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

Steve Lamberth · Jane Turpie

WRC Report No. 756/2/03

Water Research Commission

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Report to the Water Research Commission

Edited by

Steve Lamberth and Jane Turpie

WRC Report No. 756/2/03
ISBN No. 1-86845-981-0
ISBN Set No. 1-86845-978-0

February 2003

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SECTION 2

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Submitted to:
Institute of Natural Resources

February 2001

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1. INTRODUCTION

South Africa has roughly 255 functioning estuaries along its approximately 3100 km coastline. These estuaries are subject to increasing pressures, both indirectly from the effects of catchment utilisation, which affect their water supply, and directly from the increasingly large numbers of people who reside in or visit the coastal zone. Estuaries are productive systems which provide a valuable supply of goods and services, ranging from fisheries to recreational opportunities, but there have been no previous attempts to estimate the economic value of these ecosystem services, with the result that their contribution to the national economy has been under-appreciated.

Many human activities which are carried out in estuaries and their catchment areas impact directly on estuarine biodiversity and resource stocks, 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. Resident fish populations are exploited directly in estuarine recreational and subsistence fisheries. But more importantly, estuaries provide nursery areas for numerous species of fishes which 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.

The management of estuaries in South Africa has not been well organised in the past. Now, with the increasing realisation of their value, as well as of the pressures that threaten these systems, efforts are being made to redress the situation and to set in place sound decision-making processes regarding the management and conservation of estuaries. This is both in terms of the management of catchments and determination of freshwater inflows into estuaries, and in terms of the direct management of estuaries and activities within them.

One such effort is the current development of a decision support system for the management and conservation of estuarine systems being developed by the Institute of Natural Resources (INR). The latter study recognises that effective management strategies that lead to sustainable and optimal use of resources need to be built on a sound economic rationale as well as an ecological understanding. This study was commissioned by the INR to provide an overview of the economic value of estuarine fishery resources in South Africa, and to comment on the implications of the findings for estuary management.

The main aims of this study were as follows:

- To list the estuarine fish species exploited in South African fisheries, giving their degree of dependence on estuaries;
- To describe the types of estuarine and marine fisheries exploiting estuarine fishes, and their total participation and effort;
- To estimate the total catches of estuarine species in estuaries and the marine environment;
- To explain the contribution to fisheries made by different types of estuaries;
- To estimate the contribution that estuarine and estuary-dependent fishes make to the economic value of estuarine and marine catches.
- To give rough estimates of the status of stocks of important estuarine fish species; and
- To comment on the implications of the above findings for estuary management.

2. STUDY APPROACH AND METHODS

Subdivision of the study area

The South African coast can be considered in terms of three biogeographical regions:

1. the *Cool Temperate region* on the West Coast;
2. *Warm Temperate region* from Cape Point to approximately the Bashee River in the former Transkei; and
3. the *Subtropical region* to the north-east of the Bashee.

The second boundary, is rather poorly defined, largely because the presence or absence of fish is so strongly influenced by a major tropical subtraction effect from Kosi to Cape Point (Turpie *et al.* 1999), rather than any natural geographical break.

The South African coast has usually been divided into five regions for the collection of fisheries data, corresponding with the Cape Point biogeographical division, but not the second division:

1. *West coast*: Orange R. to Cape Point
2. *South coast*: Cape Point to Port Elizabeth
3. *East coast*: Swartkops to Kei River
4. *Transkei*: between Kei R. and Port Shepstone
5. *KwaZulu-Natal*: Port Shepstone to Kosi Bay

Thus the warm temperate zone is mostly divided into two sections, and the former Transkei (hitherto referred to simply as the Transkei) constitutes a very broad transition area between biogeographical zones.

Estuarine fish and their dependence on estuaries

General information on biology and distribution of estuarine fish species was obtained from Whitfield (1998) and Mann (2000). Information on which of these species are utilised 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.

Types of fisheries, participation and effort

For estuarine fisheries, we included legal and illegal seine and gillnet fisheries, recreational shore, castnet and recreational boat fisheries, as well as traditional fisheries. For marine fisheries, the recreational boat, recreational shore, recreational spear and commercial boat and beach seine and gill net fisheries were considered. Pelagic fisheries were excluded as 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 (Beckley *et al.* 2000, Hutchings & Lamberth 1999, in press a,b,c, Kyle 1995, 1999, Mann 1994, 1995, 1996, Sowman *et al.* 1997, Guastella 1994, Lamberth 2000a,b, Baird & Pradervand 1999, Baird *et al.* 1996, Pradervand & Baird in prep., Marais & Baird 1980), as well as extrapolation from coastal fisheries. For marine fisheries, participation and effort in recreational shore angling, boat fishing and spear fishing was estimated from the regional reports of the National Linefish Survey (Brouwer 1996, Brouwer *et al.* 1997, Lamberth 1996, Sauer & Erasmus 1996, Sauer *et al.* 1997, Mann *et al.* 1996, 1997, 1998, McDonald *et al.* 1998), 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 gill-net 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 & Lamberth 1999).

Estuarine catch estimates

Estimates of estuarine catches and their species composition were obtained from the literature (Hutchings & Lamberth 1999, Kyle 1995, 1996, 1999 2000a,b, Mann 1994, 1995, Beckley *et al.* 2000, Sowman *et al.* 1997, Guastella 1994, Lamberth 1996, 2000a,b, Baird & Pradervand 1999, Pradervand & Baird in prep., Baird *et al.* 1996, Marais & Baird 1980) and from unpublished data and estimates supplied by Bruce Mann (Oceanographic Research Institute), Paul Cowley (JLB Smith Institute of Ichthyology) and Steve Lamberth (Marine & Coastal Management). Estimates were based on sampling, counts of fishers, surveys, and confiscated catches. Estimates of annual catches were obtained for all estuaries on the west coast, all south coast estuaries between Cape Point and Mossel Bay, all estuaries on the south-east coast from Swartkops to Keiskamma, and all estuaries in Kwazulu-Natal. No data were available for estuaries between Mossel Bay and Port Elizabeth or for estuaries in the former Transkei. Existing data were analysed to explore relationships between catch and various parameters. General linear modelling was used to create predictive models to estimate catches for the remaining estuaries. Dependent variables used were estuary size (Brian Colloty, UPE, unpublished data), biogeographical region and estuary type (Whitfield 1992).

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 spear fishing catches, 1994-1996; Brouwer 1996, Brouwer *et al.* 1997, Lamberth 1996, Sauer & Erasmus 1996, Sauer *et al.* 1997, Mann *et al.* 1996, 1998, Lechanteur 2000, McDonald *et al.* 1998), the NMLS (commercial boat catches, recreational boat catches, 1992-1996) and catch reports from the Marine & Coastal Management Netfish System (commercial beach-seine and gill net catches, excluding KwaZulu-Natal, 1992-1996). The latter were corrected using validated catches from Lamberth *et al.* (1997) and Hutchings & Lamberth (1999, in press a,b). KwaZulu-Natal net fish catches were estimated from Beckley & 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 mainly been confined to marine commercial and recreational fisheries. Estimates of the economic contribution of each of the marine line fisheries were obtained from McGrath *et al.* (1997), based on NMLS data, and of the marine and estuarine net fisheries were obtained from Hutchings & Lamberth (1999) and Hutchings & Lamberth (in press b).

For marine fisheries, the relative contribution of each species was determined according to the methodology used by Lamberth & Joubert (1999). Fish prices were obtained in telephonic interview 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 & Lamberth (1999, in press b). 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, we assume 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 utilised 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 & 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. Species for which data were available were used as a baseline against which species which lacked data could be assessed by expert opinion. Data were obtained from various sources, e.g. the NMLS,

Mann (2000), CMS (2000). Each species was scored on a scale of 1-100, with score ranges indicating the stock as underexploited, optimally exploited, over exploited or collapsed (Griffiths *et al.* 1999).

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

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

(d) *Level of exploitation.* This was scored qualitatively on the basis of Mann (2000), CMS (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 8 life history traits, namely estuarine 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, and those displaying four or more of these characteristics scored 100 (see Lamberth & Joubert 1999 for rationale).

3. ESTUARINE FISH AND THEIR DEPENDENCE ON ESTUARIES

Categories of estuarine fish species

About 160 species occur in South African estuaries, of which about 80 species are utilised in fisheries. This report is only concerned with the latter 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 9 types (Whitfield 1994, Table 1). Category I and IIa species are entirely dependent on estuaries, as are category IV and V species. Category IIb species are largely dependent on estuaries, while numbers of category IIc species are augmented by estuaries. Category III species are found in estuaries, but are not dependent on them.

Table 1. The five major categories and subcategories of fishes which utilise southern African estuaries (Whitfield 1994).

Categories	Description
I	Estuarine species which breed in southern African estuaries. Ia. Resident species which have not been recorded spawning in marine or freshwater environments. Ib. Resident species which also have marine or freshwater breeding populations.
II	Euryhaline marine species which usually breed at sea with the 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 which 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 which may breed in both freshwater and estuarine systems.
V	Catadromous species which use estuaries as transit routes between the marine and freshwater environments but may also occupy estuaries in certain regions. Va. Obligate catadromous species which require a freshwater phase in their development. Vb. Facultative catadromous species which do not require a freshwater phase in their development

Utilised estuarine fish species and their distribution

Of the 80 utilized species, 3, 47, 21, 3 and 6 species fall into categories I to V, respectively (Table 2). Of particular importance are the category I and II species, for which management of estuaries plays a crucial role in fisheries. Catches of estuarine-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 Bashee River in the Transkei. The Cool Temperate region is relatively species poor but productive, and the fisheries include only about 19 estuarine-associated species (Table 2). 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 2). Some 28 estuarine-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.

Table 2. Estuarine-associated species caught in South African fisheries, given in order of estuarine dependence category (Table 1), and giving 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 (Port Edward to Kosi Bay). The three biogeographical provinces are separated by Cape Point and roughly at the Bashee River in the Transkei (Emanuel et al. 1992, Turpie *et al.* 1999, Maree *et al.* 2000a,b).

Species	Common name	Dependence category	Distribution				
			Cool T	Warm Temp			Subtrop
			West	South	East	Tkei	KZn
Ambassis productus	Longspine glassy	Ia					X
Ambassis gymnocephalus	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
Galeichthyes 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 sillagio	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

continued..

Table 2 continued.

Species	Common name	Dependence category	Distribution				
			Cool T	Warm Temp			Subtrop
			West	South	East	Tkei	KZn
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
Dasyatis chrysonota	Blue stingray	III	X	X	X		
Himantura uamak	Honeycomb stingray	III					X
Gymnura natalensis	Butterfly/diamond ray	III		X	X	X	X
Myliobatus aquila	Eagleray	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				
Chelidonichthyes capensis	Gurnard	III	X	X	X		
Trachurus trachurus	Maasbanker	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	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	Mozambique 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	Shortfin eel	Va		X	X	X	X
Anguilla marmorata	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	**80**		**19**	**34**	**41**	**43**	**71**

3. ESTUARINE FISHERIES

Types of fisheries, participation and effort

a. Linefishing

Linefishing may take place from the shore or from boats ranging from canoes or small dinghies to large skiboats, and using handlines or rods. Linefishing is popular in estuaries throughout South Africa, primarily as a recreational pursuit, although a small number of subsistence fishers are active, mainly from Port Elizabeth to KwaZulu-Natal. No commercial linefishing is permitted in estuaries. Angling in estuaries requires a marine recreational angling permit, and subsistence permits are in the process of being introduced.

No large scale studies of angling participation or effort in estuaries have been made in South Africa, and existing studies are confined to a few specific estuaries. On the west coast, the fishery is limited, primarily due to lack of suitable angling fish, but assuming densities similar to adjacent shorelines, there may be up to 0.12 anglers per km of estuary at any one time, or a maximum of 4400 angler days per year on west coast estuaries. This represents the effort of approximately 147 fishers (Lamberth 2000a). All the effort is currently recreational, although about 14% of these anglers admit to selling part of their catch (Lamberth 1996).

On the south coast, between Cape Point and 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 per year in estuaries along this coast. This represents the effort of approximately 2209 fishers. These effort estimates are probably extremely conservative, as the Overberg district council issues 1200 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, we estimate a total effort of 133 000 angler days and a total of 7400 anglers.

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 8000 anglers (extrapolated from Pradervand & Baird, in prep). Extrapolating to the entire east coast region, we estimate that there are approximately 168 000 angler days and 9300 anglers in total.

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 per year, representing the effort of about 19 000 anglers (McDonald *et al.* 1998, Mann *et al.* 1998). Using similar assumptions as for other parts of the South African coastline, it is estimated that there are approximately 112 000 angler days spent in estuaries, representing the effort of 5-6000 anglers.

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

The total number of anglers using estuaries in South Africa is estimated to be in the region of 67 000 (Table 3). This is not too dissimilar to van der Elst's (1989) estimate of 50 000 anglers operating from light tackle boats in estuaries.

b. Castnetting

Castnetting is mainly used by recreational and subsistence anglers to catch bait fish such as mullet, is practised throughout South Africa, and requires a castnet 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 of 1.5-4m diameter, with a mesh size of 15-20mm. 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 2m diameter, with mesh sizes of 13-20mm.

On the west coast, castnets are used regularly by about 95 recreational shore anglers, almost exclusively targeting harders, with a total effort of about 2837 angler days per year. 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 8972 angler days per year (Lamberth 1996). The amount of castnetting along the east coast is unknown, but is estimated to be about 10 800 days per year by 600 fishers (based on Brouwer 1996). Castnetting is less common in the Transkei, where there are probably about 75 castnet users, with an estimated effort of 1300 days per year. In KwaZulu-Natal, 4511 recreational castnet licences were issued in 1997 (Mann 2000). Effort is unknown, but probably amounts to at least 10 800 days per year. Also important is that a quota 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 5 700 (Table 3).

c. 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 KwaZulu-Natal, where permit-holders are restricted to the use of one net, ranging from 35-75m in length, depending on the estuary in which they operate. Minimum mesh sizes vary from 44-48mm. In addition to legal netting, substantial illegal gillnetting occurs 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.

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 (Lamberth 2000a). On the Berg River estuary, there are 120 gillnet permit holders, plus about 100 illegal operators, and annual effort is about 13 230 net days of legal effort plus at least 4000 net days of illegal effort (Hutchings & Lamberth 1999). The Rietvlei/Diep system is fished by about 10-12 poachers (Lamberth 2000a).

Along the south coast, at least 3 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 5 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 and flathead mullet. Similar effort probably takes place 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 last 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 amongst approximately 90 people, and there are roughly 90 regular illegal gillnetters, excluding transient people from Mozambique and the Pongola floodplain. In St Lucia, there are 37 gillnet permits, but an 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, Kosi.

We estimate that there are approximately 1200 gillnetters operating in estuaries in South Africa (Table 3).

d. 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 to 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 estuaries on the west, south, east and Transkei coasts, and only one permit 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 and Breede estuaries. In KwaZulu-Natal illegal seine netting is known to occur in Lake St. Lucia, Richard's Bay, Mhlatuze, Amatikulu/Nyoni, Zinkwasi, Tugela, Mlalazi, Nhlabane and Mfolozi estuaries. Some of this illegal effort is targeted at prawns. Thus the total number of seine netters using South African estuaries probably does not exceed 150 (Table 3).

e. Traditional fisheries

Traditional fishing methods, which are common in tropical countries to the north, 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 parallel 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 bonefide trappers operating about 150 traps in Kosi (Kyle 2000b). Traditional spear fishing is carried out using a long straight branch with a sharpened piece iron reinforcing 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 which are 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).

Table 3. Estimated numbers of fishers participating in different types of fisheries around the South African coast (legally and illegally).

Estuarine fisheries	West	South	East	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**	**7455**	**9350**	**5500**	**50 810**	**73 812**

* excludes castnet figures as most are anglers.

Total catches within estuaries

Of the 255 functional estuaries considered in this study, catches have been estimated for about half the estuaries (n = 129): all 9 estuaries on the west coast, 24 out of 52 estuaries on the south coast, 23 out of 54 on the east coast, none of the 67 Transkei estuaries, and all 73 estuaries in KwaZulu-Natal. In terms of biogeographical regions, data exist 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. 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 due to exclusion zones).

With the exclusion of the abovementioned estuaries, estuary size alone explains over 80% of the variation in catch in the Warm Temperate region and over 90% of variation in catch in the Cold Temperate and Subtropical regions (Fig. 1). The steeper slope in the Cold Temperate region reflects greater productivity in that region as 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 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. 2), indicating higher productivity. Note also, that temporarily closed estuaries are generally smaller than 150 ha, whereas permanently open estuaries include large estuaries of up to 500 ha.

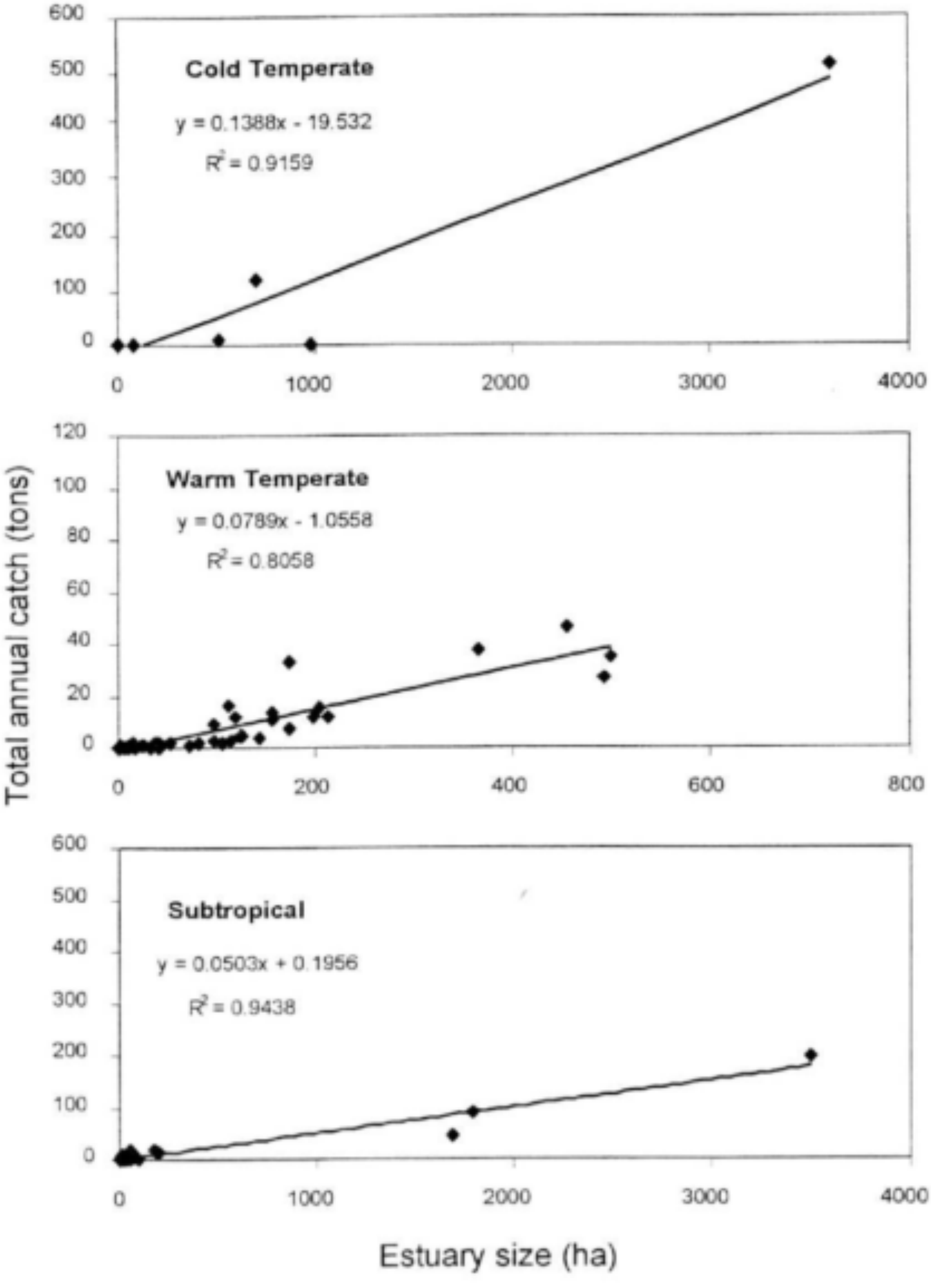

Figure 1. Relationships between estuary size and catch in each of the three biogeographical regions of the South African coast.

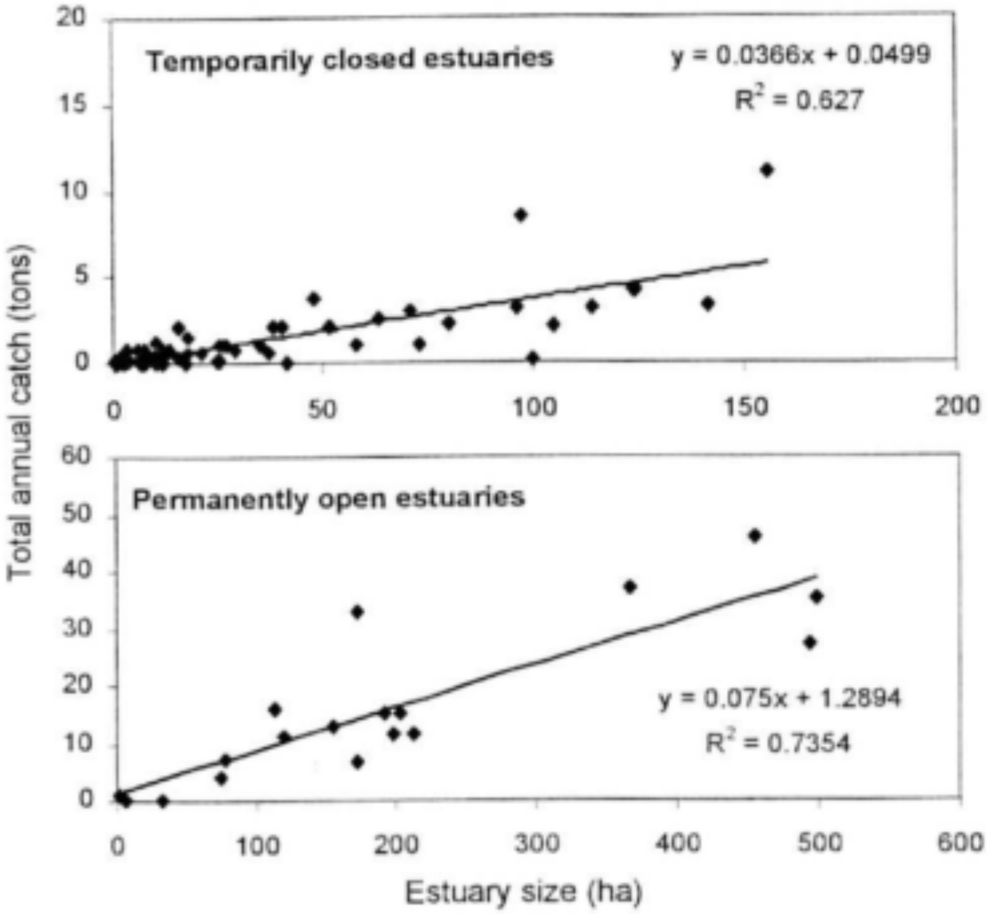

Figure 2. Difference in the relationship between estuary size and catch for permanently open and temporarily closed estuaries in the Warm Temperate and Subtropical regions.

Finally, both estuarine size (ha) and type (all 5 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) -27.23 (if Bay)
+ 5.605 (if Permanently open) + 10.140 (if River mouth)

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 1700 tons per annum, and the new estimates for the remaining 126 estuaries brings the total to 2482 tons (Table 4, details for individual estuaries in Appendix 1).

Anglers (including castnet activities) and gillnetters account for 93% of the total catch, with total catches being roughly equal for the two groups of fishers. Seine-net and traditional fisheries account for the remainder (Table 4).

Table 4. Estimated total catches (tons) per fishery for all estuaries in each of five coastal regions in South Africa.

	Estuaries	Ha	Angling	Castnet	Gill-net	Seine-net	Traps	Spear	Total	kg/ha
West	9	5 884.0	14.0	2.2	625.0	-	-	-	**641.2**	109.0
South	52	12 865.9	409.6	31.1	151.6	12.0	-	-	**604.3**	47.0
East	54	3 763.9	223.5	19.9	51.5	-	-	-	**294.8**	78.3
Transkei	67	2 611.8	141.1	12.5	32.5	-	-	-	**186.1**	71.2
KZN	73	46 810.6	245.4	52.4	296.5	72	73	16	**755.3**	16.1*
TOTAL	**155**	**71 936.2**	**1033.6**	**118.1**	**1157.0**	**84.0**	**73.0**	**16.0**	**2481.7**	**34.5**

* excluding St Lucia, the average yield for KwaZulu-Natal is 58.1kg/ha

West coast estuaries have the highest yields per ha (Table 4), reflecting the generally high fishery productivity of this 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 Kosi and St. Lucia estuaries. On the south coast, Knysna is estimated by the model to have a catch of over 250 tons, but this is likely to be an overestimate.

Catch composition

Catches within estuaries in South Africa are dominated by harders, most of which are caught on the west coast (Table 5). Spotted grunter and dusky kob are the next most important species caught in estuaries, being the main catch of the rest of the country (Table 5). 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 make up most of the remaining catch (10%). On the south coast, spotted grunter makes up 45% of catches, harder 18% and white steenbras 10%, and dusky kob makes up 6% of catch weight. On the east coast, catches are dominated by dusky cob (48%) and spotted grunter (31%). Catch composition in Transkei is unknown. In KwaZulu-Natal, catches are dominated by dusky kob (35%), flathead mullet (11%) and spotted grunter (11%), and evenfin pursemouth, Mozambique tilapia, groovy mullet, largescale mullet make up >5% of catch weight.

Table 5. Catch composition by weight and percentage, excluding Transkei catches and traditional fisheries in KwaZulu-Natal.

Species	Common name		West	South	East	KZN	TOTAL	
			Tons	Tons	Tons	Tons	Tons	%
Liza richardsonii	Harder	IIc	539.79	110.89	17.91	-	668.5	31.52
Pomadasys commersonni	Spotted grunter	IIa	-	270.62	73.51	71.88	416.0	19.61
Argyrosomus japonicus	Dusky kob	IIa	-	36.35	113.31	227.51	377.1	17.78
Mugil cephalus	Flathead mullet	IIa	10.64	13.56	2.16	72.14	98.5	4.64
Pomatomus saltatrix	Elf	IIc	62.58	0.87	1.63	1.47	66.5	3.14
Lithognathus lithognathus	White steenbras	IIa	0.22	60.22	4.47	-	64.9	3.06
Gerres methueni/rappi	Evenfin pursemouth	IIb	-	-	-	50.52	50.5	2.38
Liza dumerilii	Groovy mullet	IIb	-	13.02	0.50	35.07	48.5	2.29
Oreochromis mossambicus	Mozambique tilapia	IV	0.20	-	-	44.11	44.3	2.09
Liza macrolepis	Largescale mullet	IIa	-	-	-	35.20	35.2	1.66
Clarius gariepinus	Sharptooth catfish	IV	-	-	-	28.34	28.3	1.34
Liza tricuspidens	Striped mullet	IIb	-	26.34	1.46	-	27.8	1.31
Lichia amia	Leervis/garrick	IIa	0.79	21.13	4.09	-	26.0	1.23
Rhinobatos annulatus	Lesser guitarfish	III	0.20	22.94	-	-	23.1	1.09
Acanthopagrus berda	Perch/riverbream	IIa	0.63	-	0.67	19.33	20.6	0.97
Elops machnata	Ladyfish/tenpounder	IIa	-	-	7.38	9.36	16.7	0.79
Rhabdosargus holubi	Cape stumpnose	IIa	-	14.26	1.63	-	15.8	0.75
Leiognathus equula	Slimy	IIb	-	-	-	14.25	14.2	0.67
Rhabdosargus sarba	Natal stumpnose	IIb	-	-	-	14.17	14.1	0.67
Trachurus trachurus	Maasbunker	III	12.14	-	-	-	12.1	0.57

Continued..

Table 5 continued.

Species	Common name		West Tons	South Tons	East Tons	KZN Tons	TOTAL Tons	%
Pomadasys hasta/kakaan	Javelin grunter	iic	-	-	-	10.06	10.0	0.47
Galeichthyes feliceps	Barbel	IIb	1.55	1.62	3.58	-	6.7	0.32
Diplodus sargus	Dassie/blacktail	IIc	-	3.18	0.27	-	3.4	0.16
Lutjanus argentimactulus	River snapper	IIc	-	-	-	3.38	3.3	0.16
Myxus capensis	Freshwater mullet	Vb	-	0.46	-	2.39	2.8	0.13
Rhabdosargus globiceps	White stumpnose	IIc	0.13	2.60	0.11	-	2.8	0.13
Sparodon durbanensis	White musselcracker	III	-	2.60	0.16	-	2.7	0.13
Johnius dussumieri	Mini kob	IIc	-	-	-	2.70	2.7	0.13
Chelidonichthyes capensis	Gurnard	III	0.28	-	2.01	-	2.2	0.11
Carcharhinus leucas	Zambezi shark	IIc	-	-	-	2.17	2.1	0.10
Platycephalus indicus	Bartailed flathead	IIc	-	-	-	2.17	2.1	0.10
Muraenesox bagio	Pike conger	III	-	-	-	1.36	1.3	0.06
Chanos chanos	Milkfish	IIc	-	-	-	1.09	1.0	0.05
Monodactylus falciformis	Cape/Oval moony	IIa	0.06	0.61	0.07	-	0.7	0.03
Caranx ignobilis	Giant kingfish	IIb	-	-	-	0.70	0.7	0.03
Caranx sexfasciatus	Bigeye kingfish	IIb	-	-	-	0.70	0.7	0.03
Caranx melampygus	Bluefin kingfish	IIc	-	-	-	0.70	0.7	0.03
Caranx papuensis	Brassy kingfish	IIc	-	-	-	0.70	0.7	0.03
Diplodus cervinus	Zebra/wildeperd	III	-	0.56	0.07	-	0.6	0.03
Liza alata	Diamond mullet	IIb	-	-	-	0.58	0.5	0.03
Scomberoides lysan	Dblespotted queenfish	IIb	-	0.41	-	-	0.4	0.02
Lithognathus mormyrus	Sand steenbras	III	-	0.41	-	-	0.4	0.02
Thryssa vitrirostris	Orngemouth glassnose	IIb	-	-	-	0.41	0.4	0.02
Gerres acinaces	Smallscale pursemouth	IIb	-	-	-	0.28	0.2	0.01
Megalops cyprinoides	Oxeye tarpon	Vb	-	-	-	0.27	0.2	0.01
Dasyatis chrysonota	Blue stingray	III	0.26	-	-	-	0.2	0.01
Sarpa salpa	Strepie	IIc	-	0.15	0.07	-	0.2	0.01
Mustelus mustelus	Smooth houndshark	III	0.10	-	0.11	-	0.2	0.01
Monodactylus argenteus	Natal/Round moony	IIb	-	-	-	0.15	0.1	0.01
Pomadasys multimaculatum	Cock grunter	III	-	-	-	0.08	0.0	-
Myliobatus aquila	Eagleray	III	0.07	-	-	-	0.0	-
Sphyraena barracuda	Barracuda	IIb	-	-	-	0.05	0.0	-
Sphyraena jello	Pickhandle barracuda	IIc	-	-	-	0.05	0.0	-
Terapon jarbua	Thornfish	IIa	-	-	-	0.02	0.0	-
Glossogobius giuris	Tank goby	IV	-	-	-	0.02	0.0	-
Anguilla bengalensis	African mottled eel	Va	-	-	-	0.02	0.0	-
Anguilla bicolour	Shortfin eel	Va	-	-	-	0.02	0.0	-
Anguilla marmorata	Giant mottled eel	Va	-	-	-	0.02	0.0	-
Anguilla mossambica	Longfin eel	Va	-	-	-	0.02	0.0	-
Spondyliosoma emarginatum	Steentjie	III	0.01	-	-	-	0.0	-
Lutjanus fulviflamma	Dory snapper	IIc	-	-	-	0.01	0.0	-
Ambassis productus	Longspine glassy	Ia	-	-	-	0.01	0.0	-
Ambassis gymnocephalus	Bald glassy	Ib	-	-	-	0.01	0.0	-
Ambassis natalensis	Slender glassy	Ib	-	-	-	0.01	0.0	-
	Total catch (tons)		**629.64**	**602.79**	**235.15**	**653.49**	**2121.0**	

4. 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 per year, of which 53% is in KwaZulu-Natal (Brouwer *et al.* 1997, McDonald *et al.* 1998, Mann *et al.* 1998).

Recreational boat angling

Recreational boat fishing gear includes both rod and reels and handlines. Boats used range from small dinghies to skiboats of 6-8 m in extent, to the large tuna or striker craft. There are an estimated 12 054 recreational boat anglers, operating from 3 444 boats (McGrath *et al.* 1997), on 92 988 boat-days per year. However, in many cases, the distinction between commercial and recreational boat fishermen 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, with spearguns. There is considerable investment in fishing equipment, including wetsuits, fins and other paraphernalia in addition to spearguns. There are an estimated 7000 participants in the recreational spearfishery (Mann et al 1997), responsible for about 126 000 spearfishing days per year.

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 line fishers operating from 2 581 registered boats (Griffiths & Lamberth in prep.), for 380 800 boat-days per year.

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 44-178mm mesh size, but separate permit -holders may join their nets. Gillnet permits are issued exclusively for catching harders and St Joseph sharks *Calorhynchus capensis*, and a maximum of 10 by-catch linefish are allowed per day. All gillnet permits issued for the marine environment are on the west coast, from Yzerfontein northwards (approximately 321 permits), apart from a limited number of permits issued at Hawston on the south coast (currently 3 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 on the KwaZulu-Natal coast.

Beach-seine permit holders to the west of Walker Bay on the south coast are restricted to nets of 275m long, while on the rest of the south and east coasts they are restricted to 137m, and in KwaZulu-Natal, 100m. Minimum mesh sizes are 14mm in Kwazulu-Natal and 44mm everywhere else. 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 pilchards *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 the country.

There are approximately 2 700 people who derive some sort of income in the legal inshore net fisheries along the west and south coasts, with a total effort of approximately 32 000 net-days per year. 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 over the last three years, since the introduction of the Marine Living Resources Act.

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.

Inshore Marine Catches

The total inshore marine catch is estimated to be 27 519 tons per year (Table 6). Of this 60% is made up by the commercial linefish sector and 23.5% by the commercial netfishery, the remainder being made up of recreational fisheries. Inshore fishery catches on the west coast, which make up 53% of the total catch, are predominantly commercial, whereas recreational catches are comparable to commercial catches in the rest of the country, becoming relatively more important towards KwaZulu-Natal (Table 6).

Table 6. Inshore marine catches for different fisheries along different sections of the South African coast. All values are in tons per year.

	West	South	East	Transkei	KwaZulu-Natal	Total
Recreational shore angling	115	1 021	1 039	336	662	**3 173**
Recreational boat angling	407	171	236	No data	470	**1 283**
Recreational Spearfishing	19	79 (S & E coast)		No data	25	**123**
Commercial linefishing	10 191	2 848	2 615	39	765	**16 459**
Commercial net fishing	4 303	1 827	159	No data	192	**6 481**
TOTAL	**14 675**	**5 907**	**4 088**	**345**	**2 114**	**27 519**

Estuary-associated species in marine catches

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

The main estuary-associated species caught by recreational shore anglers are elf and strepie, which together make up over 50% of the catch. Both of these species are estuary-dependent (category IIc). Numbers of dassie (IIc) and piggy are also significant, making up more than 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 (3%), although this 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 makes up 1% of total catch. This low proportion is partly due to the collapsed status of the stock.

Zebra and white musselcracker are the most common estuary-associated species in recreational spearfishing catches, but these each only make up less than 3% of catches. However, these are category III species, and the most common estuarine-dependent species is leervis (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 summarised for each part of the coast in Table 8. 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 spear 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 certain catches in certain regions (Table 8). Historically, dusky kob and white steenbras comprised 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 (Griffiths 1997, Bennett 1993). The proportion of category IIb species in catches is generally lower than of category IIa species (Table 8).

Table 7. Percentage contribution of estuarine associated species to the overall catches in different inshore marine fisheries, and total percentage of estuarine species in catches. Figures are percentage of total biomass in all cases except Recreational Shore Angling, in which data are in numbers of fish.

			Recreational			Commercial	
Species	**Common name**		**Shore**	**Boat**	**Spear**	**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
Galeichthyes 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	IIc	2.67	-	-	-	74.97
Lutjanus argentimaculatus	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	-	-	-	-
Chelidonichthyes capensis	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/sandshark	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	Maasbunker	III	0.54	0.15	0.01	0.06	0.34
Myxus capensis	Freshwater mullet	Vb	-	-	-	-	0.02
Total % of estuarine species in catch			**83.14**	**6.79**	**6.93**	**7.40**	**83.03**

The majority of estuary-associated fish biomass in recreational shore-angling and in commercial gillnet catches is made up of category IIc species, which are species whose juveniles are found mainly in marine environments but also occur in estuaries. Category III species occur in estuaries but are not dependent on them. These make up over 10% of shore-angling catches, 3.8% of recreational boat and 4.9% of recreational spearfishing catches, but are not particularly important in commercial catches (Table 8). Category IV species are freshwater species, and thus do not feature in marine catches. Category V species have only been recorded in very small quantities in KwaZulu-Natal, though small quantities are also known to be caught elsewhere. These species are entirely dependent on estuaries, but they are normally caught in rivers, beyond the scope of this study.

Table 8. Percentage contribution of different categories of estuarine associated fish to the inshore marine fisheries in each of the coastal sections. All percentages in terms of biomass except recreational shore angling, in terms of numbers.

		Dependence category									
		Ia	**Ib**	**IIa**	**IIb**	**IIc**	**III**	**IV**	**Va**	**Vb**	Total
Recreational shore	West			0.51	0.17	41.26	13.8				55.75
	South			5.31	1.27	58.81	9.1				74.52
	East			9.00	1.64	59.64	18.6				88.98
	Transkei			11.52	1.97	45.97	3.6				63.12
	KZN			5.22	3.98	78.40	3.9				91.52
	Total			**7.12**	**2.30**	**63.31**	**10.4**				**83.14**
Recreational boat	West			0.02	<0.01	0.80	0.1				0.92
	South			7.31	<0.01	3.72	0.7				11.796
	East			0.33	0.24	0.47	1.7				2.80
	Transkei										
	KZN			0.74	0.42	1.84	9.0				12.05
	Total			**1.31**	**0.20**	**1.51**	**3.7**				**6.79**
Recreational spear	West			0.05		0.09	0.0				0.23
	South & east			0.58		0.96	6.7				8.29
	KZN			4.67	0.44		2.7				7.88
	Total			**1.31**	**0.09**	**0.63**	**4.8**				**6.93**
Commercial boat	West			0.09	<0.01	0.80	0.1				0.91
	South			7.31	<0.01	3.72	0.7				11.80
	East			27.45	0.03	0.24	0.1				27.86
	Transkei			8.08	0.91	0.01	0.2				9.26
	KZN			6.13	0.11	0.44	0.8				7.49
	Total			**5.94**	**0.02**	**1.20**	**0.2**				**7.40**
Seine & gillnet	West			1.05	0.04	80.86	1.1				83.06
	South			4.46	0.05	76.03	1.4				81.98
	East			2.16	0.97	96.59	0.0				99.73
	Transkei										
	KZN	<0.01	<0.01	45.46	27.51	4.94	0.7		0.02	0.7	79.37
	Total	**<0.01**	**<0.01**	**3.67**	**1.08**	**77.10**	**1.1**		**0.01**	**0.0**	**83.03**
Species total		1	2	14	15	19	2		4		

5. ECONOMIIC VALUE OF ESTUARINE FISH

Values considered

All values are considered in terms of value added to the economy (contribution to Gross Domestic Product). Subsistence outputs are not actually recorded as part of GDP, but would be in an ideal world. The value of subsistence fisheries was taken as the gross value of landed catches, based on the market value of fish caught. The values of commercial and recreational fisheries were calculated mainly on the basis of data in McGrath *et al.* (1997). Commercial fishery values include the value added by subsidiary industries. Recreational values comprise the expenditure by anglers on equipment and travel to fishing sites. Note that the latter may be an overestimate of value since fish are one part of a recreational package which may include enjoyment of coastal areas, etc. Furthermore, in the absence of fish, some anglers may turn to alternative recreational activities which still incur some expenditure in the economy. Nevertheless, we feel that most angling expenditure is currently attributable to the fishery resource and should be reflected as such.

The total value of estuaries to South African fisheries comprises the value of fisheries within estuaries plus the value that estuarine inputs contribute to inshore marine fisheries. These two components are discussed separately below.

Value of estuarine fisheries

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 9). This is based on an estimated total annual catch of 2 482 tons (Table 4).

Ninety-nine percent of this value (nearly R429 million) is the value of recreational angling, while net and traditional fisheries together make up the remaining 1% of value (Table 9). This distribution of values among estuarine fishery sectors is very different from the distribution of catches (Table 4), 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, which means that catch masses are made up of proportionally more individuals. Smaller fish are of 'lower quality' and do not fetch the same prices per kg as those in the larger size classes.

With over 72 000 anglers in the recreational fishery, compared with some 1350 in the commercial fisheries, these aggregate values (Table 9) translate to average values of about R6000 per recreational angler per year (expenditure), *versus* about R2800 per commercial fisher (income). The recreational value is realised as income to an unknown number of participants in subsidiary industries.

Thus substantial amounts are spent annually by large numbers of anglers in estuaries, most of whom belong to middle-upper income groups, whereas a 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 realised 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, as fishing solely for mullet and similar species in estuaries is non-profitable (Hutchings & 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 a loss of about R5 600 per annum. 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 & Lamberth in press b).

Table 9. Estimated annual value (1997 rands) of estuarine fisheries along different stretches of the South African coast.

	West	South	East	Transkei	KZN	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
Gill-net	1 925 000	466 821	158 510	100 050	913 220	**3 563 601**	0.8
Seine-net	-	36 854	-	-	221 760	**258 614**	0.1
Fish traps	-	-	-	-	224 840	**224 840**	0.1
Spear	-	-	-	-	49 280	**49 280**	<0.1
Total	**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		

Comparatively few people are involved in the traditional fisheries, which are worth just a fraction of the other fisheries, amounting to about R2300 per fisher per year in terms of subsistence income. Viewing the traditional fisheries in the same economic terms as other fisheries may be somewhat misleading in terms of their importance. It should be noted that these fisheries form an integral part of the survival of communities which 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 2000b).

A similar type of argument might by made for the commercial fisheries, especially when compared to 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 & Lamberth in press b). 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 being retired. Indeed, the net fishery contributed over 50% of income for only 10% of the fishers (Hutchings & Lamberth in press b).

Estuarine contribution to inshore marine fishery values

The total value of inshore marine fisheries is about R2.44 billion per year (1997 rands; Table 10). Approximately 83% of this value is the value of the recreational fisheries (almost all from shore angling), the remaining 17% 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 about R4300 per fisher per year, whereas the approximately 21 000 people involved in commercial fisheries gain an average of R19 000 per year (income).

Roughly half of the total inshore marine fishery value (52%) is made up of estuary-associated species (Table 10). However, not all of 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 occur in marine environments, are augmented by the presence of estuarine habitat areas. Estuarine area comprises 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 & Bennett 1985). We thus estimate that 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 R519 million per year (Table 10). In other words, this value would be lost if estuaries were 'removed' from the coastline.

The relative contribution of estuaries to fisheries varies between types of fisheries and around the coast. 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 spear-fisheries

(Table 10). Overall, the estuarine contribution to marine recreational fishery values is about R469.74 million per year. This is 90.5% 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 10).

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 10).

The overall contribution of estuaries to inshore fishery values is summarised in Table 11.

Table 10. Percentage contribution of estuarine associated fishes to the total value of the inshore marine fishing sectors in the different coastal regions, the total annual values of the fisheries, the amount and percentage of total which is comprised of 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.

	Estuary-associated species categories								Total value	Estuary fish contribution		Value due to estuaries	
	Ia	Ib	IIa	IIb	IIc	III	Va	Vb	R million	R million	%	R million	%
Recreational shore													
West			0.60	0.03	18.05	2.24			105.70	22.12	20.92	6.39	6.0
South			7.29	0.29	38.32	5.75			825.70	426.45	51.65	157.29	19.0
East			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			174.49	113.56	65.08	61.10	35.0
KZN			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**			**1852.18**	**1209.66**	**65.31**	**469.02**	**25.3**
Recreational boat													
West			0.00	0.00	0.39	0.01			112.06	0.45	0.41	0.13	0.1
South			0.37	0.00	3.77	0.22			14.48	0.63	4.36	0.22	1.5
East				0.02	1.66	2.16			0.88	0.03	3.84	0.00	0.5
KZN					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 spear													
West			0.12		0.06	0.12			7.24	0.02	0.30	0.01	0.1
S & E			0.19		0.41	8.28			43.23	3.84	0.13	8.88	0.3%
KZN			4.79	0.44		13.15			4.24	0.78	18.38	0.22	5.2
Total			**0.53**	**0.03**	**0.34**	**7.57**			**54.70**	**4.64**	**8.48**	**0.36**	**0.7**
Commercial boat													
West			0.04	0.00	0.78	0.05			188.89	1.66	0.88	0.53	0.3
South			11.09	0.00	2.50	0.20			82.09	11.33	13.80	9.72	11.8
East			36.52	0.01	0.16	0.03			86.00	31.58	36.72	31.45	36.6
KZN			7.09	0.04	0.21	0.99			29.02	2.42	8.33	2.09	7.2
Total			**11.05**	**0.00**	**0.97**	**0.15**			**386.00**	**46.98**	**12.17**	**43.79**	**11.3**
Seine & gillnet													
W.coast			3.89	0.02	72.90	1.86			11.92	9.37	78.67	3.07	25.8
S.coast			10.99	0.01	46.25	2.11			7.49	4.45	59.36	1.86	24.9
E.coast			9.12	0.50	90.04	0.03			0.41	0.41	99.70	0.15	36.6
KZN	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									**2440.94**	**1276.77**	**52.3**	**518.79**	**21.3**

Table 11. Summary of the estimated total contribution of estuaries to the annual value (1997 Rands) of inshore marine fisheries along different stretches of the South African coast, by fishery.

Estuarine contribution to marine inshore fishery values	West	South	East	Transkei	KZN	Total	%
Recreational shore	6.39	157.29	159.63	61.1	84.5	**469.02**	90.4
Recreational boat	0.13	0.22	0		0	**0.36**	0.1
Recreational spear	0.01	0.15	0.15		0.22	**0.36**	0.1
Commercial boat	0.53	9.72	31.45		2.09	**43.79**	8.4
Seine & gillnet	3.07	1.86	0.15		0.17	**5.26**	1.0
Total	**10.13**	**169.24**	**191.38**	**61.1**	**86.98**	**518.79**	
%	2.0	32.6	36.9	11.8	16.8		

Total value of estuarine fish

The total value of estuarine and estuary-dependent fisheries is estimated to be R951.75 million in 1997 Rands (Table 12). This is equivalent to R1.162 billion in 2000 rands.

Furthermore, this total estuarine fish value is rather unevenly distributed around the coast, with west coast estuaries contributing less than 2% of the total value. Estuaries along the warm temperate coast have the highest aggregate value, and average per estuary values (Table 12). East coast estuaries, in particular are worth over R75 000 per ha per year (1997 rands) in terms of fish production (Table 12).

However, average values may not be very reliable predictors of individual estuary values, which are related to several factors such as size and mouth status, as well as geographical location.

Table 12. Summary of the value of estuarine fisheries and estuary contribution to marine fisheries around different parts of the coast. Values given in 1997 Rands.

	West	South	East	Transkei	KZN	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	191.4	61.1	87.0	518.8
TOT	**17.9**	**339.7**	**284.3**	**119.7**	**190.3**	**951.7**
No estuaries	9	52	54	67	73	255
Ha	5,884	12,866	3,764	2,612	46,811	71,937
Average value/estuary (R million)	2.0	6.5	5.3	1.8	2.6	3.7
Average value/ha (R)	3,036	26,400	75,520	45,836	4,065	13,230

6. 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 & Attwood 1993, 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 were also found to have 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 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, was reduced to only 3% of anglers catches, and were almost totally absent from catches in the 1990s (Whitfield & Marais 1999).

The status of stocks 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). An maximally exploited stock (one which is exploited close to the 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, fourteen of the 80 utilised estuary-associated species are considered overexploited (Table 13). Of these, elf, dassie, kob, white steenbras, white stumpnose and natal stumpnose 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 & Joubert 1999). The stocks of six of these fourteen species are in a collapsed state, including white steenbras and kob, which are Category IIa species (Table 13). 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, as their stocks are at levels greater than 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 which are either at the edge of their range, or have a limited range, with South Africa, but they may be locally important in certain areas, e.g. pursemouths in Kosi Bay.

It is difficult to assess what contributes more to the decline of an estuarine species: estuarine habitat degradation or overexploitation. Estuarine dependence immediately creates a life-history bottleneck for many species, especially when it comes to entering temporarily closed estuaries. In addition to estuarine dependency, sex changes, spawning migrations, predictable aggregations, high age at maturity, longevity, residency and high catchability all contribute to a species vulnerability to overexploitation. For example, white steenbras exhibits seven of these life-history traits, excluding sex change, and is currently at 6% of its pristine spawner biomass, and on the critical list. Half of all species considered have vulnerable life-history characteristics in addition to estuarine dependency, and a quarter of them fall into the most vulnerable category (Table 13).

Very few of the species considered are range restricted (Table 13). A quarter of species are highly exploited throughout their range (Table 13), 23 species are under medium exploitation, and the rest are subject to medium to low 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. For most of these species, no comprehensive stock assessments have been done.

Table 13. The stock status (abundance trend) (A), vulnerability (V), range (R), exploitation level (E) and knowledge (K) of utilized estuarine-associated species in South Africa.

Family	Species	Common name	Cate-gory	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 uamak	Honeycomb stingray	III	60	90	0	50	29
Mustelidae	*Mustelus mustelus*	Smooth houndshark	III	55	90	0	100	86
Myliobatidae	*Myliobatus aquila*	Eagleray	III	60	70	0	25	43
Rhinobatidae	*Rhinobatos annulatus*	Lesser guitarfish	III	65	70	10	25	50
Ambassidae	*Ambassis gymnocephalus*	Bald glassy	Ib	55	70	0	0	29
	Ambassis productus	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	*Galeichthyes 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	Maasbunker	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*	Mozambique 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

continued..

Table 13 continued.

Family	Species	Common name	Category	CONSERVATION IMPORTANCE A	V	R	E	K
	Liza dumerilii	Groovy mullet	IIb	50	70	0	50	36
	Liza richardsonii	Harder	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
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 sillagio	IIc	65	80	0	0	7
Sparidae	*Rhabdosargus holubi*	Cape stumpnose	IIa	40	100	40	75	50
	Diplodus sargus	Dassie/blacktail	IIc	35	100	10	100	57
	Rhabdosargus sarba	Natal stumpnose	IIb	35	100	0	75	50
	Acanthopagrus 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	Zebra/wildeperd	III	35	100	40	100	36
Sphyraenidae	*Sphyraena barracuda*	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	*Chelidonichthyes capensis*	Gurnard	III	60	80	10	25	50

7. IMPLICATIONS FOR MANAGEMENT

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

However, 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 catches per unit effort and overall catches, and the value realised 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 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.

Reduced catches in estuaries are needed 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 landed catches comprise undersized fish, 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 serve to increase present abundance of certain species. For example, along the east coast of the Eastern Cape and in KwaZulu-Natal, elf has increased in numbers following increased protection (van der Elst & De Freitas 1987, Garrett & van der Elst 1990). Technically, catches could be reduced without reducing the value of the fishery, as most recreational anglers would still go fishing if they were more strictly policed. It also makes good economic sense to remove all commercial fisheries from estuaries, thereby halving the catch, but only reducing economic contribution by 1%. Commercial fishing in estuaries is predominantly gillnetting, which is unselective, usually with a high by-catch of undersized and immature linefish and other species. These species are already overexploited and this fishing pressure occurs 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 allowed into the sea.

Furthermore, subsistence and commercial effort should be excluded from temporarily closed systems, whether large or small, as these stocks are easily overexploited (Pease 1999). The protection of small and closed systems should not be done at the expense of the larger, permanently open systems, however. Protection should be levelled at all estuarine types at a rational scale, as 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 those sectors assigned less lucrative species. This is thus a further argument against including commercial fisheries in estuaries. Estuarine exploitation in South Africa should be limited to subsistence and recreational use. However the South African experience is that designated subsistence fishers soon realise 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 Kosi and St. Lucia. 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 which affect estuarine environments. Apart from the direct effect on fish stocks, recreational angling involves boat traffic and bait digging, leading to disturbance, trampling and depletion of prey for fish. More importantly, perturbations that occur in the marine environment or catchment may negatively impact on fish populations in estuaries (Whitfield & 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 & Marais 1999) in addition to individual species conservation efforts. Such policies will lead to more rational decisions in terms of all developments which affect estuarine ecology, including development of marinas (which tend to favour ichthyoplankton but not large fish - Cloete 1993).

Thus, 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 maximising resource productivity, economic benefits and biodiversity conservation. Resource productivity in both estuaries and the inshore marine environment can be enhanced by concentrating conservation efforts on estuarine stocks. Stock status can only be improved by reduction of catches. In order to minimise the cost of this, it should be targeted at fisheries which are either low value per unit catch (e.g. estuarine commercial net fisheries), 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.

ACKNOWLEDGEMENTS

This study was funded by the Water Research Commission. We gratefully acknowledge the data contributions made by Bruce Mann and Paul Cowley.

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Appendix 1. Estimated total catches by fishery for each estuary. Totals in italics estimated in this study.

Biog Reg	Coast Section	ESTUARY	Size (ha)	Type	Estimated annual catch (tons) Angling	Castnet	Gillnet	Seine	Traps	Spear	Total
C	West	Orange (Gariep)	974.5	River mouth	1.0	0.1	0.0	0.0	0.0	0.0	1.1
C	West	Olifants	701.7	Perm open	1.0	0.1	120.0	0.0	0.0	0.0	121.1
C	West	Berg (Groot)	3615.0	Perm open	10.0	1.0	500.0	0.0	0.0	0.0	511.0
C	West	Rietvlei/Diep	515.0	Temp closed	2.0	1.0	5.0	0.0	0.0	0.0	8.0
C	West	Houtbaai		River mouth	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	West	Wildevoëlvlei	75.8	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	West	Bokramspruit		Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	West	Schuster		Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C	West	Krom		Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	South	Silvermine	6.5	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	South	Sand	155.5	Temp closed	10.0	1.0	0.0	0.0	0.0	0.0	11.0
W	South	Eerste	10.2	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	South	Lourens	7.1	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	South	Sir Lowry's Pass	3.0	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	*0.0*
W	South	Steenbras	1.9	Perm open	0.0	1.0	0.0	0.0	0.0	0.0	1.0
W	South	Rooiels	10.8	Temp closed	0.0	0.1	0.0	0.0	0.0	0.0	0.1
W	South	Buffels (Oos)	17.3	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	South	Palmiet	33.0	Perm open	0.1	0.1	0.0	0.0	0.0	0.0	0.2
W	South	Bot/Kleinmond	1698.4	Lake	5.0	1.0	10.0	0.0	0.0	0.0	16.0
W	South	Onrus	41.1	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	South	Klein	2958.9	Lake	10.0	1.0	5.0	0.0	0.0	0.0	16.0
W	South	Uilskraals	104.7	Temp closed	1.0	0.1	1.0	0.0	0.0	0.0	2.1
W	South	Ratel	10.0	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	South	Heuningnes	172.5	Perm open	5.6	*0.1*	*0.0*	*1.0*	*0.0*	*0.0*	*6.7*
W	South	Klipdrifsfontein		Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	South	Breë	455.3	Perm open	40.0	1.0	3.0	2.0	0.0	0.0	46.0
W	South	Duiwenhoks	203.1	Perm open	5.0	0.1	10.0	0.0	0.0	0.0	15.1
W	South	Goukou (Kaffirkuils)	154.8	Perm open	10.0	1.0	2.0	0.0	0.0	0.0	13.0
W	South	Gourits	112.6	Perm open	10.0	1.0	5.0	0.0	0.0	0.0	16.0
W	South	Blinde		Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	South	Hartenbos	40.6	Temp closed	2.0	0.1	0.0	0.0	0.0	0.0	2.1
W	South	Klein Brak	96.0	Temp closed	2.0	0.1	1.0	0.0	0.0	0.0	3.1
W	South	Groot Brak	113.9	Temp closed	2.0	0.1	1.0	0.0	0.0	0.0	3.1
W	South	Maalgate	13.5	Temp closed							*1.8*
W	South	Gwaing		Temp closed							
W	South	Kaaimans	8.0	Perm open							*4.0*
W	South	Wilderness		Lake							
W	South	Swartvlei	1076.6	Lake							*73.9*
W	South	Goukamma	270.0	Temp closed							*19.2*
W	South	Knysna	3594.0	Bay							*244.6*
W	South	Noetsie	8.0	Temp closed							*1.4*
W	South	Piesang	92.2	Temp closed							*7.2*
W	South	Keurbooms	295.2	Perm open							*23.4*
W	South	Matjies/Bitou		Temp closed							*0.0*
W	South	Sout (Oos)	52.2	Perm open							*0.0*
W	South	Groot (Wes)	39.3	Temp closed							*0.0*
W	South	Bloukrans		River mouth							*0.0*
W	South	Lottering	17.0	River mouth							*0.0*
W	South	Elandsbos	6.0	River mouth							*0.0*
W	South	Storms		River mouth							

Appendix 1 continued.

Biog Reg	Coast Section	ESTUARY	Size (ha)	Type	Angling	Castnet	Gillnet	Seine	Traps	Spear	Total
					Estimated annual catch (tons)						
W	South	Elands		River mouth							
W	South	Groot (Oos)		River mouth							
W	South	Tsitsikamma		Temp closed							
W	South	Klipdrif		Temp closed							
W	South	Slang		Temp closed							
W	South	Krom Oos (Kromme)	240.3	Perm open							*19.7*
W	South	Seekoei	132.2	Temp closed							*9.9*
W	South	Kabeljous	117.9	Temp closed							*8.9*
W	South	Gamtoos	467.0	Perm open							*35.1*
W	South	Van Stadens	28.0	Temp closed							*2.8*
W	South	Maitland	0.2	Temp closed							*0.9*
W	East	Swartkops	499.0	Perm open	30.0	3.0	2.0	0.0	0.0	0.0	35.0
W	East	Coega (Ngcura)	10.1	Temp closed	1.0	0.2	0.0	0.0	0.0	0.0	1.2
W	East	Sundays	173.4	Perm open	25.0	3.0	5.0	0.0	0.0	0.0	33.0
W	East	Boknes	27.0	Temp closed	1.0	0.1	0.0	0.0	0.0	0.0	1.1
W	East	Bushmans	213.0	Perm open	10.0	0.5	1.0	0.0	0.0	0.0	11.5
W	East	Kariega	198.0	Perm open	10.0	0.5	1.0	0.0	0.0	0.0	11.5
W	East	Kasuka	38.0	Temp closed	2.0	0.1	0.0	0.0	0.0	0.0	2.1
W	East	Kowie	118.6	Perm open	10.0	0.3	1.0	0.0	0.0	0.0	11.3
W	East	Rufane		Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	East	Riet	73.1	Temp closed	1.0	0.1	0.0	0.0	0.0	0.0	1.1
W	East	Kleinemond Wes	80.0	Temp closed	2.0	0.2	0.0	0.0	0.0	0.0	2.2
W	East	Kleinemond Oos	35.0	Temp closed	1.0	0.1	0.0	0.0	0.0	0.0	1.1
W	East	Klein Palmiet		Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	East	Great Fish	365.7	Perm open	30.0	2.0	5.0	0.0	0.0	0.0	37.0
W	East	Old woman's	25.1	Temp closed	1.0	0.1	0.0	0.0	0.0	0.0	1.1
W	East	Mpekweni	141.4	Temp closed	2.0	0.2	1.0	0.0	0.0	0.0	3.2
W	East	Mtati	124.2	Temp closed	2.0	0.2	2.0	0.0	0.0	0.0	4.2
W	East	Mgwalana	123.6	Temp closed	2.0	0.2	2.0	0.0	0.0	0.0	4.2
W	East	Bira	97.5	Temp closed	5.0	0.5	3.0	0.0	0.0	0.0	8.5
W	East	Gqutywa	51.6	Temp closed	1.0	0.1	1.0	0.0	0.0	0.0	2.1
W	East	Blue Krans	2.5	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W	East	Mtana	15.7	Temp closed	1.0	0.1	1.0	0.0	0.0	0.0	2.1
W	East	Keiskamma	493.8	Perm open	15.0	2.0	10.0	0.0	0.0	0.0	27.0
W	East	Ngqinisa	12.7	Temp closed							*1.8*
W	East	Kiwane	18.8	Temp closed							*2.2*
W	East	Tyolomnqa	107.4	Temp closed							*8.2*
W	East	Shelbertsstroom		Temp closed							
W	East	Lilyvale	2.3	Temp closed							*1.1*
W	East	Ross' Creek		Temp closed							
W	East	Ncera	28.4	Temp closed							*2.8*
W	East	Mlele	3.6	Temp closed							*1.1*
W	East	Mcantsi	9.0	Temp closed							*1.5*
W	East	Gxulu	48.5	Temp closed							*4.2*
W	East	Goda	17.2	Temp closed							*2.1*
W	East	Hlozi	0.7	Temp closed							*1.0*
W	East	Hickman's	4.3	Temp closed							*1.2*
W	East	Buffalo	98.0	Perm open							*10.1*
W	East	Blind	0.5	Temp closed							*0.9*
W	East	Hlaze	1.5	Temp closed							*1.0*
W	East	Nahoon	57.7	Perm open							*7.3*

Appendix 1 continued

Biog Reg	Coast Section	ESTUARY	Size (ha)	Type	Angling	Castnet	Gillnet	Seine	Traps	Spear	Total
					Estimated annual catch (tons)						
W	East	Qinira	72.1	Temp closed							5.8
W	East	Gqunube	53.4	Perm open							7.0
W	East	Kwelera	50.1	Perm open							6.8
W	East	Bulura	35.5	Temp closed							3.3
W	East	Cunge	0.5	Temp closed							0.9
W	East	Cintsa	29.3	Temp closed							2.9
W	East	Cefane	82.7	Temp closed							6.5
W	East	Kwenxura	29.1	Temp closed							2.9
W	East	Nyara	17.1	Temp closed							2.1
W	East	Haga-haga	3.4	Temp closed							1.1
W	East	Mtendwe	11.2	Temp closed							1.7
W	East	Quko	36.2	Temp closed							3.4
W	East	Morgan	24.0	Temp closed							2.5
W	East	Cwili	1.2	Temp closed							1.0
W	Transkei	Great Kei	222.4	Perm open							18.5
W	Transkei	Gxara	23.9	Temp closed							2.5
W	Transkei	Ngogwane	9.1	Temp closed							1.5
W	Transkei	Qolora	22.9	Temp closed							2.5
W	Transkei	Ncizele	6.6	Temp closed							1.4
W	Transkei	Kobonqaba	26.4	Perm open							5.2
W	Transkei	Nxaxo/Ngqusi	159.5	Perm open							14.2
W	Transkei	Cebe	16.5	Temp closed							2.0
W	Transkei	Gqunqe	17.9	Temp closed							2.1
W	Transkei	Zalu	12.4	Temp closed							1.7
W	Transkei	Ngqwara	19.4	Temp closed							2.2
W	Transkei	Sihlontlweni/Gcini	11.0	Temp closed							1.7
W	Transkei	Qora	89.6	Perm open							9.5
W	Transkei	Jujura	4.8	Temp closed							1.2
W	Transkei	Ngadla	13.9	Temp closed							1.8
W	Transkei	Shixini	22.1	Perm open							4.9
W	Transkei	Nqabara	109.7	Perm open							10.8
W	Transkei	Ngoma/Kobule	10.1	Temp closed							1.6
W	Transkei	Mendu	23.8	Temp closed							2.5
S	Transkei	Mbashe	132.0	Perm open							9.4
S	Transkei	Ku-Mpenzu	13.4	Temp closed							0.0
S	Transkei	Ku-Bhula/Mbhanyana	7.6	Temp closed							0.0
S	Transkei	Ntlonyane	41.3	Temp closed							0.0
S	Transkei	Nkanya	15.5	Temp closed							0.0
S	Transkei	Xora	150.6	Perm open							10.4
S	Transkei	Bulungula	18.4	Temp closed							0.0
S	Transkei	Ku-amanzimuzama	3.7	Temp closed							0.0
S	Transkei	Mncwasa	19.2	Temp closed							0.0
S	Transkei	Mpako	13.5	Temp closed							0.0
S	Transkei	Nenga	10.0	Temp closed							0.0
S	Transkei	Mapuzi	15.9	Temp closed							0.0
S	Transkei	Mtata	168.8	Perm open							11.4
S	Transkei	Mdumbi	76.1	Perm open							6.3
S	Transkei	Lwandilana	9.7	Temp closed							0.0
S	Transkei	Lwandile	22.2	Temp closed							0.0
S	Transkei	Mtakatye	116.8	Perm open							8.6
S	Transkei	Hluleka/Majusini	14.9	Temp closed							0.0

Appendix 1 continued

Biog Reg	Coast Section	ESTUARY	Size (ha)	Type	Estimated annual catch (tons) Angling	Castnet	Gillnet	Seine	Traps	Spear	Total
S	Transkei	Mnenu	90.5	Temp closed							1.5
S	Transkei	Mtonga	32.2	Temp closed							0.0
S	Transkei	Mpande	15.0	Temp closed							0.0
S	Transkei	Sinangwana	13.2	Temp closed							0.0
S	Transkei	Mngazana	224.9	Perm open							14.5
S	Transkei	Mngazi	17.1	Temp closed							0.0
S	Transkei	Bululo	12.6	Temp closed							0.0
S	Transkei	Mtambane	10.9	Temp closed							0.0
S	Transkei	Mzimvubu	151.0	River mouth							15.0
S	Transkei	Ntlupeni	4.4	Temp closed							0.0
S	Transkei	Nkodusweni	32.6	Temp closed							0.0
S	Transkei	Mntafufu	24.1	Perm open							3.5
S	Transkei	Mzintlava	23.1	Perm open							3.4
S	Transkei	Mzimpunzi	5.1	Temp closed							0.0
S	Transkei	Mbotyi	50.4	Temp closed							0.0
S	Transkei	Mkozi	4.0	Temp closed							0.0
S	Transkei	Myekane	1.9	Temp closed							0.0
S	Transkei	Lupatana	3.6	Temp closed							0.0
S	Transkei	Mkweni	7.0	Temp closed							0.0
S	Transkei	Msikaba	15.1	Perm open							3.0
S	Transkei	Mgwegwe	8.8	Temp closed							0.0
S	Transkei	Mgwetyana	3.3	Temp closed							0.0
S	Transkei	Mtentu	52.9	Perm open							5.1
S	Transkei	Sikombe	11.5	Temp closed							0.0
S	Transkei	Kwanyana	7.1	Temp closed							0.0
S	Transkei	Mnyameni	27.9	Temp closed							0.0
S	Transkei	Mpahlanyana	3.9	Temp closed							0.0
S	Transkei	Mpahlane	3.9	Temp closed							0.0
S	Transkei	Mzamba	70.9	Perm open							6.0
S	Transkei	Mtentwana	11.4	Temp closed							0.0
S	KZN	Mtamvuna	63.5	Temp closed	2.0	0.5	0.0	0.0	0.0	0.0	2.5
S	KZN	Zolwane	0.5	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Sandlundlu	4.0	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Ku-boboyi	1.1	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Tongazi	0.8	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Kandandhlovu	1.8	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mpenjati	11.6	Temp closed	0.3	0.0	0.0	0.0	0.0	0.0	0.3
S	KZN	Umhlangankulu	9.7	Temp closed	0.2	0.1	0.0	0.0	0.0	0.0	0.3
S	KZN	Kaba	2.4	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mbizana	12.4	Temp closed	0.4	0.2	0.0	0.0	0.0	0.0	0.6
S	KZN	Mvutshini	0.9	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Bilanhlolo	2.6	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Uvuzana	0.6	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Kongweni	1.4	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Vungu	1.1	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	KZN	Mhlangeni	3.6	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Zotsha	7.3	Temp closed	0.5	0.2	0.0	0.0	0.0	0.0	0.7
S	KZN	Boboyi	1.3	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mbango	0.9	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mzimkulu	74.0	Perm open	3.0	1.0	0.0	0.0	0.0	0.0	4.0
S	KZN	Mtentweni	8.0	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2

Appendix 1 continued

Biog Reg	Coast Section	ESTUARY	Size (ha)	Type	Angling	Castnet	Gillnet	Seine	Traps	Spear	Total
					Estimated annual catch (tons)						
S	KZN	Mhlangamkulu	3.9	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Damba	1.7	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Koshwana	1.2	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Intshambili	1.7	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mzumbe	15.8	Temp closed	0.1	0.2	0.0	0.0	0.0	0.0	0.3
S	KZN	Mhlabatshane	2.3	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mhlungwa	3.1	Temp closed	0.5	0.3	0.0	0.0	0.0	0.0	0.8
S	KZN	Mfazazana	2.1	Temp closed	0.3	0.2	0.0	0.0	0.0	0.0	0.5
S	KZN	Kwa-Makosi	2.5	Temp closed	0.2	0.2	0.0	0.0	0.0	0.0	0.4
S	KZN	Mnamfu	1.3	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mtwalume	24.8	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mvuzi	0.8	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Fafa	29.0	Temp closed	0.5	0.3	0.0	0.0	0.0	0.0	0.8
S	KZN	Mdesingane	0.4	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Sezela	12.0	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	KZN	Mkumbane	0.3	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mzinto	7.0	Temp closed	0.3	0.3	0.0	0.0	0.0	0.0	0.6
S	KZN	Mzimayi	1.0	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mpambanyoni	2.3	Temp closed	0.0	0.1	0.0	0.0	0.0	0.0	0.1
S	KZN	Mahlongwa	5.9	Temp closed	0.4	0.3	0.0	0.0	0.0	0.0	0.7
S	KZN	Mahlongwana	6.8	Temp closed	0.2	0.2	0.0	0.0	0.0	0.0	0.4
S	KZN	Mkomazi	77.9	Perm open	5.0	2.0	0.0	0.0	0.0	0.0	7.0
S	KZN	Ngane	1.4	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Umgababa	17.6	Temp closed	1.0	0.5	0.0	0.0	0.0	0.0	1.5
S	KZN	Msimbazi	13.2	Temp closed	0.5	0.3	0.0	0.0	0.0	0.0	0.8
S	KZN	Lovu	10.5	Temp closed	0.5	0.5	0.0	0.0	0.0	0.0	1.0
S	KZN	Little Manzimtoti	1.5	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Manzimtoti	6.7	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mbokodweni	7.2	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Sipingo	6.8	Perm open	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Durban Bay		Bay	46.0	5.0	2.0	0.0	0.0	0.0	53.0
S	KZN	Mgeni	48.0	Temp closed	2.2	1.0	0.5	0.0	0.0	0.0	3.7
S	KZN	Mhlanga	100.1	Temp closed	0.1	0.0	0.0	0.0	0.0	0.0	0.1
S	KZN	Mdloti	58.1	Temp closed	0.5	0.5	0.0	0.0	0.0	0.0	1.0
S	KZN	Tongati	37.3	Temp closed	0.1	0.5	0.0	0.0	0.0	0.0	0.6
S	KZN	Mhlali	21.0	Temp closed	0.1	0.5	0.0	0.0	0.0	0.0	0.6
S	KZN	Seteni	1.1	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Mvoti	18.4	River mouth	0.5	0.5	0.0	0.0	0.0	0.0	1.0
S	KZN	Mdlotane	25.4	Temp closed	0.1	0.1	0.0	0.0	0.0	0.0	0.2
S	KZN	Nonoti	18.0	Temp closed	0.3	0.3	0.0	0.0	0.0	0.0	0.6
S	KZN	Zinkwasi	71.2	Temp closed	0.5	0.5	1.0	1.0	0.0	0.0	3.0
S	KZN	Tugela/Thukela	55.0	River mouth	2.0	3.0	10.0	2.0	0.0	0.0	17.0
S	KZN	Matigulu/Nyoni	192.0	Perm open	3.0	2.0	5.0	5.0	0.0	0.0	15.0
S	KZN	Siyaya	7.7	Temp closed	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S	KZN	Mlalazi	202.4	Perm open	5.0	3.0	5.0	2.0	0.0	0.0	15.0
S	KZN	Mhlathuze	1691.0	Bay	5.0	3.0	15.0	20.0	0.0	0.0	43.0
S	KZN	Richard's Bay	1800.0	Bay	68.0	10.0	2.0	8.0	0.0	0.0	88.0
S	KZN	Nhlabane	14.4	Lake	1.0	1.0	5.0	2.0	0.0	0.0	9.0
S	KZN	Mfolozi	180.0	River mouth	3.0	1.0	10.0	2.0	0.0	0.0	16.0
S	KZN	St Lucia	38290.0	Lake	70.0	10.0	150.0	30.0	0.0	0.0	260.0
S	KZN	Mgobezeleni	1.3	Lake	1.0	0.0	1.0	0.0	0.0	0.0	2.0
S	KZN	Kosi	3500.0	Lake	18.0	0.0	90.0	0.0	73.0	16.0	197.0

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Water quality modelling of estuaries

JH Slinger, S Taljaard, M Rossouw and P Huizinga

The development of estuarine water quality monitoring expertise was identified as a priority research requirement by the **Co-ordinated Programme on Decision Support for the Conservation and Management of Estuaries**. This project investigated the suitability of the one-dimensional Mike 11 Water Quality Model to predict water quality in South African estuaries. The two estuaries selected were the Berg and the Swartkops, both of which are relatively long and narrow with permanently open mouths which suit one-dimensional modelling. In addition, both are data-rich by South African standards. The model showed good correlation between measured and simulated temperature and dissolved oxygen (DO), even predicting the low DO levels in the upper reaches of the Berg Estuary in the summer, although the high variability near the mouth was underestimated. This is possibly due to insufficient data on the inshore marine environment. One area of difference between these estuaries and those of the Northern Hemisphere is the sediment oxygen demand. It was postulated that this could be the result of a relatively small freshwater input. The effect of the 'black tide' on the Berg Estuary was modelled successfully. This indicates that Mike 11 can also be used for linking water quality to biological processes.

Nutrients such as soluble reactive phosphate and silicate were strongly correlated to salinity, but total dissolved nitrogen showed no correlation to any parameter either measured or modelled. Another current limitation is that the model cannot, in its present form, simulate bacterial water quality.

Report Number: 664/1/98 **ISBN: 1 86845 438 X**

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