Age and growth of Diplodus sargus capensis and D. cervinus hottentotus (Sparidae) on the Tsitsikamma coast, South Africa.

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AGE AND GROWTH OF *DIPLODUS SARGUS CAPENSIS* AND *D. CERVINUS HOTTENTOTUS* (SPARIDAE) ON THE TSITSIKAMMA COAST, SOUTH AFRICA

by

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ABSTRACT. - The age and growth of *Diplodus sargus capensis* and *D. cervinus hottentotus*, sampled on the Tsitsikamma coast, was determined using sectioned sagittal otoliths. Both species were characterised by slow, allometric growth and in the sample were aged to a maximum age of 21 and 33 years respectively. While similar to many other sparid species, the growth rate estimated for *D. s. capensis* was considerably slower than that obtained in the Mediterranean. This discrepancy emphasises the need for more rigorous validation of ageing in sparid species. Management and conservation of these species is discussed in relation to their importance in the shore based recreational fishery in South Africa.

RÉSUMÉ. - Âge et croissance de *Diplodus sargus capensis* et de *D. cervinus hottentotus* (Sparidae) des côtes de Tsitsikamma, Afrique du Sud.

L'âge et la croissance de *Diplodus sargus capensis* et de *D. cervinus hottentotus* capturés près des côtes du parc national de Tsitsikamma ont été déterminés à partir de sections sagittales d'otolithes. Les deux espèces sont caractérisées par une croissance lente et allométrique, et les individus pêchés étaient âgés au maximum respectivement de 21 et 33 ans. Alors que cette espèce est semblable à de nombreuses espèces de Sparidae, la vitesse de croissance estimée pour *D. s. capensis* est considérablement plus lente que celle qui a été observée en Méditerranée. Cette différence met en évidence le besoin d'une validation plus rigoureuse de l'estimation de l'âge pour les espèces de Sparidae. La gestion et la conservation de ces espèces sont discutées en relation avec leur importance pour la pêche récréative en Afrique du Sud.

Key-words. - Sparidae, *Diplodus*, PSW, South Africa, Age, Growth, Otolithometry.

The blacktail, *Diplodus sargus capensis* and the zebra, *D. cervinus hottentotus* are two endemic sparid fishes found along the south-east coast of southern Africa. Both these species are abundant on inshore reef ecosystems and are consequently important to the South African recreational fishery, where they are caught along with several other sparid species, primarily by rock-and-surf anglers (Coetzee and Baird, 1981a; Joubert, 1981a; Clarke and Buxton, 1989; Coetzee *et al*., 1989; Bennett, 1991). Although they do not reach a particularly large size, both species are regarded as fine sport fish and are actively pursued by light-tackle angling enthusiasts (van der Elst, 1981; Schoemann and Schoemann, 1990).

Rock-and-surf angling is accessible to all members of the public and is an extremely popular pastime. Evidence of this popularity is shown by the approximately

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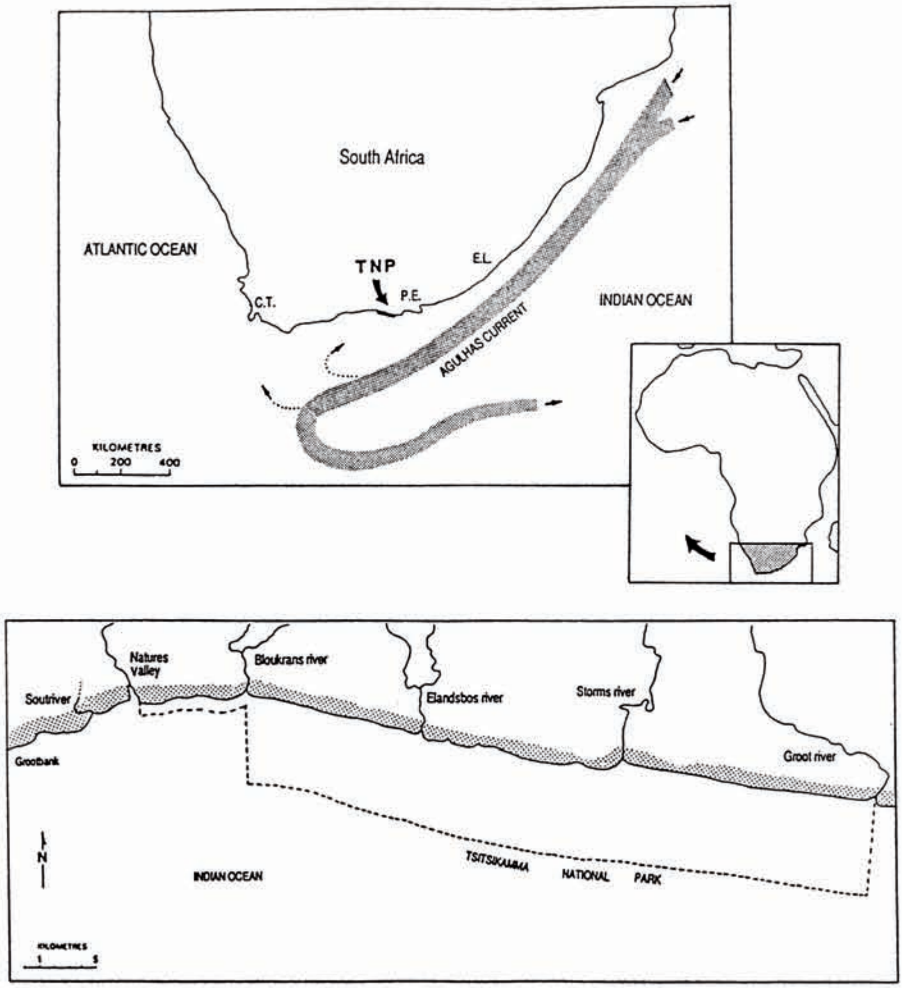

Fig. 1. - Position of the Tsitsikamma National Park on the Southern Cape coast, South Africa.

300 000 rock-and-surf anglers resident in South Africa (van der Elst, 1989) and the estimated annual growth rate of approximately six percent (van der Elst and Adkin, 1988). Steadily increasing pressure on our inshore fish resources has resulted in serial depletion of the major target species, an overall decline in catch rates and a change in the composition of catches, elasmobranchs now making up an increasingly larger proportion of the catch (Coetzee *et al.*, 1989; Clarke and Buxton, 1989; van der Elst, 1989; Bennett, 1991). This has led to a call for scientific research on which management of the resource can be based (van der Elst and Adkin, 1991).

Some research on aspects of the biology of both *Diplodus* species, particularly *D. s. capensis*, has been published (Christensen, 1978; Joubert, 1981b; Joubert and Hanekom, 1980; Coetzee, 1986; Mann and Buxton, 1992), but nothing is known about their age and growth in South African waters. The aim of this study was to estimate age using sectioned otoliths to provide information on important life history parameters such as longevity, growth rate and age at maturity. This information provides the biological basis for management of the fishery.

MATERIAL AND METHODS

Sampling was carried out between April 1989 and December 1990 in the Tsitsikamma National Park (TNP) and adjacent waters. The TNP is a large marine reserve situated on the south-east Cape coast of South Africa (Fig. 1), established in 1964. The area is closed to fishing except for a 2.7 km stretch of shoreline west of Storms River. Large fish were collected by spear and line-fishing, while juveniles (< 100 mm fork length) were collected from tidal rockpools and gullies using rotenone ichthyocide.

Each fish was measured (total, fork and standard lengths in mm), weighed (g) and sexed using visual criteria (Mann, 1992). A preliminary examination of scales from both species showed that although growth zones were distinguishable, they were difficult to enumerate, especially in old fish (cf. Beamish and McFarlane, 1987). Sagittal otoliths were therefore chosen for ageing and were removed from the otic capsules, cleaned, dried and stored in paper envelopes. Otolith width and length, to the nearest 0.1 mm, and otolith mass, to the nearest 0.001 g, were measured in order to determine the relationship between otolith growth and fish growth. Left otoliths were burned over a low intensity alcohol flame to enhance the optical clarity of the growth zones (Buxton and Clarke, 1986), embedded in clear casting resin and sectioned transversely through the nucleus using a twin-bladed, diamond edged saw. Sections were mounted on glass slides using DPX and examined under transmitted light using a low-power dissecting microscope. Growth zones consisted of a wide hyaline zones and narrow, darkly burnt opaque zones. The seasonality of zone deposition was determined by marginal zone analysis (Manooch, 1982). Annuli were independently counted by two readers on five occasions. Otoliths that had been badly sectioned or which were difficult to age (no consensus in age estimates) were rejected. A concurrent study by Lang and Buxton (1993) using oxytetracycline marking and daily increment analysis in *D. s. capensis* and *D. c. hottentotus*, validated the position of the first annulus. This avoided confusing the juvenile ring (apparent in some but not all otoliths) with the first annulus.

The von Bertalanffy growth model was chosen to represent observed length-at-age data for *D. s. capensis* and *D. c. hottentotus* as this model is generally regarded as the most suitable for expressing fish growth (Hughes, 1986). Parameter estimates were determined by iteration using the computer programme PC-YIELD (Hughes and Punt, 1988). A test of the residual differences between the data and the fitted curve revealed that the absolute-error model provided the best fit to age-at-length data for both species.

RESULTS

The morphometric relationships for *Diplodus sargus capensis* and *D. cervinus hottentotus* are summarised in table I.

Diplodus sargus capensis (Smith, 1844)

The linear relationship between otolith length and fork length and asymptotic relationship between otolith width and fish length showed that most of the growth in *D. s. capensis* otoliths occurred along the longitudinal axis. Otolith mass increased exponen-

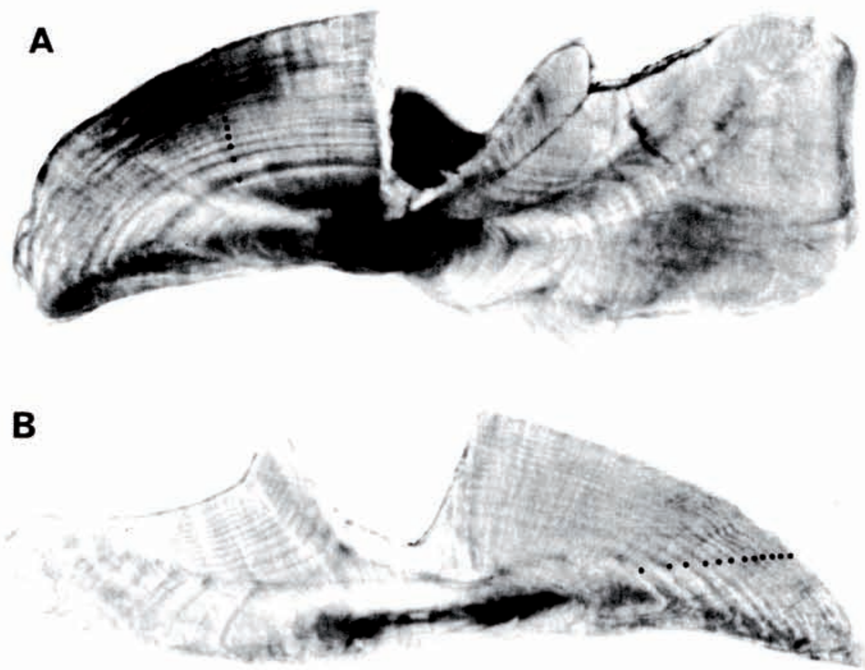

Fig. 2. - Photomicrographs of burnt and sectioned otoliths from (A) a 299 mm FL *Diplodus sargus capensis* aged at 14 years and (B) a 348 mm FL *Diplodus cervinus hottentotus* aged at 12 years (viewed under transmitted light at 13 x magnification).

Table I. - Morphometric relationships for *Diplodus sargus capensis* and *Diplodus cervinus hottentotus* sampled in the Tsitsikamma area between April 1989 and December 1990.

Species	Relationship	r^2	n
D. s. capensis	TL (mm) = 1.162601 FL (mm) + 2.553508	0.999	119
	SL (mm) = 0.890571 FL (mm) + 2.156629	0.999	119
	Total Mass (g) = 0.0000074 FL (mm) $^{3.242}$	0.999	382
D. c. hottentotus	TL (mm) = 1.160665 FL (mm) + 2.627736	0.999	107
	SL (mm) = 0.893806 FL (mm) + 2.551277	0.998	107
	Total Mass (g) = 0.0000127 FL (mm) $^{3.141}$	0.995	304
D. s. capensis	OL (mm) = 0.023691 FL (mm) + 1.58207	0.944	285
	OW (mm) = 0.114724 FL (mm) $^{0.628}$	0.902	185
	OM (g) = $e^{(-6.19742 + 0.01115 \text{ FL (mm)})}$	0.955	285
D. c. hottentotus	OL (mm) = 0.153755 FL (mm) $^{0.717}$	0.963	249
	OW (mm) = 0.113867 FL (mm) $^{0.658}$	0.838	184
	OM (g) = $e^{(-5.55233 + 0.00921 \text{ FL (mm)})}$	0.952	249

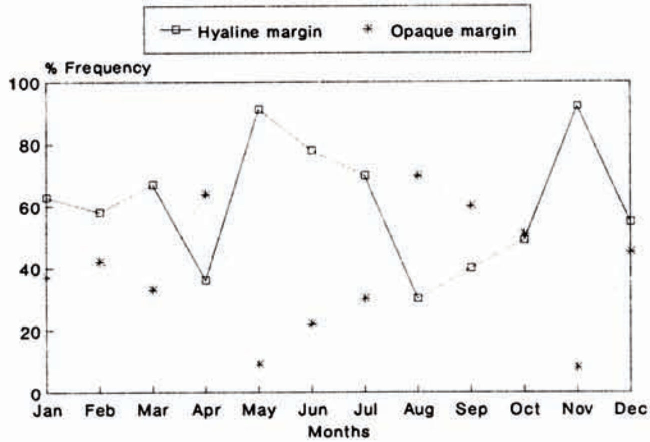

Fig. 3. - Temporal changes in the marginal zone of *Diplodus sargus capensis* sampled in the TNP from April 1989 to December 1990 (n = 270).

Table II. - Observed mean length-at-age (mm FL) and expected mean length-at-age (from the von Bertalanffy growth curve) for *Diplodus sargus capensis*.

Age	n	Males		n	Females		n	All fish	
		Obs.	Exp.		Obs.	Exp.		Obs.	Exp.
0	30	76	70	30	76	69	30	76	70
1	19	104	120	20	105	122	20	105	122
2	14	158	159	16	159	164	33	164	163
3	18	194	190	18	200	196	38	197	195
4	20	218	215	24	230	221	50	223	220
5	8	237	235	13	243	241	22	240	239
6	5	253	251	10	257	256	15	256	255
7	9	268	263	12	265	268	22	265	267
8	6	270	273	15	279	278	21	276	276
9	7	278	281	8	273	285	16	277	283
10	4	291	287	10	295	291	15	292	289
11	0	-	292	6	286	295	6	286	293
12	2	298	296	3	306	299	5	303	297
13	0	-	299	2	302	301	2	302	299
14	1	302	302	5	299	303	6	299	301
15	3	302	304	1	305	305	4	302	303
16	2	290	305	1	304	306	3	295	304
17	0	-	306	5	317	307	5	307	305
18	0	-	307	1	298	308	1	298	306
19	1	305	308	2	313	309	3	310	307
20	0	-	309	0	-	309	1	-	308
21	0	-	309	1	332	310	1	332	308

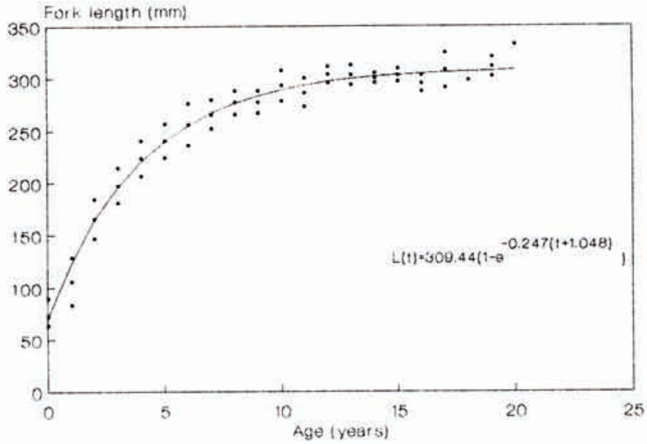

Fig. 4. - Fork length-age relationship in *Diplodus sargus capensis*, sampled in the TNP from April 1989 to December 1990 (n = 318).

tially with fish length, illustrating that otoliths became substantially thicker and heavier even after increase in fish length had tapered off. Stacking of growth zones towards the periphery of otoliths in larger fish made age determination more difficult. This is clearly illustrated in an example of a sectioned otolith from a 14 year old *D. s. capensis* in figure 2A.

A total of 337 otoliths were sectioned of which 19 (5.6%) were rejected as unreadable. The monthly frequency of occurrence of opaque and hyaline zones on the otolith margin did not provide a clear indication that these zones were deposited annually (Fig. 3). Opaque margins predominated during spring (August to October) coinciding with peak spawning in *D. s. capensis* (Mann, 1992). Hyaline growth predominated for the rest of the year (November to July) except for a peak in opaque growth recorded during April. This apparent second peak in opaque growth was the result of some annuli being split into two distinct rings near the sulcal region (cf Gauldie, 1990) which complicated

Table III. - Test of significant difference (t) between the observed mean length-at-age of male and female *Diplodus sargus capensis* (P = 0.05, * denotes a significant difference).

Age	Males FL (mm) ± SD	n	Females FL (mm) ± SD	n	d.f.	t
2	158 ± 18.61	14	159 ± 20.17	16	28	0.1667
3	194 ± 12.99	18	200 ± 17.80	18	34	1.2297
4	218 ± 18.18	20	230 ± 13.71	24	42	2.4246*
5	237 ± 15.23	8	243 ± 17.61	13	19	0.7604
6	253 ± 11.80	5	257 ± 23.25	10	13	0.3396
7	268 ± 10.40	9	265 ± 15.85	12	19	- 0.4285
8	270 ± 7.99	6	279 ± 11.71	15	19	1.7992
9	278 ± 6.73	7	273 ± 11.59	8	13	- 1.0687
10	291 ± 22.55	4	295 ± 9.39	10	12	0.4984
12	298 ± 7.07	2	306 ± 6.66	3	3	1.3964

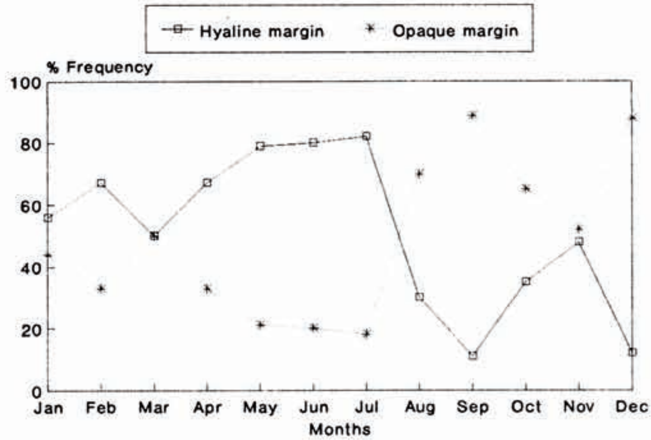

Fig. 5. - Temporal changes in the marginal zone of *Diplodus cervinus hottentotus* sampled in the TNP from April 1989 to December 1990 (n = 235).

determination of the marginal zone (see Fig. 2A). For this reason annuli were counted away from the sulcal region where split opaque zones fused into one. Validation of the first annual zone in a concurrent study by Lang and Buxton (1993) using an oxytetracycline marker and daily increment analysis, showed that only one opaque and one hyaline zone were deposited annually in juvenile *D. s. capensis*.

Observed and expected mean length-at-age for each sex is summarised in table II. No significant differences between males and females were observed, except for age 4 where the mean length of males (218 mm FL) was significantly lower than the mean length of females (230 mm FL) (Table III). The growth index ($w = L_\infty.K$), proposed by Gallucci and Quinn (1979) showed that growth was similar in males (71.7) and females (77.2). The von Bertalanffy growth curve for the entire data set is shown in figure 4. Based on length at 50% maturity for both sexes (Mann, 1992), *D. s. capensis*, which was shown to be a partial protandrous hermaphrodite, mature at 211 mm FL equivalent to an age of approximately 3 years.

Diplodus cervinus hottentotus (Smith, 1844)

With the exception that otolith growth in length and width were proportional to fish length, all other aspects of otolith growth were similar to that found for *D. s. capensis* (Table I).

A total of 292 otoliths were read of which 11 (3.8%) were rejected. An example of a sectioned otolith from a 12 year old *D. c. hottentotus* is shown in figure 2B. The monthly percentage of opaque and hyaline zones on the otolith margin indicated the probability that one opaque and one hyaline zone were deposited annually (Fig. 5). The opaque zone, deposited during August to December, coincided with the spawning season (Mann, 1992). The hyaline zone was deposited between January and July. Annual periodicity of zone formation was further validated by Lang and Buxton (1993) in juvenile *D. c. hottentotus*.

Mean length-at-age data are summarized in table IV. No significant differences between the observed mean length-at-age data for males and females was observed (Table V). Despite this, the presence of older males in the sample suggested a greater

Table IV. - Observed mean length-at-age (mm FL) and expected mean length-at-age (from the von Bertalanffy growth curve) for *Diplodus cervinus hottentotus*.

Age	n	Males		n	Females		n	All fish	
		Obs.	Exp.		Obs.	Exp.		Obs.	Exp.
0	6	77	98	6	77	91	6	77	106
1	25	134	138	25	127	138	25	134	146
2	23	175	173	34	182	178	39	185	180
3	24	217	204	35	216	211	53	219	209
4	7	248	230	17	243	238	24	245	235
5	6	254	253	12	263	261	18	260	257
6	3	251	273	10	273	280	13	268	276
7	8	283	291	3	266	295	11	278	292
8	3	319	306	1	265	308	4	306	306
9	7	311	319	5	292	319	12	303	318
10	2	328	331	3	319	328	5	323	329
11	4	334	341	4	320	335	8	327	338
12	3	335	350	3	336	341	6	335	346
13	4	343	357	2	334	346	6	340	353
14	3	347	364	1	400	351	4	360	359
15	4	359	370	7	358	354	11	358	364
16	5	375	375	3	381	357	8	377	368
17	3	359	379	3	337	359	6	348	372
18	3	375	383	3	357	361	6	366	375
19	1	372	387	2	371	363	3	371	378
20	2	396	389	1	387	364	3	393	381
21	1	417	392	0	-	366	1	417	383
22	0	-	394	1	400	366	1	400	385
23	1	414	396	0	-	367	1	414	386
24	0	-	398	0	-	368	0	-	388
25	1	420	399	0	-	368	1	420	389
26	1	401	401	0	-	369	1	401	390
27	1	392	402	0	-	369	1	392	391
28	0	-	403	0	-	370	0	-	391
29	0	-	403	0	-	370	0	-	392
30	1	440	404	1	426	370	2	433	393
31	1	450	405	0	-	371	1	450	393
32	0	-	405	0	-	371	0	-	394
33	1	480	406	0	-	371	1	480	394

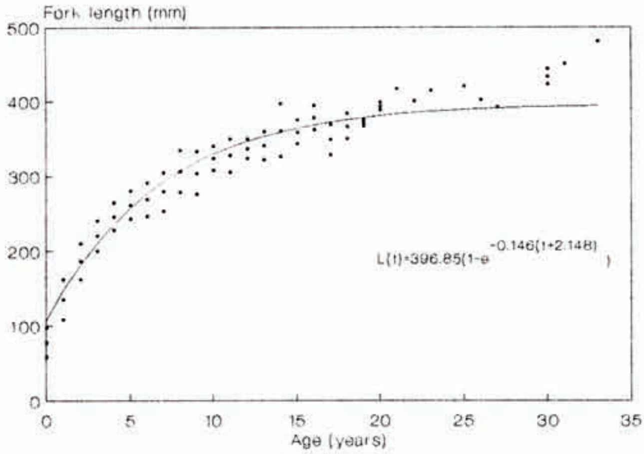

Fig. 6. - Fork length-age relationship in *Diplodus cervinus hottentotus*, sampled in the TNP from April 1989 to December 1990 (n = 281).

longevity in males. This was supported by the fact that the growth index (w) was lower in males (56.5) than in females (69.5), a reflection of slower growth rate in the former.

The von Bertalanffy growth curve for the total data set is presented in figure 6. The low L_∞ calculated for *D. c. hottentotus* (396 mm FL) in comparison with the observed maximum length (480 mm FL) can be attributed to the small sample of large fish combined with the rejection of some large otoliths due to reading difficulties. Based on the length at 50% maturity for both sexes (Mann, 1992), *D. c. hottentotus*, which was shown

Table V. - Test of significant difference (t) between the observed mean length-at-age of male and female *Diplodus cervinus hottentotus* (P = 0.05).

Age	Males FL (mm) ± SD	n	Females FL (mm) ± SD	n	d.f.	t
2	175 ± 23.29	23	182 ± 23.87	34	55	1.1125
3	217 ± 21.63	24	216 ± 22.15	35	57	- 0.1613
4	248 ± 19.65	7	243 ± 19.08	17	22	- 0.4903
5	254 ± 9.05	6	263 ± 21.28	12	16	1.0441
6	251 ± 16.77	3	273 ± 21.84	10	11	1.5881
7	283 ± 29.04	8	266 ± 4.00	3	9	- 0.9920
9	311 ± 25.25	7	292 ± 32.21	5	10	- 1.1091
10	328 ± 23.33	2	319 ± 13.20	3	3	- 0.5819
11	334 ± 26.81	4	320 ± 16.23	4	6	- 0.9253
12	335 ± 17.56	3	336 ± 11.;4	3	4	0.0277
13	343 ± 17.15	4	334 ± 28.99	2	4	- 0.4868
15	359 ± 22.43	4	358 ± 13.94	7	9	- 0.0859
16	375 ± 19.93	5	381 ± 3.51	3	6	0.5065
17	359 ± 19.60	3	337 ± 17.21	3	4	- 1.4605
18	375 ± 14.01	3	357 ± 17.79	3	4	- 1.3514

to be a rudimentary hermaphrodite, mature at 280 mm FL equivalent to an age of approximately 6 years.

DISCUSSION

The von Bertalanffy parameter estimates derived for both *D. s. capensis* and *D. c. hottentotus* showed that they were relatively slow growing, long lived species both capable of reaching ages in excess of 20 years. In *D. s. capensis* a maximum age of 21 years was recorded for a fish measuring 332 mm FL. Growth was considerably slower than that estimated for *D. s. sargus* in the Mediterranean, which reaches a maximum age of between 8 and 14 years (Man-Wai and Quignard, 1983; Wassef, 1985). Growth in *D. c. hottentotus* was also slow with a maximum recorded age of 33 years for a fish of 480 mm FL. Slow growth is not unusual in sparids (see Buxton, 1993 for review), the maxima recorded in this study falling well within the range described in the literature.

Of fundamental importance to an age and growth study of this nature, however, is the validation of the annual periodicity of growth zones (Pannella, 1974; Beamish and McFarlane, 1983). Validation most commonly involves the use of indirect methods that help to corroborate the interpretation, rather than to provide an absolute validation (Beamish and McFarlane, 1983). These methods typically include cohort analysis or marginal zone analysis (Manooch, 1982). Even though growth zones were clearly visible in the otoliths, marginal zone analysis in this study provided only weak support for the assumption that one hyaline and one opaque zone was deposited each year. A possible explanation for this may be the relatively long spawning season in both species which could spread the formation of the opaque zone. This would be compounded if spawning was asynchronous or if multiple spawnings took place. On the other hand, direct support for the assumption that the zones were annuli was provided by direct validation using oxytetracycline labelling and daily increment analysis in a concurrent study by Lang and Buxton (1993). They showed that the first hyaline and opaque zones in juvenile *D. s. capensis* and *D. c. hottentotus* (< 2 years old) were representative of one year growth. Furthermore, other studies on South African sparids all demonstrated one growth zone (hyaline and opaque) per year (Nepgen, 1977; Hecht and Baird, 1977; Coetzee and Baird, 1981b; Buxton and Clarke 1986, 1989, 1991, 1992; Pulfrich and Griffiths, 1988; Smale and Punt, 1990; Garratt *et al.*, 1993; Bennett, 1993; Buxton, 1993). It is important to caution, however, that few of these studies provided direct validation of age estimates and the work by Lang and Buxton (1993) focused on juvenile fish. This points to the need for a more detailed investigation into the depositional structure of the otoliths of these species (cf. Lang, 1992), and direct validation of ageing using otolith markers such as oxytetracycline in older fish (Brothers, 1990).

Water temperature is also an important consideration with regard to fish growth (Campana and Neilson, 1985). The TNP experiences a mean monthly sea surface temperature of between 14 and 20°C (Hanekom *et al.*, 1989). Furthermore, the area is subjected to periodic cold upwellings, particularly during the summer months following periods of strong easterly winds (Schumann *et al.*, 1982; Hanekom *et al.*, 1989). It is suggested that the impact of cold upwellings on fish growth may result in the deposition of check rings in fish otoliths which could further complicate age estimation (Campana and Neilson, 1985). Nevertheless, with the cooler water temperatures experienced along the Cape coast, it is likely that growth of both *D. s. capensis* and *D. c. hottentotus* is considerably slower than on the east coast, which is subjected to the warming influence of the Aghulas Current and a sea surface temperature range of between 21 and 27°C (van der Elst, 1981).

Implications for management

Slow growth results in a lower yield-per-unit stock, late age at maturity and a slower recovery rate after over-exploitation than in fast growing species (Buxton and Clarke, 1989). Slow growing fish, such as both *Diplodus* species, are therefore extremely susceptible to overfishing. With the present increase in angler numbers and the decrease in catch per unit effort in the South African recreational shore fishery (van der Elst, 1989), more stringent management regulations (e.g. increased minimum size limits and reduced bag limits) may be necessary to ensure adequate conservation of both species (see Attwood and Bennett, 1995). Tag and recapture results from the Segdewick-ORI Tagging Programme and visual assessments (Mann, 1992) suggest that both species are fairly resident on inshore reefs. Based on this information and because of their observed high relative abundance in De Hoop (Bennett and Attwood, 1991) and the TNP (Mann, 1992), marine reserves are considered to be one of the most valuable management options for the conservation of these and other resident linefish species (Buxton and Smale, 1989; Bennett and Attwood, 1993). In this respect, marine reserves provide both protection for the spawner stock as well as providing the potential to seed adjacent areas.

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