NATIONAL BIODIVERSITY ASSESSMENT 2011

Volume 3: Estuary Component

Technical Report

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This report forms part of a set of six reports on South Africa's National Spatial Biodiversity Assessment 2011. The full set is as follows:

Synthesis Report

Driver, A., Sink, K.J., Nel, J.L., Holness, S., Van Niekerk, L., Daniels, F., Jonas, Z., Majiedt, P.A., Harris, L. & Maze, K. 2012. *National Biodiversity Assessment 2011: An assessment of South Africa's biodiversity and ecosystems. Synthesis Report.* South African National Biodiversity Institute and Department of Environmental Affairs, Pretoria.

Technical Reports

Volume 1: Terrestrial Component

Jonas, Z., Daniels, F., Driver, A., Malatji, K.N., Dlamini, M., Malebu, T., April, V. and Holness, S. 2012. *National Biodiversity Assessment 2011: Technical Report. Volume 1: Terrestrial Component*. South African National Biodiversity Institute, Pretoria.

Volume 2: Freshwater Component

Nel, J.L. and Driver, A. 2012. *National Biodiversity Assessment 2011: Technical Report. Volume 2: Freshwater Component*. CSIR Report Number CSIR/NRE/ECO/IR/2012/0022/A. Council for Scientific and Industrial Research, Stellenbosch.

Volume 3: Estuary Component

Van Niekerk, L. & Turpie, J.K. (eds). 2012. *National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component*. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch.

Turpie, J.K., Wilson, G. and Van Niekerk, L. 2012. *National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa*. Anchor Environmental Consulting, Cape Town. Report produced for the Council for Scientific and Industrial Research and the South African National Biodiversity Institute.

Volume 4: Marine Component

Sink, K.J, Holness, S., Harris, L., Majiedt, P.A., Atkinson, L., Robinson, T., Kirkman, S., Hutchings, L., Leslie, R., Lamberth, S., Kerwath, S., von der Heyden, S., Lombard, A.T., Attwood, C., Branch, G., Fairweather, T., Taljaard, S., Weerts, S., Cowley, P., Awad, A., Halpern, B., Grantham, H. and Wolf, T. 2012. *National Biodiversity Assessment 2011: Technical Report. Volume 4: Marine and Coastal Component*. South African National Biodiversity Institute, Pretoria.

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The NBA 2011 Estuary Component project benefited considerably from the guidance and oversight provided by the NBA project team. The overarching coherence and integration between components achieved in the 2011 round of the NBA represents the collective vision and insights of the NBA project team:

Individual	Role	Institute
A Driver	Project leader	South African National Biodiversity Institute (SANBI)
Dr K Sink	Marine and Coastal	South African National Biodiversity Institute (SANBI)
Dr S Holness	Coastal and Climate Change	SANParks/Nelson Mandela Metropolitan University (NMMU)
Dr J Nel	River and Wetlands	Council for Scientific and Industrial Research (CSIR)
L van Niekerk	Estuaries	Council for Scientific and Industrial Research (CSIR)

The core NBA 2011 Estuaries Component project team comprised:

Individual	Role	Institute
L van Niekerk	Project leader, estuary health, processes and policy	Council for Scientific and Industrial Research (CSIR)
Dr JK Turpie	Estuary conservation planning	Anchor Environmental Consultants
C Petersen	Spatial Analysis	Council for Scientific and Industrial Research (CSIR)
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The following group of estuarine scientists served as members of the Estuary Reference Group and generously contributed of their time and knowledge to the project:

Individual	Role	Institute
Prof JB Adams	Estuarine vegetation and health	Nelson Mandela Metropolitan University (NMMU)
N Forbes	Invertebrates	Marine and Estuarine Research (MER)
Dr SJ Lamberth	Fish, nursery function and fisheries management	Fisheries Research, Department of Agriculture, Forestry and Fisheries (DAFF)
F MacKay	Invertebrates	Oceanographic Research Institute (ORI)
Dr S Taljaard	Water Quality and pollution	Council for Scientific and Industrial Research (CSIR)
Prof AK Whitfield	Fish	South African Institute for Aquatic Biodiversity

Individual	Role	Institute
Prof TH Wooldridge	Invertebrates	Nelson Mandela Metropolitan University

In addition to the Estuary Reference Group the input of the following specialists was essential for an integrative and accurate assessment of the estuarine biophysical processes, health and biodiversity conservation requirements:

Individual	Role	Institute
Prof G Bate	Nutrients, microalgae	Diatom and Environmental Management (DEM)
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A Childs	Nursery function	South African Institute of Aquatic Biodiversity (SAIAB)
Dr BM Clark	Conservation planning	Anchor Environmental Consultants
Dr P Cowley	Fish	South African Institute of Aquatic Biodiversity (SAIAB)
Prof D Cyrus	Fish	University of Zululand
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Dr F Engelbrecht	Climate change	Council for Scientific and Industrial Research (CSIR)
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B Mann	Fish exploitation	Oceanographic Research Institute (ORI)
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G Wilson	Conservation planning	Anchor Environmental Consultants

The following spatial analists contributed to this report:

Individual	Role	Institute
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A Maherry	Estuarine functional zone	Council for Scientific and Industrial Research (CSIR)
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Executive Summary

The National Biodiversity Assessment (NBA) 2011 follows the first National Spatial Biodiversity Assessment (NSBA) in 2004. The primary purpose of the NBA is to provide a regular high-level summary of the state of South Africa's biodiversity, with a strong focus on spatial assessment. It covers terrestrial, freshwater, estuarine and marine environments, and reports on two headline indicators for assessing the state of South Africa's biodiversity: ecosystem threat status and ecosystem protection level. Ecosystem threat status tells us how threatened our ecosystems or habitats are, and ecosystem protection level indicates how well- or under-protected our ecosystems or habitats are.

The NBA is intended for decision makers both inside and outside the biodiversity sector. Technical component reports were compiled for terrestrial, freshwater, estuarine and marine ecosystems, as listed at the beginning of this report on page ii. Technical component reports target a specialist audience, whilst the NBA 2011 summary report (Driver et al. 2012) summarises the results across all components and targets a wider audience.

A key starting point for a meaningful assessment of estuarine ecosystems was to delineate the estuarine functional zone for every estuary, which had not previously been done in South Africa. In addition national-scale pressure data were collated on freshwater inflow modification, water quality (effluent discharges, agricultural activities), artificial breaching, habitat modification and living resources exploitation.

A desktop national health assessment was concluded for nearly 300 estuaries in South Africa to address shortcomings in previous country-wide biodiversity assessments. The health assessment was based on the Estuarine Health Index developed for South African ecological water requirement studies that has been applied systematically to over 30 estuaries at various levels of data richness and confidence. National experts, all familiar with the index, were used to evaluate the systems in their region. The individual estuarine health assessment scores were then translated into health categories and aggregated for the various estuarine ecosystem types to reflect the overall ecosystem status of South Africa's estuaries. One of the major findings of the study was that while a large number of South Africa's estuaries were still in an "excellent" to "good" condition, they represented very small systems, while the larger, important nursery systems were predominantly of "fair" to "poor" quality, indicating a general decline in the health of these larger systems.

The NBA uses two headline indicators for assessing the state of South Africa's biodiversity: "ecosystem threat status" and "ecosystem protection level". Ecosystem threat status gives an indication of how threatened ecosystems are, and ecosystem protection level informs on how well- or under-protected ecosystems are. Key findings of the 2011 NBA were that about 43% of estuary types (20 types out of 46 types) are threatened, representing 79% of SA estuarine area, while 59% (27 out of 46 types) of South Africa's estuarine ecosystem types are not protected. If protection levels are evaluated as a percentage of the area protected the picture becomes even more serious, with 83% of the area of ecosystem types not protected.

The 2011 NBA also developed the National Estuary Biodiversity Plan which identifies which South African estuaries require full or partial protection. This plan represented a significant milestone in that it is the first biodiversity planning study to include all the estuaries of South Africa. Nearly 300 estuaries from the Cool Temperate, Warm Temperate and Subtropical regions were included.

The report also provides a collation of information on harvested, exploited or Red Data estuarine species. It mainly looks at plants, invertebrates and fish. The assessment highlights the loss of mangroves from a number of estuaries along the South African coast as a result of harvesting and mouth closure. It also highlights the fact that a number of overexploited fish species should be listed as Red Data Species. Many of the fish species caught in South Africa coastal waters are estuary-dependent in that they have to use estuaries to complete all, or part, of their lifecycle where they are vulnerable to intense exploitation by recreational, subsistence and commercial fishers as well as being subject to other anthropogenic and environmental pressures. In general, fish species with both an estuarine and marine phase to their lifecycle tend to be severely depleted (e.g white steenbras), while those with freshwater, estuarine and marine components to their lifecycle (e.g. eels), being exposed to cumulative pressures in these different environments, tend to be the worst off.

The NBA 2011 provides a collated species list of invasive aliens in estuaries as part of this assessment. It also highlights invasive aliens as an emerging concern, especially for plants, invertebrates and fish communities.

A review of how climate change will affect the process drivers in estuaries identified some of the vulnerabilities of South African estuaries on a regional scale. Climate change pressures on estuaries include flow modification, sea-level rise and increased temperatures and coastal storminess, leading to changes in physical processes and biological responses with an ultimate impact on ecosystem services. The review indicate that the Subtropical and Cool Temperate estuaries will be the most effected by climate change from a structural and functional perspective, while the Warm Temperate estuaries will be most vulnerable to temperature regime shifts and the associated species range extensions/contractions and community composition changes.

A number of management processes have been developed in terms of national legislation to manage pressures on estuaries and assist with biodiversity conservation, e.g. ecological flow requirements under the National Water Act (Act 36 of 1998) and Estuary Management Plans under the Integrated Coastal Management (Act 24 of 2008). The assessment discusses South Africa's legislative framework with regards to estuaries, highlights some of the key legal instruments and reports on the limited status of their implementation. Estuaries play a critical role in linking terrestrial, freshwater and marine ecosystems. The multiple pressures of flow reduction, development and overfishing call for integrated estuarine management and strong collaboration between key government departments from local to national level that deal with water, coastal development and fisheries management. The current roll out of Estuary Management Plans according to the Estuary Management Framework and National Estuarine Management Protocol has the potential to achieve this.

Key findings

1. There are nearly 300 functional estuaries in South Africa.

- In South African an estuary is considered a partially enclosed, permanent water body, either continuously or periodically open to the sea on decadal time scales, extending as far as the upper limit of tidal action or salinity penetration. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area, or, when there is little or no fluvial input, an estuary can be isolated from the sea by a sandbar and become a lagoon or lake which may become fresh or hypersaline.

2. The Lake St Lucia system represents over 55% of the estuarine area of South Africa, but is in a very poor condition.

- Although situated within the iSimangaliso Wetland Park protected area, a World Heritage Site, St Lucia is impacted upon by activities in its catchment and reduction in freshwater flows from the rivers feeding the lake.

- The most significant impact has been the artificial separation of the uMfolozi river mouth from Lake St Lucia, dating from the 1950s, reducing freshwater inflow to the lake by more than half in low flow periods.
- Combined with drought conditions, this has resulted in St Lucia being closed to the sea for much of the last decade, unable to fulfil its role as the most important nursery area for marine fish along the south-east African coastline, among other impacts.

3. Based on the proportion of estuaries in good ecological condition, 43% of estuary ecosystem types (20 types out of 46 types) are classified as threatened, representing 79% of SA estuarine area.

About 39% of South Africa's 46 estuarine types (18 types) are classified as critically endangered, 2% as endangered (1 type), 2 % as vulnerable (1 type) and 57% as least threatened (26 types). If this is considered in terms of estuarine area the situation is even more dire as 79% of South Africa's estuarine area falls within estuary types classified as critically endangered, compared with less than 1% in types that are endangered or vulnerable and 21% in types that are least threatened.

- A very small percentage (1%) of the total estuarine habitat area in South Africa is in an excellent condition. About 14% is in good condition, 31% is in a fair condition, and 54% is in a poor condition.
- About 83% of the estuarine area that falls within Ramsar sites (57 000 ha) is in a poor state, while none is in an excellent condition. Similarly, none of the 70 400 ha that falls within Important Bird Areas is in an excellent condition and 67% is in a poor condition. Collectively 72% of estuaries in Marine or other Protected Areas (65 900 ha) are in a poor condition.

4. 59% (27 out of 46 types) of South Africa's estuary ecosystem types are not protected. These unprotected types make up 83% of the total estuarine area.

- 69 estuaries in South Africa enjoy some form of formal protection, accounting for 60% (56 000 ha) of the estuarine area within South Africa. Only 14 estuaries have full no-take protection.
- The Lake St Lucia system contributes 90% of the protected estuarine area, and covers about 51 000 ha. The other protected estuaries cover a total area of just under 10 000 ha.

- Nearly 59% (27 out of 46 types) of South Africa's estuary ecosystem types are not protected. About 33% of estuary ecosystem types are considered to be well protected (15 types), while 4% are moderately protected (2 types) and 4% are poorly protected (2 types).
- If protection levels are evaluated in terms of percentage area, the unprotected types make up 83% of total area, while the estuary types that are poorly protected, moderately protected and well protected make up 2%, 14% and 2% of area, respectively.
- The National Estuary Biodiversity Plan identified 58 estuaries (20%) that require full protection and 62 (22%) estuaries that require partial protection (this includes those that already have partial protection).

5. **The total freshwater inflow of the 20 largest catchments in South Africa has been reduced by nearly 40% from the pristine condition, and freshwater flow requirements have been determined for only 12% of all estuaries.**

- The larger catchments tend to be subjected to significant water resources development, such as large dam developments and inter/intra-basin transfer schemes. These catchments often exhibit a significant decrease in resetting floods with a related significant decrease in mean annual runoff. Related ecosystem responses include increased sedimentation as a result of reduced flushing, loss of queuing effect to the marine environment and reduced nursery function.
- Smaller catchments are most often subjected to more localised water resource development such as run-of-river abstraction and forestation, leading to loss, or reduction of, base flows in summer. While the net reduction in mean annual runoff is less severe than for larger catchments, related ecosystem responses include increased mouth closure, reduced connectivity with the marine environment, reduced nursery function, and reduced production.

6. **Flow reduction, habitat modification, fishing and pollution are cumulative pressures in need of management interventions. Invasive alien species (plants, invertebrates and fish), mariculture and desalination are emerging pressures that could pose a significant risk to estuarine biodiversity.**

- Nearly 4% of all estuaries are under significant flow modification pressure, with most of these being large permanently open estuaries. An additional 18% of estuaries have experienced a moderate degree of flow modification. Flow modification is causing ecosystem type changes, for example, the Kobonqaba in the Eastern Cape and Uilkraals in the Western Cape closed for the first time in recorded history in 2010.

- 13% of South Africa's estuaries are under significant habitat modification or development pressure.
- The mouths (outlets) of about 16% of estuaries are artificially managed, but these estuaries (which include the Lake St Lucia system) account for 62% of the total estuarine habitat. Inappropriate low-lying developments are necessitating artificial mouth manipulations (e.g. breaching), of particular concern in the large lake systems like Verlorenvlei, Bot/Kleinmond, Klein, Wilderness (Touws), Swartvlei and Lake St Lucia system.
- 1% of South Africa's estuaries are under tremendous fishing pressure (Olifants, Berg, Bot and Kosi) such that fish stocks have declined significantly in these systems. Another 13% are under major fishing pressure. Fishing effort is relatively evenly distributed around the coast, but proportionately (in terms of tonnes per ha removed) much higher in the Cool Temperate estuaries.
- Approximately 2 000 tonnes of fish, comprising 80 species, are caught in South African estuaries each year.
- 84% of all estuaries are influenced by bait collection activities.
- Mangroves have been completely lost from 14 estuaries in South Africa due to excessive harvesting or ecosystem changes. In the smaller estuaries, where mangrove strands consist of one to three rows of trees, harvesting can result in complete removal of mangroves. Developmental pressures have also caused the loss of mangroves, e.g. from the Mhlanga, Little Manzimtoti, Lovu, Msimbazi, Mgababa, Ngane, Mahlongwa, Kongweni, Bilanhlolo, Mhlangankulu and Khandandlovu.
- 15% of estuaries are under significant pollution pressure and 40% under a moderate degree of pollution pressure. Fewer than 1% of all estuaries have no pollution pressures on them.

7. Freshwater (surface and groundwater) flowing into the sea is not wasted and is vital to the productivity of the nearshore coastal environment.

- Changes in freshwater flow and associated variations in turbidity, nutrients and sediment supply can impact on important ecological processes such as nursery functions, environmental cues, productivity and food web processes.
- Fisheries resources in South Africa that have, or may have been, compromised by reduced freshwater input include linefish, prawns, and filter feeding invertebrates in the intertidal and shallow subtidal zones.

- The reduction of river flow leads to a reduced sediment supply to the coast with implications for beach and subtidal habitats. Many of these habitats are also important for ecological processes.

8. While there are a range of invasive alien species (e.g. 13 plants, 11 invasive alien and 7 extra-limital fish species) in South Africa’s estuaries, they do not represent a significant overall pressure as yet.

- Thirteen invasive alien plant species, ranging from trees to water weeds, have been identified in South Africa's estuaries.
- There are at present 11 invasive alien fish species and 7 extra-limital fish species identified in the 130 estuaries for which there were data. The spreading of especially invasive predatory fish acts as a barrier to migratory species (e.g. eels and freshwater mullet) and influences the species composition and abundance of species, many of which are commercially important, in the river-estuary interface zone.
- There is a significant and growing threat to the estuarine subtidal benthic environment through the invasion and proliferation of the mollusc *Tarebia granifera* in at least 30% of KwaZulu-Natal estuaries.

9. Climate change can have serious ecological, resource and social implications

Climate change pressures include flow modification, sea-level rise and increased temperatures and coastal storminess, leading to changes in physical processes (e.g. modification in mouth conditions, salinity regimes, nutrient pulses, sediment regimes) and biological responses (e.g. production, species composition) with an impact ultimately on ecosystem services.

- The KwaZulu-Natal and West Coast estuaries will be the most affected by climate change from a structural and functional perspective, e.g. mouth state, nutrient supply, salinity distribution and ultimately production (e.g. fisheries).
- The Wild Coast, Eastern and Southern Cape estuaries will be most vulnerable to temperature regime shifts (both nearshore and land) and the associated range extensions/contractions of species and community composition changes.
- Climate change is one of many pressures acting on estuaries and should be viewed as an additional form of anthropogenic alteration (rather than a separate pressure) in an already stressed ecosystem type, i.e. climate change acts as an accelerator of ecosystem change.

10. Estuary Management Plans are developed, or in progress, for 9% of South Africa's estuaries

Over the past decade legislative responses have increased, but flow-related measures are starting to lag behind other planning processes.

- The finalisation of the National Estuarine Management Protocol, the roll out of the Estuary Management Planning Framework and the provision of resources, both human and funding, is needed to sustain this effort. At present there are 26 Estuary Management Plans in the process of being developed as part of the implementation of the Integrated Coastal Management Act (Act 24 of 2008). This includes the establishment of 12 Estuary Forums which form the vital communication platform between coastal communities and the various government departments that play a role in estuary management.
- Key legal instruments, such as the determination of the ecological water requirements of individual estuaries, provide the scientific basis for local and regional water resources planning and implementation frameworks and assist with identifying critical over-allocations of resources.
- Unfortunately, ecological water requirement studies have been undertaken for only about 12 % of all estuaries over the last decade.

Key Messages

1. Estuaries, unlike many other ecosystems, can be restored to a well-functioning, productive state.

- Estuaries are by nature resilient systems, because their fauna and flora are adapted to living in conditions of extreme change.

2. Recovery of South Africa's iconic estuary, the Lake St Lucia system, is possible.

The very poor condition of the Lake St Lucia system, which represents over half the estuarine area in South Africa, is reversible and ecosystem recovery is possible. Due to Lake St Lucia's international and national significance, the iSimangaliso Wetland Park Authority has raised funding from the Global Environment Facility (GEF) to investigate and implement a long-term solution to the hydrological issues facing the Lake St Lucia system. In parallel to this investigation the management strategy for 2011/2012 will result in the reversal of the 60 year old approach to managing Lake St Lucia; that is, allowing the uMfolozi and Lake St Lucia estuary mouths to join to form a combined mouth, and thereby allowing it to function as naturally as possible. In keeping with adaptive management, an ongoing review and evaluation based on monitoring of salinity, lake levels and ecosystem health will continue as these interventions are implemented. Ongoing national government support for the rehabilitation of the Lake St Lucia system is important.

Other specific management recommendations include:

- reducing the fishing effort within the system;
- resolving the issue related to the backflooding of the low-lying sugar cane farms so that conflict over breaching of the combined mouth does not occur (e.g. securing or protecting the properties along the lower uMfolozi);
- improving farming practices in the uMfolozi catchment and floodplain to improve water quality and limit sediment input to St Lucia.

3. Increase protection levels through the implementation of the National Estuary Biodiversity Plan

- DEA, in collaboration with SANBI, DWA and DAFF, should lead the process of endorsing and implementing the National Estuary Biodiversity Plan.

4. To adequately protect an estuary, it needs to be in a formal protected area with effective no-take zonation, and its freshwater requirements must be guaranteed.

- The Lake St Lucia system is an example of a system which is poorly protected. While being fully protected on paper, St Lucia's current ecological condition is poor (Category E) and uMfolozi is only in fair condition (Category D).

5. Estuaries provide a focal point for co-ordinated and integrated natural resource management.

- Estuaries form the link between the land and the sea and are therefore the receivers of most resource-use pressures from the surrounding land- and seascape. Estuaries should be the focal point for natural resource management and planning in the coastal domain, e.g. in the classification of water resources in terms of the National Water Act, the class of a river should be influenced by the class assigned to the estuary.

6. **Estuaries are valuable national assets providing essential ecosystem services, such as nursery functions to coastal fisheries, freshwater flows to the marine environment, replenishment of nutrients and organic material to coastal habitats, flood and sea storm protection, carbon sequestration, safe bathing areas and cultivation of plants for biofuels without freshwater.**

- Estuaries provide an important nursery function for fish, with some of the more muddy Temperate estuaries such as the Mbashe, Umtata, Keiskamma and Great Kei being particularly important for supporting collapsed marine fish resources such as white steenbras and dusky kob.
- Estuaries provide freshwater (both surface and groundwater), nutrients, detritus and sediments to the coastal environment, thereby supporting important ecological processes and the productivity of some fisheries (e.g. prawns and line fishery).
- Estuaries offer easy access, warmer waters, shallow depths, shelter and weak currents that make them very attractive to bathers.
- Estuaries contribute to the regulation of greenhouse gases and provide opportunities for carbon trading.
- South Africa's estuaries provide a significant buffer against floods with a total open water area of 61 000 ha and flood plain storage, as represented by the estuarine functional zone, of nearly 171 000 ha, of which 60% is in the Subtropical biogeographic region.
- Halophytes (salt tolerant plants such as *Sarcocornia*) can be used as an alternative energy or food source due to their high oil and protein content. By far the greatest benefits of halophyte culture is that, unlike much current biofuel production, it does not displace food crop production or use excessive quantities of fresh water.

7. **Future introduction and spread of invasive species in estuaries can be prevented.**

- While invasive alien species do not represent a significant overall pressure as yet, it is critically important that there is timeous intervention to ensure that the situation remains under control (e.g. control invasive predatory fish that act as a barrier to migratory species, and the total eradication of the alien invasive grass *Spartina alterniflora,* which is currently known to be present in only the Groot Brak estuary but which may otherwise spread).

8. Healthy estuaries support ecosystem resilience and adaption to climate change.

- Stressed ecosystems have a lower resilience to change. By increasing or maintaining the resilience of estuaries, the ability of a system to recover, for example after a flood or drought, is enhanced.
- The resilience of an estuary is influenced by the intactness of its catchment and estuarine habitats. A way to ensure resilience is the determination and implementation of estuarine ecological water requirements and the protection/rehabilitation of the estuarine functional zone.
- The processes underpinning the ecosystem services provided by estuaries, such as the assimilation and cycling of nutrients, also need to be protected if resilience is to be maintained.

Priority actions for estuarine biodiversity management and conservation

- **Restore the health of St Lucia and conserve the other estuarine lake systems.** South Africa's estuarine lake systems (St Lucia, Verlorenvlei, Bot, Klein, Wilderness, Swartvlei, Kosi) are all under tremendous pressure, and need to be managed in a more holistic manner. They are important national biodiversity assets, which often pay the price for inappropriate short-term local-level decision-making. In particular, the St Lucia system holds a major share of South Africa's estuarine biodiversity. As discussed above, the iSimangaliso Wetland Park Authority has initiated measures to combine the uMfolozi with Lake St Lucia with funding support from the Global Environment Facility (GEF) in order to restore the health of the greater ecosystem.

- **Increase protection levels through the implementation of the National Estuary Biodiversity Plan.** The development of the National Estuary Biodiversity Plan was the first step in the planning process. DEA, in collaboration with SANBI, DWA and DAFF, should lead the implementation of the National Estuary Biodiversity Plan. This should include the setting of protected area targets for Estuarine Protected Areas in the short- to medium-term, e.g. 5% of all ecosystem types will be formally protected by 2020 and 20% of all ecosystem types will have Estuary Management Plans by 2020. This also requires the integration of the National Estuary Biodiversity Plan in strategic processes such as the classification of water resources led by the DWA and the upcoming revision of the National Protected Area Expansion Strategy led by DEA.

- **Respond rapidly to emerging invasive species.** Develop protocols and procedures for the early detection, risk assessment and management of invasive alien species. For example, certain invasive alien fish species can act as a barrier to migratory species (eels and fresh water mullet) and influence the species composition and abundance of species, many of which are commercially important, in the river-estuarine interface.
- **Develop a National Coastal Biodiversity Plan.** Estuaries are not separate from the coast. To ensure their long-term functioning also requires the development of a National Coastal Biodiversity Plan that integrates marine, estuarine, freshwater and terrestrial aspects. Such a plan should be conducted at a fine enough scale to support integrated coastal development at the municipal level.
- **Ensure the total eradication of the alien invasive *Spartina alterniflora* from the Groot Brak estuary before it spreads to other estuaries.** Progress has been made, since early 2011, but it is very important that the initial field tests for chemical and mechanical control be followed up with full eradication and continuous follow up removal to ensure that this highly invasive and damaging plant species does not spread to adjacent systems along the coast.
- **Ensure that the legal definition of estuaries in South Africa includes the estuarine functional zone.** The GNR 546 Listing Notice 3 under the NEMA EIA Regulations (2010) identifies the estuarine functional zone as a sensitive area that requires environmental authorisation before a development may proceed. It is important that this consideration is also taken up by the Integrated Coastal Management Act and the National Water Act, both of which need to recognise the value of the estuarine floodplain and the threat of (back) flooding within this zone.
- **Determine ecological water requirements for all estuaries within 10 years and implement flow requirements within 5 years of their classification.** This process is likely to require a two-tiered approach in which the findings of the NBA 2011 form the basis for allocation on a national level in the classification of water resources in terms of the National Water Act. While more detailed ecological water requirement studies will be needed for water-stressed catchments or biodiversity priority areas, there is also an urgent need for strategic assessments (such as the National Water Resources Strategy) to take cognisance of estuarine flow requirements which are often substantially higher than the flow requirements of the river entering the estuary. This little-recognised fact leads to national and catchment scale water resource plans that over-estimate the water resources available for development, thus compromising the ecosystem processes that coastal communities depend upon.

- **Ensure resilience to climate change and other global change pressure through the appropriate management of the estuarine functional zone. Finalise the National Estuary Management Protocol** to ensure cooperative governance between the lead authorities that manage estuaries and roll out the development and implementation of Estuary Management Plans in terms of the Integrated Coastal Management Act.
- **Finalise and implement the National Estuary Monitoring Programme** currently being developed by DWA. This multi-tier, multi-parameter (include biotic and abiotic components) programme is based on current best practice and with sufficient funding, and support from other organs of state, could go a long way in addressing data deficiencies in future NBA assessments.
- **Development of a National Sustainability Plan for Estuarine Resources** that will ensure alignment between sectoral objectives for estuaries on a national scale. The plan should be developed in consultation with lead authorities (DEA, SANBI, DWA and DAFF) and assist with facilitating the co-operative governance between the lead agents. Once in place, it should serve as the "blue print" for a number of key sectoral resource plans and processes at various levels of governance, e.g. allocation of water resources or Total Allowable Catch in coastal fisheries.

Knowledge gaps

- **Refine estuary ecosystem types:** The NBA 2011 has started the process of refining the typing of South Africa's estuaries at a more detailed level than has previously been available. However, higher resolution input data on catchment hydrology, bathymetry, sediment structure and water quality (turbidity and salinity) is required to address the needs articulated by specialists in the execution of this study.
- **Quantification of the modification in freshwater flow to the coast on a watershed scale.** There is an urgent need for a quantification of the modification in freshwater flow to the all estuaries of South Africa. This analysis should include all current land-use, transfer schemes, discharges, dam developments and be based on the true catchment area of each individual system. These data will also form the basis of an analysis of the degree to which freshwater flow to the coast has been modified.
- **Taxonomic surveys of the invertebrates in all South African estuaries:** There is no up-to-date national dataset for South African estuarine invertebrates. Invertebrate data were last collated at a national scale more than a decade ago but little effort has been made to

address this. Future assessments and biodiversity plans cannot be refined without filling this gap in a systematic manner.

- **Taxonomic surveys of the plants in all South African estuaries:** Taxonomic revision of salt marsh species should be supported and funded so that macrophyte species lists can be updated for all estuaries. From these data, sites of rare and threatened species can be identified. Updated GIS spatial data of the habitat areas data for all estuaries is needed. This is especially important where data are older than 10 years. This would include field surveys to ground truth the data. For example detailed habitat maps for the Rietvlei/Diep system and Richards Bay Harbour are urgently required for planning proposes and to address deficiencies in the current databases. This should include the development of a database with information presented in this study plus GIS maps of all South African estuaries. This spatial data could also feed into the estuary management planning processes.
- **Invasive Species:** With the exception of plants, very little is known about invasive species in South Africa's estuaries. There is an urgent need to have a census on the occurrence of invasive alien species in different estuaries and the potential environmental impact of these on both the ecosystem function and the value derived from the estuary in question. All invasive species (freshwater, marine and estuarine) should be included in the census.
- **Nursery function for exploited and collapsed fish species.** Recent work has indicated that while most estuaries serve as nurseries, some of the more sediment rich systems are associated with "sediment deltas" in the nearshore environment which serve as nurseries for some species which represent collapsed stocks. It is of the utmost importance that these systems are identified and their nursery function quantified to ensure sustainable resource utilisation into the future. Future biodiversity plans should also include these systems explicitly to align management and conservation priorities.
- **Pollution data:** There is no systematic record of the discharges into estuaries. There is also a need to evaluate the monitoring stations above the estuaries to develop a clear perspective on what is flowing into estuaries and coastal waters.
- **The value of estuaries in South Africa:** There is very little national scale data available on the value of estuaries. As this is one of the key requirements for communicating the relevance of estuaries to coastal communities, and the country as a whole, this lack of data hinders the ability to motivate for rational decision-making.
- **Climate change:** Climate change has the potential to change the processes and functioning of South Africa's estuaries dramatically. Large and local scale climate models are becoming better at accurately predicting the drivers of change in the future. The estuarine research

community needs to make this one of their research priorities over the next decade to facilitate better adaptation strategies and ensure ecosystem resilience.

- **Sediment data:** Very little information is available on the sediment structure of South Africa's estuaries. This is a significant data gap as grain size distribution and the mud:sand ratios influence biodiversity patterns. The lack of sediment information also makes it very difficult to assess environmental change in relation to some of the major pressures such as dam development and sand mining.
- **Mapping the 3-dimensional nature of South Africa's estuaries:** Detailed systematic topographical and bathymetrical surveys are needed for all South Africa's estuaries. Cross-sectional survey data are available for less than a third of the estuaries in the country. In most cases these data are over 20 years old. Most planning processes (e.g. ecological water requirement studies, Estuary Management Plans, setback lines, spatial development plans) are of low confidence as they lack this basic information. Assessment of change (sedimentation, erosion sensitivity to flow modifications, structural developments) is therefore mostly inferred from pressure data. Improved planning and assessments urgently require a significant effort to address these basic data requirements.
- **Up-to-date surveys of the fish and bird fauna of estuaries:** National scale surveys on fish and birds in all South African estuaries were last carried out in the early 1980s. These surveys urgently need to be repeated in a once-off effort that is comparable with the earlier surveys.

Acronyms Symbols, Abbreviations and Notations

~	Approximately
< / ≤	less than / less than or equal to
> /≥	greater than / greater than or equal to
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DWA	Department of Water Affairs
ha	Hectare
m	Metre
MAR	Mean annual run-off
MSL	Mean sea level
$x10^6m^3$	Million cubic metres

Glossary of Terms

Anthropogenic	Having to do with man, or caused by humans
Aquifer	Underground layer of permeable rock, sand or gravel that conveys water
Baseflow	Baseflow consists of water derived from the intermediate and groundwater catchment/subcatchment. Baseflows constitute "dry weather" flows and are hydrologically significant in that they sustain flows into the non-rainy seasons, are important for ecological flows and also have a different water chemistry to that of stormflows.
Benthic invertebrates	Organisms living in or on sediments of aquatic habitats
Biodiversity	The variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems
Catchment	In relation to a watercourse or watercourses or part of a watercourse, this term means the area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points
Community	Assemblage of organisms characterised by a distinctive combination of species that occupy a common environment and interact with one another
Community composition	All taxa present in a community
Cumulative impact (or effect)	Cumulative impact is the impact on the environment which results from the incremental or combined effects of one or more developmental activities in a specified area over a particular time period, which may occur simultaneously, sequentially, or in an interactive manner.
Dilution	The reduction in concentration of a substance due to mixing with water
Dry and Wet years	"Dry" years are generally represented by the 10th percentile of a distribution, i.e. the "driest" year in 10 or the lowest flows in 10 years. Conversely, "wet" years are represented by the 90th percentile, i.e. the "wettest" year in 10 or the highest flows in 10 years.
Ecological integrity	Maintaining a diverse, healthy and productive natural system

Ecological water requirements (also called the Reserve)	The quantity and quality of water required: • to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be relying upon, taking water from, or being supplied from the relevant water resource, and • to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource.
Ecosystem	A community of plants, animals and organisms interacting with each other and with the non-living (physical and chemical) components of their environment
Ecosystem protection level	Indicates the extent to which ecosystems are protected, based on the proportion of each ecosystem's biodiversity target that is met in formal protected areas recognised by the Protected Areas Act.
Ecosystem threat status	Ecosystem threat status tells us how threatened South Africa's ecosystems are. Ecosystems are assessed as critically endangered, endangered, vulnerable or least threatened. Ecosystem threat status is a key headline indicator of the state of biodiversity
Effluent	Liquid fraction after a treatment process (i.e. preliminary, primary, secondary or tertiary) in a wastewater treatment works
Habitat	The natural home of an organism or community of organisms (this also includes the surrounding area)
Macroinvertebrates	Animals that have no backbone and are visible without magnification
Macrophytes	Macrophytes are (aquatic) plants that are large enough to be apparent to the unaided eye
Pollution	The direct or indirect alteration of the physical, chemical or biological properties of the natural environment, including the marine environment, so as to make it less fit for any beneficial purpose for which it may reasonably be expected to be used, or to make it harmful or potentially harmful to the welfare, health or safety of human beings or to any aquatic or non-aquatic organisms
Resource quality objectives (RQOs)	Management Objectives for a resource relating to quality of all the aspects of a water resource including: • the quantity, pattern, timing, water-level and assurance of instream flow; • the water quality, including the physical, chemical and biological characteristics of the water;

	• the character and condition of the instream and riparian habitat; and • the characteristics, condition and distribution of the aquatic biota. These objectives are set by the Department of Water Affairs and Forestry in terms of the NWA
Runoff	Runoff is the water yield from an individual catchment – the subcatchment plus the runoff from all upstream subcatchments. Runoff includes any seepage, environmental flow releases and overflows from the reservoirs in a catchment, if they are present - which is not the case in any of the simulations in this project in which baseline catchment conditions are assumed.
Temporal Terms	Inter- : between, e.g. inter-annual variability denotes variability between one year and the next. Intra- : within, e.g. intra-seasonal differences are differences within a season, i.e. from one month to the next.
Stormwater run-off	Stormwater run-off from paved areas, including parking lots, streets, residential subdivisions, of buildings, roofs, highways, etc.
Sustainability	In terms of water quality management (DWAF), this means: 'Fitness for use by other users and future generations' and the ability to assimilate waste means the ability to receive and process waste to such an extent that the water remains fit for use by its other intended users.
Waste	Any solid material or material that is suspended, dissolved or transported in water (including sediment) in such volumes, composition or manner that, if spilled or deposited in the natural environment, will cause, or is reasonably likely to cause, a negative impact
Wastewater	Water containing solid, suspended or dissolved material (including sediment) in such volumes, composition or manner that, if spilled or deposited in the natural environment, will cause, or is reasonably likely to cause, a negative impact

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1. INTRODUCTION

1.1 What is the National Biodiversity Assessment?

The National Biodiversity Assessment (NBA) 2011 follows the first National Spatial Biodiversity Assessment (NSBA) that was led by the South African National Biodiversity Institute (SANBI). The NSBA 2004 was the first comprehensive national spatial assessment of the state of biodiversity, covering terrestrial, freshwater, estuarine and marine environments. It introduced two new headline indicators for assessing the state of South Africa's biodiversity: ecosystem threat status (referred to as ecosystem status in 2004), and ecosystem protection level. Ecosystem threat status tells us how threatened ecosystems or habitats are, and ecosystem protection level indicates how well- or under-protected ecosystems or habitats are. For the first time, these indicators were comparable across aquatic and terrestrial environments.

SANBI's mandate includes reporting on the state of biodiversity in South Africa. For this reason, the decision was made to broaden the National Spatial Biodiversity Assessment to incorporate non-spatial or thematic elements, and to produce a National Biodiversity Assessment. The intention is to review the National Biodiversity Assessment at five to seven year intervals.

The primary purpose of the NBA is to provide a regular high-level summary of the state of South Africa's biodiversity, with a strong focus on spatial assessment. The NBA is intended for decision-makers both inside and outside the biodiversity sector. It feeds into and links with other policy-related processes such as state of environment reports, identification of threatened ecosystems for listing in terms of the Biodiversity Act, the National Protected Area Expansion Strategy, and the National Biodiversity Strategy and Action Plan.

The NBA 2011, like the NSBA 2004, was led by SANBI in partnership with a range of organisations. The overall results are summarised in the report: *National Biodiversity Assessment 2011: A report on the state of South Africa's biodiversity* (Driver et al. 2012).

A technical reference group was convened by SANBI in April 2009 to guide the approach taken for the NBA 2011. This group was reconvened in January 2011 to review outputs and provide guidance on key messages that should be highlighted in the NBA summary report.

The marine and coastal component is one of four components of NBA 2011. A technical report is available for each component, as listed at the front of this report. While the NBA 2011 summary report is intended for a wide audience, this technical report is intended for a more specialist audience. It explains the data used and the analysis undertaken in the 2011 assessment, highlighting advances made since 2004, and discusses the results.

Common features across the components of the NSBA 2004 and the NBA 2011 are the use of the systematic approach to biodiversity assessment and planning, and the focus on the two headline indicators of ecosystem threat status and ecosystem protection level. Each of these is discussed briefly below.

Working in an integrated and aligned way across aquatic and terrestrial environments can be challenging, as disciplines in these environments have historically developed separately, with separate sets of terminology, methods and approaches. Insisting on compatible approaches can be seen as a constraint on conventional approaches. However, the benefits are numerous, including enabling comparison across environments as well as providing a stimulus for interdisciplinary learning and innovation.

1.2 Biodiversity planning[1] in South Africa

There are several possible approaches to biodiversity assessment and planning. The approach used most often in South Africa, including in the NBA, is systematic biodiversity planning. It is based on three key principles:

- The need to conserve a **representative sample** of biodiversity pattern (the principle of representation);
- The need to conserve the **ecological and evolutionary processes** that allow biodiversity to persist over time (the principle of persistence);
- The need to set quantitative **biodiversity targets** that inform us how much of each biodiversity feature should be kept in a natural condition in order to maintain functioning landscapes and seascapes.

[1] Biodiversity planning is sometimes referred to as conservation planning. We prefer to use biodiversity planning because many people associate the term conservation planning purely with planning for the establishment and expansion of formal protected areas, rather than with influencing the way resources are used and managed throughout the landscape or seascape.

South Africa is at the forefront of biodiversity planning internationally, and the methods and techniques used in this assessment are at the cutting edge of the discipline. The NBA rests on over 30 years of research, development and practice by South African scientists, often in collaboration with colleagues from other countries.

1.3 Headline indicators: ecosystem threat status and ecosystem protection level

As explained above, the NSBA 2004 introduced two new headline indicators for assessing the state of South Africa's biodiversity: ecosystem threat status and ecosystem protection level. Ecosystem threat status gives an indication of how threatened ecosystems are, and ecosystem protection level informs on how well- or under-protected ecosystems are.

These two headline indicators have been carried forward in the NBA 2011, and will be updated again in future revisions of the NBA in order to provide a time series comparison of the state of ecosystems in South Africa. Between 2004 and 2011, methods for assessing ecosystem threat status have been refined, meaning that the results are not strictly comparable over this time period. The implications of this are discussed in greater detail in Section **Error! Reference source not found.**.

These headline indicators provide not only a way of comparing results meaningfully across the different aquatic and marine environments, but also a standardised framework which links with policy and legislation in South Africa, facilitating the interface between science and policy. There is growing recognition within government and other institutions of this framework and the need to respond to these headline indicators in planning and decision-making.

The assessment of ecosystem threat status is **completely independent** of the assessment of ecosystem protection level. As shown in Figure 1.1, ecosystem threat status is based on the condition of an ecosystem type, while ecosystem protection level is based on the extent to which an ecosystem type is formally protected. A well protected ecosystem type may thus be in poor condition, and equally an ecosystem in good condition may not be formally protected.[2]

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[2] In practice, highly threatened ecosystems are often poorly protected. However, this correlation emerges not from the nature of the analysis itself but because ecosystems in which large amounts of natural habitat have

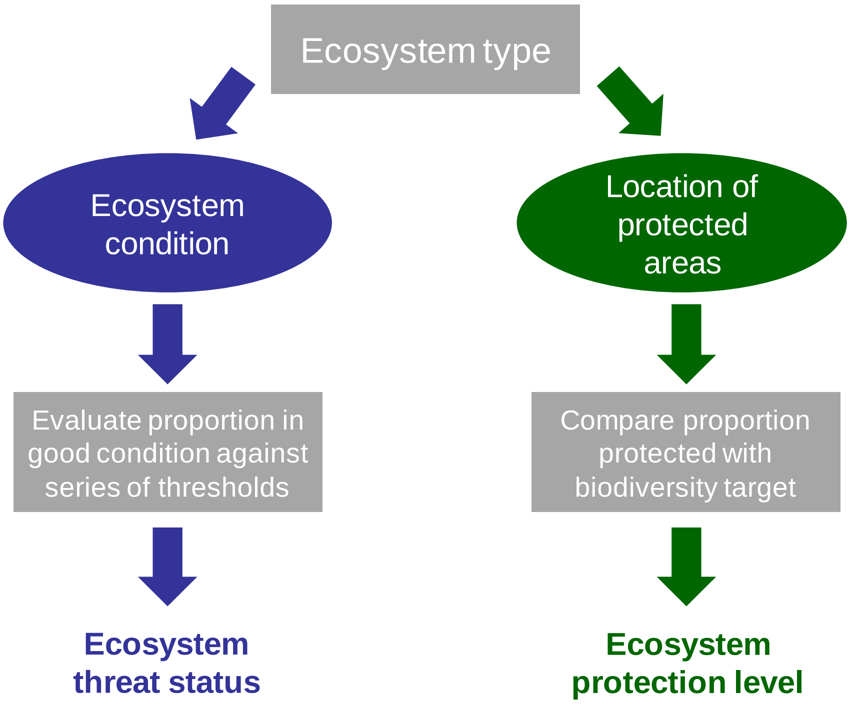

Figure 1.1 The headline indicators, ecosystem threat status and ecosystem protection level, are assessed independently of one another. Ecosystem threat status is based on the proportion of an ecosystem type in good condition, while ecosystem protection level is based on the proportion of an ecosystem type that is formally protected.

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been lost, or which have become severely degraded, tend to be those under pressure from a range of socio-economic activities that are incompatible with maintaining a well functioning ecosystem and that raise the opportunity costs of establishing protected areas.

2. STRUCTURE OF THIS DOCUMENT

An overview of the tasks undertaken as part of the NBA 2011: Estuaries Component is outlined here:

- Ecosystem services
- Estuarine functional zone
- Physical characteristics of South Africa's estuaries
- Estuarine habitat
- NBA 2011 Estuarine Typing
- Key pressures on estuaries
- Health status of estuaries
- Ecosystem threat status
- Estuary protection levels
- National Estuaries Biodiversity Plan
- Species of special concern
- Invasive alien species
- Climate change
- Legislative responses

Ecosystem services: Estuaries provide a host of ecosystem services at local, regional, national and global scales. This report briefly touches on a few important services to highlight the benefits society derive from this aquatic ecosystem type: nursery function, freshwater flows to the marine environment, carbon sequestration, flood regulation, storm protection, safe bathing areas, and estuarine plants as food, fuel and building resources.

Estuarine functional zone: This task required the delineation and mapping of South Africa's estuaries based on their physical features or processes to allow for spatial interrogation of the pressure and health data. All open water and flood plain areas were delineated using Google Earth and Spot5 imagery for 291 estuaries. The spatial delineation also provided the basis for the predicting the present ecological health status and in adding resolution to the conservation planning.

Physical characteristics of South Africa's estuaries: This section sets out to define some of the key physical characteristics of South Africa's estuaries. Important features are highlighted, and in some cases categorized to provide a more detailed perspective on estuarine biodiversity distribution and the forces that drive it. Categorization was done to reflect the dominant condition of an estuary.

Estuarine habitat: The objectives of this task were to determine the habitat surface areas of South Africa's estuaries (with a particular focus on Temperate salt marshes); provide a species list of dominant estuarine macrophytes; and identify the sites of rare and endangered species. The emphasis during this task was on those estuaries where no data are available or where the data was older than 10 years.

NBA 2011 Estuarine Typing: The current South African Estuarine Classification system (Whitfield 1992) is very broad and a more detailed analysis is required to provide more in-depth insights into the sensitivity of the individual systems to change (i.e. system resilience) and the physico-chemical drivers for species occurring in them.

Key pressures on estuaries: The Estuaries NBA 2011 made a special effort to provide a spatial indication of the current and potential future pressures (and severity) on South Africa's estuaries. Where data were available, the information was captured in an Excel spreadsheet, otherwise expert judgment (high, medium, low) was used to indicate the level of pressure. The following pressures were evaluated on a national scale:

- Flow modification;
- Pollution;
- Fishing effort; and
- Habitat destruction.

Health status of South Africa's estuaries: A key step in biodiversity management planning is the development of an understanding of the health, or condition, of an ecosystem. This aspect was not addressed as part of estuarine component of NSBA 2004 (Turpie 2004) due to a lack of funding. A 3-day national health assessment workshop was held to determine the current health status of South Africa's estuaries based on expert opinion. The estuaries of South Africa was be divided into three sections: West and South Coast (including Transkei) and KwaZulu-Natal and evaluated by regional experts.

Ecosystem Threat Status: Ecosystem threat status is one of the two headline indicators reported on in the NBA. It informs us about the degree to which our ecosystems are still intact, or alternatively losing vital aspects of their structure and functioning. Ecosystem types are categorised as critically endangered (CR), endangered (EN), vulnerable (VU) or least threatened (LT), with CR, EN and VU ecosystem types collectively referred to as threatened.

Estuary Protection Levels: Ecosystem protection level indicates the extent to which ecosystems are protected, based on the proportion of each ecosystem's biodiversity target that is met in formal protected areas recognised by the Protected Areas Act or Marine Living Resources Act. For these calculations, targets for protection were set at 20% of the estuarine habitat area of each ecosystem type. Ecosystem protection level is divided into four categories: well protected, moderately protected, poorly protected and not protected.

National Estuary Biodiversity Plan: This section presents the findings of the national biodiversity plan for the estuaries of South Africa. This assessment represented a significant milestone in that it is the first biodiversity planning study to include all the estuaries of South Africa. Nearly 300 estuaries from the Cool Temperate, Warm Temperate and Sub-tropical regions were included (Appendix A). The main objective was to identify which South African estuaries should be assigned protected area status.

Species of special concern: The report provides a collation of information on harvested, exploited or Red Data species. It mainly looks at plants, invertebrates and fish. It also highlights the fact that a number of overexploited fish species should be listed as Red Data Species.

Invasive alien species: As part of South Africa's international biodiversity obligations, it needs to report on the status of invasive aliens species every five years. The NBA 2011 provides a collated species list of invasive aliens in estuaries as part of this assessment.

How vulnerable are South Africa's estuaries to Climate Change: This section offers an overview of how climate change will affect the process drivers in estuaries and highlights some of the vulnerabilities South African estuaries display on a regional scale.

Legislative responses: A number of management processes have been developed under key legislation to manage pressures on estuaries and assist with biodiversity conservation. This final section discusses South Africa's legislative framework with regards to estuaries, highlights some of the key legal instruments and reports on the status of their implementation.

The NBA 2011 report concludes with:

- A summary of key findings and recommendations,
- Identification of the information gaps, research priorities and future assessments; and
- Recommendation for the next NBA.

Further to the above mentioned tasks, this project set out to integrate the findings of the Estuaries NBA 2011 with the recommendation and findings of the other components, especially the rivers and marine component. An essential part of this integration process is the iterative interaction throughout the life of the project between the terrestrial, freshwater and marine components. The project aimed to leave SANBI and the broader conservation planning community with a much deeper understanding of the pressures and issues related to estuary management and biodiversity conservation. This will facilitate improved integrated planning across terrestrial and aquatic ecosystems in the future.

3. ECOSYSTEM SERVICES

L van Niekerk, SJ Lamberth, J Adams, M McCord & A Childs

3.1 What are ecosystem services?

The natural environment provides a range of valuable ecosystems services (also termed goods and services) to society, including provisioning services (such as food, water and other resources), regulating services (e.g. climate regulation, as well as air and water purification), cultural services (e.g. aesthetic, spiritual, recreational, educational and cultural benefits), and life-support services (such as nutrient cycling and soil formation) (Millennium Ecosystem Assessment 2005).

The terms “goods” and “services” originate in the field of Ecological Economics. Daily (1997) defines an ecosystem service as the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life. Ecosystem goods (provisioning services), on the other hand, represent the material products that are obtained from natural systems for human use (DeGroot *et al.* 2002). Ecosystem services occur at multiple scales, from climate regulation at the global scale, to water supply at the local and regional scales (DeGroot et al. 2002). They also contribute direct or indirectly to human welfare, with those listed above being less directly connected, while food, raw materials, recreational opportunities, and aesthetic and cultural values are more directly connected.

Estuaries, in particular, are recognised as being among the most productive types of ecosystems worldwide. They are focal points for community and business activities along the coast, as they provide a wide range of opportunities and benefits. For example, Costanza et al. (1997) estimated that estuaries provide US$22,832 worth of goods and services per hectare per annum (in 1997 values), more than any other ecosystem. In South Africa, a number of studies have shown that estuaries contribute significantly to the local and national economy (Cooper et al. 2003; Lamberth and Turpie 2003; Turpie and Hosking 2005; Turpie and Clark 2007).

Local governments benefit by generating substantial revenue from higher rates that result from elevated property values along estuary shores and related economic activities, such as estuary tourism (Mander 2001). As a consequence of these benefits, coastal communities, tourists and local governments along the coast depend on estuaries as an important source of revenue. Because estuaries are natural features, the opportunities that they provide are free. Estuary services are just like any other that may be bought, except that these are generated through the functioning of the estuary ecosystem. These services can be used directly or indirectly, or they can be left as an option for future use. However, estuaries are seldom considered a local government asset, even though they generate considerable revenue for local government and communities. Because of the failure to appreciate their value, little is spent on their management. Estuaries should be regarded as an asset and managed to maintain their value. Failure to do so can have major cost implications for local governments (Mander 2001; Lamberth & Turpie 2003).

The use of estuaries should be balanced with the ability of estuaries to deliver services. There is a need to manage the demands placed on estuaries to ensure that they do not exceed the natural ability of the ecosystem. If demand exceeds supply, future well-being is reduced. If demand equals or is less than supply, the estuary will continue to supply services sustainably. This should not be seen as a constraint to economic development but should rather be seen as an opportunity to diversify the local economy. By focusing on a wide range of complementary and sustainable uses, the greatest benefits can be generated for the greatest number of people by an estuary at minimised cost to society (Mander 2001; Turpie & Lamberth 2003).

3.2 Key ecosystem services provided by estuaries

Estuarine habitats and the species they contain provide a host of important ecosystem services as summarized in Table 3.1. This section briefly touch on a few of the more important services to highlight the benefits society derive from this aquatic ecosystem type, e.g. nursery function, freshwater flows to the marine environment, carbon sequestration, flood regulation, storm protection, safe bathing areas, and estuarine plants as food, fuel and building resources.

3.2.1 Nursery Function

Lamberth and Turpie (2003) estimate that about 50% of the 160 species of fish that occur in South Africa estuaries are utilised in fisheries (subsistence, recreational and commercial). At least 60% of these species are considered entirely or partially dependent on estuaries, and are thus likely to be affected by changes in runoff.

Table 3.1 Ecosystem services of aquatic and water-dependent ecosystems, adapted from Costanza et al. (1997) and Turpie and Clark (2007), and their importance in South African estuaries.

Ecosystem services		Description	Importance in estuaries
Provisioning services (goods)	**Water**	Provision of water for subsistence and agricultural use (only applicable in fresher upper reaches)	Low
	Food, medicines	Production of fish and food plants; medicinal plants	High
	Raw materials	Production of craftwork materials, construction materials, fodder and biofuel (especially important in rural and arid areas)	Medium to high
Regulating services	**Climate regulation**	Carbon sequestration, oxygen and ozone production, urban heat amelioration	High
	Disturbance regulation	Flood control, drought recovery, refuges from pollution events	High
	Water regulation	Provision of dry season flows for agricultural, industrial and household use (only applicable in fresher upper reaches)	Low
	Erosion control and sediment retention	Prevention of soil loss by vegetation cover and capture of soil, e.g. reeds and sedges preventing bank erosion	High
	Ecological regulation	Regulation of malaria, bilharzia, liver fluke, black fly, invasive plants as salinity assist with pest control.	High
Supporting services	**Waste treatment**	High retention makes is effective in breaking down waste and detoxifying pollution. Tidal and fluvial flushing assist with dilution and transport of pollutants	Medium to high
	Refugia/ Nursery areas	Critical habitat for migratory fish and birds, important habitats or nursery areas for species	High
	Export of materials and nutrients	Export of nutrients and sediments to marine ecosystems	High
	Genetic resources	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species	Low
Cultural services (attributes)	**Structure and composition of biological communities**	The characteristics, including rarity and beauty, that lend an area its aesthetic qualities or make it attractive for recreational, religious or cultural activities	High

The total landed catch of fish taken directly from estuaries (2 480 tons per annum) is considerably lower than the total estimated catch of inshore marine fisheries (28 000 tons per annum). However, depending on bioregion and fishery sector, up to 83 % of the catch by inshore fisheries may comprise estuary-associated species. These authors estimate that the total value of estuary fisheries and the contribution of estuary fish to the inshore marine fisheries, is about R1.2 billion per annum in 2011 Rands.

The life-history characteristics of most of South Africa's coastal fish species are fairly well known allowing them to be categorised into the various levels of estuary-association developed by Whitfield (1994). Less well known is the degree of intra-specific variation in estuary-dependence between the different biogeographical regions or whether suitable nursery or spawning areas are limited due to the narrow or critical habitat requirements of some species.

For some species, the level of estuary-association appears to vary across biogeographical regions. This may have been selected for at the population level and/or a result of the behavioural and physiological plasticity of the species concerned. Knysna sandgoby *Psammogobius knysnaensis* range from having mostly estuary-resident populations on the subtropical and warm Temperate east coast to equivalent estuary and surf-zone populations on the cool Temperate west coast. On the east and south coast, dusky kob *Argyrosomus japonicus* are obligate estuary-dependent species whereas silver kob *Argyrosomus inodorus* are not and never enter estuaries there. On the cool west coast where the warm-Temperate *A. japonicus* do not occur, *A. inodorus* utilize the Orange and other estuaries, probably for feeding or as a warm-water refuge. The Angolan dusky kob *A. coronus* occurs in the sea on the cool-Temperate west coast, until the warm-Temperate Cunene, where it is dominant in estuaries and *A. inodorus* no longer occur (Lamberth et al. 2008).

Although there are close to 300 estuaries along South Africa's coast, the specific habitat requirements of some fish at certain stages of their life may make the choice of juvenile nursery habitat or spawning ground extremely limited. Small juvenile dusky kob *A. japonicus* less than 1-year old prefer the fine sediments of highly turbid estuaries being adapted to find refuge in a "viscous" environment from which other predatory fish are physiologically excluded. This type of habitat comprises less than 5 % of the total estuarine area in South Africa. Of the 20 largest catchments in the country, only four, the Mbashe, Great Kei, Mzimvubu and Mtata have estuaries with the suitable sediment and turbidity characteristics as do an undetermined number of smaller systems such as the Kwelera and Nahoon. For adolescents, the habitat requirements appear to be broader with at least 50% of large and medium size estuaries being suitable nursery environments.

White steenbras *Lithognathus lithognathus* occur from the Orange River to the warm-Temperate / subtropical transition zone on the east coast. There is an annual spawning migration to this bioregion transition zone, spawning occurring late July to September on the fluvial fans off selected estuary mouths. These fluvial fans appear to be limited with the Mbashe as the only confirmed spawning area and the Mtata, Mzimvubu and Great Kei as the only other systems having similar catchment and sediment characteristics. If *L. Lithognathus* are restricted to spawning on these few fluvial fans, the entire South African spawning habitat may be less than 50 hectares. Historically, there may have also been a west coast spawning population with the Orange having a suitable fluvial fan. Intensive beach-seine and gillnet fishing over the last 100 years may have seen this population become extinct or indiscernible.

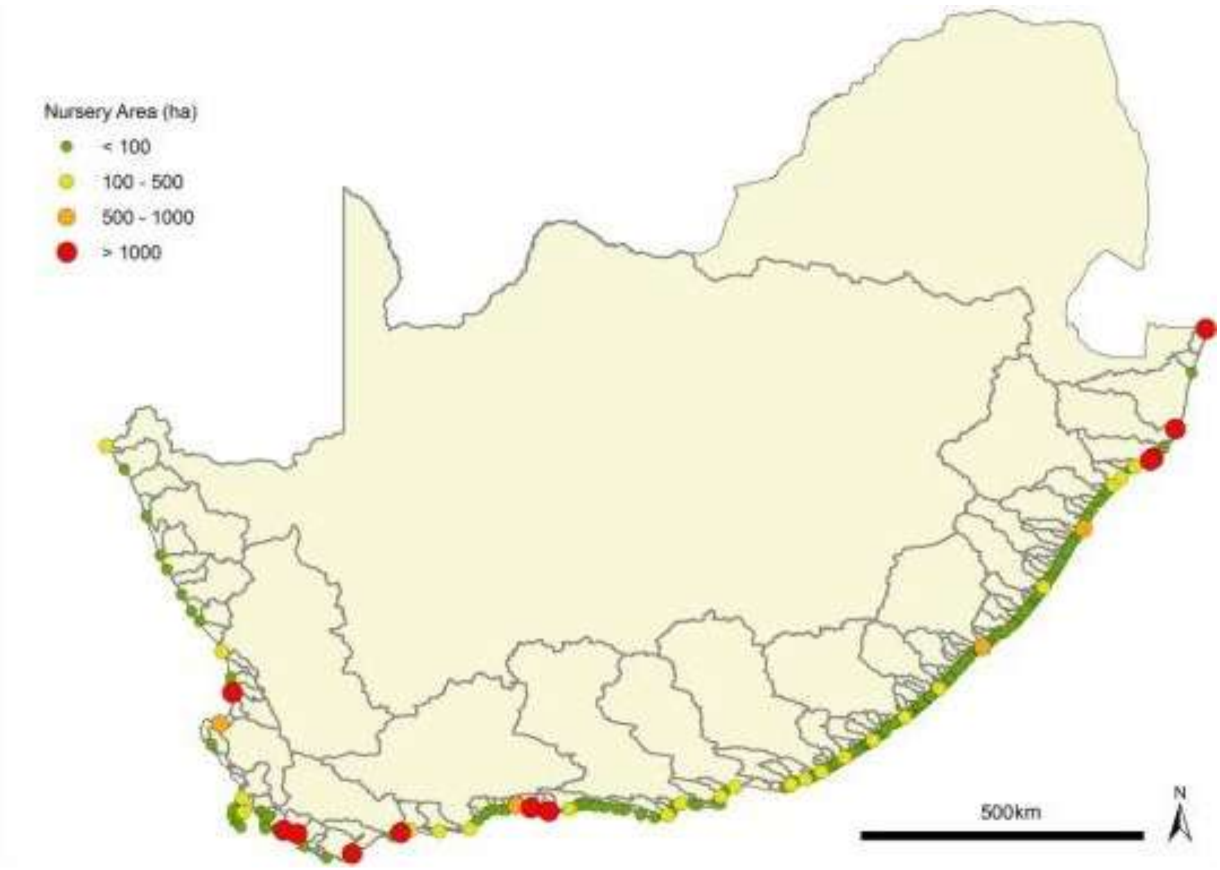

Figure 3.1 Important estuaries for nursery function

Zambezi (bull) sharks, *Carcharhinus leucas*, are a large predatory shark species commonly occurring in coastal waters of warm-Temperate, tropical and subtropical seas. It is one of few shark species physiologically capable of inhabiting salt- and freshwater systems, and is thought to utilize estuarine systems and freshwater rivers as pupping and nursery grounds. As such, estuaries are considered critical habitat for Zambezi sharks. Recent evidence suggests that, in certain parts of their distribution, Zambezi sharks exhibit philopatry to estuarine and river systems although the degree and nature of philopatry remain unknown. Studies utilizing satellite technology and acoustic telemetry have also demonstrated this species can undertake large-scale migrations, moving several thousand kilometres in a relatively short timeframe.

Zambezi sharks are taken as bycatch in fisheries throughout their range, and are increasingly targeted for the shark fin market and trophy fishing industry. Combined with increasing human-induced degradation of critical habitats Zambezi shark populations are becoming locally depleted in many areas. The species is currently listed as Near Threatened by the IUCN Red List.

In South Africa, Zambezi sharks occur from the Mozambican border to the Breede River on the southwest coast. Their occurrence in estuarine systems in South Africa is well-documented, although there is limited data available on pupping and nursery grounds. To date, the St Lucia Estuary remains the only known pupping ground for Zambezi sharks; however human activities in the estuary have likely compromised the reproductive capacity of this species.

In South Africa no studies have examined habitat requirements for neonatal, juvenile and adult Zambezi sharks. It is likely, however, that physico-chemical factors – as well as the physical characteristics of an estuary (e.g. depth, prey availability) – determine the suitability of a system for reproductive purposes. Based on these characteristics, several other estuaries have been identified as possible pupping and nursery grounds, including the Umzimvubu and Breede River systems. A rapid assessment of the physico-chemical and physical characteristics of South Africa's rivers – and therefore suitability for Zambezi sharks – indicates several of major river systems may be suitable habitat. These include (from West to East) the: Breede, Gouritz, Gamtoos, Sundays, Great Fish, Great Kei, Umtata, Umzimvubu, Mngazana, Thukela and Lake St Lucia systems. Although several of these systems may not be used for reproductive purposes, they should be considered critical habitat for ensuring the health of Zambezi shark populations in South Africa. Table 3.2 provides a summary of South Africa's important nursery areas. All estuaries larger than a 100 ha in total habitat were included in the list. In addition some smaller estuaries with known endemic fish or invertebrate species, e.g. East Kleinmonde that is the prime nursery for the Estuarine Pipefish, were also incorporated. Confirmed importance is indicated by a X, while a X? indicates unconfirmed status (but likely) as estuary and catchment characteristics indicate suitable habitat.

Table 3.2 Summary of South Africa's very important nursery estuaries

	Biodiversity	Kob species		Steenbras spawning grounds	Zambezi sharks	
		Juveniles	Sub-adults		Pupping	Juveniles
Orange (Gariep)	X		X			
Buffels	X					
Olifants	X		X			
Groot Berg	X		X			
Rietvlei/Diep	X					
Wildevoëlvlei	X					
Sand	X					
Bot/Kleinmond	X		X			
Klein	X		X			
Uilkraals	X					
Heuningnes	X		X			
Breëde	X		X		X?	X?
Duiwenhoks	X		X			
Goukou (Kaffirkui	X		X			
Gouritz	X		X			X?
Klein Brak	X		X			
Groot Brak	X		X			
Swartvlei	X					
Knysna	X	X	X			X?
Keurbooms	X		X			
Kromme	X		X			
Seekoei	X					
Kabeljous	X	X?	X			
Gamtoos	X	X?	X			X?
Swartkops	X		X			
Sundays	X		X			X?
Bushmans	X		X			
Kariega	X		X			X?
Kowie	X		X			
East Kleinemonde	X		X			
Great Fish	X		X		X?	X?

	Biodiversity	Kob species		Steenbras spawning grounds	Zambezi sharks	
		Juveniles	Sub-adults		Pupping	Juveniles
Mpekweni	X		X			
Mtati	X					
Mgwalana	X					
Bira	X					
Keiskamma	X		X	X?		X?
Tyolomnqa	X		X	X?		
Nahoon		X?	X			
Kwelera		X?	X			
Great Kei	X	X?	X	X?		X?
Nxaxo/Ngqusi	X					
Nqabara/Nqabarana	X					
Mbashe	X	X	X	X		X?
Xora	X					
Mtata	X	X?	X	X?	X?	X?
Mtakatye	X					
Mngazana	X		X		X?	X?
Mzimvubu	X	X?	X	X?	X?	X?
Mzimkulu	X		X			X?
Durban Bay	X		X		X?	
Thukela						X
Matigulu/Nyoni	X					
Mlalazi	X					
Mhlathuze	X		X		X?	X?
Richards Bay	X	X	X		X?	
uMfolozi	X	X	X		X?	X?
St Lucia	X	X	X		X	X
Kosi	X					

3.2.2 Freshwater flows to the marine environment

Freshwater flow reduction has severe consequences for marine biodiversity and resources through impacts on physical habitat, reduced nutrient inputs and alterations to important ecological processes (Gillanders and Kingford 2002, Lamberth and Turpie 2003, van Ballegooyen et al. 2007, Lamberth et al. 2009, Porter 2009). In South Africa, reduced river inputs have a significant impact on coastal and marine ecosystems around the entire South African coastline although impacts are expected to be more severe in the more nutrient poor marine environment of the east coast (van Ballegooyen et al. 2007). The impacts of altered fresh water flow reduction extend offshore with correlations between flow reduction and patterns in catches of commercial linefish documented more than 40 km offshore on the Thukela Banks (Lamberth et al. 2009).

Based on reductions in the 20 largest catchments in South Africa (those that contribute approximately1% or more of total MAR in the region), the total freshwater flow to the marine environment has been reduced by about 40% (more than 11 000 million m^3/year) (see Table 3.3). The greatest reduction is on the west coast (approximately 6 900 million m^3/year) but there are significant reductions along both the south (1 100 million m^3/year) and east coasts (2 900 million m^3/year). The larger river systems have experienced the greatest flow reduction and are therefore expected to have driven the most change in marine ecosystems. These include the Orange River on the west coast, the Thukela and Mzimvubu rivers in KwaZulu-Natal and the Breëde River in the Agulhas Bioregion.

Table 3.3 Summary of the flow modification for the 20 major cathment in South Africa

Catchment	MAR (Mill m^3/a)	% Change	% of SA Runoff
Orange/Gariep	10 833.0	56	28.6
Thukela	3 753.6	27	9.9
Mzimvubu	2 893.8	10	7.7
Breëde	1 785.0	42	4.7
Mzimkulu	1 478.2	25	3.9
Olifants	1 070.1	34	2.8
Great Kei*	1 064.1	15	2.8
Mkomazi*	1034	15	2.7
Groot Berg	916.0	46	2.4
uMfolozi	885.0	19	2.3
Mbashe*	836.0	10	2.2
Mgeni	682.9	61	1.8
Mhlathuze	645.0	20	1.7
Gouritz*	539.1	40	1.4
Great Fish**	525.4	30	1.4
Gamtoos*	500.6	35	1.3
Mvoti*	482.0	25	1.3
St Lucia	417.9	30	1.1
Mtata	377.8	54	1.0
Mtamvuna*	303.8	15	0.8

**Flow estimates provided by WSAM model and modified by expert opinion*
*** Great Fish Estuary receives additional flow through the Orange-Fish River Tunnel Transfer Scheme, but no detail is available on exactly how much (pers. comm. Prof Denis Hughes)*

The reduction of river flow leads to a reduced sediment supply to the coast with implications for beach and subtidal habitats. Reduced sediment input can change beach morphodynamic state, altering the beach biodiversity, accelerating beach erosion and can even lead to the loss of beach habitat (Harris et al. 2010). In the subtidal environment, riverine inputs provide important sediment inputs for the maintenance of unconsolidated sediment habitats. Reduced river inputs reduce the spatial extent of such habitats (van Ballegooyen et al. 2007).

Many of these habitats are also important for ecological processes. For example the endemic and imperiled white steenbras *Lithognathus lithognathus* spawns on submarine fluvial fans, a localised habitat of limited extent, associated with mixed mud and sand banks deposited by rivers in the southeast Cape coast (Bennett 1993). Changes in salinity and water temperature linked to flow alteration also impact thermohaline fronts which affects plankton feeding communities and the fish, birds and mammals that feed on the concentrated food associated with these habitats (van Ballegooyen et al. 2007).

Important processes that can be compromised through altered fresh water flow include nursery functions, environmental cues, productivity and food web processes. Increased frequency of estuary mouth closures and associated conditions due to reduced freshwater flow can also disrupt lifecycles and connectivity, and deprive fish and invertebrates of the important nursary function of estuaries (Whitfield 1998). Sediment input leads to turbidity providing an important refuge for fish which is a key component of estuarine, coastal and offshore nursary areas (Whitfield 1998, Lamberth et al. 2009). Reduced turbidity can alter predation pressure and the catchability of fisheries resources (van Ballegooyen et al. 2007). Altered freshwater flow leads to changes in important environmental cues such as those relevant for spawning, recruitment and migration (Lamberth et al. 2009). Changes in spawning intensity have been correlated with altered fresh water flow (QuiÑores and Montes 2001, Demetriades et al. 2000).

Catchment derived nutrients are an important component of coastal and marine foodwebs stimulating phytoplankton production. The impacts of reduced nutrient supplies will travel through coastal and marine ecosystems via foodwebs (van Ballegooyen et al. 2007). Reduced detritus may also impact on coastal and marine foodwebs as river-associated detritus and associated epiphytes are believed to be an important food source for microorganisms, filter feeders, detritivorous fish and invertebrates (Berry et al. 1979, Schleyer 1981, Berry and Schleyer 1983, Whitfield 1998, Porter 2009). In KwaZulu-Natal, an isotope study showed that suspended riverine particulate organic matter (terrestrial, aquatic plant material and plankton) plays an important role in supporting inshore filter-feeder communities, i.e intertidal and subtidal assemblages dominated by the sea-squirt known as red bait *Pyura stolonifera*, mussels *Perna perna*, and oysters *Striostrea margaritacea* and *Saccostrea cuccullata* (Porter 2009). Porter (2009) found that between 8 and 33% of filter-feeder diets consisted of material introduced to the sea by rivers and concluded that rivers play an important trophic role in promoting filter-feeder biomass in the Natal Bioregion. He also demonstrated the links between river, inshore and pelagic ecosystems, highlighting the need for adequate freshwater supplies for the maintenance of the integrity of coastal and marine ecosystems.

Changes in freshwater flow and associated variations in turbidity, nutrients and sediment supply can impact fisheries resources, alter catch composition and reduce the economic returns of fisheries (Lamberth and Turpie 2003, Lamberth et al. 2009). Fisheries resources in South Africa that have, or may have been compromised by reduced fresh water input include linefish (Lamberth et al. 2009), prawns (Demetriades et al. 2000), and filter feeding invertebrates in the intertidal and shallow subtidal (Porter 2009).

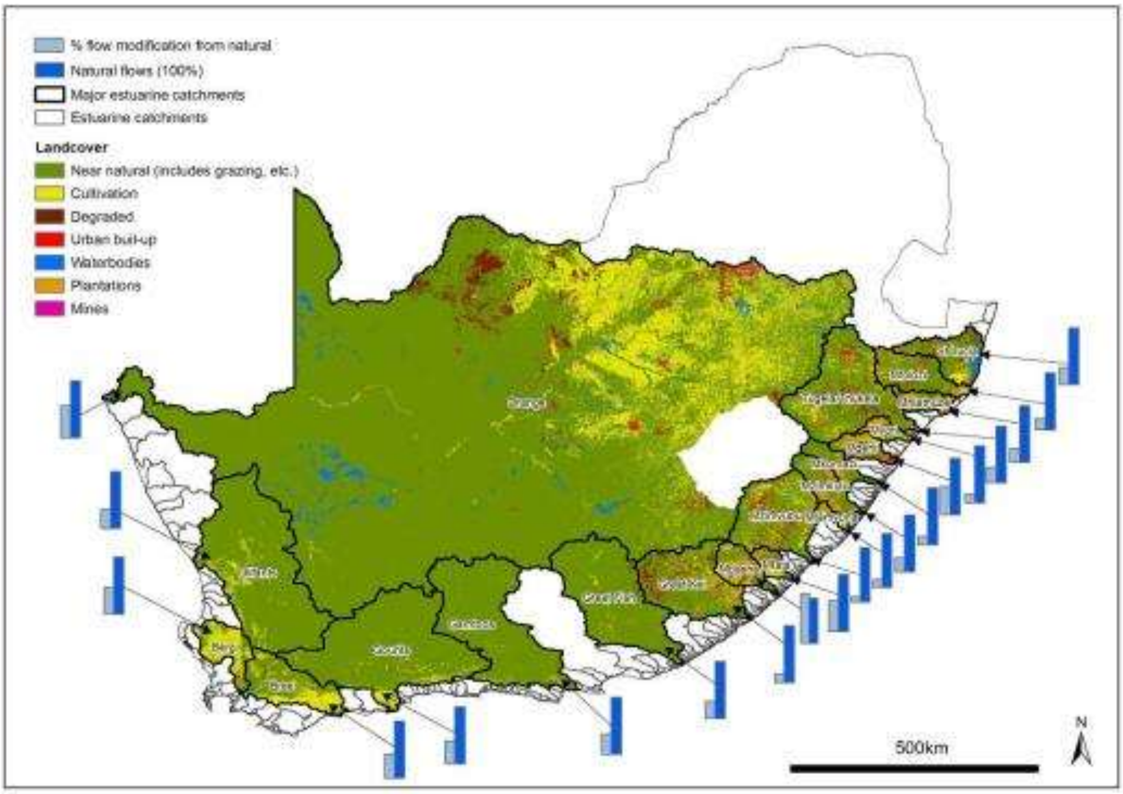

Figure 3.2 Freshwater flow modification of the 20 largest catchments of South Africa

Lamberth et al. (2009) identified significant relationships between flow and the catches of 14 linefish species (more than 90% of the total catch) on the Thukela Banks in KwaZulu-Natal. Most fish responded negatively, with reduced catches correlating with reduced flow (after a lag phase), slinger *Chrysoblephus puniceus* and squaretail kob *Argyrosomus thorpei,* the most important species in the fishery, showing the most marked response.

The ecological needs of the coastal and marine environment must be considered in the allocation of fresh water resources to ensure healthy functioning marine ecosystems that support productive and sustainable fisheries.

3.2.3 Carbon sequestration

Coastal wetlands and marine ecosystems are gaining increased attention for the carbon they store in biomass and especially sediments (Crooks et al 2011). These ecosystems sequester carbon within standing biomass, but even more within soils. Soil organic matter contains more than three times as much carbon as either the atmosphere or terrestrial vegetation (Schmidt et al. 2011). Wetlands in saline environments have the added advantage of emitting negligible quantities of methane, a powerful greenhouse gas, whereas methane production in freshwater systems partially or wholly negates short-term carbon sequestration benefits. This makes them potential sources of significant greenhouse gas (GHG) emissions if disturbed, but also valuable for nature-based approaches to climate change mitigation.

Table 3.4 Summary of potential greenhouse gas (GHG) reductions due to soil building in coastal wetlands (Source: Crooks et al 2011)

Wetland Type	Carbon Sequestration	Methane Production	Net GHG Sink
Mudflat (saline)	Low	Very Low	Low to Medium
Salt Marsh	High	Very Low	High
Freshwater Tidal Marsh	Very High	High to Very High	Neutral or variable
Estuarine Forest	High	Low	High
Mangrove	High	Low to High*	Low to High*
Sea grass	High	Low	High

**salinity dependent*

Mangroves, marshes and submerged macrophytes remove carbon from the atmosphere and lock it into the soil, where it can stay for millennia. Unlike terrestrial forests, estuarine ecosystems are continuously building carbon pools, storing significant amounts of carbon in the sediment below them. When these systems are degraded due to drainage or conversion for agriculture and mariculture, they emit large and continuous amounts of CO_2 to the atmosphere.

The most effective way to maintain wetland carbon pools and prevent emissions to the atmosphere is avoiding degradation through protection and sustainable management. Restoration of degraded estuarine ecosystems has a twofold benefit: reducing ongoing losses and rebuilding carbon stores.

Globally the current rates of degradation and loss of coastal wetlands are up to four times those of tropical forests (Crooks et al. 2011). Salt marshes and freshwater tidal marshes have lost more than 50% of their historical global coverage. Destruction of about 20% of the world's mangroves, has led to the release of centuries of accumulated carbon. This has also disturbed natural protection against storm surges and other weather events.

Protecting these estuarine ecosystems, and the carbon they store, can be of significant benefit to coastal communities, with shoreline protection and increased fisheries productivity among the co-benefits provided by healthy estuaries. Thus estuaries contribute to the resilience of coastal community while sequestering CO_2. If wetlands conservation can be linked to carbon markets, communities will have a way to pay for conservation which will generate local and global benefits (Crooks et al. 2011).

South Africa have about 11 400 ha of salt marsh, 4 300 ha of mangroves, 1 300 ha of submerged macrophytes, 6 300 ha of swamp forest, and 4 000 ha of sand and mud banks. South Africa’s current climate policies, unfortunately, contain few incentives for the protection and/or restoration of degrade coastal wetlands and estuaries. These ecosystems need to be protected and incentives provided to avoid their degradation and improve their condition in order to be included into carbon emission reduction strategies and in climate negotiations.

3.2.4 Flood regulation

South Africa’s estuaries provide a significant buffer against floods with a total open water area of 61 000 ha and flood plain storage, as represented by the estuarine functional zone, of nearly 171 000 ha, of which 60% is in the Subtropical biogeographic region.

The different types of estuaries in the different rainfall zones vary in how much flood regulation (attenuation) they can provide. Large, permanently open systems, such as the Knysna Estuary, can have such a significant storage to runoff relationship that a 1:50 year flood event will only raise the water level in the estuary by a few centimeters. In contrast, the relatively small, incised temporarily open estuaries of the KZN region provides substantially less flood regulation as a result of much lower storage to runoff relationships. Nevertheless, the estuarine functional zone still tends to provide more storage than that of most rivers channels.

Unfortunately, inappropriate development in the estuarine space is hindering the ability of estuaries to buffer the surrounding landscape against floods. Flow reduction is increasing mouth closure and thereby increasing the risk of flooding. Artificial breaching at low water levels is reducing the flushing of sediments during breachings and causing cumulative sediment buildup, thereby creating constricted outflow channels and increasing the risk of high flood levels.

An example of the unintended consequences of the disruption of these ecosystem services are the recent floods occurring at the Slang Estuary near Oesterbaai (Figure 3.3). The Slang is a very small, temporarily open/closed estuary along the south coast. The estuary runs through a dune belt and is fed by a very small catchment. Water resources development in the catchment removed the baseflows that ensured the sustained erosion of the dunes encroaching on it, and caused dune formation in the estuarine functional zone. During the floods of August 2011 the system created a new outlet channel that cut through some low lying adjacent developments.

Wetland destruction in estuary catchments is also increasing the magnitude of floods. A case in point is the destruction, through poor agricultural practices, of the peat wetlands in the Goukou and Duiwenhoks catchments. The loss of these wetlands upstream of the estuaries has changed the magnitude and duration of floods and reduced/removed baseflows during the low flow period (pers. comm. Jean Du Plessis, CapeNature).

Preventing development in the estuarine functional zone and ensuring the baseflows required to maintain open mouth conditions will ensure the continuous provision of this ecosystem service.

3.2.5 Storm protection

The sand berms that develop in front of more than 75% of South Africa's estuaries during low-flow periods, provide significant protection against elevated water levels and wave action generated by coastal storms. With the exception of the winter rain fall zone, most South African estuaries are closed during the winter, which is generally when the highest risk of severe sea storms occur. The higher the sand berm at the mouth, the greater the protection from the wave action generated by storms.

(a) Oesterbaai 1 hour before the flood

(b) New mouth being scoured

(c) Flood damage

Figure 3.3 Collage of images illustrating the power of water under flood conditions at the Slang Estuary, August 2002 (Source: T Bornmann)

For example, the second and fourth highest water levels ever recorded at the Groot Brak Estuary, 2.4 m MSL on 1 September 2008 and 2.24 m MSL on 25 May 2002 respectively, was the result of sea storms. Over-wash from the sea side caused a breaching that left the system unprotected from coastal waves. Low lying properties sustained substantial damages due to this event. Artificial breaching, development in the coastal zone, stabilization of windblown sand, sand mining and sediment trapping by dams can all reduce the ability of estuaries to provide this service.

Figure 3.4 Coastal storm overtopping sand berm at mouth and causing flooding at Groot Brak, 1 September 2008 (Source: J Kriel, DWA)

3.2.6 Safe bathing areas

South Africa's very exposed, high energy coastline has few sheltered beaches that are safe for bathing. High wave action and strong currents are more the norm than the exception.

In contrast, South Africa's nearly 300 estuaries offer easy access, warmer waters, shallow depths and weak currents that make them very attractive to bathers. These natural assets have, regrettably, been largely compromised in most urban areas (e.g. City of Cape Town and eThekwini) through poorly planned storm water runoff systems and Waste Water Treatment Works discharges.

Significant bacteriological contamination of water resources requires that local authorities prohibit access and prevent certain recreational activities to ensure human well being. The loss of safe estuary bathing areas directly impacts children and weak swimmers who are forced to use the more exposed marine environment.

3.2.7 Estuarine plants as food, fuel and building resources

Elsewhere in the world, halophytes (salt tolerant plants) are used as an alternative energy or food source due to their high oil and protein content. Oil yield of these species may be up to 30% more than conventional vegetable-oil crops such as canola and sunflowers. *Salicornia* and *Sarcocornia* are salt marsh species used as a source of oil. These and similar plants are also used as a food source, both as a staple diet and sought after culinary delight. The leaves of *Sarcocornia* species (samphires) are used in some parts of the world (e.g. USA and England) and either eaten in salads or pickled with oil and vinegar. They are also traditionally used as ingredients in soap and glass, hence the other common name, glassworts.

Traditional use of *Sarcocornia* and *Salicornia* in South Africa (see Figure 3.5) is limited, but the aquaculture industry has expressed an interest and begun exploring their potential culture. In particular there are a number of examples from around the world where halophytes have been successfully used as biofilters to remove nutrients and salts from effluent water from land based mariculture activities such as shrimp farming. Most harvesting takes place from the wild but with increased salinisation of agricultural lands halophytes are a possible future food source.

Figure 3.5 *Sarcocornia tegetaria* in Groot Brak Estuary (Source: T Riddin)

Because halophytes display rapid growth, they can be valuable in the biofuel industry, as they are a productive source of good quality ligno-cellulosic biomass, which is used to produce ethanol. An added benefit is that they are a persistent crop, not needing to be resown each growing season, nor do they require fertilizers or pesticides. By far the greatest benefits of halophyte culture are that, unlike current biofuel production, it doesn't displace food crop production nor use excessive quantities of freshwater. In many instances, halophytes are been cultured in nutrient farms to reduce elevated nutrient levels in estuary waters before these reach the sea. The resultant crops are harvested for biofuel.

Two other species from the reed and sedge community, *Juncus kraussii* and *Phragmites australis*, are commonly used in KwaZulu-Natal by the local community for mat and basketry. In the St Lucia Estuary and Umlalazi Estuary near Mtunzini, Ezemvelo KwaZulu-Natal Wildlife in collaboration with the iSiMmangaliso Wetland Park Authority, have implemented a harvesting license programmes to collect material from these systems as part of a sustainable development initiative are implemented. These and similar plants are also used in the thatching industry.

Mangroves are intensively harvested (mostly illegally) for firewood (the white mangrove *Avicennia marina*) and for building purposes (the red and black mangrove). See Section 14.1 Species of special concern for more detail on the harvesting of estuary plants.

3.3 Summary

Estuaries provide a host of ecosystem services upon which local and coastal communities depend, including:

- Nursery function for estuarine and marine fish, with some of the more muddy Temperate estuaries such as the Mbashe, Umtata, Keiskamma and Great Kei being highlighted for collapse resources such as the White Steenbras and Dusky Kob.
- Provision of freshwater (both surface and groundwater), nutrients, detritus and sediments to the coastal environment that is linked to fisheries (e.g. prawns and line fishery) and important ecological processes. Freshwater flow reduction has severe consequences for marine biodiversity and resources through impacts on physical habitat, reduced nutrient inputs and alterations to ecological processes.
- Estuaries offer easy access, warmer waters, shallow depths and weak currents that make them very attractive to bathers. These natural assets have, regrettably, been largely compromised in most urban areas through poorly planned storm water runoff systems and Waste Water Treatment Works discharges.
- Coastal wetlands and marine ecosystems are gaining increased attention for the carbon they store in biomass and especially sediments. Healthy estuaries contribute to the regulation of greenhouse gasses and provide opportunities for carbon trading.

- South Africa's estuaries provide a significant buffer against floods with a total open water area of 61 000 ha and flood plain storage, as represented by the estuarine functional zone, of nearly 171 000 ha, of which 60% is in the Subtropical biogeographic region.
- The sand berms that develop in front of more than 75% of South Africa's estuaries during low-flow periods, provide significant protection against coastal storms.
- Halophytes (salt tolerant plants such as *Sarcocornia*) can be used as an alternative energy or food source due to their high oil and protein content. By far the greatest benefits of halophyte culture are that, unlike current biofuel production, it doesn't displace food crop production nor use excessive quantities of freshwater.
- Mangroves, reeds and sedges are also used as building material and basketry.

4. THE ESTUARINE FUNCTIONAL ZONE

L van Niekerk, C Petersen, V April, F Daniels, A Maherry & T Malebu

In 2010, the estuarine functional zone – encapsulating not only the estuary water body but also supporting physical and biological processes and habitats necessary for that estuarine function and health – was listed as Notice 3 (GN R 546) under the National Environmental Management Act (NEMA), Environmental Impact Assessment (EIA) Regulations (2010). This notice stipulates that estuaries (defined by the spatial delineation of the estuarine functional zone) are "sensitive areas" that require environmental authorisation before developments within this zone may proceed. These regulations are not backdated but are meant to curb inappropriate future development in the estuarine functional zone.

The spatial demarcation of the estuarine functional zones will enable, for the first time, their explicit incorporation into planning and approval processes, such as Provincial conservation plans and municipal Integrated Development Plans. Importantly the estuarine functional zone increases the "traditional estuary" considerably, now including habitats such as floodplain areas, previously not considered essential for estuary functioning. A summary of the extent of the estuarine functional zone in South Africa is provided in Table 4.1 and Figure 4.1.

Table 4.1 Extent of the Estuarine Functional Zone per biogeographically region

Biogeographically region	Proportional Estuarine functional zone (ha)	Percentage of Total Estuarine functional zone
Cool Temperate	26 516	16
Warm Temperate	41 785	24
Subtropical	102 746	60
Total	**171 046**	**100**

This chapter details the approach and methods that were adopted in the delineation of the estuarine functional zone for South African estuaries, as well as the advantages thereof.

4.1 Approach and method

Estuaries have little permanent habitat structure; unlike for example a rainforest, as estuarine habitats are constantly forming and eroding at various temporal and spatial scales. Over longer time scales the total habitat area occupied by the various estuarine habitat types tend to remain more or less constant, while the actual spatial location of the various estuarine habitats is highly likely to change between resetting events (e.g. larger floods). This relative ephemeral nature of estuarine habitat presents an assessment and planning challenge. Biodiversity protection requires the protection of habitat and ecological and evolutionary processes. In order to do this it is important to define the space within which estuaries function to ensure their present and future health. In international literature, an estuary is defined as a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with freshwater derived from land drainage (Elliott and McLusky 2002; Cameron & Pritchard 1963; Pritchard 1967). Most South African estuaries are relatively small in comparison with those of the northern hemisphere.

The mean annual runoff of most South African rivers is very variable, fluctuating between floods and extremely low to zero flow; which has led to a number of different definitions for South African estuaries that recognise that these systems may not necessarily have a 'free connection with the sea' but are 'either permanently or periodically open to the sea' (Day 1980; Day 1981; Heydorn 1989, CSIR 1992). While Fairbridge (1980) proposed setting the upstream extent of an estuary as the limit of tidal rise, in some instances in South Africa, e.g. the Bot and Klein estuarine lakes, salinity penetration can be detected further upstream than tidal variation. This phenomenon stems from the fact that South African estuaries are microtidal (< 2 m tidal range) and in large systems the tidal rise can be barely discernible (< 5 cm) and easily masked by wind action, while more subtle hydrodynamic processes, such as diffusion, drive salinity penetration further upstream. In such cases the inland limit of salinity penetration represents the upstream boundary of an estuarine system. Back flooding under closed mouth conditions also increase the upstream penetration of salinity beyond that of the open (tidal) state.

In this assessment an estuary is defined as ''a partially enclosed permanent water body, either continuously or periodically open to the sea on decadal time scales, extending as far as the upper limit of tidal action or salinity penetration. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area or when there is little or no fluvial input an estuary can be isolated from the sea by a sandbar and become a lagoon or lake which may become fresh or hypersaline”.

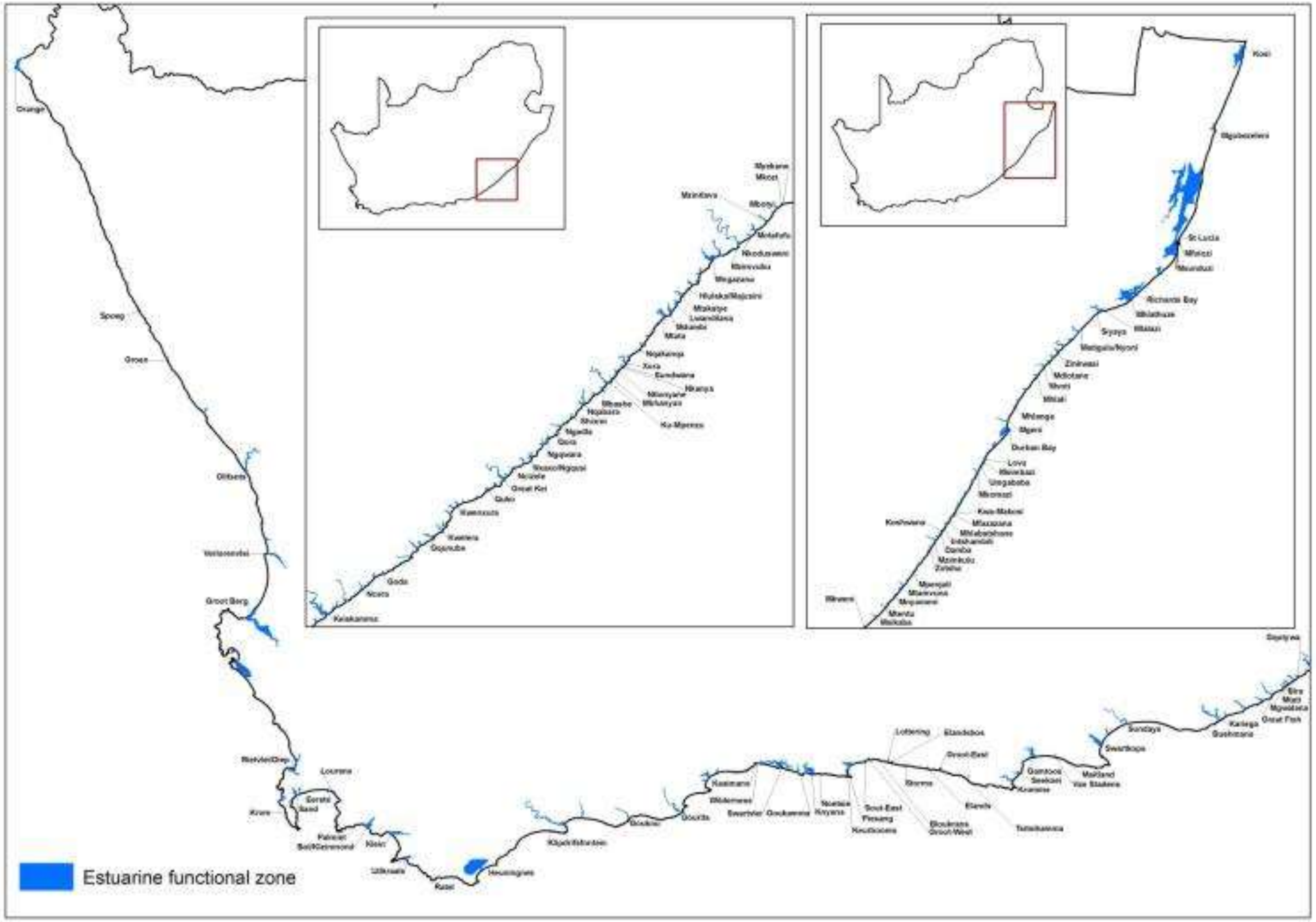

Figure 4.1 Estuarine Functional Zone for South Africa's estuaries

There are over 371 river outlets along the SA coast (see Appendix A for full list), but not all of these are deemed functional estuarine systems, i.e. representative of significant biological activity (Harrison et al. 2000). Since South Africa has a very variable climate and high energy coastal conditions, even systems that only open sporadically to the sea (e.g. every 4 – 10 years) are utilised by estuarine associated or dependent biota, e.g. by fish as nursery areas. The assessment therefore considered all permanent coastal water bodies (i.e. water bodies that do not dry out) that are sporadically or permanently linked to the sea as potentially estuarine systems, e.g. the Groen and Spoeg estuaries along the arid West coast were included, while ephemeral systems such as the Holgat, which dries out, were excluded from the assessment. In addition, using existing information and data sets (vegetation and fish) and anecdotal information, all systems were evaluated by a panel of national experts and listed as functional or not (Harrison et al. 2000). Some very small (< 500 m in length) permanent coastal water bodies that link rivers or streams to the sea were excluded from this assessment until such time as field studies have indicated that they should be considered as functional estuaries, i.e. only small systems that had data indicating they were biologically significant were included. Rivers entering the sea as waterfalls, e.g. those along the Tsitsikamma coast, were also excluded. In addition, a few small highly modified systems in urban areas were also excluded from the assessment on the basis that they were not functional systems.

In total 71 coastal inlets were not assessed, 20 in the Cool Temperate, 33 in the Warm Temperate and 28 in the Subtropical biogeographical region. It is important to note that not including these systems in the NBA assessment means that they lack adequate protection from future developments. It is therefore recommended that a separate study be under taken to demarcate these smaller and/or more ephemeral outlets and integrate them into current planning frameworks.

Mapping was undertaken for nearly 300 functional estuarine systems along the South African coastline. For each estuary the estuarine functional zone (estuarine ecosystem area) and open water areas were digitized using Spot 5 imagery (2008) and Google Earth. For the most part the images were relatively cloud free, but where cloudy conditions occurred on SPOT 5 images, Google images were used. The lateral boundaries included all the associated wetlands, intertidal mud and sand flats, beaches and foreshore environments that are affected by riverine or tidal flood events (Edgar 2000).The 5 m topographical contour (obtained from Chief Directorate Surveys and Mapping) was used as the boundary to delineate the estuarine functional zone. Where the 5 m contour was not available in digital format, orthophotos (1:10 000) were scanned, georeferenced and the 5 m contour was digitized. Where no orthophotos were available (13 systems), floodplains were mapped from Spot 5 imagery using changes in topography and vegetation types as indicators. From the estuarine functional zone delineation, spatial data such as area, length and perimeter (estuary coastline) and distance to the next system could be inferred.

The 13 estuaries for which there were no topographical data available were:

- Mngazana
- Mngazi
- Mntafufu
- Mzimvubu
- Mzintlava
- Nkodusweni
- Spoeg
- Ntlupeni
- Sinangwana
- Steenbras
- Buffels (Oos)
- Rooiels
- Groen

The estuary mouth was taken as the downstream boundary of an estuary or, where the mouth was closed, the middle of the sand berm between the open water and the sea. The upstream boundary was determined as the limits of tidal variation or salinity penetration, whichever penetrates furthest. This is in line with recent scientific studies and the administrative definition of a South African estuary (see Figure 4.4) (Van Niekerk and Taljaard 2007, DWAF 2008).

Wherever possible the upstream boundary was derived from the literature, expert judgment or field observations. In a number of systems no data were available and the upper boundary was taken as the 5 m topographical contour (bearing in mind that the tidal range in South Africa is microtidal (< 2 m) and sand bars at closed estuary mouths can sometimes build up as high as + 4.5 m MSL). The upper boundaries were also screened against other existing spatial delineations, e.g. the KwaZulu-Natal Estuaries database (Version 1.00.02) and the delineation developed for Durban estuaries (Forbes and Demetriades 2008) with preference given to data from the larger scale studies. Spatially files were converted to GoogleEarth (KMZ formats) and mailed for review to members of the Consortium for Estuarine Research and Management (CERM) for comment.

Figure 4.2 Example of spatial delineation using Google Earth. Light blue areas delineate the estuarine floodplain <5 m above msl.

Figure 4.3 Example of spatial delineation using Spot 5 (note the presence of cloud cover in the southwestern portion of the image).

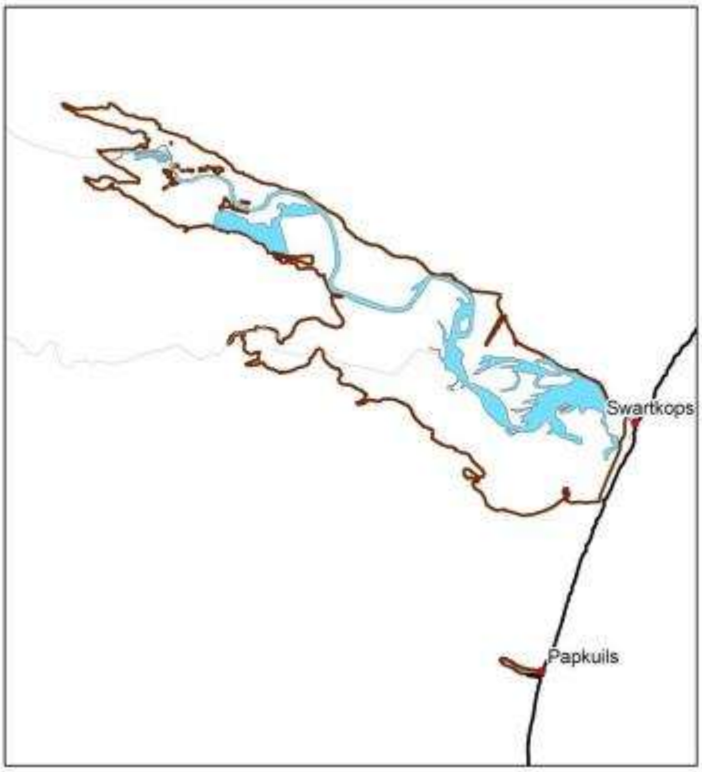

Figure 4.4. Example of openwater and estuarine functional zone delineation.

4.2 Advantages of the delineation of the Estuarine Functional Zone

South African estuaries have long suffered a lack of national scale spatial data for planning purposes. Using the 5 m topographical contour as a delineation boundary holds the following biodiversity and planning advantages:

a) The 5 m contour encapsulates most dynamic areas influenced by long-term estuarine sedimentary processes, i.e. sediment stored or eroded during floods, changes in channel configuration, aeolian transport processes, and changes due to coastal storms. Allowing for natural variability is important as these are some of the key physical processes that drive biodiversity along the South African coastline;

b) The 5 m contour encompasses the floodplain and estuarine vegetation that contribute detritus (food) and provide refuge during high flow events from strong currents. Salt-marsh vegetation can occur at distances greater than 500 m away from the surface water at a number of the larger estuaries, e.g. Olifants, Berg, Goukou and Klein Brak. Most estuarine-associated biota occurs under the 5 m contour, as this is as far as the influence of the ocean can be detected on land, even during storm conditions.

c) Temporarily open/closed estuaries (75% of South African systems) can close at water levels of between 2.5 and 4.5 m above msl. The 5 m contour allows for water-level increases due to backflooding under closed mouth conditions or wave action from high winds or exceptionally high tides;
d) In most cases, the 5 m contour allows for the inclusion of a buffer zone of terrestrial vegetation that represents the transition between terrestrial and coastal ecosystems;
e) The 5 m contour should provide a buffer zone that can allow an estuary to retreat in the event of sea-level rise due to climate change. It also allows for the inclusion of some terrestrial fringe vegetation that contribute detritus to the system and refuge areas for many animal species during floods;
f) An accurate delineation of the high-water mark is not available for the entire South African coastline;
g) Flood lines (1:50/1:100) for estuaries are often inaccurately determined under open mouth conditions, which leads to underestimation of flood heights. In the absence of long-term berm height data (which can vary substantially under different climatic conditions) the 5 m contour provides the best protection against natural hazards such as floods and storms;
h) The 5 m contour minimizes the risk of pollution to estuaries. Septic tanks are sunk about 2 m into the ground. During closed mouth conditions (and very high tides) density differences between fresh and salt water causes drainage problems or infrastructure damages if tanks are not situated not above 5 m;
i) Water resources development and land-use change in the catchment can lead to changes in mouth behaviour (e.g. change in Uilkraals Estuary type from permanently open to temporarily open/closed);
j) The 5 m contour data is available from the Chief Directorate: Surveys & Mapping, Mowbray, as a GIS layer or on black-and-white 1:10 000 orthographic maps. More detailed topographical data are not available on a national scale.

For all the above mentioned reasons it should be clear that, in some cases, the estuarine functional zone goes beyond the 5 m contour for one or more of the following reasons. In deeply incised floodplains, where the river/estuary bed may be meters below the mapped floodplain area, tidal action and/or backflooding may be detected further upstream than indicated by the 5 m contour on the topographical map. This is an artefact of the mapping process and may need site-specific data to correct.

For some narrow, deeply-incised estuaries with very large catchments the 1:20 year flood lines may be above the 5 m contour (i.e. limited floodplain area in relation to significant flood volume), e.g. Mzimkulu. In such cases it is recommended that a detailed topographical survey be conducted and the flood line estimated following engineering principles to demarcate more dynamic areas and indicate flood risk on a more local scale. The littoral active zones adjacent to an estuary can stretch beyond the 5 m contour, e.g. dune fields next to the Duiwenhoks and Sundays estuaries, and should be incorporated in the estuarine functional zone in site specific cases.

In summary, the delineation of the estuarine functional zones for South African estuaries elevated the status of estuaries from merely a points layer (X,Y data set) to spatially demarcating the space where most functions occur. While the incorporation of the estuarine functional zone under the NEMA Regulations is a major achievement, it is important that the estuarine functional zones are also recognised and incorporated into regulations to be drafted under the ICM Act (specifically Chapter 4 of the Act).

5. PHYSICAL CHARACTERISTICS

L van Niekerk, C Petersen & A Maherry

This section sets out to define some of the key physical characteristics of South Africa's estuaries. Important features are highlighted, and in some cases categorized to provide a more detailed perspective on estuarine biodiversity distribution and the forces that drive it. Categorization was done to reflect the dominant condition of an estuary. For example, categorising an estuary as a marine dominated system does not imply that it never has mixed or freshwater characteristics, but rather that it is predominantly in a saline state and that its biota should reflect that.

The project was initiated with a literature review of all the physical information available on South African estuaries. Special attention was given to grey literature as most large- scale data sets were generated as part of engineering studies to various government departments and authorities (Noble and Hemens 1978; Jezewski, Pyke and Roberts 1984, Jezewski and Roberts 1986; Allansonet al. 1990; CSIR 1986; 1987a, 1987b, 1987c; 1988). Few of these datasets were ever published. The project therefore set out to tabulate available information and update these with more recent studies, especially the more detailed ecological water requirements studies (referred to as Resource Directed Methods or Reserve studies) conducted for the Department of Water Affairs (DWA).

5.1 Rainfall Patterns

According to Brown and Jarman (1978) the South African coast spans three biogeographical regions (or climatic zones), namely the cool Temperate west coast, warm Temperate south coast and subtropical east coast. Rainfall patterns in the different regions vary greatly as a result of South Africa's highly variable climate. River inflow to the estuaries is determined by these climatic conditions, as well as the size and shape of the catchment, the latter controlling the magnitude and flow distribution of runoff (Reddering and Rust 1990). Catchment size varies significantly, ranging from very small (less than 1 km^2) to very large (greater than 10 000 km^2), with those in the cool Temperate region tending to be larger than those in the warm Temperate and subtropical regions.

The overall feature of the Mean Annual Precipitation (MAP) distribution over South Africa is that it decreases fairly uniformly westwards from the Drakensberg escarpment across the interior plateau, with rainfall patterns strongly affected by irregularities of terrain between the escarpment and the ocean along the southern and the eastern coastal margins. According to Lynch (2004), approximately 20% of South Africa receives less than 200 mm MAP, and 47% receives less than 400 mm per annum (Figure 5.1), the result of the presence of subtropical high pressure cells which inhibit rainfall generation because of predominantly subsiding air. Only about 9% of South Africa receives a MAP in excess of 800 mm. KwaZulu-Natal is the wettest region of South Africa while the Western Cape has the highest range of MAP, and the highest individual point rainfall at an estimated 3 198 mm per annum (Lynch 2004). Because rainfall-runoff processes are nonlinear, with a larger proportion of rainfall being converted to runoff as a catchment becomes wetter, it should be clear that the rainfall to runoff relationship is much higher in the Subtropical regions than in the Temperate regions. This, in turn, also suggests that on average the smaller, temporarily open/closed estuaries of the Subtropical region should be open to the sea significantly more than similar sized estuaries (fed by similar size catchments) in the Temperate coastal areas (in areas of similar wave exposure and sediment availability).

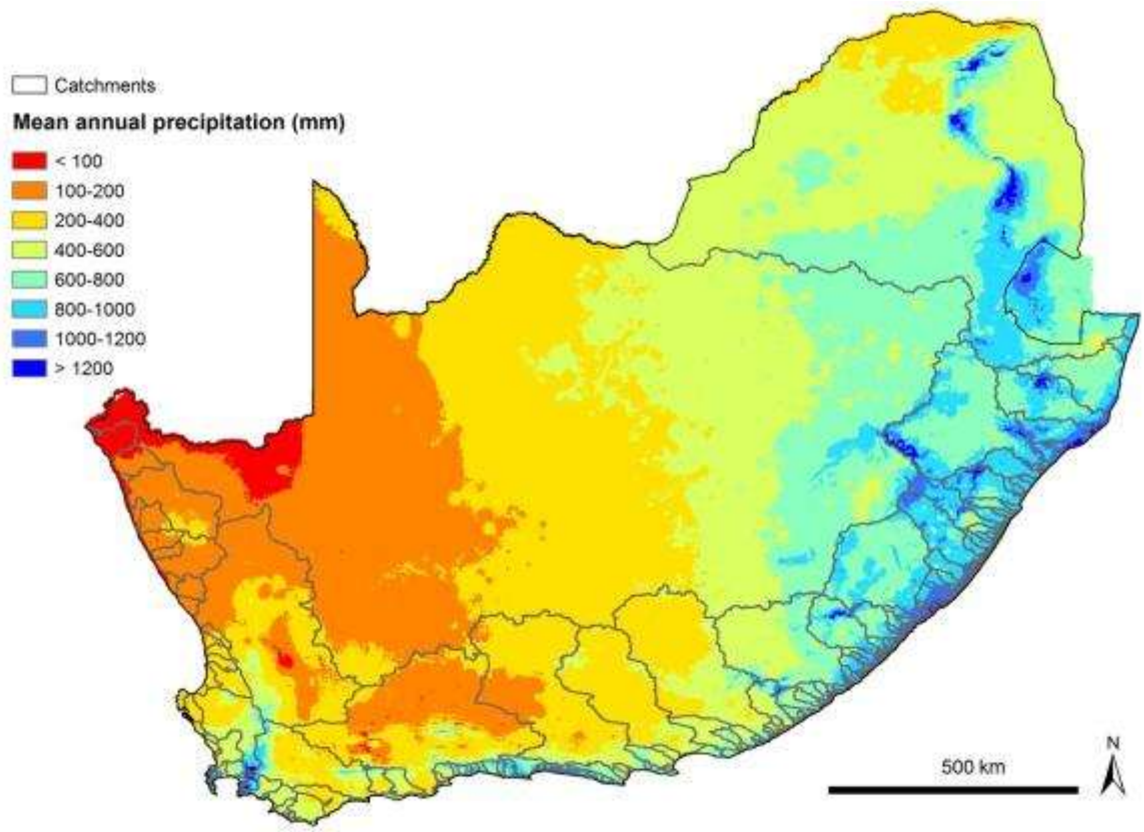

Figure 5.1 Mean Annual Precipitation of South Africa (Source: Schulze and Lynch 2007).

An area may have high or low average rainfall, a high or relatively low variability in rainfall from one year to the next, or its rainfall may be concentrated over a short rainy season or spread over a longer period. That does not, however, indicate anything about the season in which the rain falls - be it predominantly in winter, throughout the year or in summer; and if in summer whether it be in early, late or very late summer. Rainfall seasonality is an important hydrological consideration (Schulze and Maharaj 2007), particularly when viewed in light of estuarine ecological functioning and recruitment processes which predominantly occur in spring and early summer (Lamberth et al. 2008).

Rainfall seasonality, by primary catchment, is shown on the accompanying map (Figure 5.2). The winter rainfall regions have peak runoff during the winter months June, July and August. The early summer regions have rainfall concentration in December or earlier, the mid-summer rainfall region peaks in January, late summer peaks in February, and the very late summer regions rainfall peaks from March to May (Schulze and Maharaj 2007, Davies and Day 1998). The winter rainfall region in the west and the all year rainfall region in the south are seasonally clearly defined, while over the summer rainfall region the general trend is for rains to fall later as one moves towards the west (Schulze and Maharaj 2007).

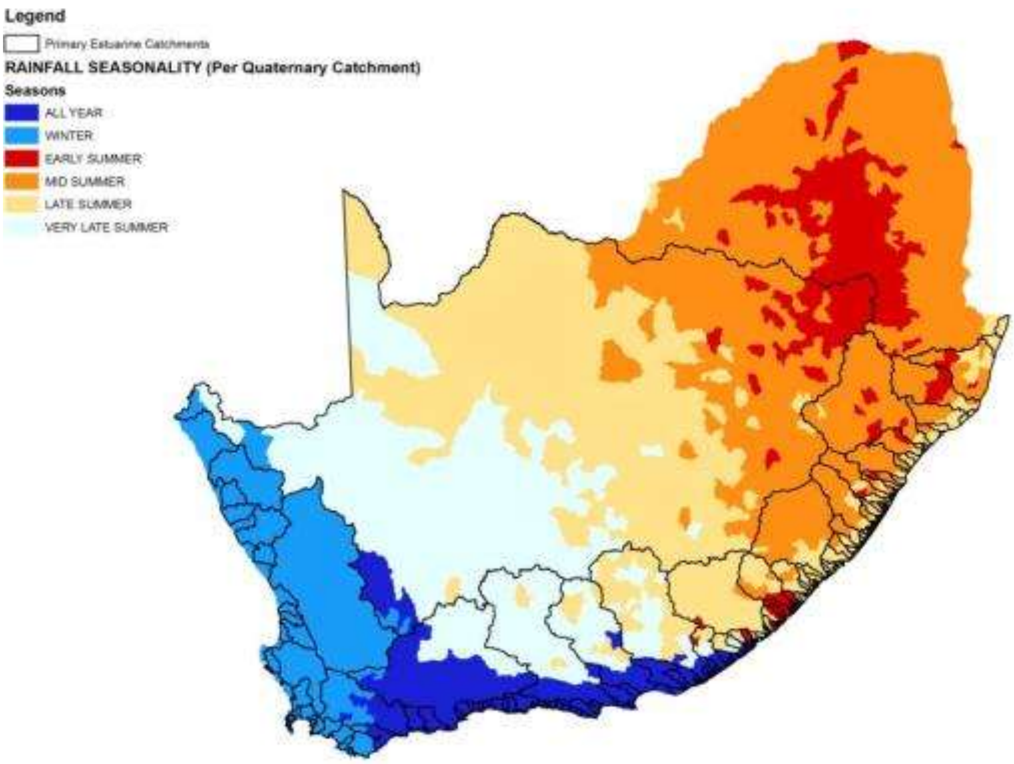

Figure 5.2 Rainfall regions in South Africa (Source: Schulze and Lynch 2007).

From the seasonality in rainfall it becomes clear that connectivity between rivers, estuaries and the sea is more established in the Subtropical region during the biological active period of spring and summer, than for the Temperate west coast and south coast regions. Estuaries fed by larger catchments spanning more than one rainfall zone represent anomalies from a coastal connectivity perspective, often sending recruitment signals when their adjacent neighbours are in low flow. For example, the Orange Estuary's peak flow is during the summer on a winter rainfall coast, the Breede is bimodal with both all year round and winter runoff peaks, the larger south coast system (Gouritz, Gamtoos, Sundays, Great Fish and Keiskamma) receive mainly late summer runoff in addition to all year round runoff, while the larger subtropical catchments deviate away from the coastal signal of late summer to mid- or early summer peaks in runoff.

5.2 Dominant catchment characteristics

The dominant catchment characteristics determining the character of river inflow to estuaries was derived from spatial data. Quaternary catchments were subdivided on a national scale into smaller primary catchments and overlaid by Super Group surficial geology[3] to determine the dominant geology type influencing water quality, e.g. Basement Complex, Carbonate Terrains, Extrusives, Fractured Metasedimentry, Karoo Dykes and Silts, Natal Group Sandstones, Surficial Deposits, Table Mountain Group Sandstone, Unclassified. Some descriptive statistics were then applied on a catchment scale to highlight physical differences along the coastline (Figure 5.3).

Following the example of Nobel and Hemens (1978), the inflowing river types were recognised: clear water, turbid water and black water (tannin rich, nutrient poor rivers) systems. The analyses showed that using absolute percentage of the geological layer coverage in a catchment could be misleading, as it is often the relative position of a feature that matters (i.e. not the percentage of runoff correlated with the feature) that ultimately drives the inflowing waters characteristics. For example, while the Duiwenhoks catchment has very little Sandstone (14%), the lower river reach and estuary is predominantly flanked by this geological formation/vegetation type and therefore displays a very clear black water signal during most of the year.

[3] Surficial geology, also referred to as Quaternary geology, refers to those unconsolidated geologic materials overlaying the bedrock.

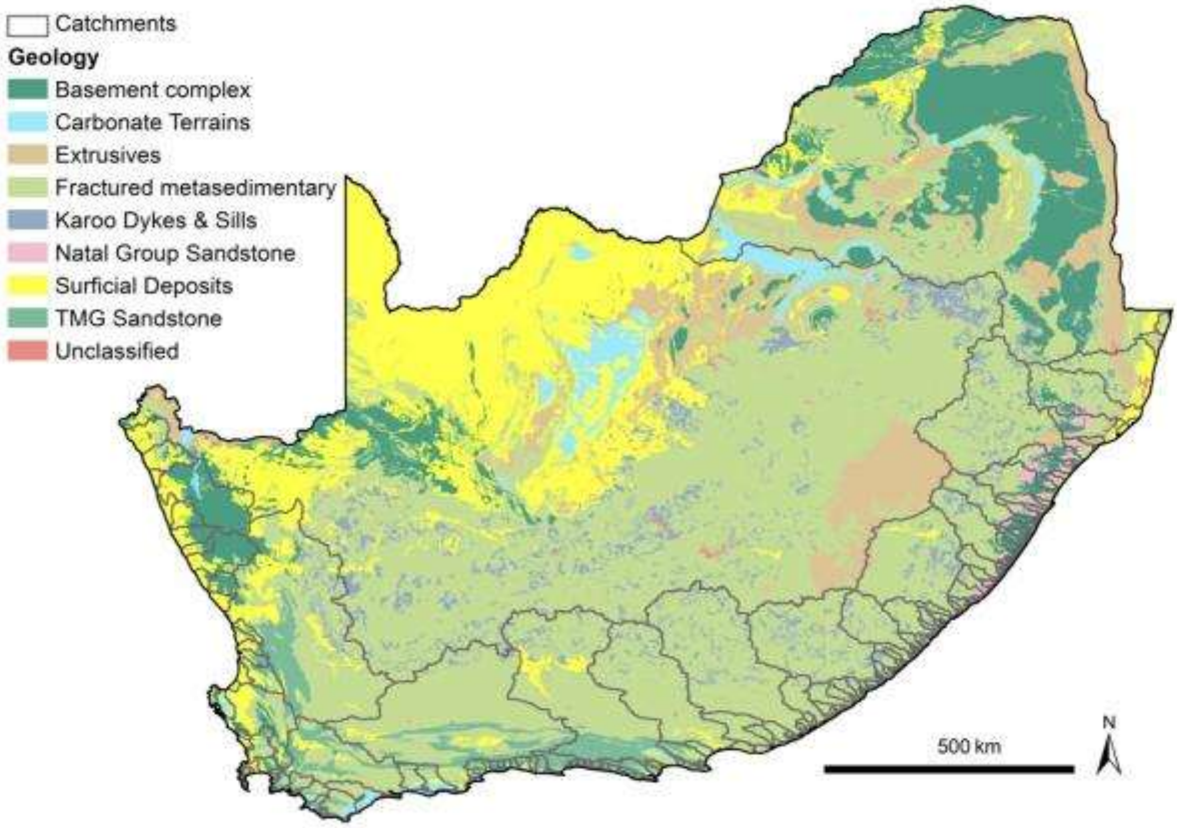

Figure 5.3 The geology of South Africa categorised according to the Super Group formations.

Only during high river flows does it exhibit the more turbid characteristics of its upper catchment. Therefore the catchments with sandstone geology (generally occurring along the coast) of more than 10% were considered black water systems unless field data or specialist opinion indicated otherwise.

After evaluating the spatial data in consultation with estuarine specialists and a terrestrial vegetation specialist (pers. comm., D Le Maitre, CSIR) it became apparent that the Pondoland estuaries were very similar in water quality and terrestrial vegetation type characteristics (CB4 Pondoland-Ugu Sandstone Coastal Sourveld) to the Cape black water systems (Mucina and Rutherford 2006). Therefore the Natal Group Aronites of the Wild coast area were classified and evaluated at a finer scale to accommodate the identified anomaly, especially since most specialists felt they represented a unique feature on that coast line and that the small Pondoland estuaries were very different from the small KwaZulu-Natal estuaries in terms of biota and water type.

Turbid estuaries were typed on the basis of their MAR, where larger catchments would cut back into the more erodible formations (e.g. Karoo formations) and flow velocities would generally be higher throughout the year than for small coastal systems. While geology was the key feature under consideration, assumptions around erodiblity were informed by the sediment yield atlas for the various regions (1 to 10) (Rooseboom et al. 1992, Le Roux et a.l 2008, updated in Msadala et al. 2010).

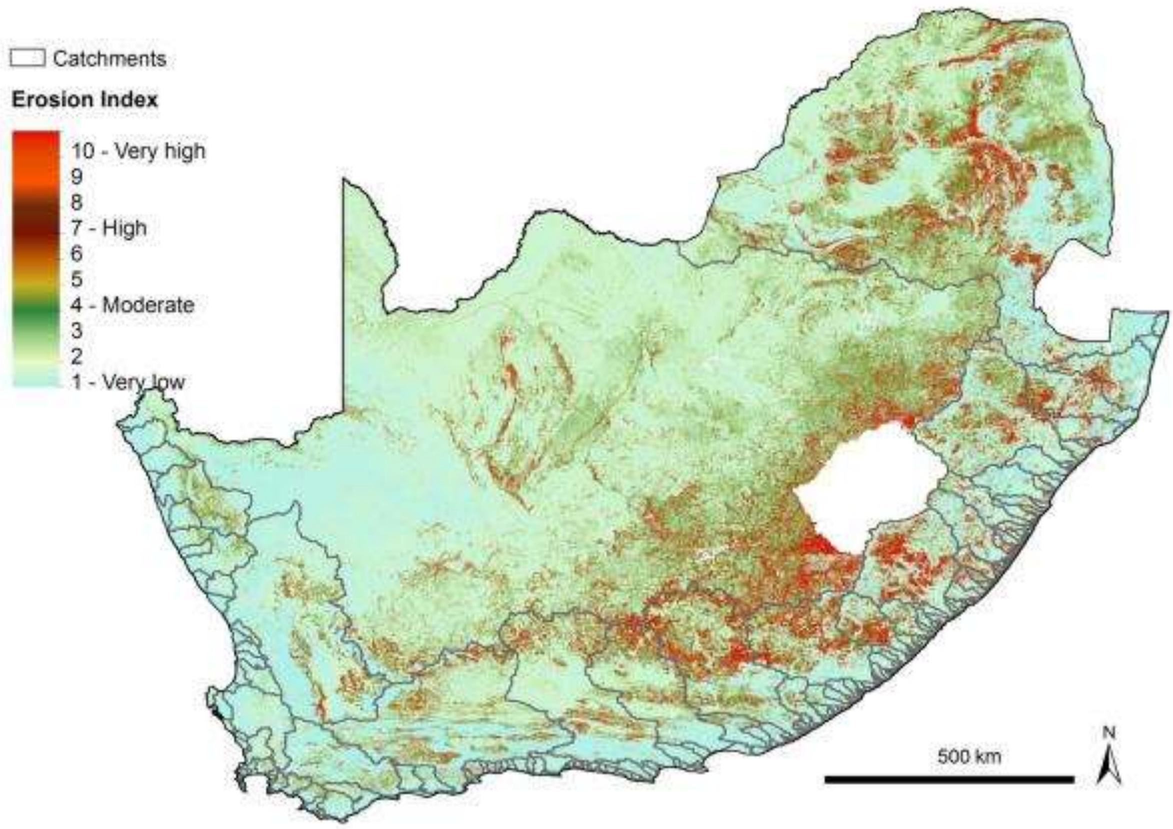

Figure 5.4 Updated sediment yield regions showing erodibility (Modified: Le Roux et al 2008).

Systems with a MAR >30 x10^6 tend to be permanently turbid, while the smaller catchments tend to have lower flow velocities in the dry season, which facilitates the development of clear water for much of the year (Figure 5.5). In some estuaries, large amounts of mud and silt are deposited by floods into estuaries, where tide and wind action causes resuspension for a significant period after the event. These more ephemeral conditions were not seen as representative of the majority state. This did raise the question whether the Wild Coast systems which drain some of the county's most erodible soils, in combination with current poor land-use practises, should be classified as turbid or clear water types. Presently floods deposit significantly more sediment in these systems leading to the perception that some of these estuaries are turbid throughout the year. In the absence of data, the classification kept to the general rule that while the estuaries might act as a sediment sink (delivered in pulses during floods), the rivers were in general running clear.

While there is value in identifying the catchment water type, it is very important that *in situ* water clarity and Secchi disk readings be done on a national scale at regular intervals to facilitate the refinement of this catchment derived classification.

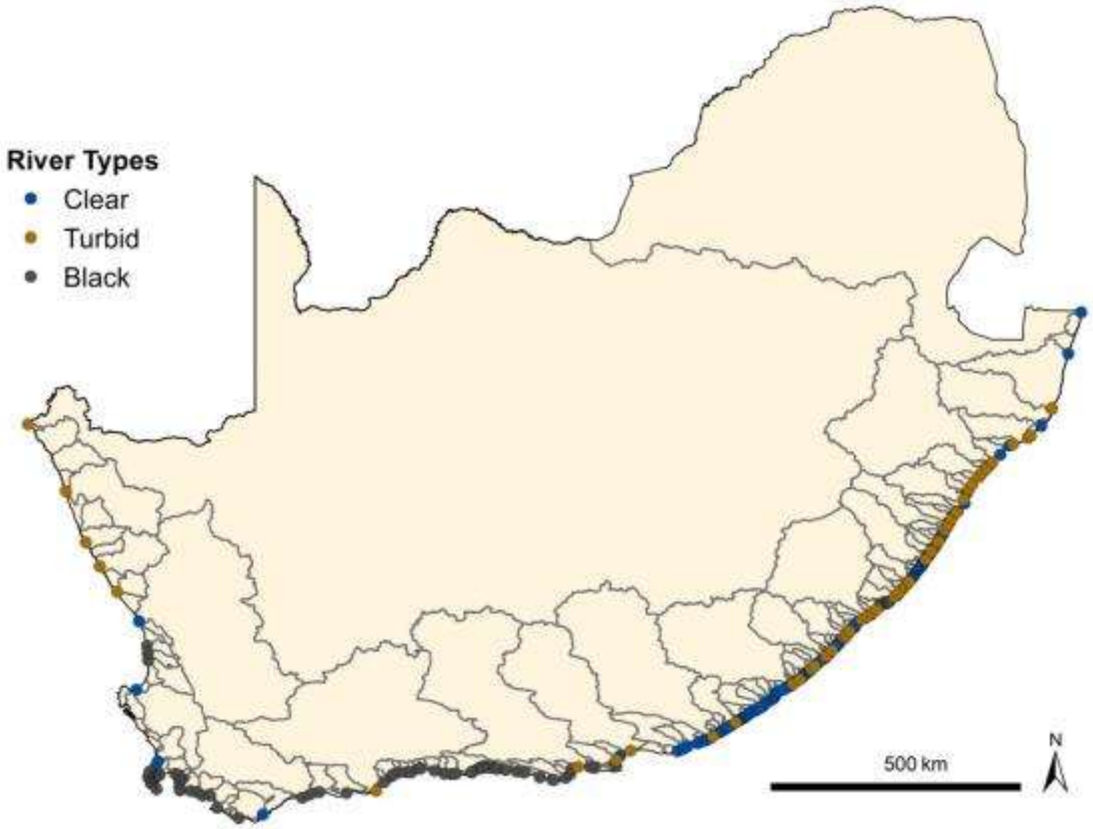

Figure 5.5 Dominant catchment type flowing into South Africa's estuaries.

5.3 Topography and size

Most estuaries in South Africa are located in incised bedrock valleys and thus are laterally confined (Cooper 2001). Some estuary channels fill their entire bedrock valley while others have a substantial floodplain, but most are confined by their bedrock valley. Only a few examples of coastal plain estuaries (i.e. estuaries formed in semi-consolidated alluvium on coastal plains) are present on the South African coast. These are mainly confined to northern KwaZulu-Natal, the Southern Cape coastal lakes area, and parts of the Cape West coast. Coastal plain estuaries are generally associated with substantial water bodies (i.e. estuarine lakes and large permanently open estuaries; Figure 5.6).

Size influences a number of estuarine characteristics, including being a predictor of community composition and abundance, with smaller systems having fewer species and lower absolute abundance. Larger estuaries also tend to have a higher diversity of habitat types than smaller systems. Estuary size can be loosely correlated with Mean Annual Runoff and catchment size but this is not always the case, e.g. Orange (Gariep) has a large catchment but relatively small estuary whereas the Kosi has a large estuarine area but small catchment.

From a process perspective large and small estuaries tend to respond differently to resetting event, i.e. major floods. Large estuaries are generally more buffered against flood scouring as they have more storage, which translates into less loss of substrate and habitat. Larger estuaries also tend to have more refugae within them (in the form of main channel areas, slack water areas and floodplains) which act as refugae during flood events. Therefore large systems can normally recruit/restock individuals from within the system after a flood (e.g. Gamtoos) while smaller estuaries tend to need recruitment from the marine environment after a major resetting event. Large systems, excluding estuarine lakes, tend to be permanently connected to the sea, while smaller systems tend to close during low seasonal flows (dry season) and drought cycles. Along the Subtropical coast, large systems are often associated with high runoff, i.e. high current velocities and resetting floods, which tend to negate the benefits larger estuaries tend to provide in the more Temperate regions.

These differences in the functioning between large and small systems are seen as more important for the less mobile species (invertebrates and plants) that recruit and establish at a slower rate after a resetting event. More mobile species such as fish and birds seem to be responding to these differences on a continuum (Turpie and Clark 2007). For example, using the data set from Harrison et al. (2000), Turpie and Clark (2007) estimated the total populations of fish for each species for each estuary and found that while larger estuaries contain more fish there was no significant difference in fish density between small and large estuaries from a total fish abundance perspective. A SIMPER analysis of this estimated total fish abundance demonstrated that, within each biogeographical zone, fish communities of smaller systems are subsets of larger systems, rather than certain types of systems having distinct types of fish communities (Turpie and Clark 2007). Their analysis suggested that the principle determinant of fish community characteristics, apart from geographic location, was estuary size.

For the NBA 2011 size was initially classified exponentially on the basis of the primary physical processes in estuaries (Large >1000ha, Medium 1000 - 100ha, Small 100-10ha, Very Small <10 ha), but this typology was further aggregated for the NBA 2011 in order to reduce the number of overall number of ecosystem features (see Chapter 7 on NBA 2011 typology for more detail).

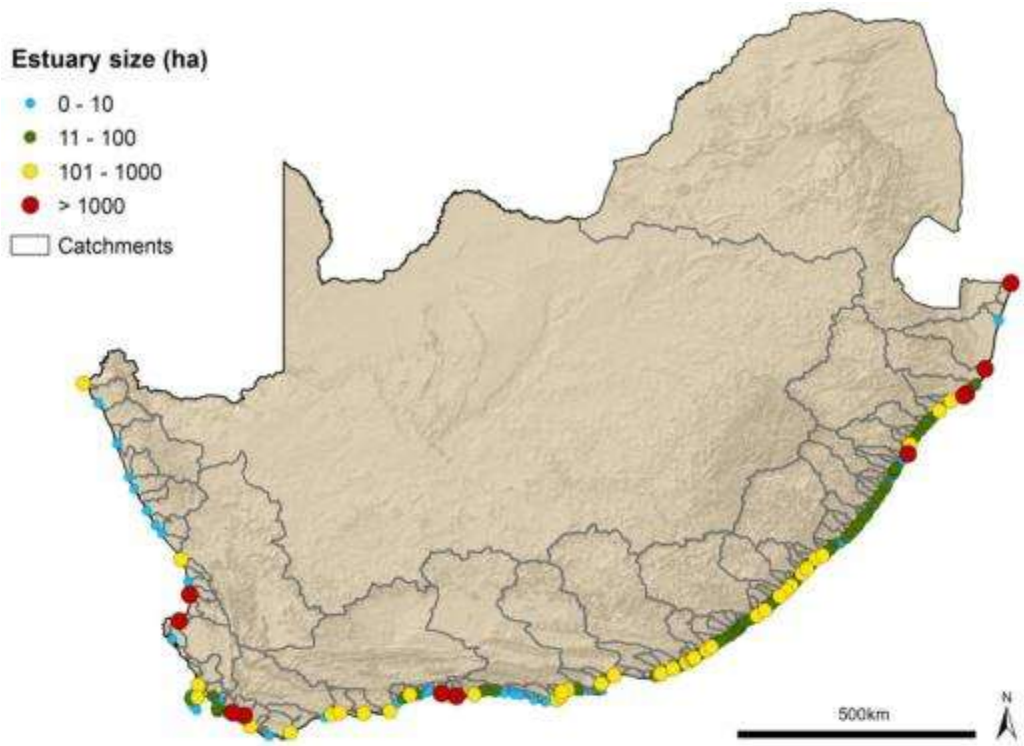

Figure 5.6 Topography of South Africa in relation to estuary size.

5.4 Physical dynamics

5.4.1 Tidal variation

South Africa's coast is generally characterised by low tidal ranges and high wave energy, making it a wave-dominated coast (Cooper 2001). Therefore the approximately 300 functional estuaries are predominantly microtidal systems (tidal range < 2 m) that are highly dynamic and shallow (average depth of 2–3 m). Owing to strong wave action and high sediment availability, more than 90% of the estuaries have restricted inlets, with more than 75% closing for varying periods of time when a sand bar forms across the mouth (Whitfield 1992). Perched estuaries tend to have more restricted mouths with limited tidal range due to their elevation relative to sea level (Figure 5.7). An additional feature is that small perched estuaries tend to drain between 30 – 70 % of their water under open mouth conditions, i.e.

they have more water column habitat when closed than open. These types of estuaries also tend to be more productive (and better nurseries) during the closed phase.

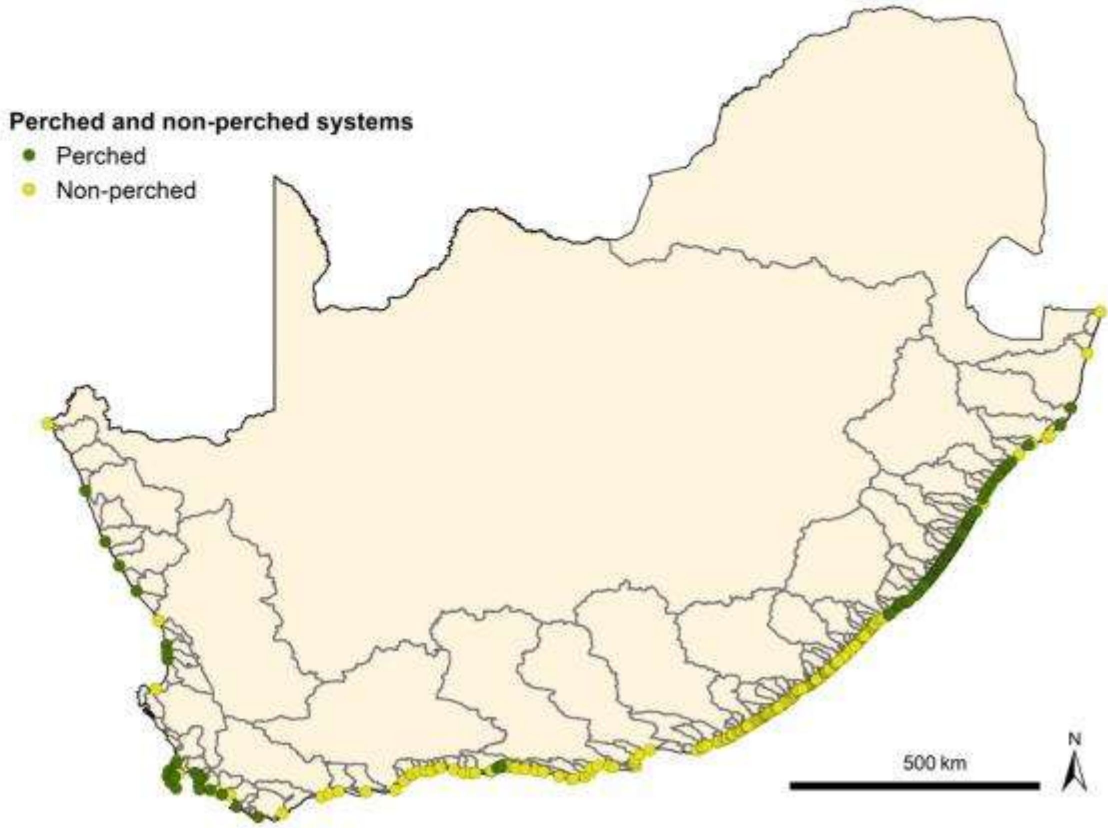

Figure 5.7 Mouth position on berm (perched, non-perched) in South Africa's estuaries.

Cooper (2001) generalized the wave energy and sediment availability along the coast of South Africa, indicating that most of the estuaries along the west coast and KZN coastline are perched. More information is required to disaggregate these general features in a meaningfully manner. Nevertheless the following generalization can be made from measured data along the coast: in permanently open estuaries the tidal range is normally greater than 1.5 m (e.g. Berg, Olifants, Sundays), between 1.5 – 0.5 m for a large temporarily open estuary (Groot Brak, Seekoei); and between 0.5 to 0.2 m for a perched or small temporarily open estuary (e.g. Buffels, Lourens, East Kleinemonde, Little Amanzimtoti). All estuaries become more constricted during the low flow season (the exceptions are Knysna and Mhtlathuze) and tend to be more open to the sea during the rainy season.

5.4.2 Mouth states

The major forces that maintain open mouth conditions are river inflow and tidal flows, while the major closing forces are wave energy and sediment availability (both marine and fluvial).

South Africa's estuaries are sensitive to changes in river runoff, the reason being that they generally discharge into a coastline with comparatively high energy, where the relatively low runoff produces rather limited scouring forces. Only about 25% of South Africa's estuaries are permanently connected to the sea (Whitfield 1992) and these systems normally have relatively high runoff throughout the year. The area covered by these estuaries is normally large enough for the tidal prism to play a significant role in maintaining open mouth conditions. In some cases the mouths are protected from high wave energy or little sediment is available to promote mouth closure (e.g. Mgazana Estuary). The majority (~75%) of South Africa's estuaries are not permanently open to the marine environment (Whitfield 1992). These types of systems are isolated from the sea by the formation of a sand berm across the mouth during periods of low river inflow or when river inflow has stopped altogether. Such estuaries stay closed until their basins fill up and the berm is breached, either as a result of high water levels in the estuary or following increased river flow. Mouth breaching may result in the removal of significant amounts of sediment. However, as soon as river flows decrease again, infilling from marine and fluvial sediment can be rapid. The Whitfield classification (1992), augmented by field observations, estuary size data (this study) and MAR was used as a basis for categorising estuaries into either open (permanently open) of closed systems (can close from time to time) (see Figure 5.8).

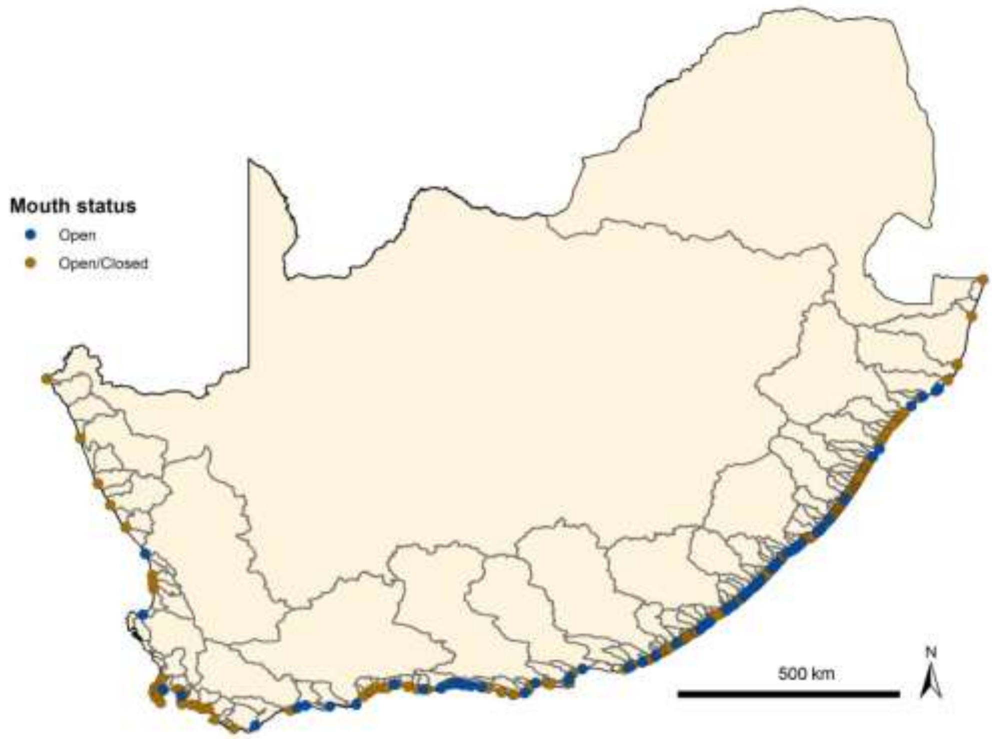

Figure 5.8 Location of permanently open (indicated in blue) versus temporarily open/closed (indicated in brown) estuaries.

5.4.3 Dominant salinity structures

The dominant salinity structure was determined by dividing the MAR by the volume of the estuary. Volume was calculated on the open water area multiplied by an average depth. Average depth in itself was problematic as most research papers report “average channel depth” and not “average estuary depth”.

For most small systems an average depth was assumed of 1.5 m and for larger estuaries 2 – 3 m depending on information and observations. While accurate bathymetry data is not available (available for less than 10% of SA estuaries) the project team had visited most of the larger systems in the course of their careers and this anecdotal information was used in the absence of data.

A major effort was made to refine the MAR. Ideally one would need to know the seasonal distribution of runoff to calculate the salinity structure of an estuary, but in the absence of that if the *MAR/Volume > 365* the estuary was considered as fresh water dominated, while *MAR/Volume < 10* was considered as marine dominated. The remaining estuaries were classified as mixed. In all cases, known systems were used to test assumptions, e.g. Breede (mixed), Kromme (marine dominated), Thukela (fresh water dominated) and anomalies were interrogated to evaluate if the findings were an artifact of the coarseness of the data or possibly real.

Some adjustments were made, in consultation with specialists, based on field experience and the bathymetry of each estuary, e.g. long shallow estuaries flush more readily than deep basin shaped estuaries.

It was felt that the methods had merit but that a higher resolution was still needed to truly inform biodiversity studies, for example defining the “% mixed state” versus “% fresh water dominated state”. As this information is dependent on seasonal inflow ranges and more accurate depth data, this request could not be addresses as part of the NBA 2011.

5.5 Future research requirements

This section provided an overview of key catchment characteristics (i.e. flow volume, seasonality of flow, and river type) and estuarine features (size, mouth state, salinity structure, tidal variation).

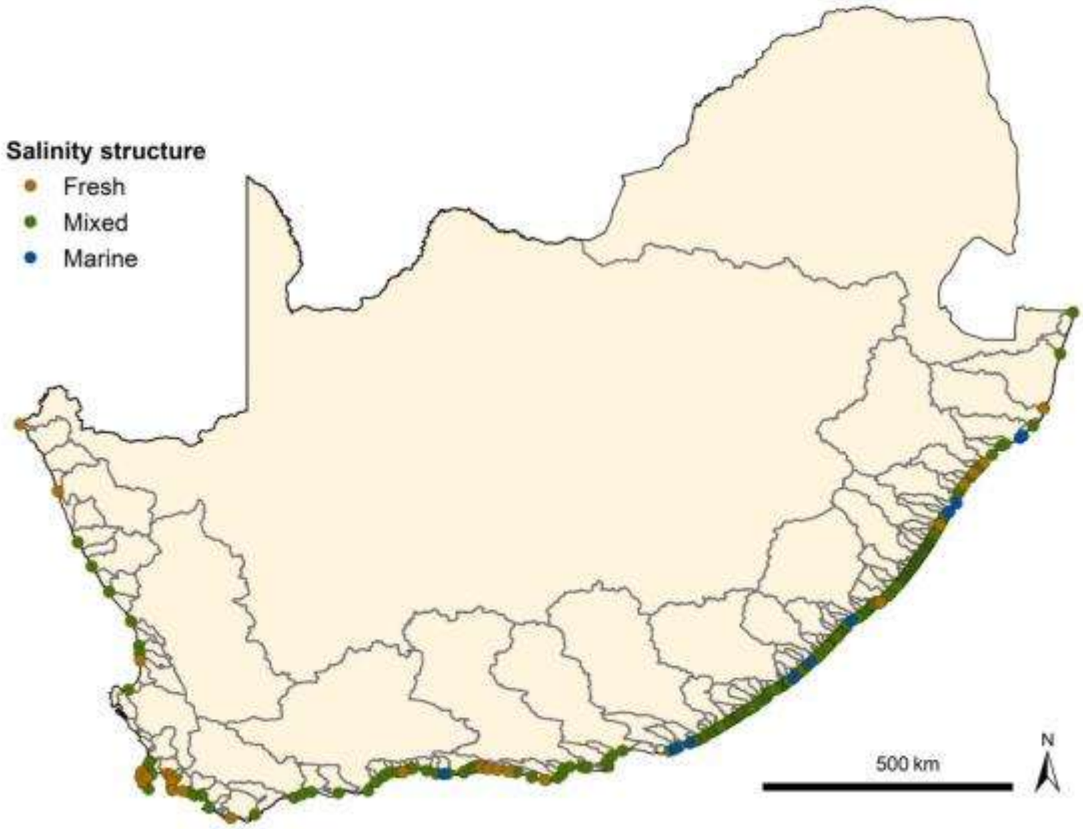

Figure 5.9 Dominant salinity structure (i.e. freshwater dominated, mixed, marine dominated) in South Africa's estuaries.

To assist with refining the key physical processes and feature of South Africa's estuaries the following high resolution input data is required:

- Catchment hydrology (Monthly flow data for natural and present conditions),
- Bathymetry (estuary volume and depth),
- Sediment structure (mud, sand and organic content), and
- Water column geochemistry (salinity structure and turbidity).

6. ESTUARINE HABITAT

JB Adams, GC Snow and DA Veldkornet

Estuaries are generally made up of a high diversity of habitat types, which include openwater area, sand and mudflats, rock and plant communities. Plant community types can be subdivided into salt marsh, mangroves, submerged macrophytes, reeds and sedges. A habitat rarity score (HR) was designed to take into consideration the number of habitats in an estuary, and the extent to which rare communities occur. This score, based on habitat area, is an essential component when determining the Estuary Importance Score, a score used to rank estuaries in terms of their conservation importance.

Panel 1: Description of estuary habitat types

Water surface area (estuary channel): This represents the habitat associated with the water column of an estuary and is measured as the water surface area. The primary producers are the phytoplankton consisting of flagellates, dinoflagellates, diatoms and blue-green algae which occur in a wide range of salinity from freshwater to marine conditions.

Sand / mudflats / rock: Habitat mapping from aerial photographs cannot distinguish between sand and mud habitats and therefore this is presented as a single area in the Botanical Database. However rock can be mapped as a separate habitat. The dominant primary producers of these habitats are the benthic microalgae.

Macroalgae: Macroalgae may be intertidal (intermittently exposed) or subtidal (submerged at all times), they may be attached or free floating (Adams et al. 1999). Filamentous macroalgae often form algal mats and increase in response to nutrient enrichment or calm sheltered conditions when the mouth of an estuary is closed. Typical genera include *Enteromorpha* and *Cladophora*. Many marine species can get washed into an estuary and providing the salinity is high enough, can proliferate. These include *Codium*, *Caulerpa*, *Gracilaria* and *Polysiphonia*.

Submerged macrophytes: Submerged macrophytes are those plants that are rooted in the bottom substrate with their leaves and stems completely submersed (e.g. *Stukenia pectinata* and *Ruppia cirrhosa*) or exposed on each low tide (e.g. the seagrass *Zostera capensis*). Zostera capensis occupies the intertidal zone of most permanently open Cape estuaries whereas *Ruppia cirrhosa* is common in temporarily open/closed estuaries. *Stukenia pectinata* occurs in closed systems or in the upper reaches of open estuaries where the salinity is less than 10 ppt.

Salt marsh: Salt marsh plants show distinct zonation patterns along tidal inundation and salinity gradients. Zonation is well developed in estuaries with a large tidal range e.g. Berg, Knysna and Swartkops estuaries. Common genera are *Sarcocornia*, *Salicornia*, *Triglochin*, *Limonium* and *Juncus*. Halophytic grasses such as *Sporobolus virginicus* and *Paspalum* spp. are also present. Intertidal salt marsh occurs below mean high water spring and supratidal salt marsh above this. *Sarcocornia pillansii* is common in the supratidal zone and large stands can occur in estuaries such as the Olifants.


Spartina maritima **in the Swartkops estuary and intertidal salt marsh in the East Kleinemonde Estuary (Source: T Riddin)**

Reeds and sedges: Reeds, sedges and rushes are important in the freshwater and brackish zones of estuaries. Because they are often associated with freshwater input they can be used to identify freshwater seepage sites along estuaries. The dominant species are the common reed *Phragmites australis*, *Schoenoplectus scirpoides* and *Bolboschoenus maritimus* (sea club-rush).


Reeds in the upper reaches of the Bushmans Estuary (Source: G Snow) and *Bolboschoenus maritimus* in the East Kleinemonde Estuary (Source: T Riddin)

Mangroves: Mangroves are trees that establish in the intertidal zone in permanently open estuaries along the east coast of South Africa north of East London where water temperature is usually above 20°C. The white mangrove *Avicennia marina* is the most widespread, followed by *Bruguiera gymnorrhiza* and then *Rhizophora mucronata*. *Lumnitzera racemosa*, *Ceriops tagal* and *Xylocarpus granatum* only occur in the Kosi Estuary.

Mangroves in the Mngazana Estuary (Source: T Riddin)

Swamp forest: Swamp forests, unlike mangroves are freshwater habitats associated with estuaries in KwaZulu-Natal. Common species include *Syzygium cordatum*, *Barringtonia racemosa* and *Ficus trichopoda*. It is often difficult to distinguish this habitat from coastal forest in aerial photographs.

(Source: T Riddin & JB Adams)

Estuarine importance indices require data on most estuaries. The available dataset for the macrophytes and habitat was in most cases taken from the old “Green book” reports of CSIR for the CAPE estuaries. These data are in most cases 30 years old, there have been substantial changes in estuaries since then, and the habitat types have been reclassified. There is therefore an urgent need for the real data for those estuaries that were included in the Green series, in addition to the other estuaries where no data are available.

This project task set out to update the Estuary Botanical Database. The habitat data provided input to the National Health Assessment, Ecosystem Threat Status, Protection Level assessment and National Biodiversity Plan.

6.1 Method

Images of the estuaries were downloaded from Google Earth and the different habitat types (intertidal salt marsh, supratidal salt marsh, reeds and sedges, channel (water surface area, sand & mud banks) were identified, using information from field trips or available photographs (see Figure 6.1). These were highlighted as polygons, saved as *.kml files and then the areas calculated using the Program GE Path 1.4.4.

The Bokramspruit, Schuster, Krom (west), Maalgate, Kaaimans, Blinde, Gwaing, Klein Brak, Rufane and Klein Palmiet estuaries were visited in 2009 to ground truth the areas covered by the different habitat types. No site visits took place for the following estuaries mainly because of inaccessibility; Ratel, Klipsdrifsfontein, Bloukrans, Lottering, Elandsbos, Elands, Groot (east), Klipdrif, Slang.

Recently completed Department of Water Affairs Resource Directed Measures (RDM) reports were checked and the areas covered by the different habitat types were updated in the Botanical Database using this new information. For most Intermediate and Comprehensive ecological water requirement studies the vegetation would have been mapped using GIS to indicate changes in the habitat types over time.

The area covered by mangroves in the Wild Coast and KwaZulu-Natal estuaries was updated from recent mapping and research studies of Pillay (CSIR) and Rajkaran (NMMU).

Figure 6.1 Example of habitat mapping using Google Earth.

Data for the Eastern Cape estuaries; Blinde, Cunge, Hlozi, Ross's and Shelbertstroom estuaries (Table 6.1) were obtained from Walker (2003). He completed a PhD study on estuaries in the East London region i.e. that area occurring between the Ciskei and Transkei coast. The study included details on the physical characteristics of the estuaries, areas for different habitat types and the areas covered by the dominant macrophytes species.

Table 6.1 Data sources for estuaries where no data were previously available.

Estuary	Reference	Estuary	Reference
Rietvlei/Diep	Management plan	Lottering	NBA 2011
Bokramspruit	NBA 2011	Elandsbos	NBA 2011
Schuster	NBA 2011	Elands	NBA 2011
Krom	NBA 2011	Groot (East)	NBA 2011
Ratel	NBA 2011	Klipdrif	NBA 2011
Klipdrifsfontein	NBA 2011	Slang	NBA 2011
Blinde	NBA 2011	Rufane	NBA 2011
Klein Brak	NBA 2011	Klein Palmiet	NBA 2011
Maalgate	NBA 2011	Shelbertstroom	Walker 2003
Gwaing	NBA 2011	Ross's Creek	Walker 2003
Kaaimans	NBA 2011	Hlozi	Walker 2003
Matjies	RDM study	Blind	Walker 2003
Bloukrans	NBA 2011	Cunge	Walker 2003

6.2 Update of the plant species list and taxonomy

Species were collected for identification in five estuaries in August 2009. These data were used to update the Botanical Database which includes species lists for the plants found in all estuaries and the area covered by the different habitat types. Macroalgae were not collected. In the Groot Brak Estuary only the salt marsh in the lower reaches was investigated. In the Kaaimans Estuary species were collected from a small intertidal patch of salt marsh accessible from the N2 road. Species were also recorded along the banks of the estuary. The Blinde Estuary was largely inaccessible and plants were only collected near the mouth. Due to greater accessibility the Klein Brak and Gwaing estuaries were sampled along the entire length.

The species data in the Botanical Database were also updated using available literature. Species were added for the Berg River Estuary (Boucher and Jones 2007), Uilkraals Estuary (Mucina et al. 2003), and the Olifants Estuary (Bornman 2002). Recent data of Prinsloo (2009) (unpublished data) was used to update the macroalgae in terms of occurrence and species name changes. For all plants taxonomic names were checked using Germishuizen and Meyer (2004). The following websites were used in conjunction with the above literature: Plantzafrica (www.plantzafrica.com); zipcodezoo (www.zipcode.com); Algaebase (www.algaebase.org).

Prof L Mucina, Curtin University, Western Australia was consulted to determine which macrophyte genera were currently undergoing taxonomic revision. Mucina also provided input on the estuaries which have important plant populations, i.e. rare, endangered, endemic, newly identified.

6.3 Results

6.3.1 Habitat Areas

Habitat area data is now available for nearly all of South Africa's estuaries. The list of estuaries included in the Botanical Database are those that were included in the National Estuary Health Assessment. Figure 4.2 provides an overview of the dominant vegetation types along the coast. While a summary of the distribution per biogeographic region is provided in Table 6.2.

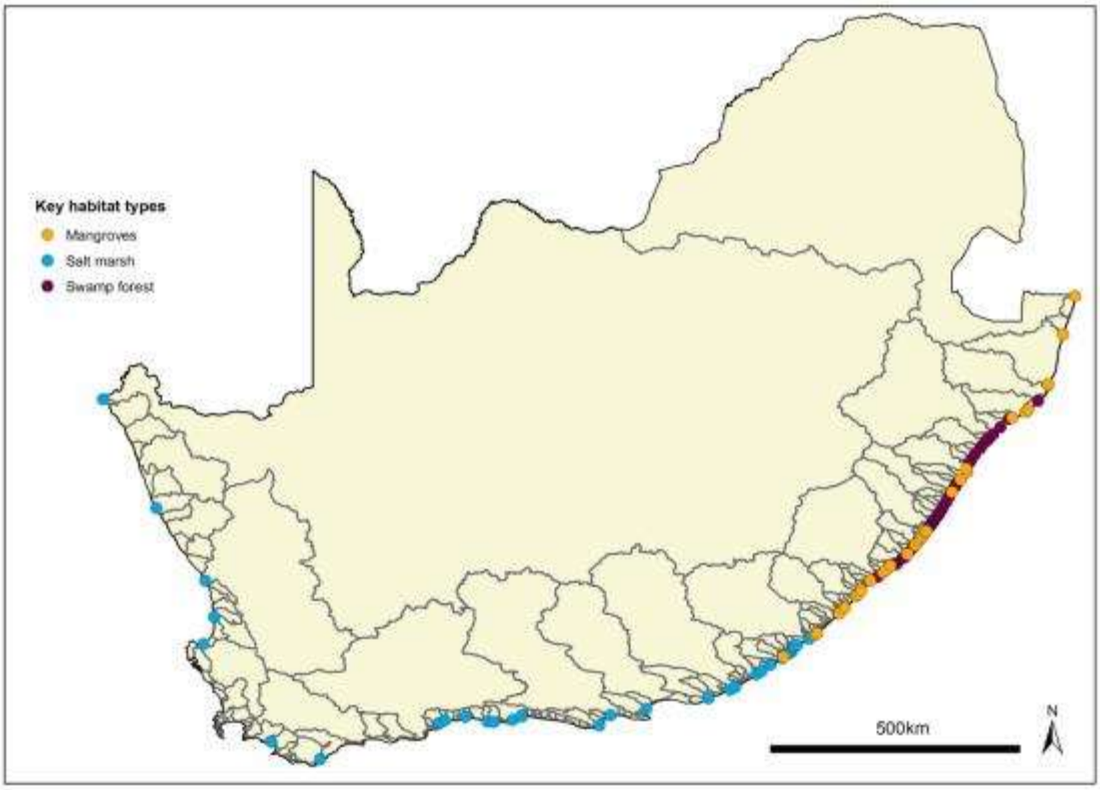

Figure 6.2 Dominant habitat types in South Africa's estuaries.

The following estuaries were added to the original estuary list and now have no area cover data: Mendwana, Kwa-Suka, Sundwana (all Transkei), Nkomba, Rocky Bay, Umlazi (canal), Bob's stream (all KwaZulu-Natal). The Baakens and Papenkuils were also added. An analysis of historical photographs would be necessary to establish whether these systems had estuarine habitat in the past as both systems are severely degraded at present as a result of canalisation and diversion and have no functional habitat. These two estuaries fall within the metropolitan area of Nelson Mandela Bay (Port Elizabeth). Habitat area data are still missing for Sout (Wes). Data for Rietvlei / Diep were obtained from a recent report on the estuary management plan. Julian Conrad provided data from a recently completed GIS map. Large supratidal salt marsh areas and reed and sedge habitats occur at Rietvlei.

Table 6.2 Summary of the total estuarine habitat in South Africa.

Habitat	Total Habitat (ha)			
	Cool Temperate	Warm Temperate	Subtropical	Total
Supratidal salt marsh	3 805	1 427	1 818	7 051
Intertidal salt marsh	1 903	1 774	634	4 310
Mangroves	0	26	2085	2111

Habitat	Total Habitat (ha)			
	Cool Temperate	Warm Temperate	Subtropical	Total
Swamp forest	0	1	4841	4841
Submerged macrophytes	495	615	217	1 327
Sand/mud banks	1 039	1 692	1286	4017
Channel	4 306	6 149	44828	55284
Rocks	6	74	16	96
Reeds and sedges	2 165	1 091	8550	11806
Total Habitat	**13 720**	**12 849**	**64275**	**90844**

Data for Richards Bay Harbour were obtained from a 1996 report "An environmental review of the Master Plan for the Port of Richards Bay" (EAS 1996). The present 1996 area cover data have been used in the Botanical Database. However it is important to note that this report indicates major loss of estuary habitat due to port expansion. Richards Bay Harbour is known to have the oldest area of mangroves in the country.

The area cover data for mangroves in KwaZulu-Natal was updated in the Botanical Database using new data from Pillay (CSIR, Table 6.3). Mangroves have been completely lost from a number of estuaries, including the Mhlanga, Little Manzimtoti, Lovu, Msimbazi, Mgababa, Ngane, Mahlongwa, Kongweni, Bilanhlolo, Mhlangankulu and Khandandlovu. These revised data may influence the national prioritization of South African estuaries in future.

Table 6.3 Updated mangrove area data for KwaZulu-Natal estuaries (Pillay unpublished).

	Area (ha)	
Name of estuary (north to south)	Ward and Steinke (1982)	Pillay (CSIR)
Kosi Bay	59	60.7
Mgobezeleni	2.5	4.5
St Lucia	160	571.0
uMfolozi**	26	-
Richards Bay/ Mhlathuze	427.5	652.1
Mlalazi	30	60.7
Mhlanga	0.5	0
Mgeni	44*	20.3
Durban Bay	15	16.0
Sipingo	12.5	3.8
Little Manzimtoti	0.5	0
Lovu	2	0
Msimbazi	0.5	0
Mgababa	0.5	0

	Area (ha)	
Name of estuary (north to south)	Ward and Steinke (1982)	Pillay (CSIR)
Ngane	0.5	0
Mkomazi	2	2.0
Mahlongwa	1	0
Kongweni	0.5	0
Bilanhlolo	0.5	0
Mhlangankulu	0.5	0
Khandandlovu	0.5	0
Mtamvuna	0.25	0.3

**Mgeni EWR (2011) study indicate that this might be mapping error*
***uMfolozi separated to indicate complete loss of mangroves from that estuary.*

The habitat areas that were calculated from Google Earth images using GE Path 1.4.4., from estuary site visits, Walker (2004), and from recent Resource Directed Measures reports (Table 6.4). These data were used to update the Botanical Excel Database (including the metadata indicating the source of the data).

Table 6.4 Revised habitat area data for South African estuaries.

Estuaries (west to east)	Length (km)	Water area	Submerged Macrophytes	Intertidal salt marsh	Supratidal salt marsh	Reeds & sedge	Sand / mud bank	Mangrove	Swamp forest
Bokramspruit	0.24	0.60				0.60			
Schuster	0.43	0.46				0.14			
Krom	0.90	7.28				1.42			
Ratel	0.97	0.94					0.39		
Klipdrifsfontein	0.49	0.60							
Blinde	0.73	1.66				0.04	0.05		
Klein Brak		77		17	278	2	10		
Maalgate	1.40	14.96					1.00		
Gwaing	1.05	3.65		1.58		0.14	2.13		
Kaaimans	2.82	15.54		0.02		0.60	5.36		
Bloukrans	0.57	2.88					0.63		
Lottering	0.32	1.66					0.38		
Elandsbos	0.64	2.09					3.04		
Elands	1.28	5.79					1.70		
Groot (East)	3.10	8.70					0.92		
Klipdrif	0.53	0.53				0.04	0.01		
Slang	0.50	0.04				0.01			
Rufane	0.30	0.01				0.80			
Klein Palmiet	0.30	0.29	0.02						
Blind	0.40	0.40		0.10	0.10	0.22			
Cunge	0.20	0.30		0.20		0.30			
Hlozi	0.20	0.40		0.30		0.20			
Ross's	0.10	1.00	0.20	0.40		0.10			
Shelbertstroom	0.05	0.30	0.10	0.14					
Updated as part of Ecological water requirement studies									
Olifants	36		47.72	91.94	143.00	60.05			
Knysna		945.52	65.94	551		38.00	265.49		
Matjies	0.6	0.51				0.19			

Estuaries (west to east)	**Length (km)**	**Water area**	**Submerged Macrophytes**	**Intertidal salt marsh**	**Supratidal salt marsh**	**Reeds & sedge**	**Sand / mud bank**	**Mangrove**	**Swamp forest**
Palmiet		21.4		0.1			11		
Sout	1.10	2.36		0.37	2.13				
Sundays	23	314		21.8		31.5	118.4		
Mtata	8.5				21.03	6.23		33.5	
Mhlanga	2.5	12.0					0.68		0.2
Mhlathuze	12.3	679	5	60		205	90	652	29
St Lucia		31610		516	1706	3789		279	
Thukela		55				12	11		1
In addition Mhlathuze had 103 ha of hygrophilous grasses and sedges									

6.3.2 Update of species list and taxonomy

The species list in the Botanical Database was updated after identification of the plants collected in the Blinde, Gwaing, Klein Brak, Groot Brak and Kaaimans estuaries. In most cases the number of species compared to that contained in the Botanical Database doubled or even trebled indicating the importance of taxonomic surveys.

The species list in the Botanical Database had 84 species occurring in 256 estuaries. Results from the recent update shows the total number of species, including intraspecific taxa is now 228 (including macroalgae). The large increase in the number of species in some estuaries may be due to the inclusion of terrestrial fringe species. The dependency of these species on the estuary requires further investigation. Of the 228 macrophyte species in the Botanical Database, 11 species had outdated names. Most of the name changes occurred for the reeds and sedges (*Cyperaceae*) (six species). It is important that estuary researchers and managers take note of these changes to ensure accurate communication.

Mucina has started to revise the taxonomy of South African salt marsh species. Work has been completed on the *Salicornia*, *Sarcocornia* and *Triglochin* genera. Research on the genus *Limonium* will commence soon. This is research in progress and therefore the macrophyte species list for South African estuaries was not used for conservation planning and prioritisation of estuaries. Mucina has identified Langebaan Lagoon, Uilskraals, Heuningnes, Gouritz, Knysna and Kromme as estuaries that have important macrophyte populations. In addition to the above mentioned a saline *Felicia* species was also found in the Heuningnes Estuary (De Mond).

Taxonomic surveys should be conducted of the plants in all South African estuaries. Taxonomic revision of salt marsh species must be supported and funded so that macrophyte species lists can be updated for all estuaries. From these data, sites of rare and endangered species can be identified.

6.4 Key Findings and Future Research requirements

South Africa's estuarine habitat comprises about 90 800ha in total. Figure 6.3 provides an overview of the size distribution of the "core" estuarine habitat in South Africa. This area data do not include the estuarine functional zone, e.g. extended flood plain areas. To allow for consistency across all evaluation and planning processes in the NBA 2011, the habitat data were used as input to the National Health Assessment, Ecosystem Threat Status, Protection Level assessment and National Biodiversity Plan.

It is strongly recommended that habitat area data should be revised for all estuaries where data are older than 10 years. This would include GIS mapping and field surveys of the identified estuaries. A database should be developed comprising the data presented in this study, including all present and future GIS maps depicting the habitats found in all South African estuaries.

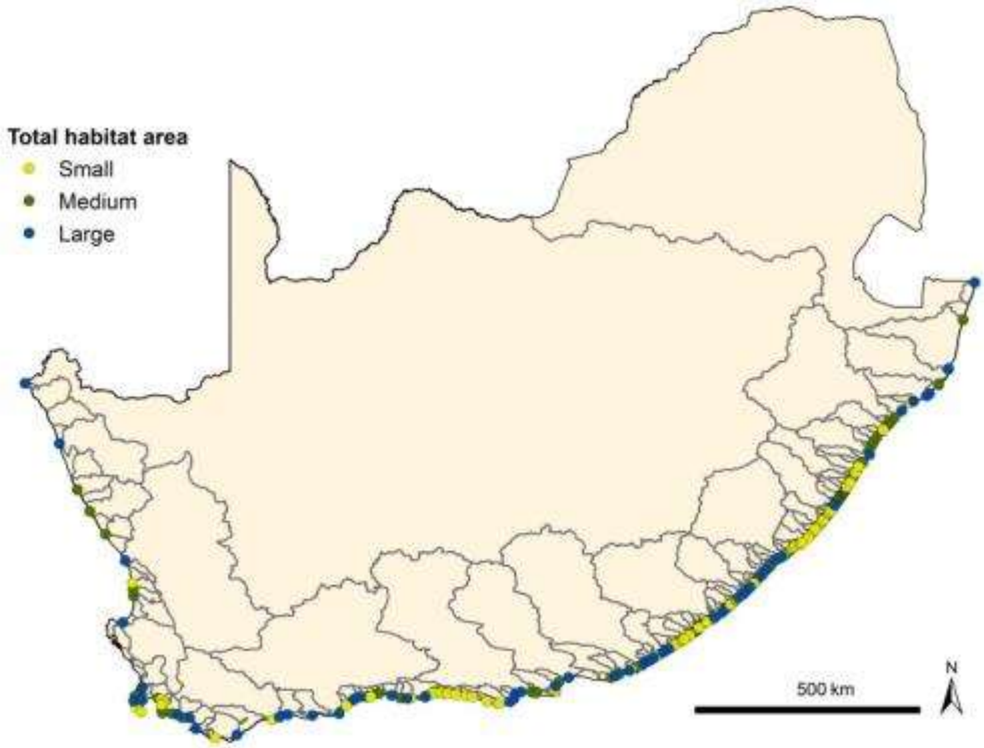

Figure 6.3 Size distribution of estuarine habitat along the South Africa coast.

7. NBA 2011 ECOSYSTEM TYPING

L van Niekerk

To allow for a comparison between estuaries and to set a framework within which it would be possible to predict the possible characteristics and biota of an estuary, a typology or classification system is required.

Estuary ecosystem types serve as surrogates for ecosystem processes and the biodiversity associated with them. In turn, the understanding of estuary ecosystem type processes facilitates the broad scale assessment of estuary resilience to anthropogenic pressures. The typing of estuaries also strives to identify which systems are similar to provide a proxy for the lack of species and abundance data for some components of the ecosystem biodiversity, e.g. meiofauna. Typing or classification schemes also assist with the identification of monitoring requirements for management purposes.

7.1 Typing or classification of estuaries

Estuaries have traditionally been traditional typed by key processes or features, or a combination thereof, eg tidal patterns, topographical, geomorphological or salinity characteristics or ecosystem energetics (Kennish 1986). Davies (1964) classified estuaries by tidal range (Microtidal (<2 m), Mesotidal (2 – 4 m), Macrotidal (6 – 4 m) and Hyper tidal (> 6m)). Nichols and Biggs (1985) focused on the tidal prism (volume of water between high and low tide) with Hypersynchronous estuaries showing an increase in tidal amplitude towards the head, Synchronous estuaries displaying and equal tidal range along their length and Hyposynchronous estuaries having a diminishing tidal range along their lengths.

A number of topographical classifications have been proposed, typing estuaries in to Drowned river valleys, Fjords, Bar build estuaries and others (Prichard 1952b and Dyer 1997). Morphological classifications in turn are generally based on the physical features resulting from the interplay between catchment runoff and sediment loads; and tides, waves and other coastal processes. These include the Dalrympie et al (1992) evolutional classification of Wave dominated or Tide dominated estuaries.

Pritchard (1955) and Cameron and Prichard (1963) classifications based on salinity structure are also very useful focussing on Highly stratified (salt wedge and Fjord types), Partially Mixed and vertically homogenous estuaries. While Hansen and Rattray (1966) proposed a stratification–circulation classification based on the densimetric Froude number. Fischer (1972) categorised estuary stratification by the estuarine Richardson number, which evaluates the ratio of the gain of potential energy due to the runoff discharge to the mixing power of the tide. In contrast, Simpson et al 1990 categorised the degree of stratification in an estuary by the amount of energy input needed to break down the stratification.

Unfortunately most of the typologies describe above are data intensive and require extensive field collection and monitoring to determine accurately in what category or type a specific estuary falls.

7.2 Applicable international regional scale classifications

National or regional level geomorphic classification schemes also need to recognise environmental parameters that are not strongly reflected in physical processes and morphology alone, such as variations in climate, vegetation, and other biological aspects. Two national classification systems that explicitly incorporate the temporarily open/closed estuary type that dominate the South African coastline are that of Australia and California.

The Australian estuaries typology are based on geomorphology as determined by the relative influence of wave, tide, and river energy (Boyd et al. 1992, Dalrymple et al. 1992, Kench 1999), with each type containing a distinctive suite of geomorphic and sedimentary features (Ozcoasts, 2012). Seven key types were identified using a systematic and quantitative geomorphological approach. These seven types were in turn inbedded in five major coastal regions that conforms to the general distribution of wave- and tide-dominated shelf environments (Harris et al. 2002).

The Australian typology links geomorphic types (Harris et al. 2002) and climate and rainfall characteristics (Heggie et al. 1999) to account for a range of coastal depositional environments. The Australian estuarine typology account for seasonality and climatic variation by identifying both positive (freshwater-dominated) and negative (evaporation-dominated) hydrodynamic examples of tide-and wave-dominated estuaries. In strongly seasonal areas that alternate between relatively high runoff and arid conditions (e.g. the wet/dry tropical climatic zone), the typology varies between the two climatic extremes. For example, in the moist tropical climatic region, an estuary that exhibits the hydrodynamic function of a tide-dominated estuary during the wet season, may exhibit the hydrodynamic function of a tidal creek (no freshwater runoff) during the dry season. Alternatively, during the dry season, the estuary may function as a 'negative' tide-dominated estuary, due to higher rates of evaporation (Heggie et al. 1999). Kench (1999) advocated a similar but parallel typology for Australian estuaries based on a morphodynamic approach that evaluates morphology-process responses such as estuarine geomorphic development, hydrodynamic processes and sedimentation. Characteristics such as climate and hydrology, wave energy, tidal energy, sediment availability, and biological processes were deemed defining features.

Jacobs et al. (2010) propose a typology for California estuaries based on their geomorphic history and the dominant physical features and processes that define it. This typology used geological origin, exposure to littoral process, and catchment size and runoff characteristics to model the likely frequency and duration of closure of the estuary mouth. Eight close mouth condition states, based on the elevation of barriers (or berms) to tidal exchange, were defined. These states were determined from historic, maps descriptions and photography.

The typology indicate that under natural conditions, the vast majority of California estuaries experienced some degree of closure, and concluded that river inflow rather than tidal influence is the most critical variable controlling mouth opening. This classification system also recognised that estuaries exist in a variety of closure states over multiyear to multi-decadal time frames and that an estuary may exist in a given closure state for periods of time ranging from days to years.

7.3 South African typologies or classification systems

At present, there are two classification systems recognised for estuaries in South Africa. The geomorphological classification used by Harrison et al. (2000) and the Whitfield (1992) classification based on 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.

Whitfield (1992) classified South Africa's estuaries based on their physiographic (tidal prism, size), hydrographic (mouth state and mixing process) and salinity characteristics. Whitfield's (1992) classification recognises five types: estuarine bay, permanently open, river mouth, estuarine lake, and temporarily open/closed estuaries.

Panel 2: Langebaan Lagoon – an estuarine bay, lagoon or coastal embayment?

Langebaan Lagoon has many of the characteristics of an estuary, including calm coastal waters that are protected from marine wave action (see photograph) and a biota that reflects many of the species usually found in estuaries. However, the system lacks a conventional estuarine salinity gradient due to the absence of any inflowing river, although there is groundwater that feeds into certain sections of the 'lagoon'. Lagoon is a poor description for the system since Langebaan (16 km long, 2-4 km wide and up to 5 m deep) is much larger and deeper than conventional coastal lagoons which are usually small and shallow.

Because Langebaan does receive a freshwater inflow from land drainage (aquifer input), and also has typical estuarine biota, Whitfield (2005) suggested that the term "coastal embayment" type of estuary be used to describe the system. Such a term would separate it from "estuarine bays" along the South African coast, all of which are fed by rivers.

Whether viewed as an estuary or as a marine ecosystem, Langebaan Lagoon, separates out as a unique coastal ecosystem type. The 2011 NBA recognised the "transitional" nature of Langebaan Lagoon and assessed it as part of the Marine Component for consistency reasons.

Source: AK Whitfield

7.4 NBA 2011 Typology

Four physical features (see Section 5 for more detail), i.e. size, mouth state, salinity structure and catchment type, of South African estuaries were combined into 46 ecosystem types comprising permutations of the features for each of the biogeographical regions (listed in Table 5.1).

Size was initially classified exponentially on the basis of the primary physical processes in estuaries (Large >1000ha, Medium 1000 - 100ha, Small 100 -10ha, Very Small <10 ha), but this typology was further aggregated for the NBA 2011 in order to reduce the number of overall number of ecosystem features. For the NBA 2011, estuary size classes were: Large >100ha, Medium 100 - 10ha, and Small <10 ha.

To further reduce the number of overall ecosystem types, features with a low occurrence (i.e. only one or two estuaries representative of a that combined ecosystem type) and had features that were straddling category boundaries, or were of a low confidence, were forced into nearby categories (e.g. Storms Estuary (12 ha) was forced into the Small category and the Spoeg (9ha) into the Medium category).

Under *catchment type* the Bushmans and Mngazana estuaries was changed from *Turbid* to *Clear*, as they were not that dissimilar from the Kariega to warrant their own type. It should also be noted that the typing focuses on natural inflow patterns and therefore from a salinity structure perspective types both the Kromme and Great Fish as *Mixed* while at present they are *Marine dominated* and *Freshwater dominated* respectively due to modified inflow regimes.

It should be clear from the discussions in Section 5 that the ecosystem typing developed for the NBA 2011 can be further refined by addressing some of the underlying drivers, namely hydrology, sedimentology and bathymetry. Nevertheless, the typing still provides a useful framework for evaluating the ecosystem threat status, condition and protection levels. The higher resolution afforded by this classification system versus the Whitfield classification allows for a more detailed assessment of the very large temporarily open/closed systems category. It is hoped that this could be refined and validated in the near future.

Table 7.1 Refined ecosystem types based on key physical features

Cool Temperate Types (12)	**Warm Temperate Types (18)**	**Subtropical Types (16)**
LargeClosedFreshTurbid	LargeClosedMarineClear	LargeClosedFreshTurbid
LargeClosedMixedBlack	LargeClosedMixedBlack	LargeClosedMixedClear
LargeClosedMixedClear	LargeClosedMixedClear	LargeClosedMixedTurbid
LargeOpenMixedClear	LargeOpenMarineBlack	LargeOpenMarineClear
MediumClosedFreshBlack	LargeOpenMarineClear	LargeOpenMarineTurbid
MediumClosedMixedBlack	LargeOpenMixedBlack	LargeOpenMixedClear
MediumClosedMixedClear	LargeOpenMixedClear	LargeOpenMixedTurbid
MediumClosedMixedTurbid	LargeOpenMixedTurbid	MediumClosedFreshTurbid
SmallClosedFreshBlack	MediumClosedMixedBlack	MediumClosedMixedBlack
SmallClosedMixedBlack	MediumClosedMixedClear	MediumClosedMixedClear

Cool Temperate Types (12)	Warm Temperate Types (18)	Subtropical Types (16)
SmallOpenFreshBlack	MediumOpenMixedBlack	MediumClosedMixedTurbid
SmallOpenMixedBlack	MediumOpenMixedClear	MediumOpenMarineClear
	MediumOpenMixedTurbid	MediumOpenMixedTurbid
	SmallClosedFreshBlack	SmallClosedFreshBlack
	SmallClosedMixedBlack	SmallClosedMixedBlack
	SmallClosedMixedClear	SmallClosedMixedClear
	SmallOpenFreshBlack	
	SmallOpenMixedBlack	

8. KEY PRESSURES ON ESTUARIES

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The threats to estuarine health and biodiversity can ultimately be grouped as follows:

- Flow modification;
- Pollution (e.g. agriculture, waste water treatment works (WWTW), industrial, sediment);
- Exploitation of living resources (fish and invertebrates);
- Habitat destruction (within estuarine functional zone); and
- Climate change (dealt with in more detail in Section 12).

The desktop assessment of the pressures that estuaries in South Africa are facing were based on readily available data and expert opinion. The estuarine functional zones of all estuaries were visually inspected on Google Earth for noticeable signs of pressures (e.g. canalisation, development, infilling, discharges). The national data sets, namely NMMU (Botanical Database; Colloty 2000, Adams et al. 2010) and CSIR (Harrison fish surveys; 2000, Harrison 2004, 2005) and unpublished reports (CSIR Series III Green reports), were used to ground truth and supplement visual observations where possible. Critical pressures were also identified during the National Health Assessment workshop (2009). Pressure data were collated, rated and captured in a spreadsheet for each estuary. This information, in combination with the estuary typing (type is indicative of resilience and sensitivity to change), were used for the National Health Assessment (Section 9).

8.1 Flow modification

Flow modification refers to both increases and decreases in freshwater inputs to an estuary. A decrease in freshwater flow results from direct abstraction (e.g. Keurbooms), dam development (e.g. Orange, Palmiet, Kromme), and the accumulative effects of small farm dams (e.g. Bushmans). While an increase in inflow results from inter-basin transfer schemes (e.g. Sundays, Great Fish), Waste Water Treatment Works (e.g. Mhlanga), and hardening of a catchment (e.g. Kuils/Eerste). Changes in Mean Annual Runoff (MAR) often hide the degree to which flows are modified, while the MAR may only be reduced by 10%, the seasonal baseflows (low flows) may be reduced by as much as 50% (due to baseflow abstraction) or elevated by 50% (e.g. by agricultural return flow).

There are no good data available on the degree to which freshwater flow to the estuaries of South Africa has been modified (i.e. increased or decreased) on a national scale. The last study of this nature was done in 1986 (DWA 1986). For the NBA, two primary sources were used to quality flow modification, i.e. recent estuary ecological water requirement studies (also known as Reserve studies) and the Water Situation Assessment Model (WSAM) (using WR2005 data).

The most accurate data available were from recent (past 10 years) ecological water requirements studies (completed for about 25 systems). Where available, this information was the preferred source for the NBA. If not, the output of the WSAM hydrological model was used. The Department of Water Affairs (DWA) developed the WSAM as a macro-scale water resource planning tool. The model provides users with a systematic approach for reconnaissance-level planning and scenario testing, while efficiently managing large volumes of information. The purpose of WSAM is to summarise information, on the availability, supply and utilisation of water resources at a national, regional and catchment level for both current and projected future situations. While considerable testing and validation of various WSAM sub-models and algorithms was undertaken as part of the model development process, this study found that the models were relatively accurate (within about 10%) in catchments where water resources were primarily developed through small farm dams, direct abstraction and land-use change. Unfortunately, the WSAM significantly under reported flow reduction in catchments where large dam development occur, and if no alternative information source was available, expert judgment was used to reflect the estimated reductions or increases (see Figure 8.1 for spatial distribution of flow modifications).

Increasing populations and a rapidly growing demand for freshwater supplies is a major threat to South African estuaries. Freshwater abstraction can result in the closure of the mouth of an estuary that is normally permanently open to the sea. The Kobonqaba Estuary in the Eastern Cape and Uilkraals in the Western Cape were recorded closing for the first time ever in 2010, with the closure of the Kobonqaba causing a major die-back of of mangrove trees *Aviciennia marina* in this system. High water level due to mouth closure resulted in flooding of the pneumatophores and drowning of the trees. Extended mouth closure is generaly associated with reduced freshwater inflow to an estuary. Baseflows are important in raising water level and keeping the mouth open and these have probably been reduced due to drought conditions and freshwater abstraction in the catchment.

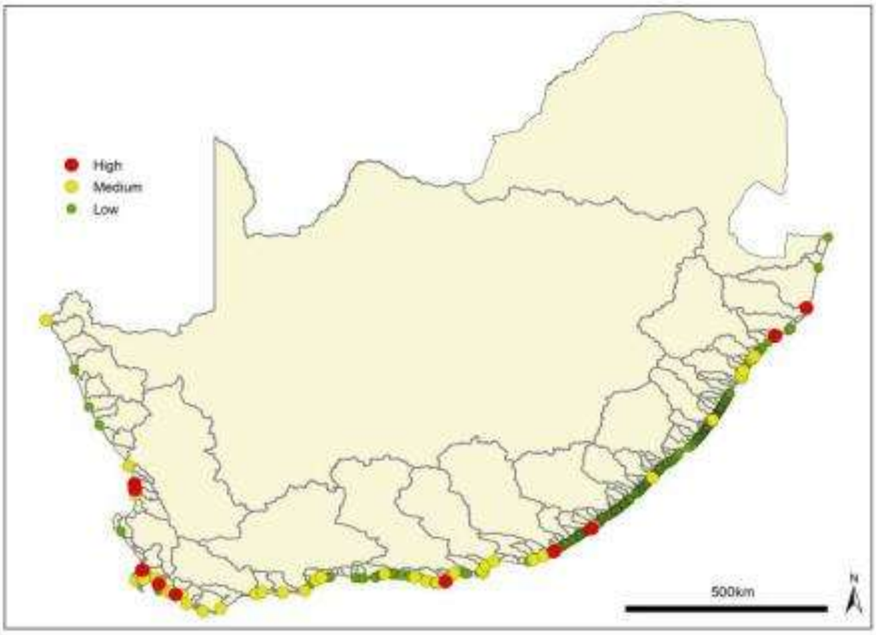


Figure 8.1 Locality map showing the degree to which freshwater inflow has been modified to the estuaries of South Africa.

Alternatively, an increase in freshwater input (e.g. waste water treatment works) can prevent the occurrence of regular mouth closure and prevent the related back-flooding and increase in estuarine habitat. An example of this is the Eerste Estuary that discharges into False Bay. This aspect was not captured by the WSAM and was therefore incorporated into the NBA assessment based on expert opinion.

The results (Figure 8.2) of the assessment indicate that 4 % of South Africa's estuaries are under significant flow modification pressure, with the 15 % of the estuaries in the Cool Temperate region under severe pressure, comprising mostly the large permanently open estuaries such as the Orange, Groot Berg and Olifants. An additional 18 % of estuaries in South Africa is under a moderate degree of flow modification pressure with the Cool Temperate (47% of estuaries in that region) and the Warm Temperate (19 % of estuaries in that region) being the most affected. Less than 5% of all estuaries in South Africa have no flow modification pressures on them – most of these are systems fed by small catchments with limited developments in their immediate environments, and are confined to either the Warm Temperate or southern Subtropical biogeographically region.

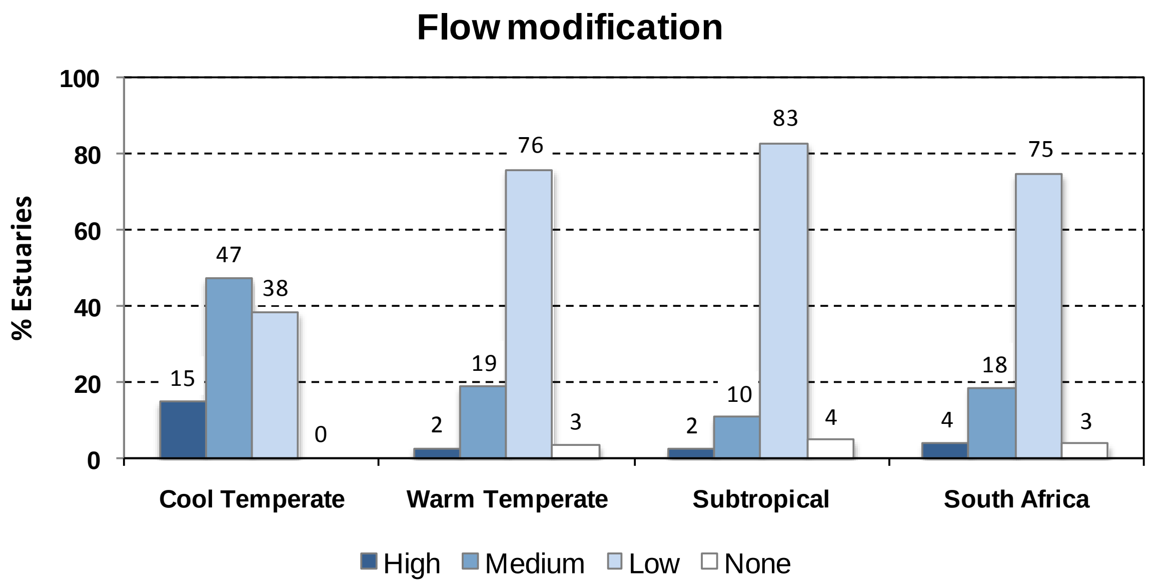


Figure 8.2 Quantification of flow modification pressures for the three biogeographical regions in South Africa.

There is an urgent need for a quantification of the modification in freshwater flow to the estuaries (all 291) of South Africa. This analysis should include all current land-use, transfer schemes, discharges, dam developments and be based on the true catchment area of each of the individual systems.

8.2 Pollution

South Africa's *National Programme of Action for Protection of the Marine Environment from Land-based Activities* list a number of key sources of pollution in estuaries (DEAT 2008), namely:

- Municipal wastewater;
- Industrial wastewater;
- Stormwater runoff (including solid waste); and
- Agricultural runoff (increased nutrients, suspended solids, herbicides and pesticides).

Numerous **municipal wastewater treatment works** (WWTW) discharge effluent into estuaries (Table 8.1). A comparison between data from 1991 and 2004 indicates that WWTW discharge volumes to estuaries have almost doubled over this period, reflecting the rapid population growth in coastal areas (DEAT 2008). While most of these discharges are subject to treatment (sometimes secondary or even tertiary), many of the WWTWs are malfunctioning thus causing pollution in estuaries (e.g. Eerste Estuary). The larger urban centres along the coast have collecting systems for municipal wastewater although problems are being encountered where deterioration of older structures result in regular spillage and seepage. Overflowing sewage pumpstations are a specific concern and regular pump failures have been recorded in systems such as the Lourens, Onrus, Klein, Bilanhlolo, Uvuzana and Mbango. Sewage pump stations are usually located close to the shore, usually the lowest point from where wastewater is pumped to WWTWs.

Smaller coastal communities often do not have reticulated sewage systems and non-sewered systems such as septic tanks and French drains are typically used for the treatment of sewage. A concern with non-reticulated systems used in these communities situated next to sensitive areas such as estuaries, is the potential impact that spillage or seepage from these systems could have on the aquatic ecosystem and other users (e.g. recreation) of the estuary. The risk of impact often increases markedly with an increase in number and density of non-sewered systems in a particular area. Where reticulated systems have been installed in some smaller coastal communities, the large seasonal fluctuation in the population (i.e. population increasing markedly during holiday seasons) is often problematic.

In addition to WWTWs discharging directly into estuaries (Table 8.1) there are also a number of WWTWs discharging into rivers just upstream from estuaries but close enough to influence estuarine health, e.g. Olifants (Lutzville), Breede (Swellendam), Gwaing (George), Qinira, Kandandhlovu, Zotsha, Mahlongwa, Mahlongwane, Msimbazi, Little Manzimtoti, Mgeni, Thukela and Mlalazi rivers. Untreated municipal wastewater also enters estuaries through stormwater runoff from informal settlement areas (e.g. Swartkops) (DEAT 2008). The installation of effective collecting systems in rapidly expanding informal settlements is also difficult to implement and results in estuarine pollution following rainfall events. Untreated municipal wastewater also enters estuaries through diffuse stormwater runoff from informal settlement areas (e.g. Swartkops) (DEAT 2008).

Table 8.1 Direct wastewater discharges into estuaries along the South African coast (updated from DEAT, 2008)

Estuary (location)	Effluent type	Estimated flow (m^3/day)
Berg (Marine Product, Laaiplek)	Industrial (Fish)	130 000
Diep (Milnerton, Cape Town)	WWTW	44 126
Wildevoëlvlei (Kommetjie, Cape Town)	WWTW	11 577
Eerste (Macassar, Cape Town)	WWTW	54 494
Hartenbos (Mossel Bay)	WWTW	6 471
Knysna (Knysna)	WWTW	3 955

Estuary (location)	Effluent type	Estimated flow (m^3/day)
Piesang	Industrial (Brine)	50*
Bushmans (Albany Water Supply, Easten Cape)	Industrial (Brine)	50
Papenkuils (Fish Water Flats, Eastern Cape**)	Industrial (General)	35000
Mvutshini (Ramsgate Kwazulu Natal)	WWTW	100
Kongweni (Margate Kwazulu Natal)	WWTW	1 900
Vungu (Uvongo Kwazulu Natal)	WWTW	100
Mpambanyoni (Park Rynie Kwazulu Natal)	WWTW	1 000
Umkomaas (Umkomaas Kwazulu Natal)	WWTW	500
Mhlanga (Mhlanga Rocks Kwazulu Natal)	WWTW	25 000
Mdloti (Mdloti Kwazulu Natal)	WWTW	400
Mvoti (Stanger Kwazulu Natal)	WWTW	1 800
Tongaati (Tongaat Kwazulu Natal)	WWTW	200
Mhlali (Ballitoville, Kwazulu Natal)	WWTW	500

**Currently discontinued*
***Generally viewed as a marine outfall*

Stormwater runoff is a major concern specifically in estuaries situated within urban areas. Contaminated stormwater runoff originates from built-up area, gardens, golf courses, parks, roads, and commercial and industrial areas. Stormwater runoff contains an array of pollutants ranging from microbial contaminants, excessive nutrients and organic matter (e.g. linked to sewage from informal settlement areas) to high suspended solid loads and toxic chemicals such as trace metals and hydrocarbons (e.g. originating from runoff draining roads, and industrial and commercial areas). Solid waste or litter is also a major pollutant component in stormwater. Other diffuse sources of litter include solid waste disposal facilities that are managed inadequately or that are illegal. Examples of estuaries where this is a problem range from larger estuaries such as Swartkops to smaller systems such as Groot Brak.

While **industrial wastewater** discharges into South African estuaries are limited (Table 8.1), there are concerns in terms of discharging such effluent into less physically dynamic and ecologically sensitive areas such as estuaries. An emerging concern is the disposal of brine (e.g. Piesang, Knysna, Bushmans estuaries) that can have detrimental impacts on these sheltered and sensitive coastal environments. Concerns with brine effluents arise form an increased demand for desalination plants (discharging brine wastewater) to provide freshwater in areas either not serviced by piped water, or to supplement limited supplies. In addition to industrial wastewater discharging directly into estuaries (Table 8.1), there are also a number of industries discharging into rivers just upstream from estuaries close enough to influence estuarine health, such as discharges into the Mzimkulu (sugar mill) and Thukela (paper mill) rivers.

Panel 3: Quantification of toxic pollutants in South African estuaries

Despite the potential ecological and human health risks posed by toxic substances such as trace metals and persistent organic pollutants (e.g. herbicides and pesticides), very little research and monitoring are being conducted on the distribution and accumulation of these compounds in South Africa estuaries.

For example, recent research detected substantial and concerning increases in the concentrations of many trace metals in some Eastern Cape estuaries (e.g. Binning & Baird 2001, Orr 2007). Jackson et al. (2009) noted that both water column and sediment concentrations of most metals in the Diep Estuary exceeded recommended local and international guidelines. Hutchings and Clark (2010) confirmed this and identified trace metal concentrations in estuarine fish from both the Berg and Diep estuaries as being in excess of South African food quality standards, thus indicating that there may be existing ecotoxic impacts and human health risks associated with consuming fish caught in these estuaries.

In general very few studies have measured toxic contamination in South African estuarine biota. For example, Watling and Watling (1982) reported on levels in some bivalve and gastropod molluscs from the Knysna Estuary, and more recently Vermeulen and Wepener (1999) and Mzimela et al (2003) reported on trace metal concentrations in mussels and fish (*Liza dumerili*) from Richards Bay harbor and the Mhlathuze Estuary respectively. Jackson et al. (2005) conducted laboratory experiments to assess the ecotoxicity of lead and zinc on the estuarine invertebrate *Callianassa kraussi* (sand prawns) and found that elevated levels of these metals, particularly at low salinities exhibited a significant detrimental influence on the brood and larval development of sand prawns. This species is ecologically (major component of benthic invertebrate biomass, important link in estuarine food webs, bio-turbator etc) and economically (sought after bait item) important.

The lack of baseline data on toxic pollutants in the sediments and biota of many South African estuaries in the face of increasing urban development and estuary utilization makes the undertaking of such studies a matter of priority. This aspect was not dealt with in a systematic manner in the NBA 2011 study, but highlighted where identified as possible pressure.

Source: Dr K Hutchings

Inappropriate agricultural practices in catchments result in contaminated agricultural runoff draining into estuaries introducing toxic substances (e.g. inappropriate use of herbicides and pesticides), excessive nutrients (e.g. inappropriate use of fertilizers), and increased suspended solid loads as a result of soil erosion. There are no data or comprehensive studies available on pollutants loads introduced to estuaries through agricultural sources. However, specific studies have shown that runoff from catchments used extensively for agriculture can contribute significantly to pollutant loading in estuaries, e.g. Olifants, Breede, Sundays. Poor agricultural practices can also contribute to increased sediment loading to the estuaries, e.g. ploughing activities on the flood plains, over grazing and trampling of riparian vegetation by livestock. An example of harmful agricultural practises is sugar cane farming along the KwaZulu-Natal coast that encroaches onto river banks and results in excessive sedimentation of estuaries, as well as the pollution of coastal aquatic systems.

Inappropriate planting in flood plains also leads to demands for the artificial breaching of estuaries when these fields become flooded. The former homelands (Transkei and Ciskei) have significant land transformation (e.g. forests to grass lands, grasslands to bare soil) leading to increase turbidity and sedimentation in these otherwise relatively pristine estuaries.

The Department of Water Affairs' operational policy for the disposal of land-derived waste water to the marine environment aims to prohibit (new) wastewater discharges into sensitive coastal areas such as estuaries (DWAF 2004). However, it will require a serious commitment from the department to enforce this policy in the light of the ever-increasing demand for municipal services (e.g. wastewater facilities) and fresh water (e.g. desalination plants) in coastal areas.

The pressure assessment attempted to derive a measure of catchment transformation by using the 2006 SA land-cover layer. Unfortunately, the data was found to be of a poor quality, with highly degraded or transformed land often classified as natural or near natural. The project therefore had to abandon this more rigorous approach for a visual evaluation of the catchment status for each estuary. It would add significant value if the national land cover map were more accurate in this regard and form the basis for future assessments.

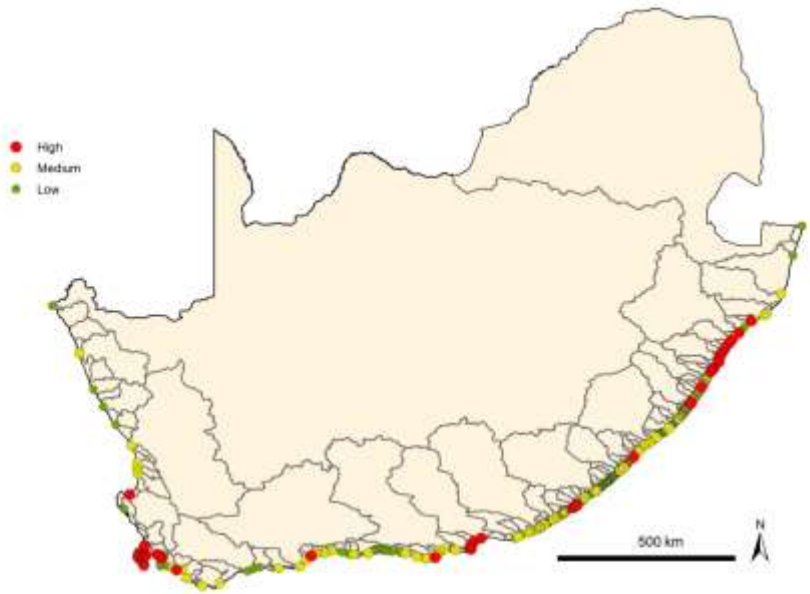


Figure 8.3 Locality map indicating the level of pollution pressure on individual estuaries

The results of the assessment indicate that 15 % of South Africa's estuaries are under significant pollution pressure, with 44% of the estuaries in the Cool Temperate region, 13% in the Subtropical region and 9% in the Warm Temperate region under severe pressure. An additional 40% of estuaries in South Africa are under a moderate degree of pollution pressure with the Subtropical (46% of estuaries in that region) and the Warm Temperate (37% of estuaries in that region) being the most affected. Less than 1% of all estuaries in South Africa have no pollution pressures on them – most of these are estuaries fed by small catchments confined to national or provincial protected areas.

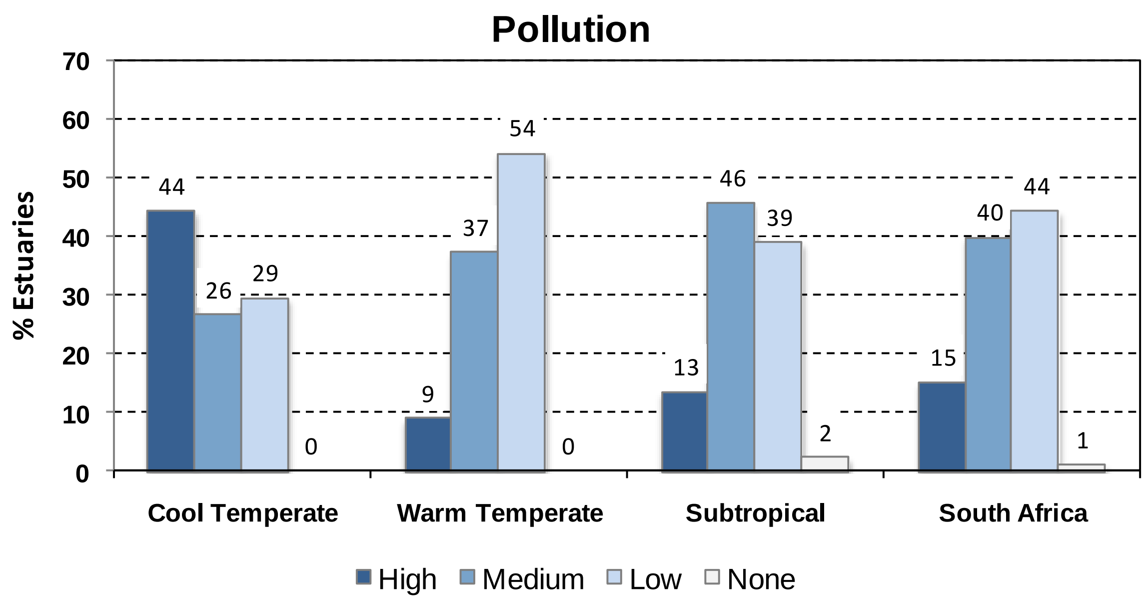


Figure 8.4 Quantification of the level of pollution pressures for the three biogeographically regions.

8.3 Exploitation of living resources

Overexploitation of living resources, predominantly fish and invertebrates in South African estuaries, influences changes in population size, biomass, sex-ratios, size/age distributions, community composition and trophic structure. In extreme cases, overexploitation can lead to recruitment failure whereby recruiting fish are systematically "mined out" after entering the estuarine nursery environment and there is no return migration to the sea or recruitment into the fisheries that depend upon them. Depending on the complexity of life-history strategies and the level of "natal" homing, recruitment back into the parental estuary may be reduced to such an extent that local extinction may occur.

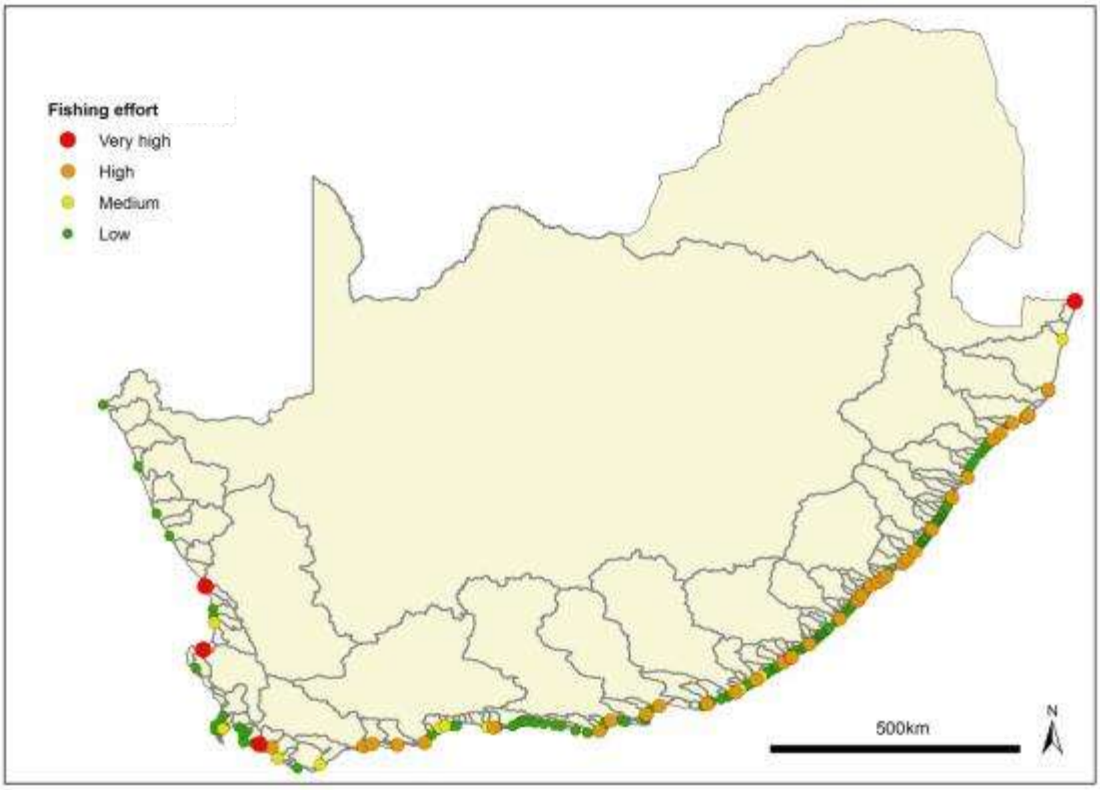


Figure 8.5 Locality map indicating fishing effort on South African estuaries.

All the large estuarine systems in South Africa are heavily overexploited, especially in terms of their linefish. Fishing effort in the Olifants, Berg, Bot and Kosi systems is extremely high and requires urgent management interventions to reduce the pressure on key nursery areas and collapsed stocks of estuary-associated species (see
Figure 8.5). Most of the catches are illicit and could be significantly reduced by dedicated compliance initiatives. Both legal and illegal effort is dominated by the use of gillnets which are cheaply available and efficient but also the most damaging in terms of selectivity and very high mortality of both juveniles and adults of prohibited bycatch species.

The results (Figure 8.6) of the assessment indicate that 1% of South Africa's estuaries are under excessive fishing pressure; especially alarming is that 9% of all Cool Temperate estuaries fall within this category. Another 13% of South Africa's estuaries are under significant fishing pressure, with 13% of estuaries in the Subtropical, 13% in the Warm Temperate and 3% in the Cool Temperate region under significant pressure. An additional 4% of South African estuaries are under a moderate degree of fishing pressure. Only about 14% of all estuaries in South Africa have no fishing pressures on them – most of these are located in national, provincial or municipal protected areas.

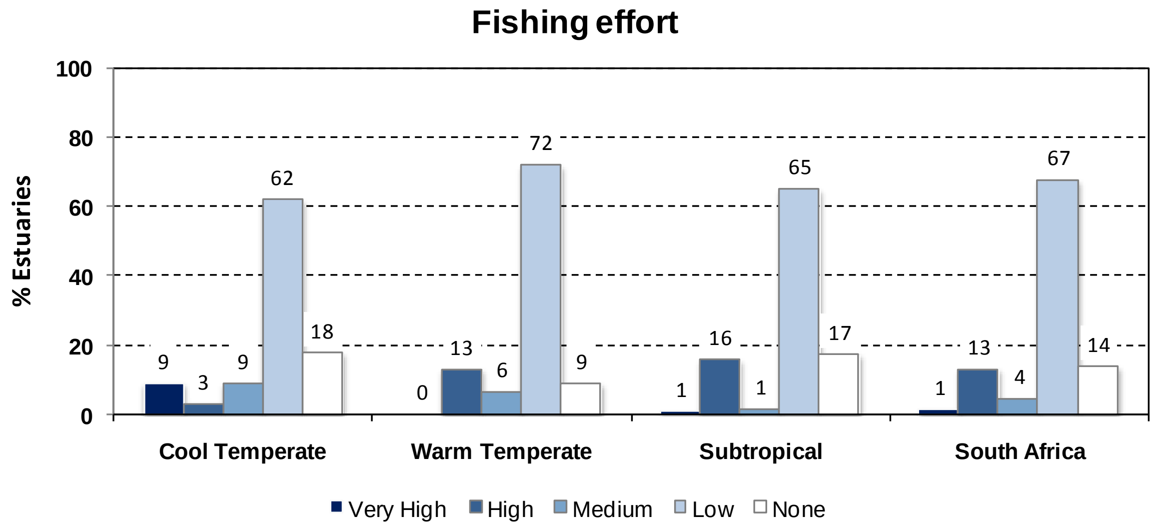
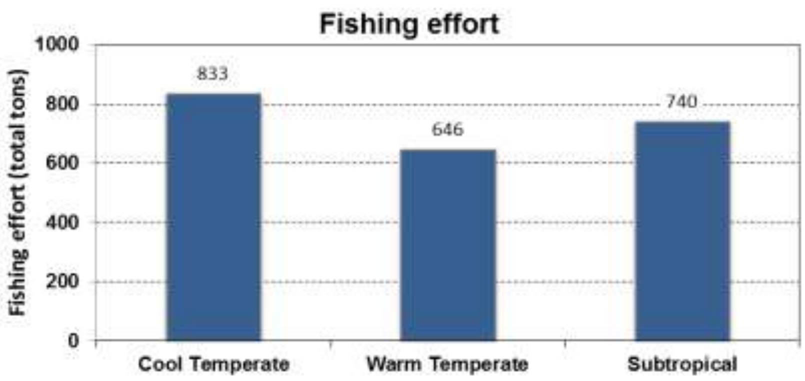


Figure 8.6 Quantification of the level of fishing pressures for the three biogeographically regions.



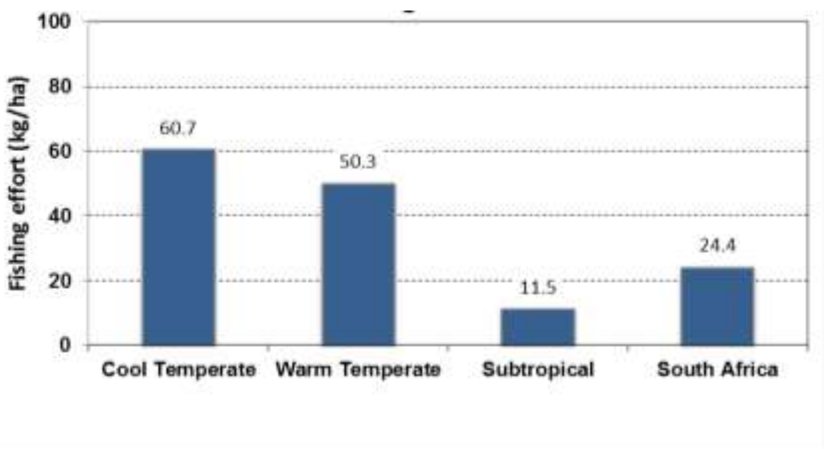


Figure 8.7 Fishing effort for the three biogeographically regions as Total annual catch (tonnes per region) and kilogram per hectare of estuarine area in each bioregion.

Figure 8.7 clearly indicates that while fishing effort is relatively equally distributed around the coast in the three biogeographical regions at 833 t, 646 t and 748 t for the Cool Temperate, Warm Temperate and Subtropical biogeographical regions respectively, the fishing pressure is significantly more in the Cool Temperate region where more than 60 t/ha in comparison with the national average of 24 t/ha is harvested annually.

Exploitation of invertebrates used as bait by recreational and subsistence anglers is a focal activity in most estuaries around the South African coast. Utilization of these living resources and the impact on other organisms and associated habitats may be persistent (e.g. close to urban environments) or more seasonal in nature (e.g. holiday resorts). In some estuaries, the impact of bait collection is considered to be very severe. Patterns of bait usage are obviously dependent on the estuary and fish species being targeted, but mud- and sand-prawns (*Upogebia africana* and *Callianassa kraussi* respectively) often emerge as the most sought after organisms (Wooldridge 2007). Pencil bait (*Solen* spp.) and bloodworm *Arenicola loveni* are also popular bait organisms.

Bait collection pressure was evaluated during the National Health Assessment on an estuary-by-estuary basis. About 84% of all South African estuaries have bait collection pressure on them but bait species are not considered overexploited in most systems as bait populations are quite resilient (Figure 8.8).

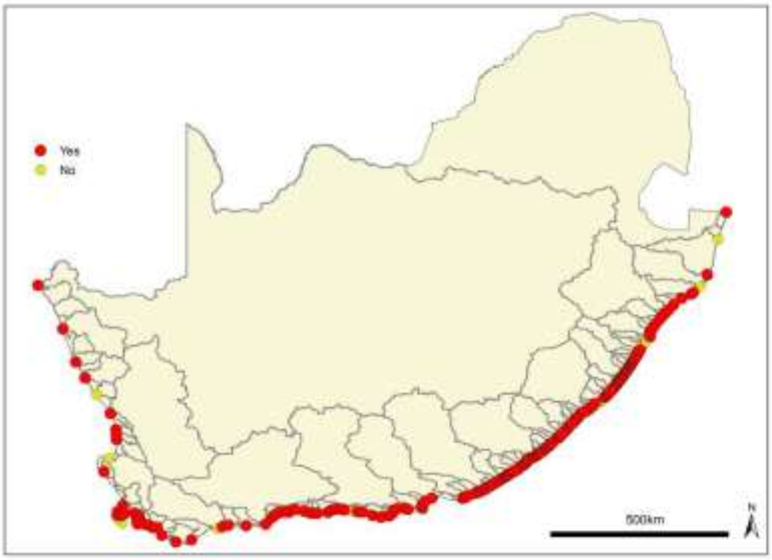


Figure 8.8 Locality map indicating estuaries that have some form of bait collection.

What is of concern is the related destruction and loss of habitat cause by inappropriate gear (e.g. bait-digging with spades). Bait collection also reduced biomass in both targeted and non-targeted invertebrate species. Small temporary open estuaries are seen as more sensitive to overexploitation than large permanently open systems and in some systems it may be appropriate to restrict bait collection, especially if water levels remain low for significant periods before breaching.

8.4 Land-use and development

Inappropriate land-use and development in and around an estuary, i.e. in the estuarine functional zone, can lead to habitat degradation, or loss, within an estuary. Low-lying developments, land reclamation, mining, infrastructure developments such as roads, bridges and jetties; or the remodelling of part of an estuary for harbour or marina construction, all create pressures (see Figure 8.9 for spatial distribution). Harbours and marinas usually involve major alteration of estuarine habitats and tidal flows. Land-use changes within the catchment and surrounding floodplain areas of the estuary are also of importance and can alter the sediment load to the coast. In addition, reduction of freshwater inflows to an estuary can also lead to alteration or loss of habitat, e.g. changing the sediment composition from sandy to muddy. Ultimately change in the structural habitat of an estuary can result in local extinctions, change in population size or biomass, change in community composition and structure, change in the ratios of generalist to specialist biota, and change in life-history strategies. It can also reduce the carrying capacity of an estuary for species higher up the food chain. Habitat degradation can also render an estuary more prone to alien invasions.

Habitat degradation or loss is above all a serious threat because of the risk of irreversible change. The degree to which each estuary’s functional zones were modified were largely visually determined (Google Earth, Spot 5) and augmented where possible by national data sets, flow requirements studies and field observations from specialists.

Some of the activities listed above are discussed in more detail as they represent ubiquitous pressures or a significant emerging pressure. One such pressure is road infrastructure, specifically bridges. There are a large number of case studies in South Africa where **bridges** across rivers and estuaries were built with little consideration of the environmental consequences (Morant and Quinn 1999).

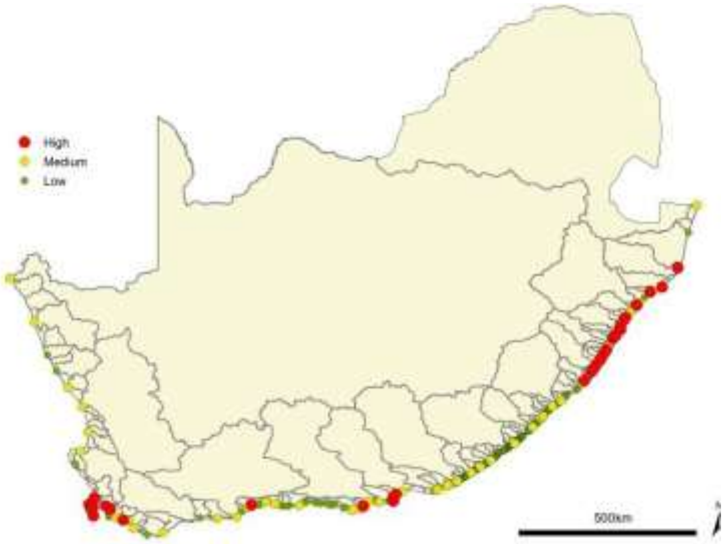


Figure 8.9 Locality map indicating habitat degradation within the estuarine functional zone.

The minimum and cheapest structure to convey a road or railway over a river or estuary, while still meeting safety requirements (e.g. 1:50 year flood), usually results in a comparatively narrow multi-span bridge with long-approach embankments. One of the obvious impacts of such bridges on estuaries is that in most cases it stabilises dynamic estuarine channels. In turn, the combination of stabilised channels and heavy floods being forced through constricted areas, leads to the extensive erosion of sediments underneath the bridge. Erosion beneath the bridge can also occur in conjunction with extensive deposition downstream from the bridge. The changes in flow velocity, and related sediment distribution, can lead to changes in habitat and biota. A typical example is the bridge spanning the Uilkraals Estuary. The 220 m long bridge compromises a 120 m causeway and a 100 m multi-span concrete bridge. It is notable that since the construction of the bridge over the Uilkraals Estuary the bloodworm *Arenicola loveni* has disappeared from the estuary upstream of the bridge (Heydorn and Bickerton 1982).

The approaches to a multi-span bridge are typically built over the floodplain vegetation (e.g. salt marshes), which are filled in with rubble and the road contructed on top (Day and Grindley 1981). Solid fill acts as an obstruction to tidal flows and an area of dead water can develop either side of the bridge span. Such dead water areas act as silt traps. In time, sandbanks and muddy shoals grow, which can reduce the tidal prism or volume of tidal water in and out of an estuary mouth. The changes in substrate can, in some instances cause the higher levels of marsh above a bridge to dry out and their production be lost to the estuary, e.g. Kromme. If tidal flows are impaired through the build-up of sediment, or bad bridge construction, this can lead to premature mouth closure in smaller temporarily open and closed estuaries, e.g. Seekoei. The most extensive series of bridges over estuaries in South Africa are those spanning systems on the KwaZulu-Natal South Coast. The South Coast railway spans every estuary, usually very close to the sea, for the entire distance from Durban to the Zothsa Estaury some 150 km to the south (Begg 1978). In addition, the N2 arterial highway and ancillary roads span the same rivers or estuaries.

The extensive and sometimes large scale physical alteration of estuarine habitat as a result of **mining** is also an important consideration as the long-term impacts on the environment have not been fully quantified and verified. The impacts of mining include: smothering by sediment deposition, increased turbidity causing reduced sunlight penetration of the water column and consequent possible reduced primary production; increased sediment concentrations resulting in decreased efficiency of filter feeders, clogging of fish gills, and other effects. There is a concern that the cumulative effect (spatially and temporally) of discharges from several mining operations may be severe.

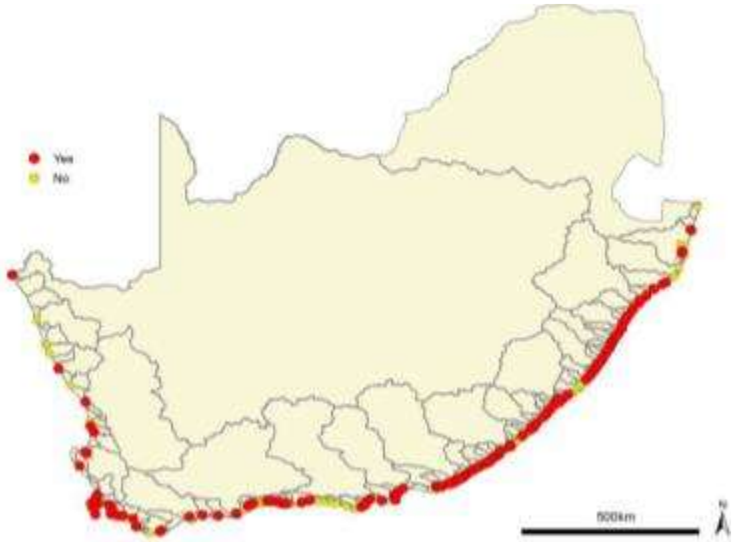


Figure 8.10 Locality map indicating estuaries that have infrastructure development (roads and bridges) within the estuarine functional zone.

The problems resulting from **sand mining** activities include aesthetic and ecological impacts (Figure 8.11) but also the long-term sustainability of the sand resource and potential implications for coastal stability (i.e. over time these cause erosion of the coastline). Of the 64 systems surveyed along the KwaZulu-Natal coast in 2007, 18 supported sand-winning operations (Demetriades 2007). These activities modify flows, produce high suspended solid loading in rivers and estuaries, as well as cause destruction of riparian and instream habitat.

Figure 8.11 Example of estuarine sand mining operations in the Mzimkulu Estuary - note the sediment plumes (Source: Google Earth).

The construction of **ports and marinas** may not be as prevalent in terms of infrastructure development but a number of large commercial ports are situated in or near estuaries, i.e. Port Elizabeth, Ngqura, East London, Durban and Richards Bay. All of these developments coincided with significant habitat destruction and/or modification. Major upgrades are currently under way to increase handling capacity and to absorb the rapid increase in commercial traffic (DEAT 2008). In addition, there are 12 proclaimed fishing harbours located mainly along the southern and western Cape coast, one of which is in an estuary, the Groot Berg. Several dedicated yacht harbours and marinas have also been built along the South African coastline from the Berg River in the west towards Port Alfred in the east. .

Dredging is vital for harbour and marina construction/expansion and maintenance of the channel and basin depths required for shipping and sailing. Potential dredging impacts include increased turbidity, smothering, changes in mouth stability, contaminated sediment (e.g. trace metals and hydrocartbons) released into the environment (DEAT 2008). Harbours and marinas, particularly those situated adjacent to cities and larger towns, are also vulnerable to pollution. Structures (e.g. quays) create areas of poor water circulation and as a result pollutants entering the sheltered areas, either from the land (e.g. contaminated stormwater runoff) or from activities in the harbour or marina (e.g. dredging), often accumulate with detrimental consequences to marine and estuarine life (e.g. causing fish kills).

The results (Figure 8.12) of the assessment indicate that 13% of South Africa's estuaries are under significant habitat modification or development pressure, with 32% of the estuaries in the Cool Temperate region, 16% in the Subtropical and 5% in the Warm Temperate region under significant pressure. An additional 33% of estuaries in South Africa are under a moderate degree of habitat modification pressure with the Subtopical (43% of estuaries in that region) and the Warm Temperate (38% of estuaries in that region) being the most significant.

Less than 10% of all estuaries in South Africa have no development pressures – most of these are estuaries confined to national, provincial or municipal protected areas.

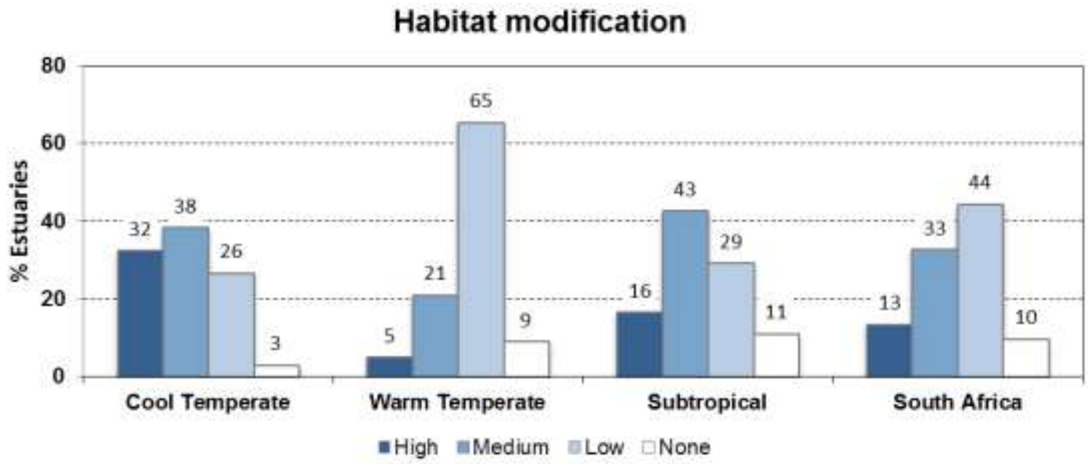


Figure 8.12 Quantification of the level of habitat modification pressures for the three biogeographical regions.

8.5 Estuary mouth manipulation

Estuary mouth manipulation can take a number of forms: artificial breaching (e.g. Bot, Swartvlei), channelisation (e.g. Seekoei, Zandvlei, Berg), or redirecting/diversion of the outlet (e.g. combined St Lucia/uMfolozi mouth). Estuary mouth manipulation may change the type of estuary, e.g. from temporarily open to permanently open. In most cases the need for mouth manipulation stems from inappropriate development in the estuarine functional zone.

The most pervasive of these manipulations is artificial breaching. Mouth manipulations are often also driven by an increase in closed mouth conditions, which in turn is linked to water resources development. For example, reduction in freshwater flow could lead to an estuary mouth being closed more frequently and for longer periods, leading to increased back-flooding of adjacent low-lying developments. This, in turn, will increase the pressure on authorities to artificially breach the mouth. A change in mouth dynamics usually results in an increase sedimentation and premature closure. This results in changes in salinity and other water quality factors. In addition, increased mouth closure can result in changes in productivity and recruitment of fish and invertebrates, impeded migration and genetic exchange and changes in the distribution of organisms (loss from certain estuaries).

Expert opinion and the KwaZulu-Natal Estuaries database were used to identify estuaries where some form of mouth manipulation was practiced. The mouths (outlets) of about 16% of South Africa's estuaries are artificially managed, but these account for 62% of the total estuarine habitat. It is apparent that inappropriate low-lying developments are forcing artificial mouth manipulations (e.g. breaching). This is partly because the backflooding area (encapsulated in the estuarine functional zone) under closed mouth conditions is not recognized explicitly by any South Africa legislation. Nearly 75% of all estuaries in South Africa close. When an estuary is closed, the water level in the estuary rises above sea level; but legally only the high water mark is recognized, not the backflooding mark. The result is pressure to artificially breach the estuary (because of inundation of housing, infrastructure, golf courses, or agricultural land that is inundated). **It is thus of the utmost importance that the ICM Act recognize backflooding explicitly i.e. the area above the high water mark up to the natural breaching level.**

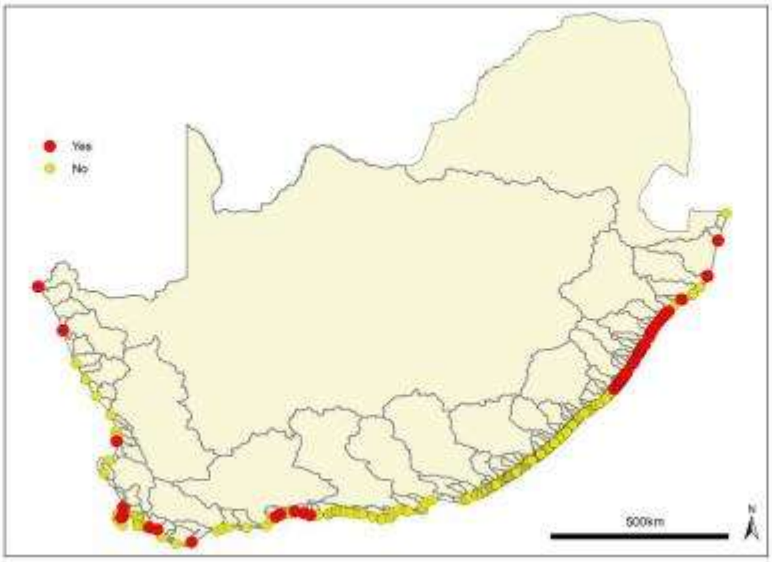


Figure 8.13 Locality map indicating estuaries known to be subjected to mouth manipulations.

Panel 4: Emerging pressure… Desalination plants

South African coastal municipalities are increasingly turning to reverse osmosis (RO) desalination technology to meet bulk water demands. RO desalination plants can be turned off during periods of low demand and are therefore particularly appealing to municipal managers of coastal resort towns where extensive, seasonal water requirement fluctuations are the norm. Recent technological advancements (improved pre-treatment, membrane material, plant design and energy recapture) have made RO technology more affordable and it is possible to commission a plant in a relatively short time period, particularly when compared to accessing other traditional bulk water supplies. Recent drought and a lack of traditional water sources in arid coastal regions (e.g. the Western Cape) have resulted in a proliferation of RO desalination plants in recent years. Conceptually, the process of RO is straightforward: high pressure pumps are used to force saline water through a semi-permeable membrane, dissolved salts and other impurities are retained and discharged as a brine waste stream and fresh product water is produced. Typical efficiency of modern RO plants utilizing sea water results in about half the volume of intake being produced as fresh water.

In reality, plants design can be complex, with extensive pre-treatment of source water required to prevent clogging and biofouling of plant infrastructure and the RO membranes. Pre-treatment typically includes filtration (aided by the addition of coagulants), pH control, the addition of anti-scalents, biocide, cleaning chemicals (weak acids and detergents) and neutralizer (if an oxidizing biocide is used). Any residual chemicals or other additives used in pre-treatment are frequently co-discharged after dilution with the brine into the receiving environment (usually the sea). Provided the brine is discharged into a suitable area with adequate mixing and offshore dilution, and a sufficient distance from sensitive habitats (reefs, estuaries, surf zones etc), impacts on the marine environment should be spatially limited and can be mitigated to some extent by discharge design. Data on the monitoring of the impacts of RO plants on the South African marine environment is however, almost nonexistent. International studies report impacts of varying significance, largely dependent on the plant size and characteristics of the receiving environment.

In terms of estuarine impacts, the development of RO desalination plants to purify sea water is preferable to extracting river or ground water and further reducing freshwater flow to estuaries. Poorly designed or situated RO desalinization plants may, however, have significant negative impacts on estuaries. The sheltered nature of many estuary mouths makes these areas appealing to marine engineers for the placement of plant infrastructure. Reducing the height of the plant above mean sea level can reduce pumping costs and avoiding the exposed shore can help protect pipelines, intake wells and discharge structures from waves and storm surges. Direct or beach well abstraction of source water from an estuary, and/or RO plant waste discharged directly into an estuary (or the adjacent nearshore from where it may enter the estuary prior to sufficient dilution), may have severe negative impacts on estuarine functioning.

To date three RO plants are known to have impacted on South African estuaries. A relatively small RO plant (0.2 million liters per day) extracts water from beach wells near the mouth of the Bushmans Estuary in the Eastern Cape and discharges brine via a pipeline directly into the estuary. Monitoring the impacts detected no elevation in salinity above background within ten meters of the discharge pipeline (Bornman & Klages 2004). This was attributed to low volumes of brine discharged relative to the total volume of the estuary water and good dispersion due to turbulent tidal mixing. The Bushmans River Estuary is also permanently open and frequently hypersaline, somewhat reducing the impacts of brine discharge.

A larger (1.5 million liters per day) RO plant was recently commissioned in Plettenberg Bay near the mouth of the temporary open Piesang Estuary in the Western Cape. Contrary to recommendations from the EIA process, extraction wells were sunk in the mouth of the estuary as sufficient depth of sand was not found on the adjacent Robberg Beach. Over a two-month trial period during the summer holiday period, the salinity of water extracted from the wells dropped from 22 PSU to 12 PSU and a substantial drop in the estuary water level took place. The estuary mouth was closed at this time and very little freshwater was entering the system. Partly out of concern about the impacts on the estuary, the plant was shut down and the municipality is currently seeking funds for an alternative marine water intake.

At Mossel Bay, pumping water from the construction site of the relatively large RO plant (15 million liters per day) drastically reduced water levels in the small temporary open Tweekuilen inlet (not assesses as part of this study). This impact was significant, but temporary in nature as operational impacts of this RO plant that has both marine pipeline intake and discharges are not expected to adversely impact the estuary.

These examples show that RO desalination plants can have impacts of varying significance on estuaries. Increasing demand for limited bulk water supplies will cause and increase in the number of desalination plants along the South African coast and involvement of estuarine scientists during the planning and construction phases and monitoring of the operational impacts will be required to mitigate against potential negative impacts on estuaries.

Source: Dr K Hutchings

Panel 5: Emerging pressure… Aquaculture and Mariculture

Aquaculture can be divided into freshwater aquaculture and marine aquaculture or mariculture (DEAT 2008). Freshwater aquaculture potentially can have an impact on the coastal marine environment when such activities lead to the pollution of river water that ultimately enters estuaries and the sea. As far as could be established, detrimental impacts of freshwater aquaculture are currently not evident in estuaries. Of greater concern is mariculture, especially land-based marine aquaculture which is growing in South Africa and includes intensive farming practices involving re-circulation and flow-through systems which include the use of ponds and brackish water environments, e.g. linked to estuarine environments.

Finfish culture, in particular, is moving towards land-based grow-out operations because of the high risk and cost of installing cages in rough seas typical of the South African coast (DEAT 2008). Inappropriate mariculture activities can contribute to the destruction of estuarine habitats, as well as to the pollution of coastal waters. For example, the construction of inlet and effluent pipelines can result in the excavation or disturbance of sensitive dunes and sandy shores. Large areas containing coastal indigenous vegetation may also be removed to make way for infrastructure. Waste from the marine aquaculture operations can also contribute to pollution of estuarine and coastal marine waters. For example, nutrient enrichment associated with the disposal of faecal matter can contribute to eutrophication, particularly in sheltered environments.

If not managed effectively, marine aquaculture operations can promote the spread of microbial contaminants, thus introducing disease to wild populations. Genetic contamination has become a major problem in the Norwegian fjords where escaped farmed salmon have interbred with, and consequently affected, the survival of wild salmon populations. This mixing of stocks has mostly been associated with sea cages but there is also the possibility that flow-through systems can have the same impact through juvenile fish escaping into the near shore environment.

9. HEALTH STATUS OF ESTUARIES

L van Niekerk, JB Adams, G Bate, D Cyrus, N Demetriades, A Forbes, P Huizinga, SJ Lamberth, F MacKay, C Petersen, S Taljaard, S Weerts, AK Whitfield & TH Wooldridge

The National Estuarine Health Assessment was a desktop procedure during which a national team of 13 regional specialists, covering the full suite of disciplines, evaluated estuary health based on the general (desktop-derived) characteristics of the estuaries. The method used was a standardized approach developed for determining the ecological water requirements of South Africa's estuaries which has been applied to about 30 systems along the coast. All the specialists that contributed to the assessment were familiar with the Estuarine Health Index from previous DWA studies.

For the National Health Assessment, the Lake St Lucia system was disaggregated into two sections (see text box below), the Lake St Lucia and the uMfolozi Estuary respectively. This was done to develop a clearer understanding of their relative contribution to the total health status of South Africa's estuaries. For a similar reason, Mhlathuze and Richards Bay Harbour were evaluated as separate estuaries, though they used to be a single system. While this is a somewhat artificial division, it was deemed necessary as collectively these systems provide for more than half of South Africa's estuarine area and could distort the results significantly. The national health assessment was therefore conducted on 291 systems in total.

Note:
The technical separation of the St Lucia and uMfolozi estuaries in this assessment was done to assist with gaining a deeper understanding of a very complex estuarine system that comprises a multitude of ecosystem processes and a range of habitat types. Throughout the assessment, the underlying assumption was that under natural conditions the two systems would have been connected, with the uMfolozi flowing into St Lucia during periods of mouth closure, i.e. St Lucia would have been more open and uMfolozi at times closed for longer periods. This technical approach should not been misconstrued as an argument for managing them as separate systems. At all times the interactions and dependencies between these two estuary mouths should be recognized and the Lake St Lucia system management as one. In other words, all management plans, ecological water requirements studies and Health Assessments should be done within the context of the high degree of connectivitly between these two estuaries - what is done to the one is done to the other - it is just the degree of resilience to a specific pressures that could differ between the two estuaries.

9.1 The estuarine health determination process

The health condition (also called the Present Ecological State) of an estuary is typically defined on the basis of current condition (i.e., the extent to which it differs from its reference or natural condition). Based on the above, estuary condition is described using six "Present Ecological State (PES)" categories, ranging from natural (A) to critically modified (F) (Table 9.1). The fact that the physical conditions in estuarine systems are more dynamic than those of other aquatic ecosystems means that severe degradation of an estuary may involve a shift from a dynamic to a more stable, or unidirectional, system. This means that the loss of dynamic function *per se* is an important indication of declining estuarine health (DWAF 2008). Thus, in an estuarine health assessment, measures of these different states need to be sufficiently robust so that different practitioners/disciplines will arrive at the same categorisation.

Table 9.1 Ecological Management Categories (DWAF 2008).

Health Condition	Description
A	Unmodified, natural.
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions and processes are essentially unchanged.
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions and processes are still predominantly unchanged.
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions and processes have occurred.
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions and processes are extensive.
F	Critically/Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions and processes have been destroyed and the changes are irreversible.

The Estuarine Health Index was calculated through consideration of the following components (DWAF 2008):

A. Abiotic

- Hydrology (% change in MAR)
- Hydrodynamics and mouth condition
- Water chemistry (salinity and combined score for other variables)
- Sediment processes

B. Biotic

- Microalgae
- Macrophytes
- Invertebrates
- Fish
- Birds

The assessment was undertaken by a multidisciplinary group of estuarine scientists (the chapter authors) in a workshop setting, based on their collective understanding of the likely impacts affecting each system. Expert knowledge and available information were all used to build up a "picture" of the probable pristine state of each estuary and the changes under current conditions. The Estuarine Health Index is applied to all levels of ecological water requirement studies (comprehensive, intermediate or rapid), with only the level of information supporting the study and level of confidence varying. For each variable the conditions are estimated as a percentage (0 – 100%) of the pristine health. Scores are then weighted and aggregated (the rules are provided in Table 9.1 and Table 9.2) so that the final score reflects the present health of the estuary as a percentage of the pristine state. Both abiotic and biotic variables are included as the relationships between the abiotic and biotic variables are often not well understood and because the biotic response to certain abiotic variables can be lagging.

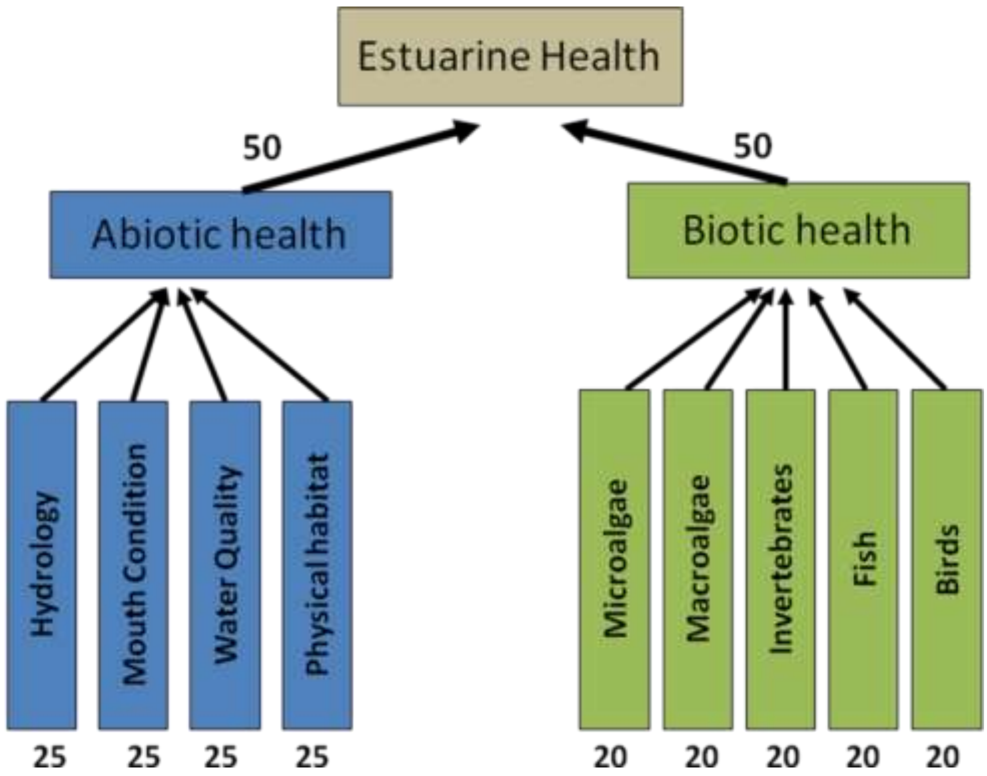


Figure 9.1 Components and weightings of the Estuarine Health Index (DWAF 2008).

Table 9.2 Calculation of the Estuarine Health Score (DWAF 2008).

No.	Variable	Example Score	Weight
Abiotic (habitat) variables			
1	Hydrology	41	25
2	Hydrodynamics and mouth condition	80	25
3	Water quality	59	25
4	Physical habitat	80	25
A. Habitat health score = weighted mean		**65**	**50**
Biotic variables			
1	Macrophytes	60	20
2	Microalgae	60	20
3	Invertebrates	70	20
4	Fish	60	20
5	Birds	90	20
B. Biological health score = weighted mean		**70**	**50**
ESTUARINE HEALTH SCORE = weighted mean of A & B		**67.5**	

For comparative reasons (with previous assessments) the individual health scores were aggregated as illustrated in Table 9.3. In estuaries, unlike in the terrestrial environment, degradation or loss of habitat seldom means a complete loss of an estuary. This can only happen if an estuary becomes completely degraded, e.g. changed into a parking lot or golf course. In most cases, degradation means loss of processes or loss of biological functionality, e.g. the estuarine space is filled with a different salinity condition or different species composition. This loss of functionally happens on a continuum, with estuaries which retain more than 90% of their natural processes and pattern being rated as Excellent and estuaries degraded to less of 40% of natural functionality rated as Poor.

Table 9.3 Schematic illustration of the relationship between loss of ecosystem condition and functionality.

Condition	≥91%	90-75	75 - 61	60 - 41	40-21	≤20
Category	A Natural	B Largely natural with few changes	C Moderately modified	D Largely modified	E Highly degraded	F Extremely degraded
State	Excellent	Good	Fair		Poor	
Functionality	Retain Process & Pattern (representation)		Loss of Process or Pattern		No Process & Pattern	

9.2 Health status of estuaries per biogeographical region

To allow for comparison with previous health assessments, the number of estuaries in different health states were aggregated for each biogeographical region (see Table 9.4).

Using "*number of estuaries"* as a measure, the NSBA 2004 analyzed the condition of South Africa's estuaries as a percentage of the total number of systems (259) (Turpie 2004). The general conclusion drawn was that the overall health of South African estuaries was considered to be relatively good. A total of 28% of estuaries were considered to be in excellent state and another 31% were in a good state. About 25% were in a fair state and only 15% were in a poor state.

Table 9.4 Summary of Estuarine health status as percentage of estuaries in the three biogeograpical regions for the NSBA 2004 (adapted from Whitfield 2000).

Biogeographical region	Condition				Total Number
	Excellent	Good	Fair	Poor	
Cool Temperate	9	9	36	45	11
Warm Temperate	27	43	18	12	127
Subtropical	31	21	32	16	121
Total	**28**	**31**	**25**	**15**	**259**

The NBA 2011, using "*number of estuaries"* as a measure (see Table 9.5 for detail), similarly found that a total of 17% of estuaries were considered to be in excellent state and another 41% were in a good state. About 35% were in a fair state and 7% were in a poor state, with this analyses being very sensitive to the condition of the large number of temporarily open/closed estuaries.

Table 9.5 Summary of the Estuarine health status as a percentage of estuaries in the three biogeograpical regions (NBA 2011).

Biogeographical region	Condition				Total
	Excellent	Good	Fair	Poor	
Cool Temperate	6	15	50	29	34
Warm Temperate	19	50	28	2	124
Subtropical	17	39	38	5	133
Total	**17**	**41**	**35**	**7**	**291**

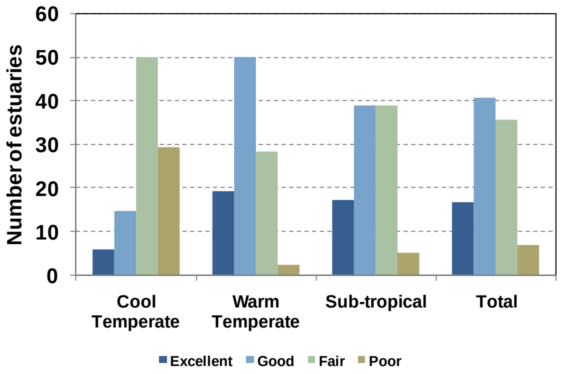
A comparison between the 2004 and 2011 studies shows about a 10% reduction in the number of estuaries in excellent state, but also that there were fewer estuaries in a really poor state. While the decline in excellent condition estuaries can be contributed to increase pressure and degradation, some of these shifts can be contributed to the more systematic approach followed during the NBA 2011 national health assessment.

This relative optimistic picture changes dramatically if “total estuarine area” (expressed as hectares habitat) is used as the measure. Table 8.6 provides a summary of the state of South Africa’s estuaries expressed as a percentage of the total habitat (ha). From this analysis it is very clear that only a very small percentage of estuarine habitats are in an excellent condition, with most of this area being located in the Warm Temperate region, i.e. the numerous small Wild Coast estuaries. Only about 1% of estuarine area is in an excellent state and only 14% of the total estuarine habitat is in a good state, once gain mostly represented by systems in the Warm Temperate biogeographical region. The NBA 2011 determined that most – 85% - of the estuarine habitat in South Africa is in a poor to fair state as illustrated in Figures 8.3 to 8.6.

Table 9.6 Summary of Estuarine health status as a percentage of total estuarine habitat in the three biogeograpical regions (number of estuaries in brackets).

	Condition				Total area (ha)
Biogeographical region	**Excellent**	**Good**	**Fair**	**Poor**	
Cool Temperate (34)	0	1	96	3	13 720
Warm Temperate (124)	7	49	45	0	12 849
Subtropical (133)	0	10	14	75	64 275
Total area (ha)	**1**	**14**	**31**	**54**	**90 844**

As the Lake St Lucia system (St Lucia and uMfolozi combined) represents more than 56% of South Africa’s estuarine habitat (51 0000 ha), its poor condition significantly influences this assessment. St Lucia’s condition is a result of the artificial diversion of the uMfolozi River from St Lucia since 1952 and an extended drought in the region with the resultant reduction in freshwater inflow. As this is a reversible state of affairs, the iSimangaliso Authority is currently implementing a strategy to join the uMfolozi and St Lucia mouths, and has also raised funding from the Global Environment Facility to investigate and implement long-term solutions. Continued national support to restore this national asset with international status will be required. (see Panel 6 for more detail).



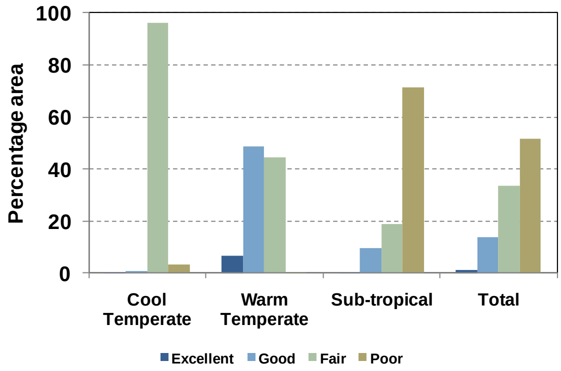


Figure 9.2 A graphic illustration of the different perspectives arising when the National Health Assessment is presented as "Number of estuaries" or "Percentage Area". The latter analysis highlights the fact that the majority of South Africa's estuarine area is in a poor to fair state.

Panel 6: Lake St Lucia system: An estuary in crisis!

Lake St Lucia is the largest estuarine system in Africa, it forms part of a World Heritage Site and is a Ramsar Site of international importance. The ecological importance of the system is well documented with its major role being that of a nursery ground for marine fish species which spawn at sea and whose juveniles are either wholly or partially dependant on St Lucia to complete their life cycles. The system is the most important juvenile fish nursery on the south-east African coastline, contributing to the fish populations over a large area of the offshore continental shelf, particularly adjacent to the Thukela Bank and Richards Bay area. In addition, it is an important nursery ground for penaeid prawns that come from South Africa's only breeding population on the Thukela Banks.

While changes in the catchments of the rivers feeding the Lake St Lucia system have affected the amount and quality of water entering the lake, the major impacts on the system have arisen through human intervention in the uMfolozi catchment. In 1911 the uMfolozi floodplain began to be converted into agricultural land for sugarcane farming. In the late 1920s, a system of drainage canals was built. By the 1940s concern was being expressed about sedimentation in the mouth region, which was attributed to the canalization of the uMfolozi River. In the early 1950s the combined mouth closed and there was extensive backflooding. This was dealt with by artificially breaching the mouth. From 1956 a separate mouth was opened for St Lucia, and since then the separation of the uMfolozi and St Lucia estuary mouths has been actively maintained. This separation was considered necessary to prevent the threat of sediment accumulation in the lake. Due to the separate mouth policy, the benefits of the uMfolozi water were lost to the estuary system. The inflow from the uMfolozi river is the driver of the combined system as it plays an important role in maintain open mouth conditions and preventing/reducing the occurrence of lethal hypersalinty levels in the Lake St Lucia system. Extensive dredging in the Narrows took place in an attempt to increase exchange with the Lake and keep the mouth open. Dredging operations lasted for over 40 years.

In June 2002 the St Lucia Estuary mouth closed as a result of drought conditions and lack of freshwater inflow from the uMfolozi River, and remained so for four years and nine months. During this period salinities throughout the system increased dramatically, with False Bay and North Lake reaching beyond 200 (seawater = 35) and Charters Creek in the South Lake going beyond 120. Such high salinity levels have never before been recorded in the system. At the same time, as the salinities were increasing due to evaporation, the water level decreased rapidly and by December 2003 the lake had separated into four compartments with only 25% of the surface area being covered by water. Due to the ongoing drought, by July 2006 only 10% of the lake's entire 350 km^2 was covered by water.

At the beginning of March 2007 cyclonic activity off the southern tip of Madagascar in the form of Cyclone Gamede resulted in a major storm surge along the entire KwaZulu-Natal Coastline. The effect on St Lucia was that the storm surge breached the estuary mouth and with levels at the time being in excess of half a meter below mean sea level, seawater poured into the system. It continued to do so for six months before finally closing again during August 2007, with the lake some 75% full and salinities throughout the system being close to that of seawater. The system remains closed to the sea with the water level only covering <50% of the lake's 350 km^2 surface area (November 2011).

During the period since closure there have been major mortalities of invertebrates, a number of fish kills, as well as a large algal bloom in the north of the system. Research results indicate that there has been a substantial decrease in the diversity of the zooplankton community, whilst benthic invertebrates showed a decline in the number of taxa, with the community composition also having changed over time. The fish fauna has shown a significant decrease in both species and numbers. In addition, the prolonged closure of the link to the sea has resulted in the nursery function for marine fish and prawn species, whose life cycle requires that their juveniles enter the estuary, being totally unavailable. Results from research in the nearshore marine environment have now linked population decreases in some adult breeding stocks to the closure of the St Lucia estuary.

Fish populations in the St Lucia system have long been subject to intensive exploitation by recreational, subsistence and commercial fishers. Prior to the extended closure, the subsistence gillnet fishery had developed to an unsustainable commercial-scale and was in the process of being phased out. This was expedited by most of the fishing area drying up. However, fishing pressure remained high and overexploitation exacerbated by fish becoming concentrated and more easily caught in some areas. This lead to an emergency closure of the lower reaches to fishing to protect some species in the early 2000s. This protection came from a ministerial level. Consequently, It is felt that although the response was quick, it could have been even more so had the iSimangeliso Authority the power to implement local fishery control measures at their discretion.

Due to Lake St Lucia's international and national significance, the iSimangaliso Authority has raised funding from the Global Environment Facility (GEF) to investigate and implement a long-term solution to the hydrological issues facing the Lake St Lucia system. In parallel to this investigation the management strategy for 2011/2012 will result in the reversal of the 56 year old approach to managing Lake St Lucia; that is, allowing the uMfolozi and Lake St Lucia estuary mouths to join to form a combined mouth, and thereby allowing it to function as naturally as possible. In keeping with adaptive management, an ongoing review and evaluation based on monitoring of salinity, lake levels and ecosystem health will be continue as these interventions are implemented.

This management strategy has been based on the review of current scientific knowledge, particularly the recent research on sources and dispersal of sediments. The proceedings of the 2010 Consortium for Estuarine Research and Management (CERM) workshop endorsed the relinkage of the uMfolozi and St Lucia estuaries and the implementation of measures that will reduce any excessive input of sediment from the former into the latter system (Bate et al. 2010). This endorsement states that: ***"Historical evidence from early maps and anecdotal evidence indicate that changes in the uMfolozi/Msunduzi floodplain have had profound impacts on the uMfolozi Estuary and indeed on the whole St Lucia lake system. The separation of the uMfolozi from St Lucia in the early 1950s resulted in a major change in the way that St Lucia functioned. Only now are we beginning to see and experience the full implications of that separation for the well-being of the ecosystem, with the lake virtually drying out completely for the first time in living memory."***

A major concern in the short- and even medium-term is that the mouth of the Lake St Lucia will remain closed for a number of years to come unless a major rain/cyclonic event delivers sufficient water to the lake for it to fill to above its normal mean lake level. This may not be the case as since 30 July 2011 the uMfolozi mouth has moved about 370 meters north towards Lake St Lucia and the park are investigating ways of expediting the joining of the systems.

Source: Prof D Cyrus (with input from B James and SJ Lamberth)

Along the West Coast the predominantly closed estuaries tend to be in a good state while the large permanently open estuaries on average were in a fair state. The numerous small temporarily open/closed estuaries around Cape Town were generally in a poor state. The National Health Assessment once again confirmed that estuaries along the south and south-east coast tend to be healthier than those in the rest of the country. The numerous small estuaries along the former Transkei/Ciskei coastal area have the best overall health. The KwaZulu-Natal south coast had the highest number of estuaries in a poor state. This was largely due to direct habitat loss and artificial breaching related to development pressures in the estuarine functional zone, as well as intensive sugar cane farming in most of the catchments. In general, urban estuaries tend to be in fair to poor health along the intensively developed areas of the Cape south-west coast, around Port Elizabeth, and along almost the entire KwaZulu-Natal coast.

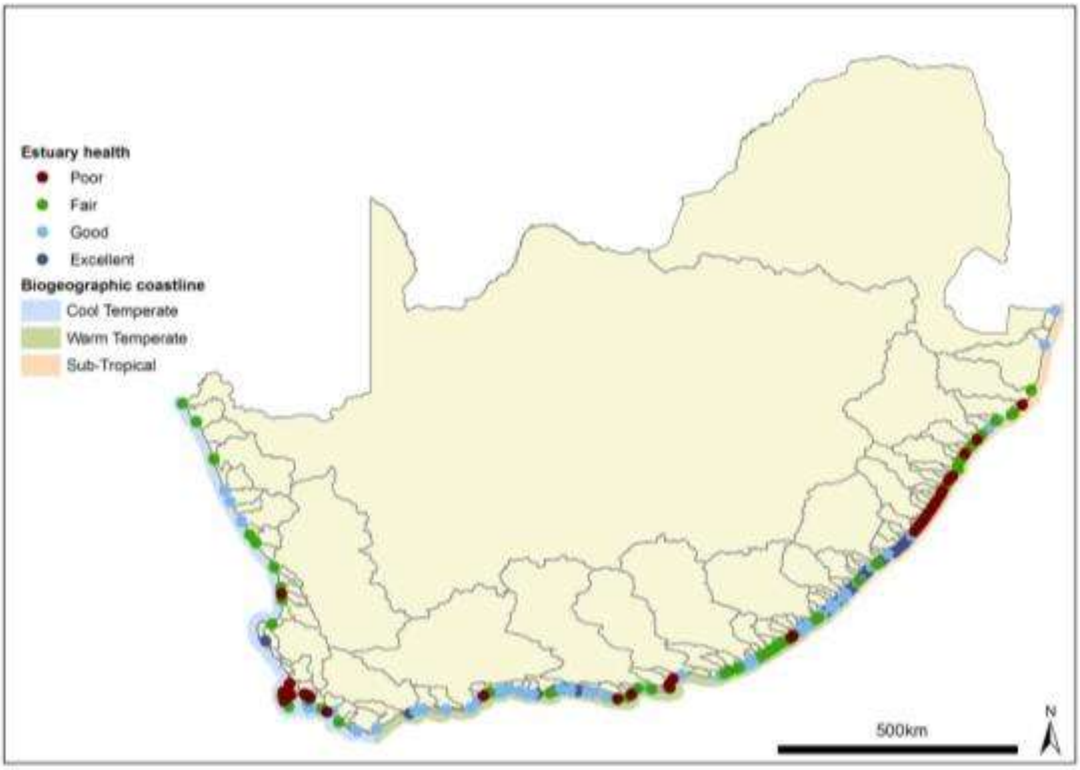


Figure 9.3 Health status of South Africa's estuaries.

The temporarily open/closed estuarine habitat types were predominantly in a good (28%) to fair (65%) state. Smaller estuaries (and their related smaller catchments) generally tend to be subjected to fewer pressures. If there were no direct development pressures (i.e. urban development), these systems tend to be healthier than larger estuaries. Large estuaries (both permanently and temporarily open) tend to have more catchment and direct development pressures and are therefore predominantly in a fair to poor state (>80%). Freshwater dominated estuaries (river mouths) tend to have the most natural resilience, but also have significantly more catchment and development pressures, with the majority (99%) of the habitat being in a fair state. The very large permanently open estuaries (estuarine bays) faired the best as they are buffered against development through strong tidal exchange, tending towards a good (38%) to fair state (40%).

The large temporarily open/closed systems (estuarine lakes) were in the worst state, with 84% of their habitat being in a poor condition. As stated above, this was largely the result of the poor condition of the St Lucia system, but it should be noted that only 10% of the estuarine lake habitat in South Africa is in a good condition. As estuarine lakes represent about 60% of South Africa's total estuarine habitat, and are very vulnerable to catchment and development pressures, it is strongly recommended that they be more effectively management and protected.

Panel 7: Verification of National Health Assessment

The findings of previous health assessments (about 30), conducted as part of ecological water requirement studies or estuary management plans (e.g. Verlorenvlei), are listed in blue in the summary table of the desktop National Health Assessment (Appendix C). Workshop participants used these more in-depth studies to bench mark their scoring under the more streamlined method of the National Health Assessment. In general, workshop participants felt that they were scoring conservatively and overestimating the condition, or current health state, of estuaries by about 5 to 10 percent. This was seen as a positive outcome, as the results of the National Health Assessment are to be used for biodiversity planning, the ecosystem threat status Assessments and the Protection Levels determinations. In this context, estuaries should not be discounted or ignored if they could contribute to biodiversity targets or headline indicators. Reasons for the elevated health scores were: lack of good hydrology (inflow data) as the WSAM did not incorporate dam developments and discharges accurately; lack of good water quality data; and the large spatial scale at which the study was conducted (i.e. estuaries were evaluated on Google Earth/Spot 5 images versus field visits).

In addition, the results of the National Health Assessment were further affirmed against a number of more detailed EWR studies conducted subsequent to this initial assessment. The results show that the National Health Assessment estimates deviated by between 1 and 14 percent from the more in-depth assessments. The desktop assessments were more accurate if the flow data was accurate, with the degree of deviation being lower in categories Excellent and Good, but less accurate in the case of highly modified systems (i.e. categories Poor and Heavily degraded).

Table 9.7 A comparison between the National Health Assesment and more detailed ecological water requirement studies.

EWR Study	Level	NBA Score	EWR Score	Score difference
Sundays (2010)	Intermediate	C (68)	C (67)	-1
Groot Berg (2010)	Intermediate	C (62)	D (59)	+3
Bushmans (2010)	Rapid	C (73)	C (72)	-1
Bot (2011)	Rapid	C (62)	C (71)	-9
Little aManzimtoti (2011)	Rapid	D (43)	E (38)	+5
Mbokodweni (2011)	Rapid	E (35)	E (33)	+2
Umzimkulu (2011)	Rapid	C (70)	B (79)	-9
Mgeni (uMngeni) (2011)	Rapid	D (47)	E (33)	+14

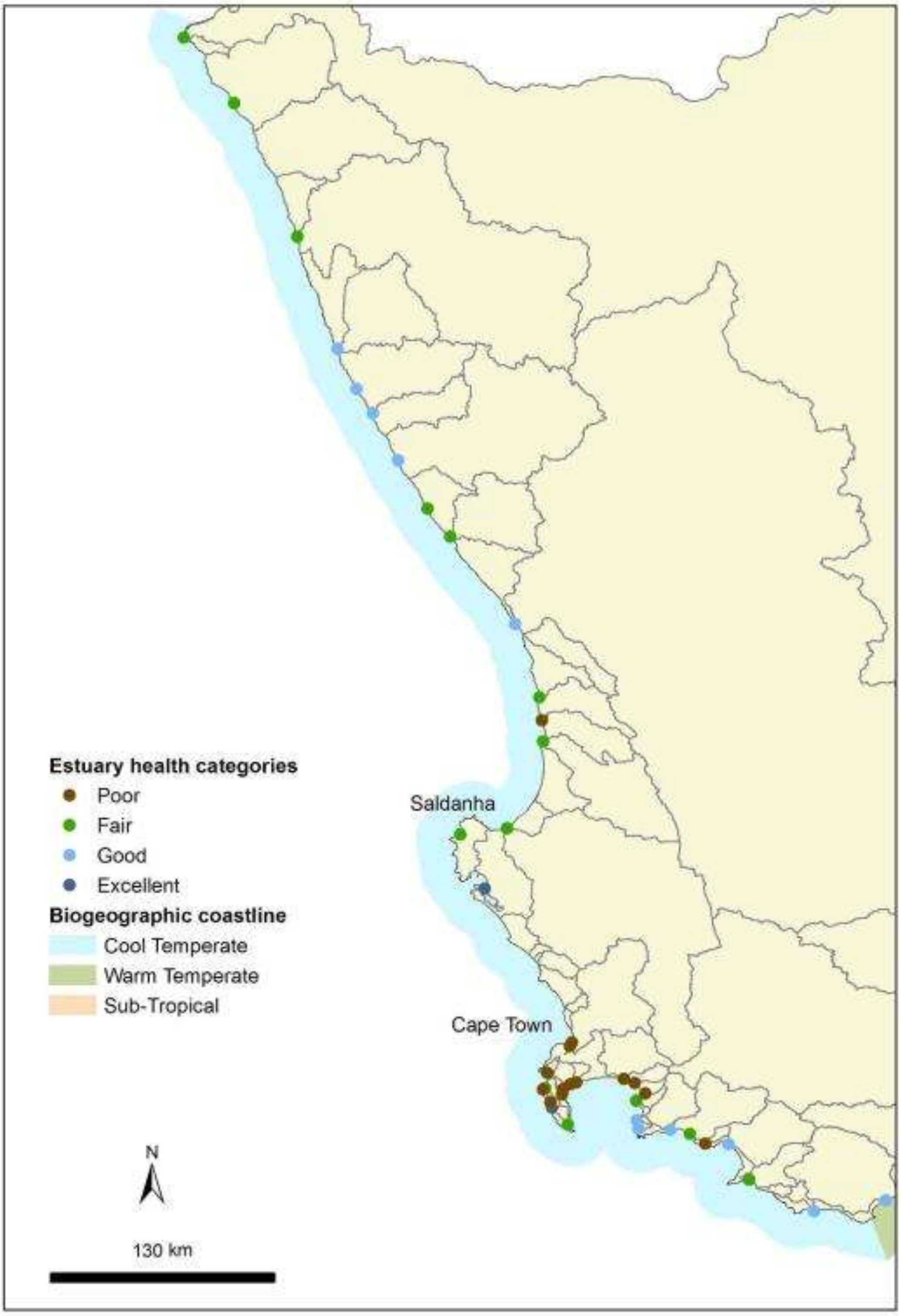


Figure 9.4 Health status of estuaries in the Cool Temperate biogeographical region.

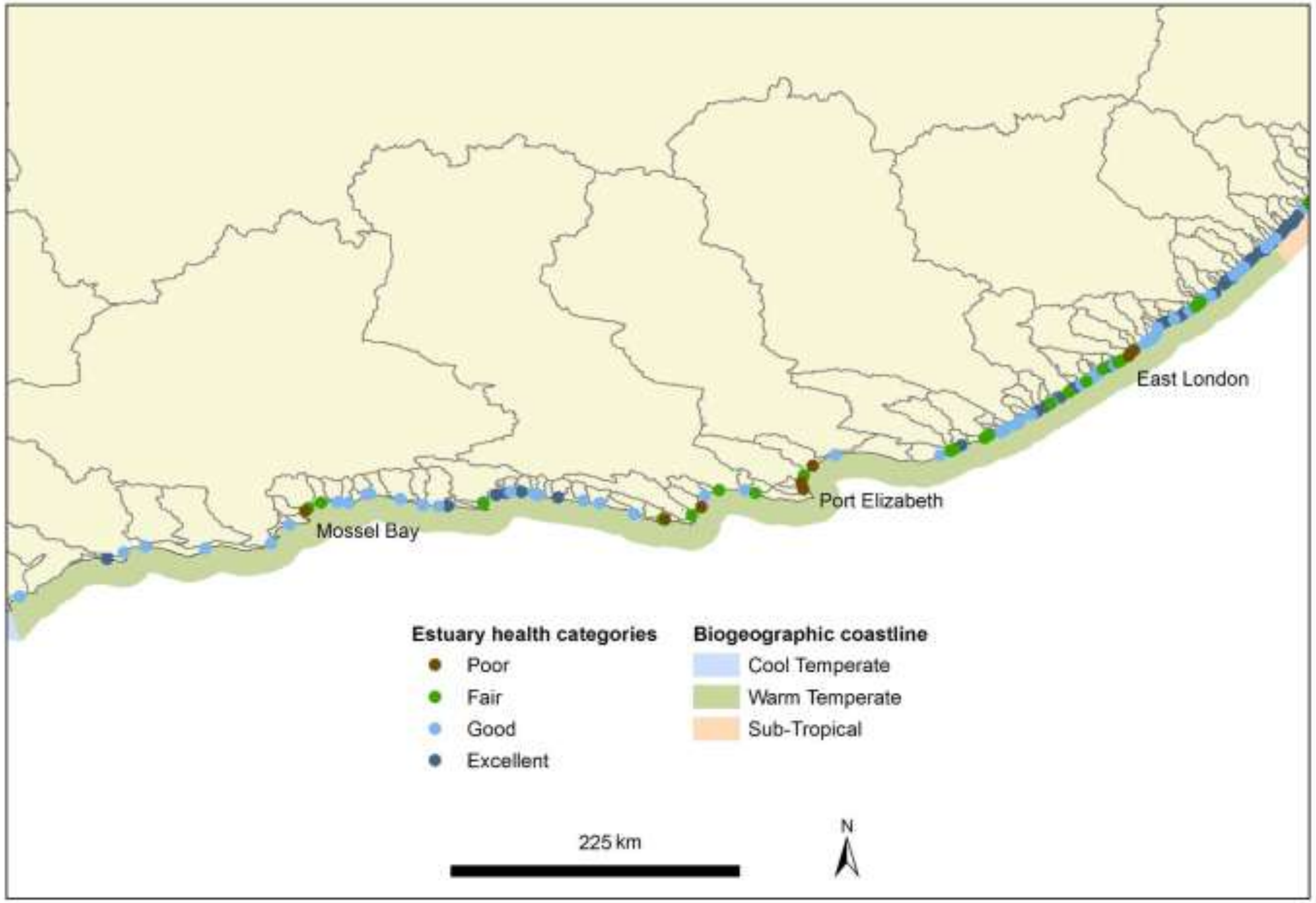


Figure 9.5 Health status of estuaries in the Warm Temperate biogeographical region.

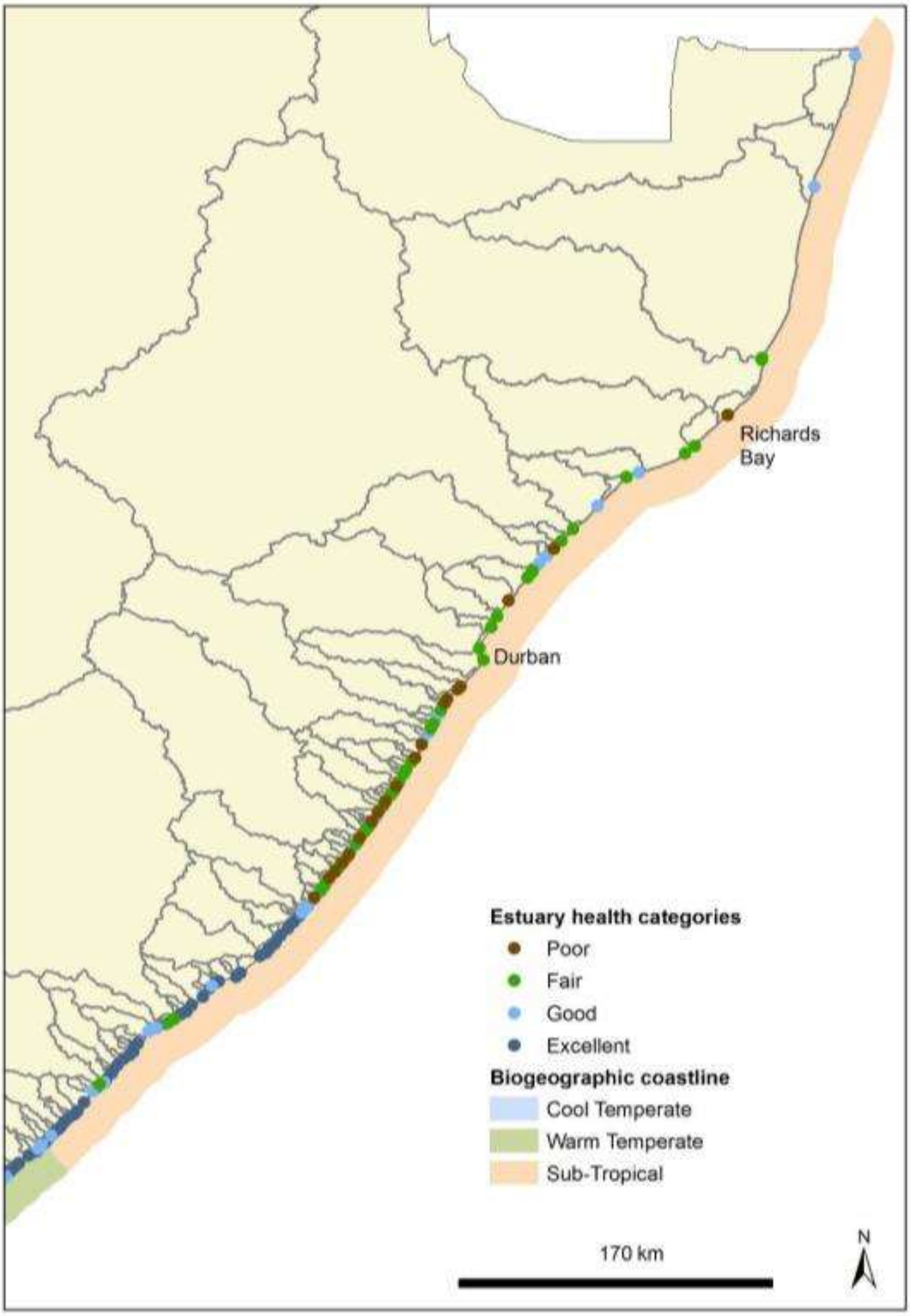


Figure 9.6 Health status of estuaries in the Subtropical biogeographical region.

9.3 Health status of Estuaries within various Coastal District Municipality

To develop a better understanding of where the most urgent need for intervention on the local authority level is required, the National Health Assessment data was also aggregated at the District / Metropolitan Municipality level (see Table 9.8 and Figure 9.7).

The Eden District Municipality has the most excellent and good condition estuarine habitat at 13% and 69% respectively. The O.R.Tambo District Municipality also comprises of a high percentage excellent (13%) and good (62%) state estuarine area. The Amatole District Municipality comprise 5% excellent and 60% good state estuarine habitat. In contrast, the Umkhanyakude, eThekwini and City of Cape Town are the three municipalities with the most estuarine habitat in a poor condition, at 85%, 72% and 44 % respectively. The Nelson Mandela Bay Metro, Ugu, Overberg and West Coast Municipalities also manage some poor condition estuaries, representing between 1 and 3% of the total estuarine area in South Africa. In addition it should be noted that the West Coast and Nelson Mandela Bay Metro had no excellent or good estuarine habitat within their municipal areas.

Table 9.8 Summary of Estuarine Health as a percentage of total estuarine habitat in the coastal District / Metropolitan Municipalities (number of estuaries in brackets).

District municipality	% of SA estuarine area	Health Condition			
		Excellent	Good	Fair	Poor
Amatole (83)	4	5	60	36	0
Cacadu (26)	3	1	8	91	0
City of Cape Town (16)	1	1	0	55	44
Eden (20)	6	13	69	17	0
eThekwini (16)	2	0	6	22	72
iLembe (9)	0	0	45	55	0
Namakwa (4)	1	0	4	96	0
Nelson Mandela Bay Metro (5)	1	0	0	97	3
O.R.Tambo (45)	2	13	62	25	0
Overberg (11)	5	0	11	88	1
Ugu (41)	1	0	26	72	2
Umkhanyakude (4)	61	0	8	7	85
Uthungulu (5)	4	0	6	94	0
West Coast (6)	9	0	0	99	1
% of total SA estuarine habitat	**100**	**1**	**14**	**31**	**54**

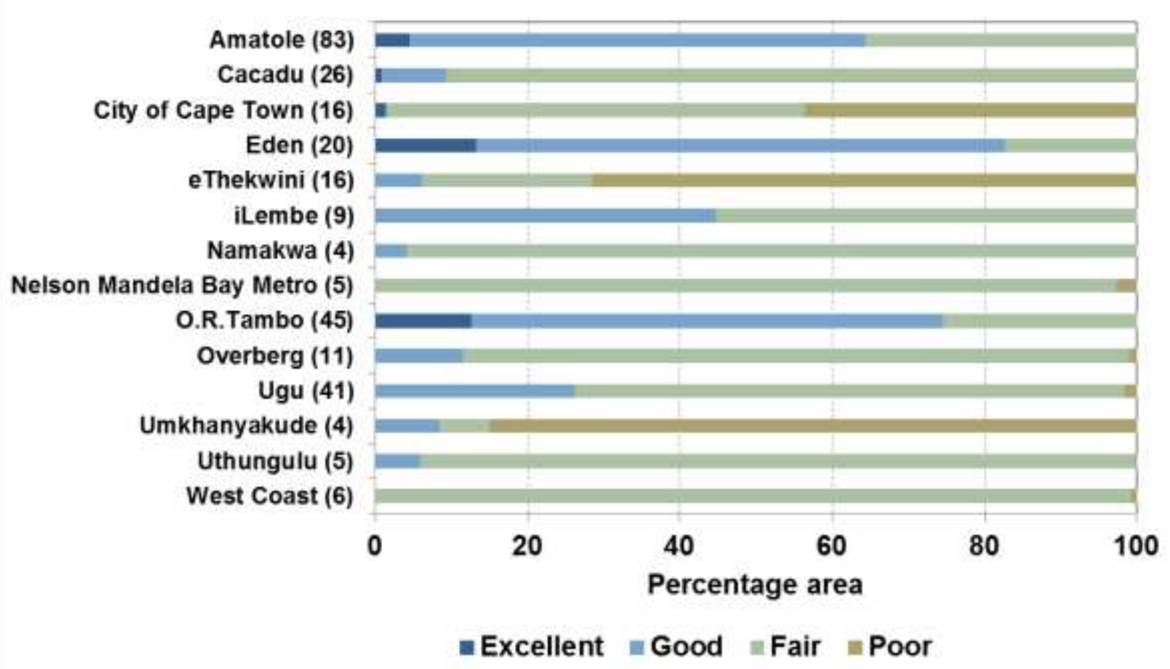


Figure 9.7 A graphic illustration of the percentage estuarine area in the coastal District / Metropolitan Municipalities in an excellent, good, fair or poor condition.

9.4 Health status of Estuaries per Catchment Management Agency

To highlight areas where flow interventions may be required, the estuary health assessment analysis was also conducted from a Catchment Management Agency perspective (see Table 9.9 and Figure 9.8). The Gouritz Catchment Management Agency had the most excellent and good condition estuarine habitat at 13% and 69 % respectively. The Mzimvubu to Kieskamma Catchment Management Agency also comprise a high percentage excellent (7%) and good (60%) state estuarine area.

Usutu to Mhlathuze and Mvoti to Umzimkulu are the two Catchment Management Agencies with the most estuarine habitat in a poor condition, at 79% and 45% respectively. The Berg, Olifants/Doorn and Breede Catchment Management Agencies also manage some poor state estuaries, representing between 1 and 4% of the total estuarine area in South Africa. It is strongly recommended that ecological water requirement studies be undertaken in the Catchment Management Agencies with a high percentage of fair to poor condition estuarine area in an attempt to halt the overall slide in condition currently being observed.

Table 9.9 Summary of Estuarine Health as a percentage of total estaurine habitat in the coastal Catchment Management Agencies.

Catchment Management Agencies	% of SA estuarine area	Health Condition			
		Excellent	Good	Fair	Poor
Berg (17)	9	0	0	96	4
Breede (11)	5	0	11	88	1
Fish to Tsitsikamma (30)	4	1	7	92	0
Gouritz (21)	6	13	69	17	0
Lower Orange (4)	1	0	4	96	0
Mvoti to Umzimkulu (64)	3	0	14	41	45
Mzimvubu to Kieskamma (128)	6	7	60	33	0
Olifants/Doorn (5)	2	0	0	96	4
Thukela (1)	0	0	0	100	0
Usutu to Mhlathuze (10)	66	0	8	13	79
% of total SA estuarine habitat	**100**	**1**	**14**	**31**	**54**

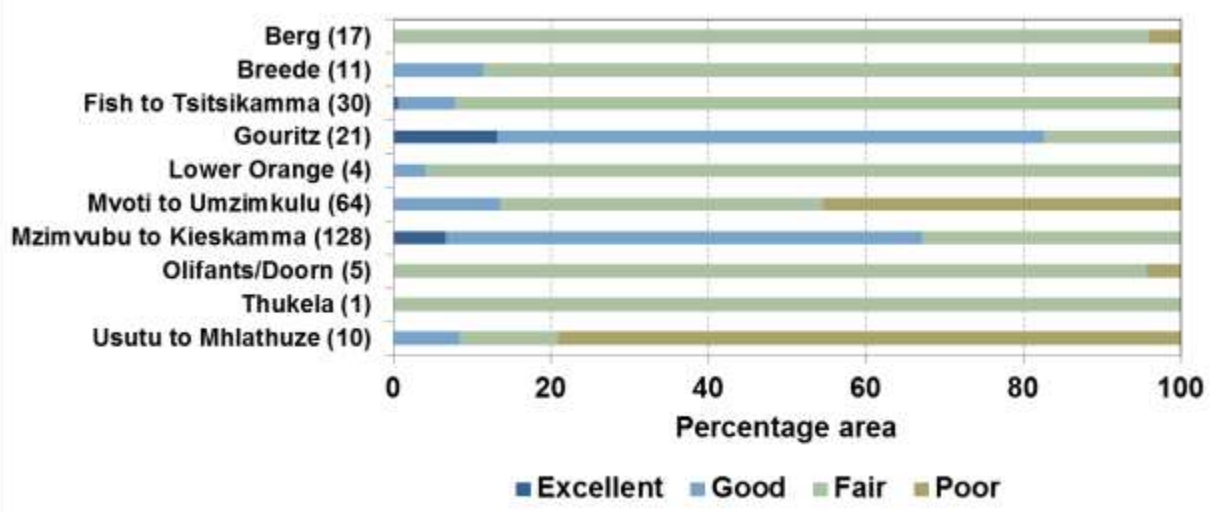


Figure 9.8 A graphic illustration of the percentage area per coastal Catchment Management Agency in an excellent, good, fair or poor condition.

9.5 Health status of Estuaries in areas of Conservation Importance

Finally, to provide an overview of the health status of estuaries in areas of conservation importance – protected areas, marine protected areas, Ramsar sites and Important Bird Areas (IBA) the percentage area in each health category was calculated. Sixty-nine estuaries form part of national, provincial or municipal protected areas or marine protected areas (refer to Section 11.1 for more details on these estuaries)

The following estuaries are listed Ramsar sites under the Ramsar convection:

- Heuningnes
- Kosi
- Orange (Gariep)
- St Lucia (including a part of uMfolozi)
- Verlorenvlei
- Wilderness

The following estuaries form part of Important Bird Areas (IBA) sites:

- Bot/Kleinmond
- Cebe
- Gamtoos
- Groot Berg
- Heuningnes
- Kosi
- Maitland
- uMfolozi
- Mhlathuze
- Mlalazi
- Msunduzi
- Mtamvuna
- Olifants
- Orange (Gariep)
- Rietvlei/Diep
- St Lucia
- Swartkops
- Van Stadens
- Verlorenvlei
- Wilderness

Of deep concern is the lack of sufficient estuarine habitat in excellent and good condition. Estuaries that fall within Ramsar sites represent 57 000 ha, of which none is in excellent condition, 8% in good condition, 9% in a fair state and the majority at 83% are in a poor state. Similarly estuaries that form part of Important Bird Areas represent about 70 400 ha, of which none are in an excellent condition, 7% in a good state, 26% in a fair state and 67% in a poor state. Collectively marine/protected areas represent about 65 900 ha, of which only 1% are in excellent health, 13% in good condition, 14% are in a fair state and 72% in a poor state.

It should once again be noted that the “St Lucia effect” is pronounced as the lake system represents a significant portion of the estuarine habitat in Ramsar sites, IBAs and marine/protected areas within South Africa. An improvement in the health of the Lake St Lucia system will result in a significantly more positive outlook as it is quite feasible to restore St Lucia to a fair or even good condition through a re-linking with the uMfolozi River.

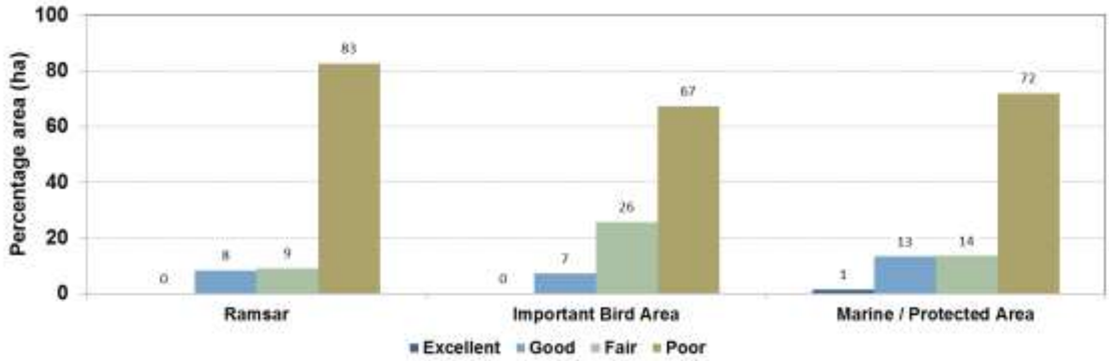


Figure 9.9 A graphic illustration of the percentage estuarine habitat in areas of conservation concern in an excellent, good, fair or poor state.

10. ECOSYSTEM THREAT STATUS

L van Niekerk and J Nel

Ecosystem threat status is one of the two headline indicators reported on in the NBA. It informs us about the degree to which our ecosystems are still intact, or alternatively losing vital aspects of their structure and functioning. Ecosystem types are categorised as critically endangered (CR), endangered (EN), vulnerable (VU) or least threatened (LT), with CR, EN and VU ecosystem types collectively referred to as threatened. For definitions of the ecosystem threat status categories, see Panel 8.

Panel 8: Definitions of ecosystem threat categories (CR, EN, VU, LT)

Critically endangered ecosystems are ecosystem types that have very little of their original extent (measured as area, length or volume) left in natural or near-natural condition. Most of the ecosystem type has been severely or moderately modified from its natural state. These ecosystem types are likely to have lost much of their natural structure and functioning, and species associated with the ecosystem may have been lost. We are in danger of losing the last remaining natural examples of these ecosystem types. Any further loss of natural habitat or deterioration in condition of the remaining healthy examples of these ecosystem types must be avoided, and the remaining healthy examples should be the focus of urgent conservation action.

Endangered ecosystems are ecosystem types that are close to becoming critically endangered. Any further loss of natural habitat or deterioration of condition in these ecosystem types should be avoided, and the remaining healthy examples should be the focus of conservation action.

Vulnerable ecosystems are ecosystem types that still have the majority of their original extent (measured as area, length or volume) left in natural or near-natural condition, but have experienced some loss of habitat or deterioration in condition. These ecosystem types are likely to have lost some of their structure and functioning, and will be further compromised if they continue to lose natural habitat or deteriorate in condition. Identified biodiversity priority areas should guide planning, resource management and decision-making in these ecosystems types.

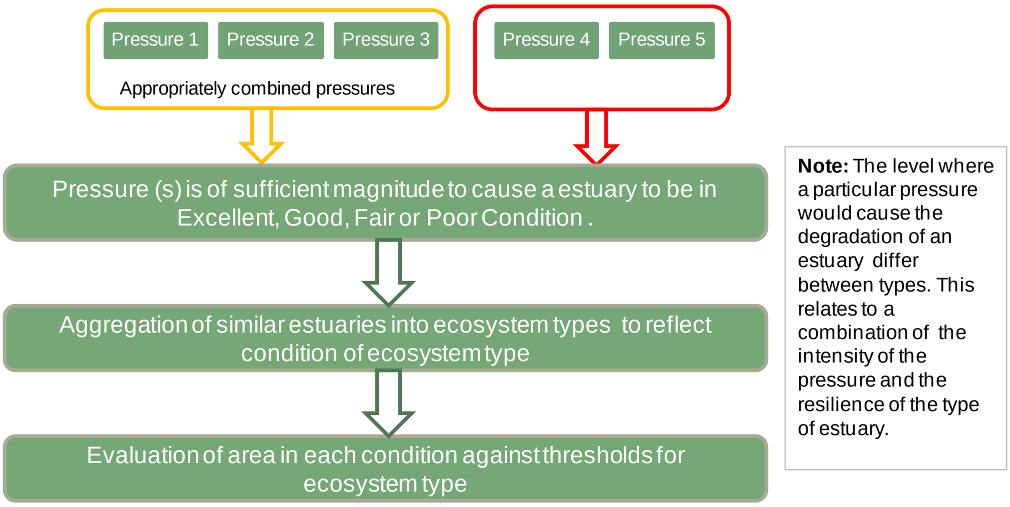
Least threatened ecosystems are ecosystem types that have experienced little or no loss of natural habitat or deterioration in condition. Identified biodiversity priority areas should guide planning, resource management and decision-making in these ecosystems types.

Threat status has been traditionally assessed for species, in the form of national or global Red Lists that draw attention to species threatened with extinction. It is more unusual for threat status to be assessed at the ecosystem level. Initial attempts to assess ecosystem threat status in the NSBA 2004 have been built on and refined in the NBA 2011, which provides a baseline for comparisons going forward.

A group of similar-type estuaries within a biogeographical zone, herein referred to as an ecosystem type, is implicitly assumed to represent a single 'ecoregional' type, supporting a characteristic suite of processes and biodiversity. The NBA 2011 identifies the status of ecosystems on the basis of their current ecological condition (Section 9). In the case of estuaries, the ecosystem threat status does not relate to the complete loss of an ecosystem type (i.e. loss due to development or infilling of the entire estuarine area) but rather to the loss or degradation of ecosystem processes and the abundance, community composition or species richness of associated biota (i.e. pattern). Critically endangered and endangered refer to a significant loss of process and pattern, while vulnerable indicate some loss of ecosystem processes and/ or abundance and distribution of biota. As a result of direct harvesting of living resources, ecosystem processes may still be intact, while the biota associated with that ecosystem type are severely degraded so the two aspects are not necessary related.

How is ecosystem threat status assessed? Figure 10.1 provides a diagram of the processes followed to aggregate condition status to ecosystem threat status. Once ecosystem types have been identified and pressures assessed, the condition or ecological integrity of ecosystems can be established. The proportion of each ecosystem type that remains in good condition is then evaluated against a series of thresholds to determine ecosystem threat status.

The first of these thresholds (often set at 20%) defines the cut-off for critically endangered ecosystems. The threshold for CR ecosystems is also known as the biodiversity target, and is the proportion of each ecosystem type that should ideally be formally protected in the long term. The second threshold (set at the biodiversity target plus 15%) defines the cut-off for endangered ecosystems, and indicates ecosystems that are close to becoming critically endangered. It acts as a warning bell. The third threshold (set at 60%) defines the cut-off point for vulnerable ecosystems. Ecosystem types that have reached this point are likely to have lost some of their structure and functioning, and will be further compromised if they continue to lose natural habitat or deteriorate in condition.



Status	Critically endangered	Endangered	Vulnerable	Least threatened
Pattern	Largely lost	Heavy impacted	Mostly intact	Intact
Process	Heavily modified	Largely modified	Moderately modified	Largely natural
Condition vs thresholds	A+B < Biodiversity Threshold*	A+B < Biodiversity Threshold plus 15%**	A+B+C < 60%***	A+B+C >= 60%

*Biodiversity pattern target (representation threshold) – 20% for estuary types
**Biodiversity target plus 15% - a warning bell that one is approaching the Biodiversity Threshold
***Ecological Function Threshold (persistence threshold) beyond which function is lost – currently set at 60%

Figure 10.1 Process and criteria by which ecosystem threat status is determined.

The assessment of ecosystem threat status links directly to the Biodiversity Act. Chapter 4 of the Act allows the Minister or an MEC to list threatened or protected ecosystems, thus providing a powerful mechanism to address biodiversity conservation effectively at an ecosystem scale. The ecosystem threat status categories used in the NBA (CR, EN and VU) have been deliberately aligned with the terms and definitions used in the Biodiversity Act.

10.1 Ecosystem threat status based on the Whitfield classification

Two estuarine classification systems for estuaries are generally recognised in South Africa. The geomorphological classification used by Harrison et al. (2000) which comprise six main types based on mouth condition (open or closed), size and the presence of a bar. The Whitfield (1992) classification is also based on physical characteristics (mainly mouth condition and size of tidal prism), and has become the more widely used classification system.

Whitfield's (1992) classification recognises five types: Estuarine Bays, Permanently Open Estuaries, River Mouths, Estuarine Lakes, and Temporarily Open/Closed Estuaries. The Whitfield (1992) classification was used in the 2004 National Spatial Biodiversity Assessment and is therefore presented here for comparative purposes. The ecosystem threat status is, however, derived from the "percentage area" and not "number of estuaries" as done in the earlier study (Turpie 2004).

Based on data and information provided in Table 10.1 it appears that most of the zonal types in the Cool Temperate and Subtropical biogeographical region are critically endangered, with only the permanently open and temporarily closed types in the Subtropical biogeographical area being least threatened. In the Warm Temperate biogeographical zone, permanently open estuaries are endangered but other estuary types are in a better position (Table 10.2). From an estuarine area perspective, 80% (7 types) are critically endangered, 7% are endangered (1 type) and 13% least threatened (6 types) (Figure 10.2).

Table 10.1 Summary of ecosystem threat status based on the Whitfield classification (percentage habitat in A, B and C categories are indicated).

Zonal Type		Total Area (ha)	A+B	A+B+C	Ecosystem Threat Status
Cool Temperate	Estuarine lake	3072	0	99	Critically endangered
	Permanently open	8351	0	16	Critically endangered
	River mouth	975	0	0	Critically endangered
	Temporarily closed	1323	7	28	Critically endangered
Warm Temperate	Estuarine bay	1926	100	100	Least threatened
	Estuarine lake	1339	100	100	Least threatened
	Permanently open	6425	27	84	Endangered
	River mouth	40	100	100	Least threatened
	Temporarily closed	3120	67	90	Least threatened
Subtropical	Estuarine bay	3192	0	0	Critically endangered
	Estuarine lake	51794	9	9	Critically endangered
	Permanently open	3168	35	94	Least threatened
	River mouth	3932	0	6	Critically endangered
	Temporarily closed	2188	44	77	Least threatened

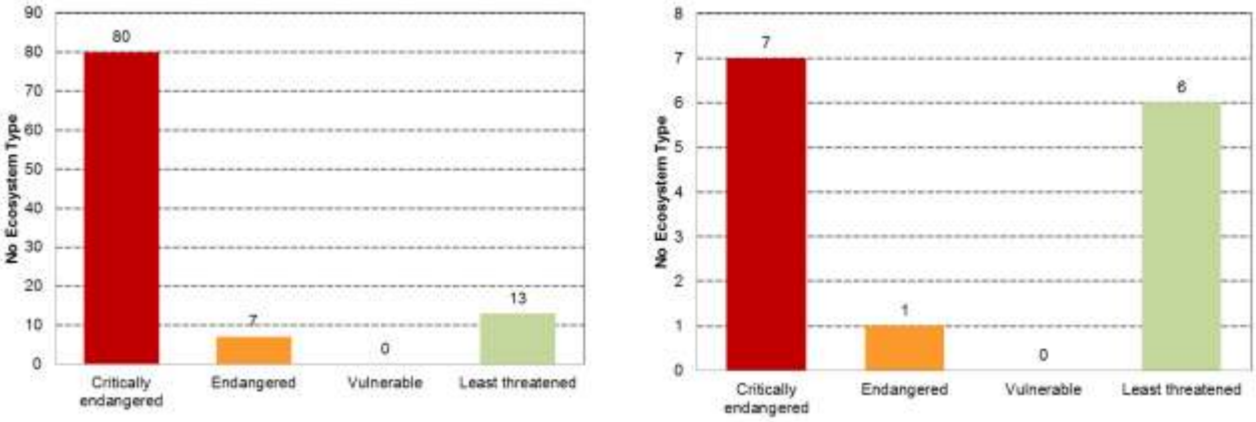


Figure 10.2 Graphic illustration of ecosystem threat status based on the Whitfield classification using percentage area and number of ecosystems types.

10.2 Ecosystem threat status based on NBA 2011 Estuarine Typing

While the Whitfield's (1992) typology was used in the 2004 NSBA, the 2004 assessment also highlighted that some estuarine researchers struggle to work within the Whitfield classification. It stressed the need to devise a more robust system of classification that will also be useful in applied conservation research. This view point was supported by the C.A.P.E. Estuaries conservation plan in which Turpie and Clark (2007) found that while the Whitfield's (1992) estuary typology is widely used, it does not necessarily explain finer nuances of the similarities and differences between different types.

The NBA 2011 therefore set out to refine the existing typology based on the characteristics described in Section 5, thus adding resolution and increasing biodiversity representation. The four main subdivisions were based on estuary size, mouth status, salinity structure and river type. While the consensus was that both "mouth condition" and "salinity structure" should be further subdivided to be truly predictive of biodiversity distribution, this was not possible within the constraints of this project. It was nevertheless felt that the higher resolution provided by the disaggregation of the Whitfield classification would allow for a more refined analyses of the ecosystem threat status and could therefore form the basis for further analyses (Table 10.2).

About 39% of South Africa's 46 estuarine types (18 types) are critically endangered, 2% are endangered (1 type), 2% are vulnerable (1 type) and 57% are least threatened (26 types). If analysed by estuarine area the situation is even more dire, with 79% of South Africa's estuarine area being critically endangered, less than 1% endangered and vulnerable and 21% least threatened (Figure 10.3 and 10.4).

Table 10.2 Summary of ecosystem threat status based on the NBA 2011 classification (percentage habitat in A, B and C categories indicated)

	Ecosystem Type	% habitat in A + B	% habitat in A+B+C	Ecosystem Threat Status
Cool Temperate	Large ClosedFreshTurbid	0	20	Critically endangered
	Large ClosedMixedBlack	0	86	Critically endangered
	Large ClosedMixedClear	0	0	Critically endangered
	Large OpenMixedClear	0	16	Critically endangered
	Medium ClosedFreshBlack	15	43	Critically endangered
	Medium ClosedMixedBlack	8	8	Critically endangered
	Medium ClosedMixedClear	0	0	Critically endangered
	Medium ClosedMixedTurbid	65	65	Least threatened
	Small ClosedFreshBlack	3	52	Critically endangered
	Small ClosedMixedBlack	56	56	Vulnerable
	Small OpenFreshBlack	100	100	Least threatened
	Small OpenMixedBlack	0	0	Critically endangered
Warm Temperate	Large ClosedMarineClear	100	100	Least threatened
	Large ClosedMixedBlack	63	88	Least threatened
	Large ClosedMixedClear	100	100	Least threatened
	Large OpenMarineBlack	100	100	Least threatened
	Large OpenMarineClear	17	100	Critically endangered
	Large OpenMixedBlack	70	78	Least threatened
	Large OpenMixedClear	0	0	Critically endangered
	Large OpenMixedTurbid	0	100	Critically endangered
	Medium ClosedMixedBlack	50	87	Least threatened
	Medium ClosedMixedClear	89	99	Least threatened
	Medium OpenMixedBlack	100	100	Least threatened
	Medium OpenMixedClear	40	62	Least threatened
	Medium OpenMixedTurbid	100	100	Least threatened
	Small ClosedFreshBlack	93	93	Least threatened
	Small ClosedMixedBlack	94	94	Least threatened
	Small ClosedMixedClear	76	99	Least threatened
	Small OpenFreshBlack	100	100	Least threatened
	Small OpenMixedBlack	70	70	Least threatened
Subtropical	Large ClosedFreshTurbid	0	0	Critically endangered
	Large ClosedMixedClear	100	100	Least threatened
	Large ClosedMixedTurbid	0	0	Critically endangered
	Large OpenMarineClear	16	16	Critically endangered
	Large OpenMarineTurbid	0	46	Critically endangered
	Large OpenMixedClear	100	100	Least threatened
	Large OpenMixedTurbid	47	84	Least threatened
	Medium ClosedFreshTurbid	0	72	Critically endangered
	Medium ClosedMixedBlack	81	100	Least threatened
	Medium ClosedMixedClear	54	86	Least threatened
	Medium ClosedMixedTurbid	23	45	Endangered
	Medium OpenMarineClear	0	0	Critically endangered

	Ecosystem Type	% habitat in A + B	% habitat in A+B+C	Ecosystem Threat Status
	Medium OpenMixedTurbid	100	100	Least threatened
	Small ClosedFreshBlack	100	100	Least threatened
	Small ClosedMixedBlack	100	100	Least threatened
	Small ClosedMixedClear	60	84	Least threatened

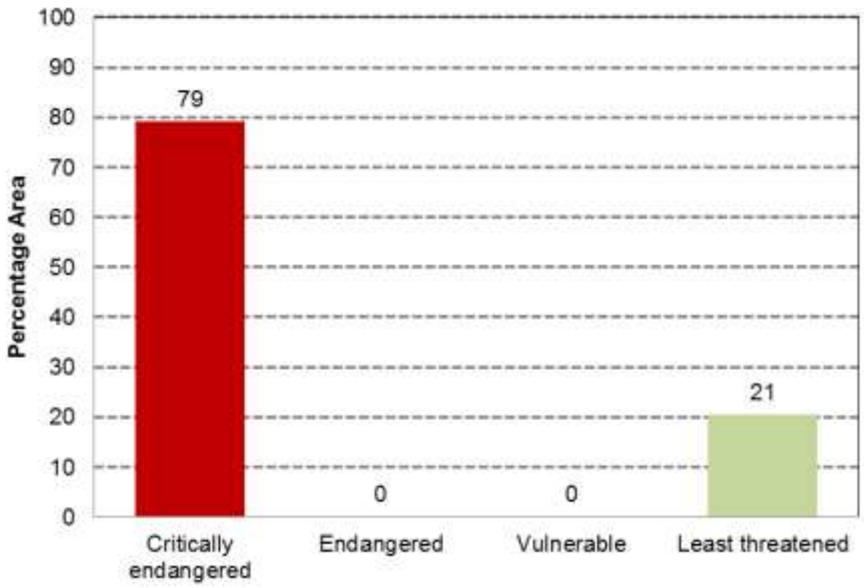


Figure 10.3 Graphic illustration of ecosystem threat status based on the NBA 2011 classification presented as percentage area of ecosystems types.

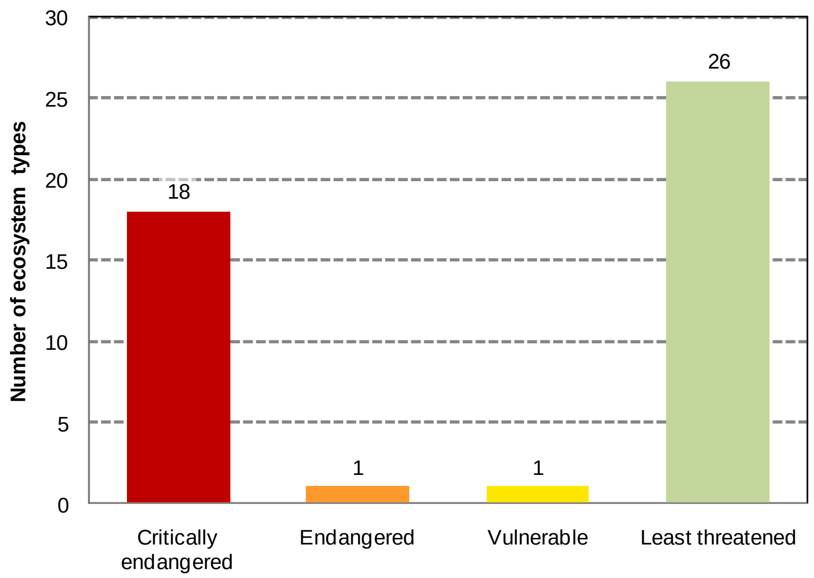


Figure 10.4 Graphic illustration of ecosystem threat status based on the NBA 2011 classification presented as number of ecosystems types.

10.3 Summary of ecosystem threat status by biogeographical region

Nearly 100% of the Cool Temperate biogeographical region habitat (represented by 12 ecosystem types) is critically endangered, while less than 1% is vulnerable and least threatened respectively. In contrast most of the ecosystem types in the Warm Temperate (18 types) are least threatened, representing 68% of the habitat in this zone, while 32% of the habitat is critically endangered. About 87% of the Subtropical estuarine habitat (16 ecosystem types) is critically endangered, while only 12% is least threatened (Table 10.3 and Figure 10.5 to Figure 10.10).

Table 10.3 Ecosystem threat status for the three biogeographical regions of South Africa estimated as a percentage of the total habitat (number of estuaries are indicated in brackets).

Biogeographical region	No of ecosystem types	Ecosystem threat status				Total area (ha)
		CR	EN	VU	LT	
Cool Temperate (34)	12	99.3 (27)	0.0	0.1 (3)	0.6 (4)	13 720
Warm Temperate (124)	18	31.9 (12)	0.0	0.0	68.1(122)	12 849
Subtropical (133)	16	87.42 (11)	0.8 (13)	0.0	11.8 (109)	64 274
Percentage area (291)	46	79.2 (54)	0.1 (13)	0.2 (3)	20.5 (225)	100
Area (ha)		71 932	81	186	18 645	90 844

10.4 Summary of ecosystem threat status by Water Management Agencies Area

To provide an indication of how effective the various Water Management Area (WMAs) are in promoting wise use of their water resources and protecting estuaries, the ecosystem threat status was calculated per individual WMA. Note that some estuaries fall on the boundaries of WMAs, in this case the estuary was allocated to the WMA within which the river catchment falls. This is especially pertinent in the case of the Gouritz WMA as the mouth and lower third of the Duiwenhoks Estuary falls within the Breede WMA, while the river and upper reaches of the estuary are within the Gouritz WMA. It is strongly recommended that DWA address this discrepancy within the delineation of the WMA boundaries on the coast.

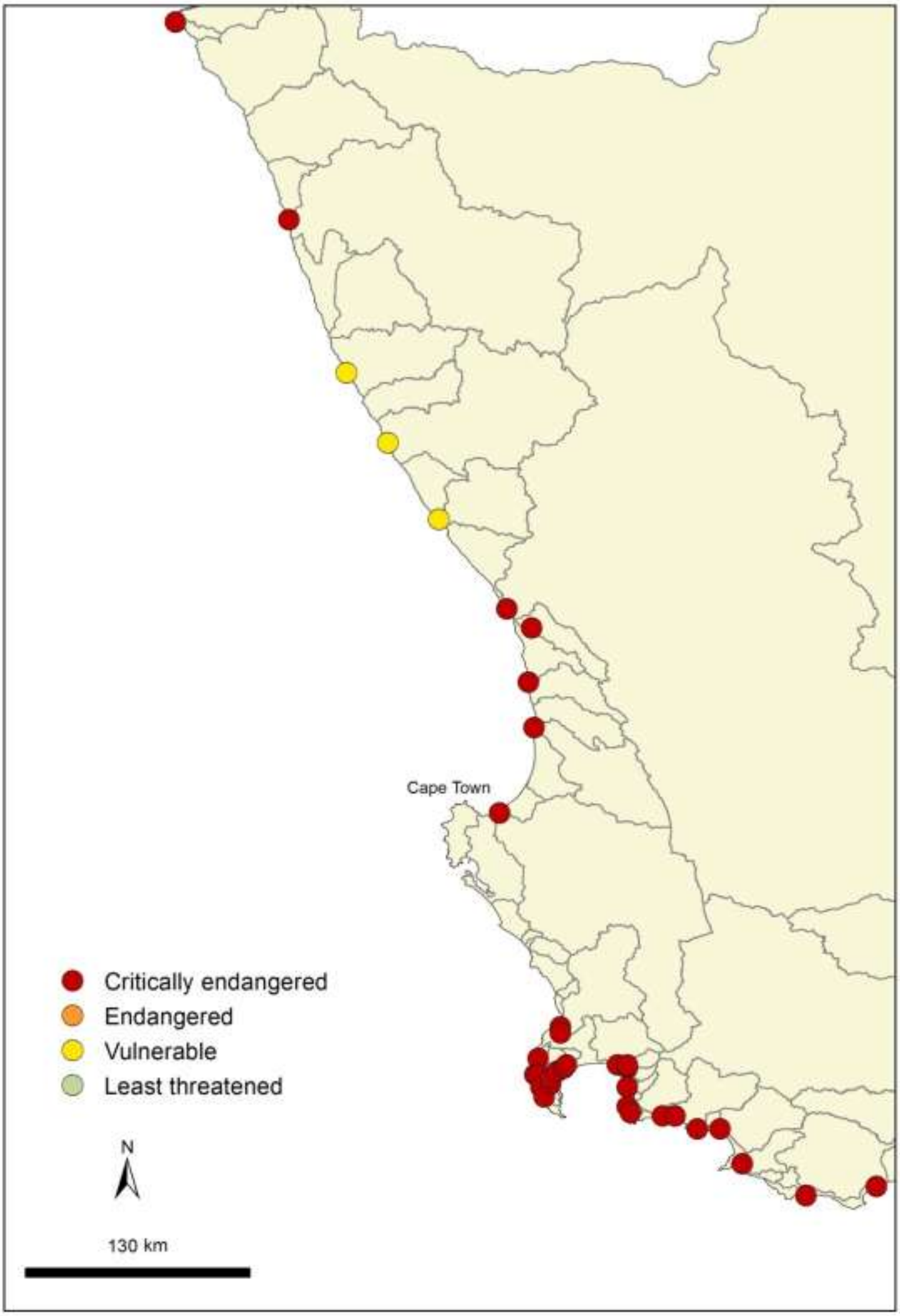


Figure 10.5 Ecosystem threat status of estuaries in the Cool Temperate biogeographical region.

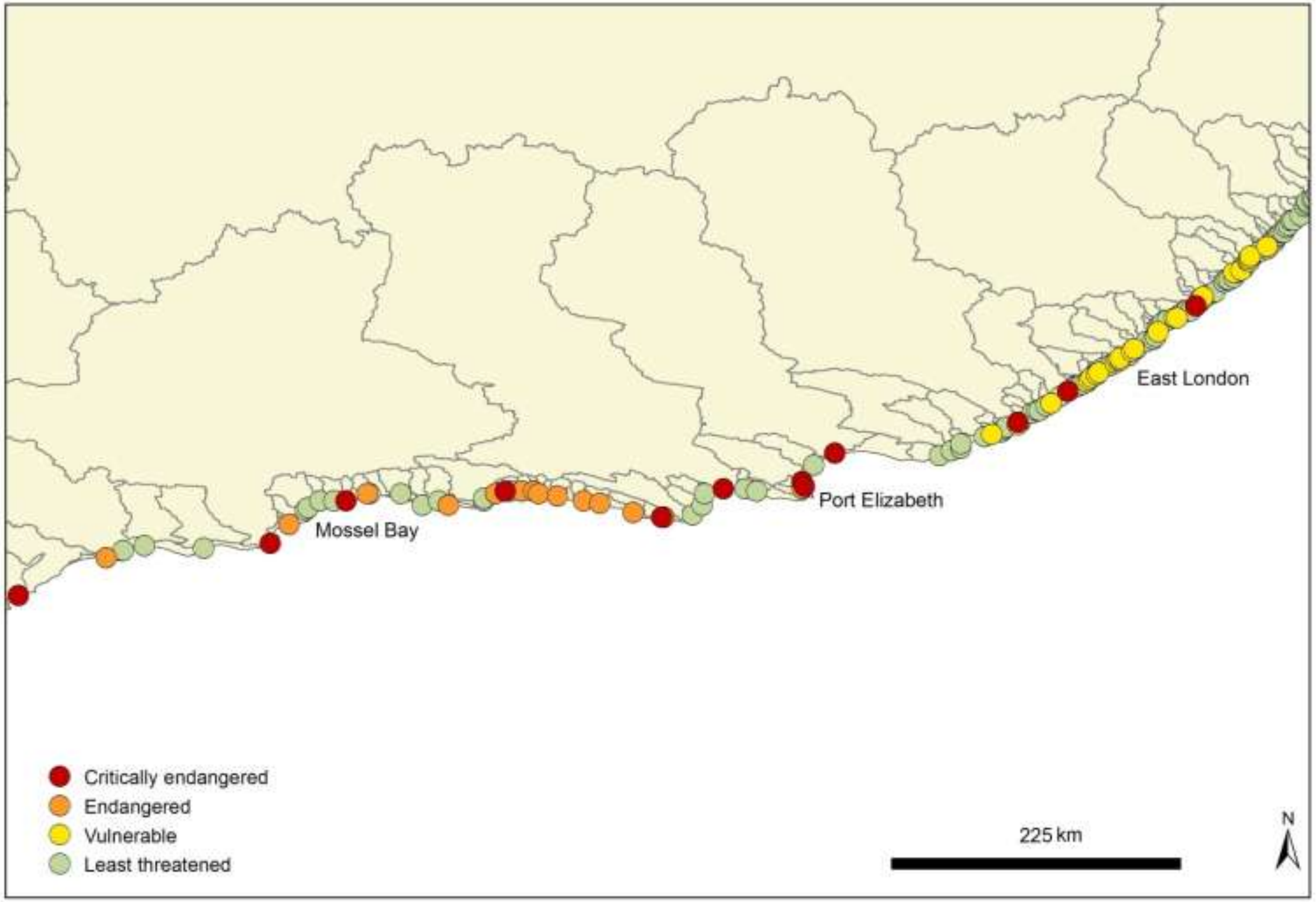


Figure 10.6 Ecosystem threat status of estuaries in the Warm Temperate biogeographical region.

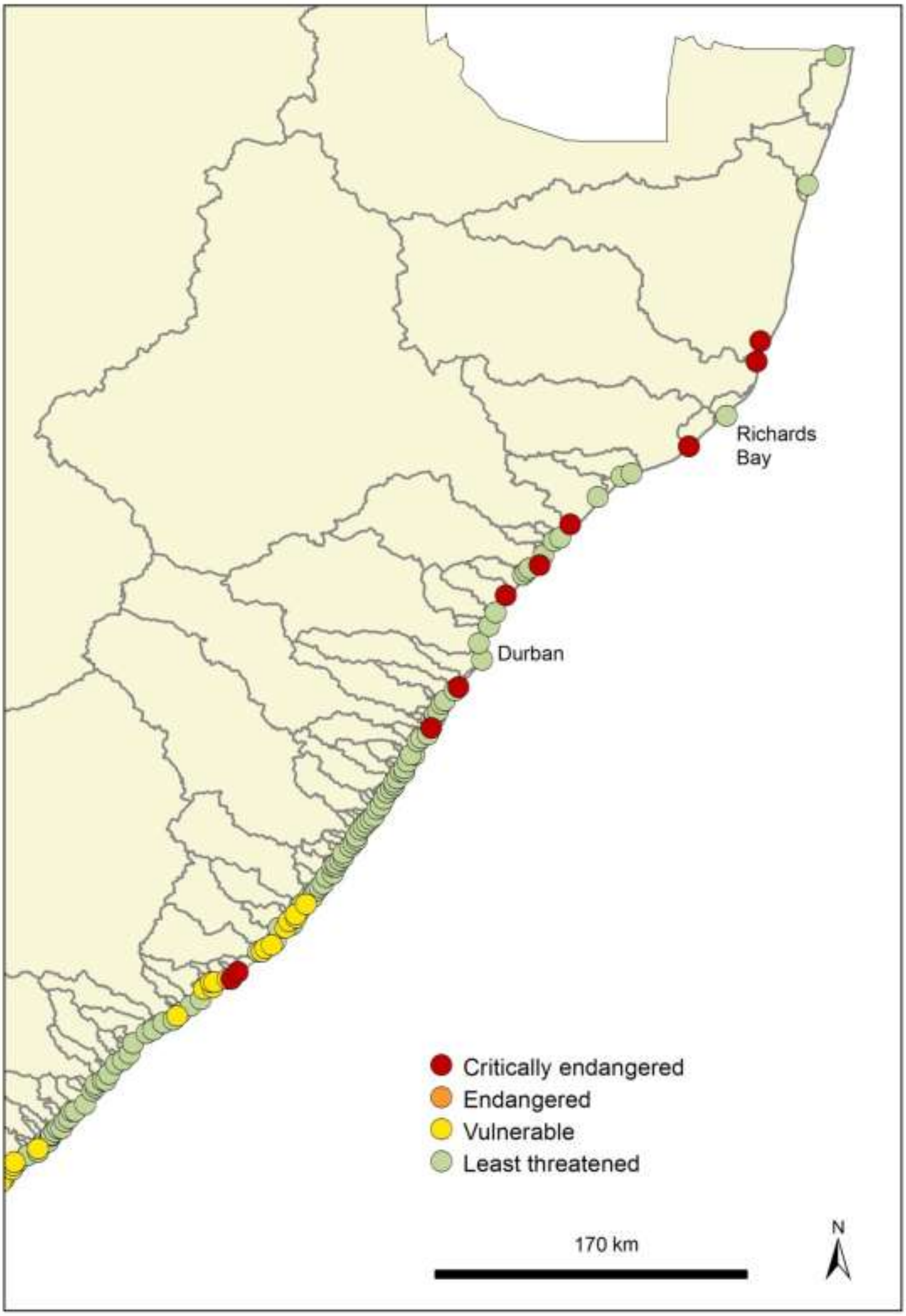


Figure 10.7 Ecosystem threat status of estuaries in the Subtropical biogeographical region.

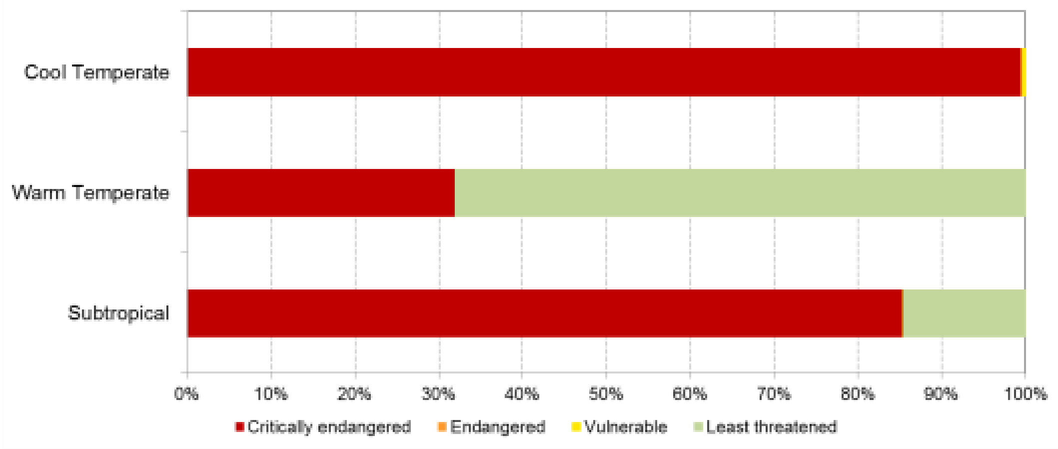


Figure 10.8 Ecosystem threat status for the three biogeograpichal regions, illustrated as a percentage of the total habitat within a region.

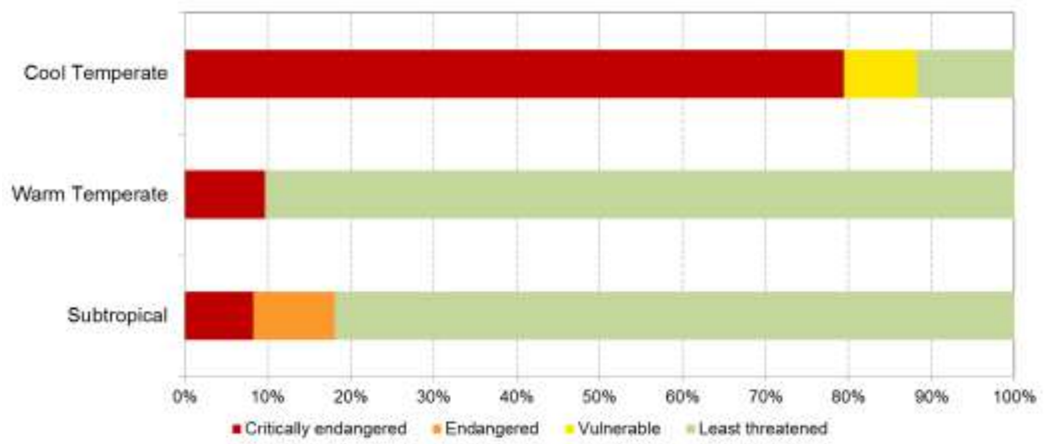


Figure 10.9 Ecosystem threat status for the three biogeograpichal regions, summarized as percentage of the total number of estuaries occurring within a region.

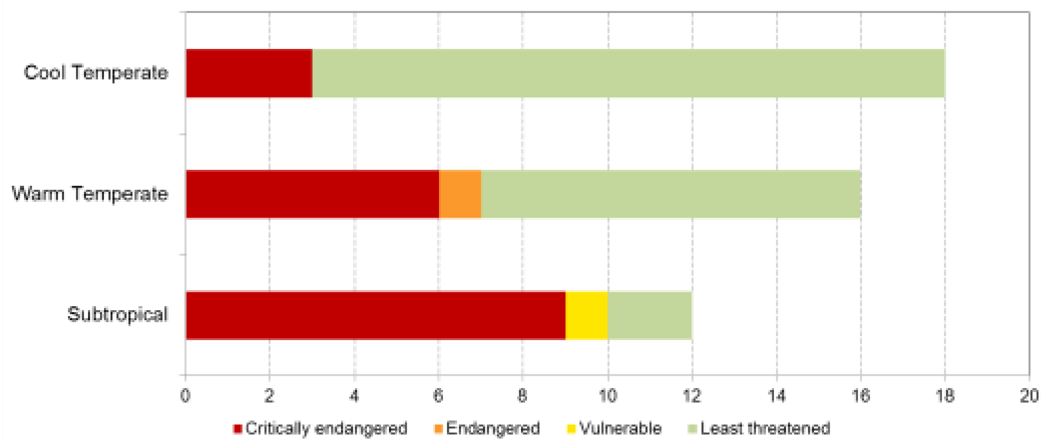


Figure 10.10 Ecosystem threat status of ecosystems types, based on the NBA 2011 classification.

The Berg, Olifants/Doring, Lower Orange, Usutu to Mhlathuze and Thukela WMAs had the greatest percentage estuarine area in the Critically endangered category, while the Gouritz and Mzimvubu to Kieskamma WMAs had the largest percentage least threatened habitats in their management domains.

The poor condition of the Lake St Lucia system is largely responsible for the Usutu to Mhlathuze's high percentage habitat in the critical endangered category. The Thukela WMA comprises only one estuary. The overall high percentage of critically endangered habitat reflects the predominantly fair to poor status of South Africa's large estuaries and the need to utilise, and protect, them more effectively.

Table 10.4 Ecosystem threat status for the 10 coastal Catchment Management Agencies, presented as percentage habitat (number of estuaries are indicated in brackets).

Catchment Management Agency	No of ecosystem types	CR	EN	VU	LT	Total area (ha)
Berg (17)	10	99.8 (14)		0.2 (2)	0.0 (1)	7 725
Breede (11)	7	89.2 (9)			10.8 (2)	4 219
Fish to Tsitsikamma (30)	11	71.1 (7)			28.9 (23)	3 370
Gouritz (21)	10	2.2 (1)			97.8 (20)	5 162
Lower Orange (4)	2	95.8 (2)			4.2 (2)	1 267
Mvoti to Umzimkulu (64)	9	47.8 (5)	17.2 (11)		35.0 (48)	2 736
Mzimvubu to Kieskamma (128)	12	25.1 (4)	0.9 (2)		74.0 (122)	5 176
Olifants/Doorn (5)	5	97.9 (3)		0.2 (1)	1.9 (1)	1 483
Thukela (1)	1	100.0 (1)				79
Usutu to Mhlathuze (10)	8	91.5 (4)			8.5 (6)	59 626
Total in SA	**46**	**81.4 (50)**	**0.6 (13)**	**0.0 (3)**	**18.1 (225)**	**90 844**

An evaluation of the percentage estuaries in the critical endangered category shows that Breede, Thukela, Usutu to Mhlathuze and Fish to Tsitsikamma have the greatest number in that catogory. While the Gouritz, Lower Orange, Mzimvubu to Kieskamma and Olifants/Doorn have the greatest percentage estuaries in the least threatened category.

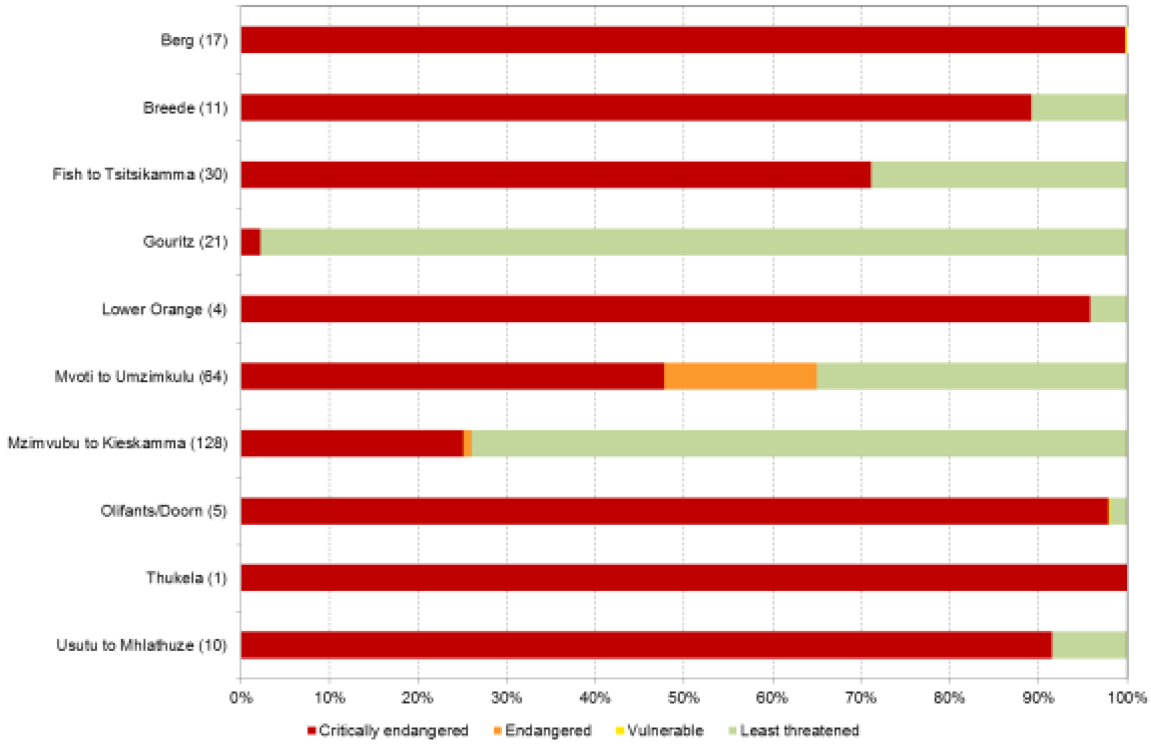


Figure 10.11 Ecosystem threat status for the 10 coastal Catchment Management Agencies, illustrated as a percentage of the total estuarine habitat in the CMA.

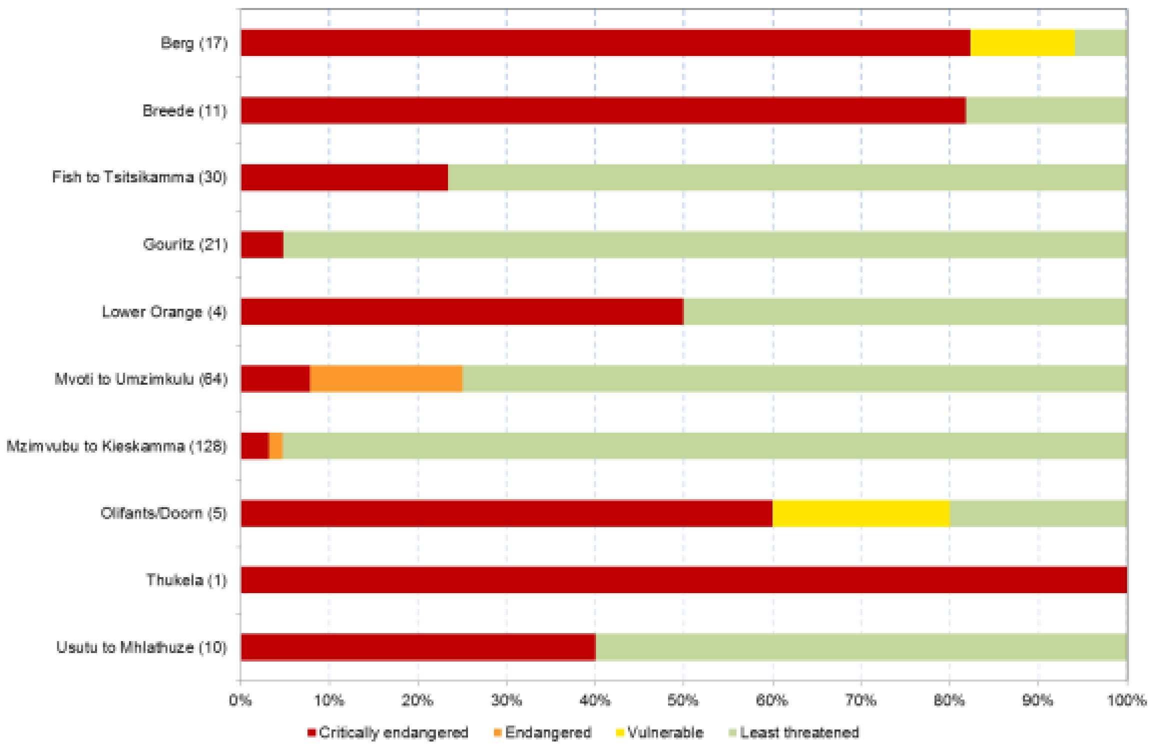


Figure 10.12 Ecosystem threat status for the 10 coastal Water Management Areas, summarized as a percentage of the total number of estuaries occurring within the WMA.

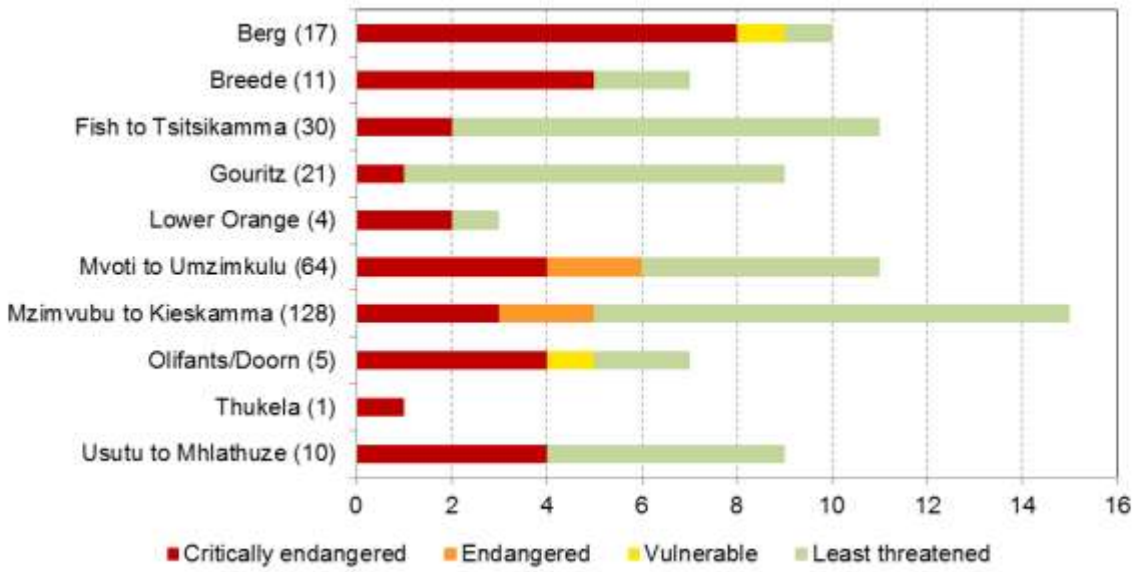


Figure 10.13 Ecosystem threat status of ecosystems types based on the NBA 2011 classification for the 10 coastal Water Management Areas.

10.5 Summary of ecosystem threat status by District/ Metropolitan Municipality

The Berg, Olifants/Doring, Lower Orange, Usutu to Mhlathuze and Thukela WMAs have the greatest percentage ecosystem area in the critical endangered category, while the Gouritz and Mzimvubu to Kieskamma WMAs have the largest percentage of least threatened habitats in their managed areas (see Table 10.5 and Figures 10.11 to 10.13 for more detail) . The poor condition of the Lake St Lucia Sytem is largely responsible for the Usutu to Mhlathuze WMA's high level of critically endangered areas. This high percentage of critically endangered habitat areas reflects the fair to poor status of South Africa's large estuaries and the need to utilise, and protect, them better. The Gouritz, Lower Orange, Mzimvubu to Kieskamma and Olifants/Doorn have the greatest percentage estuaries in least threatened category.

Table 10.5 Ecosystem threat status for the 15 Coastal District/ Metropolitan Municipalities (percentage habitat). The number of estuaries is indicated in brackets.

District Municipality	No of types	CR	EN	VU	LT	Total area (ha)
Amatole (83)	9	28.5.0 (3)			71.5 (80)	3 769
Cacadu (26)	10	66.8 (6)			33.2 (20)	2 842
City of Cape Town (16)	9	98.0 (13)		1.7 (2)	0.3 (1)	732

District Municipality	No of types	CR	EN	VU	LT	Total area (ha)
Eden (20)	9	2.2 (1)			97.8 (19)	5 159
eThekwini (16)	6	74.9 (4)	11.6 (4)		13.5 (8)	1 718
iLembe (9)	5	25.2 (2)	17.2 (2)		57.6(5)	402
Namakwa (4)	2	95.8 (2)			4.2 (2)	1 267
Nelson Mandela Metro (5)	5	93.9 (1)			6.1 (4)	532
O.R.Tambo (45)	9	16.0 (1)	3.2 (2)		80.8 (42)	1 407
Overberg (11)	7	89.2 (9)			10.8 (2)	4 219
Ugu (41)	6		24.5 (5)		75.5 (36)	822
Umkhanyakude (4)	4	91.6 (2)			8.4 (2)	55 474
Uthungulu (5)	4	93.5 (2)			6.5 (3)	4 025
West Coast (6)	5	99.6 (4)		0.0 (1)	0.3 (1)	8 476
Total for SA	**46**	**81.4 (50)**	**0.6 (13)**	**0.0 (3)**	**18.1 (225)**	90 844

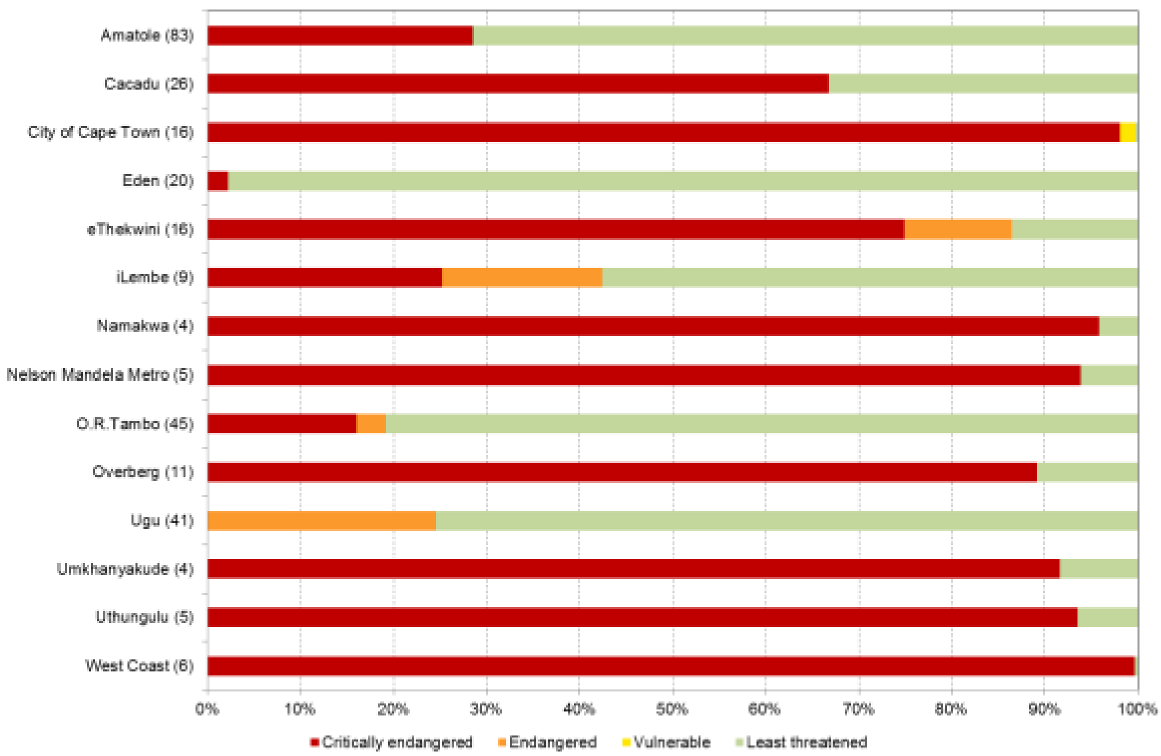


Figure 10.14 Ecosystem threat status for the Coastal District/Metropolitan Municipalities, illustrated as a percentage of the total habitat within the municipality.

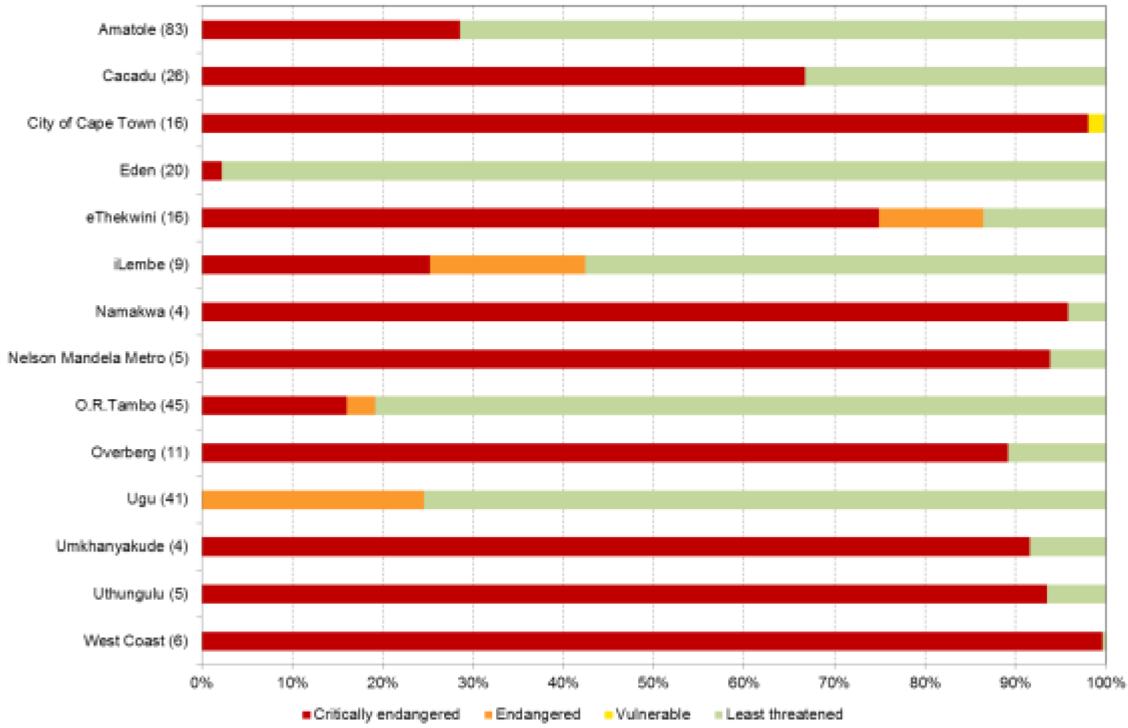


Figure 10.15 Ecosystem threat status for the Coastal District/Metropolitan Municipaliies summarized as percentage estuaries of the total number of estuaries occurring in the municipality.

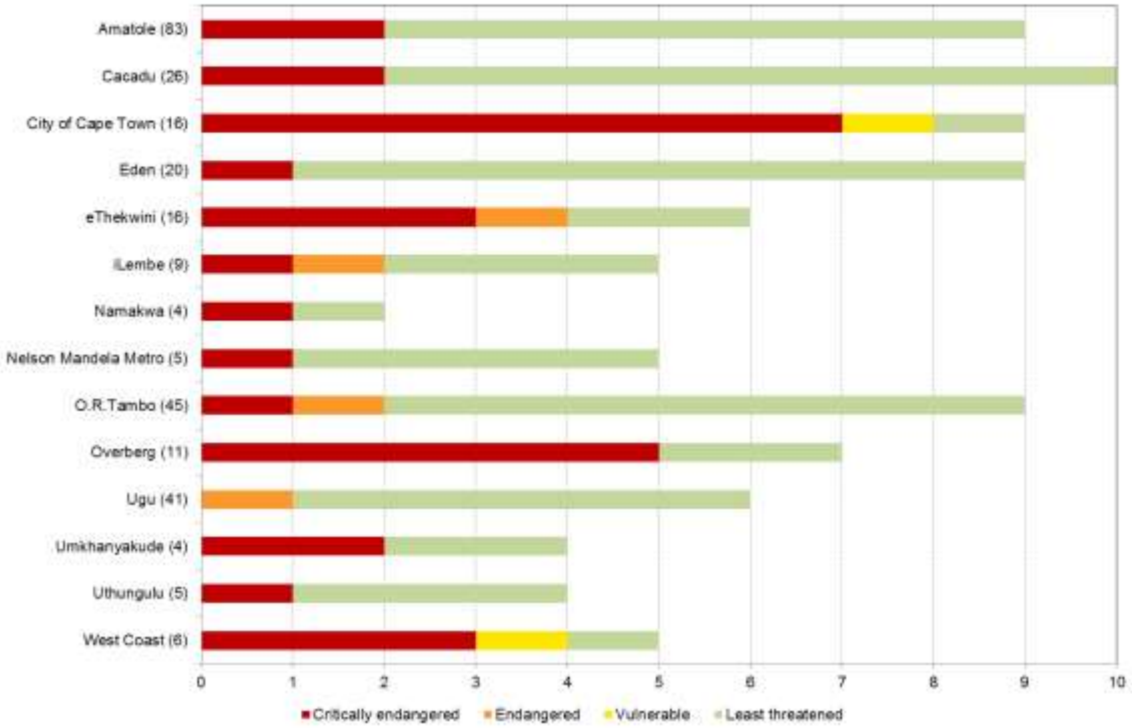


Figure 10.16 Ecosystem threat status summarised as number of ecosystems types based on the NBA 2011 classification for the Coastal District/Metropolitan municipalities.

11. ECOSYSTEM PROTECTION LEVELS

L van Niekerk and JK Turpie

11.1 Degree of protection

A total of 70 estuaries in South Africa already have some level of protection (Figure 11.1 and Table 10.1). However, only the Krom in the Western Cape, the 7 small estuaries within Tsitsikamma National Park/Marine Protected Area, Mbashe (under dispute and currently only partly protected in practice), Msikaba and Mtentu in the Eastern Cape, and Mhlanga, Mlalazi and Kosi in KwaZulu-Natal have full no-take protection. It should also be noted that although the Lake St Lucia system is listed as being fully protected in law, fishing is permitted and St Lucia Estuary's current health status is an E and that of uMfolozi Estuary is a D, thus indicating that the system is in fact poorly protected. The above-mentioned estuaries were the only estuaries considered to be fully protected by formal legislation.

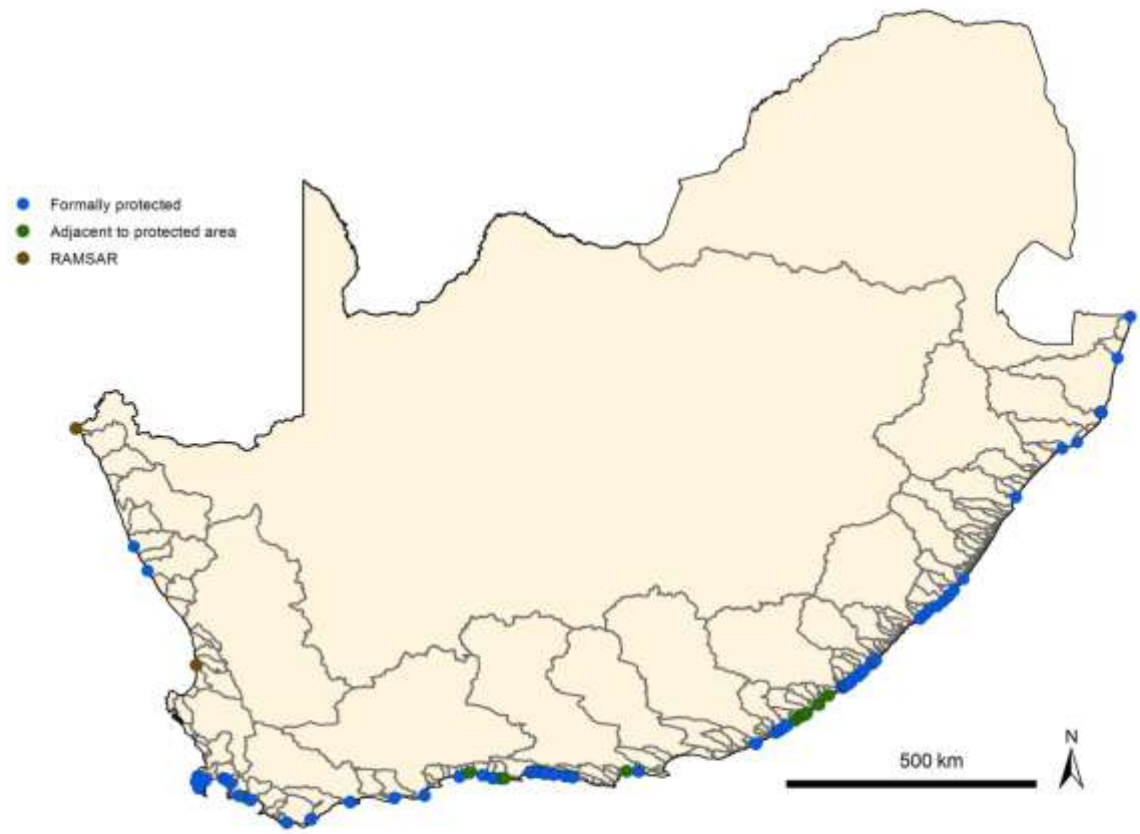


Figure 11.1 Location of formally protected and partially protected estuaries in South Africa.

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Table 11.1 Estuaries within South Africa that have some level of protection, giving the amount in a protected area, the extent of no-take protection, whether ecological water requirements have been secured, whether an estuary management plan is in place, the condition of the estuary, and the effective level of protection of the estuary (Turpie et al. 2012).

#	Estuary	Protected area	Agency	Amount of estuary in protected area	No Take Restrictions	Ecological water requirement	Estuary Management Plan	Condition	Level of protection*
1	Orange	Planned	Provincial	Part	Boat restriction	Yes		D	Medium
2	Spoeg	Namaqualand NP	SANParks	All				B	Medium
3	Groen	Namaqualand NP	SANParks	All				B	Medium
4	Diep	Rietvlei NR	Municipal	Part	Part			E	Low
5	Krom	Table Mountain NP	SANParks	Entirely				A	High
6	Wildevoëlvlei	Table Mountain NP	SANParks	Part				D	Low
7	Sand	Sandvlei NR	Municipal	<10% of estuary (Top)				D	Low
8	Heuningnes	De Mond NR	CapeNature	Part			Yes	D	Medium
9	Goukou	Stilbaai MPA	CapeNature	Part	Part		Yes	C	Medium
10	Wilderness	Wilderness Lakes NP	SANParks	Part				B	Low
11	Swartvlei	Wilderness Lakes NP	SANParks	Part		Yes		B	Low
12	Goukamma	Goukamma NR	CapeNature	Most		Yes (to A/B)		B	Medium
13	Knysna	Knysna NP	SANParks	Part		Yes	Yes	B	Low
14	Keurbooms	Keurbooms River NR	CapeNature	Part (upper reaches)		Yes	Yes	A	Low
15	Sout	De Vasselot NP	SANParks	All				A	Medium
16	Groot (W)	Tsitsikamma NP	SANParks	All	Yes			B	High
17	Bloukrans	Tsitsikamma NP	SANParks	All	Yes			A	High
18	Lottering	Tsitsikamma NP	SANParks	All	Yes			A	High
19	Elandsbos	Tsitsikamma NP	SANParks	All	Yes			A	High
20	Storms	Tsitsikamma NP	SANParks	All	Yes			A	High
21	Elands	Tsitsikamma NP	SANParks	All	Yes			B	High
22	Groot (E)	Tsitsikamma NP	SANParks	All	Yes			B	High

#	Estuary	Protected area	Agency	Amount of estuary in protected area	No Take Restrictions	Ecological water requirement	Estuary Management Plan	Condition	Level of protection*
23	Tsitsikamma	Huisklip NR	ECParks	Lower reaches		Yes		B	Low
24	Seekoei	Seekoei River NR	Municipal	Part (upper)		Yes		D	Low
25	Gamtoos	Gamtoos R. Mouth NR	Municipal	Part			Yes	C	Low
26	Van Stadens	Van Stadens NR	Municipal	All				B	Low
27	Sundays	Addo Elephant NR	Municipal	Part		Yes	Yes	C	Medium
28	Nahoon	Nahoon Estuary NR	Municipal	Very small part		Yes	Planned	C	Low
29	Mendu#	Dwesa-Cwebe MPA	DEA/DAFF	Undefined as yet	Yes			A	Medium
30	Mendwana#	Dwesa-Cwebe MPA	DEA/DAFF	Undefined as yet	Yes			A	Medium
31	Mbashe	Dwesa-Cwebe MPA	DEA/DAFF	All, but half in practice	Yes		Yes	C	High
32	Ku-Mpenzu	Dwesa-Cwebe NR	ECParks	Undefined as yet	Yes			B	Medium
33	Ku-Bhula Mbhanyana	Dwesa-Cwebe NR	ECParks	Undefined as yet	Yes			A	Medium
34	Kwa-Suka#	Dwesa-Cwebe NR	ECParks	Undefined as yet	Yes			B	Medium
35	Ntlonyane	Dwesa-Cwebe NR	ECParks	Undefined as yet	Yes			B	Medium
36	Nkanya	Dwesa-Cwebe NR	ECParks	Undefined as yet	Yes			B	Medium
37	Hluleka	Hluleka Nature Reserve	ECParks	All				A	Low
38	Nkodosweni	Pondoland MPA	DEA	Part				B	Low
39	Mtafufu	Pondoland MPA	DEA	Part				B	Low
40	Mzintlava	Pondoland MPA	DEA	Part				B	Low
41	Mzimpunzi#	Pondoland MPA	DEA	Part				B	Low
42	Kwa-Nyambalala#	Pondoland MPA	DEA	Part				B	Low
43	Mbotyi	Pondoland MPA	DEA	Part				B	Low
44	Mkozi#	Pondoland MPA	DEA	Part				A	Low
45	Myekane#	Pondoland MPA	DEA	Part				A	Low
46	Sitatsha#	Pondoland MPA	DEA	Part				A	Low

#	Estuary	Protected area	Agency	Amount of estuary in protected area	No Take Restrictions	Ecological water requirement	Estuary Management Plan	Condition	Level of protection*
47	Lupatana[#]	Pondoland MPA	DEA	Part				A	Low
48	Mkweni	Pondoland MPA	DEA	Part				A	Low
49	Msikaba	Mkambati Nature Reserve	ECParks	All				A	High
50	Butsha[#]	Mkambati Nature Reserve	ECParks	All	Yes			A	High
51	Mgwegwe[#]	Mkambati Nature Reserve	ECParks	All	Yes			A	High
52	Mgwetyana[#]	Mkambati Nature Reserve	ECParks	All	Yes			A	High
53	Mtentu	Mkambati Nature Reserve	ECParks	All	Yes		Yes	A	High
54	Sikombe[#]	Pondoland MPA	DEA	Part				A	Low
55	Kwanyana[#]	Pondoland MPA	DEA	Part				B	Low
56	Mtolane[#]	Pondoland MPA	DEA	Part				A	Low
57	Mnyameni	Pondoland MPA	DEA	Part				B	Low
58	Mpahlanyana[#]	Pondoland MPA	DEA	Part				A	Low
59	Mpahlane[#]	Pondoland MPA	DEA	Part				A	Low
60	Mzamba[#]	Pondoland MPA	DEA	Part				B	Low
61	Mtentwana[#]	Pondoland MPA	DEA	Part				C	Low
62	Mtamvuna	Pondoland MPA	DEA	Part				B	Low
63	Mpenjati	Mpenjati Nature Reserve	EKZNW	Part				B	Medium
64	Mgeni	Beechwood Nature Reserve	EKZNW	Part				D	Medium
65	Mhlanga	-	EKZNW	All	Yes	Yes		D	High
66	Mlalazi	Mlalazi Nature Reserve	EKZNW	All	Yes			B	High
67	Mhlathuze	-	EKZNW	Part				C	Medium
68	St Lucia/uMfolozi	iSimangaliso Wetland Park	ISWP Authority	90%		Yes		E/D	High/Medium
69	Mgobozeleni	iSimangaliso Wetland Park	ISWP Authority	All				B	Low
70	Kosi	iSimangaliso Wetland Park	ISWP Authority	All				B	Medium

*High = no-take for fish and invertebrates, medium = contains invertebrate no-take area

estuaries not named in the official gazette notices, but which occur within the protected area and are being managed as such.

The above-mentioned protected areas account for 65 900 ha[4] or 73% of the estuarine area within South Africa, and represent all of the eight targeted habitat types (Table 11.2). However, the St Lucia system contributes 90% towards the protected estuarine area or 56% of the total estuarine area, and covers a total of about 51 000 ha. The other fully protected estuaries cover a total area of just under 15 000 ha or only 16 % of the remaining estuarine area in South Africa. Turpie et al. (2012) found that protected areas met less than 5% of all habitat targets for Temperate estuaries. Estuaries that fall within Ramsar sites encompass about 57 000 ha, but not all Ramsar sites are formally protected in law. For example, the Orange and Verlorenvlei currently have no formal protection, although the plan for the Orange River Mouth Protected Area is in an advanced stage, with the potential of expanding it into a transfrontier park in the near future. It is hoped that Verlorenvlei would be granted similar legal protection in the near future to arrest the decline in its health and ensure an adequate supply of good quality water.

Table 11.2 Representation of habitats within fully protected estuaries and percentage of total area met (adapted from Turpie et al. 2012).

Habitat type	Total SA Habitat	Total area in fully protected estuaries (ha)	% of total SA habitat	Total fully protected estuaries minus St Lucia (ha)	% minus St Lucia	Total area in all protected & Ramsar estuaries (ha)	% of total habitat
Intertidal salt marsh	4 310	531	12	15	3	1 633	38
Supratidal salt marsh	7 051	1 757	25	51	3	2 356	33
Mangroves	2 111	898	43	393	44	1 591	75
Reeds and sedges	11 806	7 333	62	383	5	8 265	70
Channel	55 284	40 662	74	4 329	11	45 155	82
Swamp forest	4 843	4 577	95	180	4	4 619	95
Sand/mud banks	4 017	329	8	103	31	1 651	41
Submerged macrophytes	1 327	185	14	4	2	617	47
Rocks	96.2	16.1	17	16	100	16	17
Total	90 844	56 287	62	5 473	10	65 904	73

[4] This estimate was not based on a spatial analysis as the boundaries of some of the protected areas were not available for this assessment. This study therefore treated an estuary as either fully included or excluded in the protected area, while in some cases only some of the estuarine area may be formally protected.

11.2 Ecosystem Protection Levels

Ecosystem protection level indicates the extent to which ecosystems are protected, based on the proportion of each ecosystem's biodiversity target that is met in formal protected areas recognised by the Protected Areas Act or Marine Living Resources Act. For these calculations, targets for protection were set at 20% of the estuarine habitat area of each ecosystem type. Only optimum functional estuaries (not in health categories C, D, E and F) that are in formally protected areas (i.e. in national, provincial or municipal marine/protected areas) were considered as protected (i.e. contributing to biodiversity targets). Ecosystem protection level is divided into four categories: well protected, moderately protected, poorly protected and not protected (according to Table 11.3).

Table 11.3 Categories of ecosystem protection levels with all targets at 20% of area based on estuarine habitat.

Protection levels	Description
Well protected	≥100% of target in an MPA or PA
Moderately protected	50 to 99.99% of target in an MPA or PA
Poorly protected	5 to 49.99% of target in an MPA or PA
Not protected	0 to 4.99% of target in an MPA or PA

Ecosystem protection levels for the 46 NBA ecosystem types calculated according to the above-mentioned criteria are listed in Tale 11.3. Table 11.4 provides a summary of the degree of formal protection (excluding degraded estuaries, i.e. those systems not in an A or B category) and protection levels per ecosystem type for each of the three biogeographical regions.

Table 11.4 Ecosystem protection levels per ecosystem type.

Ecosystem Type	Total area (ha)	Degree of protection				% Protected	Protection level
		High	Low	Medium	None		
Cool Temperate	**13 720**	**9**		**53**	**13659**	**0.4**	
LargeClosedFreshTurbid	1 215				1215	0.0	**Not protected**
LargeClosedMixedBlack	3 528				3528	0.0	**Not protected**
LargeClosedMixedClear	224				224	0.0	**Not protected**
LargeOpenMixedClear	8 346				8346	0.0	**Not protected**
MediumClosedFreshBlack	116				116	0.0	**Not protected**
MediumClosedMixedBlack	134				134	0.0	**Not protected**
MediumClosedMixedClear	36				36	0.0	**Not protected**
MediumClosedMixedTurbid	81			53	28	65.2	**Well**
SmallClosedFreshBlack	20				20	0.0	**Not protected**
SmallClosedMixedBlack	15	9			7	56.3	**Well**

Ecosystem Type	Total area (ha)	Degree of protection				% Protected	Protection level
		High	Low	Medium	None		
SmallOpenFreshBlack	2				2	0.0	Not protected
SmallOpenMixedBlack	3				3	0.0	Not protected
Warm Temperate	**12 849**	**79**	**3970**	**47**	**8753**	**31.9**	
LargeClosedMarineClear	159				159	0.0	Not protected
LargeClosedMixedBlack	2 034		1286		748	63.2	Well
LargeClosedMixedClear	925				925	0.0	Not protected
LargeOpenMarineBlack	1 926		1926			100.0	Well
LargeOpenMarineClear	654				654	0.0	Not protected
LargeOpenMixedBlack	1 896		675		1221	35.6	Well
LargeOpenMixedClear	518				518	0.0	Not protected
LargeOpenMixedTurbid	2 930				2930	0.0	Not protected
MediumClosedMixedBlack	302	39	77	18	167	44.5	Well
MediumClosedMixedClear	954			24	930	2.5	Poorly
MediumOpenMixedBlack	22				22	0.0	Not protected
MediumOpenMixedClear	259				259	0.0	Not protected
MediumOpenMixedTurbid	138				138	0.0	Not protected
SmallClosedFreshBlack	8				8	0.0	Not protected
SmallClosedMixedBlack	29	10	7		13	56.0	Well
SmallClosedMixedClear	56			0	56	0.0	Not protected
SmallOpenFreshBlack	30	30				100.0	Well
SmallOpenMixedBlack	7			5	2	69.8	Well
Subtropical	**64 275**	**322**	**373**	**4774**	**58806**	**8.5**	
LargeClosedFreshTurbid	3 680				3680	0.0	Not protected
LargeClosedMixedClear	4 645			4645		100.0	Well
LargeClosedMixedTurbid	47134				47134	0.0	Not protected
LargeOpenMarineClear	1 373				1373	0.0	Not protected
LargeOpenMarineTurbid	3 764				3764	0.0	Not protected
LargeOpenMixedClear	127				127	0.0	Not protected
LargeOpenMixedTurbid	1 076	239			837	22.2	Well
MediumClosedFreshTurbid	213				213	0.0	Not protected
MediumClosedMixedBlack	116		94		22	81.2	Well
MediumClosedMixedClear	1 169		30	121	1017	13.0	Moderately
MediumClosedMixedTurbid	514		92		423	17.8	Moderately
MediumOpenMarineClear	27				27	0.0	Not protected
MediumOpenMixedTurbid	262	68	118		76	71.0	Well
SmallClosedFreshBlack	11		11			100.0	Well
SmallClosedMixedBlack	49	15	28		7	86.5	Well
SmallClosedMixedClear	114			8	107	6.7	Poorly
Total	90 844	410	4343	4874	81218	10.6	

Based on the criteria listed in Table 11.3, nearly 59% (27 out of 46 types) of South Africa's estuarine ecosystem types are not protected. About 33% of estuarine ecosystem types are well protected (15 types), while about 4% are moderately protected (2 types) and 13% are 4% is poorly protected (2 types) (Figure 10.3).

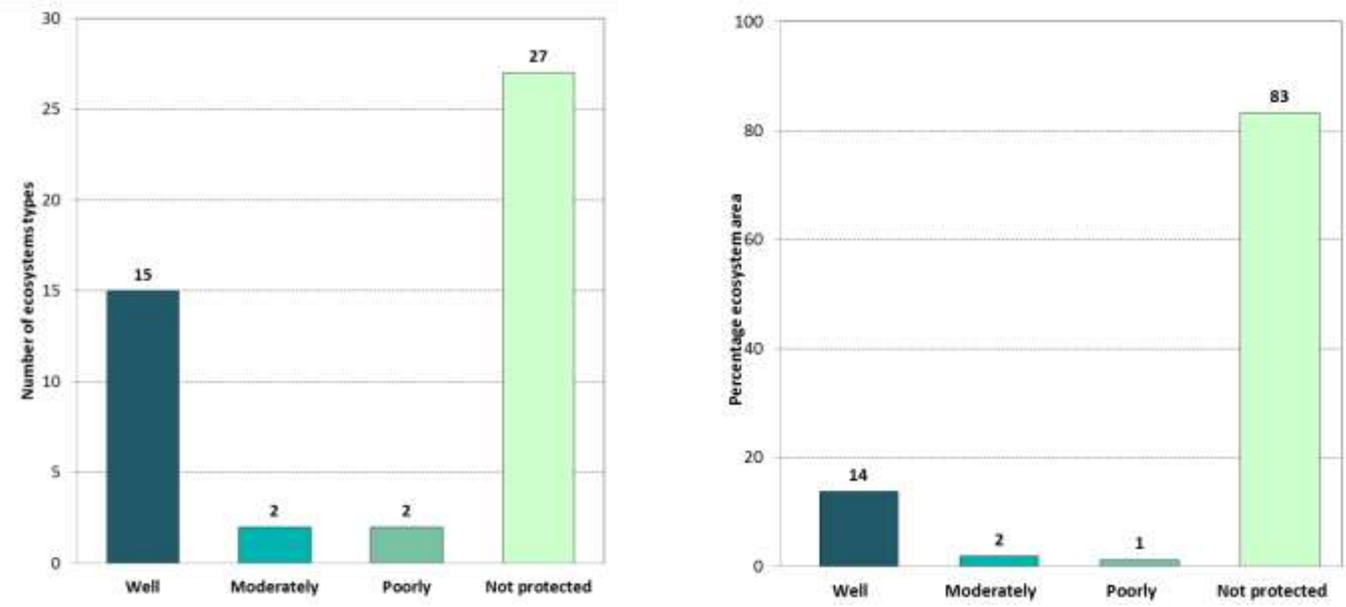


Figure 11.2 Protection levels of estuarine ecosystem types by percentage types and by percentage area in well, moderately, poorly or not protected category.

If protection levels are evaluated as the percentage area protected then the outcome becomes even more serious, with 83% of ecosystem types not protected, 1% poorly protected, 2% moderately protected and only 14% well protected.

Table 11.5 Protection levels of estuarine ecosystem types by biogeograpihical region.

Bioregion	Well	Moderately	Poorly	Not protected	Total
Cool Temperate	2	0	0	10	12
Warm Temperate	7	0	1	10	18
Subtropical	6	2	1	7	16
Total Number	**15**	**2**	**2**	**27**	**46**
SA %	**32.6**	**4.3**	**4.3**	**58.7**	**100**
Total area	**12 480**	**1 683**	**1 068**	**75 613**	**90 844**
SA %	**14**	**2**	**1**	**83**	**100**

If protection levels are evaluated as the percentage area protected, then the Cool Temperate biogeographical region has 99% of its ecosystem types not protected, followed by the Subtropical region at 88%, while the Warm Temperate region has about 44% of ecosystem types not protected. The Warm Temperate region has 48% of its ecosystem types as well protected, while the Subtropical region has only 10% it becomes clear that the Cool Temperate biogeographical region has the highest percentage, at 83%, of ecosystem types not protected (Figure 11.4), followed by the Warm Temperate region at 56% of types (see

Figure 11.5). At 44% the Subtropical region has the lowest number of ecosystem types not protected (Figure 11.6). The Subtropical region and the Warm Temperate region both have the highest number of well protected ecosystem types at 39% and 38% receptively, while the Cool Temperate on features 17% well protected ecosystem types. If protection levels are evaluated as the percentage area protected, then the Cool Temperate biogeographical region has 99% of its ecosystem types not protected, followed by the Subtropical region at 88%, while the Warm Temperate region has about 44% of ecosystem types not protected. The Warm Temperate region has 48% of its ecosystem types as well protected, while the Subtropical region has only 10% well protected. No ecosystem types are well protected in the Cool Temperate biogeographically region.

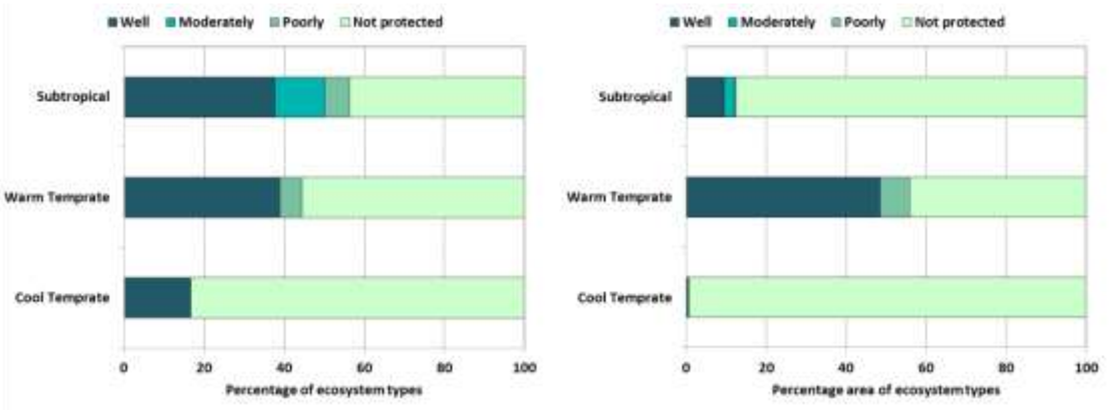


Figure 11.3 Protection levels of estuarine ecosystems by percentage types and by percentage area in well, moderately, poorly or not protected category for the three biogeographical regions.

An interesting and important finding was that if the health condition of the current degraded PA and MPA (i.e. estuaries in a C to F category) were to improve, the current protection levels of the well protected category would increase dramatically from 33% (15 types) to 46% (21 types). In terms of percentage ecosystem area, the well protected category would increase from 14% to 72%!!!! This finding indicates that a number of the current protected areas are in the correct location and, with the sound management interventions, significant progress can be achieved in the short term. It is therefore strongly recommended that degraded estuaries currently enjoying some form of formal protection (Lake St Lucia system, uMfolozi, Mgeni, Mhlanga, Seekoei, Heuningnes, Sand, Wildevoëlvlei, Diep, Orange) be restored to a functional status that allows them to fulfill their role in contributing to biodiversity targets.

Figure 11.4 Ecosystem protection Levels in the Cool Temperate biogeographical region.

Figure 11.5 Ecosystem protection levels in the Warm Temperate biogeographical region.

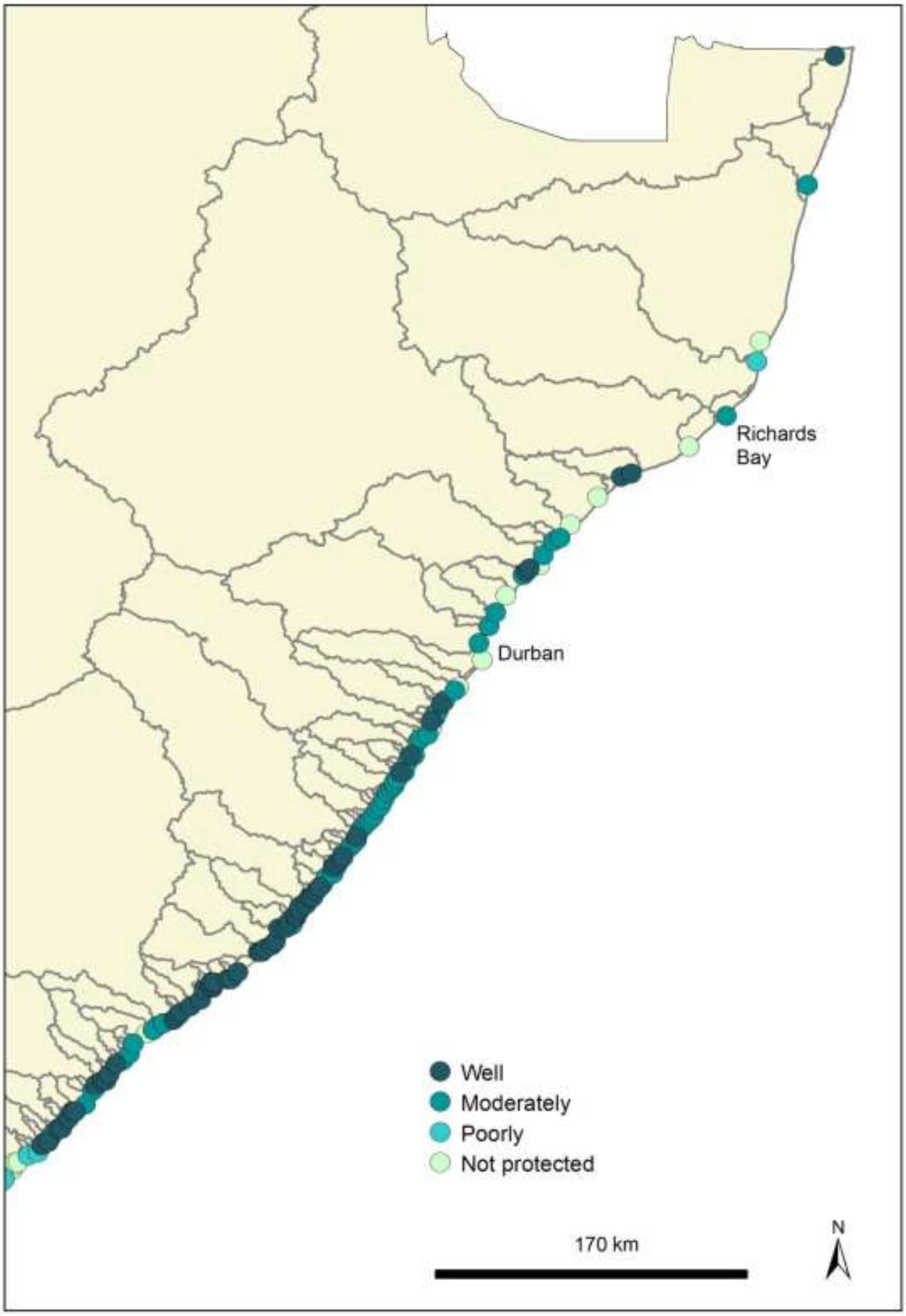


Figure 11.6 Ecosystem protection levels of the Subtropical biogeographical region.

12. NATIONAL ESTUARIES BIODIVERSITY PLAN

JK Turpie, G Wilson & L van Niekerk

The main objective of this assessment was to develop a biodiversity plan for the estuaries of South Africa by prioritising and establishing which of them should be assigned partial or full Estuarine Protected Area (EPA) status. This assessment represents a significant milestone in that it is the first conservation planning exercise to include all South African estuaries. This chapter summarises the main report (Turpie et al. 2012).

12.1 Overall approach

Biodiversity planning is an evolving field that has allowed a move from *ad hoc* protection to systematic planning that takes pattern, process and biodiversity persistence into account. More recently, attention has been focused on incorporating socio-economic realities into conservation planning, particularly in terms of minimising the management and opportunity costs of protection. While we have not explicitly taken social and economic costs and benefits into consideration, we have taken ecosystem health into account, which provides a surrogate for the former to some extent. This is because estuaries where the opportunity costs of protection are likely to be high are also likely to be heavily-utilised systems that are in a lower state of health.

Biodiversity planning typically involves the following steps (expanded from Pressey & Cowling 2001):

1. Define the planning domain: This involves defining the region within which the conservation sites will be chosen, and may have a biogeographical or political basis.
2. Define the planning units: These are the sites that may be selected for conservation. In many cases these are defined by grid squares, hexagons or cadastral units (properties).
3. Set targets: Identify conservation goals for the region and set quantitative biodiversity targets for the biodiversity features (e.g. species, macrophyte communities and ecosystem types), and quantitative targets for minimum size, connectivity or other design criteria.
4. Gap analysis: Review existing protected areas, assessing the extent to which quantitative targets have already been achieved.

5. Select new sites: Select additional areas using algorithms to identify preliminary sets of new conservation areas for consideration by managers as additions to established areas.

Having initially concentrated on the representation of species, biodiversity planning has generally evolved to incorporate ecosystem processes and now gives greater emphasis to biodiversity persistence (e.g. Cabeza & Moilanen 2001). One of the biggest challenges is setting spatially-explicit targets for the maintenance of ecological and evolutionary processes. This involves identifying the processes, finding spatial surrogates for them and then setting targets (Pressey et al. 2003). Another key challenge is delivering a plan that not only achieves representativeness but which also ensures the persistence of targeted populations and maintenance of biodiversity (Reyers et al. 2002).

The overall goals of the core Estuarine Protected Area network to be developed here were as follows (Turpie & Clark 2007):

- Representativeness: all estuary-dependent species should be represented in viable numbers in the protected areas network;
- Maintenance of ecological processes: the protected area network should allow for connectivity and interaction with other adjoining ecosystems;
- Maintenance of fishery stocks: the protected area network should provide enough protection to exploited species that they are able to act as source areas for surrounding exploited areas; and
- Feasibility of implementation: consideration should be given to the practicalities of protection in each estuary. In this assessment we considered this through decisions about whether the estuary was able to achieve full or partial protection and by favouring, where possible, healthier estuaries that offer a lower rehabilitation and opportunity cost of protection.

Conservation planning involves defining the planning domain and units, then setting targets, assessing how well the current protected areas meet those targets and selecting new planning units to meet the targets subject to some constraint such as minimising the number of sites or the costs. A variety of sophisticated algorithms have been developed for this purpose. We made use of MARXAN (operated via CLUZ).

This assessment builds largely upon the C.A.P.E. Estuaries Conservation Plan that covered the Temperate regions of South Africa only.

12.2 Planning units

A total of 289[5] estuaries from the cool Temperate, warm Temperate and sub-tropical regions were included. The main objective was to identify which South African estuaries should be assigned protected area status. Where feasible, estuaries were divided into two (non-spatially-explicit) planning units, each theoretically representing 50% of the biodiversity features of an estuary. This allowed for the possibility of partial protection, as opposed to only having the option of conserving whole estuaries.

12.3 Biodiversity targets

Targets are often defined in terms of achieving representivity in ecosystem types, habitats and species, as well as meeting population targets that ensure their viability. The overall target was to conserve a minimum of 20% of total estuarine area. Targets for ecosystem type are sometimes used as a surrogate for biodiversity for which data are lacking. In the case of estuaries, ecosystem type is generally defined using Whitfield's (1992) five estuary types (bay, river mouth, permanently open, temporarily open and lake). In this assessment estuary type was redefined on the basis of mouth state, salinity structure and freshwater type, with a total of 25 types. A target of 20% was set for the total area of each type. Sensitivity analyses were conducted by excluding type and by expanding the number of types to 46 by including size.

Habitat targets were set at 20% of the total area of each type, except for mangroves and swamp forest habitats. Nationally, mangrove and swamp forest utilisation is regulated under the National Forests Act and destruction or harvesting of indigenous trees is prohibited. While the mangrove trees and swamp forest are protected, the area under the forests and the associated estuarine habitat in many cases is not. Because of this, targets were not set for mangroves or swamp forest per se, but instead protection was given to all estuaries that contained >5 ha of these habitats by automatically including them into the core set of estuaries, thereby offering formal protection to estuaries where swamp forest or mangroves occur. Population targets, based on numbers of individuals per species, were set for estuary dependent fish and bird species (84 and 35 species, respectively) as follows: 50% of the population for red data species, 40% for exploited species and 30% for the rest. Ecosystem and landscape level processes were accommodated by ensuring that the protected area set

[5] For practical planning purposes the St Lucia/UMfolozi and Mhlathuze/Richards Bay estuaries were treated as single systems, like all other joint systems, reducing 291 to 289 systems.

had a good geographic spread, included large as well as small estuaries, and favoured healthier estuaries. Alignment with existing and/or proposed terrestrial and marine protected areas was also taken into consideration.

12.4 Site selection procedure

Biodiversity planning algorithms are used to find the most efficient, or lowest cost, solution required to meet defined biodiversity targets. We used the MARXAN site optimisation algorithm, run through a GIS interface programme called CLUZ. MARXAN starts by selecting a random set of planning units, and then makes iterative changes to the set of sites by randomly adding or subtracting planning units. At each iteration within a run, the new set is compared with the previous set, and the better one is selected. Up to 50 runs of the MARXAN application were conducted at 1 million iterations per run. The programme then selected the best output from of the 50 runs.

While socio-economic costs and benefits were not included into the analysis, estuary health was incorporated as a cost, in that more degraded estuaries were assigned exponentially increasing cost values. Highly impacted estuaries probably also have relatively high costs in terms of conservation – both rehabilitation costs as well as forgone opportunity costs.

To account for data limitations, the opinions of the scientific and management community were also taken into account. Estuary scientists and managers participated in a workshop to finalise the definition of the planning units and their feasibility for protection, and to agree on which planning units should be automatically included into the final set, giving reasons. Finally, sensitivity analyses were conducted, in which the inclusion or definition of targets for estuary types was varied.

12.5 Results and recommendations

The primary analysis, which included targets for estuary type and size, suggested that 121 planning units in 116 estuaries would be required to meet the defined targets (see Figure 12.1 and Appendix C for more detail). This amounts to about 40% of estuaries and 80% of estuarine area. Variation of targets for estuary types did not have a significant impact on the result, and thus the results from the primary analysis were used. In total 58 estuaries require full protection (20%) while 63 estuaries require partial protection (22%). Fully-protected estuaries are taken to be full no-take areas. Partial protection might involve zonation that includes a no-take area, or it might address other pressures with other types of action. In both these cases, the management objective would be to protect 50% of the biodiversity features of the partially protected estuary. Fully protected and partially protected estuaries can be considered Estuarine Protected Areas, whereas all other estuaries should be designated Estuarine Management Areas. All estuaries require a Management Plan, and these plans should be guided by the results of this assessment.

Based on the list of estuaries generated in this analysis, plus preliminary estimates of their present ecological status (health; this analysis) and their importance rating (Turpie & Clark 2007), the national and regional priorities for conservation can be determined. National priorities provide recommendations regarding the extent of protection required for each estuary, the recommended extent of the estuary perimeter that should be free from development to an appropriate setback line, and the preliminary Recommended Ecological Category (or recommended future health class) as required under the National Water Act.

Estuaries that require full protection include:

Orange	Lottering	Ku-Mpenzu	Mtamvuna
Spoeg	Elandsbos	Ku-Bhula/	Umgababa
Groen	Storms	Mbhanyana	Msimbazi
Krom	Elands	Ntlonyane	Mhlanga
Eerste	Groot (Oos)	Nkanya	Mvoti
Lourens	Tsitsikamma	Sundwana	Mdlotane
Palmiet	Maitland	Ngakanqa	Siyaya
Ratel	Gqutywa	Lwandilana	Mlalazi
Heuningnes	Ncera	Hluleka	St Lucia/ uMfolozi
Klipdrifsfontein	Kwenxura	Mntafufu	Mgobezeleni
Kaaimans	Quko	Mzintlava	Kosi
Goukamma	Ncizele	Mkozi	
Sout (Oos)	Nxaxo/ Ngqusi	Myekane	
Groot (Wes)	Ngqwara	Msikaba	
Bloukrans	Ngadla	Mtentu	

Estuaries that require partial protection include:

Olifants	Bot / Kleinmond	Gouritz	Keurbooms
Verlorenvlei	Klein	Wilderness	Kromme
Berg	Uilkraals	Swartvlei	Seekoei
Rietvlei/ Diep	Breede	Knysna	Gamtoos
Sand	Goukou	Piesang	Van Stadens

Swartkops
Sundays
Bushman’s
Kariega
Great Fish
Mgwalana
Bira
Keiskamma
Gqunube
Kwelera
Great Kei
Qora
Nqabara
Mbashe
Xora
Mtata
Mtakatye
Mngazana
Mzimvubu
Nkodusweni
Mbotyi
Mkweni
Mnyameni
Mpenjati
Zotsha
Mzimkulu
Damba
Koshwana
Intshambili
Mhlabatshane
Mfazazana
Kwa-Makosi
Mkomazi
Lovu
Durban Bay
Mgeni
Mhlali
Zinkwasi
Matigulu/ Nyoni
Mhlathuze/
RichardsBay

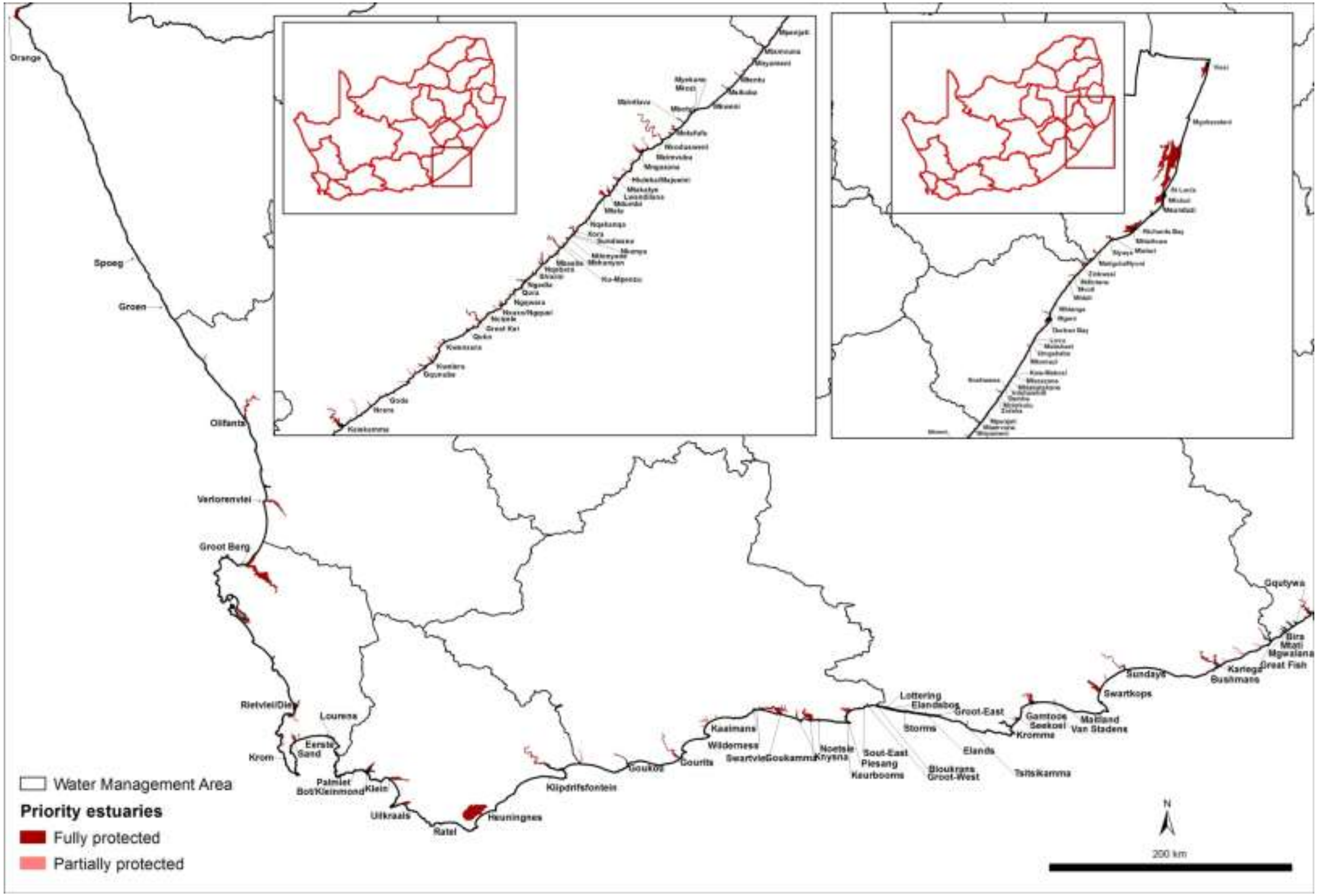


Figure 12.1 National priority estuaries for biodiversity conservation.

13. HOW VULNERABLE ARE SOUTH AFRICA'S ESTUARIES TO CLIMATE CHANGE ?

L van Niekerk, F Engelbrecht, N James, A Meyer & A Theron

Estuaries form an interface between the land and sea and are strongly influenced by runoff, wind, wave action, air and water temperatures from the land and sea. Consequently, climate change is likely to have a profound effect to the structure and functioning of estuaries, and may have a range of implications for estuarine biota (Kennedy, 1990).

13.1 Processes by which climate change may alter South Africa's estuaries

13.1.1 Ocean processes

Large scale coastal currents determine, to a large degree, coastal climate which in turn will impact on estuarine dynamics. The physical properties and circulation features of South Africa's coastal zone are determined by the two large scale ocean currents which are located very close to the South African coast, i.e. the Agulhas Current along the east and south coasts and the Benguela Current along the west coast. Any change in both currents' average positions will impact not only on the properties and circulation of the coastal zone, but will also impact on the coastal flora and fauna (including estuarine species),

It was recently demonstrated using hydrographical and satellite observations, as well as state of the art climate models, that both green house gas (GHG) induced global warming and the anthropogenic induced ozone hole have caused an intensification and southwards shift of the Southern Hemisphere Sub-tropical gyres over the last 40 years (Cai et al. 2006, and references therein). Modern global climate models based on present day atmospheric CO_2 levels and projected levels of increasing CO_2 levels, motivated by the IPCCs estimates of a 1% increase in CO_2 per year up to the year 2100, show that the above trend in the ocean circulation will continue (Saenko et al. 2005). These global predictions for oceanic climate change will have a definite impact on the coastal-open ocean circulation around South Africa.

Lutjeharms and de Ruijter (1996) argue that with global warming the Agulhas Current will exhibit increased meso-scale meandering which will force the current on average further offshore from its mean position. In the present global climate regime the Agulhas Current is located within 15 km from the shore 77% of the time. However, perturbations in the form of large-amplitude intermittent meanders (Natal Pulses) can force the current's core up to

300 km offshore. The meander modes of the Agulhas Current occur between 4 to 6 times per year. Lutjeharms and de Ruijter (1996) suggest that the meander modes will increase in frequency due to global warming and that the current will be located on average further from the coast line. This will lead to cascading impacts on the coastal climate and dynamics, e. g. rainfall and the movement of marine flora and fauna along the coast and into/out of estuaries.

The exchange of large quantities of warm water from the Indian to the Atlantic Ocean (Agulhas Leakage) via the Agulhas Retroflection influences the south and west coasts of South Africa (Figure 13.1). Agulhas Leakage occurs via the intermittent occlusion of the Agulhas Retroflection loop to form the world's largest anti-cyclonic vortices, called Agulhas Rings. Each year between 4 to 8 rings of varying sizes (200 to 400 km in diameter) are pinched off and advected north-westward into the south eastern Atlantic Ocean along the west coast of South Africa.

Two modes of the Agulhas Retroflection exist, a downstream (normal) mode (Figure 13.1a) and an upstream mode (Figure 13.1b). During the upstream mode the Agulhas Leakage is markedly reduced, which leads to cooler sea surface temperatures for the southern and western oceanic and coastal regimes, compared to during the normal Agulhas Retroflection mode. An increase occurrence in the average upstream mode will lead to drier coastal climates along the west and south of South Africa, thus impacting on river run-off and estuarine dynamics.

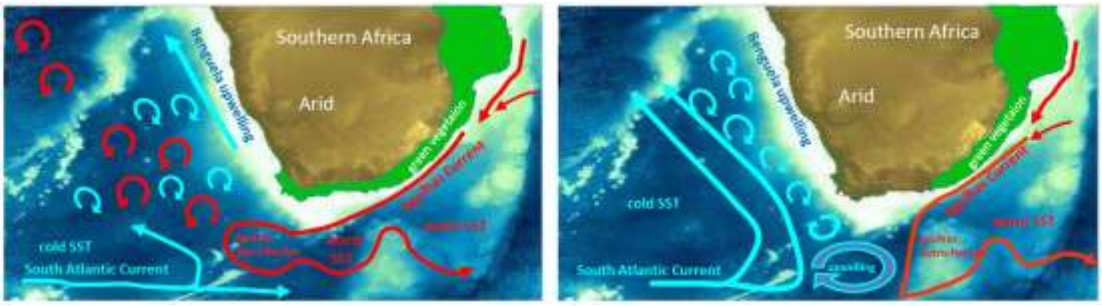


Figure 13.1 Current regimes around South Africa; (a) normal downstream mode of the Agulhas Retroflection, leading to Agulhas Leakages via warm core Agulhas Rings, (b) Upstream Retroflection mode leading to a reduction in Agulhas Leakage and cooler temperatures.

Stronger Agulhas Current transport has been predicted due to global warming. The impact of a stronger Agulhas Current on the retroflection mode is still unclear. Cai et al. (2007) and Rouault et al. (2009) indicate that the increase in Agulhas Current transport will lead to an associated stronger Agulhas Leakage with more warm Indian Ocean water passing the southern and western coasts of South Africa. The model study of Van Sebille et al. (2009)

show the opposite - that an increase in Agulhas Current transport will lead to a higher frequency of Upstream Retroflections, with a concomitant decrease in Agulhas Leakage. Either way, the impact of a stronger Agulhas Current will have definite effects on the coastal climate of South Africa.

On the western coast of South Africa the Benguela Current (or drift) will intensify and lead to more intense upwelling due to the spinning up of the Supergyre (Roemich 2007; Saenko et al. 2005). This will induce much cooler sea surface temperatures along the west coasts of South Africa than present. However, the intensification of the South Atlantic Sub-tropical gyre may also lead to increase atmospheric subsidence, less clouds, increase insolation and higher air temperature over the Benguela Upwelling System (Lutjeharms et al. 2001). The latter will result in warming of the surface water which may negate the increase upwelling of cooler waters. Another mechanism that may influence the Benguela coastal region are Agulhas Rings and filaments which drift sometimes very close up the west coast, raising the temperature of the nearshore waters and occasionally interacting with upwelling plumes, both of which have important consequences for fish recruitment (Duncombe Rae et al. 1992).

13.1.2 Rainfall and Runoff

Climate change will alter precipitation patterns which will affect the quality, rate, magnitude and timing of freshwater runoff to estuaries and will exacerbate existing human modifications of river inflows (Alber 2002; USEPA 2009). Estuarine functioning is strongly influenced by the magnitude and timing of freshwater runoff (Meynecke et al. 2006). Downscaled regional climate models (RCMs) derived from global climate models (GCMs) indicate the likelihood of increased summer rainfall over the eastern part of South Africa, the interior and the Drakensberg Mountains. The greater rainfall projected for the east would be in the form of more rain days and more days with bigger rainfalls. If these scenarios are correct, the combination of wetter antecedent conditions and larger rainfall events would result in more runoff being generated. Less rainfall is projected along the west coast and the adjacent interior, with the possibility of a slight increase in inter-annual variability. If correct, this would result in a decrease in flows and an increase in flow variability, since changes in precipitation are amplified in the hydrological cycle (Lumsden et al. 2009. Hewitson & Crane, 2006). The models also show an increase in heavy / extreme precipitation events in the summer over the east coast of KwaZulu-Natal along with an increase in rain days for much of the country, excepting possibly the extreme west / southwest (Hewitson et al. 2005). Schultze et el. (2005) predict that climate change may cause hydrological “hotspots” of change, one being the present winter rainfall region in the Western Cape. Changes in precipitation and runoff ultimately also drive changes in nutrient and sediment supply to estuaries and the coast. It will also affect related human adaptation strategies to reduce risk, e.g. increase impoundment and land use change, which will increase the rate of change in primary inputs (flow, sediment and nutrients) to estuaries and the coast.

13.1.3 Increase in the frequency and intensity of sea storms

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change predicts, an increasing frequency and intensity of extreme weather events in the 21st Century (IPCC 2007). The frequency and magnitude of severe weather events such as tropical cyclones, hailstorms, droughts and floods appears to be on the increase globally and possibly in South Africa (IPCC 2007). In South Africa, increases in either intensity or frequency, or changes in seasonal storm intensity have been recorded at a local scale albeit on a very short time-scale (Guastella and Rossouw 2009, Harris et al. 2010).

Preliminary findings indicate that there may be long-term trends in regional metocean climates, while sea level rise alone will greatly increase the impacts associated with extreme sea-storm events (Theron 2007). The regional variation in the global wave climate was demonstrated by Mori et al. (2010), who, in simulating future trends, predicted that the mean wave height might generally increase in the regions of the mid latitudes (both hemispheres) and the Antarctic ocean, while decreasing at the equator. Wang et al. (2004), Komar and Allan (2008) and Ruggerio et al. (2010) provide further evidence of a general wave height increase and increasing storm intensities in the Northern hemisphere. Such changes in the regional metocean climates are expected to have significant impacts on local coastal areas. It is therefore important to also investigate possible future climatic changes off the southern African coastline as well as the expected associated impacts. As can be anticipated, a more severe wave climate (or related oceanic wind climate) will result in more storm erosion, potentially more coastal sediment transport, and greater coastal impacts.

Preliminary analyses conducted by Rossouw and Theron (2009) found that the annual mean significant wave height (Hm_0) for the wave data collected off Richards Bay and Cape Town indicate no real progressive increase. This may appear to contradict the findings of the IPCC, as presented in PIANC (2008), but the South African results may reflect a regional aspect of the impact of climate change. Although the averages appear to remain constant, there seems to be some change in the individual storms. For example, considering the peaks of individual storms off Cape Town during the more extreme winter period (June to August), an increase of about 0.5 m over 14 years is observed. This result may be indicative of a significant increase in the “storminess” over the next few decades. It is also worth noting that the opposite occurs during summer: there has been a general decrease over the last 14 years with regard to individual storms off Cape Town. However, it must be noted that the South African wave record is too short to make any firm conclusions at present. To some extent it could be said that the preliminary “trend” indicated by the South African wave data is supported by the model predictions of Mori et al. (2010), which appear to show an increase in wave height for the South African coast of roughly 6% for extreme events (Theron et al. 2010, submitted).

Wave climate and conditions are determined by ocean winds (velocity, duration, fetch, occurrence, decay, depth, etc.). Predicted values for potential changes in oceanic wind regimes off southern African are lacking. In view of this shortcoming and to enable an assessment of the potential impacts of stronger winds, a relatively modest increase of 10% could be assumed. Thus, a modest 10% increase in wind speed, means a 12% increase in wind stress, a 26% increase in wave height, and as much as an 80% increase in wave power (Theron 2007). This means that a modest 10% increase in wind speed could also result in a potentially significant increase in coastal sediment transport rates and consequently impact on estuarine mouth regimes.

13.1.4 Sea level rise

Recent calibrated observations from satellites, are that global sea level rise over approximately the last decade has been 3.3+/- 0.4 $mm.yr^{-1}$ (Rahmstorf et al. 2007). The IPCC AR4 Report (IPCC 2007) concludes that anthropogenic warming and sea level rise will continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations are stabilised. Comparisons between approximately 30 years of South African tide gauge records and the longer term records elsewhere, show substantial agreement with global trends (Theron 2007). A recent analysis of sea water levels recorded at Durban confirms that the local rate of sea level rise falls within the range of global trends (Mather 2008). Present South African SLR rates are: west coast +1.87 $mm.yr^{-1}$, south coast +1.47 $mm.yr^{-1}$, and east coast +2.74 $mm.yr^{-1}$ (Mather et al. 2009).

The probability of sudden large rises in sea level (possibly several metres) due to catastrophic failure of large ice-shelves (e.g. Church and White 2006) is still considered unlikely this century, but events in Greenland (e.g. Gregory 2004) and Antarctica (e.g. Thomas et al. 2004) may soon force a re-evaluation of this assessment. In the longer term the large-scale melting of large ice masses is inevitable. Recent literature (subsequent to IPCC 2007) give a wide range of SLR scenarios, but most “physics/process based” projections for 2100 are in the 0.5 m to 2 m range (Rossouw and Theron 2009; Shore & Beach Special Review Issue, November 2009).

13.2 Quantification and mapping of risks

13.2.1 Changes in precipitation and runoff

In principle, all estuaries are sensitive to changes in river inflow. The four major consequences of modifications in river inflow are: changes in the extent of seawater intrusion; changes in the frequency and duration of mouth closure, decrease/increase in nutrients fluxes, and changes in the sediment deposition/erosion cycles.

i) Changes in the extent of seawater intrusion

Reduction of fluvial flow into estuaries may have a range of effects on the salinity regime. The degree to which seawater will enter an estuary is dependent on river inflow and the bathymetry of the system, i.e. seawater penetration into the more constricted upper reaches is often constrained by river inflow, with relative easy penetration into the deeper middle reaches; and with the lower reaches generally dominated by tidal flows. Often it is thus the middle reaches of an estuary that shows the most sensitivity to changes in flow (river and tidal).

For example, in large systems flow reduction may initially result in a reduction in the extent of the estuarine mixed zone i.e. that section of an estuary with salinity between 20 and 10. Further reduction in stream flow can result in the complete elimination of this mixed zone so that, effectively, the system functionally becomes an arm of the sea e.g. the Kromme Estuary (Scharler and Baird 2000; Snow, Bate and Adams 2000; Wooldridge and Callahan 2000; Strydom and Whitfield 2000; Bate and Adams 2000). If there is no inflow at all a reverse salinity gradient may develop, where the salinity at the head of the estuary may exceed that of seawater e.g. the Kariega Estuary (Bate et al. 2002; Whitfield and Paterson 2003).

In addition to supporting a resident estuarine fish assemblage, estuaries are important nursery, refuge and feeding areas for numerous marine fish species (Elliot et al. 2007). Reduced freshwater inflow may reduce the (primary) productivity of an estuary, thereby reducing the food available to juvenile fishes (Strydom and Whitfield 2000). This will have an adverse effect on fish recruitment, growth, survival and production or recruitment into the adult population (Dolbeth et al. 2010). Reduction in stream flow in temporarily open/closed systems may lead, paradoxically, to a reduction in salinity in many small systems. Reduction in inflow can lead to mouth closure and, provided that the river inflow still exceeds evaporation and seepage losses, a progressive freshening of the estuary until such time as rising water levels lead to a breaching of the berm closing the mouth, e.g. Groot Brak. The impact is an almost complete loss of the marine species with only a few estuarine and freshwater species remaining (Whitfield 2005). Mass mortalities of marine fish species have been recorded in the Bot when salinities declined to 2-3 and temperature was less than 18°C (Bennett 1985).

Increased stream flow will also reduce, or prevent salinity penetration into an estuary, i.e. increase the estuarine mixed zone. In a very small system, or if there is a significant increase in river flow, an estuary with a full salinity gradient may be turned into a fresh water dominated system, with a related reduction in water residence times and associated primary production.

ii) Changes in the frequency and duration of mouth closure

Temporarily open/closed estuaries (TOCEs) become isolated from the sea by the formation of a sand berm across the mouth during periods of low or no river inflow. Such estuaries stay closed until their basins fill up and their berms are breached by increased river flow. A major consequence of stream flow reduction is, therefore, a change in the frequency and duration of estuary mouth closure in TOCEs. In extreme cases fresh water reduction can cause permanent mouth closure.

The consequences of these physical changes for the biota can be severe. For example the mudprawn *Upogebia africana* has an obligatory marine phase of development during the larval stages. Estuary mouth closure, particularly for extended periods (e.g. >1 year), disrupts the life cycle and can result in local extinction of the mudprawn (Wooldridge and Loubser 1996). Some demersal zooplankton species exhibit tidally-phased migratory behaviour (Schlacher and Wooldridge 1995). Mouth closure removes the tidal signal and thereby disrupts the life cycles of these organisms.

Prolonged closed phases in TOCEs result in a low recruitment potential for juvenile marine fish and effectively prevent the emigration of adults back to sea (Vorwerk et al. 2003). During extended closed phases, fish populations may also decrease considerably due to predation (by other fishes, birds and mammals). For example, predation by piscivorous birds (cormorants, darter and heron) reduced the size of the Cape stumpnose *Rhabdosargus holubi* population in the West Kleinemonde Estuary by 80% (1971) and 20% (1972) respectively over a six to seven month period (Blaber 1973). In severe cases the number of fish will be so greatly reduced by predation that, should the mouth eventually open, their numbers will be so low as to make an insignificant addition to the adult population in the open sea. Alternatively the fishes may simply die in the estuary without ever having had the opportunity to breed.

In the case of birds, mouth closure will lead to a loss of tidal action which, in turn, will adversely affect the quantity and availability of intertidal benthic organisms to waders that forage mainly on intertidal mudflats. Many of these waders are Palaearctic migrants; therefore mouth closure can have an international impact on the populations of such birds. Other effects of reduced stream flow include the loss of shallow water habitats, favoured by herons, flamingos and other wading birds, and the loss of islands, which provide roosts and breeding sites safe from terrestrial predators.

iii) Changes in nutrients

Changes in river flow regimes also affect the nutrient loads entering estuaries. Freshwater flowing into estuaries is an important source of nutrients, both dissolved and particulate. Dissolved nutrients include nitrates, phosphates, silica and trace metals essential for primary production. Particulates such as organic detritus derived from riparian vegetation may, in some systems, be an important source of carbon for the estuarine food web.

Reduction in freshwater inflow (as a consequence of dam development or climate change) will reduce the quantity of nutrients entering the estuary, with the resultant impoverishment of the biota. In particular primary producers such as phytoplankton and benthic diatoms, will be adversely affected with a consequent “knock-on” effect through the entire food chain (Allanson and Read 1987). Increased freshwater inflow will likewise increase the quantity of nutrients entering the estuary, but the biological response will depend on retention. In the shallow perched estuaries of KwaZulu-Natal increased inflow goes hand in hand with, decreased retention time and therefore often results in decreased production.

iv) Decrease in the dilution and or flushing of pollutants

A decrease in river flow into some of the urban systems could extend the closed mouth conditions in some of the temporarily open/closed estuaries, where the combination of high water retention time and warmer water would provide the ideal breeding ground for some disease-causing bacteria.

An increase in inflow from rural areas, associated with higher nutrient loads from fertilizers, will increase nutrient loads to estuaries with a related increase in eutrofication. Similarly, an increase in storm runoff from urban catchments would lead to an increase in fertilisers, herbicides, pesticides, hydrocarbons and solid litter to estuaries.

v) Changes in sediment processes

Floods in estuaries scour sediment deposited during periods of low flow. This accumulated sediment is both catchment derived and brought in from the sea by flood tides. Soil erosion in catchments poses a major threat to estuaries, particularly those in KwaZulu-Natal and those in the former Ciskei and Transkei regions of the Eastern Cape Province (Morant and Quinn 1999). The potential denuding of vegetation in arid catchments (i.e. increasing the erodibility of soils) coupled with an increase in the frequency of high intensity rain events due to climate change would lead to a significant increase in the deposition of sediment in estuaries.

It is also foreseen that the potential water shortage, especially in the Western Cape, would lead to the need to build more dams to secure water supplies to urban areas and agriculture. Major dams may have the effect of capturing minor (annual) flood peaks entirely and attenuating major flood peaks. The degree to which this will occur depends on the ratio of dam volume to the MAR, the level in the dam preceding the flood, and the size of the flood. Therefore, if floods are reduced in intensity and frequency, sediment deposition and accumulation occurs and the estuaries are reduced in water volume and surface area.

Numerous small farm dams, as well as barrages and weirs, collectively may also have a major impact on the variability and duration of stream flow and consequently on estuaries. Instead of being available as stream flow the water is stored and subjected to consumption and losses, including evaporation and seepage. It is estimated that as little as 8% of the total annual runoff reaches the coastal zone (Department of Water Affairs 1986). Higher temperatures, with the related increase in evaporation due to climate change, will not only increase the need to build more farm dams but also will exacerbate the impact of existing dams on the aquatic environment.

13.2.2 Rising temperatures

Projected temperature increases in the average global surface atmosphere range from a low scenario of 1ºC to 3ºC with a potential upper rage of 6ºC by 2100 (IPCC 2007). Shallow water, such as estuaries, will exhibit greater increases in temperature than deeper waters (Rijinsdorp et al. 2009, James et al. 2008a).

Temperature influences the biology of organisms (mortality, reproduction, growth, and behaviour). Temperature can also influence interactions among organisms (e.g. predator prey, parasite-host, competition for resources)). Species are adapted to, and distributed within, specific ranges of environmental temperatures (Harrison and Whitfield 2006, Maree et al. 2000, Elliot 2002). Many organisms are more stressed near their species range boundaries (Sorte and Hoffman 2004). As temperature changes, the geographical distribution of species, depending on their tolerances or preferences, may contract or expand, leading to new and unpredictable species interactions (Murawski 1993, Harley et al. 2006, Clark 2006, Perry et al. 2005, USEPA 2009). Areas of cooling may, however, limit the ability of species to shift their distribution resulting in a decrease in the range of certain species in South Africa. Ultimately, the present species, community and assemblage composition of many South African estuaries may change.

In recent years a number of subtropical species such as the coachman *Heniochus acuminatus*, checked goby *Redigobius dewaali* and blacktip kingfish *Caranx heberi* have extended their range 200 to 1000 km south to the Breede Estuary (Lamberth, unpublished data). James et al. (2008b) and Mbande et al. (2005) highlight the increased occurrence of tropical fish species in estuaries along the East Coast of South Africa (e.g. East Kleinemonde and Mngazana). Of the six tropical species recorded in the East Kleinemonde Estuary, longarm mullet *Valamugil cunnesius* and robust mullet *Valamugil robustus*, have been recorded consistently in the estuary every year after 2002, and are found in both summer and winter indicating that water temperatures are continually within the tolerance range of these species (James et al. 2008b). In the Mngazana Estuary the proportion of tropical species recorded in winter increased from 1975 to 2002. Higher average temperatures would favour tropical species during winter, while limiting the northward penetration of certain Temperate species (Mbande et al. 2005).

Species that are unable to migrate, or compete with other species for resources, may face local or global extinction. Although higher temperatures might not result in the extinction of a species throughout its range, the species may be eliminated from part of its range.

Communities do not shift their distribution as a unit. Movement into newly suitable habitats depends on: 1) the number of adults available in the original habitat and their ability to bear young; 2) an adequate number of potential colonisers; 3) the ability of potential colonizers to move into new habitats; 4) the survival of an adequate number of individuals in the new habitat to ensure genetic diversity to meet challenges and to produce succeeding generations (Kennedy et al. 2002). Thus the loss of species from an estuary that has become too warm may reduce species diversity in that estuary in the short term, depending on the mobility of new colonizers, their ability to tolerate higher temperatures and their tolerance for the higher salinities of the marine environment. Warming is likely to result in new mixes of foundation species, predators, prey and competitors (USEPA 2009, James and Hermes 2011). For example, fishes with the most temperature sensitive distributions include many key prey species of non-shifting predators (Perry et al. 2005).

Mobile organisms such as fish, swimming crabs, and shrimp can quickly colonise new habitats, while immobile or relatively immobile invertebrates such as oysters will disperse more slowly. Changes in temperature will also affect coastal vegetation with more subtropical species moving further south, i.e. the invasion of salt marsh habitats by mangrove species (Steinke 1999, Adam 2002, Gilman et al. 2008).

Temperature also influences the amount of oxygen that water can hold, warmer water holds less oxygen than cooler water. Most aquatic organisms extract oxygen from the waterbody they live in. The effect of higher temperatures and less oxygen could be to constrict the available habitat for certain species. Temperature changes can even influence water circulation patterns within an estuary (Kennedy et al. 2002).

13.2.3 pH change

The reduction in pH that accompanies elevated CO_2 concentrations may have profound implications for coastal and marine ecosystems (Harley et al., 2006, James and Hermes 2011). The pH of surface waters may decrease by 0.3-0.4 units by 2100 under the influence of rising atmospheric CO_2 levels (Caldeira and Wickett 2003). The resulting decrease in pH will affect all calcifying organisms, as structures made of calcium carbonate would start to dissolve requiring more metabolic energy for an organism to maintain its exoskeleton. Estuarine organisms that may be affected include coralline algae, echinoderms, crustaceans and molluscs (USEPA 2009, James 2010).

13.2.4 Increase in the frequency and intensity of sea storms

A number of small to medium sized estuaries (e.g. Groot Brak) show great sensitivity to increased wave action. In general, large storms at sea create the wave conditions that will close such estuaries, unless there is significant river flow to maintain the open mouth condition. An increase in storminess due to climate change would, therefore, increase the occurrence of mouth closure and generally transport more marine sediment into an estuary than at present. Estuaries along an exposed, sediment rich coastline (e.g. parts of KwaZulu-Natal) would be more likely to close than estuaries that are fairly protected, or those located on sediment starved coastlines (e.g. the Transkei and Tsitsikamma coastlines).

13.2.5 Sea level rise

Sea level rise can either counteract the reduction in runoff to an estuary or exacerbate the effect depending on the size of the estuary, the sediment availability, and the wave energy near or at its mouth. In the case of small, temporarily open/closed estuaries sea level rise could assist in maintaining open mouth condition through increasing the tidal prism, if the system is sheltered from wave action and/or little sediment is available near its mouth. Alternatively, sea level rise could merely reset the level at which an estuary closes to the same relative height above mean sea-level, without significantly affecting the amount or duration of mouth closures. Alternatively, an increase in storminess might actually increase the frequency and or duration of the mouth closure due to increased marine sediment transport into the mouth area during sea storms. In the case of permanently open estuaries, sea level rise may lead to an increase in the saline penetration (especially in the middle reaches) and require additional freshwater to maintain the same salinity gradient as at present, i.e. it may be necessary to increase the ecological flow requirement to maintain present ecological production levels.

Climate change and sea level rise will increase the pressures on management agencies to implement assisted (and often premature) breaching as increasingly properties will be below the level of the sand berm near the mouth. The response of humans to sea-level rise may take the form of actions destructive to estuaries, such as armouring the coastline with berms or dykes that will prevent biological systems from adjusting naturally (e.g. by inland retreat of wetland). An example of an impact on the biophysical processes is the loss of salt marsh and mangroves leading to a decrease in estuarine habitat and food supply. An indirect impact is an increase in turbidity as sediment is no longer trapped by the fringing vegetation around an estuary. This, in turn, reduces light penetration thus causing a decrease in primary production by microalgae, while “tactile” feeders will benefit at the expense of “visual” feeders (e.g. estuarine round herring *Gilchristella aestuaria* vs Cape silverside *Atherina breviceps*). Furthermore, some mangrove and salt marsh systems may not be able to keep pace with more rapid levels of sea-level rise. Mangroves may out compete saltmashes in the subtropical areas in response to rising sea level (Adam 2002).

13.3 Key findings

In summary, the impacts of climate change on estuaries include:

- Changes in precipitation and runoff with the following consequences for estuaries:
  - Modifications in the extent of saline water intrusion;
  - Changes in the frequency and duration of mouth closure;
  - Decrease or increase in nutrients fluxes; and
  - Changes in the magnitude and frequency of floods and related sediment deposition/erosion cycles.
- Changes in the dilution and or flushing of pollutants;
- Rising temperatures from both the land and sea;
- Sea level rise;
- Changes in ocean circulation patterns; and
- Increase in frequency and intensity of coastal storms.

The details of this assessment are presented in **Error! Reference source not found.**. The resultant analysis shows that the KwaZulu-Natal and West Coast estuaries will be the most effected by climate change from a structural and functional perspective. In the case of KwaZulu-Natal the major driver of change is increased runoff into the numerous small, perched (estuary volume decrease by 50 to 90% when open to sea) temporarily open/closed estuaries, which will result in more open mouth conditions, a decrease in retention time and a related decrease in primary productivity and nursery function.

Table 13.1 Summary of the responses of the South African estuaries to climate change drivers

Drivers	Response	Sub-Tropical		Warm Temperate		Cool Temperate
		KwaZulu Natal	Transkei	Eastern Cape	Southern Cape	Western Cape
Changes in ocean circulation patterns	Current speed	Intensification of the Agulhas Current	Intensification of the Agulhas Current	Intensification of the Agulhas Current	Possible increase in divergence of the Agulhas Current from the coast due to Upstream Retroflection, or increase in warm saline water leakage from the Indian to the Atlantic via the Agulhas retroflection. Unclear which process will dominate.	Benguela Current (Drift) will increase with global warming due to the spin up of Southern Hemisphere Subtropical Gyres, which will lead to intensification of eastern boundary upwelling. However, this may be counteracted by increase insolation due to clear skies over the upwelling region, or the leakage of warm Agulhas waters due to rings and filaments.
	Current position	Intensification of Agulhas Current may lead to increase meso-scale meandering in this very stable current due to Natal Pulses. This will force the current on average futher off-shore	Intensification of Agulhas Current may lead to increase meso-scale meandering in this very stable current due to Natal Pulses. This will force the current on average futher off-shore	Intensification of Agulhas Current may lead to increase meso-scale meandering in this very stable current due to Natal Pulses. This will force the current on average futher off-shore	Still unclear whether upstream or down stream mode of the Southern Agulhas Current will dominate. An upstream mode will lead to an absence of the Agulhas Curent along the south western coast of south Africa.	Unknown, assume similar to present
	Upwelling	Increase shelf upwelling - due to increase pulses, topographic upwelling and Ekman veering. Increasing nutrient input and related primary production in the nearshore and lower reaches of open estuaries	Increase shelf upwelling. Increasing nutrient input and related primary production in the nearshore and lower reaches of open estuaries	Increase shelf upwelling but the coastal shelf is very wide so the effect of increased nutrient input and production on the nearshore and lower reaches of open estuaries is less apparent	Increase upwelling downstream from prominent capes due to local wind regimes. Increasing nutrient input and related primary production in the nearshore and lower reaches of open estuaries	More upwelling due to a increased wind stress, causing increase nutrient input and related primary production in nearshore and estuaries. Also a related decrease in black tide events (i.e. Berg Estuary)
Changes in precipitation	Changes in runoff	Significant increase in runoff, both in base flow and in flood events.	An increase in runoff both in base flow and in flood events.	Similar to present, with a slight increase in runoff (base flow and floods)	Similar to present, with a slight decrease in runoff with especially baseflows reduced	Significant decrease in runoff, with especially baseflows severely reduced.
	Changes in the frequency and duration of mouth closure	Temporarily open systems close less often in decreasing periods of high productivity. These system most productive when closed.	Increased flow causing a slight decrease in closed mouth conditions in temporarily open systems is expected. This could be offset by increased sedimentation.	Similar to present, but some decrease in closed conditions in temporarily open systems depending on the size of the system and the inflow regime.	Similar to present, with a some increase in closed conditions in temporarily open systems depending on the size of the system and the inflow regime.	Decrease in runoff causing a significant increase in closed conditions in temporarily open systems
	Modifications in the salinity regime	Less salinity penetration in large permanently open and smaller temporarily open systems. (KZN characterise by limited saltwater penetration under open mouth conditions resulting in fresh closed conditions.)	Some decrease in salinity penetration of permanently open systems. An increase in open mouth conditions for some smaller temporarily open systems depending on the size of the system and the inflow	Similar to present, but could have a slight decrease in salinity penetration in some large open estuaries. A slight increase in open mouth conditions for some smaller temporarily open systems depending on the size	Similar to present, but limited increase in salinity penetration in some large permanently open estuaries. Some freshening (decline in average salinity) under increased closed mouth conditions in some smaller	Significant increase salinity penetration in large permanently open estuaries, but some freshening (decline in average salinity) under increased closed mouth conditions in smaller temporarily open systems

Drivers	Response	Sub-Tropical		Warm Temperate		Cool Temperate
		KwaZulu Natal	Transkei	Eastern Cape	Southern Cape	Western Cape
			regime	of the system and the inflow regime	temporarily open systems.	
	Decrease/ increase in nutrients fluxes	Increased nutrient supply, but less retention in the large number of smaller perched systems that drain > 50 % of volume when open. Decrease in primary production. The exceptions are the estuarine lakes and bays which have higher retention and will likely have an increase in production.	Some increase in nutrient supply, more retention as systems are less perched, increased primary production	Very similar to present, but with some increase in nutrient supply, more retention as systems are less perched, increased primary production	Very similar to present, but with some decrease in nutrient supply which is not likely to be offset by increased retention. Resulting in a some loss of primary production	Decrease in nutrient supply which is not likely to be offset by increased retention. Resulting in a significant loss in primary production
	Changes in floods (magnitude, duration and frequency) and sediment deposition/erosion cycles	Increase in flooding with related increased erosion in catchments will lead to more infilling and decreased substrate stability – resulting in depauperate biotic communities as there is little floodplain habitat available on the KZN coast – floodplains mostly confined to estuarine lakes and bays.	Some increase in flooding with related increased erosion in catchments (exacerbated by current land use). This will lead to more infilling, changes of sandy habitats to muddy habitats and a decrease in substrate stability – resulting in changes in the biotic community composition	Very similar to present, with some increase in flooding and related erosion in catchment. This will lead to some infilling, changes of sandy habitats to muddy habitats and a decrease substrate stability – resulting in some changes in the biotic community composition	Very similar to present, with slight increase in flooding with a related increased erosion in catchments. This will lead to some infilling, changes of sandy habitats to muddy habitats and a decrease in substrate stability – resulting in some changes in the biotic community composition	Slight increase in flooding with some increased in erosion (exacerbated by land use changes under climate change). This will lead to some infilling, changes of sandy habitats to muddy habitats and a decrease in substrate stability – resulting in some changes in the biotic community composition
	Changes in the dilution and or flushing of pollutants	Increased flushing of pollutants from the water column and sediment. Urban nodes: Durban, Richards bay.	Increased flushing of pollutants from the water column and sediment	Very similar to present, with slight increase in flushing of pollutants from the water column and sediment. Urban nodes: East London, Port Elizabeth.	Very similar to present, with slight decrease in flushing of pollutants from the water column. Increased flooding might still assist with flushing of pollutants from sediment. Urban nodes: Cape Town.	Significant decrease in flushing of pollutants from the water column. Increased flooding might still assist with flushing of pollutants from sediment. Urban nodes: Cape Town.
Sea level rise (+0.5 – +1.0 m MSL)	Increase salinity penetration	Effect of sea level rise is offset by increased runoff.	Increased salinity penetration in the middle and lower reaches. In the upper reaches salinity penetration will be mostly similar to present, or slightly less, as runoff is generally the major driver especially if steep topography dominates.	Increased salinity penetration in the middle and lower reaches. In the upper reaches salinity penetration will be mostly similar to present mostly similar to present, or slightly less, as runoff is generally the major driver where steep topography dominates.	Increased salinity penetration in the middle and lower reaches. In the upper reaches salinity penetration will be mostly similar to present - or slightly more- as runoff is generally the major driver in the upper reaches where steep topography dominates.	Significant increase in salinity penetration in the lower, middle and upper reaches. (The topography is less steep and runoff is also likely to decrease overall in the region, the saline water could therefore penetrate significantly further upstream.)
	Increased tidal flushing/prism	Very similar to present as the region has predominantly small systems with steep topography. The exception to the rule is the large estuarine lakes and bays which have extensive flood	Very similar to present as the regional has predominantly small systems with steep topography. The exception to the rule is the larger permanently open systems that	Significant increase as the topography is less steep, especially in the case of the larger permanently open systems. The smaller systems with steep topography will be	Significant increase as the topography is less steep, especially in the case of the large estuarine lakes, bay and permanently open systems. A few small systems with steep	Significant increase as the topography is less steep, especially in the case of the large permanently open systems.

Drivers	Response	Sub-Tropical		Warm Temperate		Cool Temperate
		KwaZulu Natal	Transkei	Eastern Cape	Southern Cape	Western Cape
		plains.	have some flood plains.	similar to present.	topography will be similar to present.	
	Changes in the frequency and duration of mouth closure	Increased tidal prisms in the estuarine lakes will together with increased runoff lead to an increase in open mouth conditions.	Increase in open mouth conditions will mostly be driven by increased runoff as tidal prisms will only increase marginally. Benefits of increased sea level rise in some cases may also be offset by changes in the degree to which mouths are protected from wave action by submerged coastal features.	Increased tidal prisms in medium to larger temporarily open stems will assist with maintaining open mouth conditions. Benefits of increased sea level rise in some cases may be offset by changes in the degree to which mouths are protected from wave action by submerged coastal features.	Increased tidal prisms in medium to larger temporarily open stems and estuarine lakes will assist with maintaining open mouth conditions. Benefits of increased sea level rise in some cases may be offset by changes the degree to which mouths are protected from wave action by submerged coastal features.	Increased tidal prisms in medium to larger temporarily open stems will assist with maintaining open mouth conditions in the face of lfow reductions, but the benefits of increased sea level rise may be offset by changes in mouth protection.
Rising temperatures	Species range extensions	Slight increase in temperature from present	Significant increase in the temperature of the nearshore environment is causing a significant increase in subtropical species and a related loss of Temperate habitat	Significant increase in the temperature of the nearshore environment is causing a significant increase in subtropical species and a related loss of Temperate habitat	An increase in the temperature of the nearshore environment is causing a significant increase in subtropical species and a related loss of Temperate habitat	Slight decrease in temperature from present due to increase upwelling, Species distribution likely to remain the same.
	Changes in community composition along land – sea gradients	Similar to present	Subtropical species dominate fresh and brackish communities in the upper reaches, while Temperate species dominate lower reaches in invertebrates.	Subtropical species dominate fresh and brackish communities in the upper reaches, while Temperate species dominate lower reaches in invertebrates.	Similar to present	Similar to present
Decrease pH	Calcifying organisms require more energy to maintain dissolving exoskeleton	Reduce production in calcifying organisms	Reduce production in calcifying organisms	Reduce production in calcifying organisms	Reduce production in calcifying organisms	Reduce production in calcifying organisms
Increase in frequency and intensity of coastal storms	Changes in the frequency and duration of mouth closure	Similar to present, as KZN is largely wave dominated and increased storminess is likely to be offset by increased runoff.	Similar to present, as the estuaries in the region are generally very sheltered and increased storminess is likely to be offset by increased runoff.	Increased closure as sediment is readily available and there are less changes in runoff.	Increased closure as sediment is readily available. The exception is the Tsitsikamma coast which is generally protected and with limited sediment.	Similar to present, as smaller systems is predominantly closed due to a lack of runoff. Larger systems should remain open. The Diep which close more often.
	Changes in the frequency and duration of overwash	Increase overwash. Berm height presently 3 – 3.5 m MSL. Can increase by 0.5 – 1.0 m if sediment is available .	Increase overwash. Berm height presently 2.5– 3.0 m MSL. Can increase by 0.5 – 1.0 m if sediment is available.	Increase overwash. Berm height presently 2.5– 3.0 m MSL. Can increase by 0.5 – 1.0 m if sediment is available.	Increase overwash. Berm height presently 2.5– 3.0 m MSL. Can increase by 0.5 – 1.0 m if sediment is available.	Increase overwash. Berm height presently 2.5– 3.5 m MSL. Can increase by 0.5 – 1.0 m if sediment is available.
	Marine sediment	Increased sediment transport potential; actual increase where sufficient sediment is available.	Increased sediment transport potential; actual increase where sufficient sediment is available.	Increased sediment transport potential; actual increase where sufficient sediment is available.	Increased sediment transport potential; actual increase where sufficient sediment is available.	Increased sediment transport potential; actual increase where sufficient sediment is available.

In contrast, the West Coast estuaries will be negatively affected as a result of reduction in runoff (with a related decrease in nutrient supply) and an increase in sea level rise. This in turn will increase salinity penetration in the permanently open systems and increase mouth closure in the temporarily open estuaries. Similar to KwaZulu-Natal, the West Coast estuaries will display a decrease in primary production and a loss of nursery function.

Although the Wild Coast, Eastern and Southern Cape estuaries will also show some shifts in mouth states, nutrient supply, salinity distribution and ultimately production (e.g. fisheries), the most obvious impacts of climate change along these coastal regions will be the change in temperature (nearshore and land) and the associated range extensions of species and community composition changes. The effect of sea level rise, and related increase in tidal prism, will be less apparent along the KwaZulu-Natal coastline, where the majority of the estuaries are perched (the exception here are the estuarine lakes and bays), while it will be more apparent along the Southern and Western Cape coast with their more extended coastal floodplains.

In summary, contrary to the current monitoring programmes which are focusing on biotic responses in the biogeographic transition zones (e.g. Transkei and western Southern Cape) the most significant structural and functional changes will be in the estuaries of KwaZulu-Natal (subtropical) and the Western Cape (cool-Temperate). These changes are likely to advantage generalist species over specialist and may lead to localised extinctions.

13.4 Key climate change messages

Some of the key climate change messages for estuaries are that:

- Climate change is one of many pressures acting on estuaries and should be viewed as an additional form of anthropogenic alteration (and not a separate pressure) in an already stressed ecosystem type, i.e. climate change acts as an accelerator of ecosystem change in estuaries. It is necessary to understand the potential amplification of variability that climate change may have on the existing freshwater resource (and its use), together with the potential impact on estuarine and marine production, as well as the harvesting of resources in the marine and estuarine environments. It is thus necessary to integrate climate change and non-climate change threats. Climate change should be seen as a catalyst to fast track freshwater resource issues that need addressing, e.g. ecological water allocations (Day and Moore 2009).

- The ability to predict the response of estuaries to climate change, and to plan for how to assist estuaries to adapt to these changes is still hindered by a lack of good prediction tools and the lack of a fundamental understanding of many of the effects of climate variability on the physical, chemical and biological characteristics of the aquatic domain (Meyer, Sale Mulholland and Poff 1999). We are limited by the availability of both data (e.g. long term flow data, temperature data, mouth conditions, wave height, species data) and models (e.g. flow changes, linking hydrological regimes to ecosystem processes, large scale ocean current changes). At the same time, this uncertainty around forecasting change should not be seen as an impossible obstacle to understanding and developing adaptive mechanisms to reduce the effects of climate change on estuarine resources. Accurate forecasting is not obligatory to begin the process of adapting to climate change, as major trends are often obvious and meaningful actions can be instigated based observed trends.

- Stressed ecosystems have a lower resilience to change. By increasing or maintaining the resilience of estuaries, the ability of a system to recover after, for example an exceptional flood or drought, is enhanced. The resilience of an estuary is influenced by the intactness of its catchment and estuarine functional zone. The processes underpinning the goods and services, such as the assimilation and cycling of nutrients in estuaries, also needs to be protected if resilience is to be maintained. For example, developments within the estuarine functional zone will reduce the resilience of the system to extreme flooding, as little lateral movement would be possible. A way to ensure resilience is the determination and implementation of the Estuarine ecological water requirements (Reserves) and the protection/rehabilitation of the estuarine functional zone. Healthy estuaries equate to estuaries resilient to change.

- It is essential that climate change, and the projected effects thereof, be integrated into current plans and policies dealing with management and governance of estuaries, e.g. the water and coastal management sector. Current planning tools need to focus on integration of the synergistic effects of global change. In addition, adaptation includes adjusting to situations, developing coping strategies and impact responses. Adaptation may be behavioural or involve mitigation such as engineering solutions. This requires an adaptive management approach which is supported by monitoring and frequent review..

14. SPECIES OF SPECIAL CONCERN

J Adams, S Lambeth, J Turpie and L van Niekerk

This section provides a summary of estuarine species of special concern (i.e. species that are being harvested, exploited or Red data species).

14.1 Plants

The South African National Estuary Biodiversity Plan (Section 12, Turpie et al. 2012) sets national conservation targets for supra- and intertidal salt marsh at 20% of each estuarine habitat type at the national level. So far only 25% of the supratidal and 12% of the intertidal salt marsh is formally protected within estuaries.

The use of mangrove and swamp forest is regulated under the National Forests Act No. 84 of 1998 (RSA 1998) and destruction or harvesting of indigenous trees requires a licence. The mangrove trees and swamp forest are protected under this act but the sediment environment under the forests and the associated estuarine habitat is not designated as a nature reserve or protected area (Traynor and Hill 2008).

The taxonomy of some salt marsh species is under currently under review; this makes it difficult to determine their population sizes, report on their threat status or set targets for protection. However according to the Coastal Act 2008 all coastal wetlands, which include salt marshes and mangroves, form part of the coastal protection zone. The purpose of establishing this zone is to restrict and regulate activities in order to achieve the aims as set out in the Act. Other laws pertaining to species in these areas:

- National Environmental Management Act 1998
- Marine and Living Resources Act 1998
- The National Environmental Management: Biodiversity Act 2004
- National Forestry Act 1998

14.1.1 Status of salt marsh species

Threats to salt marsh habitats include modified river flow, grazing, invasive aliens, sea level rise, inappropriate coastal development, poor catchment practices (e.g. agricultural), trampling, mouth manipulations and pollution.

Mucina et al. (2003) noted that salt marshes, where a variety of macrophytes are found, are important in the overall functioning of estuaries. These areas are extremely stressful habitats that results in distinct zonation patterns along a tidal inundation gradient. Characteristic of a stressful environment is a low species richness and diversity and coarse vegetation patterns where only a few or single species are dominant. Some salt marsh species have been place on the National Red Data List by SANBI and these are described in the table below (Table 14.1). Mucina (Table 14.2) provided a preliminary indication of those estuaries where endemic salt marsh species may occur.

Table 14.1 Salt Marsh species that were considered important for protection due to their status on the National Red Data List.

Species	2009 National Red Data list categories**	Family	Description	limited of distribution
Cotula filifolia Thunb.	CR	Asteraceae	Intertidal salt marsh	17 estuaries
Limonium scabrum (L.f.) Kuntze	DDT	Plumbaginaceae	Supratidal salt marsh	33 estuaries
Prionium serratum (L.f.) Drége ex E.Mey.	Declining	Prionaceae		6 estuaries
Limonium depauperatum (Boiss) R.A. Dyer	EN	Plumbaginaceae	Supratidal salt marsh	1 estuary

CR=Critically endangered; EN=Endangered; DDT=(Data deficient-Insufficient information; Declining=Taxon declining but does not meet any of the five IUCN criteria but threatening processes are causing a decline; LC=Least concerned.

14.1.2 Status of mangrove species

Potential threats to mangroves in South Africa include: wood harvesting, modified freshwater flows, prolonged mouth closure (and subsequent changes to the intertidal habitat), inappropriate coastal development and poor catchment practises. An assessment of mangroves in the estuaries of KwaZulu-Natal showed that mangroves only occurred in those estuaries where the mouth was open for more than 56% of the time, with the exception of St Lucia where the mouth has been closed for longer durations but the mangrove communities have persisted because the roots of the trees were not submerged (Rajkaran et al. 2009). This study also showed that natural recruitment is taking place for all mangrove species except *Xylocarpus granatum* which consists of a few individuals in the Kosi Estuary.

Table 14.2 Preliminary identification of estuaries (west to east) where important populations of macrophytes occur (Mucina pers. comm.) The genera present and the reason for the importance are indicated.

Estuary	*Limonium*	*Plantago*	*Poecilolepis ficoidea*	*Salicornia*	*Sarcocornia*	*Spergularia*	*Triglochin*
Langebaan	-	New species	-	2 lineages	Highest diversity on west coast	New species	-
Uilskraals	1 species	New species	-	2 lineages	High no. of spp.	New species	-
Heuningnes	1 species	New species	Present	1 lineage	5 spp.	New species	2 spp.
Gouritz	1 new endemic sp. found	-	-	-	-	-	-
Knysna	1 new endemic sp. found	New species	-	Endemic lineage *S. knysnaensis*	-	New species	-
Kromme	-	New species	-	Endemic lineage *S. macrocarpa*	3 spp.	New species	2 spp

The greatest threat to the survival of mangroves is removal through harvesting. Kosi Bay and Mhlathuze Estuary were two of the larger forests that showed signs of harvesting (for example the presence of tree or branch stumps in Figure 14.1).

Figure 14.1 Stumps of harvested mangroves at Wavecrest.

In the smaller Wild Coast estuaries where mangrove strands consists of one to three rows of trees, harvesting can have a serious impact and in severe cases completely remove the mangrove habitat resulting in erosion of estuary banks. An assessment of mangroves in the Eastern Cape estuaries showed that there was complete loss of mangroves in the Mnyameni, Mzimvubu and Bulungula estuaries, while at the Mdumbi, Mzamba and Kobonqaba estuaries harvesting had resulted in more than 50% of the trees being removed (Adams et al. 2004).

However, the greatest threat to smaller estuaries seems to be altered water flow due to freshwater abstraction and the change in land use from estuarine vegetation to sugar-cane plantations. These threats affect the hydrology of estuaries and the sediment characteristics (particle size, redox, pH, salinity, temperature) of the mangrove forests, which in turn influence plant recruitment and survival rates. Flow modification can cause ecosystem type changes, e.g. the permanently open Kobonqaba Estuary closed for the first time in recorded history in 2010 causing die-back of mangroves (Figure 14.2). In KwaZulu-Natal development pressures have resulted in the complete loss of mangroves from the Mhlanga, Little Manzimtoti, Lovu, Msimbazi, Mgababa, Ngane, Mahlongwa, Kongweni, Bilanhlolo, Mhlangankulu and Khandandlovu estuaries (Rajkaran and Adams 2011). A loss of mangrove habitat has potentially decreased the diversity of organisms found in estuaries, the nursery function of the forests has been reduced and there has been a loss of protection value given by the mangroves (Gilbert and Janssen, 1998; Fondo and Martens, 1998; Laegdsgaard and Johnson, 2001; Mumby *et al.* 2003).

Figure 14.2 Dead mangroves at the Kobonqaba Estuary due to mouth closure in 2010.

Table 13.3 summarises the information on the mangrove species found in South Africa. All mangrove species, except *Avicennia marina*, occur on the DWA Protected Tree list (Gazette 835 (2010) Notice of the list of protected tree species under the National Forests Act (Act No. 84 of 1998).

Table 14.3 The status of mangrove species in South Africa.

Species	Family	No of estuaries	Max density (no of individuals per ha).	Estuary with highest density.	Average density (no of individuals / ha)*	Red Data categories
Avicennia marina (Forsk. Vierh.)	Avicenniaceae	24	37 933	Echwebeni – Richards Bay	19 839	Least Concerned
Bruguiera gymnorrhiza (L.) Lam	Rhizophoraceae	33	22 119	Kosi Bay	16 533	Least Concerned
Ceriops tagal Perr. C.B.Robinson	Rhizophoraceae	1	28 800	Kosi Bay	-	Least Concerned
Lumnitzera racemosa Willd.	Combretaceae	1	2 866	Kosi Bay	-	Least Concerned
Rhizophora mucronata (Lam).	Rhizophoraceae	12	78 000	Echwebeni – Richards Bay	34 967	Least Concerned
Xylocarpus granatum König 1784	Meliaceae	1	Only 1 individual found	Kosi Bay	Only 1 individual found.	Least Concerned

* These values are taken from data collected at Kosi Bay, St Lucia, Echwebeni and Mhlathuze Estuary (Rajkaran and Adams, *in press*).
**http://www.sanbi.org/index.php?option=com_content&view=article&id=250:red-data-lists-project&catid=125:part-of-biodiversity-topics&Itemid=793

14.2 Invertebrates

Exploitation of invertebrates used as bait by recreational and subsistence anglers is a focal activity in most estuaries around the South African coast. The burrowing prawns *Callianassa kraussi* and *Upogebia africana* are the most common bait organisms targeted by collectors (Wooldridge 2007), although pencil bait (Solen spp.) and bloodworm *Arenicola loveni* are also popular bait organisms. Sand and mud prawns are particularly abundant in warm and cool Temperate estuaries. *C. kraussi* generally occurs in sand and *U. africana* in more muddy sediments. The sand prawn is found in both permanently open and temporary open estuaries, while the mudprawn is only abundant in permanently open estuaries. Mud prawns are generally absent from estuaries that close for 'extended' periods.

Bivalve molluscs are relatively scarce in South African estuaries and they do not reach the high densities recorded in Europe. Pencil bait species such as *Solen capensis* and *S. cylindraceus* may be locally common in some estuaries (Hodgson 1987), with the former species present in sandy substrata and *S. cylindraceus* occurring in more muddy areas. Both Solen species concentrate around the inter- and sub-tidal interface. The bloodworm *Arenicola loveni loveni* is also a popular bait organism, although distribution is not restricted to estuaries. Estuarine abundance levels are highly variable and the species is easily over-exploited in some estuaries where it occurs. Bloodworms prefer sandy substrata and relatively high salinities and are therefore found on sandbanks near the mouth of open estuaries.

The Marine Living Resources Act (No. 18 of 1998) provides for the sustainable use of our marine living resources to ensure that estuaries in South Africa remain productive and biologically diverse. Bait collection is seen as an integral part of resource management and focuses on the way in which bait is collected and the maximum number of organisms that may be removed per day by collectors. The most common legal method used by invertebrate bait collectors is the prawn or suction pump. Pencil bait is more commonly collected using a length of hooked wire. In both these methods, sediment core disturbance is minimal when compared to the amount of sediment turnover using a spade or forked shovel. However, it is important to distinguish between the number of bait organisms removed and the longer term effects on the target species, associated benthic communities and birds utilizing the former undisturbed habitat.

Although a relatively small proportion of the targeted species is removed annually, bait collecting inflicts serious damage on other components of the macrofaunal assemblage (Wooldridge 2007). Those species not utilized by fishermen were negatively impacted through avian or fish predation and physical injury caused by harvesting activities. Long-term effects of bait-collecting on biota inhabiting the sediment are also apparent. The impact of bait pumping and trampling of mudflats may affect the sediment down to at least 20 cm. The impact of illegal bait collecting using a spade and overturning large volumes of sediment will also have severe negative consequences for many benthic species.

14.3 Fish

Approximately 2 000 tonnes of fish, comprising 80 species, are caught in South African estuaries each year. The harder *Liza richardsonii* (32%), spotted grunter *Pomadasys commersonnii* (20%), dusky kob *Argyrosomus japonicus* (18%) and mixed mullet (predominantly *Mugil cephalus*, *Liza dumerili* and *L. tricuspidens* 10%) provide the bulk of this catch. Most (540 t) of the harder catch is from west coast estuaries, of which more than 80% is due to illicit gillnetting. All dusky kob and spotted grunter catches are from the warm Temperate and subtropical east coast. Historically, white steenbras *Lithognathus lithognathus* contributed significantly (>20%) to estuary (and surf-zone) catches on the west and east coasts but stock collapse has since seen this drop to <3%. Harder and spotted grunter are also overexploited.

Although fishing is the predominant cause of population decline of most exploited species, other anthropogenic influences such as altered freshwater flows, aquaculture and loss of estuary habitat through development, may play an equal or greater role. The current status of the harder stock on the west coast is almost entirely a result of illegal gillnetting in the Berg Estuary where approximately 400 t of mostly small immature fish are landed annually. This has resulted in a 500-600 t drop (or halving) of catches and a substantial loss of livelihood by the legitimate commercial harder fishery in the sea.

Altered freshwater flows have influenced the recruitment success of most estuary-associated species but one of the best examples is the Natal stumpnose *Rhabdosargus sarba*. Already overexploited, prolonged drought and persistent closure of the St Lucia Estuary over the last 10 years has prevented juveniles of these estuary-dependent fish from recruiting into the system, resulting in population collapse (Mann et al. 2007, James et al. 2004),

Marine and freshwater aquaculture have the potential to directly and indirectly impact the wild populations of estuary-associated species through genetic, pathogen and parasite contamination, to the overexploitation of fry and larvae for ranching purposes. Continent-wide collapse of European and Asian anguillid eel populations has been directly attributed to a combination of all these factors. Since then, industry attention has shifted to the southern hemisphere, especially South Africa where eel populations are deemed healthier than elsewhere. Despite strict control and an embargo on imports from across this country's borders, some east coast river systems have become contaminated by parasites and other pathogens that have been traced back to illegally imported Madagascan eels (Weyl et al. 2010).

It is internationally acknowledged that there is difficulty in categorizing exploited fish species according to IUCN criteria, as well-managed stocks are kept at levels that automatically relegate them into the vulnerable category. An attempt to overcome this problem for fish caught by the inshore fisheries in South Africa was made in a prioritization exercise that used both fisheries and conservation criteria ranging from fishery participation and economic value to vulnerable life-history characteristics (Lamberth and Joubert 1998). Eleven of the top 30 fish species countrywide in terms of vulnerability, conservation and fisheries importance, and needing management attention, were estuary-associated. Seven of these; dusky kob *Argyrosomus japonicus*, white steenbras *Lithognathus lithognathus*, harder *Liza richardsonii*, spotted grunter *Pomadasys commerrsonii*, Natal stumpnose *Rhabdosargus sarba*, Cape stumpnose *Rhabdosargus holubi* and leervis *Lichia amia* are obligate estuary-dependent fish whose juveniles have to spend their first year or two in estuaries to complete their lifecycle.

Table 14.4 The stock status (% of reference or near pristine breeding potential, catch-per-unit-effort or catch composition) of important utilized estuarine-associated species in South Africa.

Species	Common Name	% Pristine	Stock Status
Argyrosomus japonicus	Dusky kob	4	Collapsed
Lithognathus lithognathus	White steenbras	6	Collapsed
Rhabdosargus globiceps	White stumpnose	20	Collapsed
Lutjanus argentimaculatus	River snapper	30	Overexploited
Pomatomus saltatrix	Elf	34	Overexploited
Diplodus capensis	Dassie/blacktail	35	Overexploited
Rhabdosargus sarba	Natal stumpnose	34 *	Overexploited
Acanthopagrus vagus	Perch/riverbream	24**	Overexploited
Anguilla spp.	Anguillid eels (4 species)	<40	Overexploited/vulnerable
Rhabdosargus holubi	Cape stumpnose	40	Optimally exploited
Myxus capensis	Freshwater mullet	<40	Overexploited/vulnerable
Liza richardsonii	Harder	<40	Overexploited
Pomadasys commersonnii	Spotted grunter	<40	Overexploited/ Optimally
Carcharhinus leucas	Zambezi shark	<40	Overexploited/vulnerable

*(James et al. 2004), ** (James et al 2008)

Given the difficulties outlined above, as well as those arising from uncertain taxonomic status, few South African estuary-associated species (especially those exploited) have been evaluated for inclusion on the IUCN Red List. The only exploited species to have made it on to the list is the white steenbras *Lithognathus lithognathus* but in the lower risk category. The Knysna seahorse *Hippocampus capensis* is endangered whereas the river pipefish *Syngnathus watermeyeri*, largetooth sawfish *Pristis microdon*, smalltooth sawfish *Pristis pectinata* and green sawfish *Pristis zijsron* are critically so. Currently the entire families of pipefish and seahorses Syngnathidae and sawfish Pristidae are on the South African Prohibited List (MLRA 1998).

Once given attention, it is likely that many more South African estuary-associated fish will find their way on to the IUCN Red List. Amongst these, are four species of the genus

Argyrosomus, all having experienced population collapse and all four local eel species of the Anguillidae which, similar to their Northern Hemisphere counterparts, are declining due to overexploitation, aquaculture related issues and changes in the quantity and quality of freshwater flow.

14.4 Birds

Turpie and Clark (2007) indicate that 107 non-passerine waterbird species have been counted in South African estuaries. Although estuary dependence is not defined for estuarine bird species listed by Hockey & Turpie (1999), bird species were considered dependent on estuaries if more than 15% of their regional population (as per Hockey et al. 2005) was found in coastal lagoons and estuaries (Turpie et al. 2012).

Thirty-five bird species were therefore considered to be estuary dependant, with eight of them listed as threatened (Table 13.4). Of the latter, the Great White and Pinkbacked Pelican are particularly dependent on the St Lucia estuary within South Africa, the former for breeding, and the latter during the non-breeding period (Turpie et al. 2012). Greater and Lesser Flamingos, while present in many wetlands throughout southern Africa, are particularly abundant at a small number of estuaries, such as the Berg and St Lucia estuaries. The African Black Oystercatcher is predominantly coastal in distribution, but many estuaries support one or more pairs of this species, and estuaries such as the Olifants estuary are frequently utilised by nonbreeding flocks of oystercatchers during winter. Caspian Terns occur at the coast and interior, but along the coast they are found mostly in estuaries, with important breeding colonies in estuaries such as the Berg and St Lucia. Damara Terns breed mainly in Namibia, and their South African population numbers only about 125 pairs. While these are mainly along the coast, some make use of the Heuningness Estuary in the Cape.

Table14.5 Threatened estuary-dependent bird species (Source: Turpie et al. 2012).

Bird species	Scientific name	Red Data Status
Pink backed Pelican	*Pelecanus rufescens*	Vulnerable
Great White Pelican	*Pelecanus onocrotalus*	Near-threatened
Greater Flamingo	*Phoenicopterus roseus*	Near -threatened
Lesser Flamingo	*Phoeniconaias minor*	Near-threatened
African Black Oystercatcher	*Haematopus moquini*	Near-threatened
Caspian Tern	*Sterna caspia*	Near-threatened
Damara Tern	*Sterna balaenarum*	Endangered
Mangrove Kingfisher	*Halcyon senegaloides*	Vulnerable

14.5 Summary

Mangroves have been completely lost from 14 estuaries in South Africa.

- In smaller Eastern Cape estuaries, where mangrove strands consist of one to three rows of trees, harvesting can have a serious impact and in severe case completely depopulate an estuary of mangroves. Complete loss of mangroves is evident in the Mnyameni, Mzimvubu and Bulungula estuaries, while at the Mdumbi,Mzamba and Kobonqaba harvesting has resulted in more than 50% of the trees being removed (Adams et al. 2004).
- In KwaZulu-Natal development pressures, changes in mouth state and water quality have resulted in the complete loss of mangroves from the Mhlanga, Little Manzimtoti, Lovu, Msimbazi, Mgababa, Ngane, Mahlongwa, Kongweni, Bilanhlolo, Mhlangankulu and Khandandlovu (unpublished data).

A total of 18 iconic estuarine associated or dependant fish species (17%) are under severe pressure.

- The stock status of important utilized estuarine-associated species in South Africa list 4 collapsed species, 13 overexploited species, and 1 optimally exploited species.
- Approximately 2 000 tons of fish, comprising 80 species, are caught in South African estuaries each year.The Natal stumpnose *Rhabdosargus sarba* population collapsed as a result of overexploitation and the persistent closure of the St Lucia Estuary.
- While few South African estuary-associated species are listed on IUCN Red List and South African Prohibited List (MLRA 1998), it is likely that many more will find their way on to the lists once attention is given, e.g. four species of the genus *Argyrosomus* and all four local eel species of the Anguillidae.

15. INVASIVE ALIEN SPECIES

L van Niekerk, S Lambeth, J Adams, and F MacKay

Invasive alien species pose a significant threat to estuaries where they cause both ecological and economic damage. Alien species can exert a significant impact upon community structure and functions, by modifying spatial and food chain resources, with direct or indirect effects on the occurrence of indigenous species (Drake et al. 1989; Leppa¨ Koski et al. 2002, Elton 1958). Economic concerns include, for example, burrowing activities that can result in damage to banks and dykes (causing embankment erosion), clogging of water intake filters of industrial cooling water and drinking water plants (during mass occurrences), and alien species preying heavily upon native species of commercial importance. . In recent years, national and international environmental policy and legislation has begun to reflect these threats and respond accordingly (e.g. CBD 1992; IMO 2004, European Commission 2008).

There are four main arguments for explaining observed settlement characteristics in estuaries (Nehring 2006), namely:

(1) Estuaries have a higher potential infection rate than other aquatic zones as a result of their high degree of exposure to direct vectors e.g. proximity to international shipping lanes and ports (ballast water and invasive species attached to the ship hulls); aqua and mariculture industries, the aquarium trade and live bait associated with fishing activities.

(2) Estuarine species have, due to their physiological characteristics, a better chance of being transported alive than marine or freshwater species and they also probably have a higher penetration and establishment potential after release.

(3) Estuaries have the greatest natural ‘indigenous species minimum’ or lowest number of indigenous species of all aquatic domains so that more alien species can potentially establish in this domain. This may be especially true in South Africa due the sporadic flushing (resetting) of system by relatively large floods. Allowing for potentially unsaturated ecological niches at times.

(4) Salt-tolerant freshwater alien species, introduced into inland waters, reach the coast in the estuaries.

The combination of brackish waters colonised by physiologically generalist species, potentially unsaturated ecological niches, and high exposure to international ship traffic in some of the larger estuaries, leads to the highest potential infection rate for any aquatic system. In addition, estuaries are also subjected to a two-sided invasion pressure by alien species, via the ocean and via inland waters. The identification of such patterns is an important prerequisite for the development of a forward-looking alien monitoring and management strategy. Terms and definitions used in this section are based on the Convention on Biological Diversity (CBD 1992, 2000): an “Alien species” is defined as a species, subspecies, or lower taxon introduced outside its normal past or present distribution. An “Established alien species” is an alien species that is reproducing in the wild and has established a durable population in an area. An “Invasive alien species” is an alien species whose establishment and spread threaten ecosystems, habitats or species with economic or environmental harm. “Introduction” is defined as the movement, by human agency, of a species, subspecies, or lower taxon outside its natural range (past or present). “Cryptogenic species” may be either a native species or an introduced species, with clear evidence for either origin being absent.

15.1 Alien Plants

Alien plants in South African estuaries can range from aquatic plants e.g. water hyacinth, water fern, parrot’s feather to terrestrial examples such as *Sesbania* and Australian *Acacia* species (Adams et al. 1999). Estuary habitats are stressful environments where plants need to be adapted to high salinity and waterlogged conditions. This limits the extent of invasive plants, particularly in the intertidal zone. The status of invasive plants in South African estuaries has received little attention in recent years. Coetzee et al. (1997) assessed the condition of estuarine macrophyte habitats in Cape estuaries. The most common impact in supratidal salt marshes was encroachment by invasive plants, followed by trampling. Invasive plants were present in 75% of the 33 Cape estuaries investigated. In a study of the False Bay estuaries, O’Callaghan (1990) showed that alien vegetation encroachment was a major factor causing changes in the estuarine vegetation. This occurred in response to disturbance, particularly when there was a restriction in tidal exchange. The Conservation of Agricultural Resources Act 43 of 1983 (CARA) classifies invasive plant species into three categories; Category 1 are prohibited weeds that must be controlled by all means; Category 2 includes plants with commercial value that may be planted in demarcated areas subject to a permit and providing that steps are in place to control them and Category 3 are ornamental plants that may no longer be planted or traded but may remain in place provided a permit is obtained and steps are taken to control their spread. The CARA status of plants found in estuaries is indicated in Table 15.5 as summarised in Richardson and van Wilgen 2004, Coetzee 1995; van Wyk and van Wilgen 2002; Zimmermann et. al.2004; Henderson et al. 2006.

Table 15.1 Invasive, alien or non-endemic species in South African estaurine habitats (modified from Coetzee 1995).

Botanical name	Common name	Estuarine plant community impacted	CARA
Acacia cyclops A.Cunn. ex G.Don	Rooikrans, Red-eye	Invades upper reaches of estuaries and rivers	1
Acacia longifolia (Andr.) Willd.	Long - leaved wattle	Invades upper reaches of estuaries and rivers	1
Acacia mearnsii De Wild.	Black wattle	Invades upper reaches of estuaries and rivers	1
Acacia saligna (Labill.) H.L.Wendl.	Port Jackson willow	Invades upper reaches of estuaries and rivers	2
Eichhornia crassipes (C.Mart.) Solms	Water hyacinth	Water column/ submerged macrophyte habitat	1
Salvinia molesta D.S.Mitch.	Kariba weed	Water column/ submerged macrophyte habitat	1
Myriophyllum aquaticum (Vell.) Verdc.	Parrot's feather	Water column/ submerged macrophyte habitat, intertidal salt marsh	1
Pennisetum clandestinum Hochst. Ex Chiov.	Kikuyu grass	Invades supratidal salt marsh	-
Pereskia aculeata Mill.	Barbados gooseberry	Supratidal salt marsh Invades riparian habitats	1
Spartina alterniflora	Smooth cord grass	Intertidal and supratidal salt marsh	?
Psidium guajava L.	Guava	Supratidal salt marsh Invades riparian habitats	2
Ricinus communis L	Castor-oil plant	Supratidal salt marsh Invades riparian habitats	2
Sesbania punicea (Cav.) Benth.	Red sesbania	Supratidal salt marsh Invades riparian habitats	1

15.2 Fish

All of the introduced or translocated fish in South African estuaries are freshwater species (Table 15.2 and Table 15.3). Most of these, e.g. smallmouth bass *Micropterus dolomieu* and carp *Cyprinus carpio*, were introduced from the northern hemisphere in the late 1800s until the 1970s to enhance freshwater angling, as indigenous fish were regarded as unsuitable. Smaller species such as bluegill sunfish *Lepomis macrochirus* and mosquitofish *Gambusia affinis* were imported either as fodder fish to feed the larger introduced species or as mosquito control. Some, e.g. guppy *Poecilia reticulata*, are home aquaria escapees that established wild populations. A similar philosophy was followed with regards to southern African species, which were translocated either as angling fish or in the hope of establishing an aquaculture industry. Range expansion of both introduced and translocated species throughout South Africa was further facilitated by interbasin transfer schemes, irrigation and stormwater networks as well as intentionally or inadvertently by recreational anglers and other water users as they moved between water bodies.

Panel 8: Emerging Pressures….. First record of the intertidal invasive plant Spartina alterniflora

In 2004, the intertidal invasive salt marsh grass, *Spartina alterniflora*, was observed for the first time in a temporarily open/closed system in South Africa, at the Groot Brak Estuary. It is a perennial, deciduous, salt tolerant grass that can grow up to 2 m tall and is found in the intertidal areas of estuaries. Its leaves are bright green to grey-green, up to 60 cm long, pointed and protrude from the stem at an angle. The plant is wind pollinated with large amounts of seed produced, sometimes in the first year. However the main form of spread is vegetative, i.e. through rhizomes/underground stems. The deep roots are capable of growth if broken off. The root system biomass is as much as five times that of the above ground biomass. *Spartina alterniflora* has spread at an alarming rate of 0.15 ha yr-1 since 2004 to occupy a present cover of 0.87 ha (2010), spreading laterally at a rate of 1.1 m yr-1 (unpublished data). If left uncontrolled, *Spartina alterniflora* has the potential to replace 42.9 ha of habitat, or 41% of the total estuarine vegetation. When the grass first establishes in an estuary, it forms monospecific circular stands. These later coalesce to form larger stands until entire open mudflats are transformed to closed habitats. It is an aggressive invader due to its ability to accrete sediment and its fast lateral expansion rates. Expansion is currently taking place in habitats in the lower to upper intertidal marsh area, displacing salt marsh species. Changes in the benthic community abundance and composition can be expected. *Spartina alterniflora* invasions also cause a trophic shift from an algal- to a detritus-based food web resulting in a loss of species richness and diversity of fish, as well as a reduction in shore and wading birds. The movement of seeds and vegetative material by tides and currents to other estuaries when the mouth is open is a significant future threat to the biodiversity of South Africa's estuaries.

It is of concern that it has taken more than 6 years to mobilize action to eradicate this highly invasive species. After much deliberation between the different management authorities, the Working for Water programme in 2011 initiated 3 trial approaches investigating eradication through hand removal and digging at some sites and chemical treatment with the non-selective systemic herbicide, glyphosate, at other sites. This is the best suited herbicide for the aquatic environment. A 0.5% foliar application was used and initial findings indicate that foliar application of herbicides is a good option for control. At the mechanical control sites which involved physical removal of Spartina there is some salt marsh growth already in cleared areas which is very encouraging. Unfortunately, there is also quite a lot of regrowth of the Spartina. At the chemical control sites there is still a lot of dead biomass which should be removed.

Tall *Spartina alterniflora* adjacent to native salt marsh in the Groot Brak Estuary.

Ongoing follow-up monitoring and control will still be required over the following years to ensure its total eradication from the Groot Brak Estuary, and the country as a whole. Working for Water will be responsible for ongoing operational aspects, such as chemical treatment. While SANBI and MNNU have entered into a five year Memorandum of Understanding (MoU) under which SANBI will support the ongoing annual monitoring and research (e.g. rate of regrowth and extend of infestation) of the Spartina to ensure the success of the eradication programme.

Source: T Riddin & JB Adams

Table 15.2 List of introduced fish species in the estuaries of South Africa

Species name	Common name	% occurrence (130 estuaries)	SA range
Micropterus salmoides	Largemouth bass	31	Olifants -Mhlathuze
Micropterus dolomieu	Smallmouth bass	24	Olifants - Thukela
Cyprinus carpio	Carp	23	Orange - Thukela
Lepomis macrochirus	Bluegill sunfish	14	Olifants - Thukela
Micropterus punctulatus	Spotted bass	14	Olifants - Thukela
Oncorhynchus mykiss	Rainbow trout	10	Sand - Thukela
Gambusia affinis	Mosquitofish	9	Berg - Knysna
Salmo trutta	Brown trout	3	Olifants - Thukela
Tinca tinca	Tench	2	Lourens - Breede
Poecilia reticulata	Guppy	2	Mgeni - Tongati
Ctenopharyngodon idella	Grass carp	2	Zeekoei - Thukela

Table 15.3 List of Extra-limital (translocated) fish species in the estuaries of South Africa

Species name	Common name	% occurrence (130 estuaries)	SA range (estuary northwards)
Tilapia sparrmanii	Banded tilapia	28	Orange - Mtamvuna
Oreochromis mossambicus	Mozambique tilapia	17	Bushmans
Clarias gariepinus	Sharptooth catfish	11	Orange - Mtamvuna
Tilapia rendalli	Redbreast tilapia	3	Sibaya, KZN estuaries?
Labeobarbus aeneus	Smallmouth yellowfish	3	Orange
Tilapia zillii	Redbelly tilapia	1	?
Oreochromis niloticus	Nile tilapia	1	Not from SA, Rift Valley

Given their freshwater origin, most of the impact of introduced and translocated fish occurs within the river estuary interface or the freshwater reaches of estuaries. In some systems, the suite of introduced species forms an effective barrier against the upstream migration of the young elvers of catadromous eels or facultative catadromous mullet. Recruitment of the larvae and juveniles of estuary-dependent marine species, and the survival of the eggs and young of estuary residents, may be severely compromised through predation by introduced species in estuarine headwaters. Introduced species may also have a competitive advantage but this is likely to be of minor consequence compared to predation. The exception is the Mozambique tilapia *Oreochromis mossambicus* which is tolerant of hypersalinity and is known to opportunistically invade river and estuary reaches from which other species have been excluded by adverse conditions (Lamberth et al. 2010). Territorial and aggressive reproductively active males may also exclude any fish of similar shape and size (Lamberth 2008).

Apart from facilitating the import and establishment of alien invasive species, marine and freshwater aquaculture have the potential to directly and indirectly impact the wild populations of estuary-associated species through genetic, pathogenic and parasitic contamination, to the overexploitation of indigenous fry and larvae for ranching purposes. Continent-wide collapse of European and Asian anguillid eel populations has been directly attributed to a combination of all these factors. Since then, industry attention has shifted to the southern hemisphere, especially South Africa, where eel populations are deemed healthier than elsewhere. Despite strict control and an embargo on imports from across this country's borders, some east coast river systems have become contaminated by parasites and other pathogens that have been traced back to illegally imported Madagascan eels (Weyl et al. 2010).

15.3 Invertebrates

Until 2004 approximately 20 alien marine species were reported for South Africa, primarily restricted to the Western Cape region (Griffiths and Day 2004). By 2011, a far wider diversity of marine and estuarine introductions was documented. To date a total of 86 introduced and 39 cryptogenic species are stated (Table 15.5) with the highest numbers of species within the Ascidiacea (18), Amphipoda (17) and Cnidaria (15). Not all alien marine species have been found in estuaries in the different biogeographic regions, Mead et al. (2011) stress that even this latest number is an initial estimate of the potential species that have become established in estuarine/marine habitats. The majority of alien species are restricted to harbours (e.g. Ciona intestinalis, Carcinus maenas, Metridium senile) and sheltered estuaries (Robinson et al. 2005). Two main issues have been identified as impeding the identification of the likely, true number of alien invertebrates 1) A small number of taxonomic experts exist in the country, in the eastern subtropics in particular where relatively fewer numbers of non-indigenous species have been reported and 2) Fewer surveys have taken place on the east coast (Griffiths et al. 2009).Table 15.4. List of introduced fish species in the estuaries of South Africa.

Although Griffiths et al. (2009) also contend that much of the shipping traffic, the most likely transport mechanism of the majority of species, has originated in Temperate regions and therefore species were readily established in the Temperate areas of South Africa.

Table 15.4 Numbers of known or suspected introduced marine invertebrates through time and by major group. (After Griffiths et al. 2009). I – Introduced; C - Cryptogenic

Taxonomic group	Griffiths et al. 1992	Griffiths 2000	Robinson et al. 2005	Griffiths et al. 2009	Mead et al. 2011,
Porifera	0	0	1	1	1 (I1)
Cnidaria	0	1	4	4	15 (I13, C2)
Polychaeta	0	1	0	0	10 (I8, C2)

Taxonomic group	Griffiths et al. 1992	Griffiths 2000	Robinson et al. 2005	Griffiths et al. 2009	Mead et al. 2011,
Cirripedia	0	0	1	2	2 (I2)
Copepoda	0	0	0	0	1 (I1)
Isopoda	0	0	2	3	11 (I6, I5)
Amphipoda	0	0	11	11	17 (I11, C6)
Decapoda	3	2	1	1	2 (I2)
Pycnogonida	0	0	0	0	1 (I1)
Gastropoda	7	7	1	1	8 (I5, C3)
Bivalvia	5	5	3	4	12 (I6, C6)
Brachiopoda	0	0	0	0	1 (I1)
Bryozoa	0	0	2	2	6 (I6)
Echinodermata	0	0	1	2	2 (I2)
Ascidiacea	0	6	3	5	18 (I9, C9)

Panel 9: Emerging Pressures….. Spread of the quilted melania – Tarebia granifera

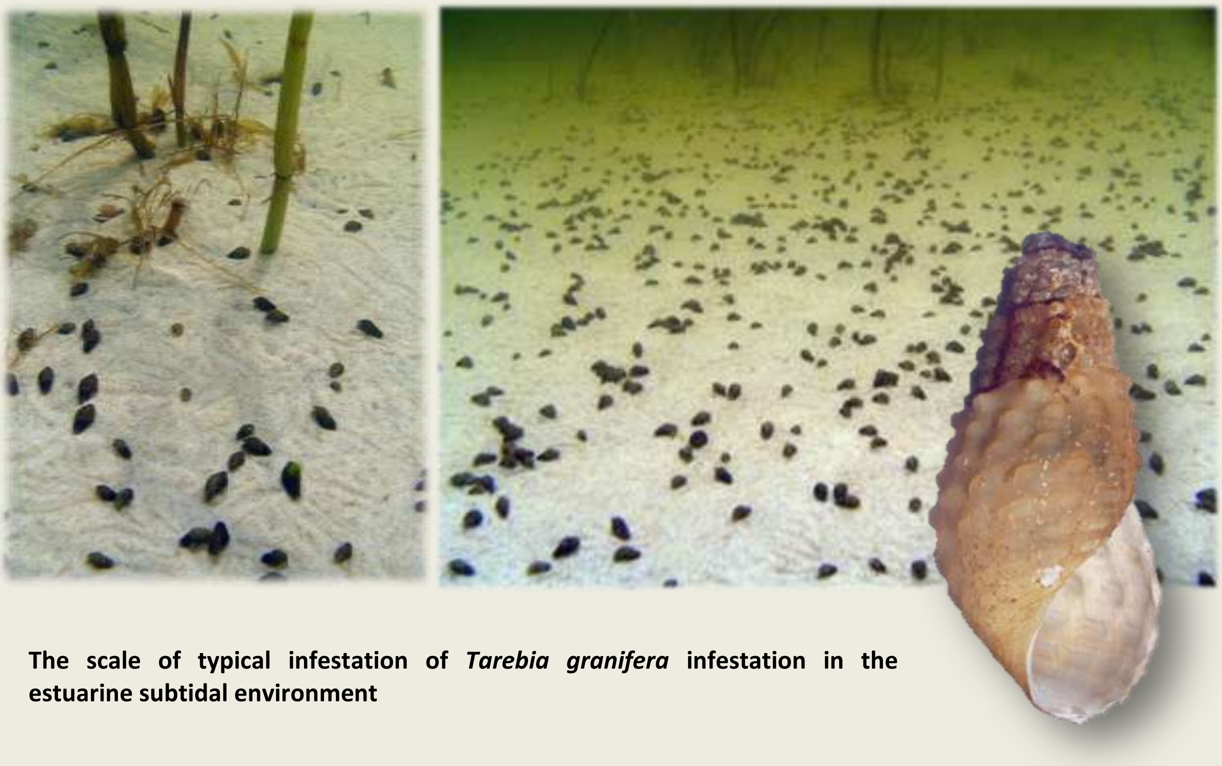
The quilted melania *Tarebia granifera* (Lamarck 1822) is an Asian mollusc species that is both parthenogenetic and ovovoviparious in reproduction nature and together with a long lifespan and slow intrinsic growth rate permits this species to be a successful invader. Being able to reproduce parthenogenetically allows this mollusc to colonise water bodies quickly where high densities form extensive mats in a variety of habitats, on both natural and artificial substrata (Appleton et al. 2009).

There has been an observable and serious invasion by the snail in coastal water bodies, including the estuaries of KwaZulu-Natal. This gastropod has a natural range from Madagascar to India, including countries in Southeast Asia, Japan and through to Hawaii. This species has been transported across the globe via the aquarium trade and is now widely distributed across the world. The appearance of *T. granifera* was first reported in South Africa in 1999 in northern KwaZulu-Natal (Appleton et al. 2009), and was most probably introduced several years earlier via the aquarium trade which receives supplies from Hong Kong and Singapore (Appleton 2003). Since then *T. granifera* has spread rapidly, occurring as far south as Port Shepstone and is spreading northwards into the Mpumalanga Province and the Kruger National Park (Appleton 2003, Wolmarans and de Kock 2006), via passive transportation by waterbirds, waterweeds on boats and trailers and through inland waterbodies (Appleton et al. 2009). *Tarebia granifera*, has been collected from 13 rivers, four lakes and two dams (Appleton et al. 2009). Moreover, this species has now been found in at least 25 estuaries within KwaZulu-Natal, including both estuarine lake systems in the iSimangaliso World Heritage Site, starting with St Lucia in 2005 (Miranda et al 2010). This rapid spread along the east coast and into the hinterland is an indication of the success of this species in being able to colonise freshwater, brack and considerably saline environments under wide ranging temperature conditions (Appleton et al. 2009, Miranda et al. 2010).

The two main concerns associated with the proliferation of *T. granifera* include firstly the changes to the lake ecology through competitive exclusion of native snail and other invertebrate populations (Chaniotis et al. 1980a; 1980b; Pointier 2001, Appleton and Nadasan 2002; Hyslop 2002; Wolmarans and de Kock 2006; Tolley-Jordan and Owen 2008). Depending on the invading environment, the full spectrum of benthic estuarine infauna and epifauna could be affected by the intense competition for space and resources inflicted by the high population densities of *T. granifera* (Appleton et al. 2009).

Other indigenous molluscs at the southern limit of their distribution may be displaced by *T. granifera* (Appleton et al. 2009). Secondly, effects on ecosystem function and processes are an issue given that *T. granifera* is not an exclusive feeder on detritus, but can use large amounts of microphytobenthos, theoretically initiating a cascade effect on the estuarine trophic environment (Miranda et al. 2011).

There are no known control measures for *T. granifera* and that the invasive process is irreversible (Pointier 2001; Appleton 2003). Molluscicides are costly and require repeated application, and are not a wise option in that they are toxic to other aquatic fauna including crustaceans and fish (Pointier 2001). While the desiccation tolerances, thermal and salinity limits, and humidity responses of *T. granifera* are known (Chaniotis et al, 1980a, Miranda et al 2010), the direct control of snails is highly unlikely because of far-reaching environmental implications (Morgan et al. 2001). There are also no known competitors or predators of *T. granifera* because it is itself a strong competitor (Cañete et al. 2004). Currently, the key suggestions for controlling the spread of *T. granifera* are methods of prevention (Appleton 2003) and making the public aware of the potential dangers of inadvertent spread of invasive molluscs (de Kock and Wolmarans 2007).



The scale of typical infestation of *Tarebia granifera* infestation in the estuarine subtidal environment

(Source: F MacKay)

16. LEGISLATIVE RESPONSES

Lara van Niekerk and Susan Taljaard

A major constraint in the effective management and wise use of South Africa's estuarine biodiversity is the fragmentation and overlap in the legislative framework. Most of current environmental legislation is aimed at providing guidance in the management and control of specific activities posing threats to the ecosystems services provided by the natural environment (including estuaries). The legislation is focuses on key sectors, rather than providing a more holistic framework within which to manage estuaries.

The large number of overlapping laws (e.g. 16 international conventions, 10 white papers, over 40 national acts (Van Niekerk and Taljaard 2003)) that define and regulate estuaries makes it difficult to conserve and manage these systems effectively. The key to resolving the legal and administrative confusion lies in aligning the institutional arrangements so that their areas of jurisdiction correspond more closely with those of the ecosystem. DEA is currently in the process of drafting the regulations to be promulgated under the Integrated Coastal Management Act. This presents an excellent opportunity to realign existing legislation and institutional arrangements and to influence pending legislation accordingly. Guiding all future management recommendations should be the fact that estuarine ecosystems are not isolated and that they function in an integrated manner at a local, regional and global scale.

16.1 National legislative framework

National legislation that is especially relevant to estuaries includes:

- National Environmental Management Act (Act 107 of 1998);
- Marine Living Resources Act (Act 18 of 1998);
- National Environmental Management: Integrated Coastal Management (Act 24 of 2008);
- National Water Act (Act 36 of 1998);
- National Environmental Management: Biodiversity Act (Act 10 of 2004);
- Local Government: Municipal Systems Act (Act 32 of 2000); and
- Conservation of Agricultural Resources Act (No. 43 of 1983).

A short summary on each of these are provided below.

16.1.1 National Environmental Management Act (Act 107 of 1998) (NEMA)

DEA is the lead agent for NEMA. NEMA provides for co-operative environmental governance through the establishment of national environmental management principles and procedures, and for their incorporation into decisions affecting the environment. NEMA emphasizes co-operative governance and assists in ensuring that the environmental and related rights in the Constitution are protected. NEMA requires the Department of Environmental Affairs to be the lead agent in ensuring the effective custodianship of the environment. In particular the Act provides that sensitive, vulnerable, highly dynamic or stressed ecosystems (such as estuaries) require specific attention in management and planning procedures, especially where subjected to significant human resource usage and development.

Various activities listed in the NEMA Environmental Impact Assessment ("EIA") Regulations (which came into effect on 2 August 2010) have a bearing on activities within the coastal zone and require environmental authorisation before they can proceed. The Regulations are especially pertinent to estuaries as many estuaries are situated within rapidly expanding development nodes along the South African coast and are under tremendous pressure from human activities. In terms of GN R 544 (listing notice 1), a Basic Assessment must be conducted and in terms of GN R 545 (listing notice 2), an EIA must be conducted. Listing notice 3 identifies activities in sensitive areas (including the estuarine functional zone) that also require environmental authorisation before they may proceed. Some waste disposal activities are also scheduled activities under these regulations.

16.1.2 Marine Living Resources Act (Act 18 of 1998) amended 2000 (MLRA)

The Department of Agriculture, Forestry and Fisheries (DAFF) is currently the lead agent for the MLRA. The objectives and principles of the MLRA deal with the utilization, conservation and management of marine living resources (including estuarine resources), the need to protect whole ecosystems, preserve marine biodiversity and minimize marine pollution, as well as to comply with international law and agreements and to restructure the fishing industry. Marine living resources includes any aquatic plant or animal, whether piscine or not, and any mollusc, crustacean, coral, sponge, holothurian or other echinoderm, reptile and marine mammals and includes their eggs, larvae and all juvenile stages, but does not include sea birds and seals.

Chapter 4 of the MLRA deals with the declaration of Marine Protected Areas (MPAs). This function is currently delegated to DEA. The Act empowers the Minister (DEA) to declare an area to be a Marine Protected Area where various activities are prohibited. These are stipulated in the Declaration of Areas as Marine Protected Areas (No R.1429, 29 December 2000) promulgated under the Act (www.info.gov.za/documents/regulations/2000.htm). The Goukou Estuary that forms part of the Stillbay MPA represents the only estuary that has been explicitly promulgated under this act. The LMRA also provides an avenue for special management measures such as the ban on dusky kob nigh fishing in the Breede Estuary.

16.1.3 National Environmental Management: Integrated Coastal Management Act (Act 24 of 2008)

DEA: Chief Directorate: Oceans and Coast is the lead agent for the ICM Act. In relation to the establishment of resource objectives, the Act aims to establish a system of integrated coastal and estuarine management in South Africa. This includes setting the norms, standards and policies for management, promote the conservation of the coastal environment and ensuring the ecologically sustainable development of the coastal zone. The Act also determine the responsible organs of state in relation to coastal areas and to give effect to South Africa's international obligations in relation to coastal matters and to provide for related matters. Chapter 4 in the Act deals with estuaries. Section 33 provides for the National estuarine management protocol and Section 34 stipulates the need for individual Estuarine Management Plans under the Act.

At present there are 26 Estuary Management Plans, in various stages of completion, being developed as part of the implementation of the ICM Act (Table 16.1). This process also includes the establishment of 12 Estuary Forums which form the vital communication platform between coastal communities and the various government departments that play a role in estuarine management. It is strongly recommended that this best practice process be formalised as part of the regulation being drafted under the ICM Act.

Table 16.1. List of Estuary Management Plans currently in varouis stages of development (Source: Pierre De Villiers, CapeNature).

Estuary	Status
Orange	Ramsar plan linked to EMP process - roll out planned for 2011/12
Olifants	Plan and forum establish, but negotiating fishing community inputs
Groot Berg	Plan and forum establish
Verloren	Plan and forum establish
Diep	Plan and forum established
Zandvlei	Plan and forum to be established in 2011
Bot	Plan and forum establish
Klein	Plan and forum establish
Uilkraals	Plan and forum will be established in 2011
Heuningnes	Plan and forum established
Breede	Plan and forum establish
Goukou	Plan and forum will be completed in 2011
Gouritz	Plan still needs to be finalized by farmers and forum will be establsihed in 2011
Knysna	Plan incorporated in PA plan and PA forum exists, but not fully integrated into

Estuary	Status
	government departments
Groot Brak	Have manangnemt plan, but needs to be broadened to EMP framework. Roll out planned for 2011/12.
Klein Brak	Plan and forum will be established in 2011
Keurbooms	Plan and forum will be established in 2011
Gamtoos	Plan and forum established
Sundays	Plan to be finalised with stakeholders and forum will be established in 2011 - emp facilitation phase
Swartkops	Plan and forum established
Nahoon	Planning process initiated
Mtentu	Plan and protected area forum to be established to lead process - 2011
Msikaba	Plan and protected area forum to be established to lead process - 2011
Mbashe	Plan still needs to bedeveloped to include local fishers
Durban Bay	Plan still needs to be developed
Isipingo	Plan still needs to be developed

Chapter 8 of the Coastal Act contains exclusive provisions dealing with Marine and Coastal Pollution Control, specifically addressing 'Discharge of Effluent into coastal waters' (administered in collaboration with DWA) and 'Incineration and Dumping at sea' (e.g. dredge spoil dumping).

16.1.4 National Water Act (Act 36 of 1998) (Water Act)

DWA is the lead agent for the National Water Act. One the important objectives of the Act is to ensure protection of the aquatic ecosystems of South Africa's water resources. Estuaries are classified as a water resource under the Water Act. The Water Resource Protection Policy (under this Act) provides detailed guidelines and procedures for the classification (i.e. predefined health status) and the setting of Resource Quality Objectives for the protection of aquatic ecosystems (including objectives for water quantity, water quality, habitat integrity and biotic integrity). Section 21 of the Water Act classifies a number of activities related to water supply/demand and waste disposal (from land-based activities) as 'water uses' that require authorisation (licensing) by DWA. The Act also identifies certain land use (e.g. activities resulting in stream-flow reduction such as afforestation and cultivation of crops) and infrastructural developments (e.g. altering the bed, banks, course or characteristics of a watercourse) as 'water uses' that require authorisation by DWA.

The determination of the ecological water requirement of individual estuaries provides the scientific basis for local and regional water resources planning and implementation, and assists with identifying critical over-allocations of water resources. Unfortunately, ecological water requirement studies have only been completed on about 12 % of all estuaries (35 systems) over the last decade.

Table 16.2 Summary of Estuarine Ecological Water Requirment studies conducted under the NWA since 2000.

Estuary	Date	EWR Level
Mata	2000	Intermediate
Nahoon	2000	Intermediate
Mdloti (03)	2003	Rapid
Mhlanga	2003	Rapid
Orange	2003	Rapid
Tsitsikamma	2003	Rapid
Breede	2004	Intermediate
St Lucia	2004	Rapid
Thukela	2004	Intermediate
Kromme	2006	Comprehensive
Olifants	2006	Comprehensive
Seekoei	2006	Rapid
Tongati	2006	Rapid
Matjies	2007	Intermediate
Mdloti (07)	2007	Intermediate
Siyaya	2007	Rapid
Sout	2007	Intermediate
Tongati	2007	Intermediate
Goukamma	2008	Rapid

Estuary	Date	EWR Level
Groot Brak	2008	Intermediate
Keurbooms	2008	Rapid
Kleinemonde	2008	Intermediate
Knysna	2008	Intermediate
Noetsie, Gwaing Maalgate and Kaaimans	2008	Unofficial pilot test desktop
Swartvlei	2008	Rapid
Groot Berg	2010	Comprehensive
Bushmans	2010	Rapid
Palmiet	2010	Rapid
Sundays	2010	Intermediate
Bot	2011	Rapid
Little Amazintoti	2011	Rapid
Mbokedeweni	2011	Rapid
Mzimkulu	2011	Intermediate
Mgeni (uMgeni)	2011	Rapid
EZotha	2011	Rapid

16.1.5 National Environmental Management: Biodiversity Act (Act 10 of 2004)

DEA is the lead agent for the Biodiversity Act. The objective of the Biodiversity Act is to provide for the conservation of biological diversity, regulate the sustainable use of biological resources and to ensure a fair and equitable sharing of the benefits arising from the use of genetic resources. The Act states that the state is the custodian of South Africa's biological diversity and is committed to respect, protect, promote and fulfill the constitutional rights of its citizens. It also recognizes that South Africa is party to, amongst others, the Convention on Biological Diversity, the Convention on Wetlands of International Importance, especially Waterfowl Habitat (Ramsar Convention) and the Convention on Migratory Species (Bonn Convention).

16.1.6 Local Government: Municipal Systems Act (Act 32 of 2000)

Department of Provincial and Local Government is the lead agent for the Municipal Systems Act. The Act deals with Integrated Development Planning (IDPs) (municipalities are obliged to prepare and to update IDPs regularly). An IDP is intended to encompass and harmonise planning over a range of sectors such as water, transport, land use and environmental management. It requires each local authority to adopt a single, inclusive plan for the development of the municipality. Chapter 5 of the Act deals with integrated development planning that sets the social and economic objectives for a particular area. The Municipal Planning and Performance Management Regulations (Government Notice R.796, 24 August

2001) promulgated in terms of this Act describe the content requirements of IDPs. The regulations, for example state that the Spatial Development Framework (SDFs), reflected in the municipality's IDP, must 'contain a strategic assessment of the environmental impact of the spatial development framework'.

It is envisage that all Estuary Management Plans be nested into local IDPs to ensure wise use and biodiversity protection. Estuary Zonation plans should also be incorporated into the SDFs of local or district municipalities.

16.1.7 Conservation of Agricultural Resources Act (No. 43 of 1983) (CARA)

Department of Agriculture, Forestry and Fisheries (DAFF) is the lead agent for CARA. The objectives of CARA is to provide for the conservation of the natural agricultural resources of South Africa by: the maintenance of the production potential of land; the combating and prevention of erosion and weakening or destruction of the water sources (including estuaries); and the protection of the vegetation and the combating of weeds and invader plants.

16.2 Key recommendations

National legislation on estuarine management is carried out largely at a local level by state bodies such as the South African National Parks Board (SANParks), provincial departments (responsible for nature conservation and environmental impact assessment) and local authorities. This approach has resulted in fragmented and inefficient estuarine management. At present, there are uncertainties as to which laws are applicable and to which areas they apply. In addition, there are uncertainties over which government departments or agencies are mandated to enforce the various laws and, finally, there is limited enforcement capacity to enforce these laws and regulations (Van Niekerk and Taljaard 2003).

A key recommendation, therefore, is the finalization of the National Estuarine Management Protocol, the roll out of the Estuary Management Planning framework and the provision of resources, both human and funding, to sustain this effort. The framework should also address the rationalisation of the planning processes, in which one plan is developed, that encompasses the requirements of protected area legislation, Ramsar, MLRA and the ICM Act.

Key legal instruments, such as the determination of the ecological flow requirement of individual estuaries, provide the scientific basis for such local and regional planning and implementations frameworks, and assist with identifying critical over-allocations of natural resources (e.g. water or living resources). The National Estuary Biodiversity Plan provides the lens through which all present, and future, resource allocations should be evaluated to ensure that national and international biodiversity targets are achieved.

17. KEY FINDINGS AND RECOMMENDATIONS

17.1 Key findings

1. There are nearly 300 functional estuaries in South Africa.

In South African an estuary is considered a partially enclosed, permanent water body, either continuously or periodically open to the sea on decadal time scales, extending as far as the upper limit of tidal action or salinity penetration. During floods an estuary can become a river mouth with no seawater entering the formerly estuarine area, or, when there is little or no fluvial input, an estuary can be isolated from the sea by a sandbar and become a lagoon or lake which may become fresh or hypersaline.

2. The Lake St Lucia system represents over 55% of the estuarine area of South Africa, but is in a very poor condition.

Although situated within the iSimangaliso Wetland Park protected area, a World Heritage Site, St Lucia is impacted upon by activities in its catchment and reduction in freshwater flows from the rivers feeding the lake.

- The most significant impact has been the artificial separation of the uMfolozi river mouth from Lake St Lucia, dating from the 1950s, reducing freshwater inflow to the lake by more than half in low flow periods.
- Combined with drought conditions, this has resulted in St Lucia being closed to the sea for much of the last decade, unable to fulfil its role as the most important nursery area for marine fish along the south-east African coastline, among other impacts.

3. Based on the proportion of estuaries in good ecological condition, 43% of estuary ecosystem types (20 types out of 46 types) are classified as threatened, representing 79% of SA estuarine area.

About 39% of South Africa's 46 estuarine types (18 types) are classified as critically endangered, 2% as endangered (1 type), 2 % as vulnerable (1 type) and 57% as least threatened (26 types). If this is considered in terms of estuarine area the situation is even more dire as 79% of South Africa's estuarine area falls within estuary types classified as critically endangered, compared with less than 1% in types that are endangered or vulnerable and 21% in types that are least threatened.

- A very small percentage (1%) of the total estuarine habitat area in South Africa is in an excellent condition. About 14% is in good condition, 31% is in a fair condition, and 54% is in a poor condition.
- About 83% of the estuarine area that falls within Ramsar sites (57 000 ha) is in a poor state, while none is in an excellent condition. Similarly, none of the 70 400 ha that falls within Important Bird Areas is in an excellent condition and 67% is in a poor condition. Collectively 72% of estuaries in Marine or other Protected Areas (65 900 ha) are in a poor condition.

4. 59% (27 out of 46 types) of South Africa's estuary ecosystem types are not protected. These unprotected types make up 83% of the total estuarine area.

- 70 estuaries in South Africa enjoy some form of formal protection, accounting for 60% (56 000 ha) of the estuarine area within South Africa. Only 14 estuaries have full no-take protection.
- The Lake St Lucia system contributes 90% of the protected estuarine area, and covers about 51 000 ha. The other protected estuaries cover a total area of just under 10 000 ha.
- Nearly 59% (27 out of 46 types) of South Africa's estuary ecosystem types are not protected. About 33% of estuary ecosystem types are considered to be well protected (15 types), while 4% are moderately protected (2 types) and 4% are poorly protected (2 types).
- If protection levels are evaluated in terms of percentage area, the unprotected types make up 83% of total area, while the estuary types that are poorly protected, moderately protected and well protected make up 2%, 14% and 2% of area, respectively.
- The National Estuary Biodiversity Plan identified 58 estuaries (20%) that require full protection and 62 (22%) estuaries that require partial protection (this includes those that already have partial protection).

5. The total freshwater inflow of the 20 largest catchments in South Africa has been reduced by nearly 40% from the pristine condition, and freshwater flow requirements have been determined for only 12% of all estuaries.

- The larger catchments tend to be subjected to significant water resources development, such as large dam developments and inter/intra-basin transfer schemes. These catchments often exhibit a significant decrease in resetting floods with a related significant decrease in mean annual runoff. Related ecosystem responses include increased sedimentation as a result of reduced flushing, loss of queuing effect to the marine environment and reduced nursery function.
- Smaller catchments are most often subjected to more localised water resource development such as run-of-river abstraction and forestation, leading to loss, or reduction of, base flows in summer. While the net reduction in mean annual runoff is less severe than for larger catchments, related ecosystem responses include increased mouth closure, reduced connectivity with the marine environment, reduced nursery function, and reduced production.

6. Flow reduction, habitat modification, fishing and pollution are cumulative pressures in need of management interventions. Invasive alien species (plants, invertebrates and fish), mariculture and desalination are emerging pressures that could pose a significant risk to estuarine biodiversity.

- Nearly 4% of all estuaries are under significant flow modification pressure, with most of these being large permanently open estuaries. An additional 18% of estuaries have experienced a moderate degree of flow modification. Flow modification is causing ecosystem type changes, for example, the Kobonqaba in the Eastern Cape and Uilkraals in the Western Cape closed for the first time in recorded history in 2010.
- 13% of South Africa's estuaries are under significant habitat modification or development pressure.
- The mouths (outlets) of about 16% of estuaries are artificially managed, but these estuaries (which include the Lake St Lucia system) account for 62% of the total estuarine habitat. Inappropriate low-lying developments are necessitating artificial mouth manipulations (e.g. breaching), of particular concern in the large lake systems like Verlorenvlei, Bot/Kleinmond, Klein, Wilderness (Touws), Swartvlei and Lake St Lucia system.
- 1% of South Africa's estuaries are under tremendous fishing pressure (Olifants, Berg, Bot and Kosi) such that fish stocks have declined significantly in these systems. Another 13% are under major fishing pressure. Fishing effort is relatively evenly

distributed around the coast, but proportionately (in terms of tonnes per ha removed) much higher in the Cool Temperate estuaries.

- Approximately 2 000 tonnes of fish, comprising 80 species, are caught in South African estuaries each year.
- 84% of all estuaries are influenced by bait collection activities.
- Mangroves have been completely lost from 14 estuaries in South Africa due to excessive harvesting or ecosystem changes. In the smaller estuaries, where mangrove strands consist of one to three rows of trees, harvesting can result in complete removal of mangroves. Developmental pressures have also caused the loss of mangroves, e.g. from the Mhlanga, Little Manzimtoti, Lovu, Msimbazi, Mgababa, Ngane, Mahlongwa, Kongweni, Bilanhlolo, Mhlangankulu and Khandandlovu.
- 15% of estuaries are under significant pollution pressure and 40% under a moderate degree of pollution pressure. Fewer than 1% of all estuaries have no pollution pressures on them.

7. Freshwater (surface and groundwater) flowing into the sea is not wasted and is vital to the productivity of the nearshore coastal environment.

- Changes in freshwater flow and associated variations in turbidity, nutrients and sediment supply can impact on important ecological processes such as nursery functions, environmental cues, productivity and food web processes.
- Fisheries resources in South Africa that have, or may have been, compromised by reduced freshwater input include linefish, prawns, and filter feeding invertebrates in the intertidal and shallow subtidal zones.
- The reduction of river flow leads to a reduced sediment supply to the coast with implications for beach and subtidal habitats. Many of these habitats are also important for ecological processes.

8. While there are a range of invasive alien species (e.g. 13 plants, 11 invasive alien and 7 extra-limital fish species) in South Africa's estuaries, they do not represent a significant overall pressure as yet.

- Thirteen invasive alien plant species, ranging from trees to water weeds, have been identified in South Africa's estuaries.

- There are at present 11 invasive alien fish species and 7 extra-limital fish species identified in the 130 estuaries for which there were data. The spreading of especially invasive predatory fish acts as a barrier to migratory species (e.g. eels and freshwater mullet) and influences the species composition and abundance of species, many of which are commercially important, in the river-estuary interface zone.
- There is a significant and growing threat to the estuarine subtidal benthic environment through the invasion and proliferation of the mollusc *Tarebia granifera* in at least 30% of KwaZulu-Natal estuaries.

9. Climate change can have serious ecological, resource and social implications

Climate change pressures include flow modification, sea-level rise and increased temperatures and coastal storminess, leading to changes in physical processes (e.g. modification in mouth conditions, salinity regimes, nutrient pulses, sediment regimes) and biological responses (e.g. production, species composition) with an impact ultimately on ecosystem services.

- The KwaZulu-Natal and West Coast estuaries will be the most affected by climate change from a structural and functional perspective, e.g. mouth state, nutrient supply, salinity distribution and ultimately production (e.g. fisheries).
- The Wild Coast, Eastern and Southern Cape estuaries will be most vulnerable to temperature regime shifts (both nearshore and land) and the associated range extensions/contractions of species and community composition changes.
- Climate change is one of many pressures acting on estuaries and should be viewed as an additional form of anthropogenic alteration (rather than a separate pressure) in an already stressed ecosystem type, i.e. climate change acts as an accelerator of ecosystem change.

10. Estuary Management Plans are developed, or in progress, for 9% of South Africa's estuaries

Over the past decade legislative responses have increased, but flow-related measures are starting to lag behind other planning processes.

- The finalisation of the National Estuarine Management Protocol, the roll out of the Estuary Management Planning Framework and the provision of resources, both human and funding, is needed to sustain this effort. At present there are 26 Estuary Management Plans in the process of being developed as part of the implementation of the Integrated Coastal Management Act (Act 24 of 2008). This includes the establishment of 12 Estuary Forums which form the vital communication platform between coastal communities and the various government departments that play a role in estuary management.
- Key legal instruments, such as the determination of the ecological water requirements of individual estuaries, provide the scientific basis for local and regional water resources planning and implementation frameworks and assist with identifying critical over-allocations of resources.
- Unfortunately, ecological water requirement studies have been undertaken for only about 12 % of all estuaries over the last decade.

17.2 Key Messages

1. **Estuaries, unlike many other ecosystems, can be restored to a well-functioning, productive state.**

- Estuaries are by nature resilient systems, because their fauna and flora are adapted to living in conditions of extreme change.

2. **Recovery of South Africa's iconic estuary, the Lake St Lucia system, is possible.**

- The very poor condition of the Lake St Lucia system, which represents over half the estuarine area in South Africa, is reversible and ecosystem recovery is possible. Due to Lake St Lucia's international and national significance, the iSimangaliso Wetland Park Authority has raised funding from the Global Environment Facility (GEF) to investigate and implement a long-term solution to the hydrological issues facing the Lake St Lucia system. In parallel to this investigation the management strategy for 2011/2012 will result in the reversal of the 60 year old approach to managing Lake St Lucia; that is, allowing the uMfolozi and Lake St Lucia estuary mouths to join to form a combined mouth, and thereby allowing it to function as naturally as possible. In keeping with adaptive management, an ongoing review and evaluation based on monitoring of salinity, lake levels and ecosystem health will continue as these interventions are implemented. Ongoing national government support for the rehabilitation of the Lake St Lucia system is important.

Other specific management recommendations include:

- reducing the fishing effort within the system;
- resolving the issue related to the backflooding of the low-lying sugar cane farms so that conflict over breaching of the combined mouth does not occur (e.g. securing or protecting the properties along the lower uMfolozi);
- improving farming practices in the uMfolozi catchment and floodplain to improve water quality and limit sediment input to St Lucia.

3. Increase protection levels through the implementation of the National Estuary Biodiversity Plan

- DEA, in collaboration with SANBI, DWA and DAFF, should lead the process of endorsing and implementing the National Estuary Biodiversity Plan.

4. To adequately protect an estuary, it needs to be in a formal protected area with effective no-take zonation, and its freshwater requirements must be guaranteed.

- The Lake St Lucia system is an example of a system which is poorly protected. While being fully protected on paper, St Lucia's current ecological condition is poor (Category E) and uMfolozi is only in fair condition (Category D).

5. Estuaries provide a focal point for co-ordinated and integrated natural resource management.

- Estuaries form the link between the land and the sea and are therefore the receivers of most resource-use pressures from the surrounding land- and seascape. Estuaries should be the focal point for natural resource management and planning in the coastal domain, e.g. in the classification of water resources in terms of the National Water Act, the class of a river should be influenced by the class assigned to the estuary.

6. Estuaries are valuable national assets providing essential ecosystem services, such as nursery functions to coastal fisheries, freshwater flows to the marine

environment, replenishment of nutrients and organic material to coastal habitats, flood and sea storm protection, carbon sequestration, safe bathing areas and cultivation of plants for biofuels without freshwater.

- Estuaries provide an important nursery function for fish, with some of the more muddy Temperate estuaries such as the Mbashe, Umtata, Keiskamma and Great Kei being particularly important for supporting collapsed marine fish resources such as white steenbras and dusky kob.
- Estuaries provide freshwater (both surface and groundwater), nutrients, detritus and sediments to the coastal environment, thereby supporting important ecological processes and the productivity of some fisheries (e.g. prawns and line fishery).
- Estuaries offer easy access, warmer waters, shallow depths, shelter and weak currents that make them very attractive to bathers.
- Estuaries contribute to the regulation of greenhouse gases and provide opportunities for carbon trading.
- South Africa's estuaries provide a significant buffer against floods with a total open water area of 61 000 ha and flood plain storage, as represented by the estuarine functional zone, of nearly 171 000 ha, of which 60% is in the Subtropical biogeographic region.
- Halophytes (salt tolerant plants such as *Sarcocornia*) can be used as an alternative energy or food source due to their high oil and protein content. By far the greatest benefits of halophyte culture is that, unlike much current biofuel production, it does not displace food crop production or use excessive quantities of fresh water.

7. Future introduction and spread of invasive species in estuaries can be prevented.

- While invasive alien species do not represent a significant overall pressure as yet, it is critically important that there is timeous intervention to ensure that the situation remains under control (e.g. control invasive predatory fish that act as a barrier to migratory species, and the total eradication of the alien invasive grass *Spartina alterniflora,* which is currently known to be present in only the Groot Brak estuary but which may otherwise spread).

8. Healthy estuaries support ecosystem resilience and adaption to climate change.

- Stressed ecosystems have a lower resilience to change. By increasing or maintaining the resilience of estuaries, the ability of a system to recover, for example after a flood or drought, is enhanced.
- The resilience of an estuary is influenced by the intactness of its catchment and estuarine habitats. A way to ensure resilience is the determination and implementation of estuarine ecological water requirements and the protection/rehabilitation of the estuarine functional zone.
- The processes underpinning the ecosystem services provided by estuaries, such as the assimilation and cycling of nutrients, also need to be protected if resilience is to be maintained.

18. INFORMATION GAPS, RESEARCH PRIORITIES AND FUTURE ASSESSMENTS

18.1 Information gaps

- **Refine estuary ecosystem types:** The NBA 2011 has started the process of refining the typing of South Africa's estuaries at a more detailed level than has previously been available. However, higher resolution input data on catchment hydrology, bathymetry, sediment structure and water quality (turbidity and salinity) is required to address the needs articulated by specialists in the execution of this study.
- **Quantification of the modification in freshwater flow to the coast on a watershed scale.** There is an urgent need for a quantification of the modification in freshwater flow to the all estuaries of South Africa. This analysis should include all current land-use, transfer schemes, discharges, dam developments and be based on the true catchment area of each individual system. These data will also form the basis of an analysis of the degree to which freshwater flow to the coast has been modified.
- **Taxonomic surveys of the invertebrates in all South African estuaries:** There is no up-to-date national dataset for South African estuarine invertebrates. Invertebrate data were last collated at a national scale more than a decade ago but little effort has been made to address this. Future assessments and biodiversity plans cannot be refined without filling this gap in a systematic manner.
- **Taxonomic surveys of the plants in all South African estuaries:** Taxonomic revision of salt marsh species should be supported and funded so that macrophyte species lists can be updated for all estuaries. From these data, sites of rare and threatened species can be identified. Updated GIS spatial data of the habitat areas data for all estuaries is needed. This is especially important where data are older than 10 years. This would include field surveys to ground truth the data. For example detailed habitat maps for the Rietvlei/Diep system and Richards Bay Harbour are urgently required for planning proposes and to address deficiencies in the current databases. This should include the development of a database with information presented in this study plus GIS maps of all South African estuaries. This spatial data could also feed into the estuary management planning processes.
- **Invasive Species:** With the exception of plants, very little is known about invasive species in South Africa's estuaries. There is an urgent need to have a census on the occurrence of invasive alien species in different estuaries and the potential

environmental impact of these on both the ecosystem function and the value derived from the estuary in question. All invasive species (freshwater, marine and estuarine) should be included in the census.

- **Nursery function for exploited and collapsed fish species.** Recent work has indicated that while most estuaries serve as nurseries, some of the more sediment rich systems are associated with "sediment deltas" in the nearshore environment which serve as nurseries for some species which represent collapsed stocks. It is of the utmost importance that these systems are identified and their nursery function quantified to ensure sustainable resource utilisation into the future. Future biodiversity plans should also include these systems explicitly to align management and conservation priorities.
- **Pollution data:** There is no systematic record of the discharges into estuaries. There is also a need to evaluate the monitoring stations above the estuaries to develop a clear perspective on what is flowing into estuaries and coastal waters.
- **The value of estuaries in South Africa:** There is very little national scale data available on the value of estuaries. As this is one of the key requirements for communicating the relevance of estuaries to coastal communities, and the country as a whole, this lack of data hinders the ability to motivate for rational decision-making.
- **Climate change:** Climate change has the potential to change the processes and functioning of South Africa's estuaries dramatically. Large and local scale climate models are becoming better at accurately predicting the drivers of change in the future. The estuarine research community needs to make this one of their research priorities over the next decade to facilitate better adaptation strategies and ensure ecosystem resilience.
- **Sediment data:** Very little information is available on the sediment structure of South Africa's estuaries. This is a significant data gap as grain size distribution and the mud:sand ratios influence biodiversity patterns. The lack of sediment information also makes it very difficult to assess environmental change in relation to some of the major pressures such as dam development and sand mining.
- **Mapping the 3-dimensional nature of South Africa's estuaries:** Detailed systematic topographical and bathymetrical surveys are needed for all South Africa's estuaries. Cross-sectional survey data are available for less than a third of the estuaries in the country. In most cases these data are over 20 years old. Most planning processes (e.g. ecological water requirement studies, Estuary Management Plans, setback lines, spatial development plans) are of low confidence as they lack this basic information. Assessment of change (sedimentation, erosion sensitivity to

flow modifications, structural developments) is therefore mostly inferred from pressure data. Improved planning and assessments urgently require a significant effort to address these basic data requirements.

- **Up-to-date surveys of the fish and bird fauna of estuaries:** National scale surveys on fish and birds in all South African estuaries were last carried out in the early 1980s. These surveys urgently need to be repeated in a once-off effort that is comparable with the earlier surveys.

18.2 Research Priorities

- **Taxonomic surveys of the invertebrates in all South African estuaries:** There is no national dataset or specimen voucher system for the *South African estuarine invertebrates*. This significant data gap was identified more than a decade ago but little effort has been made on a national scale to address this deficiency. Future assessment and biodiversity plans cannot refine on present findings without filling this gap in a systematic manner.

- **Taxonomic surveys of the plants in all South African estuaries:** The taxonomic revision of salt marsh species should be supported and funded so that macrophyte species lists can be updated for all estuaries. From these data, sites of rare and endangered species can be identified.

- **Refining the typing of estuaries:** The NBA has started the process of refining the typing of South Africa's estuaries, but higher resolution input data on catchment hydrology, bathymetry, sediment structure and water column chemistry (turbidity and salinity) is required to address the needs articulated by specialists in the execution of the NBA 2011.

- **Invasive species as a barrier to connectivity.** The spread of invasive freshwater predatory fish acts as a barrier to migratory species (e.g. eels and freshwater mullet) and compete with estuarine associated species in the river-estuary interface. This aspect needs further investigation to quantify the extent of the problem.

- **Importance of the 71 smaller and/or ephemeral outlets not addressed in this NBA.** There are over 371 river/stream outlets along the SA coast (see Appendix A for a full list), but not all of these are deemed functional estuarine systems, i.e. representative of significant biological activity (Harrison et al. 2000). In total, 71 systems were not assessed, 20 in the Cool Temperate, 33 in the Warm Temperate and 28 in the Subtropical biogeographic region. It is important to note that the exclusion of these systems from the NBA 2011 assessment leaves them somewhat under protected from future development. It is therefore recommended that a separate study be under taken to demarcate these smaller or more ephemeral outlets, to investigate their ecological importance, and finally integrate them into current planning frameworks.

- **Climate Change:** Climate change has the potential to change the processes and functioning of South Africa's estuaries dramatically. Large and local scale climate models are becoming better at accurately predicting the drivers of change in the near and far future. The estuarine community is urged to make this one of their research priorities over the next decade to facilitate better adaptation strategies and ensure ecosystem resilience.
- **Connectivity and regional importance:** Estuarine ecosystems are not independent and isolated from other ecosystems. Rather, estuaries form part of a regional, national and global ecosystem network through either a direct connection via water flows (the transport of nutrients, detritus, larvae, plankton, etc.) or indirectly via the movement of estuarine fauna. The links between individual estuaries and other ecosystems may span a few hundred metres or thousands of kilometres. Hence, a disturbance to a specific estuary may be reflected in effects on ecosystems remote from that estuary. Unfortunately, although there is ample evidence of the regional interaction and interdependence between estuaries, little quantification has been conducted in South Africa on the connectivity between systems and how to incorporate this into assessments and biodiversity plans.
- **Population genetics studies:** To allow for more detailed biodiversity planning in the future it is important that detailed *population genetics studies* be done on plants, invertebrates and fish to ensure the correct biodiversity protection measures. Preliminary findings indicate that there is a higher degree of isolation than is assumed for the less mobile species (such as plants). This work needs to be done systematically for the higher taxa as well.
- **Recruitment studies of fish and invertebrates:** Recruitment studies are urgently required to ensure sound strategic planning of estuarine biodiversity and resource allocation. While fisheries management measures have become more stringent over the last decade, the stock status of a number of exploited species have stayed the same or declined even further. Recruitment studies would shed light on an important bottle-neck in resource recovery plans, and identify estuaries of conservation and management importance.

- **Nursery function of exploited and collapsed fish species:** Recent work has indicated that while most estuaries serve as nurseries, some of the more sediment rich ones are associated with "sediment deltas" in the nearshore environment which serves as nurseries for some collapsed stock species such as dusky kob. It is important that these systems be identified and their nursery function qualified to ensure sustainable resource utilsation into the future. Future biodiversity plans should also include these systems explicitly to align management and conservation priorities.

18.3 Priority actions for estuarine biodiversity management and conservation

- **Restore the health of St Lucia and conserve the other estuarine lake systems.** South Africa's estuarine lake systems (St Lucia, Verlorenvlei, Bot, Klein, Wilderness, Swartvlei, Kosi) are all under tremendous pressure, and need to be managed in a more holistic manner. They are important national biodiversity assets, which often pay the price for inappropriate short-term local-level decision-making. In particular, the St Lucia system holds a major share of South Africa's estuarine biodiversity. As discussed above, the iSimangaliso Wetland Park Authority has initiated measures to combine the uMfolozi with Lake St Lucia with funding support from the Global Environment Facility (GEF) in order to restore the health of the greater ecosystem.
- **Increase protection levels through the implementation of the National Estuary Biodiversity Plan.** The development of the National Estuary Biodiversity Plan was the first step in the planning process. DEA, in collaboration with SANBI, DWA and DAFF, should lead the implementation of the National Estuary Biodiversity Plan. This should include the setting of protected area targets for Estuarine Protected Areas in the short- to medium-term, e.g. 5% of all ecosystem types will be formally protected by 2020 and 20% of all ecosystem types will have Estuary Management Plans by 2020. This also requires the integration of the National Estuary Biodiversity Plan in strategic processes such as the classification of water resources led by the DWA and the upcoming revision of the National Protected Area Expansion Strategy led by DEA.
- **Respond rapidly to emerging invasive species.** Develop protocols and procedures for the early detection, risk assessment and management of invasive alien species. For example, certain invasive alien fish species can act as a barrier to migratory species (eels and fresh water mullet) and influence the species

composition and abundance of species, many of which are commercially important, in the river-estuarine interface.

- **Develop a National Coastal Biodiversity Plan.** Estuaries are not separate from the coast. To ensure their long-term functioning also requires the development of a National Coastal Biodiversity Plan that integrates marine, estuarine, freshwater and terrestrial aspects. Such a plan should be conducted at a fine enough scale to support integrated coastal development at the municipal level.
- **Ensure the total eradication of the alien invasive *Spartina alterniflora* from the Groot Brak estuary before it spreads to other estuaries.** Progress has been made, since early 2011, but it is very important that the initial field tests for chemical and mechanical control be followed up with full eradication and continuous follow up removal to ensure that this highly invasive and damaging plant species does not spread to adjacent systems along the coast.
- **Ensure that the legal definition of estuaries in South Africa includes the estuarine functional zone.** The GNR 546 Listing Notice 3 under the NEMA EIA Regulations (2010) identifies the estuarine functional zone as a sensitive area that requires environmental authorisation before a development may proceed. It is important that this consideration is also taken up by the Integrated Coastal Management Act and the National Water Act, both of which need to recognise the value of the estuarine floodplain and the threat of (back) flooding within this zone.
- **Determine ecological water requirements for all estuaries within 10 years and implement flow requirements within 5 years of their classification.** This process is likely to require a two-tiered approach in which the findings of the NBA 2011 form the basis for allocation on a national level in the classification of water resources in terms of the National Water Act. While more detailed ecological water requirement studies will be needed for water-stressed catchments or biodiversity priority areas, there is also an urgent need for strategic assessments (such as the National Water Resources Strategy) to take cognisance of estuarine flow requirements which are often substantially higher than the flow requirements of the river entering the estuary. This little-recognised fact leads to national and catchment scale water resource plans that over-estimate the water resources available for development, thus compromising the ecosystem processes that coastal communities depend upon.

- **Ensure resilience to climate change and other global change pressure through the appropriate management of the estuarine functional zone. Finalise the National Estuary Management Protocol** to ensure cooperative governance between the lead authorities that manage estuaries and roll out the development and implementation of Estuary Management Plans in terms of the Integrated Coastal Management Act.
- **Finalise and implement the National Estuary Monitoring Programme** currently being developed by DWA. This multi-tier, multi-parameter (include biotic and abiotic components) programme is based on current best practice and with sufficient funding, and support from other organs of state, could go a long way in addressing data deficiencies in future NBA assessments.
- **Development of a National Sustainability Plan for Estuarine Resources** that will ensure alignment between sectoral objectives for estuaries on a national scale. The plan should be developed in consultation with lead authorities (DEA, SANBI, DWA and DAFF) and assist with facilitating the co-operative governance between the lead agents. Once in place, it should serve as the "blue print" for a number of key sectoral resource plans and processes at various levels of governance, e.g. allocation of water resources or Total Allowable Catch in coastal fisheries.

18.4 Recommendations for next NBA

Based on lessons learned during the NBA 2011 process, as well as aspects addressed in lesser detail than we would have liked, the following recommendations are made with reference to future NBAs:

- **National Health Assessment:** The method (based on ecological water requirement method under the Water Act) followed for the National Health Assessment and proved a valuable assessment framework for evaluating ecosystem change on a national scale. It is recommended that this same approach be followed for future NBAs, but with an emphasis on improved pressure data (especially hydrology, catchment land-use and pollution aspects).
- **Climate Change:** While climate change was addressed on a broad-scale from a process perceptive, more detailed work is needed to understand its impact on the functioning and biodiversity of South Africa's estuaries. A better understanding of this threat will greatly enhance our ability to take the necessary management steps

and appropriate water supply decisions. It is strongly recommended that this becomes a major trust of the next NBA.

- **Maximise the value of estuaries in South Africa:** Time and funding constraints prevented this NBA assessment process to adequately define and value the benefits society derive from South Africa's estuaries. Future NBA studies should strive to address this aspect in more detail.
- **Quantifying ecosystem interactions with the marine environment:** Our understanding of estuarine ecosystem functioning is relatively well developed, but more information is required, especially with respect to interactions and connectivity with the marine coastal zone.
- **National biodiversity planning:** While not essential to future NBA assessments, the existing proposed National Estuaries Biodiversity Plan should be periodically reviewed in the light of new pressure information; improved classification/typing; improved ecosystems services data; policy changes and development initiatives. The NBA provides a perfect national platform for the coherent roll-out of biodiversity initiatives.
- **Time-line and project integration:** The high degree of interaction among the core team members added value and facilitated integration between the various components (marine, estuarine, rivers and land). While this aspect may slow down the overall delivery time, it provides for significant knowledge transfer, learning opportunities, and ultimately a better product. In addition, a longer time frame allows for the engagement of domain specialists at time-scales more suitable for smaller individual research projects and scientific curiosity.

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Appendix A:

List of freshwater outlets along the coast of South Africa

Table A. A comprehensive list of the freshwater outlets along the coast of South Africa. The 71 river outlets not included in NBA 2011 are indicated with a X.

Not in NBA	Estuary	X_coord (E)	Y_coord (S)
	Orange (Gariep)	16° 27' 28.0943"	28° 38' 8.6783"
X	*Holgat*	16° 43' 15.6792"	28° 58' 43.946"
	Buffels	17° 3'2.26"	29° 40' 38.17"
X	*Swartlintjies*	*17°15'33.22"*	*30° 15' 47.49"*
	Spoeg	17° 21' 31.4280"	30° 28' 21.691"
X	*Bitter*	17° 26' 34.6020"	30° 35' 53.476"
	Groen	17° 34' 35.6268"	30° 50' 48.472"
X	*Brak*	17° 43' 47.2440"	31° 5' 55.9355"
	Sout	17° 50' 54.2831"	31° 14' 41.207"
	Olifants	18° 11' 13.6283"	31° 42' 3.7583"
X	*Sandlaagte*	*18°13'25.72"*	*31° 45' 52.87"*
	Jakkals	18° 18' 48.2976"	32° 5' 4.70759"
	Wadrift	18° 19' 30.9719"	32° 12' 16.509"
	Verlorenvlei	18° 19' 59.4263"	32° 18' 57.319"
X	*Papkuils*	*18° 19' 2.06"*	*32° 33' 58.53"*
	Berg (Groot)	18° 8' 37.9860"	32° 46' 11.096"
X	*Paternosterbaai*	*17° 54' 1.52"*	*32° 48' 8.96"*
X	*Langebaan*	18° 1.' 42.2831"	33° 5' 10.7196"
X	*Dwars (Noord)*	*18°13 '39.38"*	*33°24' 15.98"*
X	*Dwars (Suid)*	*18°15' 46.92"*	*33°26' 12.16"*
X	*Modder*	*18°18' 24.45"*	*33°29' 5.12"*
X	*Jacobsbaai*	*18°19' 27.45"*	*33° 31' 12.44"*
X	*Loerbaai*	*18°19' 4.72"*	*33° 32' 14.11"*
X	*Bok*	*18° 20' 2.33"*	*33° 34' 8.79"*
X	*Silwerstroom*	*18° 21' 8.74"*	*33° 34' 39.97"*
X	*Sout (Suid)*	*18°21 '21.74"*	*33° 34' 53.79"*
	Rietvlei/Diep	18° 28' 55.7148"	33° 53' 23.654"
	Sout (Wes)	18° 28' 17.7095"	33° 54' 28.925"
	Houtbaai	18° 21' 16.2000"	34° 2' 47.0075"
X	*Goeiehoop*	*18° 21' 10.15"*	*34° 5' 47.91"*
	Wildevoelvlei	18° 20' 35.8332"	34° 7' 38.6796"
	Bokramspruit	18° 19' 57.6335"	34° 8' 3.65999"
	Schuster	18° 22' 15.2651"	34° 12' 7.3619"
	Krom	18° 22' 42.2436"	34° 13' 51.391"
X	*Olifantsbos*	*18°22'58.31"*	*34° 15' 26.47"*
X	*Booiskraal*	*18°23'46.66"*	*34° 17' 14.50"*
	Buffels Wes	18° 27' 42.4151"	34° 19' 5.6532"
	Elsies	18° 25' 53.3495"	34° 9' 37.5083"
	Silvermine	18° 26' 20.1227"	34° 7' 57.9467"
	Sand	18° 28' 35.4000"	34° 6' 22.9823"
	Zeekoe	18° 30' 17.7623"	34° 5' 54.3083"
	Eerste	18° 45' 13.4028"	34° 4' 43.7771"
	Lourens	18° 48' 39.0347"	34° 6' 0.18719"
	Sir Lowry's Pass	18° 51' 53.6220"	34° 9' 20.0160"
	Steenbras	18° 49' 9.88319"	34° 11' 41.348"
	Rooiels	18° 49' 15.7620"	34° 17' 44.786"
	Buffels (Oos)	18° 49' 46.3259"	34° 20' 20.209"
	Palmiet	18° 59' 38.9075"	34° 20' 43.584"
	Bot/Kleinmond	19° 5.' 49.6751"	34° 22' 6.3516"
	Onrus	19° 10' 43.2912"	34° 25' 7.1472"
X	*Mossel*	*19°16'21.25"*	*34°24'29.86"*
	Klein	19° 17' 53.3723"	34° 25' 14.354"
	Uilkraals	19° 24' 27.4859"	34° 36' 27.176"
	Ratel	19° 44' 47.4216"	34° 46' 15.668"
	Heuningnes	20° 7' 9.28560"	34° 42' 53.244"
	Klipdrifsfontein	20° 43' 52.7951"	34° 27' 6.8616"
X	*Papkuils*	*18°18'56.85"*	*32°33'52.68"*
	Breede	20° 50' 43.1951"	34° 24' 26.762"
	Duiwenhoks	21° 0' 4.25520"	34° 21' 54.107"
	Goukou (Kaffirkui	21° 25' 24.6972"	34° 22' 42.067"
	Gouritz	21° 53' 9.25440"	34° 20' 43.227"
	Blinde	22° 0' 46.6092"	34° 12' 39.060"
X	*Tweekuilen*	*22° 6'42.11"*	*34° 9'5.51"*
X	*Gericke*	*22° 6'37.50"*	*34° 8'38.35"*
	Hartenbos	22° 7' 32.8152"	34° 6' 54.4032"
	Klein Brak	22° 8' 54.9096"	34° 5' 34.5480"
	Groot Brak	22° 14' 21.4511"	34° 3' 26.1144"
X	*Rooi*	*22°17'3.51"*	*34° 3'3.31"*
	Maalgate	22° 21' 15.9803"	34° 3' 15.8039"
	Gwaing	22° 26' 2.90039"	34° 3' 23.2883"
X	*Skaapkop*	*22°29'55.88"*	*34° 2'23.97"*
X	*Meul*	*22°32'35.86"*	*34° 0'49.26"*
	Kaaimans	22° 33' 25.4015"	33° 59' 52.130"
	Wilderness (Touws)	22° 34' 52.0571"	33° 59' 44.728"
	Swartvlei	22° 47' 46.5215"	34° 1' 53.4576"
	Goukamma	22° 56' 56.8859"	34° 4' 37.7795"
	Knysna	23° 3' 41.2308"	34° 4' 57.7416"
	Noetsie	23° 7' 44.9543"	34° 4' 49.0872"

Not in NBA	Estuary	X_coord (E)	Y_coord (S)
X	*Grooteiland*	*23°12'34.55"*	*34° 5'9.14"*
X	*Kranshoek*	*23°13'30.21"*	*34° 5'11.69"*
X	*Crooks*	*23°14'44.74"*	*34° 5'28.92"*
	Piesang	23° 22' 43.5431"	34° 3' 37.6740"
	Keurbooms	23° 22' 41.4732"	34° 2' 59.4599"
	Matjies/Bitou	23° 28' 12.6552"	34° 0' 7.07399"
X	*Brak*	*23°31'49.54"*	*33°59'49.05"*
	Sout (Oos)	23° 32' 11.5548"	33° 59' 22.207"
	Groot (Wes)	23° 34' 9.04799"	33° 58' 54.411"
X	*Helpmekaars*	*23°35'57.52"*	*33°58'48.34"*
X	*Klip*	*23°37'1.35"*	*33°58'42.35"*
	Bloukrans	23° 38' 50.8884"	33° 58' 46.721"
X	*Witels*	*23°42'8.13"*	*33°59'18.40"*
	Lottering	23° 44' 9.41999"	33° 59' 43.836"
	Elandsbos	23° 46' 4.59120"	34° 0' 12.6467"
X	*Geelhoutbos*	*23°47'8.37"*	*34° 0'22.68"*
X	*Kleinbos*	*23°48'46.99"*	*34° 0'42.70"*
	Storms	23° 54' 10.7568"	34° 1' 15.5064"
X	*Bruglaagte*	*23°56'12.23"*	*34° 1'34.57"*
X	*Langbos*	*23°58'25.39"*	*34° 1'58.79"*
X	*Sanddrif*	*24° 0'17.79"*	*34° 2'13.07"*
	Elands	24° 4' 44.7096"	34° 2' 38.3387"
	Groot (Oos)	24° 11' 42.0683"	34° 3' 35.6219"
X	*Eerste*	*24°14'39.96"*	*34° 4'41.99"*
X	*Klipdrift (Wes)*	*24°16'28.50"*	*34° 5'16.61"*
X	*Boskloof*	*24°17'41.06"*	*34° 5'31.74"*
X	*Kaapsedrif*	*24°23'13.49"*	*34° 6'20.95"*
	Tsitsikamma	24° 26' 17.9736"	34° 8' 8.13480"
	Klipdrif	24° 38' 13.3764"	34° 10' 20.521"
	Slang	24° 39' 13.3271"	34° 10' 26.864"
	Krom Oos (Kromme)	24° 50' 33.8208"	34° 8' 34.6811"
	Seekoei	24° 54' 38.6748"	34° 5' 12.0119"
	Kabeljous	24° 55' 57.0108"	34° 0' 31.7051"
	Gamtoos	25° 2' 4.97040"	33° 58' 13.529"
	Van Stadens	25° 13' 13.2455"	33° 58' 13.994"
	Maitland	25° 17' 31.0271"	33° 59' 16.933"
	Baakens	25° 37' 48.0468"	33° 57' 49.427"
	Papkuils	25° 36' 49.9896"	33° 55' 2.2548"
	Swartkops	25° 37' 58.9619"	33° 51' 58.481"
	Coega (Ngcura)	25° 41' 26.6604"	33° 47' 43.368"
	Sundays	25° 51' 13.4100"	33° 43' 18.609"

Not in NBA	Estuary	X_coord (E)	Y_coord (S)
	Boknes	26° 35' 10.5396"	33° 43' 37.822"
	Bushmans	26° 39' 49.0392"	33° 41' 41.697"
	Kariega	26° 41' 11.0364"	33° 40' 57.975"
	Kasuka	26° 44' 7.07280"	33° 39' 14.741"
	Kowie	26° 54' 5.88240"	33° 36' 13.053"
	Rufane	26° 56' 8.97719"	33° 34' 50.995"
	Riet	27° 0' 49.8671"	33° 33' 40.330"
	Kleinemond Wes	27° 2' 46.1471"	33° 32' 28.845"
	Kleinemond Oos	27° 2' 57.5699"	33° 32' 20.493"
	Klein Palmiet	27° 7' 30.5795"	33° 30' 25.257"
	Great Fish	27° 8' 26.4624"	33° 29' 42.820"
	Old Womans	27° 8' 53.0520"	33° 28' 57.975"
X	*Thatshana*	*27°11'11.80"*	*33°27'47.74"*
	Mpekweni	27° 13' 52.2336"	33° 26' 16.843"
	Mtati	27° 15' 32.6591"	33° 25' 22.360"
	Mgwalana	27° 16' 27.1704"	33° 24' 46.886"
	Bira	27° 19' 33.7116"	33° 23' 1.5360"
	Gqutywa	27° 21' 29.0844"	27° 21' 29.084"
	Ngculura	27° 22' 4.49760"	33° 21' 29.077"
	Blue Krans	27° 22' 36.7139"	33° 21' 15.771"
X	*Freshwaterpoort*	27° 24' 50.4287"	33° 20' 6.1763"
	Mtana	27° 25' 55.7940"	33° 19' 6.9779"
	Keiskamma	27° 29' 28.4388"	33° 16' 53.328"
X	*Shwele-Shwele*	27° 31' 19.3584"	33° 15' 36.460"
	Ngqinisa	27° 31' 40.5696"	33° 15' 9.8603"
	Kiwane	27° 32' 35.4012"	33° 14' 53.887"
	Tyolomnqa	27° 35' 0.31560"	33° 13' 32.779"
	Shelbertsstroom	27° 36' 56.3903"	33° 12' 25.527"
	Lilyvale	27° 38' 12.8723"	33° 11' 34.270"
	Ross' Creek	27° 39' 27.6192"	33° 10' 36.325"
	Ncera	27° 40' 5.54160"	33° 10' 12.417"
	Mlele	27° 40' 47.8631"	33° 9' 34.963"
	Mcantsi	27° 42' 7.11719"	33° 8.' 43.832"
	Gxulu	27° 43' 53.3675"	33° 7' 8.0579"
	Goda	27° 46' 30.1188"	33° 6' 3.9239"
	Hlozi	27° 48' 42.7788"	33° 5' 8.1491"
	Hickman's	27° 50' 22.8767"	33° 4' 14.984"
	Mvubukazi	27° 50' 33.7163"	33° 4' 11.9964"
	Ngqenga	27° 51' 53.5968"	33° 3' 22.7988"
	Buffalo	27° 54' 58.7448"	33° 1' 36.476"
	Blind	27° 55' 39.6983"	27° 55' 39.698"

Not in NBA	Estuary	X_coord (E)	Y_coord (S)
	Hlaze	27° 56' 57.6816"	32° 59' 21.231"
	Nahoon	27° 57' 6.13439"	32° 59' 11.176"
	Qinira	27° 57' 53.3987"	32° 58' 27.130"
	Gqunube	28° 2' 5.63639"	32° 56' 1.9535"
	Kwelera	28° 4' 37.2072"	32° 54' 26.495"
	Bulura	28° 5' 36.2076"	32° 53' 28.805"
	Cunge	28° 6' 37.5263"	32° 51' 39.157"
	Cintsa	28° 7' 1.35839"	32° 49' 53.155"
	Cefane	28° 8.' 13.5528"	32° 48' 34.070"
	Kwenxura	28° 9' 5.71680"	32° 47' 55.589"
	Nyara	28° 10' 55.2611"	32° 47' 6.8279"
	Imtwendwe	28° 14' 13.1135"	32° 46' 12.133"
X	*Haga-haga*	28° 15' 11.4659"	32° 45' 42.901"
	Mtendwe	28° 17' 9.04920"	32° 44' 26.836"
	Quko	28° 18' 34.3367"	32° 43' 32.303"
	Morgan	28° 20' 38.5691"	32° 42' 30.949"
	Cwili	28° 22' 25.4531"	32° 41' 27.214"
	Great Kei	28° 23' 9.47040"	32° 40' 47.593"
	Gxara	28° 23' 56.8679"	32° 39' 58.168"
	Gqwara	28° 24'45.07"	32°39'30.25"
	Ngogwane	28° 25'17.91"	32°38'55.31"
	Qolora	28° 26'5.79"	32°37'47.70"
	Ncizele	28°26'16.68"	32°37'42.50"
	Timba	28° 26'45.16"	32°37'31.65"
X	*Mbokotwana*	28° 27'17.44"	32°37'20.21"
	Kobonqaba	28° 29' 25.2924"	32° 36' 28.209"
	Nxaxo/Ngqusi	28° 31' 34.5323"	32° 35' 5.0315"
X	*Bowkers Bay*	28°33' 16.55"	32°33'5.19"
	Cebe	28° 35' 8.97719"	32° 31' 16.273"
	Gqunqe	28° 35' 22.2396"	32° 31' 7.6836"
	Zalu	28° 36' 11.2572"	32° 30' 9.5183"
	Ngqwara	28° 36' 50.6016"	32° 29' 39.138"
	Sihlontlweni/Gcin	28° 38' 41.3627"	32° 28' 52.957"
	Nebelele	28° 39' 21.3480"	32° 27' 45.575"
	Qora	28° 40' 24.4740"	32° 26' 46.932"
	Jujura	28° 41' 38.2596"	32° 25' 51.960"
	Ngadla	28° 42' 31.2515"	32° 25' 6.0599"
	Shixini	28° 43' 31.8467"	32° 24' 11.163"
	Beechamwood	28° 45' 7.48439"	32° 22' 29.492"
	Unamed1	28° 45' 29.4371"	32° 22' 12.151"
	Kwa-goqo	28° 45' 41.4539"	32° 21' 59.050"

Not in NBA	Estuary	X_coord (E)	Y_coord (S)
	Ku-Nocekedwa	28° 46' 40.0655"	32° 20' 55.766"
	Nqabara	28° 47' 25.1915"	32° 20' 22.970"
X	*Gume*	28° 48' 58.97"	32°19'15.01"
X	*Ngomane*	28° 49' 32.38"	32°18'48.76"
	Ngoma/Kobule	28° 50' 14.3195"	32° 18' 4.1868"
X	*Unnamed*	28° 49' 46.22"	32°18'18.95"
	Mendu	28° 52' 40.0332"	32° 16' 51.297"
	Mendwana	28° 53' 3.25679"	32° 16' 8.1336"
X	*Unnamed*	28° 53'24.33"	32°15'45.67"
	Mbashe	28° 54' 6.84359"	32° 14' 59.946"
	Ku-Mpenzu	28° 54' 51.9012"	32° 14' 37.777"
	Ku-Bhula/Mbhanyan	28° 55' 40.8108"	32° 13' 41.185"
X	*Dakana*	28° 56' 17.94"	32° 13' 13.91"
	Kwa-Suka	28° 56' 48.78"	32°12'19.06"
	Ntlonyane	28° 57' 23.9832"	32° 11' 40.930"
X	*Nyumbazana*	*28°57'42.26"*	*32°11'16.22"*
	Nkanya	28° 58' 29.4888"	28° 58' 29.489"
	Sundwana	28° 58' 55.1280"	32° 10' 24.330"
	Xora	28° 59' 44.1059"	32° 9.' 31.082"
	Bulungula	29° 0.' 41.4647"	32° 8.' 16.828"
	Ku-Amanzimuzama	29° 2' 0.17159"	32° 6.' 53.729"
	Nqakanqa	29° 3' 44.7119"	32° 5' 55.1003"
	Unamed2	29° 4' 9.60240"	32° 5' 18.9023"
	Mncwasa	29° 4' 33.8772"	32° 4.' 57.741"
X	*Lubanzi*	29° 5' 10.83"	32° 4'28.38"
X	*Mhlalane*	29° 5' 14.87"	32° 3'50.23"
	Mpako	29° 6' 27.7019"	32° 2.' 24.853"
X	*Mtonjane*	*29° 6'43.31"*	*32° 1'59.85"*
X	*Ku-Bomvu*	*29° 8'56.27"*	*31°59'19.46"*
	Nenga	29° 9' 6.51600"	31° 59' 7.7460"
	Mapuzi	29° 10' 7.37759"	31° 58' 11.812"
	Mtata	29° 11' 1.52880"	31° 57' 10.666"
	Tshani	29° 12' 31.8960"	31° 56' 41.855"
	Mdumbi	29° 12' 58.6763"	31° 55' 53.220"
	Lwandilana	29° 14' 38.1300"	31° 53' 46.312"
	Lwandile	29° 14' 51.1296"	31° 53' 27.401"
	Mtakatye	29° 16' 12.8892"	31° 51' 33.371"
	Hluleka/Majusini	29° 18' 13.0032"	31° 49' 38.668"
	Mnenu	29° 19' 48.3239"	31° 48' 27.223"
	Mtonga	29° 20' 53.8475"	31° 47' 35.739"
	Mpande	29° 21' 25.7148"	31° 45' 44.096"

Not in NBA	Estuary	X_coord (E)	Y_coord (S)
	Sinangwana	29° 22' 11.6183"	31° 45' 1.7928"
X	*Ndluzula*	*29°23'13.99"*	*31°44'28.08"*
	Mngazana	29° 25' 22.2996"	31° 41' 31.837"
	Mngazi	29° 27' 47.2824"	31° 40' 37.862"
X	*Tyityane*	*29°29'29.66"*	*31°40'5.43"*
X	*Ntloloba*	*29°30'3.59"*	*31°39'33.81"*
	Gxwaleni	29° 30' 24.8148"	31° 39' 19.706"
	Bulolo	29° 31' 3.89639"	31° 39' 2.4515"
	Mtambane	29° 31' 13.7316"	29.° -3' -1693."
	Mzimvubu	29° 32' 59.7443"	31° 37' 52.107"
X	*Mnenga*	*29°34'5.42"*	*31°37'0.66"*
	Ntlupeni	29°34'34.30"	31°36'42.18"
X	*Manzana*	*29°36'4.16"*	*31°36'1.38"*
	Nkodusweni	29° 36' 29.39"	31°35'39.42"
X	*Gugu*	*29°36'58.63"*	*31°35'6.44"*
	Mntafufu	29° 38' 15.8244"	31° 33' 45.068"
X	*Ingo*	*29°39'38.90"*	*31°32'56.92"*
X	*Ntyivini*	*29°40'3.39"*	*31°32'41.01"*
X	*Dakane*	*29°40'43.51"*	*31°32'6.49"*
	Mzintlava	29° 41' 23.2475"	31° 31' 21.518"
X	*Mguga*	*29°41'51.93"*	*31°30'45.14"*
	Mzimpunzi	29° 43' 23.1816"	31° 28' 47.852"
	Mbotyi	29° 44' 4.16400"	31° 28' 6.6287"
	Kwanyambalala	29° 44' 4.16400"	31° 28' 6.6287"
	Mkozi	29° 45' 41.6663"	31° 26' 54.722"
	Myekane	29° 46' 6.67920"	31° 26' 42.046"
	Sitatsha	29° 46' 17.00"	31°26'37.98"
X	*Cutweni*	*29°47'12.44"*	*31°26'18.65"*
X	*Mjihlelo*	*29°47'53.83"*	*31°26'9.95"*
X	*Mlambomkulu*	*29°49'18.66"*	*31°26'0.84"*
	Lupatana	29° 51' 5.32440"	31° 25' 23.811"
	Mkweni	29°52'22.20"	31°24'12.27"
X	*Maviti*	*29°53'41.28"*	*31°23'26.23"*
X	*Tezana*	*29°54'21.46"*	*31°22'31.97"*
X	*Magogo*	*29°55'10.02"*	*31°22'1.24"*
X	*Kilroe Beach*	*29°55'45.53"*	*31°21'34.37"*
X	*Mbaxeni*	*29°56'19.92"*	*31°21'3.61"*
	Msikaba	29° 58' 3.74"	31° 19' 9.20"
	Butsha	29°59'6.19"	31° 18' 45.17"
X	Kwa-Nondindwa	*29°59'22.58"*	*31°18'37.38"*
X	Daza	*29°59'50.39"*	*31°18'20.76"*

Not in NBA	Estuary	X_coord (E)	Y_coord (S)
	Mgwegwe	30° 0.' 40.9140"	31° 17' 15.554"
X	*Mkambati*	*30° 1'26.14"*	*31°16'27.98"*
	Mgwetyana	30° 2' 22.9775"	31° 15' 42.454"
	Mtentu	30° 2' 46.5539"	31° 14' 55.885"
	Sikombe	30° 4' 9.86160"	31° 13' 19.333"
	Kwanyana	30° 6' 17.6615"	31° 11' 10.791"
	Mtolane	30° 7' 37.1135"	31° 9' 34.8192"
	Mnyameni	30° 8' 1.60800"	31° 9' 7.67520"
X	*Unnamed*	*30° 8'33.86"*	*31° 8'42.80"*
	Mpahlanyana	30° 9' 36.5831"	31° 7' 27.9768"
	Mpahlane	30° 9' 53.4240"	31° 7' 9.99840"
	Mzamba	30° 10' 26.3999"	31° 6' 31.8600"
	Mtentwana	30° 11' 15.1979"	31° 5' 17.8763"
	Mtamvuna	30° 11' 37.2984"	31° 5' 4.27200"
	Zolwane	30° 12' 17.5427"	31° 4' 31.5876"
	Sandlundlu	30° 13' 44.6087"	31° 2' 33.4319"
	Ku-Boboyi	30° 14' 8.16359"	31° 2' 4.77599"
	Tongazi	30° 15' 24.5915"	31° 0' 41.1732"
	Kandandhlovu	30° 16' 9.45480"	30° 59' 50.625"
	Mpenjati	30° 17' 2.78160"	30° 58' 25.348"
	Umhlangankulu	30° 18' 11.0699"	30° 56' 43.490"
	Kaba	30° 18' 32.3604"	30° 56' 9.4776"
	Mbizana	30° 20' 5.22239"	30° 54' 31.103"
	Mvutshini	30° 20' 49.6895"	30° 53' 38.684"
	Bilanhlolo	30° 20' 56.1479"	30° 53' 24.687"
	Uvuzana	30° 21' 32.2415"	30° 52' 42.254"
	Kongweni	30° 22' 21.8495"	30° 51' 41.288"
	Vungu	30° 23' 43.1303"	30° 50' 11.345"
	Mhlangeni	30° 24' 20.1168"	30° 49' 12.810"
	Zotsha	30° 25' 25.1687"	30° 47' 22.322"
	Boboyi	30° 26' 21.2531"	30° 46' 14.509"
	Mbango	30° 26' 51.6084"	30° 45' 27.745"
	Mzimkulu	30° 27' 29.8800"	30° 44' 23.398"
	Mtentweni	30° 28' 54.1019"	30° 42' 34.534"
	Mhlangamkulu	30° 29' 54.0420"	30° 41' 17.394"
	Damba	30° 30' 37.5335"	30° 40' 20.863"
	Koshwana	30° 31' 2.27280"	30° 39' 37.137"
	Intshambili	30° 32' 11.5223"	30° 38' 13.938"
	Mzumbe	30° 32' 52.0116"	30° 36' 50.133"
	Mhlabatshane	30° 34' 17.0363"	30° 35' 4.1208"
	Mhlungwa	30° 34' 59.6459"	30° 33' 38.926"

Not in NBA	Estuary	X_coord (E)	Y_coord (S)
	Mfazazana	30° 36' 25.4339"	30° 31' 54.534"
	Kwa-Makosi	30° 36' 36.8496"	30° 31' 33.085"
	Mnamfu	30° 37' 28.9991"	30° 30' 30.272"
	Mtwalume	30° 38' 8.16000"	30° 29' 6.6300"
	Mvuzi	30° 38' 51.4104"	30° 28' 11.276"
	Fafa	30° 39' 13.0068"	30° 27' 24.073"
	Mdesingane	30° 40' 17.7275"	30° 25' 33.772"
	Sezela	30° 40' 39.8747"	30° 24' 54.046"
	Mkumbane	30° 40' 58.2060"	30° 24' 20.185"
	Mzinto	30° 42' 32.9219"	30° 22' 3.5075"
	Nkomba	30° 43' 13.3608"	30° 21' 10.357"
	Mzimayi	30° 43' 38.3448"	30° 20' 47.292"
	Mpambanyoni	30° 45' 33.4655"	30° 16' 49.432"
	Mahlongwa	30° 45' 50.1336"	30° 16' 8.8968"
	Mahlongwana	30° 47' 37.4424"	30° 13' 30.478"
	Mkomazi	30° 48' 13.9248"	30° 12' 9.3203"
	Ngane	30° 49' 1.67159"	30° 10' 43.824"
	Umgababa	30° 49' 50.6171"	30° 9' 20.4120"
	Msimbazi	30° 50' 51.5724"	30° 7' 46.2863"
	Lovu	30° 51' 27.2700"	30° 6' 19.5552"
	Little Manzimtoti	30° 52' 23.7395"	30° 4' 40.9152"
	Manzimtoti	30° 53' 4.71480"	30° 3' 30.8159"
	Mbokodweni	30° 56' 12.4367"	30° 0' 34.9524"
	Sipingo	30° 57' 4.53959"	29° 59' 45.229"
X	Umlazi	30° 58' 42.6971"	29° 58' 10.588"

Not in NBA	Estuary	X_coord (E)	Y_coord (S)
	Durban Bay	31° 3.' 45.0288"	29° 51' 58.085"
	Mgeni	31° 2.' 33.4031"	29° 48' 30.585"
	Mhlanga	31° 6.' 5.30279"	29° 42' 10.832"
	Mdloti	31° 7.' 44.9328"	29° 39' 2.1348"
	Tongati	31° 11' 5.58600"	29° 34' 24.275"
	Mhlali	31° 16' 41.4119"	29° 27' 36.575"
	Bobs Stream	31° 17' 41.0496"	29° 26' 16.717"
	Seteni	31° 18' 10.4544"	29° 25' 45.667"
	Mvoti	31° 20' 5.47439"	29° 23' 30.775"
	Mdlotane	31° 22' 25.7844"	29° 21' 8.6507"
	Nonoti	31° 24' 25.4880"	29° 19' 7.8852"
	Zinkwasi	31° 26' 36.5207"	29° 16' 53.724"
	Tugela/Thukela	31° 30' 3.62160"	29° 13' 27.310"
	Matigulu/Nyoni	31° 38' 40.3872"	29° 5' 1.30559"
	Siyaya	31° 45' 47.2968"	28° 58' 0.7716"
	Mlalazi	31° 49' 22.8971"	28° 56' 40.995"
	Mhlathuze	32° 2' 59.9675"	28° 50' 55.949"
	Richard's Bay	32° 5' 51.9611"	28° 48' 51.138"
	Nhlabane	32° 15' 25.6247"	28° 39' 41.061"
	UMfolozi	32° 25' 30.1836"	28° 23' 21.390"
	Msunduzi	32° 25' 20.8020"	28° 24' 10.461"
	St Lucia	32° 25' 29.0243"	28° 22' 57.226"
	Mgobezeleni	32° 40' 50.1419"	27° 32' 22.390"
	Kosi	32° 52' 50.8404"	26° 53' 42.626"

Appendix B:

Estuarine habitat cover in South Africa

Table B. Updated listed of Estuarine habitat cover in South Africa (based on 2010 input data).

Estuary	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds & sedges	Mangroves	Sand/mud banks	Channel	Rocks	Swamp forest	Total
Orange	83.9	107.8	0	22.02	0	108.3	652.5	0	0	974.52
Buffels	0	37.5	0	152	0	50	0.5	0	0	240
Spoeg	4.87	3.39	0	0.01	0	0	0.47	0	0	8.74
Groen	6.03	0	0	0	0	27.34	10.56	0	0	43.93
Olifants	91.94	849.1	47.72	60.05	0	76.99	227.86	0	0	1353.66
Verlorenvlei	16.2	7.56	3.68	2.3	0	0	4.5	0.5	0	34.74
Berg (Groot)	1667	2545	206	1588	0	?	793	0	0	6799
Langebaan	123.3	250.61	0	0	0	10.2	450.6	0	0	834.71
Rietvlei/Diep	0	0	0	0	0	0	0	0	0	0
Sout Wes	0	0	0	0	0	0	0	0	0	0
Hout Bay	0	0	0	17.15	0	2.53	1.37	0	0	21.05
Wildevoëlvlei	12.72	0	0	15.38	0	172.31	30.46	0	0	230.87
Bokramspruit	0	0	0	0.6	0	0	0.6	0	0	1.2
Schuster	0	0	0	0.14	0	0	0.46	0	0	0.6
Buffels Wes	0	0	0	0.48	0	1.67	1.58	0.02	0	3.75
Elsies	0	0	0	3.76	0	1.67	13.02	0	0	18.45
Krom Wes	0	0	0	1.42	0	0	7.28	0	0	8.7
Silvermine	0	0.19	2.02	2.21	0	2.01	0.09	0	0	6.52
Sand	11.55	0	0	39.76	0	7.02	97.15	0	0	155.48
Zeekoei	0	0	0.2	0.66	0	1.48	0.78	0.05	0	3.17
Eerste	0.29	0	0	1.36	0	6.15	2.4	0	0	10.2
Lourens	0	0	0	0.58	0	4.01	2.5	0	0	7.09
Sir Lowry's Pass	0	0.04	0	0	0	1.74	1.17	0	0	2.95
Steenbras	0	0	0	0	0	0	1.88	0	0	1.88
Rooiels	0	0	0.03	1.81	0	8	1	0	0	10.84
Buffels Oos	0	1.48	0	3.37	0	0.05	12.38	0	0	17.28
Palmiet	0.1	0	0	0	0	11	21.4	0.5	0	33
Bot/Kleinmond	0	92.4	32.3	373.8	0	152.3	1358.2	0	0	2009
Onrus	0	0	0	41.08	0	0	0.05	0	0	41.13
Klein	8.45	161.03	197.49	97.66	0	164.89	704.1	5	0	1338.62
Uilkraals	0	0	37.7	0	0	46	21	0	0	104.7
Ratel	0	0	0	0	0	0.39	0.94	0	0	1.33
Heuningnes	5.53	292.98	27.19	96.76	0	42.61	52.98	0	0	518.05
Klipdrifsfontein	0	0	0	0	0	0	0.6	0	0	0.6
Breede	20.5	29.55	6	4.8	0	136	1367.75	0	0	1564.6
Duiwenhoks	50.78	0	0	0	0	79.38	72.91	0	0	203.07
Goukou	44.2	0	0	0	0	62.78	47.78	0	0	154.76
Gouritz	21.07	0	0	0	0	0	91.51	0	0	112.58
Blinde	0	0	0	0.04	0	0.05	1.66	0	0	1.75
Hartenbos	2.04	13.62	0	0	0	9.21	15.72	0	0	40.59
Klein Brak	17	278	0	2	0	10	77	0	0	384
Groot Brak	13	26.6	0	2.5	0	29.9	33.1	0	0	105.1

Estuary	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds & sedges	Mangroves	Sand/mud banks	Channel	Rocks	Swamp forest	Total
Maalgate	0	0	0	0	0	1	14.96	0	0	15.96
Gwaing	1.58	0	0	0.14	0	1.82	3.65	0.31	0	7.5
Kaaimans	0.02	0	0	0.6	0	5.36	15.54	0	0	21.52
Wilderness (Touws)	6.3	7.4	4.6	11.2	0	2.1	21.1	0	0	52.7
Swartvlei	135.57	0	219.39	167.06	0	133.36	630.91	0	0	1286.29
Goukamma	1.5	5.2	0	4.1	0	0.21	7.2	0	0	18.21
Knysna	551	?	65.94	38	0	265.49	945.52	0	0	1865.95
Noetsie	0	0	0.1	2.71	0	0	5.06	0	0	7.87
Piesang	0	0	0	3.14	0	80.6	8.5	0	0	92.24
Keurbooms	72.16	41.83	88.73	146.33	0	166.27	159.42	0	0	674.74
Matjies	0	0	0	0.19	0	0	0.51	0	0	0.7
Sout Oos	0.37	0.31	0	0	0	0	2.36	0	0	3.04
Groot Wes	0	0.76	0	2.54	0	8.12	27.86	0	0	39.28
Bloukrans	0	0	0	0	0	0.63	2.88	0	0	3.51
Lottering	0	0	0	0	0	0.38	1.66	0	0	2.04
Elandsbos	0	0	0	0	0	3.04	2.09	0	0	5.13
Storms	0	0	0	0	0	0	12.1	0	0	12.1
Elands	0	0	0	0	0	1.7	5.79	0	0	7.49
Groot Oos	0	0	0	0	0	0.92	8.7	0	0	9.62
Tsitsikamma	0	0	0	1.5	0	0.5	4.5	0	0	6.5
Klipdrif	0	0	0	0.04	0	0.01	0.53	0	0	0.58
Slang	0	0	0	0.01	0	0	0.04	0	0	0.05
Krom Oos	18.13	67.17	30.98	12.95	0	89.65	189.34	0	0	408.22
Seekoei	0	8.18	14.25	26.42	0	0	83.37	0	0	132.22
Kabeljous	0	10.45	21.51	8.56	0	0	77.42	0	0	117.94
Gamtoos	92.92	80.84	5.14	40.88	0	92.12	189.35	0	0	501.25
Van Stadens	0	0	0	5.7	0	1.1	17.4	0	0	24.2
Maitland	0	0	0	4.5	0	0.25	11.4	2.5	0	18.65
Papkuils	0	0	0	0	0	0	0	0	0	0
Swartkops	165	5	12.5	4.5	0	177	135	0	0	499
Koega	0	2.3	1.2	4.3	0	0.04	2.3	0	0	10.14
Sundays	21.8	0	0	31.5	0	118.4	314	0	0	485.7
Boknes	1.5	5	0.5	6	0	0.5	6.5	0	0	20
Bushmans	118.3	0	39.8	20.9	0	?	161.9	0	0	340.9
Kariega	12.5	18.5	9.8	10.2	0	5.2	27.4	0.5	0	84.1
Kasuka	0	0	0	2.5	0	0.5	15.4	2.3	0	20.7
Kowie	35.2	0	0	6.36	0	33.99	43.08	0	0	118.63
Rufane	0	0	0	0.8	0	0	0.01	0	0	0.81
Riet	0	17.4	2.64	12.3	0	3	36.2	1.52	0	73.06
Kleinemond Wes	0	7.1	8.2	4.1	0	0.8	19.2	8.4	0	47.8
Kleinemond Oos	4.04	6.36	14.5	1.01	0	11.61	14.5	0.1	0	52.12
Klein Palmiet	0.001	0	0.02	0.22	0	0	0.29	0	0	0.531
Great Fish	46.7	152.3	0	16.6	0	10.58	139.5	0	0	365.68
Old woman's	0	0	0	14.17	0	0.1	10.7	0.15	0	25.12
Mpekweni	0	27.2	1.59	20.98	0	13.15	63.39	15.1	0	141.41

Estuary	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds & sedges	Mangroves	Sand/mud banks	Channel	Rocks	Swamp forest	Total
Mtati	0	54.25	3.2	26.2	0	1.45	180.15	21.1	0	286.35
Mgwalana	0	7.62	1.12	48.78	0	5.34	154.3	9.56	0	226.72
Bira	0	2.59	5.3	15.16	0	18.04	122.45	0	0	163.54
Gqutywa	0	1.23	2.5	3.78	0	4.47	38.1	1.56	0	51.64
Blue Krans	0	0	0	1.58	0	0.12	0.58	0.26	0	2.54
Freshwater Poort	0	0	0	0.5	0	0.1	0.15	0.15	0	0.9
Ngculura	0	0	0	0.7	0	1.15	0.5	0	0	2.35
Mtana	0	2.5	2.54	1.25	0	0.15	7.1	2.15	0	15.69
Keiskamma	210.37	91.26	11.33	103.9	0	49.18	277.82	0	0	743.86
Shwele-Shwele	0	0	0	1.34	0	0.41	5.65	0.56	0	7.96
Ngqinisa	0	0	0	2.3	0	0.12	9.05	1.2	0	12.67
Kiwane	0	0	3.56	4.56	0	0.15	8.96	1.57	0	18.8
Tyolomnqa	3.7	15.67	0	0.29	0	0.07	87.71	0	0	107.44
Shelbertsstroom	0	0	0	0	0	0	0.3	0	0	0.3
Lilyvale	0	0	0	0.5	0	0	1.8	0	0	2.3
Ross' Creek	0	0	0.2	0.1	0	0	1	0	0	1.3
Ncera	0	2.9	1	0.9	0	6.7	16.9	0	0	28.4
Mlele	0	0.4	0	0.5	0	0	2.7	0	0	3.6
Mcantsi	0	0.5	0	4	0	0.5	4	0	0	9
Gxulu	1	11.9	0	0.6	0	4	31	0	0	48.5
Goda	0	1.9	0	1.1	0	0.6	13.6	0	0	17.2
Hlozi	0	0	0	0.3	0	0	0.4	0	0	0.7
Hickmans	0	0.8	0	0.4	0	0	3.1	0	0	4.3
Mvubukazi	0	0	0	0	0	0	0.1	0	0	0.1
Ngqenga	0	0	0	0	0	0	0.1	0	0	0.1
Buffalo	0	0.1	0	0.2	0	0	97.7	0	0	98
Blind	0	0.1	0	0	0	0	0.4	0	0	0.5
Hlaze	0	0.1	0	0.7	0	0	0.7	0	0	1.5
Nahoon	2.8	0	2.3	0.2	0.6	4.5	47.3	0	0	57.7
Qinira	16.83	5.7	0	15.2	0	0	34.4	0	0	72.13
Gqunube	3.7	2.2	0.8	0.4	0	6.3	40	0	0	53.4
Kwelera	9.3	7.2	2.3	0.3	0	4.4	26.6	0	0	50.1
Bulura	2.8	5.6	0.4	2.7	0	4.6	19.4	0	0	35.5
Cunge	0	0	0	0.2	0	0	0.3	0	0	0.5
Cintsa	7	7.1	0	1	0	1.6	12.6	0	0	29.3
Cefane	28.1	21.4	0	1.9	0	8.8	22.5	0	0	82.7
Kwenxura	0	3.3	0	2.6	0	5	18.2	0	0	29.1
Nyara	1.1	6.3	0	0.6	0	1.7	7.4	0	0	17.1
Haga-haga	0	0.3	0	0.4	0	1.4	1.3	0	0	3.4
Mtendwe	0	4.1	0	5.6	0	0.2	4.2	0	0	14.1
Quko	3.9	0	0	1.2	0	0.08	31	0	0	36.18
Morgan	0	2	0	1	0	1	20	0	0	24
Cwili	0	0	0	0.6	0	0	0.6	0	0	1.2
Great Kei	5.8	6.2	0	12.3	0	8.7	189.4	0	0	222.4
Gxara	0	1.89	0	6.31	0	1.5	14.2	0	0	23.9

Estuary	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds & sedges	Mangroves	Sand/mud banks	Channel	Rocks	Swamp forest	Total
Ngogwane	0	0	0	2.35	0	2.1	4.67	0	0	9.12
Qolora	0	0	0	8.7	0	1.2	7.4	5.6	0	22.9
Ncizele	0	0	0	1.23	0	0.005	5.4	0	0	6.635
Kobonqaba	2.3	4.5	0	2.4	1.5	4.6	11.1	0	0	26.4
Ngqusi\Inxaxo	2.35	8.56	0.04	4.65	15	4.56	124.32	0	0	159.48
Cebe	0	0	0	7.63	0	1.4	7.5	0	0	16.53
Gqunqe	0	0	0	9.2	0	0.89	7.85	0	0	17.94
Zalu	0	0	0	5.2	0	0.02	7.14	0	0	12.36
Ngqwara	0	2.34	0	4.68	0	2.1	10.24	0	0	19.36
Sihlontlweni	0	0	0	2.56	0	0.05	8.4	0	0	11.01
Qora	0	0	8.5	5.67	0	10.23	65.23	0	0	89.63
Jujura	0	0	0.05	1.2	0	0.07	3.45	0	0	4.77
Ngadla	0	0	0	5.23	0	0.004	8.65	0	0	13.884
Shixini	0	0	0	5.64	0	5.23	11.23	0	0	22.1
Nqabara	0	0	1.2	4.56	8.5	4.63	89.54	0	1.23	109.66
Ngoma	0	0	0	4.32	0	4.56	1.23	0	0	10.11
Mendu	0	0	0	9.51	0	0	14.32	0	0	23.83
Mendwana										0
Mbashe	2.3	0	1.5	13.45	14	6.7	89.2	0	4.8	131.95
Ku-Mpenzu	0	0	0	4.3	0	1.24	6.54	1.3	0	13.38
Ku-Bhula	0	0	0	2.7	0	0	2.6	2.3	0	7.6
Kwa-Suka	0	0	2.3	7.6	0	0.01	8.23	0	0	18.14
Ntlonyane	0	0	0	7.99	0	3.89	29.46	0	0	41.34
Nkanya	0	0	0	7.4	0	0.05	7.52	0.5	0	15.47
Sundwana	0	0	0	2.3	0	0.01	4.32	0	0	6.63
Xora	0	12.96	2.6	10.12	16.32	17.13	91.45	0	0	150.58
Bulungulu	0	2.3	0	4.7	0	2.5	8.9	0	0	18.4
Ku-amanzimuzama	0	0	0	1.2	0	1.05	1.4	0	0	3.65
Mncwasa	0	0	0	3.7	0	0.156	15.36	0	0	19.216
Mpako	0	0	0	5.13	0	0.96	7.42	0	0	13.51
Nenga	0	0	0	2.1	0	2.17	5.74	0	0	10.01
Mapuzi	0	0	0	7.45	0	0	8.45	0	0	15.9
Mtata	0	21.03	0	6.23	33.5	5.62	102.41	0	0	168.79
Tshani	0	0	0	1.23	0	0.004	2.78	0	0	4.014
Mdumbi	0	8.17	0.05	7.9	0.5	13.88	45.57	0	0	76.07
Lwandilana	0	0	0	2.4	0	0.08	7.21	0	0	9.69
Lwandile	0	0	0	7.4	0	2.4	12.4	0	0	22.2
Mtakatye	0	18.19	1.25	7.56	9	5.21	75.6	0	0	116.81
Hluleka	0	0	0	2.35	0	4.1	8.45	0	0	14.9
Mnenu	0	0	0	44	0	0.08	46.44	0	0	90.52
Mtonga	0	0	0	15.6	0	1.2	15.4	0	0	32.2
Mpande	0	0	0	6.7	0	0.5	7.84	0	0	15.04
Sinangwana	0	0	0	7.4	0	0	5.8	0	0	13.2
Mngazana	1.25	7.4	0.8	11.4	145	5.6	45.6	0	7.8	224.85
Mngazi	0	0	0	4.6	0	0	12.5	0	0	17.1

Estuary	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds & sedges	Mangroves	Sand/mud banks	Channel	Rocks	Swamp forest	Total
Gxwaleni	0	0	0	5.6	0	0.02	4.5	0	0	10.12
Bululo	0	0	0	6.3	0	0.02	6.3	0	0	12.62
Mtambane	0	0	0	5.41	0	0.12	5.41	0	0	10.94
Mzimvubu	0	0	0	22.3	0	15.23	102.23	0	11.23	150.99
Ntlupeni	0	0	0	0.13	0	0.14	4.1	0	0	4.37
Nkodusweni	0	0	0	4.7	0	5.5	22.4	0	0	32.6
Mntafufu	0	0	0	1.5	13.7	0.75	7.65	0	0.47	24.07
Mzintlava	0	0	0	3.09	2.31	2.89	14.42	0	0.35	23.06
Mzimpunzi	0	0	0	1.41	0	0.6	3.07	0	0	5.08
Kwa-Nyambalala	0	0	0	0.02	0	0.01	0.57	0	0	0.6
Mbotyi	0	0	0	4.16	0	11.41	32.32	0	2.5	50.39
Mkozi	0	0	0	0.5	1.29	0.12	2.1	0	0	4.01
Myekane	0	0	0	0.3	0	0.49	1.13	0	0	1.92
Lupatana	0	0	0	0.22	0	0.15	2.73	0	0.45	3.55
Mkweni	0	0	0	0.34	0	0.15	5.19	0	1.32	7
Msikaba	0	0	0	0.49	0	2.81	10.94	0	0.89	15.13
Butsha	0	0	0	0.35	0	0	0.8	0	1.74	2.89
Mgwegwe	0	0	0	0.15	0	0.8	3.39	0	4.45	8.79
Mgwetyana	0	0	0	0.27	0	0.56	2.45	0	0	3.28
Mtentu	0	0	0	4.76	1.47	8.08	34.95	0	3.67	52.93
Sikombe	0	0	0	0.3	0	0.79	9.21	0	1.18	11.48
Kwanyana	0	0	0	0.71	0	0.1	6.32	0	0	7.13
Mtolane	0	0	0	0	0	0.14	1.15	0	0	1.29
Mnyameni	0	0	0	8.46	0	2.34	17.11	0	0.01	27.92
Mpahlanyana	0	0	0	0.74	0	0.1	3.01	0	0	3.85
Mpahlane	0	0	0	0.66	0	0.29	2.97	0	0	3.92
Mzamba	0	0	0	24.11	0.25	3.97	37.87	0	4.74	70.94
Mtentwana	0	0	0	0	0	1.22	10.21	0	0	11.43
Mtamvuna	0	0	0	15.23	0.3	2.36	45.69	0	0	63.58
Zolwane	0	0	0	0	0	2	0.3	0	0	2.3
Sandlundlu	0	0	0	3.25	0	3	4	0	0.25	10.5
Ku-boboyi	0	0	0	3	0	1	1.1	0	0	5.1
Tongazi	0	0	0	0	0	3	0.78	0	3	6.78
Kandandhlovu	0	0	0	2	0.5	1	1.8	0	0	5.3
Mpenjati	0	0	0	17	0	4.5	11.6	0	0	33.1
Umhlangankulu	0	0	0	4	0.5	1.5	5.8	0	4	15.8
Kaba	0	0	0.25	9	0	3	2.4	0	0	14.65
Mbizana	0	0	0	12	0	1	12.4	0	3	28.4
Mvutshini	0	0	0	0	0	3	0.88	0	0	3.88
Bilanhlolo	0	0	0	8	0.5	3.5	2.6	0	2	16.6
Uvuzana	0	0	0	4.5	0	1	0.6	0	0	6.1
Kongweni	0	0	0	4	0.5	1	1.42	0	0.25	7.17
Vungu	0	0	0	0	0	6	1.13	0	0	7.13
Mhlangeni	0	0	0	8	0	4	3.6	0	0	15.6
Zotsha	0	0	0	13	0	4	7.3	0	5	29.3

Estuary	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds & sedges	Mangroves	Sand/mud banks	Channel	Rocks	Swamp forest	Total
Boboyi	0	0	0	9	0	4	1.3	0	0	14.3
Mbango	0	0	0	8	0	2	0.9	0	2	12.9
Mzimkulu	0	0	0	18	0	11	73.9	0	15	117.9
Mtentweni	0	0	0	5	0	1	7.98	0	4.5	18.48
Mhlanga	0	0	0	69.9	0	0	30	0	0.2	100.1
Damba	0	0	0	6.25	0	2.7	1.7	0	9	19.65
Koshwana	0	0	0	10	0	1	1.18	0	6	18.18
Intshambili	0	0	0	1.5	0	1	1.7	0	6.25	10.45
Mzumbe	0	0	0	5	0	15	15.8	0	0	35.8
Mhlabatshane	0	0	0	4	0	1.5	2.27	0	11.5	19.27
Mhlungwa	0	0	1.5	7	0	4	3	0	1	16.5
Mfazazana	0	0	0	7.5	0	1	2.1	0	5	15.6
Kwa-Makosi	0	0	0	3.5	0	2	2.45	0	7	14.95
Mnamfu	0	0	0	6	0	3	1.28	0	4	14.28
Mtwalume	0	0	0	4	0	10	24.8	0	0	38.8
Mvuzi	0	0	0	15	0	2	0.8	0	0	17.8
Fafa	0	0	1.5	8	0	7	30	0	4.5	51
Mdesingwana	0	0	0.5	6	0	0.25	0.39	0	0	7.14
Sezela	0	0	0	18	0	1	9	0	0	28
Mkumbane	0	0	0	7	0	5	0.25	0	0	12.25
Mzinto	0	0	0	14	0	4	7	0	4.5	29.5
Nkomba										0
Mzimayi	0	0	0	6	0	6	0.9	0	0	12.9
Rocky Bay (30º20'01"S; 30º44'02E)										0
Mpambanyoni	0	0	0	3	0	7	2.32	0	0.25	12.57
Mahlongwa	0	0	0	7	0	1	5.9	0	0	13.9
Mahlongwana	0	0	3	5	0	2	6.84	0	4	20.84
Mkomazi	0	0	0	5	2	4.9	62.8	0	0	74.7
Ngane	0	0	0	3	0	4	1.36	0	0	8.36
Umgababa	0	0	2.5	15	0	12	17.8	0	0	47.3
Msimbazi	0	0	0	12	0	3	13.2	0	0	28.2
Lovu	0	0	0	19	0	5	10.5	0	5	39.5
Little Manzimtoti	0	0	0	2	0	1.5	1.5	0	5	10
Manzimtoti	0	0	0	5	0	7	6.67	0	2.5	21.17
Mbokodweni	0	0	0	8	0	2.5	7.24	0	0	17.74
Sipingo	0	3	0	2	3.8	1	0.8	0	16	26.6
Umlazi										0
Durban Bay	0	0	8	2	16	37	1080	0	5	1148
Mgeni	2	0	0	2	20.3	11	48	0	0	83.3
Mhlambankulu	0	0	0	0	0	0.68	12	0	0.2	12.88
Mdloti	0	0	0	10	0	7.3	33	0	7.8	58.1
Tongati	0	0	0	17.2	0	2.8	13.9	0	3.4	37.3
Mhlali	0	0	0	6	0	8	21	0	7	42
Bob's Stream										0
Seteni	0	0	0	0.25	0	2	1.13	0	4	7.38

Estuary	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds & sedges	Mangroves	Sand/mud banks	Channel	Rocks	Swamp forest	Total
Mvoti	0	0	0	1	0	3	18.4	0	0	22.4
Mdlotane	0	0	0.71	6.03	0	0	6.35	0	12.33	25.42
Nonoti	0	0	2.5	2.5	0	3	18	0	1	27
Zinkwasi	0	0	0	39.51	0	0	20.37	0	11.28	71.16
Thukela	0	0	0	12	0	11	55	0	1	79
Matigulu/Nyoni	0	0	0.5	2	0	0.5	122	0	2	127
Siyaya	0	0	0.08	5.31	0	0.21	0.76	0	1.33	7.69
Mlalazi	0	39.31	0.001	19.64	60.7	19.8	95.86	0	3.46	238.771
Mhlathuze	60	0	5	205	652.1	90	679	0	0	1691.1
Richard's Bay	52	0	0	309	267	531	869	0	16	2044
Nhlabane	0	0	1.1	7.8	0	0	5.2	0	0.3	14.4
uMfolozi	0	0	0	78	26	20	8.5	0	5	137.5
St Lucia	516	1706	181	3789	571	206	31610	0	3	38582
Mgobezeleni	0	0	0	5	4.5	0.5	1.3	0	4	15.3
Kosi	0	0	0	100	60.7	18	200	12	25	415.7

Appendix C:

Assessment of the health status of South Africa's estuaries

Table C: Desktop National Health Assessment, with individual ecological components graded from Excellent (dark blue), good (blue), fair (green) to poor (brown). A Provisional Present Ecological Status is also provided. Pressure levels are indicated as very high (VH), high (H), medium (M) or low (L). A Blank indicates the absence of a pressure.

NAME	Pressures								Health Condition												
	Change in flow	Polution	Habitat loss	Mining	Artificial Breaching	Fishing Effort(	Fishing Effort(Catches in tones)	Bait collection	Hydrology	Hydrodynamics	Water Quality	Physical habitat	Habitat State	Microalgae	Macrophytes	Invertebrates	Fish Final	Birds	Biological State	Estuary Health State (Mean)	Ecological Category
Orange (Gariep)	M	L	M		Y	L	5.0	Y													D
Buffels	L	M	M	Y	Y	L	0.1	Y													C
Spoeg	L	L	L			L	0.1	Y													B
Groen	L	L	L			L	0.1	Y													B
Sout	M	L	M				0.0														D
Olifants	M	M	M			VH	121.1	Y													C
Jakkalsvlei	H	M	L			L	0.1	Y													D
Wadrift	H	M	H			L	0.1	Y													E
Verlorenvlei	M	M	M		Y	M	10.0	Y													D
Groot Berg	M	H	M			VH	511.0	Y													D
Rietvlei/Diep	M	H	H		Y	L	0.1	Y													E
Sout (Wes)	H	H	H			L	0.1														F
Houtbaai	L	H	H			L	1.0	Y													E
Wildevoëlvlei	M	H	M			L	0.0	Y													D
Bokramspruit	L	H	L				0.0														C
Schuster	L	L	L				0.0														A
Krom	L	L	L				0.0														A
Buffels Wes	L	H	H				0.0														F
Elsies	L	H	H			L	0.1														E
Silvermine	L	H	H		Y	L	20.0	Y													D
Sand	M	H	M		Y	M	0.1	Y													D
Zeekoei	M	H	H			L	0.1	Y													E
Eerste	M	H	H			L	0.1	Y													E
Lourens	L	H	M			L	0.1	Y													C
Sir Lowry's Pass	M	H	H			L	1.0	Y													E
Steenbras	H	L				L	0.1	Y													B
Rooiels	L	L	L			L	0.1	Y													B
Buffels (Oos)	L	L	L			L	0.2	Y													B
Palmiet	M	L	M			L	70.0	Y													C
Bot/Kleinmond	M	M	M		Y	VH	0.1	Y													C
Onrus	H	H	H			L	80.0	Y													E
Klein	M	M	M		Y	H	2.1	Y													C
Uilkraals	M	M	M			M	0.1	Y													D

NAME	Pressures								Health Condition													
	Change in flow	Polution	Habitat loss	Mining	Artificial Breaching	Fishing Effort(	Fishing Effort(Catches in tones)	Bait collection	Hydrology	Hydrodynamics	Water Quality	Physical habitat	Habitat State	Microalgae	Macrophytes	Invertebrates	Fish Final	Birds	Biological State	Estuary Health State (Mean)	Ecological Category
Ratel	M	M	L			L	10.0	Y													C
Heuningnes	M	M	M		Y	M	0.0	Y													D
Klipdrifsfontein	L	L					80.0														A
Breëde	M	L	L			H	20.0	Y													B
Duiwenhoks	M	L	L			H	13.0	Y													B
Goukou (Kaffirkui	M	M	M			H	20.0	Y													C
Gouritz	M	M	M			H	0.1	Y													C
Blinde	L	M	L			L	2.1	Y													B
Hartenbos	M	H	M		Y	L	10.0	Y													D
Klein Brak	L	M	M			M	0.0	Y													C
Groot Brak	M	M	H		Y	M	1.0	Y													D
Maalgate	L	L				L	1.0	Y													B
Gwaing	L	M	L			L	0.0	Y													B
Kaaimans	L	L	L				0.0	Y													B
Wilderness (Touws)	L	M	M		Y		0.0	Y													B
Swartvlei	L	L	M		Y		4.1	Y													B
Goukamma	L	L	L		Y	M	70.4	Y													B
Knysna	L	M	L			H	0.2	Y													B
Noetsie	L	L	L			L	0.1	Y													B
Piesang	L	M	M			L	10.0	Y													C
Keurbooms	L	L	L			L	0.1	Y													A
Matjies	L	L	L			L	0.5	Y													B
Sout (Oos)	L	L				L	2.9	Y													A
Groot (Wes)	M	L	L			L	1.0	Y													B
Bloukrans	L	L				L	0.2	Y													A
Lottering	L	L				L	0.2	Y													A
Elandsbos	L	L	L			L	0.1	Y													A
Storms	L	L	L			L	0.1														A
Elands	L	L	L			L	0.1	Y													B
Groot (Oos)	M	M	L			L	1.8	Y													B
Tsitsikamma	M	M	L			L	0.1	Y													B
Klipdrif	M	M	M			L	0.1	Y													D
Slang	M	M	M			L	22.1	Y													D
Krom Oos (Kromme)	H	H	M			H	1.0	Y													D
Seekoei	M	M	H			L	2.0	Y													D
Kabeljous	L	M	M			L	19.3	Y													C

NAME	Pressures								Health Condition												
	Change in flow	Polution	Habitat loss	Mining	Artificial Breaching	Fishing Effort(	Fishing Effort(Catches in tones)	Bait collection	Hydrology	Hydrodynamics	Water Quality	Physical habitat	Habitat State	Microalgae	Macrophytes	Invertebrates	Fish Final	Birds	Biological State	Estuary Health State (Mean)	Ecological Category
Gamtoos	M	M	M			H	2.1	Y													C
Van Stadens	L	L	L			L	0.1	Y													B
Maitland	L	M	M			L	0.1	Y													C
Baakens	M	H	H			L	0.1	Y													E
Papenkuils	M	H	H			L	35.0	Y													F
Swartkops	L	H	H			H	10.0	Y													C
Coega (Ngcura)	M	H	H			L	9.0	Y													F
Sundays	M	H	M			H	0.3	Y													C
Boknes	L	L	L			L	11.5	Y													C
Bushmans	L	M	M			H	0.1	Y													C
Kariega	M	L	M			L	2.2	Y													C
Kasuka	L	L	L			L	2.0	Y													B
Kowie	M	M	M			L	0.0	Y													C
Rufane	M	M	M				0.1	Y													C
Riet	L	L	L			L	2.2	Y													B
Kleinemond Wes	L	M	L			L	2.0	Y													B
Kleinemond Oos	L	M	L			L	0.0	Y													B
Klein Palmiet	H	M	M			L	30.0	Y													D
Great Fish	M	M	M			H	0.1	Y													C
Old Womans	L	M	M			L	2.2	Y													C
Mpekweni	L	M	L			M	3.0	Y													B
Mtati	L	L	L			L	3.5	Y													B
Mgwalana	L	L	L			L	8.5	Y													B
Bira	L	L	L			L	0.2	Y													B
Gqutywa	L	L	L			L	0.1	Y													B
Ngculura	L	L	L			L	0.0														B
Blue Krans	L	L	L			L	2.1														A
Mtana	L	M	L			L	50.0	Y													B
Keiskamma	L	M	M			H	0.1	Y													C
Ngqinisa	L	M	L			L	2.0	Y													B
Kiwane	L	L	L			L	20.0	Y													B
Tyolomnqa	L	L	L			M	0.1	Y													B
Shelbertsstroom	L	M	L			L	0.1	Y													C
Lilyvale	L	M	L			L	0.1	Y													B
Ross' Creek	L	M	L			L	2.3	Y													B
Ncera	L	M	L			L	0.1	Y													B
Mlele	L	M	L			L	0.1	Y													B

NAME	Pressures								Health Condition												
	Change in flow	Polution	Habitat loss	Mining	Artificial Breaching	Fishing Effort(	Fishing Effort(Catches in tones)	Bait collection	Hydrology	Hydrodynamics	Water Quality	Physical habitat	Habitat State	Microalgae	Macrophytes	Invertebrates	Fish Final	Birds	Biological State	Estuary Health State (Mean)	Ecological Category
Mcantsi	L	M	M			L	3.2	Y													C
Gxulu	L	L	L			L	1.0	Y													B
Goda	L	L	L			L	0.1	Y													B
Hlozi	L	L	L			L	0.1	Y													B
Hickman's	L	M	L			L	0.1	Y													B
Mvubukazi	L	M	L			L	0.0	Y													B
Ngqenga	L	H	L			L	20.0														C
Buffalo	H	H	L			L	0.1	Y													D
Blind	L	H	L			L	0.1	Y													C
Hlaze	L	M	L			L	7.4	Y													C
Nahoon	M	H	M			H	2.0	Y													C
Qinira	L	M	L			M	7.7	Y													B
Gqunube	L	M	L			M	8.0	Y													B
Kwelera	L	L	L			H	2.0	Y													B
Bulura	L	M	L			H	0.1	Y													B
Cunge	L	L	L			L	3.5	Y													A
Cintsa	L	M	L			L	3.1	Y													C
Cefane	L	L	L			L	3.5	Y													B
Kwenxura	L	L	L			L	0.2	Y													B
Nyara	L	L				L	0.1	Y													A
Mtwendwe	L	L	L			L	1.0	Y													B
Haga-haga	L	L	L			L	0.1	Y													B
Mtendwe	L	L	L			L	3.8	Y													B
Quko	L	L	L			L	2.6	Y													A
Morgan	L	M	L			L	0.1	Y													C
Cwili	L	M	L			L	30.0	Y													B
Great Kei	L	M	L			H	2.3	Y													C
Gxara	L	L	L			L	0.1	Y													B
Ngogwane	L	L	L			L	1.7	Y													B
Qolora	L	L	L			L	0.1	Y													B
Ncizele	L	L	L			L	0.1	Y													B
Timba	L	L	L			L	6.0														A
Kobonqaba	L	L	L			L	3.0	Y													B
Nxaxo/Ngqusi	L	L	M			L	2.4	Y													B
Cebe	L	L	L			L	2.4	Y													B
Gqunqe	L	L	L			L	1.5	Y													A

NAME	Pressures								Health Condition													
	Change in flow	Polution	Habitat loss	Mining	Artificial Breaching	Fishing Effort(	Fishing Effort(Catches in tones)	Bait collection	Hydrology	Hydrodynamics	Water Quality	Physical habitat	Habitat State	Microalgae	Macrophytes	Invertebrates	Fish Final	Birds	Biological State	Estuary Health State (Mean)	Ecological Category
Zalu	L	L	L			L	2.4	Y													A
Ngqwara	L	L	L			L	1.5	Y													A
Sihlontlweni/Gcin	L	L	L			L	0.0	Y													B
Nebelele	L	L					7.0														A
Qora	L	L	L			L	1.3	Y													B
Jujura	L	L	L			L	1.5	Y													B
Ngadla	L	L	L			L	2.5	Y													A
Shixini	L	L	L			L	0.0	Y													B
Beechamwood		L					0.0														A
Unnamed		L					0.0														A
Kwa-Goqo		L					0.0														A
Ku-Nocekedwa		L					8.4														A
Nqabara/Nqabarana	L	L	L			L	1.0	Y													B
Ngoma/Kobule	L	L	L			L	1.0	Y													A
Mendu	L	L	L			L	0.0	Y													A
Mendwana	L	L	L				15.0														A
Mbashe	L	M	L			H	0.1	Y													C
Ku-Mpenzu	L	L	L			L	0.2	Y													B
Ku-Bhula/Mbhanyana	L	L				L	0.1	Y													A
Kwa-Suka	L	L				L	0.5	Y													B
Ntlonyane	L	M	M			L	0.1	Y													B
Nkanya	L	M	L	Y		L	0.0	Y													B
Sundwana		L				L	7.0														A
Xora	L	L	L			L	0.2	Y													B
Bulungula	L	L	L			L	0.0	Y													B
Ku-Amanzimuzama	L	L	L			L	0.0														A
Nqakanqa		L	L				0.0														A
Unnamed2		L	L				2.0														A
Mncwasa	L	L	L			L	0.5	Y													B
Mpako	L	L	L			L	0.1	Y													B
Nenga	L	M	M			L	0.1	Y													C
Mapuzi	L	M	L			L	5.5	Y													B
Mtata	M	H	M			H	0.1	Y													D
Tshani	L	M	L			L	5.0	Y													B
Mdumbi	L	L	M			H	0.1	Y													B
Lwandilana	L	L	L			L	1.0	Y													A

NAME	Pressures								Health Condition													
	Change in flow	Polution	Habitat loss	Mining	Artificial Breaching	Fishing Effort(	Fishing Effort(Catches in tones)	Bait collection	Hydrology	Hydrodynamics	Water Quality	Physical habitat	Habitat State	Microalgae	Macrophytes	Invertebrates	Fish Final	Birds	Biological State	Estuary Health State (Mean)	Ecological Category
Lwandile	L	L	L			L	5.2	Y													A
Mtakatye	L	L	L			H	0.1	Y													B
Hluleka/Majusini	L	L	L			L	6.0	Y													A
Mnenu	L	M	L			L	0.1	Y													B
Mtonga	L	L	L			L	0.1	Y													B
Mpande	L	L				L	1.0	Y													B
Sinangwana	L	L	L			L	6.7	Y													B
Mngazana	L	M	M			H	6.0	Y													B
Mngazi	L	M	L			L	0.1	Y													C
Gxwaleni	L	L				L	0.1	Y													A
Bulolo	L	L	L			L	0.0	Y													B
Mtumbane	L	L	L			L	35.2														B
Mzimvubu	L	M	L			H	0.0	Y													C
Ntlupeni	L	L	L			L	1.0														B
Nkodusweni	L	L	L			L	4.1	Y													B
Mntafufu	L	L	M			H	3.8	Y													B
Mzintlava	L	M	L			H	0.0	Y													B
Mzimpunzi	L	L	L				0.1														B
Kwa-Nyambalala	L	L	L			L	2.0	Y													B
Mbotyi	L	L	L			L	0.0	Y													B
Mkozi	L	L	L				0.0														A
Myekane	L	L					0.0														A
Sitatsha	L	L					0.0														A
Lupatana	L	L					0.0														A
Mkweni	L	L					3.2														A
Msikaba	L	M				H	0.0	Y													A
Butsha			L				0.1														A
Mgwegwe						L	0.1	Y													A
Mgwetyana						L	4.5	Y													A
Mtentu	L	L	L			H	1.0	Y													A
Sikombe	L	L				L	0.1	Y													A
Kwanyana	L	L	L			L	0.1	Y													B
Mtolane	L	L				L	3.5	Y													A
Mnyameni	L	L	M			L	0.1	Y													B
Mpahlanyana	L	L				L	0.1	Y													A
Mpahlane	L	L				L	3.7	Y													A

NAME	Pressures								Health Condition												
	Change in flow	Polution	Habitat loss	Mining	Artificial Breaching	Fishing Effort(	Fishing Effort(Catches in tones)	Bait collection	Hydrology	Hydrodynamics	Water Quality	Physical habitat	Habitat State	Microalgae	Macrophytes	Invertebrates	Fish Final	Birds	Biological State	Estuary Health State (Mean)	Ecological Category
Mzamba	L	M	L			H	0.0	Y													B
Mtentwana	L	M	H				2.5	Y													C
Mtamvuna	L	L	L		?	L	0.1	Y													B
Zolwane	L	L	M		Y	L	0.2	Y													B
Sandlundlu	L	M	M	Y	Y	L	0.2	Y													C
Ku-Boboyi	L	M	M			L	0.0	Y													B
Tongazi	L	M	M				0.2	Y													B
Kandandhlovu	L	M	M			L	0.3	Y													B
Mpenjati	L	M	M	Y	Y	L	0.3	Y													B
Umhlangankulu	L	M	M		Y	L	0.2	Y													C
Kaba	L	M	M			L	0.6	Y													B
Mbizana	L	M	M	Y	?	L	0.2	Y													B
Mvutshini	L	M	M		Y	L	0.2	Y													B
Bilanhlolo	L	M	M		Y	L	0.2	Y													C
Uvuzana	L	M	M		Y	L	0.2	Y													C
Kongweni	L	M	H		Y	L	0.0	Y													C
Vungu	L	M	L				0.2														B
Mhlangeni	L	M	M		Y	L	0.7	Y													C
Zotsha	L	M	M	Y	Y	L	0.2	Y													C
Boboyi	L	H	M			L	0.1	Y													C
Mbango	M	H	H			L	4.0	Y													E
Mzimkulu	M	M	M	Y	Y	H	0.2	Y													C
Mtentweni	L	M	M			L	0.2	Y													C
Mhlangamkulu	L	M	M			L	0.2	Y													C
Damba	L	M	M		Y	L	0.2	Y													C
Koshwana	L	M	M			L	0.2	Y													C
Intshambili	L	L	M			L	0.3	Y													B
Mzumbe	L	M	H	Y		L	0.2	Y													D
Mhlabatshane	L	L	M			L	0.8	Y													B
Mhlungwa	L	M	M			L	0.5	Y													C
Mfazazana	L	M	H			L	0.4	Y													C
Kwa-Makosi	L	M	M			L	0.2	Y													B
Mnamfu	L	M	M			L	0.2	Y													C
Mtwalume	L	M	M	Y		L	0.2	Y													D
Mvuzi	L	M	M			L	0.8	Y													C
Fafa	L	M	M	Y	Y	L	0.1	Y													D
Mdesingane	L	M	H			L	0.0	Y													C

NAME	Pressures								Health Condition												
	Change in flow	Polution	Habitat loss	Mining	Artificial Breaching	Fishing Effort(	Fishing Effort(Catches in tones)	Bait collection	Hydrology	Hydrodynamics	Water Quality	Physical habitat	Habitat State	Microalgae	Macrophytes	Invertebrates	Fish Final	Birds	Biological State	Estuary Health State (Mean)	Ecological Category
Sezela	L	H	M		Y		0.2														D
Mkumbane	L	M	M			L	0.6	Y													C
Mzinto	L	M	M		?	L	0.0	Y													C
Nkomba	L	M	H			L	0.2														C
Mzimayi	L	M	M			L	0.1	Y													C
Mpambanyoni	L	M	M	Y	?	L	7.6	Y													C
Mahlongwa	L	M	M	Y	Y	M	0.4	Y													C
Mahlongwane	L	M	M		?	L	7.0														B
Mkomazi	L	M	M	Y	Y	H	1.9	Y													C
Ngane	L	L	M		?	L	0.0	Y													B
Umgababa	L	L	M		Y		0.0														B
Msimbazi	L	L	L				0.0														B
Lovu	M	M	M	Y	Y		0.0														C
Little Manzimtoti	M	H	H		Y		0.0														D
Manzimtoti	L	H	H	Y	Y		0.0														D
Mbokodweni	M	H	H	Y	Y		0.0														E
Sipingo	H	H	H				53.0														F
Durban Bay	M	H	H			H	3.7	Y													E
Mgeni	M	H	H	Y	Y	L	0.1	Y													D
Mhlanga	M	H	M		Y	L	1.0	Y													D
Mdloti	L	H	H	Y	Y	L	0.6	Y													D
Tongati	L	H	H	Y	Y	L	0.6	Y													E
Mhlali	M	H	M	Y	Y	L	0.0	Y													C
Bob's Stream	M	M	M				0.1	Y													C
Seteni	M	M	M			L	1.0	Y													C
Mvoti	M	H	M	Y	Y	L	0.2	Y													D
Mdlotane	L	L	M			L	0.6	Y													B
Nonoti	L	M	M	Y	Y	L	3.0	Y													B
Zinkwasi	L	M	H	Y	Y	L	17.0	Y													C
Thukela	L	H	M	Y	Y	H	15.0	Y													C
Matigulu/Nyoni	L	L	L			H	0.1	Y													B
Siyaya	H	H	H			L	18.0														F
Mlalazi	L	M	M		Y	H	80.0	Y													B
Mhlathuze	L	M	H	Y		H	88.0	Y													C
Richards Bay	L	M	H			H	0.0	Y													D
Nhlabane (Present)	M	L	H	Y			0.0														D
Msunduzi	L	M	M				8.0														C

NAME	Pressures								Health Condition													
	Change in flow	Polution	Habitat loss	Mining	Artificial Breaching	Fishing Effort(	Fishing Effort(Catches in tones)	Bait collection	Hydrology	Hydrodynamics	Water Quality	Physical habitat	Habitat State	Microalgae	Macrophytes	Invertebrates	Fish Final	Birds	Biological State	Estuary Health State (Mean)	Ecological Category
UMfolozi	L	H	H	Y	Y	H	10.0	Y													D
St Lucia	H	M	H		Y	H	4.0	Y													E
Mgobezeleni	L	L	L		Y	M	300.0														B
Kosi	L	L	M			VH	0.0	Y													B

* *Ecological Category was determined by an ecological water requirement study, otherwise determined by desktop study.*

Appendix D:

National priority estuaries for biodiversity conservation

Table D. National and/or regional priorities, the extent of protection required (Full = full no-take protection, Partialpartial = no-take sanctuary zone where feasible), the recommended proportion of the estuary margin being undeveloped (or with a >100 m development setback line), and Recommended Ecological Category (after Turpie et al. 2012).

Estuary (West to East)	Current health category	National (SA) and regional (C.A.P.E.) priorities	Recommended extent of protection	Recommended degree of undeveloped margin	Recommended Ecological Category
Orange	D	SA/C.A.P.E.	Full	50%	C*
Spoeg	B	SA	Full	100%	A or BAS
Groen	B	SA	Full	100%	A or BAS
Olifants	C	SA/C.A.P.E.	Partial	50%	B*
Verlorenvlei	D	SA	Partial	50%	C
Berg	D	SA/C.A.P.E.	Partial	25%	C*
Rietvlei/ Diep	E	SA/C.A.P.E.	Partial	50%	C
Krom	A	SA/C.A.P.E.	Full	100%	A or BAS
Sand	D	SA/C.A.P.E.	Partial	20%	C
Eerste	E	SA/C.A.P.E.	Full	75%	D
Lourens	C	SA/C.A.P.E.	Full	75%	D
Palmiet	C	SA/C.A.P.E.	Full	50%	B*
Bot / Kleinmond	C	SA/C.A.P.E.	Partial	50%	B
Klein	C	SA/C.A.P.E.	Partial	50%	B
Uilkraals	D	SA	Partial	75%	C
Ratel	C	SA	Full	75%	C
Heuningnes	D	SA/C.A.P.E.	Full	75%	A or BAS
Klipdrifsfontein	A	SA/C.A.P.E.	Full	75%	A
Goukou	C	SA/C.A.P.E.	Partial	50%	B
Gouritz	C	SA/C.A.P.E.	Partial	50%	B
Kaaimans	B	SA	Full	50%	B*
Wilderness (Touws)	B	SA/C.A.P.E.	Partial	50%	A or BAS
Swartvlei	B	SA/C.A.P.E.	Partial	50%	B*
Goukamma	B	SA/C.A.P.E.	Full	75%	A*
Knysna	B	SA/C.A.P.E.	Partial	50%	B*
Piesang	C	SA	Partial	50%	B
Keurbooms	A	SA/C.A.P.E.	Partial	50%	A*
Sout (Oos)	A	SA/C.A.P.E.	Full	100%	A*
Groot (Wes)	B	SA/C.A.P.E.	Full	75%	A or BAS
Bloukrans	A	SA/C.A.P.E.	Full	100%	A or BAS
Lottering	A	SA/C.A.P.E.	Full	100%	A or BAS
Elandsbos	A	SA/C.A.P.E.	Full	100%	A or BAS
Storms	A	SA/C.A.P.E.	Full	100%	A or BAS
Elands	B	SA/C.A.P.E.	Full	100%	A or BAS
Groot (Oos)	B	SA/C.A.P.E.	Full	100%	A or BAS
Tsitsikamma	B	SA	Full	50%	B*
Kromme	D	SA/C.A.P.E.	Partial	25%	C*
Seekoei	D	SA/C.A.P.E.	Partial	25%	B*
Gamtoos	C	SA/C.A.P.E.	Partial	50%	A or BAS
Van Stadens	B	SA/C.A.P.E.	Partial	50%	A or BAS

Estuary (West to East)	Current health category	National (SA) and regional (C.A.P.E.) priorities	Recommended extent of protection	Recommended degree of undeveloped margin	Recommended Ecological Category
Maitland	C	SA/C.A.P.E.	Full	75%	C
Swartkops	C	SA/C.A.P.E.	Partial	25%	B
Sundays	C	SA/C.A.P.E.	Partial	50%	A or BAS
Bushman's	B	SA/C.A.P.E.	Partial	50%	A*
Kariega	C	SA/C.A.P.E.	Partial	50%	B
Great Fish	C	SA/C.A.P.E.	Partial	50%	B
Mgwalana	B	SA	Partial	50%	A
Bira	B	SA	Partial	50%	A
Gqutywa	B	SA/C.A.P.E.	Full	75%	A
Keiskamma	C	SA/C.A.P.E.	Partial	50%	B
Ncera	B	SA	Full	75%	B
Gqunube	B	SA	Partial	50%	A
Kwelera	B	SA	Partial	50%	A
Kwenxura	B	SA/C.A.P.E.	Full	75%	A
Quko	A	SA/C.A.P.E.	Full	50%	A
Great Kei	C	SA/C.A.P.E.	Partial	50%	B*
Ncizele	B	SA	Full	75%	B
Nxaxo/Ngqusi	B	SA/C.A.P.E.	Full	75%	A
Ngqwara	A	SA	Full	75%	A
Qora	B	SA/C.A.P.E.	Partial	75%	A
Ngadla	A	SA	Full	75%	A
Nqabara	B	SA	Partial	75%	A
Mbashe	C	SA/C.A.P.E.	Partial	75%	A or BAS
Ku-Mpenzu	B	SA/C.A.P.E.	Full	75%	B
Ku-Bhula/Mbhanyana	A	SA/C.A.P.E.	Full	75%	A
Ntlonyane	B	SA/C.A.P.E.	Full	75%	B
Nkanya	B	SA/C.A.P.E.	Full	75%	B
Sundwana	A	SA	Full	75%	A
Xora	B	SA	Partial	75%	A
Ngakanqa	A	SA	Full	75%	A
Mtata	D	SA	Partial	50%	C*
Lwandilana	A	SA	Full	75%	A
Mtakatye	B	SA	Partial	75%	B
Hluleka	A	SA	Full	75%	A or BAS
Mngazana	B	SA	Partial	50%	B
Mzimvubu	C	SA	Partial	50%	C
Nkodusweni	B	SA	Partial	75%	A or BAS
Mntafufu	B	SA	Full	75%	A or BAS
Mzintlava	B	SA	Full	75%	A or BAS
Mbotyi	B	SA	Partial	50%	A or BAS
Mkozi	A	SA	Full	75%	A
Myekane	A	SA	Full	75%	A
Mkweni	A	SA	Partial	75%	A or BAS
Msikaba	A	SA	Full	75%	A or BAS
Mtentu	A	SA	Full	75%	A or BAS

Estuary (West to East)	Current health category	National (SA) and regional (C.A.P.E.) priorities	Recommended extent of protection	Recommended degree of undeveloped margin	Recommended Ecological Category
Mnyameni	B	SA	Partial	75%	A or BAS
Mtamvuna	B	SA	Full	75%	A or BAS
Mpenjati	B	SA	Partial	75%	A or BAS
Zotsha	C	SA	Partial	50%	C
Mzimkulu	C	SA	Partial	50%	B
Damba	C	SA	Partial	50%	C
Koshwana	C	SA	Partial	50%	C
Intshambili	B	SA	Partial	50%	B
Mhlabatshane	B	SA	Partial	50%	B
Mfazazana	C	SA	Partial	50%	C
Kwa-Makosi	B	SA	Partial	75%	B
Mkomazi	C	SA	Partial	25%	B
Umgababa	B	SA	Full	50%	B
Msimbazi	B	SA	Full	75%	B
Lovu	C	SA	Partial	50%	C
Durban Bay	E	SA	Partial	25%	B
Mgeni	D	SA	Partial	25%	A or BAS
Mhlanga	D	SA	Full	75%	B*
Mhlali	C	SA	Partial	50%	B
Mvoti	D	SA	Full	75%	D
Mdlotane	B	SA	Full	75%	A
Zinkwasi	C	SA	Partial	50%	B
Matigulu/Nyoni	B	SA	Partial	50%	A
Siyaya	F	SA	Full	50%	B*
Mlalazi	B	SA	Full	75%	A or BAS
Mhlathuze/R.Bay	C	SA	Partial	50%	A or BAS
St Lucia/uMfolozi	D	SA	Full	75%	A*
Mgobezeleni	B	SA	Full	75%	A or BAS
Kosi	B	SA	Full	75%	A or BAS

*Recommended condition were determined by an ecological water requirement study, otherwise determined by desktop study.

Appendix E:

Estuary-associated fish species caught in South African fisheries

Table E.1 Estuary-associated fish species caught in South African fisheries, given in order of estuarine dependence category (Table 2.1) and distribution of catches around the coast. Distribution is divided into West coast (Orange River to Cape Point), South Coast (Cape Point to Port Elizabeth), East Coast (Swartkops to Kei River), Transkei and KwaZulu-Kwazulu Natal (Port Edward to Kosi Bay). The three biogeographical provinces are separated by Cape Point and roughly at the Mbashe River in the Transkei (Emanuel *et al*. 1992, Turpie *et al.* 1999, Maree *et al*. 2000a,b).

Species	**Common name**	**Dependence category**	**Distribution**				
			Cool Temperate	**Warm Temperate**			**Sub-tropical**
			West	South	East	Transkei	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
Acanthropagrus 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 sillago	IIc					X
Sarpa salpa	Strepie	IIc		X	X	X	X
Rhabdosargus globiceps	White stumpnose	IIc	X	X	X		
Carcharhinus leucas	Zambezi shark	IIc					X
Strongylura leiura	Yellowfin needlefish	IIc					X
Caranx melampygus	Bluefin kingfish	IIc					X

Species	Common name	Dependence category	Distribution				
			Cool Temperate	Warm Temperate			Sub-tropical
			West	South	East	Transkei	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 uarnak	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**

Table E.2. 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 uarnak	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

Table E.2 continued.

Family	**Species**	**Common name**	**Cate-gory**	CONSERVATION IMPORTANCE **A**	**V**	**R**	**E**	**K**
Mugilidae	*Myxus capensis*	Freshwater mullet	Vb	40	70	40	50	36
	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
	Acanthropagrus berda	Perch/riverbream	IIa	35	100	0	75	64
	Lithognathus mormyrus	Sand steenbras	III	20	0	0	25	14
	Spondyliosoma emarginatum	Steentjie	III	70	80	40	100	21
	Sarpa salpa	Strepie	IIc	67	90	20	100	71
	Sparodon durbanensis	White musselcracker	III	30	100	40	100	71
	Lithognathus lithognathus	White steenbras	IIa	6	100	40	100	50
	Rhabdosargus globiceps	White stumpnose	IIc	20	100	20	100	57
	Diplodus cervinus	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

Appendix F:

Estuary synonym list for KwaZulu Natal estuaries

(Source: Ezemvelo KZN Wildlife)

Table F.1 Estuary synonym list for KwaZulu Natal estuaries (Source: B Escott, Ezemvelo KZN Wildlife)

Estuary Name	SYNONYMS
Bilanhlolo	Ibilanhlolo; Big ibilanhlolo
Bobs Stream	Sharks Bay
Boboyi	Imboyboye
Damba	Domba
Durban Bay	Durban Bayhead
Fafa	iFafa
Intshambili	Ntshambili; Injambili
Isolwane	Zolwane
Kaba	Mkobi; Mkobe; Khaba
Kandandhlovu	Khandandlovu, Kandandlovu, Umkandanhlovu
Kongweni	Inkongweni
Koshwana	Ikotshwana
Kosi	
Ku-Boboyi	
Kwa-Makosi	Makosi
Little Manzimtoti	Little Amanzimtoti
Lovu	Illovu
Mahlongwa	Amahlanga, Amahlongwa
Mahlongwana	Amahlongwana
aManzimtoti	Manzimtoti
Matigulu/Nyoni	Amatikulu, (e) Matikulu, Inyoni
Mbango	Imbonga, Imbango
Mbizane	Mbizana
Mbokodweni	Umbogintwini, umbohodweni
Mdesingane	Mdezingane
Mdlotane	Ndlotane, (u)Mhlutini
uMdloti	Umdloti; Umhloti; Mhloti; Mdhloti
Mfazazana	Mfazazaan; Umfazaan; Umfazazane; Umfazaazan
uMfolozi	Mfolozi, Mfolosi
Mgababa	Umgubaba, Umgababa
uMngeni	Mngeni
Mgobozeleni	Mgobezeleni, Ngoboseleni; Ngobeseleni; Sodwana; Sordwana
Mhlabatashane (Mzimayi2)	Mhlabatshane
Mhlali	eMhlali, uMhlali
Mhlanga	Umhlanga, Ohlanga, Umslanga
Mhlangamkulu	
Mhlangeni	
Mhlatuzane	
Mhlatuze	Mhlathuze, Umhlatuze
Mhlungwa	Umhlungwa
Mkumbane	Inkombane, Umkombana

Estuary Name	SYNONYMS
Mlalazi	Umlalazi
Mnamfu	Unamfu
Mpambanyoni	Mpanbanyoni, Mpambonyoni, Umpambinyoni, Umpambumyani
Mpenjati	
Msimbazi	uMzimbasi, Umzimbezi
Mtentweni	Mtentwana, Ententweni
Mtwalume	Umtwalumi, Mtwalumi
Mvoti	Umvoti
Mvutshini	Little iBilanhlolo
Mvuzi	Uvuzi
Mzimayi	Umzimai
Mzimkulu	Mzimkhulu, Umzimkulu
Mzingazi	
Mzinto	Umzinto
Ngane	Ingane, iNgane
Nhlabane	Hlobane
Nkomba	
Nonoti	
Qhubu	
Reunion (Canal)	
Richards Bay	
Sandlundlu	Inhlanhlinhlu
Seteni	
Sezela	Isizela
Shazibe	
Sipingo	Isipingo
Siyaya	Siaya, Siyani, Siyaní, Siyai
St Lucia	
uThongathi	Tongaat; Tongaati; Thongathi; Umtongate; Tongati
Tongazi	Thongazi, Intongazi
Tugela	Thukela, Tukela
Umhlangankulu (South)	Mhlangankulu
uMkhomazi	Mkomazi, Umkomaas, Mkomanzi
Umlazi	Mlazi
Umtamvuna	Mtamvuna, Mthamvuna
Umzumbe	Umzumbe, Mzumba, Mzamba, Mzumbe
Unknown	aManzimnyama canal
Uvuzana	
Vungu	Uvongo
Zinkwazi	Zinkwasi, Sinquasi; Sinkwazi
Zotsha	Izotsha