Comparative age and growth of juvenile dusky kob (*Argyrosomus japonicus*) in three South African estuaries, with notes on diet and temperature effects.

Samuel Kakambi Mafwila

Comparative age and growth of juvenile dusky kob (*Argyrosomus japonicus*) in three South African estuaries, with notes on diet and temperature effects.

Samuel Kakambi Mafwila*

Thesis submitted as partial fulfillment of a taught

Masters of Science

(Applied Marine Science), in

Zoology Department, Faculty of Science

University of Cape Town

April 2003

Supervisors

Dr Anesh Govender*

Dr Marc. H. Griffiths[Ψ]

* Zoology Department, University of Cape Town, South Africa

Ψ Marine and Coastal Management, Private Bag X2, Rogge Bay 8012, South Africa

Dedicated to my parents,

Borniface and Valentinah Mafwila

……….with love, and my eternal gratitude.

Declaration

This dissertation documents the results of original research carried out at the Marine and Coastal Management (MCM), Department of Environmental Affairs, and Zoology Department, University of Cape Town. It has not been submitted in whole or in part for any degree or examination to any other university. The data presented here were obtained from Marine and Coastal Management, Department of Environmental Affairs. Dr Marc Griffiths (MCM) and anglers at three estuaries collected biological data from 1990 – 1991. The otolith processing and reading, and all other analyses were done by myself. All opinions expressed here, unless otherwise acknowledged, are my own. All assistance received has also been fully acknowledged.

Signed by candidate

Samuel Kakambi Mafwila
July 2003

Table of Contents

Abstract

The dusky kob *Argyrosomus japonicus* is an important commercial and recreational linefish species in South Africa. It has a wide distribution range from Cape Agulhas to the Moçambique border. Juveniles *A. japonicus* (<1070 mm) occur inshore and in estuaries where surf-zone and estuarine anglers target them. Adult *A. japonicus* (>1070 mm) are caught beyond the surf zone by linefishermen. In this study, 380 juvenile dusky kob were caught by hook and line from the Breede River, Fish River, and Keiskamma River estuaries. Age of juvenile *A. japonicus* in these three South African estuaries was estimated by counting growth rings in sectioned sagittal otoliths read under a dissecting microscope using reflected light. The reproducibility of otoliths readings was described by the average percentage error (APE) index and was found to be 0.44% (Breede), 2.78% (Fish), 0.25% (Keiskamma) for an experienced reader and 0.5% (Breede), 4.37% (Fish), 0.53% (Keiskamma) for an inexperienced reader. Comparisons of *A. japonicus* otoliths by an experienced and an inexperienced reader indicated a reasonable between-reader consistency, however, the otoliths from the Fish River estuary were more difficult to read than from the other two estuaries. The Schnute growth model was used to determine which sub-model would best describe the growth of juvenile *A. japonicus*. Linear regression lines were fitted to the age-at-length growth curves of juvenile *A. japonicus* for each estuary to determine whether there were significant differences in growth rate. It was found that growth was the highest in the Breede River estuary (113.7 mm/yr), followed by the Keiskamma River estuary (92.1 mm/yr) and the Fish River estuary (83.9 mm/yr). Variable growth rates of juvenile *A. japonicus* in the three estuaries may be related to food availability and prey item types and to a lesser extent to water temperature in the estuaries. The comparisons of estuarine diets of *A. japonicus* indicate that juvenile dusky kob in different estuaries have different dominant prey species. There were one or two taxa dominant in each estuary with *Galeichthys feliceps* (61.9%), and the *mysids* (71.8%) being the most important prey items in the Breede River and the Great Fish River estuaries respectively, while teleost *Pomadasys commersonnii* (73.8%) were the most important prey species in the Keiskamma River estuary.

Keywords: Age determination, *Argyrosomus japonicus,* growth rate, otoliths, prey item, temperature.

Introduction

There are two common species of kob (*Argyrosomus japonicus* and *A. inodorus*) in South Africa that were previously misidentified as *A. hololepidotus* (Griffiths and Heemstra, 1995). The dusky kob (*A. japonicus*) (Fig. 1) grow faster and can attain a maximum size of 70 kg (Griffiths and Heemstra, 1995). Dusky kob (*A. japonicus*) are found from the Cape of Good Hope to Moçambique (Griffiths and Heemstra, 1995), along the entire southern seaboard of Australia (Kailola *et al*., 1993, Staling 1993) and from Hong Kong northwards along the Chinese coast to southern Korea and Japan (Trewavas, 1977). Adult dusky kob inhabit the near-shore marine environment in spring to early summer in KwaZulu-Natal, and from late spring to mid-summer in the southern and southeastern Cape regions (Griffiths, 1996). Adult dusky kob are known to migrate to KwaZulu-Natal to spawn, although spawning may take place on their return to the Cape regions (Griffiths, 1996). Young juveniles (20 – 30 mm) and juveniles (> 150 mm) are found in turbid estuaries along the entire east coast where recruitment takes place. Juveniles (> 150 mm) are also found in the surf zone (Griffiths, 1996). Dusky kob are economically important sciaenids targeted by commercial and recreational fishermen (Battaglene and Talbot, 1994), and they are valued as food fish in many countries where they occur (Griffiths, 1996). Previous studies have shown that adult dusky kob occur in estuaries, the surf zone and offshore in waters 100 m deep (Griffiths, 1996). Generally dusky kob (<1 000 mm) are least likely to migrate long distances, thus they remain as distinct local populations (Griffiths, 1996). *A. japonicus* are resident in their natal estuaries (Griffiths, 1996) for the first 7 years (Griffiths, Marine and Coastal Management, *pers.comm.*).

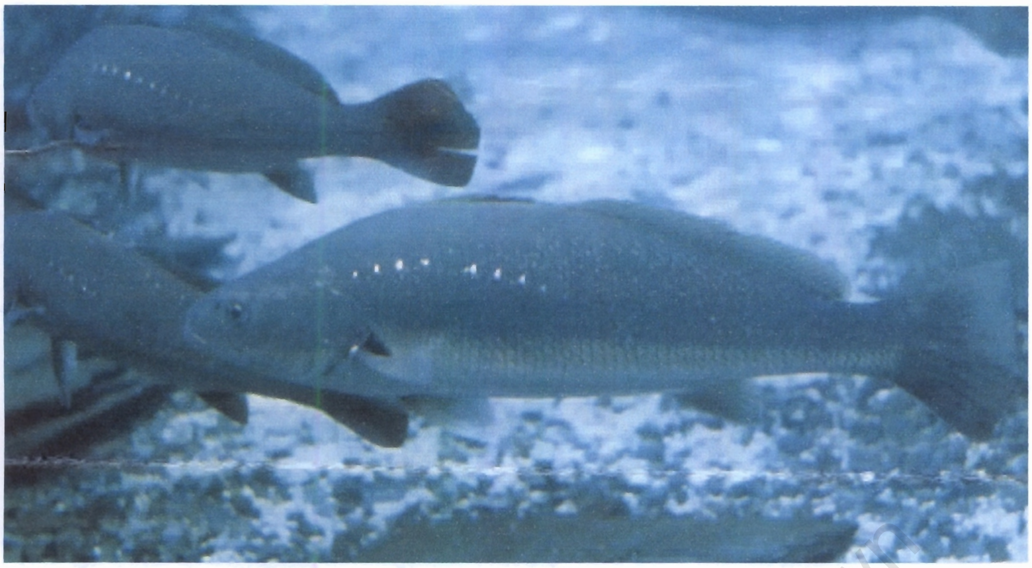


Figure 1: The South African dusky kob *Argyrosomus japonicus* (picture by M. Griffiths).

Wallace and Schleyer (1979) modeled the growth of *A. japonicus* based on the otoliths of 148 fish caught in KwaZulu-Natal estuaries by netting. Since they sampled only seven fish that were older than 7 years their study incompletely described the growth of the species (Griffiths and Hecht, 1995). The recent study by Griffiths and Heemstra (1995) has focused on age and growth of dusky kob based on otoliths from localities throughout its range of distribution in South African waters. However, very little is known about the age and growth of juvenile dusky kob (*A. japonicus)* in South African estuaries. The present study focuses on the age and growth of juvenile *A. japonicus* based on otoliths collected from three South African estuaries (Breede, Keiskamma, and Great Fish estuaries), and it relates both biological and physical factors, which could possibly affect growth. Although dusky kob have a wide distribution, spanning warm-temperate and subtropical biogeographic zones, spatial variation in growth is yet to be investigated. As adults appear to comprise a single population and it is during the resident juvenile phase that the greatest potential for variation in growth exists. This may be due to the fact that the juvenile stage in the growth of fish is the fastest and may respond the quickest to any marked changes in environmental conditions resulting in variable growth. Water temperature (Vorwerk *et al.*, 2001; Taljaard *et al.*, 2002; Lamberth, (unpublished data)) and prey type (Griffiths, 1997 a,b) have been demonstrated to vary from one estuary to another, it is possible that these could influence growth. Water temperature is known to affect growth in fish (Lee and Rinne, 1980; Bjornn and Reiser, 1991; Cunjak and Randall, 1993; Elliot and Hurley, 1997). Temperature is also known to affect food intake, respiration, digestion and assimilation in fish (Jobling, 1994, 1997; Kestemont and Baras, 2001). Thus, two major questions are addressed in this paper. Does juvenile growth rate vary between estuaries? Assuming that differences are observed, can these be related to water temperature and prey consumption?

Materials and Methods

General sampling

Samples of male and female dusky kob were obtained from hook and line fishing competitions during the summer (November to March) of 1990/1. The angling competitions were initiated by the Marine and Coastal Management (MCM) and anglers were permitted by MCM to keep sub-legal fish for the purpose of this research. These competitions were conducted in the southern Cape: Breede River estuary, and the southeastern Cape: Keiskamma and Great Fish River estuaries (Fig. 2).

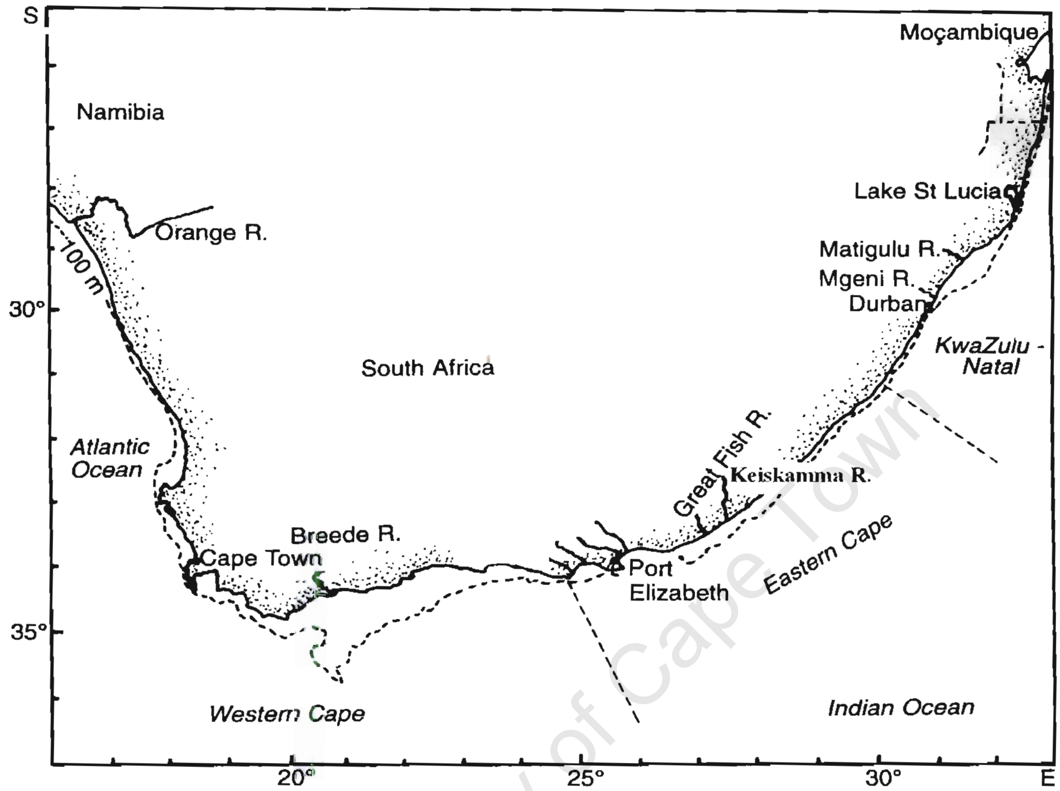


Figure 2: South African map showing localities mentioned in the text (modified from: Griffiths, 1997b)

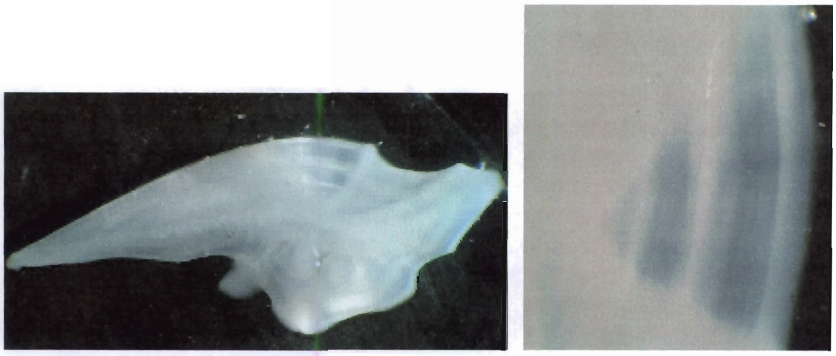
Fish were simultaneously sampled in the three estuaries during a 5-month period from November 1990 to March 1991 and a total of 380 *A. japonicus* were collected. Body size measurements such as total fish length (measured in millimeters) and fish mass (grams) were recorded (Griffiths and Hecht, 1995). Simultaneously, biological data (e.g. stomach contents) were also collected during these fishing competitions, and were analyzed *in situ* while still fresh. Analysis of the stomach content involved discarding of the bait, identification of prey items to the lowest taxon, counting and weighing them to the nearest 0.01 g (Griffiths, 1997a, b).

Age determination

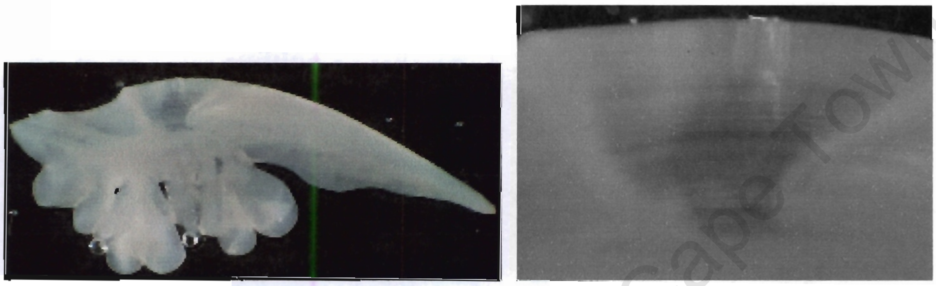
A total of 287 otoliths were used for age determination. This numbers excluded those that were older than seven years since they have attained sexual maturity while others were rejected when age counts varied between readers, and also, some otoliths were missing from their packets. Sagittal otoliths (Fig. 3) were mounted in rods of clear casting resin and sectioned through the nucleus (to a thickness of about 0.5 mm) using a low speed saw fitted with a mono-diamond-tipped blade. Sectioned otoliths were then mounted on clear glass slides and examined on a black background under a dissecting microscope (6X) using reflected light. Annuli were counted starting from the nucleus outward by concentrating more in v-ring for easy readability, assuming that each consecutive opaque (white) zone, separated by a hyaline band (dark) was an annulus (Griffiths and Hecht, 1995). The v-ring is the v-like-shape on the sectioned otoliths which shows the annuli relatively clear compared to other parts of the otoliths (Fig. 3). An experienced otolith reader and an inexperienced reader read the otoliths four times, with each count occurring on different days. If the two readings did not coincide then the otoliths were rejected. The average percentage error (APE) (Beamish and Fournier, 1981) was used to compare the readings between the two readers. The average percentage error is a valuable tool in terms of precision when determining the age of a particular fish and of assessing the reproducibility of one ager or of comparing the skills of two agers (Campana *et al.*, 1995, Beamish and Fournier, 1981). The average percentage error (APE) for the *i*th fish is defined by the following equation:

$$\mathrm{APE}_j = 100 \times \frac{1}{R} \sum_{i=1}^{R} \frac{|X_{ij} - X_j|}{X_j} \quad \text{...} (1)$$

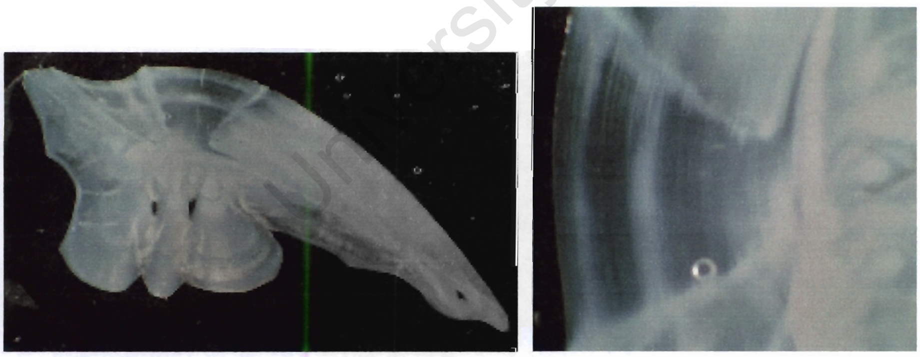
Where X_{ij} is the $_i$th age determination of the $_j$th fish, X_j is the mean age of the fish, and R is the number of times each fish is aged. The average of all APE_j is defined as the average percentage error (APE) (Beamish and Fournier, 1981). Fish older than seven years (i.e. attaining sexual maturity) were not well represented in all three estuaries and were excluded from the analysis.



(a) CR18: A three year old male fish (*TL*=52.2 cm) and a closer look at the v-ring.



(b) FR 25: A one-year-old male fish (*TL*=43.4 cm) and a closer look at the v-ring.



(c) BR 58: A three-year-old male fish (*TL*=62.5 cm) and a closer look at the v-ring.

Figure 3: Sagittal otoliths of *A. japonicus* from (a) Keiskamma, (b) Fish, and (c) Breede River estuary showing opaque and hyaline bands. (CR=Keiskamma River, FR=Fish River, BR=Breede River, and the numbers represents the otolith or fish number)

Growth determination

In this study it was assumed that growth of juvenile dusky kob could adequately be described by the Von Bertalanffy (1957) growth equation. The Von Bertalanffy (1957) has been used in many studies (Griffiths and Hecht, 1995.; Holtzhausen and Kirchner, 2001; Radebe *et al.*, 2002) to describe the growth of linefish in southern Africa, as well as other fish species around the world (Gamito, 1998.; Al-Husaini, 2002.; Horn, 2002.; Yoneda *et al.*, 2002.; Pajuelo and Lorenzo, 2002). The Von Bertalanffy growth parameters can be directly incorporated into stock assessment models (Ricker 1975., Vaughan and Kanciruck, 1982., Griffiths and Hecht, 1995) and is also generally used for estimating the natural mortality rate (Pauly, 1980). It can also be used to compare the life histories of fish (Beverton, 1992). Despite settling for the Von Bertalanffy growth model on an ad hoc basis, the Schnute growth model (Schnute, 1981) was used to determine which sub-model would best describe the growth of juvenile dusky kob. The age at length data were subjected to ANOVA (analysis of variance) and a non-parametric equivalent of ANOVA, Kruskal-Wallis test (HSD) unequal N (Zar, 1999), and these were used to test if there was a significant difference in growth of *A. japonicus* among estuaries. The growth rate of *A. japonicus* was compared for all three estuaries by looking at the slopes of linear regressions, which represented the average growth rate within the observed age classes. The F-test was initially performed to determine whether there was a significant difference among the slopes, by employing the following formula:

$$F = \frac{(SS_c - SS_P)}{(SS_P / DF_P)} \quad \ldots\ldots (2)$$

where SS_c is the residual sum of squares for the common regression, SS_p is the residual sum of squares for the pooled regression; DF_p is the residual degrees of freedom for the pooled regression (Zar, 1999). Furthermore, slope (b_1, b_2) comparisons were also performed to find out where differences lie among the estuaries, using the following formulas for the test statistic, *t*:

$$t = \frac{(b_1 - b_2)}{S_{b_1 - b_2}} \quad \ldots\ldots(3)$$

where ($\sum x^2$ = the sum of all ages squared) and the difference between the two regression coefficients' standard errors is represented as follows,

$$s_{b1-b2} = \sqrt{(s^2_{y.x})_p / (\sum x^2)_1 + (s^2_{y.x})_p / (\sum x^2)_2} \quad \ldots\ldots(4)$$

and the pooled residual mean square was calculated as

$$(s^2_{y.x})_p = \frac{(residualSS)_1 + (residualSS)_2}{(residaulDF)_1 + (residualDF)_2} \quad \ldots\ldots(5)$$

The subscripts $_1$ and $_2$ reference the two regressions lines being compared, and the critical value for t, takes the form $(n_1 - 2) + (n_2 - 2)$ degrees of freedom, thus

$$v = n_1 + n_2 - 4 \quad \ldots\ldots(6)$$

Prey Data

The stomach contents of each specimen were analyzed fresh and prey items were identified to the nearest taxon (Griffiths, 1997a,b). The prey data were analyzed based on prey importance, which is mainly assessed by calculating the percentage frequency of occurrence (%F), and this method according to Hynes (1950) indicates how often a certain prey item is selected and by calculating the percentage by mass (%M), which according to Windell and Bowen (1978) and Macdonald and Green (1983) gives an energy estimate of a particular item. There could be some discrepancies when calculating the prey importance using these methods. For instance, certain prey items could be unrealistically high when these methods are applied separately (Griffiths, 1997a). This can be exemplified in a case where one has infrequently consumed large items (partially digested), which may result in a high %M, and in a situation where a frequently consumed small item may result into a high %F (Griffiths, 1997a). In order to minimize these biases, an index of relative importance (IRI) was therefore calculated for each prey category i as a product of $\%F_i$ and $\%M_i$ (Griffiths, 1997a). This was then expressed as a percentage (Cortes, 1997), where

$$\%IRI_i = \frac{100 IRI_i}{\sum_{i=1}^{n} IRI_i} \quad \text{...(7)}$$

and n is the total number of food categories considered at a given taxonomic level (Griffiths, 1997a). An analysis of variance was applied to the mean mass of food per stomach to determine whether there is a significant difference between size classes and among estuaries. The food proportions for each size class in each estuary were also calculated and stomachs with food and without food were identified and expressed as frequencies. Due to small sample sizes in the size classes 20 – 39 cm, and 110+ cm, these size classes were left out of the statistical analysis. However, the size classes 40 – 75 cm and 75 – 110 cm were included in the food proportion analysis since they had a larger sample size. The chi-square test was used to analyze the food proportions data. Among estuaries and between size classes analyses were analyzed, the former been performed after summing up all the frequencies in each size class, disregarding the different estuaries, with the purpose of testing whether there are differences between the size classes alone.

Temperature Data

The temperature data available for the three estuaries does not coincide with the sampling periods and the full data set were not available at the time of this study, however, the mean temperature data for summer and winter were available for each estuary. The temperature data were collected from previous studies in the Breede River (2000/2001 period) (Taljaard *et al.* 2002., Lamberth (unpublished data)), Fish River and Keiskamma River (1999/2000 period) (Vorwerk *et al.*, 2001).

Results

Age Determination

The sectioned longitudinal otoliths of juvenile *A. japonicus* show distinct hyaline and opaque bands (Fig. 3). Previous studies by Griffiths (1995) and Wallace and Schleyer (1979) have shown that only one opaque zone is deposited annually in spring, which coincides with the spawning season (Griffiths, 1997) of *A. japonicus* in South African waters. The observed length and age of juvenile *A. japonicus* varied within the age groups and among the estuaries (Fig. 4).

The results in Table I show that the more experienced reader was more consistent than the inexperienced reader because of the lower APE values compared to those of an inexperienced reader. However, it is evident from both cases that it was easier to read otoliths from the Breede River and the Keiskamma River estuary than was the case with the Great Fish River estuary. In both the Great Fish River estuary and Keiskamma River estuary juvenile dusky kob had a similar mean age of 2 yrs and the Breede River estuary of 3 yrs (Fig. 4).

Table I: Results from the application of the average percentage error (APE) when comparing two otoliths readers.

Average Percentage Error (%)		
Estuary	**Experienced Reader**	**Inexperienced Reader**
Breede	0.44	0.5
Fish	2.78	4.37
Keiskamma	0.25	0.53

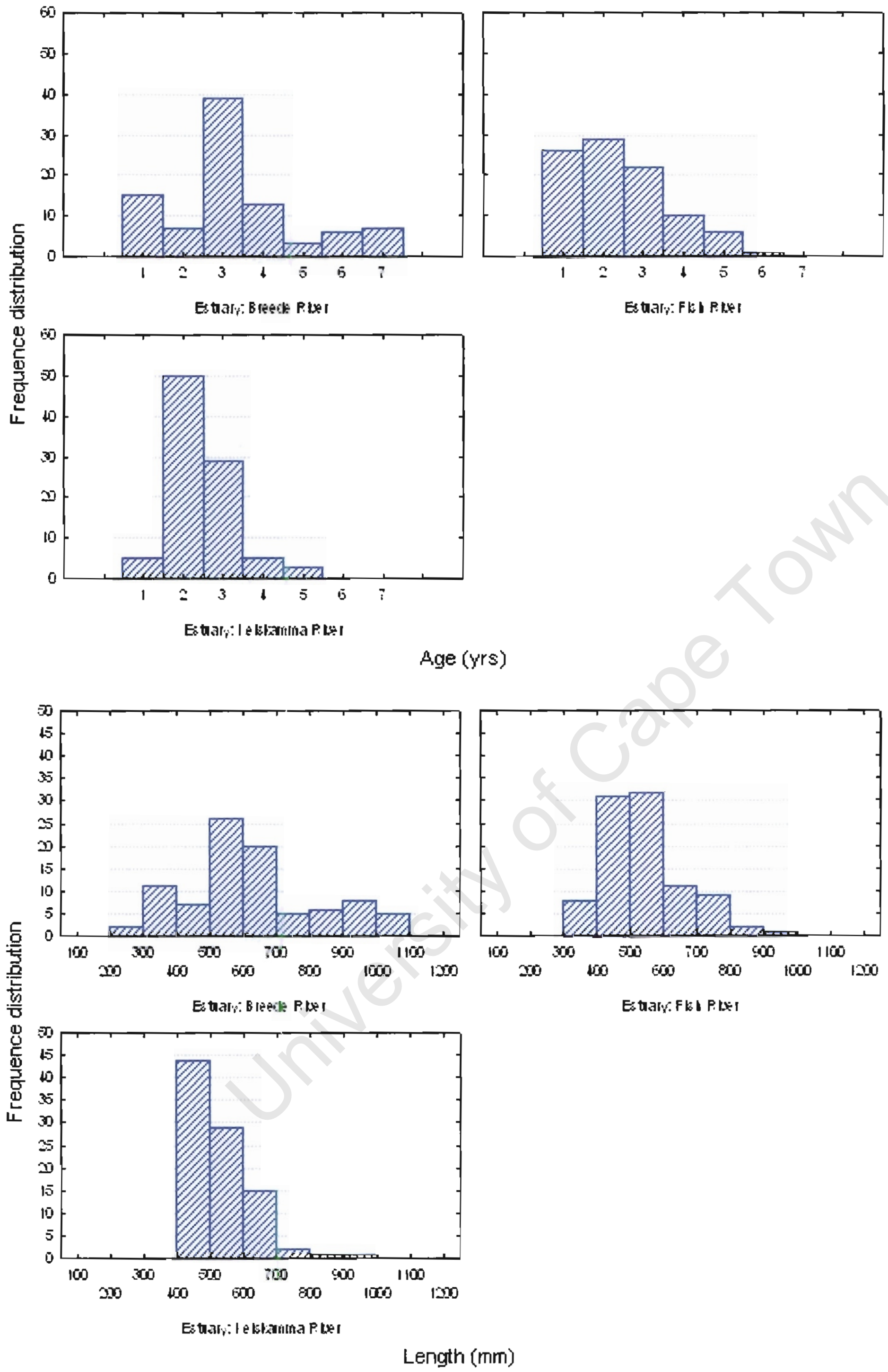


Figure 4: Histograms showing the age (years, top three) and length (mm, bottom three) distribution of juvenile *A. japonicus* caught by hook and line in the three estuaries of South Africa. (Please note that the *Y-axis* represents the number of observations or frequencies). Breede River (n = 90), Fish River (n = 94), Keiskamma River (n = 92).

Growth rate

Growth of *A. japonicus* was modeled using the Schnute model (Schnute, 1981) to determine which sub-model would best describe the growth curve. The Schnute model (see Appendix 2, 3, 4) suggested that the best fit to the data would be a linear model, since there were no fish older than seven years in the analysis, thus Von Bertalanffy fit would result in unrealistic estimates of the three parameters (L_∞, k, and t_0). Despite this, the Von Bertalanffy model was fitted to the length-at-age data. A linear regression was also fitted to the data, in order to determine the slopes of the linear regression, which in this case directly represents the growth rate of juvenile *A. japonicus* in the three estuaries (Fig. 5).

Age at length data was tested for normality (probability plot) and homogeneity of variance (Levene's test) (Zar, 1999) before performing the analysis of variance (ANOVA). The data was found to be non-normal and variances were not similar, thus the assumptions for ANOVA are violated under these conditions. The data was then log-transformed but still the assumptions for ANOVA did not hold. Therefore, a non-parametric equivalent of ANOVA, the Kruskal-Wallis test for independent variables (Zar, 1999) was applied to the data. The Kruskal-Wallis ANOVA by Ranks found a significant difference (H ($df = 2$, N = 276) = 19.37, $p = 0.0001$) in total length (mm) of juvenile dusky kob among the three estuaries. The Median test, overall median = 536 mm indicated a significant difference ($X^2 = 35.48$, $df = 2$, $p < 0.001$) among the three estuaries.

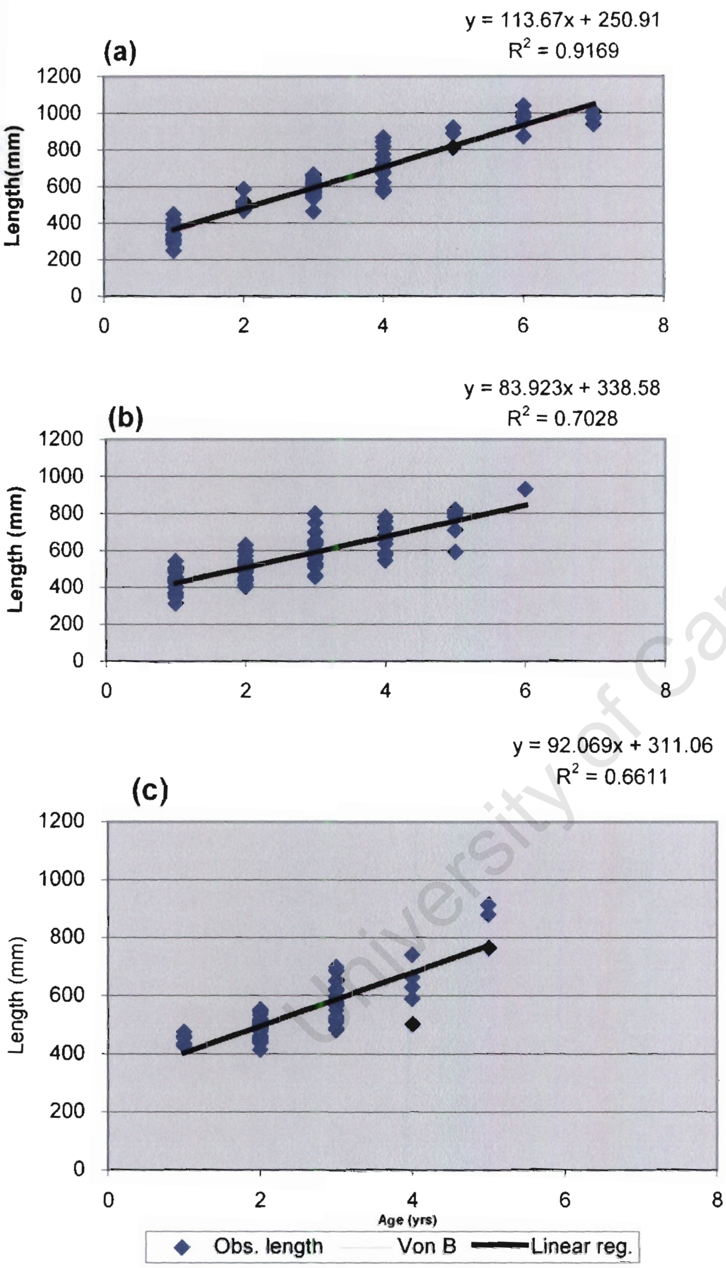
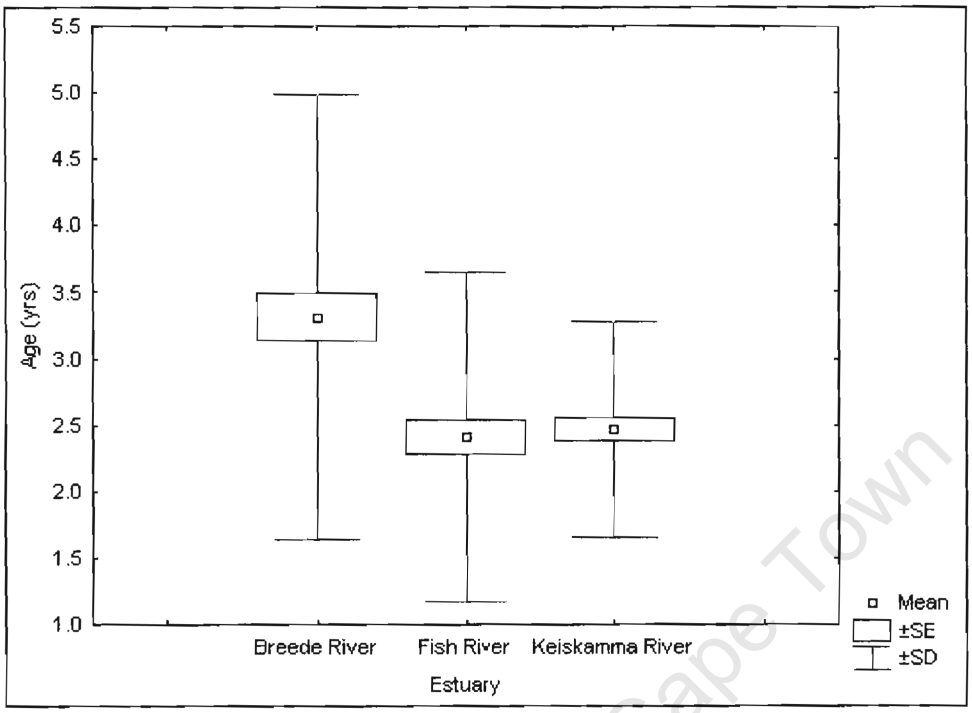


Figure 5: Von Bertalanffy and linear growth curves of juvenile dusky kob *A. japonicus* from (a) Breede, (b) Fish, and (c) Keiskamma River estuaries (NB: the Von Bertalanffy fitted lines and linear fits overlap and are indistinct from each other).

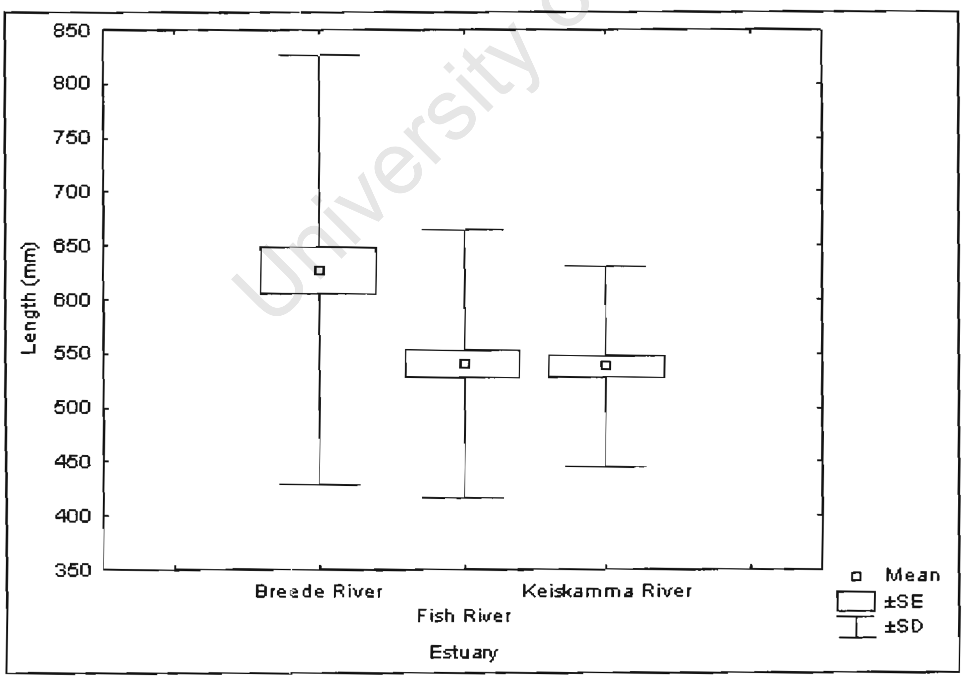
The same applies to the age (yrs) of juvenile dusky kob among the three estuaries, as there was a significant difference (H (*df* = 2, N = 276) = 22.03, $p < 0.001$) (Kruskal-Wallis ANOVA by Ranks). The Median Test for age (yrs) with the overall median of 3 years indicated a significant difference as well (Chi-square = 16.2, *df* = 2, p = 0.0003). Generally, there are significant differences both in age and length of juvenile dusky kob among the three estuaries (Fig. 6, and Appendix 1).

In order to establish where exactly does the differences lie, a multiple comparison z-values and p values for both age (yrs) and length (mm) were performed as a post hoc test to the Kruskal-Wallis test. The z' value indicated that there was a significant difference in age (yrs) between juvenile dusky kob of the Breede River estuary and the Great Fish River estuary (z = 3.63); the Breede River estuary and Keiskamma river estuary (z = 3.29), but no significant difference was observed between the Great Fish River estuary and the Keiskamma River estuary (z = 0.38). Furthermore, the p values (2-tailed) for the age of juvenile dusky kob showed that there is a significant difference between the Breede River estuary and the Great Fish River estuary (p = 0.00085); Breede River estuary and Keiskamma River estuary (p = 0.003) but the Great Fish River and Keiskamma River estuary.

Similarly, multiple comparisons were performed for the total lengths (mm) of juvenile dusky kob. There are significant differences in total length (mm) between the Breede River estuary and the Great Fish River estuary ($z = 3.21$), Breede River estuary and Keiskamma River estuary ($z = 3.56$), but no significant difference between the Great Fish River estuary and Keiskamma River estuary ($z = 0.31$). The p – values indicated a similar difference in fish total length among the estuaries, Breede River estuary and the Great Fish River estuary ($p = 0.0039$); Breede River estuary and Keiskamma River estuary ($p = 0.0011$) but the Great Fish River estuary and Keiskamma River estuary did not significantly differ. To visualize these differences in both age (yrs) and length (mm) the standard deviations, means, and standard errors were plotted (Fig. 6).



(a)



(b)

Figure 6: Box and whisker plots representing (a) age and (b) total length of *A. japonicus* from three estuaries, showing the means, standard errors, and standard deviations.

The slopes of the linear model or regression (Fig. 5, and Appendix 1) were also compared to see which estuary has the fastest and the slowest growth rate per year. The linear regression slopes show that the juvenile dusky kob grow relatively faster in the Breede River estuary (growth rate = 113.7 mm/yr), intermediate in the Keiskamma River estuary (growth rate = 92.1 mm/yr) and relatively slow in the Great Fish River estuary (growth rate = 83.9 mm/yr) (Fig 5).

Table II: The somatic growth of juvenile dusky kob from the Breede River, Great Fish River, and the Keiskamma River estuaries are compared using linear slope (growth rate) analyses. Following is the data used in the slope comparisons, italicized data were calculated from the raw data, and all others were derived from them. ($\sum x^2$ = the sum of all ages squared, $\sum y^2$= the sum of all length squared, n = number of fish; b = slope; RSS = residual some of squares, RDF = residual degrees of freedom).

Estuaries	$\sum x^2$	$\sum xy$	$\sum y^2$	n	b	RSS	RDF
Breede River	*1236*	*215265*	*38925745*	*90*	113.7	1434628	88
Fish River	*686*	*134090*	*28875443*	*94*	83.9	2665344	92
Keiskamma River	*621*	*127785*	*27432369*	*92*	92.1	1137673	90
Pooled Regression						5237645	270
Common Regression	2543	477140	95233557		96.6	5708359	272
Total Regression				*276*	386.3	16183649	274

The null hypothesis that all the slopes were equal was tested against the alternative hypothesis that they are not. The null hypothesis was rejected, thus a significant difference ($F = 12.13$, RDF = 2, 270, $p = 0.05$, Zar, 1999) was found among the slopes.

Therefore, a multiple comparisons test was performed using the student's *t*-test by comparing two slopes at a time, and the results showed that the slopes, which represent growth rate, in the Breede River estuary were significantly different from those of the Fish River and Keiskamma River estuary ($t = 4.15$, $v = 180$, $p = 0.05$: $t = 3.65$, $v = 178$, $p = 0.05$, Zar, 1999). No significant difference ($t = 1.02$, $v = 182$, $p = 0.05$, Zar, 1999) was found between the Fish River and the Keiskamma River estuary.

Prey Data Analysis

About 380 dusky kob were used in the analysis of prey items. The prey importance is based on the percentage index of relative importance (%IRI). The blanks in the Tables III, IV, and V, show that the prey items were absent in the stomachs of *A. japonicus* with food. In the Breede River *Galeichthys feliceps* (61.9%) dominated the diet of *A. japonicus* of size class 20 – 39 cm, followed by mysids (19%). For the same estuary, *Upogebia africana* dominated both size classes 40 – 75 cm and 75 – 110 cm by 80% and 68.8% respectively, while *Pomadasys olivaceum* (88.5%) dominated the 110+ cm size class (Table III).

In the Great Fish River estuary, mysids dominated the smaller size class 20 – 39 cm by 71.8%, followed by *Gilchristella estuaria* (17,7 %), and *Gilchristella estuaria* dominated the next size class 40 – 75 cm by 50.6% followed by mysids (44%) indicating a switchover to bigger prey as fish become larger in size. The 75 – 110 cm size class was dominated (60.8%) by conspecifics (*A. japonicus*), followed by octopus (19.2%) (Table IV).

The Keiskamma River estuary had only two size classes 40 – 75 cm and 75 – 110 cm, which were dominated by different prey items, *Pomadasys commersonnii* (73.8%) and *Liza richardsoni* (57.6%) respectively (Table V).

Table III: Stomach content analysis values for *A. japonicus* from the Breede River estuary (southern Cape), expressed as percentage frequency of occurrence (%F) and mass (%M) of each prey taxon. Totals are number of stomachs (F) and mass of prey (M). %IRI is the percentage index of relative prey importance at the species level. The values are shown for four size classes. (The blank cells mean the species was not present).

PREY	20 - 39 cm			40 - 75 cm			75 - 110 cm			110+ cm		
	%M	%F	%IRI	%M	%F	%IRI	%M	%F	%IRI	%M	%F	%IRI
Crustacea												
Anomura	5.3	20	4.8	33.5	69.1	80.2	52.4	50	68.8	0.9	33.3	0.5
Upogebia africana	5.3	20	4.8	31.6	66.7	80	52.4	50	68.8	0.9	33.3	0.5
Callianassa nudiceps				1.9	2.4	0.2						
Brachyura				1.2	19.1	0.5	9.5	25	6.3			
Thaumastoplax spiralis				0.2	4.8	0						
Hymenosoma orbiculare				1	14.3	0.5	9.5	25	6.3			
Isopoda				0.1	2.4	0						
Isopod sp.				0.1	2.4	0						
Macrura				2.9	4.8	0.3	11.9	25	7.8	1.4	33.3	0.8
Macropetasma africana				2.3	2.4	0.2				1.4	33.3	0.8
Paleamon pacificus				0.6	2.4	0.1	11.9	25	7.8			
Mysidacea	10.5	40	19	0.8	16.7	0.5	2.4	25	1.6			
Mysid sp.	10.5	40	19	0.8	16.7	0.5	2.4	25	1.6			
Teleostei	73.7	40	66.7	59.8	86	18.3	19	25	12.5	97.7	133.3	98.7
Galeichthys feliceps	68.4	20	61.9	4.2	16.7	2.7				12.9	33.3	7.2
Gilchristella estuaria				6.3	16.7	4						
Pomadasys olivaceum				10.9	4.8	2				79.4	66.7	88.5
Liza richardsonii				19.7	2.4	1.8						
Pomatomus saltatrix				3.4	4.8	0.6				5.4	33.3	3
Rhabdosargus holubi				0.4	2.4	0						
Sardinops sagax				0.2	4.8	0						
Engraulis capensis				8.4	19	6.1						
Hilsa kelee				4.8	4.8	0.9						
Thryssa setirostris				1.3	4.8	0.2	19	25	12.5			
Teleost remains	5.3	20	4.8	0.2	4.8	0						
Polychaeta	10.5	20	9.5	1.5	7.2	0.1	4.8	25	3.1			
Blood worm	10.5	20	9.5	1.4	2.4	0.1						
Transparent worms				0.1	4.8	0	4.8	25	3.1			
Total	**1.9**	**5**		**179.9**	**42**		**4.2**	**4**		**34.9**	**3**	

Table IV: Stomach contents of *A. japonicus* from the Great Fish River estuary (southeastern Cape), expressed as the percentage frequency of occurrence (%F) and mass (%M) of each prey taxon. Totals are number of stomachs (F) and mass of prey (M). %IRI is the percentage index of relative prey importance at species level. The values are shown for three size classes. (The blank cells mean the species was not present).

PREY	20 - 39 cm			40 - 75 cm			75 - 110 cm		
	%M	%F	%IRI	%M	%F	%IRI	%M	%F	%IRI
Crustacea									
Anomura				1.5	10.8	0.3			
Upogebia africana				1.2	9.6	0.3			
Callianassa kraussii				0.3	1.2	0			
Brachyura				0.2	6	0	4.5	20	4.5
Hymenosoma orbiculare				0.2	4.8	0	4.5	20	4.5
Megalopid larvae				0	1.2	0			
Isopoda				0.1	3.6	0			
Isopod sp.				0.1	3.6	0			
Macrura	1.2	12.5	0.3	1.8	19.3	0.8			
Macropetasma africana				0.1	1.2	0			
Paleamon pacificus				1.7	16.9	0.8			
Pink shrimp	1.2	12.5	0.3	0	1.2	0			
Mysidacea	42.4	75	71.8	22.9	66.3	44	10.8	20	10.8
Mysid sp.	42.4	75	71.8	22.9	66.3	44	10.8	20	10.8
Mollusca				0.5	2.4	0	19.2	20	19.2
Cephalopoda									
Octopus sp.							19.2	20	19.2
Gastropoda									
Gastropod sp.				0.5	2.4	0			
Teleostei	56.5	62.5	27.9	73	89	54.8	65.5	80	65.5
Galeichthys feliceps				0.6	2.4	0			
Gilchristella estuaria	21.2	37.5	17.9	30.8	56.6	50.6	0.1	20	0.1
Pomadasys commersonii				16.1	4.8	2.3			
Pomadasys olivaceum				0.4	3.6	0			
Liza richardsonii				0.6	1.2	0			
Pomatomus saltatrix				7.8	1.2	0.3	4.5	20	4.5
Argyrosomus japonicus				6.6	2.4	0.5	60.8	20	60.8
Argyrosomus inodorus				0.4	1.2	0			
Rhabdosargus holubi	28.2	12.5	8	3.5	8.4	0.9			
Sardinops sagax				5.9	1.2	0.2			
Teleost remains	7.1	12.5	2	0.3	6	0	0.1	20	0.1
Total	**8.5**	**8**		**320.3**	**83**		**75.7**	**5**	

Table V: Stomach contents of *A.japonicus* from the Keiskamma River estuary (southeastern Cape), expressed as percentage frequency of occurrence (%F) and mass (%M) of each prey taxon. Totals are number of stomachs (F) and mass of prey (M). %IRI is the percentage index of relative prey importance at species level. The values are shown for two size classes. (The blank cells mean the species was not present).

PREY	40 - 75 cm			75 - 110 cm		
	%M	%F	%IRI	%M	%F	%IRI
Crustacea						
Anomura	0	4.8	0			
Upogebia africana	0	2.4	0			
Callianassa kraussii	0	2.4	0			
Brachyura	0.2	4.8	0			
Hymenosoma orbiculare	0	2.4	0			
Megalopid larvae	0.2	2.4	0			
Isopoda	0.3	9.5	0.2	0.1	50	0.1
Isopod sp.	0.3	9.5	0.2	0.1	50	0.1
Macrura	1	14.3	0.5			
Macropetasma africana	0.4	4.8	0.1			
Paleamon pacificus	0.6	9.5	0.4			
Mysidacea	0.9	26.2	1.6			
Mysid sp.	0.9	26.2	1.6			
Teleostei	97.5	119.2	97.7	99.8	200	99.8
Galeichthys feliceps	0.6	11.9	0.5			
Gilchristella estuaria	2.1	26.2	3.6			
Pomadasys commersonii	42.8	26.2	73.8			
Pomadasys olivaceum	3.6	9.5	2.3	13.6	50	13.6
Liza richardsonii	15.4	4.8	4.8	57.6	50	57.6
Liza tricuspidens	8.4	2.4	1.3			
Argyrosomus japonicus	11.9	2.4	1.9			
Argyrosomus inodorus	0.6	2.4	0.1	4.6	50	4.6
Solea bleekeri		2.4				
Rhabdosargus holubi	10.8	11.9	8.5			
Etrumeus whiteheadi	0.3	2.4	0			
Glossogobius callidus	0	2.4	0			
Teleost remains	1	14.3	0.9	24	50	24
Total	**239.6**	**42**		**67.4**	**2**	

Food Proportions

From Table VI it is observed that the food proportions for juvenile *A. japonicus* 40 – 75 cm with stomach contents from the Breede River estuary was 65.6%, in the Fish River estuary it was 61.2% and in the Keiskamma River estuary it was 40.2% and these were not substantially different from the proportions of food found previously by Griffiths (1997 a,b) in the same estuaries. The food proportions for the size class 75 – 110 cm were, Breede River estuary (20%), Fish River estuary (33.3%) and Keiskamma River estuary (66.7%). The food proportions for stomachs with food and those without food show that there was a statistically high significant difference among estuaries (X^2 = 14.03, *df* = 2, p = 0.05, Fowler *et al.*, 1999), within the size class 40 – 75 cm. The Breede River and the Fish River estuaries had fewer stomachs with food than observed, and vice versa for the stomachs without food. While the Keiskamma River estuary had fewer observed stomachs with food than average, and vice versa for the stomachs without food. Contrary, there was no significant difference (X^2 = 2.99, *df* = 2, p = 0.05, Fowler *et al.*, 1999) among estuaries for the number of stomachs with food and those without food, in the size class 75 – 110 cm. In this category, the Breede River estuary had less observed stomachs with food than average, and vice versa for the empty stomachs.

Both the Fish River and Keiskamma River estuaries had more observed stomachs with food than average, and an opposite situation for the empty stomachs. Furthermore, there was statistically a highly significant difference (X^2 = 8.16, *df* = 1, p = 0.05, Fowler *et al.*, 1999) between size classes 40 – 75 cm and 75 – 110 cm. In the size-class 40 – 75 cm there were more observed stomachs without food than average. While the upper class 75

– 110 cm had few observed stomachs with food than average, and vice versa for the empty stomachs.

Table VI. Table showing the proportions of food of *A. japonicus* in three South African estuaries, (BR = Breede River, KR = Keiskamma River, and FR = Fish River; Total = food mass (g) per size class; Mean = food mass (g)/number of stomachs with food; Numbers in parentheses indicate the total number of fish in each size class).

				Size Classes				
	20 - 39 cm		40 - 75 cm		75 - 110 cm		110+ cm	
BR	Food Mass	%with food	Food Mass	%with food	Food Mass	%with food	Food Mass	%with food
Total	1.9	38.46 (13)	179.9	65.63 (64)	4.2	20 (20)	34.9	20 (15)
Mean	0.38		4.28		1.05		11.63	
KR								
Total	0	0 (1)	239.6	40.2 (102)	67.4	66.67 (3)		
Mean	0		5.7		33.7			
FR								
Total	8.5	66.67 (12)	320.3	61.19 (134)	75.7	33.33 (15)	1.1	100 (1)
Mean	106		3.86		15.14		1.1	

Temperature Data

Due to the lack of the availability of the full temperature data set for the three estuaries, it was not possible to perform any statistical analyses on the data available. Taking into account that water temperature could influence the growth of fish, the average seasonal (winter and summer) temperature data was utilized in this study. The results show that both the Breede River and the Fish River estuary had a similar average summer temperature of 24 °C, but was relatively lower in the Keiskamma River estuary (21 °C). On the other hand, the mean winter temperature varied among estuaries: Breede River estuary (15.7 °C), Fish River estuary (16.1 °C) and the Keiskamma River estuary (17.6 °C).

Discussion

According to Griffiths and Hecht (1995) and Griffiths (1996), the somatic growth of the South African dusky kob *A. japonicus* changes from a fast to a slow growth rate at sexual maturity, which is attained in males at about 110 cm and females at 120 cm, these lengths correspond to ages 8 and 9 years for males and females, respectively (Griffiths and Hecht, 1995). Thus the choice of using fish not older than seven years old is justified by the fact that they fall under the juvenile category, which was the prime aim of this study.

Factors that affect growth of fish in their living environments include, among others, food abundance, and water temperature (Jobling, 1994, 1997; Kestemont and Baras, 2001). In the present study, the growth rate of juvenile dusky kob was found to be significantly higher in the Breede River estuary and relatively lower in the Fish River and Keiskamma River estuaries, with the latter two estuaries having no significant difference in growth rates between them. The observed differences in growth rates of *A. japonicus* could be attributed to food availability and water temperature in these three estuaries. Taking a closer look at the water temperature, especially water temperature recorded in summer, both the Breede River and the Fish River estuaries had similar average water temperatures, but the Keiskamma River estuary was 3°C lower than the Breede River and the Fish River estuaries on average. However, all three estuaries had variable average winter water temperatures, thus making it difficult to draw significant conclusions to the observed differences in growth rates. However, the differences in average water temperature in winter shows evidently that it is relatively cooler in the Breede River estuary (15.7°C), intermediate in the Fish River estuary (16.1 °C) and relatively warmer in Keiskamma River estuary (17.6 °C). Although, the water temperature could be one of the factors playing an important role in the growth of *A. japonicus*, it is highly unlikely that a firm conclusion could be drawn using the available data. However, the physiological effect of temperature on growth is contradicted (Fry, 1971), since fast growth is supported amongst other factors by, generally, warm water, and cold-water should result in slower growth. Generally, it is evident in this study that the Breede River estuary has fast growing (Fig. 5) juvenile *A. japonicus* but has a relatively cooler water temperatures in winter, and the Fish River and Keiskamma River estuary though experiencing slower growth (Fig. 5) of juvenile *A. japonicus* despite having relatively warmer average temperatures. The reason for this contradiction is very difficult to ascertain. Intensive seasonal sampling of water temperature and other parameters such as salinity and pH, could be an option to establish a better understanding of the temperature-growth relationship in these estuaries. The geographical location could be playing an important role as well since food and water temperature could relatively be similar in the same geographical area, but different in distant geographical locations. The Fish River and Keiskamma River estuaries are close to each other in the southeastern Cape, and therefore show no significant difference in terms of growth rates of juvenile *A. japonicus*. However, their % indices of relative prey importance vary (Table III, IV, V) from one estuary to the other.

The observed lengths of *A. japonicus* varied greatly within age groups and among estuaries, and this is not unusual since it is a common characteristic of sciaenids (Beckman *et al.*, 1989; Beckman *et al.*, 1990; Murphy and Tayler, 1994; Ross *et al.*, 1995; Barbieri *et al.*, 1995). Generally, there were some relatively bigger fish (in terms of length) in the Breede River compared to the Fish River and Keiskamma River estuaries (Fig. 4).

The comparison of estuarine diets of *A. japonicus* indicates that dusky kob in different estuaries have different dominant prey species (Table III, IV, and V), in both spatial (by estuary) and size-classes. This was a representative sample in the size classes 40 – 75 cm and 75 – 110 cm, which allowed comparisons to be made among the estuaries in terms of % of stomachs with food. There is a general trend similar to that of Griffiths (1997 a), which is evident in the 40 – 75 and 75 – 110 cm size-classes. Small dusky kob 40 – 75 cm tend to feed more often than the older ones 75 – 110 cm in the Breede and Fish River estuaries, with an exception of the Keiskamma River estuary where the situation is reversed. This unusual situation could be attributed to a small sample size especially in the 75 – 110 cm size-class in Keiskamma River estuary (n = 15) (Table VI). Even though there was a wide range of prey species taken by juvenile *A. japonicus* in the three estuaries, there were only one or two taxa dominant in each estuary. In the Breede River estuary, where fast growth occurred, *Galeichthys feliceps* (61.9%) were more important, followed by mysids (19%) in the small size class 20 – 39 cm, *Upogebia africana* (80%) was most important to the size class 40 – 75 cm, it was also the most important (68.8%) for the 75 – 110 cm size-class, followed by *Thryssa setirostris* (12.8%), while for the last size-class 110+ cm *Pomadasys olivaceum* (88.5%) was the most important prey item. It is surprising that the small dusky kob 20 – 39 cm were feeding more on *Galeichthys feliceps* than any of the smaller prey items, since the prey preference of predatory fish is commonly determined by body size. As the predatory fish grows bigger then it would prey on bigger prey (Smale and Bruton, 1985). However, the *Galeichthys feliceps* consumed were small juveniles (approximately 5 cm), who are slow moving and easy to catch (Griffiths, Marine and Coastal Management, *pers comm.*).

In comparison to the Breede River estuary, the Fish River has, in terms of the %IRI, different but important prey items. It was found that the mysids (71.8%) were the most important prey items to juvenile dusky kob in the size class 20 – 39 cm, followed by 17% of unidentified teleost remains. The importance of mysids dominating this size-class makes sense, due to the predator – prey feeding relationship where smaller prey are generally eaten by smaller predators and vice versa (Smale and Bruton, 1985). For the preceding size-class 40 – 75 cm *Gilchristella estuaria* (50.6%) dominated the diet of juvenile dusky kob in the Fish River, only (Table III, IV, and V). However, in the same size-class, the mysids (44%) were also important and could be related to seasonal abundance of these two important prey items. Cannibalism in the Fish River was evident in the size-class 75 – 110 cm where the conspecific fish, *A. japonicus* (60.8%) was the most important prey species. Other important prey items for the same size class included *Octopus* (19.2%) and mysids (10.8%). The importance of *Octopus* was unexpected, since it does not naturally occur in estuaries, and juvenile dusky kob are known to be resident in estuaries, and do not migrate long distances, based on a tagging study by Griffiths

(1996). The *Octopus* may have been flushed into the estuary as paralarvae due to tidal influences (Vorwerk *et al.*, 2001).

The diet of dusky kob from the Keiskamma River estuary was dominated by *Pomadasys commersonnii* (73.8%) n the size-class 40 –75 cm, and *Liza richardsoni* (57.6%) was the most important prey in the size-class 75 – 110 cm, followed by the unidentified teleost remains (24%). Generally, the diet composition of *A. japonicus* in the three estuaries is different, in terms of the relative prey importance index.

A comparison, of the food proportions for the stomachs with and without food was performed among estuaries and between size classes (only in those with a large sample size). The among estuaries by size-class comparisons had shown a significant difference for the size-class 40 – 75 cm, and this could be attributed to the fact that the Breede River and the Fish River estuaries had more stomachs with food than average, and vice versa for the stomachs without food. It was shown that the Keiskamma River estuary had fewer observed stomachs with food than average. These deviations probably indicate that juvenile dusky kob in this size-class feed at different rates amongst the three estuaries, which could point out to differences in nutritional supplies and hence differential growth. The significant difference observed in this size class could be linked to the difference in growth rates of the juvenile dusky kob among the three estuaries. In the preceding size-class 75 – 110 cm, there was no significant differences found, among the estuaries, and this could mean that juvenile dusky kob in this size class feed at the same rate, however, there is a diverse kind of diet available to the juvenile dusky kob in any size - class.

Different prey items dominate each size-class, which suggests that these differences in diet composition could also contribute to the different growth rates of juvenile dusky kob in the three South African estuaries. Determining energy content (e.g via bomb calorimetry) was beyond the scope of this study.

An analysis between size-classes (especially those with a representative sample) had shown that there was a significant difference between size classes in terms of food proportions in the stomachs. Mainly two size-classes 40 – 75 cm, and 75 – 110 cm, which were considered here, suggest that juvenile dusky kob feed differently from one size class to another. Generally, small (in terms of length) juvenile dusky kob tend to feed more frequently than the larger ones (Griffiths, 1997a,b), possibly due to their high metabolic rate. The mean food mass of prey consumed (Table VI) generally should be related to meal size. It could be hypothesized that smaller dusky kob feed on smaller prey but more frequently while larger ones feed less frequently but on larger prey. This could account for the observed difference in the number of full stomachs observed in these two size classes.

It is evident in this study that the observed differences in growth of *A. japonicus* in the three South African estuaries is primarily caused by the difference in diet both among the estuaries and size classes. Although, there might be other factors at play contributing to the difference in growth of the juvenile dusky kob, feeding intensity and prey species are the most important. Some prey items are easy to digest and more nutritious than the others, and may support different growth rates in fish. Water temperature might have played a significant role in growth of *A. japonicus*, but we cannot show this because of inadequate data, and thus it warrants further investigation. It should be noted that fisheries managers and aquaculturists in particular, should use the estimated growth rates in this study with caution. This is the same reason why the Von Bertalanffy growth parameters and Schnute parameters were not displayed in this paper. However, this study can be compared to the juvenile growth rates of *A. japonicus* raised in captivity (mariculture). Generally, juvenile dusky kob in the Breede River estuary are relatively much bigger than juveniles of the same age in the Fish River and Keiskamma River estuaries. This could be attributed to better and favorable growth conditions in the Breede River, than other estuaries. On the other hand it could possibly be the level of fishing effort (since *A. japonicus* is susceptible to recruitment overfishing (Griffiths, 1997c), in the other estuaries, and water temperature, which may lead to slower growth, change in behavior and survival in fish (e.g Atlantic salmon) (Lee and Renne, 1980; Bjorn and Reiser, 1991; Cunjak and Randall, 1993; Elliot and Hurley, 1997; Swansburg *et al.*, 2003). Faster growing fish may be selected against as they attain the minimum size limit earlier and are thus more exposed to fishing mortality for longer (Griffiths, Marine and Coastal Management, *pers comm.*). The fact that there were also more older fish in the Breede River, than the other two estuaries, is in line with the understanding that juvenile exploitation in one area may not affect catches in another, and juvenile exploitation in all areas would probably impact on the adult population (Griffiths and Hecht, 1996).

In Fig. 4, there was no fish older than 6 years and 5 years in the Fish River and Keiskamma estuary, respectively, which could be attributed to the fact that fish in these particular age categories could be migrating early out of the estuaries to recruit into the migratory adult population, even though the targeting of older fish in these estuaries, cannot be ruled out. It is also clear from the shape and clarity of the otoliths (Fig. 3) that the juvenile dusky kob were caught from different estuaries. Otolith shape (Fig. 3) is strongly affected by environmental conditions (Campana and Casselman, 1993), even though they may not show genetic variation. This may suggest that three or more stocks of the South African dusky kob exist during their juvenile stage, noting the observed different shapes of otoliths from the three estuaries in question (Fig. 3). A study by Griffiths (1996) has shown that the juvenile dusky kob < 110 cm are fairly resident, but adult dusky kob migrate from the Cape to KwaZulu-Natal for spawning. Griffiths (1997c) has suggested that *A. japonicus* is susceptible to recruitment overfishing, and that it may have been overexploited in its entire distribution range in South African waters. Thus, management aimed at microhabitat i.e. estuaries is equally important if we are to rebuild these depleted stocks of dusky kob along their entire distribution in the South African waters.

Acknowledgements

I thank Dr Marc Griffiths (Marine and Coastal Management) for providing the data and for his supervision, to Dr Anesh Govender (University of Cape Town) for his supervision, and the Zoology Department at UCT for providing the research facilities. I would also like to thank the University of Namibia for financial support (through NORAD funds) and Irvin and Johnson for their financial support during my studies. Last but not least, I would like to thank those anglers who participated in the angling competitions and made their catches available to science.

References

AL-HUSAINI, M., AL-BAZ, A., AL-AYOUB, S., SAFAR, S., AL-WAZAN, Z., and S, AL-JAZZAF. (2002). Age, growth, mortality, and yield-per-recruit for nagroor, *Pomadasys kakaan*, in Kuwait's waters. *Fisheries Research*, **59**: 101 – 115.

BARBIERI, L.R., CHITTENDEN, M.E., and C.M. JONES. (1994). Age, growth and mortality of Atlantic croaker, *Micropogonias undulates*, in the Chesapeake Bay region, with a discussion of apparent geographic changes in population dynamics. *Fishery Bulletin of Washington*. **92**(1): 1 – 12.

BATTAGLENE, C.S and R.B, TALBOT. (1994). Hormone induction and larval rearing of mulloway *Argyrosomus hololepidotus* (Pisces: Sciaenidae). *Aquaculture*, **26**: 73 – 81.

BEAMISH, R.J and D.A, FOURNIER. (1981). A method for comparing the precision of a set of age determinations. *Canadian Journal of Fisheries and Aquatic Sciences*, **38**: 982 – 983.

BECKMAN, D.W., STANLEY, A.L., RENDER, J.H and C.A. WILSON. (1990). Age and growth of black drum in Louisiana waters of the Gulf of Mexico. *Transactions of the American Fisheries Society*, **119**(3): 537 – 544.

BERCKMAN, D.W., WILSON, C.A., and A.L. STANLEY. (1989). Age and growth of red drum, *Sciaenops ocellatus*, from offshore waters of the northern Gulf of Mexico. *Fishery Bulletin*, Washington, **87**(1): 17 – 28.

BEVERTON, R.J. (1992). Patterns of reproductive strategy parameters in some marine teleost fishes. *Journal of Fish Biology*, **41** (Suppl. B): 137 – 160.

BJORNN, T.C and D.W, REISER. (1991). Habitat requirements of salmonids in streams. In *Influences of the Forest and Rangeland Management on Salmonid Fishes and their Habitats* (Meehan, W.R., ed.), *American Fisheries Society* (Special Publication), **19**: 83 – 138.

CAMPANA, S.E., ANNAND, M.C., and J.I, McMILLAN. (1995). Graphical and statistical methods for determining the consistency of age determinations. *Transactions of the American Fisheries Society*, **124:** 131 – 138.

CAMPANA, S.E. and J.M, CASSELMAN. (1993). Stock description using otoliths shape analysis. *Canadian Journal of Fisheries and Aquatic Sciences*, **50**(5): 1062 – 1083.

CORTES, E. (1997). A critical review of methods of studying fish feeding based on analysis of stomach contents: Application to elasmobranch fishes. *Canadian Journal of Fisheries and Aquatic Science*, **54**: 726 – 738.

CUNJAK, R.A. and R.G, RANDALL. (1993). In-stream movements of young Atlantic salmon (*Salmor salar*) during winter and early spring. In *Production of juvenile Atlantic Salmon,* Salmor salar, ***in natural waters*** (Gibson, R.J and R.E, Cuttings eds), ***Canadian*** *Special Publication of Fisheries and Aquatic Sciences*, **118**: 43 – 51.

ELLIOT, J.M. and M.A, HURLEY. (1997). A functional model for maximum growth of Atlantic salmon parr, *Salmo salar*, from two populations in northwest England. *Functional Ecology*, **11**: 592 – 603.

FOWLER, J., COHEN. L and P. JARVIS. (1999). Practical Statistics for Field Biology. 2nd edition, John Wiley and Sons, New York, USA. 259pp.

FRY, F.E.J. (1971). The effects of environmental factors on the physiology of fish. In *Fish Physiology*, Vol **6** (Hoar, W.S and D.J, Randall eds), pp. 1 – 98. New York: Academic Press.

GAMITO, S. (1998). Growth models and their use in ecological modeling: an application to a fish population. *Ecological Modelling*, **113**: 83 – 94.

GRIFFITHS, M.H. (1996). Life history of the dusky kob *Argyrosomus japonicus* (Sciaenidae) off the east coast of South Africa. *South African Journal of Marine Science*, **17**: 135 – 154.

GRIFFITHS, M.H. (1997a). Feeding ecology of South African *Argyrosomus japonicus* (Pisces: Sciaenidae), with emphasis on the eastern Cape surf zone. *South African journal of Marine Science*, **18**: 249 – 264.

GRIFFITHS, M.H. (1997b). Influence of prey availability on the distribution of dusky kob *Argyrosomus japonicus* (Sciaenidae) in the Great Fish River Estuary, with notes on the diet of early juveniles from three other estuarine systems. *South African Journal of Marine Science*, **18**: 137 – 145.

GRIFFITHS, M.H. (1997c). Management of South African dusky kob *Argyrosomus japonicus* (Sciaenidae) based on per-recruit models. *South African Journal of Marine Science*, **18**: 213 – 228.

GRIFFITHS, M.H and T, HECHT. (1995). Age and growth of South African Dusky kob *Argyrosomus japonicus* (sciaenidae) based on otoliths. *South African Journal of Marine Science*, **16**: 119 – 128.

HOLTZHAUSEN, J.A and C.H, KIRCHNER. (2001). Age and growth of two populations of west coast steenbras *Lithognathus aureti* in Namibian waters based on otolith readings and mark-recapture data. *South African Journal of Marine Science*, **23**: 169 – 179.

HORN, P.L. (2002). Age and growth of Pantagonian toothfish (*Dissostichus eleginoides*) and Antarctic toothfish (*D. mawsoni*) in waters from the New Zealand subantarctic to the Ross Sea, Antarctica. *Fisheries Research*, **56**: 275 – 287.

HYNES, H.B.N. (1950). The food of fresh-water sticklebacks (*Gasterosteus acculeatus* and *Pygosteus pungittius*), with a review of methods used in studies of the food of fishes. *Journal of Animal Ecology*, **19**(1): 36 – 58.

JOBLING, M. (1994). Fish Biogenetics. London: Chapman and Hall. 366pp.

JOBLING, M. (1997). Temperature and growth: modulation of growth rate via temperature change. In *Global Warming: Implications for Freshwater and Marine Fish* (Wood, C.M. and D.G, McDonald eds), pp. 225 – 253. Cambridge: Cambridge University Press.

KAILOLA, P.J., WILLIAMS, M.J., STEWART, P.C., REICHELT, R.E., McNEE, A., and C. GRIEVE. (1993). *Australian Fisheries Resources*. Canberra; Bureau of Resource Sciences and the Fisheries Research and Development Corporation: 422pp.

KESTEMONT, P. and E, BARAS. (2001). Environmental factors and feed intake in fish. In *Food Intake in Fish* (Houlihan, D., Bourjard, T. and M, Jobling eds), pp. 131 – 156. Oxford: Blackwell Science Ltd.

LEE, R.M. and J.N, RINNE. (1980). Critical thermal maximum of five trout species in the southwestern United States. *Transactions of the American Fisheries Society*, **190**: 632 – 635.

MACDONALD, J.S. and R.H.GREEN. (1983). Redundancy of variables used to describe the importance of prey species in fish diets. *Canadian Journal of Aquatic Sciences*, **39**: 635 – 637.

PAJUELO, J, and J.M, LORENZO. (2002). Growth and age estimation of *Diplodus sargus cadenati* (Sparidae) off Canary Islands. *Fisheries Research*, **59**: 93 – 100.

PAULY, D. (1980). On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *Journal du Conseil Permanent international pour l'Exploration de la Mer*. **39** (2): 175 – 192.

RADEBE, P. V., MANN, B.Q., BECKLEY, L.E., and A. GOVENDER. (2002). Age and growth of *Rhabdosargus sarba* (Pisces: Sparidae), from KwaZulu-Natal, South Africa. *Fisheries Research*, **58**: 193 – 201.

RICKER, W.E. (1975). Computation and interpretation of biological statistics of fish populations. *Bulletin of Fish Research Board of Canada*, **191**: 382 pp.

SCHNUTE, J.[T.]. (1981). A versatile growth model with statistically stable parameters. *Canadian Journal of Fisheries and Aquatic Sciences*. **38**(9): 1128 – 1140.

SMALE, M.J. and M.N, BRUTON. (1985). Predation and prey selectivity by *Argyrosomus hololepidotus* (Osteichthyes: Sciaenidae) in South-Eastern Cape waters of South Africa. *South African Journal of Zoology*, **20**(3): 97 – 108.

TALJAARD, S., VAN NIEKERK, L and P. HUIZINGA. (2002). Specialist Report: Physical Dynamics and Water Quality. Intermediate Determination of Resource Directed Measures for the Breede River Estuary. Appendix C, CSIR Report ENV – S – 2002-020/A.

TREWAVAS, E. (1977). The sciaenid fishes (croaker or drums) of the Indo-West-Pacific. *Transactions of the Zoological Society of London*. **33** (4): 253 – 541.

VAUGHAN, D.S and P. KANCIRUK. (1982). An empirical comparison of estimation procedures for the Von Bertalanffy growth equation. *Journal du Conseil Permanent international pour l'Exploration de la Mer.* **40**: 211 – 219.

VON BERTALANFFY, L. (1957). Quantitative laws in metabolism and growth. *Quarterly Review in Biology*. **32**(3): 217 – 231.

VORWERK, P.D., WHITFIELD, A.K., COWLEY, P.D., and A.W, PATERSON. (2001). A survey of selected eastern Cape estuaries with particular reference to the ichthyofauna. *Ichthyological Bulletin*, 72.

WALLACE, J.H., and M.H. SCHLEYER. (1979). Age determination in two important species of South African angling fishes, the kob (*Argyrosomus hololepidotus* Lacep.) and the spotted grunter (*Pomadasys commersonnii* Lacep.). *Transactions of the Royal Society of South Africa*, **44**: 15 – 26.

WINDELL, J.T. and S.H. BOWEN. (1978). Methods for study of fish diets based on analysis of stomach contents. In *Methods for Assessment of Fish Production in Fresh Waters*, 3rd ed. Bagenal, T.B. (Ed.). London, Blackwell: 219 – 226.

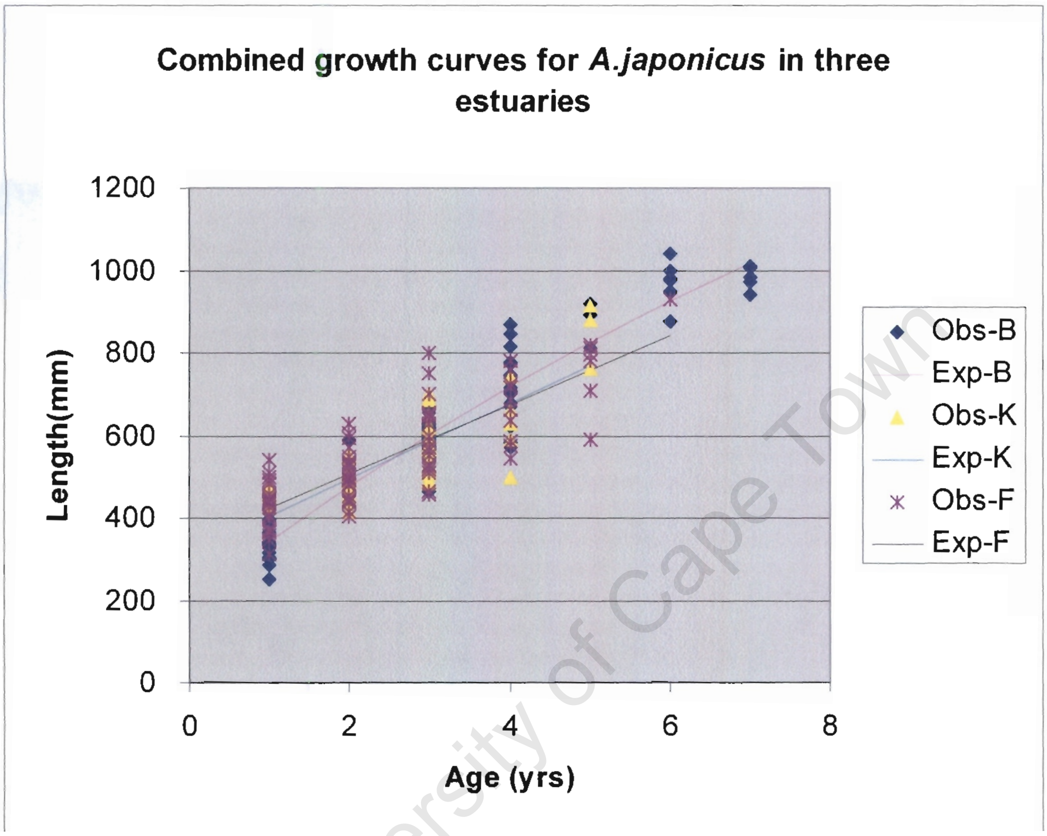
YONEDA, M., SAKAI, T., TOKIMURA, M., HORIKAWA, H, and M, MATSUYAMA. (2002). Age and growth of the lizardfish *Saurida* sp. 1 in the East China Sea using otoliths ring marks. *Fisheries Research*, **55**: 231 – 238.

ZAR, J.H. (1999). Biostatistical Analysis (Fourth Edition). Prentice Hall, New Jersey, 663pp.

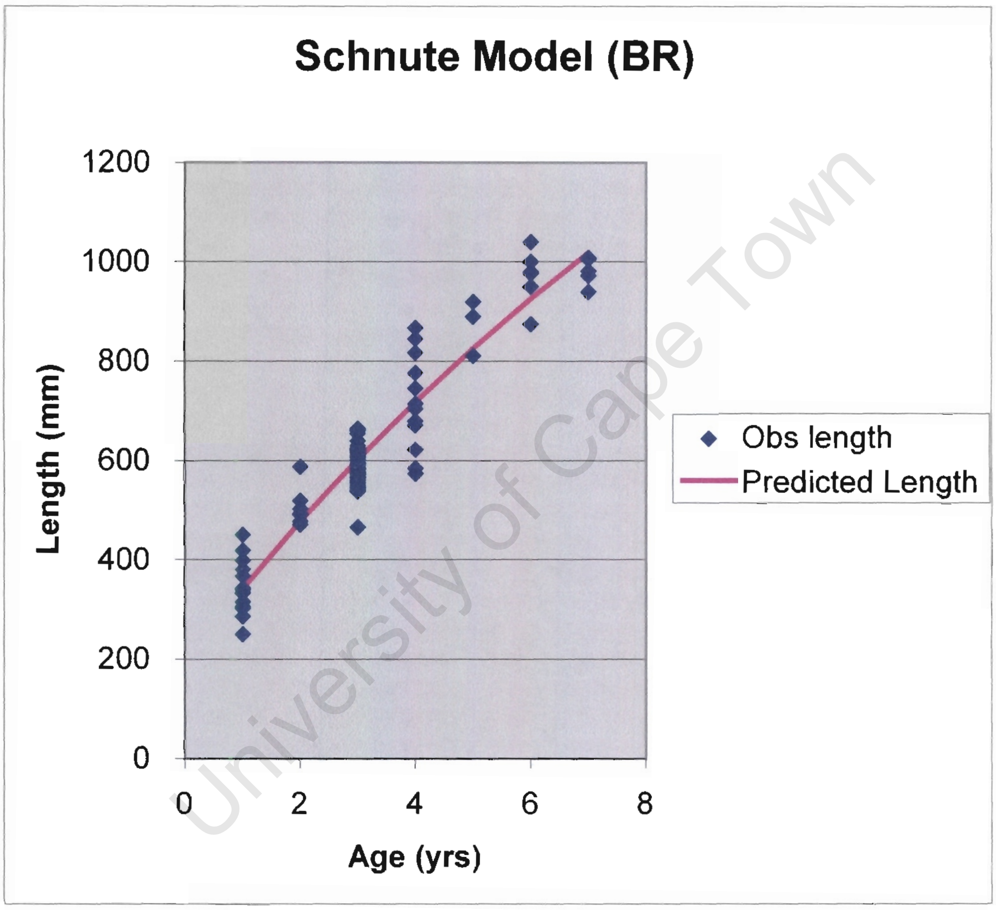
Appendices

Appendix 1

The age-length relationship for juvenile dusky kob for each of three estuaries (B = Breede River estuary; K = Keiskamma River estuary; F = Fish River estuary)

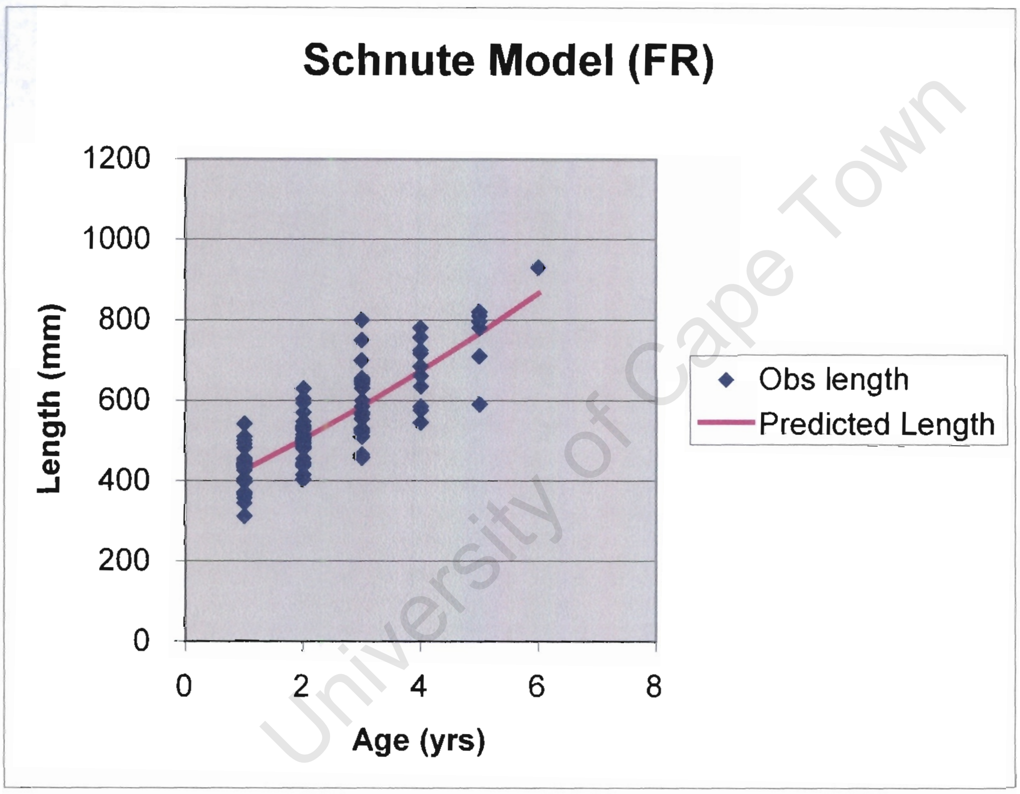


Appendix 2
The Schnute growth model fitted to age-length data for dusky kob in the Breede River estuary

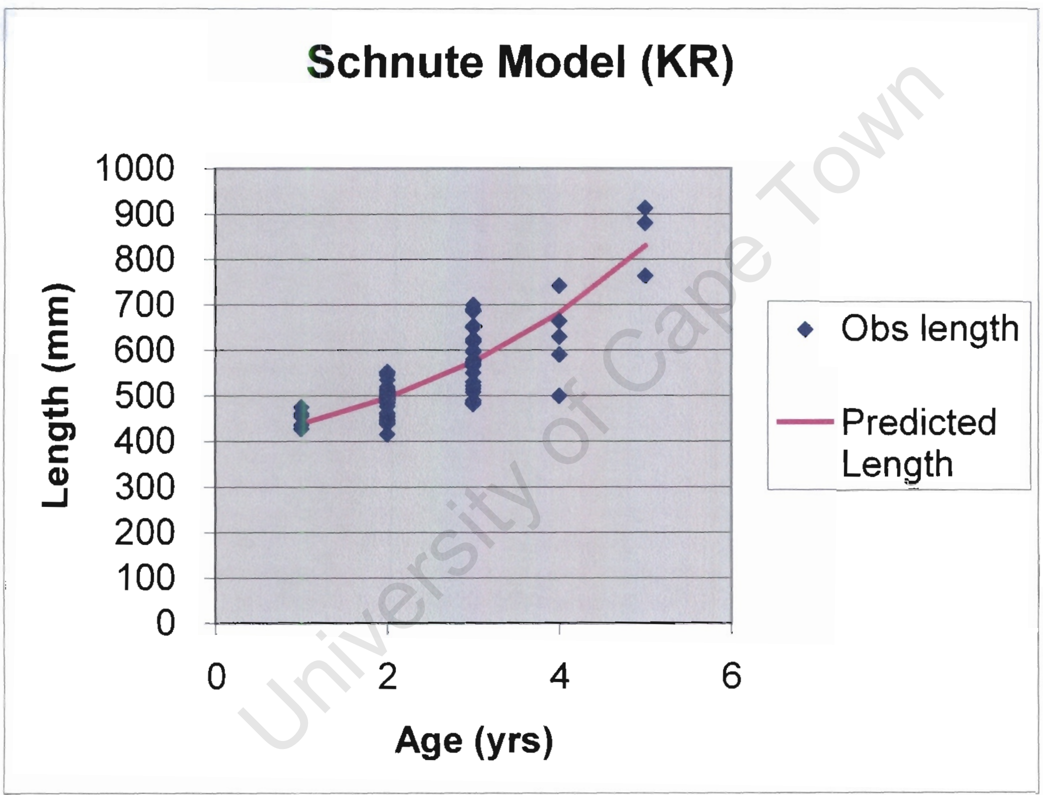


Appendix 3

The Schnute growth model fitted to age-length data for dusky kob in the Fish River estuary



Appendix 4
The Schnute growth model fitted to age-length data for dusky kob in the Keiskamma River estuary



Appendix 5

(Table showing all the parameters of the Von Bertalanffy growth and Schnute models)

Model	Parameters	Breede	Fish River	Keiskamma
Schnute	a	0.076702	-0.066601	-0.31511
	L_1	341.3	427.1	438.2
	L_2	1018.4	866.3	829.6
	t_1	1	1	1
	t_2	7	6	5
Von Bertalanffy	L_∞	2363.7	694.1	-1484.8
	k	0.076702	-0.06601	-0.31511
	t_0	-1.22343	-6.24829	…….
	SSQ	270250.2	422690.9	244231.4