Age, growth and feeding of the blue hottentot *Pachymetopon aeneum* (Pisces: Sparidae) with notes on reproductive biology

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The sparid *Pachymetopon aeneum* is a benthic carnivore feeding predominantly on hydroids, tunicates and octocorals. Juveniles and subadults occur on shallower reefs than the adults but the diet of all sizes is similar. The species is a protogynous hermaphrodite, sex reversal occurring between 200 and 300 mm forklength. Fifty per cent maturity in females occurs between 200 and 250 mm forklength. Peak reproductive activity was recorded between September and March. Otoliths were used to determine growth rate. Growth in length was described by the equation, $L_t(\mathrm{mm}) = 467{,}06(1 - e^{-0{,}1328(t-0{,}2473)})$. The relationship between length and weight, $W(\mathrm{g}) = 0{,}00001\,L(\mathrm{mm})^{3{,}149}$, was used to determine somatic growth as, $W_t(\mathrm{g}) = 2545{,}98(1 - e^{-0{,}1328(t-0{,}2473)})^{3{,}149}$. *P. aeneum* have a potential for exploitation but the combination of late maturation and protogynous hermaphroditism could lead to over-exploitation in a size-selective fishery.

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Pachymetopon aeneum, wat behoort tot die familie Sparidae, is 'n bentiese karnivoor wat hoofsaaklik van hidroïde, tunikate en sagte korale leef. Jong en onvolwasse visse word meer op subgetyriwwe gevind as volwasse visse, maar die dieet van alle groottes was dieselfde. Die spesie is 'n protoginiese hermafrodiet. Geslagsomkering vind plaas by 'n vurklengte van tussen 200 en 300 mm. Vyftig persent geslagsrypheid onder die wyfies vind tussen 200 en 250 mm-vurklengte plaas. Die piek kuitskietperiode was tussen September en Maart. Otoliete is gebruik om die groeisnelheid te bepaal. Lengtegroei kan deur die formule $L_t(\mathrm{mm}) = 467{,}06(1 - e^{-0{,}1328(t-0{,}2473)})$ beskryf word. Die verhouding tussen lengte en gewig, $W(\mathrm{g}) = 0{,}00001\,L(\mathrm{mm})^{3{,}149}$, is gebruik om somatiese groei te bepaal wat deur die formule, $W_t(\mathrm{g}) = 2545{,}98(1 - e^{-0{,}1328(t-0{,}2473)})^{3{,}149}$, beskryf word. *P. aeneum* het die potensiaal vir benutting as 'n lynvis maar die kombinasie van laatrypheid en protoginiese hermafroditisme kan lei tot oorbenutting in 'n vissery wat op grootte gebaseer is.

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The blue hottentot *Pachymetopon aeneum* (Gilchrist and Thompson), an endemic to southern Africa, is found over reefs between False Bay and Durban (Smith 1965; van der Elst 1981). Buxton and Smale (1984) show that although present intertidally, they predominate on sub-tidal reefs, being the third most abundant species between 10 and 30 m deep. In spite of this potential to be exploited, they are at present only a relatively minor component of the total linefish catch in the Eastern Cape (Smale & Buxton 1985). This work presents quantitative information on age, growth and feeding of the blue hottentot. In addition some observations on the reproductive biology are given.

Methods

Samples were obtained from fish caught by sport anglers fishing from ski-boats in the Port Elizabeth area between January 1980 and November 1984. Most of these fish were larger than 200 mm (fork length) and smaller fish were speared with the aid of SCUBA in the Noordhoek and Phil's Reef areas. In addition to these specimens some data were obtained during a survey of the ichthyofauna of the Tsitsikamma Coastal National Park using both line and spear. The sampling sites are shown in Figure 1.

The fork lengths (FL) of all fish were measured to the nearest millimetre. Mass, in grams, as well as total (TL) and standard lengths (SL) were measured in a sub-sample of fish. The relationships between these parameters were calculated by logarithmic regression analysis and expressed in the form of $W = aL^b$ (Ricker 1975), and are summarized in Table 1. Sex and gonadal development stages were

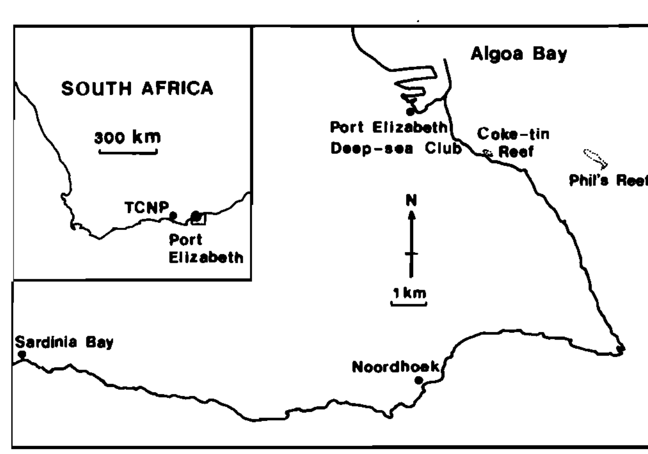

Figure 1 Map of the study area.

Table 1 Relationships between length and mass in *Pachymetopon aeneum*

Equation	r^2	n
W (g) = 0,00001 TL(mm)^{3,06}	0,99	47
W (g) = 0,00001 FL(mm)^{3,149}	0,99	47
W (g) = 0,000023 SL(mm)^{3,082}	0,99	47

determined on a visual scale from 1 to 5 summarized in Table 2. Gonado-somatic index (GSI) was calculated by expressing gonad mass as a percentage of total mass.

The stomachs of 97% of the fish were either empty or everted owing to the stress of capture and depressurisation. The contents, if any, were removed and preserved in 10% buffered formalin. Prey items were identified to the lowest possible taxon and assigned a visual percentage volume (Christensen 1978). Percentage frequency of occurrence was calculated for each prey item (Hynes 1950) and a ranking index, the frequency of occurrence multiplied by the mean percentage volume, was computed for each prey group (Hobson 1974).

For age determination, both sagittae were removed, cleaned and stored in a 70% solution of propyl alcohol. Annuli were enhanced by burning the otoliths over a low intensity spirit flame until they turned pale brown. Care was taken not to char the otolith as this tended to obscure the structure, particularly of the margin. Otoliths were viewed under reflected light with a low power dissecting microscope. Measurements of the total diameter, otolith radius and distance from the nucleus to each annulus, on the long axis, were made to the nearest 0,01 mm.

Some confusion exists regarding the terms used to describe growth zones in otoliths (Panella 1974). Much of this stems from the failure of many authors to describe clearly the techniques used when viewing their otoliths. In particular the use of the terms hyaline and opaque to describe both composition and optical properties of otoliths has been problematical. Under different light conditions a single zone can be described as either hyaline or opaque. These terms should be used with care and the distinction between fast and slow growth zones must be clearly stated.

In this study, viewed under reflected light, the fast growth zones (optically dense or opaque) appeared light brown and the slow growth zones (translucent or hyaline) appeared dark brown (Figure 2). These zones were termed light (L) and dark (D) corresponding to summer and winter growth respectively. The frequency of occurrence of light or dark zones on the otolith margin was plotted on a bi-monthly basis to determine the number of growth zones deposited per year.

Figure 2 Low power micrograph of the saggitae of *Pachymetopon aeneum*. The right otolith has been burnt and the annuli are marked with crosses. Age determined as 5 years.

Results

Feeding

Prey recorded in the stomachs of 47 *P. aeneum* between 117 and 370 mm (FL) are summarized in Table 3. All of the fish were caught in the Port Elizabeth area and although the prey found in five fish caught off Tsitsikamma compared favourably with these results, these were excluded because of the small sample size. Most of the 29 different prey items recorded belonged to three groups, the Hydrozoa, Tunicata and Octocorallia. For convenience only the major hydrozoans were listed and associated species are presented in Table 4. With the exception of mysids, the remaining prey items were relatively unimportant and possibly only occur as accidental inclusions with the major prey items. No appreciable difference was observed between the diets of small and large fish.

Reproductive biology

The relative infrequency of large fish sampled precluded a

Table 2 Classification of maturity stages in *P. aeneum*

Stage	Description
1. Virgin and Resting	Sexual organs small. Testes thin and transparent to greyish white. Ovary long and thin, pink in colour with no visible eggs.
2. Developing	Both male and female tissue increase in size. Testis shows a lateral thickening as well as an increase in length and is coloured a greyish pink. Some sperm visible in the tissue if cut and gently squeezed. The ovary increases in size particularly on the long axis filling half the visceral cavity. Colour changes from a pink to reddish orange and eggs become visible to the naked eye.
3. Ripe	Size increase continues. Testis greyish white, lobular and sperm present in both tissue and vas deferens. Ovary occupies more than half the ventral cavity, is swollen and yellow in colour. Eggs are translucent but not extruded when pressure is applied.
4. Ripe Running	Eggs and milt are extruded in response to light pressure on the belly. Most of ovary is filled with translucent eggs at this stage.
5. Spent	Testis and ovary decrease in size. Testis reddish grey in colour sperm still present in vas deferens but presence of blood indicates recent spawning. Ovary reddish orange due to presence of blood, flaccid and an obvious empty lumen. Fewer translucent eggs visible.

From stage 5 there is either a progression to the resting stage (1) or a recovery for a second spawning (stage 2).

Table 3 Prey items represented in the stomachs of *P. aeneum* between 117 and 370 mm fork length (n = 47)

Food types	% Freq. occur.	Mean % vol.	Rank
Hydrozoa	55,32	26,30	14,55
Hydrozoan remains	36,17	10,94	3,96
Thecocarpus formosus	8,51	3,62	0,31
Sertularella gilchristi	8,51	3,55	0,30
Antenella sp.	4,26	2,98	0,13
Antenella africana	2,13	1,70	0,04
Sertularella arbuscula	2,13	1,06	0,02
Halecium dichotomum	2,13	1,06	0,02
Gattya heurteli	2,13	0,43	0,01
Salacia articulata	2,13	0,11	T
Tunicata	46,81	27,32	12,79
Didemnidae sp. A	29,79	13,30	3,96
Ascidian remains	14,89	4,23	0,63
Didemnidae sp. C	14,89	4,00	0,60
Didemnidae sp. B	10,64	4,40	0,47
Didemnidae sp. D	4,26	1,06	0,05
Didemnidae sp. E	2,13	0,32	0,01
Octocorallia	51,06	17,30	8,83
Lophogorgia flammea	34,04	4,83	1,64
Octocoral remains	10,64	4,74	0,50
Eunicella papillosa	14,89	3,02	0,45
Melitodes sp.	4,26	3,19	0,14
Wrightella coccinea	8,51	1,30	0,11
Acabaria? sp.	2,13	0,21	T
Crustacea	23,40	6,83	1,60
Mysidacea	12,77	6,70	0,86
Crustacean remains	4,26	0,04	T
Amphipoda	4,26	0,04	T
Anomura	2,13	0,02	T
Brachyura (Megalopa)	2,13	0,02	T
Algae	17,02	1,74	0,30
Algal remains	8,51	1,30	0,11
Chlorophyta	4,26	0,30	0,01
Rhodophyta	6,38	0,15	0,01
Porifera	10,64	2,77	0,30
Pelecypoda	4,26	0,04	T
Pycnogonida	2,13	0,04	T
Ophiuroidea	2,13	0,04	T
Polychaeta	2,13	0,02	T
Unidentified	38,30	16,53	6,33

Table 4 Species found in association with the hydroids listed in Table 3

Listed species	Associated species
Sertularella gilchristi	*Sertularella capensis*
Sertularella arbuscula	*Campanularia morgansi* *Halecium beanii* *Halopteris glutinosa*
Thecocarpus formosus	*Corhiza scotia*
Gattya heurteli	*Monostechas faurei* *Lytocarpus filamentosus* *Halopterus glutinosa* *Gymnangium arcuatum* *Thyroscyphus aequalis* *Hebella scandens* *Symplectoscyphus macrogonus*
Salacia articulata	*Halecium* sp. *Sertularella africana* *Halopterus glutinosa* *Halecium beanii* *Campanularia morgensi*
Antenella africana	*Sertularella* sp. *Kirchenpauria pinnata* *Sertularella arbuscula*

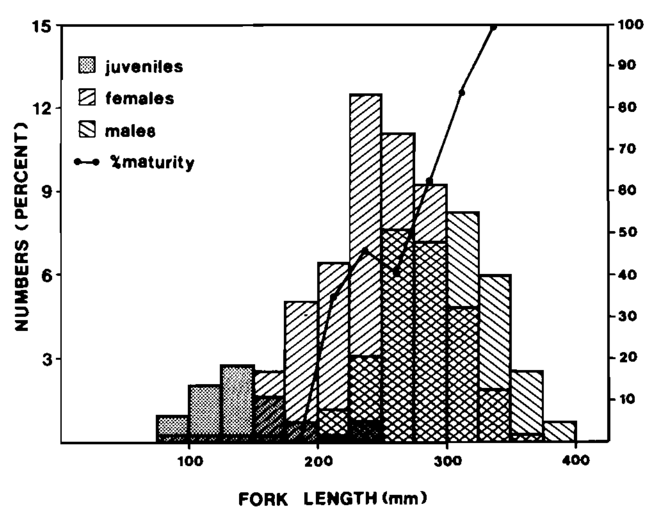

Figure 3 Length frequency analysis and percentage maturity in *Pachymetopon aeneum*.

detailed investigation of the reproductive biology of *P. aeneum*. The data do, however, provide preliminary information on reproductive seasonality, sex reversal and size at sexual maturity. Length frequency analysis of all fish sampled during the study showed a clear difference in the modal size between the sexes (Figure 3). This, and the absence of males below 200 mm suggests that they are protogynous hermaphrodites. An estimate of the size at sexual maturity was obtained by relating gonad activity to fork length, which shows that 50% maturity occurs between 200 and 250 mm (Figure 3) at an age of approximately five years (see data on age and growth later). Reproductively active fish were caught throughout the year, although the monthly GSI indicated peak spawning between September and March (Figure 4). The low GSI values in January and February are thought to be artefacts of small sample sizes in these months.

Age and growth

The relationship between otolith radius and fork length is illustrated in Figure 5. The points were best described by a power curve where FL(mm) = 28,7625OR(mm)^{1,3656} (r^2 = 0,9468, n = 261).

The bi-monthly percentage of light and dark zones on the margin of the otolith is shown in Figure 6. One light and one dark zone are deposited annually showing that otoliths may be used to estimate age. The relative width of these zones showed that growth was slow between March and August (autumn–winter) and increased between September and February (spring–summer).

A total of 196 otoliths were read of which 67 were rejected because the observations of two independent readers did

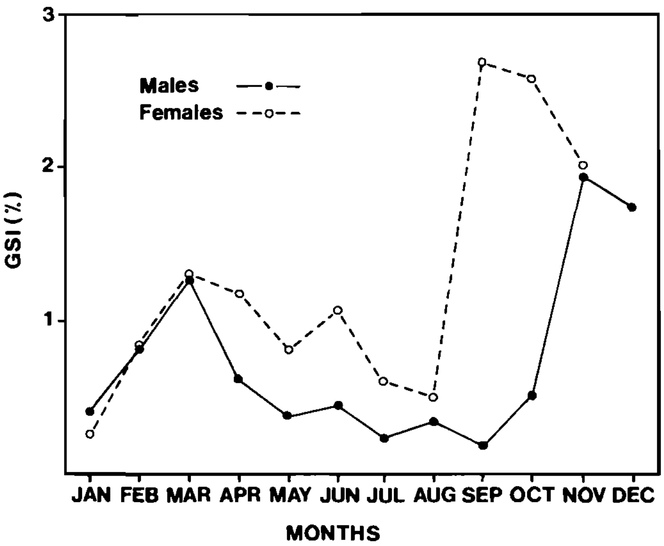

Figure 4 Monthly gonado-somatic index in *Pachymetopon aeneum*. Solid line represents males and dashed line females.

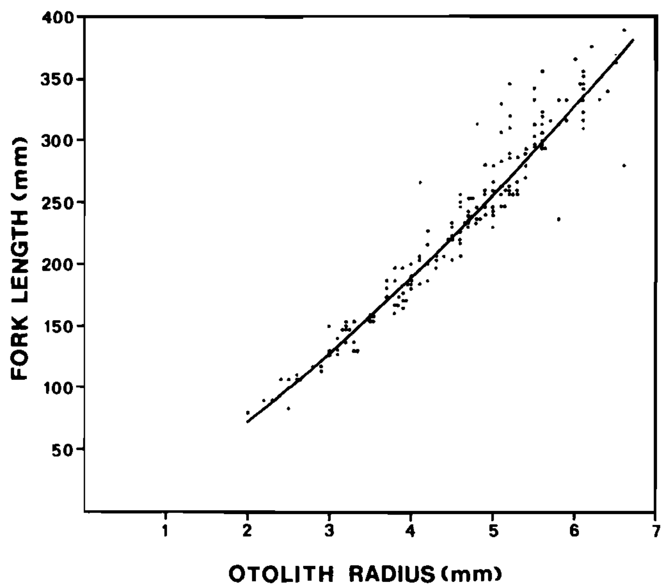

Figure 5 The relationship between otolith radius and fork length in *Pachymetopon aeneum* (n = 161).

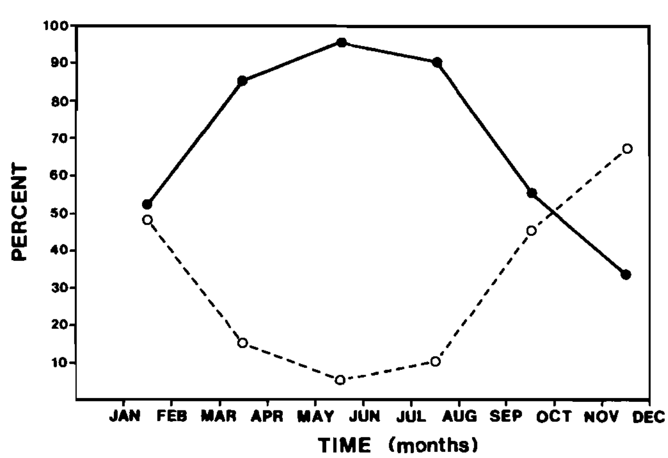

Figure 6 Temporal changes in the marginal increment in *P. aeneum* otoliths. Dashed line represents D-layer or winter growth and solid line the L-layer or summer growth.

not agree. The D-layer count together with the state of the outer edge of the otolith are related to length of the fish at capture in Figure 7. For example a 2D fish is one in the second slow growth phase while a 2L fish has two growth checks and is in the fast growth phase. A Walford regression of length-at-age (L_t) against length-at-age + 1 (L_{t+1}) was described by the equation:

$$L_{t+1} = 58{,}1022 + 0{,}8756 L_t \qquad (r^2 = 0{,}94, n = 10)$$

with a slope $b < 1$. Growth was described by the von Bertalanffy growth equation (Everhart, Eipper & Young 1975):

$$L_t(\text{mm}) = 467{,}06(1 - e^{-0{,}1328(t - 0{,}2473)}).$$

The exponent of the length-weight relationship was used to describe somatic growth:

$$W_t(\text{g}) = 2545{,}98(1 - e^{-0{,}1328(t-0{,}2473)})^{3{,}149}.$$

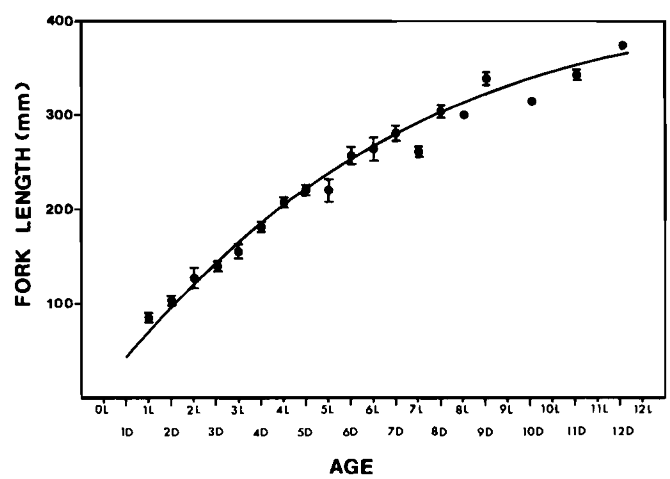

Figure 7 The relationship between length and age in *Pachymetopon aeneum*.

Table 5.1 contains the calculated lengths-at-age for 1–9-year-old fish, derived from radial measurements of all annuli on 107 otoliths (ages 10–12 were omitted because of small sample sizes). The method of Ricker and Lagler (Bagenal & Tesch 1978) was used because of the non-linear relationship between otolith radius and fork length:

$$\bar{S}n = \frac{\bar{S}Sn}{S}$$

where $\bar{S}n$ = adjusted distance to the nth annulus, $\bar{S}$ = average scale radius for a fish of observed length and S = total scale radius.

Back-calculated lengths-at-age were calculated using the equation:

$$Ln(\text{mm}) = 28{,}7625 \bar{S}n^{1{,}3656}$$

The mean back-calculated lengths-at-age are plotted together with observed mean length-at-age in Figure 8. These two curves are similar showing agreement between empirical and observed length-at-age. From the data presented in Table 5.2 the population growth rate (Gx) and individual

Table 5.1 Back-calculated fork length at age for *Pachymetopon aeneum* (ages 10 to 12 were omitted because of small sample sizes)

Age class	No.	Fork[a] length	Back-calculated lengths at successive annuli								
			1	2	3	4	5	6	7	8	9
9	2	344,5	60,2	99,3	146,2	171,0	200,2	234,3	273,4	299,1	344,5
8	6	313,7	55,9	96,9	133,5	161,9	205,0	236,7	270,8	304,8	
7	13	271,9	57,6	103,5	139,0	171,9	202,6	233,8	265,0		
6	15	247,9	57,3	108,1	145,4	178,1	211,6	244,6			
5	21	219,3	59,9	106,8	145,9	183,9	218,9				
4	15	189,3	52,2	100,6	136,7	181,5					
3	22	147,5	52,7	101,7	139,9						
2	9	115,8	57,5	105,6							
1	4	86,0	52,3								
Mean			56,1	102,7	140,9	174,7	207,6	237,3	269,7	301,9	

[a] Fork length at capture.

Table 5.2 Growth rates of *Pachymetopon aeneum* calculated from the data presented in Table 5.1

Age interval	Population growth			Mean individual growth		
	Length interval	Diff. of nat. log.	*Gx*	Length interval	Diff. of nat. log.	*G*
1–2	52,3–105,6	0,70	2,20	57,5–105,6	0,61	1,91
2–3	105,6–139,9	0,28	0,89	101,7–139,9	0,32	1,00
3–4	139,9–181,5	0,26	0,82	136,7–181,5	0,28	0,89
4–5	181,5–218,9	0,19	0,59	183,9–218,9	0,17	0,55
5–6	218,9–244,6	0,11	0,35	211,6–244,6	0,15	0,46
6–7	244,6–265,0	0,08	0,25	233,8–265,0	0,12	0,37
7–8	265,0–304,8	0,14	0,44	270,8–304,8	0,12	0,37
8–9	304,8–344,5	0,12	0,39	299,1–344,5	0,14	0,45

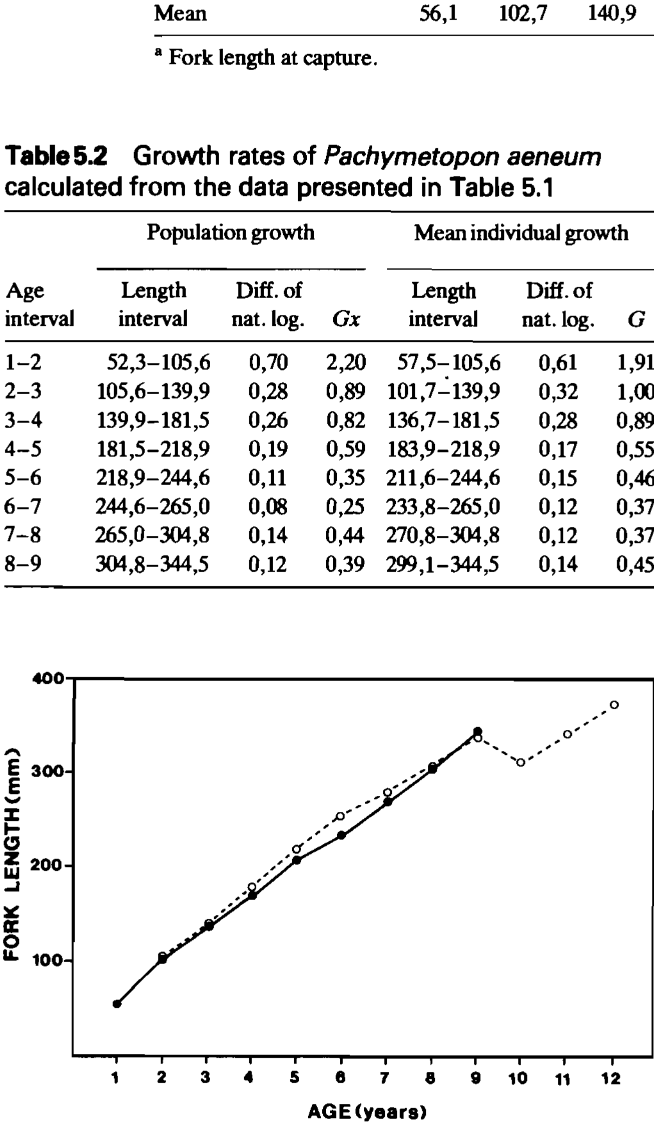

Figure 8 Observed and back-calculated length-at-age in *Pachymetopon aeneum*. Dashed line represents observed and solid line back-calculated length-at-age.

growth rate (*G*) were calculated (Ricker 1975). These values were compared to determine whether size-selective mortality was present in the fishery.

Discussion

In a recent study of the Eastern Cape ski-boat fishery, Smale & Buxton (1985) showed that catches of *Pachymetopon aeneum* were relatively small. Numerically the species contributed 0,53 and 0,39% to the total annual catch at the Port Elizabeth Deep Sea Angling Club in 1979 and 1980 respectively. However, *P. aeneum* was the third most important supra-benthic species recorded between 10 and 30 m in the Tsitsikamma Coastal National Park (Buxton & Smale 1984). Visual underwater assessments around Algoa Bay show a similar trend (own observations). Most of the fish observed at this depth were less than 250 mm (FL), larger fish appearing to prefer deeper water. Most of the large *P. aeneum* taken by line fishermen were caught between 40 and 100 m. These catches were usually accompanied by other deep-water sparids such as *Argyrozona argyrozona* (silverfish) and *Pterogymnus laniarius* (panga).

Analysis of the diet of *P. aeneum* showed that they were benthic feeders specializing in sedentary prey particularly hydroids, tunicates and octocorals. The mouthparts were well adapted for this purpose having a row of uniform cutting teeth in the upper and lower jaws. The gape was relatively small and food items were ingested in small pieces rather than being swallowed whole. Only one of the approximately 20 co-occurring sparids found between 10 and 30 m, *Boopsoidea inornata* (Frans Madame) has a diet similar to that of *P. aeneum*. Trow (1982) found that *B. inornata* also consumed considerable amounts of octocorals, ascidians and hydroids but suggested that these were ingested for their associated epibenthos. No evidence for this was found in *P. aeneum*. Although traditionally regarded as an inshore species, the congeneric *P. grande* (bronze bream) occurs on the same reefs as *P. aeneum*, down to at least 30 m. Preliminary investigations on the diet of *P. grande* indicates that competition for food between these species would be minimal as *P. grande* feeds predominantly on algae.

The results presented suggest that *P. aeneum* is a protogynous hermaphrodite with sex reversal occurring between 200 and 350 mm FL, corresponding to an age of four to nine years. Macroscopic and microscopic examination of hermaphroditic gonadal tissues showed that the development of the sexes was separate. The testis developed on the posterior end of the gonad accompanied by a progressive degeneration of the ovary, with no evidence of an invasion of the ovary by testicular tissue. This mode of development appears to be common among South African sparids having been recorded in panga, *P. laniarius* (Hecht 1976); dageraad, *Chrysoblephus cristiceps* (Robinson 1976); Roman, *C. laticeps* (Penrith 1972); red stumpnose, *C. gibbiceps* and possibly poenskop, *Cymatoceps nasutus* (own observations). This is by no means the rule as other forms of hermaphroditism have also been recorded in the Sparidae (Coetzee 1983).

The criteria listed by Moe (1969) for the successful ageing of fish using hard tissue have been satisfied in this study, showing that otoliths may be used to age *P. aeneum*. Comparing the results presented in Figure 8, there is a remarkable similarity between theoretical and observed growth, with no evidence of Lee's phenomenon. Frequently back-calculated lengths are smaller than the true average size at the age in question. Reasons for this, reviewed by Ricker (1969), include the use of incorrect body:otolith relationships in back calculations, biased sampling and selective mortality. Biased sampling and hence, selective fishing mortality were expected in this study because sport fishermen target for larger fish. Comparing the growth rates presented in Table 5.2 however, suggests otherwise. The estimated population growth rate (Gx) and individual growth rate (G) for each age group were very similar. According to Ricker (1975) these values would differ, G being higher than Gx, if size selective mortality occurred in the population. Further, Ricker (1969) postulates that only with considerable selective fishing mortality will the effects of Lee's phenomenon become apparent in a population.

The results show that selective mortality was not evident in the population and suggest that fishing pressure may not be heavy. The combination of late maturation together with protogynous hermaphroditism will however, make *P. aeneum* a candidate for rapid over-exploitation in a size-selective line fishery.

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