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THE ROLE OF ESTUARIES IN SOUTH AFRICAN FISHERIES: ECONOMIC IMPORTANCE AND MANAGEMENT IMPLICATIONS

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Existing catch data for 129 of 255 functional estuaries on the South African coastline were reviewed and the relationships between fish catch and estuary size, type and biogeographical region analysed using simple and multivariate models. The best predictive models were obtained by analysing data separately for each biogeographical region. Estuary size alone explained >80% of the variation in catch in the warm temperate region and >90% of the variation in catch in the cool temperate and subtropical region. Further analysis of the two main estuary types, i.e. permanently open and temporarily open/closed estuaries revealed a steeper regression slope and therefore greater productivity for the permanently open systems. Estuary size (ha) and type (five) were used to explain catches within the warm temperate and subtropical regions using general linear models. The models were able to explain 82 and 98% of the variance in catches for the two regions respectively, and both were significant ($p < 0.001$). These models were applied to estuary type and size data for all 246 estuaries in the two regions and a total catch of 1 840 tons per year was estimated. Including the cool temperate region the total estuarine catch in South Africa was estimated at 2 480 tons per year. In all, 50% of the estuarine catch was attributed to commercial seine and gillnet fisheries, 46% to recreational angling and 4% to traditional trap and spear fisheries. Total catch value was R433 million per year, of which 99% could be attributed to recreational angling. Estuarine contribution to the inshore marine fisheries was estimated at approximately R490 million per year, estuary-dependent species constituting 83% of the catch of the recreational shore and commercial seine and gillnet fisheries and only 7% of the catch of the recreational spearfishery and commercial and recreational boat fisheries. In 2002, the total value of estuarine and estuary-dependent fisheries was estimated to be R1.251 billion.

Key words: economic contribution, estuarine and marine fisheries, production

It is generally appreciated that estuaries are productive systems that provide a valuable supply of goods and services ranging from fisheries to recreational opportunities (Swallow 1994, Costanza *et al*. 1997, Morant and Quinn 1999). Costanza *et al*. (1997) estimated that estuaries are worth R153 000 per ha per year on average. The bulk of this value can be attributed to food production (R3 500 per ha), recreation (R2 550 per ha) and nutrient cycling (R141 000 per ha: US$1 = R6.7 in 2000). Few studies have attempted to estimate the full economic contribution of estuaries to a national economy. South Africa is well endowed with estuaries, having roughly 255 functioning estuaries along its approximately 3 100 km of coastline. Yet, the economic value of these ecosystem services is unknown. Indeed, the supply of goods and services is not even well understood in physical terms, and there is little understanding of how the characteristics of estuaries, which are highly variable, influence these services.

Partly because of a lack of incentive on account of incomplete appreciation for their full value, and owing to their situation between land and sea, the management of estuaries in South Africa has been inadequate and never a priority (Boyd *et al*. 2000). Lack of management and other attention generally means that estuaries have been subject to increasing pressures, both indirectly from the effects of catchment utilization, which affect their water supply, and directly from the increasingly large number of people who reside in or visit the coastal zone.

Many human activities carried out in estuaries and their catchment areas impact directly on estuarine biodiversity and resources, and different activities often conflict with one another through such impacts. If estuaries and their catchments are to be managed in an optimal sustainable way, it is necessary to understand the full economic value of the goods and services that they provide.

One of the most important values of estuarine systems is their contribution to fisheries. Partially or temporarily resident fish populations are exploited directly in estuarine recreational and subsistence fisheries. More importantly, however, estuaries provide nursery areas for numerous species of fish that are exploited by recreational and commercial harvesting in the inshore marine environment. These species are dependent on estuaries for the early stages of their growth (Whitfield 1994).

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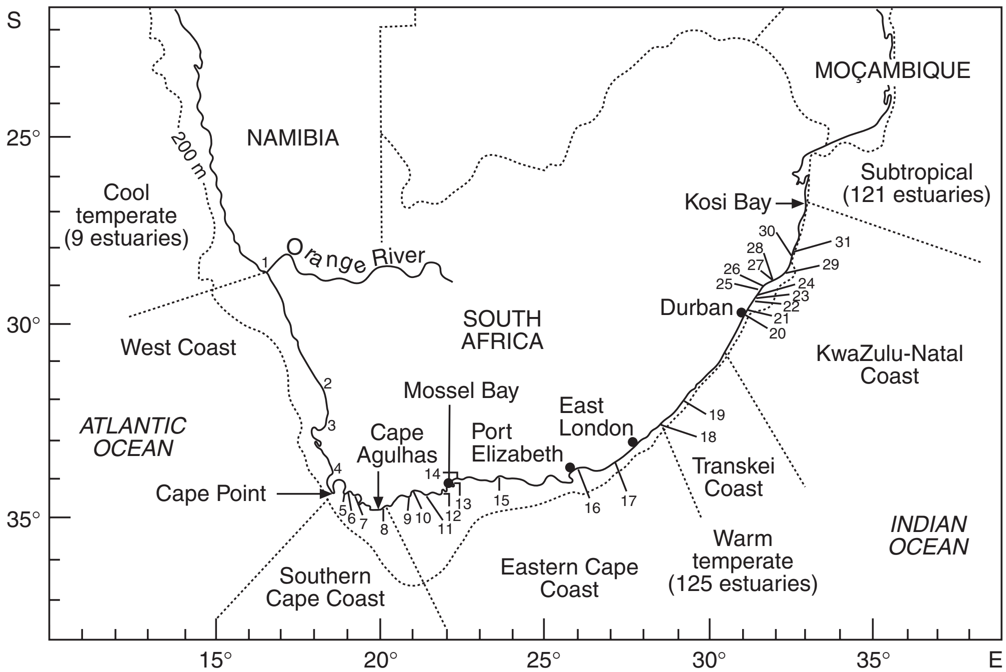

1. Orange/Gariep	11. Goukou	21. Umgeni
2. Olifants	12. Gouritz	22. Nonoti
3. Berg	13. Klein Brak	23. Zinkwazi
4. Rietvlei/Diep	14. Groot Brak	24. Thukela (was Tugela)
5. Kleinmond	15. Knysna	25. Amatikulu/Nyoni
6. Bot	16. Swartkops	26. Umlalazi
7. Klein	17. Keiskamma	27. Richard's Bay
8. Heuningnes	18. Great Kei	28. Mhlatuze
9. Breede	19. Mbashe	29. Nhlabane
10. Duiwenhoks	20. Durban Bay	30. Msundusi/Mfolozi
		31. St Lucia

Fig. 1: Map of South Africa showing the areas and estuaries (numbered) mentioned in the text

The management of estuaries in South Africa has not been well organized in the past. Now, with increasing realization of their value, as well as of the pressures that threaten them, efforts are being made to redress the situation and to set in place sound decision-making processes regarding their management and conservation (Boyd *et al*. 2000, Breen and McKenzie 2001, Turpie *et al*. 2002). This is both in terms of the management of catchments and determination of freshwater inflows into estuaries, and in terms of their direct management and activities within them.

This study reviews the available published and unpublished data on the exploitation of fish (excluding invertebrate fisheries) within South African estuaries. The main aims of this study were:

(i) to list the estuarine fish species exploited in South African fisheries, giving their degree of dependence on estuaries;
(ii) to describe the types of estuarine and marine fisheries exploiting estuarine fish, and their total participation and effort;
(iii) to estimate the total catches of estuary-associated species in estuaries and the marine environ-

Table I: The five major categories and subcategories of fish that utilize southern African estuaries (Whitfield 1994)

Category	Description
I	Estuarine species that breed in southern African estuaries Ia – Resident species that have not been recorded spawning in marine or freshwater environments Ib – Resident species that also have marine or freshwater breeding populations
II	Euryhaline marine species that usually breed at sea, with juveniles showing varying degrees of dependence on southern African estuaries 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.
III	Marine species that occur in estuaries in small numbers, but are not dependent on these systems
IV	Freshwater species, whose penetration into estuaries is determined primarily by salinity tolerance. This category includes some species that may breed in both freshwater and estuarine systems.
V	Catadromous species that use estuaries as transit routes between the marine and freshwater environments, but may also occupy estuaries in certain regions Va – Obligate catadromous species that require a freshwater phase in their development Vb – Facultative catadromous species that do not require a freshwater phase in their development

ment;

(iv) to explain the contribution to fisheries made by different types of estuaries and;

(v) to estimate the contribution that estuarine and estuary-dependent fish make to the economic value of estuarine and marine catches.

In doing so, the findings are discussed in terms of the stock status of important estuarine fish species and assessed in terms of their implications for estuary management.

METHODS AND STUDY APPROACH

Subdivision of the study area

The South African coast can be considered in terms of three biogeographical regions: the cool temperate region on the West Coast; the warm temperate region from Cape Point to approximately the Mbashe River in the former Transkei; and the subtropical region to the north-east of the Mbashe River (Fig. 1). The second boundary is rather poorly defined, largely because the presence or absence of fish is strongly influenced by a major tropical subtraction effect from Kosi to Cape Point (Turpie *et al.* 1999a), rather than any natural geographical break.

For practical purposes, the South African coast has often been divided into five regions for the collection of fisheries data, corresponding with the Cape Point biogeographical division, but not with the second division. These are the West Coast (Orange/Gariep River to Cape Point), South Coast (Cape Point to Port Elizabeth), East Coast (Port Elizabeth to Kei River), Transkei (Kei River to Port Shepstone) and KwaZulu-Natal (Port Shepstone to Kosi Bay). Thus, the warm temperate region is mostly divided into two sections, and the former Transkei (hereafter referred to as the Transkei) constitutes a very broad transition area between biogeographical zones.

Estuarine fish and their dependence on estuaries

General information on the biology and distribution of estuarine fish species was obtained from Whitfield (1998) and Mann (2000). Information on which of these species are utilized was derived from a variety of sources, including the National Marine Linefish System (NMLS) database, the Netfish System database, and various published papers and reports.

This study is only concerned with utilized fish species. Of these, different species have different degrees of association with estuaries, and estuarine fish have been classified into five broad categories of association, which may be further subdivided into nine types (Whitfield 1994, Table I). Category I and IIa species are entirely dependent on estuaries, as are Category V species. Category IIb species are largely dependent on estuaries, whereas the numbers of Category IIc species are augmented by estuaries. Category III species are found in estuaries, but are not dependent on them.

Types of fisheries, participation and effort

For estuarine fisheries, included are legal and illegal seine and gillnet fisheries, recreational shore, castnet and recreational boat fisheries, and traditional fisheries. For marine fisheries, the recreational boat, shore and spear, as well as the commercial boat, beach-seine and gillnet fisheries were considered. Pelagic fisheries were excluded because none involve estuary-associated species.

There are no comprehensive nationwide studies of estuarine fishing participation or effort. However, these were obtained from published and unpublished literature on a number of individual estuaries (Marais and Baird 1980, Guastella 1994, Mann 1994, 1995, 1996, Kyle 1995, 1999, Baird *et al.* 1996, Sowman *et al.* 1997, Baird and Pradervand 1999, Hutchings and Lamberth 1999, 2002a, b, Beckley *et al.* 2000, Lamberth 2000a, b, Hutchings *et al*. 2002, Pradervand and Baird 2002), as well as extrapolation from coastal fisheries. For marine fisheries, participation and effort in recreational shore angling, boat fishing and spearfishing was estimated from the regional reports of the National Linefish Survey (Brouwer 1996, Lamberth 1996, Mann *et al.* 1996, 1997, 1998, Sauer and Erasmus 1996, Brouwer *et al.* 1997, Sauer *et al.* 1997, Mann *et al.* 2003), and attributed to particular species on the basis of the proportion of successful fishers that had caught that species, extrapolated to the total estimated number of fishers. For the commercial boat fishery, participation was gauged as the sum of the mean number of crew carried by the boats that reported catches of particular species to the NMLS over a five-year period.

Similarly, participation for the beach-seine and gillnet fisheries was estimated as the sum of the number of permit-holders that had reported catching a particular species to the NMLS multiplied by the mean crew size (Lamberth *et al.* 1997, Hutchings and Lamberth 1999).

Estuarine catch estimates

Estimates of estuarine catches and their species composition were obtained from the literature (Marais and Baird 1980, Guastella 1994, Mann 1994, 1995, Kyle 1995, 1996, 1999, 2000a, b, Baird *et al.* 1996, Lamberth 1996, 2000a, b, Sowman *et al.* 1997, Baird and Pradervand 1999, Hutchings and Lamberth 1999, Beckley *et al*. 2000, Pradervand and Baird 2002) and from unpublished data and estimates supplied by Dr P. D. Cowley (South African Institute for Aquatic Biodiversity), Mr B. Q. Mann (Oceanographic Research Institute) and Marine & Coastal Management. Estimates were based on sampling, counts of fishers, surveys, and confiscated catches. Of the 255 functional estuaries considered in this study, information allowing catch estimates was available for about one-half of them (n = 129): all 9 estuaries on the West Coast, 24 out of 52 estuaries on the South Coast (Cape Point to Mossel Bay), 23 out of 54 on the East Coast (Swartkops to Keiskamma), none of the 67 Transkei estuaries, and all 73 estuaries in KwaZulu-Natal. In terms of biogeographical regions, data are available for all 9 estuaries in the cool temperate region, 47 out of 125 in the warm temperate region, and 73 out of 121 in the subtropical region.

In order to extrapolate the existing catch estimates to the remaining estuaries, the relationships between estuarine catches and estuary size, type and biogeographical region were analysed using simple and multivariate models. General linear modelling was used to create predictive models to estimate catches for the remaining estuaries. Dependent variables used were estuary size (B. Colloty, University of Port Elizabeth, unpublished data), biogeographical region and estuary type (Whitfield 1992). The best predictive models were obtained by analysing data separately for each biogeographical region. The St Lucia Estuary in KwaZulu-Natal, and the Bot and Klein estuaries on the South Coast, were excluded from analyses; these are large estuaries in which catches are disproportionately low (in the case of St Lucia this is partly a result of exclusion zones).

Marine catch estimates

For marine fisheries, total catches for each species were estimated from the regional reports of the National Linefish Survey (recreational shore-angling and spearfishing catches, 1994–1996; Brouwer 1996, Lamberth 1996, Mann *et al.* 1996, 1998, Sauer and Erasmus 1996, Brouwer *et al.* 1997, Sauer *et al.* 1997, Lechanteur 2000, Mann *et al*. 2003), the NMLS (commercial boat catches, recreational boat catches, 1992–1996) and catch reports from the Marine & Coastal Management Netfish System (commercial beach-seine and gillnet catches, excluding KwaZulu-Natal, 1992–1996). The latter were corrected using validated catches from Lamberth *et al.* (1994, 1995, 1997) and Hutchings and Lamberth (1999, 2002a, b). KwaZulu-Natal netfish catches were estimated from Beckley and Fennessy (1996).

It is difficult to attribute the actual contribution of individual estuaries to the marine catch, but data were disaggregated, as far as possible, to coastal sections.

Inshore marine fishery catches were analysed in terms of the amount made up of estuary-associated fish, and the percentage dependency of the total catch on estuaries. The latter was estimated on the basis of the dependence categories (Whitfield 1994) of different estuarine species in catches, assigning a percentage to each category reflecting the degree to which that species would be lost from marine catches if all estuaries were to disappear.

Economic value

Estimates of the economic value of fisheries in South Africa have been confined mainly to marine commercial and recreational fisheries. Estimates of the economic contribution of each of the marine linefisheries were obtained from McGrath *et al.* (1997), based on NMLS data, and of the marine and estuarine netfisheries were obtained from Hutchings and Lamberth (1999) and Hutchings *et al.* 2002.

For marine fisheries, the relative contribution of each species was determined according to the methods used by Lamberth and Joubert (1999). Fish prices were obtained from telephonic interviews with dealers countrywide. The mean price per kg of each species was multiplied by the total mass of that species caught, and summed to obtain the total landed catch value for each sector. The proportion that each species contributed to this landed value was multiplied by the total economic contribution of that sector (including subsidiary industries), as determined by McGrath *et al.* (1997) and Hutchings and Lamberth (1999, 2002b). Overall values obtained for each species were reduced according to the percentage dependence on estuaries for that species to estimate the estuarine contribution to the marine fishery values.

No comparable estimate of the overall economic value of estuaries has been made. Consequently, the economic value of estuarine fisheries was estimated on the basis of catch estimates. For recreational fisheries and commercial fisheries, it is assumed that the value per landed kg of fish is the same as for marine fisheries. Traditional estuarine fisheries were assigned the same value per landed kg as commercial marine gillnet fisheries, which is close to market values.

Stock status and vulnerability of utilized estuarine fish species

The conservation status of exploited estuarine fish species was gauged according to abundance (stock status), level of knowledge, endemicity, level of exploitation throughout a species' range, and vulnerable life history traits, following the methods of Lamberth and Joubert (1999), all attributes being scored on a scale of 1–100:

(a) *Abundance*. Depending on availability of data, this score was based on the percentage of pristine spawner biomass remaining, ratios of present to historical catch per unit effort (*cpue*), or ratios of present to historical contribution to total catches. Data were obtained from various sources, e.g. the NMLS (Centre for Marine Studies 2000, Mann 2000). Each species was scored on a scale of 1–100, score ranges indicating the stock as underexploited, optimally exploited, overexploited or collapsed (Griffiths *et al.* 1999).

(b) *Level of knowledge*. The 14 factors described in Van der Elst and Adkin (1999) and Mann (2000) were used for scoring the current level of knowledge for each species on a scale of 1–100.

(c) *Endemicity*. Each species was scored according to the number of regions in which it occurred, as follows: one region = 100, two regions = 60, three regions = 40, four regions = 20, southern Africa = 10, cosmopolitan = 0. Range data were mostly obtained from Smith and Heemstra (1986).

(d) *Level of exploitation*. This was scored qualitatively on the basis of the Centre of Marine studies (1999) and expert opinion. For example, a species heavily exploited throughout its range scored 100, medium = 50, and low = 0.

(e) *Vulnerability*. This was gauged using eight life history traits, namely estuary dependence, sex changes, spawning migrations, predictable aggregations, high age at maturity, longevity, residency and high catchability. Species displaying none of these characteristics scored 0, those with one, two or three characteristics scored 70, 80 or 90 respectively, and those displaying four or more of these characteristics scored 100 (see Lamberth and Joubert 1999 for rationale).

RESULTS AND DISCUSSION

Utilized estuarine fish species, their distribution and dependence on estuaries

About 160 species occur in South African estuaries, of which about 80 are utilized in fisheries. Of the 80 utilized species, 3, 47, 21, 3 and 6 species fall into Categories I–V respectively (Table II). Of particular importance are the Category I and II species, for which management of estuaries plays a crucial role in fisheries. Catches of estuary-associated fish species differ from west to east around the coast, following biogeographical changes from the cool temperate region on the West Coast through to the subtropical region north of the Mbashe River. The cool temperate region is relatively species-poor but pro-

Table II: Estuary-associated species caught in South African fisheries, given in order of estuary-dependence category (Table I), and distribution of catches around the coast. Distribution is divided into West Coast (Orange River to Cape Point), South Coast (Cape Point to Port Elizabeth), East Coast (Swartkops to Kei River), Transkei and KwaZulu-Natal (KZN; Port Edward to Kosi Bay). The three biogeographical provinces are separated by Cape Point and roughly at the Mbashe River in the Transkei (Emanuel *et al.* 1992, Turpie *et al.* 1999, Maree *et al.* 2000a, b)

Species	Common name(s)	Dependence category	Distribution				
			Cool temperate	Warm temperate			Subtropical
			West	South	East	Transkei	KZN
Ambassis productus	Longspine glassy	Ia					X
Ambassis dussumieri	Bald glassy	Ib		X	X	X	X
Ambassis natalensis	Slender glassy	Ib					X
Rhabdosargus holubi	Cape stumpnose	IIa	X	X	X	X	X
Argyrosomus japonicus	Dusky kob	IIa		X	X	X	X
Mugil cephalus	Flathead/springer mullet	IIa	X	X	X	X	X
Elops machnata	Ladyfish/tenpounder	IIa		X	X	X	X
Lichia amia	Leervis/garrick	IIa	X	X	X	X	X
Acanthopagrus berda	Perch/riverbream	IIa				X	X
Pomadasys commersonni	Spotted grunter	IIa		X	X	X	X
Lithognathus lithognathus	White steenbras	IIa	X	X	X	X	X
Monodactylus falciformis	Cape/Oval moony	IIa			X	X	X
Liza macrolepis	Largescale mullet	IIa					X
Valamugil cunnesius	Longarm mullet	IIa				X	X
Valamugil robustus	Robust mullet	IIa				X	X
Terapon jarbua	Thornfish	IIa			X	X	X
Galeichthys feliceps	Barbel	IIb	X	X	X	X	X
Sphyraena barracuda	Barracuda	IIb					X
Caranx sexfasciatus	Bigeye kingfish	IIb					X
Caranx ignobilis	Giant kingfish	IIb				X	X
Rhabdosargus sarba	Natal stumpnose	IIb				X	X
Scomberoides lysan	Doublespotted queenfish	IIb					X
Liza tricuspidens	Striped mullet	IIb		X	X	X	X
Thryssa vitrirostris	Orangemouth glassnose	IIb					X
Gerres acinaces	Smallscale pursemouth	IIb					X
Gerres methueni/rappi	Evenfin pursemouth	IIb					X
Leiognathus equula	Slimy	IIb					X
Monodactylus argenteus	Natal/Round moony	IIb				X	X
Liza alata	Diamond mullet	IIb				X	X
Liza dumerilii	Groovy mullet	IIb		X	X	X	X
Liza luciae	St Lucia mullet	IIb					X
Platycephalus indicus	Bartailed flathead	IIc			X	X	X
Diplodus sargus	Dassie/blacktail	IIc		X	X	X	X
Pomatomus saltatrix	Elf	IIc	X	X	X	X	X
Liza richardsonii	Harder	IIc	X	X	X		
Pomadasys hasta/kakaan	Javelin grunter	IIc					X
Johnius dussumieri	Mini kob	IIc			X	X	X
Sphyraena jello	Pickhandle barracuda	IIc					X
Lutjanus argentimactulus	River snapper	IIc				X	X
Sillago sihama	Silver sillago	IIc					X
Sarpa salpa	Strepie	IIc		X	X	X	X
Rhabdosargus globiceps	White stumpnose	IIc	X	X	X		
Carcharhinus leucas	Zambezi shark	IIc					X
Strongylura leiura	Yellowfin needlefish	IIc					X
Caranx melampygus	Bluefin kingfish	IIc					X
Caranx papuensis	Brassy kingfish	IIc					X
Chanos chanos	Milkfish	IIc					X
Lutjanus fulviflamma	Dory snapper	IIc					X
Valamugil buchanani	Bluetail mullet	IIc					X
Valamugil seheli	Bluespot mullet	IIc					X

(continued)

(Table II: continued)

Species	Common name(s)	Dependence category	Distribution				
			Cool temperate	Warm temperate			Subtropical
			West	South	East	Transkei	KZN
Dasyatis chrysonota	Blue stingray	III	X	X	X		
Himantura uarnak	Honeycomb stingray	III					X
Gymnura natalensis	Butterfly/diamond ray	III		X	X	X	X
Myliobatus aquila	Eagle ray	III	X	X	X		
Mustelus mustelus	Smooth houndshark	III	X	X	X	X	X
Rhinobatos annulatus	Lesser guitarfish/sandshark	III	X	X	X	X	
Epinephelus andersoni	Catface rockcod	III				X	X
Epinephelus malabaricus	Malabar rockcod	III					X
Pomadasys multimaculatum	Cock grunter	III					X
Pomadasys olivaceum	Piggy	III	X				
Chelidonichthys capensis	Cape gurnard	III	X	X	X		
Trachurus trachurus capensis	Horse mackerel	III	X	X	X		
Lithognathus mormyrus	Sand steenbras	III	X	X	X		
Otolithes ruber	Snapper kob	III					X
Trachinotus africanus	Southern pompano	III			X	X	X
Spondyliosoma emarginatum	Steentjie	III	X	X	X	X	X
Sparodon durbanensis	White musselcracker	III		X	X	X	X
Diplodus cervinus hottentotus	Zebra/wildeperd	III		X	X	X	X
Kuhlia mugil	Barred flagtail	III			X	X	X
Muraenesox bagio	Pike conger	III			X	X	X
Thrysoidea macrura	Slender giant moray	III					X
Oreochromis mossambicus	Moçambique tilapia	IV	X	X	X	X	X
Clarius gariepinus	Sharptooth catfish	IV	X	X	X	X	X
Glossogobius giuris	Tank goby	IV					X
Anguilla bengalensis	African mottled eel	Va		X	X	X	X
Anguilla bicolor	Giant mottled eel	Va		X	X	X	X
Anguilla mossambica	Longfin eel	Va		X	X	X	X
Megalops cyprinoides	Oxeye tarpon	Vb					X
Myxus capensis	Freshwater mullet	Vb		X	X	X	X
Total number of species	80		19	34	41	43	71

ductive, and the fisheries include only about 19 estuary-associated species (Table II). Numbers of estuarine species in catches almost double immediately east of Cape Point, and increase towards the east, with up to 71 species in KwaZulu-Natal (Table II). Some 28 estuary-associated species are caught only or predominantly in KwaZulu-Natal. Within regions, species composition of catches within estuaries also differs between estuaries of different types and sizes, with greater species richness associated with larger and permanently open estuaries.

Estuarine fisheries

TYPES OF FISHERIES, PARTICIPATION AND EFFORT

Linefishing — Linefishing, from the shore or from boats (canoes to skiboats), and using handlines or rods, is popular in estuaries throughout South Africa. It is primarily a recreational angling pursuit, requiring a permit. A small number of subsistence fishers are active, mainly from Port Elizabeth to KwaZulu-Natal, and subsistence permits are in the process of being introduced. No commercial linefishing is permitted in estuaries. Studies of angling participation or effort are confined to a few specific estuaries. Angling participation and effort for each region was evaluated as follows.

Angling is limited on the West Coast on account of the lack of suitable angling fish, but assuming angler densities similar to adjacent shorelines, there may be up to 0.12 anglers km^{-1} of estuary at any one time, or a maximum of 4 400 angler-days $year^{-1}$ on West Coast estuaries. This represents the effort of approximately 147 fishers (Lamberth 2000a). All the effort is currently recreational, but about 14% of the anglers

Table III: Estimated numbers of fishers participating in various types of fisheries in different regions along the South African coast (legally and illegally)

Type of fishery	West Coast	South Coast	East Coast	Transkei	KwaZulu-Natal	Total
Linefishing	147	7 400	9 300	5 500	50 000	72 347
Castnetting	95	300	600	75	4 500	5 570
Gillnetting	550	50	? 50+	? few	550	~1 200
Seine-netting	0	<5	0	?	140	~150
Traditional methods	0	0	0	0	120+	120+
Total*	697	7 455	9 350	5 500	50 810	73 812

* Excludes castnet data because most are anglers

admit to selling part of their catch (Lamberth 1996).

On the South Coast, from Cape Point to Mossel Bay, based on angler densities on adjacent shorelines and angler and boat counts on the Breede, Klein, Bot and Heuningnes estuaries, there are an estimated 66 200 angler-days year^{-1}. This represents the effort of approximately 2 209 fishers. These effort estimates are probably extremely conservative, because the Overberg district council issues 1 200 boat permits per year, mostly for the Breede River. In addition, current confusion over estuarine regulations and commercial linefish permits has led to commercial linefishers moving illegally into estuaries to an unknown extent. Extrapolating to the entire South Coast, an annual total effort of 133 000 angler-days by 7 400 anglers is estimated.

Little is known about angling effort on the East Coast, but it is estimated that there are at least 130 000 angler-days of effort expended per year in estuaries from the Swartkops to the Keiskamma, representing about 8 000 anglers (extrapolated from Pradervand and Baird 2002). Extrapolating to the entire East Coast, an annual total effort of approximately 168 000 angler-days by 9 300 anglers is estimated (Table III).

There is no information on estuarine angling for the entire Transkei coastline. However, a shore-angling survey in the Transkei found about 400 000 angler-days year^{-1}, representing the effort of about 19 000 anglers (Mann *et al.* 1998, Mann *et al.* 2003). Using similar assumptions as for other parts of the South African coastline, it is estimated that there are approximately 112 000 angler-days spent per year in estuaries in the Transkei, representing the effort of between 5 000 and 6 000 anglers.

In KwaZulu-Natal, some preliminary estimates have been made of angling effort in Kosi Bay (10 000 boat-angler outings year^{-1}), St Lucia (30 000 boat-angler outings year^{-1} and 18 000 shore-angler outings year^{-1}), Durban Bay (21 000 boat-angler outings year^{-1} and 100 000 shore-angler outings year^{-1}) and Umgeni estuary (11 000 shore-angler outings year^{-1} – Beckley *et al.* 2000, Mann *et al.* 2002). The number of anglers using estuaries in KwaZulu-Natal is estimated to be more than 50 000 (Beckley *et al.* 2000).

The total number of anglers using estuaries in South Africa is estimated to be around 67 000 year^{-1}. This value is similar to van der Elst's (1989) estimate of 50 000 anglers operating from light tackle boats in South African estuaries.

Castnetting — Castnetting is used mainly by recreational and subsistence anglers to catch bait fish such as harder (southern mullet) *Liza richardsonii.* It is practised throughout South Africa, and requires a permit. There is one commercial castnet permit in KwaZulu-Natal, for Durban Bay. The gear used is restricted to a weighted monofilament or braided nylon net 1.5–4 m in diameter, with a mesh size of 15–20 mm. On the East and KwaZulu-Natal coasts, the larger nets are used for catching linefish species, but amendments to the regulations are intended to curtail this practice. The regulations will restrict castnets to 2 m diameter, with mesh sizes of 13–20 mm.

On the West Coast, castnets are used regularly by about 95 recreational shore-anglers, almost exclusively targeting harders, with a total effort of about 2 837 angler-days year^{-1}. This accounts for approximately 1.2% of angler effort (Lamberth 2000a, b). On the South Coast, approximately 300 shore-anglers use castnets regularly, with a total effort of approximately 8 972 angler-days year^{-1} (Lamberth 1996). The amount of castnetting along the East Coast is unknown, but it is estimated to be about 10 800 days year^{-1} by 600 fishers (based on Brouwer 1996). Castnetting is less common in the Transkei, where there are at least 75 castnet users, with an estimated effort of 1 300 days year^{-1}. In KwaZulu-Natal, 4 511 recreational castnet licences were issued in 1997 (Mann 2000). Effort is unknown, but it probably amounts to at least 10 800 days year^{-1}. Also important is that an effort-limitation system has been developed for estuaries in KwaZulu-Natal, with a set number of castnet permits for each estuary (Beckley *et al.* 2000). The total number of castnetters using estuaries in

South Africa is estimated to be about 5 570 (Table III).

Gillnetting — Gillnetting is a passive form of fishing using monofilament or woven nylon nets, deployed either from a boat or walking out from the shore, in the hope that a shoal of fish will swim into them and become entangled. These nets may either drift, be staked or be anchored, but in terms of legislation they may not be left unattended, except in KwaZulu-Natal where they are set overnight and retrieved in the morning. Permits for estuaries are only issued on the West Coast and in KwaZulu-Natal, where permit-holders are restricted to the use of one net, ranging from 35 to 75 m long, depending on the estuary in which they operate. In addition to legal netting, there is substantial illegal gillnetting in estuaries throughout South Africa. Overall, catch rates dictate that the fishery changes from a largely commercial venture on the West Coast to more subsistence in nature as one moves eastwards to KwaZulu-Natal (Lamberth *et al.* 1997).

On the West Coast, gillnetting takes place in the Olifants, Berg and Rietvlei/Diep estuaries. There are 85 gillnet permit-holders in the Olifants Estuary, and an additional 20–30 people operating without permits. Annual effort is about 15 300 net-days year^{-1} (Lamberth 2000a). On the Berg River Estuary, there are 120 gill-net permit-holders, plus about 100 illegal operators, and annual effort is about 13 230 net-days of legal effort plus at least 4 000 net-days of illegal effort (Hutchings and Lamberth 1999). The Rietvlei/Diep system is fished by about 10 or 12 illegal netters (Lamberth 2000a).

Along the South Coast, at least three teams of illegal netters operate in the Bot/Kleinmond and Klein estuaries (2–6 people per team), and according to Cape Nature Conservation, up to five nets have been found in either estuary at any one time. There are also up to 10 illegal nets used in the Breede and Duiwenhoks estuaries, mostly by landowners and holiday home owners, but sometimes also by West Coast gillnetters targeting spotted grunter *Pomadasys commersonni* and flathead mullet *Mugil cephalus*. This is probably a similar level of effort in the Goukou, Gouritz, Klein Brak and Groot Brak estuaries.

Little is known about illegal gillnetting in the East Coast estuaries, but it occurs sporadically in several of these systems, where poachers often make use of cheap fine-meshed nets such as the netting used in fruit packing. It is also reported that illegal operators in this region sometimes make use of local people in rural areas to masquerade as subsistence collectors (Cowley 2000). There is evidence that gillnetting has been increasing along the East Coast over the past few years. Almost nothing is known about gillnetting activities in the Transkei.

In KwaZulu-Natal, available information suggests that there is currently gillnetting in about 12 estuaries, most of which is illegal (Beckley *et al.* 2000). In Kosi, 45 permits are rotated among approximately 90 people, and there are about 90 regular illegal gillnetters, excluding transient people from Moçambique and the Pongola floodplain (Kyle 2000a). In St Lucia, there are 37 gillnet permits, with an additional estimated 270 people operating illegally in the system. There is a small experimental gillnet fishery in the Msundusi/Mfolozi system, involving about 28 fishers. Illegal netting also occurs in Richards Bay, Nhlabane, Umlalazi, Amatikulu/Nyoni, Tugela, Zinkwazi, Nonoti, Durban Bay and Kosi Bay.

It is estimated that there are approximately 1 200 gillnetters operating in estuaries in South Africa (Table III).

Seine-netting — Seine-netting is an active form of fishing in which woven nylon nets are either rowed or walked out to encircle a shoal of fish. The net is then hauled to shore by a crew of 6–30 persons, depending on the size of the net and the length of the haul (Lamberth *et al.* 1997). There are currently no seine-net permits for estuaries on the West, South, East and Transkei coasts, and only one permit is issued in Richards Bay, KwaZulu-Natal, for mullet for bait (Beckley *et al.* 2000). Nevertheless, a small amount of seine-netting also occurs illegally in estuaries throughout South Africa, often using fine-meshed shade cloth for nets. Illegal seine-netting occurs in the Heuningnes, Breede, Duiwenhok and Groot Brak estuaries. In KwaZulu-Natal, there is illegal seine-netting in Lake St Lucia and Richard's Bay and in the Mhlatuze, Amatikulu/Nyoni, Zinkwasi, Tugela, Mlalazi, Nhlabane and Mfolozi estuaries. Some of this illegal effort is targeted at prawns. The total number of seine netters using South African estuaries probably does not exceed 150 (Table III).

Traditional fisheries — Traditional fishing methods, which are common in tropical countries to the north of South Africa, are mostly, if not exclusively, confined to the Kosi system in South Africa. These fisheries use fish traps, spears and baskets. Traditional fish traps are guide fences made of poles, sticks and brushwood collected from the surrounding coastal forest, which channel fish into a terminal collecting pen on the falling tide. There are about 120 *bone fide* trappers operating about 150 traps in Kosi (Kyle 2000b). Traditional spearfishing is carried out using a long, straight branch with a sharpened piece of iron-reinforced rod inserted in the end (Kyle 1995). Fish are stalked in the shallows and the spear is thrown at them. Fishing baskets are oblong baskets that are

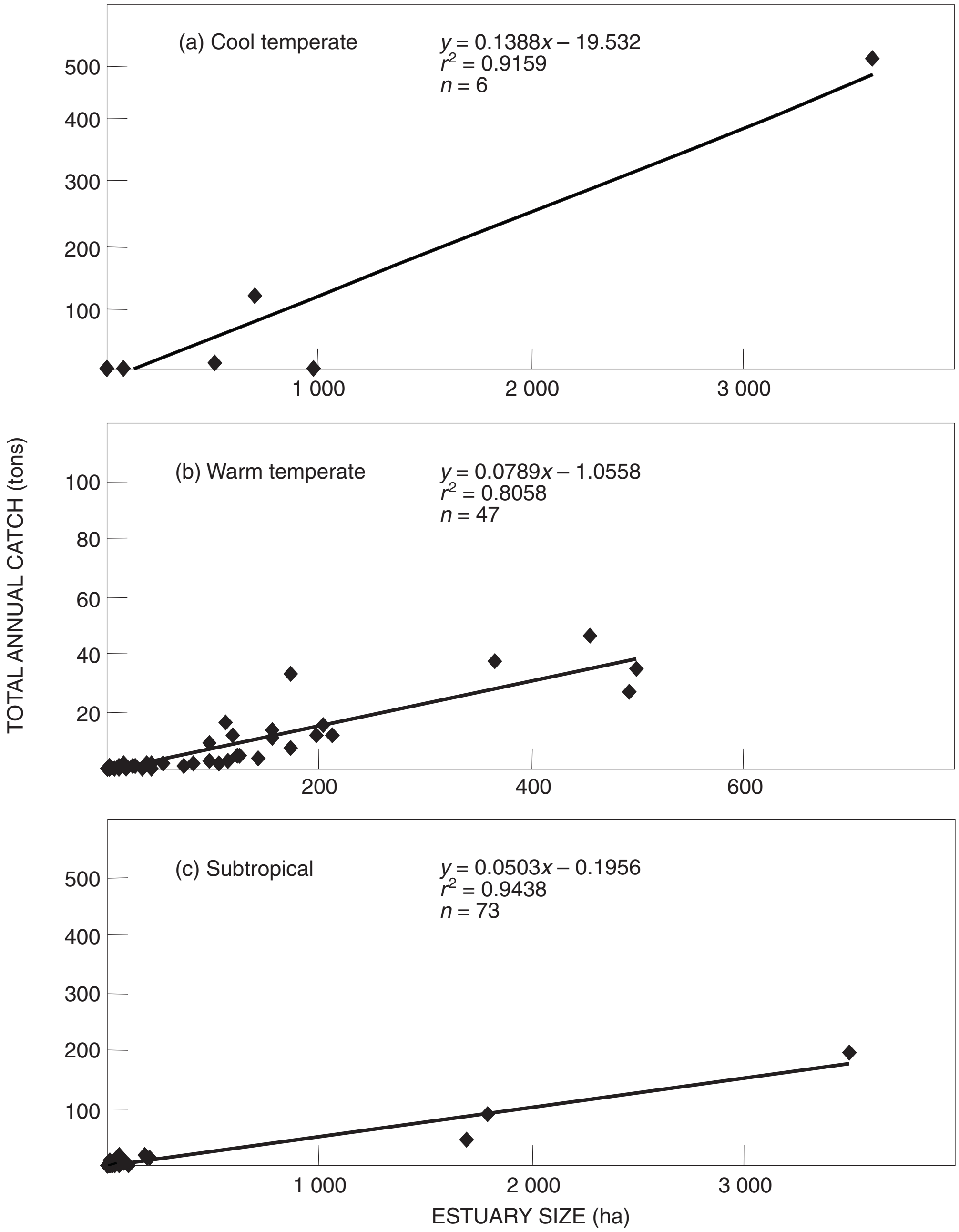

Fig. 2: Relationships between estuary size and catch in the (a) cool temperate, (b) warm temperate and (c) subtropical regions of the South African coast

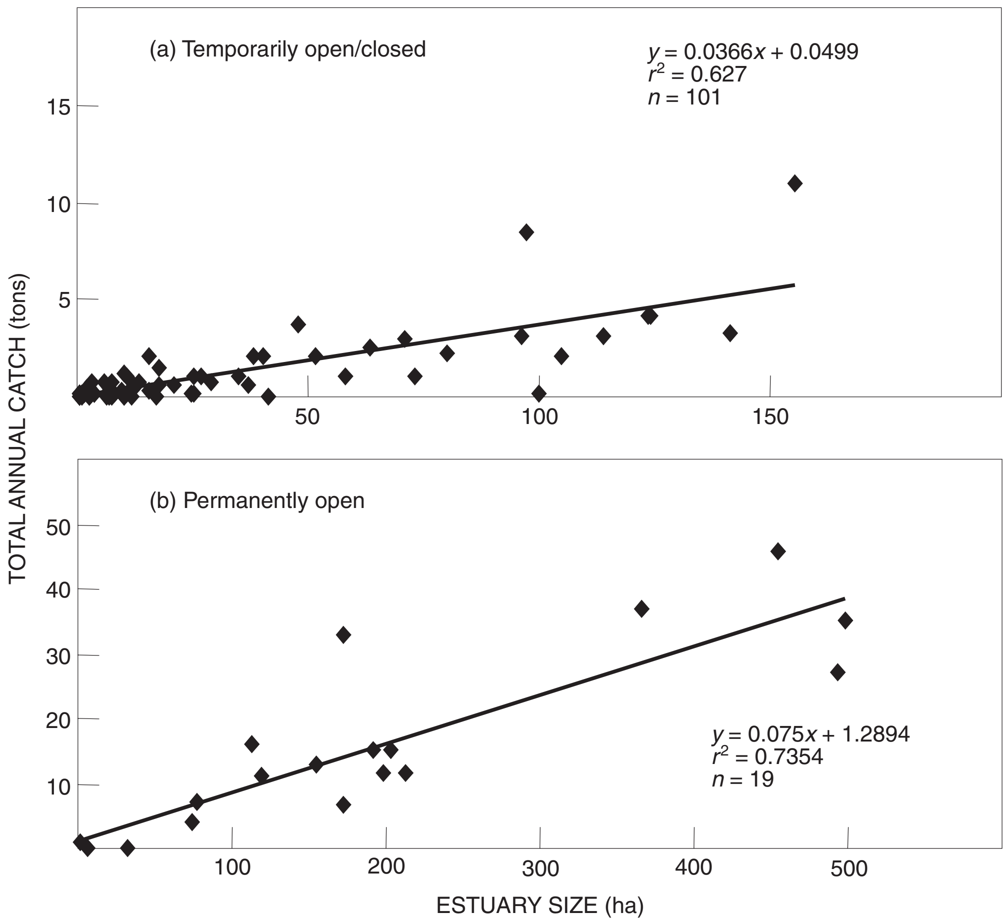

Fig. 3: Relationships between estuary size and catch in the (a) temporarily open/closed and (b) permanently open estuaries of South Africa

baited to catch fish. In addition, children also fish in the Kosi system with sticks and lines, providing a vital supply of protein to their households. An average of 50 children are found fishing in these lakes daily (Kyle 2000b).

INFLUENCE OF ESTUARY CHARACTERISTICS ON CATCH

With the exclusion of St Lucia and the Bot and Klein estuaries, estuary size alone explains more than 80% of the variation in catch in the warm temperate region and >90% of variation in catch in the cool temperate and subtropical regions (Fig. 2). The steeper slope in the cool temperate region reflects greater productivity in that region compared with the other two, which have similar slopes.

Data for the warm temperate and subtropical regions were further analysed to examine the effect of estuary type (specifically permanently open and temporarily open/closed estuaries, which are the two predominant types) on catches. The slope of the regression between estuary area and catch is steeper for permanently open estuaries (Fig. 3), indicating higher productivity. Note also that temporarily open/closed estuaries are generally <150 ha, whereas permanently open es-

Table IV: Estuarine area and estimated annual total catches for various fisheries for all estuaries in different regions along the South African coast

Regions	Number of estuaries	Area (ha)	Total annual catch (tons)							Catch rate (kg ha^{-1})
			Angling	Castnet	Gillnet	Seine-net	Traps	Spear	Total	
West Coast	9	5 884	14	2	625	–	–	–	641	109
South Coast	52	12 866	410	31	152	12	–	–	605	47
East Coast	54	3 764	224	20	52	–	–	–	296	78
Transkei	67	2 612	141	13	33	–	–	–	187	71
KwaZulu-Natal	73	46 811	245	52	297	72	73	16	755	16*
Total	255	71 937	1 034	18	1 159	84	73	16	2 484	35

* Excluding St Lucia; the average yield for KwaZulu-Natal is 58.1 kg ha^{-1} year^{-1}

tuaries include large estuaries of up to 500 ha.

Finally, both estuary size (ha) and type (all five types) were used to explain catches within the warm temperate and subtropical biogeographical regions using general linear models. Again, these models exclude the three outlying estuaries mentioned above. The models were able to explain 82 and 98% of the variance in catches for the two regions respectively. Both models were highly significant ($p < 0.001$):

Warm temperate region:
Catch (tons) = 0.904 + 0.068 × Size + 2.510 (if permanently open);

Subtropical region:
Catch (tons) = -3.461 + 0.055 × Size + 8.213 (if lake) or – 27.23 (if bay) or + 5.605 (if permanently open) or + 10.140 (if river mouth).

Estimated total estuarine catch — These models were applied to the area and type data for the remaining estuaries to estimate total estuarine catches. Existing estimates of catches for 129 estuaries amount to 1 700 tons per year, and the new estimates for the remaining 126 estuaries brings the total to 2 484 tons (Table IV).

Anglers (including castnet activities) and gillnetters account for 93% of the total catch, catches being roughly equal for the two groups. Seine-net and traditional fisheries account for the remainder (Table IV).

West Coast estuaries have the highest yields per ha (Table IV), reflecting the generally high fishery productivity of the region. Indeed, the high overall catch comes from a small number of large estuaries, mainly the Berg and Olifants estuaries. In KwaZulu-Natal, most of the catch is from the Kosi and St Lucia estuaries. On the South Coast, Knysna is estimated by the model to have a catch of >250 tons, but this is considered likely to be an overestimate.

Estuarine catch composition — Catches within estuaries in South Africa are dominated by harders, most of which are caught on the West Coast (Table V). Spotted grunter and dusky kob *Argyrosomus japonicus* are the next most important species caught in estuaries, being the main catch in the rest of the country (Table V). These three species make up 69% of the total biomass of fish caught in estuaries. On the West Coast, harders make up 86% of catches, and elf *Pomatomus saltatrix* most of the remaining catch (10%). On the South Coast, spotted grunter constitute 45% of catches, harder 18%, white steenbras *Lithognathus lithognathus* 10%, and dusky kob 6% of catch weight. On the East Coast, catches are dominated by dusky kob (48%) and spotted grunter (31%). Catch composition in the Transkei is unknown. In KwaZulu-Natal, catches are dominated by dusky kob (35%), flathead mullet (11%) and spotted grunter (11%), and evenfin pursemouth *Gerres methueni/rappi*, Moçambique tilapia *Oreochromis mossambicus*, groovy mullet *Liza dumerilii* and largescale mullet *Liza macrolepis* make up just over 5% of catch weight.

Estuarine contribution to inshore marine fisheries

TYPES OF FISHERIES, PARTICIPATION AND EFFORT

Recreational shore-angling — Most recreational shore-angling is by rod and reel, but this sector also includes those fishing from the shore, piers and jetties with handlines. A proportion of these anglers use off-road vehicles to get to less accessible fishing areas. There are an estimated 412 000 regular shore-anglers in South Africa (McGrath *et al.* 1997). The majority of recreational anglers come from the upper two quintiles of income earners in South Africa (McGrath *et al.* 1997). Total shore-angling effort amounts to approximately 2 778 000 angler-days year^{-1}, of which 53% is in KwaZulu-Natal (Brouwer *et al.* 1997, Mann *et al.* 1998, 2003).

Recreational boat-angling — Recreational boat-fishing

Table V: Estuarine species catch composition by weight and percentage in different regions along the South African coast (excluding Transkei catches and traditional fisheries in KwaZulu-Natal)

Species	Common name(s)	Category	Catch (tons)					%
			West Coast	South Coast	East Coast	Kwa-Zulu-Natal	Total	
Liza richardsonii	Harder/southern mullet	IIc	539.79	110.89	17.91	–	668.59	31.52
Pomadasys commersonni	Spotted grunter	IIa	–	270.62	73.51	71.88	416.01	19.61
Argyrosomus japonicus	Dusky kob	IIa	–	36.35	113.31	227.51	377.17	17.78
Mugil cephalus	Flathead mullet	IIa	10.64	13.56	2.16	72.14	98.50	4.64
Pomatomus saltatrix	Elf	IIc	62.58	0.87	1.63	1.47	66.55	3.14
Lithognathus lithognathus	White steenbras	IIa	0.22	60.22	4.47	–	64.92	3.06
Gerres methueni/rappi	Evenfin pursemouth	IIb	–	–	–	50.52	50.52	2.38
Liza dumerilii	Groovy mullet	IIb	–	13.02	0.50	35.07	48.59	2.29
Oreochromis mossambicus	Moçambique tilapia	IV	0.20	–	–	44.11	44.31	2.09
Liza macrolepis	Largescale mullet	IIa	–	–	–	35.20	35.20	1.66
Clarius gariepinus	Sharptooth catfish	IV	–	–	–	28.34	28.34	1.34
Liza tricuspidens	Striped mullet	IIb	–	26.34	1.46	–	27.80	1.31
Lichia amia	Leervis/garrick	IIa	0.79	21.13	4.09	–	26.00	1.23
Rhinobatos annulatus	Lesser guitarfish	III	0.20	22.94	–	–	23.13	1.09
Acanthropagrus berda	Perch/riverbream	IIa	0.63	–	0.67	19.33	20.63	0.97
Elops machnata	Ladyfish/tenpounder	IIa	–	–	7.38	9.36	16.73	0.79
Rhabdosargus holubi	Cape stumpnose	IIa	–	14.26	1.63	–	15.89	0.75
Leiognathus equula	Slimy	IIb	–	–	–	14.25	14.25	0.67
Rhabdosargus sarba	Natal stumpnose	IIb	–	–	–	14.17	14.17	0.67
Trachurus trachurus capensis	Horse mackerel	III	12.14	–	–	–	12.14	0.57
Pomadasys hasta/kakaan	Javelin grunter	IIc	–	–	–	10.06	10.06	0.47
Galeichthys feliceps	Barbel	IIb	1.55	1.62	3.58	–	6.75	0.32
Diplodus sargus	Dassie/blacktail	IIc	–	3.18	0.27	–	3.45	0.16
Lutjanus argentimactulus	River snapper	IIc	–	–	–	3.38	3.38	0.16
Myxus capensis	Freshwater mullet	Vb	–	0.46	–	2.39	2.85	0.13
Rhabdosargus globiceps	White stumpnose	IIc	0.13	2.60	0.11	–	2.84	0.13
Sparodon durbanensis	White musselcracker	III	–	2.60	0.16	–	2.76	0.13
Johnius dussumieri	Mini kob	IIc	–	–	–	2.70	2.70	0.13
Chelidonichthys capensis	Cape gurnard	III	0.28	–	2.01	–	2.29	0.11
Carcharhinus leucas	Zambezi shark	IIc	–	–	–	2.17	2.17	0.10
Platycephalus indicus	Bartailed flathead	IIc	–	–	–	2.17	2.17	0.10
Muraenesox bagio	Pike conger	III	–	–	–	1.36	1.36	0.06
Chanos chanos	Milkfish	IIc	–	–	–	1.09	1.09	0.05
Monodactylus falciformis	Cape/Oval moony	IIa	0.06	0.61	0.07	–	0.73	0.03
Caranx ignobilis	Giant kingfish	IIb	–	–	–	0.70	0.70	0.03
Caranx sexfasciatus	Bigeye kingfish	IIb	–	–	–	0.70	0.70	0.03
Caranx melampygus	Bluefin kingfish	IIc	–	–	–	0.70	0.70	0.03
Caranx papuensis	Brassy kingfish	IIc	–	–	–	0.70	0.70	0.03
Diplodus cervinus hottentotus	Zebra/wildeperd	III	–	0.56	0.07	–	0.62	0.03
Liza alata	Diamond mullet	IIb	–	–	–	0.58	0.58	0.03
Scomberoides lysan	Doublespotted queenfish	IIb	–	0.41	–	–	0.41	0.02
Lithognathus mormyrus	Sand steenbras	III	–	0.41	–	–	0.41	0.02
Thryssa vitrirostris	Orangemouth glassnose	IIb	–	–	–	0.41	0.41	0.02
Gerres acinaces	Smallscale pursemouth	IIb	–	–	–	0.28	0.28	0.01
Megalops cyprinoides	Oxeye tarpon	Vb	–	–	–	0.27	0.27	0.01
Dasyatis chrysonota	Blue stingray	III	0.26	–	–	–	0.26	0.01
Sarpa salpa	Strepie	IIc	–	0.15	0.07	–	0.21	0.01
Mustelus mustelus	Smooth houndshark	III	0.10	–	0.11	–	0.21	0.01
Monodactylus argenteus	Natal/Round moony	IIb	–	–	–	0.15	0.15	0.01
Pomadasys multimaculatum	Cock grunter	III	–	–	–	0.08	0.08	–
Myliobatus aquila	Eagle ray	III	0.07	–	–	–	0.07	–
Sphyraena barracuda	Barracuda	IIb	–	–	–	0.05	0.05	–
Sphyraena jello	Pickhandle barracuda	IIc	–	–	–	0.05	0.05	–
Terapon jarbua	Thornfish	IIa	–	–	–	0.02	0.02	–
Glossogobius giuris	Tank goby	IV	–	–	–	0.02	0.02	–
Anguilla bengalensis	African mottled eel	Va	–	–	–	0.02	0.02	–
Anguilla bicolor	Shortfin eel	Va	–	–	–	0.02	0.02	–
Anguilla marmorata	Giant mottled eel	Va	–	–	–	0.02	0.02	–

(Continued)

(Table V: continued)

Species	Common name(s)	Category	Catch (tons)					%
			West Coast	South Coast	East Coast	Kwa-Zulu-Natal	Total	
Anguilla mossambica	Longfin eel	Va	–	–	–	0.02	0.02	–
Spondyliosoma emarginatum	Steentjie	III	0.01	–	–	–	0.01	–
Lutjanus fulviflamma	Dory snapper	IIc	–	–	–	0.01	0.01	–
Ambassis productus	Longspine glassy	Ia	–	–	–	0.01	0.01	–
Ambassis gymnocephalus	Bald glassy	Ib	–	–	–	0.01	0.01	–
Ambassis natalensis	Slender glassy	Ib	–	–	–	0.01	0.01	–
Total catch (tons)			629.64	602.79	235.15	653.49	2121.07	

gear includes both rods and reels and handlines. Boats used range from small dinghies to skiboats 6–8 m long, to the large tuna or striker craft (Griffiths and Lamberth 2002). There are an estimated 12 054 recreational boat-anglers, operating from 3 444 boats (McGrath *et al.* 1997), on 92 988 boat-days year^{-1}. However, in many cases, the distinction between commercial and recreational boat-fishers is blurred, ranging from purely recreational fishers to those selling some catches to finance boating expenses or to supplement an existing income, to those who fish on a permanent commercial basis.

Recreational spearfishing — Recreational spearfishers operate from boats or swim out from the shore. There is considerable investment in fishing equipment, including wetsuits, fins and other gear in addition to spearguns. There are an estimated 7 000 participants in the recreational spearfishery (Mann *et al.* 1997), responsible for about 126 000 days year^{-1}.

Commercial boat-based linefishing — Boats used in the commercial linefishery range from small dinghies and skiboats to large decked freezer-boats, which operate to the edge of the continental shelf (Griffiths 2000). There are approximately 18 533 commercial linefishers operating from 2 581 registered boats (Griffiths and Lamberth 2002), for 380 800 boat-days year^{-1}.

Commercial gillnet and beach-seine netting — The gear and fishing methods used in these commercial fisheries are similar to those described for the estuarine fisheries. Depending on the area in which they operate, gillnetters are restricted to the use of either two or four 75 m nets of 44–178 mm mesh size, but separate permit-holders may join their nets. Gillnet permits are issued exclusively for catching harders and St Joseph sharks *Callorhynchus capensis*, and a maximum of 10 bycatch linefish are allowed per day. All gillnet permits issued for the marine environment are on the West Coast, from Yzerfontein north (approximately 321 permits), apart from a limited number of permits issued at Hawston on the South Coast (currently three permits), and occasional experimental fisheries elsewhere. In addition, illegal gillnetting occurs throughout the South African coastline, though mostly on the West and South coasts. There are an estimated 268 illegal gillnets on the West Coast, 60 on the South Coast and 120 along KwaZulu-Natal.

Beach-seine permit-holders to the west of Walker Bay on the South Coast are restricted to nets 275 m long, whereas on the rest of the South and East coasts the length is restricted to 137 m, and in KwaZulu-Natal, to 100 m. Minimum mesh sizes are 14 mm in KwaZulu-Natal, but 44 mm elsewhere. There are 84 beach-seine permits on the West Coast, 76 on the South Coast, 8 on the East Coast and 27 in KwaZulu-Natal. Except for three, the KwaZulu-Natal permits are issued exclusively for sardine *Sardinops sagax* during the annual sardine run. In addition, there are at least 10 illegal beach-seine nets in use on the South Coast, but no estimates have been made for the rest of South Africa (Lambert *et al.* 1997, Lamberth 2000a).

There are approximately 2 700 people who derive some income in the legal inshore net-fisheries along the West and South coasts, with a total effort of approximately 32 000 net-days year^{-1}. About half of the crew numbers are employed in the beach-seine fishery. There is evidence that illegal gillnetting and beach-seining activities have both increased dramatically since the introduction of the Marine Living Resources Act in 1998 (Anon. 1998).

Overall, it is estimated that there are about 431 000 recreational fishers and well over 21 000 commercial fishers active in the inshore marine environment in South Africa.

Table VI: Inshore marine catches per year for various fisheries in different regions along the South African coast

Type of fishery	Catches per year (tons)					
	West Coast	South Coast	East Coast	Transkei	KwaZulu-Natal	Total
Recreational shore-angling	115	1 021	1 039	169	662	3 037
Recreational boat-angling	407	171	236	No data	470	1 283
Recreational spearfishing	19	79*		No data	108	123
Commercial linefishing	10 191	2 848	2 615	110	1 335	17 099
Commercial netfishing	4 303	1 827	159	No data	192	6 481
TOTAL	15 035	5 950	4 096	279	2 747	28 107

* South and East coasts combined

INSHORE MARINE CATCHES

The total inshore marine catch is estimated to be 28 107 tons year^{-1} (Table VI). Of this, 60% is made up by the commercial linefish sector and 23% by the commercial net-fishery, the remainder being made up by recreational fisheries. Inshore fishery catches on the West Coast, which make up 53% of the total inshore fishery catch, are predominantly commercial, whereas recreational catches are comparable with commercial catches in the rest of the country, becoming relatively more important towards KwaZulu-Natal (Table VI).

Numerous estuary-associated species have been recorded in all types of inshore marine fisheries (Table VII). Recreational shore-angler catches and commercial gillnet and seine-net catches are dominated by estuary-associated species (83% by both number and mass). On the other hand, recreational boat- and spearfishers, and commercial boat-fishers catch a relatively small proportion of estuary-associated species, which constitute about 7% of catches (Table VII).

The main estuary-associated species caught by recreational shore-anglers are elf and strepie *Salpa salpa*, which together constitute more than 50% of the catch (Table VII). Both these species are estuary-dependent (Category IIc). Numbers of blacktail *Diplodus sargus* (IIc) and piggy *Pomadasys olivaceum* are also appreciable, constituting just over 5% of the catch. Commercial net catches are dominated by harders (75%).

The most important estuary-associated species featured in recreational boat catches is catface rockcod *Epinephelus andersoni* (3%), but it is not an estuary-dependent species (Category III). In commercial boat catches, the highly estuary-dependent dusky kob (Category IIa) features most importantly, but only contributes 1% of total catch. This low proportion is partly a result of the collapsed status of the stock (Griffiths 1997).

Zebra *Diplodus cervinus* and white musselcracker *Sparodon durbanensis* are the most common estuary-associated species in recreational spearfishing catches, but these each only make up <3% of catches. However, they are Category III species, and the most common estuary-dependent species is leervis (garrick) *Lichia amia* (1%), which is completely dependent on estuaries for the juvenile phase of its life cycle.

The contribution of different categories of estuary-associated species to inshore marine fisheries is summarized for each part of the coast in Table VIII. Category I species, which are largely resident in estuaries, hardly feature at all in inshore marine catches. Category IIa species, which are entirely dependent on estuaries, generally make up a relatively small percentage of catches, ranging from 1.3% of recreational boat and spearfish catches to 3.7% of commercial gillnet catches, 5.9% of commercial boat catches and 7.1% of recreational shore catches. However, they do make up high proportions of some catches in certain regions (Table VIII). Historically, dusky kob and white steenbras constituted a large proportion of shore-angler catches, but overexploitation of these species has led to stock collapses to present levels of 4 and 6% of pristine spawner biomass respectively (Bennett 1993, Griffiths 1997). The proportion of Category IIb species in catches is generally lower than that of Category IIa species (Table VIII).

The majority of estuary-associated fish biomass in recreational shore-angling and in commercial gillnet catches is Category IIc species, species whose juveniles are found mainly in marine environments but that also occur in estuaries. Category III species occur in estuaries but are not dependent on them. These make up just over 10% of shore-angling catches, 3.8% of recreational boat and 4.9% of recreational spearfishing catches, but they are not particularly important in commercial catches (Table VIII). Category IV species are freshwater species, and therefore do

Table VII: Percentage contribution of estuary-associated species to the overall catches in different inshore marine fisheries. Values are percentages of total biomass in all cases except for recreational shore-angling, for which data are in numbers of fish

Species	Common name(s)	Category	Percentage of total biomass				
			Recreational			Commercial	
			Shore*	Boat	Spear-fishing	Boat	Net
Acanthropagrus berda	Perch/riverbream	IIa	0.16	–	–	–	0.08
Argyrosomus japonicus	Dusky kob	IIa	1.73	0.21	–	1.18	0.65
Argyrosomus spp.	Silver and dusky kob	IIa	–	0.98	–	4.75	1.02
Elops machnata	Ladyfish/tenpounder	IIa	0.06	–	–	–	0.04
Lichia amia	Leervis/garrick	IIa	0.46	0.06	1.30	–	0.02
Lithognathus lithognathus	White steenbras	IIa	1.40	–	0.01	–	0.82
Liza macrolepis	Largescale mullet	IIa	–	–	–	–	0.18
Mugil cephalus	Flathead/springer mullet	IIa	0.12	–	–	–	0.56
Pomadasys commersonni	Spotted grunter	IIa	1.09	0.04	–	–	0.30
Rhabdosargus holubi	Cape stumpnose	IIa	2.10	0.02	–	–	0.01
Caranx ignobilis	Giant kingfish	IIb	–	0.08	–	–	–
Caranx sexfasciatus	Bigeye kingfish	IIb	–	–	–	–	0.01
Galeichthys feliceps	Barbel	IIb	0.52	0.05	–	0.01	0.06
Gerres methueni/rappi	Evenfin pursemouth	IIb	–	–	–	–	0.51
Leiognathus equula	Slimy	IIb	–	–	–	–	0.14
Liza alata	Diamond mullet	IIb	–	–	–	–	0.01
Liza dumerilii	Groovy mullet	IIb	–	–	–	–	0.18
Liza tricuspidens	Striped mullet	IIb	1.03	–	–	–	0.07
Rhabdosargus sarba	Natal stumpnose	IIb	0.76	0.08	0.09	–	0.08
Caranx melampygus	Bluefin kingfish	IIc	–	–	–	–	0.01
Caranx papuensis	Brassy kingfish	IIc	–	–	–	–	0.01
Carcharhinus leucas	Zambezi shark	IIc	–	–	–	–	0.02
Chanos chanos	Milkfish	IIc	–	–	–	–	0.01
Diplodus sargus	Dassie/blacktail	IIc	7.64	0.02	0.63	–	0.07
Johnius dussumieri	Mini kob	IIc	–	–	–	–	0.05
Liza richardsonii	Harder/southern mullet	IIc	2.67	–	–	–	74.97
Lutjanus argentimactulus	River snapper	IIc	–	–	–	–	0.03
Platycephalus indicus	Bartailed flathead	IIc	0.02	0.01	–	–	0.02
Pomadasys hasta/kakaan	Javelin grunter	IIc	0.02	0.20	–	0.02	–
Pomatomus saltatrix	Elf	IIc	27.18	0.70	–	0.27	0.91
Rhabdosargus globiceps	White stumpnose	IIc	1.40	0.57	–	0.89	0.88
Sarpa salpa	Strepie	IIc	24.30	0.01	–	0.01	0.13
Sillago sihama	Silver sillagio	IIc	0.08	–	–	–	–
Chelidonichthys capensis	Cape gurnard	III	0.20	0.04	–	0.02	0.04
Dasyatis chrysonota	Blue stingray	III	0.04	–	–	–	–
Diplodus cervinus	Zebra/wildeperd	III	0.46	0.10	2.47	–	–
Epinephelus andersoni	Catface rockcod	III	0.07	2.93	–	0.03	–
Gymnura natalensis	Butterfly/diamond ray	III	0.02	–	–	–	0.01
Lithognathus mormyrus	Sand steenbras	III	0.93	–	–	–	0.01
Muraenesox bagio	Pike conger	III	–	–	–	–	0.01
Mustelus mustelus	Smooth houndshark	III	0.26	0.16	0.01	–	0.60
Myliobatus aquila	Eagleray	III	0.06	–	–	–	0.03
Otolithes ruber	Snapper kob	III	0.04	0.24	–	0.01	–
Pomadasys olivaceum	Piggy	III	6.10	0.04	–	–	–
Rhinobatos annulatus	Lesser guitarfish	III	0.54	–	–	–	0.03
Sparodon durbanensis	White musselcracker	III	0.47	–	2.41	–	–
Spondyliosoma emarginatum	Steentjie	III	0.43	0.10	–	0.13	0.07
Trachinotus africanus	Southern pompano	III	0.26	–	–	–	–
Trachurus trachurus capensis	Horse mackerel	III	0.54	0.15	0.01	0.06	0.34
Myxus capensis	Freshwater mullet	Vb	–	–	–	–	0.02
Total percentage of estuarine species in catch			83.14*	6.79	6.93	7.40	83.03

* Numbers only

Table VIII: Percentage contribution of different categories of estuary-associated fish to the inshore marine fisheries in different regions along the South African coast. All values are percentages in terms of biomass except for recreational shore-angling, in which data are in numbers of fish

Region	Percentage of total biomass									
	Ia	Ib	IIa	IIb	IIc	III	IV	Va	Vb	Total
*Recreational shore-angling**										
West Coast			0.51	0.17	41.26	13.81				55.75
South Coast			5.31	1.27	58.81	9.13				74.52
East Coast			9.00	1.64	59.64	18.61				88.98
Transkei			11.52	1.97	45.97	3.66				63.12
KwaZulu-Natal			5.22	3.98	78.40	3.92				91.52
Total			7.12	2.30	63.31	10.41				83.14
Recreational boat-angling										
West Coast			0.02	<0.01	0.80	0.10				0.92
South Coast			7.31	<0.01	3.72	0.77				11.80
East Coast			0.33	0.24	0.47	1.75				2.80
Transkei										
KwaZulu-Natal			0.74	0.42	1.84	9.05				12.05
Total			1.31	0.20	1.51	3.77				6.79
Recreational spearfishing										
West Coast			0.05		0.09	0.09				0.23
South & East Coasts			0.58		0.96	6.74				8.29
KwaZulu-Natal			4.67	0.44		2.78				7.88
Total			1.31	0.09	0.63	4.89				6.93
Commercial boat-angling										
West Coast			0.09	<0.01	0.80	0.10				0.91
South Coast			7.31	<0.01	3.72	0.77				11.80
East Coast			27.45	0.03	0.24	0.15				27.86
Transkei			8.08	0.91	0.01	0.26				9.26
KwaZulu-Natal			6.13	0.11	0.44	0.82				7.49
Total			5.94	0.02	1.20	0.26				7.40
Seine- and gillnetting										
West Coast			1.05	0.04	80.86	1.10				83.06
South Coast			4.46	0.05	76.03	1.44				81.98
East Coast			2.16	0.97	96.59	0.01				99.73
Transkei										
KwaZulu-Natal	<0.01	<0.01	45.46	27.51	4.94	0.70		0.02	0.72	79.37
Total	<0.01	<0.01	3.67	1.08	77.10	1.16		0.01	0.03	83.03
Total number of species	1	2	14	15	19	21		4	2	

* Numbers only

not feature in marine catches. Category V species have only been recorded in very small quantities in KwaZulu-Natal, but small quantities are also caught elsewhere. These species are entirely dependent on estuaries, but they are normally caught in rivers, beyond the scope of this study.

Economic value of estuarine fish

All values are considered in terms of value added to the economy, i.e. contribution to Gross Domestic Product (GDP). However, subsistence outputs are not actually recorded as part of GDP. The value of sub-

Table IX: Estimated annual value of estuarine fisheries in different regions along the South African coast

Type of fishery	Value in Rands (1997)						
	West Coast	South Coast	East Coast	Transkei	KwaZulu-Natal	Total	%
Angling	5 803 980	169 818 301	92 657 453	58 484 198	101 735 478	428 499 410	99
Castnet	6 776	95 821	61 140	38 591	161 392	363 719	0.1
Gillnet	1 925 000	466 821	158 510	100 050	913 220	3 563 601	0.8
Seine	–	36 854	–	–	221 760	258 614	0.1
Fish traps	–	–	–	–	224 840	224 840	0.1
Spear	–	–	–	–	49 280	49 280	<0.1
Total (Rands)	7 735 756	170 417 798	92 877 103	58 622 838	103 305 970	432 959 465	
%	1.8	39.4	21.5	13.5	23.9		

sistence fisheries was taken as the gross value of landed catches, based on the market value of the fish caught. The values of commercial and recreational fisheries were calculated mainly on the basis of data presented by McGrath *et al*. (1997). Commercial fishery values include the value added by subsidiary industries such as tackle supplies and engine maintenance. Recreational values include the expenditure by anglers on equipment and travel to fishing sites.

Applying the average per-kg values of the different fisheries to the total catches in each coastal region, the total value of fisheries within South African estuaries is estimated to be about R433 million per year (1997 Rands; Table IX). This is based on an estimated total annual catch of 2 482 tons (Table IV). Almost all (99%) of this value (nearly R429 million) is attributable to recreational angling, with net and traditional fisheries together making up the remaining 1% (Table IX). This distribution of values among estuarine fishing sectors is very different from the distribution of catches (Table IV), which are equally dominated by recreational and gillnet fishing. Furthermore, the estimated value of commercial fisheries (about R3.8 million), derived from marine fishery values, may be slightly overestimated. This is because fish caught in estuaries are generally smaller than in marine catches, so catch masses are made up of proportionally more individuals. Small fish are of "lower quality" and do not fetch the same prices per kg as large fish.

With more than 72 000 anglers in the recreational fishery, compared with some 1 350 in the commercial fisheries, these aggregate values (Table IX) translate to average values of about R6 000 per recreational angler per year (expenditure), versus about R2 800 per commercial fisher (income). The recreational value is realized as income to an unknown number of participants in subsidiary industries.

Therefore, substantial amounts are spent annually by large numbers of anglers fishing in estuaries, most of whom belong to middle-upper income groups, whereas relatively few fishers from lower-middle income groups are apparently earning an average annual income well below the poverty line. Indeed, it is increasingly being realized that commercial estuarine fisheries are generally non-viable as sustainable long-term ventures. Prices for estuarine fish are often low, and operating costs are still relatively high, even though they are slightly lower than in the marine environment. The only way these fisheries can be profitable, at least in the short term, is through targeting the more vulnerable linefish species, because fishing solely for harders (mullet) and similar species in estuaries is non-profitable (Hutchings and Lamberth 1999, Beckley *et al.* 2000, Kyle 2000a). However, targeting linefish is usually only profitable for a short period until stocks become locally depleted.

Exacerbating this problem is the fact that commercial estuarine fisheries in South Africa are drastically oversubscribed, the large amount of latent effort making the fisheries economically inefficient. The investments in inputs into commercial fisheries in estuaries are often much higher than gross income. For example, gillnet permit-holders on the Berg River Estuary on average operate at an annual loss of about R5 600. It has been estimated that an effort reduction in the region of 60% is required in order to obtain maximum economic yield from this estuarine gillnet fishery (Hutchings and Lamberth 2002b).

Comparatively few people are involved in the traditional fisheries, which are worth just a fraction of the other fisheries, amounting to about R2 300 fisher^{-1} year^{-1} in terms of subsistence income. Viewing the traditional fisheries in the same economic terms as other fisheries may be somewhat misleading in terms

Table X: Percentage contribution of estuary-associated fish to the total value (1997 Rands) of the inshore marine fishing sectors in the different coastal regions, the total annual values of the fisheries, the amount and percentage of the total contributed by estuary-associated species, and the contribution of estuaries to total fishery values. The latter is calculated on the basis of 100% of the value of Category Ia, Ib, IIa, Va and Vb species, 90% of the value of Category IIb species, and 30% of the value of Category IIc species. Category III species are not included in this value

Region	Estuary-associated species								Total value (R million)	Estuarine fish contribution		Value attributable to estuaries	
	Ia	Ib	IIa	IIb	IIc	III	Va	Vb		Value (R million)	%	Value (R million)	%
Recreational shore-angling													
West Coast			0.60	0.03	18.05	2.24			105.70	22.12	20.92	6.39	6.0
South Coast			7.29	0.29	38.32	5.75			825.70	426.45	51.65	157.29	19.0
East Coast			16.25	1.13	46.15	21.48			513.00	436.12	85.01	159.63	31.1
Transkei			23.22	0.89	36.65	4.32			87.25	56.78	65.08	30.55	35.0
KwaZulu-Natal			11.47	4.46	69.15	5.51			233.29	211.32	90.58	84.50	36.2
Total			11.42	1.09	43.05	9.74			1 764.93	1 152.78	65.31	438.36	25.3
Recreational boat-angling													
West Coast			0.00	0.00	0.39	0.01			112.06	0.45	0.41	0.13	0.1
South Coast			0.37	0.00	3.77	0.22			14.48	0.63	4.36	0.22	1.5
East Coast				0.02	1.66	2.16			0.88	0.03	3.84	0.00	0.5
KwaZulu-Natal					1.08				0.58	0.01	1.08	0.00	0.3
Total			0.04	0.00	0.79	0.05			128.00	1.13	0.88	0.36	0.3
Recreational spearfishing													
West Coast			0.12		0.06	0.12			7.24	0.02	0.30	0.01	0.1
South & East coasts			0.19		0.41	8.28			43.23	3.84	8.88	0.13	0.3
KwaZulu-Natal			4.79	0.44		13.15			18.30	3.36	18.38	0.95	5.2
Total			0.53	0.03	0.34	7.57			68.76	7.22	8.48	1.09	0.7
Commercial boat-angling													
West Coast			0.04	0.00	0.78	0.05			188.89	1.66	0.88	0.53	0.3
South Coast			11.09	0.00	2.50	0.20			82.09	11.33	13.80	9.72	11.8
East Coast			36.52	0.01	0.16	0.03			86.00	31.58	36.72	31.45	36.6
KwaZulu-Natal			7.09	0.04	0.21	0.99			50.64	4.22	8.33	3.64	7.2
Total			11.05	0.00	0.97	0.15			407.62	48.78	12.17	45.34	11.3
Seine- and gillnetting													
West Coast			3.89	0.02	72.90	1.86			11.92	9.37	78.67	3.07	25.8
South Coast			10.99	0.01	46.25	2.11			7.49	4.45	59.36	1.86	24.9
East Coast			9.12	0.50	90.04	0.03			0.41	0.41	99.70	0.15	36.6
KwaZulu-Natal	0.01	0.01	57.48	2.70	25.15	6.31	0.01	0.01	0.25	0.23	91.64	0.17	67.5
Total	0.01	0.01	7.30	0.06	62.72	1.97	0.01	0.01	20.07	14.46	72.05	5.26	26.2
TOTAL									2 389.38	1 224.37	52.3	490.40	21.3

of their importance. It should be noted that these fisheries form an integral part of the survival of communities that rely on them for their protein source. Indeed, such fisheries in tropical Africa commonly contribute a high percentage of household income (Turpie *et al.* 1999b, Turpie 2000).

A similar type of argument could be made for the commercial fisheries, especially when compared to

Table XI: Summary of the estimated total contribution of estuaries to the annual value (1997 Rands) of inshore marine fisheries in different regions along the South African coast

Type of fishery	Value (R million)						
	West Coast	South Coast	East Coast	Transkei	KwaZulu-Natal	Total	%
Recreational shore-angling	6.39	157.29	159.63	30.55	84.5	438.36	89.4
Recreational boat-angling	0.13	0.22	0		0	0.35	0.1
Recreational spearfishing	0.01	0.07	0.07		0.22	1.09	0.3
Commercial boat-angling	0.53	9.72	31.45		2.09	45.34	9.2
Seine- and gillnetting	3.07	1.86	0.15		0.17	5.25	1.1
Total	10.13	169.16	191.30	30.55	86.26	490.40	
Percentage	2.1	34.5	39.0	6.2	18.2		

the recreational fishery. However, on the West Coast, where much of the commercial effort takes place, it is evident that the people involved in the fishery are not heavily reliant on the fishery contributing to their income (Hutchings and Lamberth 2002b). On the Berg Estuary, none of the fishers interviewed regarded netfishing as their main occupation, 80% of them being employed in other sectors and the remainder retired. Indeed, the net-fishery contributed more than 50% of income for only 10% of the fishers (Hutchings and Lamberth 2002b).

The total value of inshore marine fisheries is about R2.4 billion per year (1997 Rands; Table X). Approximately 82% of this is the value of the recreational fisheries (almost all from shore-angling), the remaining 18% being commercial value. Similar arguments apply to the disproportionately high value of recreational fisheries in comparison to catch ratios, as for the estuarine fisheries. The recreational value, spread among about 431 000 fishers, amounts to an average value (expenditure) of >R4 500 fisher^{-1} year^{-1}, whereas the approximately 21 000 people involved in commercial fisheries gain an average annual income of R20 000.

Roughly half the total inshore marine fishery value (52%) is made up of estuary-associated species (Table X). However, not all these fish are equally dependent on estuaries. Category Ia, Ib, IIa, Va and Vb species are 100% dependent on estuaries to complete their life cycles. Because the juveniles of Category IIb species are largely confined to estuaries, their level of dependence on estuaries was considered to be very high, and was estimated as 90%. The overall numbers of Category IIc species, whose juveniles mainly live in seawater, are augmented by the presence of estuarine habitat areas. Estuaries contribute about 30% of the juvenile habitat available to these species, and those juveniles using estuaries are frequently in better condition than those in marine habitats (De Decker and Bennett 1985). Therefore, some 30% of the marine catches of Category IIc species can be attributed to estuarine export. Thus, adjusting values according to the level of contribution that estuaries make to the catches of species of different categories, the estimated contribution from estuaries to inshore marine fisheries is 21% of the total value, or R490 million per year (Table X). Simply, this value would be lost if estuaries were "removed" from the coastline.

The relative contribution of estuaries to fisheries varies between types of fishery and geographically. The contribution of estuary-dependent species to recreational shore-angling values increases from 6% on the West Coast to 36% on the KwaZulu-Natal coast. Estuaries contribute 25% of the total value of the recreational shore-fishery, whereas they contribute only 0.3 and 0.7% to the value of the recreational boat- and spearfisheries respectively (Table X). Overall, the estuarine contribution to marine recreational fishery values is about R440 million per year. This is 90% of the total estimated estuarine contribution to marine fisheries.

The estuarine contribution to commercial boat fisheries ranges from 0.3% of value on the West Coast to a peak of 37% on the East Coast, and averages 11% for the whole coastline (Table X). Estuaries contribute a substantial portion of the value of the gillnet and seine-net fisheries, increasing from about 25% on the West and South coasts to 68% on the KwaZulu-Natal coast. However, as most of the fishery is concentrated on the west coast, the overall contribution is about 26% (Table X).

The overall contribution of estuaries to inshore fishery values is summarized in Table XI. The total value of estuarine and estuary-dependent fisheries is estimated to be R923.4 million in 1997 Rands (Table XII). This is equivalent to R1.251 billion in

Table XII: Summary of the value (in 1997 Rands) of estuarine fisheries and the estuarine contribution to marine fisheries in different regions along the South African coast

Parameter	West Coast	South Coast	East Coast	Transkei	KwaZulu-Natal	Total
Estuarine fisheries (R million)	7.7	170.4	92.9	58.6	103.3	433.0
Inshore marine (R million)	10.1	169.2	191.3	30.6	89.3	490.4
Total	17.83	339.6	284.2	89.2	192.6	923.4
Number of estuaries	9	52	54	67	73	255
Estuarine area (ha)	5 884	12 866	3 764	2 612	46 811	71 937
Average value per estuary (R million)	2.0	6.5	5.3	1.3	2.6	3.6
Average value per ha (Rands)	3 030	26 392	75 503	34 131	4 114	12 836

2002 Rands. Furthermore, this total estuarine fish value is unevenly distributed around the coast, with West Coast estuaries contributing <2% of the total value. Estuaries along the warm temperate coast have the highest aggregate value and average per estuary values (Table XII). East Coast estuaries in particular are worth >R75 000 ha^{-1} year^{-1} (1997 Rands) in terms of fish production (Table XII). However, average values may not be very reliable predictors of individual estuary values, which are related to factors such as size and mouth status, and geographical location.

Stock status of estuarine fish species

Fishing in South Africa is a rapidly-growing activity. It is already evident that the high national fishing effort has taken its toll on fish stocks. This has been quantified in coastal fisheries, where shore-angling catches per unit effort have declined markedly over the past two decades (Bennett and Attwood 1993, Attwood and Farquhar 1999, Griffiths 2000), as well as in some estuaries.

In the Swartkops and Sundays estuaries, spotted grunter and dusky kob make up 87% and 90% of angler catches respectively (Baird *et al.* 1996), indicating a tendency for anglers to concentrate their efforts on particular species, rendering them highly vulnerable to overexploitation. These fears have been confirmed by gillnetting studies in the two estuaries, which have indicated a decline in spotted grunter over the past 20 years (Baird *et al.* 1996). Similarly, catch rates of spotted grunter also declined in Durban Bay Estuary over a period of 16 years (Guastella 1994). Moreover, elf was once as abundant as spotted grunter in angler catches in the Swartkops Estuary, but it has now almost disappeared. White steenbras, a highly sought-after species, has been depleted both in estuaries and in the marine environment (Bennett 1993, Lamberth 2000c). In the Swartkops Estuary, this species formed an important component of catches in 1918, by the 1970s it had been reduced to only 3% of anglers catches, and by the 1990s it was were almost totally absent from catches (Whitfield and Marais 1999).

The status of a stock is judged as overexploited, maximally exploited or underexploited on the basis of its current size as a percentage of pristine stock size (or spawner biomass). A maximally exploited stock (one exploited close to its maximum sustainable yield) is considered to be at a level of 40–50% of pristine biomass. It should be noted that these judgements assume that current biomass is only a function of harvesting, and that carrying capacity (or maximum stock) has remained constant. In reality, the latter may also be affected by changes in habitat quality, thus also affecting current biomass.

Under the above assumptions, 14 of the 80 utilized estuary-associated species are considered overexploited, i.e. at <45% of pristine (Table XIII). Of these, elf, blacktail, dusky kob, white steenbras, white stumpnose *Rhobdosargus globiceps* and Natal stumpnose *R. sarba* are ranked in the top 30 fish across all inshore sectors in terms of catch, targetting and the number of people reliant on them (Lamberth and Joubert 1999). The stocks of six of these 14 species are in a collapsed state, including white steenbras and dusky kob, which are Category IIa species (Table XIII). A further 27 species, including spotted grunter and leervis, are regarded as maximally or optimally exploited, and are likely to be subject to additional fishing pressure in future. The remaining 40 species are considered underexploited, because their stocks are at levels >50% of pristine spawner biomass. However, with few exceptions, these are small species such as strepie, flathead mullet and striped mullet, which, on a national scale, have limited value to commercial or recreational fishers. Some of them are species that are either at the edge of their disributional range, or have a limited range, within South Africa, but they may be locally important in certain areas, e.g. evenfin

Table XIII: Stock status in terms of abundance trend (A), vulnerability (V), range (R), exploitation level (E) and knowledge (K) of utilized estuary-associated species in South Africa

Family	Species	Common name(s)	Category	Conservation importance (%)				
				A	V	R	E	K
Carcharhinidae	*Carcharhinus leucas*	Zambezi shark	IIc	45	100	0	75	57
Dasyatidae	*Dasyatis chrysonota*	Blue stingray	III	60	0	10	25	71
	Gymnura natalensis	Butterfly/diamond ray	III	60	90	40	50	50
	Himantura uarnak	Honeycomb stingray	III	60	90	0	50	29
Mustelidae	*Mustelus mustelus*	Smooth houndshark	III	55	90	0	100	86
Myliobatidae	*Myliobatus aquila*	Eagle ray	III	60	70	0	25	43
Rhinobatidae	*Rhinobatos annulatus*	Lesser guitarfish	III	65	70	10	25	50
Ambassidae	*Ambassis dussumieri*	Bald glassy	Ib	55	70	0	0	29
	Ambassis producta	Longspine glassy	Ia	55	70	10	0	29
	Ambassis natalensis	Slender glassy	Ib	55	70	10	0	29
Anguillidae	*Anguilla bengalensis*	African mottled eel	Va	50	100	10	50	50
	Anguilla marmorata	Giant mottled eel	Va	50	100	10	50	50
	Anguilla mossambica	Longfin eel	Va	50	100	10	50	50
	Anguilla bicolor	Shortfin eel	Va	50	100	10	50	50
Ariidae	*Galeichthys feliceps*	Barbel	IIb	55	100	10	75	71
Belonidae	*Strongylura leiura*	Yellowfin needlefish	IIc	55	70	0	0	21
Carangidae	*Caranx sexfasciatus*	Bigeye kingfish	IIb	55	70	0	25	43
	Caranx melampygus	Bluefin kingfish	IIc	55	70	0	25	21
	Caranx papuensis	Brassy kingfish	IIc	55	70	0	0	21
	Scomberoides lysan	Doublespotted queenfish	IIb	55	70	0	25	7
	Caranx ignobilis	Giant kingfish	IIb	45	80	0	50	50
	Trachurus trachurus capensis	Horse mackerel	III	50	70	0	100	79
	Trachinotus africanus	Southern pompano	III	50	70	10	50	21
Chanidae	*Chanos chanos*	Milkfish	IIc	55	80	0	25	43
Charangidae	*Lichia amia*	Leervis/garrick	IIa	50	90	0	75	64
Cichlidae	*Oreochromis mossambicus*	Moçambique tilapia	IV	50	0	10	50	86
Clariidae	*Clarius gariepinus*	Sharptooth catfish	IV	55	0	0	50	86
Elopidae	*Elops machnata*	Ladyfish/tenpounder	IIa	65	100	0	25	36
Engraulidae	*Thryssa vitrirostris*	Orangemouth glassnose	IIb	55	70	0	0	36
Gerreidae	*Gerres methueni/rappi*	Evenfin pursemouth	IIb	55	70	100	50	43
	Gerres acinaces	Smallscale pursemouth	IIb	55	70	0	50	29
Gobiidae	*Glossogobius giuris*	Tank goby	IV	40	70	0	0	36
Haemulidae	*Pomadasys multimaculatum*	Cock grunter	III	45	90	0	50	29
	Pomadasys hasta/kakaan	Javelin grunter	IIc	45	90	0	50	29
	Pomadasys olivaceum	Piggy	III	50	70	0	75	57
	Pomadasys commersonni	Spotted grunter	IIa	40	100	0	100	57
Kuhliidae	*Kuhlia mugil*	Barred flagtail	III	55	0	0	0	29
Leiognathidae	*Leiognathus equula*	Slimy	IIb	55	70	0	0	36
Lutjanidae	*Lutjanus fulviflamma*	Dory snapper	IIc	50	70	0	0	29
	Lutjanus argentimactulus	River snapper	IIc	30	90	0	75	29
Megalopidae	*Megalops cyprinoides*	Oxeye tarpon	Vb	60	90	0	50	14
Monodactylidae	*Monodactylus falciformis*	Cape/Oval moony	IIa	55	70	0	0	36
	Monodactylus argenteus	Natal/Round moony	IIb	55	70	0	0	21
Mugilidae	*Valamugil seheli*	Bluespot mullet	IIc	50	70	0	0	14
	Valamugil buchanani	Bluetail mullet	IIc	50	70	0	25	29
	Liza alata	Diamond mullet	IIb	55	70	0	50	29
	Mugil cephalus	Flathead/springer mullet	IIa	65	90	0	50	50
	Myxus capensis	Freshwater mullet	Vb	40	70	40	50	36
	Liza dumerili	Groovy mullet	IIb	50	70	0	50	36
	Liza richardsonii	Harder/southern mullet	IIc	45	90	10	100	26
	Liza macrolepis	Largescale mullet	IIa	50	70	0	75	29
	Valamugil cunnesius	Longarm mullet	IIa	50	70	0	0	29
	Valamugil robustus	Robust mullet	IIa	50	70	10	0	36
	Liza luciae	St Lucia mullet	IIb	50	70	100	25	14
	Liza tricuspidens	Striped mullet	IIb	65	80	40	50	0
Muraenesocidae	*Muraenesox bagio*	Pike conger	III	55	0	0	0	36
Platycephalidae	*Platycephalus indicus*	Bartailed flathead	IIc	55	70	0	0	36
Pomatomidae	*Pomatomus saltatrix*	Elf	IIc	34	100	0	100	86
Sciaenidae	*Argyrosomus japonicus*	Dusky kob	IIa	4	100	40	100	86
	Johnius dussumieri	Mini kob	IIc	55	90	0	25	29
	Otolithes ruber	Snapper kob	III	60	80	0	50	57

(continued)

(Table XIII: continued)

Family	Species	Common name	Cate-gory	Conservation importance (%)				
				A	V	R	E	K
Serranidae	*Epinephelus andersoni*	Catface rockcod	III	13	100	60	100	29
	Epinephelus malabaricus	Malabar rockcod	III	20	100	0	75	14
Sillaginidae	*Sillago sihama*	Silver sillago	IIc	65	80	0	0	7
Sparidae	*Rhabdosargus holubi*	Cape stumpnose	IIa	40	100	40	75	50
	Diplodus sargus	Blacktail/dassie	IIc	35	100	10	100	57
	Rhabdosargus sarba	Natal stumpnose	IIb	35	100	0	75	50
	Acanthropagrus berda	Perch/riverbream	IIa	35	100	0	75	64
	Lithognathus mormyrus	Sand steenbras	III	20	0	0	25	14
	Spondyliosoma emarginatum	Steentjie	III	70	80	40	100	21
	Sarpa salpa	Strepie	IIc	67	90	20	100	71
	Sparodon durbanensis	White musselcracker	III	30	100	40	100	71
	Lithognathus lithognathus	White steenbras	IIa	6	100	40	100	50
	Rhabdosargus globiceps	White stumpnose	IIc	20	100	20	100	57
	Diplodus cervinus hottentotus	Zebra/wildeperd	III	35	100	40	100	36
Sphyraenidae	*Sphyraena barracuda*	*Great* barracuda	IIb	50	80	0	50	50
	Sphyraena jello	Pickhandle barracuda	IIc	60	70	0	50	0
Teraponidae	*Terapon jarbua*	Thornfish	IIa	55	70	0	0	29
Triglidae	*Chelidonichthys capensis*	Gurnard	III	60	80	10	25	50

pursemouth in Kosi Bay.

It is difficult to assess what contributes more to the decline of an estuarine species: estuarine habitat degradation or overexploitation. Estuary-dependence immediately creates a life-history bottleneck for many species, especially when it comes to entering temporarily open/closed estuaries. In addition to estuary dependence, sex changes, spawning migrations, predictable aggregations, high age at maturity, longevity, residence and high catchability all contribute to a species' vulnerability to overexploitation. For example, white steenbras exhibit seven of these life-history traits, excluding sex change, and is currently at 6% of its pristine spawner biomass, and it has been placed on the critical list (Marine Living Resources Act 1998 – Anon. 1998). Half of all species considered have vulnerable life-history characteristics in addition to estuary-dependence, and a quarter of them fall into the most vulnerable category (Table XIII). Very few of the species are range-restricted and a quarter of them are highly exploited throughout their distributional range (Table XIII), 23 species are medium exploitation and the rest subject to medium-to-low levels of exploitation.

On the whole, knowledge of exploited estuarine fish species is poor, with three-quarters of species having low knowledge scores up to half the optimum (Table XIII). For most of these species, no comprehensive stock assessments have been done.

CONCLUSIONS

This study has shown that estuaries contribute a considerable value to the economy in terms of both estuarine fisheries and their contribution to inshore marine fisheries, the latter contribution slightly exceeding the value realized within estuaries. Although commercial catches are substantial both within estuaries and in the marine environment, it is recreational fishing activities that contribute most value to the economy, with 22 times as many participants (about half a million v. <23 000) and realizing a value more than 100 times greater per kg of fish caught. Subsistence fisheries are very localized and involve very small numbers of fishers and low values, but they are important in the context of livelihoods.

An assessment of the status of estuarine fish stocks suggests that the currently high value of estuarine fish production is probably not sustainable. Dwindling fish stocks will affect *cpue* and overall catches, and the value realized from these fisheries may well drop substantially if current trends are maintained. This would have much greater impact on commercial fisheries, upon which many people rely for their livelihoods, particularly in marine fisheries, than on recreational fisheries, which are less sensitive to catch returns. It is clear that sound management practices will need to be put in place in order to sustain these values in future, as well as to ensure the conservation of estuarine biodiversity.

Management strategies chosen for estuarine species may differ depending on socio-economic goals, e.g. whether to secure livelihoods of small-scale commercial fishers or whether to increase the overall contribution to the economy. No doubt an equitable balance of these goals is required. Nevertheless, any management strategy ultimately has to concentrate on maintaining maximal productivity of resources if benefits are to be sustained in the long term.

Linefish and netfish management is currently undergoing complete revision in order to address these challenges. A linefish management protocol has been developed (Griffiths *et al.* 1999), which requires species-specific management plans. Under the Marine Living Resources Act, estuaries fall within the marine environment, and these management plans include estuarine populations. Apart from the reduction of overall commercial effort, including in estuaries, there has been a substantial revision of bag and size limits for recreational, subsistence and commercial fisheries. With compliance, the effort directed at many of these species is likely to decrease.

Catches in estuaries need to fall to secure estuarine contributions to marine inshore fisheries. If current regulations were complied with, this would be achieved, providing the estuarine environments (e.g. freshwater inflows) were also sufficiently protected. In the recreational fishery, a large proportion of the landed catch is under legal size, ranging from 90% on the West Coast to 50 and 60% on the South and East coasts respectively (Lamberth 1996, 2000a, Cowley 2000). In other words, catches would be much lower if there was compliance. A reduction in angler pressure would almost certainly stimulate an increase in the level of abundance of certain species. For example, along the coast of the Eastern Cape and KwaZulu-Natal, elf have increased in numbers following increased protection (van der Elst and De Freitas 1988 Garratt and van der Elst 1990). Technically, catches could be reduced without reducing the value of the fishery, because most recreational anglers would still fish if they were more strictly policed. It also makes good economic sense to remove all commercial fisheries from estuaries, so halving the catch, but only reducing the economic contribution by 1%. Commercial fishing in estuaries is predominantly gillnetting, which is unselective, usually with a high bycatch of undersized and immature linefish and other species. These species are already overexploited and this fishing pressure takes place during a particularly vulnerable stage of their life, while they are in estuaries. It has already been stressed that these fisheries are seldom viable in the short term and almost never in the long term. By removing commercial fisheries, much greater recruitment will be facilitated into the sea.

Furthermore, subsistence and commercial effort should be excluded from temporarily open/closed systems, whether large or small, because these stocks are easily overexploited (Pease 1999). The protection of small and closed systems should, however, not be done at the expense of the larger, permanently open systems. Protection should be levelled at all estuary types at a national scale, because they all support different and valuable fish communities.

Ideally, different fisheries should target different species within the same estuaries. Multi-user fisheries are seldom sustainable. However, this is difficult to control, especially in those sectors assigned less lucrative species. This is therefore a further argument against including commercial fisheries in estuaries. Estuarine fishing in South Africa should be limited to subsistence and recreational use. However, the South African experience is that designated subsistence fishers soon realize the value of their non-target species, and it is hard to prevent them from shifting to these species. This often leads to chaos and user conflict, as has happened in the Kosi and St Lucia estuarine systems. Subsistence fisheries should be confined to traditional fisheries, and preferably assigned to homogenous communities. In other areas, the *ad hoc* allocation of subsistence rights should rather be addressed by finding alternative livelihoods for the fishers involved.

In general, the protection of estuarine fish resources will also depend on the sound management of activities that affect estuarine environments. Apart from the direct effect on fish stocks, recreational angling involves boat traffic and bait digging, leading to disturbance, trampling and possibly depletion of prey for fish. More importantly, perturbations in the marine environment or catchment may negatively impact fish populations in estuaries (Whitfield and Marais 1999). In particular, if freshwater requirements of estuaries are not adequately met, the resultant chemical and biophysical changes in the estuarine headwaters and in mouth condition can severely hamper fish recruitment. Indeed, freshwater inputs probably have the most important impact on species distribution, composition and abundance in estuaries. For these reasons, it is strongly advocated that a philosophy of ecosystem preservation be used in management policy (Whitfield and Marais 1999), in addition to individual species conservation efforts. Such policies will lead to more rational decisions in terms of all developments that affect estuarine ecology, including the development of marinas that tend to favour ichthyoplankton but not large fish (Cloete 1993).

In summary, the most sensible overall policy would be to conserve estuarine stocks as nursery and source areas for marine fisheries. This is the most efficient option in terms of maximizing resource productivity, economic benefits and biodiversity conservation. Concentrating conservation efforts on estuarine stocks can enhance resource productivity in both estuaries and the inshore marine environment. Stock status can only be improved by reducing catches. In order to minimize the cost of this, reductions should be targeted at fisheries that are either low value per unit catch (e.g. estuarine commercial netfisheries) or fisheries whose value is not strongly affected by catch rates (i.e. the recreational fishery, which is much smaller in estuaries than on the open coast). Conserving estuary stocks requires the sound holistic management of estuaries, a spin-off being the improved conservation of all estuarine biodiversity.

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LITERATURE CITED

ANON. 1998 — Marine Living Resources Act, 1998 (Act No. 18 of 1998). *Government Gazette S. Afr.* **395**(18930): 66 pp.

ATTWOOD, C. G. and M. FARQUHAR 1999 — Collapse of linefish stocks between Cape Hangklip and Walker Bay, South Africa. *S. Afr. J. mar. Sci.* **21**: 415–432.

BAIRD, D., MARAIS, J. F. K. and C. DANIEL 1996 — Exploitation and conservation of angling fish species in two South African estuaries. *Aquat. Conserv. mar. Freshwat. Ecosystems* **6**: 319–330.

BAIRD, D. and P. PRADERVAND 1999 — Assessment of the recreational angling fishery in Eastern Cape estuaries. In *Proceedings of the Third South African Marine Linefish Symposium*. Mann, B. Q. (Ed.). *SANCOR Occ. Rep.* **5:** 73–76.

BECKLEY, L. E. and S. T. FENNESSY 1996 — The beach-seine fishery off Durban, KwaZulu-Natal. *S. Afr. J. Zool.* **31**: 186–192.

BECKLEY, L. E., MANN, B. Q., ROBERTSON, W. D., FIELDING, P. J. and R. P. VAN DER ELST 2000 — Subsistence fishery resource assessment: Port Edward to Kosi Bay. Unpublished Report, South African Association for Marine Biological Research **193**: no pagination.

BENNETT, B. A. 1993 — The fishery for white steenbras *Lithognathus lithognathus* off the Cape coast, South Africa, with some considerations for its management. *S. Afr. J. mar. Sci*. **13**: 1–14.

BENNETT, B. A. and C. G. ATTWOOD 1993 — Shore-angling catches in the De Hoop Nature Reserve, South Africa, and further evidence for the protective value of marine reserves. *S. Afr. J. mar. Sci*. **13**: 213–222.

BOYD, A. J., BARWELL, L. and S. TALJAARD 2000 — Report on the National Estuaries Workshop, 3–5 May 2000, Port Elizabeth, South Africa. Marine and Coastal Management Implementation Workshops: var. pagination.

BREEN, C. M. and M. McKENZIE 2001 — *Managing Estuaries in South Africa: an Introduction*. Pietermaritzburg; Institute of Natural Resources: 66 pp.

BROUWER, S. L. 1996 — Evaluation of participation in, and management of, the South African linefishery in the South-East Cape. Final Report to the Sea Fisheries Research Institute, Department of Environment Affairs and Tourism, Cape Town: 34 pp.

BROUWER, S. L., MANN, B. Q., LAMBERTH, S. J., SAUER, W. H. H. and C. ERASMUS 1997 — A survey of the South African shore-angling fishery. *S. Afr. J. mar. Sci.* **18**: 165–177.

CENTRE FOR MARINE STUDIES 2000 — Assessment of marine resource availability for subsistence fisheries along the coasts of South Africa. Unpublished Report, University of Cape Town: var. pagination.

CLOETE, A. E. 1993 — Comparative assessment of ichthyofauna in three marinas. M.Sc. thesis, University of Port Elizabeth.

COSTANZA, R., D'ARGE, R., DE GROOT, R., FARBER, S., GRASSO, M., HANNON, B., LIMBURG, K., NAEEM, S., O'NEILL, R. V., PARUELO, J., RASKIN, R. G., SUTTON, P. and M. VAN DEN BELT 1997 — The value of the world's ecosystem services and natural capital. *Nature* **387**: 253–259.

COWLEY, P. D. 2000 — Utilisation of living marine resources in the estuaries between Port Elizabeth and East London, Eastern Cape Province. Unpublished Report, J. L. B. Smith Institute of Ichthyology, Grahamstown: 19 pp.

DE DECKER, H. P. and B. A. BENNETT 1985 — A comparison of the physiological condition of the southern mullet *Liza richardsonii* (Smith), in a closed estuary and the sea. *Trans. R. Soc. S. Afr.* **45**: 427–436.

EMANUEL, B. P., BUSTAMANTE, R. H., BRANCH, G. M., EEKHOUT, S. and F. J. ODENDAAL 1992 — A zoogeographic and functional approach to the selection of marine reserves on the west coast of South Africa. In *Benguela Trophic Functioning*. Payne, A. I. L., Brink, K. H., Mann, K. H. and R. Hilborn (Eds). *S. Afr. J. mar. Sci.* **12**: 341–354.

GARRATT, P. A and R. P. VAN DER ELST 1990 — Status of the fishery in Natal and Transkei. In *Marine Recreational Fishing: Resource Usage, Management and Research.* Van Der Elst, R.[P.] (Ed.) *Rep. S. Afr. natn. scient. Progms* **167**: 27–31.

GRIFFITHS, M. H. 1997 — Management of South African dusky kob *Argyrosomus japonicus* (Sciaenidae) based on per-recruit models. *S. Afr. J. mar. Sci.* **18**: 213–228.

GRIFFITHS, M. H. 2000 — Long-term trends in catch and effort of commercial linefish off South Africa's Cape Province: snapshots of the 20th century. *S. Afr. J. mar. Sci.* **22**: 81–110.

GRIFFITHS, M. H., ATTWOOD, C. G. and R. THOMSON 1999 — A new management protocol for the South African linefishery. In *Proceedings of the Third South African Marine Linefish Symposium.* Mann, B. Q. (Ed.). *SANCOR Occ. Rep.* **5**: 145–156.

GRIFFITHS, M. H. and S. J. LAMBERTH 2002 — Evaluating the marine recreational linefishery in South Africa. In *Recreational Fisheries: Ecological, Economic and Social Evaluation.* Pitcher, T. and C. Hollingworth (Eds), Oxford; Blackwell Science: 227–251.

GUASTELLA, L. A-M. 1994 — A quantitative assessment of recreational angling in Durban Harbour, South Africa. *S. Afr. J. mar. Sci*. **14**: 187–203.

HUTCHINGS, K. and S. J. LAMBERTH 1999 — Management and socio-economic considerations for the drift and beach-seine net fisheries on the west and southwestern coasts of South Africa. Final Report for Marine & Coastal Management, Department of Environmental Affairs and Tourism, Cape Town: 56 pp.

HUTCHINGS, K. and S. J. LAMBERTH 2002a — Catch-and-effort estimates for the gillnet and beach-seine fisheries in the Western Cape, South Africa. *S. Afr. J. mar. Sci.* **24**: 205–225.

HUTCHINGS, K. and S. J. LAMBERTH 2002b — Bycatch in the gillnet and beach-seine fisheries in the Western Cape, South Africa, with implications for management. *S. Afr. J. mar. Sci.* **24**: 227–241.

HUTCHINGS, K. LAMBERTH, S. J. and J. K. TURPIE 2002 — Socio-economic characteristics of gillnet and beach-seine fishers in the Western Cape, South Africa. *S. Afr. J. mar. Sci.* **24**: 243–262.

KYLE, R. 1995 — Wise use of wetlands by rural indigenous people. The Kosi Bay Nature Reserve: a case study. In *Wetlands of South Africa.* Cowan, G. I. (Ed.). Pretoria; Department of Environmental Affairs and Tourism: 273–291.

KYLE, R. 1996 — Kosi Bay Nhlange gillnetting project. A comprehensive report on the results for 1993, 1994 and 1995 and a general discussion on the project. Pietermaritzburg; KwaZulu Department of Nature Conservation: 8 pp.

KYLE, R. 1999 — Gillnetting in nature reserves: a case study from the Kosi Lakes, South Africa. *Biol. Conserv.* **88**: 183–192.

KYLE, R. 2000a — Report on estuarine gillnetting. Unpublished Report, Subsistence Fisheries Task Group, Marine & Coastal Management, Department of Environmental Affairs and Tourism, Cape Town: 7 pp.

KYLE, R. 2000b — Report on estuarine fish trapping. Unpublished Report, Subsistence Fisheries Task Group, Marine & Coastal Management, Department of Environmental Affairs and Tourism, Cape Town: 6 pp.

LAMBERTH, S. J. 1996 — The distribution of total catch and effort between all sectors of the linefishery in the south-western Cape. (Regional programme to evaluate participation in, and management of, the linefishery in the SW Cape, SE Cape and KwaZulu-Natal). Final Report to the Sea Fisheries Research Institute, Department of Environmental Affairs and Tourism, Cape Town: 22 pp.

LAMBERTH, S. J. 2000a — Current fishing activities in estuaries from the Orange River to Cape Point. Report to the Subsistence Fisheries Task Group, Marine & Coastal Management, Department of Environmental Affairs and Tourism, Cape Town: 8 pp.

LAMBERTH, S. J. 2000b — Current fishing activities in estuaries from Cape Point to Mossel Bay. Report to the Subsistence Fisheries Task Group, Marine & Coastal Management, Department of Environmental Affairs and Tourism, Cape Town: 14 pp.

LAMBERTH, S. J. 2000c — White steenbras (*Lithognathus lithognathus*). In *Status Report for Key Linefish Species.* Mann, B. Q. (Ed). *Spec. Publ. oceanogr. Res. Inst. S. Afr.* **7**: 155–157.

LAMBERTH, S. J., BENNETT, B. A. and B. M. CLARK 1994 — Catch composition of the commercial beach-seine fishery in False Bay, South Africa. *S. Afr. J. mar. Sci*. **14**: 69–78.

LAMBERTH, S. J., BENNETT, B. A. and B. M. CLARK 1995 — The vulnerability of fish to capture by commercial beach-seine nets in False Bay, South Africa. *S. Afr. J. mar. Sci*. **15**: 25–31.

LAMBERTH, S. J. and A. R. JOUBERT 1999 — Prioritizing linefish species for research and management: a first attempt. In *Proceedings of the Third South African Marine Linefish Symposium.* Mann, B. Q. (Ed.). *SANCOR Occ. Rep.* **5**: 130–137.

LAMBERTH, S. J., SAUER, W. H. H., MANN, B. Q., BROUWER, S. L., CLARK, B. M. and C. ERASMUS 1997 — The status of the South African beach-seine and gill-net fisheries. *S. Afr. J. mar. Sci.* **18**: 195–202.

LECHANTEUR, Y. A. R. G. 2000 — The ecology and management of reef fishes in False Bay, southwestern Cape, South Africa. Ph.D. thesis. University of Cape Town, South Africa: 238 pp.

MANN, B. Q. 1994 — Multiple usage of St Lucia's fish resources. Final report for the Southern African Nature Foundation: 16 pp.

MANN, B. Q. 1995 — Quantification of illicit fish harvesting in the Lake St Lucia Game Reserve, South Africa. *Biol. Conserv*. **74**: 107–113.

MANN, B. Q. 1996 — Implementation and assessment of the Lake St Lucia subsistence gill-net fishery: a case study. Unpublished Report, Oceanographic Research Institute, South Africa **128**: 14 pp.

MANN, B. Q. (Ed.) 2000 — *Southern African Marine Linefish Status Reports. Spec. Publ. oceanogr. Res. Inst. S. Afr.* **7**: 257 pp.

MANN, B. Q., BECKLEY, L. E. and R. P. VAN DER ELST 1996 — Evaluation of linefishery participation and management along the KwaZulu-Natal coast. Unpublished Report, Oceanographic Research Institute, South Africa **134**: 17 pp.

MANN, B. Q., FENNESSY, S. T. and L. E. BECKLEY 1998 — Evaluation of linefishery participation and management in the Transkei region of the Eastern Cape (Port Edward to Coffee Bay). Final Report to the Sea Fisheries Research Institute, Department of Environment Affairs and Tourism, Cape Town: 54 pp.

MANN, B. Q., JAMES, N. C. and L. E. BECKLEY 2002 — An assessment of the recreational fishery in the St Lucia estuarine system, KwaZulu-Natal, South Africa. *S. Afr. J. mar. Sci.* **24**: 263–279.

MANN, B. Q., McDONALD, A. M., SAUER, W. H. H. and T. HECHT 2003 — Evaluation of participation in and management of the Transkei shore linefishery. *Afr. J. mar. Sci.* **25**: 79–97.

MANN, B. Q., SCOTT, G. M., MANN-LANG, J. B., BROUWER, S. L., LAMBERTH, S. J., SAUER, W. H. H. and C. ERASMUS 1997 — An evaluation of participation in and management of the South African spearfishery. *S. Afr. J. mar. Sci.* **18**: 179–193.

MARAIS, J. F. K. and D. BAIRD 1980 — Analysis of anglers' catches in the Swartkops estuary. *S. Afr. J. Zool.* **15**: 61–65.

MAREE, R. C., WHITFIELD, A. K. and N. W. QUINN 2000a — Prioritisation of South African estuaries based on their potential importance to estuarine-associated fish species. Unpublished Report to the Water Research Commission, South Africa: 56 pp.

MAREE, R. C., WHITFIELD, A. K. and A. J. BOOTH 2000b — Effect of water temperature on the biogeography of South African estuarine fishes associated with the subtropical/warm temperate subtraction zone. *S. Afr. J. Sci.* **96**: 1–5.

McGRATH, M. D., HORNER, C. C. M., BROUWER, S. L., LAMBERTH, S. J., MANN, B. Q., SAUER, W. H. H. and C. ERASMUS 1997 — An economic valuation of the South African linefishery. *S. Afr. J. mar. Sci.* **18**: 203–211.

MORANT, P. D. and N. W. QUINN 1999 — Influence of man and management of South African estuaries. In *Estuaries of South Africa.* Allanson, B. R. and D. Baird (Eds). Cambridge; University Press: 289–320.

PEASE, B. C. 1999 — A spatially orientated analysis of estuaries and their associated commercial fisheries in New South Wales, Australia. *Fish. Res.* **42**: 67–86.

PRADERVAND, P. and D. BAIRD 2002 — Assessment of the recreational linefishery in selected Eastern Cape estuaries: trends in catches and effort. *S. Afr. J. mar. Sci.* **24**: 87–102.

SAUER, W. H. H. and C. ERASMUS 1996 — Evaluation of the line and net fisheries along the west coast of South Africa. Final Report to the Sea Fisheries Research Institute, Department of Environment Affairs and Tourism, Cape Town: 34 pp.

SAUER, W. H. H., PENNEY, A. J., ERASMUS, C., MANN, B. Q., BROUWER, S. L., LAMBERTH, S. J. and T. J. STEWART 1997 — An evaluation of attitudes and responses to monitoring and management measures for the South African boat-based linefishery. *S. Afr. J. mar. Sci.* **18**: 147–163.

SMITH, M. M. and P. C. HEEMSTRA (Eds) 1986 — *Smiths' Sea*

Fishes. Johannesburg; Macmillan: xx + 1047 pp.

SOWMAN, M., BEAUMONT, J., BERGH, M., MAHARAJ, G. and K. SALO 1997 — An analysis of emerging co-management arrangements for the Olifants River harder fishery, South Africa. In *Fisheries Co-management in Africa. Proceedings from a Regional Workshop on Fisheries Co-Management Research, Mangochi, Malawi, March 1997.* Normann, A. K., Nielsen, J. R. and S. Sverdrup-Jensen, (Eds). Fisheries Co-management Research Project Report **12**: 177–203.

SWALLOW, S. K. 1994 — Renewable and non-renewable resource theory applied to coastal agriculture, forest, wetland and fishery linkages. *Mar. resour. Econ.* **9**: 291–310.

TURPIE, J. K. 2000 — The use and value of natural resources in the Rufiji floodplain and delta, Tanzania. Unpublished Report to Rufiji Environmental Management Project and IUCN East African Regional Office: 108 pp.

TURPIE, J. K., ADAMS, J. B., JOUBERT, A., HARRISON, T. D., COLLOTY, B. M., MAREE, R. C. WHITEFIELD, A. K., WOOLDRIDGE, T. H., LAMBERTH, S. J. TALJAARD, S. and L. VAN NIEKERK 2002 — Assessment of the conservation priority status of South African estuaries for use in management and water allocation. *Water SA*: 191–206.

TURPIE, J. K., BECKLEY, L. E. and S. M. KATUA 1999a — Biogeography and the selection of priority areas for conservation of South African coastal fishes. *Biol. Conserv*. **92**: 59–72.

TURPIE, J. K., SMITH, B., EMERTON, L. E. and J. I. BARNES 1999b — Economic value of the Zambezi Basin wetlands. Unpublished Report to IUCN Regional Office for Southern Africa: 346 pp.

VAN DER ELST, R. P. 1989 — Marine recreational angling in South Africa. In *Oceans of Life off Southern Africa*. Payne, A. I. L. and R. J. M. Crawford (Eds). Cape Town; Vlaeberg: 164–176.

VAN DER ELST, R. P. and F. ADKIN (Eds) 1991 — Marine linefish. Priority species and research objectives in southern Africa. *Spec. Publ. oceanogr. Res. Inst. S. Afr.* **1**: 132 pp.

VAN DER ELST, R. P. and A. J. DE FREITAS 1988 — Long-term trends in Natal marine fisheries. In *Long-term Data Series Relating to Southern Africa's Renewable Natural Resources*. MacDonald, I. A. W. and R. J. M. Crawford (Eds). *Rep. S. Afr. nat. scient. Progs* **157**: 76–84.

WHITFIELD, A. K. 1992 — A characterisation of southern African estuarine systems. *Sth. Afr. J. aquat. Sci.* **12**: 89–103.

WHITFIELD, A. K. 1994 — An estuary-association classification for the fishes of southern Africa. *S. Afr. J. Sci*. **90**(7): 411–417.

WHITFIELD, A. K. 1998 — *Biology and Ecology of Fishes in Southern African Estuaries*. *Ichthyol. Monogr. J. L. B. Smith Inst. Ichthyol.* **2**: 223 pp.

WHITFIELD, A. K. and J. F. K. MARAIS 1999 — The ichthyofauna. In *Estuaries of South Africa*. Allanson, B. R. and D. Baird (Eds). Cambridge; University Press: 209–233.