



South African National Spatial Biodiversity Assessment 2004 Technical Report

Volume 3: Estuary Component

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DRAFT
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This report forms part of a set of five reports on the South African National Spatial Biodiversity Assessment 2004. The full set is as follows:

Summary Report

Driver, A., Maze, K., Lombard, A.T., Nel, J., Rouget, M., Turpie, J.K., Cowling, R.M., Desmet, P., Goodman, P., Harris, J., Jonas, Z., Reyers, B., Sink, K. & Strauss, T. 2004. *South African National Spatial Biodiversity Assessment 2004: Summary Report.* Pretoria: South African National Biodiversity Institute.

Technical Reports

Volume 1: Terrestrial Component
Rouget, M., Reyers, B., Jonas, Z., Desmet, P., Driver, A., Maze, K., Egoh, B. & Cowling, R.M. 2004. *South African National Spatial Biodiversity Assessment 2004: Technical Report. Volume 1: Terrestrial Component.* Pretoria: South African National Biodiversity Institute.

Volume 2: River Component
Nel, J., Maree, G., Roux, D., Moolman, J., Kleynhans, N., Silberbauer, M. & Driver, A. 2004. *South African National Spatial Biodiversity Assessment 2004: Technical Report. Volume 2: River Component.* CSIR Report Number ENV-S-I-2004-063. Stellenbosch: Council for Scientific and Industrial Research.

Volume 3: Estuary Component
Turpie, J.K. 2004. *South African National Spatial Biodiversity Assessment 2004: Technical Report. Volume 3: Estuary Component.* Pretoria: South African National Biodiversity Institute.

Volume 4: Marine Component
Lombard, A.T., Strauss, T., Harris, J., Sink, K., Attwood, C. & Hutchings, L. 2004: *South African National Spatial Biodiversity Assessment 2004: Technical Report. Volume 4: Marine Component.* Pretoria: South African National Biodiversity Institute.

Comments and feedback

The reports are currently in draft format. Comments and feedback are welcome, and should be sent to the lead author in each case:

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Final versions of the reports will be available at www.nbi.ac.za

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1. Introduction

This study was commissioned by the South African National Biodiversity Institute (SANBI) as part of the National Spatial Biodiversity Assessment (NSBA) of the National Biodiversity Strategy and Action Plan (NBSAP). Estuaries were included relatively late in the process, and have thus been treated relatively briefly, based on a cursory analysis of existing information. This has been done in conjunction with consultations with the estuarine research and management community through the Consortium for Estuarine Research and Management (CERM) and through individual and group meetings with estuarine scientists.

The following estuarine scientists and managers provided inputs into this study:

- Janine Adams, University of Port Elizabeth
- Tris Wooldridge, University of Port Elizabeth
- Alan Whitfield, South African Institute for Aquatic Biodiversity
- Michael Silberbauer, Resource Quality Services, Dept of Water Affairs & Forestry
- Steve Lamberth, Marine & Coastal Management, DEAT
- Alan Boyd, Marine & Coastal Management, DEAT
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- Pete Goodman, KwaZulu-Natal Wildlife
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- Jill Slinger, Delft University of Technology, Netherlands (formerly CSIR)
- Susan Taljaard, CSIR Environmentek
- Nadine Strydom, South African Institute for Aquatic Biodiversity
- Paul Martin, Nelson Mandela Metropolitan Municipality

2. Methods

2.1 Definition and typology of estuaries

An estuary is defined as "a partially enclosed coastal body of water which is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixture of sea water with freshwater derived from land drainage" (Day 1980).

There are a great many catchment systems that flow out into the sea, but many of these are extremely small and not generally considered to function as estuaries. Whitfield (2000) identified a total of 258 systems that fit the above definition of estuaries (Whitfield 2000; Figure 1). In addition, Verlorenvlei is also considered to be an estuary, although it was excluded by Whitfield (2000) because much of its estuarine functioning has been lost due to a causeway development. Thus the total number of estuaries considered in this study is 259. This list excludes Langebaan Lagoon, which bears some affinity to estuaries due to the influence of groundwater inputs, but which is more accurately classified as a marine bay.

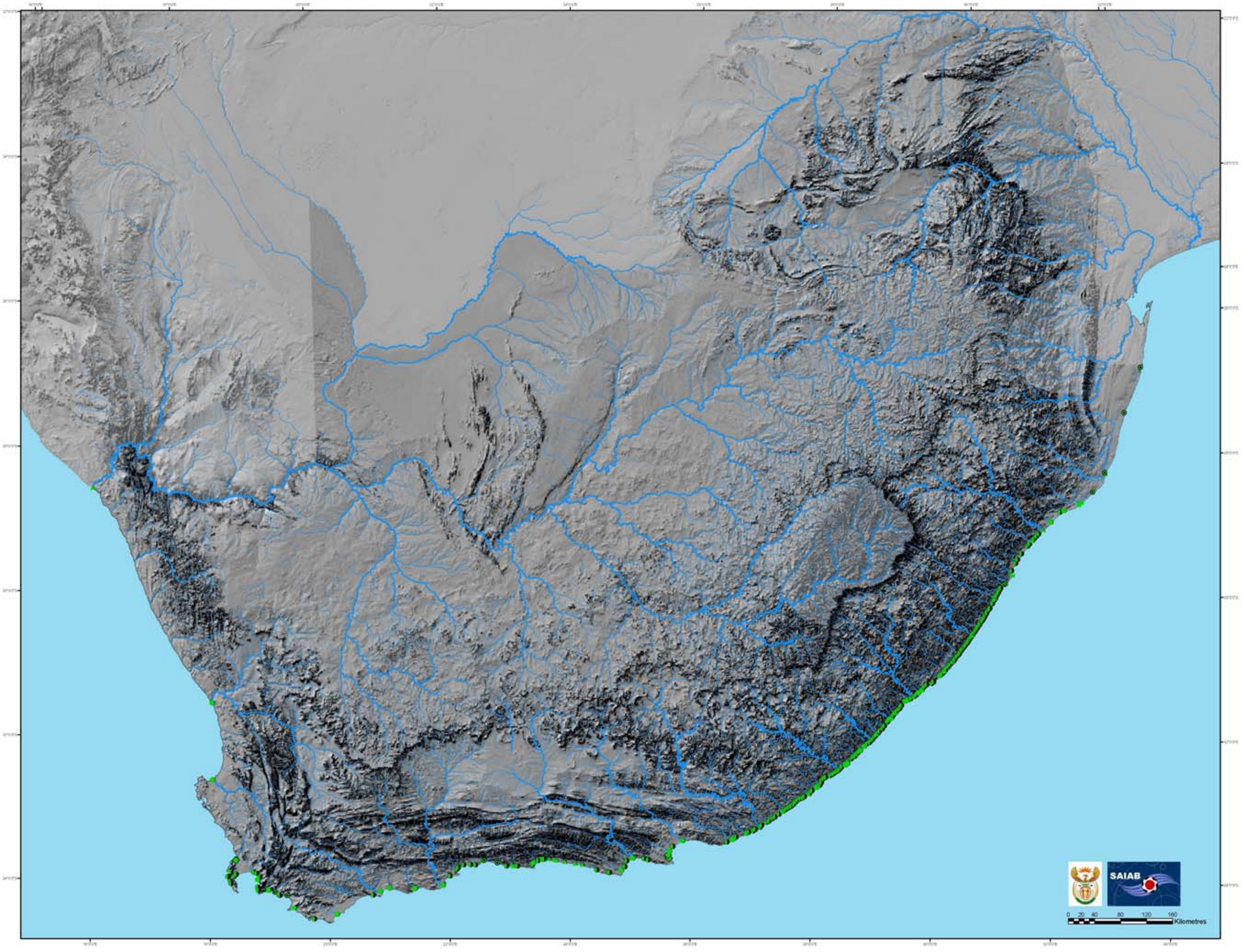

Figure 1. Location of South African estuaries (source: Department of Water Affairs & Forestry).

There are two classifications of estuaries in terms of their physical characteristics. The geomorphological classification used by Harrison *et al.* (2000) recognises six main types based on mouth condition (open or closed), size and the presence of a bar. This study uses the Whitfield (1992) classification, as it is more widely accepted than other classification systems. Whitfield's (1992) classification recognises five types:

1. Estuarine Bay
2. Permanently Open
3. River Mouth
4. Estuarine Lake, and
5. Temporarily Open.

The first three types tend to remain open to the sea on a permanent basis, whereas several lakes and all temporarily open estuaries close periodically, sometimes for periods of years. The five types can be roughly distinguished by the size of the tidal prism (amount of tidal water exchange), mixing process and their average salinity, as described in Box 1.

A few minor changes have been made for this study, in reclassifying estuaries from one type to another (Table 1). It should also be noted that some other estuaries, such as Richard's Bay and Mhlathuze have been highly modified, though still classified as estuarine bays.

Table 1. Estuaries for which classification in this study differs from Whitfield (2000).

Estuary	**Whitfield classification**	**Reclassification**	**Reason**
Palmiet	Perm	Temporarily open	Does close from time to time
Mkomazi	Perm	Temporarily open	Closes for weeks at a time
Sipingo	Perm	Temporarily open	Almost permanently closed since river inflow was diverted
Nhlabane	Lake	Temporarily open	Lake was cut off from estuary by a weir
Mfolozi	River mouth	Permanently open	Tidal for at least 15 km
Mgobeseleni	Estuarine Lake	Temporarily open	The lakes are entirely freshwater systems upstream of the estuary, and not tidally influenced

South African estuaries fall within three biogeographical zones: the Cool Temperate zone on the west coast, the Warm Temperate zone which extends approximately from Cape Point to the Mbashe River in the Eastern Cape, and the Subtropical Zone on the east coast. Estuaries within these zones have been shown to have relatively distinct faunal communities, and have also been found to differ significantly in their physico-chemical characteristics (Harrison 2004). Estuarine temperatures follow the trend for marine coastal waters, being coldest on the west coast. Warm temperate estuaries are characterised by high salinities and low turbidities due to low rainfall and runoff, high seawater input and evaporative loss, while cold temperate, and especially subtropical, estuaries have lower salinities and higher turbidity, due to relatively high runoff (Harrison 2004).

Box 1. Whitfield's (1992) Physical Classification of Estuaries.

Type	Tidal prism	Mixing process	Average salinity *
Estuarine Bay	Large (>10 x 10^6 m^3)	Tidal	20 - 35
Permanently Open	Moderate (1-10 x 10^6 m^3)	Tidal/riverine	10 - >35
River Mouth	Small (<1 x 10^6 m^3)	Riverine	<10
Estuarine Lake	Negligible (<0.1 x 10^6 m^3)	Wind	1 - > 35
Temporarily Open	Absent	Wind	1 - > 35

* Total amount of dissolved solids in water in parts per thousand by weight (seawater = ~35)

(a) ***Estuarine bay:*** Water area exceeds 1 200 ha. Natural bays (Knysna) and artificially formed bays (Durban Bay) are permanently linked to the sea and the salinity within them reflects this. Hypersaline conditions are not common and water temperatures are strongly influenced by the sea. Marine and estuarine organisms dominate these systems and extensive wetland/mangrove swamps occur.

(b) ***Permanently open estuaries:*** Vertical and horizontal salinity gradients are present and are modified by the river flow, tidal range and mouth condition. Wetlands (salt marshes), as well as submerged macrophyte beds are common and the fauna is predominantly marine and estuarine. Hypersaline conditions in the upper reaches can occur during times of severe drought. Water temperatures in this estuary type are controlled by the sea during normal conditions and by river input during flood conditions.

(c) ***River mouths:*** Riverine influences dominate the physical processes in these estuaries. Oligohaline conditions are often found. The mouth is generally permanently open but the tidal prism is small and strong riverine outflow prevents marine intrusion. During strong flood conditions the outflow of these mouths can influence the sea salinity for many kilometres. Heavy silt loads are frequent in these estuaries often resulting in shallow mouths (<2m). Water temperatures are strongly influenced by river inflow although the sea can influence bottom waters.

(d) ***Estuarine lakes:*** Water area exceeds 1 200 ha. These are usually drowned river valleys filled in by reworked sediments and separated from the sea by vegetated sand dune systems. The dune can result in complete separation of the lake from the sea that then results in a loss of estuarine characteristics and the system can be referred to as a coastal lake. Estuarine lakes can be either permanently or temporarily linked to the sea and salinity within them is highly variable. Freshwater input, evaporation and the magnitude of the marine connection are the main causes of this large salinity fluctuation. The tidal prism is small, and marine and river input have little influence on water temperatures, which are directly related to solar heating and radiation. Estuarine, marine and freshwater organisms all occur depending on the salinity condition of the system.

(e) ***Temporarily open estuaries:*** Sand bars often form in the mouths of these estuaries blocking off connection with the sea. Sand bars form as a result of a combination of low river flow conditions and longshore sand movement on the adjacent coast. Flooding is frequently the cause of mouth opening, which also results in large amounts of sediment removal. However, infilling from marine and fluvial sediment can be rapid. Hypersaline conditions occur in these estuaries during times of drought. Tidal and riverine inputs control the water temperature in these systems when the mouth is open, but is independent of them when the mouth is closed. Marine, estuarine and freshwater life forms are all found in these systems, depending on the state of the mouth.

While relatively high numbers of estuaries are found in both the Warm Temperate and Subtropical zones, only 11 are found in the Cool Temperate zone on the west coast (Table 2). In general, estuaries increase in density along the coast from west to east (Figure 1).

Table 2. Number of estuaries of each physical type in each biogeographical zone (modified from Whitfield 2000).

	Cool Temperate	Warm Temperate	Subtropical
Estuarine Bay	0	1	3
Permanently open	2	28	15
River mouth	2	6	3
Estuarine lake	0	4	2
Temporarily closed	7	88	98

2.2 Analytical framework

The large number of estuaries and their pattern of distribution around the coast plays an important role in determining an analytical framework for the NSBA, especially since the data are to be represented spatially. The NSBA requires a broad scale, spatial analysis of estuaries rather than a detailed, estuary-level approach. This requires aggregating information about estuaries in a way which would be compatible with the other components of the NSBA, as well as making sense in terms of formulating a conservation strategy for estuaries in the NBSAP.

Various characteristics such as ecological importance of estuaries have been analysed at the estuary level. These include the relative importance of estuaries in terms of birds (Turpie 1995), plants (Colloty *et al*. 2000), Fish (Maree *et al*. 2003) and invertebrates (Turpie *et al.* 2004), as well as composite analyses based on all biotic and abiotic components (Turpie *et al*. 2002, Turpie 2004a). Priority estuaries for conservation have been identified based on complementarity analysis of largely quantitative biotic data (Turpie *et al*. 2002), although more rigorous analysis incorporating more up-to-date data and a broader scope (e.g. socio-economic perspectives) is considered necessary before arriving at a final estuarine protected area system.

Several options were explored for aggregation of data for the NSBA. These included working at the scale of the three biogeographical zones or using the 50km stretches of coast used as planning units for the marine component of the NSBA. The former is very coarse, even if estuaries are differentiated by type within each of these zones. The 50km zones were considered rather arbitrary for estuaries, especially further to the west where estuaries become more sparsely distributed. Instead it was decided that it would be most sensible to analyse the situation in relation to catchment boundaries, specifically at the scale of secondary catchments. The physical characteristics and management of these catchments has an enormous influence on the characteristics and status of estuaries. The estuaries of South Africa fall into approximately 57 catchment areas around the coast, which is a convenient scale at which to work. This is not dissimilar from the level of resolution used for the marine zone, but makes a lot more sense in that management and water requirements are determined at the catchment scale.

Since estuaries are influenced by their catchment characteristics, it also follows that their characteristics, especially health and pressures, are more similar within a catchment than between catchments, thus aggregation at the catchment level will produce average indices with the least underlying variation.

2.3 Data sources and methods

Data on the physical and biotic characteristics of estuaries have been collated in various studies over the years (see summary in Turpie 2004a). Data compiled by JK Turpie of Anchor Environmental Consultants on behalf of the Consortium of Estuarine Research and Management were used as the baseline data for this study, together with additional data supplied by the Department of Water Affairs and Forestry. The data and analytical methods were devised and presented to the estuarine research community for critique before being finalised for this study. Details pertaining to each of the assessments required for the NSBA are given below.

2.1.1 Health status

There has been concern about the condition of South African estuaries since the 1970s, when it was already noted that few estuaries remained in their natural state, particularly in KwaZulu-Natal (Heydorn 1972, 1973 in Morant & Quinn 1999). In his assessment of the condition of KwaZulu-Natal estuaries, Begg (1978) found only 20 out of 72 to be in a good condition. Here, siltation was the greatest culprit, due to intensive sugar-cane cultivation in the catchments, and reduction in flow was also recognised as a problem. Heydorn & Tinley (1980) reviewed the condition of the estuaries of the former Cape Province (from the Orange to the Great Kei), and this was followed by a national assessment of the condition of South African estuaries (Heydorn 1986, 1989, Table 3). The national assessment was initiated by DWAF in response to concerns about freshwater supplies to estuaries (Morant & Quinn 1999).

Table 3. Condition of estuaries in the former Cape Province (Orange to Kei) and KwaZulu-Natal (Heydorn 1986).

	No. of estuaries	Present condition (%)		
		Good	Fair	Poor
(a) Cape				
Large	35	6	83	11
Small	118	30	41	22
Total	153	24	50	20
(b) KwaZulu-Natal				
Large	6	67	16.5	16.5
Small	66	24	49	27
Total	72	28	46	26

According to Heydorn's (1986) assessment, KwaZulu-Natal has a greater proportion of large estuaries in good condition. The pattern for small estuaries is similar in the Cape and KwaZulu-Natal, with roughly a quarter to a third of estuaries being in good condition. Overall, about a quarter of KwaZulu-Natal estuaries and a fifth of Cape estuaries were considered to be in a poor condition. The assessment of condition, however, depends strongly on how it is measured. Using fish as an index of community degradation (Ramm 1988), Ramm (1990) categorised KwaZulu-Natal estuaries as being far more degraded, with 78% falling into the "moderately, strongly or severely degraded" category.

None of these assessments incorporated the estuaries of the former Ciskei and Transkei coasts, however, which span much of the eastern half of the present Eastern Cape Province.

Whitfield (2000) conducted a recent assessment on the condition of estuaries. The estuaries were broadly classified as follows:

- **Excellent**: estuary in near pristine condition (negligible human impact)
- **Good**: no major negative anthropogenic influences on either the estuary or catchment (low impact).
- **Fair**: noticeable degree of ecological degradation in the catchment and/or estuary (moderate impact)
- **Poor**: major ecological degradation arising from a combination of anthropogenic influences (high impact).

Using these guidelines, 62% of estuaries were considered to be in good or excellent condition. This apparently higher proportion of estuaries considered to be in good condition is largely due to the inclusion of the Transkei region, where a large proportion of estuaries are in good/excellent condition. 26% of KZN estuaries were considered to be in good condition, similar to Heydorn's (1986) assessment.

Catchment health was an important factor included in the assessments by both Heydorn (1986) and Whitfield (2000). Further information is available on the utilisation of estuarine catchment areas and their deviation from natural condition in Harrison *et al*. (2000). The latter study examines 62 estuarine catchments (mainly the relatively large catchments of >500km^2) in South Africa. Systems in the Western Cape were most affected by commercial agriculture, which accounted for >40% of catchment land-use, while >20% of KwaZulu-Natal catchment areas were under commercial agriculture. More than 20% of catchments were affected by subsistence agriculture in the Transkei region of the Eastern Cape. Estuaries in the Transkei and Ciskei regions of the Eastern Cape had the highest proportion of degraded land cover in their catchments, mostly over 10%, and many exceeding 20% (Harrison *et al.* 2000). Catchments of estuaries in the southwest region of the Eastern Cape (Kromme – Great Kei) had the highest proportion of natural land cover, mostly above 70%, although most very large catchments also had a high proportion of natural land cover. Further information on Transkei systems is available, in the form of a video and aerial surveys of anglers from 1999, from CSIR Environmentek, Durban.

In addition to these general assessments of health, much work has recently been carried out on the health of certain biotic and abiotic components of estuaries. Harrison *et al*. (2000) present an assessment of the health of all South African estuaries in terms of ichthyofaunal diversity, water quality and aesthetics, and Coetzee *et al.* (1997) and Colloty *et al*. (2000) have classified selected estuaries in terms of their botanical integrity.

There are limitations to all these data, in that they are based largely on subjective assessments. Detailed methods have been developed for the systematic assessment of estuarine health as part of the Resource Directed Measures (RDM) methodology, which is used to set the freshwater Reserve for estuaries under the new National Water Act of 1998. However, these have only been carried out for a handful of estuaries at this stage. Those that have been carried out have produced results, which are most similar to Whitflield's (2000) assessment (Table 4). It was thus decided that Whitfield's assessment was the most appropriate for the purpose of the NSBA. Where discrepancies do exist, the Whitfield categories have been updated accordingly for this study by members of CERM.

The overall level of health of estuaries within a catchment was determined from the average scores, after converting Whitfield's categories to scores of 1 (= poor) to 4 (= excellent). Overall categories were based on average scores as follows (Table 5).

Finally, in order to produce a layer compatible with that of the other components of the NSBA, data on the health of individual estuaries was used to express the "ecosystem status" of each estuarine type per biogeographical zone. Ecosystem status (from least threatened to critically endangered) was determined on the basis of the proportion of estuaries in each type within each zone that were in a good or excellent state of health (Table 6).

Table 4. Assessment of health status using EFR or RDM methodology, compared with Whitfield's (2000) assessments.

Estuary	Level	PES Category	Health Status	Whitfield 2000
Orange	Rapid	D	Fair	Fair
Olifants	EFR	B	Good	Good
Berg	EFR	C	Fair	Fair
Palmiet	EFR	B	Good	Excellent
Breede	Intermediate	B	Good	Good
Great Brak	EFR	C	Fair	Fair
Tstitkamma	Rapid	A/B	Natural/Good	Good
Keurbooms	EFR	A/B	Good	Good
Swartkops	EFR	D	Fair	Fair
Sundays	EFR	C	Fair	Fair
Umtata	Rapid		Fair	Good
Great Fish	EFR	C	Fair	Fair
Nahoon	Intermediate	C	Fair	Fair
Mvoti	Rapid	B	Good	Fair
Mdloti	Rapid	C	Fair	Fair
Mhlanga	Rapid	C	Fair	Good
Mhlatuze		C	Fair	Fair
Thukela	Comprehensive	D	Fair	Poor
St Lucia	Rapid	D	Fair	Good
Bloukrans	Desktop		Natural/Good	Excellent
Lottering	Desktop		Good	Excellent
Elandsbos	Desktop		Good	Excellent
Storms	Desktop		Natural/Good	Excellent
Elands	Desktop		Good	Excellent
Groot (oos)	Desktop		Good	Excellent
Klipdrif (oos)	Desktop		Fair	Good
Slang	Desktop		Poor	Good

Table 5. Scores used to determine the overall health of estuaries within a catchment.

Overall health status	Average health score
Poor	<1.5
Fair	1.51.2.5
Good	2.51-3.5
Excellent	> 3.5

Table 6. Method to determine ecosystem status from health of estuaries within a group of estuaries.

Ecosystem status category	Proportion of estuaries in a good or excellent state of health
Critically endangered	< 30
Endangered	30 – 59
Vulnerable	60 – 79
Least threatened	80 – 100

2.1.2 Protection status

All estuaries are subject to certain regulations under the Marine Living Resources Act (MLRA), and thus enjoy some level of protection, at least on paper. In addition to this, a total of 41 estuaries have some level of protection within a formal protected area. Most of these are only partly protected. It should be noted that of the numerous Marine Protected Areas (MPA) that have been proclaimed to date under section 43 of the Marine Living Resources Act, very few have significant estuarine components, even though a number of estuaries drain into these MPAs. Table 7 lists the estuaries that fall wholly or partly within protected areas, the name of the protected area, managing agency, and what is protected. The category assigned is subjective based on the following guidelines:

High:

- whole estuary within a protected area,
- significant restrictions on consumptive and non-consumptive activities,
- significant restrictions on surrounding development

Medium:

- part of estuary within a protected area,
- some restrictions on activities,
- some restrictions on surrounding development

Low:

- part of estuary within a protected area,
- little restriction on activities,
- little restriction on surrounding development

The current protection status of South African estuaries is not clear-cut. The MLRA supersedes any legislation that might be in conflict with it, but the interpretation of this provision varies. One interpretation is that if an estuary was protected under a provincial ordinance, then this protection is now null and void. Another interpretation is that the law which is more specific to the estuary is the one that holds. Thus, if an estuary is protected specifically by a provincial ordinance then it still holds, as the MLRA does not refer to any specific estuary. The reality is that in most cases, it is still business as usual, in that estuaries that were protected under the provincial ordinances are still being treated as such. How effective this is will only be determined when an issue is brought to court (Turpie 2003a).

Apart from those within the Tsitsikamma National Park, there are no estuaries in which fishing or consumptive use of any kind is totally banned. Some estuaries are zoned and contain areas where exploitation of fish or bait is not allowed. These include the Wilderness National Park, Knysna estuary and Mtentu estuary. Banning of fishing in only part of an estuary is not considered very effective for protection of estuary fishes, however, as fish within estuaries are far more mobile than those in marine areas. The only time when such a measure can make a significant contribution to the conservation of fish species is when protecting a vulnerable part of an estuary, such as a narrow channel, which would facilitate overexploitation, such as is the case at Wilderness Lakes National Park (Turpie 2003a).

Table 7. Estuaries with some level of protection status, and the degree of protection .

Estuary	Protected area	Agency	Amount of estuary included	Category assigned
Orange*	(Planned)#	Provincial	Part	Low
Rietvlei/Diep	Rietvlei NR	Municipal	Part	Medium
Wildevoëlvlei	Table Mountain NP	SANP	Entirely (new)	Medium
Krom	Table Mountain NP	SANP	Entirely	High
Sand	Sandvlei NR	Municipal	Top <10% of estuary	Low
Heuningnes*	De Mond NR	CNC	All	High
Wilderness*	Wilderness Lakes NP	SANP	Part	Medium
Swartvlei*	Wilderness Lakes NP	SANP	Part	Medium
Goukamma	Goukamma NR	CNC	Most	High
Knysna	-	SANP	Part	Medium
Keurbooms	Keurbooms River NR	CNC	Part (upper reaches)	Low
Sout (Oos)	Tsitsikamma NP	SANP	All	High
Groot (Wes)	Tsitsikamma NP	SANP	All	High
Bloukrans	Tsitsikamma NP	SANP	All	High
Lottering	Tsitsikamma NP	SANP	All	High
Elandsbos	Tsitsikamma NP	SANP	All	High
Storms	Tsitsikamma NP	SANP	All	High
Elands	Tsitsikamma NP	SANP	All	High
Groot (Oos)	Tsitsikamma NP	SANP	All	High
Tsitsikamma	Huisklip NR	ECNC	Lower reaches	Medium
Seekoei	Seekoei River NR	ECNC	Part (upper)	Low
Gamtoos		ECNC?	Part	Low
Van Stadens	Van Stadens NR	Municipal?	All	Medium
Nahoon	Nahoon NR	Municipal	Very small part	Low
Nkodusweni	Pondoland MPA	DEAT	Tidal reaches	Low
Mntafufu	Pondoland MPA	DEAT	Tidal reaches	Low
Mzintlava	Pondoland MPA	DEAT	Tidal reaches	Low
Mbotyi	Pondoland MPA	DEAT	Tidal reaches	Low
Mkweni	Pondoland MPA	DEAT	Tidal reaches	Low
Msikaba	Pondoland MPA	DEAT	Tidal reaches	Low
Mtentu	Pondoland MPA	DEAT	Tidal reaches	Low
Sikombe	Pondoland MPA	DEAT	Tidal reaches	Low
Mnyameni	Pondoland MPA	DEAT	Tidal reaches	Low
Mpenjati	Mpenjati NR		All	High
Mgeni	Beachwood NR		Part	Medium
Mhlanga			All	High
Mlalazi		EKZNWS	All	High
Mhlathuze		EKZNWS	All	Medium
Mfolozi*	GSLWP	GSLWP Authority	All	High
St Lucia*	GSLWP	GSLWP Authority	All	High
Mgobezeleni*	GSLWP	GSLWP Authority	All	Low
Kosi*	GSLWP	GSLWP Authority	All	High

*Ramsar sites or estuaries that fall within GSLWP Ramsar site.
there is already some protection by virtue of the fact that part of the estuary is considered “no-mans land”, and fishing and general access is restricted.

Protection levels were scored from 1 (= no formal protection) to 4 (= high level of protection). The overall level of protection of estuaries within a catchment was determined from the average scores. Overall categories were based on average scores as follows (Table 8).

Table 8. Scores used to determine the overall level of protection of estuaries within a catchment.

Overall protection level	**Average protection score**
None	1
Low	< 2.5
Medium	< 3.5
High	> 3.5

Finally, in order to produce a layer compatible with that of the other components of the NSBA, levels of protection were expressed per estuarine type per biogeographical zone. Protection levels were described in relation to a target level of 30% of estuaries protected at a high level, as follows (Table 9).

Table 9. Method of describing levels of protection for estuaries within a "zone-type".

Protection status	**Proportion of target met**
Targets reached	100%
High	50-99%
Medium	20-49%
Low	<20%
None	0

2.1.3 Ecological processes

Two processes were defined as important "services" provided by estuaries: (A) provision of nursery habitat for marine species and (B) outputs to the marine zone (nutrients and sediment).

<u>A. Nursery function</u>

Estuaries provide important nursery areas for a number of marine species (Whitfield 1994, 1998), and thus make an important economic contribution to inshore fisheries (Lamberth & Turpie 2003). The importance of an estuary as a nursery area for marine species is related to a complex array of factors (Strydom *et al*. 2003). These include estuary size, which determines the amount of habitat available, the nature of the habitat (e.g. presence of favourable creeks), the productivity of the estuary (e.g. plankton abundance), and estuary type (Strydom *et al*. 2003). In general, permanently open estuaries and bays provide a nursery habitat for a much higher diversity of species than estuaries which close periodically. However, those species that are able to use temporarily open estuaries benefit from the sheltered and safe environment created while the estuary is closed (S. Lamberth, pers. comm.). Maree *et al.* (2003) also suggest that the degree of isolation influences the importance of an estuary as a nursery habitat. Various indices were explored in this study based on available data on size, type and isolation, but none could produce a pattern which satisfactorily reflected the relative nursery value of the few estuaries for which this is understood. It was thus concluded that nursery importance could not be satisfactorily estimated at the estuary level. However, it was deemed useful to consider the area of estuarine habitat available around the coast as a rough indicator of available nursery habitat, since the findings of Strydom *et al.* (2003) do suggest that estuary size is a primary determinant of nursery importance.

At the catchment level, overall nursery value of estuaries along a stretch of coast was taken to be roughly proportional to the total estuarine area. Thus four categories of importance were assigned as follows (Table 10).

Table 10. Catchment scale determination of nursery area function.

Available nursery habitat	**Total estuarine area (ha)**
Low	< 100 ha
Medium	100 - 500 ha
High	500 – 1000 ha
Very high	> 1000 ha

B. Outputs to the marine zone

Estuaries are important conduits for the transportation of sediments and nutrients into the marine zone, where they contribute to marine ecosystem productivity. A prime example is the influence of such outputs on crustacean fisheries on the east coast. We used natural mean annual runoff (MAR) as a proxy for the amount of sediment and nutrients transported into the marine zone. MAR was estimated using catchment data generated by the WR90 model, considered to be the most appropriate model for the purpose (R. Shulze, pers. comm.). Natural MAR is considered a good proxy for marine outputs given the lack of data on actual MAR and sediment or nutrient loads, especially at a national scale (J. Slinger, pers. comm.). Due to lack of data at the estuary level, the assessment is made at the catchment level only. Five categories of importance were assigned as follows (Table 11).

Table 11. Catchment scale determination of the importance of outputs to the marine zone.

Marine outputs	**Total natural MAR (Mm^3 per annum)**
Very low	< 100
Low	100 – 199
Medium	200 - 399
High	400 - 799
Very high	800 +

2.1.4 Future pressures

Estuaries are threatened by (a) the activities that occur within and immediately around them, and (b) by activities that reduce the supply of freshwater inputs.

Cowan & van Riet (1998) scored the level of threat to most estuaries in South Africa. These scores mostly describe the direct threats to estuaries described above (activities within and around estuaries), and are categorised as 1 to 5, as follows:

1: no information;
2: no known threat;
3: minor threat (e.g. some disturbance from fishing, recreation);
4: moderate threat - some serious threats, but irreparable damage not inevitable;

5: under serious threat, from one or several sources; most, if not all of the habitat is likely to be lost or major ecological changes are likely to occur unless some immediate remedial action is taken

Complementing the above data, Turpie *et al.* (2002), in collaboration with the Department of Water Affairs and Forestry (DWAF), devised a water demand index, which indicates the level of threat to an estuary's freshwater inputs. This score was compiled as the sum of scores (on a 1-5 scale) for each of the following factors:

1. The amount of water supply schemes already in operation
2. The expected need for new water supply infrastructure in an estuary catchment
3. The expected demand for abstraction licenses
4. Applications for the discharge of water containing waste

Wherever it was felt that new pressures had arisen since the above assessments were made, the scores given by Cowan & van Riet (1998) and Turpie *et al.* (2002) were updated accordingly.

For this study, the water demand score was adjusted to the same scale as the estuary threat score (1-5). Overall threat at the estuary level was taken to be the maximum of the two scores.

The overall level of future pressures on estuaries within a catchment was determined from the average scores. Overall categories were based on average scores as follows (Table 8).

Table 12. Scores used to determine the overall level of future pressures on estuaries within a catchment.

Overall future pressure	Average threat score
Low	< 3
Medium	< 4
High	< 5
Very high	5

3. Results and Recommendations

3.1 Health status of estuaries

The overall health of South African estuaries is relatively good. A total of 28% of estuaries (= 73 estuaries), are considered to be in excellent condition, and another 31% are in good condition. 25% are in a fair condition, and 15% are in poor condition. The overall picture is largely a reflection of the state of the 194 temporarily open estuaries. This group contains the most estuaries in an excellent state (31%), and the most estuaries in a poor state (19%). 25% of the 44 permanently open estuaries are still in an excellent state, 41% are in a good state and only 5% are considered to be in a poor state. The 11 river mouths follow a similar pattern. While no bays or lakes remain in an excellent state, two thirds of the six lakes are in good condition and the rest fair. Bays do not fare as well, with only one of the three in good condition and the other two in fair condition. The health state of estuaries of each type in relation to biogeographical zones is summarized in Table 13.

Table 13. Summary of the health status of estuaries of each type in each zone.

Biogeographical Region	Health category	Bay	Perm	River mouth	Lake	Temp	Total
Cool Temp	excellent					1	1
	good		1				1
	fair		1	1		2	4
	poor			1		4	5
Total			2	2		7	11
Warm Temp	excellent		4	2		28	34
	good	1	12	4	3	35	55
	fair		10		1	12	23
	poor		1			14	15
Total		1	27	6	4	89	127
Subtropical	excellent		7			31	38
	good		5	1	1	18	25
	fair	3	2	2	1	31	39
	poor		1			18	19
Total		3	15	3	2	98	121

Estuaries along the south and south-east coast tend to be healthier than those in the rest of the country (Figure 2). The catchments along the former Transkei/Ciskei coastal area have the best health. Average health state is also relatively good for the major systems on the west coast and in northern KwaZulu-Natal. Estuaries tend to be in fair to poor health along the intensively developed areas of the Cape south-west coast, around Port Elizabeth, and almost all of the KwaZulu-Natal coast.

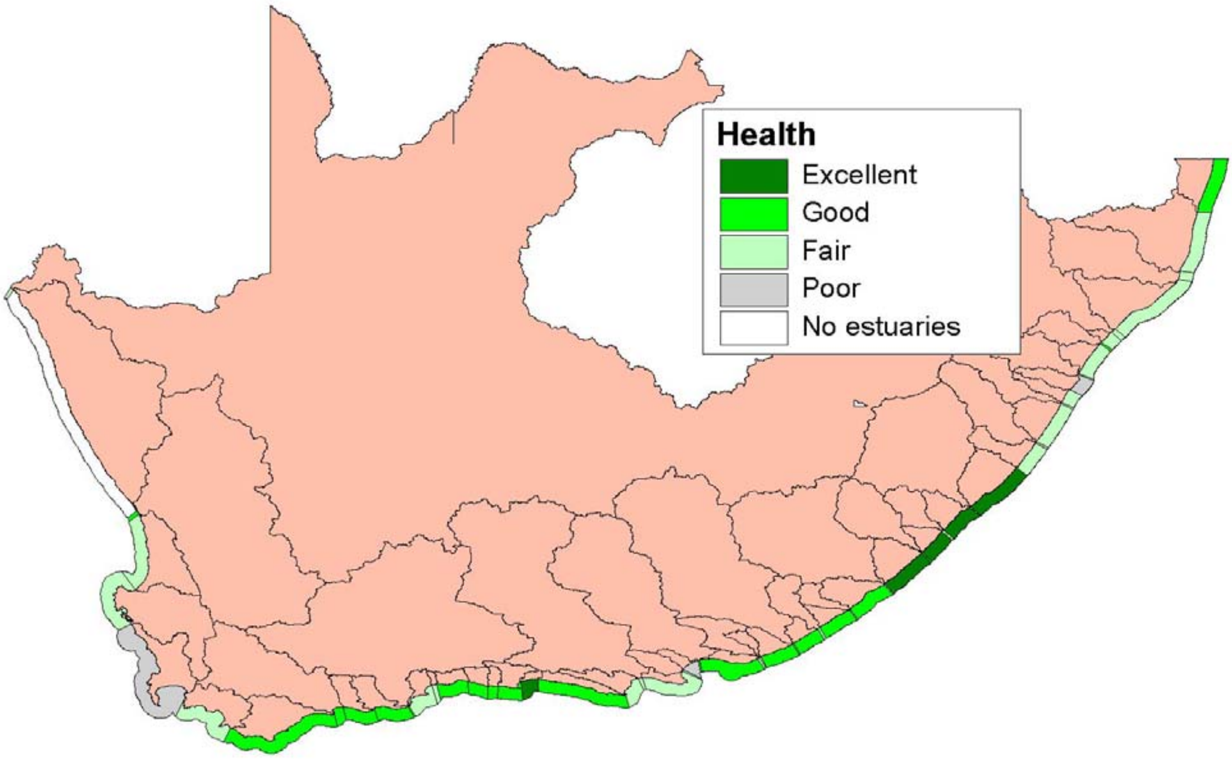

Figure 2. Map of the average state of health of estuaries per catchment.

A general trend that emerges from the catchment level analysis is that estuaries fed by larger catchments tend to be in poorer health than the estuaries in adjacent smaller catchments. This is particularly evident in the eastern half of the country, where small catchments containing several estuaries are regularly interspersed with a single estuary from a large catchment. Because the pattern breaks down on the western side, there is no correlation between estuary size and health, or between catchment runoff and average health of estuaries within a catchment at a national scale. Nevertheless, the observed spatial pattern suggests that estuaries in smaller catchments have generally been subjected to fewer pressures than those in larger catchments. In the latter case, the estuaries themselves are usually larger, and thus attract more coastal development, and the catchments are more pressured in terms of water abstraction.

The NSBA identifies the status of ecosystems from critically endangered to least threatened, on the basis of their current ecological state. It is difficult to translate this type of analysis to estuaries, since estuaries are not in danger of disappearing, but may suffer changes in ecosystem functioning resulting in a loss of biodiversity and valuable ecosystem services. Thus in this analysis, a group of estuaries which is critically endangered should be understood as being in extreme danger of suffering a loss of biodiversity, functioning and value.

For this analysis, a group of similar-type estuaries within a biogeographical zone, herein referred to as a zonal-type group, is implicitly assumed to represent a single "ecoregional" type, supporting a characteristic suite of biodiversity (including its functional aspects). If all of the estuaries in a zonal-type group are in a good condition, then the biodiversity in those estuaries is considered least threatened, and so on.

Following this reasoning, it appears that most of the zonal-type groups are endangered or critically endangered (Table 14). In the subtropical zone, all but permanently open estuaries are endangered or critically endangered, and all estuary types in the cool temperate zone are endangered or critically endangered. In the warm temperate zone, permanently open estuaries are endangered, but other estuary types are in a better position (Table 14).

Table 14. Summary of the status of estuaries of each type within each zone, based on proportion of estuaries in good or excellent state of health.

	Cool Temperate	**Warm Temperate**	**Subtropical**
Bay	-	100% Least threatened	0% Critically endangered
Perm Open	50% Endangered	59% Endangered	80% Least threatened
River mouth	0% Critically endangered	100% Least threatened	33% Endangered
Lake	-	75% Vulnerable	50% Endangered
Temp Open	14% Critically endangered	71% Vulnerable	50% Endangered

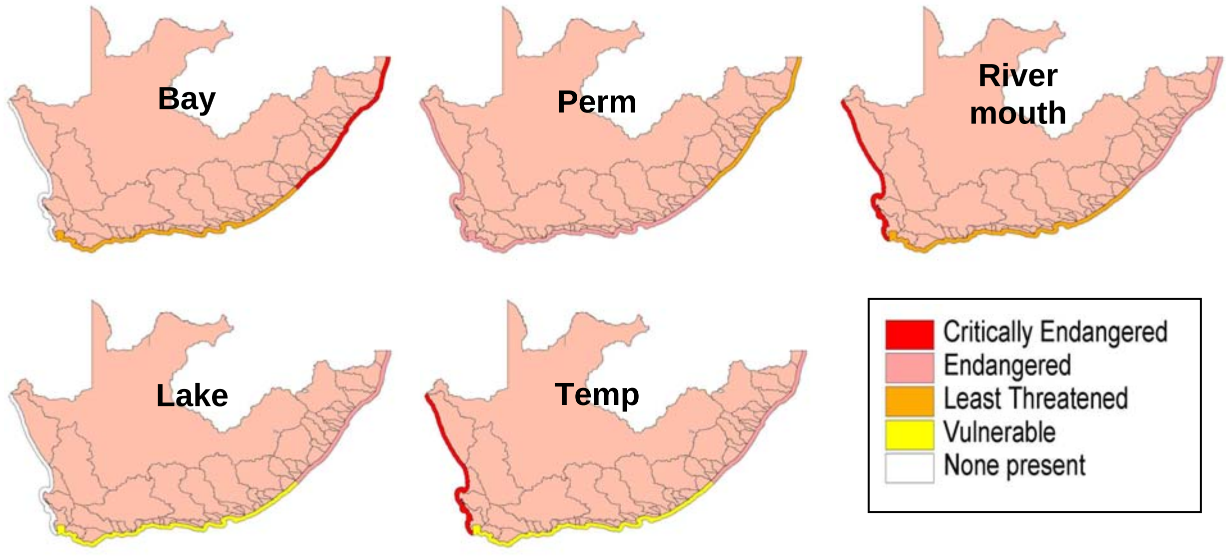

Figure 3. Status of estuarine ecosystems by zone-type.

This analysis suggests that action is required for most of the zonal-type groups. There is tremendous variability within the groups, and the action needs to be guided by catchment-level and individual health assessments of estuaries, as well as by their relative importance.

Given the strong congruency between Whitfield's (2000) assessment of estuarine health and the findings of more detailed studies undertaken since then, the health index is considered to be fairly robust. Nevertheless, there will be considerable value in undertaking empirical health studies of South African estuaries, as this will also pinpoint the causes of a system's poor health.

3.2 Current protection of estuarine ecosystems

The overall level of protection of South African estuaries is very low. Of the 41 estuaries that are included within protected areas, only 14 (5.4%) are considered to have a high level of protection. Moreover, the majority of these are very small estuaries. This is a long way from the NSBA target of 30% of estuaries protected at a high level.

The spatial distribution of estuarine protected areas is shown in Figure 4. Several well-protected areas occur in KwaZulu-Natal, including some of the country's largest estuaries (St Lucia and Kosi). On the Cape south coast, a series of small estuaries are afforded a high level of protection within the Tsitsikamma National Park. Further west, the Heuningnes and Krom estuaries fall within securely protected areas. For the remaining estuaries, protection is only partial, i.e. only parts of the estuary, or only below the high tide mark, as is the case for the estuaries within the Pondoland Marine Protected Area.

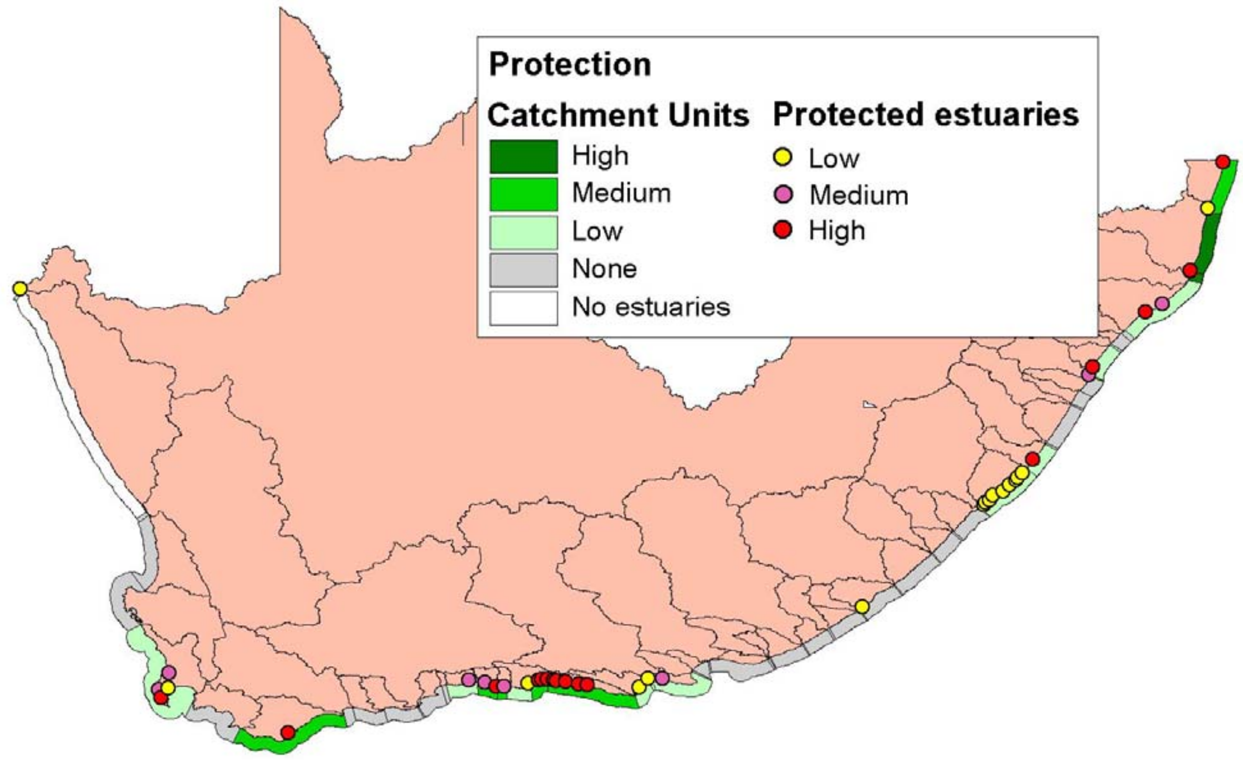

Figure 4. Map of the protection status of estuaries per catchment, and showing the locality of estuaries with different levels of protection.

It is anticipated that the targets should be representative, including representation within each zonal-type group. If the representation is to be even (30% in each group, or a minimum of 2 estuaries), then targets have only been met in warm temperate river mouths and subtropical estuarine lakes. Most other groups have none or low levels of protection with respect to this target (Table 15).

Table 15. Summary of the protection status of estuaries of each type within each zone, based on proportion of estuaries with a high level of protection.

	Cool Temperate	Warm Temperate	Subtropical
Bay		0% None	0% None
Perm open	0% None	4% Low	13% Medium
River mouth	0% None	100% Target met	0% None
Lake		0% None	100% Target met
Temp open	20% High	2% Low	2% Low

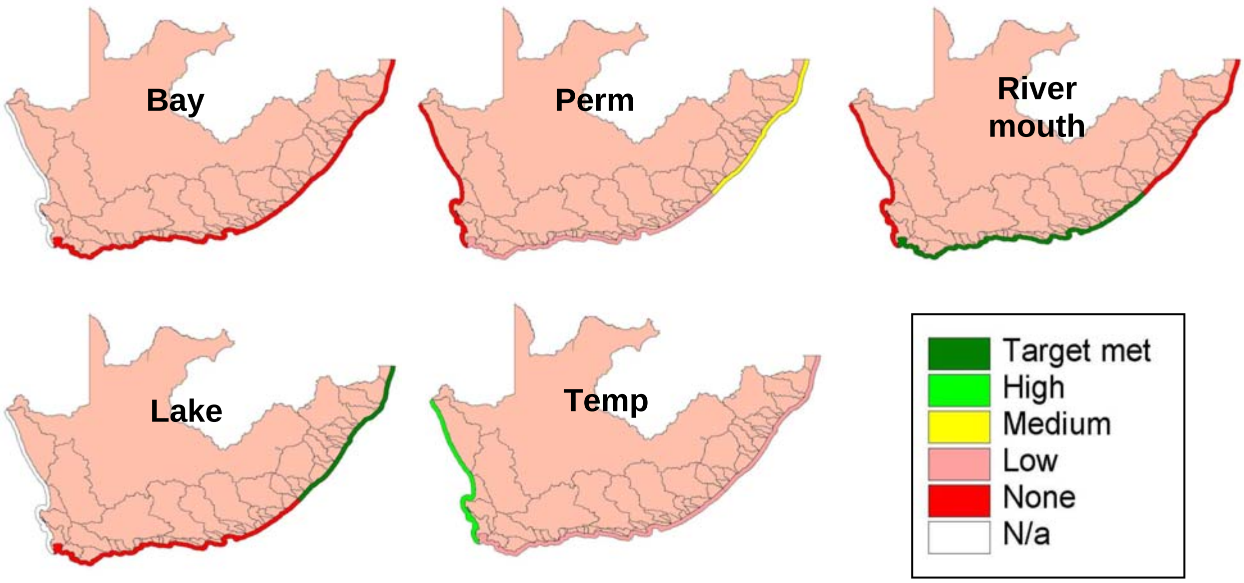

Figure 5. Protection status of estuarine ecosystems by zone-type.

These findings can be used in conjunction with biodiversity protection and other criteria in order to guide the selection of estuaries for inclusion in a protected area network. However, the current analysis is relatively limited in that it does not make provision for the relative importance of different estuary types, or the area that they cover. Gap analysis in examining estuarine protection will need to be far more comprehensive.

3.3 Ecological processes

3.3.1 Nursery area habitat

The amount of estuarine habitat per catchment area varies tremendously around the coast (Figure 6). By far the greatest amount of estuarine habitat is found along the northern KwaZulu-Natal coast, where the largest number of estuary-dependent species is also to be found. The nursery areas along this part of the coast support inshore marine biodiversity and fisheries including crustacean fisheries such as those of the Thukela banks. The subtropical zone contains 68% of South Africa's estuarine habitat. Indeed, just over half of the country's estuarine area is made up by the St Lucia estuary alone (over 38 000 ha). Despite the fact that this estuary is relatively well protected, reductions in freshwater inputs have severely compromised its functioning and thus its contribution as a nursery habitat. There is thus now a greater reliance on the remaining 11 000 ha of estuaries in the subtropical zone. The eastern half of the warm temperate zone contains a large number of fairly small estuaries that individually do not rank very highly, but collectively make up a significant area of habitat which is important for marine fish along this coast. Along the southern Cape coast, most nursery area is supplied by a few large estuaries that are relatively isolated from one another, and thus also very important at the individual estuary scale. The few large estuaries along the west coast are all considered to be important nursery areas, although relatively fewer species are dependent on them.

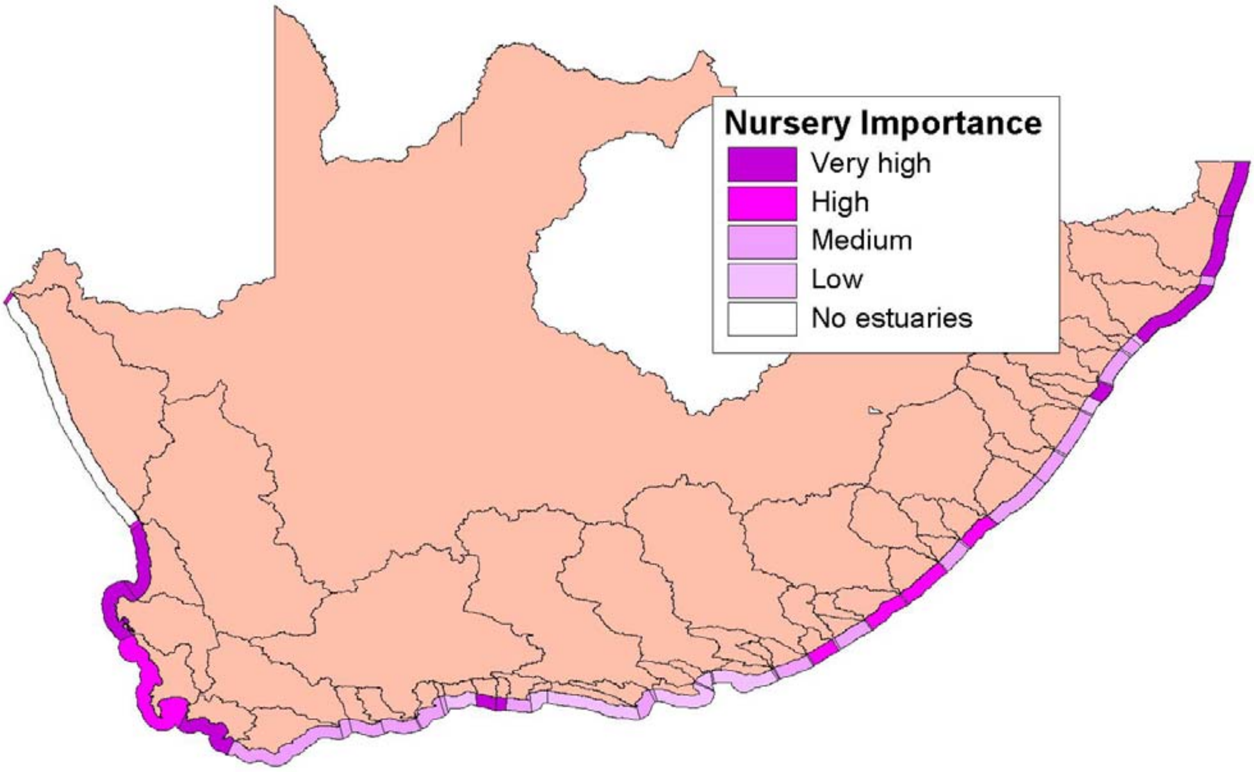

Figure 6. Map of the amount of estuarine habitat per catchment as an indicator of potential nursery area.

Table 16. Total estuarine area (ha) by estuary type for each biogeographical zone.

	Cool Temperate	Warm Temperate	Subtropical	Total
Bay		3 594	4 551	**8 145**
Perm Open	4 317	4 941	1 704	**10 961**
River mouth	975	23	224	**1 222**
Lake		5 734	41 790	**47 524**
Temp Open	591	3 158	1 391	**5 140**
Total	**5 882**	**17 450**	**49 660**	**72 992**

This assessment assumes that nursery value is a function of the overall amount of estuarine habitat. Of course the nursery area value of a hectare of estuary varies considerably according to individual estuarine characteristics. While overall estuary habitat area will give some indication of the relative nursery value, much more research is required to investigate the contribution of individual estuaries to improve this assessment.

The presence of a large amount of estuarine habitat in an area does not necessarily mean that there is more area to sacrifice. The case of St Lucia illustrates the importance of investigating the quality of those areas at a finer scale. If anything, Figure 6 serves to indicate that maintaining the ecosystem health of all estuaries is important. Estuaries may be quite different to other types of ecosystems in this regard.

Supporting this is the fact that all nursery habitat has economic value (Table 17). It is important to realise, however, that the unit value of estuarine nursery habitat differs around the coast for reasons other than the productive capacity of those habitats, such as proximity to coastal recreational centres.

Table 17. The value of estuarine fisheries and estuary contribution to marine fisheries around different parts of the coast. Values given in 1997 Rands. This excludes crustacean fisheries (Lamberth & Turpie 2003).

	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	191.3	30.6	89.3	490.4
TOTAL	**17.83**	**339.56**	**284.20**	**89.15**	**192.56**	**923.39**
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	1.3	2.6	3.6
Average value/ha (R)	3 030	26 392	75 503	34 131	4 114	12 836

3.3.2 Outputs to the marine zone

Estuaries form the conduits for the transport of riverine nutrients and sediments into the inshore marine zone. Outputs to the marine zone are highest for catchments on the west and east coasts (Figure 7), while isolated large estuaries (or large catchments) make important contributions around the entire coast. While these areas can be considered important because of the contribution they make, those zones where outputs are relatively small could be seen to be just as important in that the reliance on them could be even higher. Furthermore, the tendency for the estuaries associated with smaller catchments to close is usually much higher. Again, this provides justification for a high level of conservation for all estuaries.

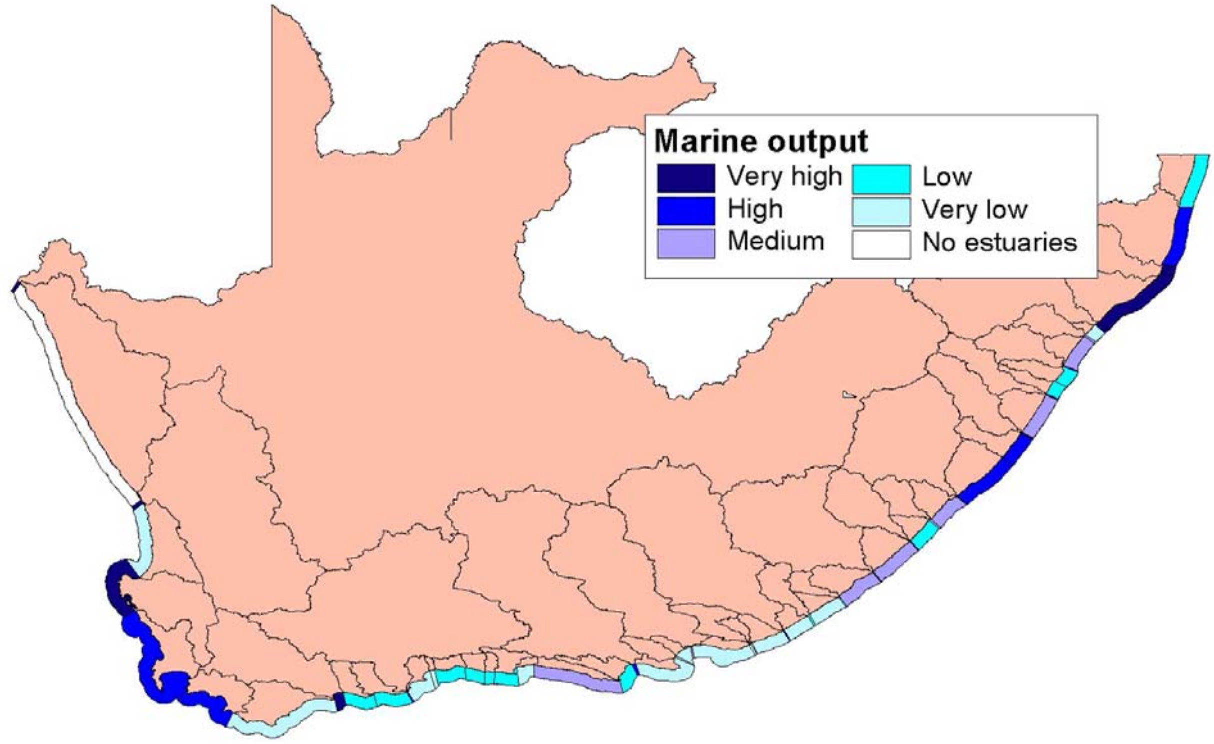

Figure 7. Map of the level of outputs to the marine zone per catchment, based on natural MAR .

The level of outputs to the marine zone is affected by the management of estuaries, particularly the manipulation of their mouths, and the amount of freshwater inputs into estuaries. It is important to note that while the National Water Act of 1998 allows for the maintenance of a reserve of freshwater inflows to estuaries, no provision is made for the needs of the inshore marine zone. These inputs are thus highly dependent on the level of health assured for estuaries. The level of freshwater inputs reserved for an estuary is currently influenced by the level of protection of an estuary, or its desired future protection status.

3.4 Vulnerability

Estuaries face a number of types of pressures. Existing pressures affect the current state of health of estuaries, as described above. It is also important to consider where future pressures lie for the purposes of conservation planning. Proximate pressures on estuaries come in two main forms: (a) direct pressures on the estuarine environment and its immediate surrounds, and (b) pressures on the freshwater supplies into estuaries. These are elaborated as follows:

Direct pressures on estuaries include:

- habitat alteration, for example due to the construction of marinas and jetties
- changes in mouth dynamics, such as the manipulation of mouths to maintain constant water levels or prevent flooding of holiday homes
- overexploitation of estuarine resources such as fish
- sedimentation of estuaries due to bad catchment or mouth management
- recreational disturbance, which is known to have a major impact on avifauna and fish
- pollution, for example release of sewage into Knysna estuary

Pressures on freshwater inputs include:

- Reductions in freshwater inputs due to upstream abstraction or afforestation
- Increase in freshwater inputs due to agricultural or sewage return flows
- Reductions in water quality, including turbidity, due to bad catchment management, polluted return flows and effluent disposal

It should always be borne in mind that these proximate pressures are driven by numerous underlying pressures, the most important of which are poverty and wealth, market failure (e.g. underpricing of ecosystem goods and services), government failure (e.g. policies which favour activities that impact on biodiversity), population dynamics and HIV/AIDS. In addition to these existing pressures, climate change poses a potentially serious future threat to estuaries, particularly along the western and southern coasts. Unless these ultimate threats are addressed, attempting to protect biodiversity from proximate pressures may prove futile in the long run.

Future pressures on estuaries are considered to be particularly high in the south-western Cape, where pressures on water supplies are immense, and along the KwaZulu-Natal coast, for similar reasons. Development is also increasing tremendously in both of these areas. There are also several parts of the southern Cape cost where future pressures are expected to be high (Figure 8).

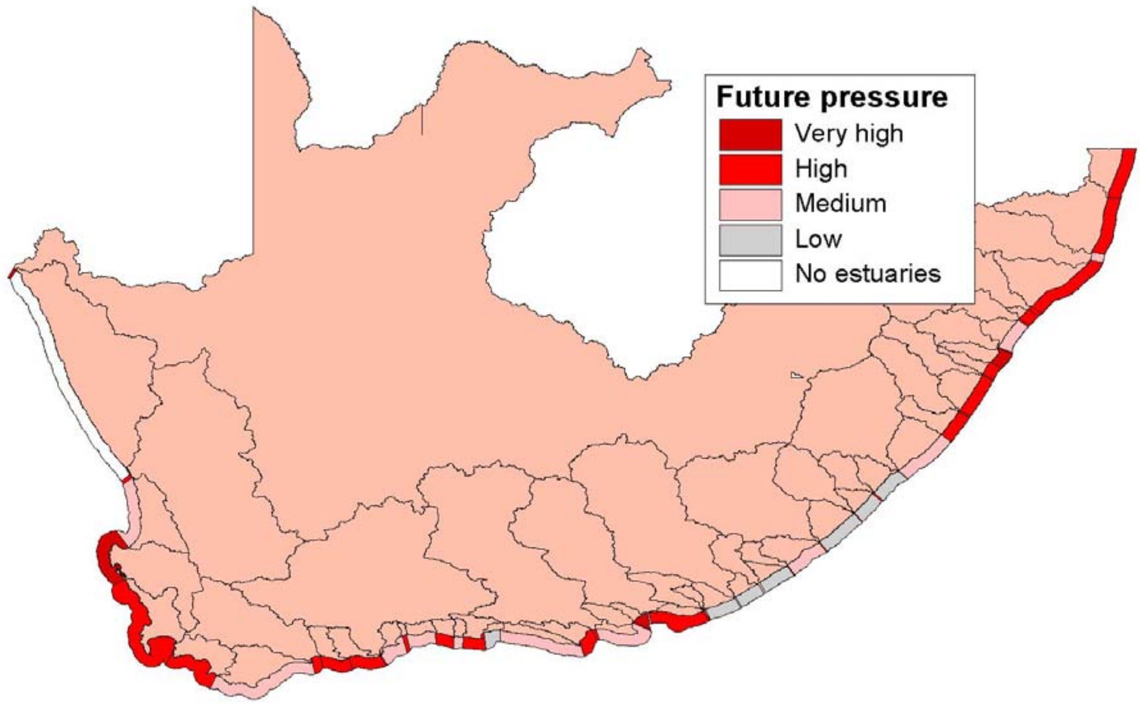

Figure 8. Map of the level of future pressures on estuaries per catchment.

The level of pressures on estuaries is summarised in Table 18 and analysed for each zone-type in Table 19 and Figure 9. The rarer estuary types are subject to the highest pressures in the subtropical zone, and all cool temperate estuary types are under high pressure. In general pressures are expected to be medium to high in all but one zone-type (warm temperate bays), suggesting that conservation action is relatively urgent.

Table 18. Summary of the future pressures to estuaries by type and biogeographical zone.

	Threat status	Bay	Perm	River mouth	Lake	Temp
Cool Temp	Medium					1
	High		1			1
	Very high		1	2		4
Warm Temp	Low		4	1	1	25
	Medium	1	7	3		31
	High		13	2	1	17
	Very high		3		2	14
Subtropical	Low		3			21
	Medium		4	1		15
	High	1	8	2	1	41
	Very high	2			1	21

Table 19. Summary of the vulnerability of estuaries of each type within each zone, based on proportion of estuaries with a high to very high level of threat.

	Cool Temperate	Warm Temperate	Subtropical
Bay	-	0% Low	100% High
Perm open	100% High	59% Medium	53% Medium
River mouth	100% High	40% Medium	66% High
Lake	-	75% High	100% High
Temp open	66% High	36% Medium	63% Medium

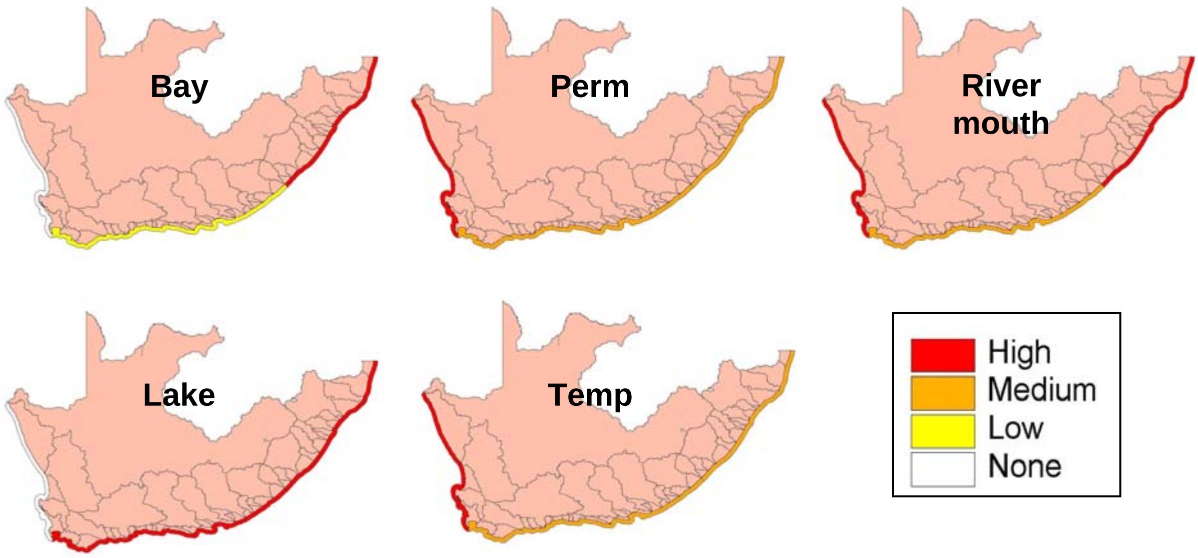

Figure 9. Vulnerability status by zone type.

3.5 Conservation priorities

There is much consensus in the South African estuarine research and management community that estuaries each tend to be unique in their characteristics (Boyd *et al*. 2000). While information has had to be summarised in terms of zone-types to align with the overall NSBA ecoregional approach, it would be naïve to pretend that the biodiversity of estuaries within a zone-type is similar, or governed by the same ecological parameters, at least to the extent that this may be the case in other types of ecosystems.

Estuary conservation needs to be approached from the perspective that all estuaries are sufficiently valuable to warrant the maintenance of their health. Fortunately, many of the human activities associated with estuaries are compatible with their conservation, when managed appropriately. Thus estuary conservation on a broad scale does not necessarily carry an opportunity cost. Nevertheless, it is also desirable to protect a core set of estuaries in a highly natural state, to the level where freshwater and other protection requirements may limit certain human economic activity or at least change its nature. This is necessary to safeguard certain endangered species (such as the estuarine pipefish), to maintain viable populations of all estuarine species, and to maintain a representative set of estuaries in their reference state.

In devising guidelines for a strategy for the conservation of estuarine biodiversity, Turpie (2003b, 2004b) envisaged assigning all South African estuaries to one of three categories, as follows:

a) Estuarine Protected Areas (EPAs), in which part or all of the estuary is a sanctuary, providing protection from consumptive use. EPAs should be selected with both biodiversity representation and socio-economic considerations in mind.
b) Estuarine Conservation Areas (ECAs) - co-managed estuaries in which general regulation is augmented by estuary-specific regulation. These are particularly suited to estuaries used primarily for recreation.
c) Estuarine Management Areas (EMA), to which general regulation applies

Ideally, the core Estuarine Protected Area network should be determined with representativeness as a major goal. Because of their *ad hoc* proclamation, the existing estuarine protected areas are inefficient at biodiversity protection in this sense (Turpie *et al*. 2002). Although it is commonly believed that top-ranking sites for biodiversity should be conserved, the conservation of the top-scoring sites only, does not generally result in an efficient solution. The top twenty estuaries contain only 89% of estuarine species. Representativeness can be achieved to a large extent by assessing priorities separately within each biogeographical zone (Turpie 1995). However, only the use of sophisticated complementarity algorithms will achieve an efficient solution, in which all species are represented in a minimum number of sites.

Using presence-absence and abundance data for estuarine species, and without specifying any estuaries for inclusion at the outset, Turpie *et al.* (2002) identified a set of 32 estuaries that would represent 100% of the species considered (Table 20). Of the estuaries making up this set, 11 already enjoy some degree of formal protection.

Table 20. Minimum set of estuaries required in a protected area network to represent 100% of species, based on complementarity analysis. Estuaries which are already protected are marked with an asterisk (Turpie *et al*. 2002).

	Estuary	Additional spp conserved	Cumulative spp conserved	%		Estuary	Additional spp conserved	Cumulative spp conserved	%
1	St Lucia *	246	246	44.9	17	Bot	2	518	94.5
2	Berg	95	341	62.2	18	Bushmans	1	519	94.7
3	Kosi*	17	358	65.3	19	Nhlabane	1	520	94.9
4	Swartkops	74	432	78.8	20	Rietvlei*	2	522	95.3
5	Nyoni*	16	448	81.8	21	Mtamvuna	3	525	95.8
6	Wildevoelvlei	11	459	83.8	22	Palmiet	4	529	96.5
7	Wilderness*	10	469	85.6	23	Mvoti	2	531	96.9
8	Manzimtoti	4	473	86.3	24	Great Kei	2	533	97.3
9	Gouritz	4	477	87.0	25	Mgeni*	2	535	97.6
10	Swartvlei	8	485	88.5	26	Mpenjati*	2	537	98.0
11	Heuningnes*	5	490	89.4	27	Mntafufu*	2	539	98.4
12	Olifants	6	496	90.5	28	Mhlali	2	541	98.7
13	Knysna*	5	501	91.4	29	Mlalazi*	2	543	99.1
14	Keiskamma	5	506	92.3	30	Kromme	2	545	99.5
15	Kariega	6	512	93.4	31	Goda	2	547	99.8
16	Lovu	4	516	94.2	32	Mbashe	1	548	100.0

The spatial spread of estuaries listed in Table 20 reflects the overall spread of estuaries in the country (Figure 10), but the proportion of estuaries of each type is not representative of the relative proportions (Table 21). The set is biased towards the largest estuary types, mainly because species diversity and population sizes are highest in these estuaries. Temporarily open estuaries are generally much smaller than the other estuary types. Nevertheless, the minimum set represents only 12% of estuaries, compared to the NSBA target of 30%. Thus, there are opportunities to increase the value of the protected area system in terms of being representative of estuarine types in each biogeographical zone. The final identification of a set of EPAs and ECAs will require substantial further research which also takes cognisance of ecosystem functions, zonal type rarity, and socio-economic factors. In addition, it should align with other conservation initiatives in adjacent marine and terrestrial areas, with a view to achieving catchment-to-coast conservation of systems.

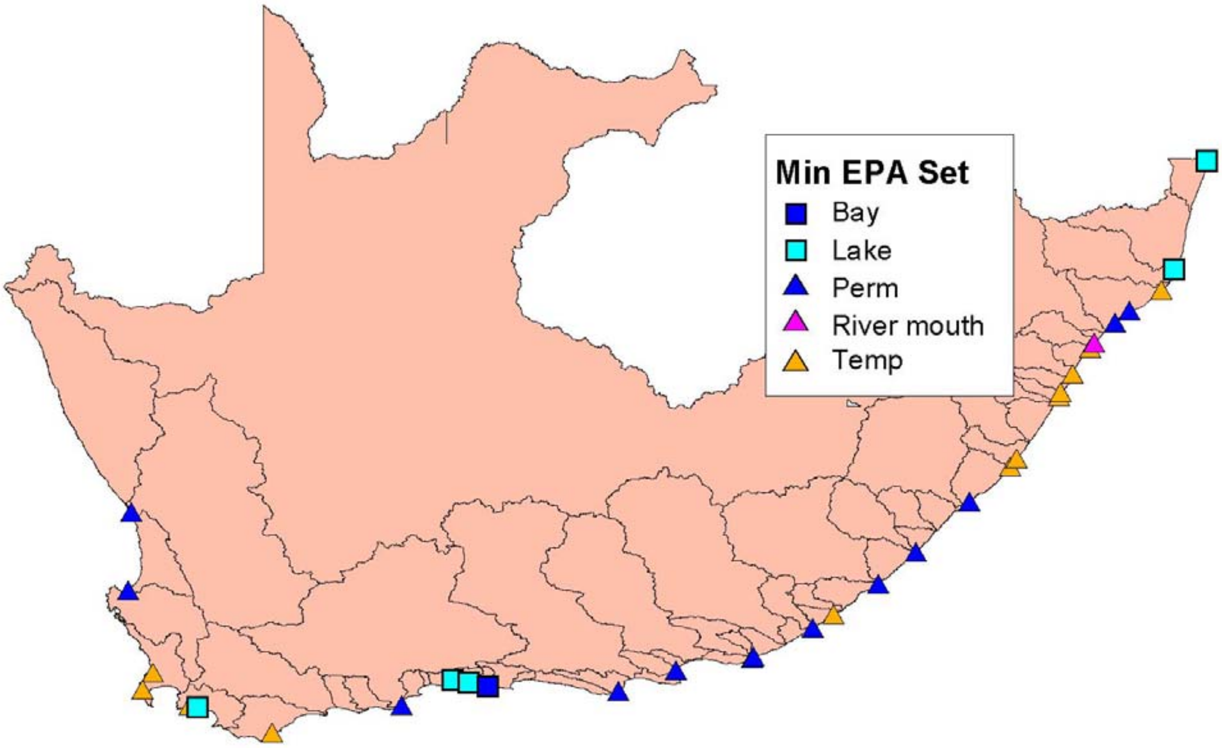

Figure 10. Location of estuaries listed in Table 20, showing estuary types.

Table 21. The representativeness of the minimum set of estuaries in terms of the types of estuaries and the biogeographical zones.

	Cool Temperate	**Warm Temperate**	**Subtropical**	**Total**
Bay	-	1 (100%)	0 (0%)	**1 (25%)**
Perm open	2 (100%)	7 (26%)	4 (27%)	**13 (30%)**
River mouth	0 0%	0 (0%)	1 (33%)	**1 (9%)**
Lake	-	3 (75%)	2 (100%)	**5 (83%)**
Temp open	2 (29%)	3 (3%)	7 (7%)	**12 (6%)**
Total	**4 (36%)**	**14 (11%)**	**14 (12%)**	**32 (12%)**

3.6 Priorities for further research

Based on this study and a meeting of CERM during 2004, the following areas are seen as priorities for research that will enable the setting of conservation priorities and appropriate management action to achieve biodiversity conservation goals and maximise the value of estuaries in South Africa:

1. A fresh look at the classification of estuaries

Many estuarine researchers struggle to work within the existing classification systems, due to inherent flaws and ambiguities. A fresh look at estuaries is required to devise a more robust system of classification that will also be useful in applied conservation research.

2. A quantitative assessment of the health of estuaries

The methods developed for the Resource Directed Measures (RDM) (Reserve determination) methodology need to be applied at a national scale, albeit at a desktop or rapid level if necessary. This will provide a better baseline from which to manage estuaries and determine their freshwater requirements, as well as for monitoring the effects of conservation efforts.

3. Quantifying ecosystem interactions with the marine environment

Our understanding of estuarine ecosystem functioning is poor, especially with respect to functions such as nursery areas and outputs to the marine zone.

4. The impacts of climate change

Very little is known as to how climate change might affect estuaries. Preliminary research indicates that it may have a major impact on the functioning and biodiversity of a large proportion of South Africa's estuaries. A better understanding of this threat will greatly enhance our ability to take the necessary management and appropriate water supply decisions.

5. Integrative conservation planning

Estuaries have fallen behind most other ecosystem types in terms of conservation planning and implementation. Such planning will need to be integrated with other conservation planning as well as with development initiatives.

4. References

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