

AGE AND GROWTH OF SOUTH AFRICAN DUSKY KOB *ARGYRO SOMUS JAPONICUS* (SCIAENIDAE) BASED ON OTOLITHS

M. H. GRIFFITHS* and T. HECHT†

The ages of dusky kob *Argyrosomus japonicus*, sampled from three regions along the South African eastern seaboard during 1991 and 1992, were determined from longitudinal sections of otoliths. The otoliths were selected from fish 35–1 750 mm total length. Ages from 0 to 42 years were recorded, but fish older than 27 were rare. Analysis of the otolith margins indicated that a single opaque and a single hyaline zone were being deposited annually. The first annulus was validated by analysis of daily increments. Observed lengths-at-age were highly variable. The fitted generalized Von Bertalanffy growth equations were:

$$L_t = 1\,473[1 - e^{-0.228(t+2.620)}]^{2.468} \text{ for females,}$$
$$L_t = 1\,372[1 - e^{-0.260(t+4.282)}]^{4.619} \text{ for males.}$$

Growth was faster in females, but in both sexes it slowed down after the age of 8. The relationships between otolith dimensions (length, height, mass and ostium to cauda distance) and fish length, in each of three regions, suggested that South African *A. japonicus* exist as three or more stocks.

Die ouderdom van vaalkob *Argyrosomus japonicus*, bemonster uit drie streke langs die Suid-Afrikaanse ooskus gedurende 1991 en 1992, is bepaal van lengtesneë van otoliete. Die otoliete is verkry uit vis 35–1 750 mm totale lengte. Ouderdomme van 0 tot 42 jaar is aangeteken, maar vis ouer as 27 was skaars. Ontleding van die otolietrand het aangetoon dat 'n enkele ondeursigtige en 'n enkele hialiene sone jaarliks neergelê word. Die eerste jaarring is deur ontleding van daaglikse inkremente bevestig. Waargenome lengte op bepaalde ouderdom was hoogs veranderlik. Die gepaste veralgemeende Von Bertalanffy-groeiwerkings was:

$$L_t = 1\,473[1 - e^{-0.228(t+2.620)}]^{2.468} \text{ vir wyfies,}$$
$$L_t = 1\,372[1 - e^{-0.260(t+4.282)}]^{4.619} \text{ vir mannetjies.}$$

Groei is sneller by wyfies, maar by albei geslagte verlangsaam dit ná ouderdom 8. Die verhoudings tussen otolietafmetings (lengte, hoogte, massa en die afstand tussen ostium en cauda) en vislengte, in elk van die drie streke, dui op die bestaan van drie of meer stapels van die Suid-Afrikaanse *A. japonicus*.

The dusky kob *Argyrosomus japonicus* has a wide distribution, occurring in both northern and southern hemispheres. It is found on the east coast of southern Africa from the Cape of Good Hope to Mozambique (Griffiths and Heemstra 1995), along the entire southern seaboard of Australia from North West Cape to the Burnette River (Kailola *et al.* 1993, Starling 1993), and from Hong Kong northwards along the Chinese coast to southern Korea and Japan (Trewavas 1977). Until recently it was misidentified as *A. hololepidotus* in both southern Africa and Australia (Griffiths and Heemstra 1995).

In South Africa *A. japonicus* is an important commercial and recreational linefish, which is abundant from Cape Agulhas to northern KwaZulu/Natal (Griffiths and Heemstra 1995). Information on its growth rate and possible stock separation is essential

to understanding its life history, for stock assessment and also for improved management advice. Wallace and Schleyer (1979) modelled the growth of *A. japonicus* from the otoliths of 148 specimens gill-netted in the estuaries of KwaZulu/Natal. Based predominantly on young fish (only seven fish older than 7 years), their derived growth function incompletely described the growth of the species. In this paper the growth of *A. japonicus* is described on the basis of data from fish ranging in age from 1 to 42 years. Samples were obtained from localities throughout its range of distribution in South African waters.

Otolith shape has proved to be a useful indicator of stock identity in fish. The otoliths of fish from different areas are generally compared on the basis of linear measurements of definable structures (Messiah 1972, Rojo 1977, King 1985, Payne 1985, Grygiel

* Sea Fisheries Research Institute, Private Bag X2, Rogge Bay 8012, South Africa

† Department of Ichthyology & Fisheries Science, Rhodes University, P.O. Box 94, Grahamstown 6140, South Africa

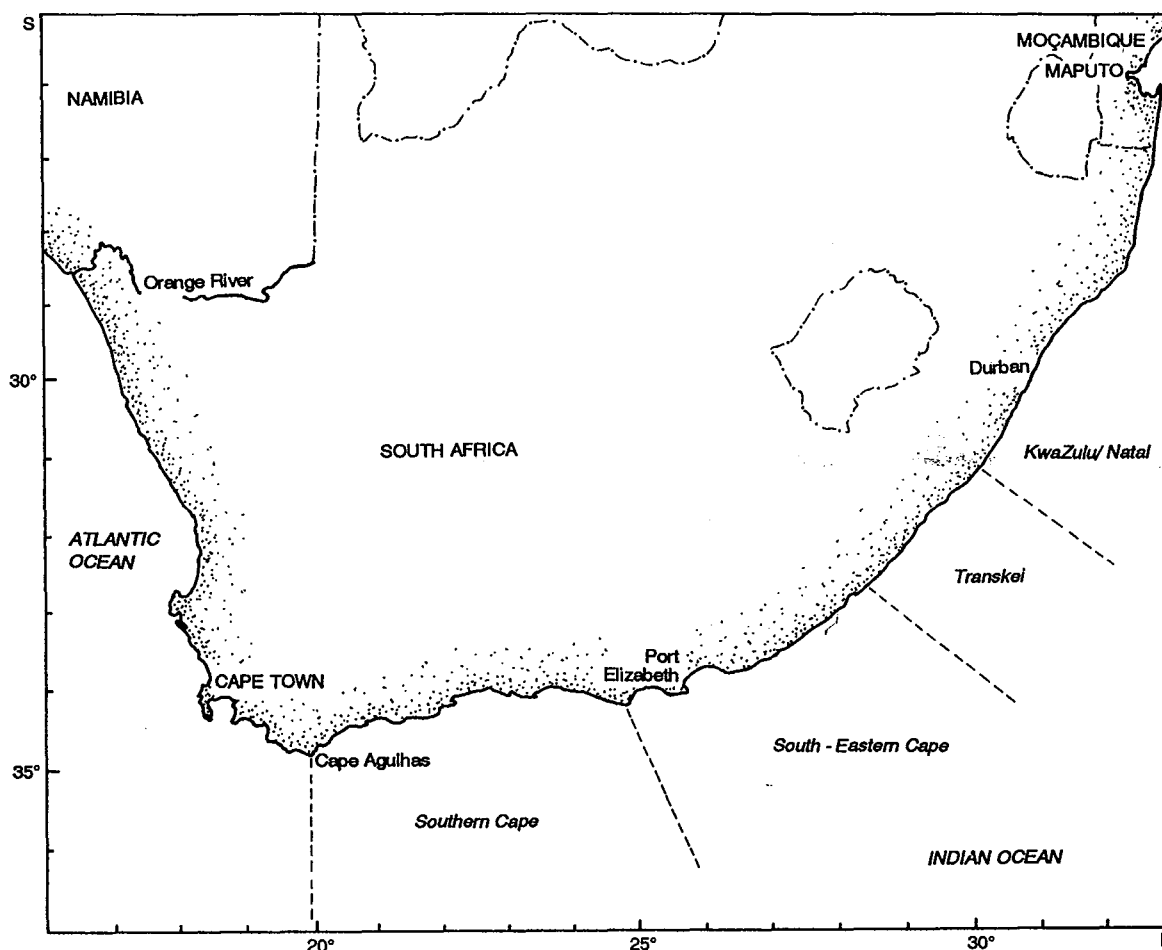


Fig. 1: Map of South Africa showing the three regions used for sampling

1987, Japp 1990, Dawson 1991, Smith 1992), or on the basis of mathematical descriptions of shape, particularly Fourier series (Bird *et al.* 1986, Castonguay *et al.* 1991, Smith 1991, Campana and Casselman 1993). The possibility of more than one stock of dusky kob existing along the South African east coast was investigated by comparing the relationships between fish length and four otolith measurements, for fish obtained from three different regions.

MATERIAL AND METHODS

The South African east coast was subdivided into four regions for sampling purposes (Fig. 1). Sagittal otoliths were collected and total fish length (nearest mm) and fish mass were recorded from male and female dusky kob caught by recreational and commercial

linefishermen operating in estuaries, in the surf zone and nearshore (beyond the surf to 100 m deep) in KwaZulu/Natal, the South-Eastern Cape and the Southern Cape during 1991 and 1992. No fish were sampled in the Transkei. Fish of total length $TL < 350$ mm were collected during scientific seine-netting expeditions. Mass was measured to the nearest gramme (<500 g), to the nearest 20 g (500 g – 5 kg), to the nearest 100 g (5 – 25 kg), or to the nearest 200 g (>25 kg). The otoliths were removed ventrally by first removing the gillrakers and then cutting away a portion of bone in the pro-otic/exoccipital region. They were lifted out of the skull with forceps, cleaned and stored dry in envelopes.

Age determination

A total of 572 otolith pairs was used for age deter-

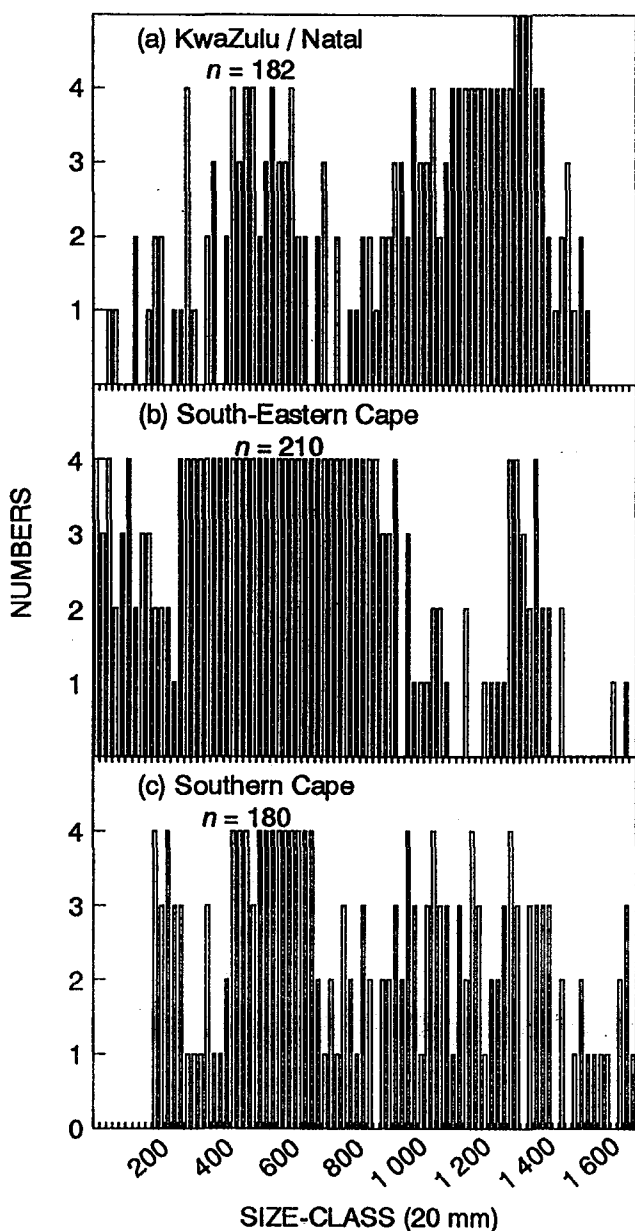


Fig. 2: Length frequency histograms of *A. japonicus* used for the growth and stock separation analyses from a) KwaZulu/Natal, b) the South-Eastern Cape, c) the Southern Cape

mination. These were selected so that, where possible, every 10-mm size-class, within the range of fish sampled (35–1 750 mm TL), was represented by two pairs (one male and one female) from each region (Fig. 2). To avoid errors resulting from there being insufficient older specimens in the collection (Hirschhorn 1974), the otoliths from all fish >1 300 mm TL were included in the analysis. Owing to the thick-

ness and the overall opacity of dusky kob otoliths, they were all sectioned. Depending on otolith size, between two and six longitudinal sections (0.5–0.7 mm) were cut from each right otolith to ensure that the focus was included. A single diamond-wafering blade was used, with a saw similar to that described by Rauck (1976). Each section was then mounted on a glass slide using DPX mountant and examined on a black background under a dissecting microscope (6 \times) and reflected light.

The number of opaque (white) zones (Fig. 3) was enumerated three times, each on a different day, without any reference to fish size. If no readings coincided the otolith was rejected. The periodicity of growth-zone deposition was determined by plotting the monthly percentages of otoliths with opaque margins. The first annulus was indirectly validated on the basis of daily increment counts. Seven otolith sections, each with one opaque zone, were mounted on SEM staves with colloidal silver. These were then polished with 0.05 μ m alumina paste, etched for 5 minutes with 0.1% HCl, rinsed with water and cleaned using ultrasound. Finally, they were coated with gold-palladium (20 nm) and viewed under a scanning electron microscope at 4 500 \times magnification. The number of daily growth increments (Fig. 4a) between the primordium (Fig. 4b) and the medial margin (Fig. 3) of each otolith was counted.

Growth in length

The Von Bertalanffy (1957), generalized Von Bertalanffy, and Richards and Schnute growth models (Schnute 1981) were fitted to the length-at-age data (excluding 0-year-old fish) for males, females and sexes combined, using an iterative, non-linear minimization procedure (Butterworth *et al.* 1989, Punt and Hughes 1989). Minimization of the sum of squared absolute (as opposed to relative) differences was used, because the residuals for this method were homoscedastic for most models fitted. One-sample run tests (Draper and Smith 1966) showed that the residuals were not randomly distributed about the three-parameter Von Bertalanffy (1957) function, using either the absolute or the relative error models. Likelihood ratio tests (Draper and Smith 1966) revealed that the four-parameter Schnute and generalized Von Bertalanffy models fitted the data best. As there was little difference between the models, and because Von Bertalanffy growth parameters can be directly incorporated in stock assessment models (Ricker 1975, Vaughan and Kanciruck 1982) used in estimating natural mortality (Pauly 1980) and are often used in comparing the life history styles of fish (Beverton 1992), the

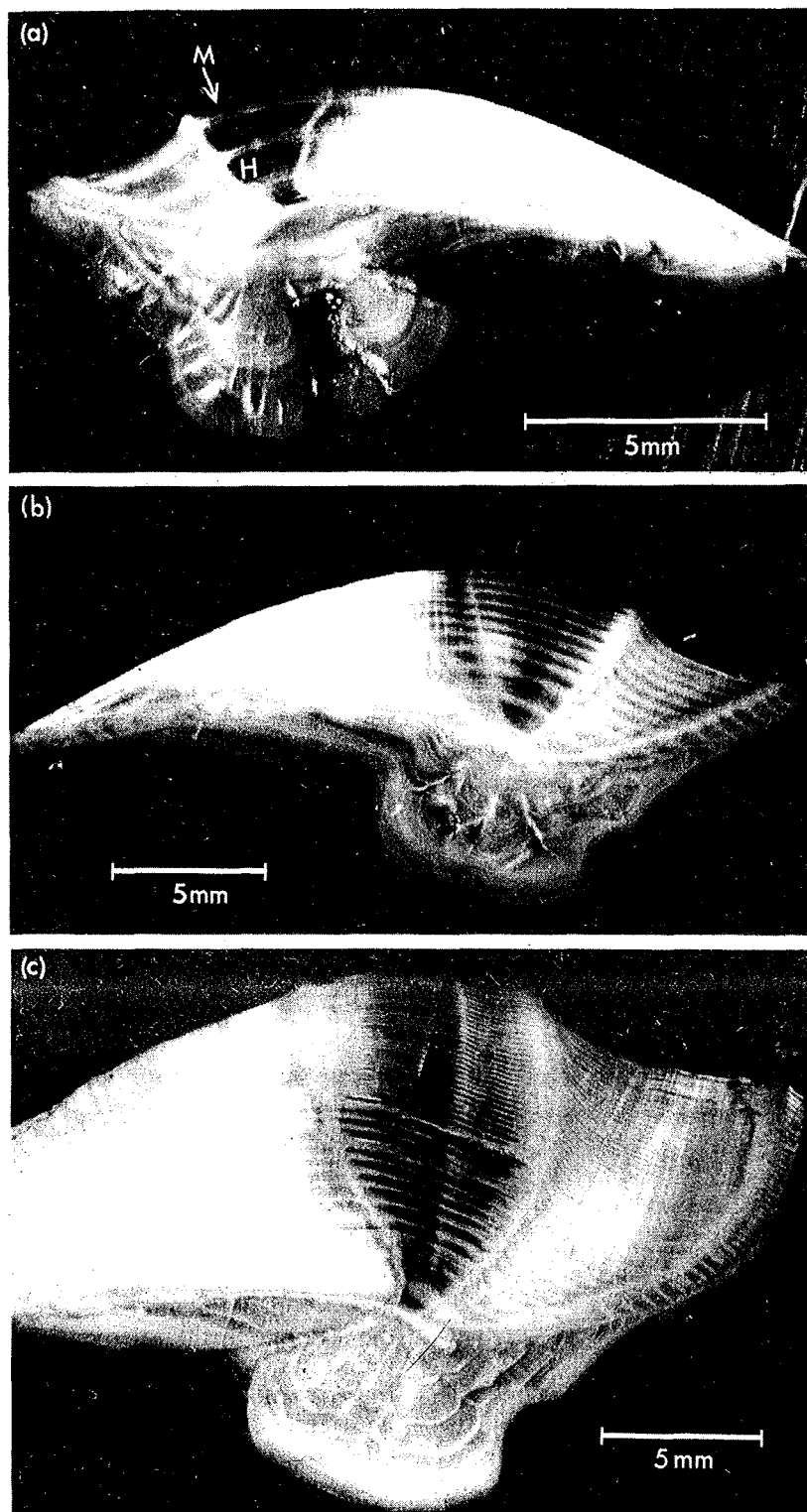


Fig. 3: Longitudinal otolith sections of a) 3-year-old, b) 11-year-old, c) 42-year-old *A. japonicus* from South Africa. O=opaque, H=hyaline, M = medial margin

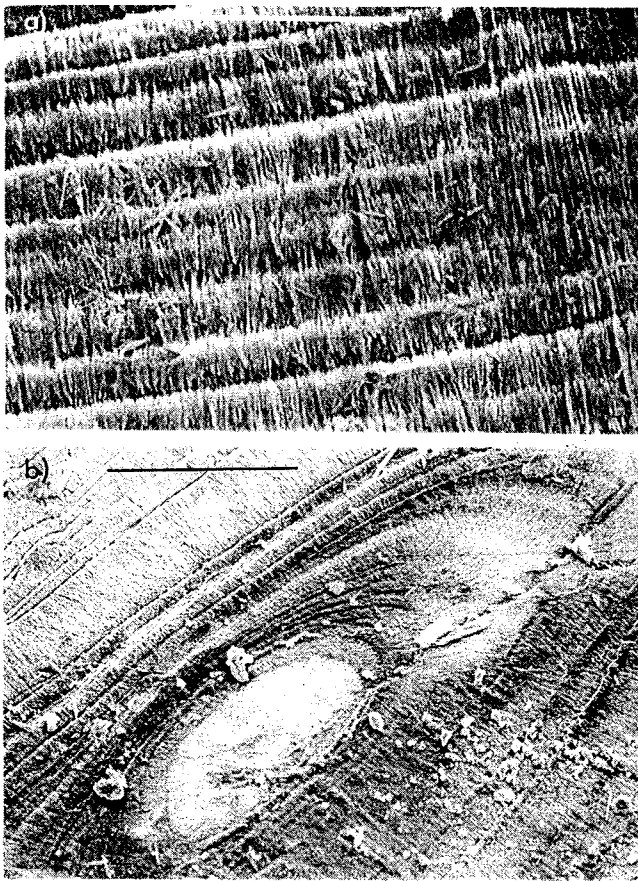


Fig. 4: a) Daily growth increments and b) the primordium of an *A. japonicus* otolith of 490 days old, as viewed with scanning electron microscopy (each bar is 10 µm)

data for the generalized form

$$L_t = L_{\infty}[1 - e^{-K(t-t_0)}]^p$$

are presented in this paper. Standard errors and the 95% confidence intervals for each parameter of the model were calculated using a non-parametric bootstrap technique (Efron 1981) and the percentile method (500 bootstraps) respectively.

To allow for the conversion of total-length-at-age to mass-at-age and standard-length-at-age, the relationships between total fish length and both mass and standard length were also derived.

Fish length/otolith dimension relationships

The left otolith from every pair used for the growth analysis (Fig. 2) was measured for length (*OL*), height

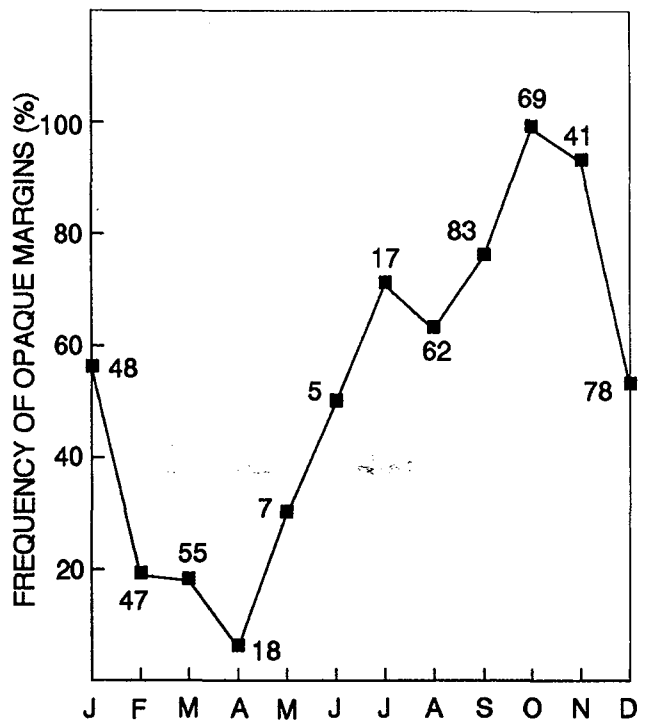


Fig. 5: Monthly frequency of *A. japonicus* otoliths (>0 years) with opaque margins off South Africa. The numbers indicate the size of the sample

(*OH*), ostium-cauda distance (*OCD*, $\pm 0,01$ mm) and mass (*OM*, $\pm 0,0001$ g) according to the methods of Griffiths and Heemstra (1995). The otolith dimension and fish length (*TL*) data were log-transformed, the relationships modelled by means of linear regression, and the results compared between areas by testing for differences in slope and intercept (Draper and Smith 1966).

RESULTS AND DISCUSSION

Age and growth

Longitudinal sections of the saggital otoliths of *A. japonicus*, of all ages, show distinct opaque and hyaline bands which can be used for age determination (Fig. 3). These were most visible in and around the window (beneath the cauda). Only 13 otoliths (2,4%) were rejected on the basis of non-matching counts. One opaque zone is deposited annually in spring (Fig. 5), which is in agreement with the finding of Wallace and Schleyer (1979), and it coincides with the spawning season (Griffiths in prep.). Between 380 and 540 daily growth increments were observed for otoliths with

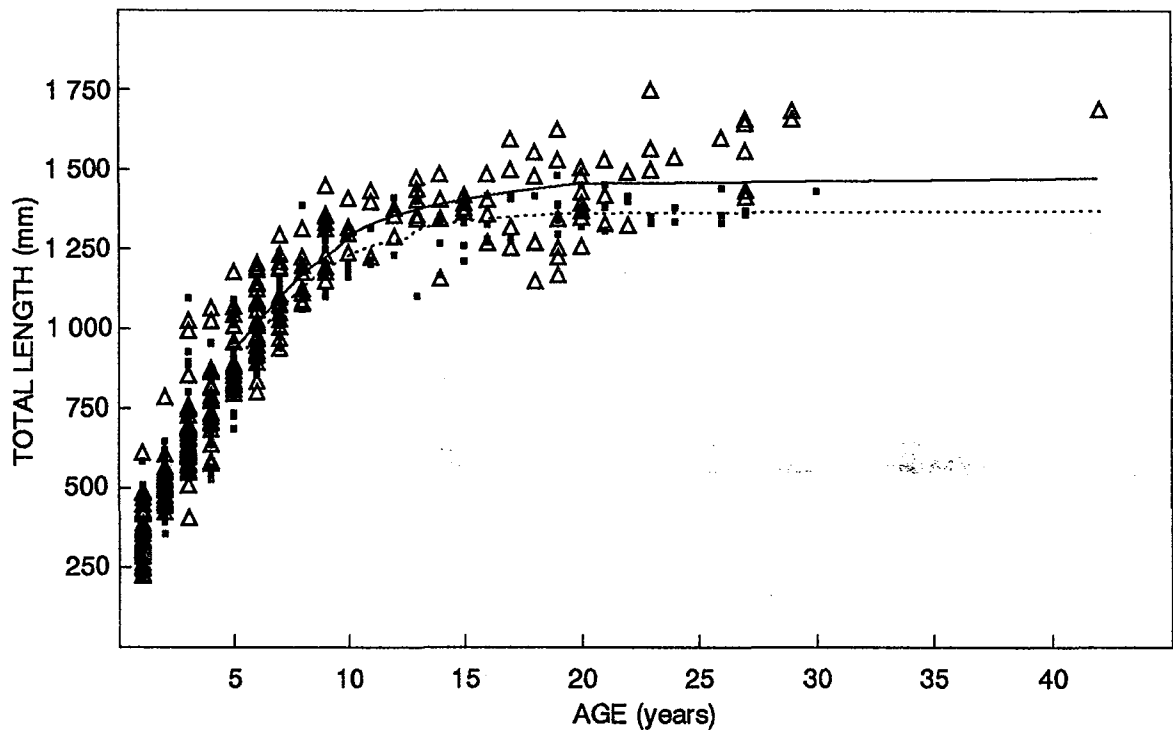


Fig. 6: Calculated Von Bertalanffy (four-parameter) growth curves and observed lengths at age for male (squares and dotted line) and female (triangles and solid line) *A. japonicus* off South Africa

one opaque zone (i.e. >360 but <720), confirming that this was the first annulus.

Observed lengths varied greatly within age-groups (Fig. 6, Table I), which is common for sciaenids, e.g. *Sciaenops ocellatus* (Beckman *et al.* 1989, Ross *et al.* 1995), *Micropogonias undulatus* (Barbieri *et al.* 1994), *Pogonias cromis* (Beckman *et al.* 1990) and *Cynoscion nebulosus* (Murphy and Taylor 1994). The four parameters of the generalized Von Bertalanffy model are given in Table II, with standard errors and the 95% confidence intervals for each parameter. A likelihood ratio test (Draper and Smith 1966) showed that the differences between male and female growth were highly significant ($F = 407.7$, $df = 4$ and 510 ; $p = 0.05$). Growth in both sexes was rapid for the first eight years, after which it slowed dramatically, but more so in males than in females (Fig. 6).

According to Roff (1983), faster female growth is a life history strategy in fish for increasing reproductive potential through increased egg production. Faster female growth has also been observed for the red drum, *Sciaenops ocellatus* (Beckman *et al.* 1989). The

transition from fast to slow growth in *A. japonicus* apparently takes place at the size at sexual maturity. Maturity of all fish is attained at about 1 100 mm TL in males and at 1 200 mm TL in females (Griffiths in prep.). These lengths correspond to ages of 8 and 9 years, respectively. Female *A. japonicus* did not appear to live longer than males. Excluding one female of 42 years and one male of 30, the remaining ages (up to 29) were evenly distributed among the sexes (Fig. 6). Although the oldest dusky kob aged was 42 years, the few fish >27 years may be the result of exploitation. According to Ricker (1963), populations which include appreciable numbers of fish older than 12 years prior to exploitation will be extremely sensitive to fishing.

The rate of growth modelled in this study was compared with that modelled by Wallace and Schleyer (1979). Owing to a truncated data range (only five fish >7 years and a maximum age of 12 years), the model of Wallace and Schleyer (1979) incompletely describes the growth of the dusky kob (Fig. 7). Nevertheless, the calculated lengths of fish from two to

Table 1: Age-length key for *A. japonicus* from South African waters, 1991 and 1992

Size-class (mm)	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	21	22	23	24	25	26	27	28	29	30	36	42																									
200- 249	5																																																								
250- 299	13																																																								
300- 349	20																																																								
350- 399	14	1																																																							
400- 449	9	6																																																							
450- 499	6	15	4	1																																																					
500- 549	2	18	6	3																																																					
550- 599		7	17	4																																																					
600- 649		5	23	4																																																					
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1 200-1 249				2	2	4	4	3	2	3																																															
1 250-1 299					2	4	4	2	1	1																																															
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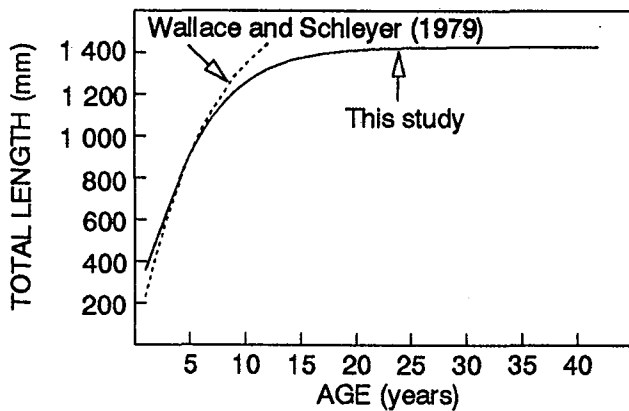


Fig. 7: Comparison of the growth curve calculated for *A. japonicus* in this study with that of Wallace and Schleyer (1979)

seven years of age are comparable. The substantially lower length at one year (220 mm TL) in the Wallace and Schleyer (1979) study (357 mm TL was the estimate in this study) can be attributed to the fact that, in the earlier study, *t* was 0,2 years and fish of 1,2-1,8 years were not regarded as one year old. The smaller one-year-olds of the present study were also about 220 mm TL (Fig. 6, Table 1).

Morphometric relationships

The length/mass and total length/standard length relationships for South African *A. japonicus* are described in Figure 8. Tests for difference in slope and intercept, after log-transformation (Draper and Smith 1966), showed that the length/mass relationships for males and females did not differ significantly.

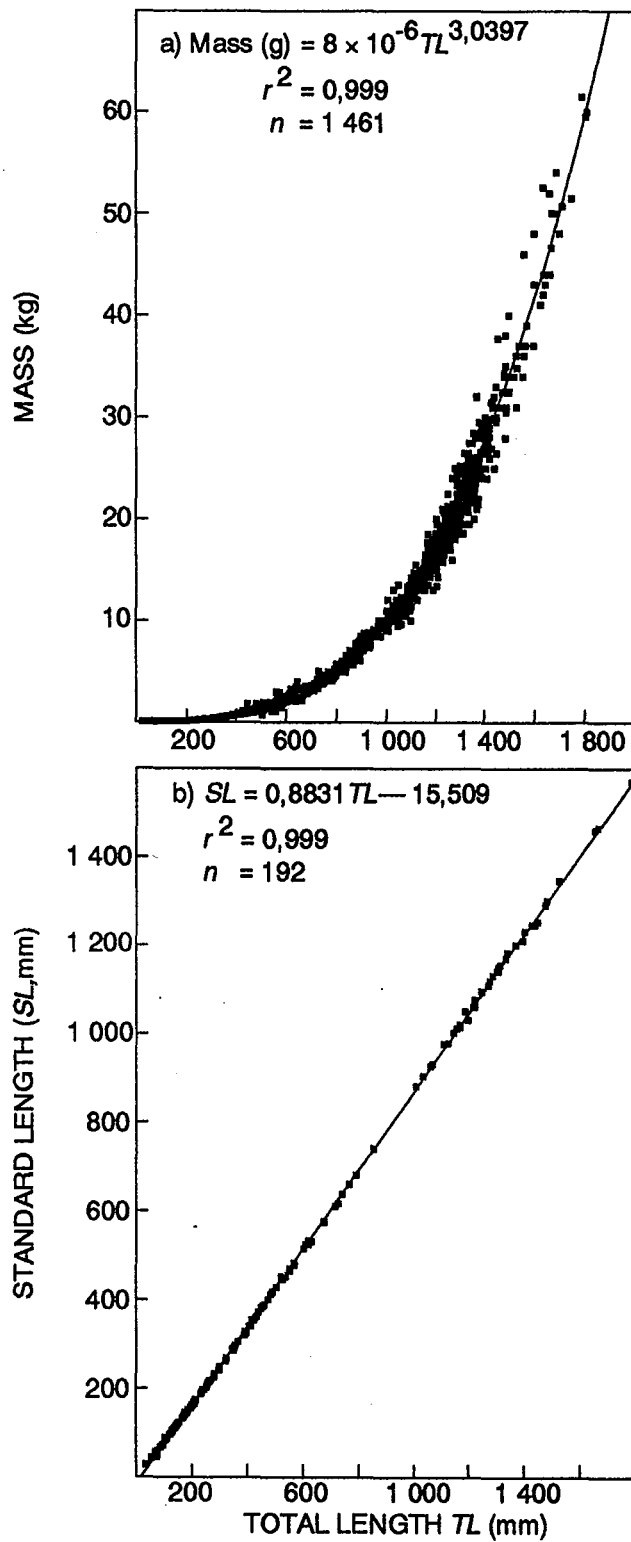


Fig. 8: Relationships between total length and a) mass, b) standard length for *A. japonicus* found off South Africa

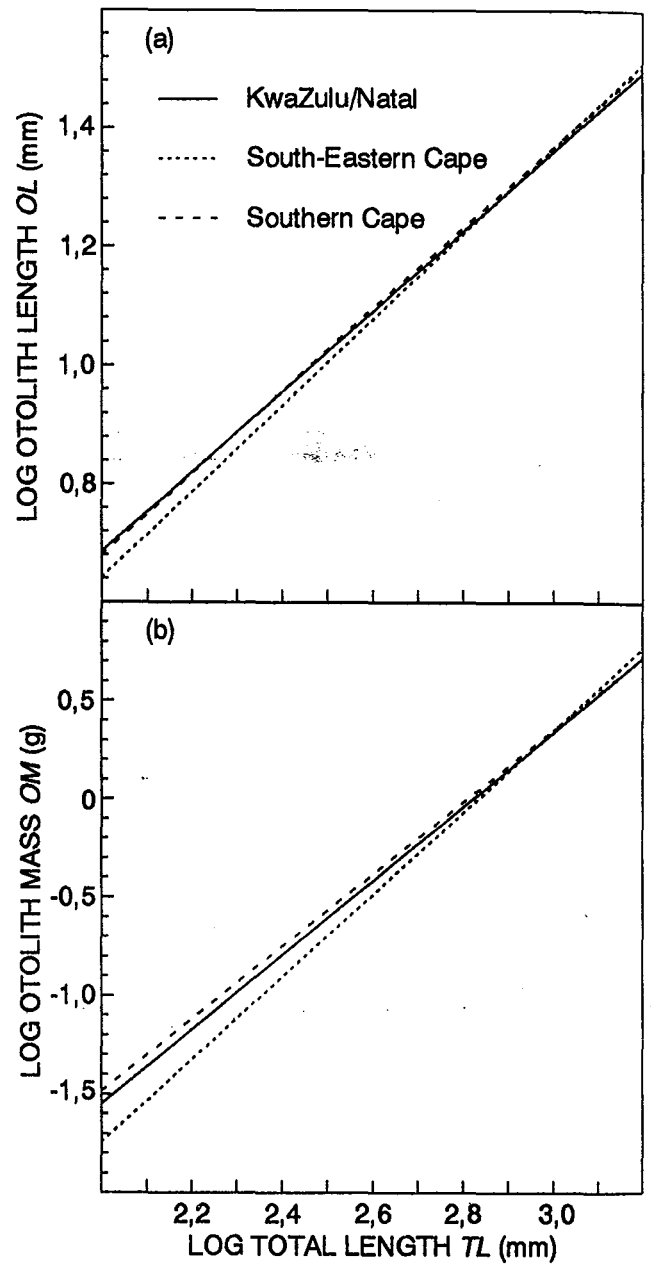


Fig. 9: Relationships between total length and a) otolith length b) otolith mass for *A. japonicus* from the three regions samples

Otolith dimension/fish length relationships

The relationships between otolith dimension and total length were significantly different between regions (Table III), but not between sexes within regions ($p > 0,05$). The relationships between *TL* and both otolith length and otolith mass for each of the three

Table II: Parameter estimates, SEs and the 95% confidence intervals (CI) for the generalized Von Bertalanffy model fitted to age data for *A. japonicus* (0-year-olds omitted)

Parameter	Value			
	K	L_{∞}	t_0	p
<i>Males (n = 262)</i>				
Model	0,260	1 372,297	-4,282	4,619
SE	0,028	18,767	9,860	2 108,380
Left 95% CI	0,199	1 343,574	-30,572	1,251
Right 95% CI	0,30	1 403,604	-0,920	8 673,815
<i>Females (n = 257)</i>				
Model	0,228	1 472,865	-2,620	2,468
SE	0,049	39,909	7,510	1 312,944
Left 95% CI	0,112	1 435,260	-30,006	0,605
Right 95% CI	0,280	1 585,783	0,280	4 912,945
<i>Both sexes (n = 519)</i>				
Model	0,241	1 427,3	-3,194	3,067
SE	0,032	19,874	6,046	1 094,626
Left 95% CI	0,155	1 403,574	-26,651	0,806
Right 95% CI	0,276	1 486,934	-0,145	2 872,233

regions are illustrated in Figure 9. As otolith shape is strongly influenced by environmental conditions (Campana and Casselman 1993), these results may not reflect genetic differences. They do, however, suggest that three or more stocks of South African *A.*

japonicus exist, for at least a substantial portion of their lives. Analysis of commercial catch returns and tagging data indicates that juvenile dusky kob (<100 mm TL) are fairly resident, but that a large proportion of the adult population migrate from the Cape to KwaZulu/Natal to spawn (Griffiths in prep.). This would imply that the adult population exists as a single stock and that genetic differences in juvenile populations are unlikely. Furthermore, while juvenile exploitation in one area would not affect catches in another, juvenile exploitation in all areas would impact on the adult population. Similarly, excessive exploitation of adults, particularly in KwaZulu/Natal, where they form easily targeted spawning aggregations (pers. obs.), could reduce recruitment levels in all regions. It would therefore be wise for *A. japonicus* to be managed on a national as opposed to a regional basis.

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Table III: The relationships between otolith dimensions and total fish length (TL) for *A. japonicus* from KwaZulu/Natal (KN), the South-Eastern Cape (SEC) and the Southern Cape (SC). The relationships for each region were statistically compared (differences in slope and intercept) after straight-line regressions were fitted to the log-transformed data

Region	Relationship†	n	r	Comparison	
				KN	SEC
KwaZulu/Natal	$OL(\text{mm}) = TL(\text{mm})^{0.674}/4,607$	176	0,991		
South-Eastern Cape	$OL(\text{mm}) = TL(\text{mm})^{0.723}/6,374$	208	0,996	SEC	**
Southern Cape	$OL(\text{mm}) = TL(\text{mm})^{0.687}/4,960$	159	0,993	SC	**
All areas	$OL(\text{mm}) = TL(\text{mm})^{0.723}/6,374$	543	0,995		
KwaZulu/Natal	$OH(\text{mm}) = TL(\text{mm})^{0.604}/4,984$	176	0,980		
South-Eastern Cape	$OH(\text{mm}) = TL(\text{mm})^{0.635}/6,180$	208	0,992	SEC	**
Southern Cape	$OH(\text{mm}) = TL(\text{mm})^{0.634}/6,022$	159	0,985	SC	*
All areas	$OH(\text{mm}) = TL(\text{mm})^{0.630}/5,931$	543	0,989		
KwaZulu/Natal	$OC(\text{mm}) = TL(\text{mm})^{0.595}/15,619$	176	0,949		
South-Eastern Cape	$OC(\text{mm}) = TL(\text{mm})^{0.588}/14,299$	208	0,984	SEC	**
Southern Cape	$OC(\text{mm}) = TL(\text{mm})^{0.629}/19,915$	159	0,966	SC	**
All areas	$OC(\text{mm}) = TL(\text{mm})^{0.589}/14,821$	543	0,969		
KwaZulu/Natal	$OM(\text{mm}) = TL(\text{mm})^{1.888}/212 701,23$	176	0,982		
South-Eastern Cape	$OM(\text{mm}) = TL(\text{mm})^{2.088}/831 782,92$	208	0,993	SEC	**
Southern Cape	$OM(\text{mm}) = TL(\text{mm})^{1.837}/145 124,25$	159	0,987	SC	*
All areas	$OM(\text{mm}) = TL(\text{mm})^{2.008}/479 004,00$	543	0,989		

† OL = otolith length, OH = otolith height, OC = ostium to cauda distance, OM = otolith mass

* = $p < 0,05$

** = $p < 0,01$

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