

**BIOLOGY AND STOCK ASSESSMENT OF THE COASTAL FISH, *SARPA SALPA*  
(SPARIDAE), OFF THE KWAZULU-NATAL COAST, SOUTH AFRICA.**

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## PREFACE

The work described in this thesis was carried out at the Oceanographic Research Institute, University of Natal, Durban from January 1994 to December 1995, under the supervision of Dr L.E. Beckley and Mr A. Govender.

These studies represent original work by the author and have not been submitted in any form to another university. Where use was made of the work of others it has been duly acknowledged in the text.

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### Abstract

This study investigated aspects of the biology of *Sarpa salpa*, such as reproduction, age and growth, and mortality, which are necessary for an assessment of the status of this species off the KwaZulu-Natal (KZN) Coast.

The importance of *S. salpa* to the shore-based fishery in KZN was evaluated using Natal Parks Board shore patrol data. These data were validated by analysing preliminary results of an independent shore-angling survey along the KZN Coast. Despite differences in the catch composition and catch rates between the two analyses, both data sources highlighted the importance of *S. salpa* to the shore-based fishery in KZN. Shore-based catches were markedly seasonal coinciding with the breeding season of the species. The species in KZN is targeted primarily to provide a supplementary source of animal protein.

An investigation of the reproductive biology of *S. salpa* indicated a protracted spawning period for the species. Size at 50 percent maturity for combined sexes was attained at 145 mm fork length. The sex ratio in shore-based catches was 1:1.6 in favour of males. A frequency distribution by size indicated that males dominated the smaller size classes while females dominated the larger size classes. Detailed histological examination of gonadal development showed that *S. salpa* has the potential for protandrous sex change.

An age and growth study based on the examination of whole otoliths indicated that *S. salpa* was relatively fast-growing and a maximum age of six years was recorded for the species. One opaque band was laid down per year. This was validated by marginal increment analysis and by an oxytetracycline labelling experiment using captive fish. Growth in *S. salpa* was described by a Von Bertalanffy growth function:

$$L_{age} (mm FL) = 224mm(1 - e^{-0.55 \text{ year}^{-1}(age+0.51\text{years})})$$

The natural mortality rate ( $M = 0.6 \text{ year}^{-1}$ ) was derived using Pauly's equation and the current fishing mortality (F) rate was estimated at  $0.8 \text{ year}^{-1}$ . The current status of *S. salpa* in the shore-based fishery was assessed by determining the effects of F and age-at-capture on the yield- and spawner biomass-per-recruit. Current levels of fishing pressure on *S. salpa* appeared to be appropriate for utilisation of the stock off the KZN South Coast. In terms of management, *S. salpa* appears to be in no need of any restrictive measures at present.

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## CHAPTER 1

### 1.1 General Introduction

The strepie, *Sarpa salpa* (Linnaeus, 1758), belongs to the teleost family Sparidae. It is a widely distributed species, occurring in the Mediterranean, north-eastern and eastern Atlantic round South Africa to southern Mozambique (Smith & Heemstra, 1986; Fischer & Bianchi, 1991). *S. salpa* is an abundant inshore species, inhabiting subtidal gullies and shallow reefs (Smale & Buxton, 1989; Verlaque, 1990; Burger, 1991). Distribution appears to be limited by the occurrence of algae, the primary dietary component of this herbivorous fish (Joubert & Hanekom, 1980; Gerking, 1984; Whitfield, 1985).

The Sparidae contribute significantly to commercial and recreational linefisheries in South Africa (Smale & Buxton, 1985; Penney, Buxton, Garratt & Smale, 1989). Catches of *S. salpa*, however, are primarily restricted to shore-based anglers. Statistics from the National Marine Linefish System (NMLS) indicate that *Pomatomus saltatrix* (elf) dominates the shore-based catch in KZN (Guastella & Nellmapius, 1993). Noteworthy is the fact that *S. salpa*, a species seldom targeted by resort visitors and never targeted by sport anglers, except as bait, is the second most abundant species in the shore-based catch.

Despite its importance in the total shore-based catch along the KZN Coast, in the 1992 revision of South African linefish legislation (Sea Fishery Regulations Act No. 12 (Section 32) of 1988), *S. salpa* was classified as a bait species. Although there is a minimum size restriction of 150 mm total length (TL), there is no limit on numbers harvested. The rationale behind this requires verification as the expected increase in fishing pressure on stocks (van der Elst, 1986), together with the ease with which *S. salpa* is harvested, are likely to ensure that the current exploitation level on *S. salpa* increases.

The distribution and abundance of *S. salpa* in the Eastern and Western Cape has been well documented (Beckley, 1983, 1985a; Lasiak, 1984a, b; Beckley & Buxton, 1989; Bennett, 1989a; Smale & Buxton, 1989; Whitfield et al., 1989; Burger, 1991) and in KZN (Berry, van der Elst, Hanekom & Smale, 1982). Joubert (1981a, b), during a survey of shore anglers' catches along the KZN Coast, reported on aspects of the reproductive biology of *S. salpa*. The current status of the *S. salpa* stock is unknown although it has been suggested that it is possibly declining (van der Elst & Adkin, 1991). This, together with its considerable contribution to shore-based anglers' catches, has resulted in *S. salpa* being categorised as a high priority species in terms of research (van der Elst & Adkin, 1991).

In this study, historic and current trends in the catch of *S. salpa* are analysed and the importance of the species to the recreational shore-based anglers' catch along the KZN Coast is evaluated. Aspects of the biology of *S. salpa* necessary for the assessment of the status of this important fishery are also presented. Present conservation status of the *S. salpa* fishery is discussed, and management options to ensure the sustained future catch of *S. salpa* are proposed.

## 1.2 Study area

Regular sampling of the KZN South Coast between Ballito Bay (31° 13'S: 29°32'E) and Port Edward (31°03'S: 30°14'E) was undertaken from January 1994 to March 1995 (Figure 1.1). This 207 km stretch of coastline is relatively straight and consists of open sand beaches interspersed with rocky outcrops (Jackson & Lipschitz, 1984). To the north these outcrops become less frequent. A semi-diurnal tidal cycle, ranging from about 0.5 metres at neap tides to 1.75 metres at spring tides occurs throughout the study area (Schumann, 1988). Tidal currents, however, are generally small. The Agulhas current is the dominant, large-scale oceanographic feature off the east coast of South Africa (Shannon, 1989). This south-west flowing current

strongly influences water movements on the continental shelf (Beckley & van Ballegooyen, 1992). This water feature in conjunction with ocean swells and wind-related currents results in vigorous water movements (Flemming & Hay, 1988) which cause rapid changes in beach level and periodic sanding-up of intertidal reefs (Harris, 1960). Coastal waters have salinities ranging between 35 ‰ and 35.5 ‰ (Schumann, 1988). The discharge of fresh water into the sea generally tends to be sporadic (Schumann, 1988). Occasional summer flooding may result in the discharge of large amounts of silt-laden water into the sea, resulting in sediment plumes extending out from major river systems, such as the Tugela River (Schumann, 1988). Water temperature along the KZN Coast is characterised by a relatively low seasonal range of between 18°C and 26°C (Natal Sharks Board, unpublished data).

### 1.3 General sampling methodology

Monthly samples of *S. salpa* were obtained from shore-based recreational anglers' catches and supplemented by researchers fishing along the KZN Coast. Small-sized fish were poorly represented in the shore-based catches and in order to obtain a full size range of fish, small *S. salpa* were netted in the Eastern Cape surf zone during October 1994. A total of 808 *S. salpa* were sampled during the study period. The KZN Coast is divided into a number of Natal Parks Board (NPB) coastal zones (Figure 1.1). The percentage contribution (by number) from the various NPB zones and from the Eastern Cape is shown in Figure 1.2.

The samples of *S. salpa* obtained were measured (millimetres fork length) and weighed using a spring balance. Fish were cut open and the sex determined whenever possible. Each gonad was assigned a visual index of maturity. Gonads were removed from the fish, weighed and placed in fixative for histological analysis in the laboratory. Otoliths were extracted from the samples for ageing purposes. At times, anglers were reluctant

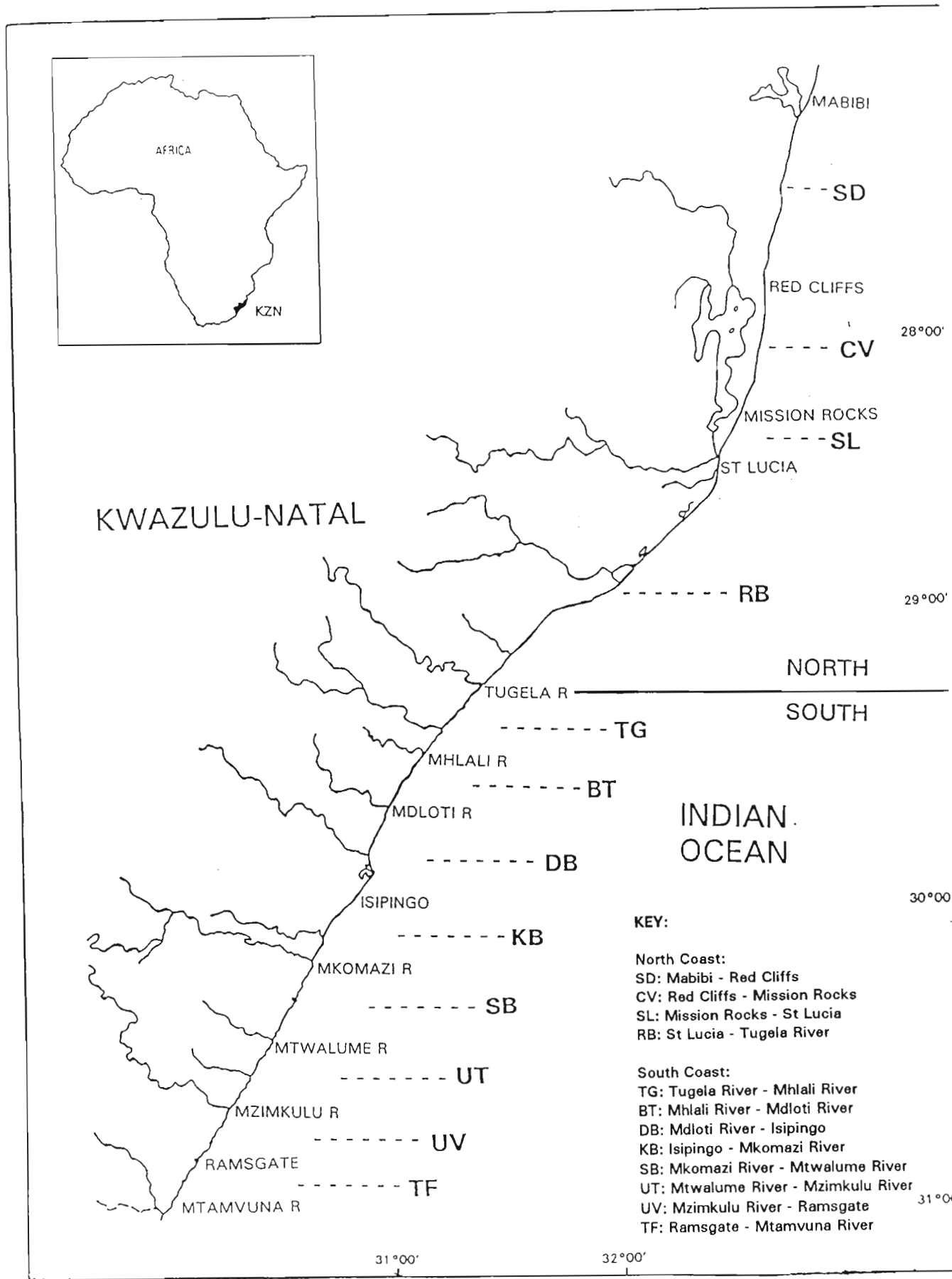


Figure 1.1: Map of the KZN Coast divided into the various NPB zones and (inset) locator map showing KZN.

to have their fish gutted and in these instances, only the length of the fish was measured.

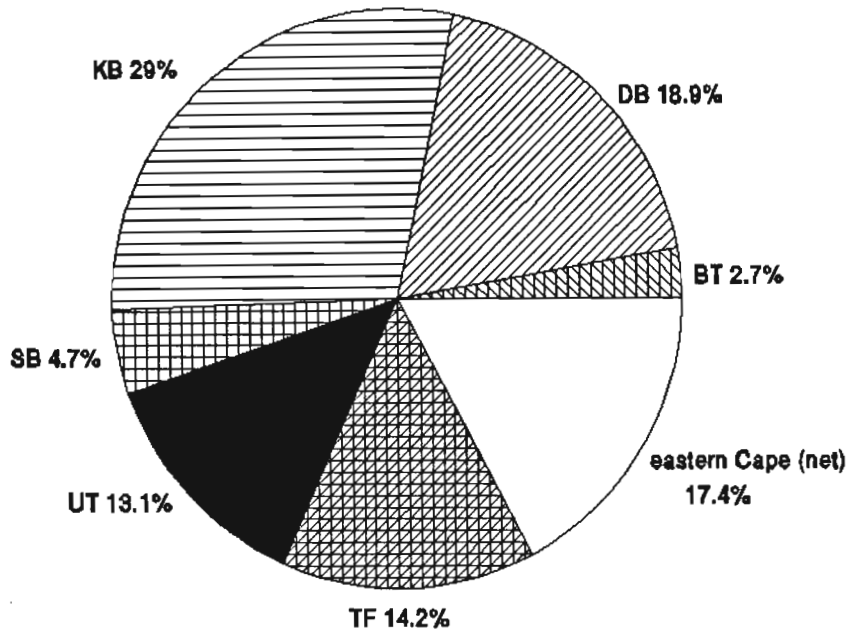


Figure 1.2: The percentage contribution of *S. salpa* collected in each Natal Parks Board zone and in the Eastern Cape (by net) to the total sample. BT = Ballito zone, DB = Durban zone, KB = Kingsburgh zone, SB = Scottburgh zone, UT = Umtentweni zone, UV = Uvongo zone, TF = Trafalgar zone.

The biological information and material collected during sampling provided the basis for the reproductive and age and growth studies described later in this thesis.

## CHAPTER 2

### THE SHORE-BASED ANGLING FISHERY OFF THE KWAZULU-NATAL COAST, WITH PARTICULAR REFERENCE TO THE CATCH OF *S. SALPA*

#### 2.1 Introduction

Marine recreational angling in KZN can be categorized into four major sectors, namely shore-based angling, ski-boat angling, estuarine angling and spearfishing. Shore-based angling represents a major component of linefishing effort along the KZN Coast (van der Elst, 1989a) and consists of two groups, namely registered club anglers who participate in sport fishing tournaments and informal anglers who fish for recreation. Although the exact extent of unregistered, non-club anglers is unknown, it has been estimated that over 53 000 marine, resident anglers operated in KZN during 1980-1982 (van der Elst, pers. comm.). The annual rate of increase of the number of sport fishermen has been estimated at 6.5% (van der Elst, 1986). Included in the informal shore-based angling sector, is the existence of a little-studied subsistence fishery, where anglers rely on their catches as an important supplementary source of protein (Joubert, 1981a, b).

It has been suggested that catches of shore-based anglers along the South African Coast are declining primarily as a result of overfishing (van der Elst, 1989a; Bennett, 1991). Decreased fishing effort along the coast seems unlikely in the future because of the open access nature of the recreational fishery, and with the continuing trend of increasing human population size in South Africa, an increased demand for protein can be expected. This will probably result in increased pressure on inshore fish stocks along the South African Coast.

Annual estimates of catch and effort are essential for marine linefish management as long-term catch and effort trends provide general indications of levels of exploitation (Hughes, 1985).

Such estimates of catch and effort require good, reliable time-series data and provide a means of monitoring a fishery. Initiated in 1984, the NMLS is a joint venture between the Oceanographic Research Institute (ORI) and the Sea Fisheries Research Institute. The programme consists of several data collection systems and provides for the processing and analysis of catch and effort data from the various linefishing sectors.

Catch and effort data documented on the NMLS are collected from a number of data sources, including shore patrol records from the NPB. Based on these records, Guastella & Nellmapius (1993) showed that *Pomatomus saltatrix* dominated the catches of shore-based anglers along the KZN Coast. Noteworthy was the fact that *S. salpa*, which is classified as a baitfish under the present legislation (Sea Fishery Regulations Act No. 12 (Section 32) of 1988), ranked second after *P. saltatrix*.

This chapter reports on the catches of shore-based anglers documented by NPB patrol officers along the KZN Coast for the period 1986-1994. Trends in the catch of this inshore fishery were determined and the importance of *S. salpa* to the inshore catch established. This chapter also presents some preliminary results of a project aimed at evaluating aspects of the shore-based fishery along the KZN Coast, which is currently being conducted by the ORI in KZN (Mann, 1994). Catch composition and catch per unit effort (CPUE) of inshore anglers were determined and used to validate the catch data derived from the NPB patrols.

## **2.2 Materials and Methods**

### **NPB patrol records**

NPB zone officers conduct patrols in their respective zones along the KZN Coast (Figure 1.1), sampling some or all sections of their zones on foot and/or using beach vehicles. The primary aim of these patrols is the enforcement of regulations (Sea Fishery Regulations Act No. 12 (Section 32) of 1988) governing the

catches of anglers along the KZN Coast (C. Coetzee, NPB, pers. comm.). Anglers are checked by NPB officers during the week or weekend and at any time of the day, but usually in daylight hours. During the majority of these patrols, the species and number of fish caught by anglers are documented by NPB officers. Biological information such as weights and lengths are not recorded. This documentation of anglers' catches by NPB officers during patrols takes place on a non-random basis because of their law enforcement function.

Shore patrol data from the years 1986-1994 were analysed. Although patrol data exist prior to 1986, they were excluded from the analysis as the number of anglers checked was not recorded. Further, records of *S. salpa* were not kept as it was perceived by the NPB that *S. salpa* was unimportant in the shore-based fishery. There was also a significant increase in patrol intensity from 1986 onwards (van der Elst, 1989b).

#### **Catch composition**

An accurate breakdown of the catch composition recorded by NPB officers was determined. At times during patrols, anglers and NPB officers are unable to identify the exact species in the catch. These fish are placed in groups according to their genus or family. For example, *Argyrosomus* spp. includes *A. japonicus* and *A. thorpei*; *Rhabdosargus* spp. includes *R. sarba* and *R. holubi*; *Trachinotus* spp. includes *T. africanus* and *T. botla*; Mugilidae includes *Liza tricuspidens*, *Liza dumerilii* and *Mugil cephalus*; *Pomadasys* spp. includes *P. commersonii*, *P. furcatum*, *P. kaakan*, *P. multimaculatum* and *P. olivaceum*.

#### **Catch rates**

Annual and monthly catch rates were calculated for *S. salpa*. The recording of time spent fishing by the anglers checked was not initially included in the patrols and has only recently (since June 1994) been incorporated into the patrol data sheet. The

average duration of an angler outing (see below) was used for the calculation of CPUE, which was expressed as the number of fish caught per angler hour (i.e. the number of fish caught per angler per hour of fishing). This measure of CPUE was derived by dividing the number of fish caught per angler checked by the average duration of a fishing outing, which was recorded during a shore-angling survey of the KZN South Coast (see below). Annual and monthly CPUE series were determined for *S. salpa*.

### **Shore-angling survey of the KZN South Coast**

A shore-angling survey was conducted on the KZN South Coast between April 1994 and August 1995. Monthly sampling was undertaken between Tinley Manor (29°27'S; 31°17'E) and Port Edward (31°03'S; 30°14'E). Stratified random sampling (Malvestuto, 1983) was carried out on 58 days according to the ratio 6 weekdays: 7 weekend days: 1 public holiday (Clarke & Buxton, 1989). A roving creel survey method (Robson, 1960; 1991) was used at sampling sites whereby the interviewer/s moved through the site intercepting anglers during or on completion of their fishing outing. A two-stage sampling method (Malvestuto, Davies & Shelton, 1978; Lester, Petzold & Dunlop, 1991) was used, whereby sampling days were randomly selected. Within each day, anglers were interviewed during three time periods. These periods as well as sample sites and the direction of the sampling route were randomly selected. Anglers were approached by beach vehicle, or on foot in less accessible areas and interviewed using a detailed questionnaire (Appendix 1). A subset of questions were used in the present analysis and is shown in Table 2.1.

Total lengths of landed fish were measured and converted to corresponding weight values using length-weight relationships derived from various sources (Appendix 2). At times it was not possible to record the lengths of landed fish. In these cases, weight values were obtained for these fish by using the mean weight value for that particular species.

Table 2.1: The subset of questions from the detailed questionnaire (Appendix 1) used in the present study.

Subject	Question
catch	i) what have you caught?
effort	ii) what time did you start fishing? iii) what time do you anticipate leaving? iv) what type of fish are you targeting?
reason for fishing	v) do you eat the fish you catch? vi) do you fish for recreation? vii) do you fish in competitions? viii) are you unemployed and fish for a living?

Numerical and weight contributions of each fish were expressed as percentages of the total catch . Catch rates were calculated using effort based on uncompleted angling trips. These were measured from the time anglers began angling (question ii) until the time of the interview. All species of fish were classified into one of the five categories (Table 2.2). *S. salpa* was allocated to the rockfish category. CPUE (expressed as number and weight of fish caught per angler hour) was determined for each species using the angling effort (hours) targeted at each category (question iv). Catch rates using total effort expended was also determined for comparison with other studies. The average duration of an angler outing was determined using responses to questions (ii) and (iii) in Table 2.1 .

Table 2.2: Summary of categories of fish used to apportion total angling effort during a shore-based survey along the KZN South Coast.

	Category	Abbreviation
1	<i>P. saltatrix</i>	-
2	Rockfish	R
3	Surffish	S
4	Gamefish	G
5	Sharks	C

## 2.3 Results

### NPB Patrol records

Over the period 1986-1994, 44 331 patrols were conducted by NPB officers during a total patrol time of approximately 152 000 hours along the KZN Coast. Collectively, these patrols covered over 363 000 kilometres of coastline.

### Catch composition

The composition of the total catch documented on the North (Mabibi-Tugela River) and South (Tugela River-Umtamvuna River) Coasts are presented in Figures 2.1 and 2.2, respectively. *P. saltatrix* dominated the catch along both sections of the KZN Coast. *S. salpa* featured prominently in South Coast catches (17.6%), but very low numbers were recorded on the North Coast. The remaining proportion of the North Coast catch was comprised predominantly of surffish, such as *Argyrosomus* spp., *Pomadasys* spp., *Trachinotus* spp. and *Rhabdosargus* spp. (Figure 2.1). Smaller rockfish species, such as *Neoscorpis lithophilus*, *Diplodus sargus* and *S. salpa* appeared in the South Coast catch (Figure 2.2). Because of the low contribution of *S. salpa* to the total catch on the North Coast, only data from the South Coast will be presented hereafter.

The annual contribution of the two dominant species caught along the KZN South Coast, namely *S. salpa* and *P. saltatrix*, to the total catch is shown in Figure 2.3. The number of *S. salpa* in the catch increased from 1986 onwards and peaked in 1991, when *S. salpa* comprised 38.4% of the total catch. In the following two years, the contribution of *S. salpa* decreased considerably to 4.9%, but recovered again in 1994. This can be explained by analysing the *P. saltatrix* contribution to the overall catch on the South Coast (Figure 2.3). Years of high *P. saltatrix* catches (1986-1987 and 1992-1994) were matched by low *S. salpa* catches

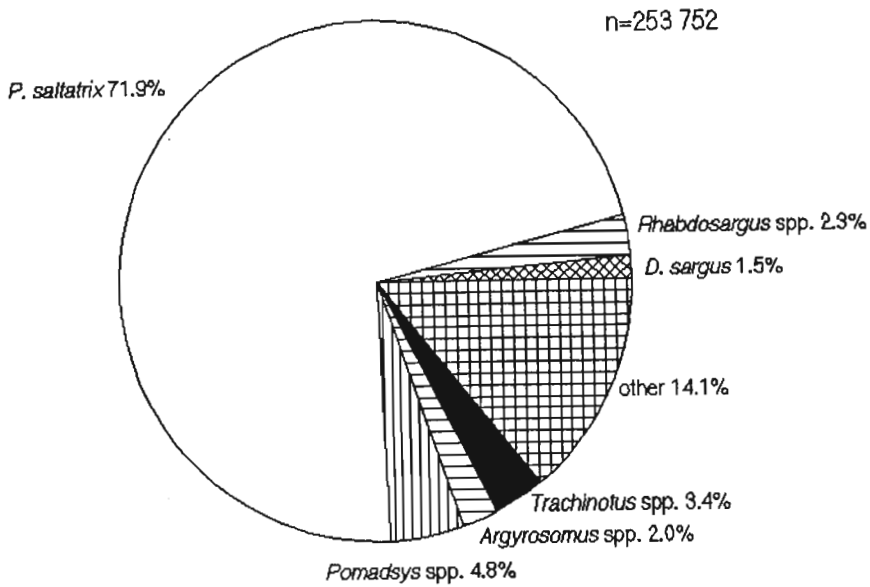


Figure 2.1: The percentage contribution (by number) of fish to the total sample documented by NPB officers on the KZN North Coast between 1986 and 1994.

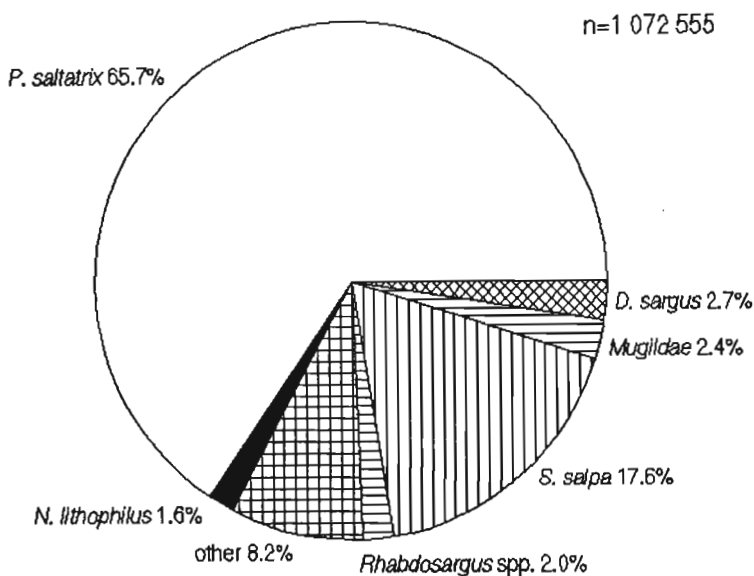


Figure 2.2: The percentage contribution (by number) of fish to the total sample documented by NPB officers on the KZN South Coast between 1986 and 1994.

while in the remaining years when *P. saltatrix* catches were down, the *S. salpa* component to the total catch increased.

The monthly contribution of *S. salpa* to the total catch on the South Coast is shown in Figure 2.4. The numerical contributions of *S. salpa* peaked during the winter months, but the data also indicated that this species was an important component of shore-angling catches throughout the year.

### **Catch rates**

Annual CPUE for *S. salpa* on the South Coast is shown in Figure 2.5. The annual estimates fluctuated in phase with the numerical contribution, except in 1988 when, although the *S. salpa* component of the catch increased, this was matched by a decrease in CPUE. Monthly CPUE on the South Coast followed a similar trend to that observed in the monthly numerical contribution of *S. salpa*, although the increased catch rate during June and July was even more marked (Figure 2.6).

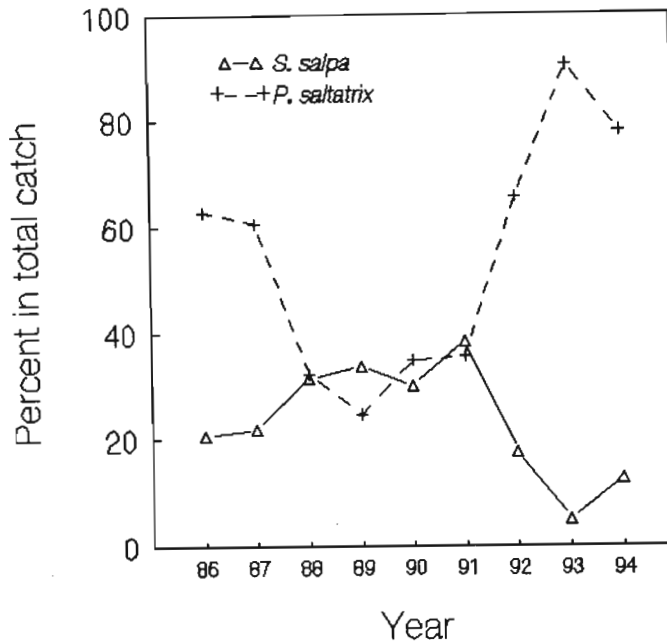


Figure 2.3: Annual percentage contribution (by number) of *S. salpa* and *P. saltatrix* to the total shore-based catch documented by NPB officers on the KZN South Coast between 1986 and 1994.

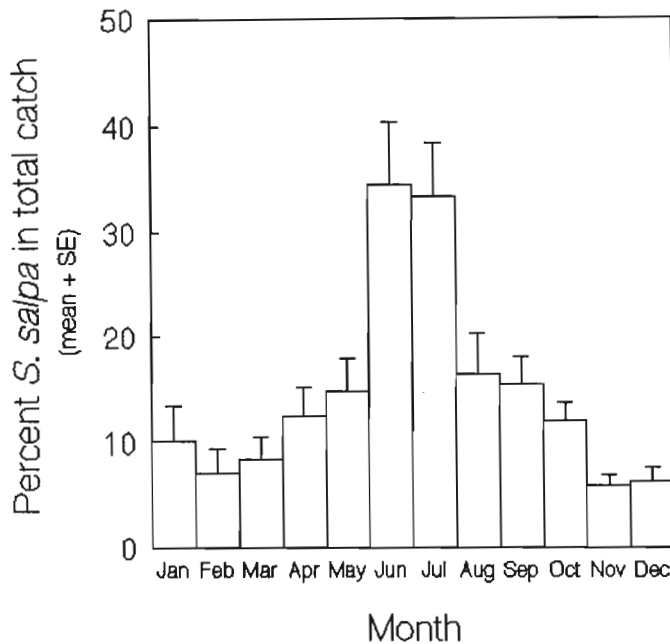


Figure 2.4: Monthly mean percentage contribution (by number) of *S. salpa* to the total shore-based catch documented by NPB officers on the KZN South Coast between 1986 and 1994. The associated standard error (SE) bars are given.

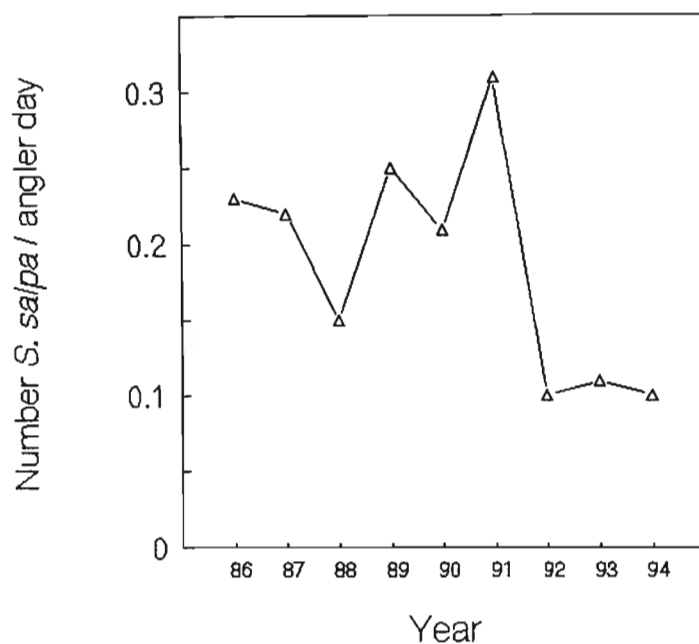


Figure 2.5: Annual catch rate of *S. salpa* in the shore-based catch documented by NPB officers on the KZN South Coast between 1986 and 1994. (data points reflect total catch of *S. salpa* divided by total angler hours).

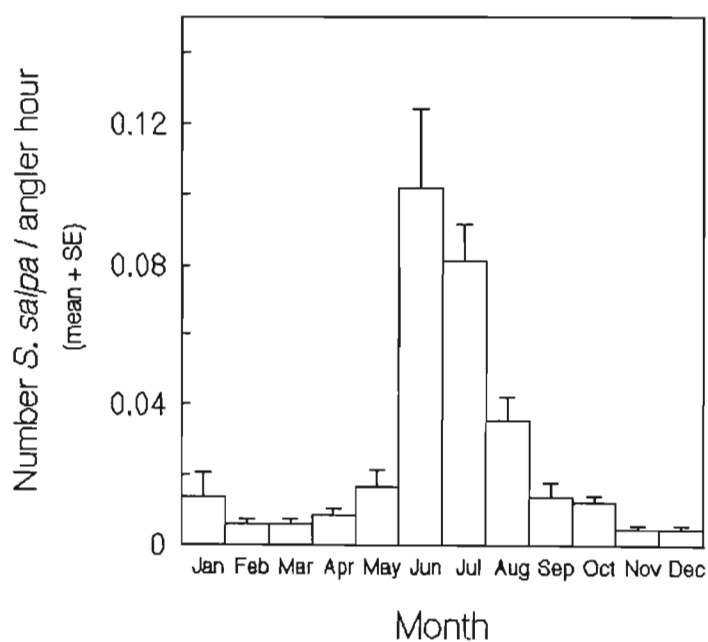


Figure 2.6: Monthly mean catch rate of *S. salpa* in the shore-based catch documented by NPB officers on the KZN South Coast between 1986 and 1994. The associated standard error bars are given.

### **Shore-angling survey**

A total of 765 angler questionnaires were completed during the roving creel surveys of the KZN South Coast. Catch and effort data was also obtained from an additional 253 anglers.

#### **Reasons for fishing**

The majority of anglers interviewed stated multiple reasons for partaking in fishing. The percentages of the 765 anglers interviewed that answered in favour of each of the reasons for fishing are shown in Figure 2.7. The majority of anglers regarded fishing as a form of recreation and most of these anglers ate the edible fish they caught. The proportion of competitive anglers was small (14.9%), while only 5.5% of anglers interviewed stated that fishing was their livelihood. These anglers were unemployed and derived financial benefit out of their catch. As the selling of fish by recreational anglers without a permit is illegal (Sea Fishery Regulations Act No. 12 (Section 32) of 1988), this percentage of anglers is probably an underestimate as it was apparent during patrols that some fishermen were reluctant to admit having sold fish. This was probably for fear of the repercussions, even though the interviewers had no official enforcement authority. The effects of intentional deceit (Jones, 1995) on other results of the questionnaire survey were considered negligible. An underestimate of the livelihood component would have resulted in an overestimate of anglers fishing for food and recreation.

#### **Catch composition**

A total of 1 099 fish, including 31 species of bony fish (Osteichthyes) and 3 species of cartilaginous fish (Chondrichthyes), were sampled along the KZN South Coast during the questionnaire survey. The overall catch composition in terms of number and weight, and CPUE estimates of recorded fish, are

shown in Table 2.3. Only fish for which length-weight relationships were available were included in the weight analysis.

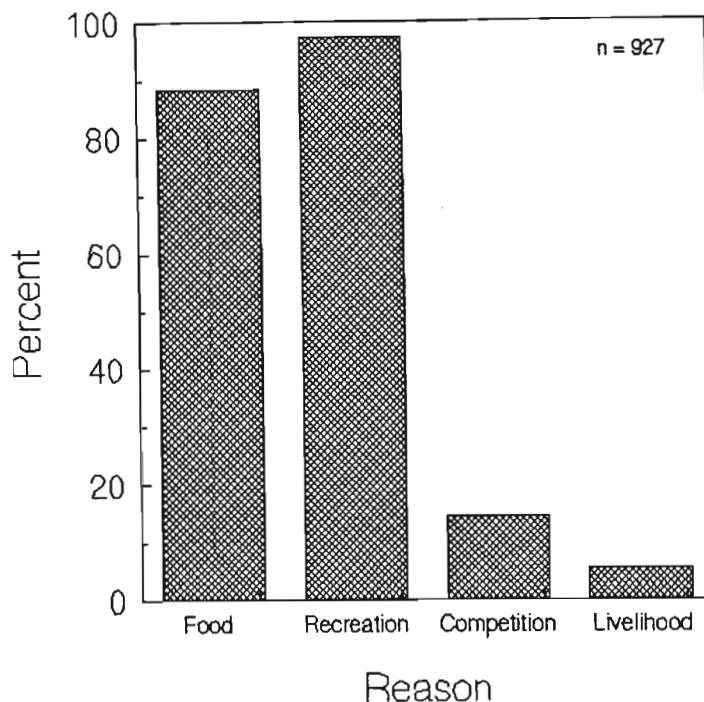


Figure 2.7: The percentage of anglers interviewed that answered in favour of each of the four reasons for partaking in fishing during a survey of the shore-based fishery off the KZN South Coast.

*S. salpa* was numerically the most important species in the total catch along the South Coast contributing 54.2%. *P. saltatrix* also featured prominently contributing 18.7% to the total catch (Table 2.3). The remaining catch was predominantly made up of small proportions of rockfish, such as *N. lithophilus*, *D. sargus*, *R. holubi* and *P. olivaceum*. *S. salpa* and *P. saltatrix* dominated the catch by weight, with each species contributing similar proportions. Although the numbers of the three species of cartilaginous fish caught were insignificant, the large sizes of these species resulted in a collective weight contribution of 15% to the total catch. The size composition of the six most abundant species is shown in Figure 2.8.

Table 2.3: Catch composition (by number and weight) and CPUE of fish sampled during a survey of the shore-based fishery along the KZN South Coast during the period April 1994–August 1995. Species are arranged in phylogenetic order according to Smith & Heemstra (1986). Species-specific CPUE values were calculated using effort directed at each category and total effort (Category C = sharks, S = surffish, R = rockfish, G = gamefish).

Species	Category	Total no	% by no	Total weight (g)	% by weight	CPUE (using category directed effort)		CPUE (using total effort)	
						(no.hr <sup>-1</sup> )	(g.hr <sup>-1</sup> )	(no.hr <sup>-1</sup> )	(g.hr <sup>-1</sup> )
<b>Carcharhinidae</b>									
<i>Carcharhinus obscurus</i>	C	4	0.4	8984	1.8	0.059	132.7	0.0013	2.84
<i>Rhizoprionodon acutus</i>	C	3	0.3	54398	11.0	0.044	803.5	0.0010	17.84
<b>Rhinobatidae</b>									
<i>Rhinobatos annulatus</i>	C	4	0.3	5672	1.1	0.059	83.8	0.0012	1.67
<b>Belonidae</b>									
<i>Strongylura leiura</i>	S	1	0.1	-	-	0.001	-	0.0003	-
<b>Platycephalidae</b>									
<i>Platycephalus indicus</i>	S	1	0.1	-	-	0.001	-	0.0003	-
<b>Kuhliidae</b>									
<i>Kuhlia mugil</i>	R	1	0.1	-	-	0.001	-	0.0003	-
<b>Serranidae</b>									
<i>Epinephelus andersoni</i>	R	1	0.1	429	0.1	0.001	0.4	0.0003	0.14
<b>Pomatomidae</b>									
<i>Pomatomus saltatrix</i>	-	206	18.7	120105	24.3	0.202	125.2	0.0607	39.39
<b>Haemulidae</b>									
<i>Pomadasys commersonnii</i>	S	10	0.9	10970	2.2	0.013	13.7	0.0033	3.60
<i>Pomadasys furcatus</i>	S	4	0.4	603	0.1	0.005	0.8	0.0013	0.20
<i>Pomadasys kaakan</i>	S	1	0.1	193	0.03	0.001	0.2	0.0003	0.06
<i>Pomadasys olivaceum</i>	S	30	2.7	699	0.1	0.031	0.7	0.0098	0.23
<b>Sparidae</b>									
<i>Cheimerius nufar</i>	R	3	0.3	166	0.03	0.004	0.2	0.0010	0.05
<i>Diplodus cervinus</i>	R	6	0.5	4191	0.8	0.006	4.4	0.0020	1.37
<i>Diplodus sargus</i>	R	73	6.6	22661	4.6	0.076	23.6	0.0239	7.43
<i>Pagellus natalensis</i>	S	3	0.3	468	0.1	0.004	0.6	0.0010	0.15
<i>Rhabdosargus holubi</i>	R	33	3.0	6911	1.4	0.034	7.2	0.0108	2.27
<i>Rhabdosargus sarba</i>	R	5	0.5	4106	0.8	0.005	4.3	0.0016	1.36
<i>Rhabdosargus thorpei</i>	R	1	0.1	1749	0.4	0.001	1.8	0.0003	0.57
<i>Sarpa salpa</i>	R	596	54.2	139044	28.2	0.621	145.0	0.1955	45.60
<b>Coracinidae</b>									
<i>Dichistius multifasciatus</i>	R	9	0.8	7136	1.4	0.009	7.4	0.0030	2.34
<b>Scorpididae</b>									
<i>Neoscorpis lithophilus</i>	R	41	3.7	15128	3.1	0.043	15.8	0.0134	4.96
<b>Monodactylidae</b>									
<i>Monodactylus argenteus</i>	R	18	1.6	-	-	0.019	-	0.0059	-
<b>Sillaginidae</b>									
<i>Sillago sihama</i>	S	4	0.4	-	-	0.005	-	0.0013	-
<b>Sciaenidae</b>									
<i>Argyrosomus japonicus</i>	S	7	0.6	27731	5.6	0.009	34.7	0.0023	8.09
<i>Otolithes ruber</i>	S	1	0.1	317	0.1	0.001	0.4	0.0003	0.10
<b>Carangidae</b>									
<i>Lichia amia</i>	G	7	0.7	62651	12.7	0.034	306.8	0.0023	20.54
<i>Scomberoides commersonianus</i>	G	1	0.1	-	-	0.005	-	0.0003	-
<i>Trachinotus botla</i>	S	2	0.2	-	-	0.003	-	0.0007	-
<i>Trachinotus africanus</i>	S	11	1.0	-	-	0.014	-	0.0036	-
<b>Pomacentridae</b>									
<i>Abudefduf vaigiensis</i>	R	1	0.1	-	-	0.001	-	0.0003	-
<b>Labridae</b>									
<i>Thalassoma purpuraceum</i>	R	2	0.2	-	-	0.002	-	0.0007	-
<b>Mugilidae</b>									
<i>Liza/Mugil spp.</i>	R	8	0.8	-	-	0.008	-	0.0026	-
<b>Soleidae</b>									
	S	1	0.1	-	-	0.001	-	0.0003	-

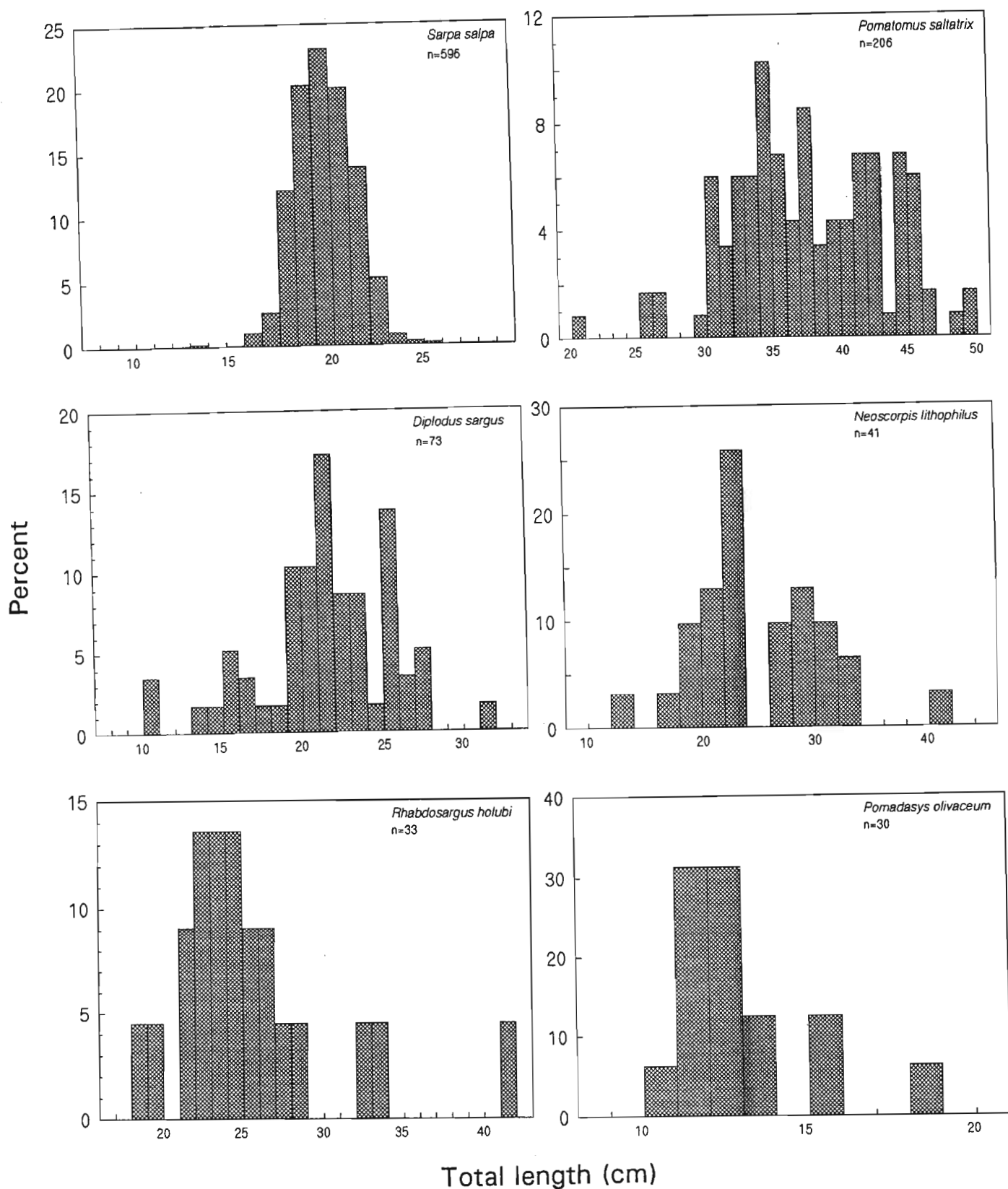


Figure 2.8: Size frequency distributions of the six most abundant species recorded in anglers' catches during a shore-angling survey of the KZN South Coast.

### Targeting of effort

A breakdown of total time spent fishing for specific categories of fish is shown in Table 2.4. *P. saltatrix* was the most sought after shore-angling species with 33.4% of total effort directed at this species. A considerable portion of time was also spent targeting species in the surffish and rockfish categories. Very little gamefishing and sharkfishing were encountered during surveys.

Table 2.4: Summary of the total angling time directed at each category of fish during a shore-based survey along the KZN South Coast.

Category of fish	Hours	% of total
<i>P. saltatrix</i>	1019.3	33.4
rockfish	959.2	31.5
gamefish	204.2	6.7
shark	67.7	2.2
surffish	798.6	26.2
Total	3049.0	-

### Catch rates

Catch and effort data was obtained from 1018 anglers interviewed during the study. The average duration of the fishing outing of these anglers was 4.9 hours (SE=0.12). On average, anglers had fished for approximately 3.0 hours (SE=0.08) when sampled, which represented a total angling effort of 3 049 hours along the South Coast (Table 2.4). This represented a CPUE of 0.36 fish.angler hour<sup>-1</sup>. In terms of weight, a total CPUE of 162 grams (g) of fish.angler hour<sup>-1</sup> was calculated. Using total effort targeted at each category of fish (Table 2.4), species specific CPUE values were calculated (Table 2.3). The catch of *S. salpa* for the amount of effort expended was much higher than that for any other species. Despite intensive effort directed at *P. saltatrix*, a relatively low value of 0.2 fish.angler hour<sup>-1</sup> was

recorded. Because of the small size of *S. salpa*, similar CPUE values by weight were recorded for this species (145 g.angler hour<sup>-1</sup>) and *P. saltatrix* (125 g.angler hour<sup>-1</sup>). Monthly CPUE values for *S. salpa* and targeting of effort at rockfish are presented in Figure 2.9. The number of interviews conducted during the winter months exceeded the number carried out in the summer months as the winter period was sampled twice during the survey period. CPUE of *S. salpa* increased during winter which coincided with an increase in effort directed at rockfish species.

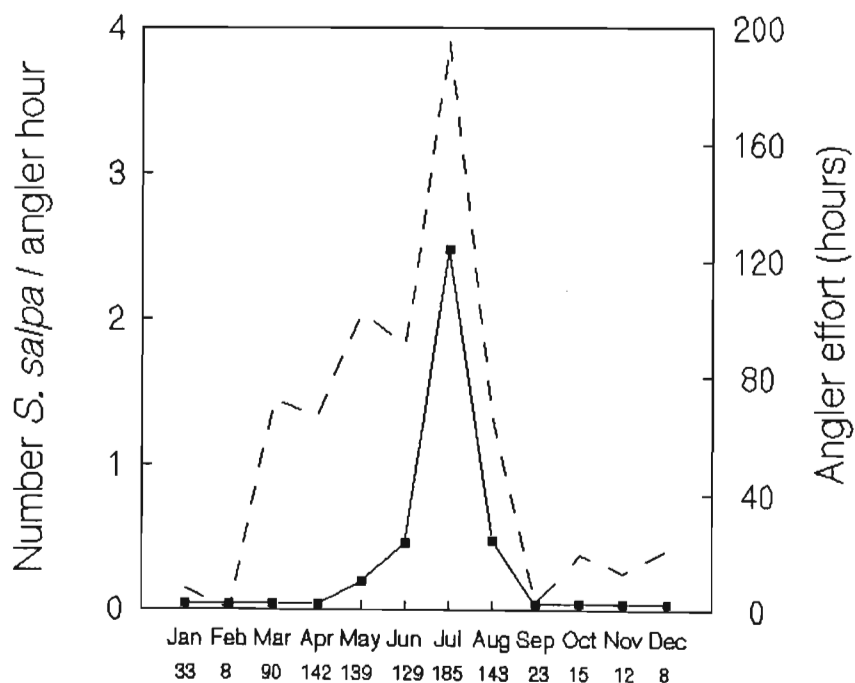


Figure 2.9: Monthly CPUE for *S. salpa* (solid line) and effort directed at rockfish (dashed line) by anglers recorded during a shore-angling survey of the KZN South Coast (The number of interviews conducted each month is shown on the primary x-axis).

## 2.4 Discussion

### The catch

*S. salpa* was poorly represented in the total catch along the North Coast (north of the Tugela River) documented by NPB patrol officers. The proportion of *S. salpa* and other rockfish species was much greater on the South Coast. This can be attributed mainly to differences in the topography of the two regions. The South Coast is characterised by intertidal rocky reefs and rock outcrops interspersed with sandy beaches (Jackson & Lipschitz, 1984). To the north, these reefs and outcrops become less common and the area is characterised by long stretches of sandy beach. *S. salpa* is a reef-associated species and the North Coast would thus be less suitable as a habitat for *S. salpa*, compared with the South Coast. Another contributing factor could be that three of the four NPB patrol zones on the North Coast, namely Cape Vidal, Sodwana and St Lucia are resort areas. The composition of anglers at these sites will be predominantly sport anglers targeting fish such as *P. saltatrix* and the larger surf and gamefish species (van der Elst, 1989b). Unlike the North Coast, the South Coast is characterised by urban ribbon development with a high population density. Large areas of the South Coast are easily accessible to all types of fishers including recreational, competitive and subsistence anglers. Higher levels of effort would, therefore, be expected to be directed at *S. salpa* and other rockfish species, resulting in increased catches of these species along this stretch of coastline.

Analysis of NPB patrol data in this study indicated that *P. saltatrix* dominated catches along the KZN South Coast. *S. salpa* was the second most abundant species, forming a much smaller component of the catch. The opposite trend was evident in the results of the ORI survey data. Although of much lower intensity, the shore-based survey was based on a random sampling strategy and the lower contribution of *P. saltatrix* can be considered to be more representative of shore-based anglers'

catches. This suggests NPB data is possibly biased in favour of *P. saltatrix*. The primary aim of NPB patrols is the enforcement of fishing regulations, particularly those governing the catch of *P. saltatrix*. (C. Coetzee, NPB, pers. comm.). Patrol effort directed at the catch of *P. saltatrix* will, therefore, result in bias towards increased numbers of this species documented. These patrols are also not undertaken on a random basis, and encounters with anglers often take place during periods of the day of peak angler density. Under these conditions of improper sample selection, the estimation of catch and effort may be biased by an unknown amount (Wade, Jones, Robson & Pollock, 1991; Jones, 1995). It is essential, therefore, that the methods of NPB data collection be taken into account when assessing the results of data collected. The existence of bias in patrol data means that any analysis of this data must be interpreted with caution.

Patrol and survey data indicated that *S. salpa* was heavily exploited for a few months of the year during winter. This increased abundance in catch rate is probably a result of the breeding migration of *S. salpa* from the Cape to KZN (Joubert, 1981a, b). Despite the bias evident in the NPB data sources, this does not completely invalidate the NPB shore patrol data, as general trends in the *S. salpa* fishery are still evident.

The closed season for *P. saltatrix*, which is currently enforced from September to November (Sea Fishery Regulations Act No. 12 (Section 32) of 1988), will have the effect of decreasing the total angling effort directed at the species assuming poaching is at a minimum. Seasonal variations in angling effort, which may arise because of factors such as closed seasons, may be treated by grouping effort data into homogenous subsets (Malvestuto, 1983; Sztramko, 1991). This was, however, beyond the scope of the present study. The majority of the total angling effort (97.8%) expended along the KZN South Coast was directed at edible species and most anglers ate the fish that they caught (88.2%). The low catch rate and effort expended targeting cartilaginous species can be attributed to their low

esteem in the shore-based fishery. These species are targeted primarily by competition anglers. According to survey data in this study, *S. salpa* was the most important species, in terms of number and weight, in the total catch of the shore-based angling fishery. The length frequency distributions of *S. salpa* and other important angling species such as *D. sargus*, *N. lithophilus*, *P. olivaceum* and *R. holubi*, indicated that a large proportion of the total catch in the shore-angling fishery along the KZN South Coast is comprised of small fish. A considerable portion of the total angling effort (31%) along the KZN South Coast was directed at these small species. The importance of small fish in the total catch has also been noted in the Eastern Cape (Clarke & Buxton, 1989). Personal observations along the South Coast have also indicated that fishing effort of many anglers is first directed at preferred species, such as *P. saltatrix*. If success is low, smaller fish, which are abundant inshore and easier to catch, are then targeted. This fishing habit is further illustrated by the annual shift in the species dominating the total catch recorded by NPB patrol officers. During years when *P. saltatrix* catches were low, the contribution of *S. salpa* to the total catch increased and vice versa (Figure 2.3).

These trends and observations indicate that many anglers along the KZN South Coast are relying on their catches as an important supplementary source of animal protein. Similar findings were observed by Joubert (1981b) during a shore-angling survey of the same area. The present survey indicated that the South Coast was also supporting a small subsistence fishery. Some 5.5% of all anglers interviewed were unemployed and were dependent on the shore-based fishery for their livelihood.

#### **Catch rates**

Catch rates based on total measured effort have generally been considered to be inappropriate when fishing effort is directed at a particular species or group of fish unless all species are

equally vulnerable to all angling methods (Malvestuto, 1983). The shore-based fishery along the southern African Coast is multi-species and a number of catch and effort analyses in this region have used total expended effort to derive CPUE for each species (Table 2.5). This is largely because of the difficulties in apportioning effort to individual species within a multi-species fishery (Westrheim, 1983; Smale & Buxton, 1985). In this study, effort was apportioned to different categories of fish. In a comparison of species-specific CPUE estimates using apportioned effort and total effort, clear differences were evident. Similar amounts of effort were directed at *P. saltatrix* and rockfish. The catch rate for *S. salpa* (using the effort directed at rockfish) was, however, more than three times greater than that for *P. saltatrix*. This is probably as a result of the ease with which *S. salpa* can be caught. A comparison of CPUE by weight yields similar values. Using total effort to derive CPUE values, the catch rate of *S. salpa* declined to 0.2 fish.angler hour<sup>-1</sup>. This is a substantial difference compared to the catch rate using effort directed at each category, and highlights the bias of using total effort expended to calculate CPUE in fisheries in which there is multispecies targeting of effort.

Recording of angling effort by NPB patrol officers has recently been implemented into the patrol set-up. Govender et al. (1995) conducted a preliminary investigation of the first four months of this catch and effort data. Their study revealed a similar trend to that observed in the above analysis of NPB patrol data, with *P. saltatrix* dominating the documented inshore catch. The catch rate of *P. saltatrix* (0.12 fish.angler hour<sup>-1</sup>) was much higher than that recorded for *S. salpa* (0.06 fish.angler hour<sup>-1</sup>) (Table 2.5) (Govender et al., 1995). The overall catch rate of 0.21 fish.angler hour<sup>-1</sup> was lower than that observed in the present survey study. This lower catch rate is probably a result of patrol officers concentrating law enforcement on anglers fishing for *P. saltatrix*. The contribution of *S. salpa*, and hence the overall catch rate of the species would, therefore, be expected to decrease.

Table 2.5: Summary of published analyses of shore-angling catches in Southern Africa. The sources of the data, the areas where the data was collected, the type of information used and CPUE for the total catch and catch of *S. salpa* are included (- denotes data not available).

Source	Location	Type of record	CPUE	
			no.fish.hr <sup>1</sup>	no. <i>S.salpa</i> .hr <sup>1</sup>
Coetzee & Baird (1981a)	St Croix Island, SE Cape	direct observation of competition anglers' catches	0.84	0.05
Joubert (1981b)	KZN South Coast	direct observation of anglers' catches	0.22	0.04
Penrith & Loutit (1982)	Terrace Bay, Namibia	angler catch cards	1.50	0.00
Clarke & Buxton (1989)	SE Cape	direct observation of anglers' catches	0.29	0.06
Coetzee <i>et al.</i> (1989)	SE Cape	posted catch cards from competition anglers	-	-
Bennett (1991)	False Bay, SW Cape	catch cards from club competitions	0.11	0.00
Bennett & Attwood (1993a)	De Hoop Marine Reserve, SW Cape	direct sampling by angling	1.94	0.002
Bennett <i>et al.</i> (1994)	SW Cape	catch cards from club competitions	0.10	0.00
Govender <i>et al.</i> (1995)	KZN South Coast	NPB patrol records	0.21	0.06
this study	KZN South Coast	direct observation of anglers' catches	0.36	0.20

Catch per unit effort data have been considered to be an index of relative fish abundance (Ricker, 1940; 1975) and have been used to measure and evaluate angler success (Robson, 1961; Erman, 1972; Low, Ulrich, Barans & Oakley, 1985). Locally, shore-based catch rates have been shown to decline over time as a result of increased angling effort (van der Elst, 1989a; Bennett, 1991). The catch rate recorded during the questionnaire survey (0.36 fish.angler hour<sup>-1</sup>), however, was higher than the 0.22 fish/angler hour recorded by Joubert (1981b) during a survey of the KZN South Coast. CPUE estimates of abundant species, such as *P. saltatrix*, *D. sargus*, *N. lithophilus* and *R. holubi* were reasonably similar between the two studies, although the catch rate of *S. salpa* in the present study was almost four times greater than that recorded by Joubert (1981b). Factors such as time of year of capture, capture methods and the sampling of different populations may, however account for size differences between

sample periods. The study areas of the present survey and Joubert's (1981) survey were similar. Furthermore, the time of sampling and the sampling methods used were also comparable. These factors were, therefore assumed to be constant between the two studies. The increases in total CPUE and CPUE for *S. salpa* between the two time periods could possibly be a result of an increase in the level of subsistence fishing subsequent to Joubert's (1981b) survey. This increased targeting of effort at *S. salpa* would have resulted in increased catches of the species. A comparison of the size composition of the catch between the two time periods indicated that the modal size in the present study was 10 mm larger than that recorded by Joubert (1981a). Over-exploitation of a species generally leads to a decrease in the mean size of the catch (Butterworth, Punt, Borchers, Pugh & Hughes, 1989). It would appear, therefore, that the *S. salpa* stock off KZN is probably sustaining this increased fishing pressure. *P. olivaceum* contributed very little to the total catch in both the NPB data and the survey. This is in contrast to Joubert's (1981b) survey where a catch rate of 0.042 fish.angler hour<sup>-1</sup> was recorded for *P. olivaceum*, and 19.6% of the total catch was comprised of this species. This may possibly be an indication of over-exploitation of the inshore stock of this species in KZN.

Comparisons of catch data from different areas are complicated by a number of factors which influence catch rate of different species. Depending on the species or classes of fish targeted by anglers, not all species will be equally vulnerable to the fishing gears or technique used (Malvestuto, 1983). A number of analyses of catch data, such as those by Penrith & Loutit (1982) in Namibia, Coetzee & Baird (1981a) and Coetzee *et al.* (1989) in the South Eastern Cape, and Bennett (1991) and Bennett, Attwood & Mantel (1994) in the South Western Cape have been based on returns submitted by competitive club anglers (Table 2.5). Small species were considered to be of little significance (except as bait) (Coetzee & Baird, 1981a) and were usually omitted from such returns which were subject to minimum size limits (Bennett

& Attwood, 1993a). Time periods of fishing effort and the transfer of effort between different habitat types for fish species will also influence catch rates of specific species (Bennett & Attwood, 1993a). Comparisons of catch data recorded in this study were therefore made with other analyses from other time periods and areas where similar sampling methods were used (i.e. based on direct observation of anglers catches or on sampling by direct angling) (Table 2.5).

The catch rate of 0.29 fish.angler hour<sup>-1</sup> recorded by Clarke & Buxton (1989) in a survey of the Eastern Cape shore-based fishery was only slightly lower than that recorded in the present study (Table 2.5). The studies were also similar in that *P. saltatrix*, *D. sargus* and *S. salpa* were numerically the most abundant species. The catch rate of *S. salpa* in the present study, however, was much higher than that recorded by Clarke & Buxton (1989) (0.06 fish.angler hour<sup>-1</sup>). This is probably a result of increased targeting of effort at *S. salpa* and hence increased catches of the species in KZN compared to the Eastern Cape.

The total catch rate recorded in this study was substantially lower than rates recorded in the De Hoop marine reserve in the South Western Cape (Bennett & Attwood, 1993a) (Table 2.5). These catch data, however, were collected in areas where fishing pressure was limited or zero. The benefits of closed areas in protecting fish stocks has been illustrated by the recording of higher catch rates in closed areas compared with areas open to fishing (Buxton & Smale, 1989; Bennett & Attwood, 1991). The catch rates of *S. salpa* in the present survey, however, exceeded, by more than an order of magnitude, those recorded by Bennett & Attwood (1991; 1993a) in the South-Western Cape. This was largely because relatively large hooks (> #1 with a gape of 10 mm) were used in the latter studies, so that fish less than approximately 24 cm (FL) were seldom caught (Bennett & Attwood, 1993a). Based on the size composition of the shore-based catch in KZN, this probably would have excluded a large proportion of the *S. salpa* population.

## 2.5 Conclusion

A comparison of survey data recorded in this study with the study of Joubert (1981b) has indicated a change in the shore-based catch along the KZN South Coast. Although substantial catches of *P. saltatrix* were recorded in both studies, the importance of *S. salpa* to the total catch appears to have increased in the present survey. This shift in the species composition could be a result of serial overfishing or of the socio-economic state of the country, for example, an increase in the number of anglers relying on their catches as a means of providing a supplementary source of animal protein.

The extensive nature of the NPB data collection system makes it an extremely valuable data source. Differences in species contribution in the results of patrol data and survey data, however, indicated the bias associated with the patrol set-up. This bias results primarily from improper sample selection (Jones, 1995) and highlights the importance of a random sampling design as a strategy which needs to be incorporated into NPB data collection. Patrol effort is currently directed at regulating *P. saltatrix* catches. It would be more advantageous to document anglers catches on a random basis, rather than on every patrol that was undertaken. This would probably result in a decrease in the amount of data collected, but would also result in the exclusion of bias from the present method of data recording.

Changes in species composition and CPUE, which were evident in the present survey, as well in the mean weight of different species are factors which can be used to evaluate long term trends in a fishery. The NPB patrol system is a valuable source of catch data providing for a long-term CPUE data series. This data collection system, with a possible revised patrol strategy to eliminate bias, provides a means for the monitoring of the shore-based fishery in KZN.

## CHAPTER 3

### REPRODUCTIVE BIOLOGY

#### 3.1 Introduction

The Sparidae have received much attention worldwide, largely because members of this family are harvested in almost all areas of their distribution (Druzhinin, 1975), and because sparids exhibit the most diversified expressions of sexuality among teleosts (Atz, 1964).

Two general reproductive styles may be recognized in this family. These include sequential hermaphroditism, where the gonad differentiates and functions as one sex and then the other. Protogynous species change sex from functional females to functional males, while protandrous species do the reverse. The second reproductive style is late gonochorism (rudimentary hermaphroditism), where immature fish possess bisexual gonads but mature as either males or females (Buxton & Garratt, 1990). Detailed studies on the reproduction of a number of sparid species important in the linefishery in South Africa have shown that the majority of fish exhibit protogynous or rudimentary hermaphroditism (Mehl, 1973; Hecht & Baird, 1977; Coetzee, 1983; Garratt, 1985, 1986, 1993a; Buxton & Clarke, 1986, 1989, 1991, 1992; Smale, 1988; Buxton, 1989, 1990; Mann, 1992), although there have been recent reports of protandry (Mann, 1992; Garratt, 1993a).

The nature of the reproductive style of an exploited species is of considerable importance to fisheries management. This aspect becomes even more relevant in the case of sex changing fish. There has been a growing awareness of the need to incorporate fish reproductive strategies into fisheries modelling (Shapiro, 1987; Buxton, 1992; Garratt, Govender & Punt, 1993). This will ultimately improve insight into the sustainability of exploited fisheries (Punt, Garratt & Govender, 1993).

Confusion exists regarding the reproductive style expressed by *S. salpa*. Historically, *S. salpa* has been described as protandrous (D'Ancona, 1949 *loc. cit.* Atz, 1964) and as a rudimentary hermaphrodite (D'Ancona, 1946 *loc. cit.* Atz, 1964; Reinboth, 1962 *loc. cit.* Atz, 1964). More recent histological work in the Mediterranean has reported that the species exhibits a partial form of protandry (Michele & Lafaurie, 1974; Febvre, Michele & Lafaurie, 1975; Michele, 1977). Joubert (1981a) described the species as a rudimentary hermaphrodite, based on macroscopic evaluation of the gonads collected during a shore-angling survey off the KZN Coast.

Other published information on the reproductive biology of *S. salpa* includes evidence of a protracted spawning season for the species extending from April to September, with peak activity being from June to August (Joubert, 1981a). As this coincided with a substantial increase in the catches of shore-based fishermen, Joubert (1981a) proposed that adult *S. salpa* undertake an annual spawning migration from the Cape to the warmer waters of KZN, followed by southward larval dispersal. Occurrence of juveniles in Cape surf zones, subtidal gullies, rock-pools and estuaries has been reported from May to September (Christensen, 1978; Lasiak, 1981, 1983, 1986; Beckley, 1985b, 1986; Bennett, 1987, 1989a; Whitfield, 1989; Whitfield et al., 1989; Whitfield & Kok, 1992).

This chapter deals with aspects of the reproductive biology of *S. salpa*. Seasonal histological and macroscopic changes in the gonads of *S. salpa* were investigated to determine seasonality in reproduction, size at sexual maturity and sex ratios. A detailed histological examination of gonadal development was undertaken to confirm the form of hermaphroditism exhibited by this species.

### 3.2 Materials and methods

Fish obtained from monthly sampling in 1994/95 were measured (mm fork length) and weighed (g). Gonads were removed, weighed, macroscopically sexed and allocated to one of four developmental stages. These maturity stages were based on criteria developed by Garratt (1985) and Buxton (1990) and modified for this study (Table 3.1).

Table 3.1: Description of the macroscopic maturity stages used for the classification of gonads of *S. salpa* sampled along the KZN Coast.

Stage	Female	Male
1 Inactive	Ovarian portion elongate and slightly rounded, translucent in colour.	Testicular portion thin and flattened, usually off-white, sometimes not visible.
2 Active	Ovaries swollen and yellow/orange in colour, eggs are visible to the naked eye.	Testes swollen and white in colour, sperm is visible in the main duct if cut and pressure is applied.
3 Ripe	Ovaries very large and yellow/orange in colour, translucent eggs visible, ovaries may be bloodshot and flaccid if some spawning has occurred.	Testes very large and swollen with sperm present in the main duct, white in colour but may become pinkish as breeding season progresses.
4 Spent	Ovaries flaccid, bloodshot and reduced in size.	Testes reduced in size, greyish white in colour.

The accuracy of macroscopic field staging of gonads has been questioned (West, 1990) and in this study it was verified using histological techniques. Gonads were removed from fish and fixed in Bouin's solution for three days and then transferred to 70% ethanol for storage. The tissues were embedded in paraffin wax, sectioned at 7  $\mu\text{m}$  and stained with Erlich's haematoxylin and eosin. As the area slightly posterior to the mid-region of the gonad has been shown to be representative of the functional state of the gonads in a number of sparids (Garratt, 1993a), the majority of sections for this study were taken from this area of the gonads.

### Spawning season

The periods of maximum reproductive activity in *S. salpa* were investigated by seasonal macroscopic assessment of the state of maturity of the gonads. For each month, the number of fish in each stage of development was expressed as a percentage of the total sample. In addition, a monthly gonadosomatic index (GSI), which involved calculating the mean proportion of gonad weight to body weight, was also calculated:

$$GSI = \frac{\text{Gonad mass (g)}}{\text{Body mass (g)}} \times 100 \quad (1)$$

### Size-at-50% maturity

The proportion of reproductively active fish (gonad stages 2 to 4) collected during the months of peak reproductive activity was expressed as a cumulative percentage of the total number of fish in each size class. Size-at-50% maturity was estimated by fitting a logistic equation of the form:

$$Y = \frac{1}{1 + \exp(-(X_{mid} - X_{0.5})/\delta)} \quad (2)$$

where  $Y$  is the cumulative proportion of mature fish in length class  $X$ ,  $X_{mid}$  is the midpoint of the class interval,  $X_{0.5}$  is the size-at-50% maturity and  $\delta$  is the length of the maturity ogive (Butterworth *et al.*, 1989).

### Gonadal development

Monthly sub-samples of gonads were histologically examined for description of gonadal development and gametogenesis. Gonads from a total of 170 fish were examined from January 1994 to March 1995.

### 3.3 Results

#### Spawning season

Difficulties were experienced in macroscopically determining the sex of inactive gonads of adult *S. salpa*. It was not always possible to identify the functional sex as the female portion in the majority of inactive gonads was usually larger than the male element and dominated the gonad. Gonads that were histologically identified as functional males often had the macroscopic appearance of female gonads. Male and female data were, therefore, not treated separately and pooled for analysis of spawning season.

Monthly distributions of the various gonad stages showed that development of gonads began as early as February (Figure 3.1). The majority of fish at this time were in the earliest stages of gonad development. The occurrence of ripe individuals from March throughout winter to September (spring) indicated a protracted reproductive season, although gonadal activity only peaked from April through to August.

An initial examination of mature male and female gonads showed the ovary and testis to be of similar size, resulting in similar GSI values (Figure 3.2). Average monthly GSI values ranged as high as ten for both sexes. The combined gonad indices confirmed the period of maximum reproductive activity, with the index peaking from April through to August.

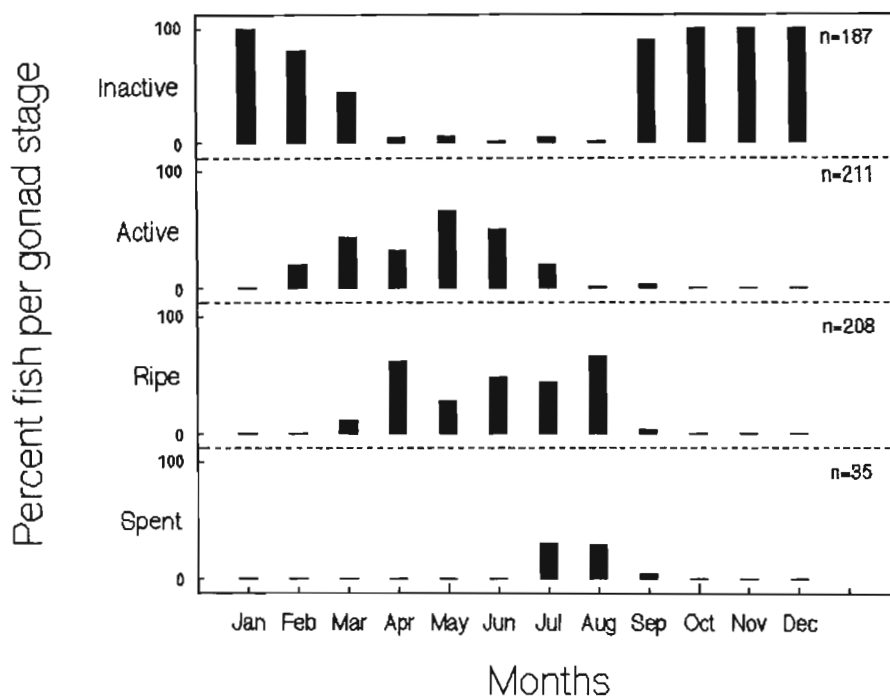


Figure 3.1: Monthly proportions of sample (males and females combined) per reproductive stage in *S. salpa* from the shore-based catch in KZN (n=641).

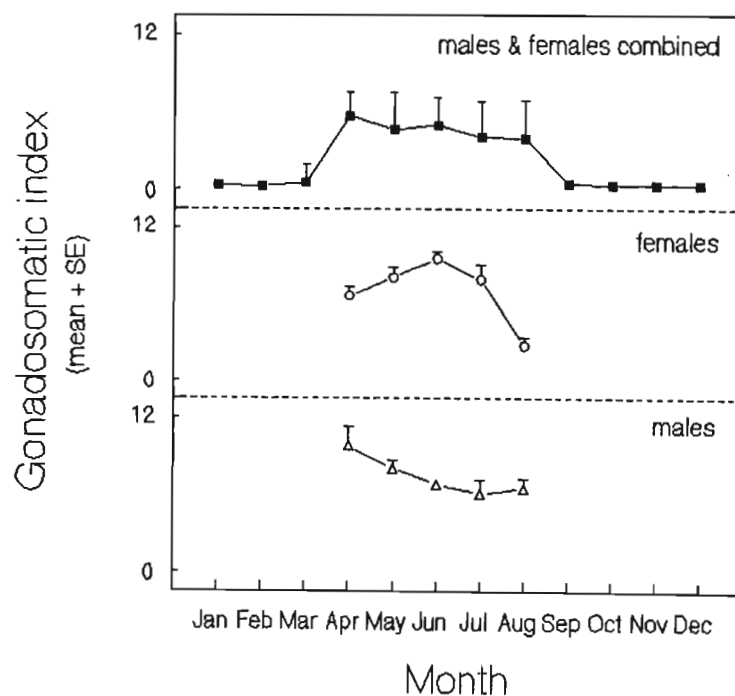


Figure 3.2: Average monthly gonad indices (males and females combined) of *S. salpa* from the shore-based catch in KZN.

### Sex ratios

Because of difficulties encountered in macroscopically determining the sex of inactive *S. salpa* individuals, only fish that were reproductively active were included in the determination of sex ratios. The overall sex ratio of reproductively active fish showed that females were outnumbered by males in the ratio (1 female: 1.6 males). A chi-squared test indicated that the deviation from a 1:1 ratio was significant at the 95% level. The distribution of sex ratios by size class (Table 3.2) indicated that male *S. salpa* predominated in the smaller size classes, after which the female proportion began to increase with a marked corresponding decrease in males. The high chi-square values indicated that the differences in the sex ratios were significant.

Table 3.2: Sex ratios by size class of reproductively active *S. salpa* from samples in the shore-based catch in KZN.

Size class (lower limit mm)	no ( $\delta$ )	no ( $\text{♀}$ )	sex ratio	chi-square
120	3	0	-	-
140	11	1	0.09	8.4
160	96	5	0.05	82.0
180	139	58	0.42	33.3
200	33	82	2.48	20.9
220	1	25	25	22.1
240	3	6	2	0.5
260	0	1	-	-
280	0	1	-	-

### Size-at-50% maturity

Size-at-50% maturity was derived from a regressive plot using the combined data for males and females (Figure 3.3). The calculation of sex-specific maturity sizes was not possible because of the low number of females in the smaller size classes. Fish < 140 mm fork length (FL) showed little evidence of sexual activity and the 50% level of maturity was attained at a FL of 145 mm (SE = 1.94) (Figure 3.3). The logistic curve provided a good fit to the data set ( $r^2=0.98$ ).

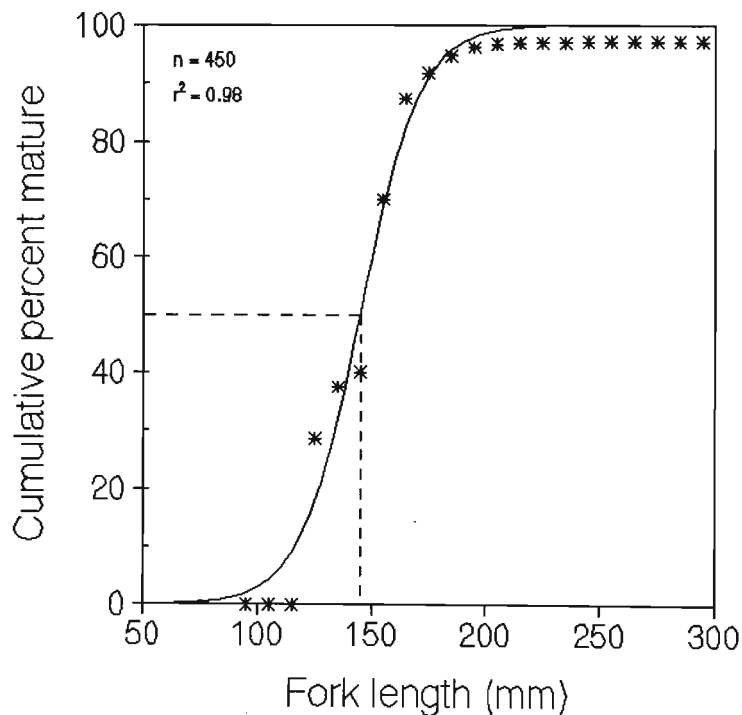


Figure 3.3: Length-at-50% maturity (males and females) of *S. salpa* from the shore-based catch in KZN.

### Gonadal development

Gonadal development in *S. salpa*, based on gross anatomical and histological observations, was described from a sample of fish of successive size classes. Four types of gonads were identified in *S. salpa*, namely juvenile, female, male, and intersexual gonads.

### **The juvenile gonad**

The gonads of fish measuring less than 80 mm FL ranged from gonadal primordia with no sex cells evident to undifferentiated gonial tissue. In larger juvenile fish (>100 mm FL), sex differentiation occurred and the gonads consisted of an ovotestis in which male and female tissue were clearly separated by connective tissue (Figure 3.4A). The female element dominated with the male element only occupying a small part of the gonad. In the female portion, oogenesis had commenced with the proliferation of gonidia but the oocytes were arrested in the previtellogenic stage. Spermatogenesis was not evident in the male element which consisted primarily of gonidia. At this stage, the sperm duct was not yet fully formed.

### **The female gonad**

The mature ovary was surrounded by the tunica albuginea, a connective tissue layer containing blood vessels and smooth muscle tissue (Figure 3.4B). Both ovaries fused posteriorly to form a short oviduct. Numerous ovigerous lamellae projected from the tunica albuginea into the ovocoele. A reduced testicular portion, which at times was not visible, consisted either of a small ridge of gonidia in the tunica albuginea of the ovary of the inactive gonad (Figure 3.4b), or of a remnant containing gonidia along the length of active ovaries. Few spermatogonia were evident in this testicular element. During the inactive period, the ovarian portion of the heterosexual gonad was always larger than the testicular remnant, and appeared to dominate the overall appearance of the gonad. This was apparent even in functional male gonads.

### **The male gonad**

The adult male testis consisted of elongated seminiferous tubules leading into secondary sperm ducts (Figure 3.4C). Posteriorly, these ducts collectively combined to form the main sperm duct.

Figure 3.4: Gonad types identified in *S. salpa* collected from shore-based catches in KZN.

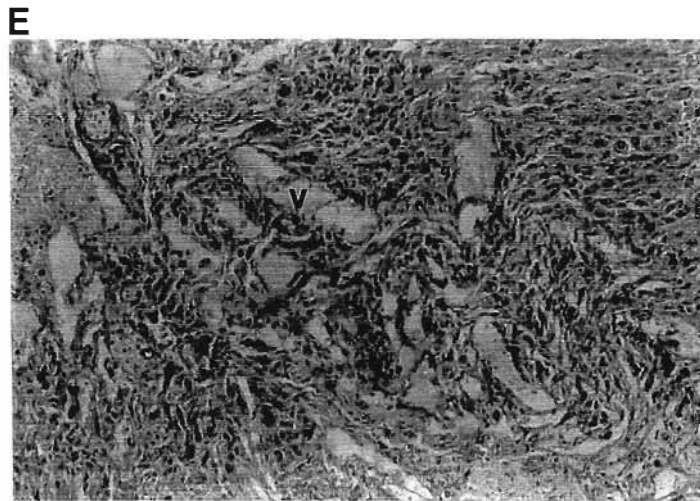
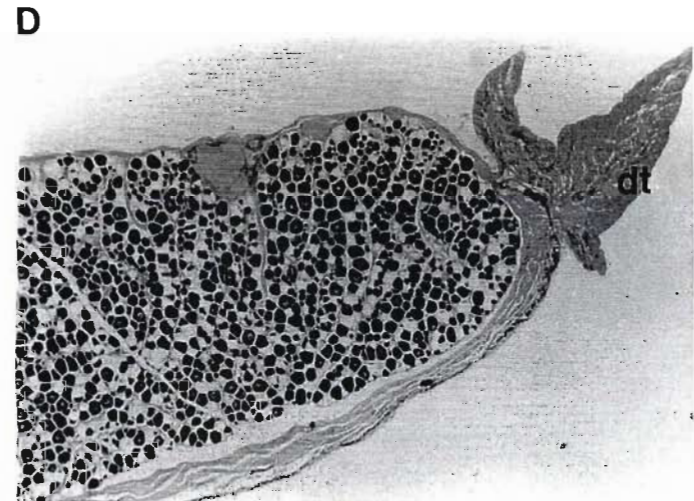
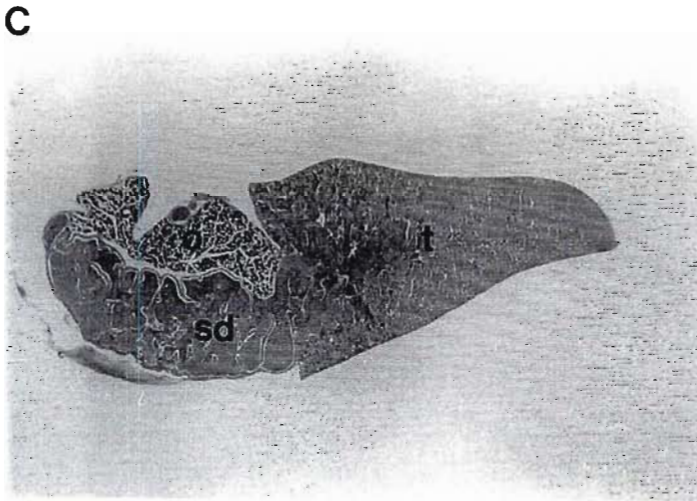
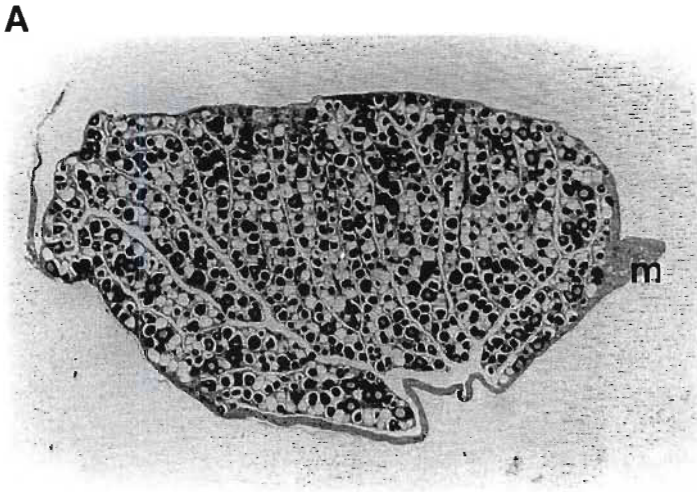
A) Section through an immature ovotestis of *S. salpa* (147 mm FL) showing the male (m) and female element (f) (x64).

B) Section through a female gonad of *S. salpa* (205 mm FL). vt=vestigial testis (x25).

C) Section through a male gonad of *S. salpa* (170 mm FL). t=testis, sd=sperm duct, o=ovary (x12).

D) Section through an intersexual gonad of *S. salpa* (195 mm FL). dt=degenerating testis (x40).

E) Section through an intersexual gonad of *S. salpa* (195 mm FL). v=vacuolation of cells (x400).



The tubules appeared to be continuous with the tunica albuginea, which surrounded the testis. In reproductively active males, the enlarged testicular portion was actively undergoing spermatogenesis through to the stage of sperm production. The testis of inactive males was characterised by the presence of a well developed sperm duct and proliferation of spermatogonia. Clusters of primary spermatocytes were often present. Unlike other sparids, where sperm has been recorded throughout the year in the main duct (Buxton, 1992; Mann, 1992), sperm was never present in the duct during the inactive male stage of *S. salpa*. A portion of female tissue, enveloped by the testis, was present and consisted of dormant oocytes in the late perinuclear stage. This female element was always visible even at the macroscopic level and was retained throughout the spawning season.

#### **The intersexual gonad**

Intersexual gonads were observed in adult fish from September to November during the inactive phase of the gonad. Macroscopically, the ovarian portion dominated the volume of these gonads (Figure 3.4D). Microscopically, this female tissue consisted of dormant oocytes at the perinuclear stage. The male element comprised a sperm duct, which suggested that these fish had functioned as males (P.A. Garratt, Two Oceans Aquarium, pers. comm.), and a testis, which appeared to be in the process of degeneration and atrophy (Figure 3.4E). This regression was characterised by extensive vacuolation of the testis.

#### **Sequence of development**

The sequence of development of these four gonad types for successive size classes is shown in Figure 3.5. Intersexual gonads could only be identified at a histological level. It was not possible to examine the gonads from all inactive individuals. It is, therefore, possible that the proportion of intersexual gonads relative to other gonad types could be higher. Intersexual gonads were observed in the 180-219 mm size classes

(Figure 3.5). The length frequency distribution showed that after the attainment of sexual maturity, there was a distinct bimodal size distribution, with males dominating the smaller and females the larger size classes, respectively.

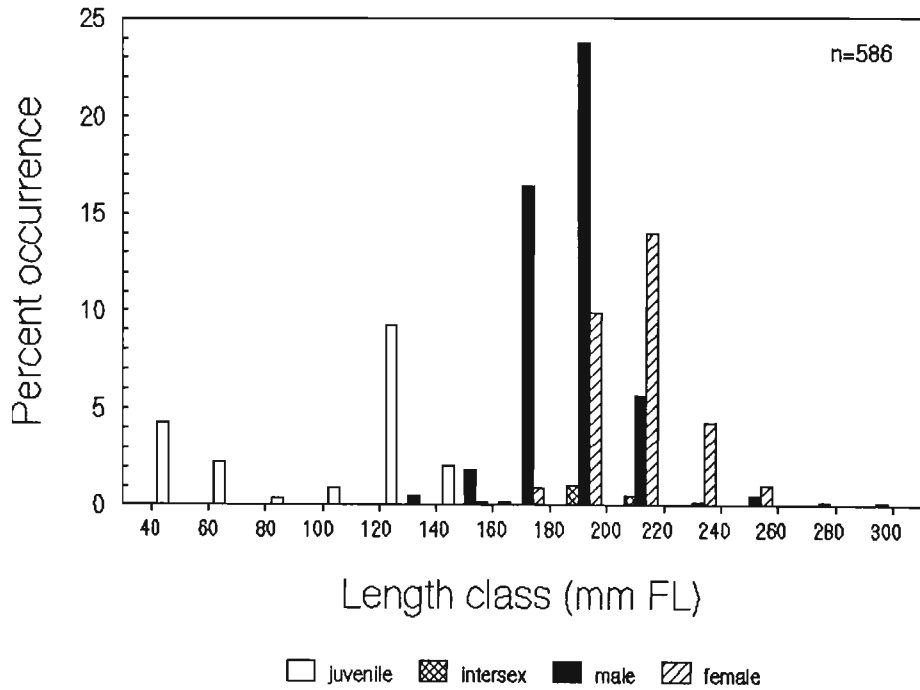


Figure 3.5: Length frequency distribution of *S. salpa* from samples of the shore-based catch in KZN with an indication of gonad type as determined by macroscopic determination.

## Gametogenesis

### Oogenesis

Oocyte maturation in *S. salpa* was described using the staging method of Buxton (1990). Although various classifications of oocyte maturation have been published, the actual processes appear to be similar and differ primarily in the number of stages (Buxton, 1990).

### Stage 1: Oogonia

Oogonia were observed throughout the year in clusters in close association with the ovigerous lamellae (Figure 3.6A). They were characterised by their small size, large nucleus and lightly basophilic cytoplasm.

### Stage 2: Perinuclear oocytes

Perinuclear oocytes were found in ovaries at all stages of development (Figure 3.6A). Polygonal pre-perinuclear oocytes were distinguished from early and late perinuclear oocytes which were larger and more ovoid in shape. Development of the oocyte was characterised by proliferation of nuclei on the periphery of the large, central nucleus. The nucleus was surrounded by a deeply basophilic cytoplasm, which decreased with intensity through the pre-, early, and late perinuclear stages.

### Stage 3: Yolk vesicle oocytes

The zona radiata formed between the cytoplasm and the zona granulosa and marked the commencement of yolk development. Primary yolk vesicles appeared first in the cytoplasm and gave rise to cortical alveoli in larger eggs (Buxton, 1990). The development of secondary acidophilic yolk vesicles followed, first appearing at the periphery of the oocyte and subsequently, throughout the cytoplasm (Figure 3.6B). Cell diameters during this stage varied greatly depending on the development of yolk vesicles.

### Stage 4: Tertiary yolk vesicle oocytes

This stage was characterised by yolk globules completely filling the cytoplasm, a nucleus with no nucleoli and a thick, eosinophilic zona radiata (Figure 3.6B). These oocytes dominated the volume of the ovary and were clearly visible to the naked

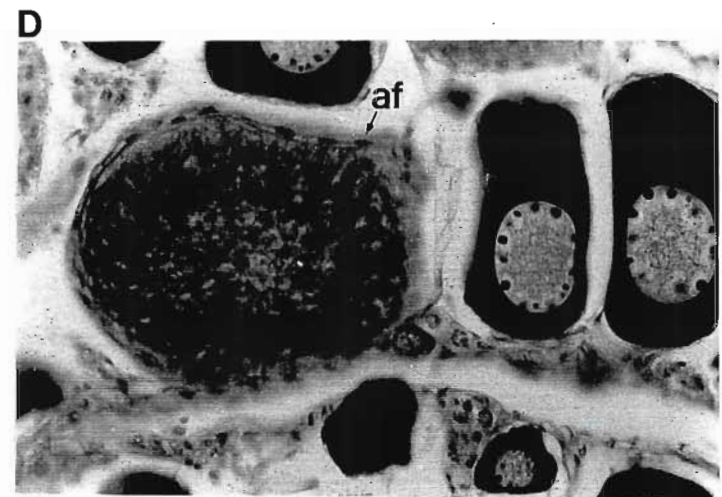
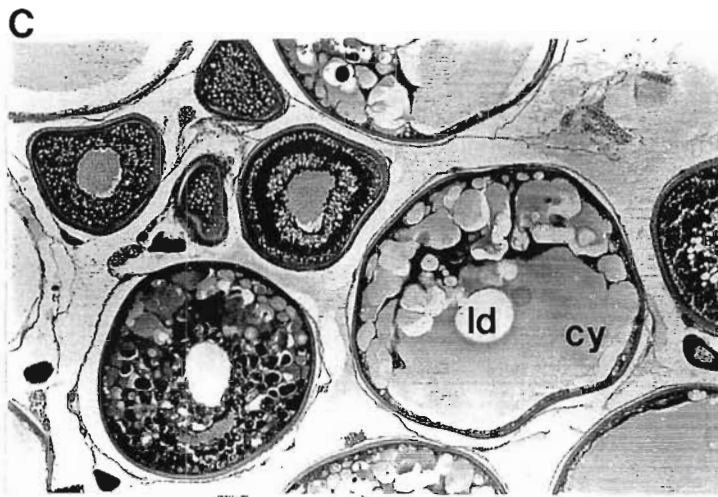
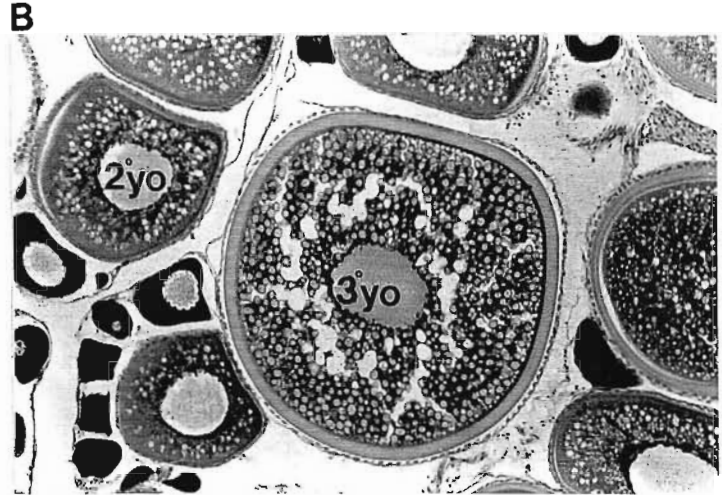
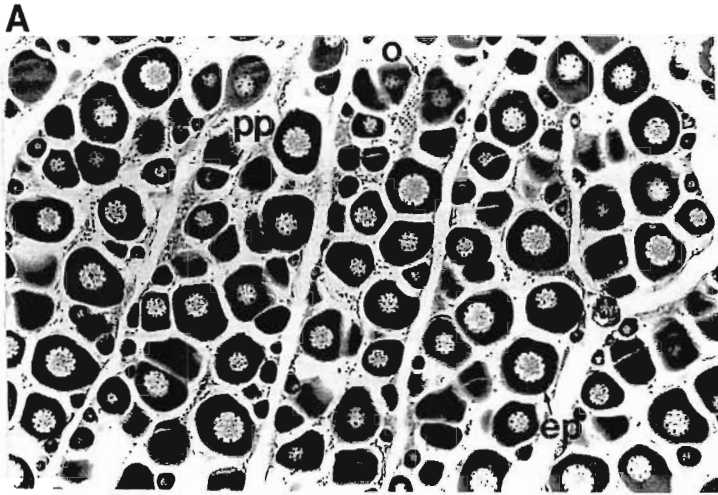
Figure 3.6: Microscopic oocyte development observed in *samples of S. salpa* collected from shore-based catches in KZN.

A) Section through an immature ovary showing pre-vitellogenic oocytes. o=ooogonial nest, pp=pre-perinuclear oocyte, ep=early perinuclear oocyte (x110).

B) Section through a developing ovary showing early vitellogenesis. 2°yo=secondary yolk vesicle oocyte, 3°yo=tertiary yolk vesicle oocyte (x120).

C) Section through a ripe ovary showing maturing oocytes with coalescing yolk (cy). ld=lipid droplet (x110).

D) Section through a spent ovary showing an atretic follicle (af) (x120).



eye. At this stage, empty spaces where eggs had been released, were evident.

#### Stage 5: Maturing oocytes

At this stage, the nuclear membrane began to degenerate. Lipid droplets began to coalesce around the nucleus and eventually formed a large oil droplet. This was followed by the migration of the nucleus to the periphery of the cell and the coalescence of yolk granules into a uniform yolk mass (Figure 3.6C). The majority of ripe eggs were distorted because of the dehydration process during histological preparation. Mature eggs were transparent and spherical in shape.

#### Stage 6: Atretic oocytes

Atresia of oocytes which had not been spawned was typical of that found in other teleosts (Crossland, 1977; Cyrus & Blaber, 1984; Buxton; 1990; Melo, 1994). Atresia was characterised by the granular appearance of the nucleus and cytoplasm, as a result of phagocytosis of the yolk by leucocytes and granulosa cells (Figure 3.6D).

### **Spermatogenesis**

#### Stage 1: Spermatogonia

Immature and inactive testes were characterised by a proliferation of spermatogonia (Figure 3.7A). These cells were large with a lightly basophilic cytoplasm. During the development of the testis, small clusters of spermatogonia were dispersed around its periphery.

#### Stage 2: Spermatocytes and spermatids

Division of spermatogonia produced a series of spermatocyte stages (Figure 3.7B), with cell size decreasing and intensity of

basophilic staining increasing with development. This proliferation was concentrated towards the centre of the testis. Spermatocytes gave rise to spermatids, which were characterised by exceptionally small size and dense basophilic staining.

#### Stage 3: Spermatozoa

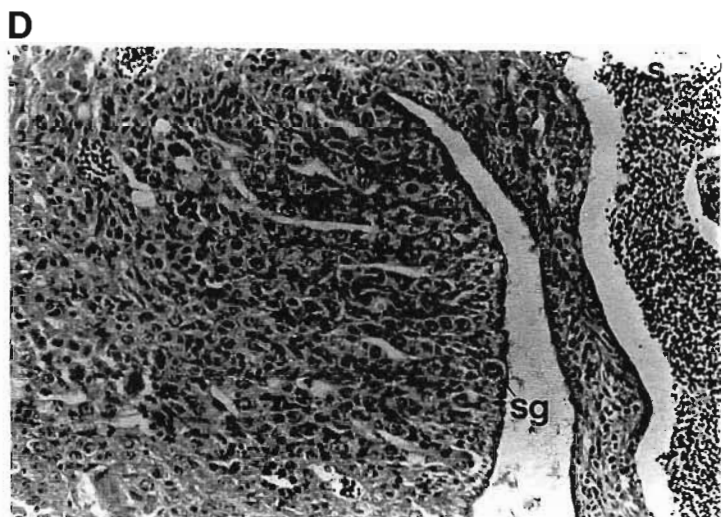
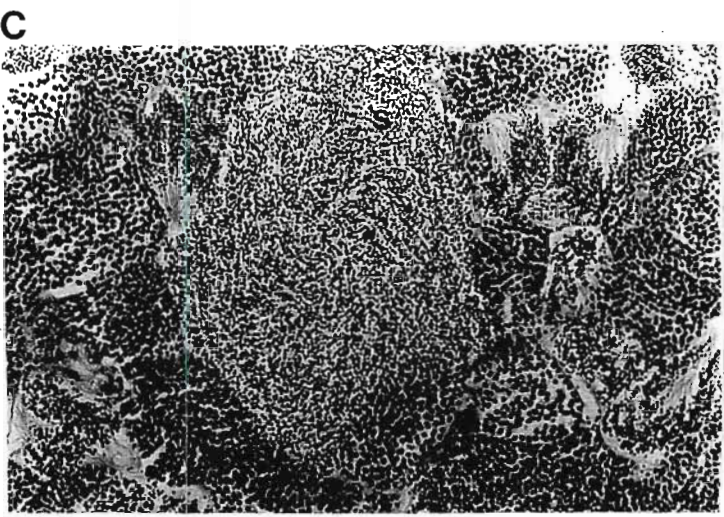
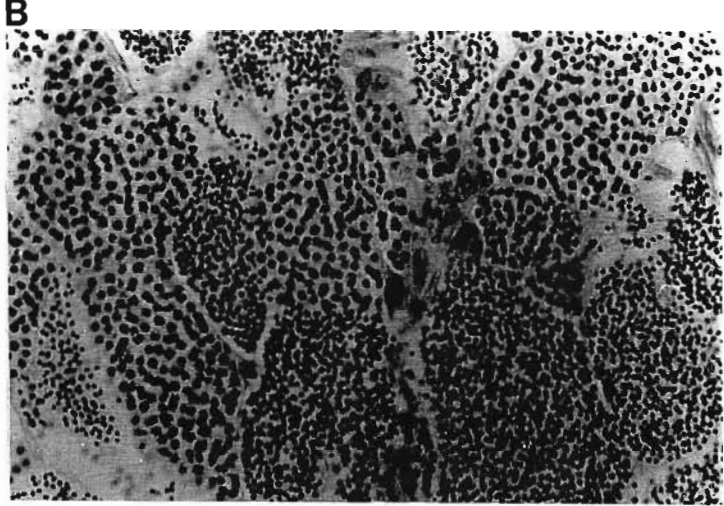
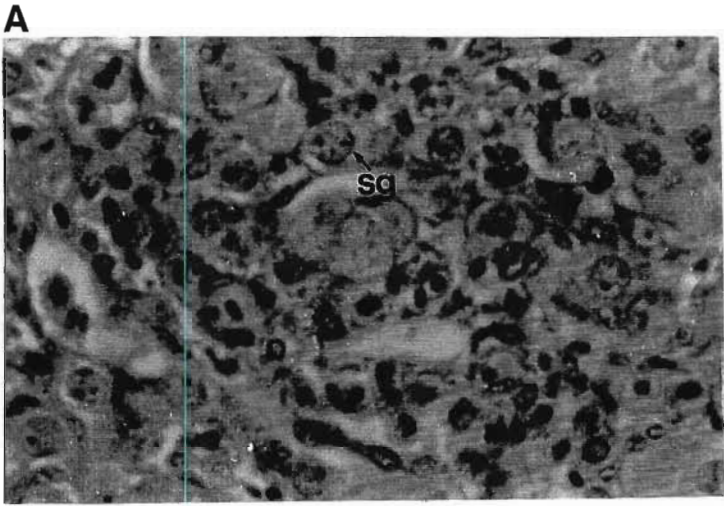
The final stage of development was the formation of spermatids, which were released into the lumen, where the maturation of spermatozoa took place (Buxton, 1990) (Figure 3.7C). This process was similar to spermatogenesis as described for a number of South African species (van der Horst, 1976; Coetzee, 1983; Buxton, 1990).

#### Stage 4: Proliferation of spermatogonia

Spent testes were characterised by proliferation of spermatogonia throughout the seminiferous lobules (Figure 3.7D). Spermatocytes were reduced to isolated clusters and sperm was still visible in the main sperm duct.

Figure 3.7: Microscopic spermatocyte development observed in samples of *S. salpa* collected from shore-based catches in KZN.

- A) Section through an immature testis during early development showing spermatogonia (sg) (x500).
- B) Section through a developing testis showing clusters of spermatocytes at different stages of development (x350).
- C) Section through a ripe testis showing sperm (s) in the seminiferous lobules (x300).
- D) Section through a spent testis showing proliferation of spermatogonia (sg) and remnant sperm (s) in the main sperm duct (x320).



### 3.4 Discussion

#### Maturity assessment

Midpoint sex-specific lengths-at-50% maturity of 145 and 165 mm FL for male and female *S. salpa*, respectively, were recorded by Joubert (1981a). The length-at-50% maturity of 145 mm FL recorded in this study matched Joubert's (1981a) estimate for males. This was expected since the majority of individuals in the lower size classes, on which this measure was based, were males. The size-at-50% maturity for both sexes is in excess of the present legal size limit of 133 mm FL (150 mm TL). However, the analysis of the size distribution of the shore-based catch (Chapter 2) indicated that the mean size of the catch was well above both the legal size limit and 50% maturity size.

#### Reproductive seasonality

Reproductive activity of *S. salpa* in this study was recorded during autumn and winter. This correlates well with the occurrence of *S. salpa* eggs recorded from April through to August off the KZN Coast (A.D. Connell, CSIR, pers. comm.). During this winter spawning season, *S. salpa* is heavily exploited. Analysis of shore-based anglers' catches (Chapter 2) indicated that the majority of *S. salpa* caught along the KZN Coast were sexually mature with a virtual absence of juveniles in the catches. This supports the proposal by Joubert (1981a, b) that adult *S. salpa* undergo a winter spawning migration from the Cape to the warmer waters in KZN. Similar northward migrations have been recorded for a number of sparids and other fish species (Ahrens, 1964; Wallace, 1975; van der Elst, 1976; Smale, 1984, 1988; Garratt, 1988; Griffiths, 1988; Bennett, 1993b). Gonadal activity has been observed in *S. salpa* in the Eastern Cape and it has been suggested that spawning also occurs in this region (Clarke, 1988). It would appear, therefore, that only part of the mature stock actually reaches KZN waters.

The actual driving force behind this north-eastward movement of fish is unclear, but may be related to water temperature. This factor has been suggested to influence reproductive seasonality (de Vlaming, 1972; Thresher, 1984) and has been proposed for a number of South African sparids (Garratt, 1985; Buxton, 1990; Mann, 1992). Warmer water temperatures along the east coast could enhance growth and development of eggs and larvae (Bennett, 1993b). Other unrelated factors inducing migration could be decreased levels of predation on eggs and larvae (Bennett, 1993b) and the possible existence of a larval dispersal mechanism involving the Agulhas Current system. Oceanographic features associated with the shoreward edge of this south flowing current appear to be involved in the dispersal of linefish larvae to nursery areas in the Cape (Beckley, 1993). The protracted reproductive season of *S. salpa* correlates well with the recruitment of early juveniles into Cape nursery areas from May through to December (Christensen, 1978; Lasiak, 1983; Whitfield, 1989; Whitfield & Kok, 1992).

The existence of a return migration is questionable. Although *S. salpa* is generally regarded as a "winter" fish by KZN anglers, which is substantiated by peaks in CPUE values and targeting of the species, it appears that at least some populations of *S. salpa* remain in the area throughout the year (Berry et al., 1982; pers. obs.). Discussions with spearfishermen operating in KZN have also indicated that *S. salpa* are encountered throughout the year. The vulnerability of *S. salpa* to capture appears to increase during the breeding season. A similar trend of exploitation has been observed in the Mediterranean (Anato, Ktari & Kamoun, 1983), and is probably because of increased feeding of reproductively active fish. The marked decline in catch rates during the rest of the year may be related to cycles of algal productivity, algae being the principal dietary component of *S. salpa* (Joubert & Hanekom, 1980). Algal biomass estimates, and hence food availability, can be expected to be higher during the summer months (Knoop, 1987) and, therefore, may explain the seasonal occurrence of *S. salpa* in shore-based catches.

Many species of fish are asynchronous or serial spawners. The spawning season of these fish is usually extended, and several batches of eggs and sperm are released (de Vlaming, 1983; Garratt, 1985). The protracted spawning season of *S. salpa* recorded in this study seems to suggest serial spawning behaviour. Further evidence includes histological examination of ripe ovaries, which showed the occurrence of oocytes in all stages of development, as well as numerous clear spaces in the ovigerous lamellae. This may be indicative of previous spawning activity (P.A. Garratt, Two Oceans Aquarium, pers. comm.). Furthermore, the low percentage of ripe-running individuals observed in this study is typical of that found for many serial spawners in which the final maturation of oocytes is believed to be a rapid process, and consequently, easily missed in samples (Garratt, 1988).

It has been suggested that the type of mating system used by fish plays a role in selection of the reproductive style expressed (Warner, 1988a). When comparing different reproductive styles, it has been hypothesised that distinctive characteristics are associated with each style (Warner, 1975, 1988a, b). Reproductive success in late gonochorists has been suggested to be unrelated to size (Warner, 1975, 1988a, b; Buxton & Garratt, 1990). Spawning may occur in pairs or in aggregations, under conditions of intense sperm competition. A large testis will be favoured in a spawning aggregation (Choat & Robertson, 1975), and hence comparable GSI values for males and females are apparent for a number of late gonochorists (Smale, 1988; Buxton & Clarke, 1991, 1992; Mann, 1992).

The shoaling behaviour of *S. salpa* would suggest an aggregating spawning behaviour and the comparable GSI ratios for males and females recorded in this study would suggest sperm competition. This, together with the lack of sexual dimorphism (dichromic) suggests that *S. salpa* probably exhibit a late gonochoristic mating system.

Monogamy or small, random mating groups, on the other hand, should be favoured in protandrous sex-changing fish (Warner, 1984; 1988a, b). However, the spawning behaviour of *Acanthopagrus berda*, a protandrous species, which has been well described (Garratt, 1993b) does not conform to the predictions of the above system. This suggests that the mating system, as well as factors unrelated to the mating system, may be involved in reproductive success (Warner, 1988a; Garratt, 1993a). Other factors which may influence a sex changing life history include environmental and demographic effects (Reinboth, 1988; Warner, 1988a; Ross, 1990) as well as factors such as differential growth and mortality (Warner, 1988a). The mating system of a species may, therefore, give some insight into the reproductive style. However, the system may not always conform to theoretical predictions, and should be viewed in conjunction with other observations. Spawning in *S. salpa* was not observed in this study and the mating system used by the species remains speculative.

### Population structure

Age at sexual differentiation in the family Sparidae varies considerably (Alekseev, 1982) and in this study was recorded in sampled individuals of *S. salpa* between 100 and 149 mm FL. Relating this to age using the estimates of growth parameters for the species (see Chapter 4), differentiation appears to occur towards the end of the first year or early in the second year of life. Similar findings have been recorded for this species in the Mediterranean (Michele & LaFaurie, 1974) and for other sparids (eg Alekseev, 1982; Francis & Pankhurst, 1988; Abou-Seedo, Wright & Clayton, 1990; Mann, 1992; Garratt, 1993a).

After the attainment of sexual maturity by *S. salpa*, the percentage frequency of gonad types in different size classes clearly showed that the ratio of males decreased with size, resulting in a distinct bimodal distribution. A similar distribution was recorded for this species by Joubert (1981a).

Although sex-differentiated bimodal size-frequency distributions and male-biased sex ratios have been widely used to diagnose the occurrence of sex-change (Sadovy & Shapiro, 1987), it must be noted that these phenomena may also be produced by other biological mechanisms such as differential growth rates and maturation, differential mortality, differential migration, and selective capture (Sadovy & Shapiro, 1987). Differences in growth could not be determined as sex specific growth estimates could not be obtained (see Chapter 4). The greater size at maturity for females may, however, partly explain the distribution. Both these mechanisms, therefore, remain as potential factors explaining the above phenomena. It is probably unlikely that differential mortality rates among males and females of the same sizes exist in a shoaling fish like *S. salpa*, particularly as these shoals do not appear to be sex-specific (pers. obs.) Selective capture and differential migration did not appear to be factors as *S. salpa* is an inshore species and the sample of fish from the KZN Coast covered a wide area and range of sizes.

Recent reports on sparids in southern African have suggested the occurrence of protandry in three species. The pathway of the reproductive style in two species, namely *A. berda* and *Rhabdosargus sarba*, involves the development of males from a bisexual immature ovotestis (Garratt, 1993a). In subsequent seasons, males may either continue to function as males or may change sex and function as females. In *D. sargus*, digynic protandry has been proposed where both males and females may be derived from the ovotestis, after which males can change sex (Coetzee, 1986; Mann, 1992). This form of partial protandry has also been proposed for *S. salpa* (as *Boops salpa*) in the Mediterranean (Michele, 1977). This diagnosis was based on the differences in the sizes of testicular and ovarian zones present in the ovotestis, as well as on the observation of remnant testicular portions in gonads identified as female. Similar observations were recorded in this study of *S. salpa*. However, the most developed element of the gonad (in size) does not always

represent the functional sex of the fish (Micale & Perdichizzi, 1994), while the persistence of the initial sex in the gonad of the final sex is not classified as a criterion when diagnosing protandry (Sadovy & Shapiro, 1987). More conclusive evidence is therefore required for the diagnosis of the sexual pattern of *S. salpa*.

Histological investigation of gonads of *S. salpa* indicated a similar sequence of gonadal development to that observed in *R. sarba* (Yeung & Chang, 1987; Garratt, 1993a) and *A. berda* (Garratt, 1993a). The extensive atresion of the testicular element in the intersexual gonads of *S. salpa* observed in this study was also very similar to the morphological characteristics recorded in the above species. This degeneration of the male element suggested these that testes would not function again. Both *A. berda* and *R. sarba* were classified as protandrous on the basis of similar observations, as well as on tagging and biopsy studies, respectively.

The mere presence of non-functional gonadal tissue of one gender in individuals containing functional (or degenerating) tissue of the other gender, however, is not sufficient to label a species hermaphroditic (Sadovy & Shapiro, 1987). The strongest indicators of protandry are transitional individuals whose gonads contain degenerating testicular tissue and developing ovarian tissue (Shapiro, 1987). Examples of such transitional gonads have been recently recorded in *D. sargus* (Mann, 1992; Micale & Perdichizzi, 1994). However, in the diagnosis of protandry of other species, oogenesis had not proceeded past the previtellogenic stage until sex separation was almost complete and the male element was reduced to a remnant (Abu-Hakima, 1984; Pollock, 1985; Yeung & Chang, 1987; Garratt, 1993a).

The fact that there are seldom traces of the previous functional sexuality in sex-changed individuals makes the diagnosis of protandry exceedingly difficult (Shapiro, 1987). In this study, histological investigation of gonads from *S. salpa* throughout its

size range provided evidence which suggested the potential occurrence of sex change in this species. Clearly, more work, perhaps in the form of experimental induction (Sadovy & Shapiro, 1987), is required for the conclusive diagnosis of protandry in *S. salpa*.

## CHAPTER 4

### AGE AND GROWTH

#### 4.1 Introduction

Age-structured techniques used for assessing the state of exploited fish stocks rely on the availability of age composition data. These data allow the determination of parameters such as growth rate, mortality and longevity, which are essential to stock assessment and management of the harvesting of fish species.

The most frequently used method of age determination in fishes is the interpretation and counting of growth zones that are deposited in hard tissues. Hard tissue bands are formed during alternate periods of fast and slow growth (or no growth at all) and may reflect various environmental or internal influences (Tesch, 1968). Otoliths, scales, opercular bones, fin rays and vertebrae are all hard tissues in which growth zones have been distinguished, and have been used to determine the age of bony fish (Jearld, 1983; Campana & Neilson, 1985). Recent ageing studies on sparids have shown that sagittal otoliths are the most suitable structures for age and growth assessment for this group (Buxton & Clarke, 1992; Mann, 1992; Buxton, 1993). Growth bands have been most visible in these structures and have, therefore, provided the most accurate estimates of age.

On obtaining age estimates using otoliths, it is imperative that these estimates be validated (Beamish & McFarlane, 1983). Direct methods of validation include the study of known-age fish (Radtke & Dean, 1982) and daily increment analysis (Campana & Neilson, 1982). Cohort analysis and examination of the marginal zone of otoliths are examples of indirect methods (Hecht & Smale, 1986). The latter validation method has been frequently used in South African studies, but has not always proven conclusive (Smale & Punt, 1991; Mann, 1992; Govender, 1993). In recent years, a more

comprehensive validation technique using a fluorochrome label has been widely used to directly validate age estimates (Wild & Foreman, 1980; Lang & Buxton, 1993; Ferreira & Russ, 1994). Oxytetracycline (OTC) is an example of such a marker which is incorporated in calcified structures, creating a fluorescent mark which can be used as a time reference mark for subsequent growth of these structures.

The growth of *S. salpa* was investigated in this study to obtain growth parameter estimates, which are necessary for a stock assessment of the species, using a per-recruit model of the Beverton and Holt (1957) type. An OTC labelling experiment was also undertaken to investigate the periodicity of growth zone formation in *S. salpa*.

## 4.2 Materials and methods

### Somatic relationships

In a sample of 400 *S. salpa* TL and FL were measured to the nearest millimetre and body mass to the nearest gram. The relationship between mass (W) and length (L) was expressed by the power relationship,

$$W = aL^b \tag{1}$$

and the TL/FL relationship by least squares linear regression.

### Age estimation

#### Otolith reading

An initial examination of scales and otoliths from *S. salpa* showed that although growth zones were distinguishable in scales, they were most easily seen and interpreted in sagittal otoliths.

Sagittal otoliths obtained from 808 fish sampled on the KZN and Eastern Cape Coasts were removed, cleaned, and stored dry in gelatin capsules and envelopes to prevent breakage.

Age estimates were obtained by reading whole otoliths against a black background under reflected light, using a low power dissecting microscope. The number of opaque bands was counted from the nucleus to the outer margin of the otolith. When necessary, otoliths were burned over a low intensity spirit flame until they turned pale brown. This treatment was used to enhance the opaque zones (Christensen, 1964; Buxton & Clarke, 1986). Each pair of otoliths was read three times by the same reader with a minimum of three weeks between readings. If two or more readings per otolith concided, then this was taken as the number of growth zones.

The precision of the age estimates was described by the index of average percent error (APE) (Beamish & Fournier, 1981) and the percent agreement technique (Kennedy, 1970). The latter method of reporting error, although used extensively to compare the precision of age determinations, is insensitive to the age distribution in the sample. The APE measures the amount of variation between age estimates, but unlike the percent agreement technique, it is not independent of the age of a species. It can, therefore, be used to evaluate the degree of precision equally for all species.

### **Validation of band formation**

#### **Marginal zone analysis**

The periodicity of opaque band deposition was determined by marginal zone analysis (Hecht & Smale, 1986). The frequency of occurrence of the opaque band on the otolith margin was plotted on a monthly basis.

## Oxytetracycline labelling

### Experimental technique

A sample of 21 *S. salpa* (110-209 mm FL) were caught by hook and line from the shore during January 1994 along the KZN South Coast. The fish were maintained at ambient light and temperature in an aerated flow-through pool (6000 litres) located at the Oceanographic Research Institute. They were fed pilchard and lettuce, and allowed to acclimate to these conditions for a period of three weeks. After the acclimation period, the water level of the pool was dropped and the fish collected. Each fish was tagged with an anchor tag inserted into the dorsal spines to enable individual identification. Individuals were measured (mm FL), and injected with Terramycin (1 ml contains 100 mg of oxytetracycline hydrochloride). Recommended dosages for sparid fish range from 50-100 mg kg/fish in the laboratory to 250 mg kg/fish in the field (Lang & Buxton, 1993). An intermediate dosage of 200 mg kg/fish (OTC) was chosen for this study. Intramuscular injections were administered to the mid-body region directly below the dorsal spines. Three control fish were not injected. The experiment was terminated after 18 months and all surviving fish were sacrificed.

### Otolith examination

Fork length of each fish was measured to the nearest millimetre. Otoliths were removed and stored dry in the dark until viewing. Otoliths were viewed whole using a stereomicroscope under fluorescent light. The position of the OTC fluorescent band was marked on the otolith. Otoliths were then viewed under reflected light and the number of opaque bands distal to the OTC mark were counted. The OTC fluorescent band on the otoliths was also viewed with a compound microscope equipped with neoflour objective lenses and photographed.

### Growth estimation

The age-length data were initially fitted to the generalised Schnute (1981) growth curve to determine if a submodel with fewer parameters could adequately describe the growth of *S. salpa*. The general form of this model which describes fish size (Y) as a function of age (t) is:

$$Y_t = [y_1^b + (y_2^b - y_1^b) \frac{1 - \exp(-a(t - T_1))}{1 - \exp(-a(T_2 - T_1))}]^{\frac{1}{b}} \quad a \neq 0, b \neq 0 \quad (2)$$

where  $y_1$  and  $y_2$  are the mean sizes corresponding to the two ages  $T_1$  and  $T_2$ . For this study,  $T_1$  and  $T_2$  corresponded to the youngest and oldest observed ages in the sample, respectively. Depending on the values of  $a$  and  $b$ , the Schnute analysis allows for the selection of alternative growth curves which adequately describe the age-length data. The runs (Draper & Smith, 1981) and homoscedasticity tests (Butterworth et al., 1989) were used to select between alternative growth curves.

A likelihood ratio test (Draper & Smith, 1981) was used to determine if alternative fits to the data set were significantly different from each other. The bootstrap method (Efron, 1981; Punt, 1994) was used to estimate the standard errors and confidence intervals of the estimates of the parameters of the chosen growth models. The software PC-YIELD (Punt, 1992) was used to implement the above.

### 4.3 Results

#### Somatic relationships

The equations describing the fork length-total length relationships (for the range 35 to 285 mm FL) are summarised in Table 4.1. A fork length-weight plot is presented in Figure 4.1.

Table 4.1: The relationships between fork and total lengths in *S. salpa* from the shore-based catch in KZN and from the netted catch in the Eastern Cape.

Equation	$r^2$	n	std error of slope	std error of constant
$FL(mm) = 0.867TL(mm) + 2.31$	0.99	400	0.0026	2.86
$TL(mm) = 1.149FL(mm) + 1.14$	0.99	400	0.0035	3.30

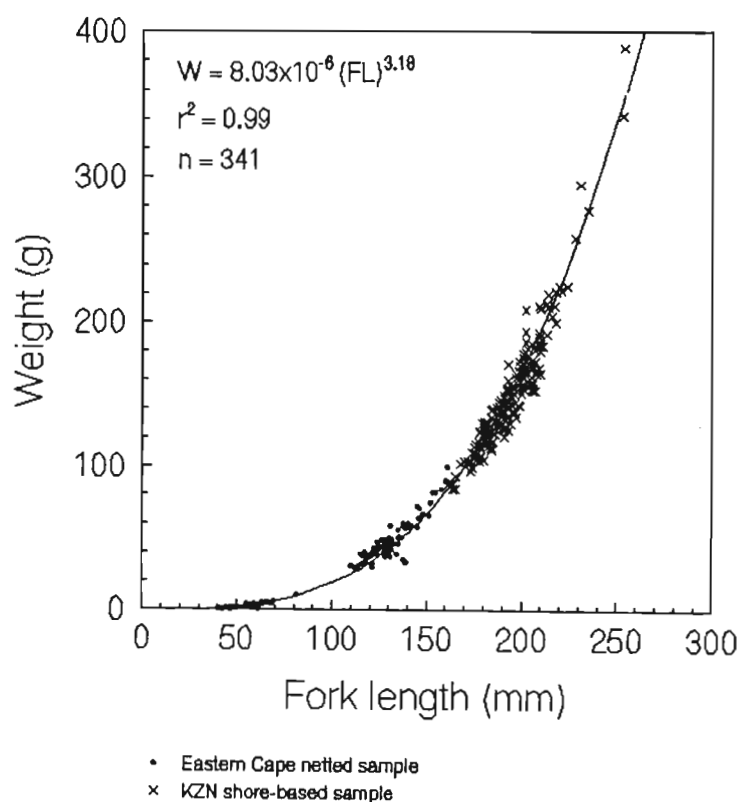


Figure 4.1: Length-weight plot of *S. salpa* from the shore-based catch in KZN and from the netted catch in the Eastern Cape.

The parameter  $b$  in the power relationship is a measure of the length:body depth ratio with a value of three indicating perfect isometric growth. *S. salpa*, like most South African sparids, has a value of  $b > 3$  (Figure 4.1), that is, there is an increase in the girth of the fish even after growth in length has slowed down (Tesch, 1968).

#### Age determination

Whole otoliths of *S. salpa* (Figure 4.2) viewed under reflected light showed a large opaque nucleus surrounded by alternating translucent hyaline and opaque bands. Upon burning the otoliths, the translucent, hyaline bands appeared brown.

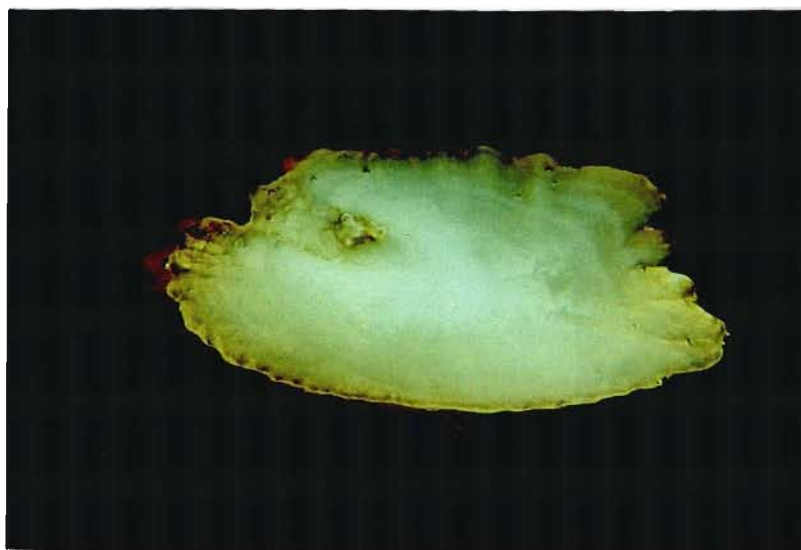


Figure 4.2: Photomicrograph of an otolith of *S. salpa* (201 mm FL) viewed under reflected light (four opaque bands are visible).

### Reproducibility of age estimates

Of the 808 otoliths read, 167 were rejected as unreadable. These otoliths were either broken, completely opaque or translucent, or had poorly defined growth zones. Of the remaining otoliths, 62% of the readings coincided on all three occasions while 32% of the readings coincided at least twice. The remaining readings (5.8%) yielded conflicting ages and were excluded from the analysis. An APE value of 3.94% was calculated from the three sets of age estimates.

### Validation

#### Periodicity of opaque ring formation

The monthly frequency of occurrence of the opaque zone on the otolith margin indicated that opaque growth predominated during winter (Figure 4.3). Hyaline growth predominated for the rest of the year except for a small peak in opaque deposition recorded during January. This minor peak could possibly indicate that two opaque zones are laid down per year.

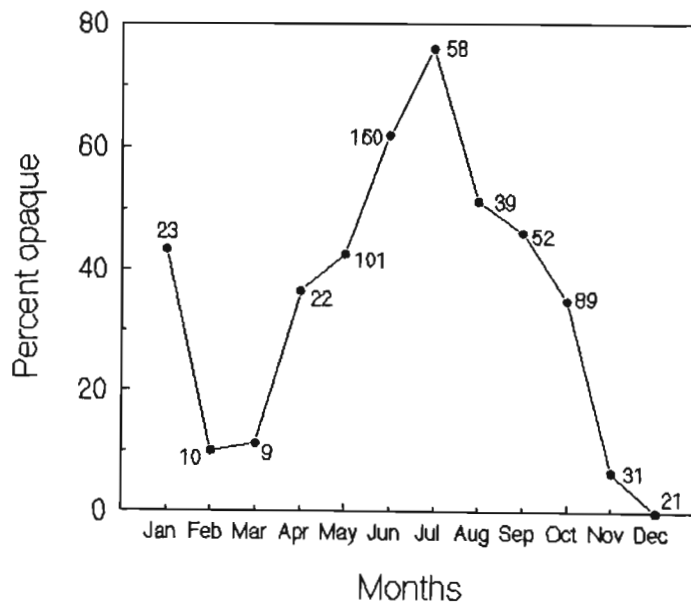


Figure 4.3: Monthly frequency of opaque edges on the otoliths of *S. salpa* from the shore-based catch in KZN and from the Eastern Cape netted sample (figures on graph represent sample sizes).

### Oxytetracycline labelling experiment

Post-treatment survival in *S. salpa* was reasonably good (81% after 30 days) and the OTC did not appear to affect the fish directly. The tags, however, appeared to cause some discomfort to the fish which were often observed rubbing the tag against the bottom of the pool. This action resulted in the dislodging of tags and after 4 months, all tags had been shed. No individual growth estimates of *S. salpa* could, therefore, be made. Wounds which resulted from tag shedding may have contributed to the mortality of individuals. Only 6 fish survived the 18 month experiment and a clear fluorescent band was displayed on the otoliths of three fish (FL = 210 mm, 208 mm, 188 mm) (Figure 4.4). Two opaque bands were recorded between the fluorescent band and the otolith margin in the otoliths from all three fish. This suggested that the opaque zones were annuli as these experimental fish survived two winter breeding periods, which corresponded to the two opaque bands distal to the OTC mark.

Although marginal increment analysis and the OTC study yielded inconclusive results, it was assumed for the purposes of growth estimation that one opaque growth zone was deposited annually.

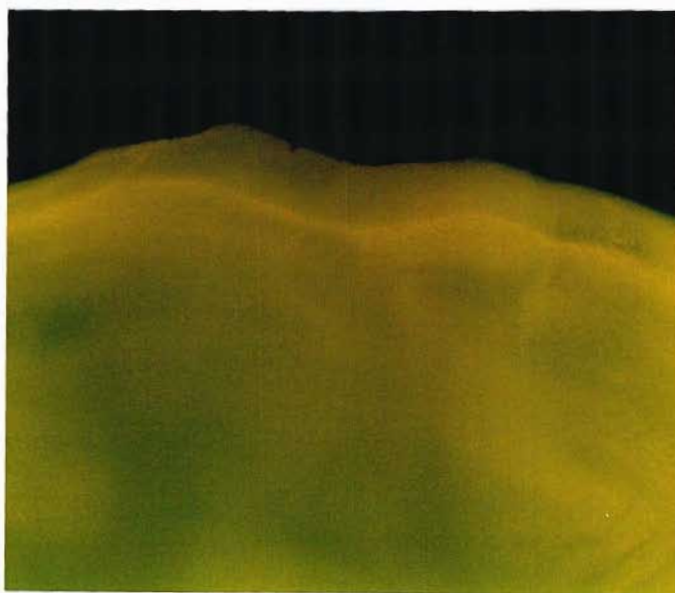


Figure 4.4: OTC mark in the otolith of *S. salpa*. The time period from intermuscular injection to death of the individual amounted to 115 days.

## Growth

The additive and multiplicative error models of the Schnute equation were fitted to the age data set. Examination of a residual plot indicated that variance of the length data for the Schnute model increased with age. The multiplicative error model was therefore, chosen over the additive model and was fitted to the generalised Von Bertalanffy (VONB) and special VONB growth equations. Although both fits satisfied the runs test, that is, the residuals showed no serial correlation at the 5% level of significance (Draper & Smith, 1981), despite log transformation, they both failed the test for homoscedasticity (i.e. the residuals are normally distributed). Although this lack of homoscedasticity will result in statistical tests having lower power, this is not of particular concern (Smale & Punt, 1991). The special VONB equation was selected over the generalised VONB equation as the former model had one less parameter and the latter model was not statistically superior ( $F=0.468$ ,  $df=583$ ).

Estimates of the values of the Schnute and special VONB growth model parameters, their estimated co-efficients of variance and 95% confidence intervals are presented in Table 4.2. The estimates of the growth parameters were reasonably determined, as indicated by their low coefficients of variance. The fit of the special VONB equation using these parameters is shown in Figure 4.5.

Attempts to fit the relative error model of the special VONB growth equation separately to male and female data sets failed as both data sets did not pass the runs tests (Draper & Smith, 1981; Butterworth *et al.*, 1989). Both data sets had linear fits with no curvature. This was probably because of the lack of sex-specific data points in the lower age classes (zero and one year old fish) in both data sets. This had the effect of increasing  $L_{\infty}$  to a size which was not considered plausible. Further attempts to obtain sex-specific growth parameters included

pooling the juvenile data set with both the male and female data sets, as well as the use of a weighting function, which can be used to assign more weight to certain points in a data set (Punt, 1992). This modification of the data sets, however, still resulted in fits which were inadequate. A summary of these attempts to obtain sex-specific curves is shown in Table 4.3.

Table 4.2: Estimates of the parameters of the Schnute, special and generalised VONB growth equations, their estimated coefficients of variation (C.V.) and 95% confidence intervals (CI) using a multiplicative error model using age-length data obtained for *S. salpa* in KZN.

Parameter	Value	C.V.	Left 95% C.I.	Right 95% C.I.
<b>Schnute</b>				
a	0.61	14.96	0.42	0.78
b	0.82	32.68	0.33	1.41
$Y_1$ mm( $T_1=0$ years)	54.95	1.21	53.60	56.22
$Y_2$ mm( $T_1=6$ years)	216.61	1.52	211.63	223.28
<b>VONB special</b>				
a	0.55	3.98	0.51	0.59
b	1.00	-	-	-
$Y_1$ mm( $T_1=0$ years)	54.70	0.99	52.60	56.83
$Y_2$ mm( $T_1=6$ years)	217.70	0.94	196.60	238.80
$L_\infty$ (mm)	224.41	1.34	220.00	229.51
K(year <sup>-1</sup> )	0.55	9.61	0.49	0.59
$t_0$ (years)	-0.51	3.17	-0.56	-0.48
<b>generalised VONB</b>				
a	0.61	17.27	0.43	0.82
b	0.82	36.87	0.28	1.37
$Y_1$ mm( $T_1=0$ years)	54.95	1.40	53.43	56.33
$Y_2$ mm( $T_1=6$ years)	216.61	1.49	210.70	223.26
$L_\infty$ (mm)	221.38	2.62	212.47	234.88
K(year <sup>-1</sup> )	0.61	17.31	0.42	0.82
$t_0$ (years)	-0.63	3.22	-1.42	-0.34

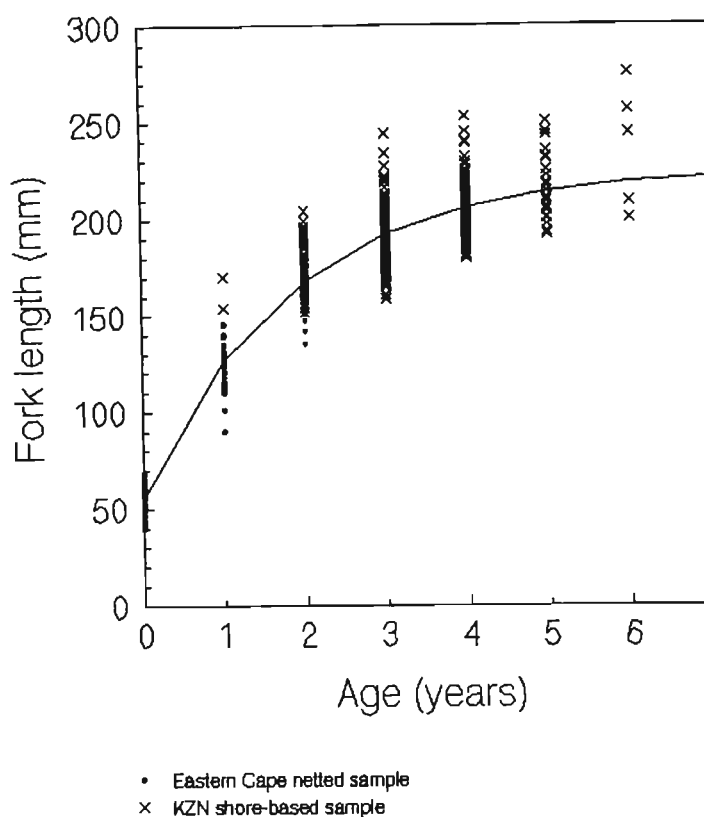


Figure 4.5: The relationship between FL and age in *S. salpa* from the shore-based catch in KZN and from the Eastern Cape netted sample.

Table 4.3: Summary of data sets used to obtain growth parameters of *S. salpa* obtained in KZN using the multiplicative error model of the special VONB equation, the respective nature of the fitted curves and results of the runs and homoscedasticity tests.

Data set	Nature of fit	Runs test	Homoscedasticity test
male	linear	passed	passed
female	linear	failed	passed
male & juvenile	curvi-linear	passed	failed
female & juvenile	curvi-linear	failed	failed
pooled	curvi-linear	passed	failed
weighting function	slight curvature	failed	failed

#### 4.4 Discussion

##### Precision

Age estimation in South African sparids has proved difficult as a result of the phenomenon of stacking of growth zones towards the otolith margin, particularly in older fish (Buxton & Clarke, 1989, 1991, 1992; Smale & Punt, 1991; Mann, 1992). In many of these cases, because of the large robust nature of the otoliths, sectioning of these structures has been necessary. In this study, the translucency of *S. salpa* otoliths allowed for the reading of these structures without the need of sectioning and there was no evidence of stacking. The oldest age estimate obtained in this study was six years and the phenomenon of stacking was not evident. An APE value of 3.94% indicated that reproducibility of age determinations was better than that obtained for another South African sparid, *Chrysoblephus puniceus* (A. Govender, Oceanographic Research Institute, pers. comm.).

##### Validation

Marginal increment analysis indicated that opaque deposition, which is representative of discontinuous growth (Campana & Neilson, 1985) coincided with the peak in gonad maturation. Similar findings have been recorded in studies on other sparids in South Africa (Mann & Buxton, 1995). It is expected that somatic growth will be at its lowest when other energy demanding processes such as gonad investment are high (Buxton, 1987). The minor peak in opaque deposition recorded during January in this study suggested that opaque deposition was possibly biannual. The results of the OTC study, however, suggested annual deposition of the opaque band. The growth zones in this study were assumed to be representative of annual increments as the majority of studies on South African sparids have shown growth zones to be annuli (Hecht & Baird, 1977; Nepgen, 1977; Coetzee & Baird, 1981b; Buxton & Clarke, 1986, 1989, 1991, 1992; Pulfrich

& Griffiths, 1988a; Smale & Punt, 1991; Buxton, 1993; Garratt et al., 1993).

The majority of fluorochrome labelling studies have used tag-and-recapture of wild individuals to directly validate age estimates (Leaman & Nagtegaal, 1987; Murphy & Taylor, 1991; Francis, Paul & Mulligan, 1992; Sadovy, Figuerola & Roman, 1992; Rien & Beamesderfer, 1994). The initial high tag-shedding rates observed in *S. salpa* in this study made it feasible to label tank fish only. Growth of fish has been shown to be affected by changes in behaviour and food availability (Beamish & McFarlane, 1987). These are effects which could arise within the confinements of a tank and the exact extent of these effects on growth of *S. salpa* in this study were unclear. Nevertheless, fish in captivity have been used to successfully validate opaque bands directly (Bumguardner, 1991; Nordeide, Holm, Ottera, Blom & Borge, 1992).

### **Growth**

The use of the VONB model to describe growth has been criticised for several reasons. These include the use of variables (such as  $t_0$ ) which have little biological meaning (Knight, 1968; Schnute, 1981), and the absence of parameters which take into account seasonal changes in growth rate (Pauly, 1980; Moreau, 1987). Nevertheless, the VONB model has been used extensively to describe the growth of southern African sparids (Hecht & Baird, 1977; Nepgen, 1977; Coetzee & Baird, 1981b; Buxton & Clarke, 1986, 1989, 1991, 1992; Pulfrich & Griffiths, 1988a; Smale & Punt, 1991; Mann, 1992; Buxton, 1993; Garratt et al., 1993). The growth model provides for a simple description of growth which can be compared between species and species groups. The special or original form of the VONB equation was chosen for this study because it contains fewer parameters than the generalised form of the equation.

The VONB parameters showed that *S. salpa* was relatively fast growing, with maximum age recorded at six years. The zero aged sample of fish in this study were obtained in October, three months after the peak spawning period (see Chapter 3). This period (June to July) can be assumed to be the arbitrary birthdate of the species and probably in part explains the large deviation of  $t_0$  from zero.

Substituting the growth parameters obtained in this study in the special VONB equation, an estimated fork length of 127 mm for fish aged one was obtained. Assuming that growth is constant in different geographic areas, this early growth estimate for *S. salpa* was similar to those obtained by Christensen (1978) (128 mm), Lasiak (1983) (107 mm) and Whitfield & Kok (1992) (124 mm) using length frequency analysis of specimens obtained in Eastern Cape nursery areas. However, it is faster than the rate reported by Smale & Buxton (1989) (72-107 mm) for *S. salpa* in Eastern Cape subtidal gullies.

Studies on age and growth of other sparids in South Africa have indicated that most are long-lived and slow growing. Growth coefficients are generally low, ranging from  $0.1 \text{ year}^{-1}$  to  $0.3 \text{ year}^{-1}$ , and the majority of species attain ages in excess of 20 years (see Buxton, 1993 for review). The majority of this research, however, has focused on the larger sized species and thus the value of  $K$  recorded in this study for *S. salpa*, a small sized fish, is relatively high when compared with these species.

Ideally, comparisons of growth parameters between populations and species should use  $L_\infty$  and  $K$  values together as they are inversely correlated (Knight, 1968). Galucci and Quinn (1979) proposed an index of growth ( $w = L_\infty \cdot K$ ), where  $w$  is the growth rate near  $t_0$ . This index allows for robust growth comparisons. However, the use of the parameter  $w$  should still be restricted to comparisons of species with similar longevity and  $t_0$  values (Moreau, 1987). In this study, a maximum age of six years was recorded for *S. salpa*. A comparison of growth parameters recorded in this study

with values recorded for other sparids, such as *Boops boops* (Tsangridis & Filippousis, 1991), *Pagellus bellottii* (Koranteng & Pitcher, 1987), *Lithognathus mormyrus* (Kraljević, Dulčić, Pallaoro, Cetinić & Jug-Dujaković, 1995) and *Acanthopagrus australis* (Pollock, 1982), which attain similar maximum ages to that of *S. salpa*, is shown in Table 4.4. All species had high growth rates, resulting in similar, high  $w$  values.

The inability to model sex-specific growth curves for *S. salpa* is a direct consequence of the relative lack of sex identity data in the smaller age classes (0-1 years). If differential growth rates do exist, then this will have consequences for the stock assessment procedure, in which case, the assessment methods must be applied to data for each sex. The potential for sex-change in *S. salpa* identified in this study (see Chapter 3) may further complicate the modelling of growth of the species. The effects of sex change, which result from one sex developing sequentially from the opposite sex, on growth are complex, although attempts have been made to incorporate this phenomenon into the growth equation (Bannerot, 1984; Ross, 1987; Garratt *et al.*, 1993). The difficulties encountered in modelling sex-specific curves means that estimates of growth parameters, which are requirements for per recruit analysis have to be based on pooled age data. This aspect needs to be taken into consideration when assessing the outcome of stock assessment models such as the yield per recruit model.

Table 4.4: Summary of VONB growth parameters and  $w$  values for selected sparids for comparison with estimates obtained for *S. salpa* in KZN.

Species	K (year <sup>-1</sup> )	L <sub>∞</sub> (mm)	w	Reference
<i>Acanthopagrus australis</i>	0.51	295	150.5	Pollock (1982)
<i>Boops boops</i>	0.4	360	144.0	Tsangridis & Filippousis (1991)
<i>Pagellus bellottii</i>	0.380	257	97.7	Koranteng & Pitcher (1987)
<i>Lithognathus mormyrus</i>	0.30	362	108.6	Kraljević <i>et al.</i> , (1995)
<i>Sarpa salpa</i>	0.55	224	123.2	this study

\* all L are FL measurements, except for *B. boops* which is a TL measurement

## CHAPTER 5

### STOCK ASSESSMENT

#### 5.1 Introduction

The formulation of strategies for the management of the harvesting of fish stocks usually requires an assessment of the status of the stock and estimates of its potential yield. Management advice for many South African sparid linefisheries (Pulfrich & Griffiths, 1988b; Smale & Punt, 1991; Buxton, 1992; Bennett, 1993a; Punt *et al.*, 1993) is often based on yield-per-recruit (YPR) analysis (Beverton & Holt, 1957).

The YPR model describes the change in biomass (resulting from natural and fishing mortality as well as growth) of a cohort of fish following recruitment to the fishery. The biomass of the cohort (year class) is calculated as the product of the numbers and the mean weight of individuals in that age class (Sissenwine & Sheperd, 1987; Butterworth *et al.*, 1989). The model assumes that under steady state conditions (constant growth, recruitment and mortality) the annual yield is equal to the total yield from a year class that has been fished over its entire lifetime (Beverton & Holt, 1957). The YPR is used by fisheries managers to evaluate the effects of different levels of fishing pressure on the potential yield of a stock and to determine the optimal age (or size) of capture of a species.

A number of biological reference points exist in fisheries stock assessment which are used to assess the status of fish stocks. These are usually expressed in terms of fishing mortality rates ( $F$ ) (Sissenwine & Sheperd, 1987).  $F_{\max}$  is the fishing mortality rate which maximizes YPR without regard to whether sufficient spawning biomass is conserved. This ultimately depletes the spawning stock and reduces future recruitment (Clarke, 1991). A more conservative approach to harvesting is the  $F_{0.1}$  strategy. This refers to the fishing rate at which the slope of the YPR

curve falls to 10% of its value at the origin (Gulland, 1968; Gulland & Boerema, 1973).  $F_{0.1}$  usually provides a yield close to the maximum YPR, although it is invariably much lower than  $F_{max}$ , so it is not likely to deplete the spawning stock as severely (Clark, 1991; Rivard & Maguire, 1993).

Fishing also affects the spawning potential of a stock (Gabriel, Sissenwine & Overholtz, 1989). In the Beverton and Holt (1957) model, as with yield, the spawning biomass of a stock is also usually normalised to the number of recruits entering the fishery. The combined effects of fishing mortality and the age-at-first capture serve to reduce the spawning biomass of a cohort over its lifetime. Fishing mortalities maintained at levels which reduce the spawning biomass to not less than 50% ( $F_{50\%}$ ) of its unfished level have been recommended in order to prevent recruitment failure (Butterworth *et al.*, 1989). More recently, however, it has been suggested that the  $F_{50\%}$  strategy is too conservative and spawning biomasses maintained at 35% ( $F_{35\%}$ ) of the pristine level have been recommended (Clark, 1991). This level of fishing mortality will provide high yields at low risk, even if nothing is known about the spawner-recruit relationship.

Knowledge of mortality is essential for stock assessment and is normally represented by an instantaneous mortality ( $Z$ ), being made up of natural mortality ( $M$ ) and fishing mortality ( $F$ ). Estimating natural mortality in harvested stocks is extremely difficult and the majority of studies have utilised Pauly's (1980) empirical equation because of a paucity of data. This equation assumes that natural mortality is similar to that of other species which grow at the same rate under similar temperature regimes.

In this chapter, the current status of the fishery for *S. salpa* was assessed by determining the effects of fishing mortality ( $F$ ) and age-at-capture on the YPR and spawner biomass-per-recruit (SBPR).

## 5.2 Materials and methods

### Mortality estimation

The instantaneous natural mortality rate (M) was estimated from the Pauly (1980) equation:

$$\log M = -0.0066 - 0.279 \log L_{\infty} + 0.65 \log K + 0.463 \log T \quad (1)$$

where  $L_{\infty}$  and  $K$  are estimates of the Von Bertalanffy growth equation and  $T$  is the mean annual environmental temperature of the range of the species. A mean environmental temperature of 21°C (Natal Sharks Board, unpublished data) was used for the KZN South Coast.

The total instantaneous mortality rate ( $Z$ ) was estimated from the slope of the descending limb of a catch curve, that is, by plotting the natural logarithm of age frequency against age to all fully recruited ages. Before constructing the catch curve an age-length key was prepared from age-length data obtained from otolith reading. This was combined with the total length frequency of the whole catch to give the full catch age frequency distribution. The instantaneous fishing mortality rate ( $F$ ) was obtained by substitution into the equation:

$$F = Z - M \quad (2)$$

### Per recruit analyses

The effects of  $F$ ,  $M$  and age at capture on YPR and SBPR were determined from the following equations (Punt, 1992):

$$YPR = \int_{t_c}^{\infty} F \cdot N'(t) \cdot W_t \cdot dt \quad (3)$$

where  $t_c$  = the age-at-50% capture

$F$  = instantaneous fishing mortality

$N'(t)$  = the proportion of recruits alive at time  $t$  when the number of recruits = 1

$W_t$  = mean mass of a fish of age  $t$

This implies that all fish of a given age become vulnerable to fishing at a particular time in a given year (Ricker, 1975).

$$SBPR = \int_{t_m}^{\infty} N'(t) \cdot W_t \cdot dt \quad (4)$$

where  $t_m$  = age-at-50% maturity

$N'(t)$  = the proportion of recruits alive at time  $t$  when the number of adults = 1

The software PC-YIELD (Punt, 1992) was used to generate YPR and SBPR curves and to estimate  $F_{0.1}$  and  $F_{50\%}$  values.

### 5.3 Results

#### Mortality estimation

The estimate of the instantaneous natural mortality rate using Pauly's (1980) empirical equation was  $0.6 \text{ year}^{-1}$ . The age frequencies used in the estimation of total instantaneous mortality are shown in Table 5.1. The catch curve yielded a total mortality of  $1.41 \text{ year}^{-1}$  (Figure 5.1). Assuming  $M$  equals

0.6 year<sup>-1</sup>, a fishing mortality rate of 0.81 year<sup>-1</sup> was calculated by simple substitution into equation 2.

Table 5.1: Age frequencies of *S. salpa* (males and females combined) sampled in the shore-based catch in KZN. Age frequencies were obtained by transforming length frequency data using an age-length key (n=1092).

Age (years)	Age frequency
1	11
2	71
3	607
4	323
5	71
6	9

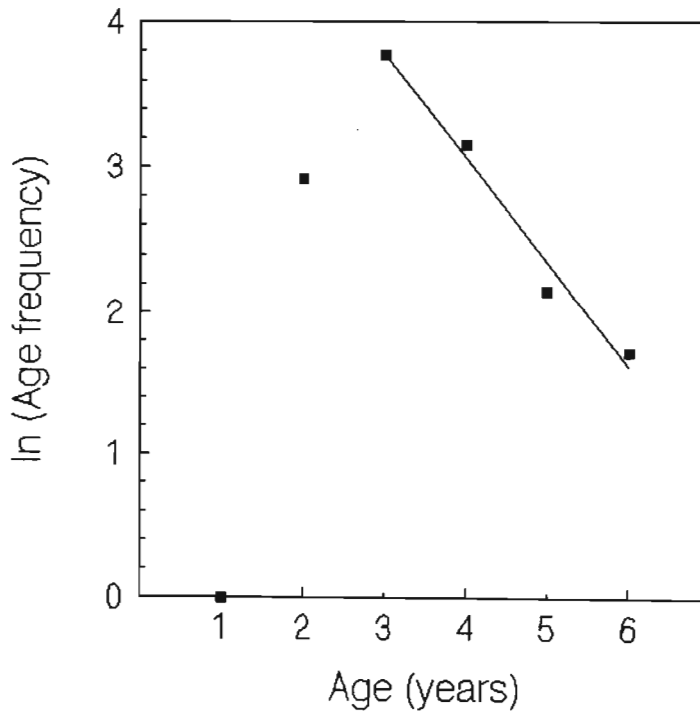


Figure 5.1: Catch curve for *S. salpa* obtained in KZN based on age frequency data . The regression line was fitted using least squares regression.

### Per-recruit analyses

The responses of YPR and SBPR to  $F$  were modelled for values of  $F$  up to two times the current estimated  $F$  of  $0.81 \text{ year}^{-1}$  (Figures 5.2 and 5.3). *S. salpa* recruit into the fishery at the minimum legal size limit (133 mm FL; 150 mm TL; age-at-first capture ( $t_r$ ) = 1.13 years). An age-at-50% capture ( $t_c$ ) of 2.68 years was calculated by the cumulative size frequency method. This value was comparable to an age-at-full recruitment of 3 years obtained from the top of the catch curve (Figure 5.1). The age-at-50% capture ( $t_c$ ), in addition to the age-at-first capture ( $t_r$ ) to the fishery, were used in the analysis. The input parameters used in the model are shown in Table 5.2.

Table 5.2: Parameter estimates used in performing per-recruit analysis of *S. salpa* obtained in the shore-based catch in KZN.

Parameter	Value
a	$8.0275 \times 10^{-6}$
b	3.18
$L_\infty$ (mm)	224
K ( $\text{year}^{-1}$ )	0.55
$t_0$ (years)	-0.51
M ( $\text{year}^{-1}$ )	0.6
F( $\text{year}^{-1}$ )	0.81
$t_m$ (females) (years)	1.9 (Joubert, 1981a)
$t_r$ (years)	1.13
$t_c$ (years)	2.68

At the calculated value of natural mortality of  $M = 0.6 \text{ year}^{-1}$ , YPR increased with increasing values of  $F$  and at  $t_c = 2.68$ , YPR was maximised at very high levels of  $F$  (Figure 5.2). Using the age-at-first capture ( $t_r$ ), there was little improvement in YPR at fishing mortalities higher than  $0.9 \text{ year}^{-1}$ .

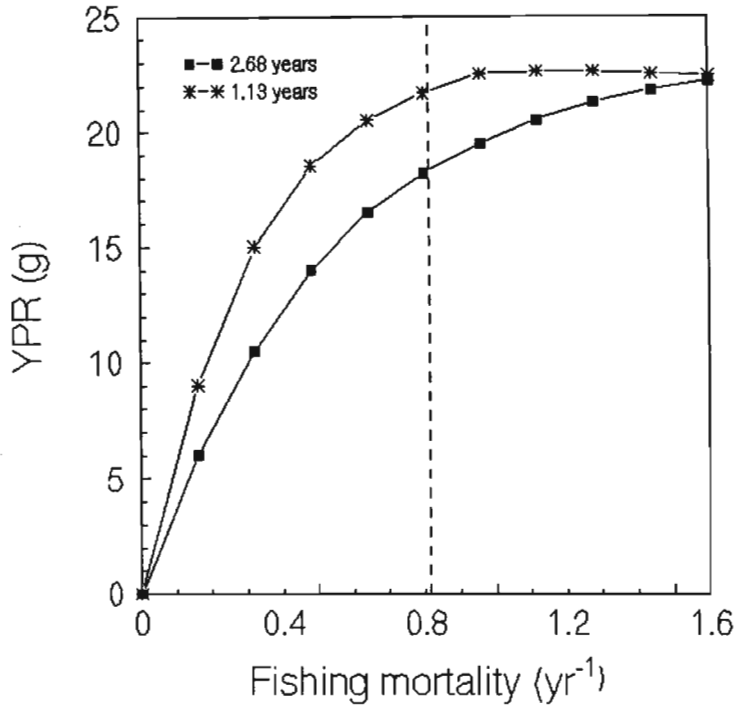


Figure 5.2: YPR as a function of increasing fishing pressure for *S. salpa* along the KZN Coast using the age-at-50% capture (2.68 years) and the age-at-first capture (1.13 years). (dashed line indicates current fishing mortality).

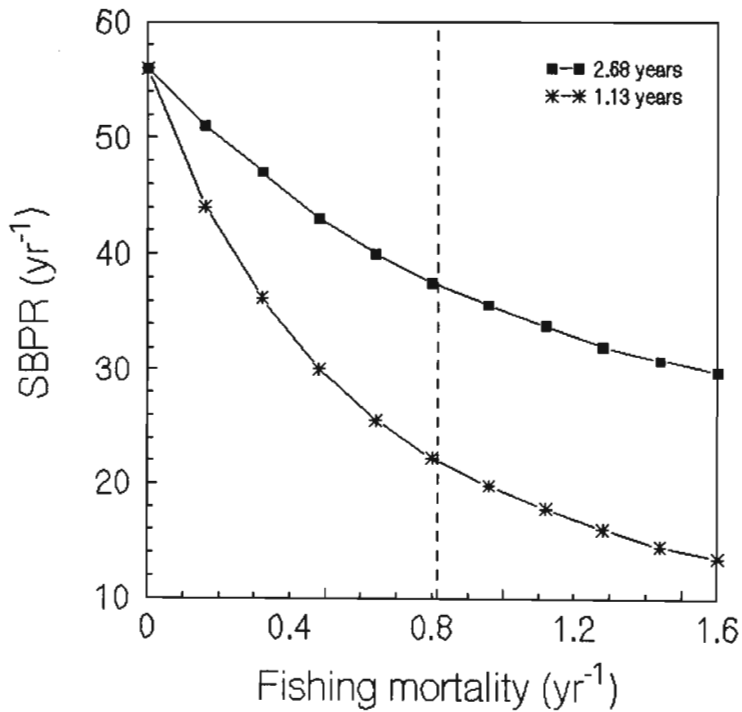


Figure 5.3: SBPR as a function of increasing fishing pressure for *S. salpa* along the KZN Coast using the age-at-50% capture (2.68 years) and the age-at-first capture (1.13 years). (dashed line indicates current fishing mortality).

The spawning biomass per recruit, using the age-at-50% capture, even at fishing rates double that of the observed value, was reduced by 45% (Figure 5.3). However, using the age-at-first capture ( $t_1$ ), the spawning biomass dropped to 50% of the unexploited level at a  $F$  between 0.5 and 0.6 year<sup>-1</sup>. Using the age-at-first capture to the fishery in the analysis is probably over-conservative as the contribution of fish around this size limit of 133 mm FL (150 mm TL) to the total catch is extremely small (see Figure 2.8; S. Brouwer, Rhodes University, pers. comm.). The age-at-50% capture is probably more representative and will be used in the results presented hereafter.

A relatively high natural mortality rate of 0.6 year<sup>-1</sup> was estimated for *S. salpa*. The standard deviation of Pauly's (1980) estimate is equivalent to a range of one third to three times the best estimate of  $M$  (Gulland, 1988).  $M$  can, therefore, vary between 0.2 and 1.8 year<sup>-1</sup>. Per recruit studies in South Africa have revealed the importance of obtaining accurate estimates of  $M$  (Bennett, 1988; 1993a). Assuming reasonable confidence in the estimate of  $Z$ , a range of  $F$  (0.81 to 1.21 year<sup>-1</sup>) and  $M$  (0.2 to 0.8 year<sup>-1</sup>) values were used to evaluate their effects on biological reference points, namely  $F_{0.1}$ ,  $F_{35\%}$  and  $F_{50\%}$ .

The per recruit models were sensitive to  $F$  and  $M$ , shown by the relative change in the reference points as a result of varying these parameters (Table 5.3). With decreasing  $M$ , increasing fishing pressure resulted in reduced reference point values. At the lower levels of  $M$  (0.2 to 0.4),  $F_{0.1}$  was reached at values below the corresponding fishing mortality rate. Similarly, a reduction in the spawning biomass to 50% of the pristine biomass was reached at the lower limits of  $M$ . However, over the whole range of  $F$  and  $M$  values,  $F_{35\%}$  values always exceeded the observed fishing mortality.

Table 5.3: Input parameters of M and F to the per recruit model and relative changes in biological reference values ( $t_c = 2.68$  years).

M	F	$F_{0.1}$	$F_{50\%}$	$F_{35\%}$
0.8	0.61	1.70	4.64	>1
0.7	0.71	1.42	3.28	>1
0.6	0.81	1.19	2.31	>1
0.5	0.91	1.02	1.67	>1
0.4	1.01	0.88	1.25	>1
0.3	1.11	0.77	0.98	>1
0.2	1.21	0.68	0.79	>1

#### 5.4 Discussion

A natural mortality estimate of  $0.3 \text{ year}^{-1}$ , obtained by means of a catch curve in a pristine area, was calculated for the sparid, *Chrysoblephus puniceus* off the KZN Coast (Punt *et al.*, 1993). *S. salpa* is a smaller sized fish and would be expected to have a higher natural mortality. *S. salpa* has also been recorded in the diet of a number of piscivores (Hutchings, 1968; Van der Elst, 1979; Smale & Bruton, 1985; Smale, 1986a, b; Bennett, 1989b; Smale, 1991) and predatory effects will serve to increase natural mortality (Gulland, 1983a; Medley, Gaudian & Wells, 1993). The value of  $0.6 \text{ year}^{-1}$  estimated using Pauly's (1980) relationship was fairly insensitive to temperature and is probably a reasonable estimate of the natural mortality rate for *S. salpa*.

A low standard error estimate ( $SE=0.23$ ) for the Z estimate was derived from the catch curve. The total mortality rate of  $1.41 \text{ year}^{-1}$  estimated from the catch curve in this study can, therefore, be assumed to be estimated with reasonable confidence. A number of factors were assumed to be negligible when estimating the total mortality rate from the catch curve. These included minimal emigration and immigration. Although there is a

migration of first breeding *S. salpa* from the Cape to KZN, there is no evidence to suggest a return migration of *S. salpa* after spawning (see Chapter 3), as is the case for other South African species (van der Elst, 1976; Garratt, 1988). Estimates of  $Z$  from a catch curve can be affected by changes in hook selectivity (Gulland, 1983b). However, the little difference in the size distribution of *S. salpa* sampled by Joubert (1981) and in this study indicates that hook selectivity has not changed.

A relatively high fishing mortality value ( $0.81 \text{ year}^{-1}$ ) was obtained for *S. salpa*, assuming  $M = 0.6 \text{ year}^{-1}$ . This is probably an over-estimate as *S. salpa* is only extensively exploited on the KZN South Coast for four months of the year during the breeding season. Catch rates decline markedly over the rest of the year (Chapter 1), and therefore this high fishing mortality rate is not maintained throughout the year.

The per recruit model is relatively easy to use and compared to other stock assessment techniques, the input requirements are usually readily available. The use of per recruit modelling however, involves a certain number of assumptions, which may limit its predictive abilities. The most basic of these is constant recruitment. This assumption has been suggested to be appropriate for reef fishes where carrying capacity and growth, rather than recruitment, appear to be limiting factors (Huntsman, Manooch III & Grimes, 1983). Recently however, this theory has been challenged and more attention has been directed towards recruitment as an important source of variation in reef habitats (Doherty, 1987; Doherty, 1991). Inclusion of recruitment in this per-recruit study was not possible as the stock-recruitment relationship for *S. salpa* is unknown.

Per recruit analyses on the family Sparidae have shown the extreme sensitivity of slow growing, long-lived species to over-exploitation (Huntsman *et al.*, 1983; Smale & Punt, 1991; Buxton, 1992; Vaughan, Huntsman, & Manooch III, 1992; Bennett, 1993a). Slow growth and longevity are growth characteristics which result

in a lower yield per unit stock, an older age at maturity and a slower recovery rate after heavy exploitation (Buxton & Clarke, 1989). Ricker (1963) suggested that fish populations containing age year classes over 12 years in age in appreciable quantities were extremely sensitive to exploitation.

The results of this YPR model study indicated that an increase in fishing mortality for *S. salpa* of up to 1.19 year<sup>-1</sup> ( $F_{0.1}$ ) will produce a corresponding increase in YPR without reducing the spawner biomass to biologically critical levels. The current value of  $F$  is much less than 1.19 year<sup>-1</sup>, indicating that, under the  $F_{0.1}$  strategy, no biological over-exploitation of this species exists at present. The relatively fast growth rate recorded in this study, as well as the early age (or size) at which sexual maturity is attained, will serve to reduce the vulnerability to over-exploitation and allow for faster recovery rates (Medley *et al.*, 1993). At present, *S. salpa* is heavily harvested for only a few months of the year during winter off the KZN South Coast (Chapter 2). This fishing pattern, which is unlikely to change in the future, will also have the effect of reducing vulnerability to over-exploitation.

Analysis of  $F_{35\%}$  values over a range of natural and fishing mortalities showed no signs of over-exploitation. However, using the more conservative reference point ( $F_{50\%}$ ), the spawning biomass is reduced to below half its pristine level, at the lower limits of  $M$  with corresponding higher  $F$  rates. The natural mortality rate, however, is probably closer to the calculated value of 0.6 year<sup>-1</sup> (see above). These analyses indicate that, unlike other sparid stocks, the current level of fishing in KZN is appropriate for utilisation of the *S. salpa* resource. The stock can, therefore, probably sustain increased levels of fishing pressure without depleting the spawning stock to a biologically critical level.

This study has also exposed the possible existence of sex-change in *S. salpa*. This life history characteristic could have major

influences on the population dynamics of *S. salpa*. Sex change complicates the application of YPR, particularly when there is size-selective fishing mortality on a population, and there have been attempts to incorporate sex change into per recruit analysis (Bannerot, 1984; Buxton, 1992). More recently, these contributions were extended by another study which identified a growth spurt at sex change for a South African sparid, *C. puniceus* (Garratt et al., 1993). Growth parameters based on pooled length-at-age data were considered inappropriate for per-recruit modelling of the species and a per-recruit model which allowed for sex change followed by growth acceleration was developed (Punt et al., 1993). Clearly, reproductive strategies need to be incorporated into predictive fisheries modelling (Shapiro, 1987). As more information becomes available on the life history of *S. salpa*, stock assessment procedures will need to be re-evaluated.

## CHAPTER 6

## MANAGEMENT CONSIDERATIONS

The shore-based recreational fishery along the South African Coast is governed by a series of catch restrictions, which were recently revised in 1992 under the Sea Fishery Regulations Act No. 12 (Section 32) of 1988. These restrictions are based on two strategies. The first strategy, in the form of minimum size limits, reduces the age range of catchable fish. The second method involves limiting effort, which is undertaken by enforcing regulations governing bag limits, closed seasons or marine reserves. These tactics are based on ensuring adequate recruitment through protection of the spawner stock (Buxton, 1992) and were introduced to reduce fishing mortality on fish populations which had shown steady declines in CPUE (van der Elst, 1989a; Bennett, 1991).

Angling fish species in South Africa are classified into one of five categories depending on their status and corresponding management needs (Table 6.1). These various categories of species are subject to different management strategies and furthermore, serve to allocate certain components of the resource to those fishermen that will derive greatest benefit from those species (SAMLMA, 1992). These categories and their associated management measures are shown in Table 6.1.

Table 6.1: The 1992 classification of categories of fish passed under the Sea Fishery Regulations Act No. 12 (Section 32) of 1988.

	Category	Definition
1	critical	Fish in need of extreme protection and conservation
2	restricted	Fish in need of special management
3	exploitable	Fish that can sustain commercial, recreational and subsistence harvesting
4	recreational	Fish that are of prime value to recreational sport angling
5	bait	Fish that are a prime source of bait

*S. salpa* is classified in the baitfish category. Species in this category are defined as being a prime source of bait. These species are plentiful in the marine environment and contribute insignificantly to the linefish catch (van der Elst, 1985). Although a size limit of 150 mm TL is in place for *S. salpa*, unlimited catches of the species are allowed.

This study has shown that *S. salpa* is numerically the most abundant fish caught by shore-based anglers along the KZN South Coast. The species is harvested primarily for subsistence needs in KZN, that is, providing a source of animal protein. It is apparent, therefore, that the allocation of *S. salpa* to the baitfish category, according to the definition, is incorrect. This probably represents the outdated view of *S. salpa* being primarily a source of bait rather than an important foodfish. Similarly, a number of other species in the baitfish category, such as *P. olivaceum* and Mugilidae, have also been observed to be utilised as food (Joubert, 1981a, b; pers. obs.). It is recommended, therefore, that current legislation governing the baitfish category be revised. This could possibly take the form of a name change of the category, which implies the use of these species for subsistence needs, rather than as a source of bait.

#### **Current and future management options**

Assessment of the stock of *S. salpa* in this study showed no evidence of over-exploitation of the species in KZN. If in the future, there are indications of over-exploitation of the stock of *S. salpa*, then management measures aimed at conserving the stock may have to be introduced.

At present, a size limit of 150 mm TL governs the catch of *S. salpa*. Minimum size limits have been recommended to be set above the size at maturity (van der Elst, 1985) or in the case of sex changing species, at a level above the size at sex change (Buxton, 1993). Small *S. salpa* contributed insignificantly to

the total catch in KZN. Furthermore, increasing the size limit to Joubert's (1981a) size at maturity for females will provide protection for only 10% of the total inshore catch (Figure 6.1). A size limit governing catches in KZN, therefore, has little effect as a management measure for *S. salpa* in KZN. However, this size limit is applicable to shore-based catches of *S. salpa* nationwide. The size distribution of the catch in the Eastern Cape, where *S. salpa* features prominently in shore-based catches (Clarke & Buxton, 1989; S. L. Brouwer, Rhodes University, pers. comm.) should, therefore, also be assessed in relation to the present size limit. A monitoring project is currently being conducted in the Eastern Cape and preliminary analyses indicate the modal size of the catch is similar to that in KZN (S.L. Brouwer, Rhodes University, pers. comm.). As in KZN, the numbers of *S. salpa* landed around the present size limit are minimal. It would appear, therefore, that for a minimum size limit to be effective for *S. salpa*, the limit needs to be set at a level above the size at maturity (or size at sex change) of the species. The implementation of such a strategy at present, however, does not appear necessary and probably represents an ineffective management strategy for the conservation of the species.

Management measures in the form of closed seasons are generally proclaimed to coincide with periods when a species is most susceptible to harvesting (Buxton, 1987). A clear seasonal trend in the catch of *S. salpa* is evident on the KZN Coast, with catches peaking for only a few months of the year during winter. Setting a closed season during this period would have serious social implications, while prohibiting the catch of *S. salpa* during any other time of the year would provide little or limited protection. A further complicating factor is the fact that catches of *S. salpa* in the Eastern Cape appear to peak in summer (S. Brouwer, Rhodes University, pers. comm.). This makes the application of a nationwide closed season problematical and thus, an unsuitable management option for *S. salpa*.

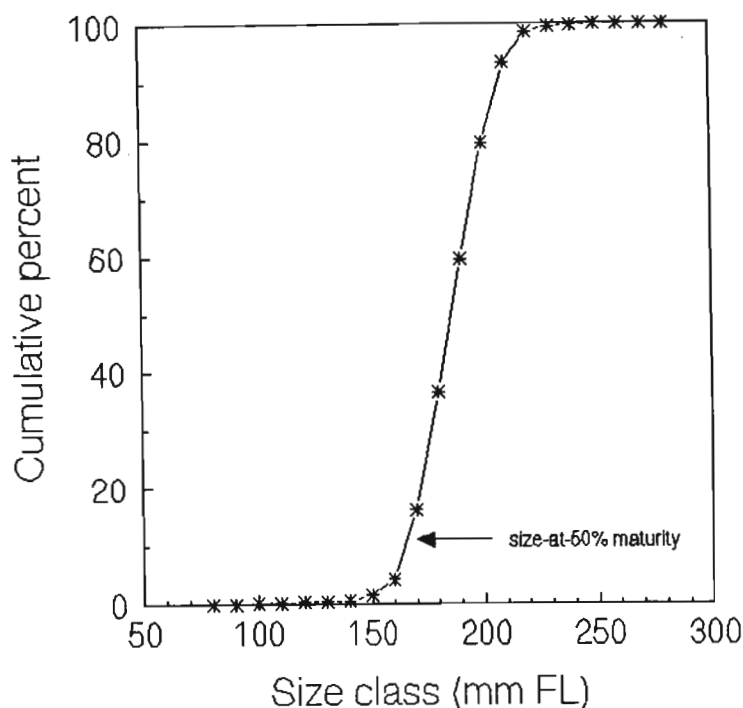


Figure 6.1: Cumulative percentage frequency in relation to fork length of *S. salpa* sampled in the shore-based catch in KZN. Size-at-maturity refers to Joubert's (1981a) size-at-50% maturity for females.

The open access nature of the recreational fishery means that direct control on total fishing effort is not possible and only the catch can be limited (Attwood & Bennett, 1995). Although shore-based recreational anglers have unlimited access to the fishery, their catches can be restricted by bag limits. These bag limits serve to proportion the catch more evenly between participants in a fishery. In the event that restrictive measures are required for *S. salpa* in the future, a bag limit appears to be the only feasible option. Numerically large catches of *S. salpa* are frequently made by anglers during the breeding period. However, the small size of *S. salpa* would require that the bag limit be higher than that for other larger South African recreational linefish in order that an angler would be able to catch an adequate mass of fish. This is important because of the nature of the *S. salpa* fishery in KZN which is

largely a subsistence one providing the users with a supplementary source of animal protein.

The establishment of marine reserves is a conservation option which has received much attention recently (Buxton & Smale, 1989; Attwood & Bennett, 1990, 1994; Bennett & Attwood, 1991, 1993b; Buxton, 1992; Bennett, Attwood & Mantel, 1994). Marine reserves may range from areas in which fishing is totally banned to zoned areas in which fishing may be permitted, but only under certain conditions (or using certain gear). Obviously, the effect on yields will differ accordingly (Medley *et al.*, 1993). The success of a marine reserve will depend on its ability to seed adjacent areas by juvenile and/or adult migration, egg or larval dispersion or both (Buxton, 1987).

The effectiveness of such a management option for *S. salpa* requires some knowledge of the movement patterns of this species. Although there is some understanding of the annual spawning migration of *S. salpa*, very little is known about localised movements and the extent to which marine reserves will benefit the stock of *S. salpa* is, therefore, unclear. Nevertheless, marine reserves afford protection to all species within the closed area and so must be viewed as a multispecies management measure.

An advantage of closed areas as a management tool is in the ease with which they may be enforced, relative to the considerable amount of enforcement effort required for the remainder of the suite of regulatory options discussed above (Bennett, 1991, 1992). Marine reserves have been shown to be a viable management option, particularly with respect to reef fishes (Buxton & Smale, 1989; Bennett & Attwood, 1991, 1994). They should, therefore, have an important role to play in the future management of the multispecies recreational linefishery in South Africa.

A matrix summarizing possible management options and the suitability of each option available for the conservation of *S. salpa* along the South African Coast with respect to fishing pressure is shown in Table 6.2.

Table 6.2: Summary of management strategies available for the conservation of *S. salpa*.

Fishing pressure	Management option			
	Minimum size limit	Bag limit	Closed season	Marine reserve
current	no	no	no	recommended
increase	possibly	yes	no	recommended
decrease	no	no	no	no

### Summary

This study has indicated that *S. salpa* is a major contributor to the shore-based fishery in KZN. The species is targeted predominantly as a means of providing a source of animal protein. Shore-based catches, which consist predominantly of adult fish, are markedly seasonal coinciding with the breeding season of the species. Despite this, current levels of fishing pressure on *S. salpa* appear to be appropriate for utilisation of the stock off the KZN South Coast. The relatively fast growth rate and early maturity of the species recorded in this study will have the effect of decreasing the rate at which over-exploitation occurs. In terms of management, *S. salpa* appears to be in no need of any restrictive measures at present. Should the stock of *S. salpa* show signs of decline, a bag limit for the species appears to be a viable option.

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Appendix 1: The questionnaire used to interview anglers during a shore-angling survey of the KZN South Coast

SHORE ANGLING QUESTIONNAIRE

Section A: (to be completed by interviewer)

Locality: \_\_\_\_\_ Date: \_\_\_\_\_ Time: \_\_\_\_\_ Rodsused: \_\_\_\_\_ Beachvehicle: \_\_\_\_\_

Bait: Pilchard \_\_\_\_\_ Squid \_\_\_\_\_ PinkPrawn \_\_\_\_\_ Other(specify) \_\_\_\_\_

Angler age: \_\_\_\_\_

Composition: 1 2 3 4  
M  
F

Section B: (Catch and effort)

What time did you start fishing? \_\_\_\_\_ What time do you anticipate leaving? \_\_\_\_\_

What type of fish were you targeting? \_\_\_\_\_

How many days have you spent fishing in the last week \_\_\_\_\_, month \_\_\_\_\_ and in the last 12 months? \_\_\_\_\_

Do you ever fish at night? \_\_\_\_\_ If YES, how often in the last 12 months? \_\_\_\_\_

Which stretch of coast do you normally fish? \_\_\_\_\_

Which fishing club do you belong to? \_\_\_\_\_

How many years have you been fishing? \_\_\_\_\_

Section C: (Attitude to management)

Do you have a bait licence in your name? YES / NO If YES, what type: \_\_\_\_\_

Which of the following regulations, in your opinion, are effective in managing our fish stocks? (YES / NO)

Minimumsize limits? \_\_\_\_\_ Baglimits? \_\_\_\_\_ Closedseasons? \_\_\_\_\_ Marine reserves? \_\_\_\_\_

(Ask each regulation specifically e.g. Have you ever kept an undersize fish?)

Minimumsize limits? \_\_\_\_\_ Baglimits? \_\_\_\_\_ Closedseasons? \_\_\_\_\_ Marine reserves? \_\_\_\_\_

Have you ever sold your catch? \_\_\_\_\_

	Target 1	Target 2
Species: _____		
Minimum size: _____		
Bag limit: _____		
Closed season: _____		

Has your catch ever been inspected? YES / NO If YES, how often in the last month? \_\_\_\_\_ 12 months? \_\_\_\_\_

While fishing have you ever reached your bag limit? YES / NO If YES, specify for which species? \_\_\_\_\_

Section D: (Economics)

What is your occupation? (write in detail) \_\_\_\_\_

If unemployed/retired what was your last occupation? \_\_\_\_\_

Where do you live (postal code)? \_\_\_\_\_

Are you on an overnight, weekend or longer trip/holiday? (i.e. staying away from home) YES / NO

If YES (i.e. trippers/ holiday makers), where are you staying? (postal code) \_\_\_\_\_

What method of transport did you use to come on this trip? (describe vehicle type, model etc.) \_\_\_\_\_

How many people came with you on this trip? \_\_\_\_\_ How many of this group will be fishing? \_\_\_\_\_

How many days will you spend away from home on this trip/holiday? \_\_\_\_\_

How many days of this trip/holiday will you spend fishing? \_\_\_\_\_

What is the estimated cost of your trip/holiday? (all members excluding transport) \_\_\_\_\_

How far did you travel to come fishing today (kilometres one way) \_\_\_\_\_

What method of transport did you use (describe vehicle type, model etc.) \_\_\_\_\_

Appendix 1: (cont.)

If own vehicle, specify number of people in vehicle \_\_\_\_\_ How many of this group are fishing? \_\_\_\_\_

How much did you spend this outing on: Bait? \_\_\_\_\_ Refreshments? \_\_\_\_\_ Other? \_\_\_\_\_

How much have you spent on general tackle in the last month? (line, hooks, sinkers etc.) \_\_\_\_\_

Expenditure on rods or reels in the last 12 months? \_\_\_\_\_

What is the estimated value of all your R & S fishing equipment? (i.e. what would they sell it for?)

Beach vehicle? \_\_\_\_\_ Rods? \_\_\_\_\_ Reels? \_\_\_\_\_ Tackle? \_\_\_\_\_

Is your beach vehicle used exclusively for fishing? \_\_\_\_\_

Why do you fish? Food \_\_\_\_\_ Recreation \_\_\_\_\_ Competition \_\_\_\_\_ Livelihood \_\_\_\_\_ Other (specify) \_\_\_\_\_

Section E: (general)

Have you ever caught a tagged fish? YES / NO If YES, what happened to the tag? (specify) \_\_\_\_\_

Has fishing deteriorated over the years? YES / NO If YES, what is the cause of this decline?

Pollution \_\_\_\_\_ Siltation \_\_\_\_\_ Seinenetting \_\_\_\_\_ Gillnetting \_\_\_\_\_ Trawling \_\_\_\_\_ Overfishing (commercial) \_\_\_\_\_

Overfishing (recreational) \_\_\_\_\_ Other (specify) \_\_\_\_\_

Would you be prepared to pay for a marine angling licence to provide funds for fisheries conservation?

YES / NO (Give reason for answer) \_\_\_\_\_

If YES, how much would you be prepared to pay for a licence of this nature? \_\_\_\_\_

Do you participate in any other form of fishing? \_\_\_\_\_

SPECIES	NO.	TOTAL LENGTH

\* REMEMBER TO RECORD DISCARDED SPECIES

Appendix 2: Summary of length weight regressions used in the analysis of the shore-angling survey off the KZN South Coast

Species	a	b	Source
<b>Class: Osteichthyes</b>			
<i>Argyrosomus japonicus</i>	0.000028	2.84	Marais & Baird (1981)
<i>Cheimerius nufar</i>	0.000024	2.571	Garratt (1984)
<i>Dichistius multifasciatus</i>	0.000012	3.15	Joubert (1981a)
<i>Diplodus cervinus</i>	0.000013	3.14	Mann (1992)
<i>Diplodus sargus</i>	0.000033	2.994	Joubert (1981a)
<i>Elops machnata</i>	0.000029	2.53	Marais & Baird (1980)
<i>Epinephelus andersoni</i>	0.000017	2.96	van der Elst (1988)
<i>Lichia amia</i>	0.000073	2.73	van der Elst (1988)
<i>Neoscorpis lithophilus</i>	0.000014	3.08	Joubert (1981a)
<i>Otolithes ruber</i>	0.000017	2.86	NMLS, unpublished static data report
<i>Pagellus natalensis</i>	0.000016	3.06	NMLS, unpublished static data report
<i>Pomadasys commersonii</i>	0.000014	2.96	Marais & Baird (1980)
<i>Pomadasys furcatum</i>	0.000024	2.90	NMLS, unpublished static data report
<i>Pomadasys kaakan</i>	0.000066	2.713	van der Elst (unpublished data)
<i>Pomadasys olivaceum</i>	0.000014	3.07	Joubert (1981a)
<i>Pomatomus saltatrix</i>	0.000013	2.93	van der Elst (1976)
<i>Rhabdosargus holubi</i>	0.000024	2.96	van der Elst & Adkin (1988)
<i>Rhabdosargus sarba</i>	0.000018	2.972	van der Elst (unpublished data)
<i>Rhabdosargus thorpei</i>	0.000018	3.13	NMLS, unpublished static data report
<i>Sarpa salpa</i>	0.000008	3.18	(this study)
<i>Trachinotus botla</i>	0.000019	2.94	NMLS, unpublished static data report
<b>Class: Chondrichthyes</b>			
<i>Carcharhinus obscurus</i>	0.000024	2.68	van der Elst & Adkin (1991)
<i>Rhinobatos annulatus</i>	0.000001	3.17	Rossoux (1983)
<i>Rhizoprionodon acutus</i>	0.000048	2.98	van der Elst & Adkin (1991)