THE STATUS OF THE RIVERBREAM, *ACANTHOPAGRUS BERDA* (SPARIDAE), IN ESTUARINE SYSTEMS OF NORTHERN KWAZULU-NATAL, SOUTH AFRICA

by

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ABSTRACT

Acanthopagrus berda is an estuarine-dependent fish species which is widespread in the tropical Indo-Pacific. In South Africa, it is particularly abundant in the three large northern KwaZulu-Natal estuarine systems, namely Kosi Bay, St Lucia and Richards Bay. In these systems, *A. berda* is harvested by a variety of methods, including traditional fish traps, gillnets and hook and line.

The importance of *A. berda* to the different fisheries was evaluated by analysing all the available monitoring data specific to catches in these three systems. *A. berda* was found to be one of the five most important species taken in both the gill net and recreational fisheries at Kosi Bay and St Lucia. It was less important in the marine-dominated Richards Bay system. Catches were generally seasonal, with trends in catch per unit effort (*cpue*) for *A. berda* related to annual spawning migrations. The long-term trend in *cpue* for this species in the Kosi recreational fishery showed a disturbing downward trend.

Ages of *A. berda* specimens caught in northern KwaZulu-Natal estuaries were determined by examining whole otoliths. Age estimates were validated by marginal zone analysis and oxytetracycline labelling, which indicated that opaque deposition occurs primarily from September to November each year. The reproducibility of age estimates was described by a coefficient of variation of 10%. The special von Bertalanffy growth curve was found to best describe the growth of *A. berda*. The parameters of the von Bertalanffy growth curve indicated that *A. berda* in northern KwaZulu-Natal is slow growing, attaining at least 16 years of age.

The age and growth parameters and mortality estimates from catch curves were used to complete a per-recruit stock assessment of the species. The results of the spawning biomass per-recruit model using different ages of first capture indicate that *A. berda* is at 47% to 55% of its unfished level. Although these results may indicate that *A. berda* in northern KwaZulu-Natal is not at present overexploited, longevity coupled with late maturation, sex change, estuarine dependency, increasing catches of *A. berda* and poor monitoring give cause for concern for the continued sustainable use of this species in northern KwaZulu-Natal.

PREFACE

The work described in this dissertation was carried out at the Oceanographic Research Institute in Durban, from June 2000 to December 2001, under the supervision of Dr L. E. Beckley and Mr B. Q. Mann.

These studies represent original work by the author and have not otherwise been submitted in any other form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it is duly acknowledged in the text.

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CHAPTER ONE

GENERAL INTRODUCTION

The riverbream or perch, *Acanthopagrus berda* (Family Sparidae), is widespread in the tropical Indo-Pacific region, occurring from South Africa to India, northern Australia and Japan (Smith and Heemstra 1986). In South Africa, it is found in estuaries along the east coast, where its range extends southwards to Port Elizabeth ($33^0$58'S; $25^0$36'E), although specimens have occasionally been found as far west as Swartvlei on the Western Cape Coast. Members of the family Sparidae are some of the most valued commercial and recreational angling species taken in southern Africa. Sparids occur in temperate and tropical waters worldwide, and are usually concentrated in shallow waters, with some (such as *Acanthopagrus* species) entering and living in estuaries. This family is particularly speciose in southern Africa, being represented by 41 species, of which 25 are endemic (Smith and Heemstra 1986). *Acanthopagrus berda* and *A. bifasciatus* are the only representatives of the *Acanthopagrus* genus found in southern Africa.

Various species belonging to the genus *Acanthopagrus* are harvested in fisheries throughout the Indo-Pacific region (Abu-Hakima 1984). In Kuwait, *Acanthopagrus* species are valuable fish that are caught in large numbers by commercial fishermen using stake nets, fish traps, fish pots (gargoor) and trawl nets. They are also targeted in the recreational fishery, which is becoming increasingly larger (Samuel and Mathews 1987).

In Australia, the endemic yellowfin bream, *A. australis,* and black bream, *A. butcheri*, are harvested in large numbers by both commercial and recreational fishers (Pollock 1980; Pollock and Williams 1983; Kailola *et al.* 1993; West and Gordon 1994). *A. butcheri* is a temperate water species, found in southern and western Australia, and is so abundant in large estuarine systems, that it comprises over 60% of the recreational catch and 22% of the commercial catch taken in the large Gippsland Lakes system (Conran and Coutin 1995). *A. australis* and *A. berda* are abundant in tropical and subtropical estuaries in eastern Australia. Although *A. berda* is only targeted by recreational anglers in these systems, it is often more abundant than the commercially important *A. australis* (Sheaves 1992).

In South African estuaries, *A. berda* is harvested by a variety of methods, which include hook and line, gill nets and traditional fish traps. It is an important component of the recreational and subsistence catch taken in the three large northern KwaZulu-Natal estuaries, namely Kosi Bay (26^{0}54'S; 32^{0}53'E), St Lucia (28^{0}23'S; 32^{0}25'E) and Richards Bay (28^{0}49'S; 32^{0}05'E). Analysis of catch data from these areas has shown that *A. berda* is one of the five most abundant species taken in the recreational and subsistence fisheries in these systems (James *et al.* 2001; Mann *et al.* in press(b)).

A. berda is one of 22 species of fishes found in South Africa that are dependent on estuaries in the juvenile phase of their life cycles (Wallace *et al.* 1984). Adult *A. berda* are also estuarine-dependent, rarely being found in the marine environment. Like many other members of the sparid family, *A. berda* has the potential to change sex and is one of several known protandrous sparids in South Africa (Garratt 1993a). *A. berda* is a fairly small sparid and, although the maximum length recorded for the species is 750mm TL, the majority caught in South African waters are < 400mm TL (Smith and Heemstra 1986).

The current status of the *A. berda* stock in South African estuaries is unknown, although it has been suggested by several workers that it is declining (van der Elst 1977; Begg 1978; Day *et al.* 1981; Whitfield 1998). This, together with its dependence on estuaries, led van der Elst and Adkin (1991) and Mann and Radebe (2000) to categorise *A. berda* as a high priority species in terms of research. The reproductive and feeding biology of *A. berda* have been studied in South Africa (Wallace 1975b; Wallace and van der Elst 1975; Harrison 1991; Garratt 1993a), but no work has been published on the age and growth and stock status of this species in South Africa.

Estuaries are the meeting place of freshwater from rivers and saltwater from the sea, and, as such, they are unique environments which provide shelter to many fish species. There are several different definitions of estuaries, but the one most applicable to this study is that given by Day (1980), who stated that an estuary is " a partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is variation of salinity due to the mixture of sea water with freshwater derived from land drainage."

There are approximately 250 estuaries (with a total area of 600 km^2) along the 3000 km coastline of South Africa, which extends from Ponto do Ouro in the east to the Orange River in the west (Whitfield 1998). These estuaries can be divided into three basic types depending on their distribution. There are approximately 117 subtropical estuaries, 123 warm temperate estuaries and 10 cool temperate estuaries in South Africa (Whitfield 1998). Subtropical estuaries predominate, with estuaries in KwaZulu-Natal occupying an area of approximately 400 km^2. Over 80% of this area is contributed by the St Lucia and Kosi lake systems in northern KwaZulu-Natal (Whitfield 1998).

Estuaries are highly productive systems and support some of the most prolific fisheries in the world (Houde and Rutherford 1993). Estuaries also act as nursery areas for many species of fishes, which are either exploited in estuaries or in coastal fisheries later in their life cycles (Houde and Rutherford 1993). The role of estuaries as nursery areas is particularly important in South Africa, where there are no sheltered inshore waters. In areas such as southwestern Australia, inshore waters are sheltered by reefs and islands and can be used as alternative nursery areas by many marine species (Lenanton 1982; Potter *et al.* 1990; Whitfield 1998).

The dependence of fish species on estuaries ranges from total to opportunistic. Whitfield (1994) divided South Africa's estuarine associated fish species into five categories depending on their degree of dependence (Table 1.1). Of the 101 species wholly or partially dependent on ecologically viable estuaries for their survival, 29 species are taken by anglers and an additional 21 (mostly Mugilidae) by subsistence fishers (Wallace *et al.* 1984).

In the United States, it is estimated that over 50% of the total fishery harvest is comprised of species that are either completely estuarine, or dependent on estuaries during some stage of their life cycles. This percentage is even higher in areas such as the Gulf of Mexico, where estuarine-dependent species dominate catches (Houde and

Rutherford 1993). Values are similar in Australia, where estuarine-dependent species contribute 42% to the mean annual catch of elasmobranchs and teleosts (Lenanton and Potter 1987).

Table 1.1. A summary of the dependence of six categories of fish on South African estuaries (after Whitfield 1994).

Category	Relationship to South African estuaries
I	Estuarine species which breed in southern African estuaries
II	Euryhaline marine species which usually breed at sea with the juveniles showing varying degrees of dependence on southern African estuaries. Further subdivided into: Ia. Resident species which have not been recorded spawning in the marine or freshwater environment. Ib. Resident species which also have marine or freshwater breeding populations.
III	Marine species which occur in estuaries in small numbers but are not dependent on these systems. Further subdivided into: IIa. Juveniles dependent on estuaries as nursery areas. IIb. Juveniles occur mainly in estuaries, but are also found at sea. IIc. Juveniles occur in estuaries, but are usually more abundant at sea.
IV	Euryhaline freshwater species, whose penetration into estuaries is determined primarily by salinity tolerance. Includes some species which may breed in both freshwater and estuarine systems.
V	Obligate catadromous species which use estuaries as transit routes between the marine and freshwater environments.

Subtropical and tropical estuaries are zones of high productivity and, as such, they tend to support substantial fisheries. In subtropical and tropical estuaries, three types of fisheries occur: subsistence/artisanal fisheries, where fishers are generally poor, and the catch is consumed or traded locally; commercial, where the catch is sold for financial gain; and recreational, where anglers catch fish for sport. Large recreational fisheries in subtropical and tropical estuaries are confined to South Africa, Australia and the United States (Blaber 1997). Recreational fishing is becoming increasingly popular in these countries. In Australia, recreational angling is the third most popular outdoor activity in the country, with 26% of recreational angling taking place from boats in estuaries (Kailola *et al.* 1993). In South Africa, at least 412 000 anglers participate in the various sectors of the marine recreational fishery and these numbers are estimated to be increasing at a rate of approximately 2% per annum (McGrath *et al.* 1997).

There are large commercial fisheries in the estuaries of Australia and the United States and, although commercial fishing is prohibited in South African estuaries, estuarine-dependent species such as dusky kob, *Argyrosomus japonicus* and white steenbras *Lithognathus lithognathus* are frequently caught by coastal commercial fishermen (Day *et al.* 1981).

In South Africa, estuaries are areas of high effort for recreational and subsistence fishers, as these systems are highly productive, sheltered and easily accessible (Baird *et al.* 1996). Subsistence fisheries were only formally recognised in South Africa with the promulgation of the Marine Living Resource Act (MLRA) in 1998. Subsistence fishers capture a substantial proportion of the estuarine catch in South Africa using rod or handlines, netting and traditional fishing methods (fish traps) (Cockcroft *et al.* in press). Approximately 28 000 fishers are involved in subsistence fishing in South Africa, and the majority of true subsistence fishing occurs along the east coast (Clark *et al.* in press).

Latitude affects both the diversity and abundance of fish species found in estuaries. Over 230 species of fishes have been recorded in the subtropical estuaries of KwaZulu-Natal (Wallace 1975a), while the temperate Cape estuaries support approximately 150 species (Day *et al.* 1981). Similar trends have been observed in Australia, where temperate estuaries such as the Swan, Peel-Harvey and Blackwood estuaries support fewer than 60 species of fishes (Potter *et al.* 1990).

The majority of species found in southern Mozambique, KwaZulu-Natal and Transkei estuaries are tropical in origin (Day *et al.* 1981). Consequently, catches by subsistence and recreational anglers in these systems are made up of a variety of Indo-Pacific species, such as *Acanthopagrus berda*, *Rhabdosargus sarba*, Mugilidae species, *Pomadasys commersonnii* and *Argyrosomus japonicus* (Mann *et al.* in press(b); James *et al.* 2001). South of the Transkei, species diversity of fishes declines rapidly (Day *et al.* 1981) and anglers' catches are dominated by species such as *A. japonicus* and *P. commersonnii*. In the temperate Sundays and Swartkops estuaries in the Eastern Cape

P. commersonnii and *A. japonicus* together account for about 90% of recreational anglers catches (Baird *et al.* 1996).

The aim of the present study was to assess the status of the riverbream, *Acanthopagrus berda,* in estuarine systems of northern KwaZulu-Natal. The objectives of the study were to:

- assess the importance of *A. berda* to fisheries in Kosi Bay, St Lucia and Richards Bay,
- estimate the age, growth and mortality of *A. berda* in these systems,
- assess the status of the *A. berda* stock in northern KwaZulu-Natal using per-recruit analyses.

The importance of *A. berda* to the different fisheries in northern KwaZulu-Natal systems was evaluated by analysing all the available monitoring data specific to catches in these three systems (Table 1.2). KwaZulu-Natal Wildlife (KZNW) is the responsible regional fishing management and conservation agency with powers delegated to it by the national Department of Environmental Affairs and Tourism (Directorate: Marine and Coastal Management). Recreational angling in Kosi Bay, St Lucia and Richards Bay is monitored by voluntary catch cards or KZNW shore patrols. Subsistence fishing (fishtraps and gillnets) is monitored intermittently by KZNW in some estuaries.

Table 1.2. Fisheries monitoring data used in this study

Catch statistics:			
	Kosi	St Lucia	Richards Bay
Recreational angling	Catch cards	Catch cards	—
	—	KZNW shore patrols	KZNW shore patrols
Gillnets	KZNW data	KZNW data	KZNW data
Fish traps	KZNW data	N/A	N/A
Size frequency data:			
Recreational angling	ORI tagging data	—	—
Gillnets	KZNW data	KZNW data	—
Fish traps	KZNW data	N/A	N/A

Ages of *A. berda* specimens caught in northern KwaZulu-Natal estuaries were determined by examining whole otoliths. Age estimates were validated by marginal zone analysis and oxytetracycline labelling. The age and growth parameters and mortality estimates from fishery catch curves were used to complete a per-recruit stock assessment of the species.

CHAPTER TWO

KOSI BAY FISHERIES

Introduction

The Kosi estuarine system (Figure 2.1), which consists of four connected lakes, is located on the north-east coast of South Africa, and extends from 26°50'S to 27°11'S and 32°38'E to 32°53'E (Begg 1978; Begg 1980). The system covers an area of approximately 3836ha and runs parallel to the Indian Ocean, behind coastal dunes (Wallace 1975a). The four lakes drain through a permanently open estuary, which opens to the sea two kilometres south of the Mozambique / South African border. The southernmost lake, Amanzimnyama is completely fresh, but the other three lakes are influenced by the sea, and thus support a euryhaline fauna (Blaber 1978). The Kosi system is unique in KwaZulu-Natal, in that it is a large, clear water system. The two small rivers which enter the system rise in leached acid sands and, as a consequence, carry little silt (Mountain 1990). The clear water of the system, together with the proximity of the lakes to tropical waters, result in a diverse fish fauna (Blaber 1980). A total of 163 fish species has been recorded in the system. The diverse fish fauna supports a recreational fishery, a recent gill net fishery and a traditional trap fishery.

Recreational anglers began utilising the system towards the end of the 1940s, fishing from small boats in the three northern lakes (Makhawulani, Mpungwini and Nhlange). Since 1950, there has been a camping facility, which is used primarily by recreational anglers, on the north-western shore of Lake Nhlange (Kyle 1986). There is also a limited amount of recreational shore angling that takes place at the mouth of the system from the north bank. The small reef just inside the mouth and the beach south of the mouth fall into sanctuary areas closed to fishing. Local children also fish by rod and line from the banks of the system for small species such as the pouter, *Gerres acinaces,* and thornfish, *Terapon jarbua*, the latter frequently being viewed as a pest by recreational anglers (Kyle 1992).

Gillnetting has been carried out illegally in the Kosi estuarine system since the early 1950s (Kyle 1999). However, in April 1992 an experimental gillnet fishery was established in Lake Nhlange in an attempt to sustainably harvest certain target fish species. Kyle (1992) believed that gillnetting could effectively target freshwater species such as the sharptooth catfish (or barbel), *Clarius gariepinus* and the Mozambique tilapia, *Oreochromis mossambicus*, which are not often caught by other fishing sectors. The largescale pursemouth, *Gerres methueni*, which is caught in small numbers by the trap fishermen and various mullet species, which are abundant in the system, were also included as target species.

Kosi Bay is the only estuarine system in South Africa, in which fish are caught using traditional fish traps or fish kraals. Fish traps have been used by the local inhabitants of Kosi Bay for centuries, and have changed very little with time (Tinley 1964). Traps are made entirely from indigenous plants, such as mangroves, and are built in the estuary and the two northernmost lakes (Kyle 1981). Each trap consists of a guide fence, usually running from the banks inwards, which leads to a heart-shaped entrance called a palisade. The guide fence and the palisade act as a maze to guide fish into either a circular valved enclosure or a valved basket trap. Both the enclosure and the basket have a narrowly constricted valve so that it is easy for fish to enter, but not to escape. Each trap may have from one to 16 baskets. Traps catch fish as they exit the lakes, predominantly with the outgoing tide (Tinley 1964; Kyle 1981).

The Kosi estuarine system forms part of the Kosi Bay Nature Reserve, which was proclaimed in 1987, and has recently been incorporated into the Greater St Lucia Wetland Park (GSLWP). KwaZulu-Natal Wildlife (KZNW) is the management authority responsible for the protection and management of the GSLWP, which was declared a World Heritage Site in 1999. Prior to amalgamation with Natal Parks Board (now KwaZulu-Natal Wildlife) in 1998, Kosi Bay Nature Reserve was managed by the KwaZulu Department of Nature Conservation.

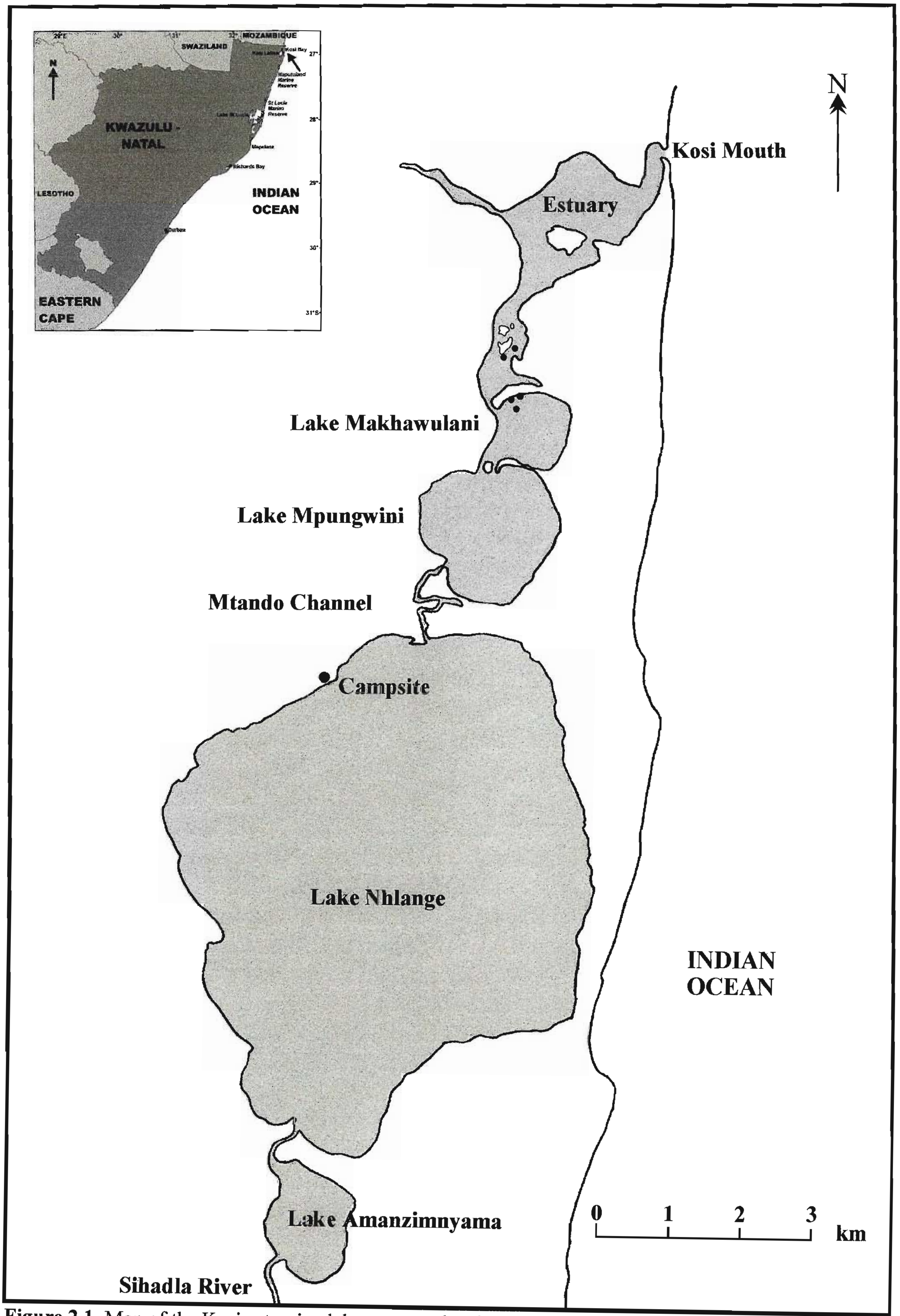


Figure 2.1. Map of the Kosi estuarine lake system; dots indicate the position of traps 53-57.

This chapter provides an analysis of all the available monitoring data for the recreational, gillnet and trap fisheries in the Kosi estuarine system. In particular, attention is focused on catches of the riverbream, *Acanthopagrus berda.*

Methods

The recreational fishery

The National Marine Linefish System (NMLS) was developed in 1984 in order to assist in monitoring of the South African linefishery. The NMLS is a catch and effort data base which was set up as a cooperative venture between Marine and Coastal Management (MCM) and the Oceanographic Research Institute (ORI), where ORI deals with recreational angling and MCM deals with commercial linefishing (van der Elst and Penney 1995). Catch and effort data are collected from a number of sources. Since 1986 recreational anglers fishing from small boats at Kosi Bay have been requested to complete catch cards after each fishing outing.

The catch cards, which are made available at the fish cleaning site, are completed voluntarily by anglers, and collected from the site by KZNW staff. Where possible, KZNW staff also visit the campsite to encourage and assist fishermen in filling out catch cards. There is no cross-check on the accuracy of reporting. The angling details recorded are date, locality, number of anglers per boat, time spent fishing and catch (number and estimated mass per individual fish). Each catch card represents a complete angling outing. The completed catch cards are sent to ORI in Durban, for entry onto the NMLS database and subsequent analysis.

In this study, recreational catch card data from 1986 to 1999 were analysed to determine total catch, catch composition, catch per unit effort (*cpue*) and annual trends in the numbers and mass of *A. berda*. Owing to the inability of fishermen to accurately identify all fish to species level, certain species were grouped at genus level.

There are numerous biases in the voluntary NMLS data, which can affect analyses. These biases include prestige bias, digit bias, unintentional misreporting, deliberate misreporting, apathy and non-response bias (Pollock *et al.* 1994). Prestige bias refers to the tendency of some anglers to overestimate the number and size of fish caught, while digit bias occurs when anglers round up or round down the mass or number of fish caught. Misreporting may be unintentional, as anglers are often unable to distinguish between different fish species, or intentional out of fear of prosecution. Apathy in completing cards is also problematic. In addition, effort by and efficiency of KZNW staff in collecting catch cards has varied over time. There is also occasionally confusion by some anglers who enter marine shore angling data on estuarine catch cards.

The gillnet fishery

The experimental gillnet fishery was introduced to Lake Nhlange using a phased approach and initially in 1992 five permits were issued (Kyle 1999). Following assessment, the number of permits issued was increased in July and August 1993 and again in December 1994, so that by the end of 1994 thirty-five permits were being issued each month. In 1997 the number of permits issued was further increased to a total of 45 and maintained at this level (Kyle 1999).

Each permit was allocated to an individual in the community, and this allowed for the use of a 30m gillnet, with no restrictions on mesh size or net fabric. Netting was only allowed at night, as this was thought to increase the proportion of target species in the nets, and netting was restricted to the weedy margins of Lake Nhlange (Kyle 1999).

Catch monitors were selected and trained from each of the communities by KZNW. Monitors were stationed at sites identified by the fishermen, to which all catches were brought for recording. Data recorded included the date of fishing, permit number, number and species of fish caught and, where possible, the total length of each fish measured to the nearest cm. Completed sheets were later sent to ORI, in Durban, and entered onto a database. These data were analysed to determine trends in catch composition, seasonal trends in catch per unit effort and length frequencies of *A. berda*

The trap fishery

Since 1981 the nature conservation authority has monitored the fish traps at Kosi Bay at various levels of intensity. Between April 1981 and March 1985 a detailed study was undertaken, whereby all the traps in the system were monitored on a daily basis (Kyle 1986). Thereafter, owing to financial constraints, only a small sub-sample of the traps was monitored.

During the extensive monitoring period, the area in which trapping occurred was divided into five sections and all the traps were numbered. Monitors from the local community were employed by the conservation authority to record catches from each area on a daily basis. Monitors intercepted trap owners as they emptied their traps and recorded the date, trap number, fish species, number caught and measured the total length of each fish caught. The results from the extensive monitoring period are detailed in Kyle (1986).

From April 1985 monitoring was only continued in a sub-sample of 9-11 traps, which previously had caught approximately 12% of the total number of fish in the catch. From 1990, the number of traps monitored was further decreased, so that only five traps were being monitored consistently each year (Figure 2.1). These data were later sent to ORI, in Durban, and entered onto a database. Trap data from 1985 to 1998 were analysed from the traps numbered 53-57 to determine catch composition, percentage contribution of *A. berda* to the total catch, length frequencies of *A. berda*, and *cpue* for *A. berda* on an annual and monthly basis.

Results

The recreational fishery

Angling effort

The number of angling outings at Kosi Bay, reported on catch cards, increased from 510, at the inception of the NMLS project, to a peak of 2 379 in 1994, declining thereafter to 892 in 1999 (Table 2.1). The number of anglers per boat outing varied little throughout the study period, with a mean of 3.07 anglers per outing (S.D. = 0.25). The mean number of hours fished per outing was also fairly stable throughout the study period, ranging from 4.9 to 6.2 hours, with a mean of 5.3 hours per outing (S.D. = 0.53). The total number of hours fished in a year that were monitored (Table 2.1) followed the same pattern as the number of angling outings reported and was highest between 1993 and 1996, and lowest at the beginning and end of the study period. Care should be taken in interpreting these results as they often reflect the amount of effort put into collecting catch cards, rather than an actual increase or decrease in angling effort.

Table 2.1. Angling effort from the Kosi system between 1986 and 1999 recorded on NMLS catch cards.

Year	Number of boat outings recorded	Mean number of anglers per outing	Mean number of hours per outing	Total hours of fishing monitored
1986	510	3.7	5.4	2 343
1987	991	3.1	4.9	4 517
1988	1601	3.1	4.9	7 674
1989	1181	3.0	5.1	5 970
1990	1060	3.1	5.1	5 370
1991	1312	3.0	5.0	6 235
1992	1003	3.1	5.6	5 265
1993	1973	2.9	5.2	10 054
1994	2379	2.9	5.1	11 619
1995	2288	2.9	5.2	11 464
1996	1698	3.1	5.2	8 223
1997	825	3.2	5.5	3 916
1998	653	3.3	6.2	3 611
1999	892	2.6	5.8	4 824

Catch composition

Based on the information provided by anglers, a total of 17 families and 34 species were recorded in the catches from 1986 to 1999 (Table 2.2). Teleosts accounted for 33 of the species, while elasmobranchs were only represented by one species. Species believed to have been caught by marine shore anglers, who incorrectly completed estuarine catch cards, were excluded from the analysis.

Figure 2.2 a and b depict the catch composition for the 14-year study period by numbers and mass, respectively. *A. berda* was one of the five most important species caught by recreational anglers in Kosi Bay, contributing 6% of the catch by numbers but only 2% by mass. *Pomadasys* spp. (almost exclusively *Pomadasys commersonnii*), was the most prominent genus caught in terms of both numbers and mass, at 54% and 57% respectively.

Table 2.2. Species reported on catch cards by recreational anglers in the Kosi system from 1986 to 1999. (This species list is subject to bias, including unintentional and intentional misreporting by anglers and should not be viewed as a species checklist for the system).

Family	Scientific name	Common name	Number
Dasyatidae	*Himantura uarnak*	honeycomb stingray	39
Elopidae	*Elops machnata*	springer	828
Muraenesocidae	*Muraenesox bagio*	pike conger eel	21
Chanidae	*Chanos chanos*	milkfish	381
Clariidae	*Clarius gariepinus*	sharptooth catfish	410
Belonidae	*Ablennes hians*	needlefish	86
Platycephalidae	*Platycephalus indicus*	bartail flathead	28
Serranidae	*Epinephelus lanceolatus*	brindle bass	1
	Epinephelus spp.	rockcod	54
Teraponidae	*Terapon jarbua*	thornfish	15
Haemulidae	*Plectorhinchus* spp.	unspecified rubberlip	2
	Pomadasys commersonnii	spotted grunter	19 651
	Pomadasys kaakan	javelin grunter	2
	Pomadasys multimaculatum	cock grunter	1
	Pomadasys spp.	unspecified grunter	39 522
Lutjanidae	*Lutjanus russelli*	Russell's snapper	5
	Lutjanus argentimaculatus	river snapper	1 708
Sparidae	*Acanthopagrus berda*	riverbream	2 595
	Lithognathus mormyrus	sand steenbras	3
	Rhabdosargus holubi	Cape stumpnose	237
	Rhabdosargus sarba	Natal stumpnose	2 365
	Rhabdosargus spp.	unspecified stumpnose	4 443
Monodactylidae	*Monodactylus* spp.	unspecified moony	5
Sciaenidae	*Argyrosomus japonicus*	dusky kob	64
	Johnius dorsalis	mini-kob	1
	Otolithes ruber	snapper kob	12
Carangidae	*Caranx ignobilis*	giant kingfish	191
	Caranx papuensis	brassy kingfish	239
	Caranx sem	blacktip kingfish	129
	Caranx sexfasciatus	bigeye kingfish	183
	Caranx spp.	unspecified kingfish	3 118
	Scomberoides spp.	queenfish	332
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	265
Mugilidae	*Mugil cephalus*	flathead mullet	1
Sphyraenidae	*Sphyraena jello*	pickhandle barracuda	346
	Sphyraena barracuda	great barracuda	7
	Sphyraena spp.	unspecified barracuda	864
total			78 149

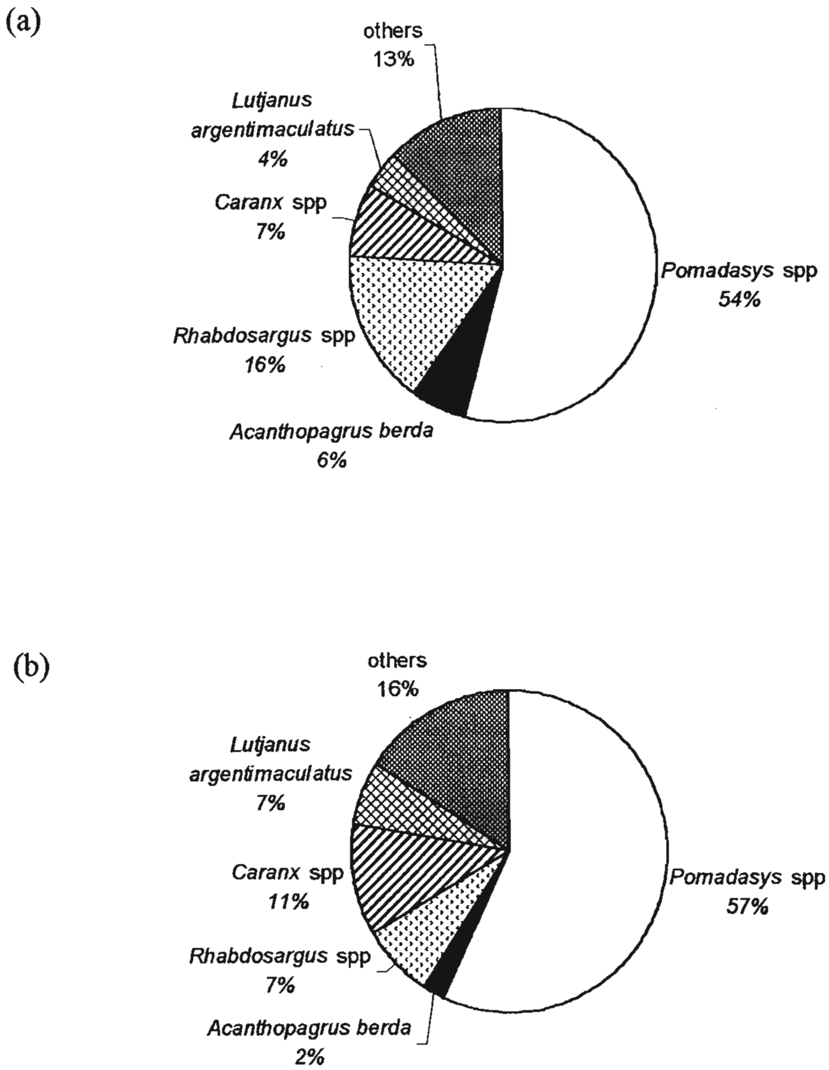


Figure 2.2. Catch composition of recreational angling species caught in the Kosi system between 1986 and 1999 by (a) numbers and (b) mass.

Annual trends in the percentage contribution of *A. berda* to the total catch by numbers and mass are depicted in Figure 2.3 a and 2.3 b, respectively. The percentage contribution of *A. berda* by mass to the total catch remained fairly constant from 1987 to 1995, but then declined sharply from a high of 4.1% in 1994 to a low of 0.6% in 1999, while the contribution by numbers declined from 1996.

(a)

(b)

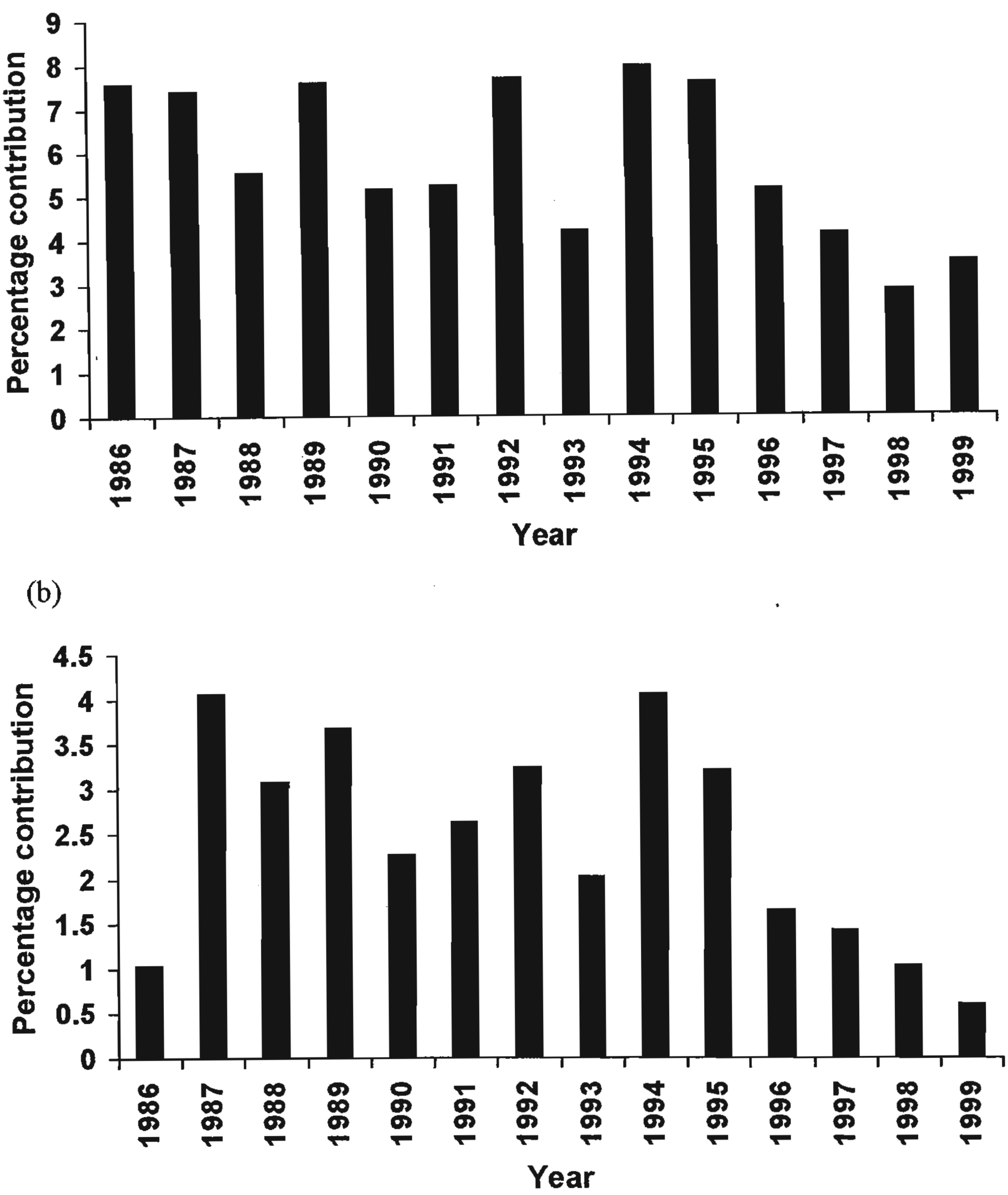


Figure 2.3. Percentage contribution of *A. berda* to the annual recorded recreational catch in terms of (a) numbers and (b) mass between 1986 and 1999.

The number of *A. berda* caught by recreational boat anglers in the Kosi system was estimated at 334 per annum (≅0.2 mt). This was calculated by multiplying the number of *A. berda* caught per outing against the actual number boat outings in the system (2300 per annum) estimated by James *et al.* (2001).

Catch per unit effort (cpue)

Annual trends in total *cpue* (all species) for the Kosi estuarine system are depicted in Figure 2.4. *Cpue* was at its lowest in 1988 and 1995 at 0.13 fish/angler/h and 0.19 kg/angler/h, and highest at the beginning and end of the study period. The mean *cpue*, for the study period, was 0.16 fish/angler/h (S.D. = 0.031) and 0.25 kg/angler/h (S.D. = 0.062). Regression analysis of *cpue*, revealed a slight decrease in terms of *cpue* by numbers but a slight increase in *cpue* by mass.

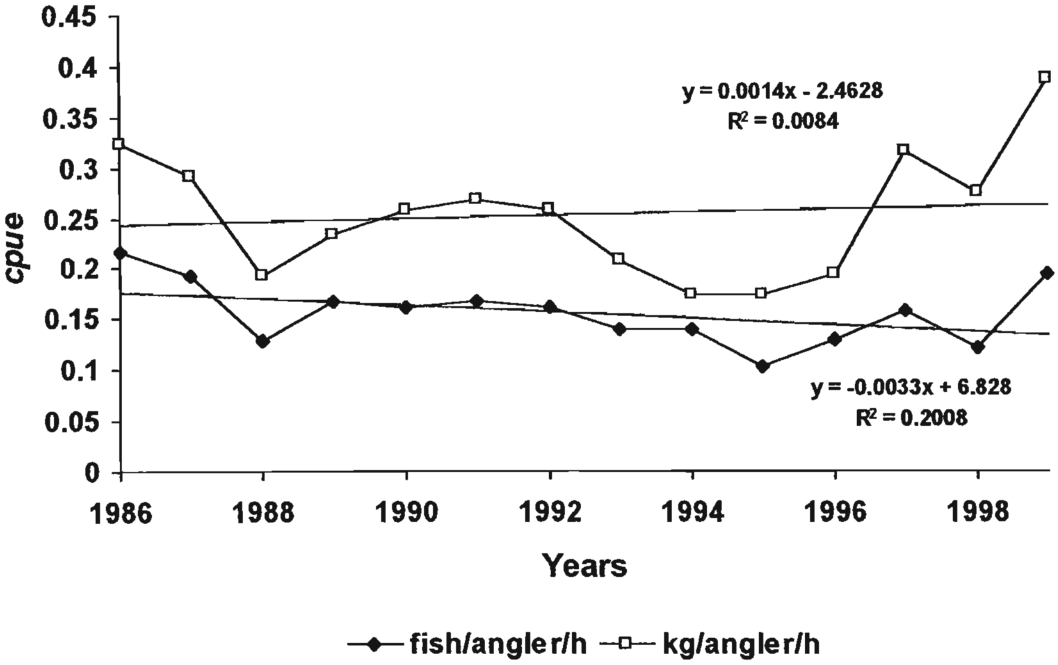


Figure 2.4. Annual *cpue* for all angling species reported on catch cards in the Kosi system between 1986 and 1999.

Total *cpue* appeared to be correlated with the number of outings reported. Regression analysis of the number of outings reported against *cpue* (numbers and mass), depicted in Figure 2.5 a and b, indicated r^2 values of 0.43 and 0.71, respectively. Further, there is a strong positive correlation (r^2 = 0.85) between the number of angler outings reported and the percentage of zero catches reflected on cards (Figure 2.6). This indicates that the higher the number of outings reported, the greater the percentage of zero catches reflected on cards.

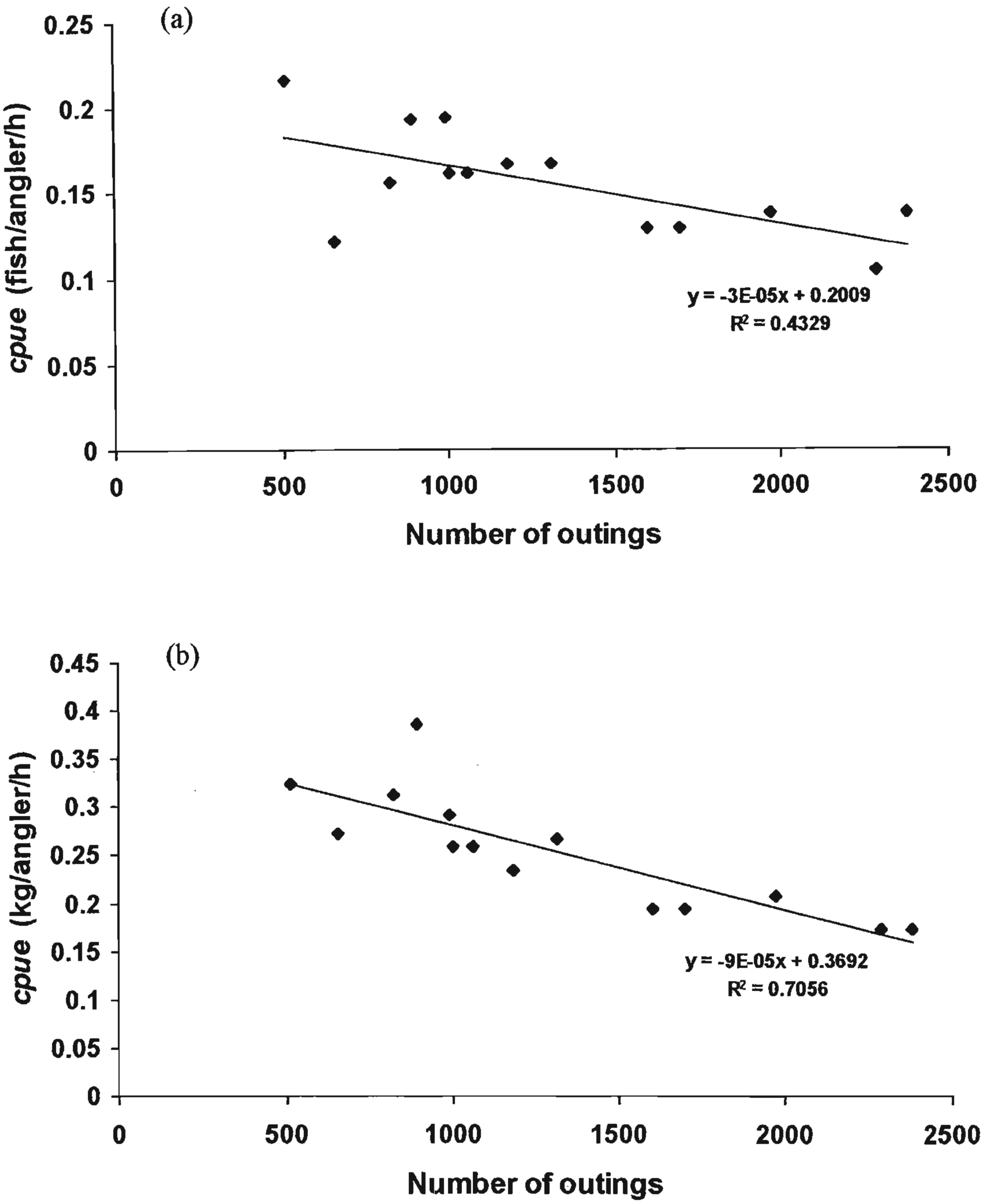


Figure 2.5. Regression of the number of outings reported against (a) fish/angler/h and (b) kg/angler/h

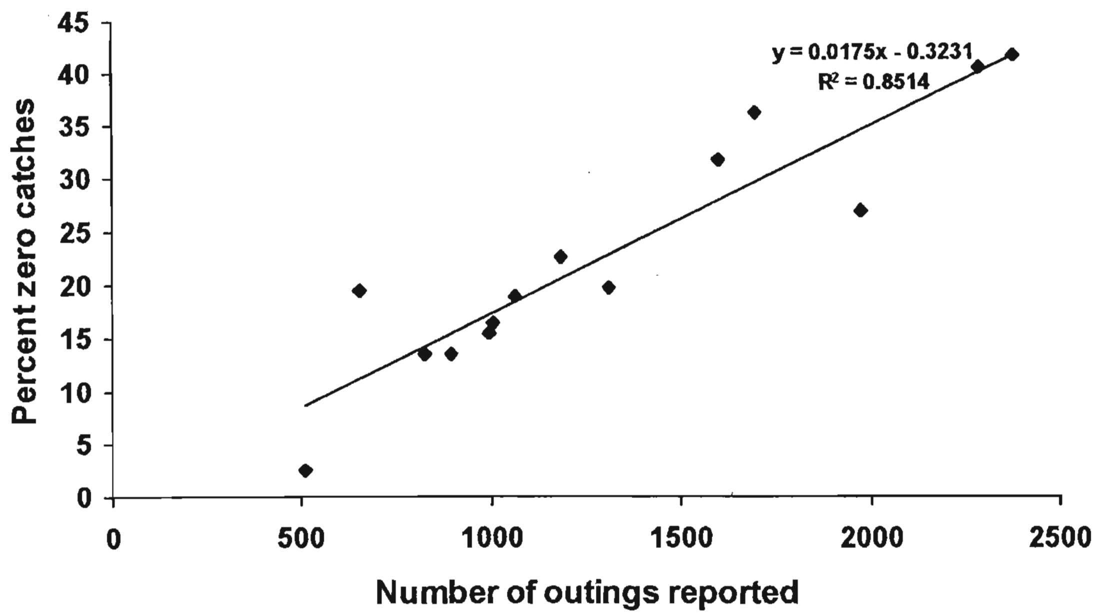


Figure 2.6. Regression of the number of outings reported against percentage zero catches.

Although there were no apparent trends in total *cpue* (all species), *cpue* (fish/angler/h) for *A. berda* declined significantly (p=0.0024) from 1986 onwards (Figure 2.7). The mean *cpue* for *A. berda* was 0.009312 fish/angler/h.

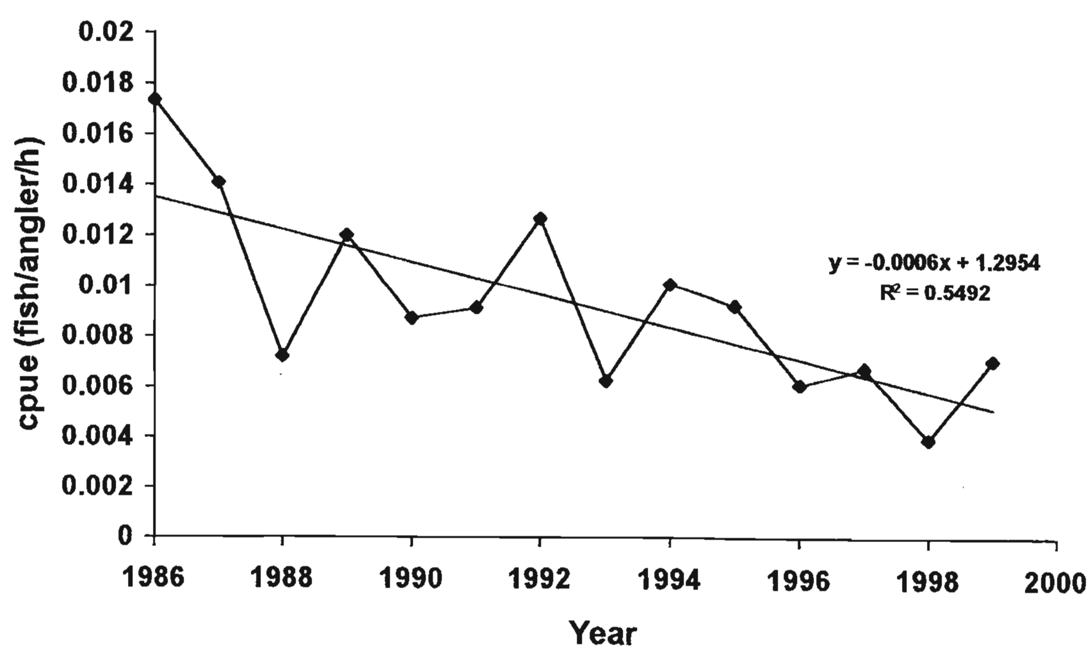


Figure 2.7. Annual trends in *cpue* of *A. berda* from the Kosi system between 1986 and 1999.

Size frequency

The lengths of fish are not recorded on catch cards, and the weights recorded are generally estimates, and must therefore be viewed with caution. The mean mass of *A. berda* reported in catches was fairly stable throughout the study period with a range of 0.6 to 0.9kg.

The gillnet fishery

Catch composition

A total of 21 families of fishes, represented by 31 species, was caught in the Kosi Bay gillnets between 1992 and 1998 (Table 2.3). The catch composition in terms of numbers is depicted in Figure 2.8. Catches were dominated by *Gerres methueni*, which comprised 56% of the catch. Other target species, such as *Oreochromis mossambicus* (13%) and Mugilidae (7%) comprised a much smaller percentage of the total catch. *A. berda* contributed 4% to the total catch by numbers. The percentage contribution of larger species such as Mugilidae and *Pomadasys* spp. would increase their importance in terms of weight of landed catch.

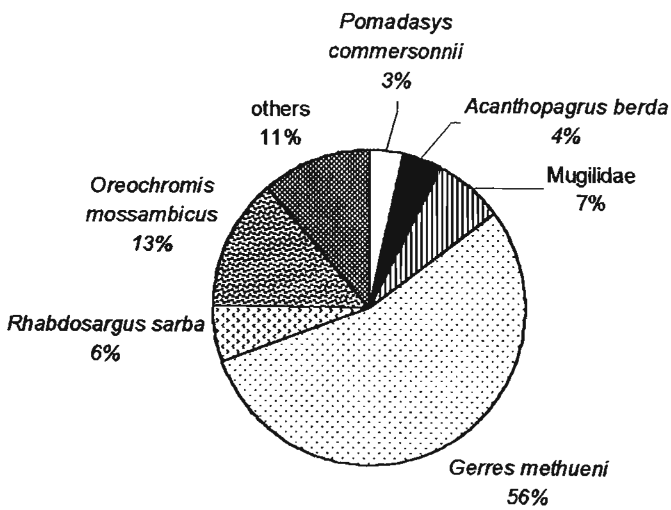


Figure 2.8. Catch composition of species caught in the Kosi system gillnet fishery (numbers) between 1992 and 1998.

Table 2.3. Species recorded in gillnet catches in the Kosi system between 1992 and 1998.

Family	Scientific name	Common name	Number
Albulidae	*Albula vulpes*	bonefish	566
Anguillidae	*Anguilla marmorata*	Madagascar mottled eel	32
		unspecified eels	9
Chanidae	*Chanos chanos*	milkfish	65
Clariidae	*Clarius gariepinus*	sharptooth barbel	2714
Belonidae	*Ablennes* spp.	unspecified needlefishes	2
Hemiramphidae	*Hemiramphus far*	spotted halfbeak	3
Platycephalidae	*Platycephalus indicus*	bartail flathead	132
Ambassidae	*Ambassis* spp.	unspecified glassies	136
Serranidae	*Epinephelus andersoni*	catface rockcod	1
Teraponidae	*Terapon jarbua*	thornfish	197
Haemulidae	*Pomadasys commersonnii*	spotted grunter	5 464
Lutjanidae	*Lutjanus argentimaculatus*	river snapper	1 098
	Lutjanus spp.	unspecified snapper	13
Sparidae	*Acanthopagrus berda*	riverbream	6 606
	Rhabdosargus sarba	Natal stumpnose	9 420
Monodactylidae	*Monodactylus* spp.	unspecified moonies	1 386
Gerreidae	*Gerres acinaces*	smallscale pursemouth	967
	Gerres methueni	evenfin pursemouth	87 110
Scianidae	*Argyrosomus japonicus*	dusky kob	1
Carangidae	*Caranx* spp.	unspecified kingfish	3 586
	Scomberoides lysan	doublespotted queenfish	143
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	21 267
Labridae	*Thalassoma trilobatum*	ladder wrasse	4
	Thalassoma spp.	unspecified wrasse	228
Mugilidae	*Crenimugil crenilabis*	fringelip mullet	1
	Myxus capensis	freshwater mullet	3 043
	Valamugil buchanani	bluetail mullet	5
	Valamugil robustus	robust mullet	2 054
	Liza alata	diamond mullet	1 190
	Mugil / Liza spp.	unspecified mullet	11 276
Sphyraenidae	*Sphyraena* spp.	unspecified barracuda	159
		unspecified teleosts	244
total			159 122

It was estimated that 944 *A. berda* (0.3mt) are caught in the legal gillnets each year, but it is unknown how many are caught by illegal netters. The percentage contribution of *A. berda* to the annual gillnet catch is depicted in Figure 2.9. Percentage contribution of *A. berda* to the catch peaked in 1995 and 1996, at 7% and 4% respectively, and was very low in 1998 when *A. berda* contributed only 1% to the total catch. Similarly, annual *cpue* (fish/net/night) for *A. berda*, which is depicted in Figure 2.10, peaked from 1995-1997 and declined in 1998. The mean *cpue* for *A. berda* throughout the study period was 0.268 fish/net/night (S.D.=0.161). Figure 2.11 depicts average *cpue* for *A. berda* on a monthly basis. There were no apparent seasonal trends in *cpue* for *A. berda* in the gillnet fishery.

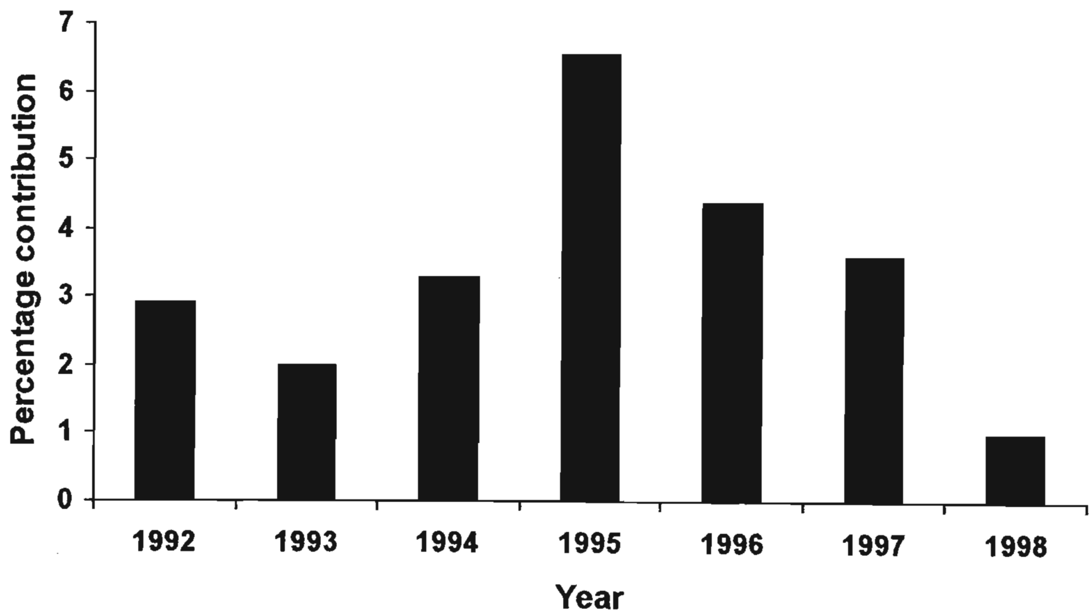


Figure 2.9. Percentage contribution of *A. berda* to the annual recorded catch (numbers) in the Kosi system gillnet fishery between 1992 and 1998.

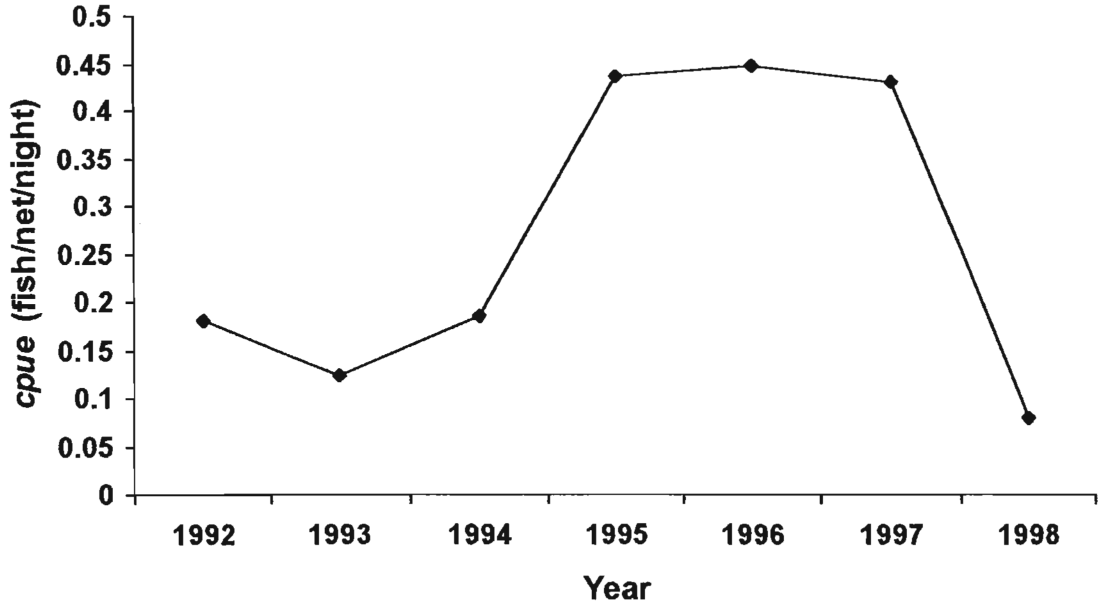


Figure 2.10. Annual *cpue* trends in the numbers of *A. berda* caught in the Kosi system gillnet fishery between 1992 and 1998.

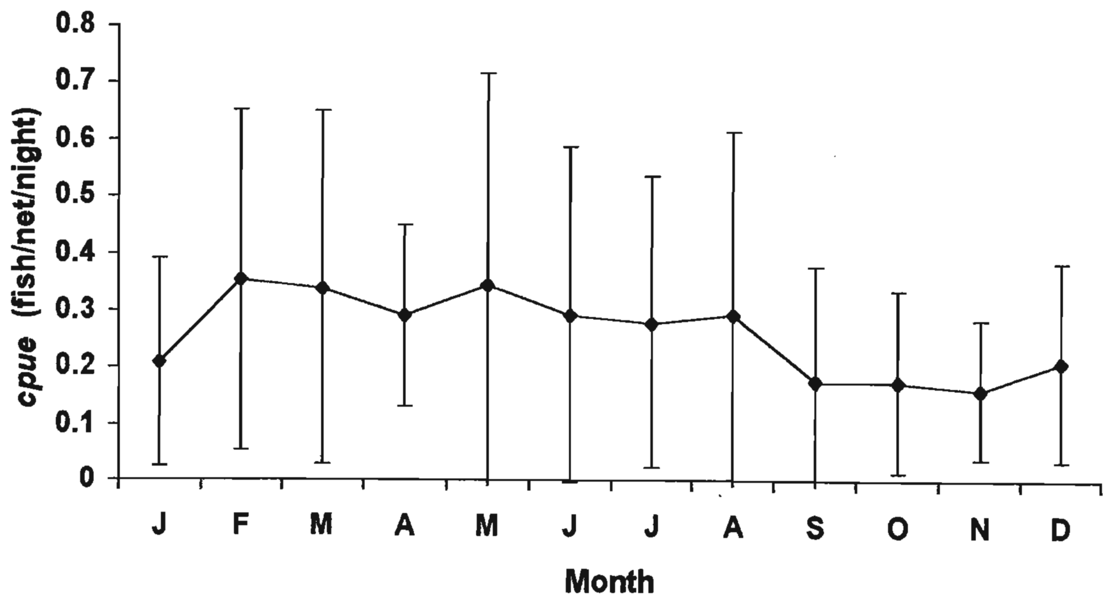


Figure 2.11. Mean monthly *cpue* for *A. berda* caught in the Kosi system gillnet fishery between 1992 and 1998; error bars are standard deviation of mean.

Length frequency distribution of A. berda

The length frequency of all measured *A. berda* caught in the Kosi gillnet fishery is shown in Figure 2.12. The mean length of fish caught in the gillnet fishery was 254mm TL, which is just above the minimum size limit for the species (250mm TL), specified in the regulations of the Marine Living Resources Act (No. 18 of 1998). Of the *A. berda* caught in the gillnets, only 61% were ≥ the minimum size limit, while 75% were ≥ the length at 50% maturity (230mm TL) (calculated in chapter 6). Length frequencies varied slightly on an annual basis (Figure 2.13), with the average length of *A. berda* caught decreasing in 1995, 1996 and 1997, when large numbers were caught in the gillnets.

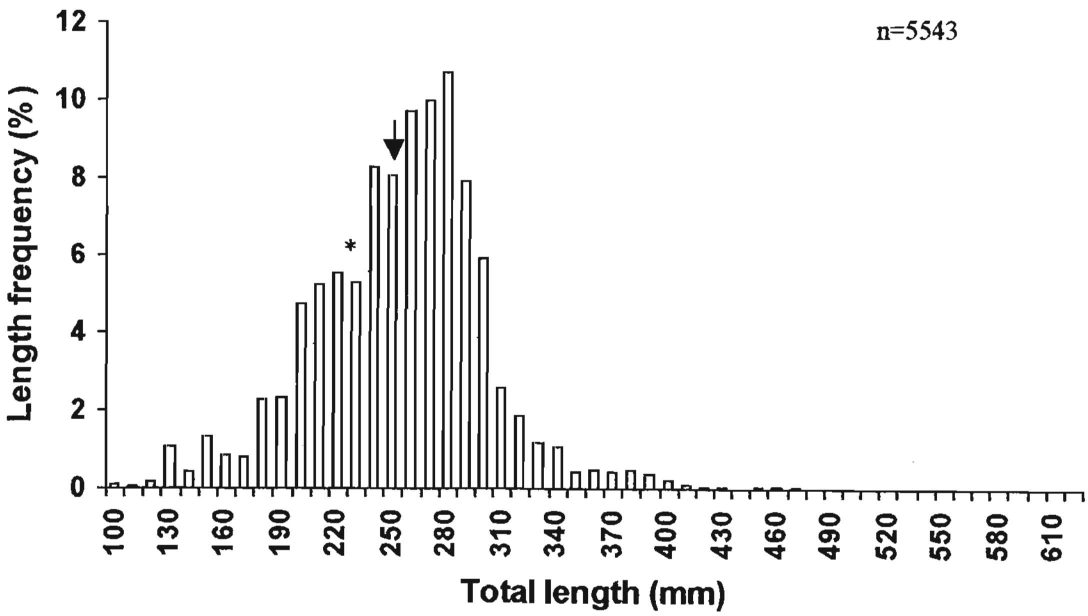


Figure 2.12. Length frequency distribution of all *A. berda* recorded from gillnets between 1992 and 1998 (The * depicts the size at 50% maturity and the arrow the minimum size limit).

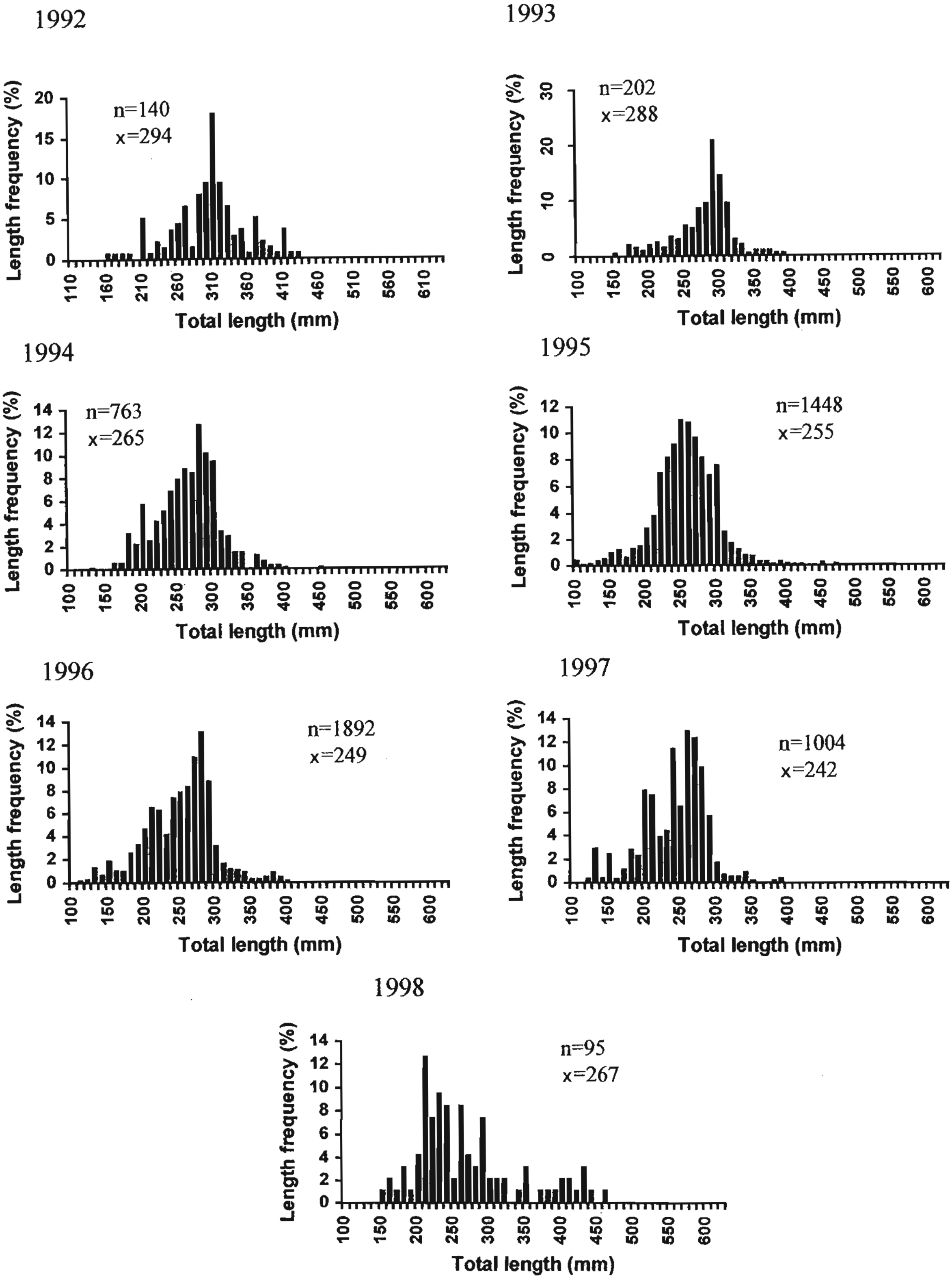


Figure 2.13. Length frequency distributions of *A. berda* caught in Kosi gillnets between 1992 and 1998 (x indicates the mean length (mm TL) of fish measured).

The trap fishery

Catch composition

A total of 22 families represented by at least 33 species of fishes was caught in the Kosi Bay fish traps between 1985 and 1998 (Table 2.4). During the intensive study, from 1981-1985, when all the traps were monitored, Kyle (1986) found that *A. berda* was the third most important species taken in the traps. Catches of *A. berda* remained very stable from year to year, with *A. berda* contributing a mean of 6.5% to the total catch (S.D.=0.67), which amounted to a mean of 2 708 *A. berda* per year (and 1.9mt per year). *P. commersonnii* and *M. cephalus* dominated the catch, contributing 32.5% and 25.1%, respectively, to the catch by numbers.

In contrast to Kyle's (1986) study it was found that *A. berda* contributed only 2% of the catch by numbers between 1985 and 1998 (Figure 2.14). The percentage contribution of *A. berda* to the catch was very low because no *A. berda* were recorded from the sample of five traps monitored after 1994 (Table 2.5). *P. commersonnii* and Mugilidae dominated the catch by numbers, contributing 29% and 35% respectively to the catch by numbers.

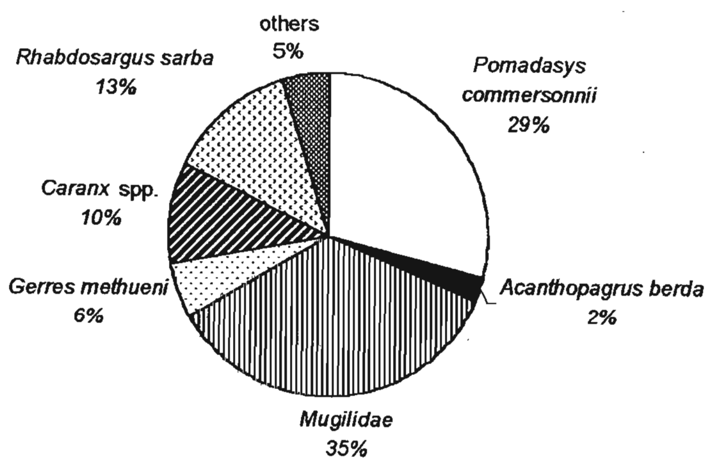


Figure 2.14. Catch composition of species caught in the traps numbered 53 to 57 in the Kosi system between 1985 and 1998.

Table 2.4. Species recorded in fish trap catches in the Kosi system from 1985 to 1998.

Family	Scientific name	Common name	Number
Albulidae	*Albula vulpes*	bonefish	458
Anguillidae	*Anguilla marmorata*	Madagascar mottled eel	1
Chanidae	*Chanos chanos*	milkfish	1 017
Clariidae	*Clarius gariepinus*	sharptooth catfish	1
Belonidae	*Ablennes* spp.	unspecified needlefishes	24
Hemiramphidae	*Hemiramphus far*	spotted halfbeak	6
Platycephalidae	*Platycephalus indicus*	Bartail flathead	111
Ambassidae	*Ambassis* spp.	unspecified glassies	11
Serranidae	*Epinephelus andersoni*	catface rockcod	1
	Epinephelus epistictus	brown rockcod	22
Pomatomidae	*Pomatomus saltatrix*	shad	28
Haemulidae	*Pomadasys commersonnii*	spotted grunter	19 234
Lutjanidae	*Lutjanus argentimaculatus*	river snapper	282
	Lutjanus spp.	unspecified snapper	2
Sparidae	*Acanthopagrus berda*	riverbream	1 631
	Rhabdosargus holubi	Cape stumpnose	47
	Rhabdosargus sarba	Natal stumpnose	8 677
Gerreidae	*Gerres acinaces*	smallscale pursemouth	16
	Gerres methueni	evenfin pursemouth	3 858
Sciaenidae	*Argyrosomus japonicus*	dusky kob	2
	Alectis indicus	Indian mirrorfish	2
	Caranx spp.	unspecified kingfish	6 544
	Scomberoides lysan	doublespotted queenfish	170
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	85
Labridae	*Thalassoma trilobatum*	ladder wrasse	5
Scaridae	*Scarus* spp.	parrotfishes	17
Mugilidae	*Myxus capensis*	freshwater mullet	993
	Valamugil buchanani	bluetail mullet	1 077
	Valamugil robustus	robust mullet	1 262
	Liza alata	diamond mullet	1 947
	Liza macrolepis	large-scale mullet	125
	Mugil / Liza spp.	unspecified mullet	17 916
Sphyraenidae	*Sphyraena* spp.	barracuda	532
Cynoglossidae		unspecified tonguefishes	13
		unspecified teleosts	230
total			66 347

The percentage contribution of *A. berda* to the annual catch (Table 2.5) was not stable, as it peaked in 1986 at 22% and then varied from between 0.07% to 3.5%. No *A. berda* were caught in the monitored traps after 1994. This was not related to decreasing trends in trap catches, as the highest total catch was recorded in 1996 (Table 2.5).

Table 2.5. The number of *A. berda, P. commersonnii* and Mugilidae caught in the monitored traps numbered 53-57 in the Kosi system between 1985 and 1998.

Year	Total fish caught	*A. berda* (No.)	% of total catch	*P. commersonnii* (No.)	% of total catch	Mugilidae (No.)	% of total catch
1985	999	18	1.8	436	43.6	167	29
1986	4 666	1 026	22	1 228	26.3	621	17
1987	2 194	22	1	596	27.2	789	43.5
1988	5 909	152	2.6	1 564	26.5	1 977	41.6
1989	6 135	217	3.5	1 723	28.1	2 061	41.9
1990	6 043	39	0.6	2 835	47	1 410	32.2
1991	4 000	41	1.0	881	22	1 100	45.3
1992	4 456	99	2.2	850	19.1	1 793	45.9
1993	6 424	15	0.2	869	13.5	2 664	45.3
1994	3 076	2	0.1	1 094	35.6	644	35.8
1995	5 032	0	0	656	13	1 678	48.4
1996	9 198	0	0	3 698	40.2	673	11.2
1997	4 148	0	0	1 446	34.9	447	15.7
1998	4 121	0	0	1 358	33	1 892	56.2
TOTAL	66 401	1 631	2	19 234	29	23 320	35

The mean monthly percentage contribution of *A. berda* to trap catches (traps 53-57) between 1985 and 1998 is depicted in Figure 2.15. Despite large variation in the data, it is evident that catches of *A. berda* peaked between April and August each year.

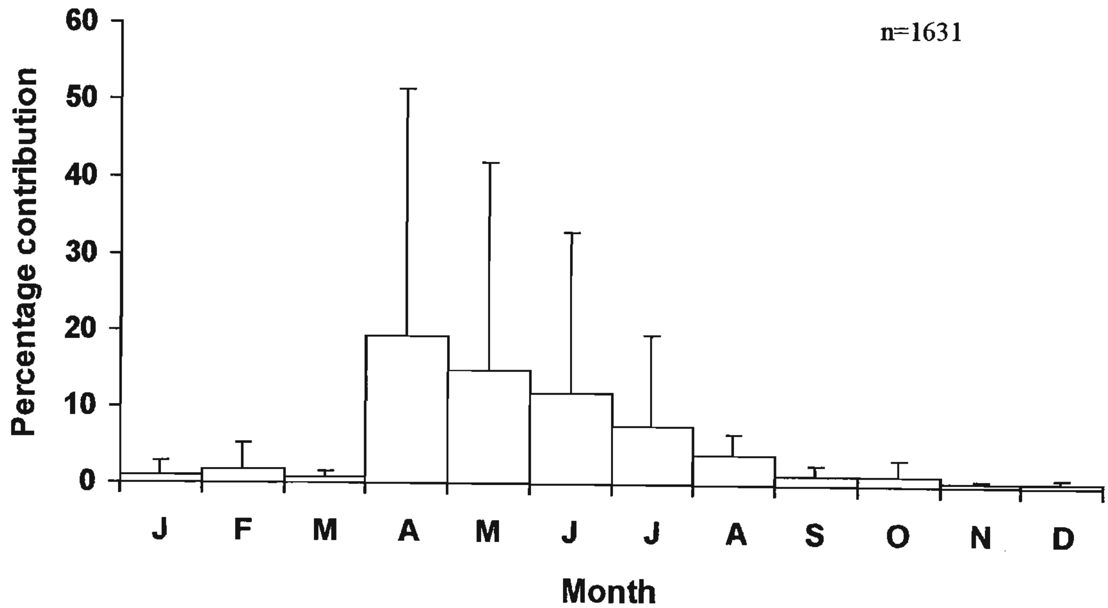


Figure 2.15. Mean monthly percentage contribution (by numbers) of *A. berda* to the Kosi system trap catch (traps 53 to 57) between 1985 and 1998.

Length frequency distribution of A. berda

Despite a substantial decrease in the number of *A. berda* caught in the monitored traps after 1989 most *A. berda* measured were in the size range between 250mm TL and 350mm TL (Figure 2.16). Of the *A. berda* recorded in these traps 98.8% were ≥ the legal size limit (250mm TL), while almost all *A. berda* caught (99.8%) were ≥ the size at 50% maturity (230mm TL). The average length of *A. berda* caught in traps 53 to 57 remained fairly stable from year to year (Figure 2.17).

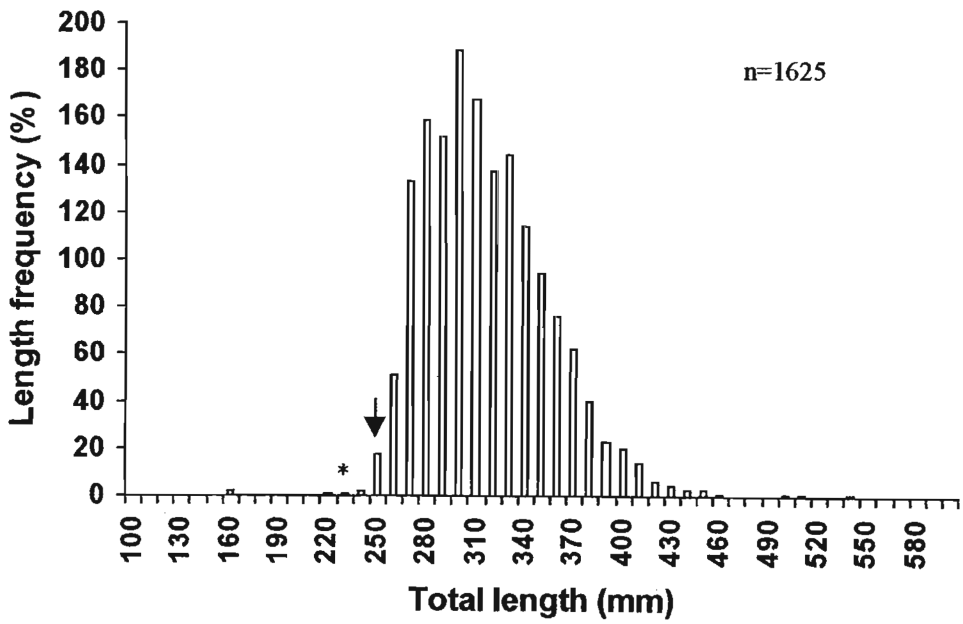


Figure 2.16. Length frequency distribution of all *A. berda* caught in traps 53 to 57 in the Kosi system between 1985 and 1998 (The * depicts the size at 50% maturity and the arrow the minimum size limit).

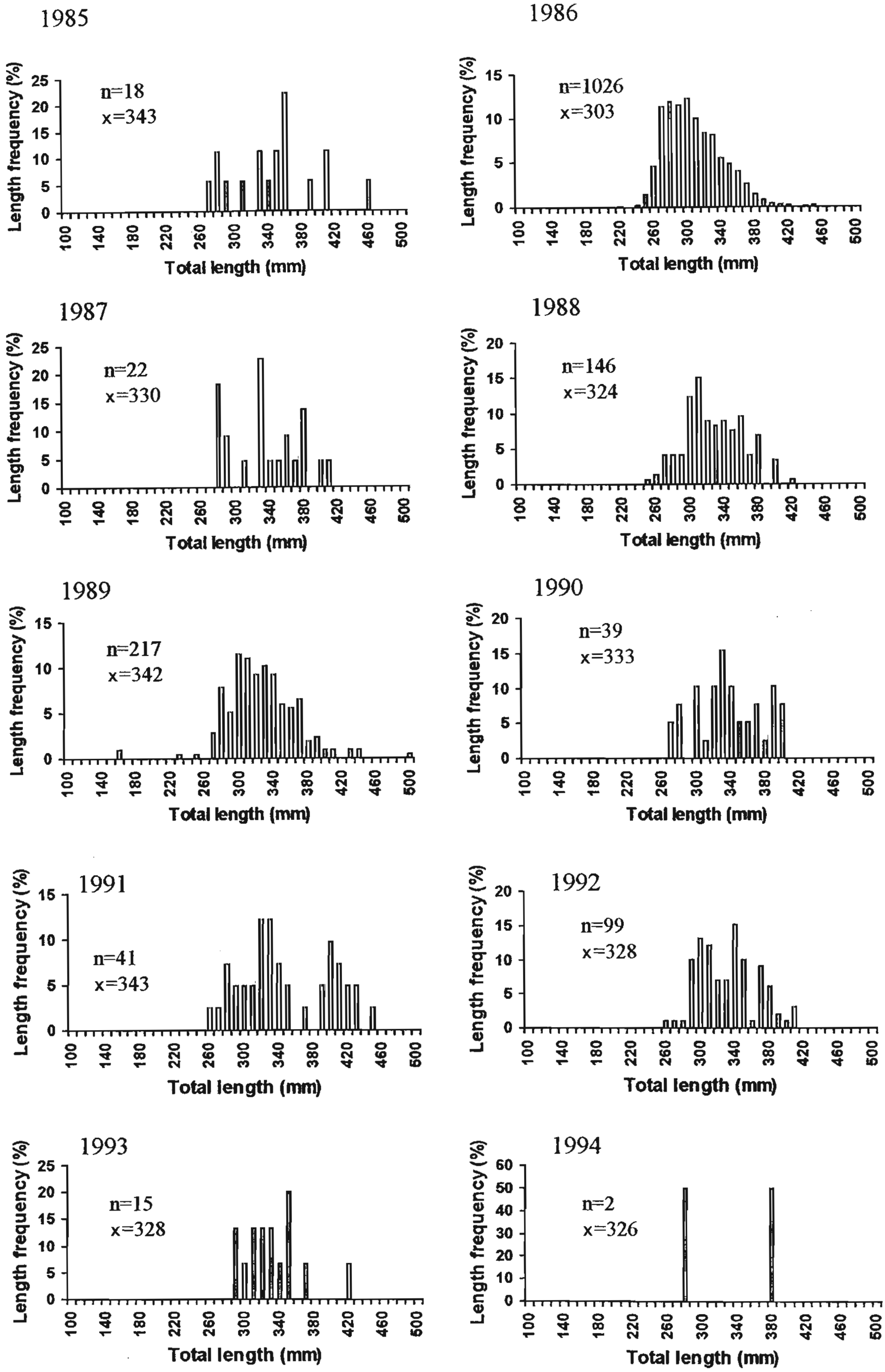


Figure 2. 17. Length frequency distributions of *A. berda* caught in Kosi Bay fish traps (53 to 57) between 1985 and 1994 (x indicate the mean length (mm TL) of fish measured).

Although no *A. berda* were caught in the five monitored traps (53 to 57) since 1995, recent data provided by R. Kyle (KZNW, pers. comm.) showed that a total of 494 *A. berda* was caught in 15 traps recently monitored near the mouth of the estuary during July 2001. The length frequency of *A. berda* caught in these traps is shown in Figure 2.18. It is apparent that smaller *A. berda* have been caught in these traps, with most *A. berda* falling into the size range between 240mm TL to 270mm TL (mean size = 269 mm TL).

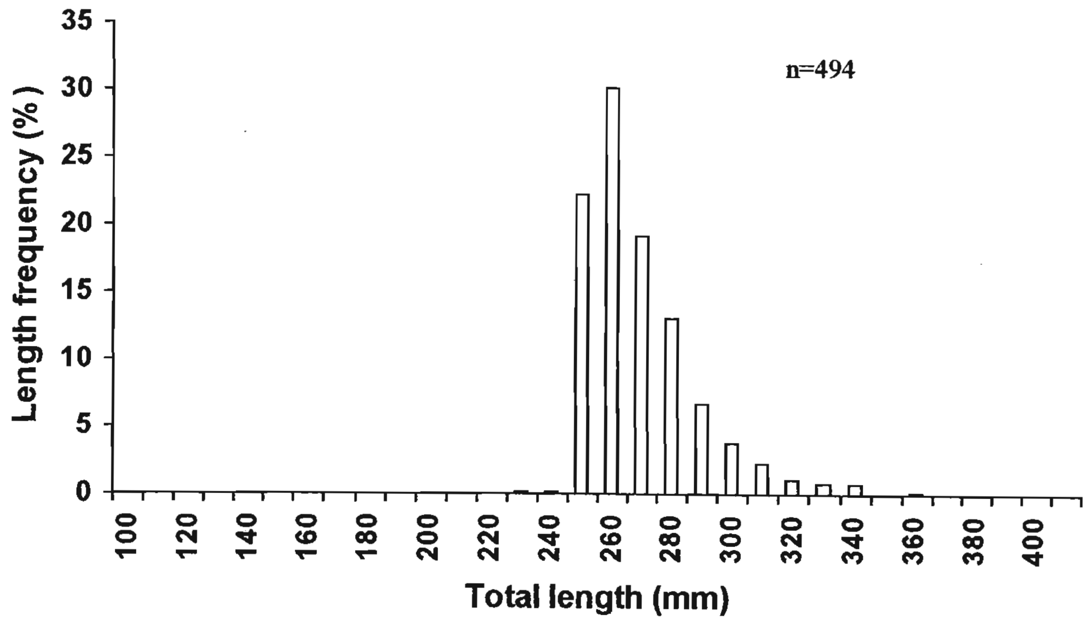


Figure 2.18. Length frequency distribution of *A. berda* caught in 15 fish traps monitored by KZNW near the mouth of the Kosi estuary in July 2001.

Discussion

The recreational fishery

The Kosi estuarine system has been accessible to recreational anglers since the 1940s. Recreational angling takes place principally from small boats and is restricted to Lakes Makhawulani, Mpungwini and Nhlange (Kyle and Robertson 1997). The number of outings recorded decreased from 1994, when a maximum number of 2 379 outings was recorded. As the number of visitors to Kosi Bay has not declined in recent years (R. Kyle, KZNW, pers. comm.), the reduction in recorded outings is a reflection of reduced effort in collection of catch cards by KZNW rather than a reduction in the actual number of boat outings. As not all anglers complete catch cards at Kosi, this type of monitoring underestimates the total number of boat outings. The actual number of boat outings at Kosi Bay was estimated to be an average of 2 300 (± 738 sd) outings per annum between 1988 and 1996 (James *et al.* 2001).

Despite the possibility of misidentification (bias), recreational anglers reported a total of 17 families, comprising 34 species, in their catches from the Kosi estuarine system over the 14-year study period. The most frequently caught species in the Kosi system were *Pomadasys commersonnii*, *Rhabdosargus sarba*, *Caranx* spp. (predominantly *C. sexfasciatis* and *C. ignobilis*), *A. berda* and *L. argentimaculatus*. *Pomadasys commersonnii* dominated catches, by numbers and mass, as this species is abundant throughout the system at all times of the year (Wallace 1975a). The presence of species such as Carangidae and *L. argentimaculatus* in the catches can be attributed to the clear water of the Kosi system, as these species are visual predators, which favour clear water (van der Elst 1977).

A. berda, which is found throughout the Kosi system, comprised 7% of the catch by numbers and 2% by mass. However, the percentage contribution of *A. berda* to the total catch, by numbers and mass, decreased from 1994 onwards, so that by 1999 *A. berda* contributed only 3% to the catch by numbers and 0.6% by mass.

The analysis of *cpue* between 1986 and 1999 revealed distinct annual fluctuations in both the numbers and the mass of fish caught per angler hour. Fluctuations in *cpue* were found to be closely correlated to the number of cards collected. When the number of outings reported was low (1990-1992, and 1997-1999), *cpue* was higher than when the number of outings reported was high (1993-1996). This phenomenon is believed to reflect a bias in the data, as during periods when the number of cards collected was high (i.e. KZNW staff actively issue and collect cards), more unsuccessful (zero catch) fishing trips were recorded, contributing to a more realistic *cpue*. However, when fewer cards were submitted (i.e. less collecting effort by KZNW staff), it was generally only the successful angling outings that were reported by avid anglers, leading to a biased increase in *cpue*.

As *cpue* can be used as a measure of fish abundance, the overall stable trend of *cpue* suggests that there is little change in the overall fish abundance, and that recreational catches appear to be sustainable. However, *cpue* for *A. berda* has shown a significant downward trend throughout the study period. *Cpue* for *Lutjanus argentimaculatus*, which is also an estuarine-dependent species, showed a similar decline (James *et al.* 2001).

These trends may reflect a decrease in abundance of both species in the Kosi system. *A. berda* is an estuarine-dependent species, and the Kosi population is fairly isolated from populations in other estuaries, as adults appear to be virtually confined to the estuary (Garratt 1993a). In addition to being estuarine-dependent, *A. berda* is a partial protandrous hermaphrodite (some males change sex to females), which potentially makes it more vulnerable to overfishing, as larger fish are primarily females (Garratt 1993a). A decline in *cpue* for *A. berda* in St Lucia, attributed to estuarine degradation, has also been reported (van der Elst 1977; Mann 1994).

The mean mass of *A. berda* in catches remained relatively stable throughout the study period. Consequently, these results cannot be used in conjunction with decreasing *cpue* to show that the *A. berda* population in Kosi is declining. Decreasing trends in *cpue*, in conjunction with decreasing length or weight frequencies, are often used as an indication of overfishing of a species (Iversen 1996). The mass recorded by anglers must, however, be viewed with caution as anglers usually estimate mass, and measurements are thus subject to considerable prestige and digit bias.

The gillnet fishery

The legalised Kosi Bay gillnet fishery was established in an attempt to sustainably harvest certain fish species, which are either viewed as abundant or under exploited (Kyle 1999). Analysis of the gillnet fishery showed that a total of 21 families, represented by 31 species of fishes was caught between 1992 and 1998. Of the species caught, target species accounted for 81% of the catch by numbers. *A. berda* featured prominently in the catch, accounting for 4% of the total catch by numbers.

Catches of *A. berda* in the gillnets increased substantially in 1996 and 1997 and declined in 1998. Likewise, *cpue* (fish/net/night) for the species peaked from 1995-

1997 and declined in 1998. The decline in catches of *A. berda* came at a time when the number of permits issued increased from 35 to 45, and may, in combination with the other fisheries, reflect overfishing of the species. Environmental variables, such as salinity and water temperature, which are fairly stable in Lake Nhlange (Blaber 1978), are unlikely to have a large influence on the numbers of *A. berda* caught. According to Blaber (1978), salinity in Lake Nhlange ranges from fresh in times of flood to 5‰, but usually remains relatively stable at about 3‰. *A. berda* is well adapted to tolerate low salinities, and is one of the few species that has been recorded in salinities of less than 1‰ in Lake Nhlange (Blaber 1997).

Gillnets are set in the reedy margins of Lake Nhlange, and away from the channels, as it was shown that this increased the catch of target species and minimised interference with fish migrations between the lakes (Kyle 1999). However, these large areas of shallow water and abundant marginal vegetation are favoured habitats of species such as *A. berda*, which feed on benthic invertebrates living in the shallows (Blaber 1978). Consequently, species such as *A. berda* are caught in the gillnets in addition to target species.

As the gillnets are set only in Lake Nhlange and not in the estuary there were no seasonal trends observed in *cpue* for *A. berda*. *A. berda* have been shown to migrate to the estuary mouth to spawn (Garratt 1993a). Consequently, seasonal increases in catches of *A. berda* would be expected in the estuary and the channels through which they migrate, but not necessarily along the margins of Lake Nhlange.

A large percentage of the *A. berda* caught in the gillnets were found to be below the minimum legal size limit (39%), while 25% of the catch was below the length at 50% maturity. Kyle (1999) found that gillnets also caught a large proportion of undersized *P. commersonnii* (36%) and *R. sarba* (11%), which are important species in the recreational catch. There was also a slight reduction observed in the mean length of *A. berda* caught on an annual basis.

The trap fishery

The local inhabitants of Kosi Bay have used fish traps, or kraals, to catch fish as they migrate into and out of the estuary for over 400 years (Mountain 1990). Although fish traps are not unique to the Kosi system, they are the only traditional traps that are still in use in South Africa today (Mountain 1990). Similar traps are used in estuaries in East Africa, particularly Rio Inharrime in Mozambique, but many of these traps have fallen into disuse because of the availability of gillnets (Blaber 1997). Fish traps mainly catch fish which are migrating towards the estuary and sea. The most numerous fish caught are species such *Pomadasys commersonnii* and Mugilidae, which migrate into estuaries as small juveniles, remain in the estuary until maturity, and then return to the sea as adults (Kyle 1986). Traps also catch species such as *A. berda* which spend most of their lives in the estuarine system and migrate to the mouth of the estuary to spawn (Garratt 1993a). *A.berda* are therefore especially vulnerable to capture just prior to and during their spawning aggregation.

An earlier study by Kyle and Robertson (1997) found that traps caught approximately 5% of the mature *A. berda* population annually, and were therefore not seen as a threat to the population. The number of traps operational in the Kosi system has remained relatively constant for nearly 50 years (Kyle submitted). However, in the last few years the number of traps, and particularly the number of baskets per trap, has increased substantially (Figure 2.19). In addition, traps are now increasingly being set in the channel connecting the estuary to the lakes and close to the small reef near the mouth where *A.berda* spawn (R. Kyle, KZNW, pers. comm.). As such, fish traps are likely to be having an increasing impact on the fish populations of the system, particularly on the populations of estuarine-dependent species, such as *A.berda* which migrate down to the mouth through the estuarine system.

The study by Kyle (1986) was the most accurate assessment of actual trap catches taken in the Kosi estuarine system, as all the existing traps were monitored. He found that *A. berda* comprised 6.5% of the total catch. After 1985, monitoring was restricted to a sub-sample of five traps (53-57), which are situated along the shallow margins of Lake Makhawulani. These traps catch approximately 12.5% of the total trap catch by numbers. According to R. Kyle (KZNW, pers. comm.) *A. berda* are not abundant in this part of the estuarine system and catches of *A. berda* in these traps were minimal and erratic. *A. berda* contributed 22% to the total catch in 1986, while in other years *A. berda* only contributed between 0.07% and 3.5% to the catch. No *A. berda* were caught after 1994. At this stage it is not possible to speculate on the reason for the disappearance of *A. berda* from trap catches in this area of the system. As a consequence, no estimate of the annual *A. berda* catch made by fish traps subsequent to Kyle's (1986) estimate was possible.

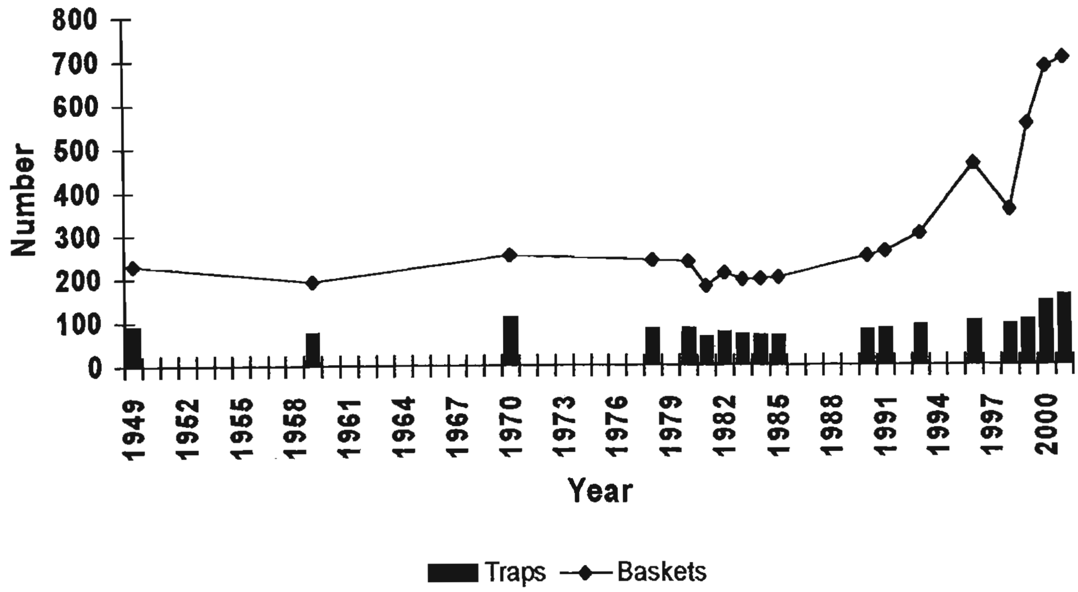


Figure 2.19. The number of traditional fish traps and baskets at Kosi Bay between 1949 and 2001 (after R. Kyle, submitted).

Despite the limitations of the data, catches showed distinct seasonal trends, with the percentage of *A. berda* in catches increasing between April and August each year. *A. berda* aggregate in the mouth of the estuary to spawn between May and August each year (Garratt 1993a), and it is then that they are particularly susceptible to capture in the traps.

The monitored traps caught fairly large *A. berda,* with nearly all of the *A. berda* caught being above the length at 50% maturity, and the minimum size limit. Kyle (1986) has shown that when the water level in the lakes is high (following heavy rains), laterally compressed fish species, such as *A. berda,* are able to escape through the gaps between the sticks composing the basket of the traps. *A. berda,* also known as "slim jannie" (clever Johnny), is the only fish species which tries to escape near the surface of the water, where the gaps between the sticks tend to be wider.

Despite an absence of *A. berda* in the monitored traps after 1994, substantial numbers are still being caught in the traps in the estuary, which are increasing in number and extending closer to the mouth. Analysis of July 2001 data from 15 traps near the mouth, provided by R. Kyle (KZNW, unpubl. data.), showed that 494 *A. berda* were caught during one month. It was also disturbing to note that the length frequency of *A. berda* caught in these traps was smaller than the length frequency of *A. berda* caught in the monitored traps prior to 1994.

Concluding remarks

As accessibility improves, the Kosi estuarine system is becoming an increasingly popular angling destination. The north-eastern corner of Maputaland has been earmarked as a trans-national tourism axis and, as a result, a new road is being built which will greatly increase the accessibility of the area. This should result in an increase in the number of visitors to the area, particularly as the Kosi estuarine system is already considered a prime angling venue. Increased tourism will place additional pressure on the fish resources of the Kosi estuarine system, which are already under increasing pressure from artisanal / subsistence fishers.

The number of fish traps and gillnets in the system has increased substantially in recent years, as unemployment levels in the area increase and fishers recognise the commercial value of their catches (R. Kyle, submitted). Trap catches increased from about 40 000 fish in 1981 to a high of 93 000 fish in 1993. Although the number of legal gillnet permits issued has been capped at 45 at present, catches by illegal gill netters in the system persist and are substantial (Kyle 1999; submitted).

Despite an unfortunate absence of long-term data on the numbers of *A. berda* caught in fish traps, the increasing number of fish baskets on traps, encroachment of traps into the estuary and declining trends in *cpue* recorded in the recreational and gill net fisheries gives cause for concern. *A. berda* is an estuarine-dependent species, which is rarely recorded in the marine environment and, as such, the adult population in the Kosi estuarine system is fairly isolated and therefore vulnerable to estuarine degradation and overfishing. Declines in *cpue* for this species in the recreational and gillnet fisheries may be indicating that the combined current level of harvesting by all sectors of the Kosi fishery is too high to be sustainable.

CHAPTER THREE

ST LUCIA FISHERIES

Introduction

The St Lucia estuarine system, located in northern KwaZulu-Natal ($28^0 23'$S and $32^0 25'$E), is the largest estuarine system in Africa, covering an area of 35 000ha and comprising approximately 80% of the estuarine area in KwaZulu-Natal (Begg 1978, Day 1981, Blaber 1980). The system consists of two connected lakes which exit to the sea via a 21km long channel, known as the estuary Narrows (Wallace 1975a).

Five rivers, which together have a total catchment area of 9 000 km^2, flow into the system (Figure 3.1). The largest of these is the Mkuze River, which flows through an extensive wetland area before entering the lake (Wallace 1975a). Despite the large size of the system the mean depth is <1m. The shallow nature of the system, together with a variable water supply, results in extreme long-term salinity fluctuations, which have a severe impact on the fauna and flora (Blaber 1980).

St Lucia was declared a game reserve in 1895, making it one of the oldest protected areas in Africa. The system now forms part of the Greater St Lucia Wetland Park, which is managed by KwaZulu-Natal Wildlife (KZNW). St Lucia has also been recognised by the Ramsar convention as a wetland of international importance and was declared a World Heritage Site in 1999.

The system has extensive mud-banks rich in benthic fauna and prolific marginal vegetation, which make it an important habitat for juvenile and adult fish (van der Elst 1977). A total of 108 species of fishes has been recorded in the St Lucia system, many of which are species which enter the estuary as juveniles seeking food and shelter (Blaber 1980).

The St Lucia system is one of the most popular recreational angling destinations in the country, attracting an estimated 15 000 anglers per year (Mann *et al.* in press(b)). KZNW provides accommodation for visitors at St Lucia estuary, Charters Creek, False Bay and Fanies Island (Figure 3.1) and there is also accommodation provided by the private sector at St Lucia village. Angling in St Lucia takes place mainly from small motorised boats which are launched from slipways at St Lucia estuary, Charters Creek, False Bay and Fanies Island. Shore angling is mostly confined to the lower reaches of the estuary (Mann *et al.* in press(b)). Most of the eastern side of North Lake is set aside as a wilderness area in which no angling is permitted (Figure 3.1).

The fish resources in St Lucia are also harvested by net fishers. Gillnets are a passive form of fishing, in which monofilament or braided nylon nets are suspended from a line of floats at the surface and weighed down by small lead weights (de Villiers 1989; Lamberth *et al.* 1997). Gillnets were first introduced to South Africa in the 1860s by Portuguese and Italian fishermen, but have only been used in St Lucia since the 1960s (Mann 1995). The conservation authority responsible for the management of St Lucia has, in the past, banned the use of gillnets as they were perceived as having a negative impact on fish populations and were difficult to control. Extensive illegal netting continued to take place in the northern parts of the system, around the tribal areas of Nibela, Mduku and Nkundusi (Figure 3.1), and in an attempt to control this an experimental gillnet fishery was implemented in the above areas in 1995 (Mann 1996).

This chapter provides an analysis of all the available monitoring data for the recreational and gillnet fisheries in St Lucia. In particular, attention is focussed on catches of the riverbream, *Acanthopagrus berda*.

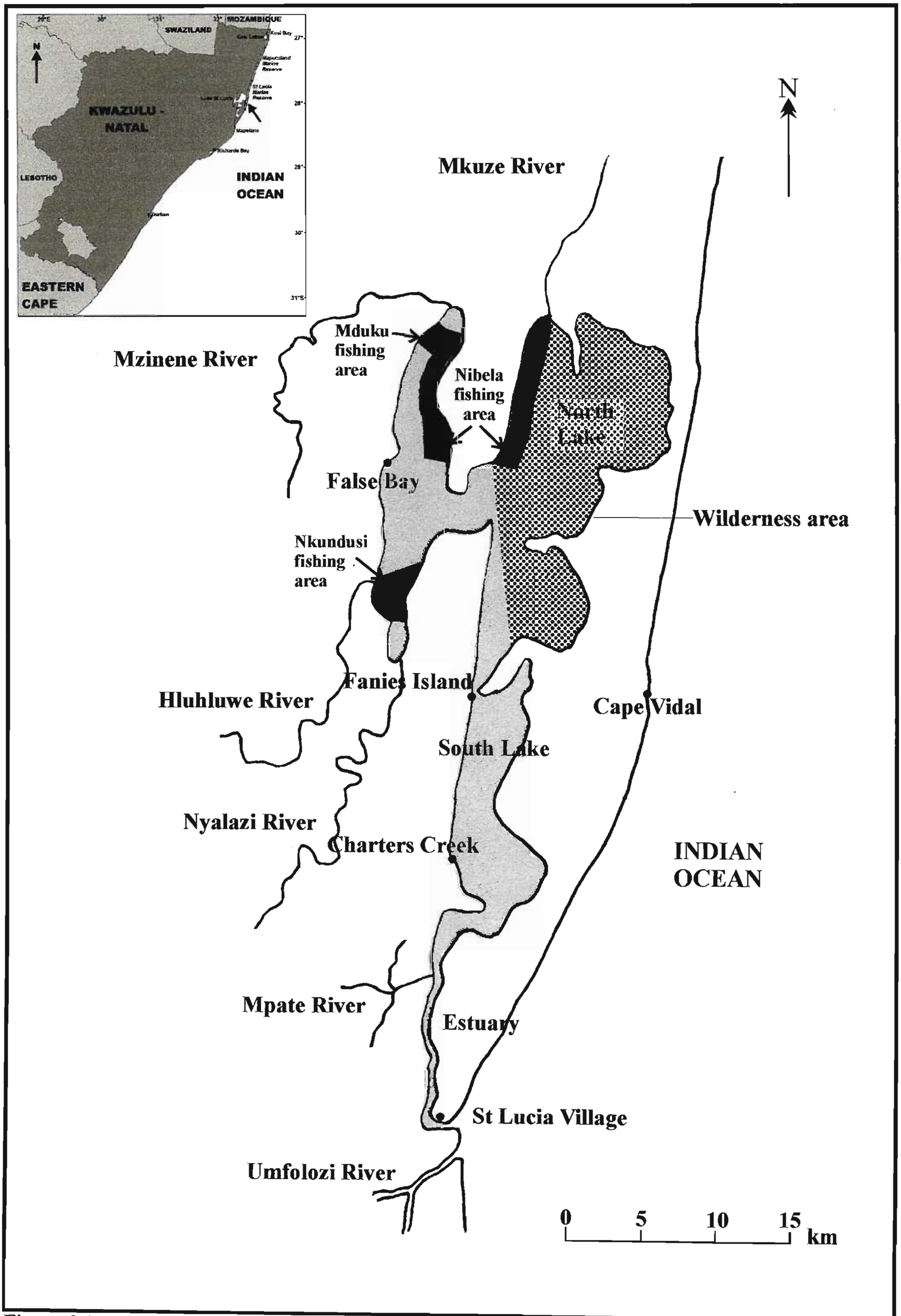


Figure 3.1. Map of the St Lucia estuarine lake system

Methods

The recreational fishery

In St Lucia, boat anglers are requested to voluntarily complete NMLS catch return cards after each fishing outing. Information recorded on catch cards includes date, locality, number of anglers per boat, hours fished, number of each fish species caught and their respective individual weights.

Catch cards are distributed and collected by KZNW field rangers at boat slipways at Charters Creek and St Lucia estuary. However, at Fanies Island and False Bay, catch cards are issued to visitors at the entrance gates to the campsite and anglers are requested to place completed cards in a marked postbox on departure. The completed cards are then sent to ORI in Durban where the data are captured onto the NMLS database.

Data collected from all sites between 1986 and 1999 were analyzed to determine trends in catches, angling effort and catch per unit effort (*cpue*) for *A. berda*. Data were analyzed from each site separately as well as from all sites combined. Data from False Bay and Fanies Island were eventually combined (referred to as North Lake) as the collection of catch cards from these venues was poor and erratic. As some anglers were unable to accurately identify all fishes to species level, certain species were grouped at genus level. There may also be a certain amount of misidentification of less common species by anglers.

Recreational shore angling in St Lucia is monitored to a limited extent by KZNW shore patrols. Shore patrols were first started in 1985, to inspect recreational shore angling in KwaZulu-Natal and are one of the main sources of NMLS data in the province (van der Elst and Penney 1995). Patrols are carried out in 15 zones along the KwaZulu-Natal coast and are undertaken by KZNW officers either on foot or using beach vehicles. Patrols take place at anytime of the day, but usually during daylight hours. Although shore patrols are a major source of data, the primary objective is law enforcement, and they are thus subject to numerous biases, particularly spatial, temporal and avidity bias (Pollock *et al.* 1994; Mann-Lang 1996).

During patrols anglers' catches are checked by KZNW rangers during a fishing outing and the data therefore represent incomplete fishing outings. As such, estimation of total catch and effort is often difficult. Data recorded usually include the species and number of fish caught, but biological data such as lengths and weights are not recorded.

Prior to 1999 shore patrols by KZNW field officers were conducted sporadically along the shores of the St Lucia estuary. Subsequently, patrols improved and shore patrol data from 1999 and 2000 were analysed to determine the catch composition of the St Lucia estuary shore-based fishery.

The gillnet fishery

In an attempt to control illegal netting in St Lucia an experimental fishery was established by KZNW in areas of North Lake in March 1995. The aim of this experimental fishery was to target Mugilidae and provide a controlled method whereby poor, rural neighbours to the park could gain access to the fish resources in the lake (Mann in press). This fishery was monitored from March 1995 to March 1998 (Mwanyama *et al.* 1998), but subsequently monitoring ceased due to a lack of funds. Furthermore, a recommendation has been made that the experimental fishery should be terminated due to a complete lack of compliance, the large percentage of recreational linefish species in the catch and the strong commercial motivation of the netters themselves (Mann in press). Nevertheless, extensive gill netting is still taking place in the system.

During the experimental phase of the fishery (March 1995 to March 1998) 30 permits were issued, with 5 issued to the Mduku community, 10 to the Nkundusi community and 15 to the Nibela community. Following assessment, the number of permits was increased to 37 in April 1996, with the number of permits issued to Mduku increasing to 7 and the number issued to Nkundusi increasing to 15. Each permit allowed the use of a single 30m multifilament gillnet with a stretched mesh size of 90 to 110mm. These net specifications were to reduce the capture of juvenile fish and to ensure a catch suitable for a subsistence netting operation.

Monitors were selected from each of the three tribal communities and trained in fish identification and recording of catch and effort data. Catches were recorded on a daily basis and, as netting was only allowed at night, each morning the catches were brought to a central landing site in each area. Monitors, stationed at the landing sites, recorded the catch and measured the total length of each fish to the nearest cm. Each month catch records were submitted to ORI in Durban, and later to Scientific Services at KZNW Head Office in Pietermaritzburg for capture onto a database (Mwanyama *et al.* 1998).

These data were analysed for this study to determine trends in catch composition, monthly trends in the numbers and mass of *A. berda* caught, seasonal trends in catch per unit effort and length frequencies of *A. berda.* Data from the three areas, namely Nibela, Mduku and Nkundusi, were combined to undertake these analyses.

Results

The recreational fishery

Angling effort

The number of boat angling outings reported on catch cards from the St Lucia system between 1986 and 1999 are depicted in Figure 3.2. An average of 4 885 catch cards was collected annually between 1986 and 1992 but since then, the number of cards has declined steadily to a low of 1 764 in 1998. Most catch cards were collected from the estuary and Charters Creek, but the proportion of cards collected from Charters Creek has declined since 1995. Relatively few cards were collected from Fanies Island and False Bay, and the completion of catch cards from these two areas was very erratic. Care should thus be taken in interpreting these results, as they, to a large extent, reflect the amount of effort put into completing and collecting catch cards, rather than trends in angling effort.

The number of anglers per boat outing varied little throughout the study period, with a mean of 2.8 anglers per boat (S.D. = 0.20). The number of hours fished per outing ranged from 5.2 to 8.4 hours, with a mean of 6.4 hours per outing (S.D. = 0.96).

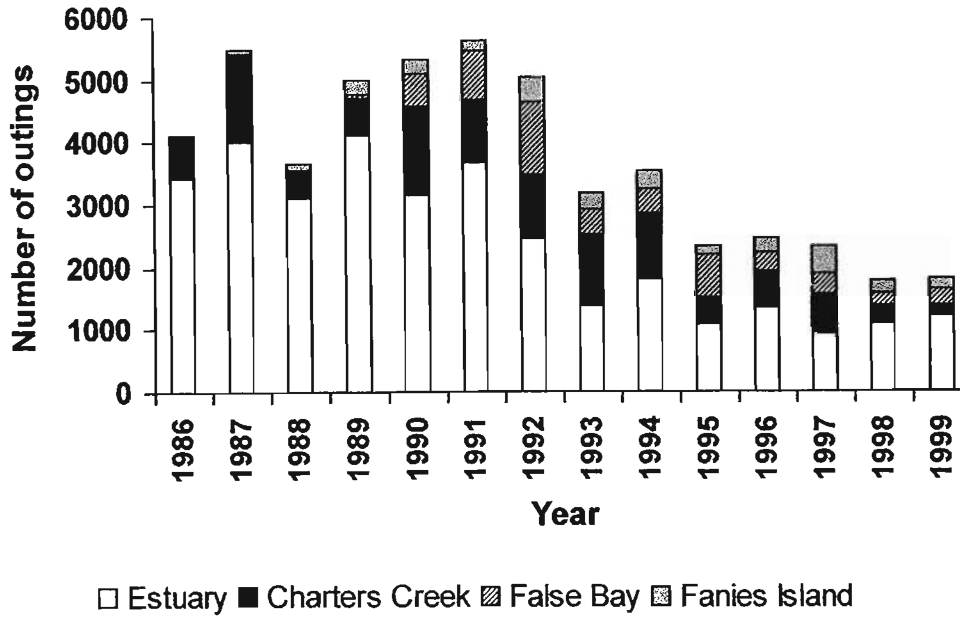


Figure 3.2. Number of boat outings reported on catch cards in the St Lucia system from 1986 to 1999.

Catch composition

Twenty-seven fish families represented by 55 species were recorded on catch cards from 1986 to 1999 (Table 3.1). Teleosts accounted for 47 of the species, while elasmobranchs accounted for eight of the species. The composition of catches, by numbers and mass, from all sites at St Lucia, during the period 1986 to 1999 are shown in Figure 3.3 a. Dusky kob *Argyrosomus japonicus*, grunter *Pomadasys* spp. (predominantly *P. commersonnii* but also including *P. kaakan, P. multimaculatum* and *P. olivaceum*), riverbream *Acanthopagrus berda*, stumpnose *Rhabdosargus* spp. (predominantly *R. sarba* but also including *R. holubi*), springer *Elops machnata* and mini-kob *Johnius dorsalis*

Table 3.1. Species reported on catch cards by recreational anglers in the St Lucia estuarine system from 1986 to 1999 (This species list is subject to bias, including unintentional and intentional misreporting by anglers).

Family	Scientific name	Common name	Number
Elasmobranchs			
Carcharhinidae	*Carcharhinus limbatus*	blackfin shark	6
	Rhizoprionodon acutus	milk shark	2
	Carcharhinus leucas	Zambezi shark	26
Sphyrnidae	*Sphyrna* spp.	hammerhead shark	165
Odontaspididae	*Carcharias taurus*	ragged tooth shark	1
Dasyatidae	*Himantura uarnak*	honeycomb stingray	77
	Gymnura natalensis	diamond ray	7
	Himantura gerrardi	brown stingray	4
Teleosts			
Elopidae	*Elops machnata*	springer	3 393
Megalopidae	*Megalops cyprinoides*	oxeye tarpon	1
Muraenesocidae	*Muraenesox bagio*	pike conger eel	294
Chanidae	*Chanos chanos*	milkfish	2
Clariidae	*Clarius gariepinus*	sharptooth catfish	1472
Belonidae	*Strongylura leiura*	needlefish	9
Platycephalidae	*Platycephalus indicus*	bartail flathead	12 33
Serranidae	*Epinephelus lanceolatus*	brindle bass	3
	Epinephelus spp.	unspecified rockcod	448
Teraponidae	*Terapon jarbua*	thornfish	1 221
Pomatomidae	*Pomatomus saltatrix*	elf	2083
Haemulidae	*Pomadasys commersonnii*	spotted grunter	26 465
	Pomadasys kaakan	javelin grunter	274
	Pomadasys multimaculatum	cock grunter	210
	Pomadasys olivaceum	pinky	71
	Pomadasys spp.	unspecified grunter	15 858
Lutjanidae	*Lutjanus russelli*	Russels snapper	3
	Lutjanus argentimaculatus	river snapper	246
Sparidae	*Acanthopagrus berda*	riverbream	28 195
	Diplodus cervinus hottentotus	zebra	2
	Diplodus sargus capensis	blacktail	25
	Lithognathus mormyrus	sand steenbras	1
	Rhabdosargus holubi	Cape stumpnose	443
	Rhabdosargus sarba	Natal stumpnose	6 493
	Rhabdosargus spp.	unspecified stumpnose	4 787
Monodactylidae	*Monodactylus* spp.	unspecified moony	50
Gerreidae	*Gerres* sp.	unspecified pursemouth	1
Sillaginidae	*Sillago sihama*	silver sillago	92
Sciaenidae	*Argyrosomus japonicus*	dusky kob	42 247
	Argyrosomus thorpei	squaretail kob	338

	Johnius dorsalis	mini-kob	26 277
	Otolithes ruber	snapper kob	1 521
Lobotidae	*Lobotes surinamensis*	tripletail	10
Carangidae	*Caranx ignobilis*	giant kingfish	5
	Caranx sem	blacktip kingfish	85
	Caranx sexfasciatus	bigeye kingfish	5
	Caranx spp.	unspecified kingfish	762
	Scomberoides spp.	unspecified queenfish	21
	Trachinotus africanus	southern pompano	98
	Trachinotus botla	largespot pompano	19
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	70
Mugilidae	*Mugil cephalus*	flathead mullet	1
	Liza tricuspidens	striped mullet	1
		unspecified mullet	203
Sphyraenidae	*Sphyraena jello*	pickhandle barracuda	49
	Sphyraena spp.	unspecified barracuda	52
Trichiuridae	*Trichiurus lepturus*	cutlass fish	197
		unidentified fish and shark species	5 427
total			171 051

were the most prominent species caught. *A. japonicus* and *Pomadasys* spp. dominated the catch, together comprising 50% of the catch by numbers and 82% of the catch by mass.

Species composition was, however, not uniform throughout the whole system. Catches in the estuary (Figure 3.3 b) were dominated by *Pomadasys* spp. and *A. berda*, while in South Lake (Figure 3.3 c) and North Lake (Figure 3.3 d) *A. japonicus* was the most prominent species caught in terms of both numbers and mass. *J. dorsalis* also featured prominently in catches by numbers from North Lake.

Annual trends in the contribution of *A. berda* to the total catch (all sites combined) by numbers is depicted in Figure 3.4. The percentage contribution of *A. berda* to the catch peaked in 1994 at 37%, and remained relatively high thereafter. The total catch made by boat anglers in the St Lucia estuarine system was estimated at 62.7mt and 64.5mt for 1992 and 1993, respectively (Mann *et al.* in press(b)). Using these values an average of 3.8mt of *A. berda* are estimated to be caught by recreational anglers in the St Lucia system each year.

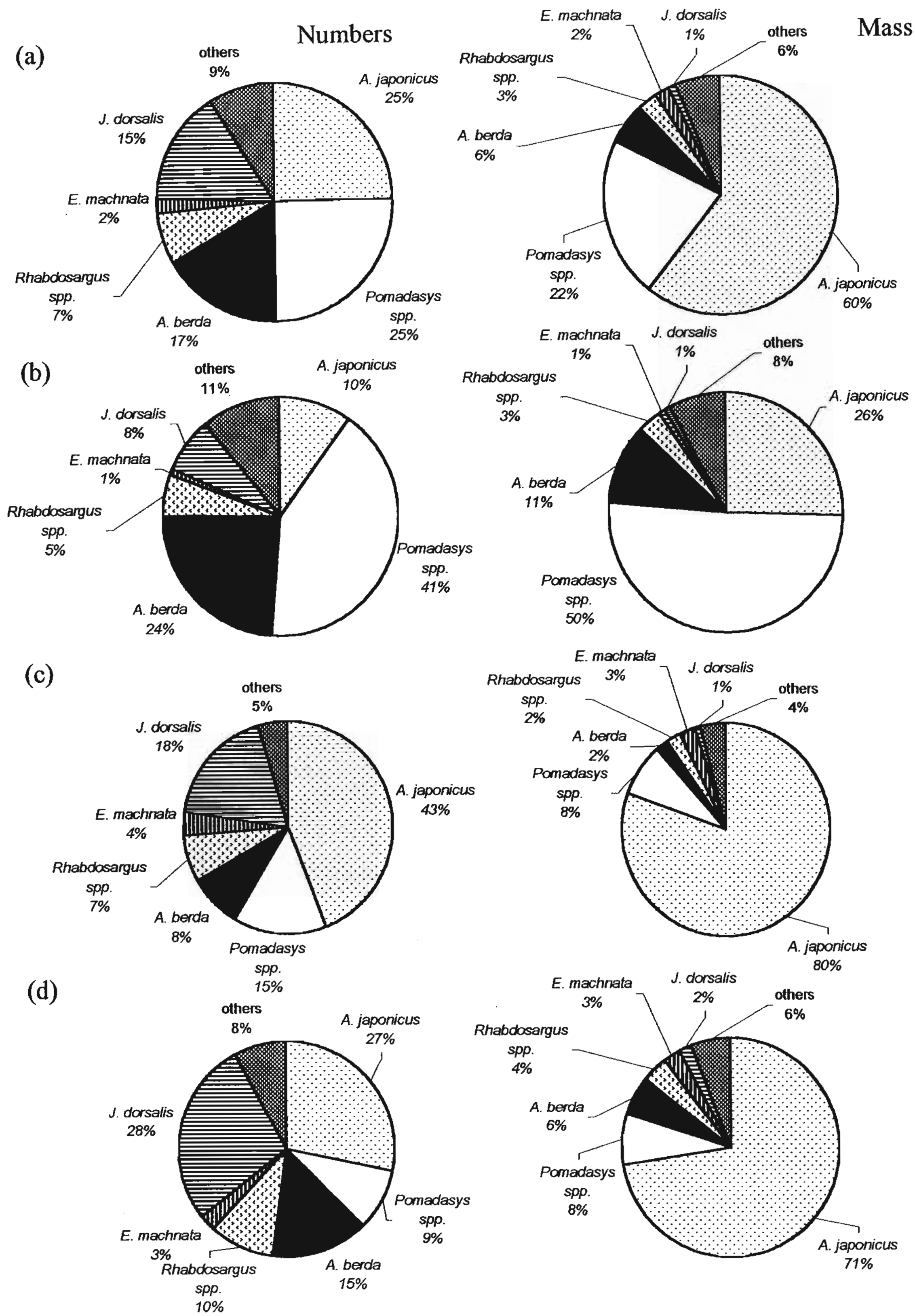


Figure 3.3. Catch composition by numbers and mass of recreational angling species caught in (a) the whole St Lucia estuarine system, (b) estuary, (c) South Lake (Charters Creek) and (d) North Lake (Fanies Island and False Bay), between 1986 and 1999.

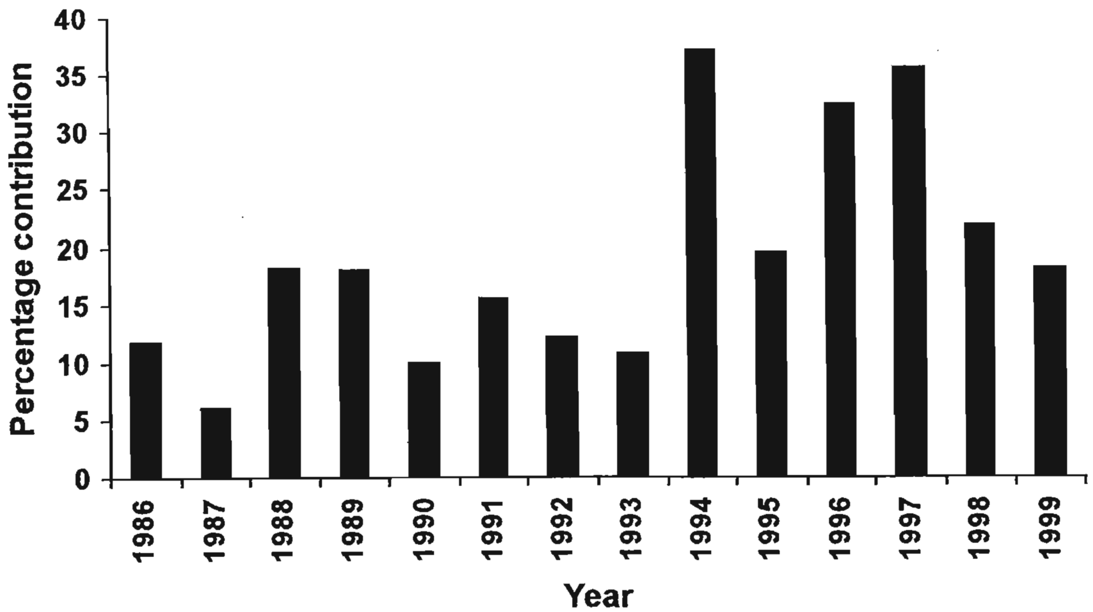


Figure 3.4. Percentage contribution of *A. berda* to the annual recorded recreational angling catch (numbers) in St Lucia between 1986 and 1999

Catch per unit effort (cpue)

The mean *cpue* (all species) for the whole system was 0.19 fish/angler/h (S.D.=0.054) and 0.28 kg/angler/h (S.D.=0.073). *Cpue* for *A. berda* fluctuated widely throughout the study period (Figure 3.5). Despite annual fluctuations in *cpue* for *A. berda* in the whole system, regression analysis revealed an overall upward trend, although this was not significant (r^2=0.24, p=0.08). The average *cpue* for *A. berda* throughout the study period was 0.035 fish/angler/h (S.D.=0.021). Lake salinity and annual trends in *cpue* (fish/angler/h) for *A. berda* in the whole system are depicted in Figure 3.6. An increase in *cpue* was recorded in 1988, 1994 and again between 1996 and 1997. Increases in *cpue* appeared to be related to salinity of the lake and the state of the estuary mouth. The peak in *cpue* in 1988 followed floods in September 1987, the peak in *cpue* in 1994 followed a 10-month period of mouth closure in 1993 and the large peak in *cpue* between 1996 and 1997 was closely correlated with a decrease in lake salinity over this period.

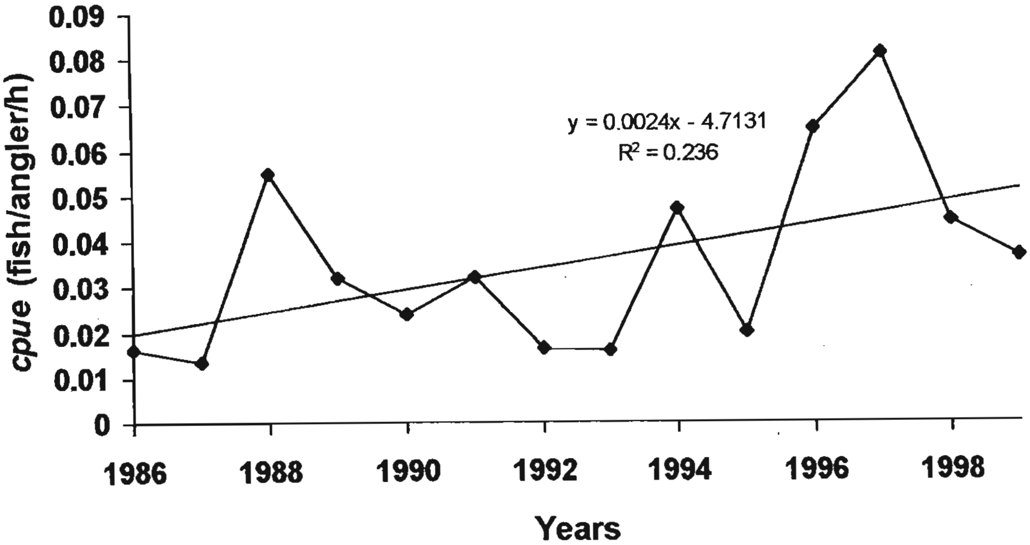


Figure 3.5. Annual *cpue* trend in the numbers of *A. berda* caught in the St Lucia recreational fishery between 1986 and 1999.

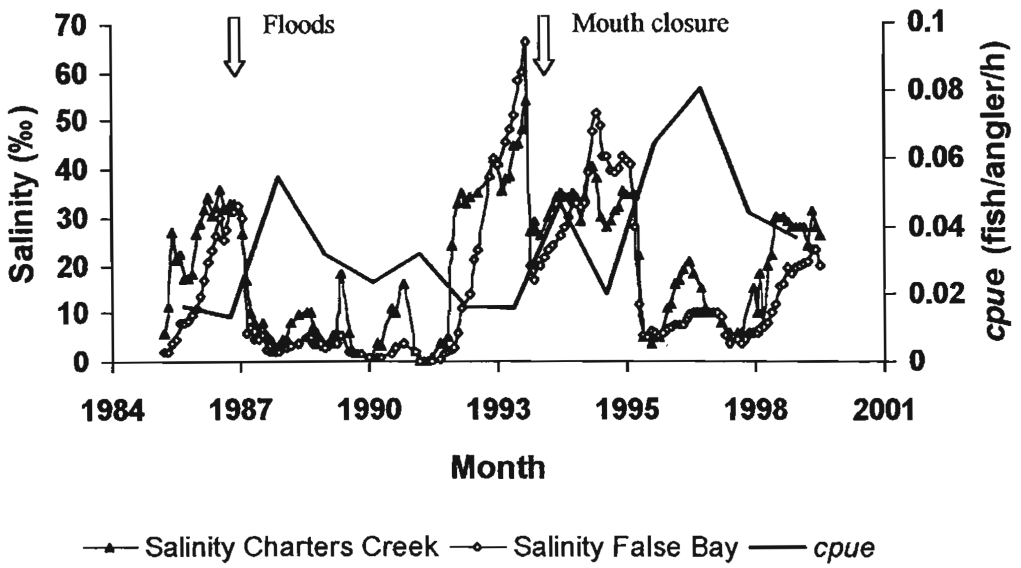


Figure 3.6. Lake salinity and *cpue* for *A. berda* from the whole St Lucia system between 1986 and 1999.

Shore angling

A total of 15 families, represented by 27 species of fishes were recorded in shore anglers catches between 1999 and 2000. The composition of the shore-based catch, determined from KZNW shore patrols conducted in the estuary is depicted in Figure 3.7. *A. berda* was the most prominent species in the catch (28%) followed by *P. commersonnii* (13%). The thornfish *Terapon jarbua* (10%) also featured prominently in catches. A large proportion of the catch (32%) consisted of low numbers of many species, most of which were also recorded in the boat-based catch cards.

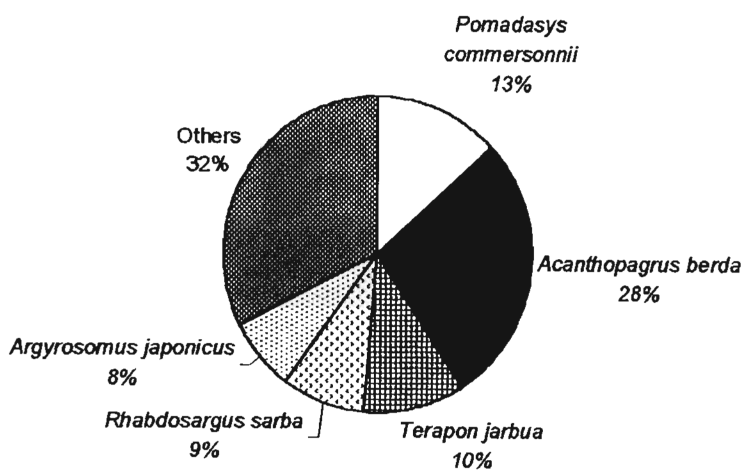


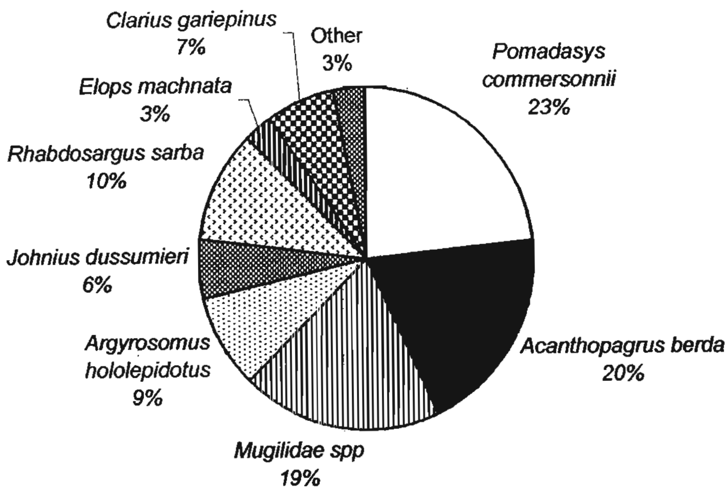
Figure 3.7. Composition of the catch taken by shore-anglers in St Lucia estuary as determined by KZNW shore patrols between 1999 and 2000.

The gillnet fishery

Catch composition

A total of 18 families, comprising 23 species of fishes was caught in the St Lucia gillnet fishery between 1995 and 1998 (Table 3.2). The catch composition in terms of numbers and mass are depicted in Figure 3.8. *A. berda,* contributed 20% of the catch by numbers, and 10% by mass. Although mugilid species were the main target species in this fishery and dominated the catch by mass (27%), they were only the third most important species caught by number (19%).

(a)



(b)

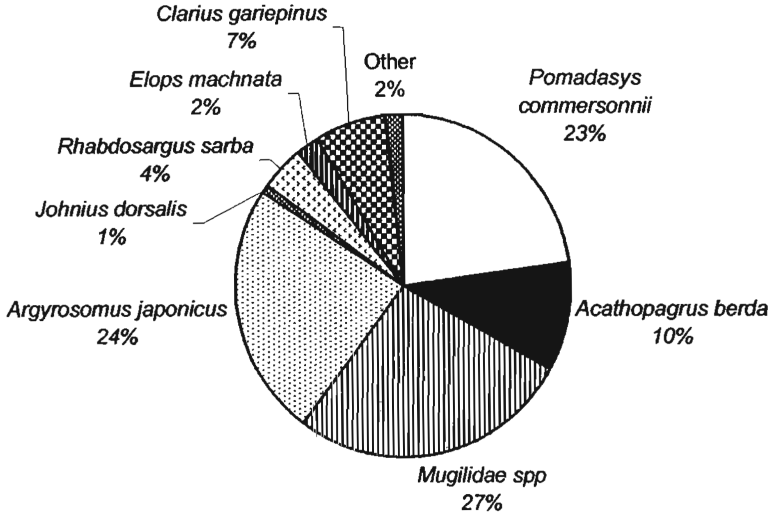


Figure 3.8. Catch composition of species caught in the St Lucia gillnet fishery in terms of (a) numbers and (b) mass between 1995 and 1998.

Table 3.2. Catch composition in the St Lucia gillnet fishery from March 1995 to March 1998.

Family	Scientific name	Common name	Number
Elasmobranchs			
Carcharhinidae	*Carcharhinus leucas*	Zambesi shark	36
Teleosts			
Elopidae	*Elops machnata*	springer	2 358
Megalopidae	*Megalops cyprinoides*	oxeye tarpon	87
Muraenesocidae	*Muraenesox bagio*	pike-conger	3
Engraulidae	*Thryssa vitrirostris*	bony	39
Chanidae	*Chanos chanos*	milkfish	89
Clariidae	*Clarius gariepinus*	sharptooth catfish	5 626
Belonidae	*Strongylura leiura*	yellowfin needlefish	257
Platycephalidae	*Platycephlaus indicus*	bartail flathead	556
Haemulidae	*Pomadasys commersonnii*	spotted grunter	19 715
	Pomadasys kaakan	javelin grunter	2
Lutjanidae	*Lutjanus argentimaculatus*	river snapper	12
Sparidae	*Acanthopagrus berda*	riverbream	16 555
	Crenidens crenidens	white karanteen	2
	Rhabdosargus holubi	Cape stumpnose	151
	Rhabdosargus sarba	Natal stumpnose	8 791
Sciaenidae	*Argyrosomus japonicus*	dusky kob	7 517
	Johnius dorsalis	mini-kob	4 854
Leiognathidae	*Leiognathus equula*	slimy	35
Carangidae	*Caranx* spp.	kingfish	79
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	1 249
Mugilidae	*Mugil / Liza* spp.	unspecified mullet	16 346
Sphyraenidae	*Sphyraena* sp.	barracuda	1
total			84 360

The total monthly catch of *A. berda* caught in terms of numbers and mass is depicted in Figure 3.9. The number and mass of *A. berda* caught peaked between May 1996 and May 1997, with a maximum number of 1 447 *A. berda* caught in February 1997. The majority of these fish were caught in the southern part of False Bay (Nkundusi). On average, 6 151 *A. berda* specimens were caught per year in the gillnet fishery, which amounted to an average of 4mt.

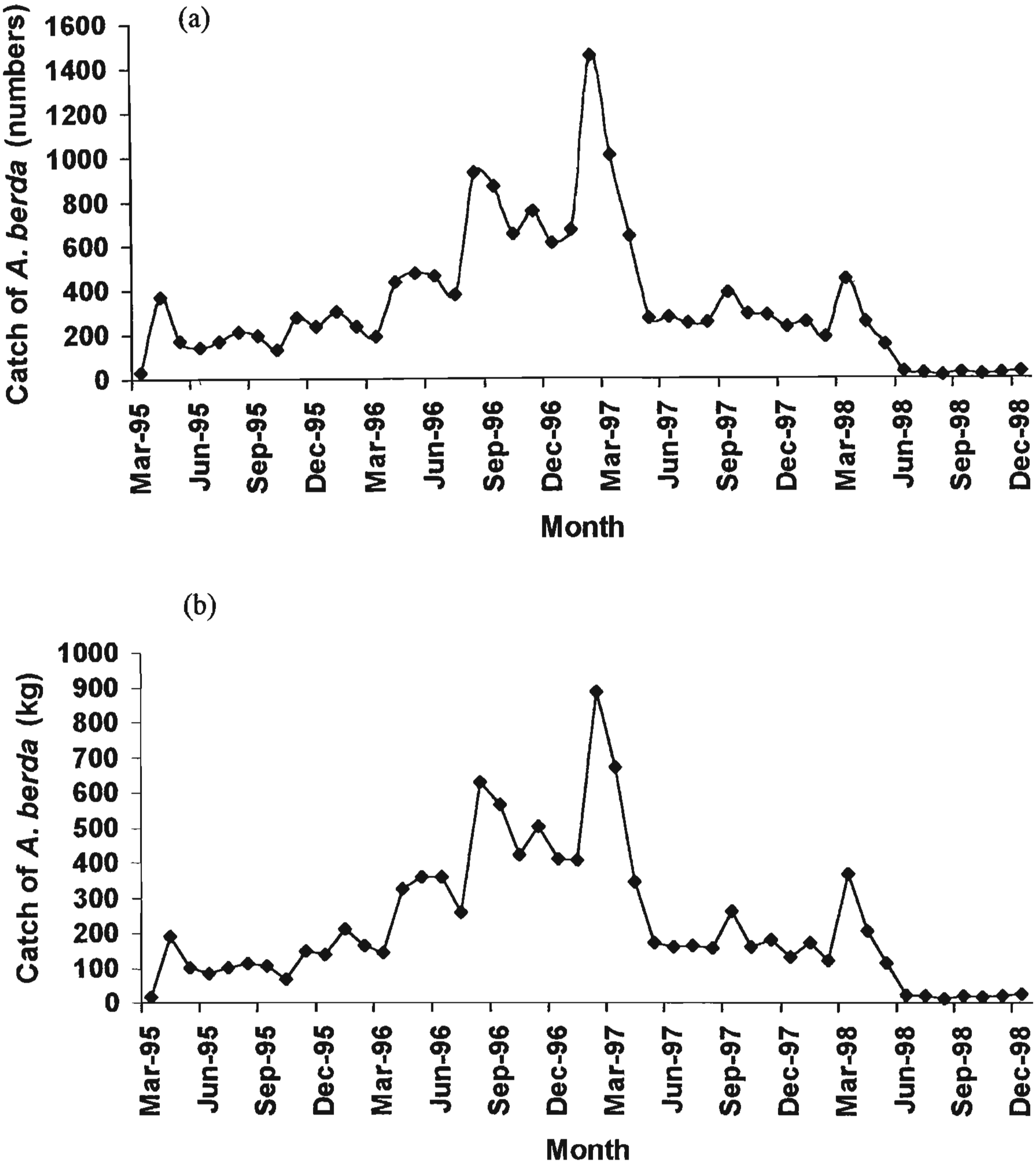


Figure 3.9. Total monthly catch of *A. berda* in terms of (a) numbers and (b) mass recorded in the St Lucia gillnet fishery between 1995 and 1998.

Catch per unit effort of A. berda

Figure 3.10 depicts average *cpue* (fish/net/night) for *A. berda* on a monthly basis in the gillnet fishery. *Cpue* in the lake was generally highest in the summer months prior to and after the mouthward migration, which takes place from May to August each year.

Average total monthly *cpue* for *A. berda,* depicted in Figure 3.11 was generally below 1.0 fish/net/night and the average *cpue* was 0.79 fish/net/night (S.D.=0.50). The peak in February 1997, coincided with decreased salinity in False Bay during this period. Regression analysis revealed a slight downward trend in *cpue* with time, but the study period was too short to reveal significant long-term trends in *cpue*.

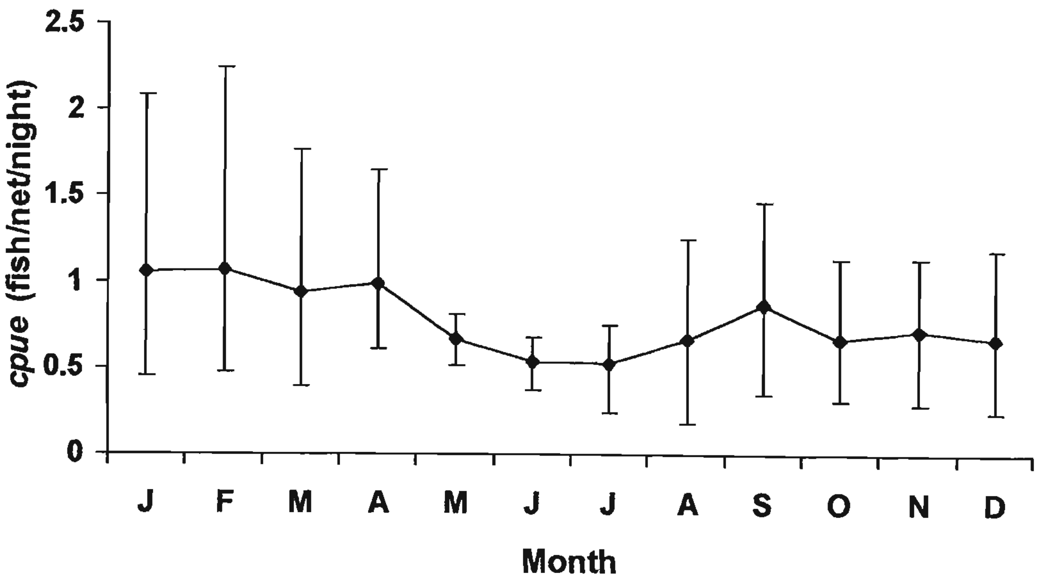


Figure 3.10. Mean monthly *cpue* for *A. berda* caught in the St Lucia gillnet fishery (March 1995 to March 1998).

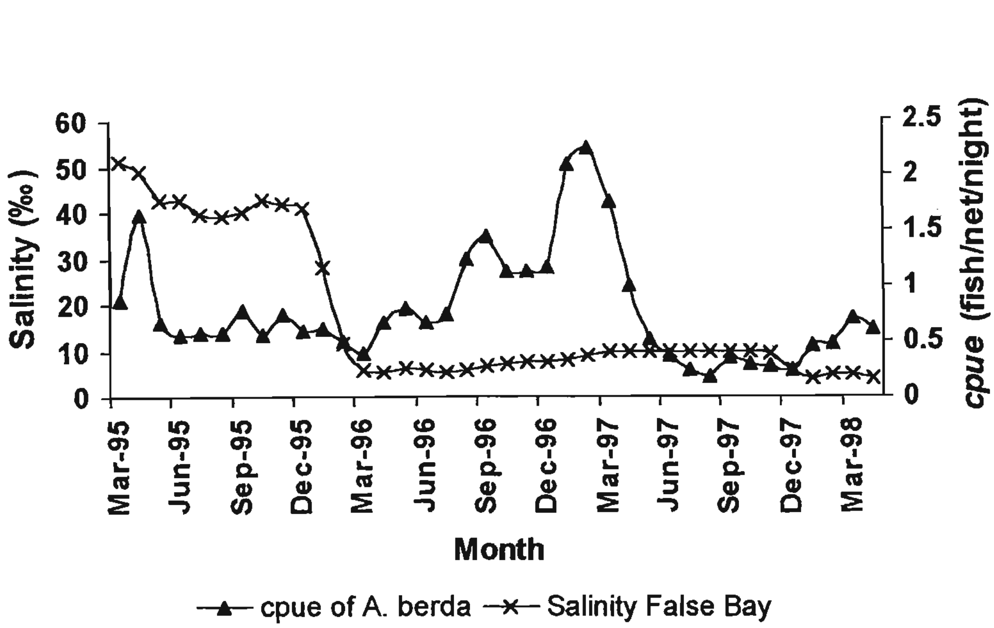


Figure 3.11. *Cpue* trends in the number of *A. berda* caught per month in the St Lucia gillnet fishery (March 1995 to March 1998) and monthly salinities measured in False Bay.

Length frequency distribution of A. berda

The length frequency of *A. berda* caught in the gillnet fishery is depicted in Figure 3.12. Most *A. berda* fell into the size range 200-360mm TL. Of the *A. berda* caught in the gillnets, 83% were ≥ the legal size limit of 250mm TL, and 89% were ≥ the length at 50% maturity (230mm TL). Length frequencies showed little variation on an annual basis, although the average length of fish caught in the nets increased slightly between 1995 and 1998 and a large percentage (25%) of the catch in 1997 consisted of *A. berda* of 320mm-330mm TL (Figure 3.13).

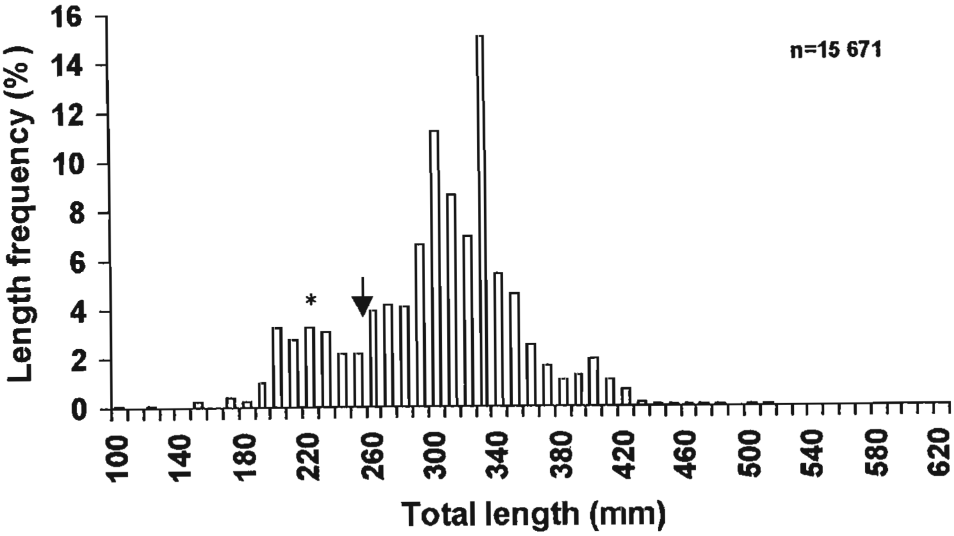


Figure 3.12. Length frequency distribution of all *A. berda* recorded from gillnets between March 1995 and March 1998 (The * depicts the size at 50% maturity and the arrow the minimum size limit).

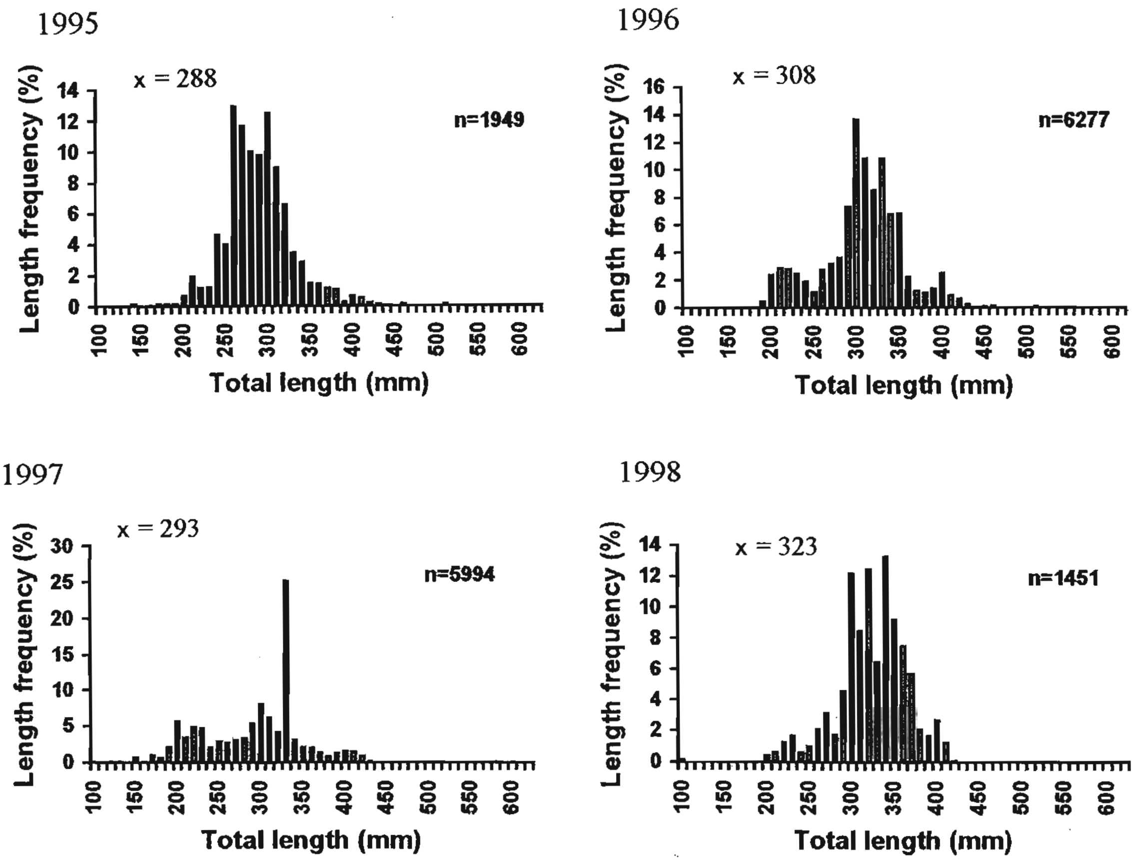


Figure 3.13. Length frequency distributions of *A. berda* caught in gillnets between 1995 and 1998 (x indicates the mean length of fish measured).

Discussion

The recreational fishery

St Lucia is one of the most popular angling destinations in the country, attracting thousands of anglers who fish from boats and who catch a considerable amount of fish. The annual catch taken by recreational boat anglers was estimated at approximately 63mt in 1993 (Mann *et al.* in press(b)). The recreational catch may now be even larger than this as angling effort is believed to be increasing at a rate of 2% per annum (McGrath *et al.* 1997). Despite a probable increase in angling effort in the system, the number of catch cards collected at St Lucia has declined. This decreasing trend is probably not linked to an actual decrease in angling effort but simply reflects diminishing effort in submission and collection of angling data. This trend is cause for concern and the conservation authority is urged to improve the collection of recreational catch and effort data in order to maintain monitoring of the recreational fishery in this world heritage site.

Anglers recorded a total of 55 species at St Lucia throughout the study period. The majority of these species were marine species, which are either estuarine-associated or estuarine-dependent to various degrees (Whitfield 1998). Only two freshwater species were recorded in catches, namely *Clarius gariepinus* (sharptooth catfish) and *Oreochromis mossambicus* (Mozambique tilapia). Catfish are only caught in False Bay and North Lake when the salinity is less than 5‰ (B. Mann, ORI, pers. obs.). Along with *A. japonicus*, *P. commersonnii*, *Rhabdosargus sarba*, *J.dorsalis* and *E. machnata*, *A. berda* was one of the most important species taken by recreational anglers.

The catch composition was slightly different in North and South Lake when compared with the estuary. In the estuary *A. berda* and *Pomadasys* spp. dominated the catches, while in the lakes *A. japonicus* was by far the most prominent species caught in terms of both numbers and mass, and very few *A. berda* were caught. Both *A. berda* and *P. commersonii* migrate through the estuary on a seasonal basis. *A. berda* aggregate and spawn in the mouth region between May and August (Garratt 1993a), while *P. commersonnii* migrate through the estuary in spring and early summer, to spawn in the inshore marine environment, before returning to the estuary in large numbers to feed (Wallace 1975a). In contrast, *A. japonicus* enter the system as juveniles and spread throughout the system, returning to the sea as sub-adults and there is no evidence of seasonality (Wallace 1975a).

The recorded catch composition (1986-1999) from St Lucia estuary was similar to that recorded during Natal Coastal Angling Union (NCAU) competitions held at St Lucia mouth between 1956 and 1976 (van der Elst 1977) where *A. japonicus*, *Pomadasys* spp., *Rhabdosargus* spp., *E. machnata* and *A. berda* were the most important euryhaline species taken. Between 1956 and 1976 NCAU competitions were fished by shore anglers both in the surf and along the bank of the first kilometre of the estuary and are, therefore, not directly comparable with light-tackle boat catch data reported on catch cards. Nevertheless, this broad comparison suggests that there has been relatively little change in species composition of the main species caught at St Lucia during the past 20 years.

The most important physical factor affecting the fish fauna in St Lucia is salinity, which fluctuates widely from year to year (van der Elst 1976). Salinity in the system ranges from as high as 80‰ to 100‰ during extreme droughts to as low as 0‰ during floods (Taylor 1993). The large surface area and shallow nature of the St Lucia system leads to high levels of evaporation, such that evaporation exceeds precipitation. Runoff from the catchment is required to compensate for this effect. During extended dry periods freshwater inflow into the system is considerably reduced, and the water level then drops to below sea level. Seawater then enters the system during high tides. The combination of increased salt-water input and continued evaporation results in hypersalinity (Wallace 1975a).

Fluctuations in *cpue* for *A. berda* and other angling species in St Lucia were found to be closely related to salinity of the lake and the state of the estuary mouth (Mann *et al.* in press(b)). Catches of *A. berda* increased during periods of low salinity, and also after floods and periods of mouth closure. Floods in September 1987 resulted in scouring of the estuary mouth, with associated reduction in salinity and increased turbidity, and it is likely that good recruitment followed this event (Harris and Cyrus 1996). *Cpue* for *A. berda* also increased in 1994, after a ten-month period of mouth closure. Wallace (1975a) attributed increases in fish abundance in the estuary during periods of mouth closure to seaward movement of fish from the lake. As fish abundance is obviously related to mouth condition and prevailing salinities, maintaining adequate freshwater inflow and ensuring that the entire system continues to function as an estuary are considered to be of prime importance in the management of St Lucia's fish resources (Mann *et al.* in press(b)).

Despite annual fluctuations in *cpue*, regression analysis revealed a slight increase in *cpue* for *A. berda* (although this was not significant). Percentage contribution of *A. berda* to the total catch at St Lucia has also shown an increasing trend. This was interesting as van der Elst (1977) reported a decline in *cpue* for *A. berda* in the estuary between 1956 and 1976. *Cpue* for *A. berda* has shown a declining trend in Kosi Bay, which by comparison to St Lucia has suffered little estuarine degradation (James *et al.* 2001).

The shore-based catch determined from KZNW patrols in the estuary, was similar to the boat-based catch in the estuary, in that *A. berda* and *P. commersonnii* were the most important species caught by number. However, the shore angling catch was more varied and a number of other species together contributed a large percentage of the catch.

The gillnet fishery

Gillnetting in St Lucia has been extremely difficult to control as it occurs in remote areas of the lake, around the tribal areas of Mduku, Nkundusi and Nibela. Attempts to regulate the fishery, by establishing a small subsistence fishery, were largely unsuccessful owing to a lack of compliance by netters and demands for commercialization of the fishery (Mann in press). Illegal netting in the system is still rife, and it is believed that catches taken by illegal netters are much greater than catches taken in the recreational fishery. In 1992 it was estimated that between 91 and 135 mt of fish were caught by illegal netters per annum. Using the mean value (113 mt) it is estimated that at least 11.3mt of *A. berda* are caught by illegal netters per annum, which is substantially more than the 3.8mt estimated to be caught by recreational anglers per annum.

In order to reduce the overlap between the recreational and gillnet sectors an attempt was made to target the experimental gillnet fishery on detritivorous species such as mugilids, which are lightly exploited by recreational anglers. Analysis of the St Lucia experimental fishery showed that of the 23 species caught, at least 14 were also frequently caught by recreational anglers. This high species overlap between the two fishery sectors has thus placed increased fishing pressure on the important linefish species in the system.

Although the legal gillnets did catch many recreational species such as *A. berda* and *P.commeronnii*, they were fairly selective for larger fish, and fish <200mm TL were rarely caught. Of the *A. berda* caught in the gillnets, 83% were found to be ≥ the minimum size limit in the recreational fishery (250 mmTL), and 89% were ≥ the size at 50% maturity (230mm TL). The overall mean length recorded in the gillnet fishery was 301mm TL. The St Lucia gillnets were found to catch fewer undersized *A. berda* than the Kosi Bay gillnets, in which 35% of the *A. berda* caught were less than the legal limit. This is probably because a minimum mesh size of 90mm stretched mesh was stipulated for the St Lucia fishery, whereas no mesh size specifications are stipulated for the Kosi Bay gillnet fishery.

Cpue for *A. berda* was generally highest in the summer months, prior to and after the spawning season. This was probably due to migration of mature *A. berda* into the estuary, from the lakes, before the spawning season and return migration of spent *A. berda* to the lakes, after the spawning season. Wallace (1975a) found that *A. berda* catches in the estuary narrows increased from May to July.

As in the recreational fishery, *cpue* for *A. berda* in the gillnets was closely correlated with salinity, as peak gillnet catches coincided with periods of low salinity. The three year study of the experimental gillnet fishery was too short to reveal long term trends in *cpue*.

Concluding remarks

It is apparent from this study that while large numbers of *A. berda* are caught by recreational anglers in St Lucia, substantially more are caught by illegal netters in this system. Illegal netting is a persistent problem which needs to be addressed. Even in the absence of downward trends in *cpue* for *A. berda,* in the recreational and gillnet fisheries, it is well known that overall fish catches at St Lucia have declined significantly in recent years, and that fishing has had a considerable impact on estuarine-dependent linefish species (Mann *et al.* in press(b)). A previous study at Lake St Lucia (van der Elst 1977) already pointed to a significant decline in catches of *A. berda* in the system. Fishing effort in both the recreational and gillnet fisheries have subsequently increased and it is likely that current levels of harvesting may be having a detrimental effect on the *A. berda* population in Lake St Lucia, particularly during periods of high lake salinity.

CHAPTER FOUR

RICHARDS BAY FISHERIES

Introduction

Richards Bay, located at $28^0 49$'S and $32^0 05$'E on the KwaZulu-Natal north coast, was first described by Portuguese sailors in the 15^{th} century, who named it Rios dos Peixos, which means river of many fish (Harris and Cyrus 1997). The original system, depicted in Figure 4.1, was described as a typical Natal estuary, as it was large and shallow (the average depth was 0.3-0.6 m) with a muddy bottom, high turbities, moderate salinities and a shallow exit to the sea (Millard and Harrison 1954; Day *et al.* 1981; Harris and Cyrus 1997). It acted as a nursery area for juvenile prawns and estuarine-associated fish species, as well as providing an important foraging area for adult fish, especially from the families Haemulidae and Sparidae. Consequently, Richards Bay was one of the richest fishing estuaries in Natal (Millard and Harrison 1954). However, in the early 1970s the construction of a deep-water harbour was started at Richards Bay. The estuarine system was divided into two sections by a 4km levee (Figure 4.2) and the shallow mouthed estuary was completely transformed by dredging and the construction of quays (Begg 1978).

In order to conserve part of the estuarine system and to prevent the silt load from the Mhlathuze River from entering the harbour, the southern section, which comprised one third of the original system, was left relatively undisturbed and proclaimed as a nature reserve or sanctuary area (Mann *et al.* 1998). The Mhlathuze river, which fed the original system, was diverted and opened to the sea via a new mouth. The Mhlathuze estuary has subsequently become a delta of the Mhlathuze river, with distributory channels winding through mangroves and over mud flats (Day *et al.* 1981).

The northern side is now a dredged deep-water harbour, in which considerable harbour and industrial development has taken place (Begg 1978). Richards Bay is now the largest harbour in the country, in terms of available area and volumes of cargo handled. Richards Bay is the largest exporter of coal in the country, although other products such as wood chips, rock phosphate, chrome ore and titania slag are exported (Enslin 2001). The old mouth was modified extensively and dredged to a depth of 24m (Brackenbury 1991). Dredging of the mouth increased tidal exchange, which resulted in increased salinities and decreased turbidities and thus a more marine dominated system (Harris and Cyrus 1997). The harbour now covers an area of 1 443 ha (the original system covered 3 000ha). Despite massive physical changes to the system, the harbour and sanctuary areas are still being utilised by many estuarine-associated species. About 80 species of fishes have been recorded in the Mhlathuze estuary in recent years (Weerts and Cyrus 1999).

The fish resources are utilised by both recreational anglers and subsistence gillnetters. Recreational angling takes place in the harbour, both from boats and from the shore, and catches of shore-anglers are monitored by KZNW shore patrols. Although gillnetting and seine netting occurs illegally in the Mhlathuze estuary, an attempt was made to legalise the fishery in 1996. KZNW issued five 30m gillnet permits to netters operating in the sanctuary, and monitored their catches. However, monitoring of catches only lasted for approximately two years and the quality of these data was very poor. The permits have subsequently been withdrawn (1998) although illegal gillnetting persists in the system.

This chapter provides an analysis of catches taken by shore-based recreational anglers in the harbour, based on KZNW shore patrol data, and an analysis of the catches made by the temporarily legal gillnet fishery, based on KZNW monitoring data.

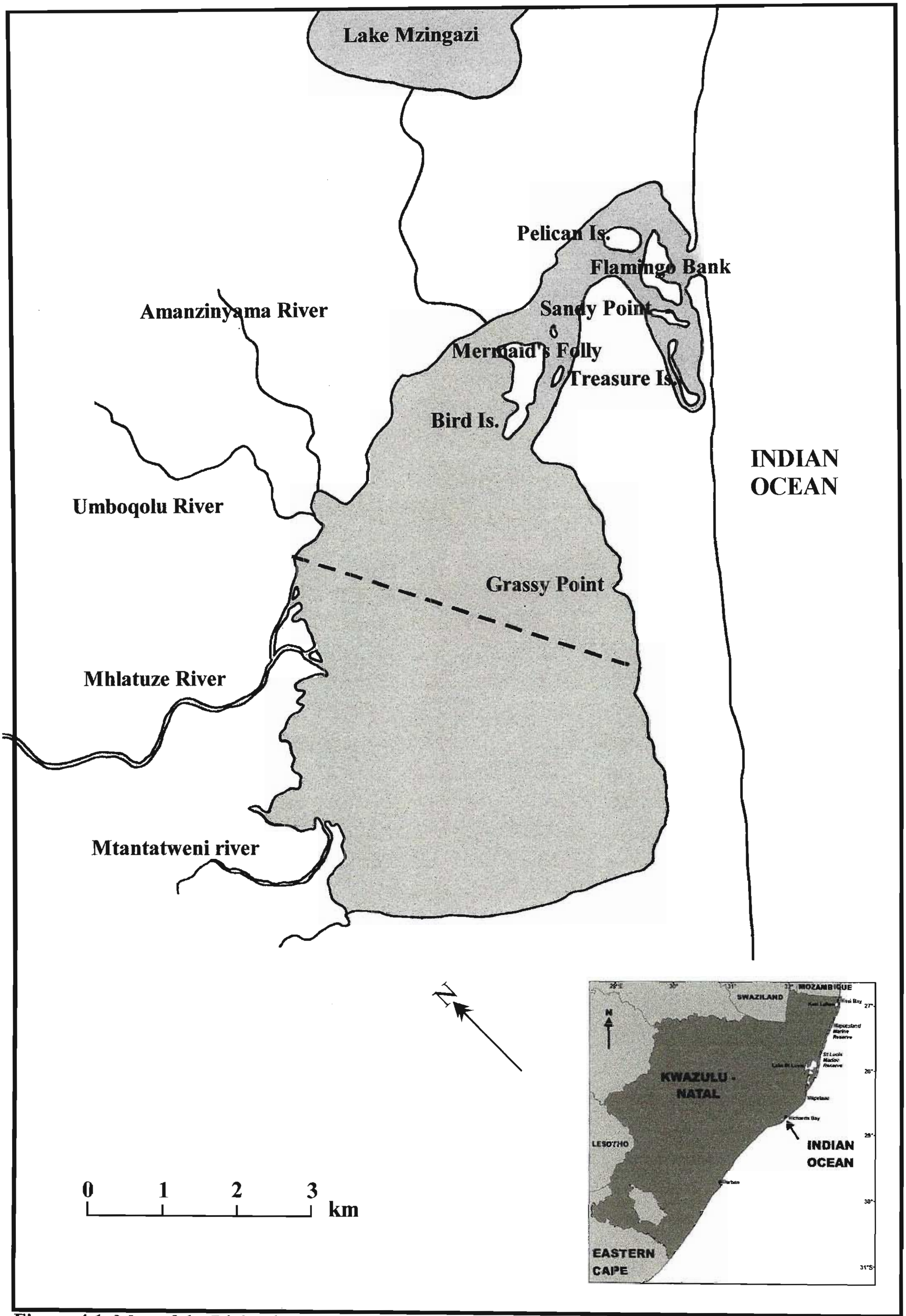


Figure 4.1. Map of the Richards Bay estuary prior to harbour development (1964).

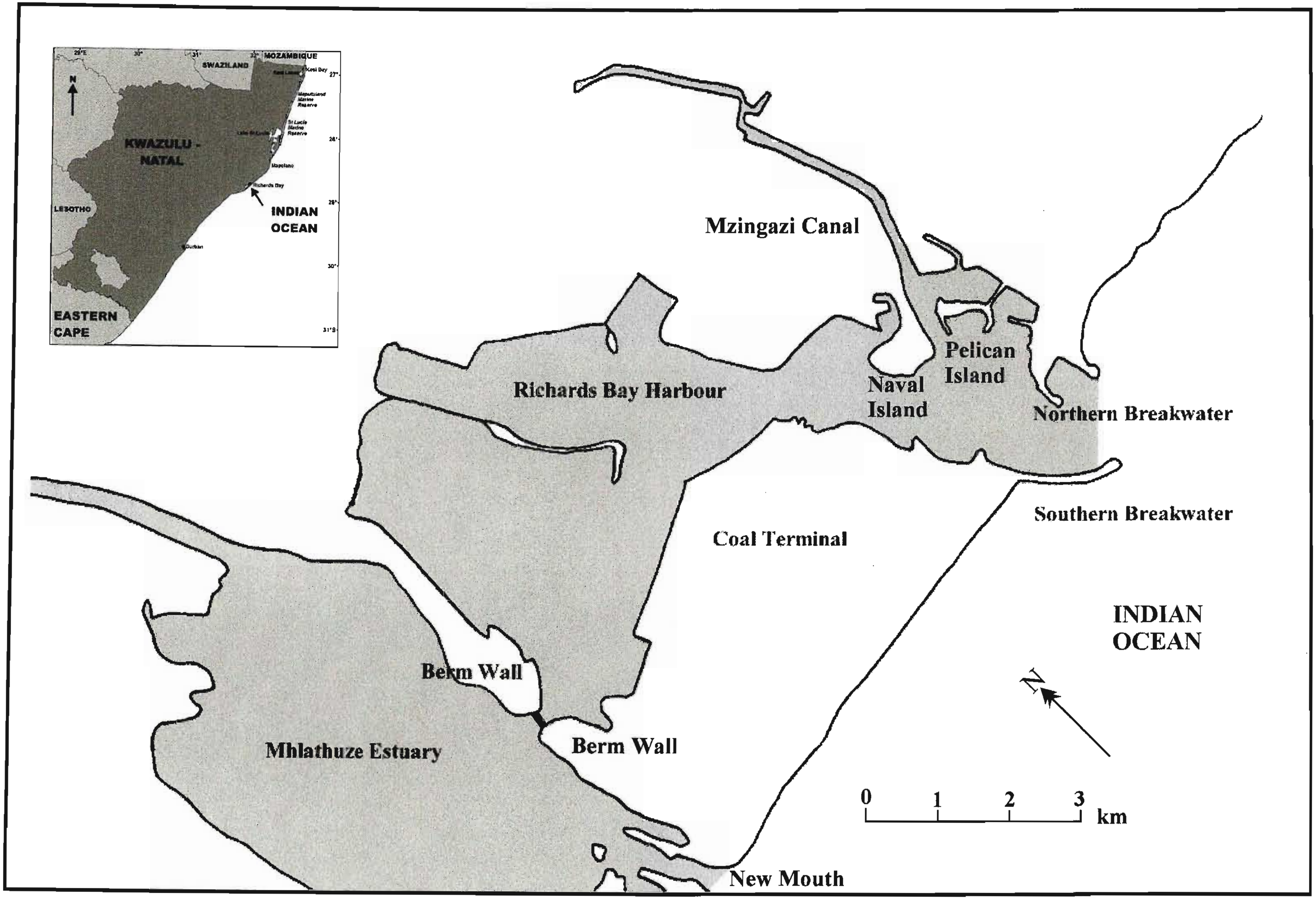


Figure 4.2. Map of the Richards Bay harbour and Mhlatuze Estuary post development (2001).

Methods

The recreational fishery

NMLS shore patrol data from 1991 to 2000 were analysed to determine catch composition and the percentage contribution of *A. berda* to the total catch. Effort data (i.e. the number of hours fished) have only been collected since 1998, and as a result only three years (1998-2000) were analysed for *cpue* information.

The gillnet fishery

In order to assess the sustainability of the experimental gillnet fishery in Richards Bay monitors were employed by KZNW between November 1996 and February 1998. Data recorded by monitors included the date, duration of netting, species and numbers caught. Total lengths (mm) were also measured, but these were highly inaccurate as most *A. berda* were reportedly between 800mm TL and 900mm TL. In order to prevent seasonal bias only the data for January 1997 to December 1997 were analysed to determine catch composition and *cpue* for *A. berda.*

Results

The recreational fishery

Angling effort

The number of KZNW patrols undertaken around Richards Bay harbour (estuarine patrols) has increased substantially since 1986 (Figure 4.3) and by 2000, this number exceeded 700. Owing to the limited amount of data available prior to 1991, the data were only analysed from 1991 onwards.

Catch composition

A wide diversity of marine and estuarine fishes (sharks and teleosts) was recorded in anglers catches from 1991 to 2000 (Table 4.1). *Pomatomus saltatrix* was the most frequently caught species, comprising 31% of the total catch, followed by *Pomadasys* spp., which comprised 19% of the total catch (Figure 4.4). *Pomadasys* spp. include *P. kakaan*, *P. commersonnii*, *P. multimaculatum* and *P. olivaceum*, although *P. olivaceum* and *P. commersonnii* dominated catches. A substantial proportion of the catch (21%) was made up by a large number of different species, with few individuals of each species. *A. berda* comprised only 2% of the recorded shore-angling catch in Richards Bay harbour.

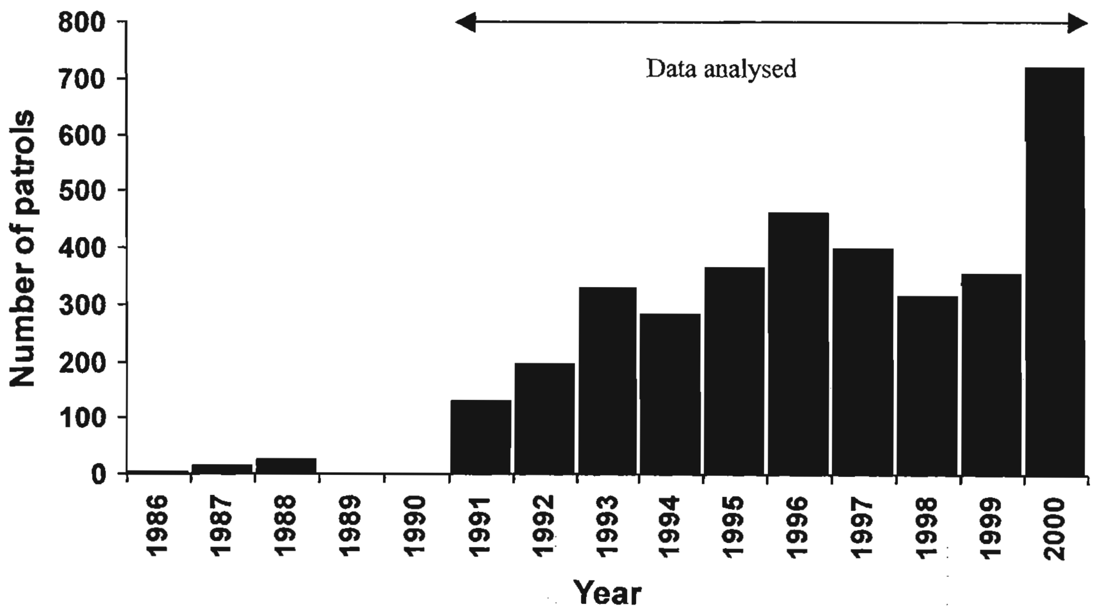


Figure 4.3. The number of shore patrols undertaken by KZNW officers around Richards Bay harbour between 1986 and 1991.

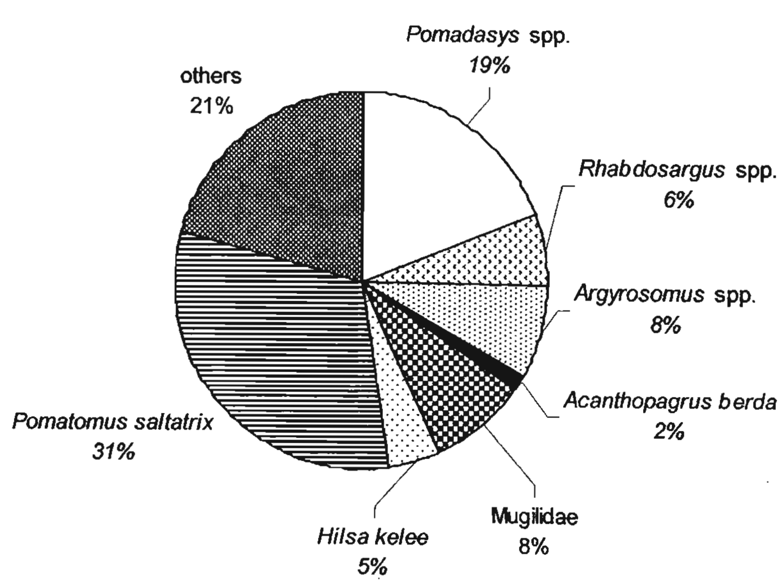


Figure 4.4. The percentage contribution by major species to the total catch (numbers) documented by KZNW shore patrols between 1991 and 2000 in Richards Bay harbour.

Table 4.1. Species recorded during KZNW shore patrols in Richards Bay harbour between 1991 and 2000.

Family	Scientific name	Species name	Number
Elasmobranchs			
Carcharhinidae	*Carcharhinus limbatus*	blackfin shark	15
	Carcharhinus obscurus	dusky shark	353
	Rhizoprionodon acutus	milk shark	57
	Carcharhinus leucas	zambezi shark	3
Sphyrnidae	*Sphyrna* spp.	hammerhead shark	17
Lamnidae	*Carcharodon carcharias*	great white shark	5
Rhinobatidae	*Rhinobatus annulatus*	lesser sandshark	19
	Rhynchobatus djiddensis	giant guitarfish	5
Dasyatidae	*Himantura uarnak*	honeycomb stingray	17
	Dasyatis marmorata chrysonota	blue stingray	1
	Gymnura natalensis	diamond ray	9
	Himantura gerrardi	brown stingray	25
		unspecified elasmobranchs	119
Teleosts			
Elopidae	*Elops machnata*	tenpounder	43
Albulidae	*Albula vulpes*	bonefish	14
Muraenidae	*Thyrsoidae macrura*	Slender giant moray	1
Muraenesocidae	*Muraenesox bagio*	pike conger eel	39
Clupeidae	*Hilsa kelee*	kelee shad	990
Chanidae	*Chanos chanos*	milkfish	7
Clariidae	*Clarius gariepinus.*	freshwater barbel	1
Ariidae	*Galeichthys* sp.	barbel	5
Plotosidae	*Plotosus nkunga*	eel barbel	4
Belonidae	*Strongylura leiura*	yellowfin needlefish	7
Zeidae	*Zeus faber*	John dory	1
Platycephalidae	*Platycephalus indicus*	bartail flathead	158
Serranidae	*Epinephelus andersoni*	catface rockcod	139
	Epinephelus marginatus	yellowbelly rockcod	13
	Epinephelus rivulatus	halfmoon rockcod	1
	Epinephelus spp.	unspecified rockcod	36
Teraponidae	*Terapon jarbua*	thornfish	126
Pomatomidae	*Pomatomus saltatrix*	elf	6 741
Haemulidae	*Plectorhinchus* sp.	unspecified rubberlip	1
	Pomadasys commersonnii	spotted grunter	1 857
	Pomadasys furcatum	grey grunter	1
	Pomadasys kaakan	javelin grunter	39
	Pomadasys multimaculatum	cock grunter	35
	Pomadasys olivaceum	pinky	2 141
	Pomadasys spp.	unspecified grunter	122
Dinopercidae	*Dinoperca petersi*	lampfish	253
Lutjanidae	*Lutjanus rivulatus*	speckled snapper	1
	Lutjanus russellii	Russel's snapper	12
	Lutjanus argentimaculatus	river snapper	34
	Lutjanus sp.	unspecified snapper	1
Sparidae	*Acanthopagrus berda*	riverbream	371

	Cheimerius nufar	santer	11
	Chrysoblephus puniceus	slinger	12
	Diplodus cervinus hottentotus	zebra	22
	Diplodus sargus capensis	blacktail	716
	Lithognathus mormyrus	sand steenbras	1
	Pachymetopon grande	bronze bream	5
	Polyamblyodon germanum	german	32
	Polysteganus undulosus	seventyfour	1
	Rhabdosargus holubi	Cape stumpnose	193
	Rhabdosargus sarba	Natal stumpnose	1 025
	Rhabdosargus thorpei	bigeye stumpnose	19
	Rhabdosargus spp.	unspecified stumpnose	60
	Sarpa salpa	strepie	323
Lethrinidae	*Lethrinus nebulosus*	blue emperor	4
	Lethrinus sp.	unspecified emperor	1
Coracinidae	*Caracinus multifasciatus*	banded galjoen	1
Scorpidae	*Neoscorpis lithophilus*	stonebream	84
Ephippidae	*Tripterodon orbis*	spadefish	5
Monodactylidae	*Monadactylus falciformis*	Cape moony	61
Gerreidae	*Gerres* spp.	pursemouth	8
Drepanidae	*Drepane longimanus*	concertina fish	86
Mullidae	*Parupeneus* sp.	goatfish	1
Sillaginidae	*Sillago sihama*	silver sillago	113
Sciaenidae	*Argyrosomus japonicus*	kob	790
	Argyrosomus thorpei	squaretail kob	953
	Johnius dorsalis	mini-kob	21
	Otolithes ruber	snapper kob	208
	Umbrina canariensis	baardman	2
		unspecified kob	78
Lobotidae	*Lobotes surinamensis*	tripletail	1
Carangidae	*Alectis ciliaris*	threadfin mirrorfish	9
	Alectis indicus	indian mirrorfish	5
	Alectis spp.	unspecified mirrorfish	2
	Caranx ignobilis	giant kingfish	6
	Caranx papuensis	brassy kingfish	1
	Caranx sem	blacktip kingfish	3
	Caranx sexfacsciatus	big-eye kingfish	3
	Caranx spp.	unspecified kingfish	179
	Decapterus russelli	indian scad	2
	Lichia amia	leervis	193
	Megalaspis cordyla	torpedo scad	28
	Scomberoides tol	needlescale queenfish	6
	Scomberoides spp.	unspecified queenfish	112
	Trachinotus africanus	southern pompano	39
	Trachinotus botla	largespot pompano	90
Cichlidae	*Oreochromis mossambicus*	Mocambique tilapia	4
Labridae		unspecified wrasse	4
Scaridae	*Scarus* spp.	parrotfish	2
Mugilidae	*Liza/Mugil* spp.	unspecified mullet	1 849
Sphyraenidae	*Sphraena* sp.	barracuda	1

	Sphyraena jello	pickhandle barracuda	5
Trichiuridae	*Trichiurus lepturus*	cutlass fish	333
Scombridae	*Scomber japonicus*	mackerel	2
	Scomberomorus commerson	king mackerel	5
	Scomberomorus plurilineatus	queen mackerel	3
	Euthynnus affinis	eastern little tuna	5
	Rastrelliger kanagurta	Indian mackerel	9
	Sarda orientalis	bonito	2
Balistidae		unspecified triggerfish	1
Tetraodontidae	*Amblyrhynchotes honckenii*	evileye blaasop	30
		unspecified teleosts	224
Total			21 833

The percentage contribution of *A. berda* to the annual catch is depicted in Figure 4.5. The percentage of *A. berda* in the catch peaked in 1992, when *A. berda* contributed 4.9% to the catch by numbers, but since then *A. berda* has only contributed between 0.7% to 1.9% of the total catch.

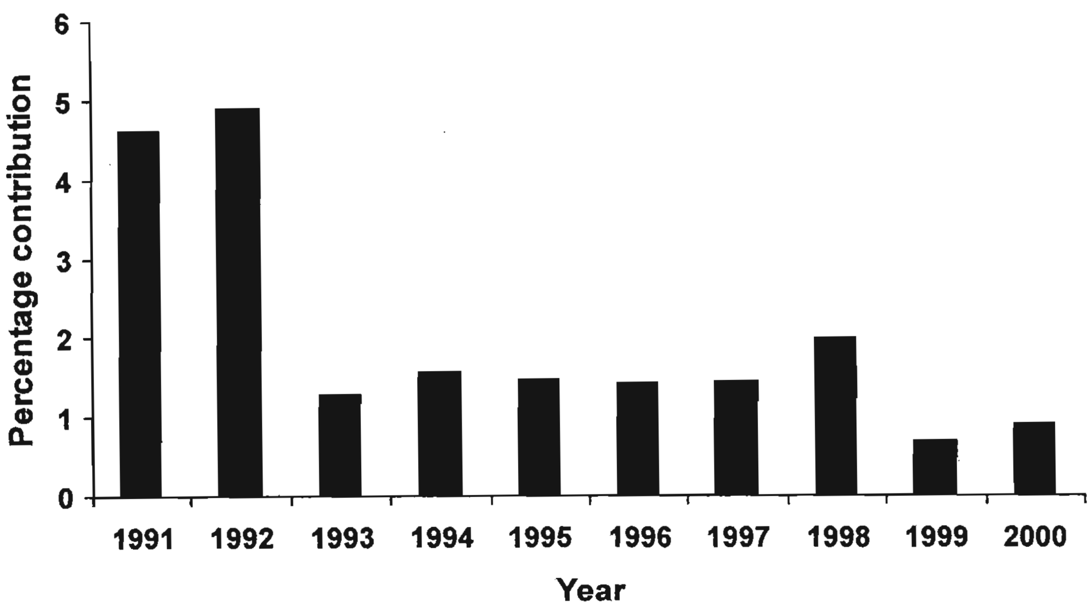


Figure 4.5. The percentage contribution of *A. berda* to the total catch documented by shore patrols in Richards Bay harbour between 1991 and 2000.

The mean monthly percentage contribution of *A. berda* to the total catch between 1991 and 2000 is depicted in Figure 4.6. It is evident that despite variation in the data, highest catches of *A. berda* were generally made between March and May, and again in August.

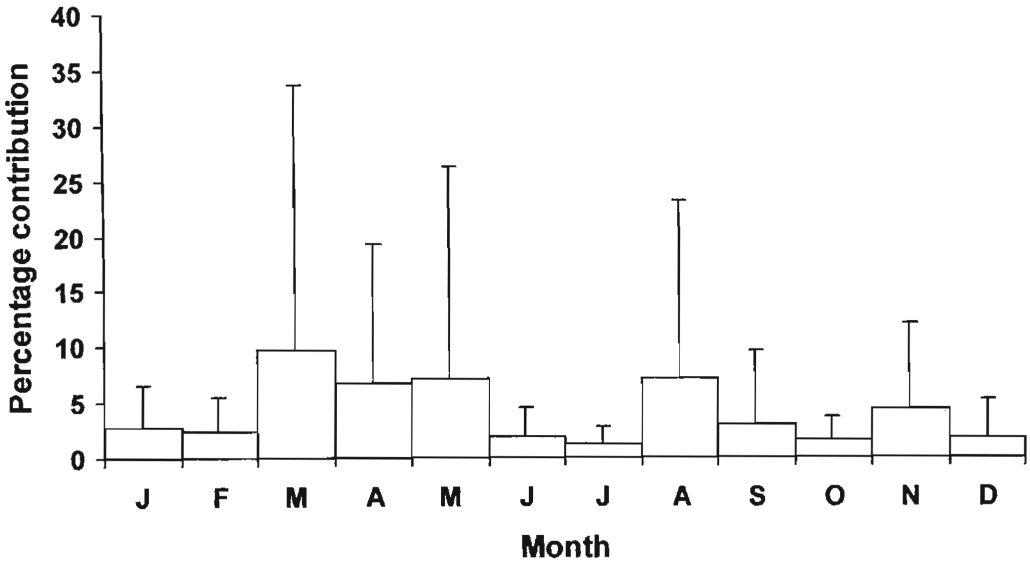


Figure 4.6. Mean monthly percentage contribution of *A. berda* to the total catch documented by shore patrols in Richards Bay harbour between 1991 and 2000; error bars are standard deviation of mean.

Catch per unit effort (cpue)

The mean *cpue* for all species caught by recreational anglers was 0.0875 fish/angler/h (S.D.=0.02) (Table 4.2). *Cpue* for *A. berda* was highest in 1998, at 0.0014 fish/angler/h. However, the differences in *cpue* between years were minimal, as so few *A. berda* were recorded. The mean *cpue* for *A. berda* was 0.000921 fish/angler/h (S.D.=0.0004).

Table 4.2. Catch per unit effort by recreational anglers obtained from KZNW shore patrols in the Richards Bay harbour between 1998 and 2000.

Year	Total fish recorded	*A. berda* recorded	Monitored effort (hrs)	Total *cpue* (fish/angler/h)	*Cpue* for *A. berda* (fish/angler/h)
1998	757	17	12156.25	0.0653	0.00140
1999	947	7	11101.9	0.0937	0.00063
2000	930	17	23218.15	0.1034	0.00073
Mean	878	13.7	15492.1	0.0875	0.00092

The gillnet fishery

Catch composition

No single species dominated catches made by the gillnet fishers in the Mhlatuze estuary (Richards Bay Nature Reserve) (Figure 4.7). Mugilidae contributed 19% by number, with *A. berda, P. kaakan*, and *A. japonicus* each contributing 11%. *P. commersonnii, P. indicus, P. saltatrix, E. machnata* and *Rhabdosargus* spp. also contributed significantly, with the remaining 3% made up of unidentified species.

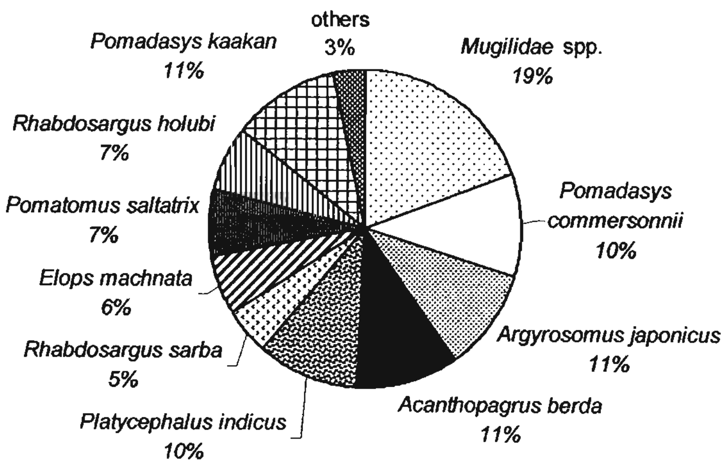


Figure 4.7. The percentage contribution (numbers) of fish species in the Mhlatuze estuary gillnet fishery between January 1997 and December 1997.

Catch per unit effort for A. berda

Cpue on a monthly basis, depicted in Figure 4.8, indicated that the catch rate for *A. berda* increased in the winter months of June, July and August but was also high in January. The mean *cpue* for the study period was 0.032 fish/net/night (S.D.=0.025).

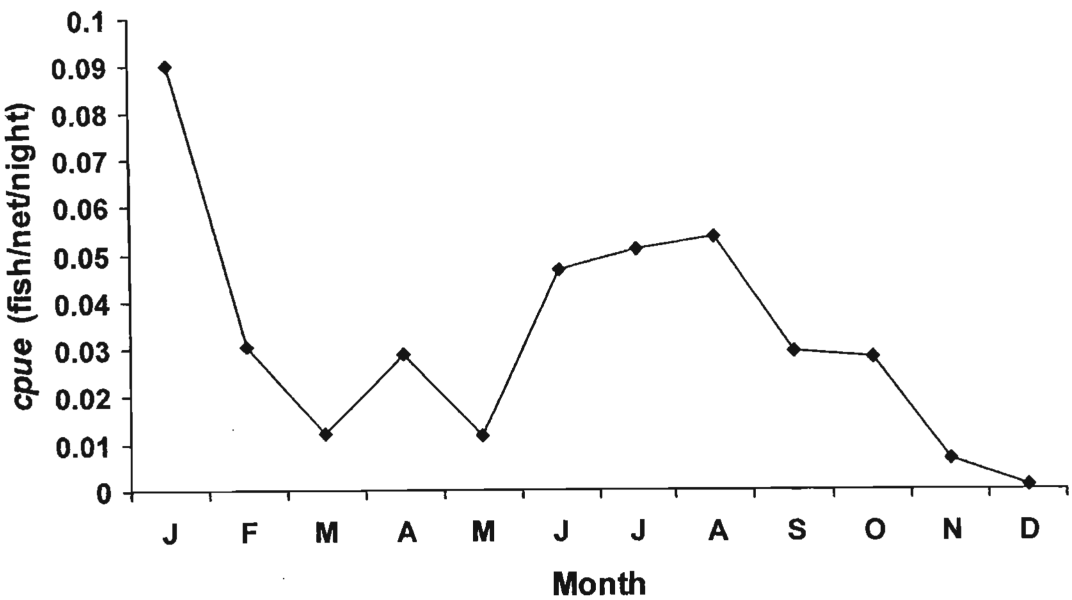


Figure 4.8. Mean monthly *cpue* for *A. berda* caught in the Mhlathuze estuary gillnets between January 1997 and December 1997.

Discussion

The recreational fishery

A total of 94 species of fishes, comprising 43 families was recorded from shore anglers' catches in Richards Bay harbour, which was far greater than in St Lucia, Kosi Bay and even Durban harbour, where 85 species were recorded in shore-anglers catches (Gaustella 1994; Pradervand *et al.* submitted). This diversity of species is due to the marine nature of the harbour, which can now be considered an embayment rather than an estuary (Whitfield 1998). Richards Bay is one of three coastal bays in South Africa, the others being Durban harbour and Knysna, and one of two bays in the subtropical zone. Development of Richards Bay into a harbour resulted in an increase in the tidal range in both the harbour and the estuary, so that the harbour now supports a largely marine fish fauna, as opposed to an estuarine fish fauna (Begg 1978; Whitfield 1998). This is evident by the large variety of sharks which are caught in the harbour, including the great white shark, *Carcharodon carcharias.* Many of the fish species recorded were caught off the breakwaters (e.g. *Pomatomus saltatrix*, and several reef species), that extend out into the sea. Several of the species recorded in catches are more commonly taken from boats fishing at sea.

A. berda, which is an estuarine-associated species, was fairly insignificant in catches of shore-anglers in the harbour, as it comprised only 2% of the catch by numbers between 1991 and 2000. This percentage is probably an overestimate, as high catches of *A. berda* in 1992 (when it contributed 5% to the catch) increased this value. Between 1993 and 2000 *A. berda* only contributed between 0.7% to 1.9% to the total catch. Anglers do, however, target *A. berda* in the more estuarine parts of the harbour such as Mzingazi Canal (L. Beckley, ORI, pers. comm.)

The marine species *Pomatomus saltatrix* was the dominant species in the catch, contributing 31% of the catch. Marine species such as *P. saltatrix* are targeted in the entrance channel of the harbour, which is wide and deep. In Durban harbour, marine species, such as *P. saltatrix* and *S. salpa*, were also caught close to the harbour entrance, but they made up a much smaller percentage of the total shore-based catch (Gaustella 1994; Pradervand *et al.* submitted). The number of *P. saltatrix* in the catch may be an overestimate, as van der Walt (1995) found that shore-patrol data is often biased in the favour of *P. saltatrix*, as the primary aim of KZNW shore patrols is enforcement of regulations, particularly for those regarding *P. saltatrix*.

A variety of *Pomadasys* spp. (predominantly *P. commersonni* and *P. olivaceum*) also contributed significantly to the catch. Richards Bay is one of the only estuarine systems, apart from Durban harbour, in which *P. olivaceum* features prominently in catches. *P. olivaceum* is primarily a marine species which is able to utilise coastal bays as they are more marine in nature than typical estuaries. Stenohaline marine fishes utilising the mouth regions of coastal bays increase the species richness in these systems (Whitfield 1998).

As only small numbers of *A. berda* are caught in the harbour, the *cpue* for this species was very low (the average *cpue*=0.000921 fish/angler/h) and it was difficult to determine any significant long-term trends in *cpue*. The total *cpue* for the system (0.0875 fish/angler/h) was slightly higher than that recorded in Durban harbour, where Pradervand *et al.* (submitted) estimated *cpue* in the shore-based fishery at 0.071 fish/angler/h.

As was found in St Lucia and Kosi Bay catches of *A. berda* generally increased during the spawning season, and may provide evidence that *A. berda* spawn in the harbour despite the disturbed nature of this system.

The gill net fishery

The Mhlathuze estuary was designed to preserve part of the original estuarine system. However, opening of the new mouth resulted in a substantial increase in tidal exchange in the system, so that an estimated 88% of the water in the estuary is exchanged during each tidal cycle (Day *et al.* 1981). Construction of the levee and elimination of reed swamps also resulted in large volumes of sediment being deposited in the estuary (Weerts and Cyrus 1999). Despite extensive physical changes to the system, it is still considerably more estuarine in nature than the harbour, and has the largest stand of mangroves in South Africa (Mann *et al.* 1998). As a consequence, estuarine-associated species dominate the icthyofauna of the Mhlathuze estuary (Weerts and Cyrus 1999).

Gillnet catches in the sanctuary were comprised largely of estuarine-associated species and, as such, *A. berda* featured much more prominently in gillnet catches, than in the shore-based harbour catches. *A. berda* contributed 11% to the catch by numbers, although unidentified Mugilidae as a family comprised the largest percentage of the catch. As in the harbour, catches of *A. berda* increased during the spawning season, from June to August and also in January.

The mean *cpue* for the study period was 0.04 fish/net/night, which was much less than the 0.79 fish/net/night, recorded in the St Lucia system, indicating that *A. berda* are probably less abundant in the Mhlathuze estuary, which has been substantially altered by man. This can be largely attributed to the drainage and canalisation of the Mhlathuze swamp for the planting of sugarcane. This swamp acted as an important filter which reduced siltation of the estuary. Furthermore, it is estimated that two thirds of the sanctuary area is exposed at low tides, and the remainder is very shallow (Branch and Branch 1981). Reduction of available habitat may, therefore, have reduced the abundance of fish populations in this system, particularly estuarine-dependent species such as *A. berda*.

Concluding remarks

Overall, relatively little is known about fish catches in the Richards Bay system, as they are only monitored by KZNW shore patrols, which are undertaken primarily for law enforcement. Considerable catches are made from boats in the harbour, which are not monitored, apart from occasional boat inspections. Estuarine bays are fairly unique systems, in that they attract not only estuarine-associated marine species, but also many marine stragglers, and as such they have a larger diversity of fish species than any other estuarine type (Whitfield 1998). Although work has been done on the fisheries of Durban harbour (Gaustella 1994; Pradervand *et al.* submitted), Richards Bay remains poorly studied. Richards Bay is a relatively recent harbour (built in the mid 1970s), and is located in a growing industrial node with associated population increase. Consequently, fishing as a recreational activity is becoming increasingly popular in Richards Bay. A more detailed study of the recreational fishery in Richards Bay is currently being undertaken by ORI, and this study will provide more insight into the importance of *A. berda* to recreational angling in the harbour.

Although *A. berda* is not important in shore-based harbour catches, they are being caught in large numbers in the Mhlathuze estuary, which is more estuarine in nature than the harbour. Monitoring of the gillnet fishery has stopped, but this illegal fishery continues in this protected area and serious consideration should be given to the future management of this system.

CHAPTER FIVE

AGE AND GROWTH OF *ACANTHOPAGRUS BERDA*

Introduction

In order to undertake a stock assessment, and thus determine the harvest that a fish stock can sustain, it is necessary to determine the age structure and growth rate of the species (Gulland 1983). Fast growing, short-lived species are usually able to sustain more fishing pressure than slow-growing, long-lived species, which mature later in life (Musick 1999).

The age of many animals, including fish, can be determined by examining hard tissues, such as scales, otoliths, bones and teeth, which show growth patterns related to changes in somatic growth rate (Jearld 1983). Previous studies have found that in sparid fishes, otoliths are the best structures for age determination (Smale and Punt 1991; Buxton and Clarke 1992; Bennett 1993; Mann and Buxton 1997; Chale-Matsau *et al.* 2001). The otoliths or earbones of fish are part of the auditory-equilibrium organ, known as the labyrinth. The labyrinth consists of three fluid-filled semi-circular canals, which are linked by three sac-like chambers called the sacculus, lapillus and astericus. It is within these chambers that the three pairs of otoliths can be found. The sacculus, the largest chamber, contains the sagittal otoliths, which are large and frequently used in ageing. The other chambers house the smaller lapillus and astericus otoliths (Secor *et al.* 1992; Smale *et al.* 1995). The sagittal otoliths of *A. berda*, shown in Figure 5.1, are rhomboidal in shape, becoming oblong with growth and are of moderate thickness (Smale *et al.* 1995).

Otoliths consist of calcium carbonate ($CaCO_3$) deposited in a protein matrix (otolin). In the otoliths of most fish, one wide increment, called a hyaline increment, and one narrow increment, called on opaque increment, are usually deposited annually, reflecting changes in the ratio of $CaCO_3$ and otolin (Bagenal 1974)

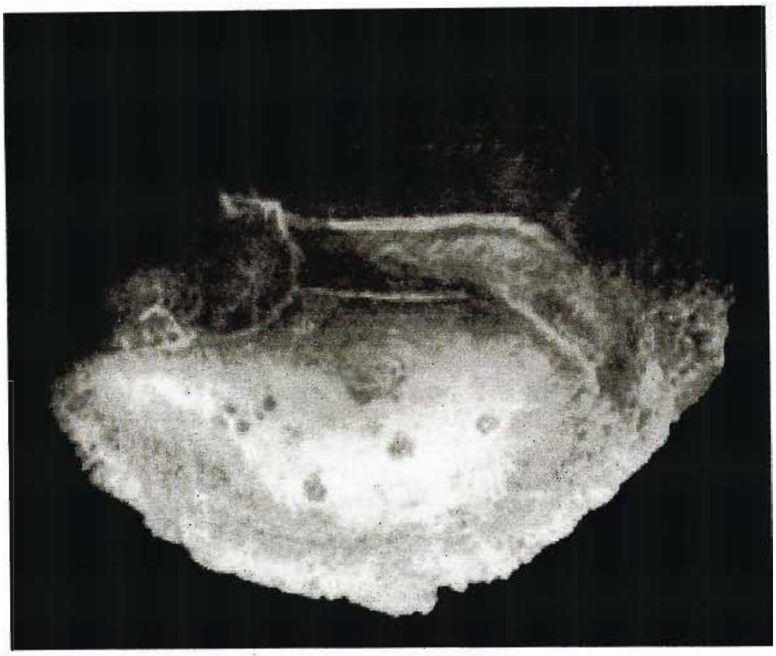


Figure 5.1. Sagittal otolith of *A. berda* (after Smale *et al.* 1995)

However, it is very important to validate age estimates as changes in behaviour, food availability and environmental factors can alter the deposition rates of different materials within otoliths, resulting in the formation of "sub-annual" rings or false checks (Beamish and McFarlane 1987; Lai *et al.* 1996). It is especially important to validate age estimates of *A. berda* as Pollock (1982) found that not all increments observed in the Australian yellowfin bream, *Acanthopagrus australis*, were annual.

Direct methods of age validation include the study of known age fish, daily increment analysis and otolith marking. It is possible to use chemicals, such as fluorochrome labels, to mark structures, including otoliths, scales and vertebrae. These chemicals are incorporated into calcifying tissues such as otoliths during osteogenesis, usually within one day of administration, and form a time reference marker as they fluoresce under ultraviolet light (Thomas *et al.* 1995, Beamish and McFarlane 1987; Lai *et al.* 1996). Indirect methods of validation include cohort analysis and marginal increment analysis, although these methods are less reliable, as it is often difficult to discern increments near the otolith margin (Geffen 1992).

Though age and growth of *A. berda* has been studied in Kuwait (Samuel and Mathews 1987) no work has been published on age and growth of the species in South Africa. In this chapter the age and growth of *A. berda* was investigated in order to obtain the growth parameters necessary to undertake a per-recruit stock assessment of the species. An oxytetracycline labeling experiment was also conducted in order to validate age estimates.

Methods

Length relationships

The relationship between FL and TL (measured to the nearest centimetre) from a sample of 146 *A. berda* obtained from catches confiscated by KZNW, was expressed by the linear relationship $y = ax + b$.

Age estimation

A large sample of *A. berda* was collected during a seine netting survey of the fishes of the Mhlatuze estuary at Richards Bay, conducted between 1987 and 1991 (van der Elst, ORI, pers. comm.). The fork length (FL) of each fish was measured (mm), and, where possible, sex was macroscopically determined. Sagittal otoliths were removed from the auditory bullae, cleaned, dried and stored in paper envelopes. In addition to this archived collection of otoliths, opportunistic samples were collected by spearing *A. berda* in Kosi Bay and using rod and line in Durban harbour (29^{0}52'S; 31^{0}03'E) during the period 1998 to 2000.

A total of 403 otolith pairs were available for ageing. Age estimates were obtained by counting the number of opaque increments in whole otoliths. The otoliths were placed in a solution of glycerine, as this was found to enhance the visibility of growth increments, and read under reflected light, against a black background, using a low power dissecting microscope. One otolith from each pair was read twice by a primary reader and once by a second reader. Readings were made at least two weeks apart, with no reference to previous readings or fish length. Age estimates were only used if two or more of the readings coincided. In order to determine the relationship between otolith growth and fish growth one otolith from each pair was measured for otolith length and height (to the nearest 0.1mm) and mass (to the nearest 0.001g).

To ensure that age estimates from whole otoliths were reliable, otoliths from a sub-sample of 60 *A. berda* were sectioned and age estimates compared with those obtained from the whole otoliths. The difference between age estimates from whole and sectioned otoliths was plotted against the age estimates obtained from the sectioned otoliths. Thereafter, linear regression techniques as used by Newman *et al.* (2000) were used to determine if significant relationships existed between the readings obtained from the whole and sectioned otoliths. The sub-sample was selected based on the lengths of the fish, the length and weight of the otoliths, and the ages estimated. Otoliths were sectioned using the methods described by Mann and Buxton (1997).

Precision of age estimates was determined by estimating the coefficient of variation (CV) (Chang 1982), which expresses, as a percentage, the standard deviation of replicated age counts per fish as a fraction of the mean. The CV is given by the equation:

$$CV = 100 \times \left[\frac{1}{N} \sum_{j=1}^{N} \left[\frac{\sqrt{\sum \frac{(X_{ij} - X_j)^2}{R-1}}}{X_j} \right] \right] \qquad 5.1$$

where N is the total number of fish aged, R is the number of times each fish was aged, X_{ij} is the *i*th age determination of the *j*th fish and X_j is the average age calculation for the $_j$th fish

In order to validate whether single opaque increments were deposited annually, marginal increment analysis and oxytetracycline labelling was performed. Marginal increment analysis required examining the outer margin of the otoliths on a monthly basis for the presence of opaque increments on the edge. In order to avoid biasing the results, the margins of the otoliths were examined with no knowledge of the time of year when the otoliths were collected.

To undertake an oxytetracycline (OTC) labelling experiment to validate annual deposition of growth increments (Beamish and McFarlane 1987), a sample of eight *A. berda* ranging in size from 131mm FL to 204mm FL was caught near Durban in the Umgeni Estuary ($29^0$49'S; $31^0$02'E), using hook and line in July 2000. The fish were transported to an aerated flow-through pool (6000 litres) located at Sea World, Durban and allowed to acclimate for a period of 2 weeks. Thereafter, the fish were caught, measured and tagged by inserting an IDENTIPET passive transponder (microchip) below the left pectoral fin. Each fish was injected intramuscularly with a 0.5mg.kgfish^{-1} dosage of Terramysin (1ml contains 100 mg of oxytetracycline hydrochloride), as recommended by Lang and Buxton (1993). The fish were then returned to the pool and fed daily on chopped sardine and hake.

Unfortunately, as a result of fungal infection, the injected fish died after 11 months in captivity. However, all fish were re-measured and the otoliths removed and stored in the dark until viewing. The otoliths were examined whole under low magnification using reflected ultra-violet light. The position of the fluorescent OTC band was marked on the otoliths and the number of opaque and translucent increments distal to the fluorescent band counted.

Age-at-length data for males, females and both sexes combined were fitted to a special von Bertalanffy growth model using an iterative, non-linear minimization procedure. The special von Bertalanffy growth model has the form:

$$L(t) = L_\infty \left[1 - \exp^{(-k(t-t_0))}\right] \qquad 5.2$$

where L_∞ is the asymptotic mean length, K is the curvature parameter and t_0 is the mean age at zero length.

In an attempt to reduce the variability in the age-at-length data a single birthdate was assigned to *A. berda* as recommended by Williams and Bedford (1974). As opaque zone formation was shown to predominate during October for local *A. berda*, this month was assigned as the birthdate (Figure 5.6). By allocating a single birthdate to *A. berda* seasonal trends in growth could be observed and, as a result, a seasonal growth model (Pauly and Gaschutz 1979) was also fitted to the age-at-length data. The seasonalised version of the von Bertalanffy growth model has the form:

$$L(t) = L_{\infty}\left[1 - \exp^{(-k(t-t_0)-(CK/2\pi)\sin(2\pi(t-t_s)))}\right] \qquad 5.3$$

where t_s sets the beginning of the sine wave, and C expresses the amplitude of the growth oscillations.

This is a special von Bertalanffy equation with an extra term of:

$$(CK/2\pi)\times\sin(2\pi(t-ts)).$$

This extra term produces seasonal oscillations of the growth rate. The parameter C, the amplitude, takes values between 0 and 1. When C = 0, the seasonal equation reduces to the special von Bertalanffy equation, while the higher the value of C the more pronounced the seasonal oscillations (Sparre and Venema 1997).

The runs and homoscedasticity tests (Punt 1992) were used to determine the goodness of fit of the growth models and a likelihood ratio test (Draper and Smith 1981) was used to determine whether the models were significantly different from each other. Five hundred bootstraps, each with a sample size of 395, were run to calculate standard errors and confidence intervals of the parameters for the different growth models. The software PC-YIELD (Punt 1992) and SPSS for Windows (1999) were used to undertake the above analyses.

Results

Length relationships

A plot of the linear relationship between FL and TL ($y = 1.1078x - 0.0748$) is given in Figure 5.2.

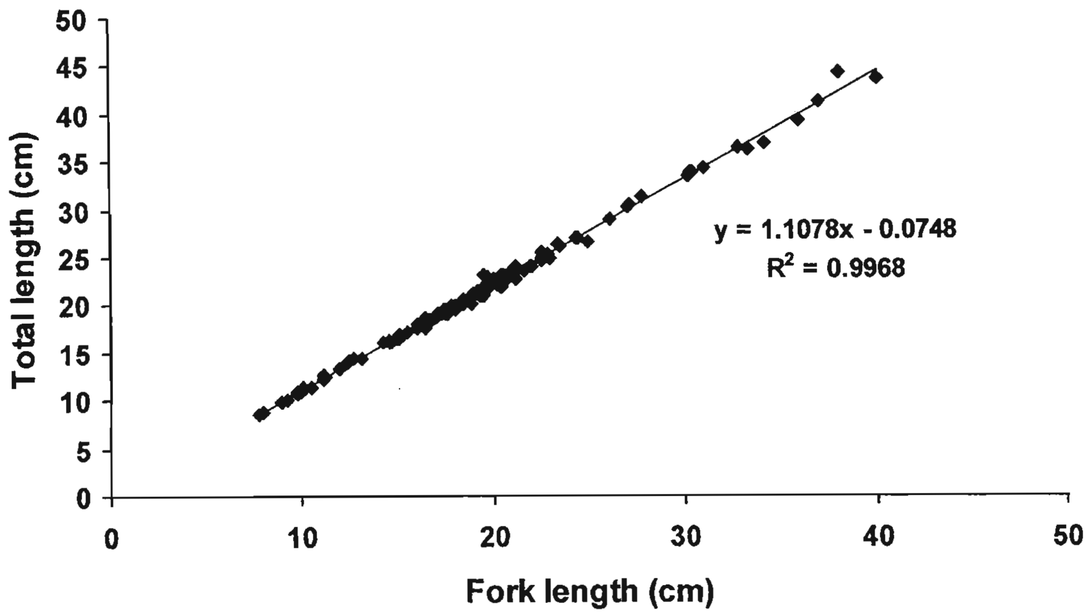


Figure 5.2. The relationship between fork length and total length from a sample of 146 *A. berda.*

Age determination

The fish sampled ranged in length from 70mm FL to 470mm FL (Figure 5.3). Males and juveniles dominated the smaller size classes and females the larger size classes. Despite a predominance of females, some males were also recorded in the larger size classes.

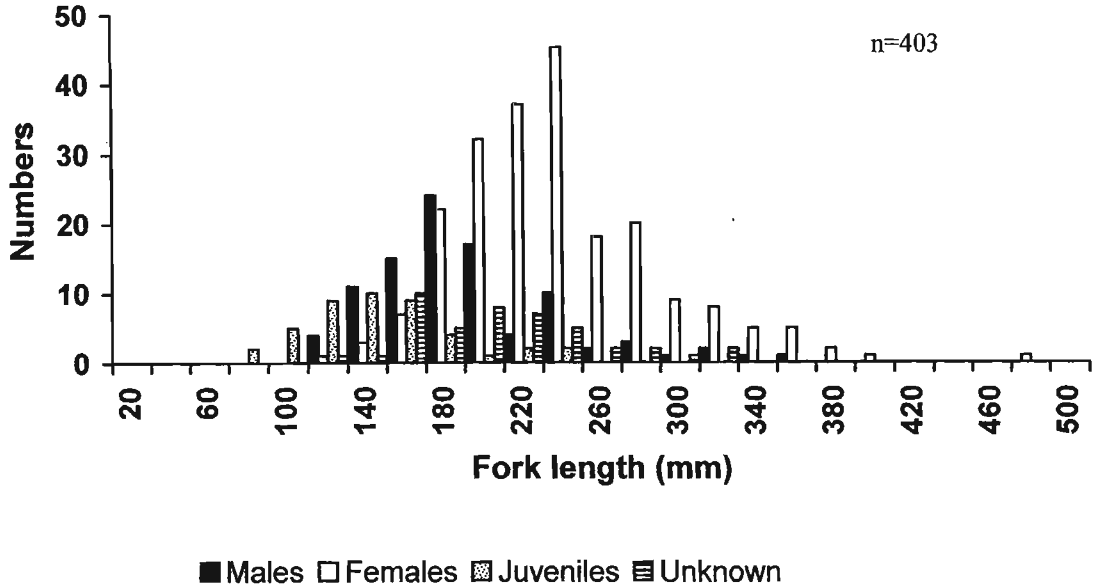


Figure 5.3. Length frequency and sex of 403 *A. berda* caught for ageing purposes in northern KwaZulu-Natal estuaries between 1987 and 2001.

Otolith length and otolith width increased linearly with fork length (Figure 5.4 a and b), indicating that in *A. berda* otoliths (which are rhomboidal in shape) growth occurs along both the lateral and longitudinal axes. The relationship between otolith mass and fork length was exponential (Figure 5.4 c), indicating that *A. berda* otoliths continue to get heavier and thicker as fish growth (in length) slows down.

Age estimates from whole otoliths were not significantly different from ages estimated from sectioned otoliths (p=0.12). The age estimates derived from the whole otoliths were neither consistently higher or lower than those estimated from the sectioned otoliths (Figure 5.5), so all the otoliths were read whole. Of the 403 otoliths read, 57% of readings coincided on all three occasions, while 40% coincided twice. The remaining 3% yielded conflicting ages and were excluded from the analysis.

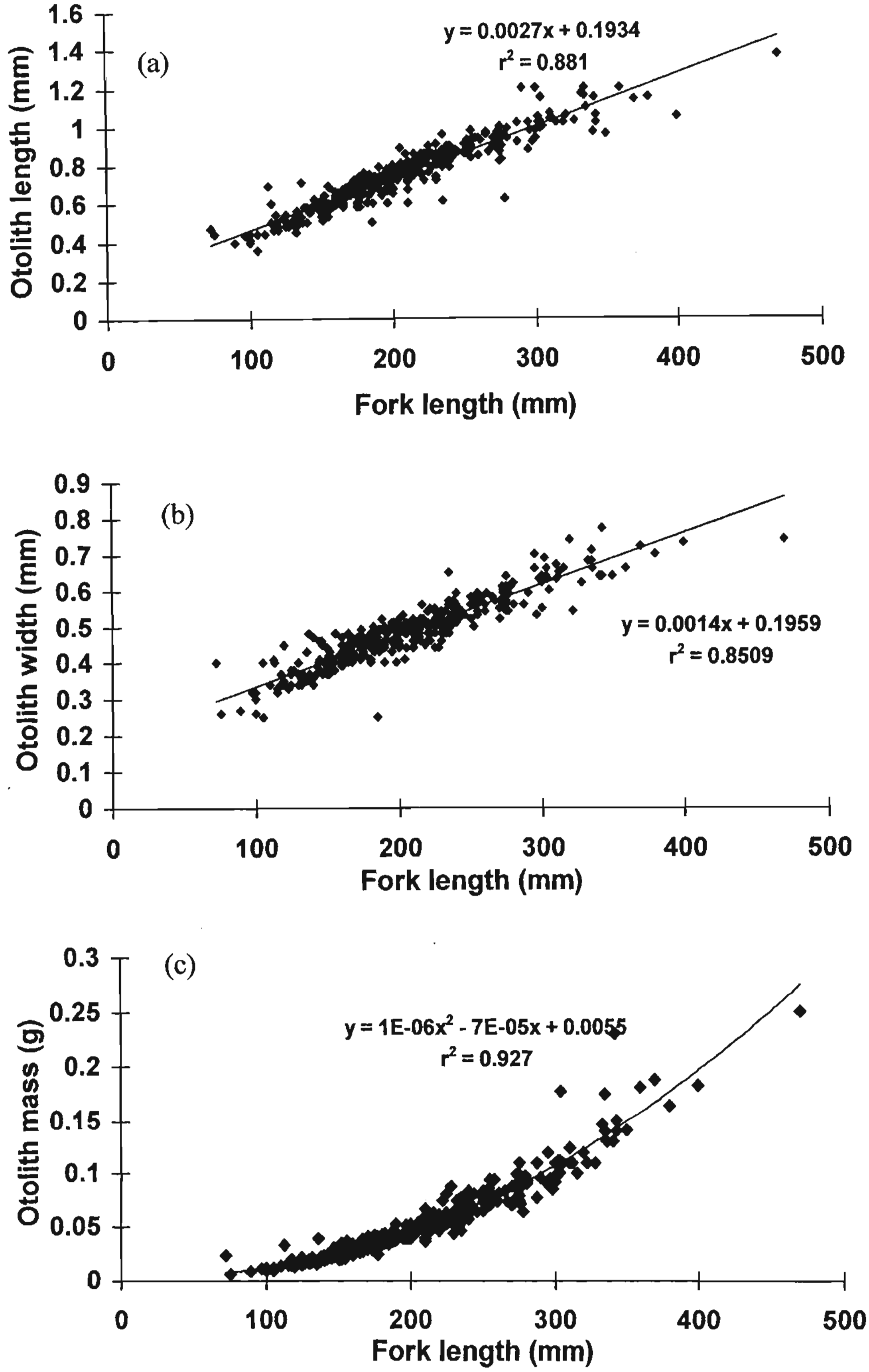


Figure 5.4. Relationships between Fork length and (a) otolith length, (b) otolith height and (c) otolith mass for *A. berda* from northern KwaZulu-Natal.

A CV of 10% was recorded for the three sets of age readings, indicating good agreement between readings. Marginal increment analysis (Figure 5.6) indicated that opaque increment deposition occurs primarily from September to November each year.

Oxytetracycline labelling provided an additional method of validation. The eight *A. berda* specimens used in the oxytetracycline experiment survived for 10 to 11 months. A fluorescent OTC band could be seen on all the otoliths of the fish used in the experiment (Figure 5.7). One translucent increment and the beginning of an opaque increment, on the margin, could be discerned distal to the OTC mark on each otolith. These results provide strong evidence that one opaque and one hyaline increment are deposited annually.

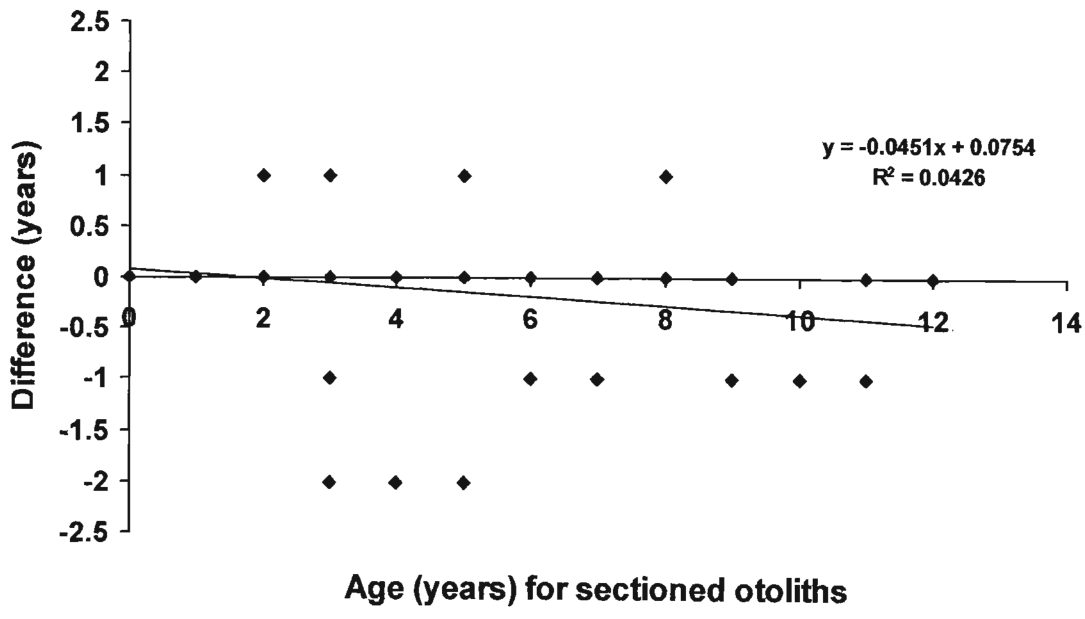


Figure 5.5. The difference between age estimates obtained from whole and sectioned otoliths plotted against age estimates from sectioned otoliths of *A. berda*.

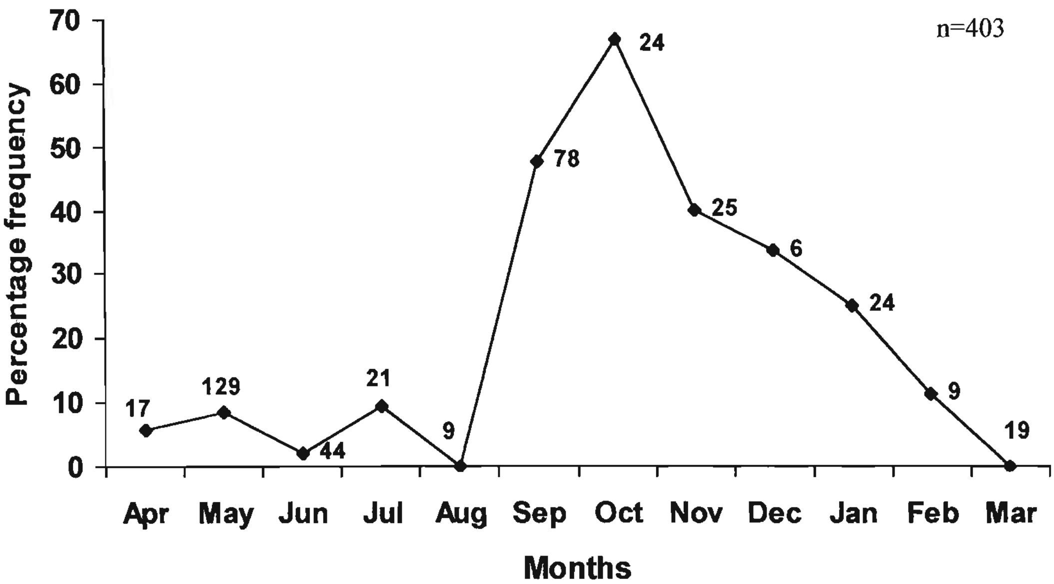


Figure 5.6. Percentage frequency of otoliths with opaque increments on their margins plotted against months of the year (numbers on the graph refer to the number of fish sampled in each month).

Figure 5.7. Photomicrograph of a whole otolith from *A. berda* (211mm TL) injected with oxytetracycline. A fluorescent band is discernable one opaque and one translucent increment in from the margin of the otolith.

The maximum age recorded was 16 years, with most of the sampled *A. berda* lying in the age classes between one and seven years. Observed lengths were highly variable within age classes (Figure 5.8).

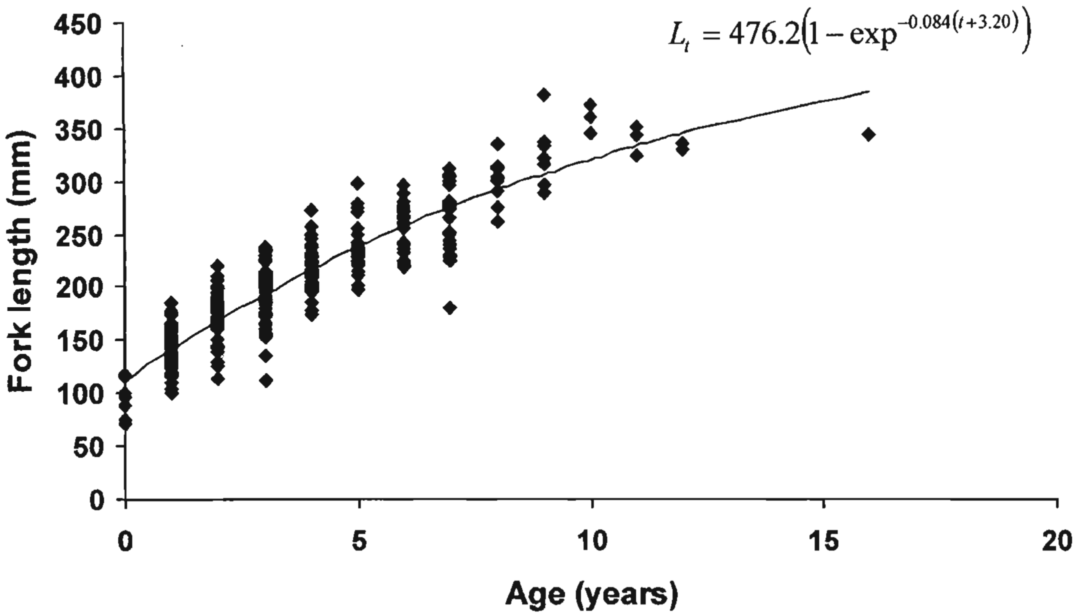


Figure 5.8. A special von Bertalanffy growth curve fitted to the age-length data for *A. berda* (males and females combined) caught in northern KwaZulu-Natal estuaries between 1987 and 2001.

Growth

Both the special von Bertalanffy and the seasonal version passed the runs test, which indicates that the residuals were randomly distributed at the 5% level of significance. However, both models failed the test for homoscedasticity at the 5% level, indicating that the residuals were not normally distributed. A likelihood ratio test (Draper and Smith 1981) revealed that the special von Bertalanffy growth model, assuming an absolute error structure, was statistically superior (F = -5.0, df = 2 and 380) to the seasonal von Bertalanffy growth model.

Attempts were made to fit the special von Bertalanffy growth model to the male and female data sets separately. However, the female data set failed the runs test and displayed a linear fit with no curvature. This was probably due to the small number of females in the lower length classes (Figure 5.3). There were also a large number of juveniles and fish that were not sexed in the data set, which made sex-specific analyses problematic. As a result, the growth models were fitted to the full data set. Estimates of the parameters of the special von Bertalanffy model, their standard errors and their 95% confidence intervals are shown in Table 5.1, while the special von Bertalanffy growth curve is depicted graphically in Figure 5.8. As all the fisheries data were in total length, the lengths used in the ageing study were also converted to total lengths using the relationship derived between FL and TL. A special von Bertalanffy model was then fitted to these data for use in the per-recruit analyses (the parameters are given in the next chapter).

Table 5.1. Estimates of the parameters of the special and seasonal von Bertalanffy growth models for *A. berda*, their standard errors and 95% confidence intervals (CI)

Parameter	Value	S.E.	Left 95% CI	Right 95% CI
Special von Bertalanffy				
L_∞	475.877	49.365	412.396	600.117
K	0.084	0.015	0.056	0.112.
T_0	-3.194	0.334	-3.915	-2.640
Seasonal von Bertalanffy				
L_∞	472	64.639	344.286	599.740
K	0.086	0.018	0.050	0.121
T_0	-2.665	0.383	-3.423	-1.908
C	0.563	0.141	0.285	0.842
T_s	0.086	0.035	0.016	0.156

Discussion

Most of the fish used in this study were <300mm FL and were obtained by seine netting. Subsequent spearing and hook and line fishing succeeded in obtaining larger specimens necessary for the growth curve. A large proportion of the *A. berda* population sampled in this study was female, probably because relatively few fish < 160 mm FL were sampled.

This contrasted with the work of Tobin and Sheaves (1997) in north-eastern Australia where their samples yielded a large number of fish < 160mm FL, which were all males. Although length separation of sexes is a good indicator of sex change in a species, not all male *A. berda* change sex (Tobin and Sheaves 1997). Although there were relatively few males larger than 180mm FL in this study, some males were represented in most of the larger size classes.

Growth increments in otoliths of *A. berda* were found to be reasonably clear, suitable for ageing whole and there was also good agreement between age readings. It is apparent that whole otoliths did not consistently underestimate the ages of older fish, as found by Sarre and Potter (2000) during a similar study on *Acanthopagrus butcheri*. Stacking of the growth increments in older fish, which reduces readability and is often apparent in the otoliths of many other sparid species (Smale and Punt 1991; Buxton and Clarke 1989; Bennett 1993; Mann and Buxton 1997; Chale-Matsau *et al.* 2001), was not found to be a problem in *A. berda*. There was also a great deal of size variability within age groups, which has also been observed in *Acanthopagrus butcheri* from the Gippsland Lakes of south-eastern Australia (Morison *et al.* 1998), and may be common to the *Acanthopagrus* genus.

In this study marginal increment analysis and oxytetracycline labelling were used to validate age estimates, and showed strong evidence that one opaque increment is deposited annually. These results are consistent with results from other South African sparid species, which have also been shown to deposit one opaque increment annually (Coetzee and Baird 1981; Buxton and Clarke 1986; 1989; 1992; Buxton 1993, van der Walt and Beckley 1997; Chale-Matsau *et al.* 2001).

Growth of fish, especially in temperate areas, varies seasonally with growth slowing down in the cooler winter months (Pitcher and Macdonald 1973; Moreau 1987). Although *A. berda* is a sub-tropical species it is mostly confined to estuaries, which, because of their shallow nature, are subjected to wider seasonal temperature fluctuations than the coastal waters off KwaZulu-Natal. Several researchers (Pitcher and MacDonald 1973; Cloern and Nichols 1978; Pauly and Gaschutz 1979; Hanumara and Hoenig 1987; Pawlak and Hanumara 1991) have criticised the von Bertalanffy growth model for not taking seasonal fluctuations in growth into account. In this study, a special von Bertalannfy growth model and its seasonalised version were fitted to the age-at-length data for the combined sexes. However, as the special von Bertalanffy has fewer parameters, and was statistically superior to the seasonal growth model, it was used in further analyses.

As *A. berda* is known to change sex from male to female, growth differences between genders do need to be addressed in future studies. Sex-changing individuals may experience different somatic growth rates during their life cycle, which in turn may affect per-recruit analyses (Garratt *et al.* 1993, Punt *et al.* 1993). All growth models failed the test for homoscedasticity. Failure of this test means that application of other statistical tests have lower power. This problem has also been encountered by Smale and Punt (1991) and van der Walt and Beckley (1997) for other sparids.

The special von Bertalanffy growth curve revealed that *A. berda* in northern KwaZulu-Natal is a slow growing species (K = 0.084) capable of reaching at least 16 years of age. The L_∞ of 476mm FL was much larger than the observed lengths of the fish in the sample, but below the maximum length recorded for the species (750mm TL).

A. berda in northern KwaZulu-Natal exhibits considerably slower growth than *A.berda* from Kuwait, which reaches a maximum age of 14 years and has a K value of 0.325 (Samuel and Mathews 1987). Growth was, however, faster than that recorded for *A. butcheri* in southeastern Australia (Morison *et al.* 1998). *A. berda* also exhibits slower growth than a number of other South African sparid species (see Buxton 1993 for a review), although it does not appear to have the same longevity as some of the larger species, such as *Cymatoceps nasutus* which is known to reach ages of up to 45 years (Buxton and Clarke 1989).

Slow growth has important management implications for fisheries. Slow growing species tend to mature later in life and therefore have a low production-biomass ratio and a low yield per unit stock (Adams 1980). As a consequence they are susceptible to overfishing. In the light of this, the age and growth parameters obtained have been used in the following chapter to undertake yield-per-recruit analyses to assess the state of the *A.berda* stock in northern KwaZulu-Natal estuaries.

CHAPTER SIX

STOCK ASSESSMENT OF *ACANTHOPAGRUS BERDA*

Introduction

Stock assessments are used to provide fishery managers with information on the biological or economic effects of fishing on a stock (Sparre and Venema 1997). In South Africa, per-recruit analyses are recommended in the linefish management protocol as a method of assessing the status of the numerous linefish species (±200) harvested by commercial, recreational and subsistence fishers (Griffiths *et al.* 1999).

Managers should strive to avoid situations where fishing pressure escalates to such an extent that overfishing occurs. Growth overfishing occurs when fish are caught too soon, before they have had a chance to grow. Recruitment overfishing occurs when so many adult fish are caught, that the few remaining are unable to produce enough eggs to replenish the population, and recruitment into the fishery is impaired (Pauly 1994).

Yield-per-recruit models can be used to determine the effects of various ages-at-first capture and fishing effort (expressed as fishing mortality) on the yield of a single recruit (Beverton and Holt 1957). The input parameters required are somatic growth and mortality rates. These models are relatively simple, but a number of major assumptions are made. The model assumes a steady stock structure i.e. that the total yield of the population is equivalent to the lifetime yield of a single year class, that the fish of a cohort are all hatched on the same date, and that recruitment and selection are "knife-edged" (Sparre and Venema 1997). Although a number of major assumptions are made, yield-per-recruit models are commonly used when there is a lack of long-term catch and effort data and no knowledge of the stock recruitment relationship (Griffiths *et al.* 1999).

Yield-per-recruit models can be used to derive a number of biological reference points, which provide managers with an indication of how to maximise yield, while avoiding overfishing (Sparre and Venama 1997). The yield-per-recruit curve often has a maximum, called the maximum yield, from which one can determine the corresponding fishing mortality that maximises yield-per-recruit (F_{MAX}). Maintaining fishing mortality at F_{MAX} only prevents growth overfishing, and does not take spawning biomass into consideration. In addition, when mortality rates are high, as is often the case with tropical species, the yield-per-recruit curve may not reach a maximum within a reasonable range of fishing mortality (King 1995).

A more conservative benchmark is $F_{0.1}$, which is the effort level at the point where the slope of the yield curve is 10% of its value at the origin (Sissenwine and Shepherd 1987). $F_{0.1}$ is a more conservative management strategy, as it is usually much lower than F_{MAX}. Increasing fishing effort above $F_{0.1}$ provides small increases in yield, often at a much greater economic cost (Butterworth *et al.* 1989).

Biological reference points based solely on yield-per-recruit models do not prevent recruitment overfishing. In addition to yield-per-recruit, it is important to consider the behaviour of spawning biomass-per-recruit with fishing mortality (Butterworth *et al.* 1989). Spawning biomass-per-recruit models express the average spawning biomass of survivors as a function of fishing mortality (Sparre and Venema 1997). Recruitment overfishing, and subsequent stock collapse, is likely to occur for most fish stocks when the spawning biomass-per-recruit is reduced to <20-30% of its unfished level (Clark 1991, Griffiths *et al.* 1999).

In this chapter, the status of the fishery for *A. berda* in Kosi Bay and St Lucia was assessed by determining the effects of age-at-first-capture (t_c) and fishing mortality (F) on the yield-per-recruit (YPR) and spawning biomass-per-recruit (SBPR). The status of the fishery for *A. berda* in Richards Bay was not assessed, as there were insufficient length frequency data available from this system.

Methods

Mortality estimation

The instantaneous natural mortality (M) was estimated using the methods of Pauly (1980), Rikhter and Efanov (1977) and Hoenig (1983). These equations are given below:

$$\ln M = -0.0152 - 0.279 \ln L_{\infty} + 0.6543 \ln K + 0.4634 Log T \qquad \text{Pauly (1980)} \qquad 6.1$$

where T is the mean water temperature in ^{0}C, with L_{∞} in cm and K and M in yrs^{-1}
Mortality was estimated using three different temperatures, 17^{0}C, 24^{0}C and 27^{0}C, which represented the temperature range recorded in St Lucia (Begg 1978).

$$M = \frac{1.521}{\left(t_m^{\;0.720}\right)} - 0.155 \qquad \text{Rikhter and Efanov (1977)} \qquad 6.2$$

where t_m is the age (in years) at which 50% of the stock is sexually mature.

$$\ln(Z) = 1.46 - 1.01 \times \ln(t_{max}) \qquad \text{Hoenig (1983)} \qquad 6.3$$

where t_{max} is the maximum age encountered. This method estimates M for relatively unexploited stocks (i.e M $\cong$ Z which is the total mortality rate).

The instantaneous total mortality rate, Z, was estimated separately for the different fishing sectors in Kosi Bay and St Lucia, from the slope of the descending limb of catch curves (Appendix I). A catch curve is a plot of the natural logarithms of numbers caught against age. To construct catch curves a normalised age/length key was constructed using the age-at-length data (Appendix II). An age/length key shows, for each length class of fish, the fractional age-frequency distribution. Using this key, the length frequency data from each fishery could be converted into age frequency data. For Kosi Bay, recreational data was obtained from the ORI tagging database.

The instantaneous fishing mortality rate, F, was estimated for Kosi Bay and St Lucia, by substituting Z and M into the equation:

$$F = Z - M \qquad 6.4$$

Age-at-first capture

The age-at-first capture (t_c) was converted from the length-at-first capture (l_c). Length-at-first capture was determined for each fishery by fitting a straight line, or sigmoidal curve (depending on the fishery), to the ascending portion of the length frequency distribution. Length-at-first capture was taken as the value corresponding to half the maximum frequency (Hughes 1986; Pulfrich and Griffiths 1988; Buxton 1992). Age-at-first capture in the recreational fishery was estimated by converting the minimum size limit (250mm TL) into an age using the von Bertalanffy growth equation.

Age at 50% maturity

The length at which 50% of *A. berda* are mature (t_m) was estimated by fitting a logistic curve to the frequencies of mature fish in each length class determined by Wallace (1975b). The logistic curve is described by the following equation:

$$Y = \frac{1}{1 + \exp^{\left(\frac{-(X_{mid} - X_{0.5})}{\delta}\right)}} \qquad 6.5$$

where Y is the proportion of mature fish in each length class X, X_{mid} is the midpoint of the length class, $X_{0.5}$ is the length at 50% maturity and δ is a value between 0 and 1, which describes the steepness of the curve (Butterworth *et al.* 1989). The length at 50% maturity was then converted to age using the von Bertalanffy growth equation.

Per recruit analyses

Using the Beverton and Holt (1957) model, yield-per-recruit was derived from:

$$YPR = \sum_{t=0}^{t\max} W_t \times N_t \times \frac{S_t F_t}{S_t F_t + M}\left(1 - \exp^{-(S_t F_t + M)}\right) \qquad 6.6$$

where S_t is the selectivity of the fishing gear on fish in age t years. Selectivity was assumed to be knife-edged, i.e.

$$S_t = \begin{Bmatrix} 0 & if\, t < t_c \\ 1 & if\, t \geq t_c \end{Bmatrix} \qquad 6.7$$

where t_c is age-at-first capture. W_t is the mean mass of individual fish in the cohort at age t. W_t was calculated using the von Bertalanffy equation expressed in weight rather than length:

$$W_{t+0.5} = a\left(L_\infty\left(1 - \exp^{(-K(t+0.5-t_0))}\right)\right)^b \qquad 6.8$$

where a and b are the parameters of the length mass relationship $W(g) = aL(mm)^b$ given by Mann and Radebe (2000). N_t refers to the numbers of fish in the cohort at age t, and was given by the equation:

$$N_t = N_{t-1} \times \exp^{(-(F_{t-1}+M_{t-1}))} \qquad 6.9$$

The selectivity of each fishing sector (gillnets, fish traps, recreationals) is different and yields were therefore estimated separately for each by substituting the selectivity and fishing mortality for each sector into equation 6.6. The individual yields for each sector were summed to give total yield. In order to estimate yield per sector, the contribution of different sectors to total fishing mortality in each system was required. This was estimated using the ratio of *A. berda* caught by the different sectors, which were derived using the relative annual catch (mass) of *A. berda* by each sector (Appendix III).

The relative proportion of the total fishing mortality contributed by each sector was initially assumed to be equal to the proportion of the total catch contributed by each. These proportions were multiplied by the total fishing mortality to obtain the fishing mortality for each sector and the yield-per-recruit for each sector was estimated. A nonlinear optimisation routine (Solver in Microsoft Excel) was used to minimise the difference between observed catch ratios per sector and estimated catch ratios derived from the model, by iteratively changing the relative contribution of each sector to the total instantaneous fishing mortality. Using these values, the yield-per-recruit model was run over a range of fishing mortality values to produce yield-per-recruit curves.

Per-recruit models were run separately for Kosi Bay and St Lucia. *A. berda* are caught by different sectors in each system (there are no fish traps in St Lucia) and the adult population in each system is relatively discrete, with the adults rarely being recorded in the sea between the two estuarine systems.

The spawning biomass-per-recruit model was run for each system and is given by the equation:

$$SBR = \sum_{t=o}^{t\max} M_t \times W_t \times \frac{S_t F_t}{S_t F_t + M}\left(1 - \exp^{-(S_t F_t + M)}\right) \qquad 6.10$$

where M_t is the maturity of fish in age t years, and is a "knife-edge" process like selectivity, i.e.

$$M_t = \begin{Bmatrix} 0 \;\; if\; t < t_m \\ 1 \;\; if\; t \geq t_m \end{Bmatrix} \qquad 6.11$$

where t_m is the age at which 50% of the population is mature.

The sensitivity of the results to values of age-at-first capture and natural mortality was tested by running the models over a range of values of these parameters.

Results

Mortality estimation

The estimates of instantaneous natural mortality (M), using the Pauly (1980) empirical equation, ranged from 0.24 to 0.30 year^{-1}, depending on the environmental temperature (Table 6.1). The estimate of M using the Rikhter and Efanov (1976) equation was unrealistically high (0.45 year^{-1}), while the Hoenig (1983) equation produced an estimate of M (0.26 year^{-1}) very similar to that obtained using the Pauly (1980) formula, with a mean environmental temperature of 23^{0}C. Consequently, the M used in further analyses was 0.28 year^{-1}.

Table 6.1. Instantaneous natural mortality estimates for *A. berda*

Equation	T (^{0}C)	M (year^{-1})
Pauly	17	0.24
Pauly	23	0.28
Pauly	27	0.30
Rikhter and Efanov	-	0.45
Hoenig	-	0.26

The catch curves yielded total mortality estimates of between 0.43 year^{-1}and 0.59 year^{-1}in Kosi Bay and 0.52 year^{-1} in St Lucia (Table 6.2). As estimates were fairly similar for each fishery in Kosi Bay a mean total mortality of 0.51 year^{-1} was used for this system. Although gillnet data is not ideal for estimating Z, as there is selectivity involved, the Z estimate derived from the St Lucia gillnets was used for this system, as recreational data was not available. Using an M of 0.28 year^{-1} a fishing mortality rate of 0.23 year^{-1}was calculated for Kosi Bay and 0.24 year^{-1} for St Lucia. Age-at-first capture (t_c) ranged between 3 and 5 years depending on the fishing gear used (Table 6.2).

Table 6.2. Total instantaneous mortality rate estimates for *A. berda*

Data sets	t_c	Z	S.E
Kosi Bay gillnets	3	0.59	0.066
Kosi Bay fish traps	4	0.43	0.062
Kosi Bay recreational anglers (tagging data)	4	0.50	0.098
St Lucia gillnets	5	0.52	0.046
Average Kosi Bay	4	0.51	0.075
Average St Lucia	5	0.52	0.046

Age-at-50% maturity

Length at 50% maturity was derived from a logistic curve using combined data for males and females given in Wallace (1975b). From the logistic curve (Figure 6.1) the length at 50% maturity was calculated at 23cm TL. Using the von Bertalanffy growth equation the age at 50% maturity was calculated to be 3.6 years.

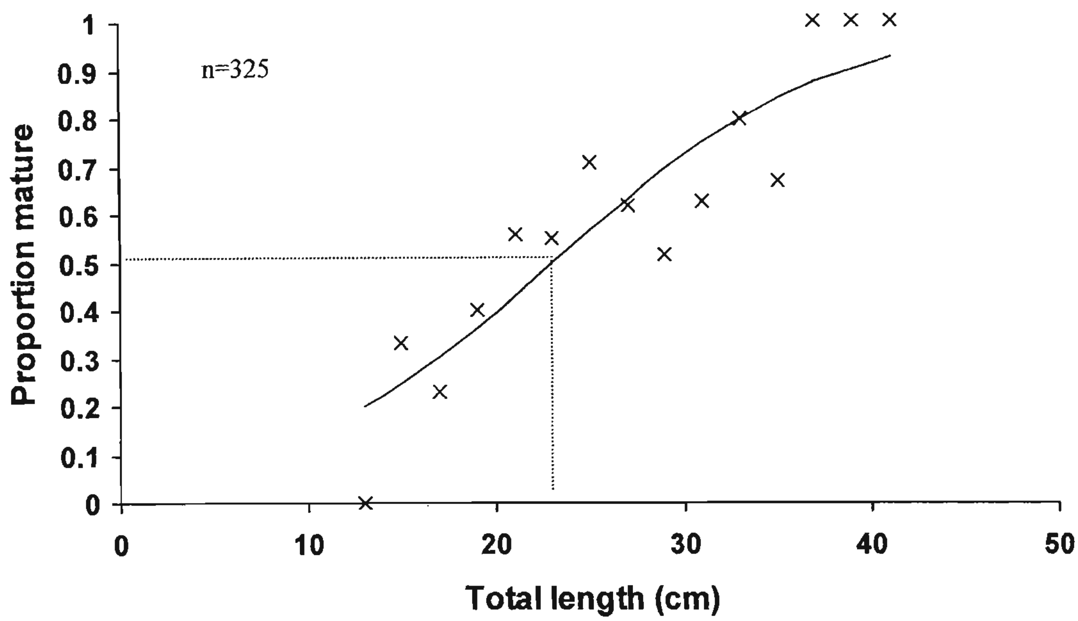


Figure 6.1. Length at 50% maturity (males and females) of *A. berda* from a sample collected in the estuaries of KwaZulu-Natal by Wallace (1975).

Per-recruit analyses

The input parameters used in the yield-per-recruit analyses for Kosi Bay and St Lucia are given in Table 6.3.

Table 6.3. Input parameters used in the per-recruit model for *A. berda* at Kosi Bay and St Lucia.

Parameter	Kosi Bay	St Lucia
a	0.0000128	0.0000128
b	3.09	3.09
L_∞ (mm)	529.8	529.8
K (year^{-1})	0.08	0.08
t_0 (years)	-3.22	-3.22
M (year^{-1})	0.28	0.28
F (year^{-1})	0.23	0.24
F^T (fish traps)	0.174	—
F^G (gillnets)	0.031	0.215
F^R (recreational)	0.025	0.025
t_m (years)	3.6	3.6
t_c (years) fish traps	4	—
t_c (years) gillnets	3	5
t_c (years) recreational	4	4

Kosi Bay

Yield was highest in the trap fishery, although it levelled off at a fishing mortality of approximately 0.8 year^{-1}(Figure 6.2). Yield was lower in the recreational and gillnet fisheries, but the gillnet curve increased monotonically, due to the lower age-at-first capture. Overall, the total yield in the system did not reach a peak, and consequently F_{MAX} could not be determined. Spawning biomass-per-recruit was estimated to be at 47% of the pristine level (Figure 6.3) at the current level of F (0.23). The biological reference points at the current level of fishing mortality are shown in Table 6.4 (for definitions of biological reference points refer to appendix IV).

Table 6.4. Biological reference points for the *A. berda* population in Kosi Bay.

Reference point	Fishing mortality
$F_{0.1}$	0.7
F_{SB25}	0.6
F_{SB40}	0.3
F_{SB50}	0.2

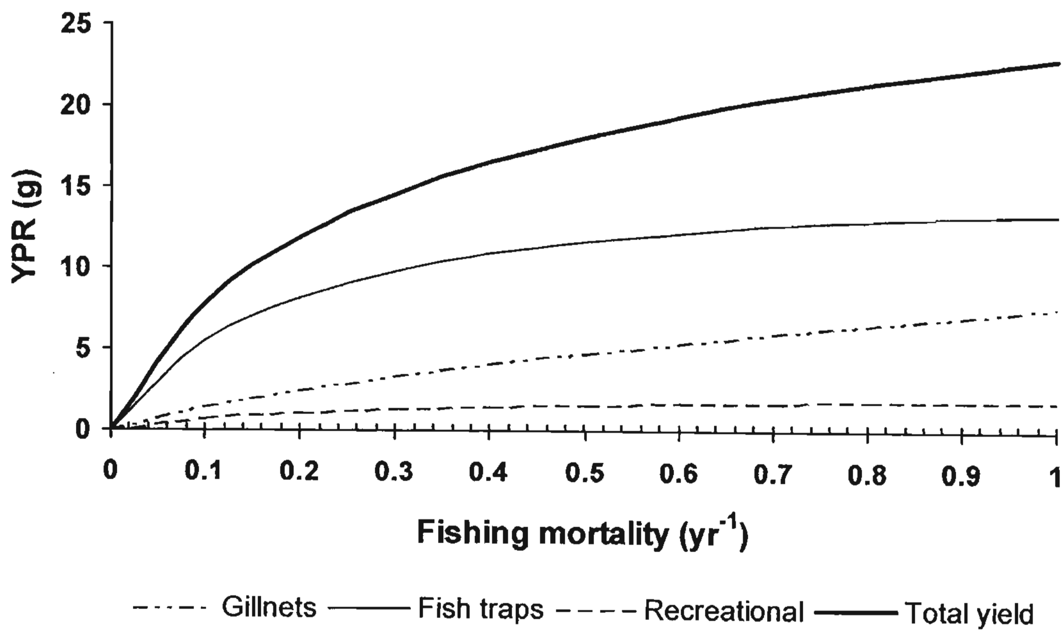


Figure 6.2. Yield-per-recruit for *A. berda* in Kosi Bay

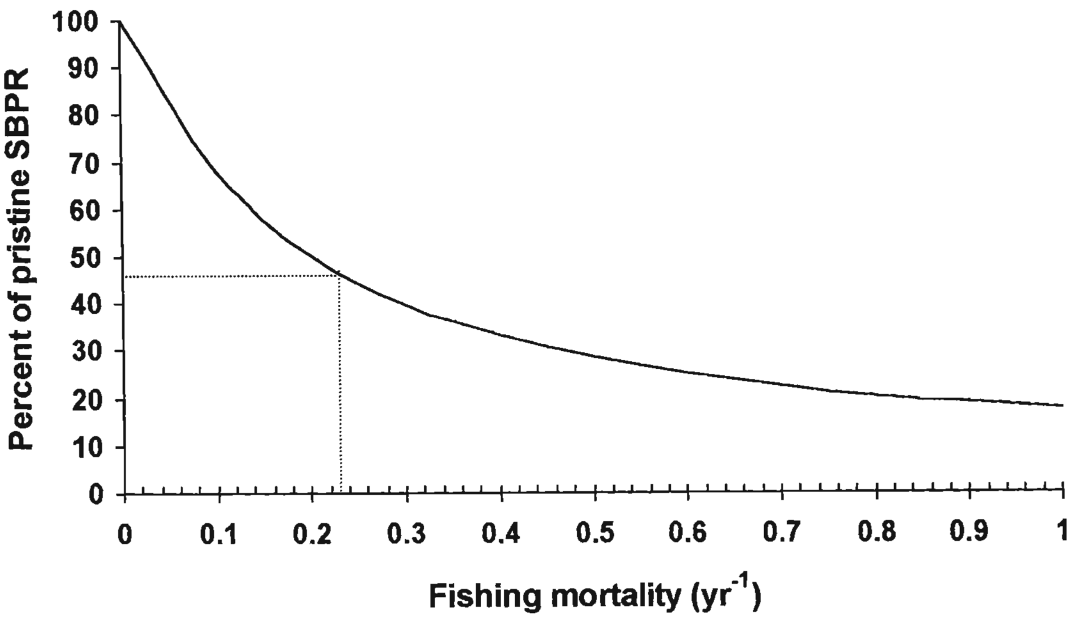


Figure 6.3. Percent of pristine spawning biomass-per-recruit for *A. berda* in Kosi Bay.

The model was sensitive to changes in instantaneous natural mortality (M) and age-at-first capture (t_c) (Figure 6.4). Increasing natural mortality by 0.1 resulted in F_{SB50} increasing from 0.20 to 0.29 (Table 6.5). Conversely, decreasing natural mortality by a factor of 0.1 resulted in F_{SB50} decreasing to 0.15. Increasing age-at-first capture by a year, in each fishery, resulted in F_{SB50} increasing to 0.3, while decreasing age-at-first capture by one year resulted in F_{SB50} decreasing to 0.15.

Table 6.5. Input parameters of M and t_c to the per-recruit model and relative changes in the biological reference point F_{SB50}.

M	t_c	F_{SB50}
0.18	t_c current	0.15
0.38	t_c current	0.29
0.28	t_c current	0.20
0.28	t_c + 1 year	0.30
0.28	t_c − 1 year	0.15

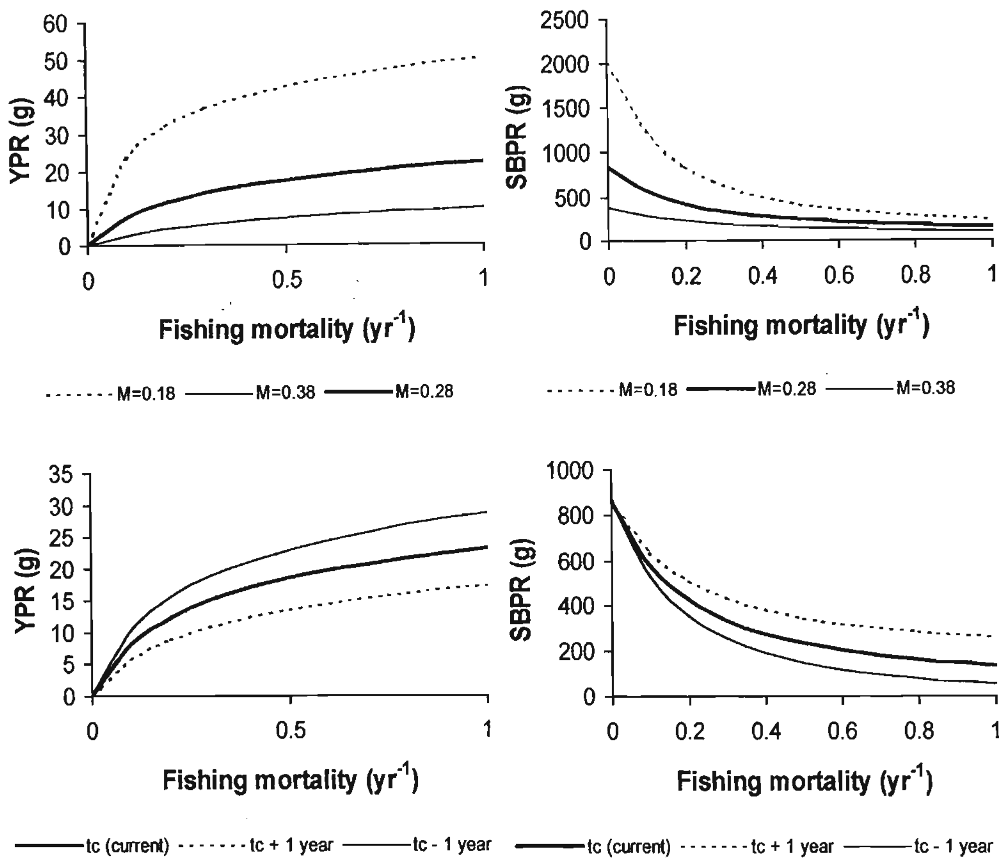


Figure 6.4. The effects of altering natural mortality (M) and age-at-first capture (t_c) on the spawning biomass-per-recruit and yield-per-recruit curves for Kosi Bay.

St Lucia

The input parameters used in the per-recruit analysis are given in Table 6.3. Yield in the recreational fishery increased monotonically, even though this fishery takes a much smaller proportion of the total catch (Figure 6.5). This was due to the lower age-at-first capture in this fishery. Overall, the total yield in the system did not level off, consequently, F_{MAX} could not be determined. Spawning biomass-per-recruit was estimated to be at 55% of the pristine level (Figure 6.6) at the current level of F (0.24). The biological reference points at the current level of fishing mortality are shown in Table 6.6.

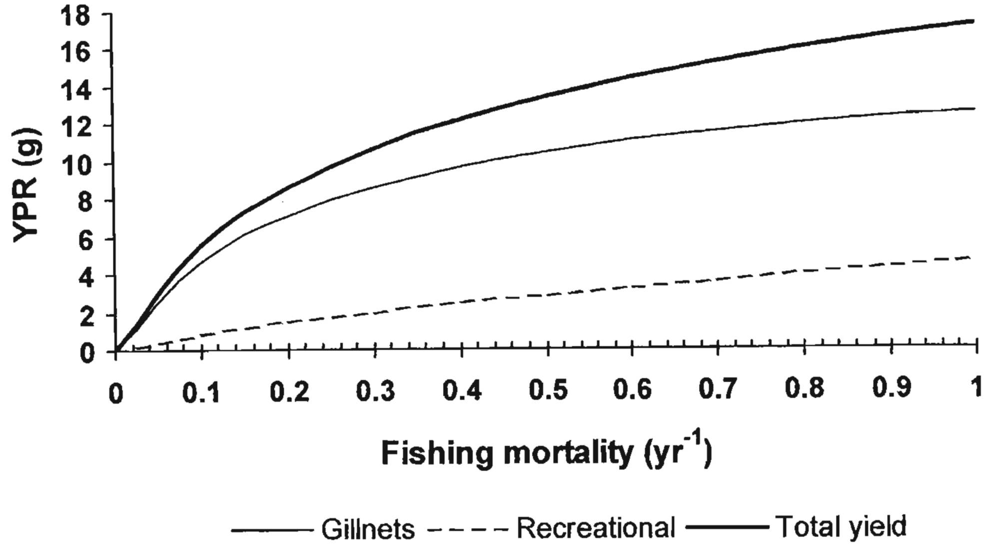


Figure 6.5. Yield-per-recruit for *A. berda* in St Lucia.

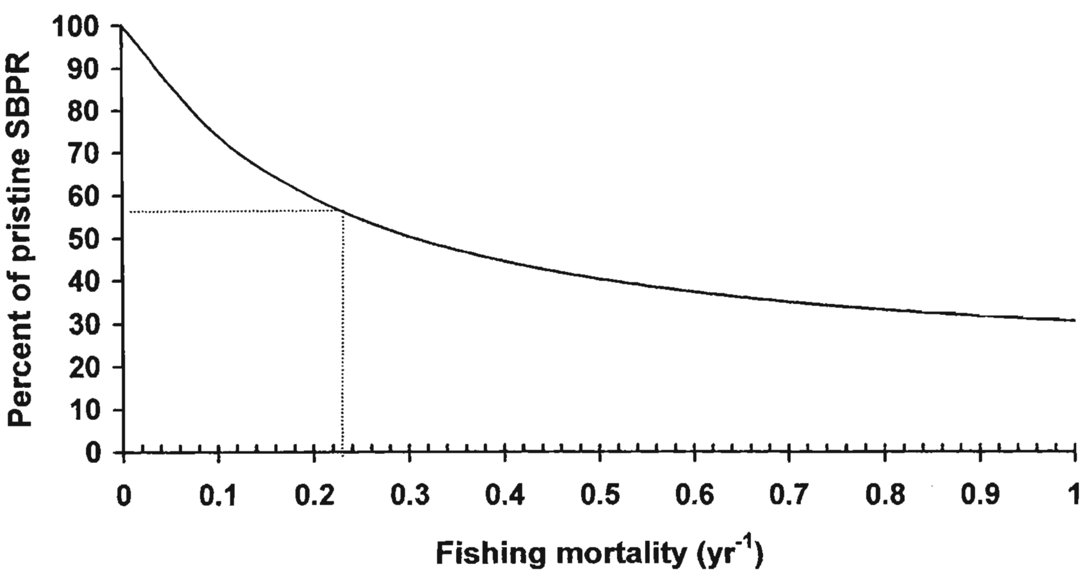


Figure 6.6. Spawning biomass-per-recruit for *A. berda* in St Lucia

Table 6.6. Biological reference points for the *A. berda* population in St Lucia

Reference point	value
$F_{0.1}$	0.8
F_{SB25}	1.89
F_{SB40}	0.5
F_{SB50}	0.3

The St Lucia model was also sensitive to changes in instantaneous natural mortality (M) and age-at-first capture (t_c). Yield increased with a lower natural mortality and a lower age-at-first capture, although F_{SB50}, was attained at a lower level of fishing mortality (0.2). Spawning biomass increased with a lower natural mortality and a higher age-at-first capture (Figure 6.7; Table 6.7).

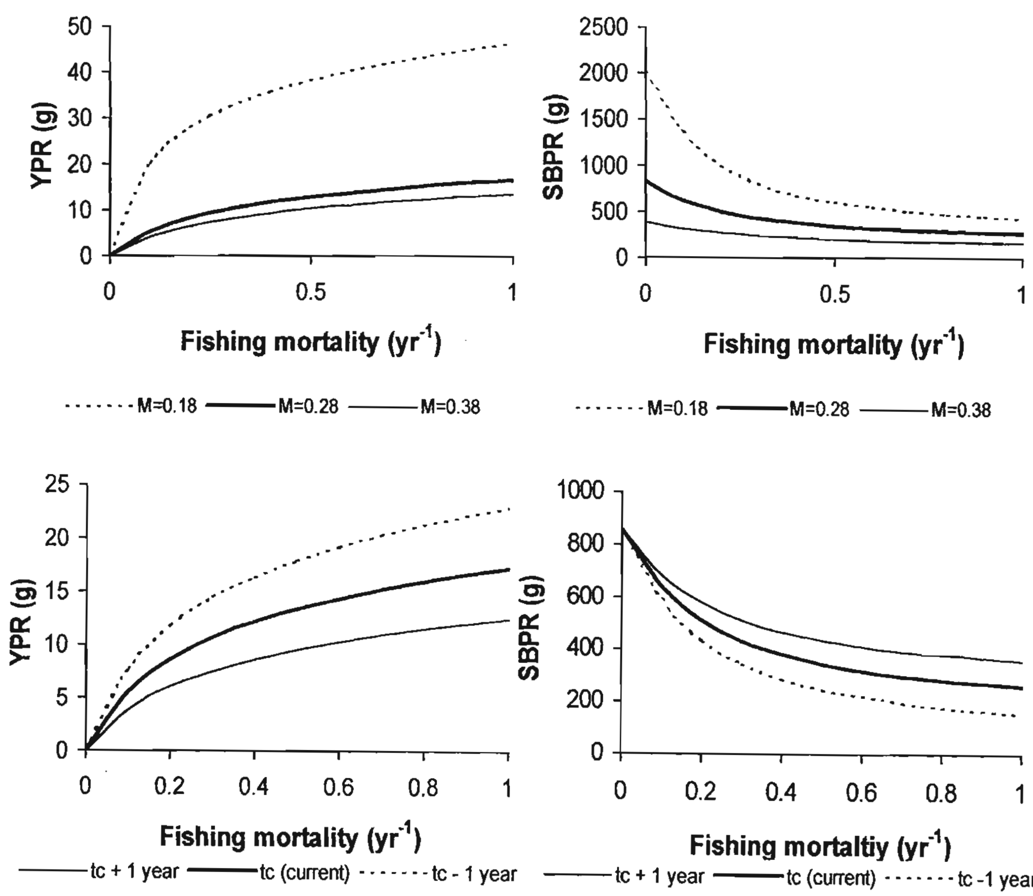


Figure 6.7. The effects of altering natural mortality (M) and age-at-first capture (t_c) on yield-per-recruit and spawning biomass-per-recruit for *A. berda* caught in St Lucia.

Table 6.7. Input parameters of M and t_c to the per-recruit model and relative changes in the biological reference point F_{SB50}.

M	t_c	F_{SB50}
0.18	t_c current	0.20
0.38	t_c current	0.53
0.28	t_c current	0.30
0.28	t_c + 1 year	0.52
0.28	t_c – 1 year	0.20

Discussion

Natural mortality for *A. berda* was estimated at approximately 0.28 $year^{-1}$. This value was within the range estimated for a number of similar coastal fish species found in South African waters (Table 6.8). The natural mortality estimates obtained using the Pauly (1980) and Hoenig (1983) methods were very similar, indicating that natural mortality was reasonably estimated. This view was strengthened by the insensitivity of the Pauly model to changes in water temperature (Mann *et al.* in press(a); van der Walt 1995).

Table 6.8. A comparison of the natural mortality estimates for some South African coastal fish species

Species	Natural mortality ($year^{-1}$)	Reference
Chrysoblephus puniceus	0.3	Punt *et al.* (1993)
Pterogymnus laniarius	0.28	Booth and Buxton (1997)
Neoscorpis lithophilus	0.29	Mann *et al.* (in press(a))
Acanthopagrus berda	0.28	This study

The estimates of Z obtained from catch curves in Kosi Bay were fairly similar, and the standard errors on these estimates were very low, indicating that Z has been estimated with reasonable confidence. The estimates of fishing mortality (0.23 $year^{-1}$ in Kosi Bay and 0.24 $year^{-1}$ in St Lucia) were close to the natural mortality rate (0.28 $year^{-1}$). Maintaining F at M is often quoted as a 'rule of thumb' management strategy, which maximises yield (Gulland 1971), although there is little empirical evidence to support this belief (Clark 1991).

The per-recruit model of Beverton and Holt has often been criticised as being too simplistic as it makes a number of major assumptions and fails to take natural fluctuations, most notably, in recruitment, into consideration (Gulland and Boerema 1972). Assuming constant recruitment may be especially problematic when applied to estuarine species, where fishing and anthropogenic effects impact on resources (West and Gordon 1994). In addition, excluding variability in recruitment provides little guide to fishing levels at which recruitment overfishing occurs (King 1995).

The assumption of knife-edge selection was probably valid for *A. berda*. The model was also run using selection ogives, calculated using FISAT (Gayonilo *et al.* 1996), and gave very similar results. As age-at-first capture was easier to manipulate using a knife-edge function, all models were run based on the assumption of knife-edge selection. The assumption of knife-edge maturity was, however, violated, as mature fish were present in most of the smaller length classes. However, using an age at 50% maturity is expected to reduce this variability and provide representative results (Fennessy 2000).

The assumption of constant fishing mortality and natural mortality is difficult to evaluate, although fishing mortality has probably increased in recent years. Modelling separate natural mortality rates for each age class is complex and was not attempted in this study. The assumption of complete mixing within the fish stock is probably violated for *A. berda* as each population is fairly discrete, with adult fish rarely leaving individual estuaries. However, to avoid this problem, per-recruit models were run separately for each system.

Although this model is simplistic, and makes a number of major assumptions, in the absence of a stock-recruitment relationship and long-term catch and effort data it can provide managers with an indication of the status of a stock (Griffiths *et al.* 1999).

Often multiple fisheries exploit a single stock and, if highly selective gear such as gillnets are used, the selectivity and fishing mortality will differ in each fishery (Shirakihara *et al.* 1989). Yield-per-recruit curves should be adjusted to take this into consideration, but this has rarely been done. In this study, an attempt was made to determine the contribution of each fishery to the total fishing mortality, and in so doing, run separate yield-per-recruit curves for each fishery. These estimates were based on the ratios of estimated total catch per sector, and were therefore only as accurate as the estimates of total catch. Models were run separately for Kosi Bay and St Lucia.

The per-recruit model for Kosi Bay indicated that the trap fishery (which catches the most *A. berda* in the system) has the greatest influence on YPR and SBPR, while in St Lucia, the gillnet fishery has the greatest influence on YPR and SBPR. Removal of the recreational fishery from the model hardly decreased the total YPR and only increased the SBPR from 55% to 56% of pristine levels. The models were fairly sensitive to M and t_c, as indicated by the change in the biological reference point (F_{SB50}) when these parameters were changed. It is difficult to determine the true age-at-first capture, especially in the recreational fishery where undersized fish are often kept.

Age-at-first capture was very different in the gillnet fisheries of Kosi Bay (3 years) and St Lucia (5 years). In St Lucia net restrictions were implemented for the experimental fishery, while no net restrictions are enforced in Kosi Bay. The difference in age-at-first capture appeared to have a large influence on the state of the stocks in the two systems. Decreasing age-at-first capture to 3 years in the St Lucia gillnet fishery (i.e. so that it was the same as Kosi Bay) decreased the SBPR from 55% to 38% of pristine levels. With the large amount of illegal netting taking place in St Lucia where mesh size is variable (Mann 1995), the latter situation is quite possible.

According to the $F_{0.1}$ strategy, the current level of fishing mortality is well below optimal levels in both Kosi Bay and St Lucia. However, this management strategy, although more conservative than F_{MAX}, takes no account of the effect of fishing mortality on the spawning stock or subsequent recruitment (Clark 1991). The new management protocol for the South African linefishery recommends classifying linefish species into four management categories based on biological reference points derived from spawning biomass-per-recruit models. Stocks are classified as under-exploited if the spawning biomass is greater than 50% of unfished levels, optimally-exploited if spawning biomass is between 40 to 50% of unfished levels, over-exploited between 25 and 40%, and collapsed if spawning biomass lies below 25% of unfished levels (Griffiths *et al.* 1999). According to this classification system the *A. berda* stock is currently optimally-exploited in Kosi Bay and under-exploited in St Lucia.

A. berda, is fairly slow growing, but does not have the same longevity as some of the larger temperate water sparids, such as the black mussel cracker, *Cymatoceps nastus* (45 years) (Buxton and Clarke 1989) and the white steenbras, *Lithognathus*

lithognathus (25-30 years) (Bennett 1993). Long-lived, slow growing species have been shown to be extremely susceptible to overfishing, with the *L. lithognathus* stock estimated to be at only 6% of pristine spawning biomass (Bennett 1993).

Per-recruit models do not take sex change into consideration. Species that change sex (protogynous and protandrous hermaphrodites) may be more susceptible to overfishing than gonochorists (Bannerot *et al.* 1987; Punt *el al.* 1993; Coleman *et al.* 1996). This tends to complicate yield per recruit models, as the assumption of constant recruitment may fail at higher levels of exploitation than gonochoristic species (Buxton 1992). Punt *et al.* (1993) addressed this problem by incorporating sex change, followed by a growth spurt, into per-recruit models for the protogynous sparid *Chrysoblephus puniceus*, while Buxton (1992), incorporated sex change, as a knife-edged process, into the per-recruit models for the protogynous sparids *C. laticeps* and *C. cristiceps*.

Protandrous species may be particularly susceptible to overfishing, as fishing tends to remove the larger females. Blaber *et al.* (1999) postulated that the protandrous habit of *Tenualosa macrura* and *T. toli* (Family Clupeidae) has rendered them particularly vulnerable to overfishing resulting in drastic declines of both species.

Unlike *T. macrura* and *T. toli, A. berda* is a partial protandrous hermaphrodite, meaning that not all fish in the population change sex. In addition, the sex change process takes place across a broad size range of the population (Tobin and Sheaves 1997). *A. berda* may use sex change to compensate for the removal of large females by fishing, and thus retain the sex ratio of the population. Based on this assumption, Mann (1992) suggested that partial hermaphrodites should be considered no different from gonochoristic species from a management perspective. Huntsman and Shaaf (1994), found that some protogynous groupers (Serranidae) are able to maintain the numerical sex ratio of their populations through behaviourally mediated sex change, and were thus no different from gonochoristic species.

In South Africa many species belonging to the family Sparidae have been categorised as over-exploited (Mann 2000) and, although this study suggests that *A. berda* is currently optimally-exploited in Kosi Bay and under-exploited in St Lucia, management of the stock should be based on a precautionary approach. For many fisheries around the world the precautionary approach is advocated where available data are inadequate (Punt *et al.* 2001). Per-recruit analyses also make a number of major assumptions and have been shown, in this study, to be very sensitive to natural mortality and age-at-first capture.

CHAPTER SEVEN

GENERAL DISCUSSION AND MANAGEMENT RECOMMENDATIONS

Life history and behavioural characteristics make several fish species vulnerable to over-exploitation (Coleman *et al.* 1999). This is particularly true for many members of the Sparidae, which are extremely popular linefish species in southern Africa. Recent studies have shown that many of these species are currently over- exploited (Buxton 1992; Punt *et al.* 1993; Bennett 1993; Chale-Matsau *et al* 2001). *Acanthopagrus berda*, although estuarine throughout its life cycle, shares many life history traits with the reef-dwelling members of the sparid family.

Life history traits

The interaction of life history parameters has a strong influence on the response of a species to fishing pressure (Adams 1980). Species are generally categorised on a continuum between r and k selected animals. R-selected animals are generally small, fast-growing, early-maturing species with a high fecundity, such as the Clupeidae. These species generally have a high maximum sustainable yield and recover rapidly from overfishing. In contrast, k-selected animals tend to be large, slow-growing, late-maturing species with a low fecundity, low maximum sustainable yield and slow recovery rate from overfishing (Musick 1999).

A. berda exhibits many k-selected characteristics, which will influence its response to exploitation. It is slow growing, with a k coefficient of 0.083 (from the von Bertalanffy growth equation). According to Musick (1999), animals with k coefficients at or below 0.1 seem to be particularly vulnerable to over-exploitation. In addition, *A. berda* is long-lived, capable of reaching ages in excess of 16 years. Populations of long-lived animals often decline rapidly, as they are unable to respond as strongly or as rapidly as short-lived animals to reductions in their populations (Musick 1999).

A. berda mature at an age of 3.6 years, which although relatively late, is at a small size (230mm TL). Length frequency analysis has shown that very few *A. berda* are caught below this length in the trap and gillnet fisheries in Kosi Bay and St Lucia. This reduces the risk of recruitment overfishing. There are no estimates of fecundity for *A. berda* but it is likely that they produce similar numbers of eggs to *A. butcheri*, which have been shown to be highly fecund (Kailola *et al.* 1993). High fecundity is an r-selected trait, which may decrease a species susceptibility to overfishing.

Behavioural characteristics

Behavioural characteristics may exacerbate the effects of fishing on a population. *A. berda* has the potential to change sex from male to female, and although sex change has been shown to increase some species' vulnerability to overfishing (Bannerot *et al.* 1987; Huntsman and Shaaf 1994), it is believed that this is not the case with *A. berda*. As with other small sparids, such as *Rhabdosargus sarba* and *Diplodus sargus capensis* (Garratt 1993b; Mann and Buxton 1997), *A. berda* is a partial protandrous hermaphrodite, which may be able to compensate for the loss of larger females from fishing by smaller males changing sex.

A. berda is an estuarine species, with only a marine egg and larval phase (Smith and Heemstra 1986). Consequently, populations in different estuaries are fairly discrete and vulnerable to localised overfishing. Recreational anglers and subsistence fishers are active in estuaries because of the high abundance of fish, and the accessibility and sheltered nature of estuarine environments (Baird *et al.* 1996). *A. berda* may compensate for this by having a wary nature. Known locally as "Slimjannie" or Clever Johnny, *A. berda* has earned a reputation as a clever fish, which is often able to escape capture. Smith and Heemstra (1986) describe *A. berda* as a cunning, furtive and wary species which rarely takes bait in clear water. This may partly explain the observed difference in the recreational *cpue* between Kosi (0.0093fish/angler/h) and St Lucia (0.035fish/angler/h), as the latter system is generally turbid.

A. berda is also known to form large localised spawning aggregations. In the Kosi estuary *A. berda* has been shown to aggregate and spawn in the immediate vicinity of the estuary mouth (Garratt 1993a). Individuals constantly enter and leave the aggregation, which fluctuates in size from between 200 to 1500 individuals. It is estimated that approximately 32 000 to 76 915 adult *A. berda* move down to the estuary mouth to spawn each year (Garratt 1993a). Similar aggregations are believed to occur in other estuarine systems (Wallace 1975a; Garratt 1993a) and seasonality in catch data given in this study would support this hypothesis.

It is while moving down the system to form large spawning aggregations at the mouth that *A. berda* is particularly vulnerable to capture in the Kosi Bay fishtraps. The traps are not only increasing in number, but are also encroaching into the mouth region of the estuary, and therefore catching *A. berda* as they aggregate to spawn. Species that form spawning aggregations are more susceptible to over-exploitation than those which do not (Coleman *et al.* 1996; Dameier and Colin 1997). Heavy fishing of spawning aggregations may result in declining catches, decreases in the mean size of individuals and in the mean size of the aggregation (Dameier and Colin 1997). Perhaps the most relevant example of the effects of heavy fishing on spawning aggregations is the collapse of the South African fishery for the endemic, reef-dwelling sparid, *Polysteganus undulosus* (seventy-four). *P. undulosus* aggregate and spawn on offshore reefs in southern KwaZulu-Natal. Extensive targeting of spawning shoals in the 1960s and 1970s lead to a collapse of this stock, which is now economically extinct (Penney *et al.* 1989; Garratt 1996; Chale-Matsau *et al.* 2001). It has been shown during this study that the mean length of individuals caught in the traps at Kosi Bay has declined during the period 1985 to 2001, coinciding with a decrease in *cpue* for *A. berda* in the recreational linefishery.

As an estuarine-dependent species, *A. berda* is also extremely vulnerable to the effects of estuarine degradation. Degradation of many of South African estuaries has already taken place (Wallace *et al.* 1984), and it is estimated that 26% of the estuaries in KwaZulu-Natal are in poor condition (Heydorn 1986). The principal cause of estuarine degradation are physical activities which decrease freshwater inflow. These include the canalisation of rivers, damage caused by bridge construction, drainage of wetlands, water abstraction and the construction of dams and weirs (Cyrus 1991). Decreasing freshwater inflow ultimately leads to the loss of certain habitat types through the shallowing of channels, reduced sediment scour, increased salinity and reduced tidal exchange (Cyrus 1991; Whitfield 1992). Estuarine degradation affects the abundance of fish populations, particularly species such as *A. berda* which are dependent on ecologically viable estuaries for their survival.

In summary, many of the life history and behavioural traits of *A. berda* increase its susceptibility to overfishing. Like the black bream (*A. butcheri*) from Western Australia, it is probably at moderate risk to over-exploitation, as it shares many of the same life history and behavioural traits. Table 7.1 shows an assessment of the vulnerability of *A. butcheri* to over-exploitation (after Harrison 2001) and the inferred vulnerability of *A. berda*, based on life history and behavioural traits.

Table 7.1. Vulnerability of the estuarine *Acanthopagrus* species to over-exploitation (after Harrison 2001)

Biology	**Black bream** *Acanthopagrus butcheri*	**Riverbream** *Acanthopagrus berda*
Age at maturity	Moore River 4 years Swan River 2 years	KZN 3.6 years
Size at 50% maturity	Swan River female=218mm TL male=212mm TL	KZN 230mm TL
Maximum weight/size	Swan River female=480mm TL male=475mm TL	Kosi Bay 740mm TL St Lucia 741mm TL
Spawning times	August-January	May-August
Fecundity	Multiple spawner, range 13 000-612 000 eggs	Likely to be a multiple spawner (Garratt 1993)
Abundance	Moderate in limited locations	Moderate in limited locations
BIOLOGICAL RISK	Moderate	Moderate
Habitat	Estuarine	Estuarine
Behavioural traits		Spawning aggregations
Fishing pressure	High/increasing	Moderate/increasing
Value eating/fishing	High	Moderate/high
Other issues	Limited gene exchange among isolated populations and heavy fishing pressure around population centres.	Suspected limited gene exchange among isolated populations and heavy fishing pressure by subsistence trap fishing
VULNERABILITY DUE TO FISHING AND ENVIRONMENTAL FACTORS	Moderate/high	Moderate/high
LEVEL OF RISK OF OVER-EXPLOITATION	Moderate, due to isolated nature of fisheries and localised depletion issues	Moderate, due to isolated nature of fisheries and localised depletion issues

Management of the A. berda stock

A. berda is harvested by a variety of fishing methods including hook and line, traditional traps and gillnets. It has been shown to be one of the most important species taken by recreational anglers and subsistence fishers in Kosi Bay and St Lucia and is currently managed as a recreational linefish under the Marine Living Resources Act (No. 18 of 1998). The South African linefishery, which has recreational, commercial and subsistence components, catches approximately 200 species of fishes, of which less than 50 make up the majority of the catch. No commercial linefishing is permitted in estuaries (Penney 1997). The recreational linefishery consists of shore and boat-based anglers. Estuarine angling, depending on the locality, is practised primarily by shore-based anglers (Pradervand *et al.* submitted), with boats only used in larger estuarine systems, such as Kosi Bay, St Lucia, Richards Bay and Durban Bay.

Prior to 1985 there was very little management of the South African linefishery, with only few species being protected by minimum size limits. In response to growing concern regarding the status of many linefish stocks, a comprehensive suite of national management measures was introduced in December 1984 (Penney 1997). Species were divided into groups, depending on the level of protection required, and a number of management measures introduced (see Appendix V for a summary of the linefishery regulations). Restrictive measures on the recreational linefishery include minimum size limits, daily bag limits, closed seasons and closed areas (Penney *et al.* 1989).

According to this scheme *A. berda* is classified as a recreational species, which may not be sold by any sector, including commercial and subsistence fishers. The management measures applied to *A. berda* include a minimum size limit of 250mm TL, and a bag limit of five per person per day. The protection afforded to *A. berda* by these management measures are, however, minimal, as most *A. berda* in Kosi Bay and St Lucia are caught by the subsistence trap and gillnet sectors where minimum sizes and bag limits are not applicable or enforceable.

Subsistence fishing has only recently been officially recognised in South Africa (Marine Living Resources Act No. 18 of 1998). Prior to 1998, there were no systems in place to manage or control this type of fishing. Consequently, the Chief Directorate: Marine and Coastal Management (MCM) appointed a Subsistence Fishers Task Group (SFTG) to makes recommendations about definitions of subsistence fishing and modes of management (Branch *et al.* in press). In this regard the task group has come up with a comprehensive definition of subsistence fishing, but formal regulations for control of subsistence fishing have yet to be finalised (Branch *et al.* in press).

Despite the new linefish management measures implemented in 1985, many linefish species are currently over-exploited and it is believed that regulations have failed to protect resources (Griffiths 1997). Consequently, Griffiths *et al.* (1999) drafted a new management protocol for the South African Linefishery, which calls for operational management procedures (OMPs) for each linefish species. Operational management procedures, which are based on stock assessments, assess and monitor the status of fish stocks, and base management plans on the findings of the stock assessments and discussions between the scientists, industry and managers (Butterworth et al. 1997). *Cpue* data can be used as an indicator during this procedure to provide information on trends in stock size as well as trends in catch composition and the distribution of catch between sectors (Griffiths *et al.* 1999).

The present study aimed to determine the status of *A. berda* in northern KwaZulu-Natal, and thus determine whether the current regulations for the species are appropriate. This is particularly relevant in the light of the new management protocol, the lack of restrictions placed on subsistence fishers, and the moderate susceptibility of this species to over-exploitation.

Per-recruit analysis revealed that the *A. berda* stock is currently at 46% of pristine spawning biomass in Kosi Bay (Figure 7.1). According to Griffiths *et al.* (1999), this places the *A. berda* stock in Kosi Bay in the optimally-exploited category (40-50%

$SB/R_{F=0}$). It is recommended by the management protocol that if a stock is optimally-exploited the current management regulations should remain unaltered.

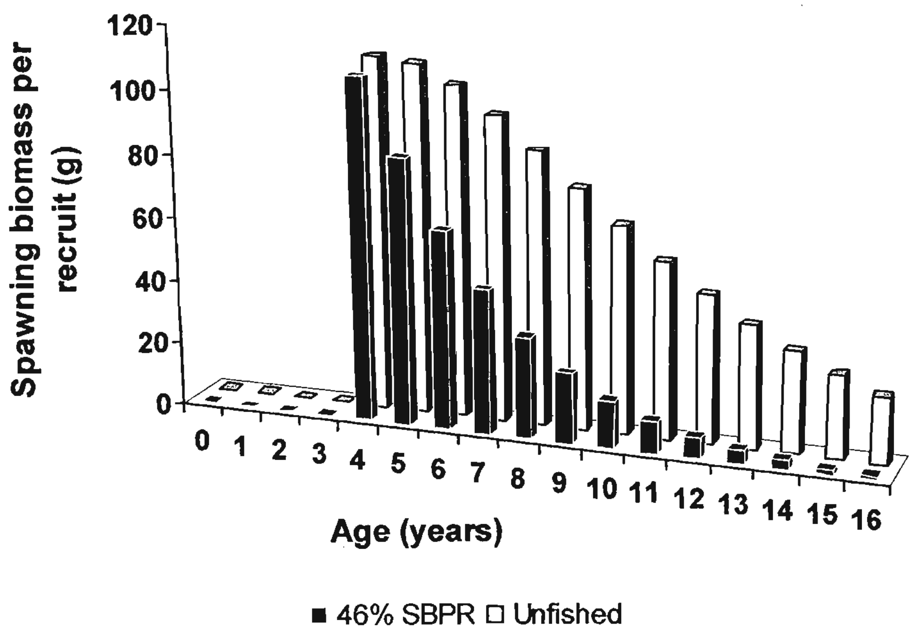


Figure 7.1. The current spawning stock structure for *A. berda* in Kosi Bay relative to an unfished population

These results must, however, be viewed with caution, as the models are extremely sensitive to age-at-first capture. Determining the true age-at-first capture in each fishery is often problematic, especially in the recreational fishery, where catches are not measured and fishermen often catch undersized *A. berda*. Decreasing the age-at-first capture by a year in each fishery would place *A. berda* in the over-exploited category (36% of pristine spawning biomass). There is therefore a very fine line between *A. berda* being optimally-exploited and over-exploited. In addition, *cpue* data showed that catches in the Kosi Bay recreational fishery are declining. *Cpue* data is often used as an indicator of changes in population size (FAO 1976). The mean size of *A. berda* recorded in traps near the estuary mouth in 2001 was also much lower than that recorded prior to 1994, a further indicator that management should be of a precautionary nature.

Based on the susceptibility of this species to over-exploitation, declines in *cpue*, and the sensitivity of the per-recruit model to age-at-first capture, a number of management recommendations for the Kosi Bay stock are proposed. In the light of the small contribution that recreational anglers make to the overall *A. berda* catch, it is recommended that the current recreational restrictions remain unaltered. The number of public access sites to the estuary and lakes and boat launching facilities should, however, be restricted, to prevent recreational angling catches from escalating dramatically. As the traps catch by far the largest percentage of *A. berda* in the system, and are encroaching into the channels and estuary (Kyle submitted), it is recommended that the lower Kosi estuary and mouth region, where *A. berda* aggregate and spawn, should be kept free of traps. The number of fish traps and baskets should also be restricted and these should be spread more evenly through the system, and not concentrated towards the mouth. The channels between the lakes should be kept open and no netting or fish traps should be allowed to extend into these channels. Within the lakes and upper estuary a channel should be kept between kraals on either side. Finally, gillnetting should be restricted to Lake Nhlange only and the current level of effort (45 permits) should not be exceeded.

Per-recruit analyses for the St Lucia system revealed that the St Lucia stock is currently at 55% of pristine spawning biomass (Figure 7.2). This places it in the under-exploited category (>50%$SB/R_{F=0}$). Griffiths *et al.* (1999) recommend that for under-exploited stocks, fishing levels could be slowly increased to maintain the stock at the target reference point (40% $SB/R_{F=0}$). *Cpue* for this species also showed no declining trends in any of the fisheries in the system. However, van der Elst (1977) showed a downward trend in *cpue* of *A. berda* between 1956 and 1977 based on NCAU competition data. In the light of the many problems associated with stock assessments, the problems encountered with the monitoring data, and the moderate susceptibility of *A. berda* to over-exploitation, it is recommended that the current management measures for recreational anglers remain unaltered in this system.

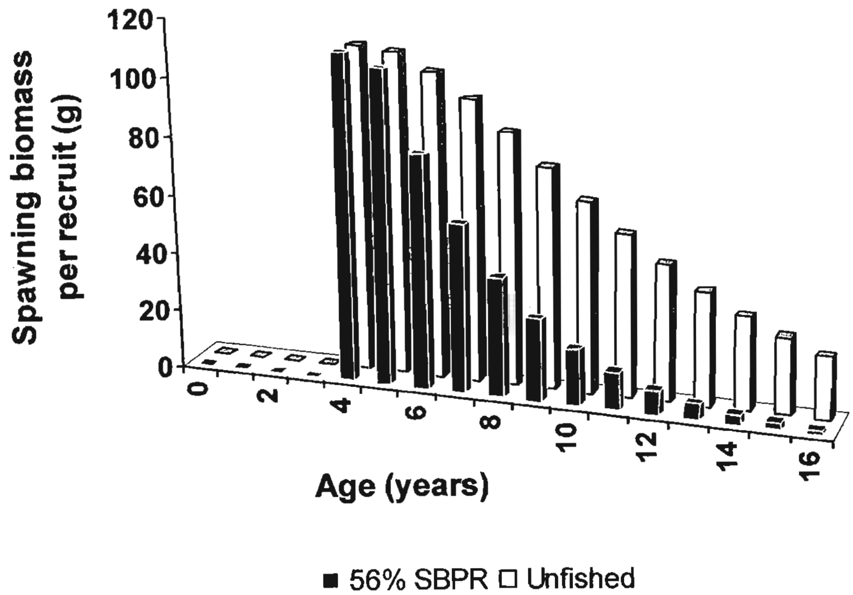


Figure 7.2. The current spawning stock structure for *A. berda* in St Lucia relative to an unfished population.

The St Lucia stock is probably in a healthier state than the Kosi Bay stock, as the St Lucia system is much larger (300 km^2) than the Kosi Bay system (36km^2), and most of the eastern side of north lake is set aside as a wilderness area, in which no fishing is allowed. Despite the increase in illegal netting in the system (Mwanyama *et al.* 1998), the gillnets currently used appear to target larger *A. berda* and because there is no netting in the mouth of the system, the annual spawning aggregations are not targeted. Nevertheless, the problem of illegal gillnetting in St Lucia is a difficult one which needs to be resolved (Mann in press).

Per-recruit assessments could not be undertaken for Richards Bay, as there were no length frequency data available for this system. *A. berda* appear to be caught in low numbers in the marine-dominated Richards Bay harbour and as much of the harbour area is closed to fishing it is unlikely that this species is over-exploited in the harbour. Furthermore, the adjacent Mhlatuze estuary falls into an estuarine protected area where recreational fishing is prohibited, except in the mouth region. Consequently, it is recommended that the current management restrictions should remain unaltered for the recreational fishery in the harbour. As in Lake St Lucia, the illegal gill and seine net fisheries in the Mhlatuze estuary are problematic and need to be urgently addressed by MCM and KZNW, the national and provincial management authorities.

The monitoring system

This study has shown that in order to adequately assess the status of fisheries in these estuaries, the monitoring systems need to be improved. Recreational angling in St Lucia and Kosi Bay is monitored by voluntary catch cards, which are the angler survey method least likely to provide accurate and representative data. Biases associated with catch cards include prestige bias, misidentification of fish species, inaccurate weight or length data and high non-response rates (Pollock *et al.* 1994). In addition to the numerous biases associated with this survey method, the filling out and collection of catch cards has declined markedly in recent years in both Kosi Bay and St Lucia.

In order to undertake more effective analyses of recreational fishing data, the catch card system needs to be improved. In the Greater St Lucia Wetland Park (including Kosi Bay and St Lucia) and other estuarine systems KZNW should have a field ranger present at the landing sites to ensure completion of catch cards, especially during busy periods. However, in addition to catch cards, KZNW staff should conduct random access-point type boat inspections, as are currently undertaken for the offshore skiboat fishery. These not only provide a more accurate assessment of catch and effort as rangers are trained in fish identification, but also provide a means of validating catch cards (van der Elst and Penney 1994). For this to become a reality, more effort and financial support needs to be allocated to the collection of recreational fishing data.

Shore patrols, which are carried out regularly in Richards Bay harbour and to a limited extent in St Lucia, are a more accurate angler survey method, as they are carried out by trained KZNW rangers. Shore patrols are the largest source of NMLS data, but they still have numerous biases associated with them. As the principal aim of shore patrols is law enforcement they are biased towards areas of high effort, and no biological information (lengths or weight) are recorded. In order to increase the usefulness of these data, it is suggested that KZNW rangers record lengths of fish caught, thereby enabling stock assessments to be conducted on the data collected.

Subsistence fisheries in Kosi Bay and St Lucia are monitored by the conservation authority responsible for the management of these systems (KZNW). The monitoring system in place for the gillnet fishery in Kosi Bay appears to be the most successful, as all legal nets are monitored and lengths of the majority of fish caught are recorded. However, in St Lucia and the Mhlatuze estuary at Richards Bay there are major problems and monitoring systems have collapsed.

In contrast to the gillnet fishery at Kosi Bay, only a small number of the Kosi Bay traps are monitored. These traps are not set in areas frequented by *A. berda*, and consequently *A. berda* are rarely recorded in these trap catches, despite being the third most important species taken in this fishery. It is recommended that monitoring should be expanded to include a representative sample of traps throughout the system. In this way the impact of the trap fishery on the Kosi fish populations, and in particular the *A. berda* population, can be more accurately assessed.

Summary

This study indicated that *A. berda* was one of the five most important species taken in recreational and subsistence catches in Kosi Bay, St Lucia and Mhlatuze estuary. It is less important in anglers' catches in the marine-dominated Richards Bay harbour. Life history and behavioural traits, such as slow growth, spawning aggregations and estuarine dependence, interact to make this species moderately vulnerable to over-exploitation. Per-recruit analyses indicated that the *A. berda* stock in Kosi Bay was currently optimally-exploited. However, as these models are sensitive to age-at-first capture and as recreational angling *cpue* data suggests a decline in the population, a number of management recommendations are proposed, such as restricting the number of fish traps, keeping the channels in the lower estuary and mouth free of traps and restricting gillnetting to Lake Nhlange. The *A. berda* stock in the larger St Lucia system appears to be under-exploited, and consequently the current management measures for this species in St Lucia should remain unaltered. Owing to the lack of length frequency data from Richards Bay, a stock assessment was not done for this system, but it is unlikely that the stock is over-exploited. However, the proliferation of subsistence fishing in KwaZulu-Natal and the absence of management measures for subsistence fishing in estuaries at a national level does provide cause for concern, especially for estuarine-dependent species such as *A. berda.*

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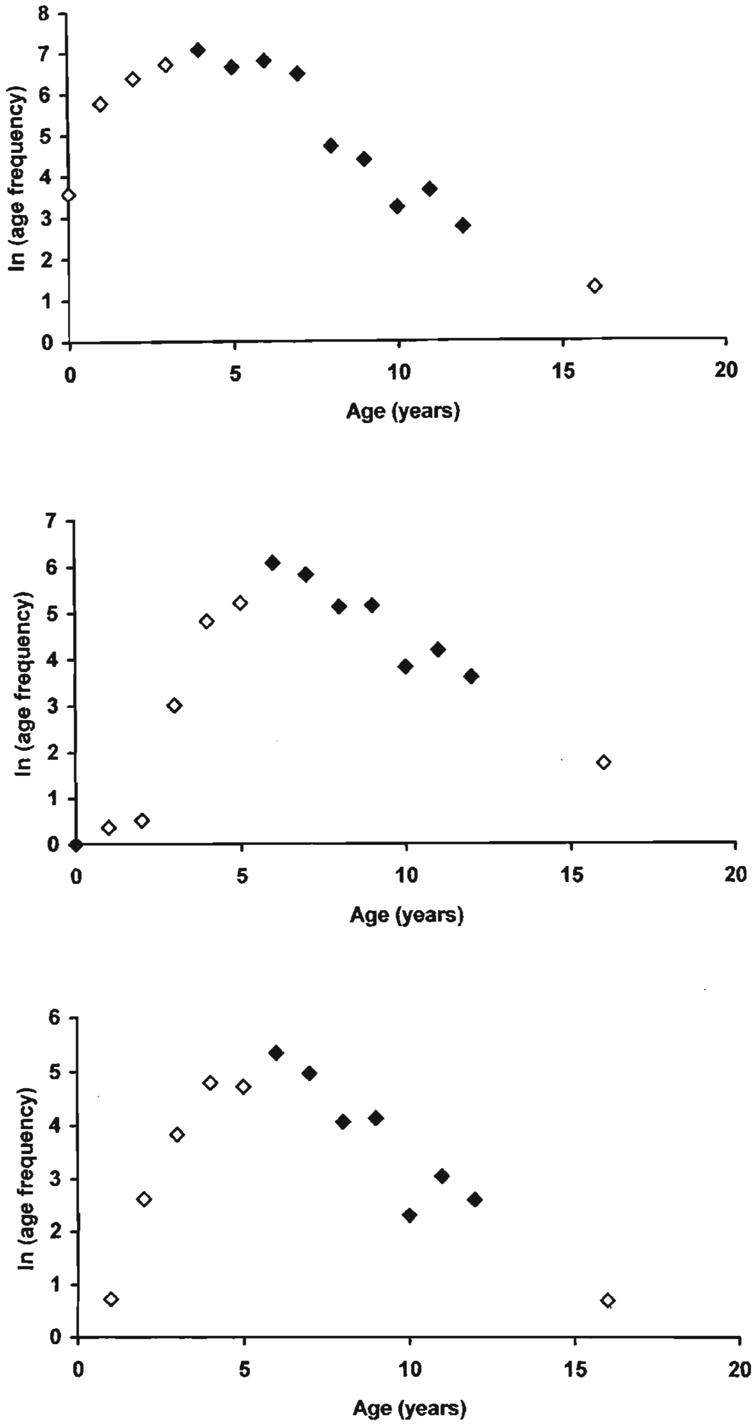
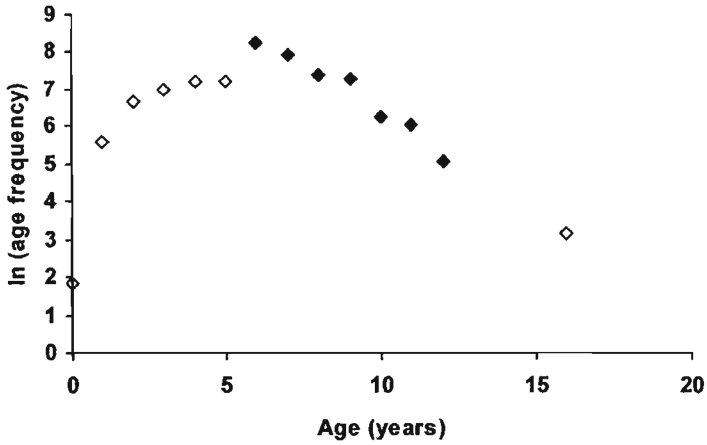
Appendix I:



Catch curves for *Acanthopagrus berda* in Kosi Bay, based on (a) gillnets, (b) fish traps, and (c) recreational tagging data. Solid diamonds indicate points used to calculate Z from the descending limb of the catch curve.



Catch curve for *Acanthopagrus berda* in St Lucia, based on gillnets. Solid diamonds indicate points used to calculate Z from the descending limb of the catch curve.

Appendix II: Age-length key for *Acanthopagrus berda* caught in northern KwaZulu-Natal.

Size class (mmTL)	0	1	2	3	4	5	6	7	8	9	10	11	12	16	Age frequency
70-80	1														1
80-90	1														1
90-100	1														1
100-110	1														1
110-120	3	3													6
120-130	2	2	1	1											6
130-140		9	1												10
140-150		11	1												12
150-160		8	2	1											11
160-170		15	6	1											22
170-180		5	9	3											17
180-190		9	11	5											25
200-210		5	13	6	2			1							27
220-230		1	9	10	2										22
230-240			7	11	4	1									23
240-250			4	11	8	1									24
250-260			1	8	17	2									28
260-270			1	2	8	5	5	1							22
270-280				3	8	5	2	2							20
280-290				2	4	11	8	3							28
300-310					3	1		5							9
310-320					1	4	5		1						11
320-330							4	1							5
330-340					1	3	6	4	2						16
340-350							2	1		1					4
350-360							1	1	1	1					4
360-370						1		5	4						10
370-380								1	2	1					4
380-390										1		1			2
400-410										1			1		2
410-420									1	1	2	1	1	1	7
420-430												1			1
430-440											1				1
440-450											1				1
450-460										1					1

Appendix III: Definitions of biological reference points used in the per-recruit analyses.

F_{MAX}	The fishing mortality rate that maximises yield-per-recruit
$F_{0.1}$	The fishing mortality rate at which the slope of the yield-per-recruit curve is at 10% of the value at the origin
F_{SB25}	The fishing mortality rate at which spawning biomass-per-recruit is at 25% of pristine (i.e. unharvested) levels.
F_{SB40}	The fishing mortality rate at which spawning biomass-per-recruit is at 40% of pristine (i.e. unharvested) levels.
F_{SB50}	The fishing mortality rate at which spawning biomass-per-recruit is at 50% of pristine (i.e. unharvested) levels.

Appendix IV: Relative annual catch of *Acanthopagrus berda* taken by each fishing sector.

	Percentage of total catch (numbers)	Percentage of total catch (mass)	Estimate of the mass (tonnes) caught per year	Estimate of the numbers caught per year
Kosi Bay				
Recreational angling	7	3	0.2	334
Legal gillnets	4	–	0.3	944
Fish traps	6.5	–	1.9	2 708
St Lucia				
Recreational angling	17	6	3.8	–
Legal gillnets	20	10	4.0	6 150
Illegal gillnets	–	–	13.5	

Appendix V: South African linefish regulations (after Sea Fisheries 1998).

SPECIALLY PROTECTED SPECIES	CRITICAL LIST	RESTRICTED LIST	EXPLOITABLE LIST	RECREATIONAL LIST	BAIT LIST	SIZE RESTRICTION
Brindle bass Potato bass Natal wrasse great white shark saw fishes seventy-four	poenskop red steenbras	bludger blue hottentot dageraad dane elf/shad englishman hake kob red stumpnose rock cods roman scotsman slinger west coast steenbras zebra	blueskin Cape gurnard Cape snoek Cape yellowtail carpenter/silverfish dorado/dolphinfish Elasmobranchs # (excluding great white shark, ragged tooth shark, spotted gulley shark, leopard and striped catshark) geelbek hottentot javelin grunter king mackeral/couta panga queen mackeral Natal snoek red tjor-tjor sand soldier santer (soldier) snapper salmon tunas # white stumpnose	baardmans/bellman banded galjoen billfishes # blacktail bronze bream Cape knifejaw Cape stumpnose galjoen garrick/leervis John brown kingfish # (excluding bludger) large-spot pompano leopard catshark Natal knifejaw ragged tooth shark **riverbream** river snapper southern pompano springer spotted grunter spotted gulley shark stonebream striped catshark swordfish white musselcracker white steenbras	anchovies # chub mackeral # fransman # garfishes # glassies half beaks # horse mackeral mullets # pinky sardines # sauries # scads # steentjie strepie cutlassfish wolfherring	2.5cm: glassy 7.5cm: pinky 15cm: strepie 20cm: Cape stumpnose dassie/blacktail 22cm: hottentot 25cm: Natal stumpnose **riverbream** carpenter slinger white stumpnose 30cm: bronze bream dageraad elf/shad roman santer scotsman red stumpnose zebra 35cm: galjoen squaretail kob 40cm: baardmans kob red steenbras river snapper seventy-four spotted grunter west coast steenbras spotted rock cod white-edged rock cod yellowbelly rock cod 50cm: poenskop 60cm: geelbek musselcracker snoek white steenbras 70cm: garrick
NONE	2 PER PERSON PER DAY	5 IN TOTAL PER PERSON PER DAY	10 IN TOTAL PER PERSON PER DAY	10 IN TOTAL BUT ONLY 5 OF THE SAME SPECIES	UNLIMITED	

The # indicates that the regulations apply to all species belonging to the group.