ASPECTS OF THE BIOLOGY OF THE MUSSELCRACKER, *SPARODON DURBANENSIS*, AND THE BRONZE BREAM, *PACHYMETOPON GRANDE*, (PISCES : SPARIDAE), WITH NOTES ON THE EASTERN CAPE RECREATIONAL ROCK-ANGLING AND SPEAR FISHERIES

Thesis

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BY

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ABSTRACT

The musselcracker, Sparodon durbanensis, and the bronze bream, Pachymetopon grande, are important components of rock-angling and spearfishing catches in the Eastern Cape. Aspects of their biology, including age and growth, reproduction, nursery areas and feeding, were investigated to provide a basis for the rational exploitation of the resource.

Both species are slow-growing and long-lived. Growth in S. durbanensis was described by the von Bertalanffy growth equation:

$$Lt(mm) = 1021.2\left(1-e^{-0.0900(t-0.709)}\right).$$

The von Bertalanffy growth model did not describe the total data set in P. grande, but by excluding the zero and one year old fish the data were described by:

$$Lt(mm) = 461.1\left(1-e^{-0.153(t+1.640)}\right).$$

Detailed histological examination of gonadal development showed that S. durbanensis and P. grande are rudimentary hermaphrodites. Both species had restricted breeding seasons which coincided with peak exploitation. Results indicated that both species are group spawners with pelagic eggs. Size at 50% maturity in S. durbanensis and P. grande was determined at 350 and 300mm fork length, respectively, corresponding to ages of 4.5 and 5.5 years. Intertidal pools functioned as nursery areas for S. durbanensis during the first year, whereas subtidal waters were more important for larger juveniles. P. grande juveniles were commonly observed on subtidal weed beds to a depth of 10m.

A size-related change in the diet of S. durbanensis was observed. The juveniles were omnivorous, feeding predominantly on gastropods, echinoids and chlorophytes. The adults fed on a variety of large, reef-associated invertebrates. P. grande were omnivorous, with macroalgae being the principal dietary component. This species appears to utilise the storage and extracellular carbohydrates of the macroalgae. Results showed that macroalgal degradation by gut endosymbionts and the utilisation of macroalgal epibionts does not appear to occur in this species.

A detailed analysis of catch composition and catch per unit of effort in the Port Elizabeth rock-angling fishery and the Eastern Cape spearfishery emphasised the recreational importance of S. durbanensis and P. grande. The localised distribution, slow growth and late maturation in both species results in their being susceptible to over-exploitation in these size-selective fisheries. Current legislation protecting these fish is discussed in relation to the findings of this study and additional management measures are proposed.

CHAPTER 1 - INTRODUCTION

The musselcracker, Sparodon durbanensis (Castelnau 1861), and the bronze bream, Pachymetopon grande (Günther 1859)(Pisces : Sparidae) are important species in the South African recreational fishery, but are not sufficiently abundant to be of commercial significance (Smith & Heemstra 1986). Both species have relatively localised distributions. S. durbanensis is endemic to South Africa, occurring in coastal waters from the Western Cape to Natal. P. grande is found over shallow reefs from the Southern Cape to Madagascar (van der Elst 1981; Smith & Heemstra 1986).

Although recreational fisheries do not usually produce direct financial benefits comparable with those of commercial fisheries, their economic implications can be significant. A study of the Eastern Cape ski-boat fishery (Smale & Buxton 1985) showed that although the value of the catch was relatively low (R270 000), high capital investment (R17 million) and annual running costs (R1.65 million) were involved. By comparison, the economic value of the freshwater fishery in the Transvaal, excluding the trout fishery, was estimated at an annual expenditure of R32 million with a capital investment of R130 million. The annual landed mass of the catch was estimated at 9 650kg (Cadieux 1980). Similar trends have been observed internationally. For example, a study of the value of anadromous salmonid fisheries in two rivers in Oregon (USA) showed that although the recreational catch (25 000 fish) accounted for only 31% of the total catch its economic value ($3.3 million) was 5.96 times that of the commercial fishery ($0.594 million)(Everest 1979). Similarly, the Florida (USA) marine sport fishery is valued at $200 million whereas the commercial fishery is valued at $39 million and in California it has been estimated that expenditure by sport anglers exceeded the market value of their catch by a factor of 5.5 (van der Elst 1976a). These studies clearly show that the economic value of recreational fisheries does not lie in the landed value of the catch but in the related industries they support. These include the tourist trade as well as the manufacturers and distributors of bait, fishing tackle, vehicles and outdoor and boating equipment.

The importance of recreational fisheries must not only be viewed in terms of their direct and indirect effects on the economy. Also important are the recreational benefits associated with sport fishing. These benefits, in terms of their psychological or sociological importance, are almost impossible to evaluate because of differences in culture, social standing, income and motivation (relaxation, competition, etc.) amongst resource users (Stevenson & Nixon 1976). An indication of the recreational value may be obtained from the popularity of the activity. During the 1977-1978 angling season 117 093 licensed anglers spent an estimated 3.14 million man days fishing in the Transvaal's dams and rivers (Cadieux 1980). Van der Elst (1976a) estimated that 250 000 people enjoy marine sport fishing as a recreational pursuit in South Africa. Of these, an estimated 60 000 operate in Natal with the relatively small ski-boat sector fishing during an estimated 2.6 million hours per year.

The continuing trend of increasing human population size in South Africa will result in increasing numbers of sport fishermen. This may be compounded by the general increase in the demand for outdoor recreation, associated with increased personal affluence and leisure time in developed nations (Berger & Berger 1972; Gerdes, Ochse, Stander & van Ede 1981). An annual growth of 6.5% is expected in the number of marine sport fishermen in South Africa (van der Elst 1986). Many of the species which are of recreational importance are also exploited by commercial fisheries. An increasing human population will result in an increased demand for protein and therefore increased pressure on fish resources by the commercial sector.

Much of the South African continental shelf is narrow, usually not extending more than 15 nautical miles offshore. Many of the more popular linefish species are associated with the relatively shallow reefs on the continental shelf. In addition, many of these species are endemic to Southern Africa. These factors contribute to limited fish resources which in some cases (van der Elst 1976b; Smale 1985; Garratt 1986a; Buxton 1987) have already shown significant declines in abundance and mean size.

In 1977 the Executive Committee of the South African National Committee for Oceanographic Research recognised the urgent need for information to manage the South African commercial and recreational linefish resource. The increasing pressures on the resource by commercial fishing, recreational angling, spearfishing and environmental degradation were identified and the Marine Linefish Research Programme was initiated to develop a scientifically-based management strategy for the resource (Anon. 1979). In 1982 the first marine linefish workshop was held where the need for research on S. durbanensis and P. grande was recognised. These were categorised as top and medium priority species, respectively, in terms of their research requirements (Wallace & van der Elst 1983).

Prior to this study detailed information on the biology of these two species was limited. Brownell (1979) described the early development of S. durbanensis. Beckley (in press) analysed the length composition and diet of juvenile S. durbanensis sampled from intertidal pools in the Port Elizabeth area.

In this study the biology of the two species as well as aspects of the recreational fisheries in the

Eastern Cape were examined. Study areas and data collection are discussed in Chapter 2. Age and growth in the two species is described in detail in Chapter 3. Chapter 4 deals with aspects of their reproductive biology including size at sexual maturity, reproductive seasonality, sex ratio and nursery areas. Oogenesis and spermatogenesis are described and spawning behaviour is discussed. Feeding in the two species is discussed in Chapter 5. Catch composition and catch per unit of effort (CPUE) in the Port Elizabeth rock angling fishery and the Eastern Cape competitive spearfishery are presented in Chapter 6.

The study concludes with a summary of those life history characteristics of the two species which are considered to be important with respect to management of the resource. Current conservation legislation is discussed and additional measures are proposed.

CHAPTER 2 - STUDY AREAS

The study area extended from Knysna to East London (Figure 1). The topography of this coastline is highly variable but a general description of the area is provided below (Hydrographer S.A. Navy 1985).

The coastline between Knysna and Cape Seal consists mainly of high rocky cliffs interspersed with a few sandy bays. North-west of Cape Seal the coast curves to the north and east to form the head of Plettenberg Bay. The first 12km NNE of Cape Seal is generally sandy. Thereafter the coast extends for approximately 133km in an easterly direction to Cape St Francis. The first half of this stretch, the Tsitsikamma coastline, consists mainly of high sandstone cliffs intersected by deep ravines at the mouths of numerous rivers. The shore of the eastern half of Plettenberg Bay is generally rocky with several off-shore reefs and occasional small sandy bays. St Francis Bay is mainly sandy with a rocky coastline to the west of Cape Recife. The shores of Algoa Bay are generally sandy with rocky ledges at Woody Cape and Cape Padrone. Bird Island, approximately 8.5km SSW of Woody Cape, is a low, 19 hectare island fringed by rocky ledges. In the vicinity of Bird Island there are two smaller islands as well as several areas of high relief reef. The area from Cape Padrone to Great Fish Point consists of rocky outcrops alternating with sandy beaches. The coastline between Great Fish Point and East London is mostly sandy with occasional rocky outcrops.

Diving observations showed that S. durbanensis and P. grande were most frequently observed over inshore (<20m) reefs. From the description of the coast it is clear that the area between Knysna and East London consists of large areas of sand. Even in areas with predominantly rocky coastlines, such as the Tsitsikamma Coastal National Park and the area west of Cape Recife, inshore reefs may be interspersed with large tracts of sand. The distribution of S. durbanensis and P. grande is therefore patchy, due to the variable distribution of shallow-water reefs.

Biological information on S. durbanensis and P. grande was collected from the catches of rock-anglers and spearfishermen operating between Knysna and East London, from August 1984 to March 1987. By monitoring spearfishing competitions large numbers of these relatively uncommon fish were sampled. Data collection from spearfishing competitions was sporadic and, as a result of competition rules, fish were generally larger than the minimum mass of 1kg. Other sampling techniques provided lower sample numbers but were valuable in that they provided regular (monthly) samples. In recreational fisheries the quality of the catch (size of individual fish) is generally more important than the quantity (total bag) resulting in an

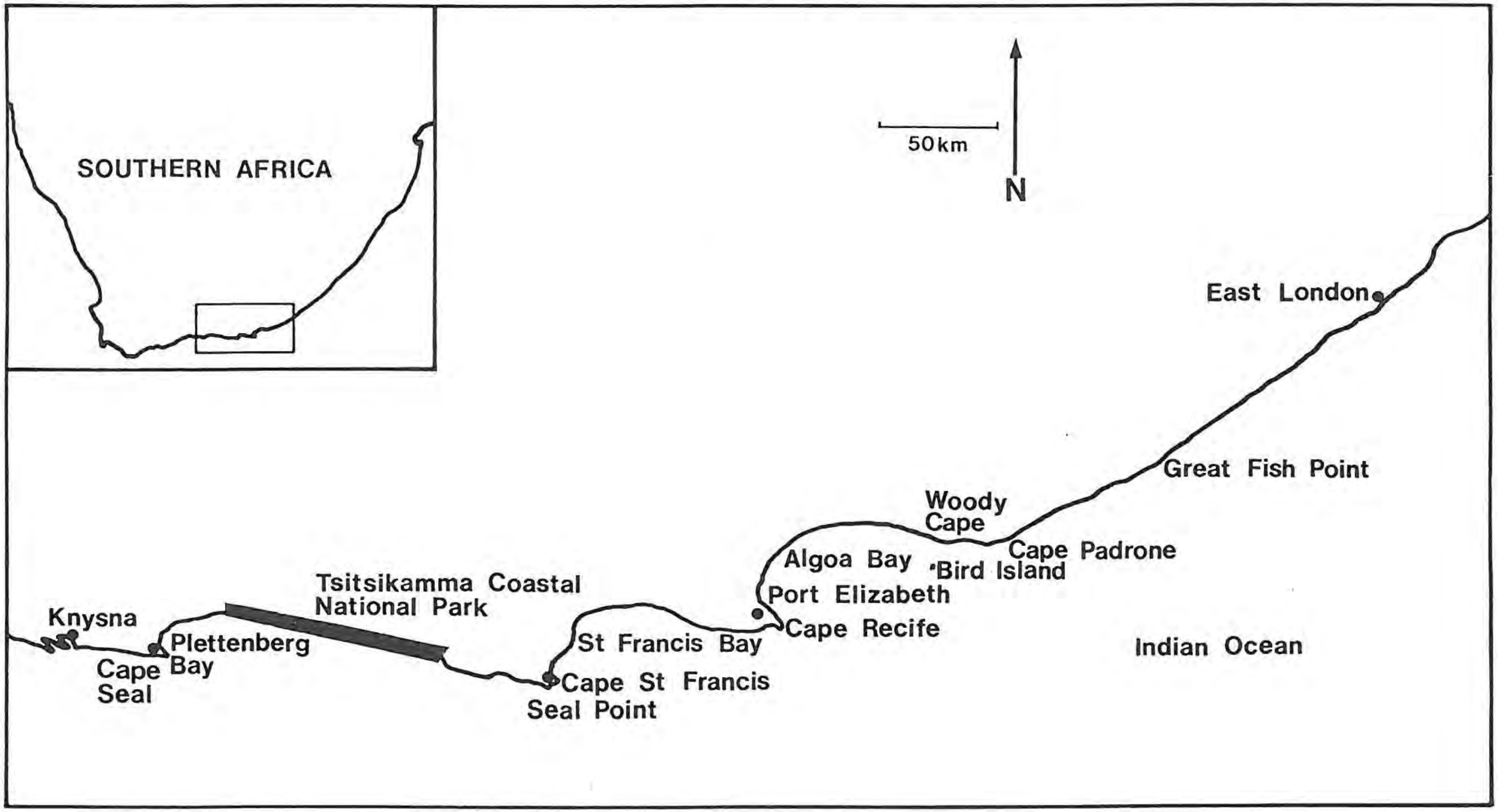


Figure 1. Map of the study area showing the places mentioned in the text.

over-representation of large fish in the catch. To obtain fish in the size classes not represented in the recreational catches, specimens were speared by research divers using SCUBA. This type of sampling was limited to inshore reefs (<20m) in the Tsitsikamma Coastal National Park and off the rocky coastline west of Port Elizabeth. Juvenile S. durbanensis were also collected by rotenone sampling in shallow (<2m) subtidal waters between Lookout Point and Schoenmakerskop (Figure 2). The numerical contribution of the different areas to the total sample of S. durbanensis and P. grande is presented in Figures 3a & b, respectively. The numerical contribution of the different sampling techniques to the total sample of S. durbanensis and P. grande is presented in Figures 4a & b, respectively.

Sampling was most intensive in the Port Elizabeth area (Figure 2). The area between Schoenmakerskop and Cape Recife is characterised by jagged rocks of quartzitic sandstone, with numerous pools and gullies. Within Algoa Bay, from Cape Recife to Flat Rocks, there is a gently sloping rock platform of calcareous sandstone (Beckley 1985a). Researchers regularly speared fish from three reefs off the rocky coastline west of Cape Recife. The Patie, a wreck located inshore of Thunderbolt Reef, lies on flat reef in 9m of water. The reef is mainly covered by the rhodophyte, Plocamium corallorhiza. Suicide Reef, located approximately 0.5km offshore, is a high relief reef, reaching the surface from a depth of approximately 15m. Pyura stolonifera (red bait) dominated the reef crests whereas rhodophytes were commonly found on the flat reefs and boulder beds between the areas of high relief reef. The dive site off Schoenmakerskop consisted largely of flat reef and boulder beds interspersed with sand, at a depth of approximately 12m. The reefs were dominated by macroalgae.

The sample from the Tsitsikamma Coastal National Park was obtained exclusively by researchers spearfishing with SCUBA on three inshore reefs in the vicinity of Storms River mouth (Figure 5). The subtidal topography in this region comprises a series of parallel sandstone reefs separated by sand filled valleys (Buxton & Smale 1984). The Knoll is a prominent reef, in about 10m of water, which breaks the surface at low tide. Waterfall Reef is a high relief reef located at a depth of approximately 15m. These reefs were similar to Suicide Reef in terms of macroscopic appearance and encrusting benthic organisms. Rheeders' Knoll is found in slightly deeper water. Macroalgae were uncommon but echinoderms and filter feeders were abundant.

The large sample of both species obtained at Cape St Francis, Bird Island and Knysna resulted from the monitoring of spearfishing competitions held in these areas.

Detailed descriptions of the sampling procedures and the processing of the various samples are provided in the appropriate chapters. The various sampling techniques were all selective in

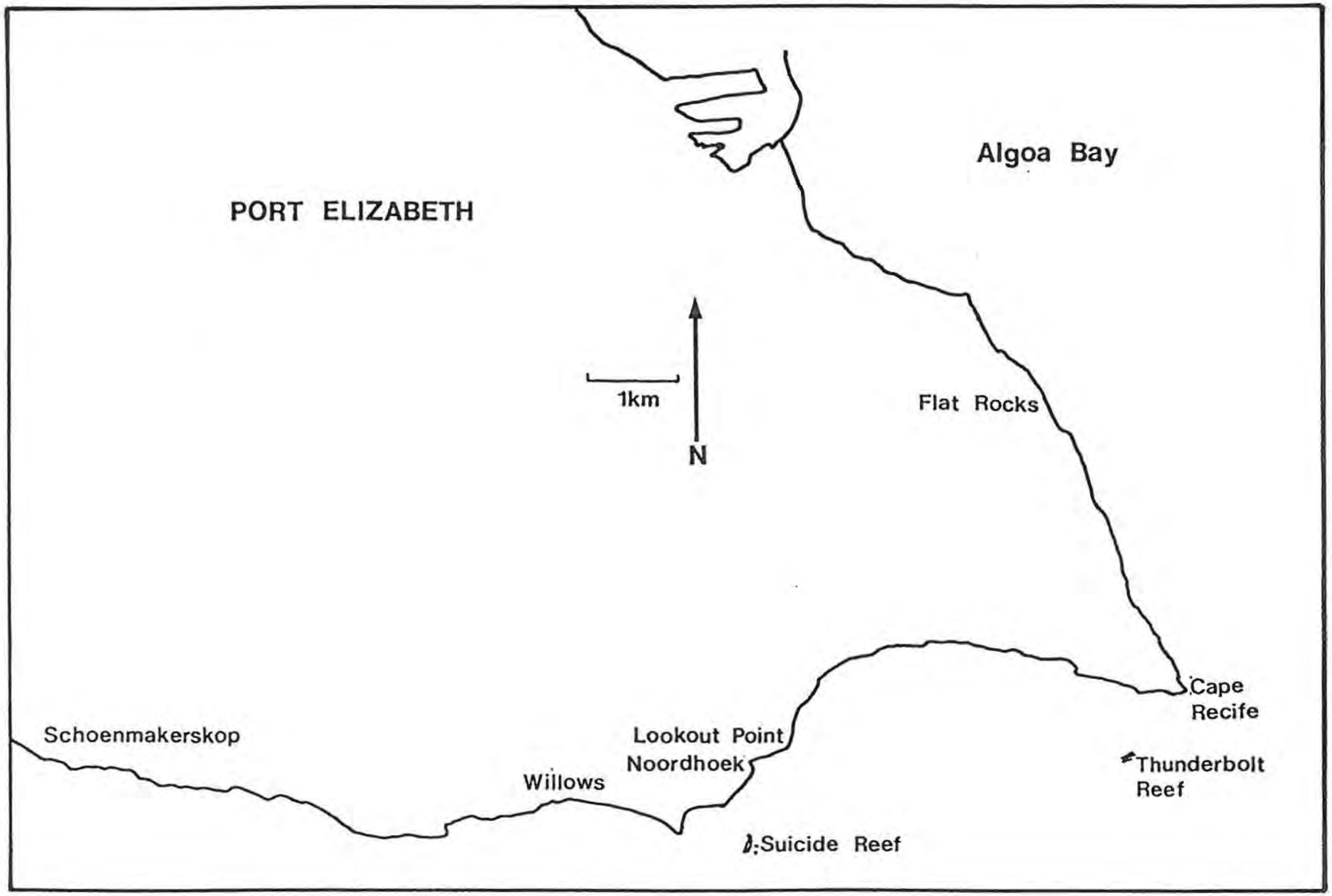


Figure 2. Map showing sampling sites in the Port Elizabeth area.

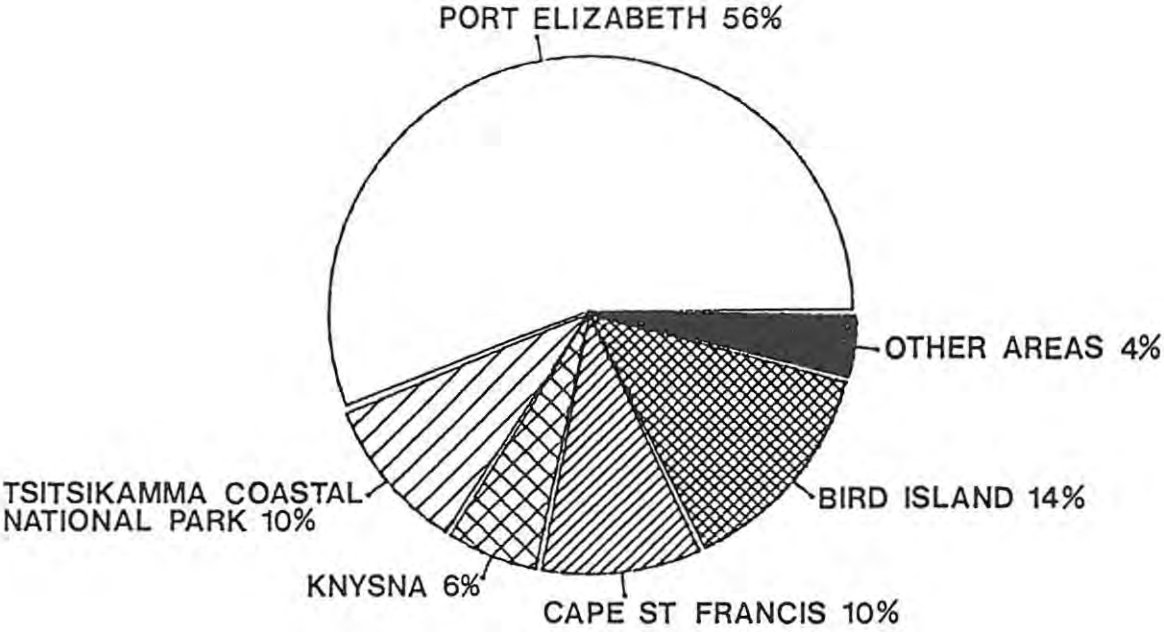


Figure 3a. The numerical contribution of the different areas to the total sample of Sparodon durbanensis collected between Knysna and East London from August 1984 to March 1987 (n = 344).

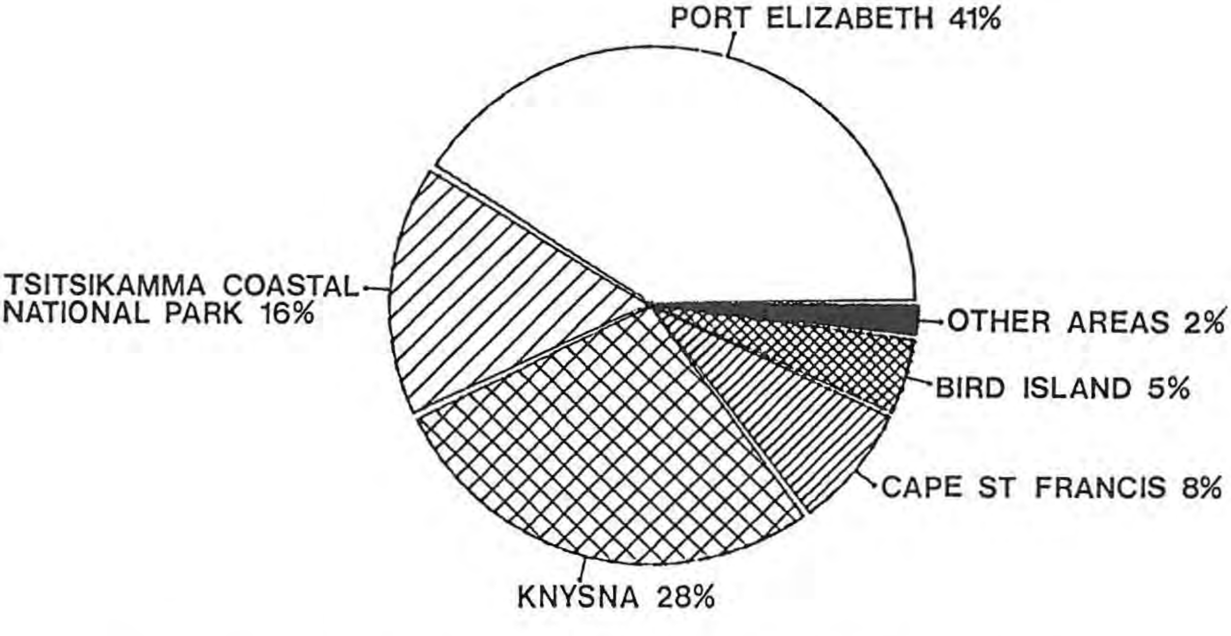


Figure 3b. The numerical contribution of the different areas to the total sample of Pachymetopon grande collected between Knysna and East London from August 1984 to March 1987 (n = 690).

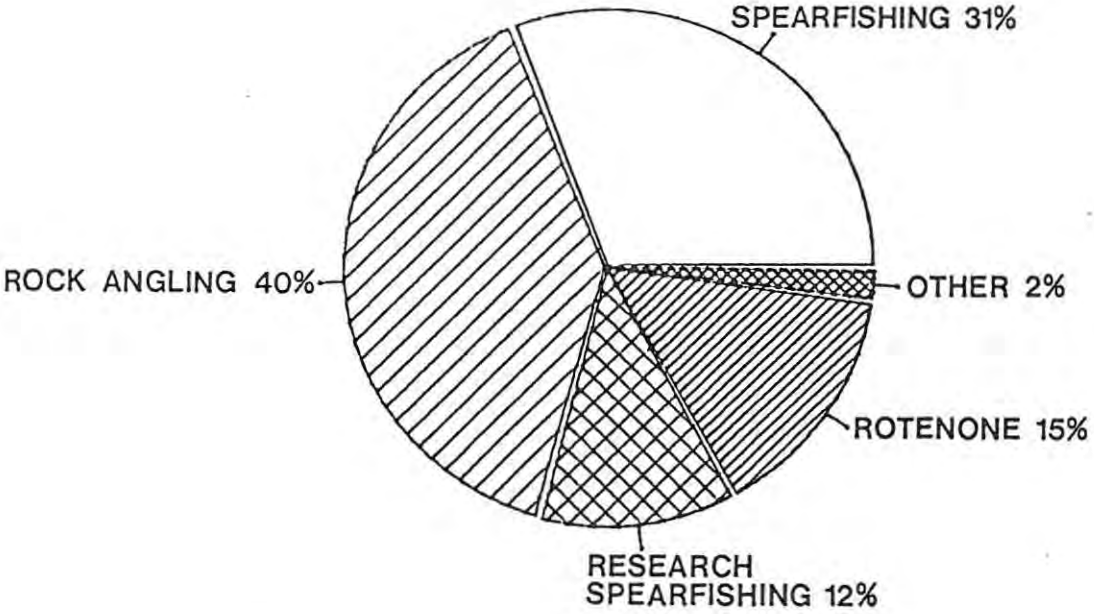


Figure 4a. The numerical contribution of the different sampling techniques to the total sample of Sparodon durbanensis collected between Knysna and East London from August 1984 to March 1987 (n = 344).

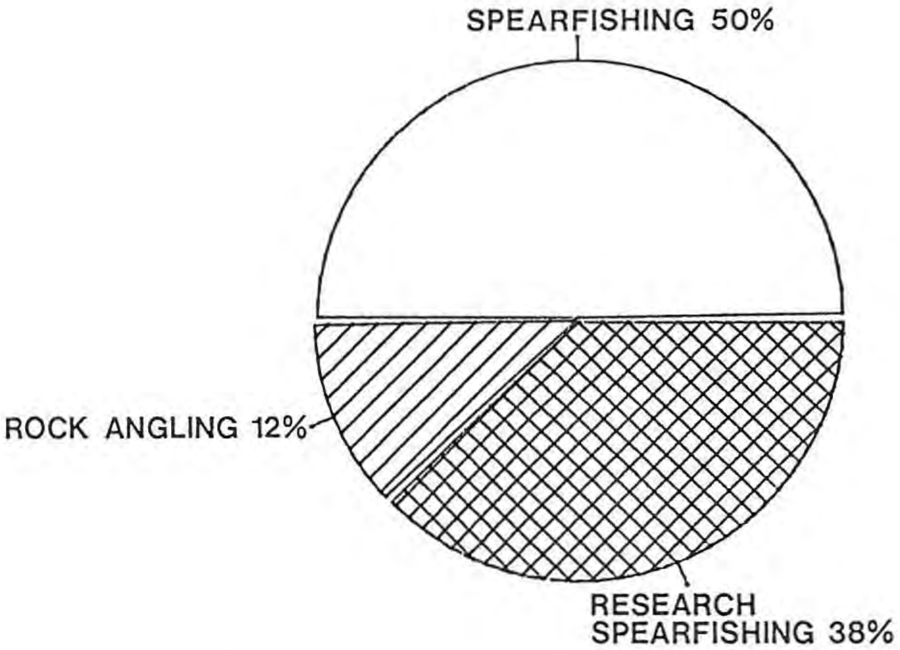


Figure 4b. The numerical contribution of the different sampling techniques to the total sample of Pachymetopon grande collected between Knysna and East London from August 1984 and March 1987 (n = 690).

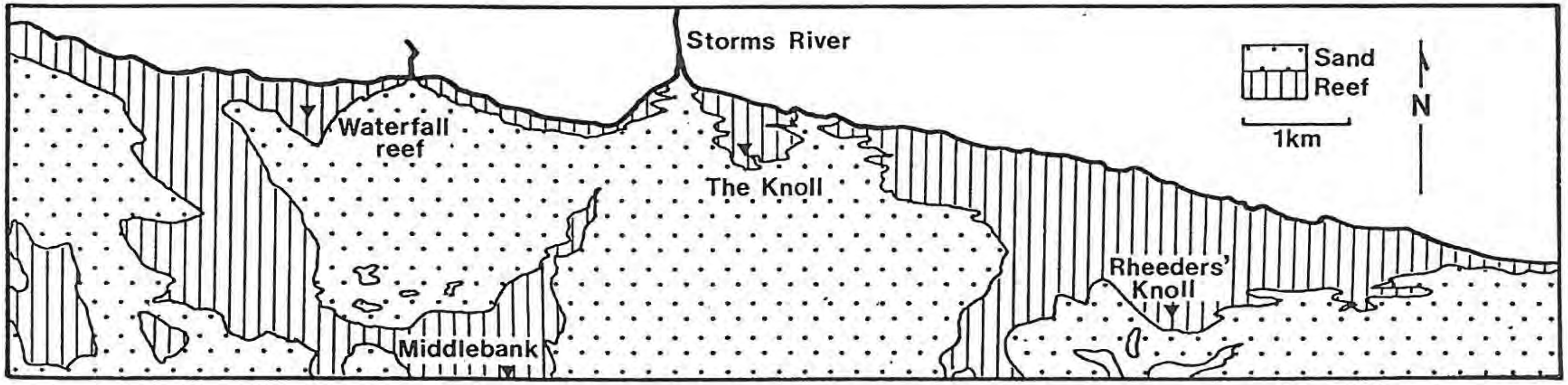


Figure 5. Map showing sampling sites in the Tsitsikamma Coastal National Park (after Buxton 1987).

terms of the length composition of catches. The selectivity of the gear precluded estimates of population structure (Ricker 1975) and consequently no attempt was made to compare the length composition of S. durbanensis and P. grande sampled from the different areas.

CHAPTER 3 - AGE AND GROWTH

INTRODUCTION

The use of mineralised tissues to determine the age of fish accurately is one of the most useful features in fish biology and fisheries science (Bagenal 1974). As early as 1759 Hederström (in Ricker 1975) proposed that vertebral ring counts reflected accurate age and growth assessment of pike (Esox lucius) and several other species. Growth zones in other hard tissues including scales, operculae, teeth, fin rays, otoliths, metapterygoids and cleithra have subsequently been intensely investigated in age and growth assessments of pike (Casselman 1974). Carlton & Jackson (1968) showed that eye lens masses could also be used to determine age in carp (Cyprinus carpio).

Several age and growth studies of South African sparids have been published. In all cases growth zones in whole otoliths were used for ageing (Nepgen 1977; Hecht & Baird 1977; Coetzee & Baird 1981a; Buxton & Clarke 1986). In this study numerous hard tissues were examined to evaluate their usefulness for age and growth determination in S. durbanensis and P. grande.

METHODS

Total, fork and standard lengths of fish were measured to the nearest millimetre. Total body mass and eviscerated mass were determined in grams. The relationships between these parameters were expressed in the form of $y = ax^b$ (Ricker 1975).

Dorsal fin spines, pectoral fin rays, vertebrae, operculae, scales and otoliths from 15 S. durbanensis and 15 P. grande were examined to determine the structure most suitable for age and growth assessment. Fin spines and rays were mounted in casting resin and transverse sections were cut near the base of the fin using a twin-bladed saw (Rauck 1976). The sections, approximately 0.3mm thick, were examined under transmitted light using a low power dissecting microscope. Vertebrae and operculae were examined macroscopically. Scales were examined on a dark background, under reflected light, using low power microscopy and also with a microfiche reader.

No clear pattern was discernible in the growth zones of operculae and vertebrae of both species. Transverse sections of spines and rays were readable but in both species the growth zones were less well-defined than those of the otoliths. Scales showed regrowth (replacement scales), particularly in older fish. The use of vertebrae and operculae and to a lesser extent spines and rays also resulted in some mutilation of the fish. Several anglers and spearfishermen objected to the disfigurement of their catch, particularly if the catch was to be photographed or marketed. Since descaling and evisceration are standard marketing procedures the use of scales and otoliths for age determination was preferable.

Sagittal otoliths were taken from fish sampled between Bird Island and Tsitsikamma from August 1984 to September 1986. The otoliths were removed from the auditory bullae, cleaned and stored dry in manilla envelopes. Measurements of otolith width and length were made to the nearest 0.02mm. Otolith mass was determined to the nearest 0.0001g. Sagittae were burned over a low intensity flame to enhance the growth zones (Buxton & Clarke 1986). Otoliths were sectioned through the nucleus, using the technique described for fin spines and rays. The sections were mounted on microscope slides and examined under transmitted light using low power magnification. The narrow, darkly-burnt, opaque zones were counted. All otoliths were examined at least five times and if less than three readings coincided the otolith was rejected.

A number of methods have been employed in the validation of age and growth studies including the Petersen distribution method, marking experiments, daily growth ring analysis, tank experiments with fish of known age and marginal increment analysis (Hecht & Smale 1986). The small sample size and low catch per unit of effort of S. durbanensis and P. grande (see Chapter 6) precluded the use of length frequency analysis (Petersen method) or marking experiments (tagging or oxy-tetracycline marking) for validation of age in these species. Daily growth ring analysis and tank studies were beyond the scope of this project and therefore validation was restricted to an analysis of otolith marginal increments. The percentage frequency of occurrence of opaque and hyaline zones on the otolith margin was plotted on a monthly basis to determine the number of growth zones deposited annually.

The von Bertalanffy growth model is generally regarded by fisheries biologists as being the most suitable for expressing fish growth (Pauly 1979; Hughes 1986). Although several other growth formulae have been proposed all have failed to become established in fisheries science. Pauly (1979) suggested that this may be attributed to a number of factors including: their inability to provide insight into growth processes, their failure to allow for inter-stock comparisons, their difficulty in handling and fitting to sets of length-at-age data and because all were derived on the basis of empirical considerations or on biological reasoning that was apparently erroneous. For these reasons, the von Bertalanffy growth curve was chosen to represent the observed length-at-age data for S. durbanensis and P. grande. The form of the von Bertalanffy growth equation employed was:

$$l(t) = L_{\infty}\left(1 - e^{-K(t-t_0)}\right)$$

where $l(t)$ is the length at age t, L_{∞} is the theoretical maximum length according to the equation and K and t_0 are constants. In terms of this model, t_0 is the age at which the fish would commence growing from length $l = o$ (Hughes 1986). A variety of methods of fitting this curve to the observed length-at-age data for the two species were investigated. The choice of a particular method depended on the data distribution about the fitted curve. The use of the appropriate method was essential as results can be markedly method-dependent (Hughes 1986). The absolute error model (Hughes 1986) was most suitable for describing growth in S. durbanensis and P. grande. This model assumes errors of the type:

$$l(t) = l_{V.B.}(t) + \varepsilon^{\alpha}$$

where $l(t)$ is the observed length of fish α at age t

$\alpha = 1 \,..\, N$, N being the total number of fish in the sample

$l_{V.B.}(t)$ is the predicted length at age according to the von Bertalanffy equation.

The errors (ε^{α}) are "absolute" and are assumed to be normally distributed with constant variance. This model therefore describes data which have a constant variance for each age class and consequently equal weight is given to each individual fish age-length data pair when fitting the von Bertalanffy growth curve. The von Bertalanffy growth curve parameters were determined by minimising the function:

$$SS_A = \sum_{\alpha=1}^{N}\left(l^{\alpha}(t) - l_{V.B.}(t)\right)^2 = \sum_{\alpha=1}^{N} (\varepsilon^{\alpha})^2$$

by using a standard non-linear minimisation package (Hughes 1986).

RESULTS

The length-mass relationships for S. durbanensis and P. grande are summarised in Tables 1 and 2, respectively. The relationships between otolith measurements (length, width and mass) and fork length for the two species are presented in Tables 3 and 4.

Whole, burnt otoliths of S. durbanensis (Figure 6a & b) and P. grande (Figure 6e & f) showed a large, unburnt nucleus surrounded by alternating narrow, burnt and wide, unburnt zones. In

TABLE 1. Relationships between length and mass in Sparodon durbanensis, sampled between Knysna and East London from August 1984 to March 1987.

Equation	r^2	n
T.L.(mm) = 1.127073 F.L.(mm)$^{0.999}$	1.000	220
S.L.(mm) = 0.783097 F.L.(mm)$^{1.021}$	1.000	220
Mass(g) = 0.000018 F.L.(mm)$^{3.037}$	0.999	220
Ev.Mass(g) = 0.000014 F.L.(mm)$^{3.061}$	0.999	220

Ev.Mass = Eviscerated Mass.

TABLE 2. Relationships between length and mass in Pachymetopon grande, sampled between Knysna and East London from August 1984 to March 1987.

Equation	r^2	n
T.L.(mm) = 1.140417 F.L.(mm)$^{0.997}$	0.999	622
S.L.(mm) = 0.7985 F.L.(mm)$^{1.016}$	0.998	622
Mass(g) = 0.000022 F.L.(mm)$^{3.046}$	0.987	622
Ev.Mass(g) = 0.000022 F.L.(mm)$^{3.007}$	0.991	622

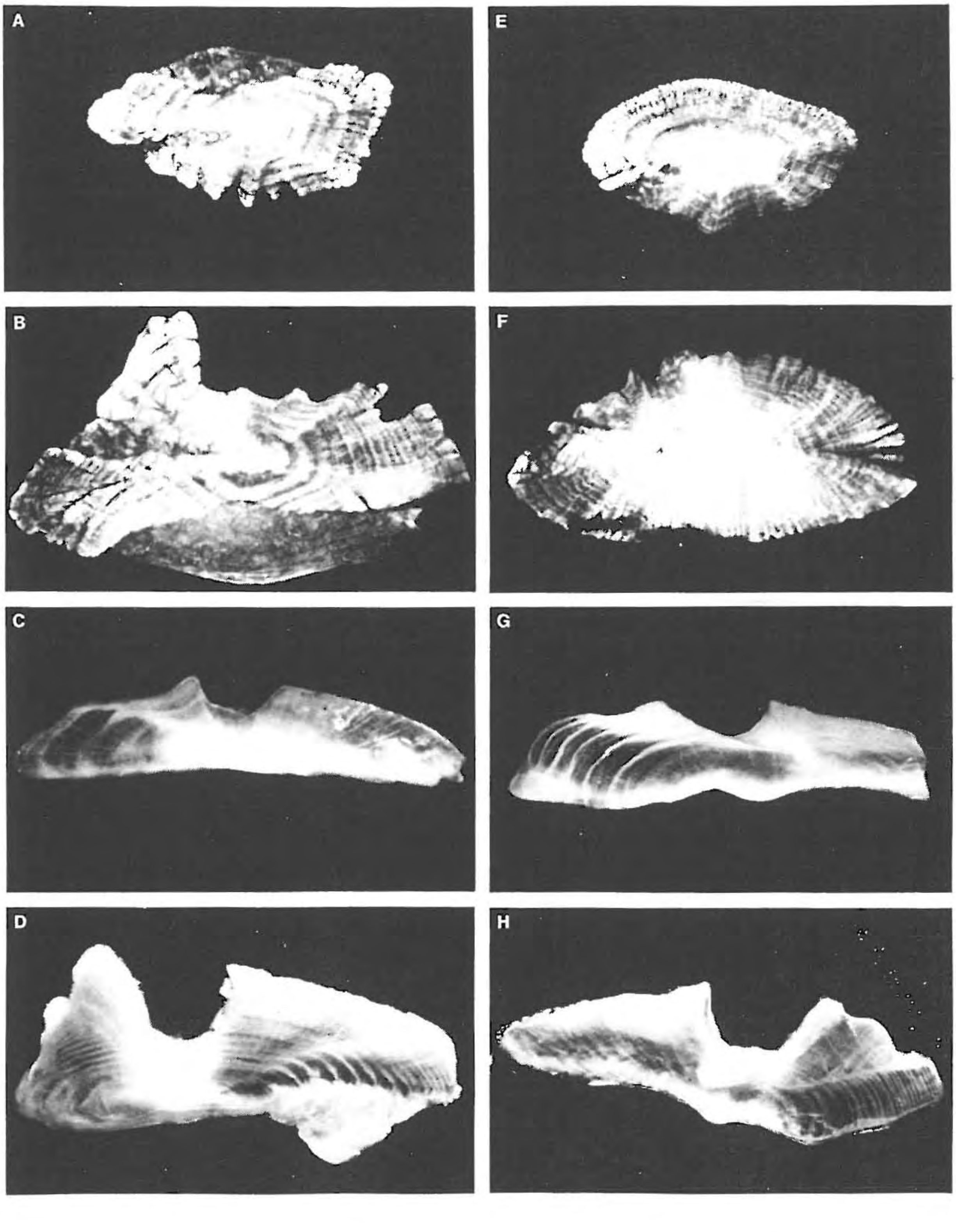
Ev.Mass = Eviscerated Mass.

TABLE 3. Relationships between otolith measurements (length, width and mass) and fork length in Sparodon durbanensis, sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986.

Equation	r^2	n
$F.L.(mm) = 7.700\ O.L.(mm)^{1.766}$	0.967	200
$F.L.(mm) = 13.47\ O.W.(mm)^{2.105}$	0.970	110
$F.L.(mm) = 2372.44\ O.M.(g)^{0.640}$	0.901	110

TABLE 4. Relationships between otolith measurements (length, width and mass) and fork length in Pachymetopon grande, sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986.

Equation	r^2	n
$F.L.(mm) = 11.092\ O.L.(mm)^{1.455}$	0.964	200
$F.L.(mm) = 16.92779\ O.W.(mm)^{1.722}$	0.924	231
$O.M.(g) = 0.008e^{0.007F.L.(mm)}$	0.942	200


A
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H

whole, unburnt otoliths (examined on a dark background under reflected light) a large, white (opaque) nucleus, surrounded by alternating narrow, dark (hyaline) and wide, white (opaque) zones, was observed. These observations suggest that the narrow hyaline zones are primarily burnt by heating the otolith over a low intensity flame. A different perspective was, however, obtained by examination of thin transverse sections of S. durbanensis and P. grande otoliths (Figure 6c & d and Figure 6g & h, respectively). In sectioned otoliths of both species a wide, opaque nucleus, surrounded by alternating wide, hyaline and narrow, opaque zones, was observed. In addition the narrow, opaque zones appeared to be primarily burnt during the heating process. These results are consistent with those recorded by Buxton (1987) for Chrysoblephus laticeps and Chrysoblephus cristiceps, two sparids occurring on deeper reefs in the same area. Buxton (1987) attributed these differences in the optical properties of whole and sectioned otoliths to observational errors resulting from three dimensional effects in whole otoliths.

The musselcracker, S. durbanensis

With growth, the relationship between otolith width and fork length was asymptotic, where the increase in otolith width was relatively small compared to the increase in fork length (Figure 7). A similar result was obtained by substituting otolith length for otolith width (see Table 3). Otolith growth by mass was, however, relatively proportional to growth in fish length (Figure 8). These results indicate that growth in length of S. durbanensis is represented by an increase in otolith thickness, and hence in mass, and to a lesser extent in otolith width and length. This may be attributed to a "stacking" (sensu Blacker 1974) of otolith growth zones one upon the other in larger fish. Photomicrographs of thin transverse sections of sagittae from a small and a large fish clearly show this stacking effect (see Figure 6c & d). The difficulties experienced in ageing large S. durbanensis using whole otoliths can be ascribed to this phenomenon. Growth zones were easily observed in the whole otoliths of small fish (see Figure 6a) but, because of stacking, became difficult to distinguish at the otolith margin in larger specimens (see Figure 6b). The stacking of otolith growth zones has been observed in a number of other species including sole, plaice, turbot, redfish (Sebastes spp.) and horse mackerel (Blacker 1974).

A total of 290 S. durbanensis otoliths were read, of which 66 (22%) were rejected. The frequency of occurrence of opaque and hyaline zones on the otolith margin, plotted on a monthly basis, is presented in Figure 9. One opaque and one hyaline zone were deposited annually, opaque growth predominating between June and September and hyaline growth between October and May.

The absolute error model (Hughes 1986) gave the most appropriate fit to the length-at-age data

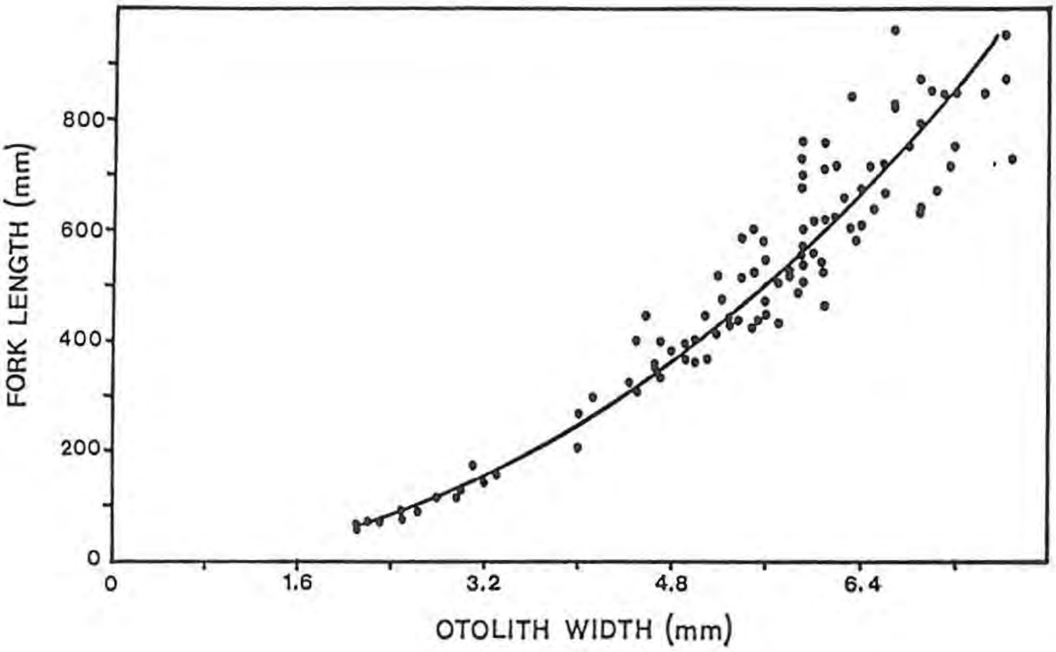


Figure 7. The relationship between otolith width and fork length in Sparodon durbanensis sampled between Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 (n = 110).

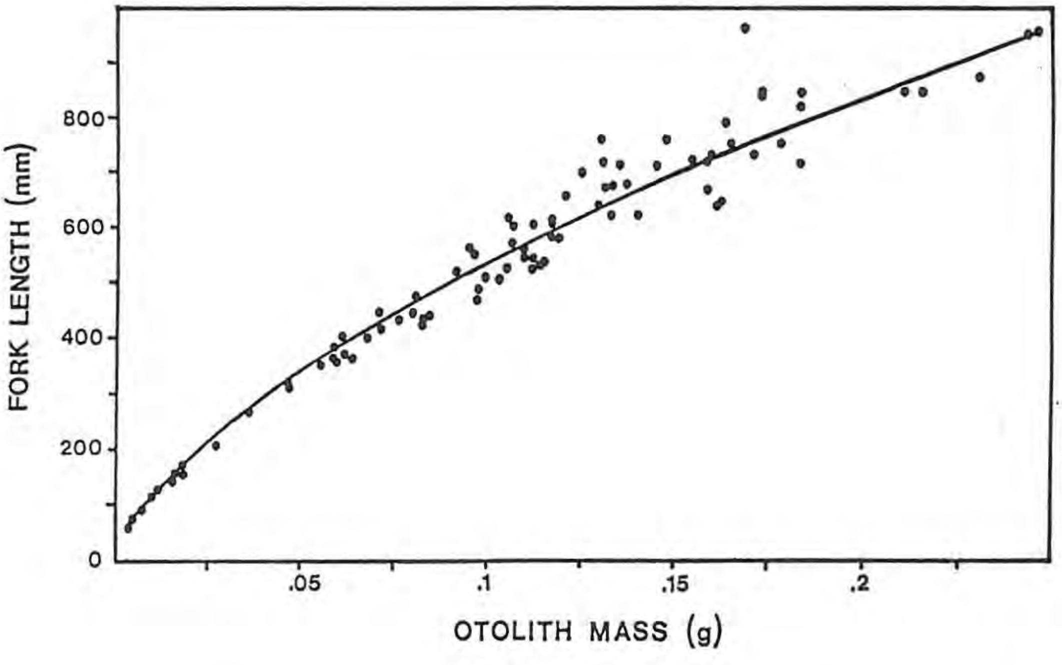


Figure 8. The relationship between otolith mass and fork length in Sparodon durbanensis sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 (n = 110).

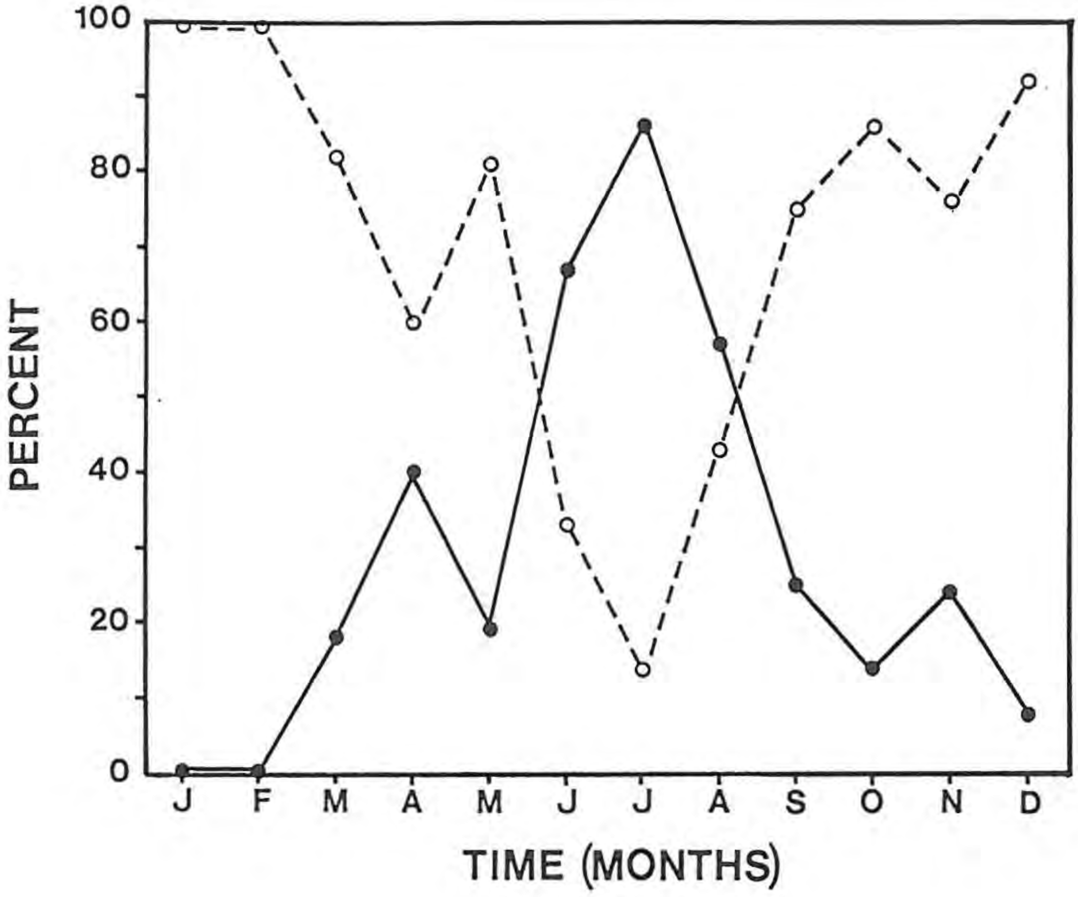


Figure 9. Temporal changes in the marginal increment of Sparodon durbanensis otoliths, sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986. The solid line represents opaque growth and the dashed line hyaline growth (n = 224).

for males, females and for the total data set (males, females, juveniles and individuals where sex was not determined due to evisceration by anglers or spearfishermen). Mean length-at-age data are summarised in Table 5a. A Student's t-test showed no significant difference in the observed mean length-at-age data for males and females (Table 5b). The von Bertalanffy growth curves for males, females and the total data set are presented in Figures 10a - c, respectively. The presence of older males than females in the age and growth analysis should not be taken to indicate that the lifespan of male S. durbanensis exceeds that of females. This is evidenced by similar length frequency distributions for male and female fish (see Chapter 4) and no significant difference in the mean length-at-age of the two sexes. The absence of large females from the data set can be attributed to the small sample of large fish combined with a high rejection rate of large otoliths due to reading difficulties. This resulted in very few fish in the larger size classes being successfully aged. Growth in S. durbanensis was slow and maximum age exceeded 31 years.

The bronze bream, P. grande

Stacking of otolith growth zones also occurred in P. grande (see Figure 6g & h). A power relationship between otolith width and fork length (Figure 11) and an exponential relationship between otolith mass and fork length (Figure 12) also indicated an increase in otolith thickness and in mass, rather than in width, with growth. The exponential relationship between otolith mass and fork length in P. grande, as opposed to the power relationship in S. durbanensis, may be explained by a difference in growth form as evidenced by the von Bertalanffy growth curves (compare Figures 10c & 14a). In P. grande growth in length becomes asymptotic comparatively early on in life. Otolith growth continues, however, resulting in the exponential relationship between otolith mass and fork length.

A total of 423 otoliths were read of which 73 (17%) were rejected. The monthly percentage of opaque and hyaline zones on the otolith margin indicated that one opaque and one hyaline zone were deposited annually. The opaque zone was deposited between June and November (Figure 13) and the hyaline zone between December and May.

Beverton's method of fitting the von Bertanlaffy growth curve to mean length-at-age (Ricker 1975) was unsuitable for the data set (Clarke & Buxton 1986). So too were the three models described by Hughes (1986), in which all data pairs are evaluated in the fitting of the curve. In many species the growth rate of juveniles may not follow a von Bertalanffy shape (Ricker 1975, G. Hughes, University of Cape Town, pers. comm.). By omitting the zero age fish from the fit (n = 338) the relative (non-log) error model (Hughes 1986) fitted the data. This fit, however, placed considerable emphasis on the lower aged fish and associated larger errors for the older fish (in

TABLE 5a. Observed mean length-at-age and expected mean length-at-age (from the von Bertalanffy growth curve) for Sparodon durbanensis.

Age (Years)	Males		Females		All Fish	
	Observed mean length (mm)	Fitted mean length (mm)	Observed mean length (mm)	Fitted mean length (mm)	Observed mean length (mm)	Fitted mean length (mm)
0	-	-	-	-	54	-67
1	-	-	-	-	77	26
2	-	-	-	-	118	112
3	-	-	-	-	147	190
4	278	228	255	259	218	262
5	358	308	392	327	381	327
6	363	378	361	389	363	387
7	420	441	417	446	411	441
8	486	496	487	497	490	491
9	551	545	539	544	549	537
10	572	588	586	587	578	579
11	656	626	629	626	638	617
12	722	660	661	661	685	652
13	732	690	729	694	730	683
14	747	716	700	723	698	712
15	741	740	775	750	765	739
16	676	760	855	775	795	763
17	714	779	786	797	757	786
18	750	795	860	817	823	806
19	-	809	745	836	745	824
20	808	822	820	853	815	841
22	-	843	953	882	953	871
23	863	851	-	-	863	884
26	959	872	-	-	959	916
31	871	893	-	-	871	954

TABLE 5b. Test of significant difference between the observed mean length-at-age of male and female *Sparodon durbanensis*, sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 ($p = 0.05$).

Age (Years)	Males			Females			d.f.	t
	Mean Length (mm)	Std. Dev.	n	Mean Length (mm)	Std. Dev.	n		
5	358	4.24	2	392	31.40	4	4	1.4393
6	363	54.27	8	361	37.45	5	11	0.0665
7	420	70.43	12	417	34.36	6	16	0.0705
8	486	29.04	7	487	61.29	9	14	0.0220
9	551	62.35	12	539	63.25	8	18	0.4179
10	572	64.99	7	586	21.80	5	10	0.4693
11	656	48.14	4	629	30.64	7	9	1.1245
12	722	82.79	4	661	46.37	6	8	1.5126
13	732	52.72	4	729	56.81	5	7	0.0785
15	741	4.95	2	775	34.71	5	5	1.3172
17	714	84.15	2	786	97.02	3	3	0.8547
20	808	65.91	4	820	59.27	5	7	0.2972

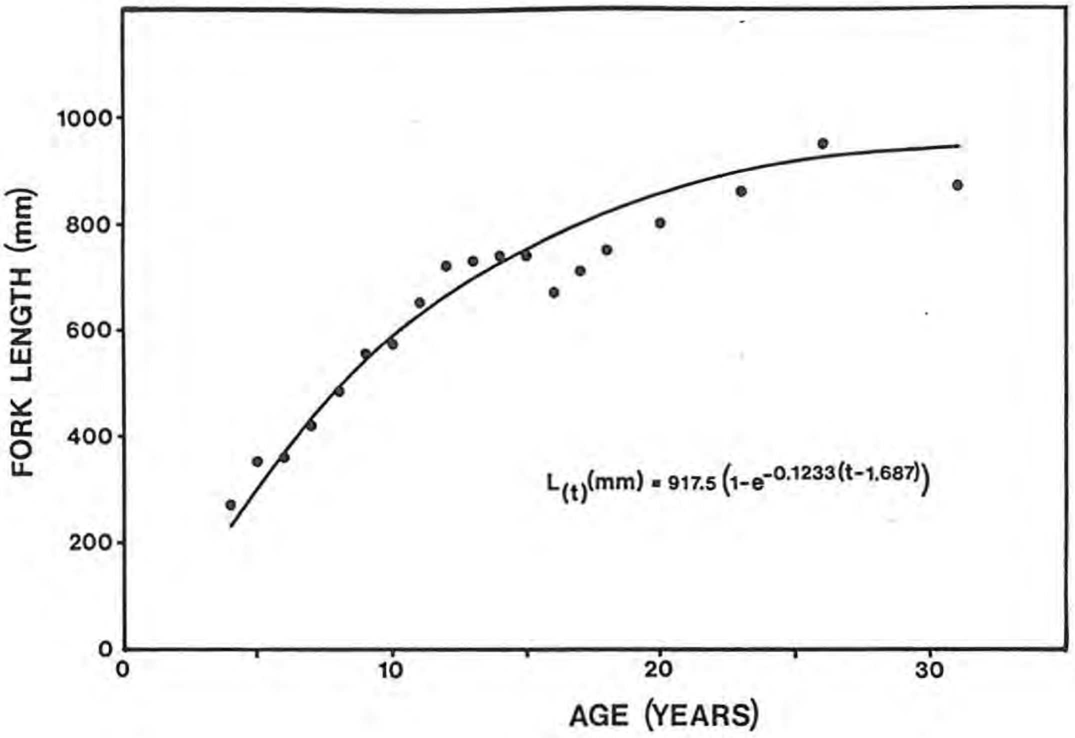


Figure 10a. The relationship between fork length and age in male <u>Sparodon</u> <u>durbanensis</u> sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 (n = 76).

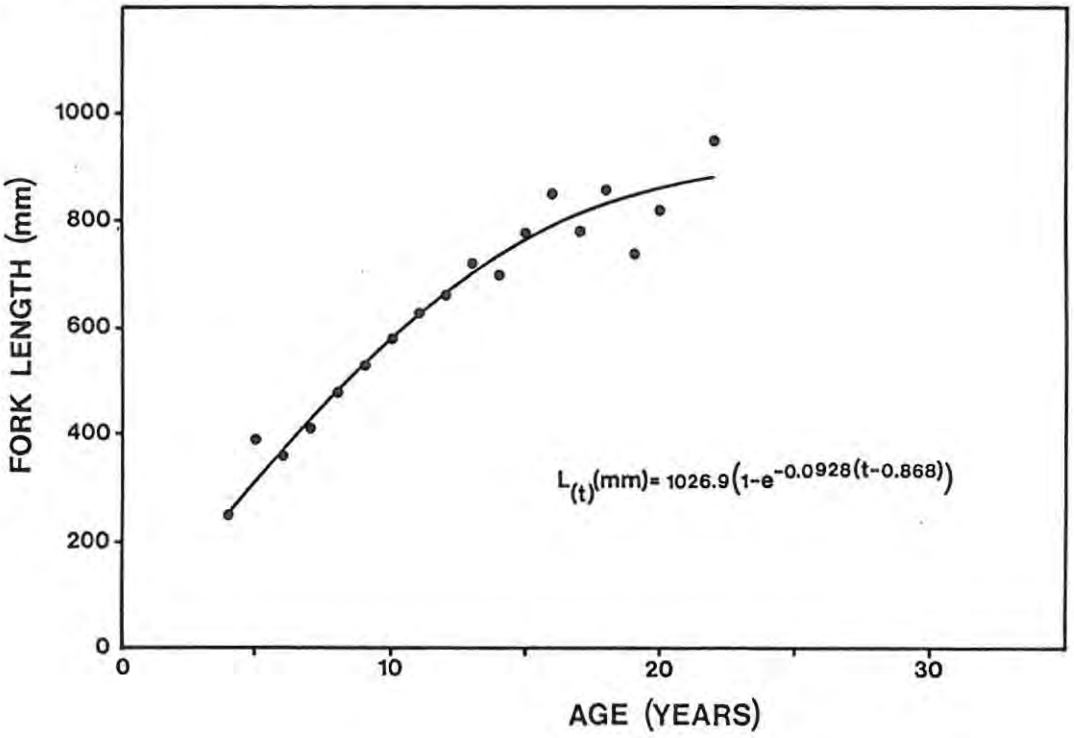


Figure 10b. The relationship between length and age in female <u>Sparodon</u> <u>durbanensis</u> sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 (n = 79).

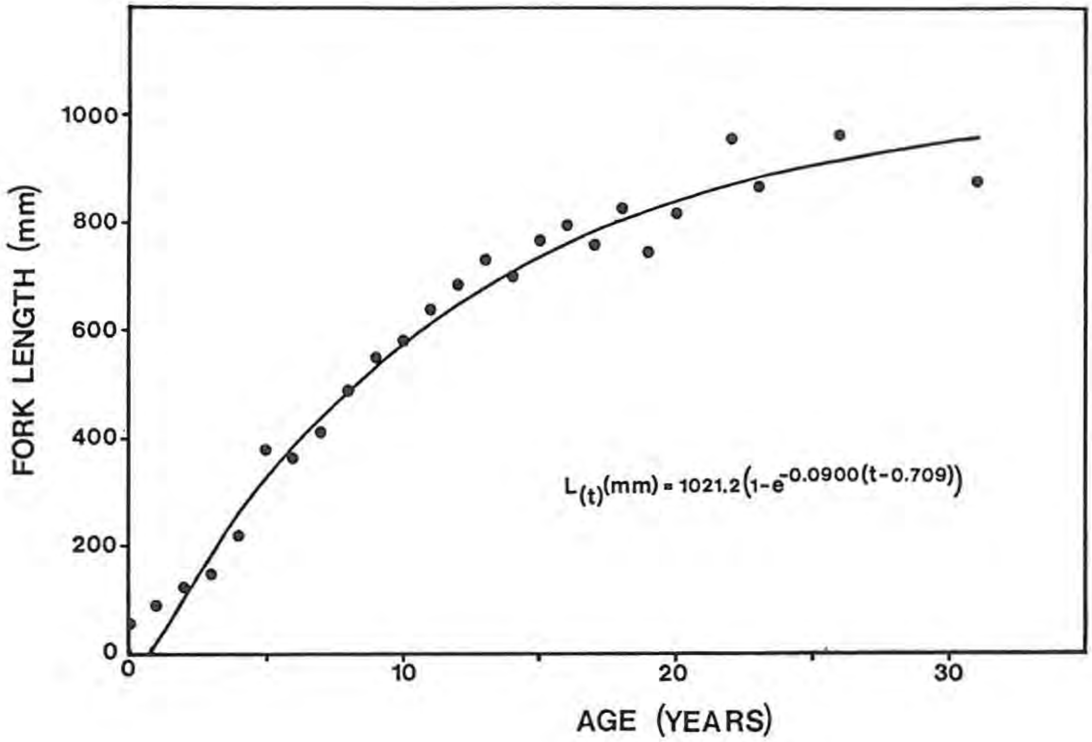


Figure 10c. The relationship between length and age in Sparodon durbanensis, sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 (Total data set, n = 224).

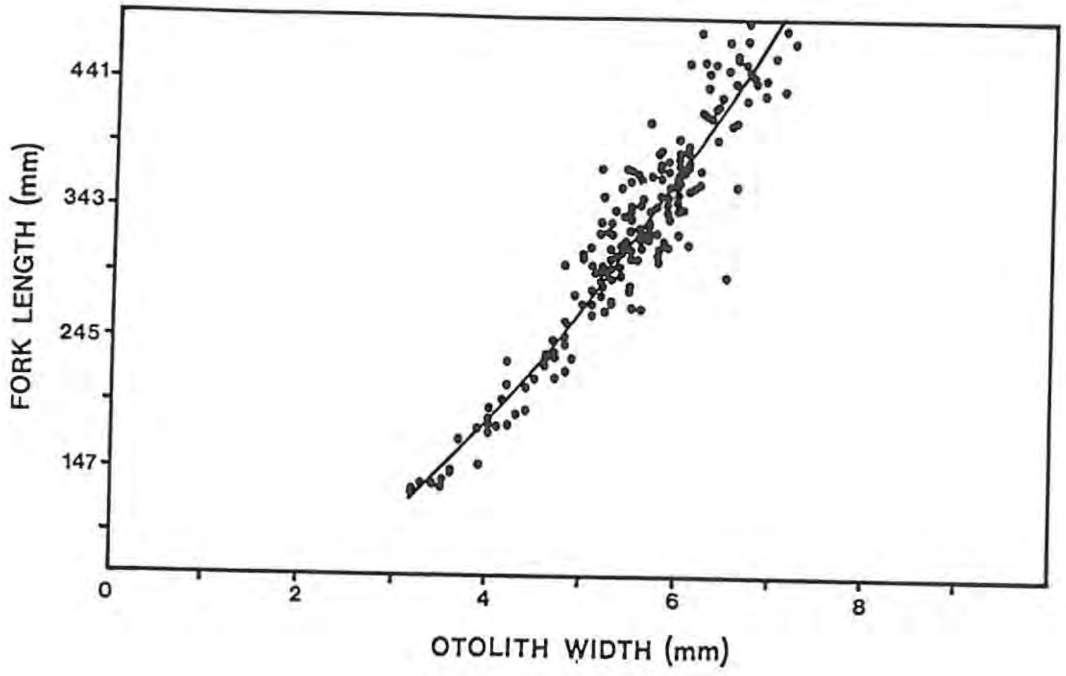


Figure 11. The relationship between otolith width and fork length in Pachymetopon grande sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 (n = 200).

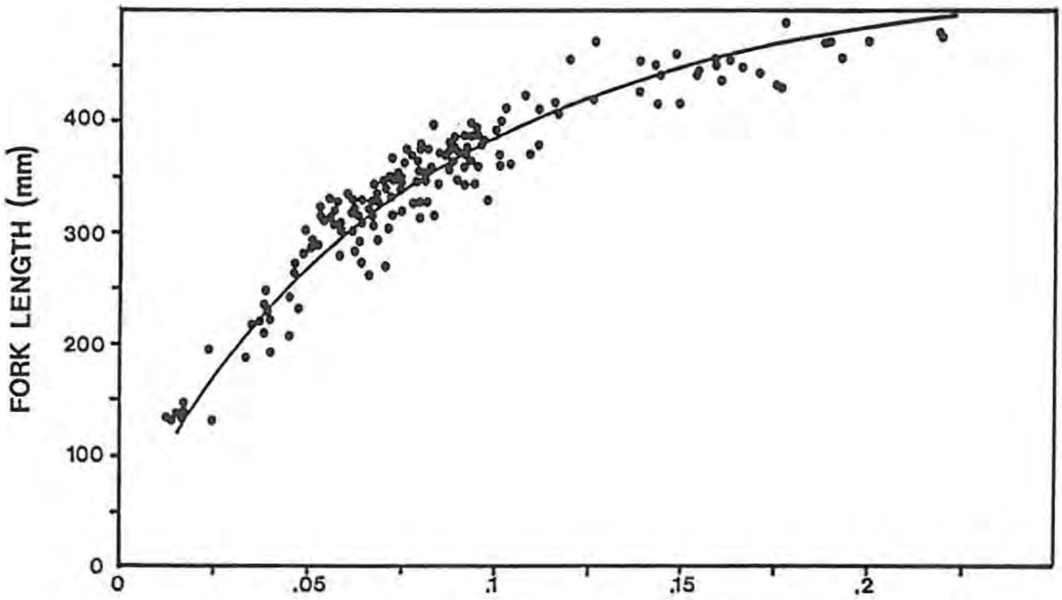


Figure 12. The relationship between otolith mass and fork length in Pachymetopon grande sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 (n = 200).

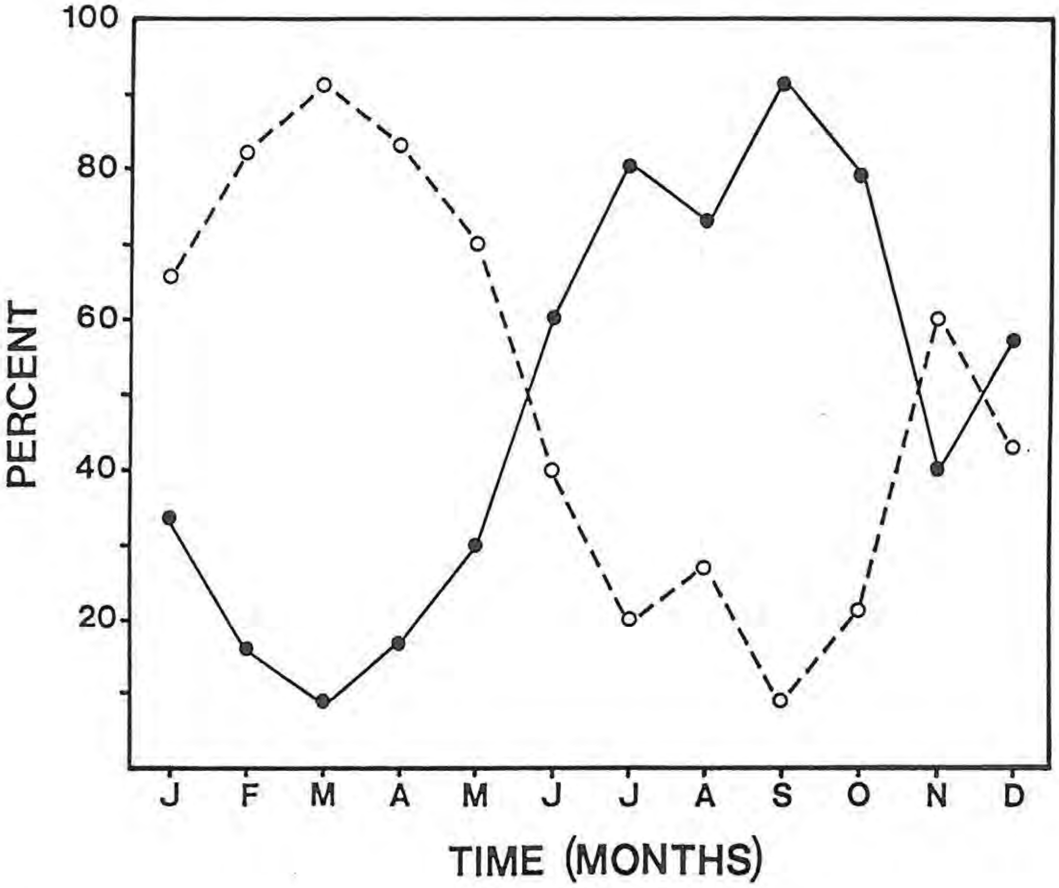


Figure 13. Temporal changes in the marginal increment in Pachymetopon grande otoliths sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986. The solid line represents opaque growth and the dashed line hyaline growth (n = 350).

order to include juvenile fish). This resulted in a low L_∞ in the von Bertalanffy growth equation:

$$Lt(mm) = 445.9\left(1-e^{-0.173(t+1.108)}\right).$$

By omitting the zero and one year old fish the relative error model did not fit the data, whereas the absolute error model (Hughes 1986) provided a good fit. This relationship is presented in Figure 14a. Separate analyses for males and females are presented in Figures 14b & c, respectively. The absolute error model provided the most appropriate fit to both data sets. Mean length-at-age data are summarised in Table 6a. A Student's t-test showed no significant difference between the mean length-at-age of males and females (Table 6b). In P. grande the relative growth rate was initially fast, tapering off rapidly after approximately 10 years. The maximum recorded age was 38 years. This fish was not particularly large (F.L. = 487mm; mass = 2900g), the maximum recorded size in this study being 45mm longer (F.L. = 532mm; mass = 3700g). This indicates that maximum age is probably considerably greater than that recorded above.

DISCUSSION

The terminology of otolith structure relating to age and growth studies is not standardised and is often conflicting (Pannella 1974; Campana & Neilson 1985; Buxton & Clarke 1986; Buxton 1987). Otolith growth zones are most frequently described by the terms opaque and hyaline. Inconsistent use of these terms by different authors may have resulted from the varying appearance of these zones under different lighting conditions (Botha 1971; Blacker 1974; Pannella 1974). The more recent use of the terms fast and slow growth (Pannella 1971, 1974), incremental and discontinuous growth (Mugiya, Watabe, Yamada, Dean, Dunkelberger & Shimuzu 1981; Campana & Neilson 1985) and light and dark bands (Buxton & Clarke 1986) indicate efforts to avoid this confusion.

Opaque and hyaline zones have high and low optical densities, respectively. Blacker (1974) in his review of otolith structure and growth and the use of otoliths for age determination stated, "...aquarium experiments designed to elucidate the interpretation of growth zones confirmed that zones were laid down in an annual pattern of a wide, opaque, growth (or summer) zone followed by a narrower, hyaline, resting (or winter) zone".

Pannella (1971, 1974) investigated daily growth in otoliths using acetate replicas and scanning electron microscopy. He concluded that opaque zones consisted of thicker increments than

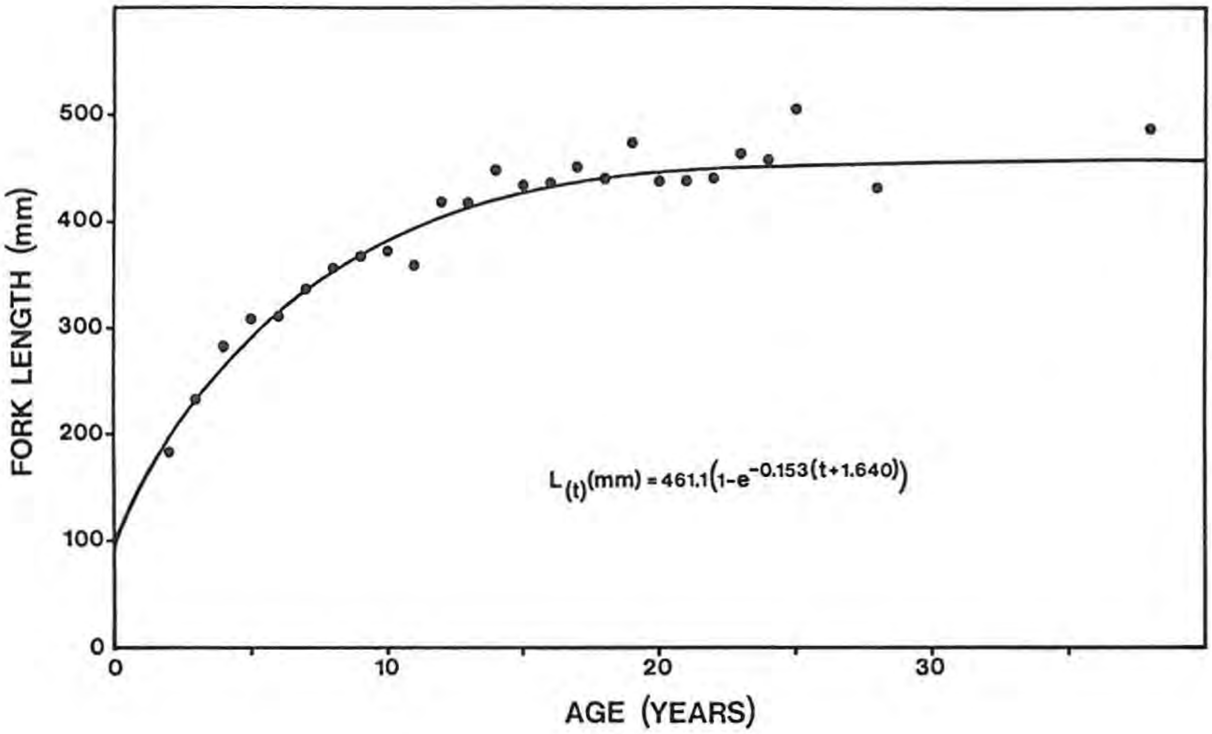


Figure 14a. The relationship between length and age in Pachymetopon grande, sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 (ages zero and one were excluded from the analysis, n = 326).

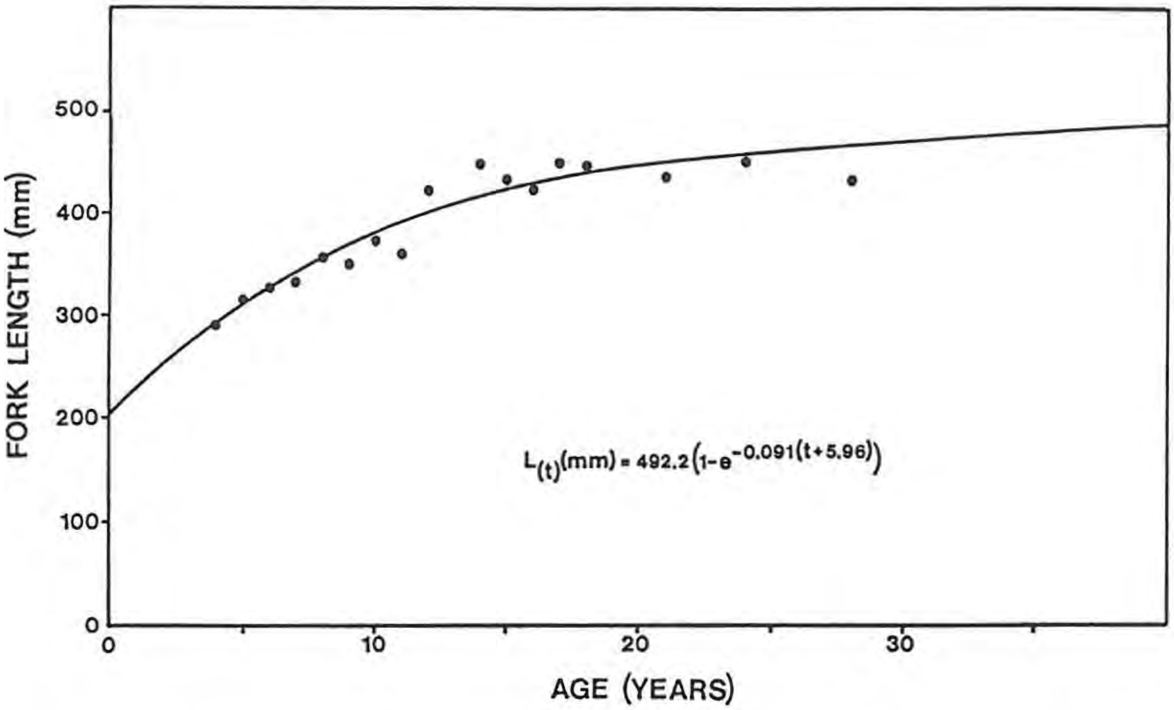


Figure 14b. The relationship between length and age in male Pachymetopon grande, sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 (n = 102).

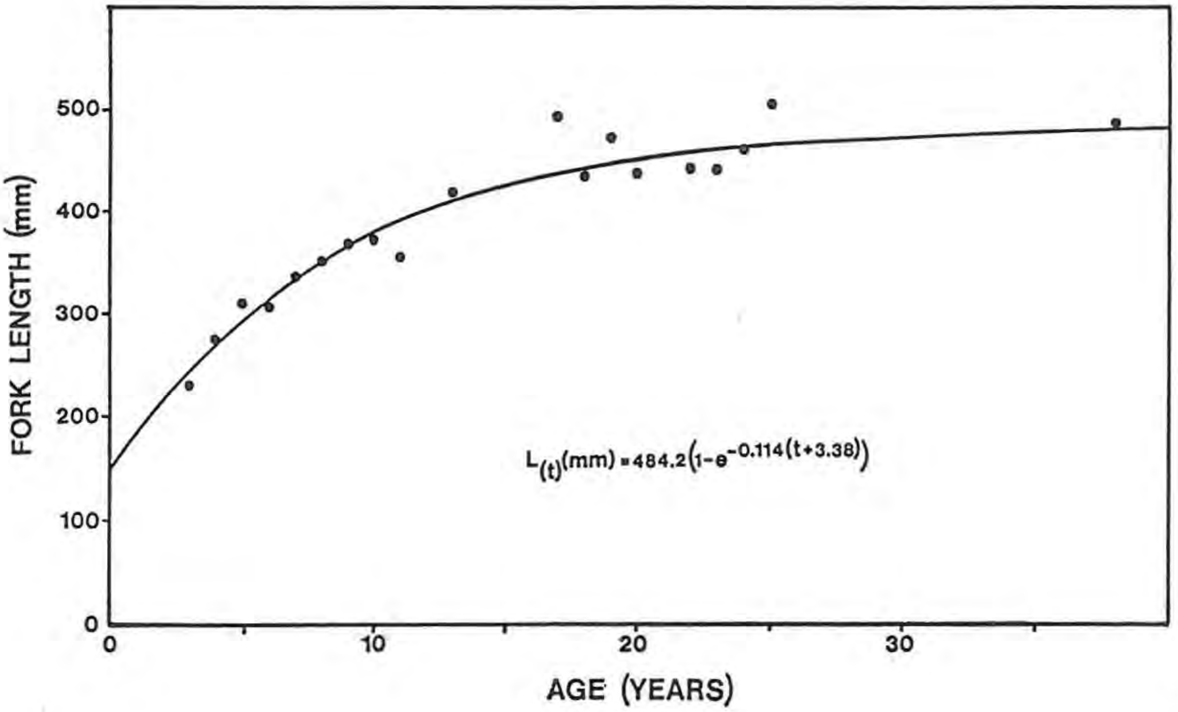


Figure 14c. The relationship between length and age in female Pachymetopon grande, sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 (n = 148).

TABLE 6a. Observed mean length-at-age and expected mean length-at-age (from the von Bertalanffy growth curve) for *Pachymetopon grande*.

Age (Years)	Males		Females		Total*	
	Observed mean length (mm)	Expected mean length (mm)	Observed mean length (mm)	Expected mean length (mm)	Observed mean length (mm)	Expected mean length (mm)
0	-	206	-	155	-	102
1	-	231	-	190	-	153
2	-	254	-	222	183	197
3	-	274	233	250	234	234
4	291	293	275	275	284	266
5	315	311	314	298	307	294
6	328	326	307	318	311	318
7	334	341	338	336	337	338
8	358	354	354	351	355	355
9	354	366	369	366	366	370
10	373	377	372	379	372	383
11	360	387	355	390	358	394
12	421	396	-	400	419	404
13	-	405	417	409	417	412
14	448	412	-	417	448	419
15	434	419	-	425	434	425
16	422	425	-	431	436	430
17	450	431	492	438	450	434
18	449	437	435	442	439	438
19	-	441	473	446	473	441
20	-	446	438	451	438	444
21	437	450	-	-	437	447
22	-	-	442	457	440	448
23	-	-	441	460	464	450
24	455	460	460	463	458	452
25	-	-	505	465	505	453
28	432	470	-	-	432	456
38	-	-	487	480	487	460
40	-	485	-	481	-	460

*total is all fish excluding ages 0 and 1.

TABLE 6b. Test of significant difference between the observed mean length-at-age of male and female Pachymetopon grande, sampled between the Tsitsikamma Coastal National Park and Bird Island from August 1984 to September 1986 (p = 0.05).

Age (Years)	Males			Females			d.f.	t
	Mean Length (mm)	Std. Dev.	n	Mean Length (mm)	Std. Dev.	n		
4	291	27.64	6	275	21.51	5	9	1.0658
5	315	21.62	9	314	31.77	18	25	0.0612
*6	328	17.97	13	307	17.02	16	27	3.2561
7	334	21.63	16	338	21.63	22	36	0.5717
8	358	24.56	20	354	24.11	19	37	0.4590
9	354	19.29	9	369	25.16	30	37	1.7201
10	373	23.73	10	372	19.78	14	22	0.1542
11	360	19.24	5	355	9.02	3	6	0.4743

*significantly different.

hyaline zones and represented periods of fast growth. He considered Irie's (1955, 1960) and Dannevig's (1956) interpretation of the opaque zone representing a period of slow growth to be either observational or semantic mistakes. More recent investigations of otolith microstructure (Mugiya et al. 1981; Campana & Neilson 1985), however, showed relatively narrow opaque zones representing periods of discontinuous growth. Both Pannella (1974) and Campana & Neilson (1985), however, considered the fast growth/incremental zone to consist largely of calcium carbonate. In contrast, Radtke & Targett (1984) considered the incremental zone to be proteinaceous. Charring of the protein constituent of otoliths can be achieved by gentle heating over a low intensity flame (Christensen 1964).

The confusion surrounding the interpretation of otolith growth zones does not affect zone counts and therefore age determination (Buxton 1987). It does, however, give rise to the following question: Does the narrow, darkly-burnt, opaque zone observed in thin transverse sections of S. durbanensis and P. grande otoliths represent a period of discontinuous growth, or does it reflect a short period of rapid growth?

In both species the occurrence of the hyaline zone on the otolith margin and gonadal activity showed a similar seasonal pattern (Figures 15 & 16). It is generally accepted that breeding cycles are timed to ensure that offspring are produced at the optimal period for the survival of the young (Berger, Negus, Sanders & Gardner 1981). The opaque nucleus in both species may therefore reflect an initial period of rapid growth during optimal environmental conditions. If this is the case, the wide hyaline zones represent long periods of slow growth and the narrow opaque zones short periods of rapid growth. The similar seasonal patterns in the breeding seasons and otolith hyaline zone deposition in both species, provides evidence to support this interpretation. Somatic growth is expected to be lower during the breeding season because of the high energetic costs of producing large numbers of gametes. The relatively slow growth of both species provides additional evidence to support this interpretation because the predominance of hyaline growth would result in relatively slow growth in both species.

Alternatively, one could argue that the narrow opaque zones represent periods of discontinuous or slow growth. In both species peak opaque zonation occurred during late winter and it is possible that the colder water temperatures and shorter photoperiod associated with winter (Chapter 4) retard somatic growth. If this is the case the breeding season in both species would coincide with a period of fast growth. This is possible if the energetic costs of reproduction are lower than some seasonally determined energetic gain during the reproductive period. In both species the major dietary items are abundant on subtidal reefs throughout the year. It is possible, however, that the energetic value of the diet changes seasonally, e.g.

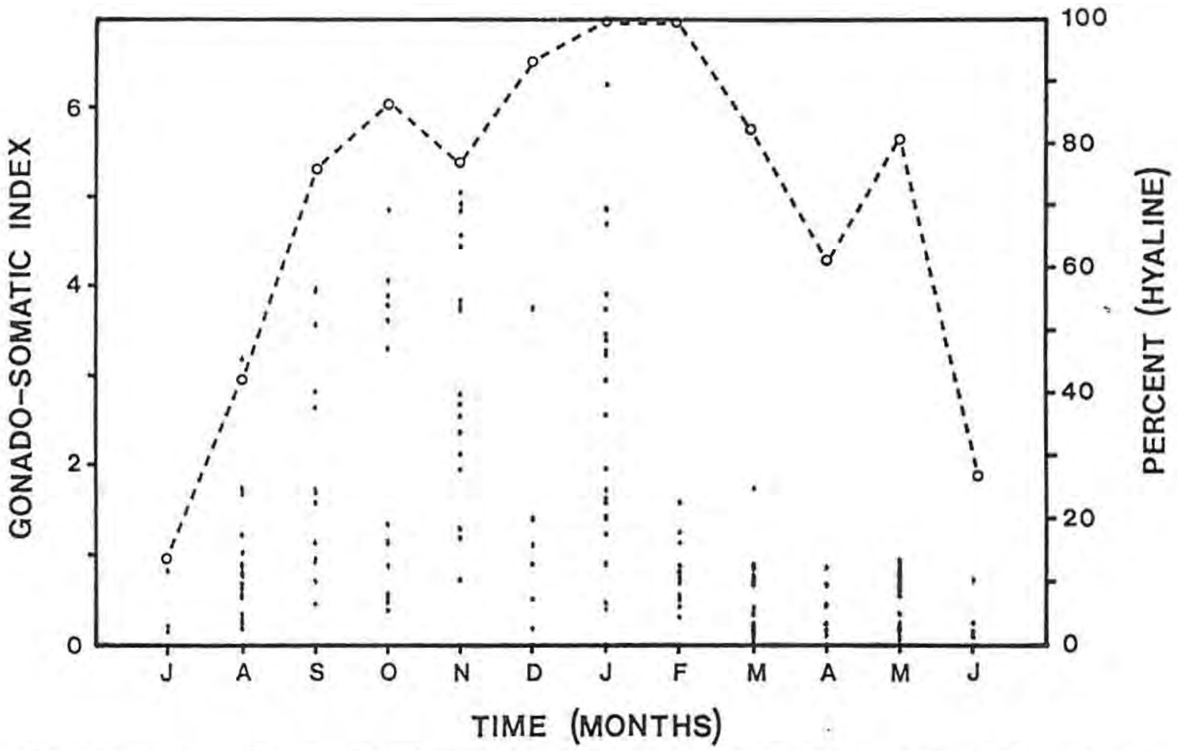


Figure 15. The relationship between hyaline deposition in otoliths and the seasonal variation in gonado-somatic index for Sparodon durbanensis, collected between Knysna and East London from August 1984 to March 1987.

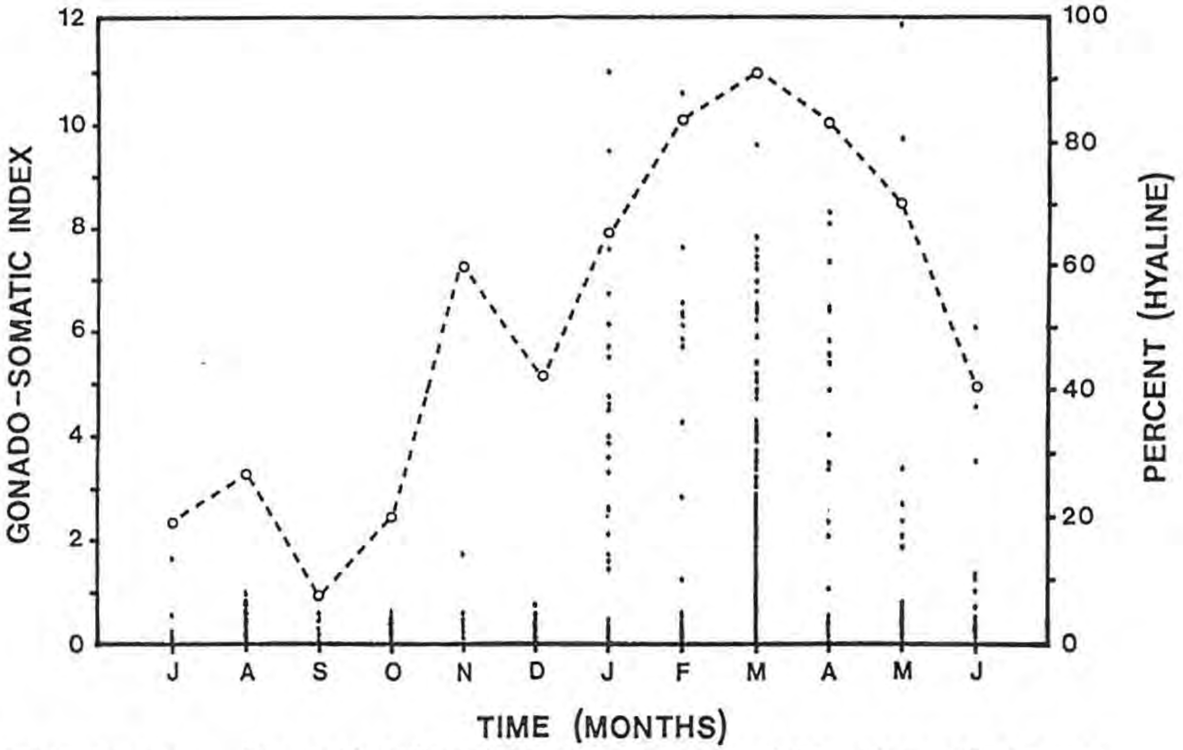


Figure 16. The relationship between hyaline deposition in otoliths and seasonal variation in gonado-somatic index for Pachymetopon grande, collected between Knysna and East London from August 1984 to March 1987.

seaweeds may be more palatable at the beginning of the annual cycle or invertebrates may be temporally more nutritive depending on gonadal development. Increased water temperatures could stimulate foraging activity and consequently somatic growth. Angler catches indicate that both species forage diurnally. Increased photoperiod would therefore increase potential foraging times and possible somatic growth. This argument agrees with the more recent work on otolith microstructure and diurnal rhythm in otolith formation (Mugiya et al. 1981; Campana & Neilson 1985).

Detailed studies investigating the formation of daily and seasonal growth zones, the chemical and optical properties of these zones and the poorly understood relationship between increment width and somatic growth (Campana & Neilson 1985) are necessary to solve the confusion surrounding otolith zone interpretation. The possibility of interspecific differences in otolith zone deposition also requires investigation.

The stacking of growth zones in the otoliths of older fish prevented the use of whole otoliths for age determination. In sectioned otoliths incorrect selection of the cutting plane may result in large measurement errors without affecting the ring count. This was shown by cutting three serial sections through the nuclear region in a number of otoliths from both species. In S. durbanensis the otolith margin is irregular (see Figure 6b) as opposed to the relatively smooth margin in P. grande otoliths (see Figure 6f). This resulted in even greater variation in otolith width measurements in sections of S. durbanensis sagittae. The measurement errors associated with sectioned otoliths prevented the determination of back-calculated lengths-at-age in both species. Back-calculated lengths-at-age can be used to determine Rosa Lee's phenomenon (Ricker 1975) which occurs when the mortality rate of the larger fish in a year class is greater than that of the smaller fish. This may be detected when back-calculated lengths-at-age, from scales or otoliths, provide a smaller estimated size than the true average size in question (Ricker 1975). The inshore recreational fishery is a size-selective fishery, large fish being targeted for by both anglers and spearfishermen. Rosa Lee's phenomenon may therefore be expected in S. durbanensis and P. grande where faster growing individuals would be recruited in to the fishery at an earlier age. Back-calculated lengths-at-age may also provide an estimate of early growth in studies where juveniles can not be sampled. The availability of juveniles of both species did not make this necessary.

The observed mean length of one year old S. durbanensis, sampled in the shallow subtidal, was 77mm F.L. (86.4mm T.L.). A study of S. durbanensis in intertidal pools in the Port Elizabeth area (Beckley, in press), using length frequency analysis, showed that juveniles were recruited into the pools in mid-summer and obtained a total length of approximately 80mm by the following spring. Beckley's results therefore support the interpretation of the first annulus in this study.

S. durbanensis and P. grande are shown to be relatively slow-growing and long-lived species. An examination of age and growth studies of South African sparids (Table 7) showed a similar trend in other species. The maximum observed lengths for some of these species (Smith & Heemstra 1986) are considerably larger than those recorded in the studies. In addition, the oldest aged fish in some studies were substantially smaller than the largest fish recorded in the studies. The inability to sample the largest specimens of many of these species combined with difficulties experienced in aging older fish (particularly when using whole otoliths), indicates that maximum age in these species may be considerably greater than that reported.

Slow growth and longevity are important management considerations. Ricker (1963) suggested that fish populations which include upwards of 12-15 age groups in appreciable quantities, prior to exploitation, are extremely sensitive to fishing. He indicated that in some species as little as 5% catch per annum could result in a major reduction in the relative weight of older fish in the stock. In addition, slow growth typically results in a slower recovery rate after over-exploitation (Adams 1980). Much of the importance of S. durbanensis and P. grande, to the recreational fisheries, lies in their relatively large size. Legislation governing the exploitation of these species should therefore be aimed at ensuring a constant, relatively low level of exploitation (Ricker 1963, Adams 1980, Sharp 1987) with maintenance of a relatively large mean size.

TABLE 7. Summary of age and growth studies of South African Sparidae.

SPECIES	COMMON NAME	VON BERTALANFFY GROWTH EQUATION	MAX LENGTH IN STUDY (cm)	AGE (YEARS)	REFERENCE
Pachymetopon blochii	Hottentot	$L_t = 42.04\left(1-e^{-0.144376(t+1.203109)}\right)$	38.3	9	Nepgen (1977)
Argyrozona argyrozona	Carpenter	$L_t = 74.49\left(1-e^{-0.07076(t+1.524)}\right)$	72.0	11	Nepgen (1977)
*Pterogymnus laniarius**	Panga	$L_t = 48.1\left(1-e^{-0.19(t+0.32)}\right)$	47.9	11	Hecht (1976) Hecht & Baird (1977)
*Cheimerius nufar**	Santer	$L_t = 95.356\left(1-e^{-0.0654(t+2.6177)}\right)$	70.5	22	Coetzee & Baird (1981a)
Pachymetopon aeneum	Blue hottentot	$L_t = 46.706\left(1-e^{-0.1328(t-0.2473)}\right)$	40.0	12	Buxton & Clarke (1986)
Chrysoblephus laticeps	Roman	$L_t = 41.544\left(1-e^{-0.1578(t+0.2858)}\right)$	44.9	18	Buxton (1987)
Chrysoblephus cristiceps	Dageraad	$L_t = 57.689\left(1-e^{-0.1147(t+0.5296)}\right)$	58.6	22	Buxton (1987)
Pachymetopon grande	Bronze bream	$L_t = 46.11\left(1-e^{-0.153(t+1.64)}\right)$	53.2	38	This study
Sparodon durbanensis	Musselcracker	$L_t = 102.12\left(1-e^{-0.0900(t-0.709)}\right)$	95.9	31	This study
Cymatoceps nasutus	Poenskop	$L_t = 108.95\left(1-e^{-0.0502(t+2.885)}\right)$	109.9	45	Buxton & Clarke (Unpubl. results)

*Measurements refer to total lengths (cm). All other measurements are fork lengths (cm).

CHAPTER 4 - REPRODUCTION

INTRODUCTION

It can be argued that reproduction is the central feature of an animal's life history, with all other aspects resulting from and reflecting selection for maximum reproductive success (Thresher 1984). A thorough knowledge of the reproductive biology of a species is therefore fundamental to understanding its' ecology and to determining a conservation strategy for the species.

The Southern African sparid fauna consists of 41 species contained in 22 genera and four sub-families. Of these, 25 species are endemic with another four, including P. grande, extending as far as Madagascar or Mauritius (Smith & Heemstra 1986). Most of these species are important to the commercial or recreational fisheries, but detailed studies of the reproductive biology of only eight species have been conducted. These are: Cheimerius nufar (Coetzee 1983, Garratt 1986a), Chrysoblephus puniceus (Garratt 1986a & b), Lithognathus lithognathus (Mehl 1973), Pterogymnus laniarius (Hecht & Baird 1977), Diplodus sargus capensis (Coetzee 1986), Petrus rupestris (Smale, in press) and Chrysoblephus laticeps and Chrysoblephus cristiceps (Buxton 1987). Garratt (1986b) reviewed the occurrence of hermaphroditism in South African sparids and stated that protogyny, protandry, rudimentary hermaphroditism and gonochorism had been recorded. Detailed studies, including histological examination of the gonads, have shown that in many cases these initial observations were superficial and incorrect. This particularly applied to a number of rudimentary hermaphrodites which were originally classified as gonochorists. This information is summarised in Table 8. Garratt (1986a) and Buxton (1987) have shown that sex reversal may present special management problems in size-selective fisheries. This results from the large fish, mainly of one sex, being selectively removed from the population with a resultant imbalance in the sex ratio. Rudimentary hermaphrodites may be viewed as functional gonochorists (Buxton & Garratt 1987) and may therefore be less complex to manage.

Prior to this study the reproductive biology of both S. durbanensis and P. grande was poorly understood. Brownell (1979), from the recruitment of juvenile S. durbanensis into intertidal pools, suggested a protracted breeding season for this species, extending from August to January. The distribution of juvenile P. grande was unknown, with Beckley (1985a) noting their "conspicuous absence from tidal pools" in the Port Elizabeth area. Penrith (1972) stated that P. grande was gonochoristic but provided no evidence to substantiate this observation.

TABLE 8. A literature review of the occurrence of hermaphroditism and gonochorism in South African Sparidae.

Species	Previous description	Reference	Current description	Reference
Argyrozona argyrozona			Gonochorist	Nepgen (1977)
Boopsoidea inornata			Gonochorist	Penrith (1972)
Cheimerius nufar			Rudimentary hermaphrodite	Coetzee (1983), Garratt (1986a)
Chrysoblephus cristiceps			Protogynous hermaphrodite	Robinson (1976), Buxton (1987)
Chrysoblephus gibbiceps	Gonochorist	Penrith (1972)	Rudimentary hermaphrodite	Buxton (1987)
Chrysoblephus laticeps			Protogynous hermaphrodite	Penrith (1972), Buxton (1987)
Chrysoblephus puniceus			Protogynous hermaphrodite	Garratt (1986a & b)
Diplodus sargus capensis	Gonochorist	Penrith (1972)	Rudimentary hermaphrodite	Coetzee (1986)
Lithognathus aureti			Protandrous hermaphrodite	Lucks (1970)
Lithognathus lithognathus			Rudimentary hermaphrodite	Mehl (1973)
Pachymetopon aeneum			Protogynous hermaphrodite	Buxton & Clarke (1986)
Pachymetopon blochii			Gonochorist	Nepgen (1977)
Pachymetopon grande	Gonochorist	Penrith (1972)	Rudimentary hermaphrodite	This study
Petrus rupestris	Gonochorist	Penrith (1972)	Rudimentary hermaphrodite	Smale (in press)
Polysteganus undulosus			Gonochorist	Ahrens (1964), Penrith (1972)
Pterogymnus laniarius	Gonochorist	Penrith (1972)	Protogynous hermaphrodite	Hecht & Baird (1977)
Rhabdosargus globiceps			Gonochorist	Penrith (1972)
Sarpa salpa			Rudimentary hermaphrodite	Joubert (1981a)
Sparodon durbanensis			Rudimentary hermaphrodite	This study
Spondyliosoma emarginatum			Gonochorist	Penrith (1972)

MATERIALS AND METHODS

A total of 322 S. durbanensis and 658 P. grande were examined to provide information on reproductive seasonality, size at sexual maturity, sex-ratio, gonadal development and juvenile distribution.

Reproductive seasonality

Gonads were dissected from the fish and weighed to the nearest 0.1g. The reproductive condition was recorded using the macroscopic gonad staging categories in Tables 9a & b (Buxton & Clarke 1986). To confirm the breeding season determined by macroscopic staging, a monthly gonado-somatic index (GSI) was calculated:

$$\text{GSI} = \frac{\text{gonad mass (grams)}}{\text{eviscerated body mass (grams)}} \times \frac{100}{1}$$

Fat content is an important coefficient of condition in fish. The most accurate method for determining fat content is by chemical analysis (Nikolsky 1963). This method was impractical in this study as both species are relatively large and the majority of fish were sampled under field conditions. The mass of the internal fat, expressed as a percentage of the total mass of the fish has, however, been shown to be a reliable index of total fat (Nikolsky 1963). In S. durbanensis fat was observed between the lining of the visceral cavity and the muscles of the body wall. The relative inaccessibility of this fat, combined with the time constraints of field sampling, prevented the removal and weighing of fat reserves. In P. grande fat reserves were deposited mainly in the visceral cavity. Fish were gutted in the field and the viscera were placed in labelled plastic bags and fat was separated from the viscera in the laboratory. A visceral fat index (VFI) was calculated on a monthly basis:

$$\text{VFI} = \frac{\text{visceral fat (grams)}}{\text{eviscerated body mass (grams)}} \times \frac{100}{1}$$

In P. grande a prominent fat body was usually associated with the dorso-posterior region of the gonad. This "gonadal fat" was quite distinct from the fat associated with the other organs. Gonadal fat was also weighed as an index of body fat reserves:

TABLE 9a. Description of the macroscopic appearance of ovarian development in Sparodon durbanensis and Pachymetopon grande (Buxton & Clarke 1986).

Reproductive Stage	Macroscopic Appearance
1. Inactive/resting (recovering spent)	Ovaries small and narrow in diameter, translucent, pinkish-orange in colour.
2. Developing	Ovaries swollen, yellow in colour.
3. Ripe	Ovaries very large, yellow in colour, translucent eggs.
4. Ripe-running	Roe extrudes from cloaca when pressure is applied to the ovary.
5. Partially spawned/ spent	Ovaries flaccid, bloodshot and reduced in size.

TABLE 9b. Description of the macroscopic appearance of testicular development in Sparodon durbanensis and Pachymetopon grande (Buxton & Clarke 1986).

Reproductive Stage	Macroscopic Appearance
1. Inactive/resting (recovering spent)	Testis small and narrow in diameter, greyish white in colour.
2. Developing	Testis swollen and white in colour.
3. Ripe	Testis very large, white in colour, sperm exuded when testis is cut and pressure is applied.
4. Ripe-running	Milt flows freely on handling of the fish.
5. Partially spawned/ spent	Testis bloodshot and greyish white in colour. Reduced in size.

$$\text{GFI} = \frac{\text{gonadal fat (grams)}}{\text{eviscerated body mass (grams)}} \times \frac{100}{1}$$

Size at sexual maturity and sex ratio

Size at sexual maturity was determined by recording the proportion of active (developing, ripe, ripe-running and partially spawned) fish during the breeding season for each size class. In *S. durbanensis* 100mm size classes were used whereas in *P. grande* the sample was divided into 30mm size classes. The adult sex ratio for both species was determined using fish larger than the length at 50% maturity.

Gonadal development

Sub-samples of gonads were fixed in Bouin's solution (Humason 1979) for histological examination. After 3-4 days the tissues were transferred to a 50% propyl alcohol solution for storage.

The tissues were embedded in paraplast, sectioned at 7μ and stained using Harris's haematoxylin and eosin Y (Humason 1979). Sections were examined using light microscopy.

Nursery areas

The depth distribution of juvenile and sub-adult fish was determined from diving observations in inshore waters (<38m) in the Port Elizabeth area and in the Tsitsikamma Coastal National Park.

RESULTS

Reproductive seasonality

In *S. durbanensis* individual gonado-somatic indices showed that reproductive activity extended from August to January (Figures 17a & b). Ripe running fish were recorded from November to January. In *P. grande* ripe running fish were recorded in January, March and April and individual gonado-somatic indices indicated reproductive activity from January to June (Figures 18a & b). The breeding season in both species was correlated with photoperiod and water temperature (Figure 19).

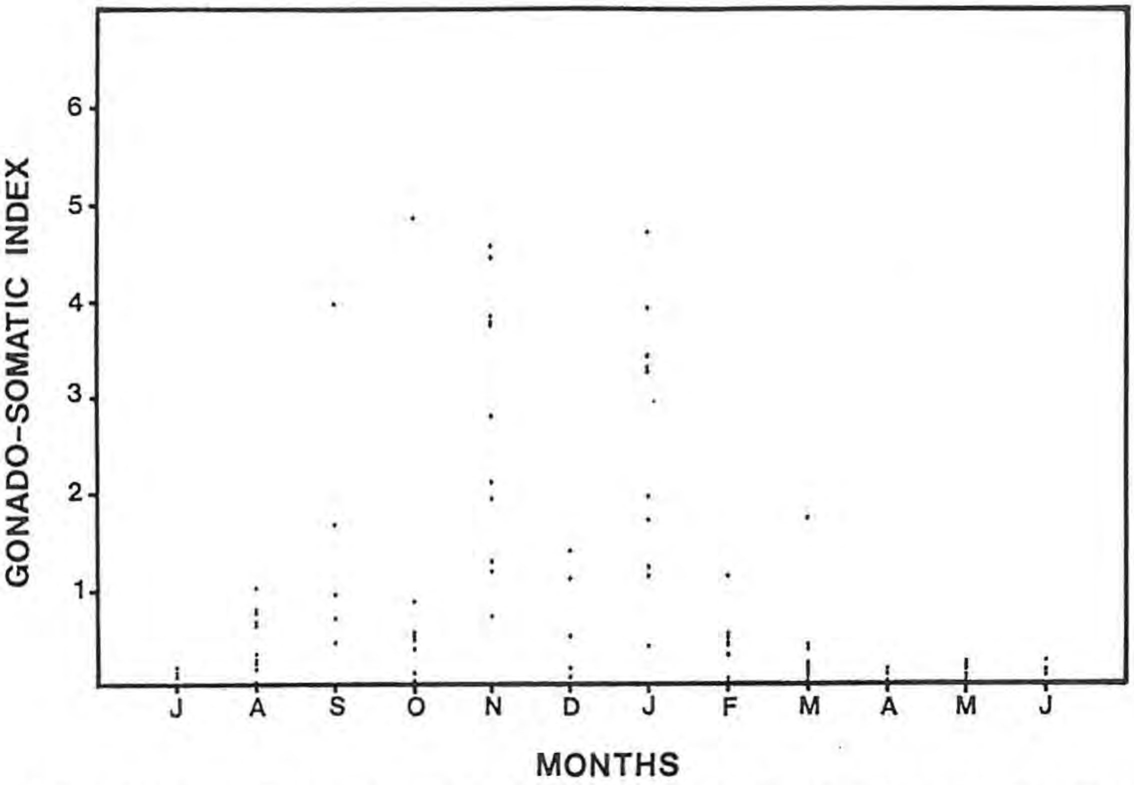


Figure 17a. Seasonal variation in gonado-somatic index for male Sparodon durbanensis, sampled between Knysna and East London from August 1984 to March 1987 (n = 88).

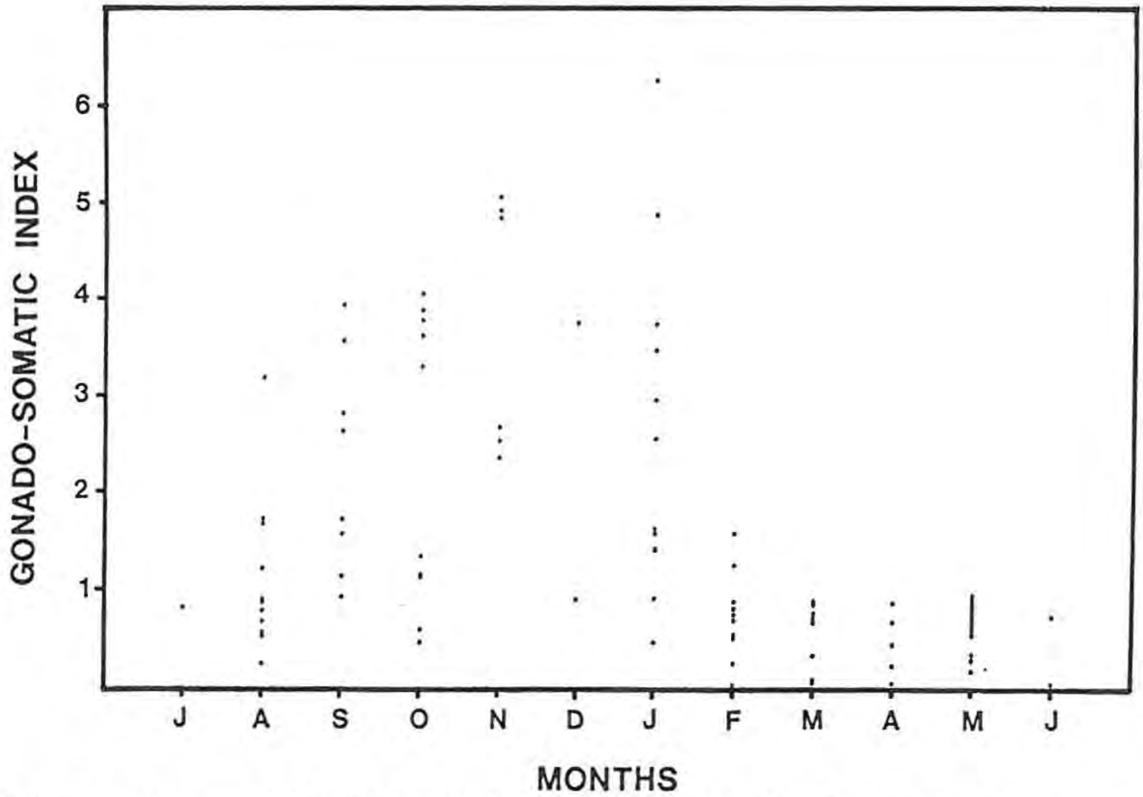


Figure 17b. Seasonal variation in gonado-somatic index for female Sparodon durbanensis, sampled between Knysna and East London from August 1984 to March 1987 (n = 86).

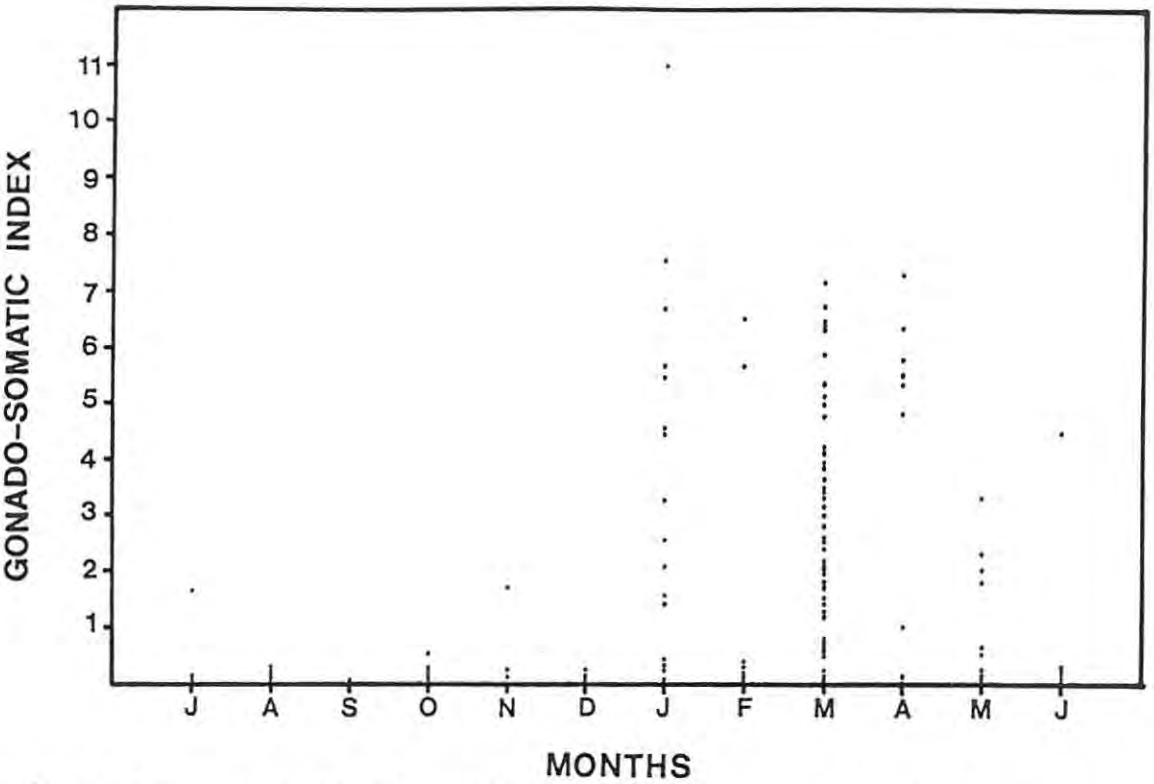


Figure 18a. Seasonal variation in gonado-somatic index for male Pachymetopon grande, sampled between Knysna and East London from August 1984 to March 1987 (n = 209).

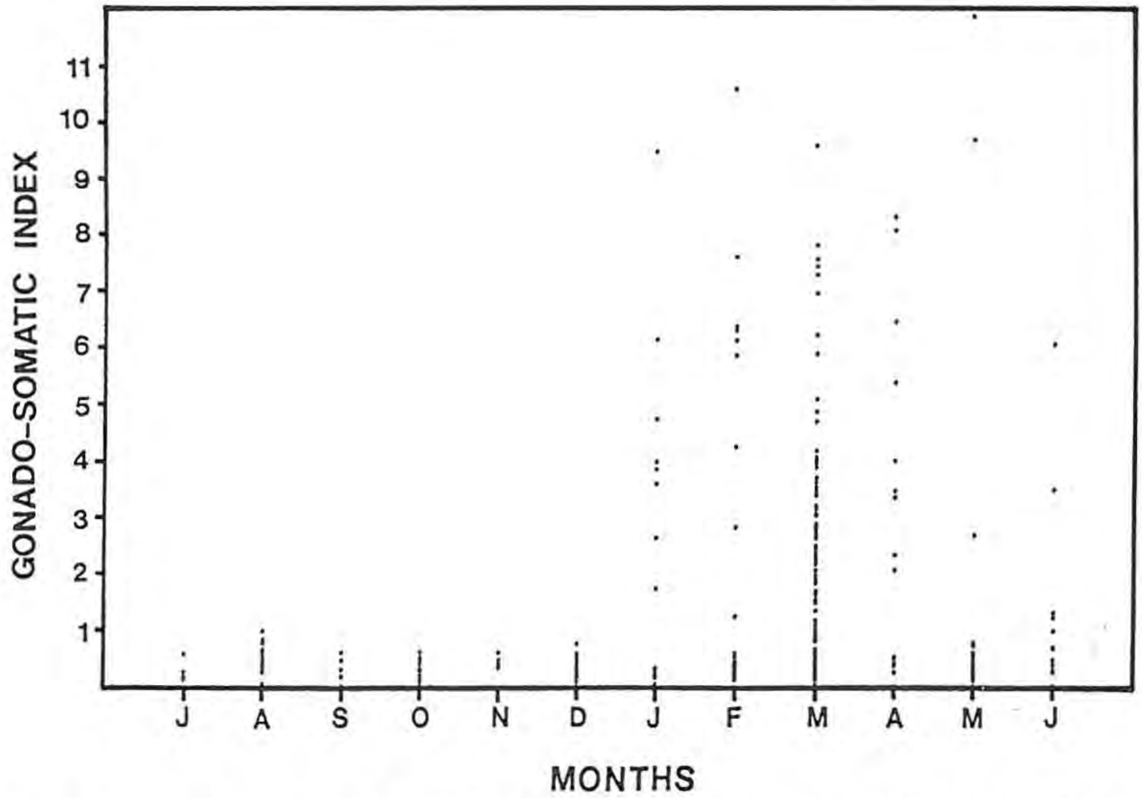


Figure 18b. Seasonal variation in gonado-somatic index for female Pachymetopon grande, sampled between Knysna and East London from August 1984 to March 1987 (n = 268).

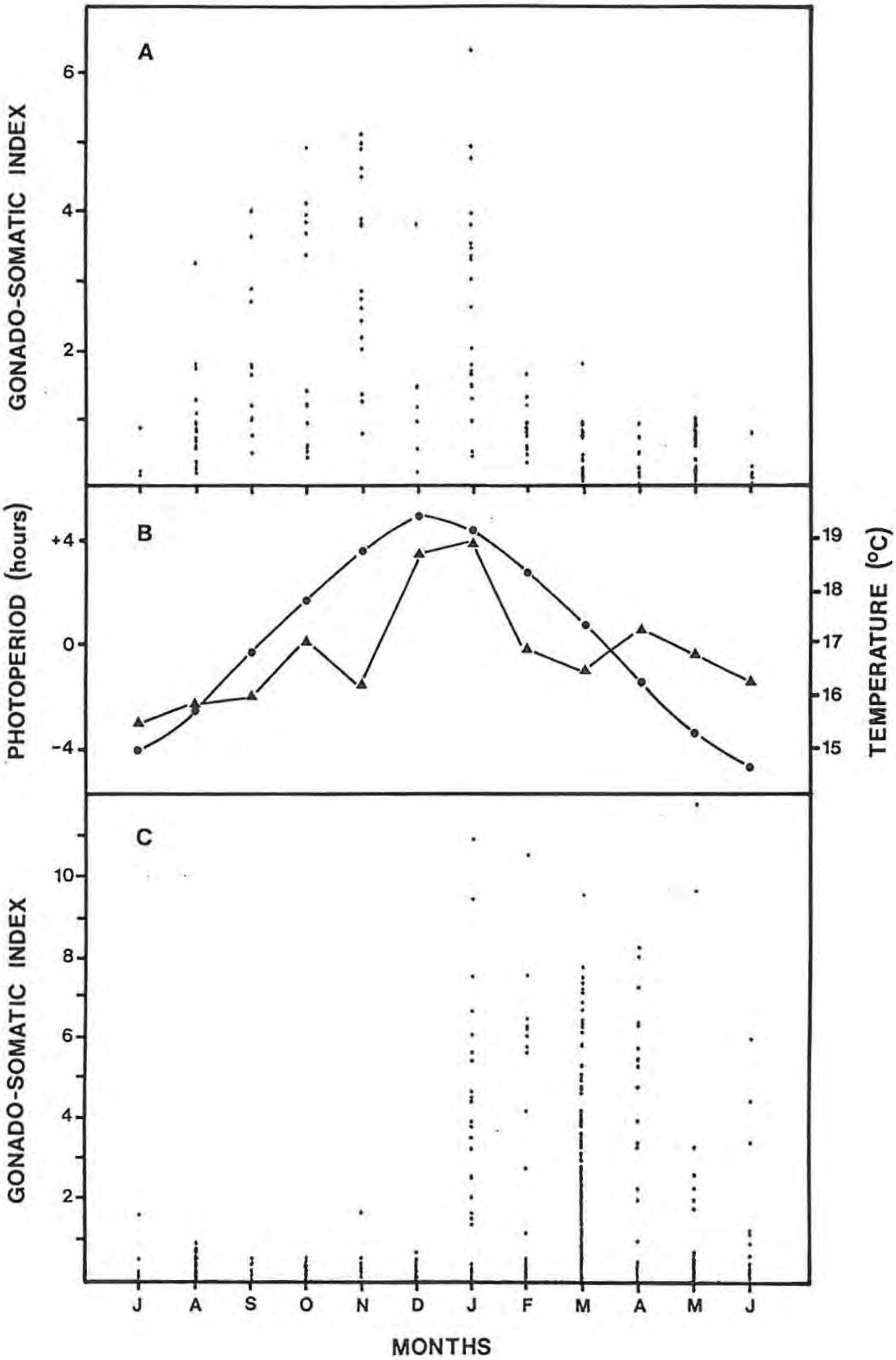


Figure 19. (A) Seasonal variation in gonado-somatic index for <u>Sparodon durbanensis</u> (n = 184) and (C) <u>Pachymetopon grande</u> (n = 477), together with mean monthly sea temperatures (▲) and photoperiod (●) in the Tsitsikamma (B). Both species were sampled between Knysna and East London from August 1984 to March 1987.

In P. grande the visceral fat index showed a sharp decline from February to May with reserves increasing from August to February (Figure 20a). The gonadal fat index was fairly constant throughout the year with a possible peak between March and May (Figure 20b).

Size at sexual maturity and sex ratio

High winds during late winter and spring frequently resulted in adverse diving conditions. This, combined with the low numbers of small musselcracker in angler catches (see Chapter 6), resulted in poor samples of S. durbanensis in the smaller size classes during the breeding season. The results do, however, provide a preliminary estimate of 50% maturity (350mm F.L.) for this species (Figure 21). This corresponded to an age of approximately 4.5 years. In P. grande 50% maturity was determined at a fork length of approximately 300mm (Figure 22) and an age of 5.5 years.

The sex ratio of adult S. durbanensis (F.L. > 350mm) was 1:1.07 (male:female; n = 222). A chi-square test showed no significant difference from the "expected" 1.1 sex ratio (χ^2 0.05,1 = 0.2883). The sex ratio of adult P. grande (F.L. > 300mm) was 1:1.16 (male:female; n = 283) which was not significantly different from the 1:1 ratio (χ^2 0.05,1 = 3.0418).

Gonadal development

The gonads of S. durbanensis and P. grande were suspended from, and situated on both sides of, the dorsal mesentery in the posterior region of the peritoneal cavity. Both gonads developed, although occasionally either the left or the right gonad was considerably smaller.

Length frequency distributions of males, females and juveniles are presented for S. durbanensis and P. grande in Figures 23 and 24, respectively. In P. grande several hermaphrodites were recognised macroscopically and were included in the analysis. Hermaphrodites in P. grande were most frequently observed in the smaller size classes. Males and females, in both species, showed similar length frequency distributions.

Histology of the ovary and oogenesis

The walls of the ovary consisted of the tunica albuginea, a thick layer of connective tissue containing blood vessels and smooth muscle fibres. The tunica albuginea projected into the ovocoele to form ovigerous lamellae and fused posteriorly to form a common oviduct. The oocytes were located in the lamellae, embedded in loose connective tissue (Figure 25a).

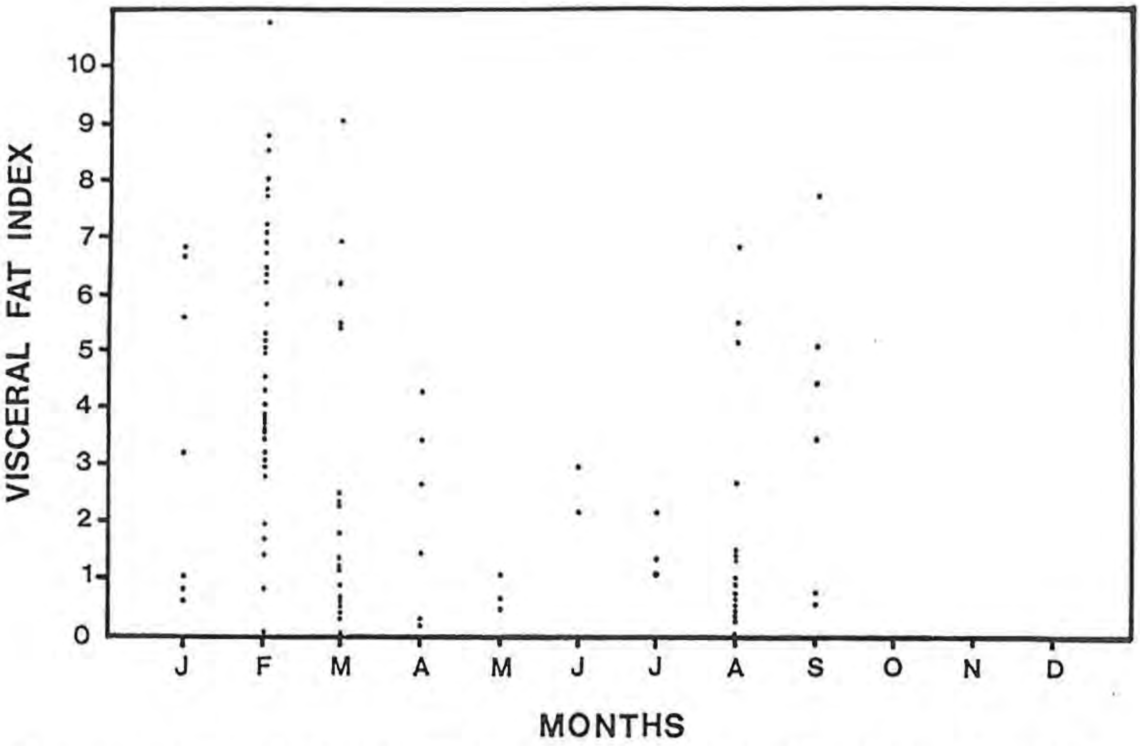


Figure 20a. Seasonal variation in visceral fat index for Pachymetopon grande, sampled between the Tsitsikamma Coastal National Park and East London from January 1985 to September 1985 (n = 118).

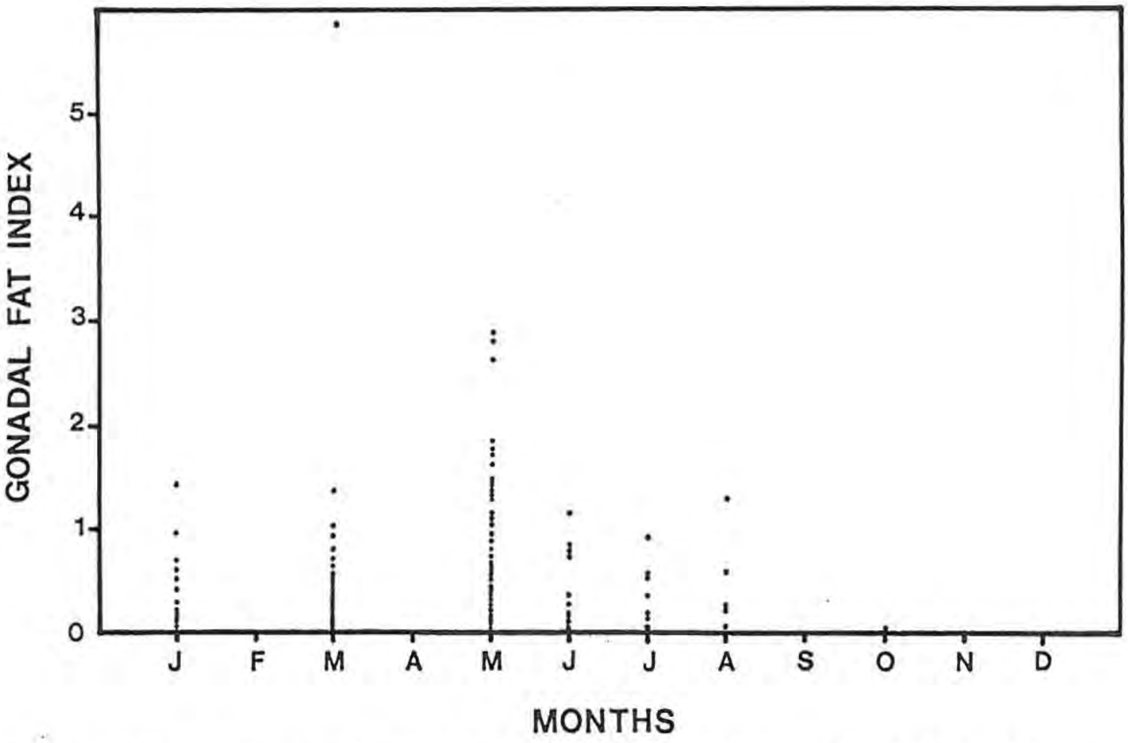


Figure 20b. Seasonal variation in gonadal fat index for Pachymetopon grande, sampled between Knysna and East London from June 1985 to March 1987 (n = 287).

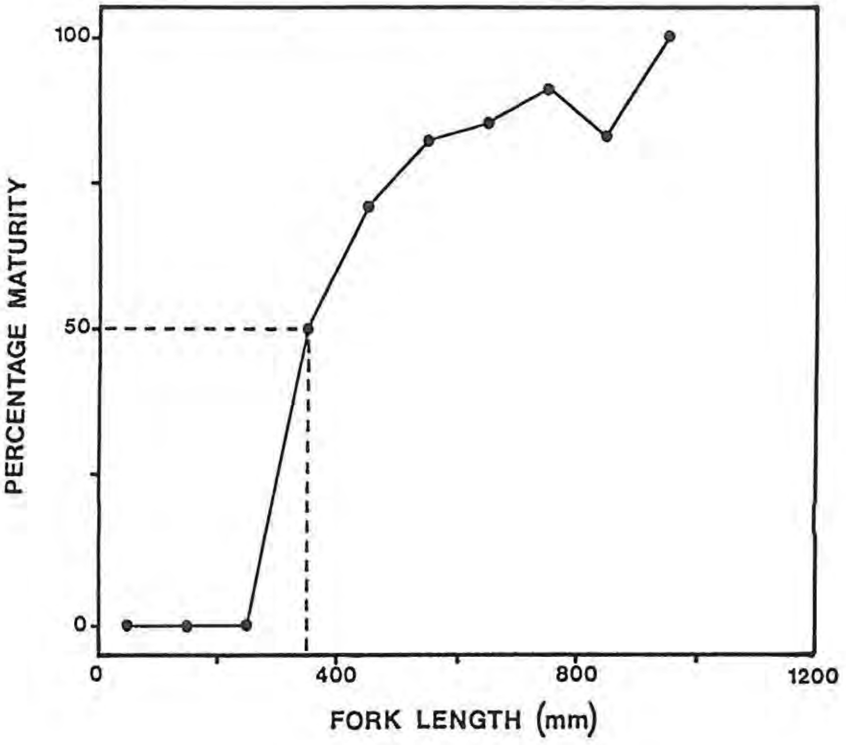


Figure 21. Length at sexual maturity in <u>Sparodon durbanensis</u>, sampled between Knysna and East London from August 1984 to March 1987 (n = 58).

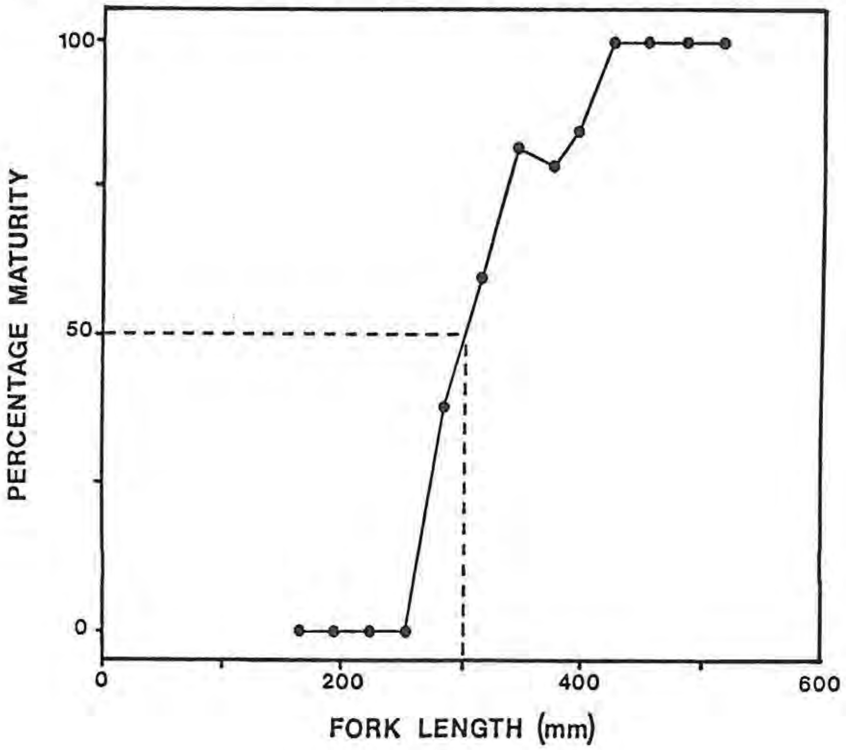


Figure 22. Length at sexual maturity in <u>Pachymetopon grande</u>, sampled between Knysna and East London from August 1984 to March 1987 (n = 240).

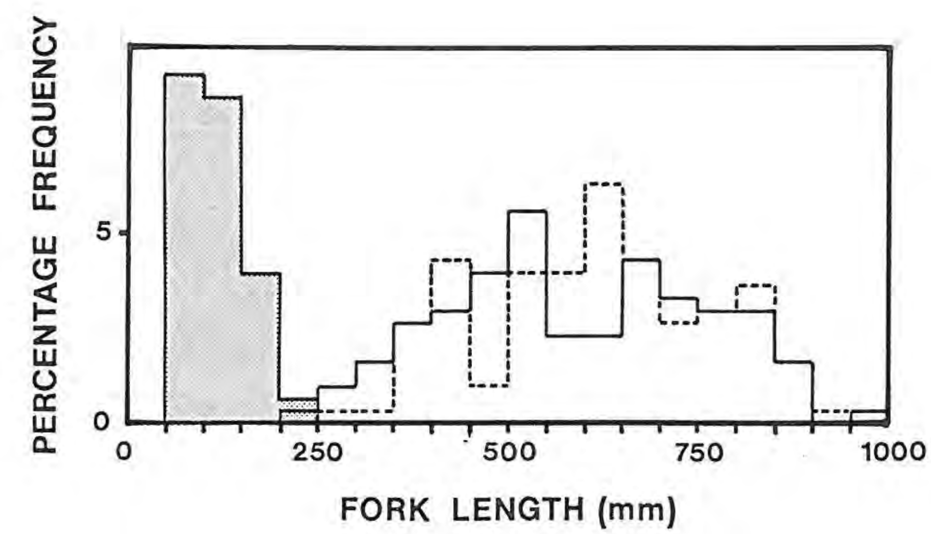


Figure 23. Length frequency analysis in _Sparodon durbanensis_, sampled between Knysna and East London from August 1984 to March 1987 (n = 301)(▭ males; ⬚ females; ▨ juveniles).

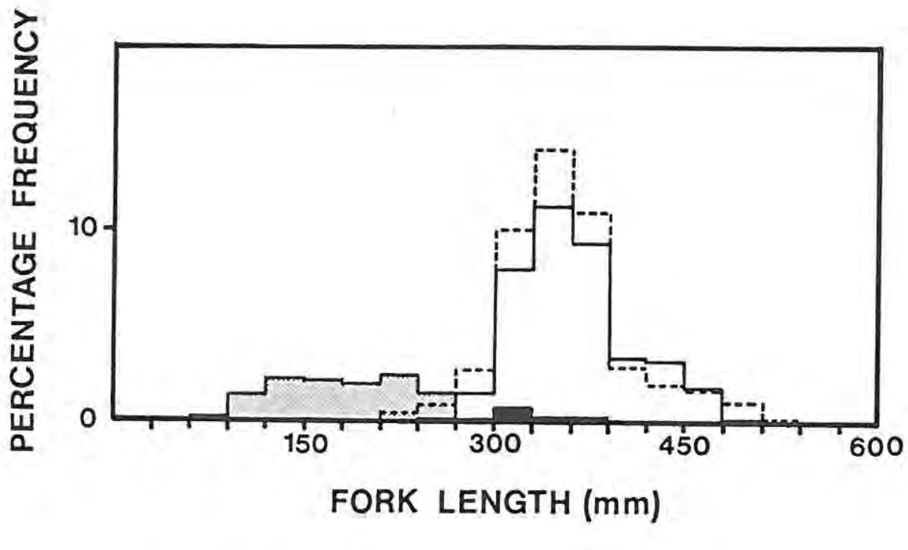
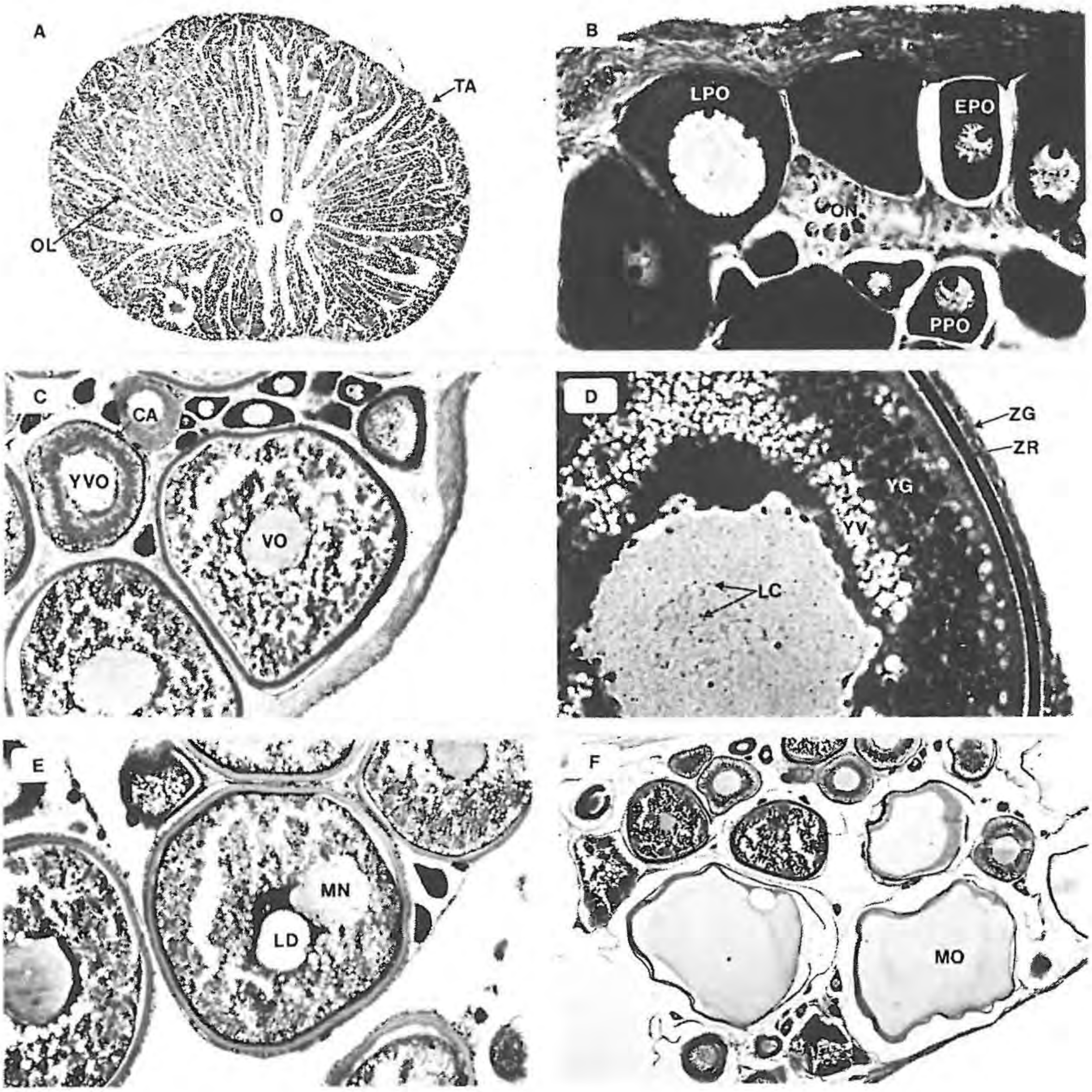


Figure 24. Length frequency analysis in _Pachymetopon grande_, sampled between Knysna and East London from August 1984 to March 1987 (n = 656) (▭ males; ⬚ females; ▨ juveniles; ■ hermaphrodites).


A
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The classification of oocyte development was based on criteria used by Yamamoto (1956a), Moe (1969), Coetzee (1983) and Cyrus & Blaber (1984). Oogenesis was similar in both species and, unless otherwise stated, the following description applied to both S. durbanensis and P. grande.

Stage 1. Oogonia (Figure 25b).

Oogonia were most frequently observed at the periphery of the ovigerous lamellae. Although present throughout the year, they were most abundant when vitellogenesis was absent. Oogonia were characterised by their small size, relatively large nucleus and lightly basophilic cytoplasm. No attempt was made to distinguish between the pre-synaptic, synaptic and post-synaptic oogonia described by Yamamoto (1956a).

Stage 2. Pre-vitellogenic Oocytes (Figure 25b).

Pre-vitellogenic oocytes were observed throughout the year but were most common in the inactive or recovery phase. They were irregular in shape and had a strongly basophilic cytoplasm. The nuclei were large, with prominent basophilic nucleoli. The development through early peri-nucleolar, peri-nucleolar and late peri-nucleolar stages (Yamamoto 1956a) was characterised by an increase in size, an increase in the number of nucleoli and a decrease in the intensity of cytoplasmic staining.

Stage 3. Yolk Vesicle Formation (Figure 25c & d).

The oocytes increased in size and changed shape, becoming more spherical. Yolk vesicles were first observed at the periphery of the cell and subsequently surrounding the nucleus. A non-cellular membrane, the zona radiata, formed between the follicular layer (theca and granulosa) and the developing oocyte. Yolk vesicle oocytes were found in S. durbanensis in spring and P. grande in summer. Coetzee (1983) and Braekevelt & McMillan (1967) attributed the vacuolated appearance of yolk vesicles to the 'washing out' of primary yolk during routine histological preparation. A more detailed cytochemical analysis (Yamamoto 1956b & 1957) indicated that the yolk vesicles gave rise to the cortical alveoli, a polysaccharide containing zone at the periphery of the ooplasm, and did not participate in the formation of massed yolk.

Stage 4. Vitellogenesis (Figure 25d & e).

This stage was characterised by the appearance of acidophilic yolk globules. Yolk globules were first observed in the cytoplasm between the yolk vesicle layers but were later distributed throughout the cytoplasm. The yolk globules at the periphery of the cell were slightly larger than those towards the nucleus. At the same time the yolk vesicles surrounding the nucleus became enlarged. The nucleus was well-defined with prominent lampbrush chromosomes, chromatin granules and peripheral nucleoli. The zona radiata thickened and pore canals were visible as cross striations. With further development oocytes continued to expand and reached a maximum size prior to ovulation. The nucleus lost definition and nucleoli, lampbrush chromosomes and chromatin granules could no longer be distinguished. The yolk vesicles coalesced to form a prominent lipid droplet which displaced the nucleus off-centre.

Stage 5. Maturing Oocytes (Figure 25f).

Coalescence of yolk globules resulted in a predominantly eosinophilic ooplasm. Histological examination of ripe tissue was unsatisfactory, the oocytes collapsing during the dehydration process due to lipid accumulation (Coetzee 1983). A ripe running P. grande female was sampled by spear in the Tsitsikamma Coastal National Park. The ripe eggs were placed in sea-water and examined under a light microscope. The oocyte diameter was approximately 0.85mm. A large, centrally placed lipid droplet of approximately 0.08mm was observed. The unfertilised eggs were buoyant in sea water. Only one ripe running S. durbanensis female was sampled. The field conditions under which this fish was sampled prevented low power microscopic examination of the ripe eggs. The large oil droplet and small size of the mature eggs in both species are characteristic of pelagic spawners (Coetzee 1983; Buxton 1987; Thresher 1984) although Craik & Harvey (1987) suggest that most of the buoyancy in pelagic eggs results from their high aqueous content rather than from lipids.

Stage 6. Atretic Oocytes (Figure 26a-c).

Atretic oocytes most commonly occurred during, or just after, the breeding season. Atresia was observed in pre-vitellogenic and vitellogenic oocytes. Atresia of stage 2 oocytes (pre-vitellogenic) was evidenced by the granular appearance of the nuclear matrix and cytoplasm. In stage 3 oocytes (yolk vesicle oocytes) atresia resulted in cytoplasmic disorganisation, a loss of nuclear integrity, and a change in appearance from a relatively turgid sphere to a flaccid, irregular-shaped cell. Atresia of vitellogenic oocytes was evidenced by the glandular appearance of the cell, with the follicular layer surrounding a degenerate mass of yolk globules and vesicles.

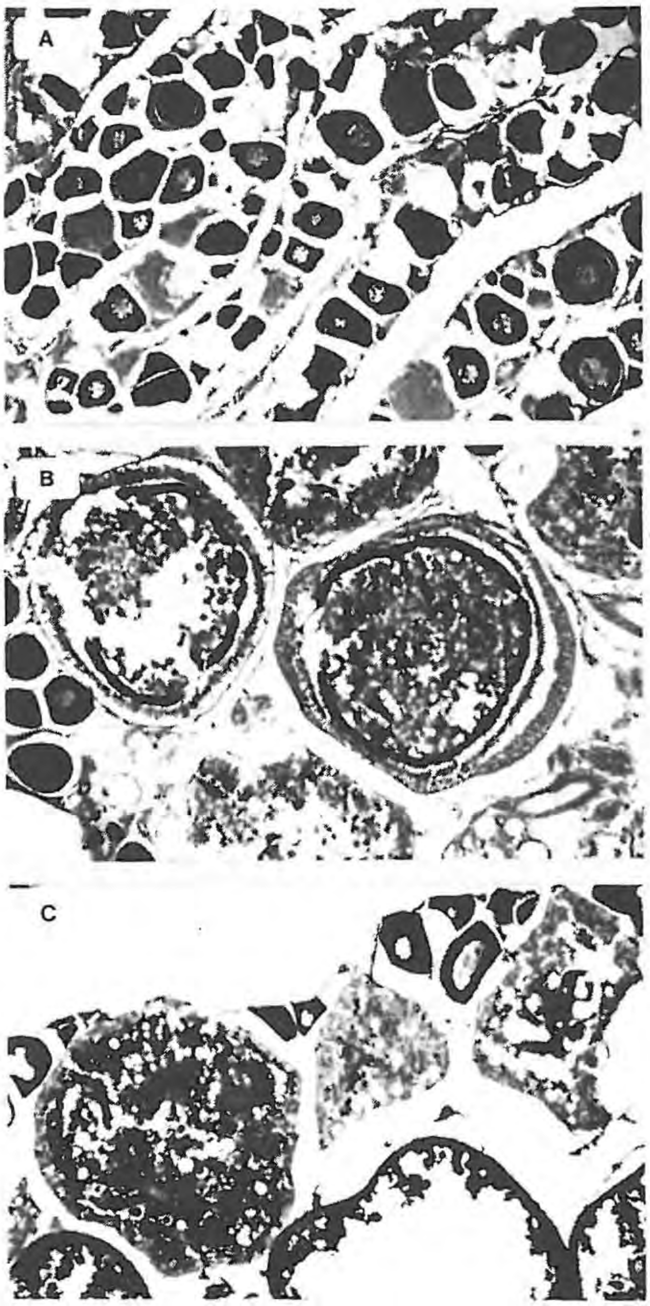


Figure 26. Photomicrographs showing ovarian atresia in *Sparodon durbanensis* and *Pachymetopon grande*.

A. Section of a *Sparodon durbanensis* ovary in the post-spawning condition. Large scale ovarian atresia is apparent, including oocytes in the pre-vitellogenic stages (x 40).

B. Section of a *Pachymetopon grande* ovary showing atresia of vitellogenic oocytes. Distinct zoning of the cytoplasm is apparent which according to Yamamoto (1956c) is a preliminary process to the partial reabsorption of the egg (x 160).

C. Section of a *Sparodon durbanensis* ovary showing atresia of late vitellogenic oocytes. Numerous yolk globules and oil droplets are visible and the cells have a characteristic glandular appearance (x 40).

Histology of the testis and spermatogenesis

In the testes of both species the tunica albuginea protruded internally forming the walls of the elongated seminiferous lobules. The lobules led into collecting ducts which combined to form the main sperm ducts surrounding the rudimentary oviduct (Figure 27a). Spermatogenesis was divided into four descriptive stages based on criteria used by Parkes (1968), Moe (1969), Coetzee (1983) and Cyrus & Blaber (1984). Spermatogenesis was similar in both species and the following description applied to both S. durbanensis and P. grande.

Stage 1. Spermatogonia (Figure 27b).

Spermatogonia were most frequently associated with the tunica albuginea but were also commonly observed in the connective tissue matrix of the internal lamellae. Spermatogonia were recognised by their large size, prominent cytoplasm and by the lightly basophilic chromatin in their nuclei.

Stage 2. Spermatocytes.

Spermatogonia divide to form spermatocytes which were distinguished from spermatogonia by their smaller size, reduced cytoplasm and by the concentration of basophilic chromatin in their nuclei.

Stage 3. Spermatids (Figure 27b).

Spermatocytes divide to form spermatids. Spermatids were easily recognised by their intensely staining (basophilic) nuclei and absence of visible cytoplasm.

Stage 4. Spermatozoa (Figure 27b).

Spermatozoa were characterised by their small size and densely staining nuclei and were present in the testes throughout the year. The evidence of spermatozoa in the testis is therefore a poor indicator of spawning activity in S. durbanensis and P. grande.

No attempt was made to distinguish between primary germ cells and spermatogonia (Cyrus & Blaber 1984), primary and secondary spermatocytes, or to trace the generations of spermatogonia that occurred before spermatocyte formation. It was also difficult to distinguish early spermatogonia from oogonia (Figure 27c).

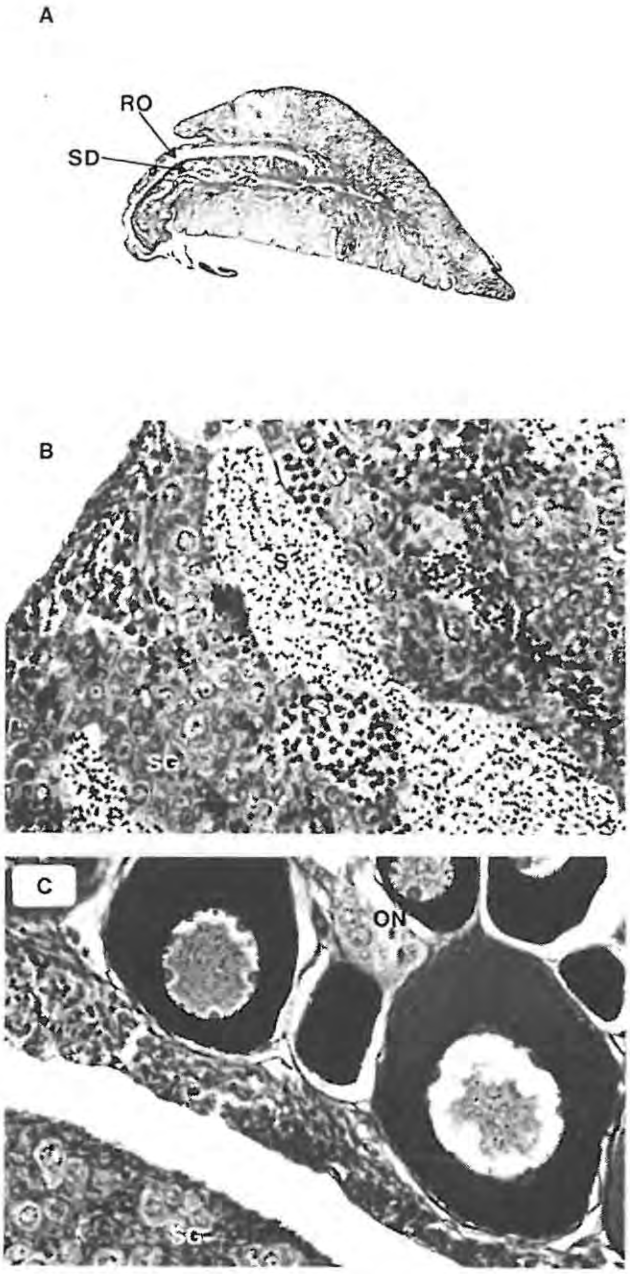


Figure 27. Photomicrographs showing the histology of the testis and spermatogenesis in *Sparodon durbanensis* and *Pachymetopon grande*.

A. Transverse section of a *Sparodon durbanensis* testis showing the rudimentary oviduct (RO) and the main sperm duct (SD) (x 6.6).

B. Section of a *Pachymetopon grande* testis showing spermatogonia (SG), spermatids (SC) and a lobule filled with sperm (S) (x 160).

C. Section of a *Pachymetopon grande* ovotestis showing the similarity between spermatogonia (SG) and oogonia (ON) (x 160).

The ovotestis

In small fish of both species each gonad comprised an ovotestis. The ovarian and testicular elements were separated by connective tissue, the typical pattern in the ovotestes of Sparidae (Atz 1964). Posteriorly the tunica albuginea of the ovarian elements fused to form a common oviduct. The sperm ducts were located in the connective tissue surrounding the oviducts. Very young fish possessed non-functional gonads with varying degrees of ovarian and testicular development. In large fish, either the ovary or the testis became dominant resulting in either a functional female or male. In the testis of both species early stage oocytes were observed surrounding a rudimentary oviduct. No rudimentary testicular tissue was observed in the ovaries of either species.

In S. durbanensis the early gonad was dominated by spermatogonia (Figure 28a). Two developmental pathways were observed. A volumetric increase in the ovarian element resulted in the development of a functional female (Figure 28b). Alternatively, continued testicular development resulted in the development of a functional male. In this case, the ovarian element persisted as a few isolated early stage oocytes, surrounding a rudimentary oviduct (Figure 28c). The testicular elements of the ovotestes of S. durbanensis were inactive and no evidence of fish first functioning as males and then differentiating into females (protandry) was obtained.

In P. grande ovarian tissue dominated the early gonad, the testicular element being present as a small ridge of spermatogonia on the ventral surface of the ovary (Figure 29a). Continued development of the ovary resulted in a functional female (see Figure 25a). In the development of a functional male, the testicular element increased in size, enveloping the ovary (Figure 29b-d). This testicular enlargement was accompanied by large scale ovarian atresia, resulting in a few isolated pre-vitellogenic oocytes surrounding a rudimentary oviduct in the adult testis. In some cases this ovarian atrophication involved oocytes in a relatively advanced stage of development (yolk vesicle oocytes). Coetzee (1986) suggested that active spermatogenesis in the ovotestis of Diplodus sargus capensis indicated a special type of protandric development, where such individuals had the capacity to develop into either sex. The presence of yolk vesicle oocytes in the ovotestis of P. grande should not, however, be taken to represent a special form of protogyny. No vitellogenic oocytes, either developing or atretic, were observed in P. grande ovotestes and gonadal development is not necessarily indicative of spawning activity. Smale (in press) recorded "abnormal" atretic primary yolk vesicle oocytes in the ovotestes of Petrus rupestris, a sparid commonly found on deeper reefs off the south-east coast of South Africa. These observations suggest that oogenesis may be common in the ovotestes of developing male sparids which exhibit rudimentary hermaphroditism. This ovarian development may serve

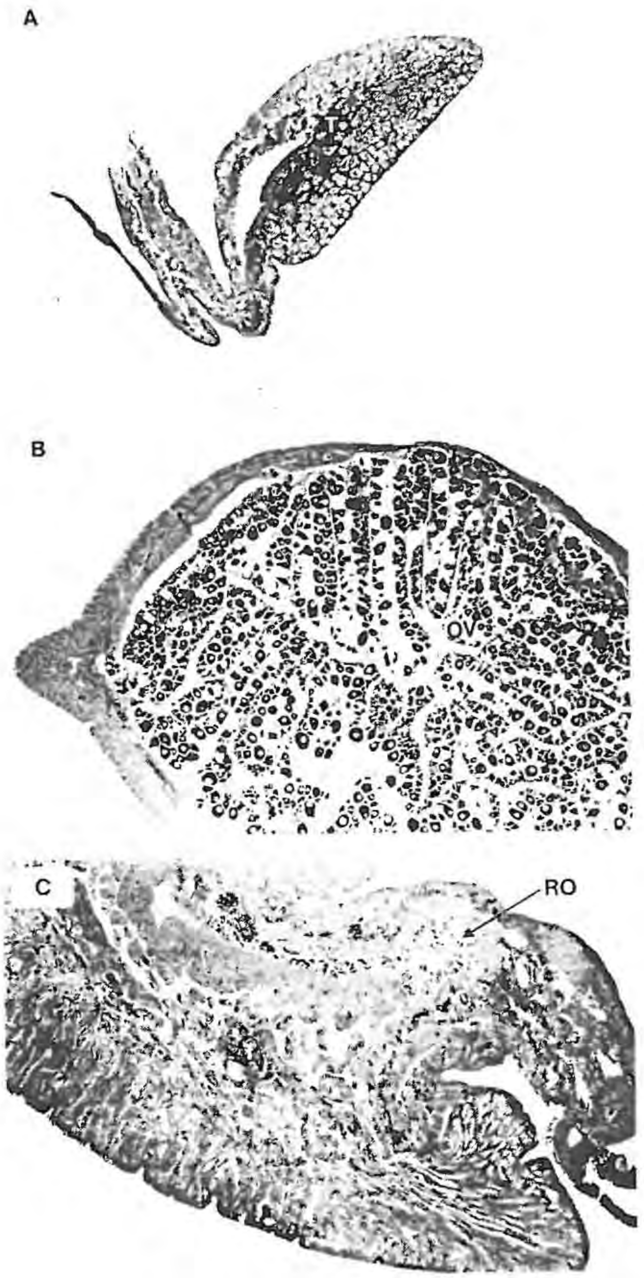


Figure 28. Photomicrographs showing ovarian and testicular development in <u>Sparodon durbanensis</u>.

A. Transverse section of the gonad of a small juvenile (F.L. = 177mm). The dominance of spermatogonia in the early gonad is apparent . T = testis (x 16).

B. Transverse section of the ovotestis of a developing female (F.L. = 301mm). The testis (T) is seen as a ridge of tissue on the ventral surface of the ovary (OV). A volumetric increase in the ovarian element results in the development of a functional female (x 10).

C. Transverse section of the gonad of a small male (F.L. = 417mm). The ovarian element persists as a few early stage oocytes surrounding the rudimentary oviduct (RO). T = testis (x 16).

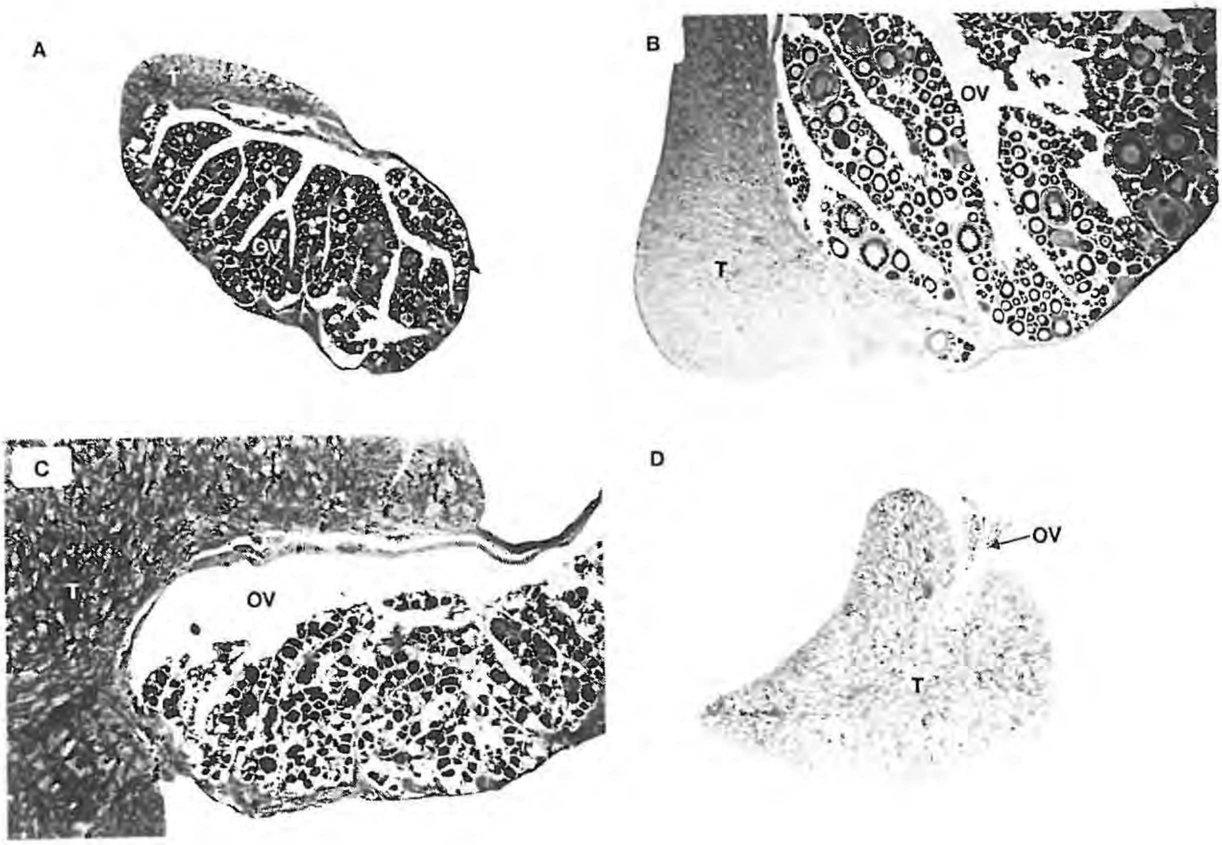


Figure 29. Photomicrographs showing testicular development in <u>Pachymetopon grande</u>.

A. Transverse section of the ovotestis of a sub-adult fish (F.L. = 288mm) showing the testis (T) as a small ridge of tissue on the ventral surface of the ovary (OV) (x 10).

B. Transverse section of the ovotestis of a developing male (F.L. = 269mm). The testicular element (T) enlarges, enveloping an atretic ovary (OV) (x 10).

C. Transverse section of the ovotestis of a developing male (F.L. = 320mm) showing progressive ovarian atrophication (x 10).

D. Transverse section of the gonad of a functional male (F.L. = 322mm) showing a dominant testis (T) and reduced ovary (OV) (x 6.6).

some hormonal function but may also merely reflect the recent evolutionary history of the species.

These histological results indicate that *S. durbanensis* and *P. grande* are rudimentary hermaphrodites in which maturation of either the testis or the ovary appears to follow a stage of sub-adult intersexuality where non-functional elements of both sexes are present.

Nursery areas

The length frequency distribution of juvenile *S. durbanensis*, collected using rotenone, is presented in Figure 30. No *P. grande* were collected using this sampling technique. Diving observations showed that small *S. durbanensis* were common in the shallow subtidal (<2m). *P. grande* were most commonly observed over flat reefs, dominated by the rhodophyte *Plocamium corallorhiza*, down to approximately 10m. Juveniles of both species were sampled by spear.

DISCUSSION

Reproductive seasonality

A number of studies provide preliminary information on reproductive seasonality in South African Sparidae (Table 10). These results indicate that South African sparids generally breed during spring and summer. In *S. durbanensis* and *P. grande* the gonado-somatic indices showed fairly restricted breeding seasons but the factors which result in this synchrony in gonadal development in the individuals of each species, and consequently in the appearance and development of larvae, are not known.

Photoperiod and temperature have been the most frequently studied environmental factors with respect to control of sexual cycling. Photoperiod is most commonly temperature sensitive and has been shown to act independently of temperature in only two species (de Vlaming 1972). Garratt (1986a) showed good correlation between gonad maturation and increasing photoperiod in *Chrysoblephus puniceus* and *Cheimerius nufar*, but no correlation with water temperature. Close correlation between breeding season and both photoperiod and temperature has, however, been demonstrated in *Cheimerius nufar* (Coetzee 1983), *Chrysoblephus cristiceps* and *Chrysoblephus laticeps* (Buxton 1987). In *S. durbanensis* peak reproductive activity was also closely correlated with increased photoperiod and water temperature. This was not, however, observed in *P. grande*.

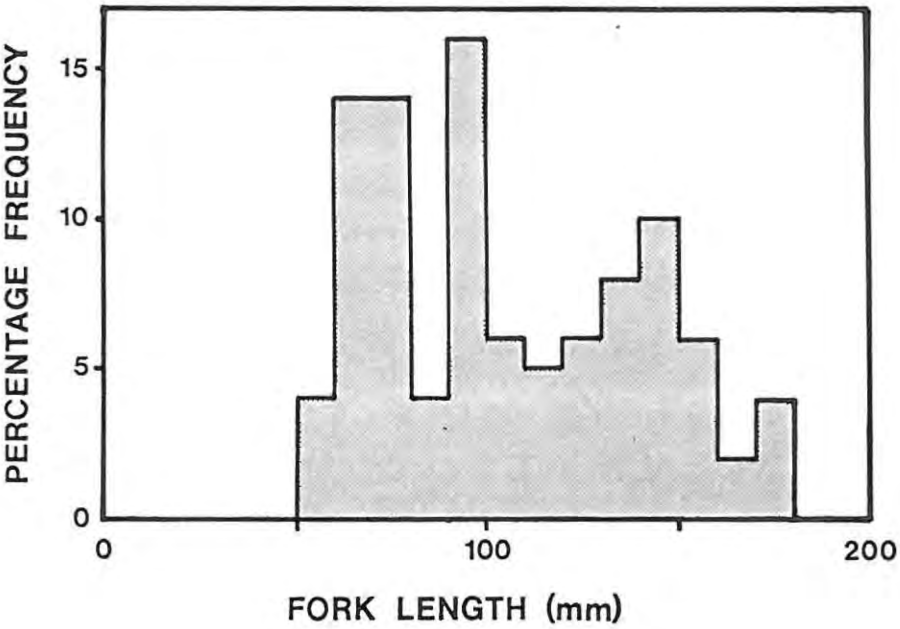


Figure 30. Length frequency analysis of juvenile Sparodon durbanensis, sampled by rotenone poisoning of shallow (<2m) subtidal waters in the Port Elizabeth area from October 1985 to September 1986 (n = 49).

TABLE 10. A literature review of the peak breeding seasons in South African Sparidae.

Species	Breeding Season	Reference
Argyrozona argyrozona	Oct - Feb	Nepgen (1977)
Cheimerius nufar	Aug - Oct	Coetzee (1983), Garratt (1986a)
Chrysoblephus cristiceps	Nov - Jan	Buxton (1987)
Chrysoblephus laticeps	Oct - Jan	Buxton (1987)
Chrysoblephus puniceus	Aug - Oct	Garratt (1986a)
Diplodus sargus capensis	Oct - Feb	Coetzee (1986)
Lithognathus lithognathus	July - Aug	Mehl (1973)
Pachymetopon aeneum	Sept - March	Buxton & Clarke (1986)
Pachymetopon blochii	All year	Nepgen (1977)
Pachymetopon grande	Jan - June	This study
Petrus rupestris	June - Oct	Smale (in press)
Polysteganus undulosus	July - Oct	Ahrens (1964)
Pterogymnus laniarius	Sept - May	Hecht & Baird (1977)
Rhabdosargus globiceps	Aug - Feb	Talbot (1955)
Sparodon durbanensis	Aug - Jan	This study

Good correlations between breeding season and photoperiod and temperature do not necessarily indicate that these factors are the environmental cues stimulating gonadal development. A terrestrial example of this is the stimulation and inhibition of reproductive cycling in the rodent, Microtus montanus, by seasonal changes in chemical compounds in the plant food resources. This strategy ensures that offspring are produced at the optimal time for survival of the young. (Berger, Sanders, Gardner & Negus 1977; Negus & Berger 1977; Berger et al. 1981). Lumping of reproductive data, collected for this species, over several years would probably result in a good correlation between the increased photoperiod and temperature associated with spring. Chemical cues, however, enable close tracking of the food resource and optimal timing of reproductive effort in a variable environment.

P. grande is the only South African sparid in which peak breeding has been recorded from late summer to mid-winter. P. grande is restricted to the warmer waters from the south-east Cape coast to Madagascar. Other South African sparids with similar distributions, including Cheimerius nufar and Polysteganus undulosus, appear to breed during spring (Ahrens 1964; Coetzee 1983; Garratt 1986a). No geographical trends in reproductive cycling were therefore apparent. P. grande is predominantly herbivorous whereas the other species in Table 10 are largely carnivorous or omnivorous. It is possible that this dietary difference is responsible for the difference in reproductive timing. Macroalgal productivity cycles are less marked in the subtidal environment than those in the intertidal. Biomass measurements are however, lowest during April in the Port Elizabeth area (W. du Preez, University of Port Elizabeth, pers.comm.). The breeding season in P. grande may therefore be timed to ensure that the settlement of juveniles on subtidal reefs coincides with the beginning of the macroalgal annual cycle. Unfortunately at present the early life history of the species, including the duration of egg and larval phases, is unknown.

Berger et al. (1981) suggested that in terrestrial mammals photoperiod changes were sufficient reproductive cues in species with longevities of several years, living in highly predictable environments. The seasonal aspects of exogenous regulation of teleost reproductive cycles has, however, been poorly examined and few generalisations can be made with regard to phylogenetic, geographic or ecological relationships (de Vlaming 1972).

Van der Elst (1981) stated that musselcracker were more numerous along the east coast in winter and the south coast in summer. Discussions with spearfishermen operating in Natal waters indicated that S. durbanensis were most commonly encountered during June and July. Eastern Cape anglers and spearfishermen generally consider peak "cracker season" to extend from August to December. This period coincides with the breeding season in this species. A study of the Port Elizabeth rock-angling fishery (see Chapter 6) showed that S. durbanensis were caught throughout the year and that peak catches, between August and November, coincided with a seasonal targeting of effort at this species. Research divers, spearfishing with SCUBA between the Tsitsikamma Coastal National Park and Port Elizabeth, sampled S. durbanensis throughout the year. In addition large numbers of musselcracker were sampled out of "cracker season" at the three National Spearfishing Championships held in Eastern Cape waters (see Chapter 6).

These results indicate that S. durbanensis are present in Eastern Cape waters throughout the year. The apparent increase in musselcracker in Natal waters during the winter months may reflect a preference for relatively cool water rather than a seasonal migration. The warm temperate distribution of S. durbanensis provides circumstantial evidence in support of this statement (Mary-Louise Penrith 1972). The above results suggest that the seasonality of S. durbanensis catches in the Eastern Cape probably results from a seasonal targeting of effort at breeding schools and not from a seasonal migration. The increased availability of fish at this time may result from environmental or behavioural factors. Turbulent inshore conditions, resulting from the strong south-easterly winds usually associated with late winter and spring in the Eastern Cape, may result in musselcracker foraging in relatively shallow water and therefore being more susceptible to exploitation by rock-anglers during this period. Similarly, the energetic requirements of reproduction may cause musselcracker to forage more actively during the breeding season, with consequent increased exploitation by anglers. Increased intra-specific interactions during the breeding season in S. durbanensis may also result in decreased diver awareness, with consequent increased spearfishing catches. These observations are largely speculative and an intensive tagging study would clarify whether S. durbanensis exhibit seasonal migrations.

P. grande is generally regarded as a "summer fish" by Eastern Cape anglers (Dave Alcock, Port Elizabeth, pers. comm.). This is substantiated by peak CPUE values and a seasonal targeting of effort at this species between September and April in the Port Elizabeth rock-angling fishery (see Chapter 6). Diving observations, however, showed that this species was present throughout the year. These results indicate that maximum exploitation of P. grande also occurs during the breeding season and that the seasonality in P. grande catches may also result from a seasonal targeting of effort at aggregations of fish in breeding condition.

Animals in relatively good condition show high total body fat reserves when compared to those in poor condition, where these reserves have been mobilised. Fat reserves may be mobilised during periods of migration, reproduction or nutritional stress (Nikolsky 1963; Fishelson, Montgomery & Myrberg 1985a). Fat content is not only important from the quantitative aspect but also in terms of its' composition. Fats which consist principally of unsaturated fatty acids are deposited for daily expenditure, while fats with a predominance of saturated acids are deposited to form a reserve against particularly stressful periods such as migration (Nikolsky 1963).

Fishelson et al. (1985a) showed the presence of a retro-peritoneal fat body closely associated with the gonads of tropical surgeonfishes. The appearance, consistency and thermal composition of the body differed from omental fat within the body cavity. Both omental fat and gonadal fat reserves declined with gonadal development but the omental fat declined more rapidly. This difference was attributed to omental fat having a broader role in metabolism, with gonadal fat being mobilised to support gonadal function during stressful reproductive periods.

Despite the absence of data in some months and the relatively small sample sizes, the visceral fat index and gonadal fat index in P. grande showed definite trends. Visceral fat reserves declined with gonadal development whereas gonadal fat reserves were relatively constant throughout the year. These results indicate that the energetic demands in this species were normally met by the mobilisation of visceral fat reserves and that gonadal fat may be specifically reserved to support gonadal development during periods of stress.

Spawning behaviour

In S. durbanensis and P. grande the gonado-somatic indices of male fish were comparable with those of females, during the breeding season. Buxton (1987) considered relatively large testis size to be indicative of group spawning behaviour, the large testis being advantageous under conditions of intense sperm competition. S. durbanensis and P. grande were frequently observed in schools of up to 30 large fish, during the breeding season. Research spearfishing showed that these schools contained individuals of both sexes. These observations combined with the marked seasonality of angler catches discussed previously, provides evidence in support of group spawning behaviour in both species. In group spawners little sexual selection would occur and monomorphism would therefore be expected. Both S. durbanensis and P. grande appear to be monomorphic, although it is possible that temporary colour differences involving male-specific colour patterns during courtship and spawning occur (Thresher 1984). Monomorphism may therefore provide additional evidence in support of group spawning behaviour in S. durbanensis and P. grande.

Sex ratio

Histological examination of gonadal development, the similar length frequency distributions of males and females and the presence of hermaphrodites in the smaller size classes, provides evidence for rudimentary hermaphroditism in S. durbanensis and P. grande. The presence of an ovotestis in the early stages of development prevented the accurate determination of the functional sex. As a result, only fish larger than the length at 50% maturity were used to determine the sex ratio. The adult sex ratios of 1:1.07 (male:female; n = 222) in S. durbanensis and 1:1.16 (male:female; n = 283) in P. grande were not significantly different from a 1:1 ratio. Krebs & Davies (1981) suggest that a deviation from 1:1 in the sex ratio results in the rarer sex being at an advantage and therefore adults which produce offspring of the rare sex will be favoured by natural selection. Therefore, only when the sex ratio is 1:1 will the success of males and females be equal and the population stable. When the investment in producing offspring of opposite sex differs, the stable strategy in evolution is, however, for parents to invest equally in the two sexes and not to produce equal numbers (Krebs & Davies 1981). The definition of rudimentary hermaphroditism, according to Atz (1964), is normal hermaphroditism exhibited by an individual that functions only as a male or only as a female. According to Kosswig (1932 in Atz 1964), this type of hermaphroditism occurs only in species with genotypically determined sex. Krebs & Davies (1981) suggest that in a species in which sex is determined genetically there is little evidence that the sex ratio can vary from 1:1.

If S. durbanensis and P. grande are group spawners the potential for polygamy would be reduced (Buxton 1987) and minimal sexual selection would occur. An operational sex ratio close to unity is therefore expected (Emlen & Oring 1977). From the discussion above it is not surprising that the sex ratio in S. durbanensis and P. grande was not significantly different from the expected 1:1 ratio.

Nursery areas

The nursery function of inshore waters and estuaries for juvenile fish is well documented (Lenanton 1982; Blaber, Young & Dunning 1985). It has been postulated that these areas provide suitable food and shelter for juvenile fish. In addition it has been demonstrated that many juveniles prefer shallow waters of high turbidity, possibly because they are linked to areas of high productivity and at the same time enhance escape from predators (Blaber 1981). The nursery function of estuaries (Wallace & van der Elst 1975; Day, Blaber & Wallace 1981; Wallace, Kok, Beckley, Bennett, Blaber & Whitfield 1984), the surfzone of sandy beaches (Lasiak 1981, 1983), surf zone reefs (Berry, van der Elst, Hanekom, Joubert & Smale 1982), shallow areas with soft substrata (Smale 1984; Buxton, Smale, Wallace & Cockcroft 1984) and tidal rock pools (Beckley 1985a & b; Bennett & Griffiths 1984; Bennett 1987) has been shown for a number of South African marine fish species. The degree of dependence on a particular habitat varies for different species (Wallace, Kok, Beckley, Bennett, Blaber & Whitfield 1984).

Gibson (1969, 1982) in his reviews of the biology and behaviour of intertidal fishes suggested that the intertidal zone may serve as a favourable nursery habitat for a number of fish species. The presence of juvenile S. durbanensis in tidal rock pools along the south and east coasts is well documented (Christensen 1976; Beckley 1985a & b; Day, Field & Penrith 1970; Brownell 1979). Juveniles of this species are also found in shallow subtidal areas (Buxton & Smale 1984; Christensen 1976; Bennett 1987). Beckley (1985a) recorded a single specimen of 18mm from the Zostera beds in the lower reaches of the Swartkops estuary.

Bennett (1987) noted the low numbers (Day et al. 1970) and absence (Bennett & Griffiths 1984; Jackson 1950; Bennett 1987) of juvenile S. durbanensis from tidal pool studies in the South-western and Western Cape, although he stated that they were commonly observed in shallow subtidal waters. Similarly, Bennett (1987) noted that juvenile S. durbanensis were rare (Christensen 1976) or absent (Christensen & Winterbottom 1981) in Eastern Cape tidal pool studies. On the basis of these observations Bennett (1987) suggested that Beckley (1985a) over-stressed the importance of tidal rock pools as a nursery area for S. durbanensis.

The mean length of juvenile S. durbanensis sampled in shallow subtidal waters in the Port Elizabeth area (Figure 30) was 106 ± 34.7mm F.L. with 65% of the sample being larger than 100mm T.L. Beckley (in press) performed a similar analysis on juvenile S. durbanensis collected from tidal rock pools in the same area and showed a mean length of 53mm T.L. with 95% of the sample smaller than 100mm T.L. These results indicate that tidal rock pools may be important nursery areas for small juveniles, with juveniles older than one year (>77mm F.L.) being more commonly found in subtidal areas. Subtidal rotenone sampling, combined with spearfishing and visual estimates of the size of subtidal juvenile S. durbanensis, could be used to determine whether a similar distributional pattern occurs in the Southern and South-western Cape.

To summarise, a detailed histological examination of gonadal development combined with length frequency analysis showed that S. durbanensis and P. grande are rudimentary hermaphrodites. Both species have fairly restricted breeding seasons which coincide with maximum exploitation by the recreational fishery. This peak in exploitation appears to result from a seasonal targeting of angler effort at schools of fish in breeding condition, and combined with relatively late maturation in both species, is an important consideration with respect to management. Results indicate that both species are group spawners with pelagic eggs. The spawning behaviour as well as the egg, larval and early juvenile stages of the life cycles of both species, however, remain unknown. The nursery function of shallow subtidal weed beds for juvenile P. grande was established. The importance of intertidal pools as nursery areas during the first year of life, with subsequent utilisation of the shallow subtidal, for S. durbanensis juveniles was suggested. The combination of late maturation, slow growth and longevity make both species particularly susceptible to over-exploitation in the size-selective recreational fisheries. These aspects are discussed in relation to the management of the resource in Chapter 7.

CHAPTER 5 - FEEDING

INTRODUCTION

Much of our current understanding of the autecology, production and ecological role of fish populations has been derived from dietary studies based on the analysis of the contents of the alimentary tract (Windell & Bowen 1978). Two main categories of study exist. The one examines the diet of a fish population with a view to assessing a species' nutritional standing in the context of the community. This includes dietary comparisons between different sub-groups of the same species or different species living in the same or comparable habitats as well as studies of feeding periodicity and seasonal variation in the diet. The other category comprises studies which attempt to estimate the total amount of food consumed by a fish population and may involve calculation of a daily ration or an energy budget (Hyslop 1980). This study was restricted to the former category.

The trophic relationships of South African reef fishes are poorly understood compared with those of fish inhabiting tropical reefs (Smale 1986). Recent studies have, however, provided information on several species (Nepgen 1977; Christensen 1978; Joubert & Hanekom 1980; Coetzee & Baird 1981a; Nepgen 1982; Bennett, Griffiths & Penrith 1983; Buxton 1984; Garratt 1984; Buxton & Clarke 1986; Smale 1986; Coetzee 1986; Bennett & Griffiths 1986; Buxton 1987; Pulfrich 1987). With the exception of an analysis of the contents of the alimentary tracts of juvenile S. durbanensis, sampled from intertidal pools in the Port Elizabeth area (Beckley, in press), the diets of S. durbanensis and P. grande have received no attention to date. This study provides quantitative information on the diet of these two species sampled from subtidal waters in the Eastern Cape.

Berg (1979) recorded differences in the contents of the oesophagus and stomach when compared to those of the entire digestive tract. He showed that differential digestion and passage rates of prey in the alimentary tract may cause errors in the determination of dietary importance. For this reason this study was restricted to an analysis of the contents of the alimentary tract between the last gill arch and the gut caecae (Christensen 1978). This section of the alimentary tract is hereafter referred to as the "stomach".

ANALYSIS OF THE DIET OF THE MUSSELCRACKER, S. DURBANENSIS

Methods

Stomachs were collected from 191 fish sampled by spear or from anglers' catches between

Knysna and East London between August 1984 and March 1987. A further 34 stomachs were collected by monthly rotenone sampling, in shallow (<2.0m) subtidal waters in the Port Elizabeth area, from October 1985 to September 1986. The fork length (F.L.) of each fish was measured to the nearest millimetre. Stomach contents were removed and preserved in a buffered 10 percent formalin solution. The contents were washed in running water using a sieve with a mesh size of 0.4mm. Examination of several stomachs taken from small fish, by dissection in water under a microscope, showed that this mesh size was sufficient to retain the smallest prey items in the diet.

Hyslop (1980) proposed that the best measure of dietary importance was one where both the amount and the bulk of a food category were recorded. A numerical percentage contribution was not applicable to all food categories in this study, the algal component not occurring in discrete units and mastication of prey resulting in difficulty in estimating the numbers of some species e.g. Pyura stolonifera. The frequency of occurrence method, however, provided a useful measure of the amount of each food category. Gravimetric determination of bulk contribution was not suitable for analysing stomach contents from small fish because of the small stomach capacities and the small size of individual prey. This problem could not be solved by pooling the wet weights of each food category (Hyslop 1980) because of the small sample size (n = 42). Consequently, a subjective visual estimate of volumetric contribution (Pillay 1952) was used. This was substituted by gravimetric determination of the bulk contribution in large fish, where the prey items were much larger (Cailliet 1976; Hyslop 1980). Surface water was removed from the prey items by blotting on tissue paper (Parker 1963) and the wet mass of each prey category was determined to the nearest 0.01g. A ranking index, the frequency of occurrence multiplied by the mean percentage volume (or mass) (Hobson 1974), was computed for each prey category.

Results

A large proportion of the fish were collected using rotenone (15.1%) or spear (51.1%), thereby minimising regurgitation of stomach contents resulting from stress during capture (Randall 1967). Stomach eversion, resulting from barotrauma (Smale & Bruton 1985; Payne, Rose & Leslie 1987), was not observed in this species because of its relatively shallow distribution. As a result a large proportion (72%) of stomachs contained food. This is considerably greater than that observed for Chrysoblephus laticeps (3%), a sparid inhabiting deeper reefs in the same area (Buxton 1984).

Observations of S. durbanensis feeding in the 20m diameter main tank of the Port Elizabeth

Oceanarium showed that the musselcracker first mouthed its' prey and then orientated it in the mouth. This was followed by crushing of the prey between the powerful molars and the blowing of the undigestible remains, such as shell fragments, from the mouth. This feeding behaviour made prey identification, particularly of gastropods, extremely difficult. The only prey items for which undigestible remains were common in the stomach contents were Parechinus angulosus and Perna perna, where the exoskeleton was not easily separated from the internal tissue, by the fish, during feeding. This undoubtedly resulted in an over-emphasis of the importance of these prey categories in the gravimetric analysis. An attempt to overcome this by determining the tissue mass less shells (Hyslop 1980) would have led to an underestimate of their importance, the soft tissues of these prey categories being largely unrecognisable in the stomach contents.

The largest fish collected by rotenone sampling of shallow subtidal waters was 177mm F.L. The shallow subtidal distribution of juvenile fish resulted in a separate analysis of the stomach contents of fish between 56 and 177mm F.L. (Table 11) and larger than 177mm F.L. (Table 12).

Gastropods, echinoids, chlorophytes, small crustaceans and polychaetes were the most important dietary categories in small fish (56 - 177mm F.L.). These juveniles alternate between three different feeding behaviours (Hughes 1980). They function as searchers, where they actively forage for macroscopic prey such as cirripeds and polychaetes. They also browse herbivorously and carnivorously, where only part of each prey item is eaten, without killing it. These browsing habits are evidenced by the presence of chlorophytes, gastropod sensory tentacles and the tube feet of sea urchins in the stomach contents. It is likely that the tentacles and tube feet are later regenerated, a phenomenon that has been documented in both molluscs and echinoderms (Barnes 1968; Hughes 1980).

Gastropods, solitary ascidians, echinoids, amphineurans, pelecypods and pagurids were the most important prey in the larger fish (>177mm F.L.)(Table 12). These fish can be classified as searchers, the algal and hydroid component being ingested incidentally when removing large invertebrate prey from the reef and/or because the exoskeletons of the prey may act as substrata for these sedentary organisms. The large fish were separated into two size categories 178 - 400mm F.L. and larger than 400mm F.L. In this species 50% maturity was attained between 300 and 400mm F.L. These two size categories can therefore be considered to represent sub-adult and adult fish respectively. Results of these analyses are presented in Tables 13 and 14. Of significance was the shift in diet with increasing size, from relatively small invertebrates such as small gastropods, anomurans, polychaetes and cirripeds to large prey such as Pyura stolonifera, Perna perna and Haliotis midae. Prey items of intermediate size such as Parechinus angulosus and amphineurans were important across the size range.

TABLE 11. Stomach content analysis of juvenile *Sparodon durbanensis* between 56mm and 177mm fork length, sampled by rotenone poisoning of shallow (<2m) subtidal waters in the Port Elizabeth area from October 1985 to September 1986 (n = 33).

Prey Species	% Freq.Occur.	Mean % Vol.	Rank
GASTROPODA	51.52	14.15	729.04
Patellidae	9.09	3.79	
Patella longicosta	6.06	3.09	
Littorina spp.	6.06	0.45	
Gastropod tentacles	18.18	3.58	
ECHINOIDEA	36.36	11.42	415.42
Parechinus angulosus	3.03	0.12	
Tube feet	33.33	11.30	
CHLOROPHYTA	30.30	9.64	292.01
CRUSTACEA	27.27	6.85	186.78
Crustacean Remains	24.24	5.76	
AMPHIPODA	30.30	5.45	165.29
Caprellidea	9.09	2.36	
Gammaridea	21.21	2.24	
CIRRIPEDIA	12.12	10.88	131.86
Chthalamus dentatus	3.03	2.61	
Tetraclita squamosa	3.03	0.15	
Tetraclita serrata	3.03	2.06	
POLYCHAETA	18.18	3.45	62.81
ISOPODA	12.12	2.27	27.55
ANOMURA	9.09	0.97	8.82
Paguridae	9.09	0.97	
COPEPODA	15.15	0.36	5.51
MACRURA	6.06	0.85	5.14
MOLLUSCA	6.06	0.52	3.12
ALGAE	9.09	0.33	3.03
AMPHINEURA	3.03	0.03	0.09
AMORPHOUS	63.64	26.30	1673.80
UNIDENTIFIED	15.15	6.33	95.96

TABLE 12. Stomach content analysis of *Sparodon durbanensis* larger than 177mm fork length, sampled between Knysna and East London from August 1984 to March 1987 (n = 127).

Prey Species	% Freq.Occur.	Mean % Mass	Rank
GASTROPODA	51.18	27.12	1387.80
Gastropod remains	38.58	6.94	
Haliotidae	2.36	0.77	
Haliotis midae	3.15	13.12	
Haliotis parvum	0.79	0.35	
Amblychilepas scutella	0.79	0.20	
Crepidula spp.	0.79	0.02	
Crepidula porcellana	1.57	0.01	
Patellidae	8.66	0.61	
Patella longicosta	2.36	0.06	
Patella tabularis	0.79	0.06	
Patella barbara	0.79	0.37	
Turbo cidaris cidaris	0.79	0.07	
Turbo sarmaticus	2.36	2.89	
Mayena gemmifera	0.79	1.32	
SOLITARY ASCIDIANS	25.20	19.56	477.27
Pyura stolonifera	24.41	19.25	
ECHINOIDEA	25.98	15.14	393.40
Parechinus angulosus	25.98	15.14	
AMPHINEURA	10.24	16.72	171.10
Dinoplax gigas	10.24	16.72	
PELYCYPODA	7.87	13.69	107.81
Perna perna	4.72	5.81	
Ostreidae	0.79	0.16	
Chlamys tinctus	0.79	0.00	
Venus verrucosa	0.79	7.12	
Pinctada capensis	0.79	0.61	
ANOMURA	18.11	1.12	20.37
Paguridae	18.11	1.12	
MOLLUSCA	18.90	0.86	16.30
RHODOPHYTA	16.54	0.35	5.80
CIRRIPEDIA	11.02	0.36	3.95
BRACHYURA	0.79	2.05	1.62
CRUSTACEA	7.87	0.13	1.03
POLYCHAETA	5.51	0.12	0.67
Gunnarea capensis	2.36	0.08	
ALGAE	7.87	0.08	0.65
CHLOROPHYTA	4.72	0.04	0.17
PISCES	2.36	0.02	0.04
OPHIUROIDEA	3.15	0.01	0.03
Ophionereis spp.	0.79	0.01	
COPEPODA	0.79	0.00	0.00
AMPHIPODA	2.36	0.00	0.00
MACRURA	0.79	0.00	0.00
HYDROZOA	1.57	0.00	0.00
Sertularella spp.	0.79	0.00	0.00
COLONIAL ASCIDIANS	0.79	0.01	0.00
AMORPHOUS	40.16	2.38	95.45
UNIDENTIFIED	7.09	0.26	1.81

TABLE 13. Stomach content analysis of sub-adult *Sparodon durbanensis* between 178mm and 400mm fork length, sampled between Knysna and East London from August 1984 to March 1987 (n = 27).

Prey Species	% Freq.Occur.	Mean % Mass	Rank
GASTROPODA	85.19	63.05	5371.00
Gastropod remains	77.78	57.14	
Patellidae	22.22	3.41	
Patella longicosta	11.11	2.50	
ECHINOIDEA	14.82	9.92	146.95
Parechinus angulosus	14.82	9.92	
ANOMURA	25.93	4.47	115.81
Paguridae	25.93	4.47	
AMPHINEURA	3.70	6.73	24.94
Dinoplax gigas	3.70	6.73	
POLYCHAETA	7.41	2.63	19.51
Gunnarea capensis	7.41	2.63	
CIRRIPEDIA	11.11	1.74	19.34
CRUSTACEA	11.11	0.31	3.44
RHODOPHYTA	3.70	0.07	0.25
MOLLUSCA	7.41	0.01	0.08
PISCES	3.70	0.01	0.04
ALGAE	3.70	0.01	0.04
AMORPHOUS	55.56	11.04	613.39

TABLE 14. Stomach content analysis of adult *Sparodon durbanensis* larger than 400mm fork length, sampled between Knysna and East London from August 1984 to March 1987 (n = 100).

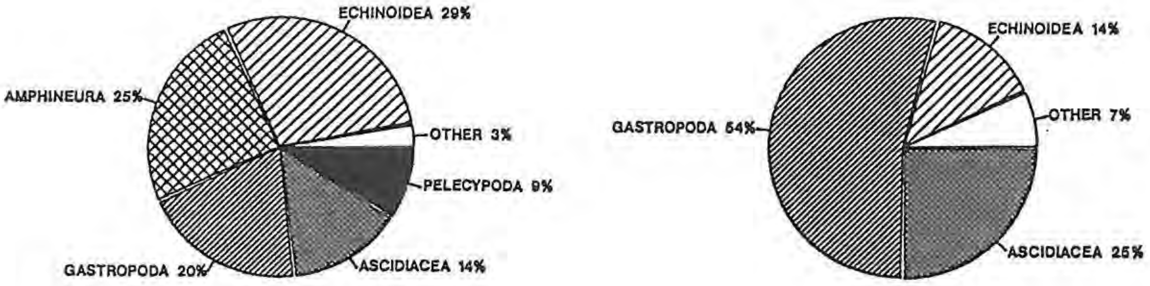
Prey Species	% Freq.Occur.	Mean % Mass	Rank
GASTROPODA	42.00	26.19	1099.90
Gastropod remains	28.00	5.64	
Haliotidae	3.00	0.79	
Haliotis midae	4.00	13.46	
Haliotis parvum	1.00	0.36	
Amblychilepas scutella	1.00	0.20	
Crepidula spp.	1.00	0.02	
Crepidula porcellana	2.00	0.01	
Patellidae	5.00	0.54	
Patella tabularis	1.00	0.06	
Patella barbara	1.00	0.38	
Turbo cidaris cidaris	1.00	0.07	
Turbo sarmaticus	3.00	2.97	
Mayena gemmifera	1.00	1.35	
SOLITARY ASCIDIANS	31.00	20.06	621.77
Pyura stolonifera	31.00	19.75	
ECHINOIDEA	29.00	15.28	442.98
Parechinus angulosus	29.00	15.28	
AMPHINEURA	12.00	16.97	203.69
Dinoplax gigas	12.00	16.97	
PELECYPODA	10.00	14.05	140.45
Perna perna	6.00	5.96	
Ostreidae	1.00	0.17	
Chlamys tinctus	1.00	0.00	
Venus verrucosa	1.00	7.30	
Pinctada capensis	1.00	0.62	
MOLLUSCA	22.00	0.88	19.46
ANOMURA	16.00	1.04	16.61
Paguridae	16.00	1.04	
RHODOPHYTA	20.00	0.36	7.16
CIRRIPEDIA	11.00	0.32	3.54
BRACHYURA	1.00	2.10	2.10
Pseudodromia rotunda	1.00	2.10	
CRUSTACEA	7.00	0.13	0.89
ALGAE	9.00	0.08	0.76
POLYCHAETA	5.00	0.06	0.28
Gunnarea capensis	1.00	0.01	
CHLOROPHYTA	6.00	0.04	0.22
OPHIUROIDEA	4.00	0.01	0.04
Ophionereis spp.	1.00	0.01	
PISCES	2.00	0.02	0.03
COLONIAL ASCIDIANS	1.00	0.01	0.01
HYDROZOA	2.00	0.00	0.00
Sertularella spp.	1.00	0.00	
COPEPODA	1.00	0.00	0.00
AMPHIPODA	3.00	0.00	0.00
MACRURA	1.00	0.00	0.00
AMORPHOUS	36.00	2.15	77.52
UNIDENTIFIED	9.00	0.26	2.35

A regional analysis of the diet is presented in Figure 31. Because of the size-related change in diet this comparison was restricted to fish larger than 400mm F.L. Ranked values of the prey items were expressed as a percentage, and prey groups representing less than 4% by rank were excluded from the analyses. The analyses of fish sampled off Knysna and Tsitsikamma were noticeable in that different invertebrate classes dominated the diets. The solitary ascidian, P. stolonifera (90%) was the dominant prey in the diet of fish sampled off Knysna, whereas a variety of gastropods (89%) were important in the diet of fish sampled off Tsitsikamma. The minor importance of P. stolonifera in the diet of fish sampled off Tsitsikamma (4% wet mass ; 15% frequency of occurrence) is interesting in that this species was abundant on the reefs where S. durbanensis were sampled. This may indicate selective feeding, with gastropods being taken in preference to P. stolonifera. The diets of fish sampled off Port Elizabeth, Bird Island and Cape St Francis showed greater diversity. Spearmans' rank correlation test (Zar 1984) showed no significant difference between the diets of fish sampled off Port Elizabeth and Cape St Francis ($R.S._{0.05(2),5} = -0.5$), Cape St Francis and Bird Island ($R.S._{0.10(2),4} = 0.8$) or Port Elizabeth and Bird Island ($R.S._{0.05(2),5} = 0.15$). Of interest, however, was the absence of amphineurans and the low incidence of pelecypods in the diet of fish sampled off Bird Island. Mussels, Perna perna, are abundant on reefs in this area and the low incidence of pelecypods may, once again, be indicative of feeding selectivity in this species.

Discussion

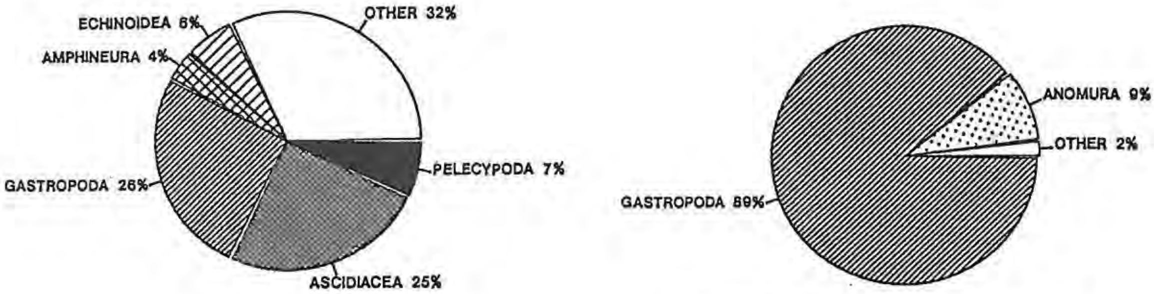
Algae (36%) and copepods (15%) ranked as the second and sixth most important prey groups in the diet of small fish (0 - 177mm F.L.), in terms of frequency of occurrence. These values are considerably lower than those observed for juveniles sampled from intertidal pools in the same area, where algae (88%) and harpacticoid copepods (75%) were the most frequent food items (Beckley, in press). This difference may be attributed to a shift from omnivory to carnivory, resulting from a size-related change in dentition. The juveniles in intertidal pools were mostly younger than one year old. At age 1+ they became infrequent in the pools and had acquired the adult dentition (Beckley, in press). The marked decrease in the importance of copepods, in the diet of subtidal juveniles, may be a direct result of the reduced importance of the algal component. Seaweeds serve as a micro-habitat for a diverse and abundant epifauna, providing shelter from predators, wave action and desiccation. Beckley & McLachlan (1980) showed that copepods were an important component of the littoral seaweed epifauna off St Croix Island, Algoa Bay. The copepod contribution to the diet of juvenile S. durbanensis therefore probably resulted from incidental ingestion by fish browsing on macrophytes.

The intertidal and shallow subtidal distribution of juveniles may be linked to predation pressure



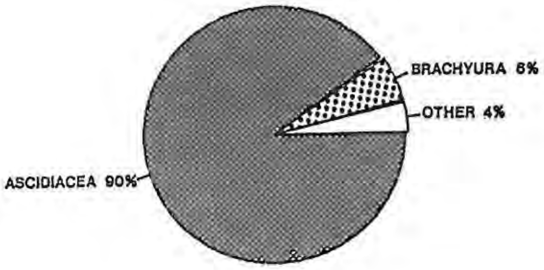
PORT ELIZABETH (n=47)

BIRD ISLAND (n=21)



CAPE ST FRANCIS (n=9)

TSITSIKAMMA COASTAL NATIONAL PARK (n=13)



KNYSNA (n=9)

Figure 31. A comparison of the stomach contents of Sparodon durbanensis larger than 400mm fork length, sampled from five different localities between August 1984 and March 1987.

and suitable food associated with shallow water (Blaber & Blaber 1980). Predation on S. durbanensis has not been recorded in the literature but avian predators may be important in the intertidal pools whereas piscivorous fish are likely to play a more important role in the subtidal environment. The abundance of chlorophytes and invertebrates in the shallows is likely to be important with respect to the distribution of the juveniles because of their ability to switch between searching, omnivorous browsing and carnivorous browsing behaviours. These different feeding behaviours may be of particular significance during the first year of life, when S. durbanensis juveniles occur predominantly in intertidal pools where food resources may be a major limiting factor (Bennett et al. 1983). By browsing carnivorously on gastropod tentacles and the tube feet of sea urchins, juvenile S. durbanensis are utilising prey items which, by virtue of their relatively large size, are not usually accessible to fish inhabiting this zone. In addition, regeneration may result in these resources being renewable over a relatively short time period which would be significant in an environment where food is in short supply.

A size-related change in the diet was also observed in sub-adult and adult fish. These changes in the diet were reflected in morphological changes with increasing size. The larger specimens have the heaviest dentition of all South African sparids (Smith 1938). The upper and lower pairs of central chisel-like incisors, the extensive molars, powerful jaws and blunt head are adapted to manipulate hard-shelled, well-attached invertebrate prey. The large depth along the whole body maximises turning and acceleration and the predominance of white muscle fibres (pers. obs.) provides power at high activity levels (Webb & Keyes 1981). These factors, combined with a size-related increase in gape, enable the adult fish to cope with the larger, more robust invertebrates inhabiting the turbulent inshore zone. The morphology of the species suggests adaptation to the inshore reef environment. Barnard (1927), however, stated that this species was abundant on the Agulhas bank. In addition, prey items usually associated with sandy substrata, including sand mussels and sand dollars, have been recorded in the diet (van der Elst 1981). This species was not, however, caught in a small mesh trawling survey off the Cape South Coast (Wallace, Kok, Buxton & Bennett 1984), where predominantly sandy substrata were sampled at depths ranging from 4.5 - 100m.

Hughes (1980) stated that searchers have wide diets and are opportunistic feeders, attacking all encountered prey within their physical capabilities. In addition, their total time spent pursuing or handling prey is short relative to the time spent searching during a foraging period. This sort of feeding pattern is to be expected amongst animals which forage over a wide range of habitat patches and, therefore, encounter diverse types of prey. Diving observations showed that S. durbanensis occurred over a variety of reef types, ranging from flat boulder beds interspersed with sand, to high relief reef. Gastropods, echinoids and amphineurans were most frequently observed on the former reef type whereas P. stolonifera and P. perna were normally associated with the latter. The observed regional differences in the diet of adult S. durbanensis may have resulted either from geographical variation in the availability of prey or from habitat patch selection by anglers or spearfishermen. The paucity of benthic surveys in the study area, the free ranging behaviour of the fish and the inability to obtain sufficiently large samples of fish in the different regions on a regular basis precluded full evaluation of these results.

ANALYSIS OF THE DIET OF THE BRONZE BREAM, P. GRANDE

Methods

Dietary data were collected from 57 P. grande sampled mainly by spear (98%) between Port Elizabeth and Knysna from February 1985 to March 1987. The fork length of each fish was measured to the nearest millimetre, and total and eviscerated mass were determined in grams. The contents of the alimentary tract were removed and stomach and hindgut contents were weighed and preserved separately in a buffered 10 percent formalin solution.

Stomach contents were washed in running water using a sieve with a mesh size of 0.2mm. In 52% of the stomachs examined the mass of the contents was large and the small size of individual dietary items made the sorting of the contents impractical. Consequently, sub-samples from these stomachs were analysed (Chan & Chau 1979). Sub-samples were taken using a modified Folsom-splitter (James & Wörner 1978). This resulted in sub-samples small enough to be sorted in a reasonable time period (one to two hours) and large enough to be representative of the total sample. In most cases the sub-sample comprised 1/8 or 1/16 of the original sample. The majority of the dietary items were sorted macroscopically, however, the smallest food items were identified under a dissecting microscope.

The stomach contents were analysed using the methods described for S. durbanensis. The subjective visual estimate of volumetric contribution was used in analysing the stomach contents of juvenile fish smaller than 232mm F.L. This was replaced by a gravimetric determination of bulk contribution in the larger fish.

Initial observations showed that the algal component of the diet was relatively undigested during its passage through the alimentary tract. This was evidenced by the ability to classify macrophytes from rectal samples to species level. The nutritional value of macroalgae, to this species, was therefore questioned.

The presence of microbial gut endosymbionts, and consequently the ability to degrade complex algal polysaccharides, was investigated by microscopic examination (x 400 magnification) of the gut lining as well as the intestinal contents (Fishelson, Montgomery & Myrberg 1985b).

Herbivorous fish may utilise the non-cellulose component of macrophytes (Montgomery & Gerking 1980; Edwards & Horn 1982). The most important macroalgae (Plocamium spp.) in the diet of P. grande have a slimy texture and, therefore, the possibility that the fish were feeding on the mucous coating of the weed was investigated. Thin sections of fresh samples of Plocamium corallorhiza were obtained by freeze microtomy. These sections were examined using light microscopy to determine the thickness of the mucous layer.

A number of feeding studies have indicated that epibionts (especially diatoms and bacteria) on the ingested macrophytes may contribute significantly to the diet of herbivorous and omnivorous fishes (Blaber 1974; Christensen 1978; Joubert & Hanekom 1980; Horn, Neighbors, Rosenberg & Murray 1985). This possibility was investigated using scanning electron microscopy. Samples of P. corallorhiza were taken from the reef ($n = 4$) as well as from the oesophagus ($n = 4$), stomach ($n = 4$) and hindgut ($n = 8$) of P. grande ($n = 6$). The samples were fixed in a solution of 2.5% gluteraldehyde in a phosphate buffer. The samples were rinsed in phosphate buffer, air dried and coated with gold using a sputter coater. The specimens were viewed using scanning electron microscopy.

Results

An analysis of the mass of the contents of the alimentary tract in relation to the total mass of P. grande showed that dietary contents may comprise as much as 12.05% of the body mass, with a mean value of 8.59±2.26% ($n = 30$). This result indicates the effect that different levels of gut fullness may have on total mass. Consequently in this study eviscerated mass was used in all calculations involving body weight.

An analysis of the stomach contents of P. grande larger than 330mm F.L. (50% maturity occurs in the 300 - 330mm F.L. size class), sampled between Knysna and Port Elizabeth, is summarised in Table 15. These results indicate that adult P. grande are omnivorous, browsing on a variety of organisms inhabiting shallow water (<20m) reefs.

Algae were the dominant dietary category, being present in all the stomachs examined and comprising 62.56% of the diet in terms of mass. Twenty species of algae were recorded, of which the majority (68%) were fleshy rhodophytes. Red algae of the genus Plocamium were

TABLE 15. Stomach content analysis of adult *Pachymetopon grande*, larger than 330mm fork length, sampled between Knysna and Port Elizabeth from January 1985 to March 1987 (n = 46), (T(trace) = <0.01%).

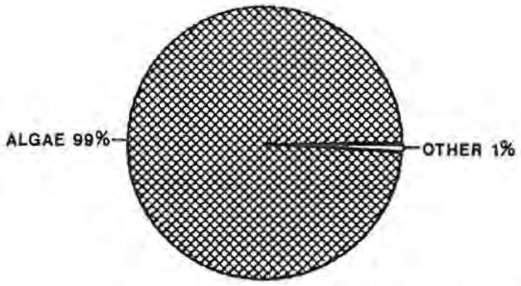
Species	% Frequency of Occurrence	Mean % Volume	Rank
ALGAE	**100.00**	**62.56**	**6256.00**
Plocamium corallorhiza	43.48	21.49	
Plocamium suhrii	65.22	21.42	
Champia compressa	47.83	3.49	
Laurencia flexuosa	17.39	3.49	
Plocamium rigida	43.48	2.06	
Dictyota liturata	30.43	0.84	
Arthrocardia spp.	13.04	0.40	
Hypnea rosea	10.87	0.38	
Chondrococcus spp.	28.26	0.24	
Calliblepharis fimbriata	4.35	0.21	
Cheilosporum sagittatum	6.52	0.10	
Gelideum cartilagineum	4.35	0.10	
Gelideum pristoides	2.17	0.10	
Arthrocardia conpulosa	2.17	0.10	
Amphiroa bowerbankii	4.35	0.06	
Ceramium spp.	8.70	0.03	
Acrosorium spp.	2.17	0.01	
Amphiroa ephedraea	2.17	0.01	
Laurencia natalensis	2.17	0.01	
Corallina spp.	2.17	T	
Unidentified algae	54.35	8.02	
HYDROZOA	**78.26**	**13.76**	**1076.86**
Lytocarpus filamentosus	34.78	3.40	
Sertulariidae	19.57	3.03	
Thecocarpus formosus	28.26	0.48	
Lafoeidae	15.22	0.44	
Plumulariidae	26.09	0.35	
Thyroscyphus spp.	10.87	0.34	
Halopterinae	4.35	0.06	
Solanderiidae	2.17	0.06	
Plumulariinae	4.35	0.05	
Aglaophenia pluma	13.04	0.03	
Sertularella goliathus	4.35	0.02	
Pycnotheca spp.	4.35	0.01	
Thecocarpus flexuosus umbellatus	2.17	0.01	
Unidentified Hydrozoa	73.91	5.48	
OCTOCORALLIA	**52.17**	**14.05**	**732.99**
Eunicella papillosa	26.09	5.09	
Xenia spp.	23.91	4.35	
Lophogorgia flammea	10.87	1.48	
Homophyton spp.	2.17	0.32	
Unidentified Octocorallia	36.96	2.81	
COLONIAL ASCIDIACEA	**34.78**	**3.79**	**131.82**
Polyclinum spp.	6.52	1.14	
Didemnidae	2.17	T	
Unidentified Colonial Ascidacea	28.26	2.65	
CRUSTACEA	**78.26**	**0.99**	**77.48**
Caprellidea	65.22	0.44	
Amphipoda	52.17	0.32	
Tanaidacea	6.52	0.13	
Isopoda	15.22	0.05	
Crustacean remains	2.17	0.05	
MOLLUSCA	**28.26**	**0.26**	**7.35**
Gastropoda	21.74	0.21	
Pelecypoda	15.22	0.05	
Shell fragments	2.17	T	
Molluscan remains	2.17	T	
PORIFERA	**6.52**	**2.02**	**13.17**
BRYOZOA	**17.39**	**0.34**	**5.91**
POLYCHAETA	**8.70**	**0.05**	**0.44**
OPHIUROIDEA	**2.17**	**T**	**T**
UNIDENTIFIED	**28.26**	**0.05**	**1.41**
AMORPHOUS	**10.87**	**0.18**	**1.96**

most important, comprising 71.88% of the mass of the macroalgal component. Six species of coralline algae (Cheilosporum sagittatum, Arthrocardia conpulosa, Amphiroa bowerbankii, Amphiroa ephedraea, Arthrocardia spp. and Corallina spp.) were recorded, but these were of minor importance accounting for only 1.07% of the total mass of macroalgae. One species of brown algae (Dictyota liturata) was frequently present in the stomach contents (30.43%) but was unimportant in terms of percentage mass contributions (0.84%). Adult P. grande also feed on a variety of invertebrates of which hydroids, octocorals, colonial ascidians and small crustaceans appeared to be most important. Small crustaceans and molluscs were probably ingested incidentally by fish browsing on macroalgae and hydrozoans.

A regional analysis of the diet is presented in Figure 32. Ranked values of the different dietary categories were expressed as percentages. Macroalgae ranked most important in all areas, with the fish sampled off Port Elizabeth feeding almost exclusively on this dietary category. A comparison of the diet of fish sampled from two dive sites in the Tsitsikamma Coastal National Park indicated that the diet of P. grande was largely depth-dependent. The Knoll occurs in shallower water than Rheeders' Knoll and consequently macroalgae are more abundant. This difference in the benthic composition of the two areas is reflected in the dietary composition. In the fish sampled from Rheeders' Knoll the macroalgal component was reduced. This corresponded with the observed increase in the importance of invertebrates, in particular octocorals, which are more commonly found on the deeper reefs.

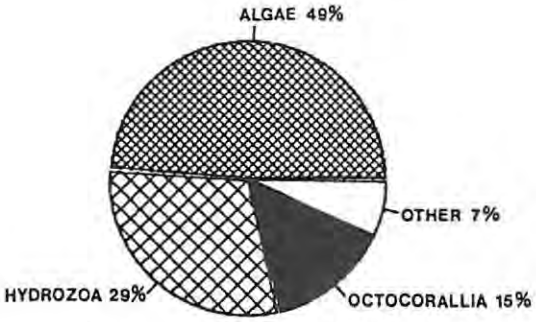
Separate analyses of the stomach contents of P. grande smaller than 240mm F.L. and larger than 330mm F.L. are summarised in Tables 16 and 17 respectively. This dietary comparison of juvenile (size at first maturity is larger than 240mm F.L.) and adult (size at 50% maturity is approximately 300mm F.L.) P. grande was restricted to fish sampled in relatively shallow (<15m) water off Port Elizabeth to avoid variation resulting from depth or geographical differences. The diet of juvenile and adult P. grande was largely similar, with macroalgae ranking the most important dietary category, both in terms of percentage frequency of occurrence and mean percentage mass. The rhodophyte, P. corallorhiza, was the most important species in both groups. Other dietary categories including Hydrozoa, Crustacea and Octocorallia were frequently observed in the stomach contents of both juvenile and adult fish, but were relatively unimportant because of their minor bulk contribution.

Microscopic examination of the gut lining and the intestinal contents showed that consistent microbial populations were absent. This, combined with the low level of macroalgal digestion indicated that gut endosymbionts were not involved in primary or secondary digestion of macrophytes, or in the supply of micronutrients in P. grande (Fishelson et al. 1985b).



PORT ELIZABETH (n=12)

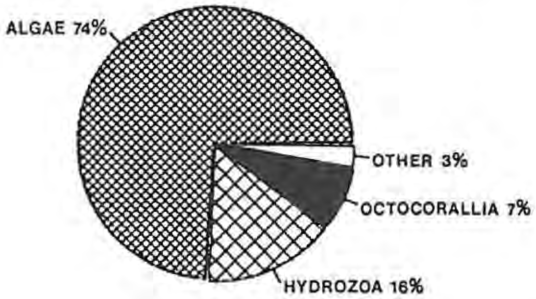
OTHER	% RANK
COLONIAL ASCIDIACEA	0.66
HYDROZOA	0.04
OCTOCORALLIA	0.04
CRUSTACEA	T
UNIDENTIFIED	0.06
AMORPHOUS	0.04



KNYSNA (n=11)

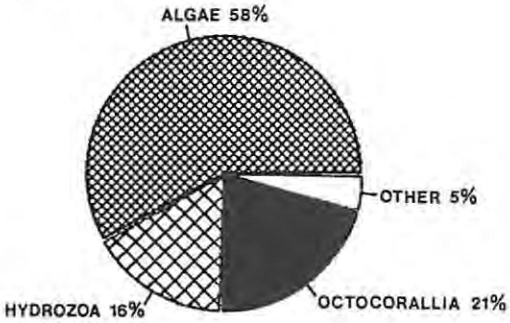
OTHER	% RANK
CRUSTACEA	2.36
PORIFERA	2.27
COLONIAL ASCIDIACEA	1.63
MOLLUSCA	0.33
BRYOZOA	0.13
POLYCHAETA	T
UNIDENTIFIED	T

TSITSIKAMMA COASTAL NATIONAL PARK



KNOLL (n=13)

OTHER	% RANK
COLONIAL ASCIDIACEA	1.33
CRUSTACEA	1.05
MOLLUSCA	0.23
POLYCHAETA	0.03
PORIFERA	0.01
OPHIUROIDEA	T
BRYOZOA	T
UNIDENTIFIED	T
AMORPHOUS	0.01



RHEEDERS (n=11)

OTHER	% RANK
COLONIAL ASCIDACEA	2.35
CRUSTACEA	1.36
BRYOZOA	0.49
MOLLUSCA	T
UNIDENTIFIED	0.01
AMORPHOUS	0.02

Figure 32. A comparison of the stomach contents of *Pachymetopon grande* larger than 330mm fork length, sampled from four different localities between February 1985 and March 1987.

TABLE 16. Stomach content analysis of juvenile *Pachymetopon grande*, between 88mm and 232mm fork length, sampled off Port Elizabeth between March 1985 and April 1986 (n = 11).

Species	% Frequency of Occurrence	Mean % Volume	Rank
ALGAE	**100.00**	**86.81**	**8681.00**
Plocamium corallorhiza	100.00	49.86	
Ceramium spp.	72.73	22.18	
Champia compressa	36.36	6.18	
Chondrococcus spp.	18.18	2.82	
Plocamium suhrii	9.09	0.02	
Unidentified algae	72.73	5.75	
HYDROZOA	**81.81**	**9.30**	**760.83**
CRUSTACEA	**100.00**	**2.39**	**239.00**
Amphipoda	100.00	1.23	
Caprellidea	54.55	0.45	
Isopoda	45.45	0.27	
Mysidacea	18.18	0.10	
Copepoda	9.09	0.09	
Crustacean remains	27.27	0.25	
OCTOCORALLIA	**27.27**	**1.33**	**36.27**
PYCNOGONIDA	**9.09**	**0.09**	**0.82**
GASTROPODA	**9.09**	**0.01**	**0.09**
UNIDENTIFIED	**18.18**	**0.11**	**2.00**
AMORPHOUS	**9.09**	**0.27**	**2.45**

TABLE 17. Stomach content analysis of adult Pachymetopon grande, larger than 330mm fork length, sampled off Port Elizabeth between February 1985 and May 1986 (n = 12), (T(trace) = <0.01%).

Species	% Frequency of Occurrence	Mean % Volume	Rank
ALGAE	**100.00**	**94.10**	**9410.00**
Plocamium corallorhiza	100.00	66.79	
Champia compressa	94.99	11.77	
Laurencia flexuosa	25.00	7.96	
Hypnea rosea	16.66	1.38	
Plocamium rigida	50.00	1.15	
Gelidium cartilagineum	8.33	0.13	
Plocamium suhrii	16.66	0.03	
Laurencia natalensis	8.33	0.03	
Dictyota liturata	8.33	0.03	
Amphiroa bowerbankii	8.33	T	
Ceramium spp.	8.33	T	
Unidentified algae	75.00	4.83	
COLONIAL ASCIDIACEA	**16.66**	**3.78**	**62.97**
HYDROZOA	**41.66**	**0.09**	**3.75**
Pycnotheca spp.	8.33	0.01	
OCTOCORALLIA	**8.33**	**0.41**	**3.42**
CRUSTACEA	**25.00**	**0.01**	**0.25**
Isopoda	8.33	0.01	
Amphipoda	16.66	T	
Caprellidea	8.33	T	
UNIDENTIFIED	**75.00**	**0.08**	**6.00**
AMORPHOUS	**8.33**	**0.49**	**4.08**

Scanning electron microscopic examination of the samples of P. corallorhiza taken from the reef and from the alimentary tract of P. grande showed low numbers of epibionts. No trends, either in number or state of digestion of epibionts, were observed in the samples taken from the different regions of the alimentary tract (Figure 33a & b). The only areas where epibionts were observed in significant numbers were areas where the weed appeared to have been damaged (Figure 33c). This may indicate that undamaged P. corallorhiza is an unsuitable substratum for epibionts, either because the smooth surface prevents attachment or because the mucous coating of the weed serves as a chemical defense against settlement.

Microscopic examination of thin sections of P. corallorhiza showed that the mucous layer coating the weed was extremely thin. A microscopic comparison of fresh with ingested weed, to determine the degree of mucous digestion, was therefore not feasible. The ability of P. grande to digest storage and extracellular carbohydrates could further be investigated by feeding experiments using ^{14}C labelled macroalgae as a food source (Conacher, Lanzig & Larkum 1979; Horn et al. 1985). This however, was beyond the scope of this study.

Discussion

Macroalgae were the principal dietary component, across the size range, analysed in P. grande. P. grande did not masticate their food, did not appear to feed on epibionts on the macroalgae and did not seem to harbour a microbial population capable of degrading the cellulose component of seaweeds. These results indicate that P. grande can digest major fractions of algal nutrients without the mechanical destruction of algal cells (Conacher et al. 1979; Montgomery & Gerking 1980).

In herbivorous marine fish which appear to be incapable of cellulose digestion, either with endogenous enzymes or gut endosymbionts, dietary composition is frequently consistent with predictions based purely on the macroalgal biochemistry (Montgomery & Gerking 1980). Fleshy algae are generally superior to calcareous (coralline) algae as a food resource on the basis of ash, calories, total protein and total lipid content. In addition, on the basis of nutrient and energy content, Chlorophyta are superior to Phaeophyta and both are superior to Rhodophyta. However, when the digestibility of storage and extracellular carbohydrates is considered Chlorophyta and Rhodophyta are predicted superior to Phaeophyta (Montgomery & Gerking 1980). A more recent study (Edwards & Horn 1982) has indicated that Rhodophyta may be taken in preference to Chlorophyta. This may result from the variable composition of extracellular polysaccharides, the acid-labile bonds linking the polysaccharide subunits and the broad substrate specificity of many glucosidases which may combine to make the extracellular

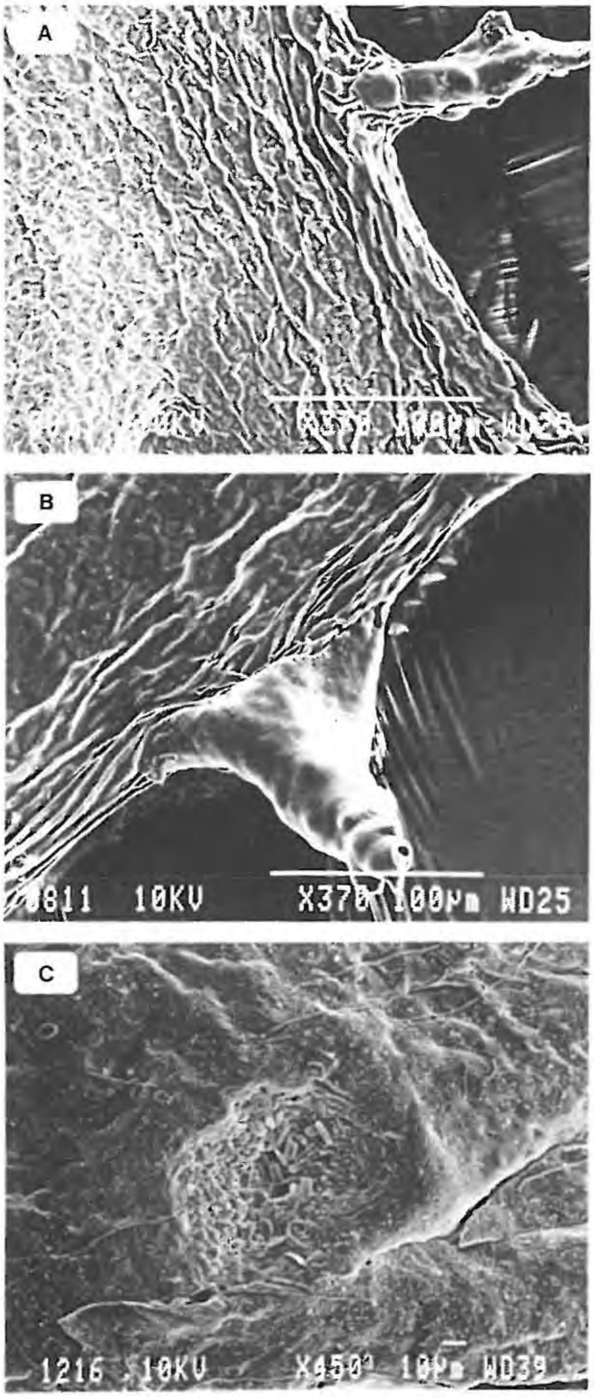


Figure 33. Scanning electron micrographs showing the low number of epibionts on Plocamium corallorhiza sampled from either the stomach (A) or hindgut (B) regions of the alimentary tract of Pachymetopon grande. Epibionts were, however, observed in significant numbers where the weed appeared to have been damaged (C).

carbohydrates of this group more susceptible to digestion than those of the Chlorophyta (Montgomery & Gerking 1980; Horn, Murray & Edwards 1982).

The macroalgal composition of the diet of P. grande is consistent with these predictions. The absence of Chlorophyta from the diet may be explained by the low abundance of this group on the subtidal reefs (deeper than 9m) where P. grande were speared (pers. obs.). This may be attributed to chromatic adaptation in Chlorophyta whereby the photosynthetic pigments are compatible with the wavelength of red light. This results in this group being restricted to the upper reaches of the photic zone (Simons 1976). Coralline algae were unimportant in the diet even though diving observations showed that they were abundant on the reefs. Phaeophyta were also unimportant in the diet, particularly in terms of bulk contribution. By contrast, fleshy rhodophytes comprised 97.23% of the identified macroalgae in terms of percentage mass. These results suggest that P. grande is a selective browser, feeding principally on fleshy rhodophytes because of their comparatively high nutritive value and readily digestible extracellular carbohydrate component. Macroalgae are generally low in protein content, a component critical to growth (Montgomery & Gerking 1980). The invertebrate component of the diet of P. grande probably plays a major role in satisfying this dietary requirement.

At present these conclusions are largely speculative and a thorough investigation of the biochemistry of local algal species, including studies on the role of secondary defensive compounds, is required. This combined with feeding selectivity and assimilation studies (using ^{14}C labelled algae as a food source) will contribute significantly to our understanding of herbivory in Southern African marine reef fishes.

CONCLUSION

A number of the important prey species in the diet of S. durbanensis including Haliotis midae (abalone), Perna perna (mussels), Turbo sarmaticus (ollycrock), Patellidae (limpets) and Pyura stolonifera (red bait) are utilised by man for food and bait. These intertidal and shallow subtidal invertebrates are an important source of protein to lower income groups in certain areas of Southern Africa (Branch 1975; Hockey and Bosman 1986). In addition some species such as H. midae and P. perna are regarded as delicacies and are exploited commercially. The increasing demand for food associated with a rapidly growing human population, coupled with the increased bait requirements of an expanding sport fishery, is likely to result in increased exploitation pressure on this resource. Similarly, the macroalgae utilised by P. grande as a food source may have the potential for commercial exploitation as fertiliser, food or for industrial purposes e.g. Gelidium pristoides and Gelidium cartilagineum as a supply of agar (Simons 1976).

The exploitation of these organisms by man may affect the localised distribution of *S. durbanensis* and *P. grande*. This also applies to disturbances affecting inshore reefs, either natural, e.g. sedimentation, or man-induced, e.g. pollution. These factors are, however, unlikely to be major management considerations with respect to these two species, owing to their opportunistic diets and their association with a variety of inshore reef types.

CHAPTER 6 - THE EASTERN CAPE RECREATIONAL ROCK-ANGLING AND SPEAR FISHERIES

GENERAL INTRODUCTION

The South African marine sport fishery can be categorised into four major sectors, namely gamefishing, ski-boat angling, rock and surf angling and spearfishing. S. durbanensis and P. grande are of no interest to the gamefishing sector and are rare in ski-boat anglers' catches (Smale & Buxton 1985). They are rarely taken by surf anglers because of their association with inshore reefs but, because of their palatability and relatively large size, are highly prized in the Eastern Cape rock-angling and spear fisheries. Catch composition and catch per unit of effort (CPUE) were investigated in the Port Elizabeth rock-angling fishery and at three National Spearfishing Championships held in the Eastern Cape. This investigation was primarily aimed at establishing the importance of S. durbanensis and P. grande to the inshore recreational fisheries. The data do, however, provide an insight into these fisheries and may serve as a basis for future monitoring of the resource.

Fishing mortality is assumed to be proportional to fishing intensity and therefore CPUE is an index of stock abundance (Cushing 1968). With exploitation, as effort increases it can be expected that CPUE will gradually diminish. Butterworth (1985) indicated that given a CPUE time series, a decline of more than 50% of that level at the inception of the fishery reflects biological over-exploitation. Long term CPUE data series therefore provide a means of monitoring a fishery. Important factors affecting CPUE within a given fishery are weather conditions, the behaviour of fish and gear selectivity. In rare cases, the chances of capture decrease as the density of fish increases, an effect known as gear saturation. Factors such as these, which affect the catchability of fish, may necessitate estimates of stock which are independent of CPUE (Cushing 1968). CPUE is, however, the basic measure of density used by fisheries biologists (Gulland 1969; Butterworth 1985).

A characteristic feature of recreational fisheries is the limited amount of scientific information available (Butterworth 1985). In a multi-species fishery long term declines in CPUE may be masked by a re-targeting of effort at less desirable species. In addition, over-exploitation of a particular species may be evidenced by a decrease in the mean size of the catch (Butterworth 1985). These factors illustrate the requirement for detailed species-specific catch records (including catch composition, size composition and CPUE) for determining long term trends in the fishery. Butterworth (1985) also emphasised the requirement for some index of total effort to achieve this objective.

THE PORT ELIZABETH ROCK-ANGLING FISHERY

Introduction

Studies on the recreational shore-angling fishery in southern Africa are few and have used various methods to evaluate catch composition and CPUE. These include obtaining estimates of total catch and total effort (Penrith & Loutit 1982; Coetzee & Baird 1981b), analysis of angler catch returns (R. van der Elst, Oceanographic Research Institute, Durban, unpublished results), opportunistic shore patrols (van der Elst 1980; Joubert 1981b) and analysis of angling club and competition records (van der Elst 1979; Baird, Ritchie, Tregoning, Coetzee & Winter 1984; Coetzee, Baird & Tregoning 1987). Collection of total catch and total effort data is usually only feasible in small areas or those with restricted access. Analysis of angler catch returns may be biased due to varying degrees of angler support. Opportunistic shore patrols may not include representative samples of conditions affecting the fishery and analysis of angling club and competition records is biased in favour of the competitive and usually more successful angler. This study was unique in that it attempted to monitor a fishery using a statistically random sampling technique that removed such bias.

Methods

Sampling was restricted to the predominantly rocky coastline between Flat Rocks and Schoenmakerskop. The topography of this area was discussed briefly in Chapter 2. Port Elizabeth is a major metropolitan area with a population of 522 883 (1985 census, Mrs Olivier, Central Statistical Services, pers.comm.) and much of the effort of local rock-anglers is concentrated along this relatively short stretch of coastline. The area was patrolled using a four wheel drive vehicle with foot patrols to inaccessible areas.

Anglers were interviewed on 120 randomly selected sampling days between 17 August 1985 and 26 August 1986. A preliminary analysis of data for the first four months showed a significant difference between the number of anglers interviewed on weekdays and those interviewed on weekends and holidays. This resulted in a stratified random selection of sampling days, using the ratio of 6 weekdays:3.5 weekends:1 public holiday as a basis, for the rest of the sampling period (11 February to 26 August 1986). In addition, the weekday sampling ratio was increased to one in two days during peak school holidays (when the school holidays of the four provinces coincided). The starting times and the direction of sampling (east to west/west to east) along the 17.5km of coastline were also determined using random number tables. The relatively low number of anglers fishing from the rocks at night (pers. obs.) as well as practical difficulties encountered in sampling rock-anglers' catches at night (such as the inability to see fishermen) resulted in sampling being restricted to daylight hours.

The stratification of sampling, mentioned above, resulted in increased numbers of anglers being interviewed and consequently more precise estimates of CPUE, as well as increased collection of biological material, without affecting the random design of the study. CPUE was assumed to be independent of the day of the week on which sampling occurred and consequently no attempt was made to analyse data collected on weekdays, weekends and holidays separately. This, however, would be essential in a study involving calculations of total catch and total effort, an aspect not feasible in this study due to time constraints.

Information recorded included angler information (starting time of angling, time of interview, club angler or not, race, number of rods used and baits used), catch details (species, lengths, masses and number and species of fish returned unharmed to the sea) and environmental parameters (sea conditions, water temperatures, wind conditions, time of day, tides, barometer readings, cloud cover, humidities and air temperatures). Water temperatures and subjective estimates of sea state and water clarity were obtained in the field. The other environmental conditions were obtained from the meteorological office at the H.F. Verwoerd Airport, at the start and end of each sampling period.

In some cases mutilation of the catch by anglers (evisceration and filleting) prevented length and/or mass determination. In instances in which only one value was known the remaining value was calculated using length-mass relationships. Where neither the mass nor the length values were known, the mean value for that particular species was used in calculations of total catch and CPUE. Observations showed that the number of rods used varied amongst individual anglers. The majority (97.4%) of anglers used only one rod at a time with the remainder fishing at least part of the time with two rods. Other studies of southern African shore-angling fisheries have used the angler hour, angler day and angler week as measures of effort (van der Elst 1979, 1980; Coetzee & Baird 1981b; Joubert 1981b; Penrith & Loutit 1982; Coetzee et al. 1987). The angler hour was considered the most appropriate measure of effort in this study. CPUE was expressed as the mass of fish as well as the number of fish per angler hour.

Results

Angler composition

A total of 2 531 anglers were interviewed during the study. Anglers were categorised according to whether they were registered club anglers or not, and on the basis of race, sex and whether the angler was an adult or a child. A total of 323 (12.8%) anglers were registered with angling clubs affiliated to the Eastern Province Rock and Surf Angling Association. The categorisation of anglers on the basis of race, sex and age group was subjective. These results are summarised in Table 18 and are related to the Port Elizabeth population figures for the different race groups (1985 census, Mrs Olivier, Central Statistical Services, pers.comm.). Despite the relatively small white population in Port Elizabeth (26%), this race group accounted for 77.7% of anglers interviewed. By contrast, blacks comprised 46.5% of the population but accounted for only 0.6% of anglers. Relatively few women and children participated in this recreational activity, adult males accounting for 90.3% of anglers interviewed.

The Catch

A total of 1 328 fish weighing 932.14kg were caught during 4612.7 hours, a CPUE of 202.1 grams/angler hour or 0.288 fish/angler hour. Monthly catch composition and CPUE are summarised in Table 19. Data for August 1985 and August 1986 were combined. The size range, mean length and mean mass for different species is presented in Table 20. Only fish for which the length and/or the mass was known were included in this analysis.

Seven species of cartilaginous fishes (Chondrichthyes) and twenty-six species of bony fishes (Osteichthyes) were sampled during the study. Cartilaginous fishes were unimportant numerically (2%) but, because of their relatively large size, were a significant component of the catch in terms of mass (15.1%). The CPUE of cartilaginous fishes was 30.43 grams/angler hour. Eastern Cape anglers generally regard cartilaginous species as "trash fish" and consequently many are released, used for bait or killed and discarded (Smale & Buxton 1985, pers.obs.). A list of fish released by anglers during this study (Table 21) confirms this observation, the majority of the fish being either cartilaginous species or those of small size. Bony fishes comprised 98% of the catch numerically and 84.9% by mass. The CPUE of bony fish was 171.65 grams/angler hour.

The most important species in the catch in terms of percentage mass contribution were Pomatomus saltatrix (37.0%), S. durbanensis (15.0%) and Diplodus sargus capensis (9.6%). P. grande was the fifth most important species in terms of mass, comprising 6.2% of the catch. Most important numerically were P. saltatrix (30.3%), Sarpa salpa (21.5%) and D. sargus capensis (18.4%). S. durbanensis and P. grande were the sixth most important species numerically, each comprising 3.2% of the catch.

TABLE 18. Categorisation of anglers, interviewed during a survey of the Port Elizabeth rock-angling fishery between August 1985 and August 1986, according to race, sex and age group (n = 2 531). These figures are related to Port Elizabeth population figures for each race group.

	Race			
	White	Coloured	Asian	Black
Number of adult males	1 759	427	87	12
Number of adult females	25	3	1	1
Number of male children	178	24	5	2
Number of female children	5	2	0	0
Total	1 967	456	93	15
% Anglers interviewed	77,7	18,0	3,7	0,6
Total P.E. population	135 779	136 943	6 914	243 247
% P.E. population	26,0	26,0	1,3	46,5

TABLE 19. Monthly catch composition and catch per unit of effort in the rock-angling fishery off Port Elizabeth during 1985/1986. Species are arranged in phylogenetic order according to Smith and Heemstra (1986). The monthly composition of catches is shown by mass and by number. (All number values in brackets).

Months	S	O	N	D	J	F	M	A	M	J	J	A				
No. of Sampling Days	11	10	14	8	9	9	10	12	6	13	6	12				
Effort (Angler Hours)	364.82	256.93	328.10	318.88	312.45	196.93	423.91	790.52	148.45	663.78	215.75	592.18				
Species													Mass Number	CPUE g.hr^{-1}	% No.	% Mass
CHONDRICHTHYES																
CARCHARHINIDAE																
Carcharhinus brachyurus	21 000 (1)												21 000 (1)	4.55	0.1	2.3
Carcharhinus obscurus								12 000 (2)					12 000 (2)	2.60	0.2	1.3
Mustelus mustelus				1 800 (1)	26 800 (2)	48 000 (3)							76 600 (6)	16.61	0.5	8.2
Triakis megalopterus				1 800 (1)	2 300 (1)								4 100 (2)	0.89	0.2	0.4
SCYLIORHINIDAE																
Haploblepharus fuscus	1 010 (1)	2 154 (4)		1 550 (1)				1 000 (1)					5 714 (7)	1.24	0.5	0.6
Poroderma africanum	5 550 (1)											5 300 (1)	10 850 (2)	2.35	0.2	1.2
Poroderma pantherinum	3 470 (2)							2 030 (1)			2 916 (2)	1 670 (1)	10 086 (6)	2.19	0.5	1.1
OSTEICHTHYES																
PLOTOSIDAE																
Plotosus nkunga				1 075 (1)				1 075 (1)					2 150 (2)	0.47	0.2	0.2
ARIIDAE																
Galeichthys spp.				275 (1)			1 500 (1)		251 (2)				2 026 (4)	0.44	0.3	0.2

TABLE 19 cont. Monthly catch composition and catch per unit of effort in the rock-angling fishery off Port Elizabeth during 1985/1986. Species are arranged in phylogenetic order according to Smith and Heemstra (1986). The monthly composition of catches is shown by mass and by number. (All number values in brackets).

Months	S	O	N	D	J	F	M	A	M	J	J	A				
No. of Sampling Days Effort (Angler Hours)	11 364.82	10 256.93	14 328.10	8 318.88	9 312.45	9 196.93	10 423.91	12 790.52	6 148.45	13 663.78	6 215.75	12 592.18				
Species													Mass Number	CPUE $g.hr^{-1}$	% No.	% Mass
CHEILODACTYLIDAE																
Cheilodactylus fasciatus	57 (1)							25 (1)	125 (2)		193 (3)		400 (7)	0.09	0.5	T
Chirodactylus brachydactylus	236 (2)							504 (4)			73 (1)		813 (7)	0.18	0.5	0.1
SERRANIDAE																
Acanthistius sebastoides	371 (1)	67 (1)						470 (1)					908 (3)	0.20	0.2	0.1
Epinephelus guaza	825 (1)							85 (1)					910 (2)	0.20	0.2	0.1
POMATOMIDAE																
Pomatomus saltatrix	6 600 (7)			3 168 (5)	19 939 (30)	18 496 (23)	29 995 (34)	78 557 (96)	15 103 (19)	81 496 (95)	44 781 (41)	46 294 (53)	344 429 (403)	74.67	30.3	37.0
SCIAENIDAE																
Argyrosomus hololepidotus			10 261 (3)	2 450 (1)	2 500 (1)	5 418 (2)		1 550 (1)		2 400 (2)			24 579 (10)	5.33	0.8	2.6
Umbrina canariensis		3 500 (2)			1 300 (1)								4 800 (3)	1.04	0.2	0.5
CORACINIDAE																
Coracinus capensis				545 (1)						2 850 (2)			3 395 (3)	0.74	0.2	0.4
SCORPIDIDAE																
Neoscorpis lithophilus					600 (1)			1 141 (1)		1 356 (2)		450 (1)	3 547 (5)	0.77	0.4	0.4
HAEMULIDAE																
Pomadasys olivaceum								- (1)		- (1)			- (2)	-	0.2	-

TABLE 19 cont. Monthly catch composition and catch per unit of effort in the rock-angling fishery off Port Elizabeth during 1985/1986. Species are arranged in phylogenetic order according to Smith and Heemstra (1986). The monthly composition of catches is shown by mass and by number. (All number values in brackets).

Months	S	O	N	D	J	F	M	A	M	J	J	A				
No. of Sampling Days	11	10	14	8	9	9	10	12	6	13	6	12				
Effort (Angler Hours)	364.82	256.93	328.10	318.88	312.45	196.93	423.91	790.52	148.45	663.78	215.75	592.18				
Species													Mass Number	CPUE g.hr^{-1}	% No.	% Mass
SPARIDAE																
Rhabdosargus holubi	3 304 (10)	215 (1)	215 (1)	2 694 (10)	410 (1)	290 (1)		2 785 (13)	150 (2)	125 (2)		904 (6)	11 092 (47)	2.40	3.5	1.2
Sparodon durbanensis	13 456 (3)	8 012 (4)	36 431 (8)		13 300 (2)	580 (3)	21 260 (6)	7 625 (5)	5 095 (2)	4 417 (2)	229 (4)	29 125 (4)	139 530 (43)	30.25	3.2	15.0
Diplodus sargus capensis	8 966 (31)	4 744 (10)	9 320 (22)	6 935 (15)	990 (3)	3 107 (5)	5 556 (11)	10 976 (36)	2 333 (8)	12 235 (41)	5 551 (12)	18 697 (50)	89 410 (244)	19.38	18.4	9.6
Diplodus cervinus hottentotus	385 (1)	122 (1)	925 (1)	3 180 (4)	1 450 (1)	595 (1)	1 970 (2)	2 711 (6)	700 (2)	958 (2)	55 (1)	935 (4)	13 986 (26)	3.03	2.0	1.5
Cymatoceps nasutus		1 322 (2)	480 (1)	934 (2)	1 440 (2)	1 100 (1)		1 566 (2)		826 (1)		264 (1)	7 932 (12)	1.72	0.9	0.9
Lithognathus lithognathus	4 310 (3)	3 550 (1)	1 952 (2)	1 300 (1)		2 462 (2)		2 984 (3)		2 500 (1)			19 058 (13)	4.13	1.0	2.0
Boopsoidea inornata	243 (3)	50 (2)		340 (2)			393 (1)	515 (6)	68 (2)		21 (1)	667 (2)	2 297 (19)	0.50	1.4	0.2
Gymnocrotaphus curvidens				219 (1)				1 625 (3)				850 (1)	2 694 (5)	0.58	0.4	0.3
Sarpa salpa	1 707 (13)	642 (4)	1 532 (9)	3 746 (22)	940 (6)	685 (4)	1 450 (10)	6 986 (49)	1 200 (6)	5 932 (42)	3 550 (25)	13 033 (95)	41 403 (285)	8.98	21.5	4.4
Pachymetopon grande	15 066 (12)	5 730 (5)	9 339 (4)	1 850 (2)	14 890 (10)	1 000 (1)	5 339 (5)	1 500 (1)				3 232 (3)	57 946 (43)	12.56	3.2	6.2
Cheimerius nufar					810 (2)		710 (2)						1 520 (4)	0.33	0.3	0.2
MUGILIDAE	270 (2)			230 (1)	235 (1)	410 (1)	209 (1)	5 623 (28)	499 (3)	1 050 (4)	977 (8)	5 754 (24)	15 257 (73)	3.31	5.5	1.6
CLINIDAE	212 (5)		182 (6)	408 (8)				274 (8)		138 (2)	55 (4)	74 (2)	1 343 (35)	0.29	2.6	0.1
TETRAODONTIDAE																
Amblyrhynchotes honckenii								365 (2)					365 (2)	0.12	0.2	T
Total mass (g) of fish Total number of fish	87 038 100	30 108 37	70 637 57	34 499 80	87 904 64	82 143 47	68 382 73	143 972 273	25 524 48	116 283 199	58 401 102	127 249 248	932 140 1 328			

TABLE 20. Size range, mean length and mean mass of species sampled in a survey of the Port Elizabeth rock-angling fishery between August 1985 and August 1986. Species were arranged in phylogenetic order according to Smith & Heemstra (1986).

Species	Size range (mm)	Mean Length (mm)		Mean Mass (g)		n
		$\bar{x}$	s.d.	$\bar{x}$	s.d.	
**Carcharhinus brachyurus*	- -	1528	-	21000	-	1
**Carcharhinus obscurus*	- -	1070	-	6000	-	
**Mustelus mustelus*	790 -1610	1361	301	12767	6157	6
**Triakis megalopterus*	- -	780	0	2050	354	2
**Haploblepharus fuscus*	390 - 685	547	104	816	458	7
**Poroderma africanum*	970 - 980	975	7	5425	177	2
**Poroderma pantherinum*	602 - 745	668	63	1681	463	5
**Plotosus nkunga*	- -	522	-	1075	-	1
Galeichthys spp.	196 - 578	307	182	507	666	4
Cheilodactylus fasciatus	114 - 163	147	18	57	19	6
Chirodactylus brachydactylus	144 - 217	179	30	116	46	7
**Acanthistius sebastoides*	152 - 266	225	63	303	210	3
**Epinephelus guaza*	179 - 364	272	131	455	523	2
Pomatomus saltatrix	282 - 599	398	40	855	284	362
**Argyrosomus hololepidotus*	407 - 767	610	109	2458	1075	10
**Umbrina canariensis*	472 - 540	495	39	1600	361	3
Coracinus capensis	265 - 415	342	75	1132	631	3
Neoscorpis lithophilus	275 - 355	308	30	709	259	5
Pomadasys olivaceum	- -	-	-	-	-	2
Rhabdosargus holubi	114 - 308	197	61	236	219	44
Sparodon durbanensis	91 - 872	424	228	3245	3863	41
Diplodus sargus capensis	78 - 385	224	53	366	236	216
Diplodus cervinus hottentotus	116 - 388	249	85	538	447	26
Cymatoceps nasutus	217 - 354	286	41	661	259	10
Lithognathus lithognathus	265 - 610	438	96	1466	941	13
Boopsoidea inornata	100 - 260	162	52	121	119	18
Gymnocrotaphus curvidens	153 - 351	237	84	539	517	5
Sarpa salpa	85 - 263	185	26	145	60	234
Pachymetopon grande	258 - 481	348	52	1348	674	43
Cheimerius nufar	208 - 295	270	42	380	138	4
MUGILIDAE	157 - 379	244	46	209	128	67
*CLINIDAE	92 - 225	144	33	38	32	32
**Amblyrhynchotes honckenii*	179 - 195	187	11	183	25	2

*Total length (all other fish were measured using fork length).

TABLE 21. A list of the species released by anglers in a survey of the Port Elizabeth rock angling fishery between August 1985 and August 1986.

Species	Number released
OSTEICHTHYES	
CLINIDAE	59
Diplodus sargus capensis	37
Sarpa salpa	31
Amblyrhynchotes honckenii	6
Sparodon durbanensis	5
Galeichthys spp.	5
Boopsoidea inornata	5
Rhabdosargus holubi	4
Diplodus cervinus hottentotus	3
Lithognathus lithognathus	3
Pachymetopon grande	1
Cymatoceps nasutus	1
*Rock cods	5
*Bream	1
Unidentified small fish	8
CHONDRICHTHYES	
Haploblepharus fuscus	9
Poroderma africanum	1
Poroderma spp.	2
*Gully sharks	5
Unidentified sharks	4

*Eastern Cape anglers frequently include Clinidae, *Epinephelus guaza* and *Acanthistius sebastoides* in the "rock-cod" category. "Bream" generally refers to the family Sparidae. "Gully sharks" are usually either *Mustelus mustelus* or *Triakis megalopterus*.

NOTE: Only three of the released fish were tagged (SFW/ORI tagging project). These included *Sparodon durbanensis* (481mm fork length), *Diplodus sargus capensis* (270mm fork length) and *Poroderma africanum* (900mm total length).

The monthly CPUE values for the total catch and for the most important species (P. saltatrix, S. salpa, D. sargus capensis, S. durbanensis and P. grande) are presented in Figures 34 to 39. The CPUE, expressed as grams/angler hour, for the total catch was fairly constant throughout the year (Figure 34). The relatively high values for January and February resulted from the presence of Mustelus mustelus in the catch. Although this shark species was insignificant numerically, the large size of individual fish resulted in mass contributions of 30.5% and 58.4% during these months, respectively. The CPUE, expressed as the number of fish/angler hour peaked during late winter and early spring. This increase resulted from increased numbers of P. saltatrix and S. salpa in the catches.

Monthly CPUE values for P. saltatrix were low during spring and early summer (Figure 35). This period, however, coincided with maximum exploitation of S. durbanensis (see Figure 38). Catches of S. salpa were markedly seasonal with peak CPUE values during July and August (Figure 36). Monthly CPUE values for D. sargus capensis (Figure 37) showed a peak between April and December, but indicated that this species was an important component of rock-angling catches throughout the year. The monthly CPUE values for S. durbanensis (Figure 38) showed that although this species was caught throughout the year peak exploitation coincided with the breeding season between August and January. Monthly CPUE values for P. grande (Figure 39) showed that this species was caught throughout the year, with maximum exploitation occurring during summer. Peak exploitation also coincided with the breeding season in this species.

A separate analysis of the catches of non-club and club anglers showed marked differences in catch composition and CPUE (Table 22). Although club anglers comprised only 12.8% of anglers interviewed they accounted for 15.1% of the catch numerically and 27.4% of the catch in terms of mass. The CPUE of club anglers was 297.33 grams/angler hour compared to the 171.65 grams/angler hour for non-club anglers. In addition club anglers had higher CPUE values for the "more desirable" angling species such as S. durbanensis, P. grande, Lithognathus lithognathus, Umbrina canariensis and Argyrosomus hololepidotus. The smaller species such as Diplodus sargus capensis, Sarpa salpa, Boopsoidea inornata and Clinidae were less common or absent from the catches of club anglers. These results indicate that club anglers are generally more successful (experienced) than non-club anglers and that they tend to target for the larger, "more desirable" species.

Targeting of Effort

It is difficult to apportion effort to an individual species in a multi-species fishery (Crawford 1981; Crawford & Crous 1982; Westrheim 1983; Smale & Buxton 1985). Large S. durbanensis and P. grande are, however, relatively selective feeders and anglers target for them by using selected

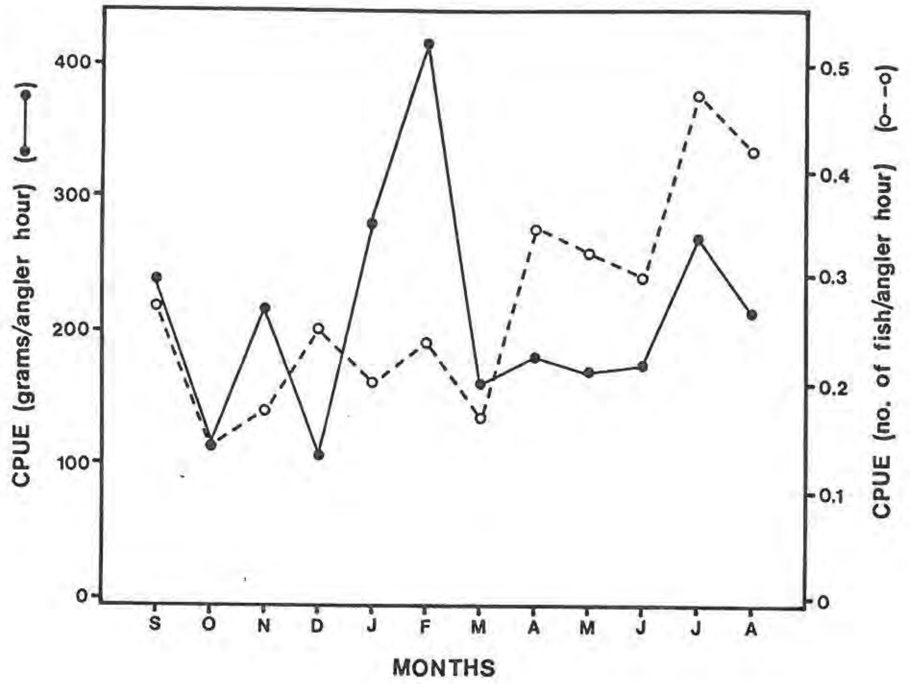


Figure 34. The monthly catch per unit of effort for the total catch in a survey of the Port Elizabeth rock-angling fishery between August 1985 and August 1986.

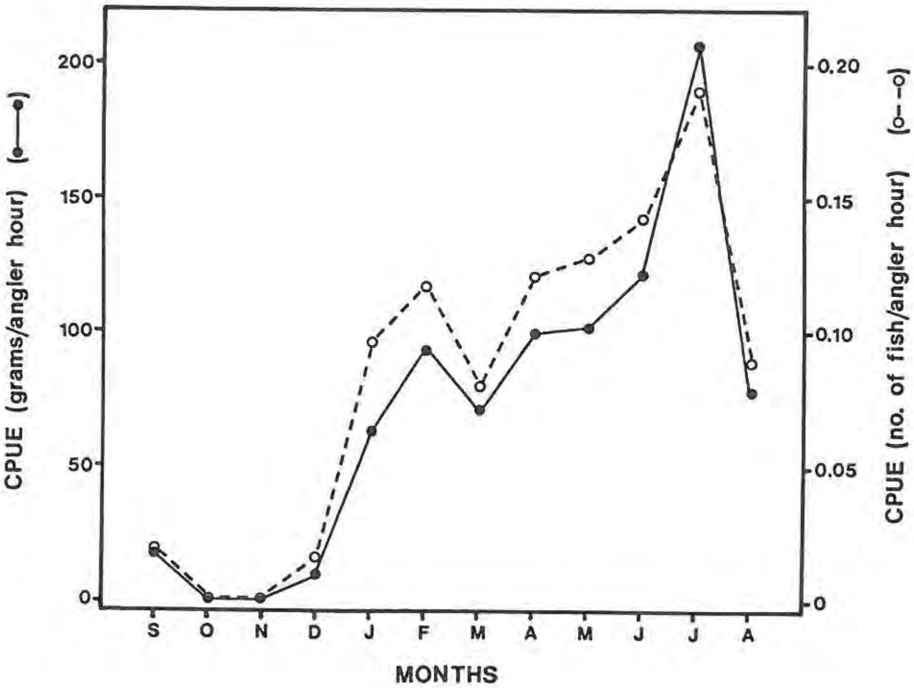


Figure 35. The monthly catch per unit of effort for <u>Pomatomus saltatrix</u> in a survey of the Port Elizabeth rock-angling fishery between August 1985 and August 1986.

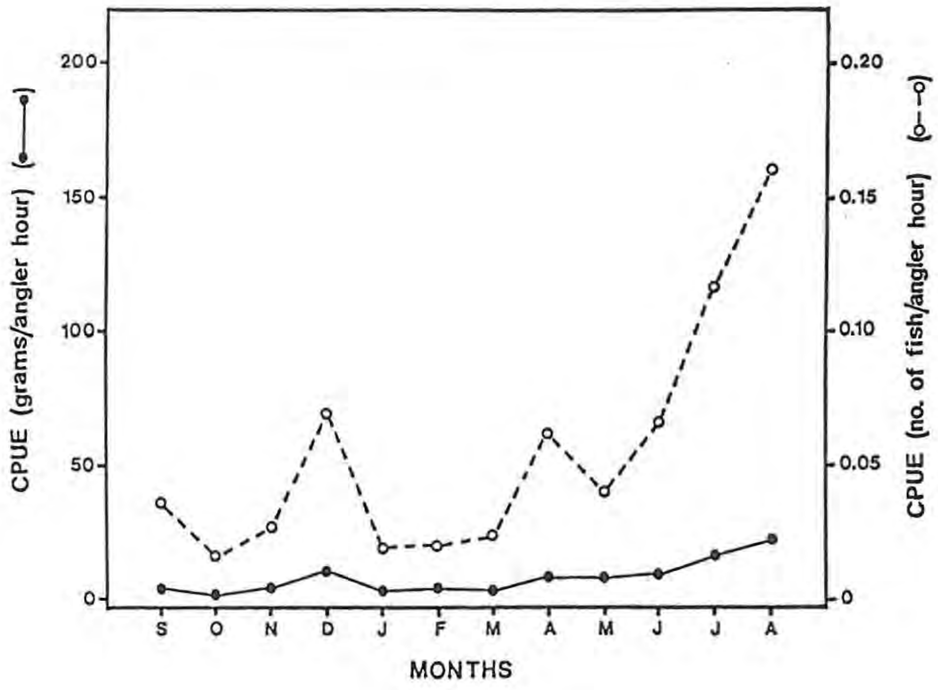


Figure 36. The monthly catch per unit of effort for Sarpa salpa in a survey of the Port Elizabeth rock-angling fishery between August 1985 and August 1986.

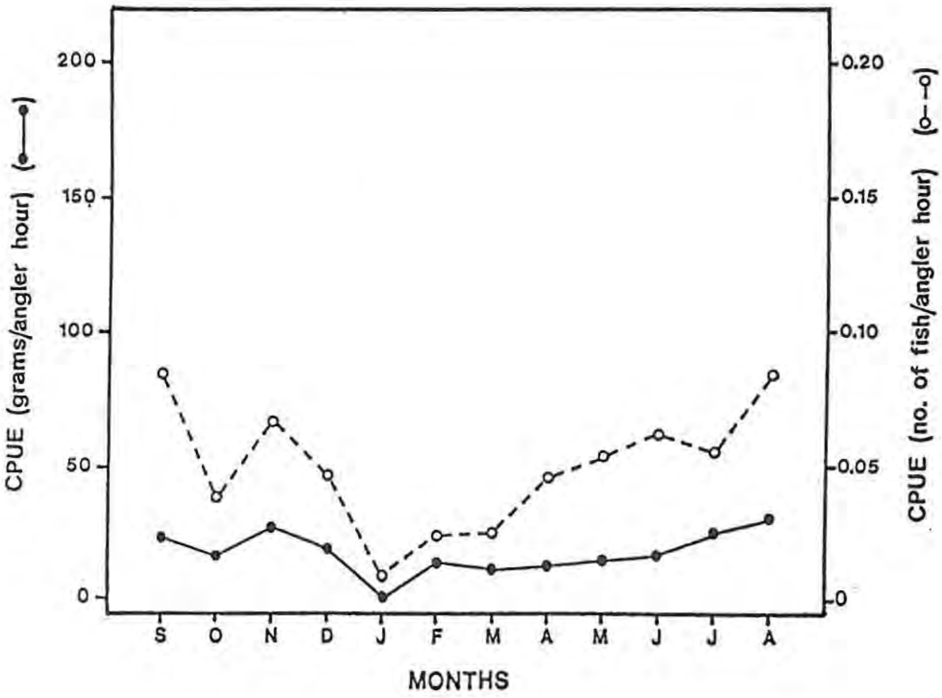


Figure 37. The monthly catch per unit of effort for Diplodus sargus capensis in a survey of the Port Elizabeth rock-angling fishery between August 1985 and August 1986.

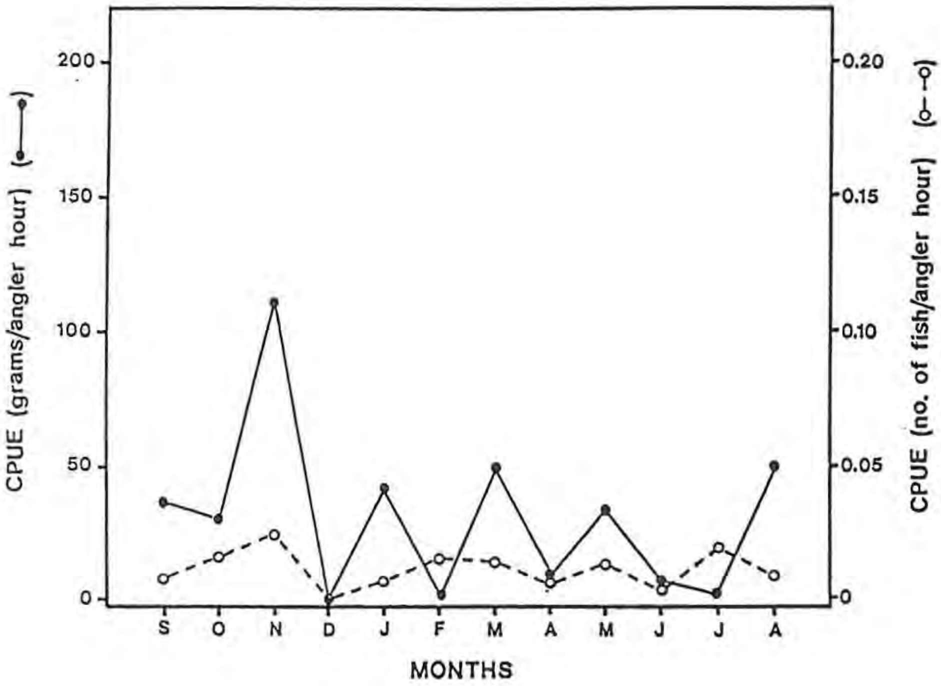


Figure 38. The monthly catch per unit of effort for Sparodon durbanensis in a survey of the Port Elizabeth rock-angling fishery between August 1985 and August 1986.

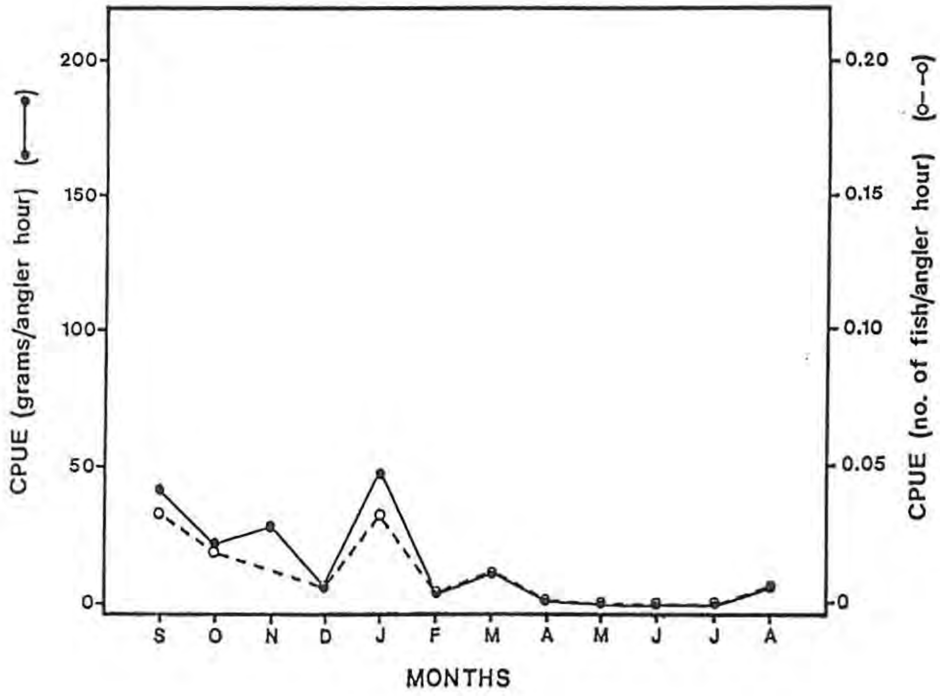


Figure 39. The monthly catch per unit of effort for Pachymetopon grande in a survey of the Port Elizabeth rock-angling fishery between August 1985 and August 1986.

TABLE 22. Catch composition and catch per unit effort of non-club and club anglers in a survey of the Port Elizabeth rock-angling fishery between August 1985 and August 1986.

	Non-club anglers			Club anglers		
Species	No.	Mass (g)	CPUE (g/hr)	No.	Mass (g)	CPUE (g/hr)
Pomatomus saltatrix	338	282 863	75.35	65	61 566	71.72
Sparodon durbanensis	34	78 948	21.03	9	60 582	70.57
Diplodus sargus capensis	211	77 080	20.53	33	12 330	14.36
Mustelus mustelus	4	40 600	10.81	2	36 000	41.93
Sarpa salpa	262	37 494	9.99	23	3 909	4.55
Pachymetopon grande	15	21 016	5.60	28	36 930	43.02
Carcharhinus brachyurus	1	21 000	5.59	-	-	-
MUGILIDAE	68	14 317	3.81	5	940	1.09
Diplodus cervinus hottentotus	25	13 516	3.60	1	470	0.55
Carcharhinus obscurus	2	12 000	3.20	-	-	-
Poroderma africanum	2	10 850	2.89	-	-	-
Lithognathus lithognathus	8	10 658	2.81	5	8 400	9.78
Argyrosomus hololepidotus	5	9 968	2.66	5	14 611	17.02
Poroderma pantherinum	5	7 836	2.09	1	2 250	2.62
Cymatoceps nasutus	11	6 832	1.82	1	1 100	1.28
Rhabdosargus holubi	36	5 719	1.52	11	5 373	6.26
Haploblepharus fuscus	6	5 279	1.41	1	435	0.51
Triakis megalopterus	2	4 100	1.09	-	-	-
Coracinus capensis	2	2 850	0.76	1	545	0.63
Gymnocrotaphus curvidens	4	2 475	0.66	1	219	0.26
Neoscorpis lithophilus	4	2 406	0.64	1	1 141	1.33
Boopsoidea inornata	19	2 297	0.61	-	-	-
Plotosus nkunga	2	2 150	0.57	-	-	-
CLINIDAE	34	1 343	0.36	-	-	-
Acanthistius sebastoides	3	908	0.24	-	-	-
Chirodactylus brachydactylus	7	813	0.22	-	-	-
Amblyrhynchotes honckenii	3	548	0.15	-	-	-
Galeichthys spp.	3	526	0.14	1	1 500	1.75
Cheilodactylus fasciatus	7	400	0.11	-	-	-
Cheimerius nufar	1	190	0.05	3	1 330	1.55
Epinephelus guaza	1	85	0.02	1	825	0.96
Umbrina canariensis	-	-	-	3	4 800	5.59
Pomadasys olivaceum	2	-	-	-	-	-

baits. Anglers using abalone (Haliotis midae), giant chitons (Dinoplax gigas), ollycrock (Turbo sarmaticus), venus ear (Haliotis spadicea), limpets (Patellidae) and red rock crab (Plagusia chabrus) as bait accounted for 73.7% of the S. durbanensis catch in terms of mass and 44.2% numerically. The preferred baits for P. grande are pink prawn (Callianassa kraussi), sand mussels (Donax serra) and swimming prawns (Penaeidae) and accounted for 91.4% of the P. grande catch by mass and 89.4% by number. Pilchard (Sardinops ocellatus) was the principal bait of anglers targeting for elf (P. saltatrix). The monthly percentage of anglers using each of these bait categories is presented in Figure 40. These results indicate that anglers targeted for S. durbanensis between August and December, for P. grande between September and April, and for P. saltatrix between December and September.

Environmental data

Considerable environmental data were collected during the study but no attempt was made to correlate this information with CPUE because of the relatively low catches. Butterworth (1985) stated that little success had been achieved world-wide in developing relationships between fisheries data, including CPUE, and environmental factors. Such relationships would, however, improve predictive ability and consequently management.

Discussion

Comparison with other South African Shore-angling Studies.

The observed CPUE of 202.1grams/angler hour was considerably lower than the figure of 853.6grams/angler hour recorded for anglers fishing off St Croix Island, Algoa Bay (Coetzee & Baird 1981b). This difference may be attributed to the availability of species generally regarded as offshore linefish species (Cheimerius nufar, Chrysoblephus laticeps, Chrysoblephus cristiceps, Chrysoblephus gibbiceps, Polysteganus praeorbitalis and Atractoscion aequidens) and because data were collected exclusively from club anglers in the latter study. The relative inaccessibility of the island and consequently lower level of exploitation may also have been a contributing factor.

The CPUE of 0.218 fish/angler hour observed for shore-anglers at selected sites along the Natal coast (Joubert 1981b) was slightly lower than that recorded in the present study (0.288 fish/angler hour). P. saltatrix, D. sargus capensis and S. salpa were numerically the most important species in both areas comprising 52% and 70% of the catch, respectively. These results indicate the importance of the above species in the shore-angling fishery along the east coast of South Africa.

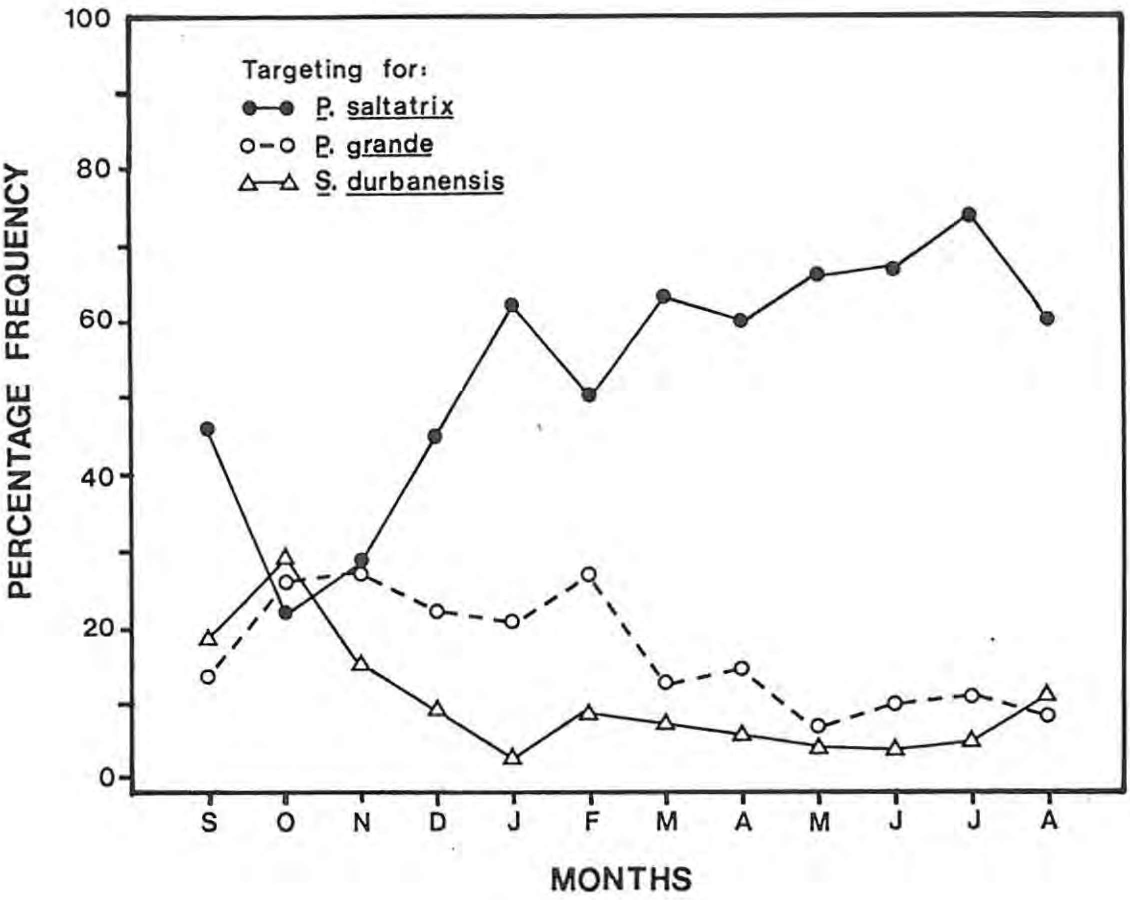


Figure 40. The seasonal targeting of angler effort at Pomatomus saltatrix, Pachymetopon grande and Sparodon durbanensis in terms of the preferred bait categories for each of these species. The data were collected from 2 531 anglers in a survey of the Port Elizabeth rock-angling fishery between August 1985 and August 1986.

The observed CPUE (0.288 fish/angler hour) was substantially lower than the value of 1.5 fish/angler hour observed for shore-anglers fishing at Terrace Bay, South West Africa/Namibia (Penrith & Loutit 1982). The relatively few species but high CPUE values observed in the Terrace Bay study are characteristic of the lower species diversity and greater abundance associated with the intertidal and shallow water fauna of the west coast (Brown & Jarman 1978).

Angler Composition

In this study the ratio of club anglers to non-club anglers was 1:7.84. An average of 1 248 anglers were registered with the Eastern Province Rock and Surf Angling Association during the 1985/1986 angling seasons. Using these figures an estimated 11 032 anglers operated in the Eastern Cape during the study period. The number of anglers registered with the Eastern Province Rock and Surf Angling Association increased on average by 5.5% (range 2.98 - 7.31%) per annum between 1983 and 1986 (Tony Perry, Port Elizabeth, pers. comm.). This result is similar to van der Elst's (1986) estimation of an annual growth of 6.5% in the number of marine sport fishermen in South Africa and indicates steadily increasing pressure on the inshore recreational fish resources in the Eastern Cape.

This study showed that White anglers (77.7%) outnumbered Coloureds (18%), Asians (3.7%) and Blacks (0.6%). These differences were even more noticeable when the population figures for the different race groups were considered. This comparison indicated that angling was most popular amongst Whites followed by Asians, Coloureds and Blacks. A similar trend was observed in the per capita income of the different groups. Whites had the highest average annual per capita income (R3 614.70) in Port Elizabeth, followed by Asians (R1 869.10), Coloureds (R789.58) and Blacks (R460.28) (1985 census, Mrs Olivier, pers. comm., Central Statistical Services). Only two percent of anglers interviewed used hand lines, the rest possessing at least one rod and reel, indicating considerable capital investment in fishing tackle. These results, combined with the low CPUE, the high proportion of club anglers (12.8%) and the importance of premier angling species such as Pomatomus saltatrix, S. durbanensis and P. grande in the catches, indicate that the Eastern Cape rock-angling fishery is primarily a recreational fishery.

By contrast, Joubert (1981b) suggested that the Natal shore-angling fishery comprised a subsistence as well as a sport fishery. Joubert suggested that the European anglers (27% of the total) fished primarily for sport and consequently targeted for the larger species, whereas fish was an important supplementary source of protein for non-European anglers (73% of the total) resulting in a targeting of effort at the smaller species which were easier to catch.

The Catch

The low CPUE of cartilaginous species in this study (30.43 grams/angler hour) may largely be attributed to their relatively low esteem in the fishery, as evidenced by the high proportion returned to the water. By contrast, cartilaginous species were the major component, in terms of mass, of competitive rock and surf angling catches in the Eastern Cape (Coetzee et al. 1987). Most angling competitions in the Eastern Cape take place along sandy stretches of coast. The importance of cartilaginous fish in competitive angling catches may largely be attributed to a targeting of effort at these species because of their relatively large size (Coetzee et al. 1987) but may also result from the preference of certain key species such as Dasyatis pastinaca and Rhinobatus annulatus for sandy areas.

The elf, Pomatomus saltatrix, was the most important species in the catch, both numerically and in terms of mass. The low CPUE for this species between September and December (see Figure 35) can largely be attributed to the closed season which extends from 1 September to 30 November. The CPUE increased from January to July with a minor peak in February. van der Elst (1976b) stated that during June and July P. saltatrix became less frequent in the Cape, migrating northwards to Natal to spawn. More recent studies (Coetzee & Baird 1981b; Smale & Buxton 1985), however, showed a relatively extended season, with considerable variation in peak CPUE in Eastern Cape waters. The latter studies do, however, show summer and spring peaks in CPUE. In this study an early summer peak would have been masked by the recently introduced closed season legislation. The peak in July most probably corresponds with the early spring peak observed by others. The results do, however, show that P. saltatrix is a major component of Port Elizabeth rock-angling catches for much of the year.

Joubert (1981b) also observed a peak in CPUE for Sarpa salpa during July and August and from his information on reproduction in this species (peak spawning occurring between June and August), suggested a winter breeding migration from Cape to Natal waters. Gonadal activity has been observed in S. salpa in Eastern Cape waters during October (pers. obs.) indicating that spawning may also occur in the Cape.

The monthly CPUE values for S. durbanensis and P. grande showed that, although both species were present throughout the year, maximum exploitation occurred during their breeding seasons. These results indicate that large fish in breeding condition are particularly susceptible to exploitation by the recreational fishery.

Targeting of Effort

The monthly percentage of anglers using the different bait categories (see Figure 40) indicated a seasonal partitioning of effort between Pomatomus saltatrix and S. durbanensis and to a lesser extent between P. saltatrix and P. grande. The seasonal availability of S. durbanensis and P. grande undoubtedly contributes to this partitioning of effort, however, this effect can largely be attributed to the closed season for P. saltatrix. Although this legislation has resulted in substantial stock recovery in P. saltatrix (R. van der Elst, Oceanographic Research Institute, Durban, pers. comm.), these results suggest that it may have adverse effects on other vulnerable species, including S. durbanensis and P. grande, because of a re-direction of angling effort. This result illustrates the difficulties experienced in managing multi-species fisheries and shows that the use of different baits by anglers can provide valuable information with respect to targeting of effort in such fisheries. The success of this technique obviously depends on the dietary preferences of the key species in the fishery.

Conclusion

Shore-angling is a rapidly expanding recreational pursuit in the Eastern Cape. Discussions with anglers suggest that catches of some species e.g. poenskop, Cymatoceps nasutus, have already declined dramatically. Historical records are largely limited to angling club and competition records and, due to the bias associated with such data, long term trends in the fishery have been difficult to establish (P. Coetzee, University of Port Elizabeth, pers. comm.). The random sampling design of this study is advantageous in that it includes all environmental conditions and excludes bias resulting from data collected exclusively from competitive anglers. Such bias may include a species direction of effort and increased CPUE values resulting from increased angling intensity. Reliance on the public for the supply of accurate data sets is also avoided, a problem with card returns and angling club records. A major disadvantage of the technique is that it is time-consuming and requires intensive field work by qualified personnel. A major limitation of the study was that, due to time constraints, monitoring was restricted to a one year period. In addition, no attempt was made to determine total catch and total effort. The number of anglers registered with the Eastern Province Rock and Surf Angling Association does, however, provide an index of effort.

Despite these shortcomings, this study provides a baseline for the future monitoring of the fishery. By repeating such surveys over a number of years effects resulting from annual variation can be evaluated and long term trends in the fishery may be established. Such trends may be evidenced by obvious changes in species composition, the mean mass of the different species and CPUE. Alternatively, changes may be more subtle and may initially be reflected by changes in angler composition, gear or the targeting of effort. It is clear, however, that long term monitoring is fundamental to developing the most suitable management plan for the South African marine linefishery.

THE NATIONAL SPEARFISHING CHAMPIONSHIPS

Introduction

Individuals and teams representing the different provinces compete annually in the South African National Spearfishing Championships. The venue is rotated to distribute the advantage gained from spearfishing in "home waters", between the different teams.

Current marine linefish legislation (Anon. 1984) limits sportfishermen, including spearfishermen, to 10 fish per man per day of which no more than five can be from the "protected" species list. These protected species are largely endemic and many already show signs of over-exploitation (van der Elst 1985). These bag limits do not apply to fish on the "unrestricted" species list, a list of species which are assumed to be relatively abundant and/or wide ranging and includes game fish, bait fish, sharks, skates and rays. Minimum size legislation and the closed seasons for Pomatomus saltatrix, Polysteganus undulosus, Petrus rupestris and Coracinus capensis are also applicable to spearfishermen. This legislation is summarised in Appendices 1 and 2.

Following the announcement of these regulations, the National Spearfishing Officer of the South African Underwater Union obtained permission from the Minister of Environmental Affairs and Tourism for participants in provincial trials and National Spearfishing Championships to exceed the bag limits for regulated and protected species. Permission was also obtained to sell the catch, excluding decommercialised species (at present only the galjoen, Coracinus capensis), in order to partially offset competition costs. The closed seasons do, however, apply to competitive spearfishing.

These concessions imply that virtually unlimited exploitation takes place during spearfishing competitions. This, however, is not the case. The strict competition rules, summarised below, severely limit size distribution as well as species composition of catches:

1. Only "edible" fish may be weighed in. The term edible is fairly loose but excludes all elasmobranchs as well as some teleosts such as members of the families Ariidae, Plotosidae and Molidae as well as the order Anguilliformes.

2. No competitor may spear more than two fish of a particular species per day.

3. There is a minimum qualifying mass of 1kg for individual fish, except for Lichia amia, which must be 3kg. Each fish meeting these minimum size requirements is referred to as a "weigher".

4. Each "weigher" automatically qualifies for 1 point with an additional 0.1 points being allocated for each 100 grams up to and including a maximum mass of 3kg. Fish of 3kg or larger therefore qualify for the maximum allocation of four points.

The National Spearfishing Championships were held off Port Elizabeth and Cape St Francis during February 1985. Diving was restricted to the area west of Cape Recife, between Noordhoek and Schoenmakerskop and between Cape St Francis and Seal Point. The championships were held off Bird Island during May 1986 and off Knysna, between the Heads (34°04'9S, 23°03'7E) and Gericke Point (34°02'S, 22°46'E) during February 1987. A brief description of these areas is provided in Chapter 2.

Methods

At all three championships fish were weighed in daily, at a centralised weigh-in point. Fish were weighed to the nearest 0.1kg. CPUE was calculated as the number of fish/man/diving hour as well as the mass of fish/man/diving hour. Fish smaller than 1kg did not qualify as "weighers" and were excluded from the analysis.

Results

An analysis of catch composition and CPUE at the three National Spearfishing Championships is presented in Table 23. Similar analyses from the different localities are presented in Tables 24-26.

During the three National Spearfishing Championships 2 287 fish weighing 4487.7kg and representing 29 species were speared during 1649 man hours. This provided a CPUE of 1.39 fish/man/hour or 2.72kg/man/hour. The highest CPUE values were observed off Bird Island where 2.66 fish/man/hour and 5.87kg/man/hour were recorded. The most important species in the catch in terms of percentage mass were Cape knifejaw (Oplegnathus conwayi 24.6%), Roman (Chrysoblephus laticeps 14.2%), red stumpnose (Chrysoblephus gibbiceps 8.9%), musselcracker (S. durbanensis 7.6%) and bronze bream (P. grande 6.7%). Most important numerically were O. conwayi (24.7%), C. laticeps (17.1%), John Brown (Gymnocrotaphus curvidens 9.3%), P. grande (9.2%) and C. gibbiceps (7.1%).

TABLE 23. Summary of catch composition and catch per unit of effort at the National Spearfishing Championships held in the Eastern Cape from 1985-1987 (n = 2287; total mass = 4487.7kg; diving hours = 1649; CPUE was measured as kg/man/hour and number of fish/man/hour).

Species	%No	%Mass	Mean Mass (kg)		Size Range (kg)	CPUE (kg/hr)	CPUE (no./hr)
			$\bar{x}$	s.d.			
Oplegnathus conwayi	24.7	24.6	2.0	0.64	1.0 - 5.6	0.668	0.343
Chrysoblephus laticeps	17.1	14.2	1.6	0.37	1.0 - 2.7	0.386	0.238
Chrysoblephus gibbiceps	7.1	8.9	2.5	0.90	1.0 - 4.6	0.242	0.098
Sparodon durbanensis	2.9	7.6	5.2	3.57	1.0 - 15.7	0.208	0.040
Pachymetopon grande	9.2	6.7	1.4	0.48	1.0 - 3.7	0.181	0.127
Gymnocrotaphus curvidens	9.3	5.3	1.1	0.13	1.0 - 1.7	0.145	0.129
Petrus rupestris	3.6	5.2	2.9	1.81	1.0 - 10.6	0.142	0.050
Epinephelus guaza	4.4	5.2	2.3	1.20	1.0 - 6.8	0.141	0.061
Diplodus cervinus hottentotus	5.9	4.0	1.3	0.28	1.0 - 2.2	0.108	0.082
Umbrina canariensis	1.8	3.0	3.3	2.35	1.0 - 9.9	0.082	0.025
Coracinus capensis	3.8	3.0	1.5	0.47	1.0 - 3.3	0.082	0.053
Chirodactylus brachydactylus	4.8	2.8	1.1	0.12	1.0 - 1.5	0.075	0.067
Cymatoceps nasutus	1.4	2.2	3.1	2.76	1.0 - 12.4	0.060	0.019
Lichia amia	0.5	2.1	8.7	2.77	4.1 - 13.5	0.058	0.007
Seriola lalandi	0.4	1.6	7.2	5.96	2.4 - 18.6	0.044	0.006
Chirodactylus grandis	0.9	1.6	3.5	1.41	1.6 - 6.0	0.045	0.013
Pomatomus saltatrix	0.5	0.5	2.0	0.80	1.2 - 3.5	0.014	0.007
Chrysoblephus cristiceps	0.2	0.5	4.1	1.31	1.7 - 5.3	0.012	0.003
Lithognathus lithognathus	0.5	0.4	1.4	0.28	1.0 - 2.0	0.010	0.007
Cheimerius nufar	0.2	0.2	1.9	0.92	1.0 - 3.3	0.006	0.003
Atractoscion aequidens	0.1	0.1	2.0	0.60	1.4 - 2.6	0.002	0.001
Seriola rivoliani	0.1	0.1	1.4	0.19	1.1 - 1.5	0.002	0.002
CARANGIDAE	0.1	0.1	1.1	0.08	1.0 - 1.2	0.002	0.002
Epinephelus chabaudi	0.1	0.1	1.6	0.60	1.0 - 2.2	0.002	0.001
Sarpa salpa	0.0	0.0	1.1	0	1.1	0.001	0.001
Argyrosomus hololepidotus	0.0	0.0	1.0	0	1.0	0.001	0.001
Parascorpis typus	0.0	0.0	1.0	0	1.0	0.001	0.001
Neoscorpis lithophilus	0.0	0.0	1.0	0	1.0	0.001	0.001
Pachymetopon aeneum	0.0	0.0	1.1	0	1.1	0.001	0.001

TABLE 24a. Summary of catch composition and catch per unit of effort at the National Spearfishing Championships held off Port Elizabeth during February 1985 (n = 133; total mass = 247.8kg; diving hours = 180; CPUE was measured as kg/man/hour and number of fish/man/hour).

Species	%No	%Mass	Mean Mass (kg)		Size Range	CPUE	CPUE
			$\bar{x}$	s.d.	(kg)	(kg/hr)	(no./hr)
Oplegnathus conwayi	43.6	46.4	2.0	0.58	1.0 - 3.4	0.639	0.322
Pachymetopon grande	20.3	16.3	1.5	0.47	1.0 - 2.9	0.224	0.150
Epinephelus guaza	3.8	8.5	1.6	0.49	1.0 - 2.4	0.044	0.028
Petrus rupestris	6.8	8.0	2.2	1.12	1.0 - 5.1	0.111	0.050
Diplodus cervinus hottentotus	6.0	3.8	1.2	0.14	1.0 - 1.4	0.052	0.044
Sparodon durbanensis	0.1	3.5	8.7		8.7	0.048	0.005
Chrysoblephus gibbiceps	5.3	3.1	3.0	0.91	1.7 - 4.3	0.117	0.039
Cymatoceps nasutus	3.0	3.1	1.9	0.46	1.0 - 2.6	0.042	0.022
Chrysoblephus laticeps	3.0	2.7	1.7	0.24	1.0 - 2.1	0.038	0.022
Gymnocrotaphus curvidens	4.5	2.5	1.0	0.05	1.0 - 1.1	0.034	0.033
Coracinus capensis	1.5	1.0	1.3	0.10	1.0 - 1.4	0.014	0.011
Chirodactylus brachydactylus	1.5	0.1	1.1	0.10	1.0 - 1.2	0.012	0.011

TABLE 24b. Summary of catch composition and catch per unit of effort at the National Spearfishing Championships held off Cape St Francis during February 1985 (n = 692; total mass = 1400.1kg; diving hours = 360; CPUE was measured as kg/man/hour and number of fish/man/hour).

Species	%No	%Mass	Mean Mass (kg)		Size Range	CPUE	CPUE
			$\bar{x}$	s.d.	(kg)	(kg/hr)	(no./hr)
Oplegnathus conwayi	20.7	22.7	2.2	0.70	1.0 - 5.6	0.883	0.397
Chrysoblephus laticeps	13.7	11.9	1.8	0.44	1.0 - 2.7	0.462	0.264
Petrus rupestris	7.1	11.5	3.3	1.70	1.2 - 7.7	0.446	0.136
Epinephelus guaza	8.8	9.8	2.3	1.00	1.0 - 5.6	0.383	0.169
Gymnocrotaphus curvidens	14.6	8.3	1.2	0.14	1.0 - 1.7	0.324	0.281
Chirodactylus brachydactylus	12.0	6.8	1.2	0.12	1.0 - 1.5	0.264	0.231
Chirodactylus grandis	2.9	5.1	3.6	1.43	1.6 - 6.0	0.198	0.056
Pachymetopon grande	5.1	4.6	1.8	0.67	1.0 - 3.7	0.179	0.097
Chrysoblephus gibbiceps	2.6	4.2	3.2	0.98	1.4 - 4.6	0.162	0.050
Diplodus cervinus hottentotus	4.3	3.1	1.4	0.34	1.0 - 2.2	0.119	0.083
Sparodon durbanensis	2.4	3.0	2.5	1.41	1.0 - 6.8	0.116	0.047
Coracinus capensis	3.3	2.7	1.6	0.44	1.0 - 2.7	0.103	0.064
Seriola lalandi	0.3	2.6	17.9	0.70	17.2 - 18.6	0.099	0.006
Lichia amia	0.6	2.6	9.2	1.27	7.3 - 10.6	0.103	0.011
Cymatoceps nasutus	0.9	0.7	1.8	0.96	1.0 - 3.8	0.029	0.017
Seriola rivoliani	0.4	0.3	1.4	0.19	1.1 - 1.5	0.011	0.008
Umbrina canariensis	0.1	0.1	1.3	0	1.3	0.003	0.003
Argyrosomus hololepidotus	0.1	0.1	1.0	0	1.0	0.003	0.003

TABLE 25. Summary of catch composition and catch per unit of effort at the National Spearfishing Championships held off Bird Island during May 1986 (n = 412; total mass = 909.1kg; diving hours = 155; CPUE was measured as kg/man/hour and number of fish/man/hour).

Species	%No	%Mass	Mean Mass (kg) $\bar{x}$	s.d.	Size Range (kg)	CPUE (kg/hr)	CPUE (no./hr)
Chrysoblephus gibbiceps	13.1	17.2	2.9	0.50	1.8 - 3.8	1.009	0.348
Sparodon durbanensis	7.0	16.6	5.2	2.80	1.0 - 15.7	0.971	0.187
Chrysoblephus laticeps	15.0	12.8	1.9	0.35	1.1 - 2.6	0.749	0.400
Oplegnathus conwayi	13.3	12.7	2.1	0.72	1.0 - 3.6	0.745	0.355
Gymnocrotaphus curvidens	11.2	5.7	1.1	0.13	1.0 - 1.5	0.333	0.297
Diplodus cervinus hottentotus	8.5	5.2	1.4	0.31	1.0 - 2.1	0.306	0.226
Cymatoceps nasutus	4.1	5.2	2.8	1.55	1.2 - 7.1	0.305	0.110
Pachymetopon grande	6.6	4.2	1.4	0.37	1.0 - 2.5	0.246	0.174
Coracinus capensis	4.6	4.1	2.0	0.58	1.0 - 3.3	0.239	0.123
Seriola lalandi	1.9	4.0	4.6	2.96	2.4 - 11.4	0.236	0.052
Epinephelus guaza	3.2	2.7	1.9	0.83	1.0 - 3.9	0.157	0.084
Pomatomus saltatrix	2.9	2.6	2.0	0.80	1.2 - 3.5	0.151	0.077
Chrysoblephus cristiceps	1.0	2.1	4.7	0.62	3.7 - 5.3	0.121	0.026
Lithognathus lithognathus	2.7	1.7	1.4	0.28	1.0 - 2.0	0.102	0.071
Petrus rupestris	1.5	1.5	2.3	1.40	1.0 - 4.8	0.087	0.039
Chirodactylus brachydactylus	2.7	1.3	1.1	0.07	1.0 - 1.2	0.075	0.071
Atractoscion aequidens	0.5	0.4	2.0	0.60	1.4 - 2.6	0.026	0.012
Sarpa salpa	0.2	0.1	1.1	0	1.1	0.007	0.006

TABLE 26. Summary of catch composition and catch per unit of effort at the National Spearfishing Championships held off Knysna during March 1987 (n = 1050; total mass = 1930.7kg; diving hours = 954; CPUE was measured as kg/man/hour and number of fish/man/hour).

Species	%No	%Mass	Mean Mass (kg) $\bar{x}$	s.d.	Size Range (kg)	CPUE (kg/hr)	CPUE (no./hr)
Oplegnathus conwayi	29.4	28.7	1.8	0.55	1.0 - 3.7	0.581	0.324
Chrysoblephus laticeps	22.0	18.0	1.5	0.29	1.0 - 2.5	0.365	0.242
Chrysoblephus gibbiceps	7.9	8.5	2.0	0.80	1.0 - 4.1	0.171	0.087
Pachymetopon grande	11.5	8.1	1.3	0.35	1.0 - 3.4	0.164	0.127
Sparodon durbanensis	1.8	7.3	7.5	4.24	1.5 - 15.3	0.149	0.020
Umbrina canariensis	3.8	6.9	3.3	2.35	1.0 - 9.9	0.140	0.042
Diplodus cervinus hottentotus	6.0	4.0	1.2	0.21	1.0 - 2.1	0.081	0.066
Gymnocrotaphus curvidens	5.7	3.3	1.1	0.08	1.0 - 1.3	0.067	0.063
Epinephelus guaza	2.0	3.3	3.0	1.66	1.0 - 6.8	0.066	0.022
Coracinus capensis	4.2	3.0	1.3	0.29	1.0 - 2.2	0.061	0.046
Lichia amia	0.7	3.0	8.4	3.30	4.1 - 13.5	0.061	0.007
Petrus rupestris	1.7	2.1	2.3	2.16	1.0 - 10.6	0.043	0.019
Cymatoceps nasutus	0.5	1.7	6.7	4.81	1.0 - 12.4	0.035	0.005
Chirodactylus brachydactylus	1.3	0.8	1.1	0.10	1.0 - 1.3	0.016	0.015
Cheimerius nufar	0.5	0.5	1.9	0.92	1.0 - 3.3	0.010	0.005
CARANGIDAE	0.3	0.2	1.1	0.08	1.0 - 1.2	0.003	0.003
Epinephelus chabaudi	0.2	0.2	1.6	0.60	1.0 - 2.2	0.003	0.002
Chrysoblephus cristiceps	0.1	0.1	1.7	0	1.7	0.002	0.001
Chirodactylus grandis	0.1	0.1	2.8	0	2.8	0.003	0.001
Parascorpis typus	0.1	0.1	1.0	0	1.0	0.001	0.001
Neoscorpis lithophilus	0.1	0.1	1.0	0	1.0	0.001	0.001
Pachymetopon aeneum	0.1	0.1	1.1	0	1.1	0.001	0.001

Discussion

The majority of the species taken by spearfishermen are also exploited by either ski-boat anglers or rock and surf anglers, or both. The Cape knifejaw, O. conwayi, and the John Brown, G. curvidens, are, however, primarily spearfishing species. In comparison, the elf (P. saltarix) was heavily exploited by Eastern Cape recreational linefishermen (Coetzee & Baird 1981b; Smale & Buxton 1985; this study) but was poorly represented in the spearfishing catches.

O. conwayi was the most important species in the spearfishing catches, both in terms of percentage mass and percentage number. G. curvidens was the third most important species numerically but because of its small size was less important in terms of mass. The reverse applied for S. durbanensis and the red steenbras, Petrus rupestris, which were relatively important in terms of mass, because of their large size.

Spearfishing is the smallest of the four marine sport fishing sectors. Due to the relatively low number of participants, combined with the large area in which they operate, monitoring of non-competitive catches is extremely difficult. Data collection at the National Spearfishing Championships was, however, cost effective in terms of monetary expenditure as well as time invested. This resulted from a large number of divers operating in a relatively small area during a short time period. Unfortunately the results are biased because data were collected from the most accomplished spearfishermen in the country. Competition rules such as the points allocation system, the limit of 2 fish/species/man/day and the exemption from certain linefish regulations also bias the results. To date no information has been published on catch composition and CPUE in the South African spearfishery and despite the above biases, the results provide an indication of the relative availability of fish larger than 1kg.

It would be unrealistic to attempt to compare data from the National Spearfishing Championships held in the different areas because many factors may contribute to observed differences in catch composition and CPUE. Observed differences may result from geographical variation in the fish fauna, seasonal variation in the availability of target species or differences in the diving conditions. The temporal restrictions (short periods of irregular sampling) associated with data collection from spearfishing competitions precluded any evaluation of these factors. Of interest, however, are the relatively high CPUE values for Bird Island. Buxton (1987) noted an increase in the size and number of Chrysoblephus cristiceps in the areas of Algoa Bay which were furthest from the major launching sites at Port Elizabeth. The spearfishing results therefore support his suggestion that reef fish stocks have been heavily exploited in the near vicinity of Port Elizabeth.

In conclusion, these results represent the first attempt to analyse the Eastern Cape spearfishery. Monitoring of non-competitive spearfishing catches is at present impractical, and data collected from competitions is biased. The results do, however, provide information on catch composition and CPUE which in the long term (provided competition rules remain fairly constant) will contribute to our understanding of the spearfishery in different areas and possibly the linefishery as a whole.

CHAPTER 7 - GENERAL DISCUSSION AND MANAGEMENT CONSIDERATIONS

Many of the species exploited by Eastern Cape rock-anglers and spearfishermen are also exploited by the recreational and commercial line-boat sectors. Multi-species fisheries are generally considered to be difficult to manage (Sainsbury 1982; Smale & Buxton 1985). This is further complicated when the benefits derived from the resource differ amongst the resource users. Economic, recreational, nutritional and social benefits may be associated with the linefish resource (van der Elst 1985). The management strategies needed to satisfy these benefits are not necessarily compatible (Gulland 1978; Butterworth 1985; van der Elst 1985). The prime objective should be to manage the linefish resource in a manner in which the harvest will provide the greatest overall benefit to the community (van der Elst 1985). Clearly, no single conservation measure is sufficient in a multi-species, multi-user fishery and the need for a suite of management options has been identified (Smale & Buxton 1985; Butterworth 1985; Buxton 1987).

S. durbanensis and P. grande are generally not taken by the recreational or commercial line-boat sectors. They were, however, the second and fifth most important species in the Port Elizabeth rock-angling fishery, contributing 15% and 6.2% of the total mass of the catch, respectively. Their relatively large size resulted in both species being less important numerically. S. durbanensis was the fourth most important species in the Eastern Cape spearfishery in terms of mass (7.6%) and accounted for 2.7% of the catch numerically. P. grande was slightly less important in terms of mass (6.7%) but was numerically more important (9.2%). These results clearly indicate the importance of these species to the inshore recreational fisheries.

This chapter evaluates the management options applicable to S. durbanensis and P. grande in relation to their life history characteristics and their importance to the recreational fishery. Current conservation legislation is evaluated and possible alternatives are discussed.

LIFE HISTORY CHARACTERISTICS OF S. DURBANENSIS AND P. GRANDE

Comparative studies of life history parameters are of particular value in fisheries biology (Adams 1980). The life history characteristics which were considered to be important in S. durbanensis and P. grande were relatively slow growth, longevity and late maturation. Their association with shallow water reefs, coupled with a limited global distribution, was also an important management consideration.

Age determination, by otolith growth zone analysis, resulted in relatively low K-values (Pauly

1983) in the von Bertalanffy growth equations for both species. This may be considered indicative of relatively slow growth in these species (Adams 1980).

S. durbanensis and P. grande are relatively long-lived, with lifespans in excess of 40 years. The observed longevities may indicate that adult mortality is low (Buxton 1987). The relatively low densities of juveniles in intertidal pools and in the inshore (<40m) environment, in spite of obviously high fecundities (evidenced by small eggs and large GSI values), probably indicates that mortality in both species is high during early ontogeny (Buxton 1987).

Late maturation was observed in S. durbanensis and P. grande with 50% maturity attained at ages of approximately 4.5 and 5.5 years, respectively.

Slow growth, longevity, relatively late maturation, large body size, iteroparity and relatively high adult survivorship are typical of K-selected (Stearns 1976; Adams 1980), precocial (Balon 1981) or Type II (Sharp 1987) species. The apparent high fecundity and low parental investment per young in both species, as evidenced by small eggs and large GSI values, are generally considered to be r-selected (altricial) traits (Buxton 1987). This apparent anomaly in life history strategies may be explained by bet-hedging theory (Stearns 1976; Buxton 1987). This theory predicts that selection will favour reduced reproductive effort and longevity in fluctuating environments where juvenile mortality is affected. Large GSI values are not necessarily indicative of high reproductive investment (Grahame 1977; Buxton 1987), because relative to brood care, the cost of producing large numbers of small ova or sperm may be low. Adams (1980) stressed the importance of assessing the life history strategy of a species in a relative sense. Therefore, although the reproductive investment, in terms of GSI values, of S. durbanensis and P. grande may be higher than some of the South African sparids examined to date (Buxton 1987), the overall reproductive effort may be low compared to other South African marine linefish, such as Galeichthys spp., which have large ova and exhibit mouth brooding behaviour (Tilney 1987).

The interaction of life history characteristics has a strong effect on the response of a species to fishing pressure (Adams 1980). The majority of the life history characteristics of S. durbanensis and P. grande are typical of K-selected species. Fisheries based on K-selected species are characterised by constant catches resulting from stable population sizes (Adams 1980; Sharp 1987). These fisheries are, however, more susceptible to over-fishing and stock depletion (Adams 1980; Ricker 1963). The slow growth associated with K-selected species results in a slower recovery rate after over-exploitation (Adams 1980; Buxton 1987). A combination of delayed maturation in K-selected species and early recruitment into the fishery may also affect the recruitment potential of the species (Buxton 1987). In fisheries based on K-selected species, the maximum yield per recruit occurs at lower levels of fishing mortality and at later ages at first entry than in fisheries based on r-selected species and extremely K-selected species may only be suitable for trophy fisheries (Adams 1980).

CONSERVATION OPTIONS

South African marine linefishermen are divided into four sectors with respect to legislation governing the resource. At present the catch of full-time commercial fishermen is controlled by using a licensing system to limit access to the fishery, as well as closed seasons and minimum size regulations. The restrictions applicable to full-time commercials also apply to semi-commercial fishermen. In addition semi-commercial fishermen are limited to a total of 5 fish on the protected species list per man per day (Appendix 1). Sport anglers and spearfishermen may catch an unlimited number of fish on the unrestricted list (Appendix 1). They are however, limited to a total of 10 fish, of all other species, per man per day. Of these 10 fish not more than five may be on the protected list. Closed seasons and minimum size restrictions are also applicable to sport anglers and spearfishermen. Spearfishermen in Natal are further restricted by a minimum size limit of 2kg. Other regulatory measures utilised in the protection of the South African marine linefish resource include closed areas and decommercialisation. In a sport fishery the size of individual fish (quality) is most often more important than bag size (quantity). To satisfy this demand it may be necessary to maintain the stock at a level greater than that at maximum sustainable yield (Butterworth 1985). The recreational importance of S. durbanensis and P. grande may therefore necessitate a modified management approach. In the following sections the applicability of different regulatory measures for the two species is assessed.

Closed Areas

Closed areas reduce total fishing effort to some extent (Gulland 1978) and would therefore serve as a conservation measure for all species which are present in the area and are exploited by the fishery. Clearly the species which benefit most from closed areas are those in which resident breeding populations are protected. From a fishery perspective, the success of a closed area depends on its ability to seed adjacent areas by juvenile and/or adult migration, egg and larval dispersion, or both (Buxton 1987). An assessment of the effectiveness of closed areas as a conservation measure for S. durbanensis and P. grande requires a thorough understanding of their movement patterns. At present this aspect of their biology is poorly understood, but should they be wide-ranging the effectiveness of closed areas as a conservation measure would be severely reduced and would depend to a large degree on the size of the area.

Restrictions on the type of gear used

Restrictions on the use of the most efficient types of gear have been considered as an admission of failure to achieve optimum management from an economic point of view (Gulland 1978). This, however, need not necessarily be the case and can be well illustrated by the prohibition of gill-netting of galjoen, Coracinus capensis, (Bennett & Griffiths 1986). Although angling and spearfishing are comparatively inefficient methods of capture, the benefits of this legislation to the recreational fisheries and the consequent economic repercussions, may well surpass the value of the landed catch previously taken by gill nets. S. durbanensis and P. grande are almost exclusively exploited by the rock-angling and spearfishing sectors. Spearfishermen are already restricted to some extent in that the use of SCUBA is illegal. Any further restrictions on gear, such as the control of hook size and use of nylon line by anglers (van der Elst 1985) or the prohibition of the use of boats by spearfishermen would be detrimental to the fishery in terms of the pleasure derived from the pursuit, and may also have a negative economic effect on industries related to the recreational fishery.

Limitation of the total amount of fishing

The amount of fishing may be limited, not by reducing the number of participants in the sport (van der Elst 1985), but by limiting the number of anglers fishing in a particular area on a daily or weekly basis. This has worked well in inland waters such as the syndicate owned trout streams in the Eastern Transvaal and may be applicable to areas of high angling pressure such as Beachwood and the St Lucia estuary in Natal or Cape Recife and the Sundays River surf off Port Elizabeth.

Closed Seasons

At present four species of marine linefish are protected by closed seasons in South Africa. These include Pomatomus saltatrix, Polysteganus undulosus, Petrus rupestris and Coracinus capensis. The closed seasons are proclaimed to protect a species over a particularly vulnerable period of the life cycle. This period frequently coincides with the breeding season, when aggregations or migrations of fish may result in increased catches (Buxton 1987). The primary effect of closed seasons in long-lived species is the reduction of total effort, and consequently total catch, during a period when the fish are particularly susceptible to exploitation. In long-lived species spawning occurs in successive seasons and the maintenance of a viable spawning stock is independent of the season in which the fish are caught. Improved recruitment, by preventing exploitation until after breeding, is therefore less noticeable in long-lived species (Buxton 1987).

The closed season, minimum size legislation and bag limits for P. saltatrix have resulted in a considerable stock recovery (R. van der Elst, Oceanographic Research Institute, pers.comm.). The closed season for this species may, however, have had an adverse effect on species such as S. durbanensis and P. grande due to a re-direction of effort. Clearly this type of effect is an important management consideration in multi-species fisheries.

This study showed a seasonal targeting of effort at S. durbanensis and P. grande during their breeding seasons. Clearly the implementation of closed seasons over the breeding seasons would reduce total effort, and consequently total catch, considerably. The breeding season for S. durbanensis coincides with the closed season for P. saltatrix. These two species account for 52% of the catch of Port Elizabeth rock anglers in terms of mass and 33.5% numerically. By implementing a closed season for S. durbanensis during this period much of the appeal of this fishery would be lost. In addition effort would be re-directed towards species such as P. grande and Diplodus sargus capensis. The implementation of closed seasons for S. durbanensis and P. grande should therefore be considered only as a last resort because of the negative effect on the recreational fishery as well as multi-species repercussions resulting from a re-direction of effort.

Bag limits

Bag limits were an important component of a series of fishing regulations introduced in 1984, aimed at optimal utilisation of the South African Marine linefish resource (van der Elst 1985). Bag limits are usually aimed at maintaining the catch at a level offering adequate protection to the parent stock thereby ensuring sufficient recruitment (Buxton 1987). An indirect effect of this measure is the equalisation of catches, achieved by reducing the bag taken by the more successful anglers and thereby increasing the availability of fish for the less successful anglers (Allen 1955 in Buxton 1987).

The effectiveness of a bag limit for a particular species depends on the relationship between bag sizes before and after legislation. Buxton (1987) showed that the catch of the majority of recreational boat anglers in the Port Elizabeth area was substantially lower than that allowed by current legislation. He suggested that the implementation of bag limits has had little effect on the fishing habits in the area and were unlikely to improve the state of reef fish stocks.

This study showed that rock-anglers in the Port Elizabeth area caught a total of 515 fish on the protected species list (Appendix 1) during 4612.2 angler hours, providing an average of one protected fish for every 9 angling hours. Elf, Pomatomus saltatrix, accounted for 78% of this catch. The average catch of protected fish, other than elf, was one fish for every 41.18 angler hours. A total of 934 fish, including unrestricted species, were caught, providing a catch rate of one fish for every 4.92 angler hours. These results indicate that the current legislation of 5 protected fish/man/day and a total of ten fish/man/day (excluding unrestricted species) does not affect the catches of the majority of Port Elizabeth rock-anglers.

The schooling and migratory behaviour of P. saltatrix results in "runs' in the fishery when large numbers of this species are caught in relatively short time periods. The limit of five protected fish/man/day clearly benefits this species under such circumstances. The other species in the Port Elizabeth rock-angling fishery, however, appear to derive little benefit from current bag limit legislation. This may be attributed to a combination of a low CPUE and the absence of runs in the fishery.

A number of the species on the protected species list are particularly susceptible to exploitation by spearfishermen. The limit of five protected fish/man/day is therefore more relevant to this sector.

In the Eastern Cape the catch composition of rock-anglers is considerably different to that of the recreational ski-boat sector (Smale & Buxton 1985) whereas spearfishermen exploit species common to both sectors. Current bag limits appear to offer little protection for rock-angling species other than P. saltatrix and results indicate that additional legislation, aimed specifically at the inshore recreational species is required.

Size limits

The rationale presented for size limitation is often confused. On the one hand maximum size limits are argued for on the basis that the largest fish are the most fecund and should therefore not be removed from the population. Alternatively, a minimum size limit is frequently set at some value above the length at 50% maturity, in the belief that the fish should be allowed to spawn at least once prior to being subjected to exploitation (Butterworth 1985). In a recreational fishery where sport fishermen are generally targeting for trophy fish the implementation of a maximum size limit is less practical. Butterworth (1985) suggested that by setting the age at first capture at a size larger than 50% maturity, increased spawning does not necessarily occur. At present there is no minimum size limit for P. grande and a limit of 40cm total length for S. durbanensis. This study showed that 23.4% (58 fish) of the recreational catch (248 fish) of S. durbanensis was smaller than the minimum size limit. Rock-anglers were largely responsible for this figure, 32.6% (45 fish) of their catch (138 fish) being undersized. In comparison, only 10.3% (11 fish) of the catch of spearfishermen (107 fish) was undersized. Eighty percent of the catch of S. durbanensis and 96% of the catch of P. grande was larger than the calculated sizes at 50% maturity (350mm and 300mm F.L., respectively). Slow growth, late maturation, longevity and the likelihood of low adult mortality in S. durbanensis and P. grande present a strong case in favour of stringent minimum size legislation in these species.

Decommercialisation

The galjoen, Coracinus capensis, is the only South African linefish which is protected by legislation preventing the commercial marketing of a species. Current legislation, however, prevents sport fishermen from selling their catch. S. durbanensis and P. grande may be exploited by spearfishermen or anglers operating from B category (semi-commercial licensed) craft. The fact that these fishermen may market these species makes the illicit marketing of S. durbanensis and P. grande by recreational fishermen and dealers more difficult to control.

S. durbanensis and P. grande are premier rock-angling and spearfishing species. Their relatively low abundance (Smith & Heemstra 1986), slow growth and late maturation, however, makes them unsuitable for commercial exploitation. The social and economic importance of the recreational fishery provides a strong argument in favour of decommercialisation of these fish.

FINAL DISCUSSION AND CONCLUSIONS

S. durbanensis and P. grande may be regarded as "trophy" fish in the recreational fishery, a consequence of their palatibility and relatively large size. The localised distribution of these fish, both geographically and because of their association with shallow water reefs, combined with slow growth and late maturation, makes them susceptible to over-exploitation in the size-selective rock-angling and spear fisheries.

In a multi-species fishery, each species should ideally be harvested at its maximum sustainable yield. The complications of multi-species interactions (Gulland 1987; Sharp 1987) and the inability to direct fishing effort at a particular species, however, creates problems. This may result in the resource managers having to accept a regime where some species will be over-exploited (Butterworth 1985).

Spearfishermen can select both the size and the species taken. Fish taken by rock-anglers do not suffer from barotrauma or net damage, although the effects of capture stress are unknown. These fish may therefore be returned unharmed to the water with little or no effort on behalf of the angler. The introduction of species specific restrictions are therefore a practical management strategy in the spearfishing and shore-angling fisheries.

One of the main objectives of the South African Marine Linefish Management Plan, introduced in 1984, was that regulations should be relatively uncomplicated and easily applied in a standardised fashion throughout the country (van der Elst 1985). Butterworth (1985) suggested that reliance on a single conservation measure was inadvisable, owing to the limited scientific information available on the linefishery, and that a suite of conservation measures was expedient pending more detailed analysis. It is clear that conservation options for S. durbanensis and P. grande which conform to the general pattern of legislation governing linefish exploitation are more desirable. The following recommendations for the management of S. durbanensis and P. grande are therefore proposed:

1. Decommercialisation of both species.

2. (a) An increase in the minimum size limit for S. durbanensis. Although the existing minimum size limit for this species exceeds the size at 50% maturity, it is felt that the importance of this species to the recreational fishery lies in its relatively large size. Discussions with club anglers indicated that they would support a minimum size limit of 5kg, corresponding to a total length of 675mm. The acceptance of a 2kg limit on all species by Natal spearfishermen and a 70cm limit for Lichia amia indicates that sportfishermen are already conditioned, to some extent, to stringent size limits. A minimum size limit of 65cm total length (approximately 4kg) is recommended for S. durbanensis.

   (b) Immediate implementation of a minimum size limit for P. grande. This should be set at a minimum of 330mm total length, corresponding to the size at 50% maturity. A minimum size limit of 40cm total length (approximately 1.5kg) is recommended.

Decommercialisation would enable more efficient enforcement of current legislation prohibiting the sale of these species by recreational fishermen. The minimum size legislation would help maintain the quality of these fish in the recreational fishery and should improve recruitment by reduced exploitation of spawning individuals. Should future trends in the fishery indicate over-exploitation of these species, additional measures such as closed seasons over the breeding seasons and reduced bag limits would need to be considered.

A disturbing result of this study is the apparent disregard for existing linefish legislation by many fishermen. This was evidenced by the substantial proportion of undersized fish (23.4% in the case of S. durbanensis) as well as catches of Pomatomus saltatrix during the closed season and bag sizes for this species in excess of 5 fish/man/day. South Africa has a coastline extending approximately 3 000km (Robinson, Siegfried & Visser 1985) and adequate enforcement of fisheries legislation is consequently difficult. Intensive educational programmes are therefore necessary to create a conservation awareness amongst the resource users.

In conclusion, the applicability of species specific catch restrictions, combined with the rapid growth in our knowledge of the basic biology of the most important species, provides the basis for healthy shore-angling and spearfisheries in the Eastern Cape. The future of these fisheries is, however, largely dependent on the close co-operation of the fishermen, improved law enforcement by the authorities and long-term monitoring of the fisheries by the scientific community.

APPENDIX 1. Categorisation of South African marine linefish species with respect to existing conservation legislation.

Unrestricted	Protected	Regulated
Tribe: Thunnini	*Acanthopagrus berda*	All other species
Thyrsites atun	*Pomatomus saltatrix*	
Family: Istiophoridae	*Lichia amia*	
Argyrosomus spp.	*Chrysoblephus anglicus*	
Seriola lalandi	*Chrysoblephus laticeps*	
Scomber japonicus	*Chrysoblephus gibbiceps*	
Trachurus trachurus	*Petrus rupestris*	
Sarpa salpa	*Chrysoblephus cristiceps*	
Spondyliosoma emarginatum	*Polysteganus undulosus*	
Family: Mugilidae	*Chrysoblephus puniceus*	
Family: Synodontidae	*Cheimerius nufar*	
Pagellus natalensis	*Polysteganus praeorbitalis*	
Class: Chondrichthyes	*Cymatoceps nasutus*	
Merluccius spp.	*Epinephelus andersoni*	
Argyrozona argyrozona	*Epinephelus albomarginatus*	
	Epinephelus guaza	
	Sparodon durbanensis	
	Gymnocrotaphus curvidens	
	Pachymetopon grande	
	Oplegnathus spp.	
	Parascorpis typus	
	Umbrina spp.	

APPENDIX 2. Table showing existing minimum size limits and closed seasons for South African marine linefish species.

Species	Minimum Size	Closed Season
Sarpa salpa	15cm	
Diplodus sargus capensis	20cm	
Rhabdosargus holubi	20cm	
Chrysoblephus laticeps	20cm	
Rhabdosargus globiceps	20cm	
Pachymetopon blochii	22cm	
Chrysoblephus cristiceps	25cm	
Rhabdosargus sarba	25cm	
Cymatoceps nasutus	25cm	
Petrus rupestris	25cm	1 Sep to 30 Nov
Acanthopagrus berda	25cm	
Polysteganus praeorbitalis	25cm	
Polysteganus undulosus	25cm	1 Sep to 30 Nov
Argyrozona argyrozona	25cm	
Chrysoblephus puniceus	25cm	
Cheimerius nufar	25cm	
Pomatomus saltatrix	30cm	1 Sep to 30 Nov
Epinephelus andersoni	30cm	
Epinephelus albomarginatus	30cm	
Epinephelus guaza	30cm	
Coracinus capensis	35cm	15 Oct to 28 Feb
Atractoscion aequidens	40cm	
Pomadasys commersonni	40cm	
Argyrosomus hololepidotus	40cm	
Sparodon durbanensis	40cm	
Argyrosomus thorpei	40cm	
Lithognathus lithognathus	40cm	
Thyrsites atun	60cm	
Lichia amia	70cm	

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