).

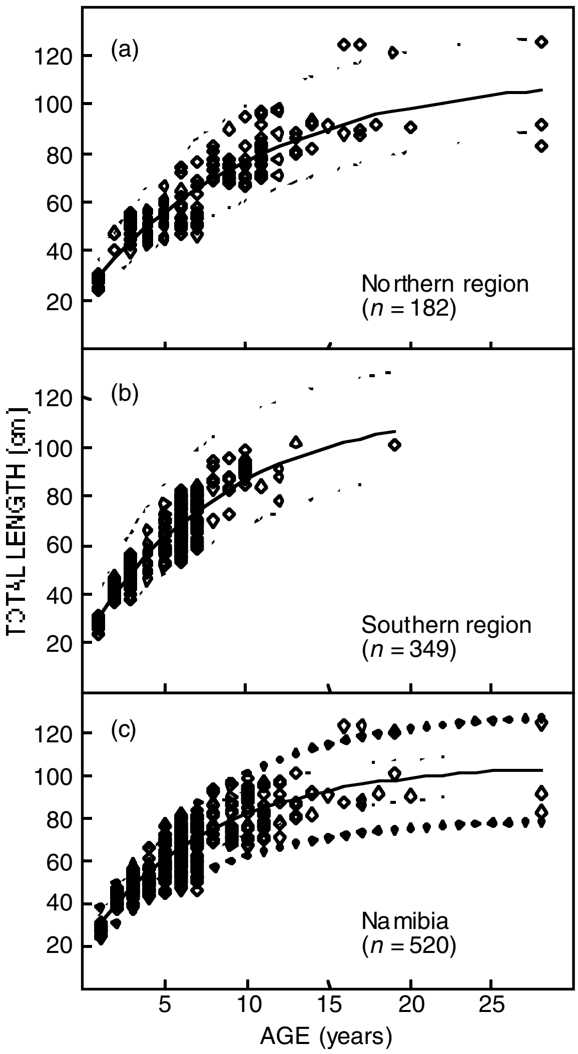

Fig. 4: The Von Bertalanffy growth model (solid lines) and 95% confidence intervals (dashed lines) fitted to the observed age-length data for *A. inodorus* from (a) the northern region, (b) the southern region and (c) both regions combined. For the combined regions, additional 95% intervals have been estimated using relative residuals (dotted lines)

It was assumed that the growth of recaptured kob could be described adequately by the Von Bertalanffy growth function and that the growth rate (K·year^{-1}) could be calculated using the following equation:

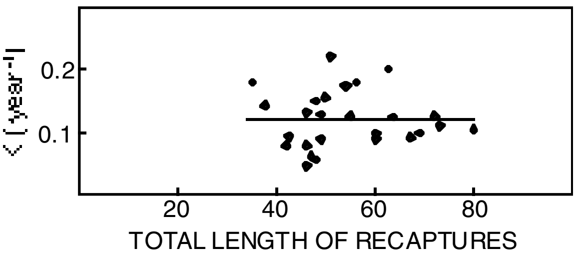

Fig. 5: Estimates of K for individual Namibian *A. inodorus* from mark-recapture data. The line denotes the mean growth rate

$$K = \frac{1}{\Delta t} \ell n \left[\frac{L_\infty - L_1}{L_\infty - L_2} \right] \quad , \qquad (1)$$

where Δt denotes days free, L_1 is the length at marking and L_2 is the length at recapture. Asymptotic length (L_∞) was set arbitrarily at 116 cm, the value estimated using otolith readings for silver kob sampled in the southern region. Using Equation 1, the value of K, defined as a rate at which the asymptote is reached, was estimated for each recaptured fish. Sensitivity of the estimate was evaluated on the basis of 95% confidence intervals of L_∞, obtained from fish sampled in the southern region.

RESULTS

Opaque and translucent bands were clearly visible on the otoliths examined (Fig. 3). The precision estimates (*APE*) for the southern region ranged between 1.5 and 15.4%, with an overall mean of 6%. Some 3% were rejected on the basis of non-matching counts. The overall precision for the northern region was 7% (range = 2–18%), with a rejection rate of 3%. In all, 2% of the otoliths examined could not be read.

Silver kob from the southern region were generally younger than those from the north. Only six fish in the south were aged 11 years and older, whereas 48 individuals of that age were found in the north. The combined age-length data (Table I) show that individual length-at-age varied considerably. For example, the length of silver kob aged 6 years ranged over a 40-cm length span.

The three-parameter Von Bertalanffy model provided the best fit for silver kob in both regions. The relative

Table II: Growth parameter estimates, standard error (*SE*) and the 95% confidence intervals (*CI*) for the Schnute and the Von Bertalanffy growth models fitted to *A. inodorus* length-at-age data from the southern and northern regions and for both regions combined data. An indication of the goodness of fit by testing randomness of residuals (*z*-value) and homoscedasticity (*F*-value) are given. The estimate of K obtained by mark-recapture calculations is also given

	Growth parameters								
	a	b	L_1	L_2	t_1	t_2	$K \cdot year^{-1}$	L_∞	t_0
Southern region (n = 349)[1]									
Schnute (z = 0.920, F = 3.69)	0.148	0.757	30.112	103,216	1	19			
SE	0.064	0.557	0.872	6.103					
Left 95% *CI*	0.025	–0.610	28.357	92.923					
Right 95% *CI*	0.312	1.830	32.061	117.444					
Northern region (n = 183)[2]									
Schnute (z = 0.198, F = 0.030)	0.123	0.602	30.092	102.295	1	28			
SE	0.047	0.593	1.089	5.435					
Left 95% *CI*	0.029	–0.700	27.889	93.991					
Right 95% *CI*	0.221	1.835	32.044	116.302					
Regions combined (n = 520)									
Schnute (z = 3.246*, F = 1.065)	0.181	0.470	31.154	97.285	1	28			
SE	0.049	0.570	1.079	4.656					
Left 95% *CI*	0.071	–0.627	28.744	92.153					
Right 95% *CI*	0.266	1.758	33.260	109.820					
Southern region (n = 349)[1]									
VBGF (z = 0.920, F = 2.92)							0.120	116	–1.47
SE							0.016	8	0.20
Left 95% *CI*							0.089	103	–1.91
Right 95% *CI*							0.157	136	–1.10
Northern region (n = 183)[2]									
VBGF (z = 0.198, F = 0.033)							0.094	112	–2.29
SE							0.013	8	0.33
Left 95% *CI*							0.070	100	–3.03
Right 95% *CI*							0.121	130	–1.70
Regions combined (n = 520)									
VBGF (z = 3.13*, F = 2.15)							0.136	103	–1.58
SE							0.011	4	0.19
Left 95% *CI*							0.114	96	–1.97
Right 95% *CI*							0.160	111	–1.25
Mark-recapture data (n = 26)									
VBGF							0.120[3]		

* Did not pass the runs test
[1] Includes 11 otoliths of one-year-old fish from the central region
[2] Includes all 30 otoliths of fish from the central region
[3] Using L_∞ and t_0 from the southern region

error structure provided a better fit than the absolute error structure, because residual size increased with increasing age. Growth rates of males and females in both regions did not differ significantly ($p > 0.05$), and therefore the data for both sexes were pooled. There was a significant difference in growth ($p < 0.05$) between the southern and the northern regions. The derived parameters of the Schnute model and the Von Bertalanffy growth function (*VBGF*) are shown in Table II. The Schnute model and the *VBGF* fit on the pooled data for northern and southern silver kob failed the randomness tests (*VBGF*: $z = 3.13$, $F = 3.11$: Schnute model: $z = 3.246$, $F = 1.07$). The residuals indicated that this was possibly a result of the one-year-old fish (which all showed positive residuals) over-estimating the mean length for that age-class (Fig. 4).

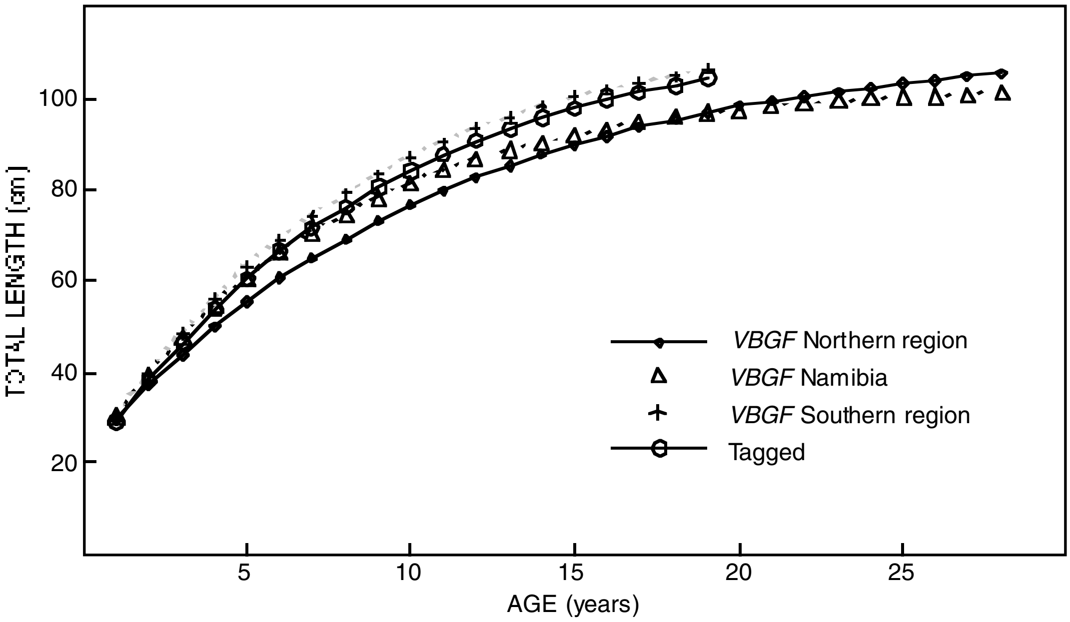

Fig. 6: Calculated length-at-age, using Von Bertalanffy parameters derived from otolith readings and from mark-recapture data for *A. inodorus* from the northern and southern regions and from Namibia (both regions combined). The *VBGF* growth parameters $t_0 = -1.5$ and $L_\infty = 116$ cm, obtained from the analysis of the southern region otolith data, were used for the tagging data

The Von Bertalanffy growth curve for the regions combined is similar to that of young fish from the southern region and of old fish from the north (Fig. 4).

Many of the data points for the regions combined lie outside the estimated 95% confidence intervals when using the bootstrap technique, which seems unrealistic (Fig. 4). Therefore, the 95% confidence intervals were estimated as the mean length multiplied by $(1 \pm 2\gamma)$, where γ is the constant coefficient of variation in length-at-age (0.119), estimated as the standard deviation of relative residuals (Beyer *et al*. 1999).

Von Bertalanffy growth data for the northern region were derived mainly from old fish, whereas data from the south were obtained from young fish. The inflection between 7- and 8-year-olds (Fig. 3) was not accounted for in the fitted *VBGF*. The inflection is more marked in the observed growth data for the northern region (Fig. 4), which coincides with the age at which silver kob start their annual spawning migration off Namibia (Kirchner 1999).

The value of K using recapture data and an L_∞ of 116 cm, ranged between 0.047 and 0.221 (Fig. 5). The average value of K was estimated to be 0.120 (± 0.009). The sensitivity test for L_∞ gave a K value of 0.152 (± 0.011) for an L_∞ of 103 cm and 0.092 (± 0.007) for an L_∞ of 136 cm. However, Namibian silver kob rarely attain a length exceeding 120 cm and the average length of large fish within a shoal is around 100 cm (Kirchner 1999). The growth rate of silver kob from the southern region was similar to the growth rate obtained from the tagging study (Fig. 6).

The growth pattern of silver kob differed between the Namibian and South African populations (Fig. 7). Growth was rapid in Namibian silver kob during the first year, but thereafter annual growth decreased exponentially (Fig. 7). According to various models describing the growth of South African silver kob (Griffiths 1996), after an initial growth of 30 cm in their first year, they followed a bell-shaped pattern, with no apparent growth after an age of 18 years. However, Namibian kob continued to grow, albeit slowly, after that age.

DISCUSSION

The overall precision estimates (*APE*) of between

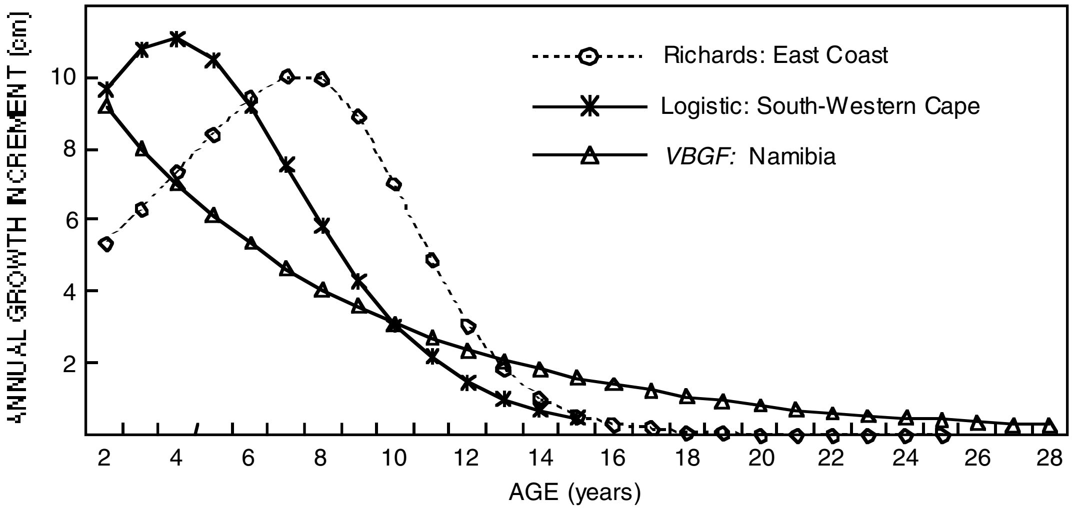

Fig. 7: Comparison of annual growth increments of *A. inodorus*, derived from the Richards model fitted to data from the east coast of South Africa, and the logistic model fitted to the data for the South-West Cape (from Griffiths 1996), and the Von Bertalanffy model (*VBGF*) fitted to the data from Namibia. Growth for the first year was 30 cm for all three stocks

6 and 7% attained here was slightly higher than those reported for other sciaenids. Using sectioned otoliths, Beckman *et al*. (1988) achieved a precision of 0–4% for red drum *Sciaenops ocellatus* and Barger (1985) attained an *APE* of 1% for Atlantic croaker *Micropogonias undulatus*.

The significant difference in growth rate between the southern and northern silver kob could imply the presence of two allopatric stocks in Namibian waters. However, tagging data show that there is a mixture of silver kob in the central region off Namibia, consisting of populations from both the southern and northern regions (Kirchner 1999). Moreover, silver kob marked in the southern region have not been recaptured in the northern region, and vice versa. Further, 1-year-olds are virtually absent from the south and 1 and 2-year-olds are rare in the north. Fish of that age are normally only found in the central region, described by Kirchner (1999) as the juvenile silver kob ground. Annual growth of silver kob 1–4 years old in the south was 2–3 cm per year faster than those in the north. Differences in annual growth between those two regions were minimal in fish older than four years (Fig. 7).

There is no evidence to suggest any genetic difference in silver kob between the southern and northern populations off Namibia. Growth differences could be ascribed to differences in environmental conditions and food availability. The diet of silver kob in the northern region consists mainly of pelagic fish, shrimps and squid, whereas shrimps are the major food source of silver kob in the southern and central regions (Kirchner 1999).

Given that tagged silver kob moved into the central region from both the northern and southern regions, the Namibian kob stock can be regarded as a single, homogeneously mixed population unit. Therefore, for stock assessment purposes, data from the two regions can be pooled to obtain values of growth parameters.

Growth determined partially by the mark-recapture data from the southern region (Fig. 6) follows a similar growth pattern to that obtained using Von Bertalanffy parameters from the same area. The similarity in the growth curves using the mark-recapture data and the Von Bertanlanffy parameters (using otolith reading) seems to validate the assumption that one hyaline and translucent ring are laid down annually by the Namibian silver kob. Annual ring formation in otoliths was also found for South African silver kob (Griffiths 1996) and dusky kob *A. japonicus* (Griffiths and Hecht 1995).

ACKNOWLEDGEMENTS

We thank Drs M. Kerstan from Marine and Coastal Management and A. Bosman for their constructive comments and advice on an initial draft of this paper, Dr A. Govender from the Oceanographic Research Institute in Durban and an anonymous reviewer for their comments on the submitted manuscript, which greatly improved it. Finally, we thank the Namibian Ministry of Fisheries and Marine Resources for making the data available for publication.

LITERATURE CITED

ANON. 1993 — Sea Fisheries Regulations. *Government Gazette of the Republic of Namibia* **Act 29 of 1992** (Section 32): 55 pp.

BARGER, L. E. 1985 — Age and growth of Atlantic croakers in the northern Gulf of Mexico, based on otolith sections. *Trans. Am. Fish. Soc.* **114**: 847–850.

BEAMISH, R. J. and D. A. FOURNIER 1981 — A method for comparing the precision of a set of age determinations. *Can. J. Fish. aquat. Sci.* **38**: 982–983.

BECKMAN, D. W., WILSON, C. A. and A. L. STANLEY 1988 — Age and growth of red drum, *Sciaenops ocellatus*, from offshore waters of the northern Gulf of Mexico. *Fishery Bull., Wash.* **87**(1): 17–28.

BEYER, J. E., KIRCHNER, C. H. and J. A. HOLTZHAUSEN 1999 — A method to determine size-specific natural mortality applied to westcoast steenbras *Lithognathus aureti* in Namibia. *Fish. Res.* **41**(2): 133–153.

DRAPER, N. R. and H. SMITH 1966 — *Applied Regression Analysis*, 2nd ed. New York; Wiley: 709 pp.

EFRON, B. 1982 — The jackknife, the bootstrap and other resampling plans. Philadelphia; Society for Industrial and Applied Mathematics: 92 pp.

GRIFFITHS, M. H. 1996 — Age and growth of South African silver kob *Argyrosomus inodorus* (Sciaenidae), with evidence for separate stocks. *S. Afr. J. mar. Sc*i. **17**: 37–48.

GRIFFITHS, M. H. and T. HECHT 1995 — Age and growth of South African dusky kob *Argyrosomus japonicus* (Sciaenidae) based on otoliths. *S. Afr. J. mar. Sci.* **16**: 119–128.

GRIFFITHS, M. H. and P. C. HEEMSTRA 1995 — A contribution to the taxonomy of the marine fish genus *Argyrosomus* (Perciformes: Sciaenidae), with descriptions of two new species from southern Africa. *Ichthyol. Bull. J. L. B. Smith Inst. Ichthyol.* **65**: 40 pp.

KIRCHNER, C. H. 1999 — Population dynamics and stock assessment of the exploited silver kob (*Argyrosomus inodorus*) in Namibian waters. Ph.D. thesis University of Port Elizabeth: 240 pp.

KIRCHNER, C. H. and J. E. BEYER 1999 — Estimation of total catch of silver kob *Argyrosomus inodorus* by recreational shore-anglers in Namibia, using a roving-roving creel survey. *S. Afr. J. mar. Sci.* **21**: 191–199.

KIRCHNER, C. H. BOSMAN, A and J. I. BARNES (in press) — Estimation of the economic value of the Namibian recreational rock-and-surf fishery. *S. Afr. J. mar. Sci.* **22**.

PUNT, A. E., 1992 — PC-Yield II user's guide (version 2.2). *Rep. Benguela Ecol. Progm. S. Afr.* **26**: 31 pp.

RAUCK, G. 1976 — A technique of sawing thin slices out of otoliths. *Ber. dt. wiss. Kommn Meeresforsch.* **24**(4): 339–341.

SCHNUTE, J. [T.] 1981 — A versatile growth model with statistically stable parameters. *Can. J. Fish. aquat. Sci.* **38**(9): 1128–1140.