C.A.P.E. Regional Estuarine Management Programme

DEVELOPMENT OF A CONSERVATION PLAN FOR TEMPERATE SOUTH AFRICAN ESTUARIES ON THE BASIS OF BIODIVERSITY IMPORTANCE, ECOSYSTEM HEALTH AND ECONOMIC COSTS AND BENEFITS

FINAL REPORT

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EXECUTIVE SUMMARY

Introduction

This study forms part of the Cape Action Plan for the Environment (C.A.P.E.) Regional Estuarine Management Programme. The main aim of the overall programme was to develop a strategic conservation plan for the estuaries of the Cape Floristic Region (CFR), and to prepare detailed management plans for each estuary. The estuary programme was divided into three phases. The first phase, of which this project forms a part, was to establish the overarching conservation plan and prepare detailed management plans for a few selected systems.

The overall objective of this study was to identify (in collaboration with estuarine managers and scientists and the broader stakeholder community) which CFR estuaries should be assigned Estuarine Protected Area (EPA) status and to prioritise estuaries in need of rehabilitation, on the basis of an updated classification of estuaries in terms of health, conservation importance and socio-economic value.

Overall approach

The study focused on the 149 temperate South African estuaries (slightly broader than the limits of the CFR, for biogeographical reasons) and comprised 5 main tasks:

1. *Filling biodiversity data gaps*. This entailed updating botanical, fish and bird data for temperate South African estuaries in order to update the existing biodiversity importance rating of estuaries. This entailed habitat mapping, augmenting the bird database with new bird count data, collecting new fish data and providing the first analysis of comprehensive data collected on fish of several Cape estuaries. The latter part of the study served to investigate the reliability of the fish data collected in a once-off survey by Harrison *et al.* (2000) for use in determining biodiversity importance and for conservation planning.
2. *Update the estuary importance scores*. This was done using the same approach as in Turpie *et al.* (2002, 2004), but with data updated in the above task. In addition, fish importance scores were updated using estimated total fish populations rather than catch data as was done in the previous assessments.
3. *Health assessment*. Several studies have provided health assessments of estuaries, leading to confusion as to which is most accurate. This study sought to analyse the results of comprehensive estuarine health assessments in order to find a reliable rapid method that could be applied more widely using known physical parameters.
4. *Describe economic value of estuaries*. A few studies have been carried out on the economic value of various South African estuaries. Since, comprehensive studies of each system would not be feasible, this study had to come up with a method of estimating the subsistence, recreational/tourism, nursery and existence value of each estuary in the study area. Surveys of the general public and estate agents were carried out to determine how estuarine characteristics influenced their value. Relevant data were also collected for each system using aerial photographs and key informant interviews.
5. *Conservation planning*. This task involved
    a. identifying conservation goals for the CFR and setting quantitative conservation targets for species, vegetation communities and estuary types, and quantitative targets for minimum size, connectivity and other design criteria.
    b. Reviewing existing conservation areas (gap analysis) and assessing the extent to which quantitative targets have already been achieved
    c. Reviewing best practice and developing a method for integrating ecological and socio-economic data in the selection process
    d. Selecting additional estuaries using algorithms to identify preliminary sets of new conservation areas for consideration by managers as additions to established areas, and
    e. Identifying and prioritising systems in need of rehabilitation.

6. *Workshop to obtain stakeholder input*. The detailed methods and results of the above tasks were presented to key members of the estuarine research and management community during a two day workshop. The feasibility of inclusion of each planning unit was agreed upon in plenary, as was a list of planning units (partial or whole estuaries) that should be included as conservation areas. Finally, participants reviewed the health of each estuary and discussed the feasibility, desirability, and priority for rehabilitation.

Biodiversity importance of temperate estuaries

Our current knowledge on the biodiversity of temperate estuaries in South Africa has been well described in Allanson & Baird (1999) as well as in more recent literature, and is not reiterated in detail in this study. This section concentrates on updating existing data sets in order to update the importance rating of South African estuaries, as well as examining the value of the data on which the importance rating is based, and evaluating its usefulness in the conservation planning process.

Gaps in vegetation data included accurate estimates of habitat areas for some estuaries as well as data on habitat areas for some of the smaller estuaries. This study addressed the former gap by undertaking detailed mapping of six of the more important temperate estuaries. This was fewer estuaries than planned due to the time taken to compile maps of sufficient accuracy to be of use for detailed conservation planning and management at a later stage of this process. Habitat areas are known for some 85% of the 149 temperate estuaries in the South Africa, accounting for about 94% of the total area of temperate estuaries. Most unmapped estuaries are very small systems of little conservation importance. Information on the total area of each habitat was also updated.

The rapid survey conducted by Harrison *et al.* (2000) provided fish data on most South African estuaries. This data set is advantageous in that it provides opportunity for comparison. However, comprehensive work that has been carried out on a few systems suggests that there is a high degree of variability and that the rapid surveys might not provide a sufficiently accurate reflection of the fish fauna of estuaries. We entered and analysed the raw data collected over several seasons and several years for eight large temperate estuaries (Lamberth & Clark unpublished data), in order to compare the results obtained from comprehensive versus rapid sampling. Whereas Harrison undertook 4 to 12 seine hauls for each system, our data were the result of 72 to 527 hauls per system. In addition we also repeated a rapid sampling exercise for nine small to medium estuaries, ten years after Harrison's data were collected. The repeated rapid samples were somewhat different from the originals, but the differences within estuaries were still smaller than the differences between estuaries. The comprehensive studies resulted in higher estimates of fish density and species richness, with these differences being positively related to estuary size and diversity. In other words, rapid sampling tends to underestimate the importance of larger, richer systems relative to smaller systems. The biggest discrepancies lay in two of the most common species (*Liza richardsonii* and *Gilchristella aestuaria*). With comprehensive sampling there is a greater probability of catching a large shoal than in a rapid sampling exercise, thus increasing estimates of population sizes in each estuary. The results of comprehensive sampling are sufficiently different that it would e a mistake to mix comprehensive and rapid data in a comparative analysis. It was concluded that the Harrison data provide an adequate estimate of the rank order of estuaries in terms of their importance for fish.

Bird data were similarly sampled once around the country, apart from the Ciskei-Transkei coast, but this was some 25 years ago. The Ciskei-Transkei gap was filled by Turpie *et al.* 2004, and this study updated the data for some 30 estuaries using up-to-date Co-Coordinated Waterbird Counts (CWAC) data. An anomalously high count on the Berg estuary was removed, which lowered its score but not its importance rating.

The fish and bird importance ratings were recalculated using the updated datasets. In the case of fish, the analysis was rerun using estimates of total fish populations rather than sampling catches, based on raw data provided by T. Harrison. The changes, particularly in the latter, resulted in some significant changes in the biodiversity importance ratings of many estuaries, but had a smaller effect on the overall importance rating of estuaries, which also takes other measures into account.

Assessment of estuarine health

Existing information on the health of estuaries was reviewed, and compared with the recent health assessments conducted during Resource Directed Measures (RDM) studies on estuaries. The latter entailed the use of detailed methodology and multiple specialists in order to assess the percentage similarity of each estuary relative to the reference (~ natural) condition. The analysis showed that there was fair congruence between the RDM-generated health scores and Whitfield's (2000) health assessment (in terms of excellent, good, fair or poor condition), although with a correlation coefficient of only 39%. There was no relationship (or possibly even a slight negative relationship) between the RDM scores and the more recent Estuarine Fish Community Index of Whitfield & Harrison (2006). Further analysis of RDM data showed that the RDM health score is slightly better correlated with the percentage of natural Mean Annual Runoff reaching the estuary (%MAR), and that the health of smaller estuaries was more sensitive to the %MAR than larger systems. However these results could not be extrapolated as a rapid health assessment in this study, due to it being impossible to obtain present day MAR data (to calculate %MAR) for all systems within the timeframe and budget of this study. Thus, Whitfield's (2000) assessment is considered to be the best interim measure of estuarine health available at this stage.

Economic value of estuaries

Research into the economic value of estuaries has gained some momentum in the last few years, but valuation studies have only been carried out on a handful of systems. Since this study required an understanding on the value of each of the estuaries in the conservation planning domain, a broader approach was required. Within a modified Total Economic Value framework, we considered the subsistence, property, tourism, nursery and existence value of all temperate estuaries in South Africa (Orange-Mdumbe).

Subsistence value was evaluated using the raw survey data collected as part of the Subsistence Fisheries Task Group assessment (Clark *et al.* 2002). These data were reanalysed to isolate the numbers of fishers, catches and values of individual estuaries throughout the study area. Data were available for 58 of the 149 estuaries, and estimates were interpolated for the remaining systems based on expert knowledge of those systems. Numbers of attendant fishers ranged from none to 135, with most estuaries supporting fewer than 40 fishers. Total estimated subsistence value ranged from zero to R800 000 per estuary, with an average of R70 000.

Property value of estuaries is the premium paid for access to or views of estuaries and represents the value or willingness to pay for that amenity. It is usually estimated using a form of multiple regression (hedonic pricing analysis) or through expert (estate agent) estimates. Property value has been estimated for a handful of South African estuaries. Using data collected for 15 systems, it was found to be very difficult to predict property value on the basis of easily obtainable estuary characteristics. Thus we collated property value data and interviewed estate agents throughout the temperate region, providing a rapid assessment of the property value for each of the remaining systems. Some 77 estuaries had a positive property price premium, ranging from about R1 million to R2 billion per estuary, but most fell in the R10 – 50 million range. The total property value associated with temperate estuaries (i.e. the estuary premium alone) was estimated to be in the order of at least R10.6 billion (a capital value). This value was converted to an annual value akin to the income generated in the property sector, and translates to a total of about R320 million per year.

Tourism value of an estuary is reflected in visitors' expenditure on travel and accommodation. However, only a portion of the recreational experience, and hence part of this expenditure, can be attributed to the estuary itself. Again, detailed studies of this value have only been carried out for a handful of estuaries. Tourism value is not correlated with property value and thus could not be extrapolated in this way. Tourism value was thus estimated by interpolation between estuaries of known value, based on expert understanding of these systems. The majority of estuaries had a tourism value of between R10 000 and R1 million per annum, with a total value of some R2.08 billion in terms of annual turnover generated in the retail and tourism sectors.

The *nursery value* of estuaries is the value that they contribute to marine fishery production as a result of providing nursery areas for commercially or recreationally valuable species. This value has already been estimated on a regional level by Lamberth & Turpie (2003), and was disaggregated to individual systems on the basis of area. The majority of estuaries had a nursery value in the range of R100 000 to R10 million per annum, with a total of R773 million for temperate estuaries.

The *existence value* of estuaries is the feeling of satisfaction that their existence generates. People are willing to pay to maintain that feeling and this willingness to pay (WTP) is used to reflect this value in monetary terms. A previous study suggested that the existence value of all South African estuaries is in the order of R93 million per annum. However, this study required understanding how different systems contribute to that value, recognising that people would have greater affinity to some systems than others. We carried out a Contingent Valuation Survey of some 605 people in the Western Cape. The survey ascertained people's willingness to pay for the conservation of estuaries, but also required respondents to rate a range of different estuaries for which photos and information were provided. The same estuaries were scored in terms of their scenic beauty in a separate survey of 125 respondents. Willingness to pay was related to income and extrapolated by income group. The study again suggested an overall WTP of R90 million for South African estuaries. Respondents mainly took scenic beauty and biodiversity importance into account when rating individual estuaries, but the scores were very well correlated with scenic beauty alone. This allowed extrapolation of scores to all other estuaries based on an independent rating of scenic beauty, and the scores were used to disaggregate the overall WTP for all estuaries in South Africa. In addition, it was ascertained from the survey that poorer members of society favoured higher levels of development around estuaries (average 48%) than wealthier people (average 25%), but nevertheless all felt that at least 50% of estuaries should remain undeveloped.

Development of an integrated conservation plan

Conservation planning is a rapidly 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. This study went one step further in including the estimated economic benefits of conservation as well as the management and opportunity costs.

Conservation planning involves defining the planning domain and planning 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 economic costs. A variety of sophisticated algorithms have been developed for this purpose. We made use of MARXAN (operated via CLUZ), and Excel's SOLVER.

This study was originally required to work within the C.A.P.E.'s terrestrial planning domain. However, since this does not coincide with coastal biogeographic boundaries, the planning domain was extended to include all temperate estuaries, i.e. from the Orange to the Mdumbi estuaries, a total of 149 estuaries. The conservation plan aimed to select planning units that would be managed as no-take estuarine protected areas. All but the smallest estuaries were divided into two planning units, to allow for the possibility of conserving part of an estuary as a no-take area as opposed to only having the option of conserving whole systems.

Targets are often defined in terms of achieving representivity of ecosystem types, habitats and species, as well as meeting population targets that ensure their viability. In the case of estuaries, ecosystem type is generally defined using Whitfield's (2002) five estuary types (bay, river mouth, permanently open, temporarily open and lake). However, these are defined on the basis of physical rather than biotic characteristics. We carried out a multivariate analysis of fish and birds using total abundance data. This suggested that, in the case of fish, geographic location (west to east) and estuary size were the principle determinants of fish communities, and not estuary type. Communities in small estuaries were largely subsets of the communities found in larger estuaries, and the density of fish remains fairly constant across all size groups of estuaries. In the case of birds, four main groupings of estuaries were identified: (A) Large open systems with diverse avifauna, notably waders, (B) brackish, lake-like systems with an abundance of waterfowl, (C) sandy estuaries with a dominance of gulls and terns, and (D) small oligotrophic systems which are depauperate in terms of avifauna. C and D communities are largely subsets of A-type communities, but B-type communities are somewhat different, aligning with the avifauna of freshwater wetlands. Thus in essence, when the focus is put on estuary dependent birds, there is a similar situation as for fish. Thus targets were not set according to estuary type, although it was considered desirable to include a range of physical types in the final protected area set. Habitat targets were set as a percentage of total area of each type. The species targeted were estuary-dependent fish and bird species. Whitfield's (1989) comprehensive listing of estuary dependent fish species was used. Estuary-dependent bird species have not previously been defined and were taken as species for which more than 15% of the regional population would be found in coastal wetlands. Targets were not set for tropical species for which less than 15% of the estuarine population occurs in temperate estuaries. This left a total of 38 fish and 33 bird species for which population targets were set, at 50% of the regional (temperate estuarine) 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 had a good geographic spread, included large as well as small estuaries, and aligned with existing and/or proposed terrestrial and marine protected areas.

Existing protection is weak, with only 2% of the area of temperate estuaries under full protection. These protected areas account for less than 5% of all but one of the habitat targets, and less than 5% of the targeted populations of most fish and bird species.

In selecting the set of protected areas to meet conservation targets, management costs, opportunity costs and the benefits of protection were taken into account, with the aim of achieving conservation targets at the lowest net cost or highest net benefit. Management costs were estimated for six estuaries and this was used to derive a relationship of cost to estuary size, ranging from less than R250 000 to about R2 million per annum. Opportunity costs were considered in terms of the cost of withholding water for alternative uses, since more water would have to be reserved for estuaries with protected status. Based on an analysis of past RDM studies it was estimated that the water sacrifice would amount to roughly 15% of the natural MAR, resulting in a widely differing quantity of water from estuary to estuary. The marginal cost of this water was estimated on the basis of a recent study elsewhere in the country, and adjusted by the water demand score initially devised using data from DWAF, which was applied to each estuary. Thus the cost per unit of water was higher in catchments where the demand was high relative to supply. Some 47% of estuaries would have a total water opportunity cost of less than R1 million per annum, but the remainder are estimated to have potential costs of up to R2.75 billion per annum. The value or benefits of estuaries are described above. These values would be expected to change over time, depending on whether or not the system is under protection. Estimates were made as to how each of the different types of value would change (up or down) with no protection, partial or full protection. This change in value was also taken into account in estimating the overall net cost or benefit of each potential set of protected areas in the iterative site selection procedure.

Site selection algorithms are useful in automating the process of meeting targets subject to constraints. However, they do not substitute entirely for expert understanding. Thus the opinions of the scientific and management community were also taken into account in a two-day workshop. Participants agreed on the estuaries for which protection of the entire estuary would be infeasible, and also agreed on a set of estuaries which ought to be included in the final set. Thus we ran the analysis using (A) an efficiency set, in which only infeasible options were excluded and existing EPAs included, and (B) a consensus set, which also included the estuaries voted for in plenary. Most of these were voted in because of their alignment with terrestrial or marine protected areas, but other reasons included biodiversity importance, special characteristics (e.g. naturally turbid systems) and *de facto* protected status (i.e. inaccessibility).

Ten analyses were conducted, in which five variations of cost were used for the efficiency and consensus set, respectively. This was done in order to demonstrate how different (incomplete) approaches differ in their outcome from a holistic approach in which all costs and benefits are taken into account. Using a minimum set approach, 50 (efficiency) or 60 (consensus) planning units would be required to meet the targets, whereas if all costs and benefits are included, then the optimum set is 122 (efficiency) or 124 (consensus) planning units in order to meet the targets while maximising the net benefits (or minimising net costs). Thus some 80% of estuaries are included in the final set. This is due to the fact that in many cases, the benefits of partial protection outweigh the management and opportunity costs. These estuaries are all selected before additional estuaries are selected to meet outstanding biodiversity targets. The findings of this study suggest that a much greater level of protection of estuaries is desirable from a socio-economic perspective than would be necessary just in order to meet biodiversity conservation targets. This shows the importance of integrating socio-economic considerations into what has up to now been a largely bio-centric process. The partial protection of 80% of estuaries is also desirable from a management perspective, in that it facilitates the introduction of an almost universal sanctuary zone in each estuary which is marked by standard markers, which in turn facilitates the education of the public about the protection system.

Finally, estuaries were prioritised in terms of the need for rehabilitation, and the type of rehabilitation required was described.

Management recommendations

Because of the high number of etuaries involved, it is recommended that all estuaries are zoned using similar types of zones and markings, and that each estuary may contain a fully-protected area, or **sanctuary area** (including a portion of the terrestrial margin which is protected from development and excessive use), and a **conservation area** (which includes the remainder of the terrestrial margin). The latter might be zoned in a number of different ways, depending on the vision and requirements for that estuary. Table 1 below summarises the recommended amount of protection for each of the estuaries in the study area.

Table 1. Summary of the recommended extent of protection required and priority for rehabilitation for each of the estuaries in the study area, giving whether the estuary is part of the core set required to meet biodiversity targets, the extent of protection required (in terms of proportion of targeted habitats and populations requiring full protection in a sanctuary), the recommended proportion of terrestrial marginal area to be included as a no-development area, and the water requirement, designated in terms of the recommended management class. Note that the recommended extent of protection and water requirements should be seen as ideal goals.

Estuary (West to East)	Core biodiversity set	Recommended extent of sanctuary protection	Recommended extent of undeveloped margin	Recommended minimum water requirement (management class)[1]	Priority for rehabilitation (blank = not required)
Orange	Core	Half	50%	B/C[2]	High
Olifants	Core	Half	50%	A/B	High
Verlorenvlei		Half	50%	B/C	High
Berg	Core	Half	50%	A/B	High
Rietvlei/ Diep	Core	Half	50%	A/B	High
Hout Bay		None	-	D	Low
Wildevoëlvlei		None	-	D	Low

[1] Management class denotes the future state of health of the estuary, from A (near natural) to D (functional), and with A-class systems having greater water requirements than D-class systems.
[2] Cannot allow for special water requirement due to cost

Estuary (West to East)	**Core biodiversity set**	**Recommended extent of sanctuary protection**	**Recommended extent of undeveloped margin**	**Recommended minimum water requirement (management class)[1]**	**Priority for rehabilitation (blank = not required)**
Bokramspruit		None	-	D	Low
Schuster		None	-	D	
Krom	Core	All	100%	A/B	
Silvermine		All	25%	B/C	Low
Sand	Core	Half	25%	A/B	High
Eerste	Core	All	75%	A/B	High
Lourens	Core	All	75%	A/B	Med
Sir Lowry's Pass		None	-	D	Low
Steenbras		All	50%	B/C	
Rooiels		All	50%	B/C	
Buffels (Oos)		All	50%	B/C	
Palmiet	Core	All	50%	A/B	
Bot / Kleinmond	Core	Half	50%	A/B	High
Onrus		None	-	D	Med
Klein	Core	Half	50%	A/B	High
Uilkraals		All	75%	B/C	High
Ratel		All	75%	B/C	
Heuningnes	Core	All	75%	A/B	
Klipdrifsfontein	Core	All	75%	A/B	
Breede[3]		Part	25%	B/C	High
Duiwenhoks		None	-	D	High
Goukou	Core	Half	50%	A/B	High
Gourits	Core	Half	50%	A/B	High
Blinde		None	-	D	
Hartenbos		None	-	D	Med
Klein Brak		None	-	D	High
Groot Brak		None	-	D	High
Maalgate		None	-	D	
Gwaing		None	-	D	Med
Kaaimans		None	-	D	
Wilderness	Core	Half	50%	A/B	High
Swartvlei	Core	Half	50%	A/B	High
Goukamma	Core	All	75%	A/B	High
Knysna	Core	Half	50%	A/B	High
Noetsie	Core	Half	50%	A/B	
Piesang		None	-	D	Med
Keurbooms[4]	Core	Half	50%	A/B	High
Matjies		None	-	D	
Sout (Oos)	Core	All	100%	A/B	
Groot (Wes)	Core	Half	75%	A/B	High
Bloukrans	Core	All	100%	A/B	
Lottering	Core	All	100%	A/B	Low
Elandsbos	Core	All	100%	A/B	Low
Storms	Core	All	100%	A/B	
Elands	Core	All	100%	A/B	Low
Groot (Oos)	Core	All	100%	A/B	Low

[3] Included post-hoc due to stakeholder concern for its biodiversity importance, but cannot allow for special water requirement due to cost

[4] Included Keurbooms instead of Piesang due to biodiversity importance, but it may not be possible to make special provision for water due to cost.

Estuary (West to East)	Core biodiversity set	Recommended extent of sanctuary protection	Recommended extent of undeveloped margin	Recommended minimum water requirement (management class)[1]	Priority for rehabilitation (blank = not required)
Tsitsikamma		None	-	D	Low
Klipdrif		None	-	D	Med
Slang		None	-	D	Low
Kromme	Core	Half	50%	A/B	High
Seekoei	Core	Half	50%	A/B	High
Kabeljous		Half	50%	B/C	High
Gamtoos	Core	Half	50%	A/B	High
Van Stadens	Core	Half	50%	A/B	
Maitland	Core	All	75%	A/B	Low
Swartkops	Core	Half	50%	A/B	High
Coega (Ngcura)		None	-	D	
Sundays	Core	Half	50%	A/B	High
Boknes		None	-	D	
Bushman's	Core	Half	50%	A/B	High
Kariega	Core	Half	50%	A/B	High
Kasuka		Half	50%	B/C	
Kowie		Half	50%	B/C	High
Rufane		None	-	D	
Riet		All	75%	B/C	
West Kleinemonde		Half	50%	B/C	
East Kleinemonde		Half	50%	B/C	
Klein Palmiet		None	-	D	
Great Fish	Core	Half	50%	A/B	High
Old woman's		All	75%	B/C	Low
Mpekweni		Half	50%	B/C	Med
Mtati	Core	Half	50%	A/B	
Mgwalana		Half	50%	B/C	
Bira		Half	50%	B/C	
Gqutywa	Core	All	75%	A/B	
Blue Krans		None	-	D	
Mtana		All	75%	B/C	
Keiskamma	Core	Half	50%	A/B	High
Ngqinisa		All	75%	B/C	
Kiwane		All	75%	B/C	
Tyolomnqa		Half	50%	B/C	Low
Shelbertsstroom		None	-	D	High
Lilyvale		All	50%	B/C	
Ross' Creek		None	-	D	
Ncera		All	75%	B/C	
Mlele		All	75%	B/C	
Mcantsi		All	75%	B/C	Med
Gxulu		Half	50%	B/C	High
Goda	Core	All	75%	A/B	
Hlozi		None	-	D	
Hickman's		All	75%	B/C	Low
Buffalo		None	-	D	High
Blind		None	-	D	Low
Hlaze		None	-	D	High
Nahoon		None	-	D	High

Estuary (West to East)	Core biodiversity set	Recommended extent of sanctuary protection	Recommended extent of undeveloped margin	Recommended minimum water requirement (management class)[1]	Priority for rehabilitation (blank = not required)
Qinira		Half	50%	B/C	
Gqunube		Half	50%	B/C	Med
Kwelera		Half	50%	B/C	Med
Bulura		Half	50%	B/C	Med
Cunge		None	-	D	
Cintsa		Half	50%	B/C	Med
Cefane		Half	50%	B/C	
Kwenxura	Core	All	75%	A/B	
Nyara		All	75%	B/C	
Haga-haga		All	75%	B/C	
Mtendwe		All	75%	B/C	
Quko	Core	Half	50%	A/B	
Morgan		None	-	D	Med
Cwili		None	-	D	Low
Great Kei	Core	Half	50%	A/B	Low
Gxara		All	75%	B/C	Low
Ngogwane		All	75%	B/C	Low
Qolora		All	75%	B/C	
Ncizele		All	75%	B/C	
Kobonqaba		All	75%	B/C	Low
Nxaxo/Ngqusi	Core	All	75%	A/B	
Cebe		All	75%	B/C	
Gqunqe		All	75%	B/C	
Zalu		All	75%	B/C	
Ngqwara		All	75%	B/C	
Sihlontlweni/Gcini		All	75%	B/C	
Qora	Core	Half	75%	A/B	
Jujura		None	-	D	Low
Ngadla		All	75%	B/C	Low
Shixini	Core	All	75%	A/B	Low
Nqabara		Half	75%	B/C	
Ngoma/Kobule		All	75%	B/C	
Mendu		All	75%	B/C	
Mbashe	Core	All	75%	A/B	Low
Ku-Mpenzu	Core	All	75%	A/B	
Ku-Bhula/Mbhanyana	Core	All	75%	A/B	
Ntlonyane	Core	All	75%	A/B	
Nkanya	Core	All	75%	A/B	
Xora		Half	75%	B/C	
Bulungula		All	75%	B/C	
Ku-amanzimuzama		None	-	D	
Mncwasa		All	75%	B/C	
Mpako		All	75%	B/C	
Nenga		All	75%	B/C	
Mapuzi		All	75%	B/C	Med
Mtata		None	-	D	High
Mdumbi	Core	Half	75%	A/B	

This study is well poised to provide important input into the development of broader plans which will affect the direct management of and water supply to estuaries. This study has made recommendations as to the final set of estuaries to be afforded some level of protection, and how much protection there should be. Although there has been stakeholder input to this process, it will be necessary for DEAT and DWAF to formally endorse the conservation plan laid out in Table 1, before proceeding with the next steps.

The next step on the road towards implementing an estuarine protected area system is to develop a set of management plans for each of the estuaries in the region. Under the C.A.P.E. programme, this will cover estuaries from the Olifants to the Swartkops (i.e. within the Cape Floristic Region). Thus the onus will be on Marine and Coastal Management to ensure that the programme is extended to other parts of the country. It is recommended that DEAT (MCM) also undertakes a conservation planning exercise for the estuaries of subtropical region (all estuaries north of Mdumbi estuary), and extends the C.A.P.E. initiative to include all South African estuaries.

Development of a management plan for each estuary should include defining the spatial extent of the sanctuary zone, based on expert knowledge of the targeted habitats and populations, to ensure that the recommended level of protection (Table 7.1) is met.

Following the completion of the management plans, it will be necessary to gazette the relevant aspects of the plans. This could be done in batches, as it may take several years to complete management plans for all the estuaries.

A standard system of communication (e.g. flags, map styles, zone types and names) needs to be developed so that people familiar with the set up on one estuary will easily understand it on any other estuary. Management plans should also be similarly written in a uniform style.

Management plans should make provision for monitoring the success of the conservation actions on estuaries. Conservation and management strategies should be reviewed and updated from time to time, using an adaptive management philosophy.

TABLE OF CONTENTS

1. INTRODUCTION

This study forms part of the Cape Action Plan for the Environment (C.A.P.E.) Regional Estuarine Management Programme. The main aim of the overall programme was to develop a strategic conservation plan for the estuaries of the Cape Floristic Region (CFR), and to prepare detailed management plans for each estuary. The estuary programme will be divided into three phases. The first phase, of which this project forms a part, is to establish the conservation plan and prepare detailed management plans for a few selected systems. The latter involved piloting the proposed National Estuarine Management Protocol (van Niekerk *et al.* 2004), paving the way for preparation of management plans for the remaining systems. This study concentrates on the development of the overarching conservation plan.

Conservation planning is a rapidly evolving area of research in which numerous approaches have been explored around the world in recent years. Systematic conservation planning replaces the somewhat *ad hoc* way of selecting conservation areas in the past, and is becoming increasingly holistic in terms of ecological goals and in terms of integrating conservation and development needs in a region.

Having first concentrated on the representation of species, conservation 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 relevant processes, finding spatial surrogates for these, and setting targets for them (Pressey *et al.* 2003). Another key challenge is delivering a plan that not only achieves representativeness but which ensures the persistence of targeted populations and maintenance of biodiversity (Reyers *et al.* 2002). In many respects, the C.A.P.E. programme has set the standard for systematic conservation planning (Balmford 2003). Much of its success has been attributed to its two-pronged approach of involving stakeholders early on in the process, coupled with scientific rigour, resulting in wide ownership of the terrestrial conservation plan. The C.A.P.E. planning processes also yielded some important lessons, such as the fact that species-level planning cannot be entirely substituted by a habitat-based approach (Balmford 2003).

In addition, it is becoming increasingly recognised that conservation planning cannot take place in isolation of an understanding of socio-economic pressures and values. There have been some attempts to incorporate species geography and human development patterns in order to assess vulnerability in conservation planning (Abbitt *et al.* 2000). Nevertheless, while there has been some consideration of the direct costs involved (e.g. Balmford *et al.* 2000, Frazee *et al.* 2003, Moore *et al.* 2004), there has been little integration of ecological and economic considerations in regional-level planning initiatives (see Faith & Walker 2002). Socio-economic factors are also potentially very important in identifying the most appropriate types of conservation intervention. Thus resource economics is playing an increasing role in conservation planning.

While many South African estuaries do enjoy some level of conservation status, there is still a need for a systematic, integrated conservation plan which integrates inputs from a range of stakeholders as well the scientific community. This has already been recognised as one of the priorities for the C.A.P.E. programme. A substantial amount of work has already been carried out on estuaries which can inform this process. Among numerous studies which collate information on South African estuaries, Turpie (1995) prioritised estuaries in terms of waterbirds in a test of alternative site selection methods for conservation, Maree & Whitfield (2003) performed a similar analysis of fish, and Colloty *et al.* (2001) and subsequent work established the botanical importance of a large proportion of South African estuaries. In a collaborative effort of the estuarine research community these analyses were later updated using complementarity analysis to produce a minimum representative set of estuaries, taking plants, invertebrates, fish and birds into account (Turpie *et al.* 2002), which was also adopted by the National Spatial Biodiversity Assessment (Driver *et al.* 2004). As part of the Eastern Cape Estuaries Management Programme and in collaboration with both estuary managers and scientists, Turpie (2004a) also developed guidelines for a strategy for the conservation of estuarine biodiversity in South Africa, which included the proposal for three types of estuary management: estuarine protected areas (EPAs), co-managed estuarine conservation areas (ECAs) and estuarine management areas (EMAs), which together provide for active management of *all* estuaries in the country.

The latter studies all acknowledged a need to improve some of the datasets, and the need to take socio-economic considerations into account before finalising a set of estuarine protected areas, such as the trade-offs involved in estuary development and in the allocation of freshwater flows to alternative uses. Working towards this goal, Turpie *et al.* (2004) collated much of the existing data on all South African estuaries, identified ongoing data collection efforts and undertook additional work to fill some key gaps, while Turpie & Hosking (2005) collated existing work on the economic value of estuaries. Following national-level work on the value of estuaries in terms of their fisheries (Lamberth & Turpie 2003), Turpie (2005) recently conducted a pilot study on the estuarine attributes that generate different types of value (e.g. tourism value, existence value), the results of which informed the design of this study.

The overall objective of this study was to identify (in collaboration with estuarine managers and scientists and the broader stakeholder community) which CFR estuaries should be assigned protected area (PA) status and to prioritise estuaries in need of rehabilitation, on the basis of an updated classification of estuaries in terms of health, conservation importance and economic value. The study was broadened to include all temperate South African estuaries, since the CFR falls within this larger biogeographical zonation.

2. STUDY APPROACH

2.1 Task 1. Filling biodiversity data gaps

Turpie *et al.* (2004) undertook an analysis of all data available for South African estuaries and augmented this by collecting additional data on estuarine invertebrates. The updated database was used to update estuary importance scores developed by Turpie et a. (2001). However, it was acknowledged that there were some important deficiencies in this data. Some of the main issues that apply to the CFR estuaries are that (i) size data are incomplete and are questionable for certain systems, (ii) the botanical data is severely out of date and habitat maps are only available for a few systems (iii) importance for fish is based on Harrison's rapid sampling of all estuaries, but the robustness of these have not yet been tested data to establish whether they should be augmented with more comprehensive sampling, (iv) comparable invertebrate data are only available for a few systems, species richness has been modelled, but the model has not been tested by ground-truthing, and (v) bird data for many systems is some 25 years out of date.

2.1.1 Vegetation/habitat mapping

Detailed mapping was carried out for seven of the largest and most important systems, in order to better inform both the health and importance assessments. Mapping was carried out in GIS, and was ground-truthed. It was originally proposed to do ten systems, but the number had to be reduced due to budgetary and time constraints, with some systems taking up to over 30 person-days to complete the GIS work alone.

2.1.2 Fish data

Several estuaries in the C.A.P.E. region have been comprehensively sampled over the past few years, but most of these data existed only in raw form (datasheets) and have not been analysed. Comprehensive data were collated and entered for twelve systems (Lamberth unpublished, Clark unpublished), with up to 298 seine net samples per system. In addition, another nine estuaries were sampled to augment Harrison's data (filling gaps) and to provide additional data on small estuaries for comparison with Harrison *et al.* (2000). The results for these systems were then compared with the results from the Harrison data set, which extends to most estuaries in the country. The objective was to ascertain if the Harrison data could reliably indicate the relative importance of different systems, or if any adjustment would need to be made to this data set.

2.1.3 Bird data

There are numerous gaps in the bird data that were available at the time of Turpie *et al.*'s (2002) importance analysis. Additional count data were collated from existing sources and by direct counts for 30 systems. In addition, data used in previous analyses were updated to reflect more recent data where possible. The bird importance scores were then updated.

2.2 Task 2. Assessment of conservation importance

Conservation importance of estuaries was tackled in terms of the abundance of habitats and species that they contain and in terms of their ecological functions, including in a broader coastal context. This builds on existing evaluations (e.g. Turpie *et al.* 2002, 2004) and the data collected in Task 1. Note that the conservation importance may form an input into conservation planning but is not the only basis of selection of a set of protected areas.

However, conservation importance will play an important role in determining the freshwater inputs and should be an important factor in devising the management plan for an estuary.

This desktop task involved updating the data sets described in Turpie *et al.* 2004 with additional available data and the data collected in Task 1, checking and refining the scoring index where necessary, and applying this to updated data to reclassify estuaries in terms of their conservation importance.

2.3 Task 3. Health assessment

The health state of South African estuaries has been estimated by several authors using a variety of indicators concentrating on different aspects of estuaries. Concern about the condition of South African estuaries grew in the 1970s, when it was already noted that few estuaries remained in a near pristine condition, particularly in KwaZulu-Natal (Heydorn 1972, 1973 in Morant & Quinn 1999). In his assessment of the condition of KwaZulu-Natal estuaries, Begg (1978) found only 20 out of 72 estuaries to be in a good condition. Heydorn & Tinley (1980) conducted a review of the estuaries of the former Cape Province (from the Orange to the Great Kei), and this was followed by a national assessment of the condition of South African estuaries (Heydorn 1986). Ramm (1988, 1990) used fish as an index of community degradation, and Harrison *et al.* (2001) estimated the health of all South African estuaries on the basis of their fish communities, water quality and an aesthetic index. The most recent broad scale assessment of estuarine health is by Whitfield (2000). Harrison's work has since been updated to a new index, though based primarily on biotic characteristics (Harrison & Whitfield 2006). Although several assessments have been made that incorporate CFR estuaries, there is not always agreement as to the state of health of individual systems. In addition to the broad scale assessments, a comprehensive index of estuarine health was developed by Taljaard, Turpie and Adams in conjunction with the estuarine community, for use in the setting of the freshwater Reserve (Resource Directed Measures - RDM). This has been applied to several estuaries around the country, including the Olifants, Breede, Tsitsikamma, Kromme and Seekoei estuaries in the CFR.

Given the amount of information available, it was proposed that this task involved analysis of the data for estuaries for which RDM health studies have been carried out, in order to test the reliability of simple predictors of health (e.g. % MAR, estuary size), and updating of the existing health assessments of all CFR estuaries, as necessary, using improved physical data (e.g. estimates of %MAR, or improved size estimates) in order to produce a rapid-level classification of CFR estuaries in terms of health.

2.4 Task 4. Describe the economic value of estuaries

Estuaries provide goods and services which generate a range of economic values and contribute to national income. Although Costanza *et al.* (1997) provided a rough estimate of the average *global* value of estuaries (US$22 832 per ha per year) which suggested they were highly valuable; there have been very few empirical studies of the economic value of estuaries. A few studies have been carried out on individual systems in South Africa, the most comprehensive work having taken place in the Knysna estuary. Such studies are costly and time-consuming, however. In anticipation of this study, a pilot study was carried out (Turpie unpublished data) which explored the possibility of finding predictors of different types of value generated by estuaries, so that estimates could be made on the basis of more solid data rather than simply scoring based on expert opinion. The results of the pilot study suggested that there are some predictive relationships and that this avenue was worth pursuing further.

In order for this task to inform the conservation planning exercise it was necessary to identify the types of values and trade-offs that would be relevant. These include values associated with biodiversity conservation (such as existence value and indirect use value), and values associated with consumptive or non-consumptive use (such as subsistence and recreational values), as well as the values associated with catchment developments that put demands on water quantity and quality. Recognising that some of these values will be difficult to estimate accurately, it was also necessary to decide on the most appropriate measures to use in the study. In summary, this task involved the following:

1. Identifying economic values and trade-offs that need to be considered in conservation planning;
2. Collating existing information on subsistence/commercial use of CFR estuaries;
3. Gathering relevant economic data on tourism and property values;
4. Gathering relevant economic data on water demand and value;
5. Using existing data to assess the indirect (e.g. nursery) value of fisheries;
6. Augmenting existing data on non-use value (survey W Cape residents); and
7. Classifying estuaries in terms of their economic importance.

2.5 Task 5. Conservation planning

The aim of this task was to design a conservation plan that would meet biodiversity targets at minimal economic cost, taking opportunities and constraints into consideration, and to prioritise estuaries in need of rehabilitation.

The identification of a network of protected estuaries required consideration of the representation of different types of estuaries and estuarine biodiversity, and the long-term maintenance of species, communities and ecological processes. The conservation plan also needed to take into account the sensitivity of systems to perturbation, irreplaceability, vulnerability of particular species, existing threats and socio-economic trade-offs. Synergistic and antagonistic relationships between aspects of ecosystem health and socio-economic value were identified and taken into consideration as far as possible. This project also took into consideration the C.A.P.E.'s marine, terrestrial and freshwater conservation planning initiatives such as the Garden Route Initiative and the Kogelberg Biosphere Reserve Initiative, and other national-level initiatives where appropriate.

The task involved the following:

1. Identifying conservation goals for the CFR and setting quantitative conservation targets for species, vegetation communities and estuary types, and quantitative targets for minimum size, connectivity or other design criteria;
2. Reviewing existing conservation areas (gap analysis), and assessing the extent to which quantitative targets have already been achieved;
3. Reviewing best practice and developing a method (e.g. algorithms) for integrating ecological and socio-economic data in the selection process;
4. Selecting additional estuaries using algorithms to identify preliminary sets of new conservation areas for consideration by managers as additions to established areas;
5. Identifying and prioritising systems in need of rehabilitation.

2.6 Task 6. Workshop to obtain stakeholder input

The detailed methods and results of the above tasks were presented to key members of the estuarine research and management community during a two day workshop. The workshop provided an overview of the project and its aims and the proposed conservation planning approach, as well as feedback on the results of the biodiversity and economics studies. Proposed conservation targets and the definition of estuary protection were discussed and agreed upon. Participants were given the opportunity to make individual votes on the estuaries they thought should or should not be included in a conservation plan. The feasibility of including each planning unit was agreed upon in plenary, as was a list of planning units (partial or whole estuaries) that should be included as conservation areas. Finally, participants reviewed the health of each estuary and discussed the feasibility and desirability of rehabilitation, and its relative priority. The input gained from the workshop was then used to finalise the conservation plan.

3. BIODIVERSITY IMPORTANCE OF TEMPERATE ESTUARIES

3.1 Introduction

Our current knowledge on the biodiversity of temperate estuaries in South Africa has been well described in Allanson & Baird (1999) as well as in more recent literature. Turpie *et al.* (2002) collated existing biophysical data in order to determine the relative conservation importance of all South African estuaries, and identified several important data gaps. Following further work on estuaries, the importance rating was updated by Turpie *et al.* (2004). In general there is information on broad habitat areas, fish and birds for a large proportion of estuaries, but detailed information on invertebrates is available for a small percentage of systems. Turpie *et al.* (2004) attempted to circumvent this problem by collecting and collating data from enough systems to be able to predict invertebrate species richness for each system. Better data on the presence, abundance and biomass of invertebrates will take years of dedicated research. This study thus focussed on the habitats, fish and birds of temperate estuaries, and these groups formed the focus of the conservation planning exercise. It was assumed that adequate conservation of the latter groups would take care of the invertebrates, though it must be noted that there will always be exceptions to this type of rule.

The aim of this task was to improve our understanding on habitats, fish and birds as far as was feasible within the limitations of this study. This included assessing the usefulness of existing data sets in terms of determining the biodiversity importance of estuaries and for setting biodiversity conservation targets. In addition, since conservation planning often involves setting targets for ecosystem types, we sought a typology of estuaries from a biodiversity perspective and evaluated the current typologies from this perspective.

3.2 Vegetation

3.2.1 Improving existing data set with detailed mapping

The aim of this exercise was to produce detailed vegetation maps for some of the more important systems for which vegetation data were poor. These data were required for conservation planning exercises for this and other components of the C.A.P.E. estuaries programme. The original aim was to produce detailed present vegetation and habitat maps for 16 estuaries, viz.

- **5 priority estuaries:** Olifants, Klein, Heuningnes, Breede & Gamtoos
- **11 others:** Palmiet, Kleinmond, Bot, Uilenkraals, Duiwenhoks, Goukou, Gouritz, Groot Brak, Knysna, Keurbooms/Bitou & Swartkops.

However, the mapping exercise proved extremely time consuming, and only six maps could be produced with the available budget: Olifants, Klein, Heuningnes, Gouritz, Keurbooms/Bitou and Gamtoos. The approach of fewer detailed maps rather than many rough maps was taken because ultimately it is hoped that all the estuaries will be mapped in detail, providing a basis for site-level conservation planning and monitoring.

The task involved a two step process in which vegetation mapping was done firstly at a crude scale using historic as well as recent satellite and aerial photographs (Figure 3.1). These vegetation maps were later updated/confirmed/corrected through ground-truthing work using GPS field mapping at each site, in which vegetation was recorded at a number of points and boundaries between different vegetation communities recorded as a series of polylines using a GPS system operated with ArcPad 7 (Figure 3.2 and Figure 3.3). Photographs and plant specimens were also taken during the field surveys.

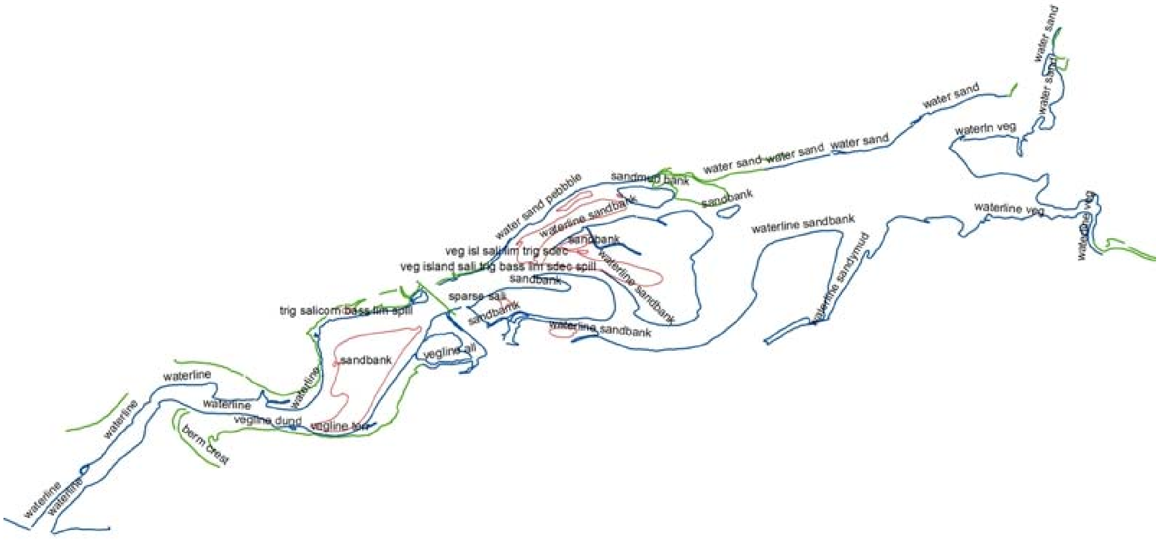


Figure 3.1. Example of basic data collected on site using GPS.

Figure 3.2. Example of ground-truthing an aerial photograph using GPS points

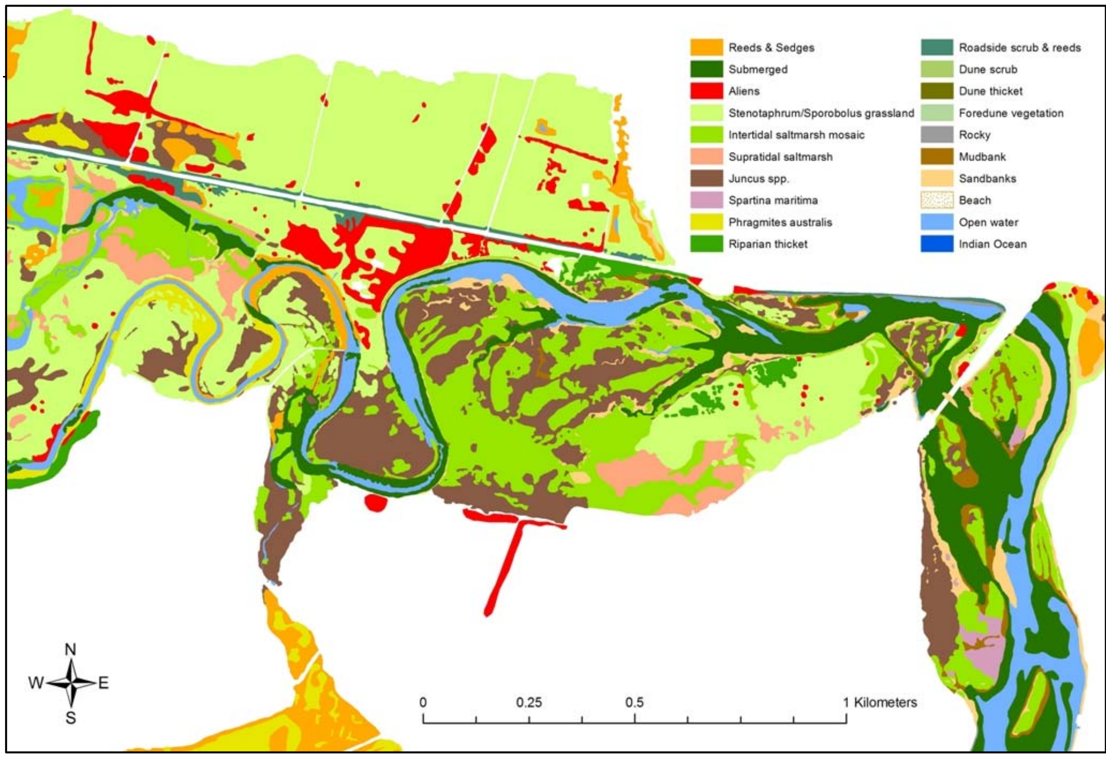


Figure 3.3. The level of detail provided by vegetation maps completed for this project.

3.2.2 Results

The six estuary maps are shown in Appendix 1. The area data were used to update the existing estuary vegetation database based on Colloty *et al.* (2001).

The current layout of the Heuningnes estuary mouth area differed substantially from the aerial photograph, giving an indication of the dynamic changes in its mouth (Figure 3.4). In addition, the areas mapped as estuarine far exceeded the area considered to be estuary in the 'green book' (Bickerton 1984) on the Heuningnes estuary (Table 3.1).

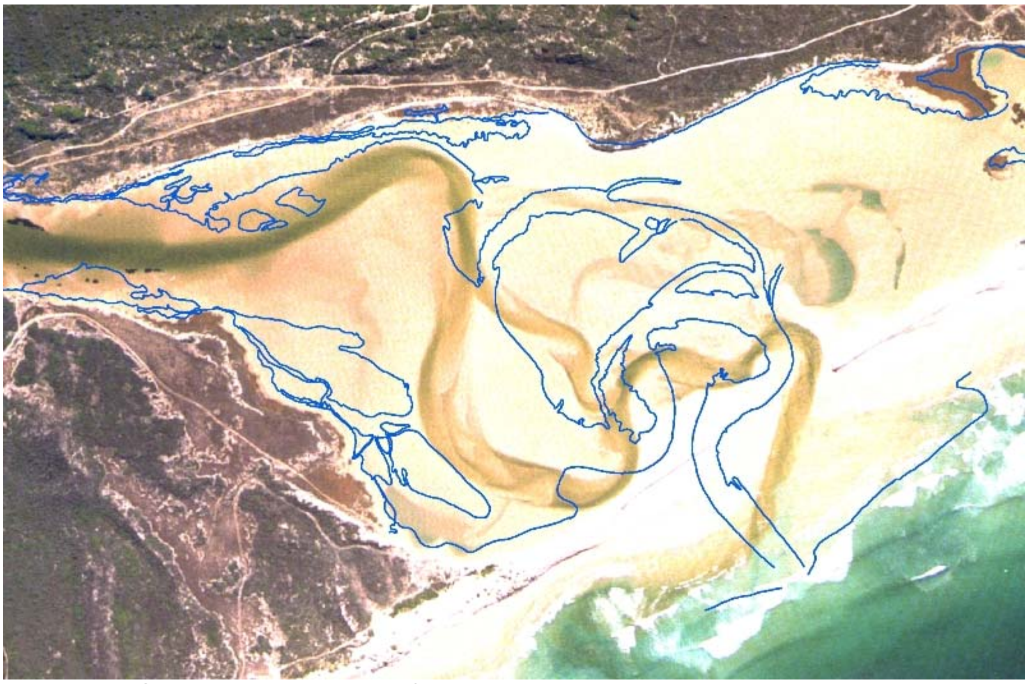


Figure 3.4. Changes in the mouth of the Heuningnes estuary

Table 3.1. Habitat areas estimated in this study compared with those given in Bickerton (1984) for the Heuningnes estuary

	Area 2006 (ha)		Bickerton (1984) values
Estuarine water area	52.98	Water	39.37
Saltpans	46.31		
Sandbanks	42.61	Sand	101.86
Intertidal saltmarsh	5.53		
Saltmarsh sedges and rushes	89.09		
Sarcocornia saltmarsh	68.37		
Supratidal saltmarsh	38.59	Saltmarsh	28.15
Floodplain mosaic saltmarsh	186.02	Grazed flood plains	69.72
Reeds and sedges	7.67	Reed swamps	3.13
Submerged macrophytes	27.19		
Total	**564.36**	**Total**	**242.23**

3.2.3 Summary of habitat areas in temperate estuaries

The areas of different habitats have been estimated for a total of 127 of the 149 temperate estuaries considered in this study (Table 3.2). Most of the estuaries for which data are missing are small (Table 3.3). Thus while area estimates have only been made for 85% of estuaries, this covers 94% of the total area of 25 095 ha. Whereas some habitats are fairly common (unvegetated channel area, which accounts for some 45% of the estuarine area, and reeds and sedges), others are rare in the study area (swamp forest and mangroves).

Table 3.2. Estimated total area of each habitat type within temperate estuaries.

Habitat	Area (ha)	% of total area	% of estuaries in which habitat occurs (n = 127)
Supratidal salt marsh	3 997	17.0	54
Intertidal salt marsh	1 829	7.8	37
Reeds and sedges	2 413	10.2	90
Swamp forest	6	0.03	2
Mangroves	90	0.4	6
Sand/mud banks	3 228	13.7	83
Submerged macrophytes	1 289	5.5	36
Channel	10 516	44.6	99
Rocks	206	0.9	18
Total	**23 573**		

Table 3.3. Estuaries for which habitat area data are missing. Estuaries of unknown area were assumed to be 2 ha in subsequent analyses.

Estuary	Area (ha)	Estuary	Area (ha)
Rietvlei/Diep	515	Lottering	17
Bokramspruit	?	Elandsbos	6
Shuster	?	Elands	5
Krom	?	Groot (East)	5
Ratel	10	Klipdrif	?
Klipdrifsfontein	?	Slang	?
Blinde	?	Rufane	?
Klein Brak	96	Klein Palmiet	?
Maalgate	14	Shelbertstroom	?
Gwaing	?	Ross’s Creek	?
Kaaimans	8	Hlozi	?
Matjies	?	Blind	?
Bloukrans	5	Cunge	?

3.3 Fish

3.3.1 Introduction

Much of the current understanding on fish populations in the region under consideration has been summarised by Whitfield (1998). He reports that from a fish perspective, two biogeographic regions are recognisable – a cool temperate west coast region which includes all estuaries on the west coast and a warm temperate south coast region which includes estuaries between Cape Point and the Mbashe River. The cool temperate estuaries are reportedly low in diversity and are dominated by relatively few species, most of which are endemic to southern Africa. Warm temperate estuaries are considered transitional between the cool temperate estuaries to the west and the warm temperate systems to the east, and most contain species that are representative of all three biogeographic regions. The warm temperate estuaries harbour a higher diversity than the cool temperate west coast systems but less than the subtropical systems. The warm temperate and subtropical estuaries, however harbour a lower proportion of endemic species than do the cool temperate estuaries.

Whitefield (1998) also splits fish species found in estuaries (termed estuary-associated fish species) into five different categories of together with a number of sub-categories:

I. Estuarine residents:
   a. Breeding only in estuaries
   b. Breeding mainly in estuaries
II. Marine migrants whose juveniles are:
   a. Wholly estuary dependent
   b. Mainly estuary dependent
   c. Weakly estuary dependent
III. Marine stragglers
IV. Freshwater migrants
V. Catadromous migrants:
   a. Obligate freshwater phase
   b. Facultative freshwater phase

Species in categories Ia, IIa, and Va are considered wholly dependent on estuaries, while those in categories Ib, IIb and c, and Vb are considered partially dependent on estuaries. At least 21% of the fish species (32 species) that occur in estuaries in South Africa are considered to be entirely dependent on estuaries, while a further 45% (71 species) are considered partially dependent on these systems (Whitfield 1998). This distinction is important from a conservation perspective, as species that are wholly or partially dependent on estuaries must be given priority over those that simply use estuaries opportunistically. Similarly, endemic species and those whose core distribution range falls within the Cape region should be prioritised over those ranges overlap only partially with the Cape region.

3.3.2 Overview of available fish data

Surveys have been completed for fish populations in most estuaries between the Orange and the Mdumbi. Turpie *et al.* (2004) lists only 11 estuaries for which fish surveys have not been completed. Without a doubt the most extensive of these surveys was completed by Harrison *et al.* (2000) who sampled fish populations in 138 out of the 149 estuaries in this region. Most other surveys have covered one or two estuaries only, with some covering up to 10 systems (e.g. Vorwerk *et al.* 2003). While many of these data sets provide detailed coverage of the estuaries in question, including seasonal and inter-annual variability, variations in the gear used, the sampling approach, and sampling intensity, mean that comparisons between surveys are not necessarily valid. This is of some concern from a conservation planning perspective, as it is assumed that data available for each system is equivalent. This is particularly concerning in the case of an estuary that is not particularly species rich but has been surveyed very intensively and as a result has a high species count, and as such is rated more highly than a species rich system that has only been surveyed in a cursory manner and has a low species count. There is likely to be a trade-off therefore, between using the most comprehensive data available for each system or possibly the most recent survey data for each system, versus using data that is known to be comparable between systems.

3.3.3 Analysis of the implications of using the Harrison data set

Its is our contention that the use of comparable data offers greater benefits from a conservation planning perspective provided that it does indeed provide an accurate and comparable perspective on all estuaries in the planning domain. For this reason we elected to use data from Harrison *et al.* (2000) but cross checked this against recent data collected specially for this purpose (as part of this study) as well as comprehensive data available for a number of key systems in the region covering a range of different estuary types and sizes.

Several estuaries in the C.A.P.E. region have been comprehensively sampled over the past few years, but most of these data existed only in raw form (datasheets) and have not been analysed. Comprehensive data were collated and entered for eight systems (Lamberth unpublished, Clark unpublished; Table 3.4), with up to 527 seine net samples per system. Up to 67 000 data points were entered per estuary.

The results for these systems were then compared with the results from the Harrison data set (Harrison *et al.* 2000), which extends to most estuaries in the country. The objective was to ascertain if the Harrison data would reliably indicate the fish fauna and relative importance of different systems, or if any adjustment would need to be made to this data set.

Table 3.4. Estuaries for which comprehensive fish data were collated

Estuary	Size	Seine hauls by Harrison	Seine hauls this study
Olifants	416.8	8	73
Berg	2 078.9	12	527
Diep	515.0	4	106
Heuningnes	172.5	9	36
Breede	455.3	10	298
Duiwenhoks	203.1	8	76
Gouritz	112.6	5	72
Goukou	154.8	7	72

In addition, seine net surveys were conducted of a total of nine estuaries spanning a range of sizes (1-270 ha) and estuary types (permanently open, and temporally open/closed system). One of these systems (the Bokramspruit) had been omitted from Harrison's *et al.* (2000) survey. Number of hauls per estuary ranged from 1-10, with a total of 54 hauls across all nine systems.

Table 3.5. Estuaries for which additional fish data were collected

Estuary	Size (ha)	Seine hauls by Harrison	Seine hauls this study
Bokramspruit	-	0	2
Schuster	-	4	1
Onrus	41.1	4	4
Uilkraals	104.7	4	10
Blinde	-	3	5
Maalgate	13.5	3	5
Kaaimans	8.0	3	8
Groot (Wes)	38.5	10	9
Goukamma	270.0	5	10

Data on the abundance and biomass of fish in these estuaries is presented in Table 3.6 and Table 3.7. Total area sampled amounted to nearly 14 000 m^2.

Data from these estuaries were then compared with data collected by Harrison *et al.* (2000), to evaluate to what extent differences in the timing of the sampling and the time elapsed between surveys (more than 10 years for most systems) had affected the results. A multivariate comparison of these data indicated that the relative similarity of the faunal composition within systems across the two surveys (based on the species composition and abundance of fish in the two surveys) is greater than that between systems (as indicated by the relative differences among and between different estuaries on an ordination plot - Figure 3.5). This analysis suggests at a superficial level at least, that data collected by Harrison *et al.* (2000) remain valid for conservation planning purposes at this time. However it does also highlight the variability in the results in systems for which sample sizes are low.

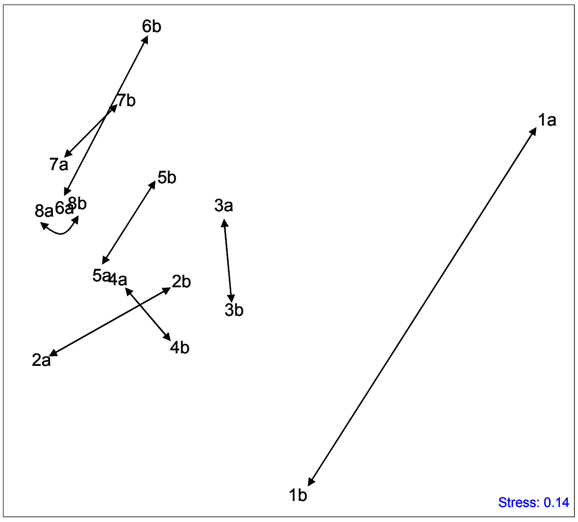


Figure 3.5. Comparison between seine net data collected by Harrison *et al.* (2000) and this study from the Schusters (1),Onrus (2), Uilkraals (3),Blinde (4), Maalgate (5), Kaaimans (6), Groot (Wes) (7), Goukamma (8). Samples from this study are marked with an "a" and those from Harrison with a "b".

Table 3.6. Species composition and abundance of fish (expressed as average number per ha) in seine net hauls from estuaries sampled during this study

	Estuary		Bokramspruit	Schusters	Onrus	Uilkraals	Blinde	Maalgate	Kaaimans	Groot (W)	Goukamma
	Sampling date		19-Mar-06	19-Mar-06	17-Mar-06	16-Mar-06	15-Mar-06	15-Mar-06	14-Mar-06	13-Mar-06	12-Mar-06
	No. hauls		2	1	4	10	5	5	8	9	10
	Area sampled (m²)		150	40	950	3 000	955	2 300	1263	2 250	2 920
Number											
Gilchristella aestuaria	estuarine round herring	Ia	0.0	0.0	18 242.1	0.0	6 586.4	3 056.5	213.8	0.0	1 065.1
Atherina breviceps	silverside	Ib	0.0	0.0	31.6	176.7	0.0	0.0	0.0	8.9	150.7
Caffrogobius multifasciatis	prison goby	Ib	0.0	0.0	0.0	0.0	0.0	0.0	63.3	182.2	164.4
Caffrogobius nudiceps	nude goby	Ib	0.0	0.0	0.0	6.7	10.5	0.0	0.0	0.0	0.0
Psammogobius knysnaensis	Knysna sand goby	Ib	0.0	0.0	13 284.2	1 043.3	596.9	17.4	395.9	84.4	321.9
Sygnathus acus	pipefish	Ib	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4
Lithognathus lithognathus	white steenbras	IIa	0.0	0.0	0.0	0.0	0.0	0.0	633.4	186.7	41.1
Monodactylus falciformis	Cape moony	IIa	0.0	0.0	0.0	0.0	0.0	0.0	15.8	151.1	54.8
Mugil cephalus	flathead mullet	IIa	0.0	250.0	10.5	36.7	0.0	0.0	79.2	22.2	0.0
Pomadasys commersonii	spotted grunter	IIa	0.0	0.0	0.0	0.0	0.0	0.0	15.8	0.0	0.0
Rhabdosargus holubi	Cape stumpnose	IIa	0.0	0.0	0.0	0.0	0.0	56.5	649.2	2 960.0	616.4
Galeichthyes feliceps	barbel	IIb	0.0	0.0	0.0	0.0	0.0	0.0	7.9	0.0	0.0
Heteromycteris capensis	Cape sole	IIb	0.0	0.0	0.0	213.3	52.4	91.3	0.0	40.0	13.7
Liza dumerilii	groovy mullet	IIb	0.0	0.0	0.0	3.3	0.0	100.0	308.8	0.0	24.0
Solea bleekeri	blackhand sole	IIb	0.0	0.0	0.0	6.7	0.0	0.0	0.0	13.3	20.5
Diplodus s. capensis	blacktail	IIc	0.0	0.0	13 157.9	0.0	0.0	0.0	0.0	0.0	24.0
Liza richardsonii	harder	IIc	6 666.7	0.0	1 315.8	3 036.7	3 466.0	4 160.9	6 809.2	1 804.4	832.2
Rhabdosargus globiceps	White stumpnose	IIc	0.0	0.0	210.5	110.0	0.0	0.0	0.0	97.8	0.0
Amblyrhynchotes hokenii	evil eye blassop	III	0.0	0.0	0.0	33.3	0.0	0.0	0.0	0.0	0.0
Gnathanodon speciosus	golden Kingfish	III	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0
Rhinobatos annulatus	sandshark, guitar fish	III	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0
Galaxias zebratus	Cape galaxias	IV	0.0	19 750.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tilapia mossambicus	Mozambique tilapia	IV	0.0	0.0	494.7	0.0	0.0	0.0	0.0	0.0	0.0
Myxus capensis	freshwater mullet	Vb	0.0	0.0	21.1	0.0	41.9	0.0	348.4	4.4	6.8
Unidentified 1	Unidentified 1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4
	All species		6 666.7	20 000.0	46 768.4	4 686.7	10 753.9	7 478.3	9 540.8	5 560.0	3 342.5

Table 3.7. Biomass of fish estimated from seine net hauls for estuaries sampled during this study

	Estuary		Bokramspruit	Schusters	Onrus	Uilkraals	Blinde	Malgate	Kaaimans	Groot (W)	Goukamma
	Sampling date		19-Mar-06	19-Mar-06	17-Mar-06	16-Mar-06	15-Mar-06	15-Mar-06	14-Mar-06	13-Mar-06	12-Mar-06
	No. hauls		2	1	4	10	5	5	8	9	10
	Area sampled (m^2)		150	40	950	3 000	955	2 300	1 263	2 250	2 920
Mass (Kg per ha)											
Gilchristella aestuaria	estuarine round herring	Ia	0.0	0.0	5 033.7	0.0	2 612.6	4 027.0	227.2	0.0	642.1
Atherina breviceps	silverside	Ib	0.0	0.0	15.8	48.7	0.0	0.0	0.0	9.3	71.6
Caffrogobius multifasciatis	prison goby	Ib	0.0	0.0	0.0	0.0	0.0	0.0	274.0	150.7	171.9
Caffrogobius nudiceps	nude goby	Ib	0.0	0.0	0.0	11.0	51.3	0.0	0.0	0.0	0.0
Psammogobius knysnaensis	Knysna sand gobi	Ib	0.0	0.0	2 483.2	700.7	406.3	10.4	137.0	46.7	132.5
Sygnathus acus	pipefish	Ib	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8
Lithognathus lithognathus	white steenbras	IIa	0.0	0.0	0.0	0.0	0.0	0.0	15 645.3	7 622.2	14 719.2
Monodactylus falciformis	Cape moony	IIa	0.0	0.0	0.0	0.0	0.0	0.0	23.8	228.4	9.6
Mugil cephalus	flathead mullet	IIa	0.0	10 000.0	156.8	303.3	0.0	0.0	4 092.6	0.0	0.0
Pomadasys commersonii	spotted grunter	IIa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhabdosargus holubi	Cape stumpnose	IIa	0.0	0.0	0.0	0.0	0.0	2 580.4	12 340.5	16 476.9	2 330.5
Galeichthyes feliceps	barbel	IIb	0.0	0.0	0.0	0.0	0.0	0.0	4.8	0.0	0.0
Heteromycteris capensis	Cape sole	IIb	0.0	0.0	0.0	233.3	52.4	188.3	0.0	32.9	7.5
Liza dumerilii	groovy mullet	IIb	0.0	0.0	0.0	496.7	0.0	3 676.1	11 601.7	0.0	4 267.1
Solea bleekeri	blackhand sole	IIb	0.0	0.0	0.0	33.3	0.0	0.0	0.0	63.1	23.3
Diplodus sargus capensis	blacktail	IIc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5
Liza richardsonii	harder	IIc	18 226.7	0.0	24 482.1	42 492.0	5 420.9	66 629.1	8 384.8	5 453.3	23 995.2
Rhabdosargus globiceps	white stumpnose	IIc	0.0	0.0	2.1	52.7	0.0	0.0	70.5	0.0	0.0
Amblyrhynchotes hokenii	evil eye blassop	III	0.0	0.0	0.0	70.3	0.0	0.0	0.0	0.0	0.0
Gnathanodon speciosus	golden kingfish	III	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.1	0.0
Rhinobatos annulatus	sandshark, guitar fish	III	0.0	0.0	0.0	58 020.0	0.0	0.0	0.0	0.0	0.0
Galaxias zebratus	Cape galaxias	IV	0.0	13 400.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tilapia mossambicus	Mozambique tilapia	IV	0.0	0.0	714.7	0.0	0.0	0.0	0.0	0.0	0.0
Myxus capensis	freshwater mullet	Vb	0.0	0.0	552.6	0.0	3 717.3	0.0	3 884.4	38.7	2 750.0
Unidentified 1	unidentified 1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
	All species		18 226.7	23 400.0	33 440.0	102 462.0	12 260.7	77 110.9	56 687.3	30 145.3	49 133.6

Results for the comprehensively-surveyed estuaries are summarised in Table 3.9. Some 69 species were recorded in the eight estuaries examined in detail. While some species were caught in very large numbers, several were recorded in numbers of fewer than 5 in total or for a single system. This illustrates to some extent the number of species that are relatively rare and that one might expect to miss in a rapid sampling exercise.

Whereas it is to be expected that rapid sampling will decrease the probability of sampling all species, another pertinent question is to what extent comprehensive sampling provides a better idea of fish abundance. In general the average density of fish recorded with comprehensive sampling was higher than in the rapid sampling (Figure 3.6). There was a fair relationship between the average density of fish in comprehensive and rapid sampling if two of the most abundant fish – *Gilchristella aestuaria* and *Liza richardsonii* were excluded. The slope of 0.4 shows that rapid sampling tends to underestimate the density of fish in estuaries where abundance is higher. This effect might be reduced if a geometric mean is applied to the comprehensive data, as data are somewhat skewed. This is not of serious concern though as conservation plans generally seek to conserve a proportion of the population of a particular species (rather than an absolute number of individuals).

There were large discrepancies in the average abundance of *Liza richardsonii* at the Diep and Olifants estuaries, and extremely large discrepancies for *Gilchristella* at all estuaries (Table 3.8). This may simply be a function of slight differences in mesh size (pointing to the use of a slightly larger mesh sized used by Harrison et al. 2000).

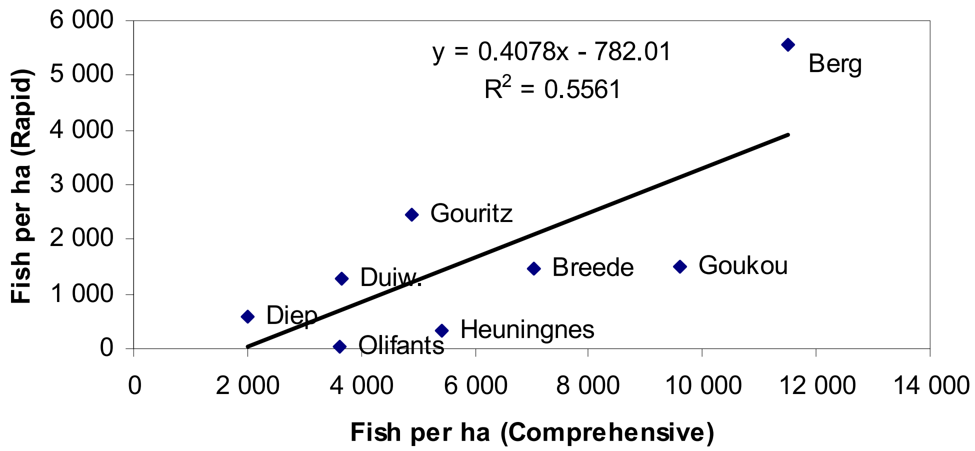


Figure 3.6. Average density of all fish except *Gilchristella* and *Liza richardsonii* estimated from comprehensive sampling versus rapid sampling of 8 estuaries.

Table 3.8. Average density of *Liza richardsonii* and *Gilchristella aestuaria* estimated from comprehensive versus rapid sampling, and the factor by which they differ.

	Liza richardsonii			***Gilchristella aestuaria***		
	Comprehensive	**Rapid**	**Factor**	**Comprehensive**	**Rapid**	**Factor**
Olifants	93 588	8 625	10.9	80 873	96	843.9
Berg	35 547	9 089	3.9	13 230	567	23.3
Diep	91 945	3 692	24.9	24 402	0	
Heuningnes	4 225	2 344	1.8	7 099	1 059	6.7
Breede	2 710	1 190	2.3	1 495	30	49.8
Duiwenhoks	1 979	1 504	1.3	4 636	125	37.1
Goukou	4 909	1 995	2.5	26 564	171	155.0
Gouritz	3 806	700	5.4	37 152	1 033	36.0

Table 3.9. Species composition and abundance of fish (expressed as average number per ha) in seine net hauls from 8 Cape estuaries for which data were collated for this study.

Estuary	Olifants	Berg	Diep	Heuning-nes	Breede	Duiwen-hoks	Goukou	Gouritz
No. hauls	73	527	106	36	298	76	72	72
Area sampled (m^2)	14,600	135,698	21,200	7,200	59,600	15,200	14,400	14,400
Atherina breviceps	1 282.2	4 569.3	8.0	448.6	370.8	264.5	668.8	2.1
Anguila sp.	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0
Amblyrhynchotes hokenii	0.0	0.4	0.0	0.0	4.0	5.3	15.3	5.6
Argyrosomus japonicus	0.0	0.0	0.0	19.4	4.0	2.0	0.0	0.0
Caffrogobius sp.	0.0	3 093.9	872.6	62.5	3 443.8	1 854.6	2 702.1	0.0
Caranx heberi	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.7
C. jari	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
C vale	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chaetodon marleyi	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Chelidonichthyes capensis	3.4	1.5	0.0	0.0	0.2	0.0	0.0	1 561.8
Clarias gariepinus	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Clinus supeciliosus	134.2	85.6	6.1	0.0	25.5	15.1	10.4	0.0
Cyprinus carpio	0.0	73.2	37.7	1.4	0.3	0.0	0.0	0.0
Dasyatis chrysonota	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.7
Diplodus cervinus	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0
Diplodus s. capensis	0.7	0.0	0.0	2.8	64.4	0.7	756.9	1.4
Engraulis capensis	0.0	0.5	0.0	0.0	0.3	0.0	0.0	14.6
Engraulis japonicus	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Etrumeus terres	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Gilchristella aestuaria	80 872.6	13 229.5	24 401.9	7 098.6	1 495.3	4 635.5	26 563.9	37 152.1
G spec	0.0	0.0	0.0	0.0	0.3	0.0	0.7	0.7
Galaxias zebratus	0.0	1.9	107.5	0.0	0.0	0.0	0.0	0.0
Galeichthyes feliceps	0.0	4.5	0.0	16.7	1 010.2	117.8	97.9	502.1
Gambusia affinis	0.0	15.8	26.4	0.0	0.0	0.0	0.0	0.0
Haploblepharus pictus	3.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Hemiramphus far	0.0	0.0	0.0	0.0	4.5	0.0	0.7	0.0
Heteromycteris capensis	6.8	0.0	0.0	583.3	120.0	67.8	386.1	198.6
Hyporhamphus capensis	0.0	0.0	0.0	83.3	8.1	0.0	0.0	2.1
Iso natalensis	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Lepomis macrochirus	378.1	5.3	0.0	0.0	2.5	0.0	0.0	0.7
Lichia amia	0.0	4.1	0.0	187.5	7.0	3.9	10.4	4.2
Lithognathus lithognathus	0.7	19.9	0.9	98.6	88.4	5.3	28.5	37.5
Lithognathus mormyrus	0.0	0.0	0.0	13.9	18.8	0.0	10.4	1.4
Liza dumerilii	0.0	0.0	0.0	104.2	286.7	319.7	136.1	791.7
Liza richardsonii	93 588.4	35 546.7	91 945.3	4 225.0	2 709.6	1 978.9	4 909.0	3 806.3
Liza tricuspidens	0.0	0.0	0.0	1.4	1.7	11.2	4.9	2.8
Micropterus dolomieu	225.3	11.5	0.0	0.0	0.5	0.0	0.0	0.0
Micropterus salmoides	0.0	0.0	0.0	16.7	0.8	0.0	0.0	0.0
Monodactylus argenteus	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Monodactylus falciformis	0.0	0.0	0.0	22.2	176.5	35.5	670.1	7.6
Mugil cephalus	106.2	333.4	34.0	16.7	15.6	17.1	6.3	29.9
Myliobatos Aquila	0.0	0.4	0.0	0.0	0.5	0.0	0.0	0.7
Myxus capensis	0.0	0.0	8.0	0.0	14.8	118.4	20.1	4.9
Omobranchus woodii	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Oreochromis mossambicus	0.7	1 226.6	608.5	0.0	2.5	0.0	0.0	0.0
Pomadasys olivaceum	0.0	0.0	0.0	0.0	54.2	0.7	1.4	125.0
Pomatomus saltatrix	26.7	169.4	63.2	1.4	10.6	0.7	2.8	18.8
Pomodasys commersonii	0.0	0.0	0.0	5.6	1.5	1.3	0.0	15.3

Estuary	Olifants	Berg	Diep	Heuning-nes	Breede	Duiwen-hoks	Goukou	Gouritz
Psammogobius knysnaensis	544.5	1 575.8	0.0	1 545.8	272.5	201.3	289.6	413.2
Pseudobarbus burchelii	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0
Pseudobarbus rubescens	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Redigobius dewaalii	0.0	0.0	0.0	0.0	3.2	0.0	0.7	0.0
Rhabdosargus globiceps	16.4	7.0	0.5	769.4	37.9	10.5	256.9	0.7
Rhabdosargus holubi	0.0	0.1	0.0	1 279.2	313.6	150.7	3 314.6	499.3
Rhinobatos annulatus	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0
Rhonobatos blochii	8.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Sardinops sagax	0.0	0.1	0.0	0.0	1.0	0.0	0.0	0.0
Sarpa salpa	0.0	0.1	0.0	0.0	2.0	0.0	9.7	0.0
Solea bleekeri	1.4	136.3	0.0	44.4	236.6	443.4	126.4	636.1
Spodyliosoma emarginatum	0.0	0.0	0.0	0.0	2.9	0.0	29.9	0.0
Sygnathus acus	755.5	142.9	0.0	88.9	399.3	3.3	35.4	5.6
Therapon jarbua	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Tilapia sparmanii	136.3	0.0	238.7	0.0	1.3	2.0	0.0	0.0
Tinca tinca	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0
Trachurus trachurus	0.7	0.0	0.0	0.0	1.3	0.7	0.7	0.0
Blennies	0.0	0.0	0.0	1.4	5.4	0.0	0.0	0.0
Puffer_Aret	0.0	0.0	0.0	1.4	1.5	0.0	0.0	0.0
SB Goatfish	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Cowfish	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0

An analysis of the species richness to sampling effort suggested that while the effort in sampling these estuaries was extensive, most had not reached the point where the species-effort curve had flattened out (Figure 3.7). Harrison *et al.* (2000) sampled until their instantaneous species-effort curve began to flatten (T. Harrison, pers. comm.). According to the curves in Figure 3.7, the actual number of samples taken in that study would not have yielded close to 100% of species. For example, for the Duiwenhoks estuary about 62 hauls were needed for the curve to begin to flatten out. Harrison *et al.* (2000) made ten hauls at this estuary, netting a total of 17 species (63%). This fits exactly with the pattern found in the comprehensive data (Figure 3.7), but the retrospective analysis shows that the curve was actually still very steep at this point. It is important to note that there is a temporal element to this as well, as the comprehensive data have been collected over a number of seasons and a number of years. Thus the results indicate that the fish fauna of estuaries is fairly dynamic over time, something which corroborates our biological understanding of these populations (P. Cowley, SAIAB, pers. comm.). If one were to remove non-estuary-dependent marine species from the analysis, the curve would probably flatten out at a sample size closer to Harrison *et al.*'s 2000 estimate.

The percentage of species recorded in Harrison *et al.*'s (2000) data set relative to the comprehensive data set decreased with estuary size (Figure 3.8), suggesting that the effect described above is greatest for larger estuaries. This is to be expected since the larger systems are likely to have a higher probability of being visited by marine species. If the discrepancy is mainly driven by non-estuary dependent marine species, then it is not a major concern in the context of a conservation planning study, particularly as these species are unlikely to be targeted in a conservation plan. A similar argument could be put forward for the importance rating of an estuary, though it would be desirable that these species do feature in an importance rating.

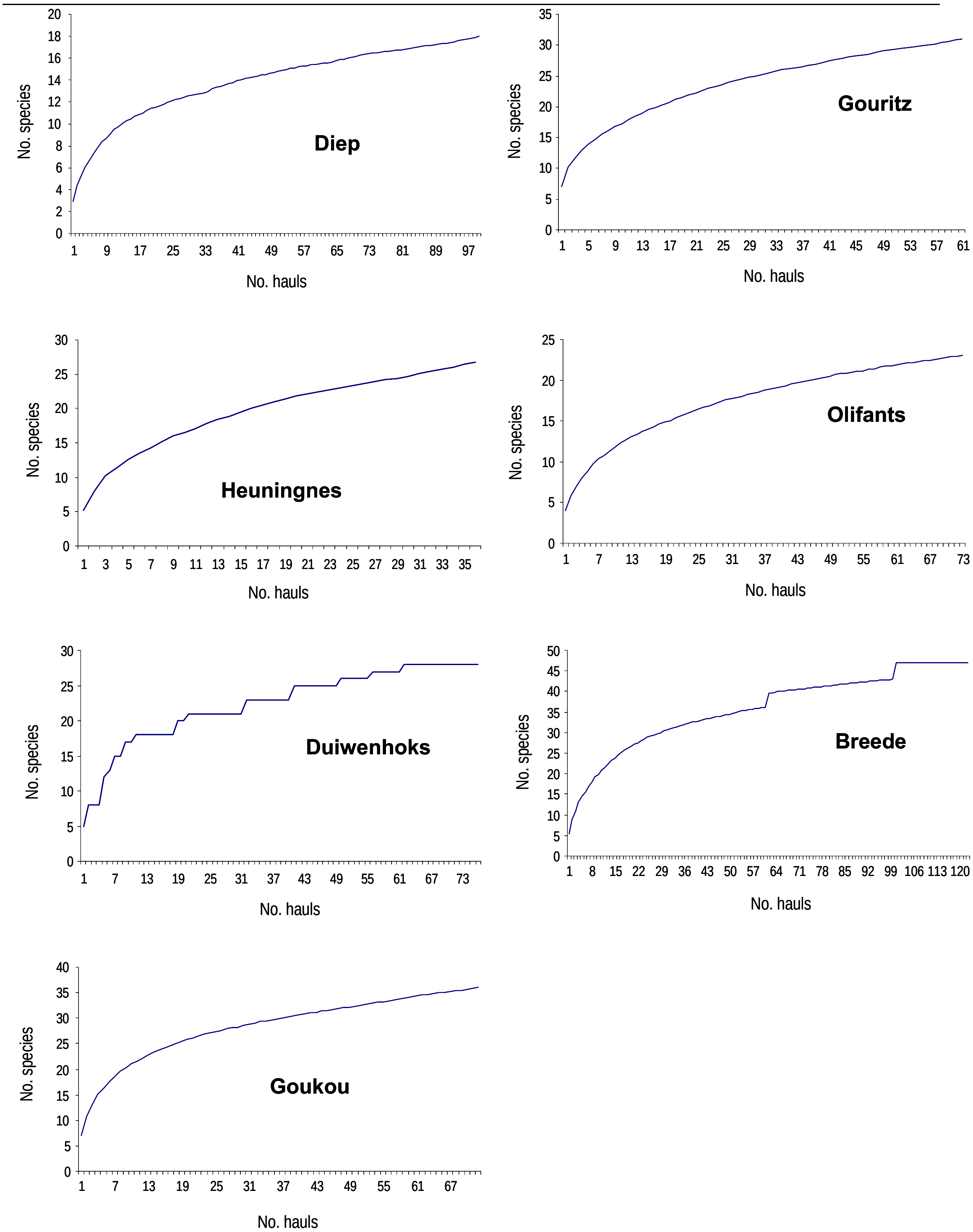


Figure 3.7. Species effort curves for the comprehensively surveyed estuaries for which data were collated in this study. Crosses indicate number of hauls under taken by Harrison *et al.* (2000) and number of species recorded.

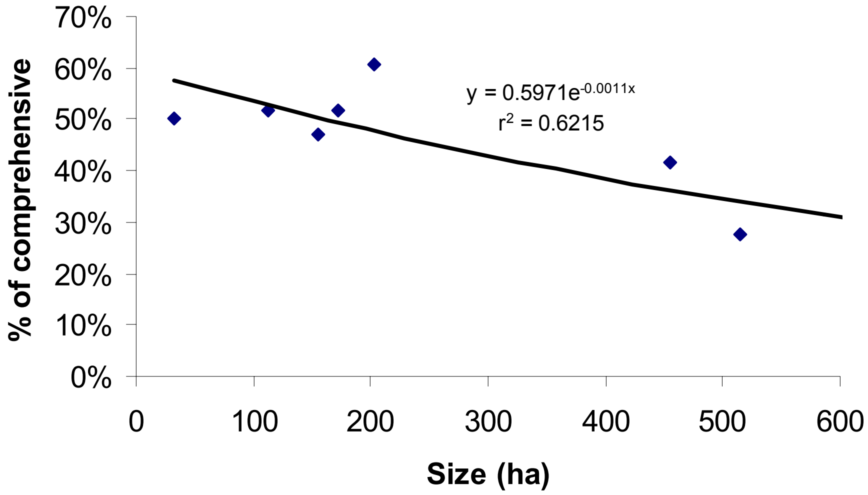


Figure 3.8. Species richness recorded by Harrison *et al.* (2000) as a percentage of that recorded in comprehensive surveys of the same estuaries vs. estuary size.

The numbers of species recorded by Harrison *et al.* (2000) correlates well with that collected in the more comprehensive surveys (r^2 = 84%; Figure 3.9), indicating that their data provide a good indication of the relative but not necessarily the absolute richness of the systems in question. However, multivariate analyses indicate that the two types of surveys (rapid vs. comprehensive) clearly yield quite different results, with the level of similarity between the same estuaries sampled in a comprehensive manner being lower than that among estuaries sampled using the same level of effort (Figure 3.10). (Note that this is linked to the transformation applied to the data that elevates the importance of the medium and low abundance species to the very abundance species from completing dominating the results.) Results of the latter analyses clearly indicate that while data from Harrison *et al.* (2000) provide an accurate representation of the relative richness of the systems, data from comprehensive and less detailed cannot easily be combined for conservation planning purposes.

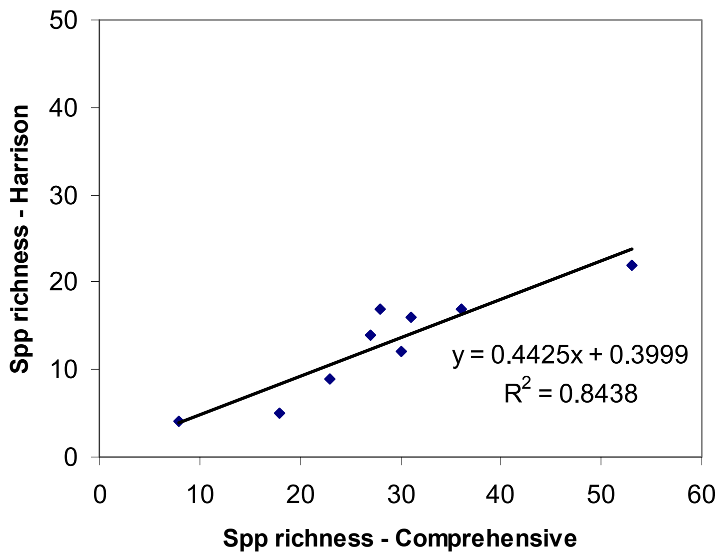


Figure 3.9. Comparison between numbers of species recorded by Harrison *et al.* (2000) and during comprehensive surveys by Lamberth (unpublished) and Clark (unpublished) for a section of estuaries in the Cape region.

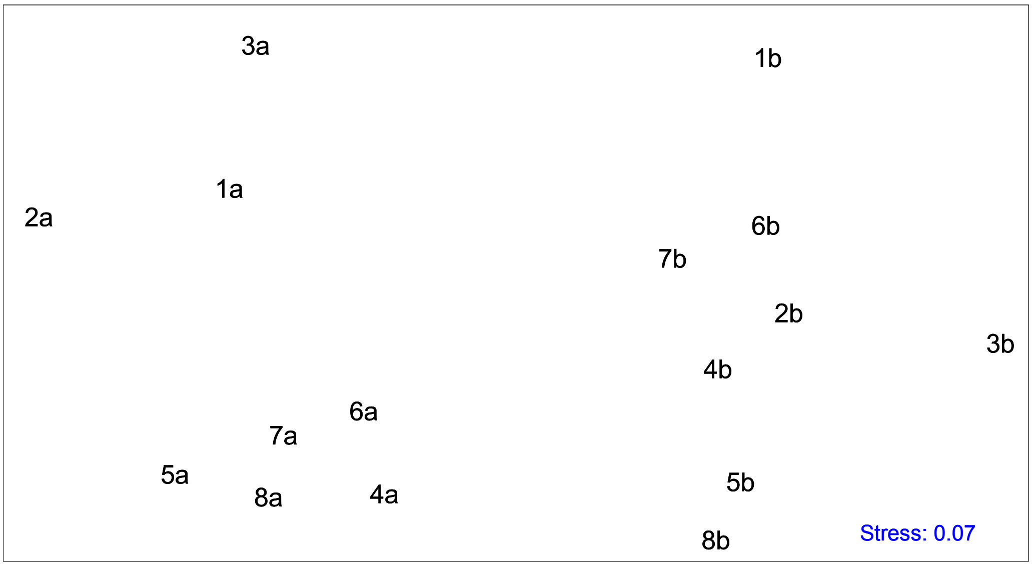


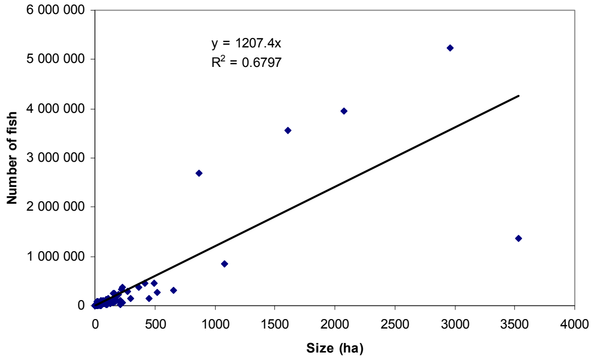
Figure 3.10. Comparison between seine net data collected by Harrison *et al.* (2000) and data collated for study (Lamberth unpublished & Clark unpublished) from the Olifants (1), Berg (2), Diep (3), Heuningnes (4), Breede (5), Duiwenhoks (6), Goukou (7), and Gouritz (8). Samples from Harrison are marked with the character "a" and those collated for study (Lamberth unpublished & Clark unpublished) with a "b".

In summary, we can conclude from this analysis that for the purposes of conservation planning, one can only use data collected with comparable levels of effort from all estuaries in the planning domain, which in this case implies that we should use only data collected by Harrison *et al.* (2000), supplemented where necessary with data collected from other surveys of similar intensity. We can also conclude that while data collected by Harrison *et al.* (2000) is more than 10 years old, it still provides a good representation of the fish fauna of estuaries in the study area (at least those that we surveyed in this study).

3.3.4 Fish abundance and estuary size

Using the data set from Harrison *et al.* (2000), the total populations of fish were estimated for each species for each estuary. This was done by extrapolating the average density of fish in the sampling to the channel plus intertidal area of each estuary. Species caught in gillnets were included in the extrapolation, under the assumption that relative seine to gill net effort remained sufficiently constant from estuary to estuary. There are flaws in this method, notably in mixing seine and gillnet sampling, and also in extrapolation to areas of different depths, meaning that these should be considered rough estimates. However, there is no better way of estimating abundance with this type of data.

An analysis of total fish abundance showed that while larger estuaries contain more fish, as expected, there was no significant difference in fish density between small and large estuaries (Figure 3.11, Table 3.10). This has important implications for a conservation planning exercise, as discussed in the final chapter.



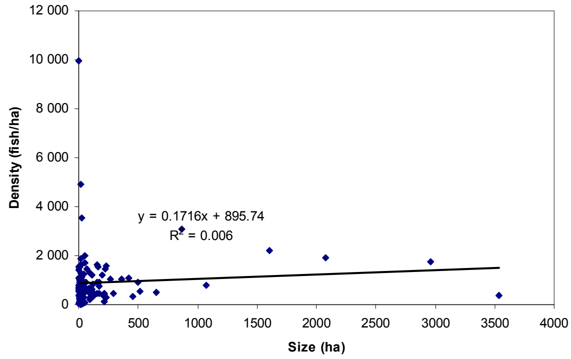


Figure 3.11. Relationship between fish abundance and density and estuary size. Based on raw data supplied by Trevor Harrison.

Table 3.10. Average numbers and densities of fish in different size systems. Based on raw data supplied by Trevor Harrison.

Size category (ha)	Sample size (n)	Average no. fish	Fish per ha
0 – 10	56	2 520	821
10.1 – 125	95	27 400	732
125.1 – 1250	33	268 000	770
> 1250	6	4 750 000	1125

3.4 Birds

3.4.1 Overview and update of bird data

Until the 1970s, very few data existed on estuarine birds. Then in the summers of 1979 – 81, a counting exercise was carried out along the entire South African coast, in which a large proportion of coastal wetlands and estuaries were counted on a once-off basis (Ryan & Cooper 1985, Ryan *et al.* 1986, Underhill & Cooper 1984). This covered some 178 estuaries, but missed out the former Ciskei and Transkei coasts. In addition a number of research projects were carried out on individual systems in the 1970s to 1990s, such as St Lucia (Whitfield 1978), Swartkops (Martin 1991, Turpie 1994), Bot (Stewart & Bally 1995) and Berg estuaries (Velasquez & Hockey 1992, Kalejta & Hockey 1994, Hockey 1993).

The 1979-81 counts, augmented by counts from other studies where they existed, were used by Turpie (1995) in an analysis of the importance of estuaries for waterfowl, and subsequently in the computation of the conservation importance of estuaries (Turpie *et al.* 2002). Turpie *et al.* (2004) augmented the available information by conducting a bird count of the Transkei coast, updating estuary importance scores in the process. Another important source of bird count data is the Co-ordinated Waterbird Counts (CWAC) programme managed by the Avian Demography Unit at the University of Cape Town. While the CWAC programme supplied annual summer and winter counts for about 23 South African estuaries by 1997, a lot more estuaries have since been added. These data also provide the opportunity to update the original count data which are by now very out-of-date. (Note that bird counts do not suffer from the same effort bias as was the case with the fish data and hence there was no problem in combining data from different data sets.)

In using bird count data there is always an issue as to whether to use mean, median or maximum numbers counted for each species. Mean or median count data may give a realistic picture of what might be conserved if a site is protected, whereas maximum count data may give a better picture of the importance of a site. However, if the counting effort is variable, then using the maximum counts would produce an importance bias in favour of estuaries that had been counted more often. Thus, where more than one count was available, Turpie (1995) used median counts. The Berg River estuary was problematic in that the first major count subsequent to the 1980 count produced a very much higher number of birds (Hockey 1993). This later count was used by Turpie (1995) and subsequent studies, producing a very high importance rating for the Berg estuary. However, Turpie (2007) analysed the CWAC data from 1994 to present and argued that the Hockey (1993) count (which used extrapolation) was anomalous, with the CWAC counts being more similar to the older counts.

Thus in this study, the bird data updated in Turpie *et al.* (2004) have been updated again with all available CWAC data on temperate estuaries, including for the Berg estuary. There are still no data for 23% of temperate estuaries, though these are mostly very small and only cover 7.4% of the area. The reason for the lack of data is generally that they have not been considered worth counting due to their lack of birds. Recent count data exist for about 22% of estuaries accounting for 61% of total area, and we still rely on old data for about a third of estuaries and area (Table 3.1).

Table 3.11. Bird count data sources used in this study

Data source	Number of estuaries	% estuaries	% of total estuarine area
No data	34	23	7.4
Underhill & Cooper 1984	52	35	31.9
CWAC (recent)	30	20	52.8
Turpie *et al.* 2004	29	19	4.4
Other unpublished data (recent)	4	3	3.5

3.5 Updated conservation importance rating

3.5.1 Estuary importance rating in terms of fish

Data from Harrison *et al.* (2000) fish surveys was used by Turpie *et al.* (2002, 2004) to generate estuary importance scores in terms of fish. Importance scores were derived from rarity scores and assigned on the basis of ranked percentiles. The rarity scores were influenced by the species richness of the system and the relative rarity of each species found in that system.

Assigning scores in this way assumes that all estuaries have been equally well sampled. We used data from the comprehensive surveys to test whether this assumption was indeed valid. Data collated for the comprehensively surveyed estuaries, was used to assess how much effort should be put into surveying an estuary before the species-effort curve flattens out, and whether this is affected by estuary size. Results of this analysis are described in section §3.3.3 (Figure 3.7). In most cases the species-effort curve only begins to flatten out after 20-30 hauls have been completed, and continues to climb at a slow rate from this point onwards. Comparing the number of species recorded by Harrison *et al.* (2000) to that recorded in the comprehensive surveys, it is evident that the proportion of species recorded in the former surveys ranges from 28-67% and that this declines as estuary size increases (Figure 3.8). Thus while Harrison *et al.* (2000) did scale the sampling effort in relation to estuary size, the extent to which this was done was insufficient and has resulted in a disproportionately low species counts for the larger estuaries, and hence a disproportionately low rarity score for the larger systems. Nevertheless, the constant way in which species richness found in rapid sampling relates to species richness in comprehensive sampling suggests that correcting the under sampling of richer systems would not impact on the rank order of the rarity score, and hence would not significantly alter the importance score, all other things equal.

However, Turpie *et al.* (2002, 2004) based the rarity score on the numbers of fish sampled by Harrison *et al.* (2000). This study has produced population estimates, which provide a better measure of the relative importance of systems, correcting to a large extent for the under sampling of large systems, at least in terms of abundance if not species richness. Thus the rarity scores were recalculated using these estimates (Figure 3.12). The effect of changing to actual abundance data is reflected in the greater range of the rarity scores. This is due to the larger variation in abundance of species from estuary to estuary than was the case when using actual catch data. The only drawback of this approach was that abundance could not be calculated for some estuaries for which effort data were not obtained. Most of these were KwaZulu-Natal estuaries. The original scores were thus retained for those systems.

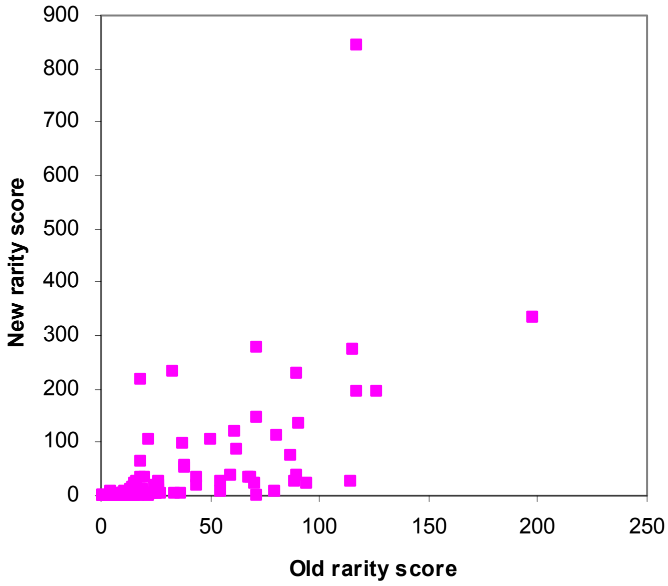


Figure 3.12. Changes in fish rarity scores for all temperate estuaries

The difference in the new importance scores from the old scores is shown in Figure 3.13. While the majority of estuaries stayed within 10% of their original score, some changed markedly. For example, the Orange estuary score changed from 60 to 100.

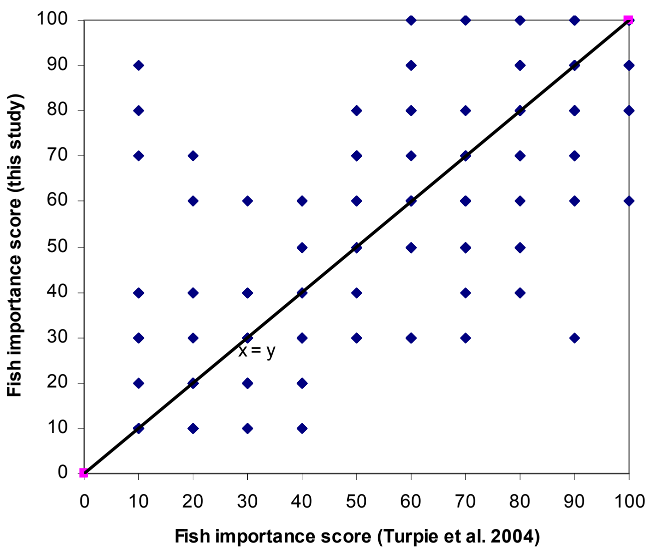


Figure 3.13. Changes in fish importance scores for all South African estuaries

3.5.2 Estuary importance rating in terms of birds

Data from bird counts were collated for a total of 107 non-passerine and two passerine (wagtail) species, for all South African estuaries. The rarity scores described in Turpie *et al.* (2002) were recomputed using the updated data. Changes in the rarity scores are shown in Figure 3.14. The exercise resulted in changes in the bird importance scores for several estuaries. While the rarity score for the Berg changed dramatically (the outlying point in Figure 3.14), it remained within the top 10% percentile, thus still scoring 100.

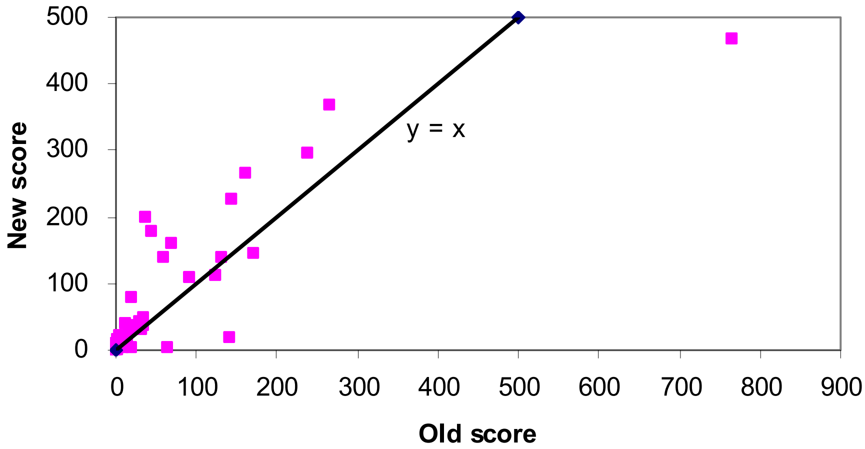


Figure 3.14. Comparison of the bird rarity scores of temperate estuaries before and after the data were updated for this study.

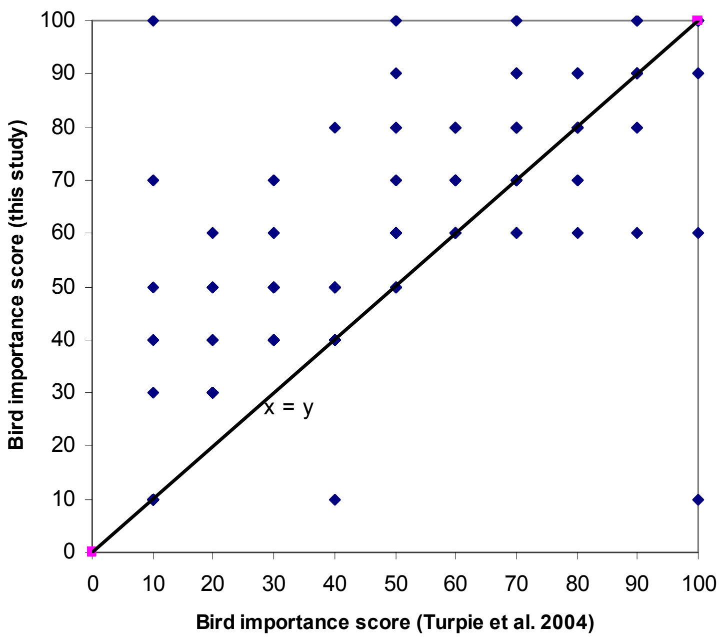


Figure 3.15. Comparison of the updated bird importance scores with those from the 'Amazon project' (Turpie *et al.* 2004).

3.5.3 Updated biodiversity importance rating

Changes in the fish and bird scores had a measurable effect on the biodiversity importance rating of a large number of estuaries (Figure 3.16). The new ratings are listed in Appendix 2.

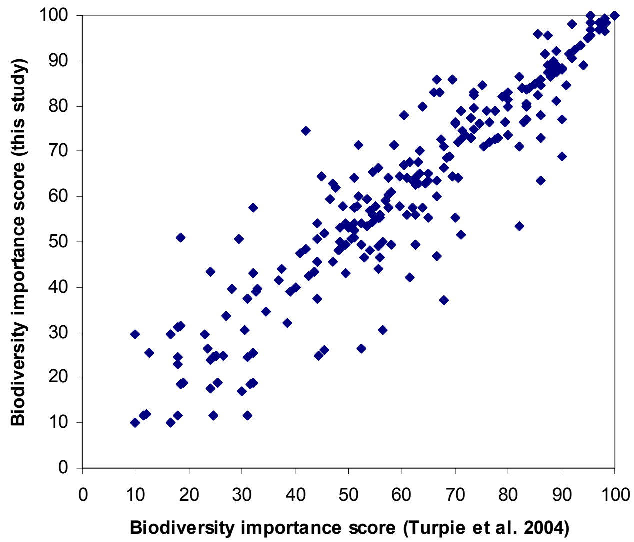


Figure 3.16. Comparison of the updated biodiversity importance scores with those from the 'Amazon project' (Turpie *et al.* 2004).

3.5.4 Overall estuary importance rating

The overall estuary importance rating computed in Turpie *et al.* (2002) and updated by Turpie *et al.* (2004) was recomputed using the updated botanical, fish and bird data. Details for all estuaries in South Africa are given in Appendix 2. Changes in rankings between Turpie *et al.* (2004) and this study are largely due to the changes in the fish importance score. In general there was no major movement of importance scores as a result of this study (**Figure 3.17**).

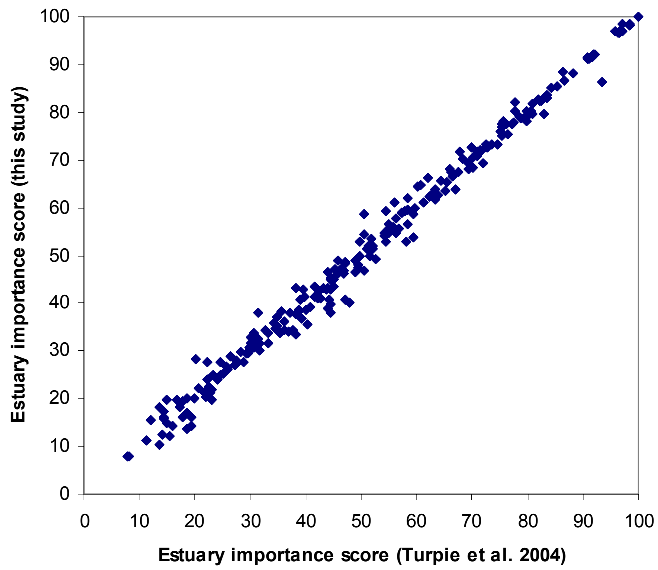


Figure 3.17. Comparison of the updated estuary importance scores with those from the 'Amazon project' (Turpie et al. 2004).

The top 40 estuaries and their former rankings are shown in Table 3.12. Three-quarters of these are temperate estuaries.

Table 3.12. Top 40 estuaries in South Africa in terms of the updated importance rating of South African estuaries. Temperate estuaries are marked with an asterisk.

	Overall importance score	Rank (this study)	Rank (Turpie *et al.* 2004)	Rank (Turpie *et al.* 2002)
Knysna*	100	1	1	1
Orange*	99	2	4	7
Berg*	98	3	3	3
Olifants*	98	4	2	2
Klein*	97	5	9	9
Kosi	97	6	5	4
Swartvlei*	97	7	7	6
Bot/Kleinmond*	97	8	8	8
St Lucia	97	9	6	5
Durban Bay	92	10	11	88
Swartkops*	92	11	12	11
Gamtoos*	92	12	16	14
Great Fish*	92	13	13	12
Mfolozi	91	14	14	13
Keiskamma*	91	15	17	15
Mngazana	91	16	15	22
Kromme*	88	17	20	17
Keurbooms*	88	18	18	16
Breë*	87	19	19	18
Mhlathuze	86	20	10	10
Mlalazi	85	21	21	20
Mpekweni*	85	22	22	23
Duiwenhoks*	84	23	23	33
Heuningnes*	83	24	24	25
Mbashe*	83	25	25	28
Mtati*	83	26	29	19
Wilderness*	83	27	27	24
Kariega*	82	28	28	27
Wildevoëlvlei*	82	29	39	59
Mgwalana*	82	30	30	21
Goukou*	80	31	34	32
Great Kei*	80	32	40	52
Kowie*	80	33	32	31
Mtata*	80	34	26	29
Mzimvubu	80	35	31	36
Xora*	80	36	33	37
Mzimkulu	79	37	38	128
Nxaxo/Ngqusi*	79	38	36	41
Matigulu/Nyoni	79	39	37	35
Kabeljous*	78	40	45	42

4. ASSESSMENT OF ESTUARINE HEALTH

4.1 Overview of existing data

Heydorn & Tinley (1980) reviewed the condition of the estuaries of the former Cape Province (from the Orange to the Great Kei), and this was followed by a national assessment of the condition of South African estuaries (Heydorn 1986; Table 4.1). This assessment suggested that 11% of large estuaries and 22% of small estuaries were in a poor condition. This assessment did not include the estuaries of the former Ciskei and Transkei coasts, however, which span much of the eastern half of the present Eastern Cape Province.

Table 4.1. Condition of estuaries in the former Cape Province (Orange to Kei) (Heydorn 1986)

	No. of estuaries	Present condition (%)		
		Good	Fair	Poor
Large	35	6	83	11
Small	118	30	41	22
Total	153	24	50	20

Whitfield (2000) conducted an assessment on the condition of estuaries of the entire coast. The estuaries were broadly classified by Whitfield (2000) as follows:

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

Based on this assessment, the overall health of South African estuaries was considered to be relatively good. In the temperate regions, 28% of estuaries were considered to be in excellent condition, and another 44% in good condition, 21% in a fair condition, and 16% in poor condition (Whitfield 2000).

Catchment health was an important factor included in the assessments by both Heydorn (1986) and Whitfield (2000). Further information is available on the utilisation of estuarine catchment areas and their deviation from natural condition in Harrison *et al.* (2000). The latter study examines 62 estuarine catchments (mainly the relatively large catchments of >500 km^2) in South Africa. Systems in the Western Cape were most affected by commercial agriculture, which accounted for >40% of catchment land-use, more than 20% of catchments were affected by subsistence agriculture in the Transkei region of the Eastern Cape. Estuaries in the Transkei and Ciskei regions of the Eastern Cape had the highest proportion of degraded land cover in their catchments, mostly over 10%, and many exceeding 20% (Harrison *et al.* 2001). Catchments of estuaries in the southwest region of the Eastern Cape (Kromme – Great Kei) had the highest proportion of natural land cover, mostly above 70%, although most very large catchments also had a high proportion of natural land cover.

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

Turpie (2004b) used Whitfield's assessment to derive a broad picture of estuarine health for the National Spatial Biodiversity Assessment (Figure 4.1). This analysis also noted that in the eastern part of the country, the estuaries fed by larger catchments tend to be in poorer health than the estuaries in adjacent smaller catchments.

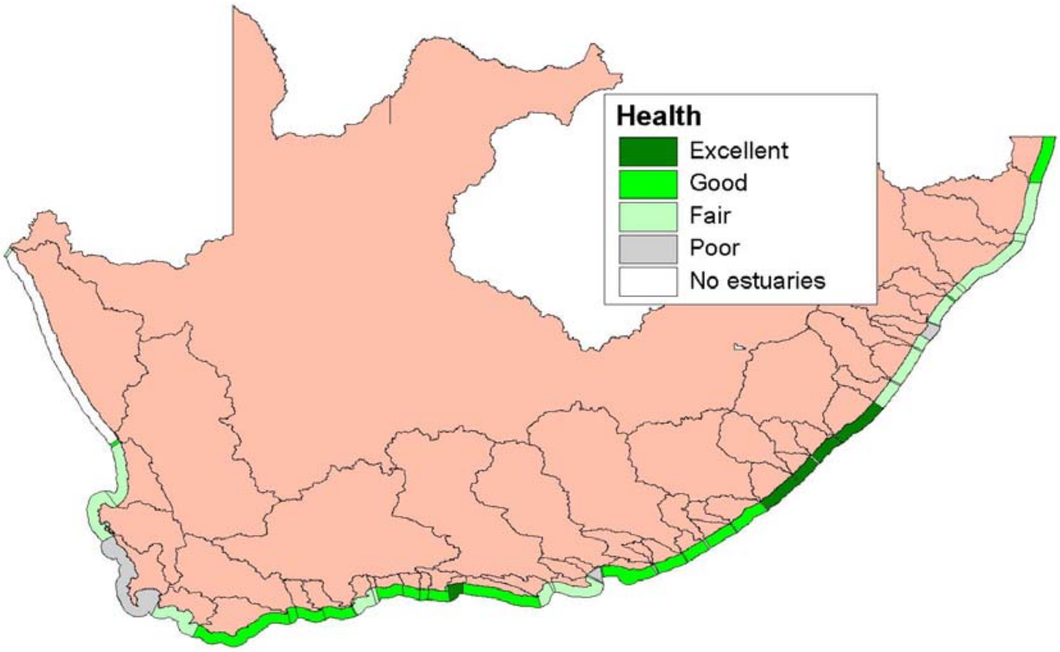


Figure 4.1. Map of the average state of health of estuaries per catchment (after Turpie 2004b)

More recently, Harrison & Whitfield (2004) developed a multimetric fish index, the Estuarine Fish Community Index (EFCI), as a single measure of estuarine condition. The index is made up of 14 measures that represent the species diversity, composition, abundance, nursery function and trophic integrity of fish communities. These measures are related to a reference condition deduced from fish community data collected by Harrison *et al.* (2000). Harrison & Whitfield (2006) then applied the index to data collected for 190 estuaries. Index values ranged from 18 (very poor) to 66 (very good). However, there was a only a weak correlation between this index and Whitfield's (2000) health ratings, and was better correlated with Turpie *et al.*'s (2002) habitat importance index, which is a measure of importance rather than health.

4.2 Testing the various health assessments

Detailed methods have been developed for the systematic assessment of estuarine health as part of the Resource Directed Measures methodology which is used to set the freshwater Reserve for estuaries under the new National Water Act of 1998. These have only been carried out for a handful of estuaries at this stage, however. Nevertheless, these studies provide the opportunity to test the reliability of some of the above assessments.

There is a positive though fairly weak correlation between Whitfield's (2000) health assessment and the health scores obtained in the RDM studies (Figure 4.2). There is no positive correlation between Harrison and Whitfield's (2006) EFCI and the RDM health scores (Figure 4.3). In fact there is a weak negative relationship between these indices. This suggests that Whitfield's (2000) health assessment provides a rough indication, while the EFCI is not suitable as a measure of estuarine health.

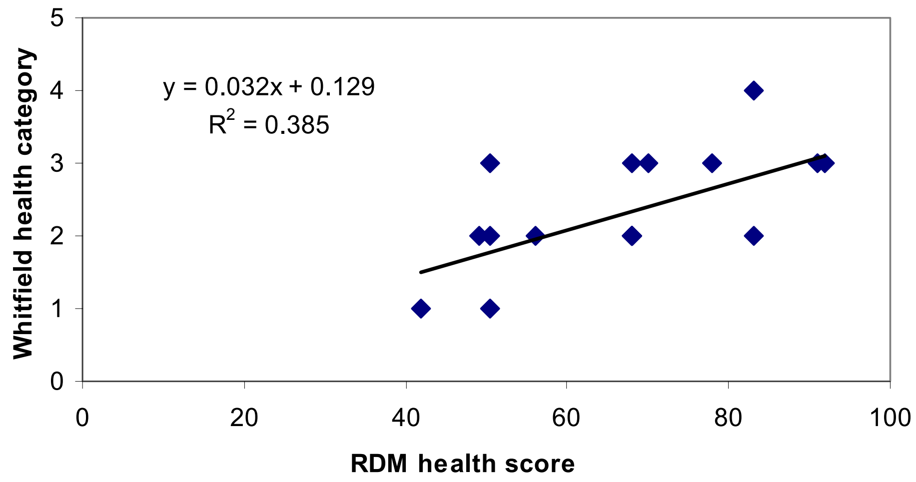


Figure 4.2. Relationship between Whitfield's health category and the health score derived in RDM studies

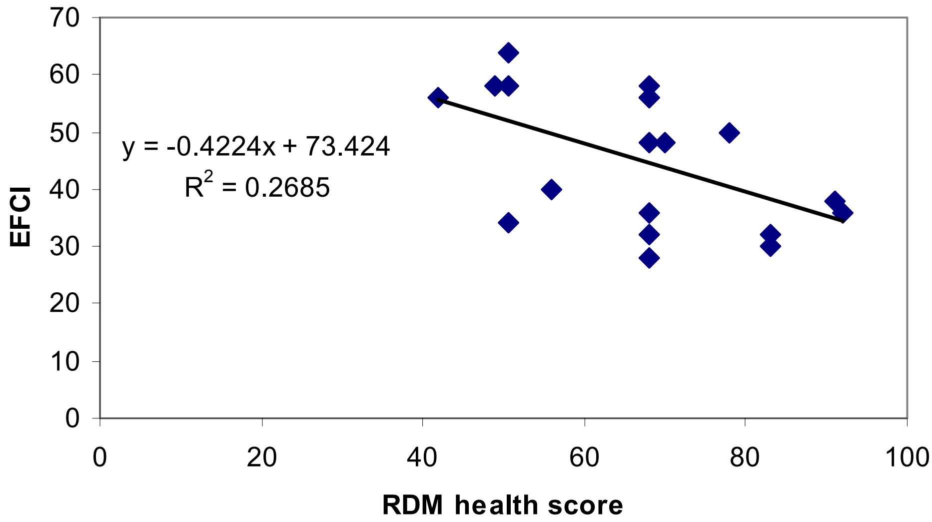


Figure 4.3. Relationship between Harrison & Whitfield's (2006) Estuarine Fish Community Index (EFCI) and the health score derived in RDM studies

4.3 Devising a new rapid health assessment

One of the objectives of this study was to attempt to provide a more empirically-derived indication of the health of C.A.P.E. estuaries than the past assessments. The only way in which to conduct a more reliable rapid health assessment would be to devise an index that could be tested against estuaries for which the health has been thoroughly assessed.

It would be reasonable to assume that estuarine health will be a function of the present day MAR as a percentage of natural MAR that reaches the estuary (%MAR), the size of the estuary, the level of disturbance in the catchment and the level of development around the estuary. While %MAR affects salinity and mouth condition, the size of the estuary is hypothesised to determine how sensitive the system is to a proportional change in MAR, with smaller systems being more sensitive than larger ones.

There is a correlation between %MAR and the RDM health score which is slightly stronger than that between the Whitfield assessment and RDM health score (Figure 4.4). However, estuary size does not appear to play a role in explaining the variance.

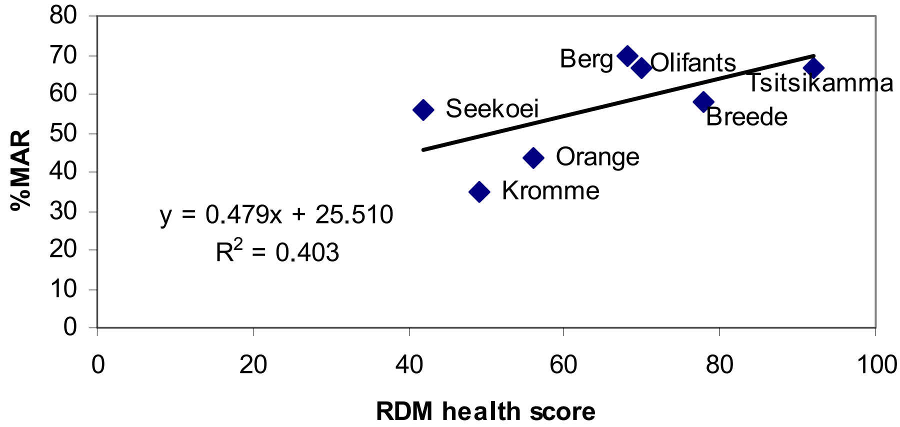


Figure 4.4. Relationship between %MAR and RDM health score

Nevertheless, results of the scenario analyses within the RDM studies suggest that smaller systems are more sensitive to changing %MAR, in that their health score declined more rapidly in relation to declining %MAR than larger systems (Figure 4.5).

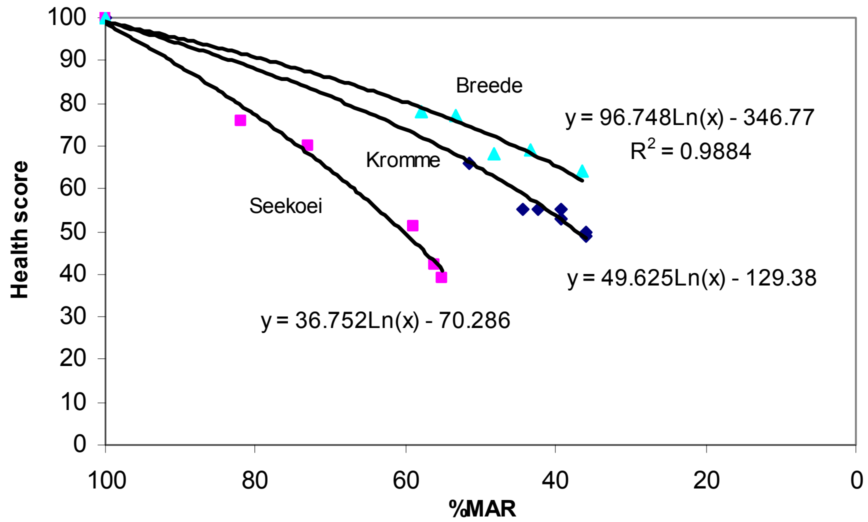


Figure 4.5. Relationship between %MAR and RDM health score for three Warm Temperate estuaries: the Breede (455 ha), Kromme (250 ha) and Seekoei (125 ha).

RDM studies have also been carried out on two cold temperate estuaries – the Orange and Olifants. There was also a strong relationship between %MAR and health score for the Olifants estuary, but the relationship was not as clear for the Orange River estuary, with several scenarios yielding lower-than expected health scores (Figure 4.6).

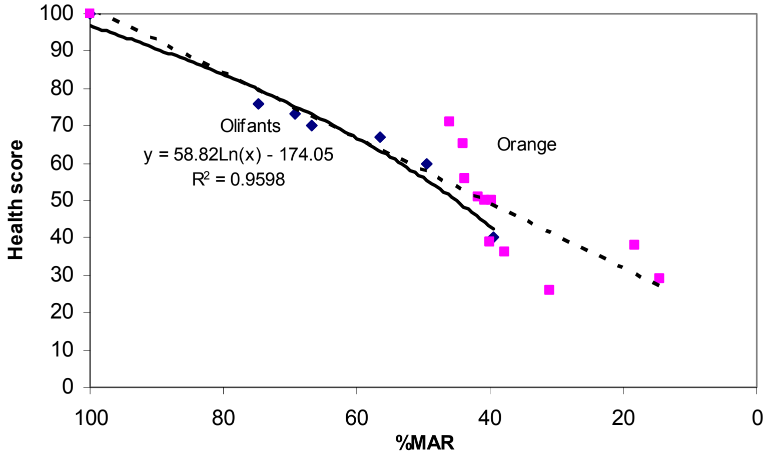


Figure 4.6. Relationship between %MAR and RDM health score for two Cold Temperate estuaries: the Orange (975 ha) and Olifants (700 ha excluding paleo-saltmarsh).

The overall trend of increasing slope with decreasing estuary size was destroyed when these estuaries were plotted together with the Warm Temperate estuaries, with the slope of the Olifants relationship declining more steeply than that of the Breede and suggesting greater sensitivity. Workshop discussion on this issue concluded that the trend of increased sensitivity with decreased size is probably real, but could not come up with an explanation for the difference in west and south coast estuaries. Estuaries that have more seasonal inflow may be more sensitive than similar-sized estuaries with less seasonal variation in flow. The Orange and Olifants estuaries receive most of their flow in summer and winter, respectively. The Kromme and Seekoei estuaries are located in catchments with year-round rainfall. The anomaly, however, is the Breede, which receives mostly winter rainfall.

It is possible that the relationship might prove better when estuaries are ordered in terms of annual flow in Mm^3 as a measure of scale rather than estuary size. Indeed, the Breede has a higher natural MAR than the Olifants, even though the estuary has a smaller area.

In some instances it might be difficult to derive a clear relationship between %MAR and health, because flow regimes can be modified in different ways to arrive at a %MAR. Nevertheless, it is clear from the above that %MAR is probably the most important indicator of estuary health, but that other factors such as size (in terms of natural flow) are probably also important. It is thus clear that it would be extremely fallacious to derive an index for use in rapid health assessment that did not include %MAR. The main problem is that information on %MAR is not available for many estuaries other than those for which flow assessments have been done. Thus even the simple relationship derived above cannot be used to estimate the health of other systems in the bioregion. The calculation of %MAR was well beyond the scope of this study, thus it was decided that Whitfield's (2000) health assessment would be the best interim measure. Although Whitfield did not have data on flow, he would have taken some cues from water quality, development in the catchment, catchment degradation and level of development around the estuary.

5. ECONOMIC VALUE OF ESTUARIES

5.1 Introduction

Research into the economic value of estuaries in South Africa has gained some momentum over the past few years. This has been a result of an appreciation of the role these systems play in generating a number goods and services which are valuable in local and regional economies. Presenting an estimate of the overall contribution of estuaries to the national economy in terms of various types of value (recreational, subsistence, indirect contribution to established sectors and existence value) can be a powerful tool for gaining support. The well known estimation for the economic value of the entire global system by Costanza *et al.* (1997), though criticised for its "broad-brush" approach, was instrumental in raising awareness of the importance of these systems and highlighting the powerful tool resource economics could be. General consensus, however, is that estuaries remain undervalued in terms of their contribution to a range of economic values from recreation to livelihoods (Cooper *et al.* 2003).

The importance of understanding the value of conserving estuaries or at least managing them for sustainable has become vital for managers and policy makers who are increasingly being faced with difficult decisions regarding water extraction and development of surrounding areas. These factors have direct impacts on estuarine systems which can affect their contribution to economic well being. An understanding of what factors affect this contribution would be helpful in weighing up the costs and benefits of these decisions. These interests and concerns culminated in a recent workshop on estuarine systems and the role of resource economics in their management (Turpie & Hosking 2005). This workshop illustrated the range of studies that have been conducted and highlighted research trends and gaps that currently exist.

Existing studies have largely followed a case by case approach in which one (e.g. Turpie *et al.* 2005) or sometimes a small group of estuaries (e.g. Cooper *et al.* 2003) are selected as the focus for investigation. These studies, though useful in understanding the magnitude and types of value which users and the general public attach to estuaries, do not allow a comprehensive understanding of the factors which determine value and the estimation of overall value. Policy makers tend to focus on the "bigger picture" at the national level, while many managers are under pressure to assess value in systems which have not been studied and which may never be due to time and financial constraints (Turpie & Hosking 2005). The latter values are crucial in justifying local planning and development decisions which impact these systems. There is thus significant pressure to develop methods to determine or predict value for the full suite of South African estuaries under the constraints of resources currently available to researchers. To this end, Hosking *et al.* (2002, 2006) have conducted contingent valuation studies of a number of South African estuaries in order to value users' willingness to pay for water to maintain a stated hypothetical level of biodiversity in these systems. In theory, this can be compared with the water users' willingness to pay for water to determine the optimal allocation of freshwater. From these studies it is hoped to derive a predictive relationship on the value of freshwater inputs which can be extrapolated to all systems. However, there are a number of flaws in using a contingent valuation approach to do this, mainly involving its inflexibility (a single scenario is described for each estuary), uncertainty (the scenario is related to a very roughly defined volume of water), and due to the fact that it does not adequately deal with ecosystem services (which cannot be valued by the lay public) or non-water related issues (such as management of consumptive use).

This objective of this study was to produce a rough first estimate of all the different types of value associated with each of South Africa's temperate estuaries, based on existing information and additional data collected for this study, part of which was collected as a Resource Economics assignment for the Conservation Biology Masters Programme at the University of Cape Town and part of which was collected for an MSc thesis. The way in which these values might be expected to change with conservation action and the associated costs are dealt with in the chapter on conservation planning.

5.2 Total Economic Value framework

Wetland valuation is generally undertaken within the framework of Total Economic Value, which includes direct use, indirect use and non-use values. The total economic value generated by a wetland can be categorised into different types of value (Figure 5.1), providing a useful framework for analysis.

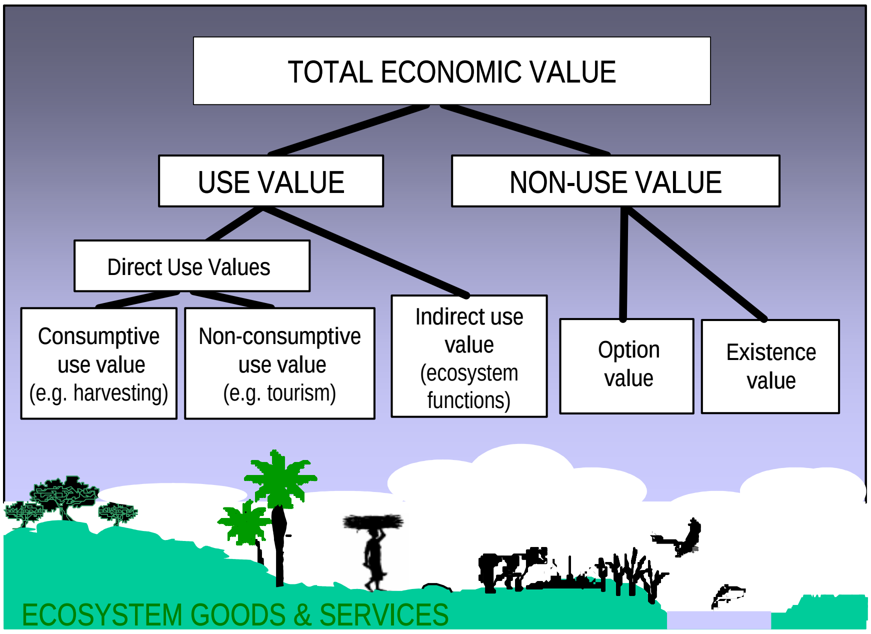


Figure 5.1. The classification of ecosystem values that make up Total Economic Value (Turpie *et al.* 1999).

5.2.1 Direct use values (subsistence & recreational)

Direct use values result from economic activity and are generated through the consumptive or non-consumptive use of an estuary's natural resources. Direct use values are generated through commercial and subsistence uses such as livestock grazing, fishing, wild plant use and hunting and through recreational uses such as angling, bait collecting, bird watching, photography and water sports. Values are generated through consumptive use (e.g. angling) and non-consumptive use (e.g. bird watching). Rather than separating consumptive and non-consumptive value, as conventionally done within the Total Economic Value framework, Turpie *et al.* (2006) separated direct use value into household use (largely consumptive) and tourism use (both consumptive and non-consumptive), for ease of analysis. A similar approach is taken in this study in that we have separated subsistence and recreational use.

South Africa's estuaries are an important recreational resource. A high proportion of estuaries are used primarily as recreational areas. These range from remote estuaries which are visited by hikers, to those with sizeable development. A large proportion of estuaries feature resort hotels and villages, some of which have grown into towns. Recreational value is held by both residents of and visitors to these areas. While numerous people visit estuaries temporarily, there are also significant numbers of people that feel sufficiently strongly about particular estuaries to invest in property around them, either for temporary or permanent residence. Recreational value thus manifests itself in two ways in the economy: as investment in property, which translates into economic impact through turnover in real estate, and expenditure by visitors, which translates into economic impact through turnover in the trade and tourism sector. In this study we refer to these values as property value and tourism value, respectively.

5.2.2 Indirect use values (ecosystem services)

Ecosystem functions may either generate outputs that form inputs into production processes elsewhere (in other words the benefits are realised off-site), or they result in engineering cost savings by performing functions that would otherwise require costly infrastructure or man-made processes. The provision of ecosystem services is generally positively related to the level of health or integrity of ecosystems.

The indirect use values associated with estuaries include the following most commonly-cited services:

1. *Refugia and nursery areas:* Estuaries provide critical breeding or feeding habitat for certain species that contribute to livelihoods and economic production elsewhere. This is the main service for which estuaries are known.
2. *Waste treatment and water purification*: Many wetlands are thought to have the capacity of breaking down wastes and detoxifying pollution, complementing the service provided by rivers of dilution and transport of pollutants. In the case of estuaries, this service may be provided to a limited extent; although there is no downstream use of freshwater, estuaries may help to dilute pollution of the estuary itself and of the marine environment.
3. *Carbon sequestration:* Wetlands are believed to be carbon sinks and therefore contribute towards reducing carbon emissions. This is a contentious issue, however, as most estuarine vegetation is short-lived and nutrients are recycled or released through burning. Most of this is not legitimate in terms of the 'additionality' required for carbon trading. In estuaries, 'legitimate' carbon sequestration probably only occurs in mangrove swamps.

In this study, we have concentrated on the nursery value of estuaries, since there is insufficient data on the waste treatment and carbon sequestration aspects. However, it is considered likely that the nursery value captures the bulk of the indirect value of estuaries.

5.2.3 Option (future) value

Option value is the future value of resources and services offered by ecosystems such as possible medicinal, leisure, agricultural or industrial uses. Option value is particularly important when there is still uncertainty regarding the potential use and value of the ecosystem later on (Nhuan *et al.* 2003; Perman *et al.* 1996, Barbier 1993). Even though an estuary may be underutilised at present, it may possibly be valuable for scientific research, education, tourism and other commercial enterprises which would increase its economic value in the future (Barbier 1993). Another way that the option value of an ecosystem may be raised is if the neighbouring local community have uncertain incomes (Nhuan *et al.* 2003). If there is not a readily available social welfare scheme for them to fall back on, they may be dependent upon basic commodities that they could harvest from the ecosystem to tide them over in times of need. A quasi-option value is the value obtained from not undertaking irreversible activities in order to retain options for future use of the ecosystem (Perman *et al.* 1996). The option value of ecosystems is a discussion point only. It is not possible to estimate true option value, though quasi-option value may be estimated.

5.2.4 Existence value

Non-use values include both existence value and bequest value. Existence value is the value of simply knowing that an estuary and its biodiversity are protected. This is despite the fact that they (the persons to whom the value is ascribed) do not derive any direct personal benefit. Bequest value is similar and is expressed when the current generation puts a conservation value on an area in order to preserve it for future generations (Pearce & Turner 1990, Barbier 1993). Local communities may regard the estuary as part of their heritage and link it to aspects of their beliefs, culture and traditions and therefore wish to be able to pass their customs and heritage that have developed around the wetland onto their future generations (Barbier 1993). It is extremely difficult to predict future option values as these will be closely correlated to future incomes and people's preferences (Barbier 1993). Although far less tangible than the use values, non-use values are reflected in society's willingness to pay to conserve these resources, and with appropriate market mechanisms, can be captured through transfers and converted to income.

5.2.5 Total economic value

Total economic value is theoretically the sum of all the above values, though depending on how they are measured they are not always strictly additive. The main consideration in adding values is to make sure that there is no double-counting.

Direct and indirect use values are of particular importance in a developing country context, where a critical national objective is to create growth in income and employment. These values are manifested directly or indirectly in tangible income and employment. Existence values inherently are not manifested in income and employment, and they are often highest in richer societies and in developed countries.

5.3 Subsistence use value

5.3.1 Data sources

Subsistence use of all estuaries between the Orange and the Mdumbe were evaluated using survey data collected as part of the Subsistence Fisheries Task Group assessment (Clark *et al.* 2002). These data were collected by a team of enumerators who were tasked with interviewing key informants knowledgeable regarding subsistence fishing activities in a series of eight regions spanning the South African coastline. A definition of subsistence fishers was recently developed by Branch *et al.* (2002) as "…*poor people who personally harvest marine resources as a source of food or to sell them to meet basic needs of food security; they operate on or near to the shore or in estuaries, live in close proximity to the resource, consume or sell the resources locally, use low technology gear (often as part of a long-standing community-based or cultural practice), and the kinds of resources they harvest generate only sufficient returns to meet the basic needs of food security*". Survey data used in this study were, however, collected prior to the development of this definition. In the absence of a suitable definition, key informants supplying information for the study were allowed to formulate their own definitions of what constitutes a subsistence fisher. Some variation from one estuary to another can be expected due to difference in definitions applied in separating subsistence from other kinds of fishers (e.g. commercial and recreational fishers). To minimise this bias, means were calculated from as many estimates as possible for the numbers of fishers and resources harvested from each estuary. Of the 149 estuaries in the region, multiple estimates were available for 21 systems, single estimates for 37 systems, while estimated or interpolated values (based on estuary size and location) were used for the 91 remaining systems.

5.3.2 Numbers of fishers and resources used

The estimated total number of fishers per estuary ranged from 0 up to a maximum of 135, with most estuaries supporting between 0 and 40 fishers (Figure 5.2). Variation in the estimated number of fishers operating on each estuary exhibited no clear coastwise trend (Figure 5.3). Resources harvested by subsistence fishers include fish, sand/mud prawns, swimming prawns, polychaete worms, and estuarine crabs.

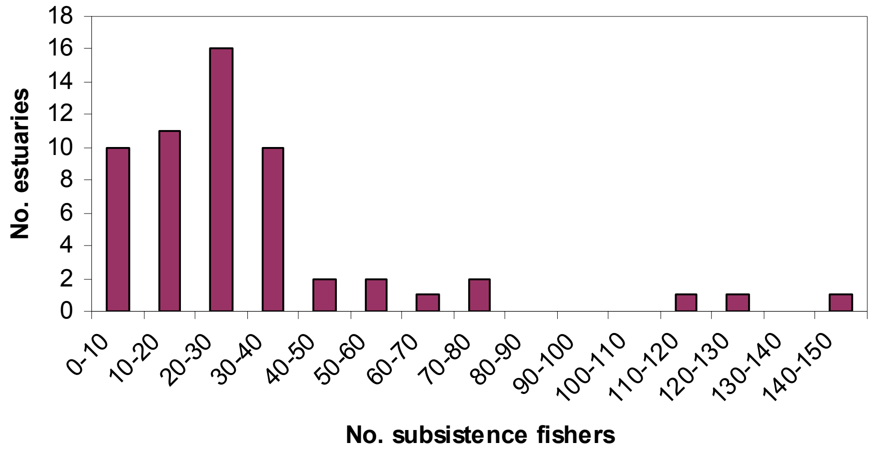


Figure 5.2. Frequency distribution of the number of subsistence fishers per estuary for estuaries between the Orange and Mdumbe (data from Clark *et al.* 2002).

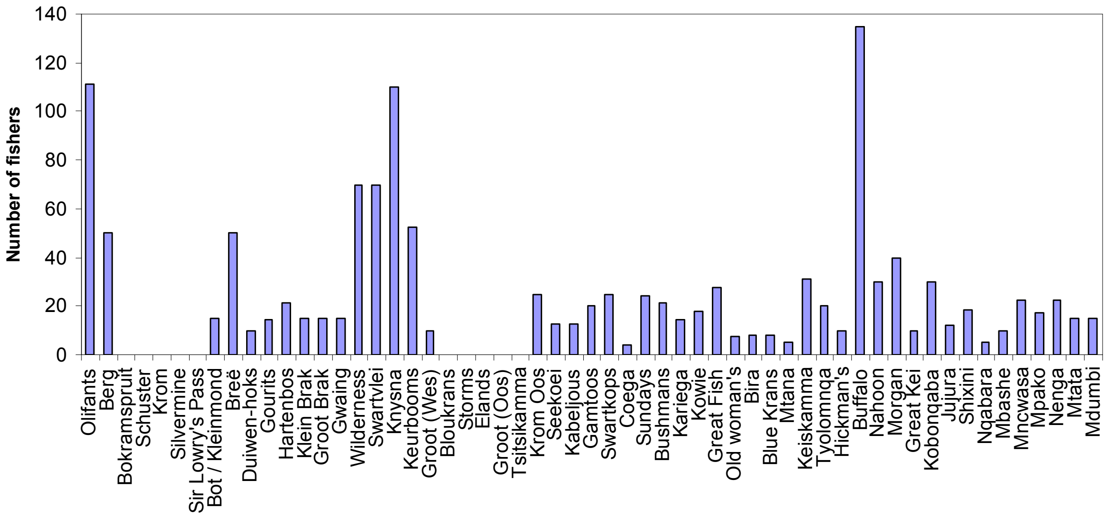


Figure 5.3. Estimated number of subsistence fishers active on estuaries between the Olifants and Mdumbe estuary (data from Clark *et al.* 2002).

An average of 6000 sand or mud prawns and 1200 fish were collected per estuary per year, although this varies considerably among estuaries (Figure 5.4). Much of the fish collected would probably have been consumed by the true subsistence fishers while the sand and mud prawns could only have been used as bait or sold as such. Fish were most important on the western and eastern edges of the study area. Harvesting of polychaete worms was also widespread in the region but accounted for a relatively small proportion of the catch (average

900 worms per estuary per year). Swimming prawns and estuarine crabs were only important in estuaries in the eastern portion of the study area (Figure 5.4).

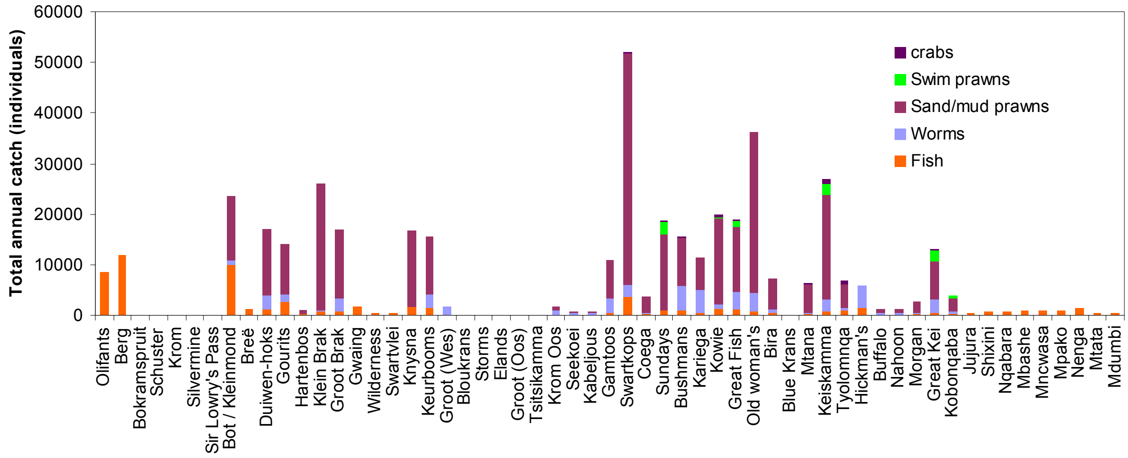


Figure 5.4. Variation in quantities of resources harvested by subsistence fishers in temperate South African estuaries (data from Clark *et al.* 2002). Based on survey data, but estimates are rough.

5.3.3 Estimated value of subsistence harvest

An estimate of the value of the annual subsistence catch from each estuary was derived by multiplying catches of the various resources by estimated value for each as proffered by the fishermen themselves (data from Branch *et al.* 2002). Values used were as follows: fish – R2 each, sand/mud prawns – R20 for 80 individuals, worms – R0.50 each, swimming prawns – R10 for 20 individuals, and crabs – R2 each. Using these estimates, total estimated value of resources harvested by subsistence fishers ranged from zero to R800 000 per annum, and the majority of estuaries were valued at R10 – R50 000 per annum (Figure 5.5). No clear trend was evident in the values moving from west to east nor was there a significant correlation with estuary size. The top twenty estuaries in terms of subsistence value are listed in Table 5.1.

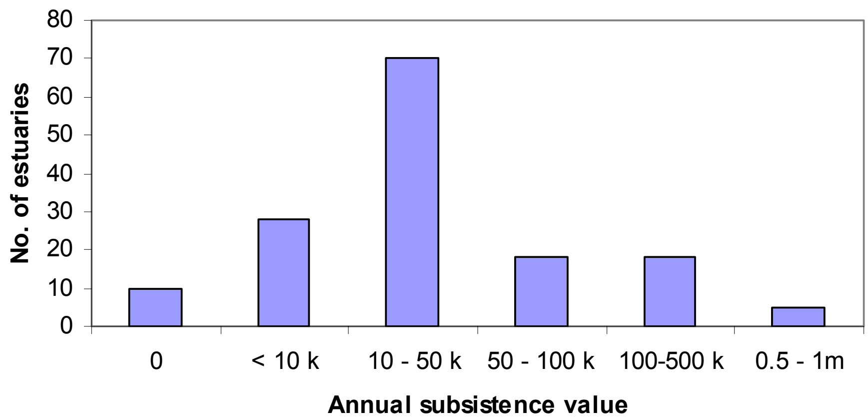


Figure 5.5. Frequency distribution of the estimated value of resources harvested by subsistence fishers in 149 temperate South African estuaries.

Table 5.1. Top 20 temperate estuaries in terms of subsistence value

Estuary	Subsistence value (R/y)	Estuary	Subsistence value (R/y)
Swartkops	808 953	Keiskamma	269 621
Knysna	786 500	Kowie	183 912
Olifants	756 500	Kariega	174 086
Berg (Groot)	600 000	Gamtoos	156 750
Bushman's	465 239	Buffalo	156 600
Bot/Kleinmond	421 875	Gourits	137 867
Keurbooms	379 006	Nxaxo/Ngqusi	133 623
Great Fish	360 349	Klein Brak	128 632
Groot Brak	273 925	Breë	120 000
Sundays	273 889	Goukou	120 000

5.4 Property value

5.4.1 Review

Property values associated with natural environment are typically investigated using the Hedonic Pricing Method. The Hedonic Pricing Method is a multivariate statistical technique which allows non-market valuation of the characteristics of a commodity rather than of the entire commodity itself (UNEP 1995, Mahan *et al.* 2000, Bolitzer & Netusil 2000, Freeman 1993, Lutzenhiser & Netusil 2001, Price 2003, Hobden *et al.*2004). The method is based on the premise that a commodity, such as a house, can be defined as bundle of measurable characteristics or variables (e.g. size, location, views) that together determine the total price of the commodity being investigated (Russell 2001). This approach assumes it is possible to isolate the contribution of a given variable and thus estimate the relative proportion of the full price paid for a commodity that can be attributed to that given characteristic or variable. The general formula used in a hedonic valuation includes a suite of variables falling under four broad categories and is described by the equation (following Pearce & Turner 1990):

Property price = f (property variables, neighbourhood variables, accessibility variables, environmental variables)

The Hedonic Pricing Method assumes that consumers have access to the entire housing market and can differentiate among or between variables of a property and as such there is a sufficiently wide variety of choices on all characteristics that no one is stuck in an indecisive situation (Kulshreshtha & Gillies 1993, UNEP 1995, Russell 2001). It also assumes that the market is in or near equilibrium (Russel 2001). While these assumptions may not always hold true, it is accepted that this method provides a reasonable approximation of the actual values.

Numerous studies have used the Hedonic Pricing Method to investigate the value of aquatic environments to nearby property owners in urban areas (Bin & Polasky 2002; Mahan *et al.* 2000; Turpie *et al.* 2003). Bin & Polasky (2002) used the Hedonic Pricing Method to measure how inland and coastal wetlands affect nearby residential property values in Carteret Country, North Carolina. They found that proximity to coastal wetlands has a positive association with the nearby property value, while inland wetlands lower the value in a neighborhood. Reducing the distance to the nearest coastal wetland by 1000 feet raised the property price by \$1010 at the initial distance of one mile, while the same change for inland wetlands decrease the property price by \$567 (Bin & Polasky 2002). Mahan *et al.* (2000) estimated the value of four different wetlands types (forested, scrub-shrub, emergent vegetation and open-water wetlands) as well as lakes and rivers or streams in the Portland, Oregon. They found that wetland type influences the value of residential property and that the wetlands influence property values for other amenities such as parks, lakes, rivers and streams. Increasing the size of the nearest wetland to a residence by one acre increased the residence's value by $24. Similarly, decreasing the distance to the nearest wetland by 1000 feet increased the property value of $436. However, property values were not influenced by wetland type (Mahan *et al.* 2000).

Alternatively, property may be valued by interviewing residents or estate agents (expert opinion) as to how they value a particular attribute (Price 2003, Hobden *et al.* 2004, Turpie *et al.* 2003, van Zyl & Leiman 2001, 2004). Van Zyl & Leiman (2001) used both the Hedonic Pricing Method and expert opinion (estate agents) to estimate the economics of open spaces for the City of Cape Town. They found that well-maintained wetlands are amongst those with the greatest potential to positively influence property values. Both van Zyl & Leiman (2001) and Turpie *et al.* (2003) concluded that expert opinion provided a good approximation of the results of a more data-intensive Hedonic Pricing Method. Both approaches "have similar features and rely on speculative choice of variables, assumptions about arithmetic form and interaction of variables, and on hidden subjective judgements" (Price 2003).

A handful of studies have applied the above methods to determine the property price premium attributable to estuaries in South Africa (van Zyl & Leiman 2001, Cooper *et al.* 2003, Turpie *et al.* 2003, Turpie 2006, Maswime 2006). Two of these were comprehensive studies that involved large datasets and use of the Hedonic Pricing Method (van Zyl & Leiman 2001, Turpie 2006). The remainder employ expert opinion garnered through interviews with estate agents.

Van Zyl & Leiman (2001) estimated the property price premium for the Sandvlei estuary. Sandvlei is surrounded by four residential areas: Lakeside/Muizenberg North to the west, Muizenberg to the south, Marina Da Gama to the east, and Sheraton Park and Frogmore Estate to the north. Sufficient sales data could only be obtained for Marina Da Gama. The statistical analysis yielded reasonably comparable results to the estate agent interviews (R76.7 million vs. R87.5 million, respectively).

Cooper *et al.* (2003) carried out a rapid assessment of the recreational and property values of four estuaries. Based on interviews with estate agents as to the number of properties with a view and the average premium associated with the view, they estimated the property premium values as follows: Berg: R11.9 million; Breede: R50.0 million; Knysna: R2.0 billion; Keiskamma: R1.0 million.

Using a similar approach, but with multiple estate agents, Turpie *et al.* 2003b estimated the property value of a view of the Knysna estuary as in the region of R1.4 – R2 billion, similar to that obtained by Cooper *et al.* (2003).

Turpie (2006) undertook a more comprehensive hedonic valuation study at the Kromme and Seekoei estuaries in the Eastern Cape, in which data were collected from door-to-door surveys. At the Kromme Estuary, there are a total of 4584 erven and 2555 properties in the Cape St Francis to Kromme River area, of which 45% are occupied by permanent residents. Most households have boats and make use of the estuary. Distance to the estuary was a significant factor determining property prices in the area. Based on the property price premium associated with river-front property, the overall property value contributed by the estuary was conservatively estimated as R578 million. There are a total of 2300 erven and 770 properties in the vicinity of the Seekoei Estuary, of which about 60% are occupied by permanent residents. There is relatively little use of the estuary, and on average only 1 in 10 households have a boat. House prices were significantly correlated with size and proximity to the beach, but proximity to the estuary was not a significant factor (Turpie 2006).

5.4.2 Approach to value all estuaries individually

This study incorporates and builds on the results of an MSc project linked to this study by Takalani Maswime. Maswime (2006) collated property value data for selected Cape estuaries in order to investigate any relationships between total property value or the estuary premium and estuary characteristics. Several estate agents were interviewed at each of 16 estuaries. The aim was to find a relationship that could easily be extrapolated to all other estuaries in the region in order to generate a rough estimate of the estuary premium component of property value.

Based on the findings of the MSc study, it was impossible to extrapolate to other estuaries, necessitating further primary data collection. Thus the property price premium associated with proximity to the remaining estuaries for which information was lacking was estimated using information on property numbers and values gathered from estate agents and aerial photographs. The latter part of the study was purely desktop, involving telephonic interviews rather than site visits. In cases where data could not be obtained from estate agents directly, reasonable estimates were interpolated from existing data and data gathered from internet sources (estate agency websites). In each case the total premium was calculated relative to a base price (price of a house relatively far from the estuary and with no view of it).

The total property price premium was then converted to an annual value, expressed as direct income (value added) generated in the real estate sector.

5.4.3 Results

As for other studies, Maswime (2006) showed a high premium associated with proximity to an estuary (Figure 5.6). However, there was no significant correlation of the average or aggregate premium associated with an estuary and the physical characteristics of the estuary, such as size and accessibility.

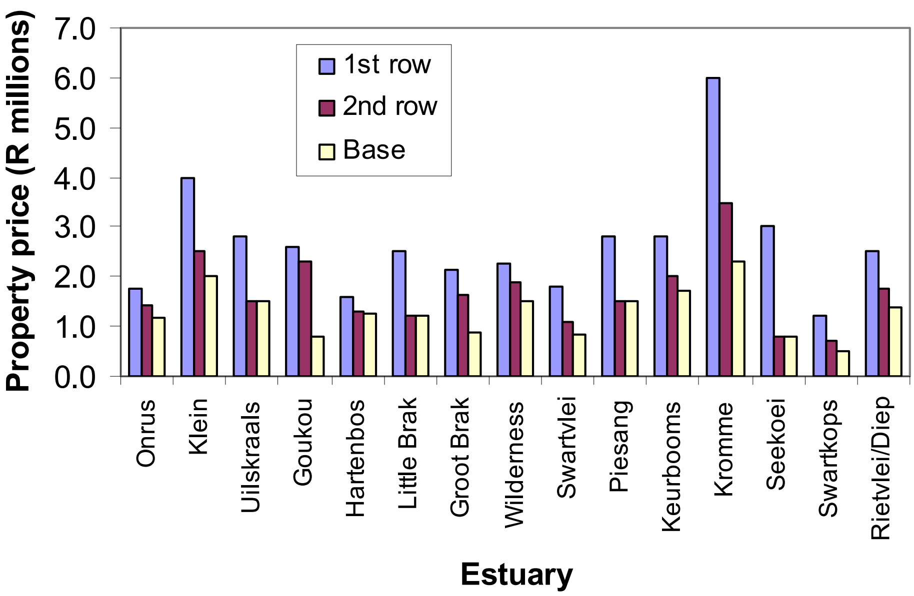


Figure 5.6. Property prices for the front and second rows of houses around 15 estuaries in relation to the base price for a house without close access to or view of the estuaries.

However, subsequent regression of these data against scenic beauty scores (see following section) revealed that the average premium associated with estuary proximity was significantly correlated with scenic beauty.

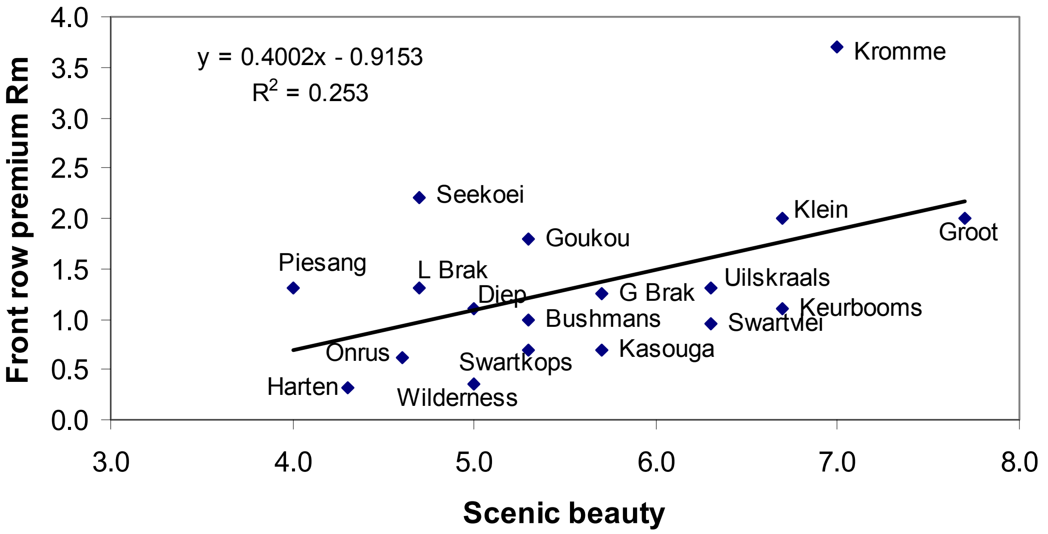


Figure 5.7. Relationship between estuary frontage premium and the scenic beauty of estuaries, scored on a scale of 1 – 10.

Because of the low fit of the above relationship, this was not sufficiently reliable for extrapolation to other estuaries, necessitating further data collection (see methods).

In the final data set, 77 estuaries (55% of those in the study area) were estimated to have a measurable property price premium. This ranged from about R1 million to R2 billion, but most frequently fell into the R10 – 50 million range. The total property value associated with temperate estuaries was estimated to be in the order of R10 656 million.

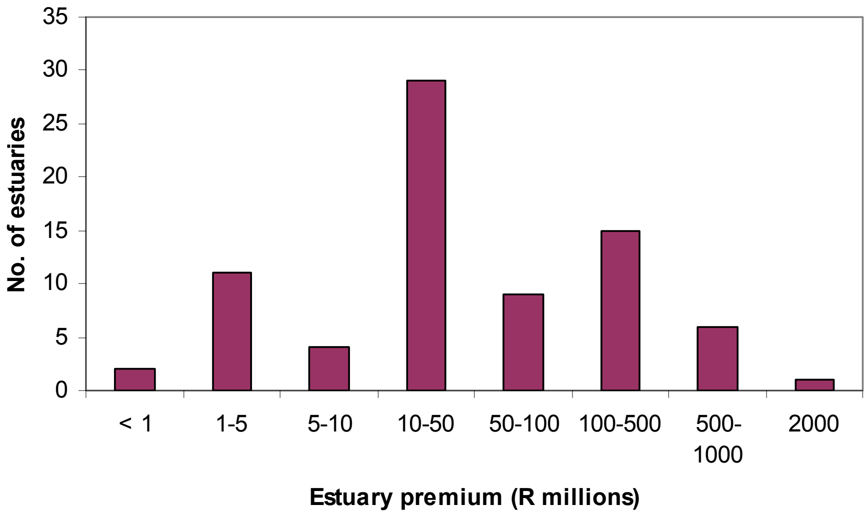


Figure 5.8. Frequency distribution of total property value attributed to estuaries for the 77 estuaries for which there was a measurable property price premium. A further 71 estuaries have no (or negligible) property price premium associated with them.

Since property values are capital values, these are incompatible measures when compared with values expressed per unit time such as tourism expenditure or subsistence values. Thus the total property premium for each estuary was converted to annual turnover in the real estate sector based on estimated turnover rates of property and the commission accruing to the property sector. For example, in the Kromme study (Turpie 2006) the R578 million property premium translated to about R17.7 million in terms of direct value added to national income in the real estate sector per annum. Using the same method, the annual contribution by estuaries to the real estate sector of the economy was estimated to be in the order of R320 million per annum. This is just a fraction of the real estate sector income generated by turnover of properties at the developments around estuaries, of course, as it is based on the premium alone. The top 20 estuaries in terms of property value are listed in Table 5.2

Table 5.2. Top 20 temperate estuaries in terms of property value attributable to estuary

Estuary	Property value (R m)	Estuary	Property value (R m)
Knysna	1 400.0	Gourits	369.0
Breë	884.1	Swartvlei	317.1
Bushman's	730.0	Sundays	265.0
Rietvlei/Diep	657.2	Berg (Groot)	207.5
Kowie	613.1	Wilderness	188.0
Kromme	578.0	Morgan	180.0
Goukou	523.2	Kwelera	165.0
Bot/Kleinmond	452.1	Kariega	156.0
Groot Brak	413.4	Swartkops	155.0
Keurbooms	399.0	West Kleinemonde	143.0

5.5 Tourism value

5.5.1 Review

Visitors to estuaries generate expenditure on accommodation, in restaurants and in the retail sector. Not all tourism expenditure in visiting estuary resorts is attributable to the estuary itself, as there are often multiple attractions associated with the area, such as beaches, villages and surrounding natural areas. Nevertheless, it is possible to derive the expenditure that is attributable to the estuary by asking visitors about their motivations for coming and their use of the area. Expenditure by visitors has an impact on the local economy, though not necessarily on the national economy. If an estuary plays a role in attracting visitors to the country, then it would also have a benefit in terms of adding value to the national economy. This is certainly the case for some systems, such as Knysna and Keurbooms, though the impact is relatively minor because of the relatively small role that estuaries play in the context of the large number of reasons for visiting South Africa (Turpie *et al.* 2003). For the most part, South African estuaries are enjoyed primarily by South Africans. Nevertheless the expenditure by tourists is a partial measure of their Willingness to Pay for using the estuary as a recreational amenity, and hence provides an estimate of the welfare benefit derived by these visitors.

Few studies have attempted to estimate the recreational value of South African estuaries. Cooper *et al.* (2003), for example, estimated the recreational expenditure associated with about four estuaries, but these estimates were based on very small sample sizes and did not account for the role of other attractions.

Using the travel cost method, Turpie & Joubert (2001) estimated the recreational value of the Sandvlei estuary in Cape Town to be in the order of R713 500. It is important to note that this is the only method that provides an estimate of consumer surplus[5], which is a truer measure of recreational value. The actual expenditure incurred was much lower than this.

Turpie & Joubert (2005) estimated the recreational use value of the Knysna estuary. The topographical features of the area, the estuary and surrounding forests together make Knysna a highly attractive location. Knysna has a population of just over 51 000, of whom about 22 000 are economically active. The town plays host to an estimated 843 000 visitors per year (2002 estimate), of whom almost half are overnight visitors. About 27% of visitors at any one time are foreign. South African visitors, and particularly foreign visitors, have a much wealthier profile than the town inhabitants. South African visitors tend to visit Knysna specifically, while foreigners tend to have Knysna as one stop on a multiple destination trip. The Knysna estuary contributes about 60% of the value of Knysna for both residents and visitors. Based on a survey of some 1 000 visitors, it was estimated that about R1 billion of visitors' expenditure on visiting Knysna could be attributed to the estuary (Turpie & Joubert 2005).

Based on household surveys, Turpie (2006) estimated that the Kromme and Seekoei estuaries account for approximately R25 million and R3 million in terms of visitor expenditure per annum. Again this is a fraction of the total visitor expenditure in those areas. The estuaries accounted for about 17% and 10% of the attraction of those areas, respectively (Turpie 2006). Similarly, the Goukamma estuary was estimated to account for about R350 000 in terms of annual visitor expenditure (Turpie *et al.* 2007).

5.5.2 Approach to value all estuaries individually

Because so little work has been carried out on the tourism use value of estuaries, new estimates had to be derived for the tourism value of estuaries for this study. Visitor expenditure was not correlated with property value, so the latter could not be used as a guide. Thus four known tourism values for estuaries (Knysna, Kromme, Seekoei and Goukamma) were used as benchmarks against which estimates were made based on expert knowledge and understanding of each of the estuaries in the study area. These are thus rough estimates, but likely to be in the right order of magnitude.

5.5.3 Results

Unlike in the case of property values, all estuaries have some level of tourism value. These range from very low values for systems that might only be visited in passing by hikers, to high values for estuaries that have a high level of tourism infrastructure associated with them. Thus to some degree, the tourism value of an estuary is closely tied to the level of development around the estuary, even though the individuals assign value to particular estuaries for very different reasons and often in very different proportions. Indeed, tourists that seek a wilderness experience may have a more valuable experience at a less developed than a more developed estuary (i.e. having higher willingness to pay for the former), but the tourists that enjoy more developed estuaries (because of the variety of things to do, social scene, etc) tend to be more numerous.

Only 23 estuaries were estimated to have a tourism value of under R10 000, with the majority of estuaries being estimated to be worth between R10 000 and R1 million in terms of tourism value attributed to the estuary itself (Figure 5.9). The total annual tourism value of temperate estuaries was estimated to be some R2.08 billion per annum. The top 20 temperate estuaries in terms of tourism value are listed in Table 5.3.

[5] Consumers' surplus: a net benefit realised by consumers when they buy a good at the prevailing market price. It is the difference between the maximum price consumers would be willing to pay and that which they actually pay for the units of the good purchased.

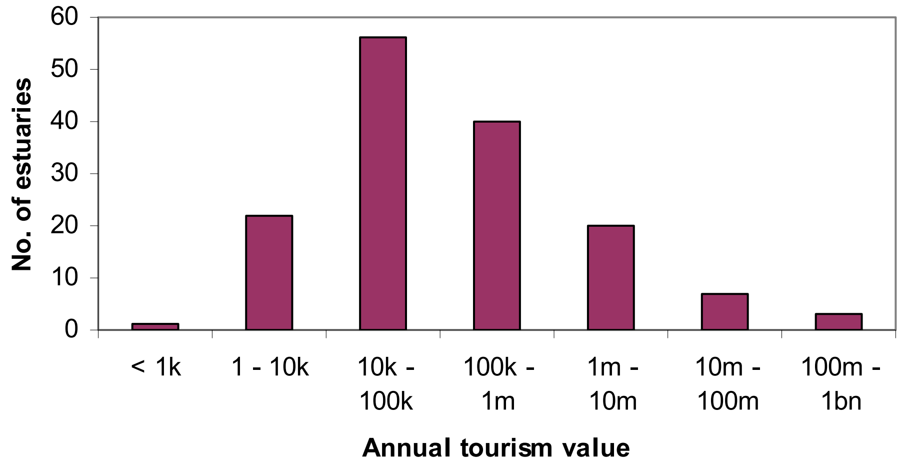


Figure 5.9. Frequency distribution of annual tourism value attributed to the 149 temperate estuaries.

Table 5.3. Top 20 temperate estuaries in terms of tourism value attributable to estuary

Estuary	**Tourism value (R m /y)**	**Estuary**	**Tourism value (R m / y)**
Knysna	1000	Bushman's	10
Keurbooms	400	Groot Brak	10
Klein	200	Sundays	10
Wilderness	100	Berg	10
Swartvlei	75	Nahoon	10
Goukou	50	Cintsa	10
Swartkops	50	Morgan	7.5
Breë	25	Bot/Kleinmond	5
Kromme	25	Kwelera	5
Kowie	20	Kariega	5

5.6 Nursery value

5.6.1 Review

Estuaries are very productive systems mostly due to high nutrient inputs, while also providing sheltered habitat and nursery grounds for many organisms which can either be exploited directly in the estuary or later in life in coastal areas (Costanza *et al.* 1997, Cooper *et al.* 2003). Freshwater flow and the frequency and duration of estuary mouth openings are major factors affecting estuarine biota, and particularly the juveniles of marine organisms that use them as nursery grounds (Whitfield 1994, Strydom *et al.* 2003) either directly through habitat availability, or indirectly through their impact on system productivity (Islanders & Kingsford 2002). Factors that make estuaries suitable nursery habitats are increased food, higher temperature, turbid waters and lower salinities, all of which can be changed by a change in freshwater input (Islanders & Kingsford 2002).

In South Africa estuaries act as nursery areas for linefish species and penaeid prawns caught in inshore marine environments. Since the latter fisheries operate mainly along the KwaZulu-Natal coast (Demetriades & Forbes 1993), this study concentrates solely on the line fisheries.

The contribution by estuaries as feeding grounds for adult fish is difficult to quantify and has not been considered here.

Lamberth & Turpie (2003) estimated the economic value of estuarine fishery resources in South Africa. The study considered both direct use of fish within estuaries and the role of estuaries as a nursery area for inshore marine fisheries. All types of fisheries ranging from subsistence to commercial and recreational fisheries were included. Some 80 estuarine fish are utilised, these species varying in their degree of association with estuaries. Based on available information on catches for a number of estuaries, a relationship was found between catch and estuary size, type and biogeographic zone. This was used to extrapolate existing data to the remaining estuaries. The values were estimated as value added to the economy, in the form of the contribution to Gross Domestic Product (GDP) and, in the case of commercial fisheries, included the value added by subsidiary industries. Subsistence fisheries were taken as the gross value of landed catches, calculated on the basis of the market value of fish caught. Recreational values comprise the expenditure by anglers on equipment and travel to fishing sites. The latter may overestimate the value since fish are one part of a recreational package that may include other elements, such as enjoyment of coastal areas or alternative recreational activities in the absence of fish (Lamberth & Turpie 2003). Based on the types of association of different species with estuaries, about 21% of the value of inshore marine catches was attributed to estuaries. The total value of estuarine and estuary-dependent fisheries was estimated to be just under R1 billion (1997 Rand), which works out to an average of R13 230 per ha for all South African estuaries.

5.6.2 Approach to value all estuaries individually

The value estimates in Lamberth & Turpie (2003) were provided for different coastal sections:

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

In this study, the values per coastal section were disaggregated to individual estuaries on the basis of their size. Thus, the assumption was made that open and closed estuaries contributed equally on a per ha basis. This is reasonable in that closed estuaries provide better (more sheltered and typically warmer, largely predator free) growing environments but open estuaries are more available for recruitment.

5.6.3 Results

The total nursery value of the estuaries in the study area was estimated to be in the order of R773 million per annum, ranging from R900 to R167 million per estuary. The majority of estuaries were estimated to have a nursery value in the range of R100 000 to R10 million per annum (Figure 5.10).

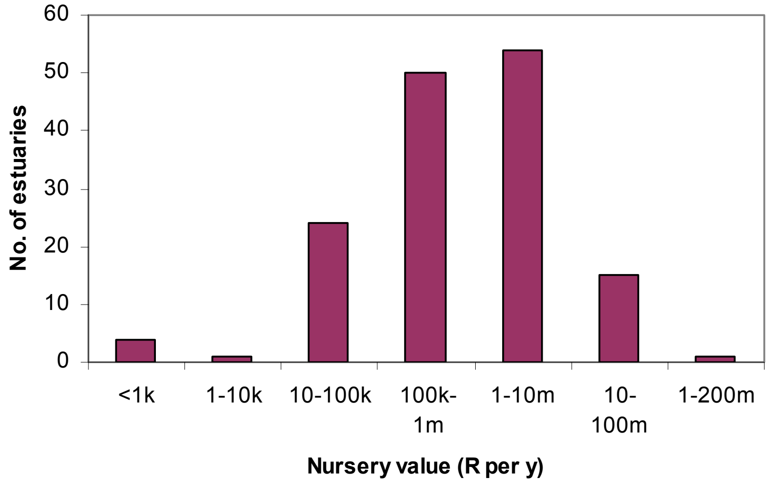


Figure 5.10. Frequency distribution of estimated annual nursery value of the 149 temperate estuaries

Table 5.4. Top 20 temperate estuaries in terms of nursery value

Estuary	Nursery value (R m / y)	Estuary	Nursery value (R m / y)
Knysna	167.6	Keurbooms	13.8
Klein	81.3	Kariega	13.0
Swartvlei	50.2	Goukamma	12.6
Bot/Kleinmond	46.7	Breë	12.5
Swartkops	32.8	Sundays	11.4
Keiskamma	32.5	Kromme	11.2
Great Fish	24.1	Mpekweni	9.3
Gamtoos	21.8	Mtati	8.2
Bushman's	14.0	Mgwalana	8.1
Wilderness	14.0	Kowie	7.8

5.7 Existence value

5.7.1 Review

Non-use value is typically estimated using the Contingent Valuation Method (CVM). CVM is used to estimate the values associated with resources or products which do not currently fall under existing markets, and thus utilise a simulated market approach (Mitchell & Carson 1989, Garrod & Willis 1999). A 'stated preference' method, CVM elicits a stated willingness-to-pay (WTP) from respondents which is contingent on a hypothetical scenario coming about (Arrow *et al.* 1993). Though CVM has been identified as being open to a number of biases, many of which are applicable to survey methods in general, it remains the most widely used and one of the only methods available for estimating non-use values (Carson *et al.* 1996). Over 1 600 studies, related to environmental decision-making and policy were recorded by Gregory (1999 cited in Chee 2004) as having made use of the CVM method. Although there has been an estimate of the non-use value of South African biodiversity in general (Turpie 2003), Turpie & Savy (2005) produced the first estimate of the non-use values of estuaries in South Africa, as well as of the Knysna estuary in particular.

In Turpie & Savy's (2005) study, 505 respondents were interviewed in the Western Cape. More than two thirds (71%) of survey respondents exhibited some level of WTP for the conservation of South African biodiversity in general. While there was a high level of ignorance regarding South African estuaries, two thirds of respondents had at least heard of the Knysna estuary or "Knysna Lagoon". The willingness to pay of Western Cape residents for South African estuaries was R19 million. Extrapolated to all South Africans, this suggests a total non-use value for South African estuaries of some R93 million per annum. Based on the proportion of their WTP for conservation that they would allocate to Knysna estuary itself, the total non-use value of the estuary to the Western Cape population was estimated as R2.7 million. Extrapolated to all South Africans, the non-use value of the Knysna estuary was estimated to be some R9.7 million per annum.

Nevertheless, the above study did not disaggregate the total WTP among each of South Africa's estuaries. In a way this value should not be disaggregated, in that it really represents South Africans' WTP for preserving estuarine biodiversity. CVM studies have repeatedly shown that WTP is not area-sensitive. In other words, people's WTP to protect estuaries might be expected to be similar irrespective of whether 50 000 ha or 500 ha were required for biodiversity conservation. This is evident from the above study where the existence value of the Knysna estuary was apparently some 10% of the value of all estuaries. No doubt, disproportionately high results would have been obtained no matter what estuary was highlighted at the end of the CVM. Thus if the outputs of this study result in the effective protection of estuarine biodiversity, then the above value of R93 million is the public's WTP to achieve that conservation plan.

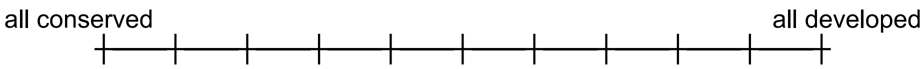
However, it must also be acknowledged that the public might derive different amounts of existence value from different estuaries. In other words, the configuration of estuaries chosen for conservation may affect aggregate existence value. Thus, for this study a survey was carried out that aimed to determine how the characteristics of an estuary affect its individual existence value.

5.7.2 Approach to value all estuaries individually

A valuation study was carried out using a combination of contingent valuation and conjoint valuation (choice modelling) methodology. A total of 605 people were surveyed throughout the Western Cape by a total of 18 enumerators, all students of the University of Cape Town. Each interview took roughly ten minutes to complete.

Respondents were first asked a series of questions on the following:
- Level of interest in nature
- Willingness to pay towards conservation in SA as a whole
- The way in which they would like their contribution to be spread among the major biomes, including estuaries
- Their level of experience with South African estuaries

In addition, respondents were asked to indicate what they felt the optimal level of development for estuaries should be, using the following pictorial scale:



Overall willingness to pay for estuaries was estimated by extrapolating the above results (WTP for conservation x % allocation to estuaries) to the South African population.

In order to disaggregate this or earlier estimates of aggregate WTP for estuarine biodiversity, it was necessary to establish a relationship between existence value and estuary characteristics for which data could be collected for all estuaries.

Respondents were thus asked to provide scores on how they valued 5 estuaries based on information about their biodiversity importance, level of development, size and appearance (from pictures). They were asked to estimate how different factors such as the above contribute to an estuary's existence value. The results of these questions were used to find a relationship between a value score and estuary characteristics that could be used to apportion overall existence value among all the estuaries involved.

A second survey was conducted in which 125 respondents were asked to score the 14 different estuaries used in the first survey in terms of their scenic beauty alone. The aim of this exercise was to get an independent view on their scenic beauty without any knowledge of their other attributes. Following this, four people were asked to assign beauty scores to all the estuaries in the country, based on aerial photographs. Their judgement was compared with that of the general public (for 14 estuaries) before the data were used for analysis.

5.7.3 Willingness to pay for estuary conservation

Some 95% of respondents were from the Western Cape. The sample was not representative of race groups in the Western Cape or South Africa as a whole (Table 5.5), nor of income categories (Figure 5.11), but a good spread of income categories was nevertheless obtained. Thus assuming that income is the primary predictor of WTP, as opposed to any cultural differences due to race, data were analysed in terms of income category and extrapolated accordingly.

Table 5.5. Race composition of the sample compared with provincial and national population.

Race	% in sample	% in W Cape	% in SA
Asian	1	1	4
Black	21	21	64
Coloured	32	55	13
White	46	23	19

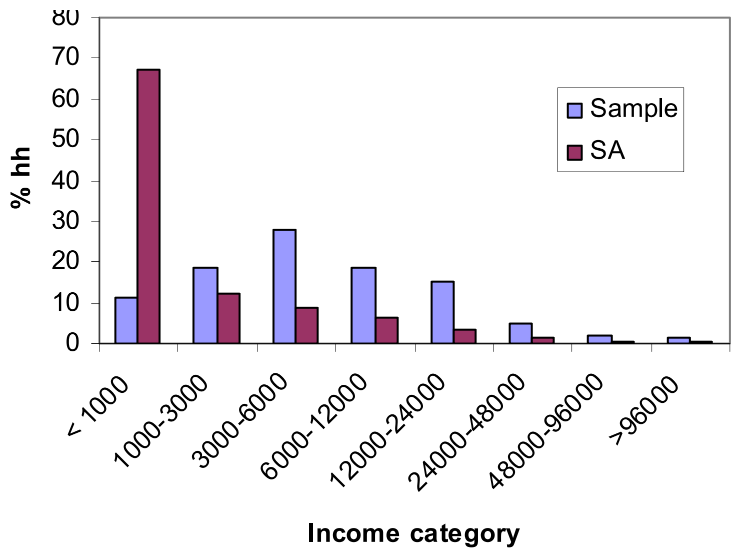


Figure 5.11. Distribution of household iincome categories of respondents and the corresponding pattern in the country.

The percentage of respondents that were willing to pay towards conservation in South Africa was positively correlated with stated level of interest in nature and with income, as expected, therefore leading credence to the results obtained in the study. Among households that had a positive WTP, the amount was also correlated with interest levels and income. The overall average WTP (taking zero responses into account), was strongly positively related to income (Figure 5.12). There were also differences in WTP by race group but these could not be separated from income effects.

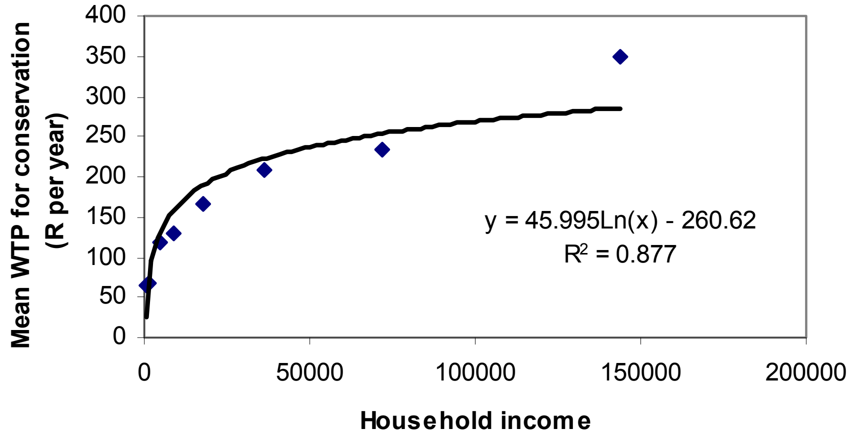


Figure 5.12. Respondents' overall willingness to pay towards conservation in South Africa, in relation to their household income level (using midpoints of income categories).

In terms of how the contribution to conservation should be allocated, respondents favoured coastal/marine habitats, forest areas, and rivers/wetlands, and apportioned an average of 8.4% to estuaries (Figure 5.13).

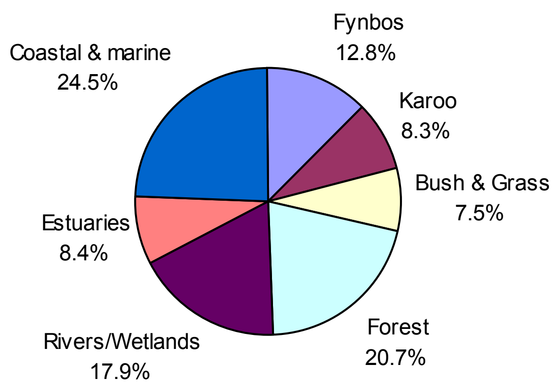


Figure 5.13. Overall average desired distribution of conservation donations to different biomes and habitats.

This proportion was applied to the above estimates of WTP in order to estimate average WTP for estuaries per income group. The latter values, extrapolated to the estimated number of households per income group from Census 2001 data, yielded an overall WTP of some R80.8 million per year (Table 5.6). This is not dissimilar to Turpie & Savy's (2005) earlier estimate of about R90 million.

Table 5.6. Average WTP for estuaries per income group, and estimated overall WTP for estuary conservation in South Africa

Household Income	WTP for estuaries	No. of households	WTP SA
< 1000	5.5	7 899 814	43 728 400
1000-3000	5.7	1 451 103	8 239 685
3000-6000	9.9	1 026 987	10 116 586
6000-12000	10.9	733 958	7 993 479
12000-24000	13.9	429 139	5 964 974
24000-48000	17.6	153 895	2 707 436
48000-96000	19.6	49 125	961 527
>96000	29.3	38 598	1 130 093
TOTAL			**80 842 180**

5.7.4 Value of individual systems

The average scores assigned to the different estuaries are shown in Figure 5.14. There was no significant difference in the scores among different race or income groups.

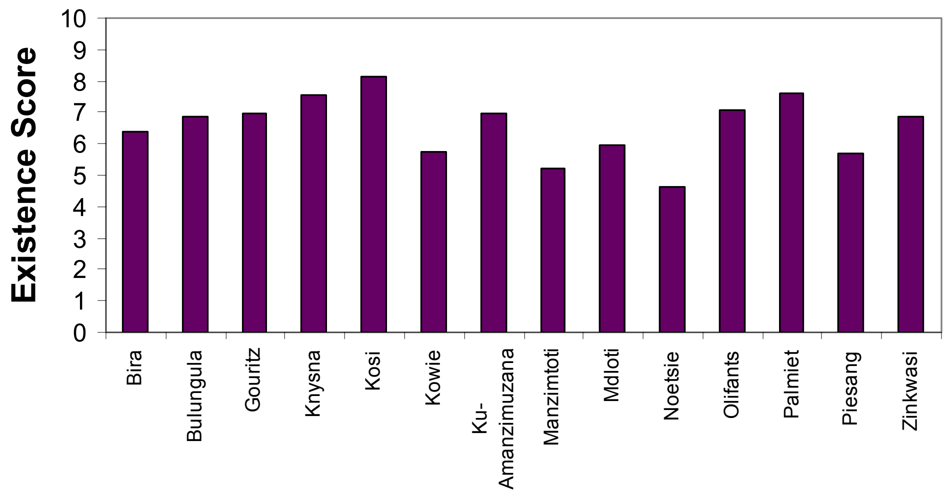


Figure 5.14. Average existence value score assigned by respondents to each of 14 different estuaries

Respondents claimed that scenic beauty and biodiversity were the main factors contributing to the existence value of a particular estuary. Size and level of development were mostly considered inconsequential, as was the remoteness of the system. However, the economic and subsistence contribution was considered slightly more important, suggesting that they valued estuaries for the contribution to society as well as to biodiversity.

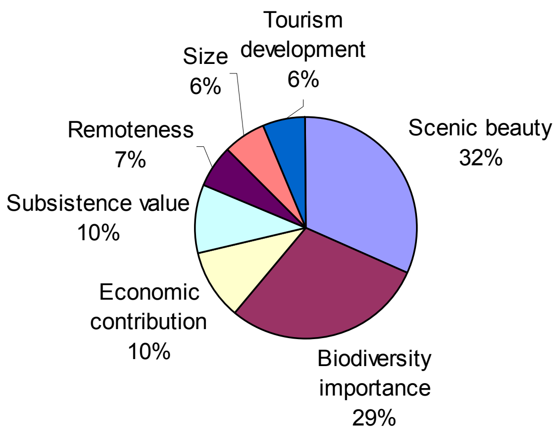


Figure 5.15. The way in which respondents claimed to weight different factors in determining the existence value of an estuary

However, the scores given by respondents correlated very strongly with an independently-determined scenic beauty score (Figure 5.16), and the other factors did not add significantly to the relationship. Thus, in practice, scenic beauty was apparently the predominant driver of the existence value of estuaries. This is understandable in that the general public can probably appreciate beauty more easily than they can appreciate biodiversity importance.

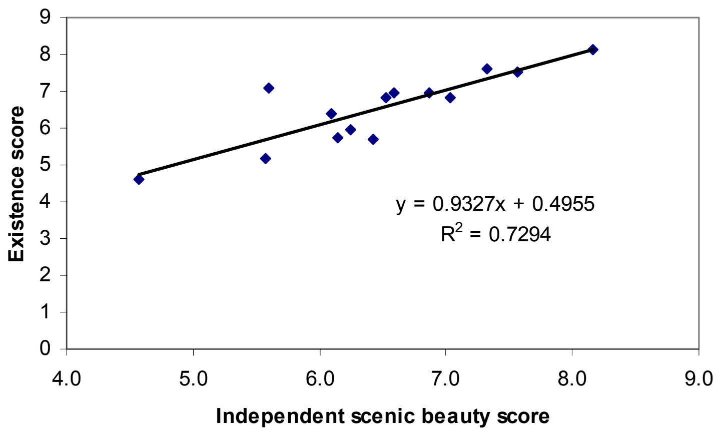


Figure 5.16. Relationship between existence value scores and interdependently determined scenic beauty scores for 14 estuaries.

We thus used scenic beauty as the basis for allocating the overall WTP among all the estuaries in the country. Since the scenic beauty scores for the whole data set were generated by a different group of people, we first tested their reliability against the average scores of 125 respondents for the 14 estuaries described above. The scores were significantly correlated ($r^2 = 0.64$).

The nature of this method meant that there is not a large range in the derived existence value of individual estuaries. The value ranged from about R50 000 to R500 000 per estuary. This is about an order of magnitude lower than the stated existence value of a single estuary when it is singled out but is considered to be a reasonable estimate thereof given the reasons outlined above. The top 40 estuaries in terms of existence value are listed in Table 5.7.

Table 5.7. Top 40 temperate estuaries in terms of existence value

Rank	Estuary	Rank	Estuary
1	Mpako	21	Breë
2	Bulungula	22	Palmiet
3	Shixini	23	Qolora
4	Knysna	24	Kaaimans
5	Goukamma	25	Elandsbos
6	Kwenxura	26	Kromme
7	Ngqwara	27	Berg
8	Gwaing	28	Heuningnes
9	Duiwenhoks	29	Cefane
10	Sout (Oos)	30	Mbashe
11	Qora	31	Gxulu
12	Groot (Wes)	32	Lottering
13	Ngadla	33	Gqunqe
14	Nyara	34	Sihlontlweni/Gcini
15	Maalgate	35	Jujura
16	Mendu	36	Bloukrans
17	Cebe	37	Storms
18	Ncizele	38	Ku-amanzimuzama
19	Bot/Kleinmond	39	Steenbras
20	Gamtoos	40	Matjies/Bitou

5.7.5 Public opinion on estuary development vs. conservation

The majority of respondents felt that the optimal level of development around South African estuaries lay between zero and 50% (Figure 5.17), with an overall average score of 40%. There were differences between income groups, but these differences were less marked than expected. Wealthier respondents favoured lower levels of development (average 25%), whereas poorer respondents favoured more development (average 48%).

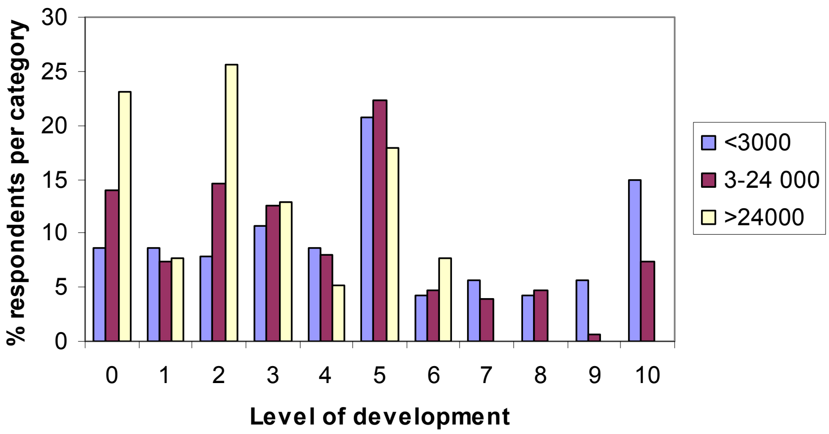


Figure 5.17. Proportion of respondents favouring different level of development around estuaries in South Africa. Respondents are split into three income groups, in terms of average monthly household income.

5.8 Summary

The values estimated above are summarised for each estuary in Table 5.8, highlighting estuaries for which certain types of value are noteworthy. This information will be useful not only in conservation planning, but in guiding the vision behind management planning for individual estuaries.

Table 5.8. Preliminary estimates of the recreational, subsistence and nursery value of estuaries, and the their relative existence value (which is largely associated with scenic beauty). Highest values are shown in bold.

Estuary (West to East)	Recreational value (R millions/y)	Subsistence value (R millions/y)	Nursery Value (R millions/y)	Scenic/Existence value
Orange	0.05-0.5	<0.05	1-5	Medium
Olifants	0.05-0.5	**>0.5-1**	1-5	Medium
Verlorenvlei	1-5	<0.05	<0.1	Medium
Berg	**10-20**	**>0.5-1**	5-10	Medium
Rietvlei/Diep	**20-50**	<0.05	0.5-1	Medium
Houtbaai	<0.05	<0.05	<0.1	Low
Wildevoëlvlei	0.5-1	<0.05	0.1-0.5	Low
Bokramspruit	<0.05	<0.05	<0.1	Low
Schuster	<0.05	<0.05	<0.1	Low
Krom	<0.05	<0.05	<0.1	Low
Silvermine	1-5	<0.05	0.1-0.5	Medium
Sand	1-5	<0.05	1-5	Low
Eerste	<0.05	<0.05	0.1-0.5	Medium
Lourens	<0.05	<0.05	0.1-0.5	Medium
Sir Lowry's Pass	<0.05	<0.05	<0.1	Low
Steenbras	1-5	<0.05	<0.1	Medium
Rooiels	1-5	<0.05	0.1-0.5	Medium
Buffels (Oos)	1-5	<0.05	0.1-0.5	Medium
Palmiet	0.5-1	<0.05	0.5-1	**High**
Bot/Kleinmond	**10-20**	0.1-0.5	**20-50**	**High**
Onrus	1-5	<0.05	1-5	Medium
Klein	**>100**	0.05-0.1	**50-100**	Medium
Uilskraals	1-5	<0.05	1-5	Medium
Ratel	<0.05	<0.05	0.1-0.5	Medium
Heuningnes	0.5-1	<0.05	1-5	Medium
Klipdrifsfontein	0.05-0.5	<0.05	<0.1	Medium
Breë	**50-100**	0.1-0.5	**10-20**	**High**
Duiwenhoks	1-5	0.05-0.1	5-10	**High**
Goukou	**50-100**	0.1-0.5	1-5	Medium
Gourits	**10-20**	0.1-0.5	1-5	Medium
Blinde	0.05-0.5	<0.05	<0.1	Medium
Hartenbos	1-5	<0.05	1-5	Medium
Klein Brak	5-10	0.1-0.5	1-5	Medium
Groot Brak	**20-50**	0.1-0.5	5-10	Medium
Maalgate	<0.05	<0.05	0.5-1	**High**
Gwaing	<0.05	<0.05	<0.1	**High**
Kaaimans	0.05-0.5	<0.05	0.1-0.5	**High**
Wilderness	**>100**	0.05-0.1	**10-20**	Medium
Swartvlei	**50-100**	0.05-0.1	**50-100**	Medium
Goukamma	0.05-0.5	<0.05	**10-20**	**High**
Knysna	**>1bn**	**>0.5-1**	**>100**	**High**
Noetsie	0.05-0.5	<0.05	0.1-0.5	Medium
Piesang	1-5	<0.05	1-5	Medium

Estuary (West to East)	**Recreational value (R millions/y)**	**Subsistence value (R millions/y)**	**Nursery Value (R millions/y)**	**Scenic/Existence value**
Keurbooms	**>100**	0.1-0.5	**10-20**	Medium
Matjies/Bitou	<0.05	<0.05	<0.1	Medium
Sout (Oos)	<0.05	<0.05	1-5	**High**
Groot (Wes)	5-10	<0.05	1-5	**High**
Bloukrans	0.05-0.5	<0.05	<0.1	Medium
Lottering	0.05-0.5	<0.05	0.5-1	Medium
Elandsbos	0.05-0.5	<0.05	0.1-0.5	**High**
Storms	0.05-0.5	<0.05	<0.1	Medium
Elands	0.05-0.5	<0.05	<0.1	Medium
Groot (Oos)	0.05-0.5	<0.05	<0.1	Medium
Tsitsikamma	<0.05	<0.05	<0.1	Medium
Klipdrif	<0.05	<0.05	<0.1	Medium
Slang	<0.05	<0.05	<0.1	Medium
Kromme	**20-50**	0.1-0.5	**10-20**	Medium
Seekoei	1-5	<0.05	5-10	Medium
Kabeljous	0.5-1	<0.05	5-10	Medium
Gamtoos	1-5	0.1-0.5	**20-50**	**High**
Van Stadens	1-5	<0.05	1-5	Medium
Maitland	<0.05	<0.05	<0.1	Medium
Swartkops	**50-100**	**>0.5-1**	**20-50**	Medium
Coega (Ngcura)	<0.05	<0.05	0.5-1	Low
Sundays	**10-20**	0.1-0.5	**10-20**	Medium
Boknes	5-10	<0.05	1-5	Medium
Bushmans	**20-50**	0.1-0.5	**10-20**	Medium
Kariega	5-10	0.1-0.5	**10-20**	Medium
Kasuka	1-5	<0.05	1-5	Medium
Kowie	**20-50**	0.1-0.5	5-10	Low
Rufane	0.5-1	<0.05	<0.1	Low
Riet	0.5-1	<0.05	1-5	Medium
West Kleinemonde	1-5	<0.05	5-10	Medium
East Kleinemonde	5-10	<0.05	1-5	Medium
Klein Palmiet	<0.05	<0.05	<0.1	Medium
Great Fish	1-5	0.1-0.5	**20-50**	Medium
Old woman's	<0.05	0.05-0.1	1-5	Medium
Mpekweni	1-5	<0.05	5-10	Medium
Mtati	0.5-1	<0.05	5-10	Medium
Mgwalana	0.05-0.5	<0.05	5-10	Medium
Bira	1-5	<0.05	5-10	Medium
Gqutywa	<0.05	<0.05	1-5	Medium
Blue Krans	<0.05	<0.05	0.1-0.5	Medium
Mtana	<0.05	<0.05	1-5	Medium
Keiskamma	0.05-0.5	0.1-0.5	**20-50**	Medium
Ngqinisa	<0.05	<0.05	0.5-1	Medium
Kiwane	<0.05	<0.05	0.5-1	Medium
Tyolomnqa	1-5	0.05-0.1	1-5	Medium
Shelbertsstroom	0.05-0.5	<0.05	<0.1	Medium
Lilyvale	0.5-1	<0.05	0.1-0.5	Medium
Ross' Creek	0.05-0.5	<0.05	<0.1	Medium
Ncera	<0.05	<0.05	1-5	Medium
Mlele	0.05-0.5	<0.05	0.1-0.5	Medium
Mcantsi	0.05-0.5	<0.05	0.1-0.5	Low
Gxulu	<0.05	<0.05	1-5	Medium
Goda	0.05-0.5	<0.05	0.5-1	Medium
Hlozi	<0.05	<0.05	<0.1	Medium
Hickman's	0.05-0.5	0.05-0.1	0.1-0.5	Medium
Buffalo	0.05-0.5	0.1-0.5	1-5	Low

Estuary (West to East)	**Recreational value (R millions/y)**	**Subsistence value (R millions/y)**	**Nursery Value (R millions/y)**	**Scenic/Existence value**
Blind	<0.05	<0.05	<0.1	Low
Hlaze	0.05-0.5	<0.05	<0.1	Medium
Nahoon	**10-20**	0.05-0.1	1-5	Medium
Qinira	1-5	0.1-0.5	1-5	Medium
Gqunube	1-5	0.05-0.1	1-5	Medium
Kwelera	5-10	0.05-0.1	1-5	Medium
Bulura	0.05-0.5	0.05-0.1	1-5	Medium
Cunge	<0.05	<0.05	<0.1	Medium
Cintsa	**10-20**	<0.05	1-5	Medium
Cefane	0.5-1	0.05-0.1	1-5	Medium
Kwenxura	<0.05	<0.05	1-5	**High**
Nyara	<0.05	<0.05	0.5-1	**High**
Haga-haga	0.05-0.5	<0.05	0.1-0.5	Medium
Mtendwe	<0.05	<0.05	0.5-1	Medium
Quko	0.05-0.5	0.05-0.1	1-5	Medium
Morgan	**10-20**	0.05-0.1	1-5	Medium
Cwili	0.05-0.5	<0.05	<0.1	Medium
Great Kei	1-5	0.1-0.5	5-10	Medium
Gxara	0.05-0.5	<0.05	0.5-1	Medium
Ngogwane	0.05-0.5	<0.05	0.1-0.5	Medium
Qolora	1-5	<0.05	0.5-1	**High**
Ncizele	0.05-0.5	<0.05	0.1-0.5	**High**
Kobonqaba	0.05-0.5	0.05-0.1	0.5-1	Medium
Nxaxo/Ngqusi	1-5	0.1-0.5	1-5	Medium
Cebe	0.05-0.5	<0.05	0.1-0.5	**High**
Gqunqe	0.05-0.5	<0.05	0.1-0.5	Medium
Zalu	0.05-0.5	<0.05	0.1-0.5	Medium
Ngqwara	0.05-0.5	<0.05	0.1-0.5	**High**
Sihlontlweni/Gcini	1-5	<0.05	0.1-0.5	Medium
Qora	1-5	0.05-0.1	1-5	**High**
Jujura	0.05-0.5	<0.05	0.1-0.5	Medium
Ngadla	0.05-0.5	<0.05	0.1-0.5	**High**
Shixini	0.05-0.5	<0.05	0.5-1	**High**
Nqabara	0.05-0.5	<0.05	1-5	Medium
Ngoma/Kobule	0.05-0.5	<0.05	0.1-0.5	Medium
Mendu	0.05-0.5	<0.05	0.5-1	**High**
Mbashe	0.5-1	0.05-0.1	1-5	Medium
Ku-Mpenzu	0.05-0.5	<0.05	0.1-0.5	Medium
Ku-Bhula/Mbhanyana	<0.05	<0.05	0.1-0.5	Medium
Ntlonyane	0.5-1	<0.05	0.5-1	Medium
Nkanya	0.05-0.5	<0.05	0.1-0.5	Medium
Xora	0.5-1	0.05-0.1	1-5	Medium
Bulungula	0.05-0.5	<0.05	0.1-0.5	**High**
Ku-amanzimuzama	<0.05	<0.05	<0.1	Medium
Mncwasa	<0.05	<0.05	0.1-0.5	Medium
Mpako	1-5	<0.05	0.1-0.5	**High**
Nenga	1-5	0.05-0.1	0.1-0.5	Medium
Mapuzi	0.05-0.5	<0.05	0.1-0.5	Medium
Mtata	0.05-0.5	<0.05	1-5	Medium
Mdumbi	0.05-0.5	<0.05	1-5	Medium

6. DEVELOPMENT OF AN INTEGRATED CONSERVATION PLAN

6.1 Introduction

Conservation planning is a rapidly evolving area of research for which numerous approaches have been explored around the world in recent years. Systematic conservation planning replaces the relatively *ad hoc* way of selecting conservation areas in the past, and is becoming increasingly holistic in terms of ecological goals and in terms of integrating conservation and development needs in a region. However, a major challenge for conservation planning is to identify priority areas that incorporate biological and environmental patterns and processes (Knight & Cowling 2003). In South Africa and Australia, systematic conservation planning has, over the past years, become a widely accepted methodology in establishing new protected areas to protect biodiversity (von Hase *et al.* 2003). Systematic conservation planning involves several principles, and has numerous distinctive characteristics (Margules & Pressey 2000).

Conservation 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 grid squares, hexagons or by cadastral units (properties).
3. **Set targets**: Identify conservation goals for the region and set quantitative conservation targets for the conservation units (e.g. species, vegetation communities and ecosystem types), and quantitative targets for minimum size, connectivity or other design criteria.
4. **Gap analysis**: Review existing conservation 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 first concentrated on the representation of species, conservation 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 and finding spatial surrogates for them and setting targets for these (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). In many respects, the C.A.P.E. programme has set the standard for systematic conservation planning (Balmford 2003). Much of its success has been attributed to its two-pronged approach of involving stakeholders early on in the process, coupled with scientific rigour, resulting in wide ownership of the terrestrial conservation plan. The C.A.P.E. planning processes also yielded some important lessons, such as the fact that species-level planning cannot be entirely substituted by a habitat-based approach (Balmford 2003).

In addition, it is becoming increasingly recognised that conservation planning cannot take place in isolation of an understanding of socio-economic pressures and values. There have been some attempts to incorporate species geography and human development patterns within the conservation planning framework in order to assess vulnerability in conservation planning (Abbitt *et al.* 2000). Nevertheless, while there has been some consideration of the direct costs involved (e.g. Balmford *et al.* 2000, Frazee *et al.* 2003, Moore *et al.* 2004, Osano *et al.* 2005), there has been little integration of ecological and economic considerations in regional-level planning initiatives (see Faith & Walker 2002). Socio-economic factors are also potentially very important in identifying the most appropriate types of conservation intervention. Thus, resource economics is playing an increasing role in conservation planning.

The selection of estuarine protected areas has to take both biodiversity targets and economic costs and benefits into consideration. If an estuary is proclaimed a protected area, then it will gain advantage in the priority it receives for water allocation as well as limiting activity within and around the estuary. These factors result in opportunity costs associated with the loss of water availability for alternative activities upstream, as well as in opportunity costs of limiting development around an estuary, or effects on property prices if certain forms of recreation are excluded. Protection of a system may also yield economic gains, however, in that it may boost an ecotourism-based economy, the outputs of the estuary to marine fisheries, and the option and non-use (existence) values associated with protection of a system.

The biodiversity targets may be met by different combinations of estuaries, but each of these combinations is likely to have a different net economic impact. If conservation is to be successful, these economic costs will have to be minimised.

Another consideration is the sheer practicality of establishing a protected area at an estuary. Factors that should be considered are the degree to which a protected area is enforceable, or to which access can be limited. Both the economic and practical aspects are likely to differ substantially for a partially versus a wholly protected area. Whereas a partially protected system is likely to have lower opportunity costs, it is potentially less practical in some instances in that users will have to understand the boundaries. Practicalities may also influence decisions on whether protection of fewer large systems or several small systems is preferable.

6.2 Biogeography and the planning domain

The C.A.P.E. planning domain is based primarily on the extent of the Cape Floristic Kingdom (Figure 6.1).

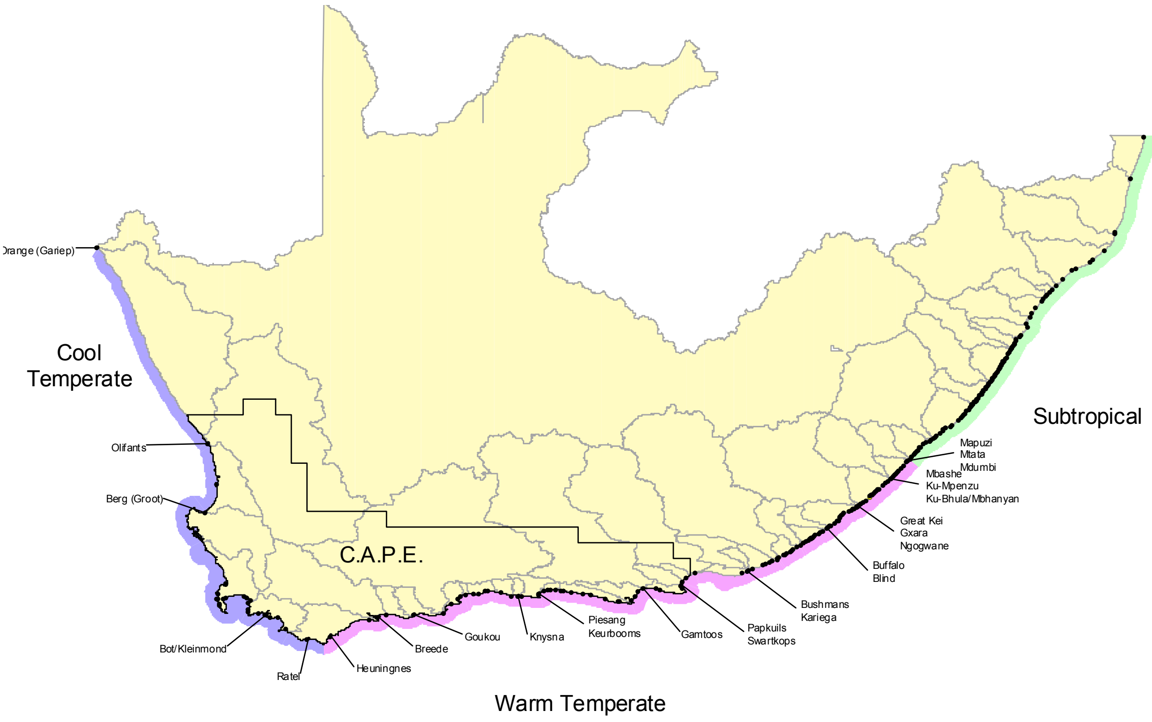


Figure 6.1. Distribution of estuaries in relation to three biogeographic zones, secondary catchment areas and the C.A.P.E region (Olifants R. to Swartkops R.).

From a terrestrial perspective, this makes good biogeographic sense. The coastal limits of this area include the approximately 62 estuaries from the Olifants to the Swartkops. However, this stretch of coast does not correspond to the biogeographic zonation of the South African coast.

The general biogeographic pattern that has been identified for the South African coast is one of a Cool Temperate West Coast Province extending from the Orange River south to somewhere between Cape Point and Cape Agulhas, a Warm Temperate South Coast Province extending east to the area of Mbashe to Port St. Johns, and a Subtropical East Coast Province which extends north from there into Mozambique (Brown & Jarmon 1978, Emanuel *et al.* 1992, Turpie *et al.* 2000). Based on the clear patterns demonstrated for intertidal invertebrates and coastal fishes, the breaks are generally taken to be at Cape Point and the Mbashe. (Lombard *et al.* (2004) recently further subdivided the cool temperate province into a northern Namaqua Province (extending from the Orange River down to Cape Columbine) and a South-western Cape bioregion (from Columbine to Cape Point) but this was mostly to accommodate differences in algal distribution patterns.) While some groups display a clear south coast zone (with several species endemic to this zone), it appears to be more of an overlap zone for coastal and estuarine birds (Siegfried 1981, Hockey *et al.* 1983, Hockey & Turpie 1999). The only other study of estuarine biogeography is for fish, and describes the breaks between the three zones being at Cape Agulhas and the Mdumbi estuary, north-east of the Mbashe (Harrison 2002). The westerly break is largely driven by the high abundance of a few species in the cool temperate region. East of Cape Point, all groups are largely characterised by a gradual eastward change in species and an increase in species richness.

The C.A.P.E. coast falls within two of the three coastal biogeographical provinces. Since conservation planning should ideally seek targets within each biogeographic province, it stands to reason that the planning domain for this part of the project should be extended to include the two temperate provinces in their entirety. This means that the number of estuaries under consideration is increased to 149, from the Orange to the Mdumbi (Figure 6.1).

6.3 Definition of planning units

The conservation planning exercise was concerned with the identification of areas to be designated as **fully-protected**, with no-consumptive use or excessive disturbance, and with provision made for adequate ecological functioning, such as provision of adequate freshwater inflow.

Previous planning excercises have selected estuaries as etiher in or out of a protected area set, suggesting that an estuary should be considered as a planning unit. However, given the fact that it would often be infeasible to protect an entire estuary as a fully-protected no-take zone, due to political and economic pressures, it was decided to consider part protection as a feasible option for most systems, potentially requiring more sites than if just whole estuaries were considered. Thus most of the estuaries were split into two planning units. This was done for all systems where a split would potentially be practical or feasible, but excluded the systems that were below about 30 ha, which were left as whole units.

The planning domain included a total of 149 estuaries. Since most estuaries were split into two parts, there were a total of 210 planning units under consideration.

6.4 Conservation units: ecosystem types, habitats, species and populations

6.4.1 Estuarine typologies and their relevance to biota

There are a two classification systems for estuaries in South Africa. 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. 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:

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

Because of the tendency to include ecosystem types in generating conservation targets, this typology was used in the National Spatial Biodiversity Assessment (NSBA; Turpie 2004). The National Biodiversity Strategy and Action Plan (NBSAP) suggests the approach of identifying targets within ecosystem types, with an overall target of 30% representation in protected areas. For estuaries, the analysis of current levels of protection, health and threats were done in terms of the five types of estuaries defined by Whitfield (1992). If targets were set as a percentage of each estuary type, then the majority of conserved systems would be temporarily open (Table 6.1). If the 30% is taken as area, then this would be spread more evenly across different estuary types, with permanently open being the most represented.

Table 6.1. Typical characteristics of the 5 types of estuaries defined by Whitfield (1992)

Type	Typical size	Typical mouth condition	Number in temperate provinces	%	Total area (ha)	%
Bay	Large	Open	1	1%	3 594	15%
Permanently open	Med to large	Open	30	22%	9 257	40%
River mouth	Small to large	Open	8	6%	998	4%
Lake	Large	Closed	4	3%	5 734	25%
Temporarily open	Small to med	Closed	95	69%	3 749	16%
TOTAL			**138**		**23 332**	

Typologies defined for South African estuaries have never really been tested in terms of its relevance to estuarine biodiversity, and as such may not be a suitable way of dividing estuaries for target-setting. Thus we reviewed the literature and performed multidimensional scaling analyses of fish and bird abundance data, in order to investigate how estuaries grouped for those taxonomic groups in relation to Harrison's (2000) and Whitfield (2002) typology. It was also important to establish whether the communities in distinct estuary types are different from one another or simply subsets of one another.

Within each biogeographical zone, Harrison & Whitfield (2006b) found that estuarine fish communities were influenced by a combination of estuary size and mouth condition. They defined three main types of estuaries: small closed, medium closed and large open systems. They found that open estuaries have relatively high species richness, mainly due to the presence of marine species, and moderate to large closed estuaries have reduced species richness due to reduced access by these marine species. Small closed estuaries have the lowest species richness due to their small area and greater isolation from the sea. Whereas some species are largely restricted to permanently open systems, there are few that are restricted to small or closed systems. Nevertheless, some species are relatively more important in small closed estuaries (Harrison & Whitfield 2006b).

We conducted a similar analysis, but used total estimated abundance data of each species in each estuary, generated from the raw data collected by Trevor Harrison. This analysis suggested that the principle determinant of fish community characteristics, apart from geographic location, was estuary size (Figure 6.2). Mouth condition did not have a consistent influence, except inasmuch as mouth condition is correlated with size. A SIMPER analysis 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 (Figure 6.3).

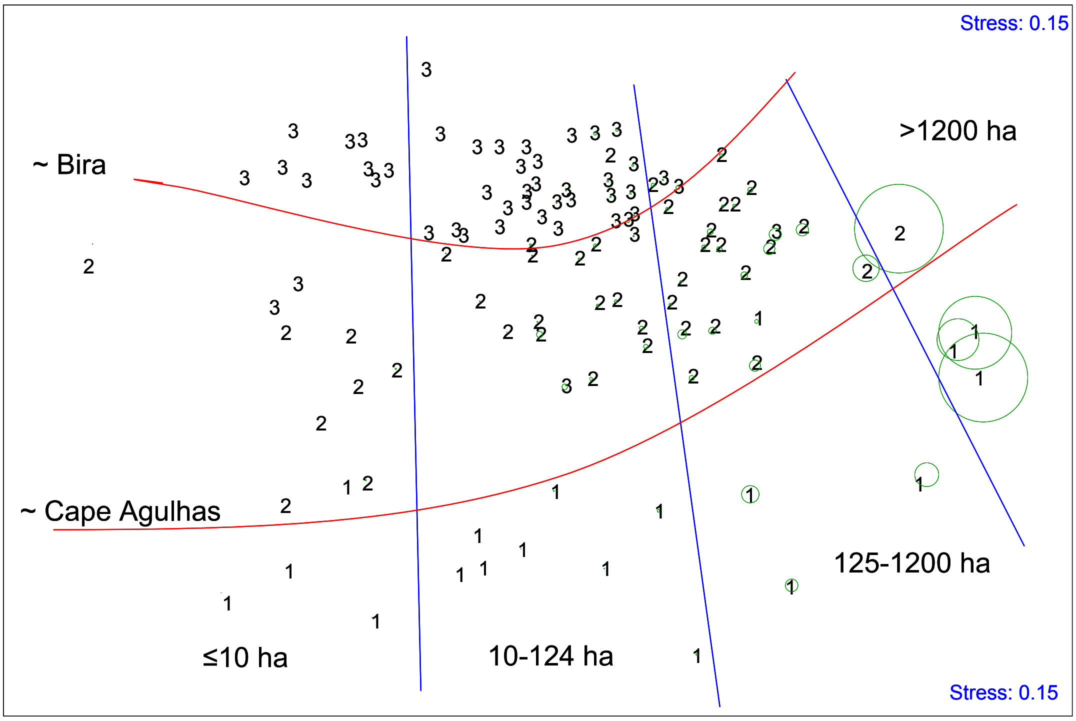


Figure 6.2. MDS plot showing how estuary fish communities are influenced by size and geographic position. Estuaries labels 1, 2 and 3 refer to their position west of Cape Agulhas, between Cape Agulhas and Bira, or east of Bira, respectively. Blue lines separate estuaries of different sizes. Sizes are also indicated by the size of the green circle.

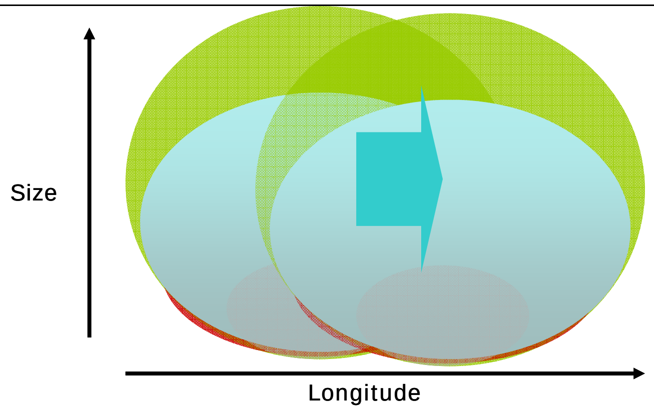


Figure 6.3. Schematic diagram showing that estuary fish communities change gradually around the coast, and small communities are mostly subsets of larger communities.

Multidimensional scaling (MDS) and cluster analysis of bird communities in temperate estuaries suggested four main groupings for birds (Figure 6.4). Type A estuaries are large open systems that support diverse waterbird communities and are characterised by high numbers of waders. Type B estuaries are systems that have restricted or closed mouths, frequently have brackish lake characteristics, and support large waterfowl communities. Some systems (A/B) can have a mixture of these characteristics. Type C are typically medium to large sandy estuaries, often support gull and tern roosts, but have relatively low overall diversity. Type D systems are depauperate and are generally small and nutrient poor.

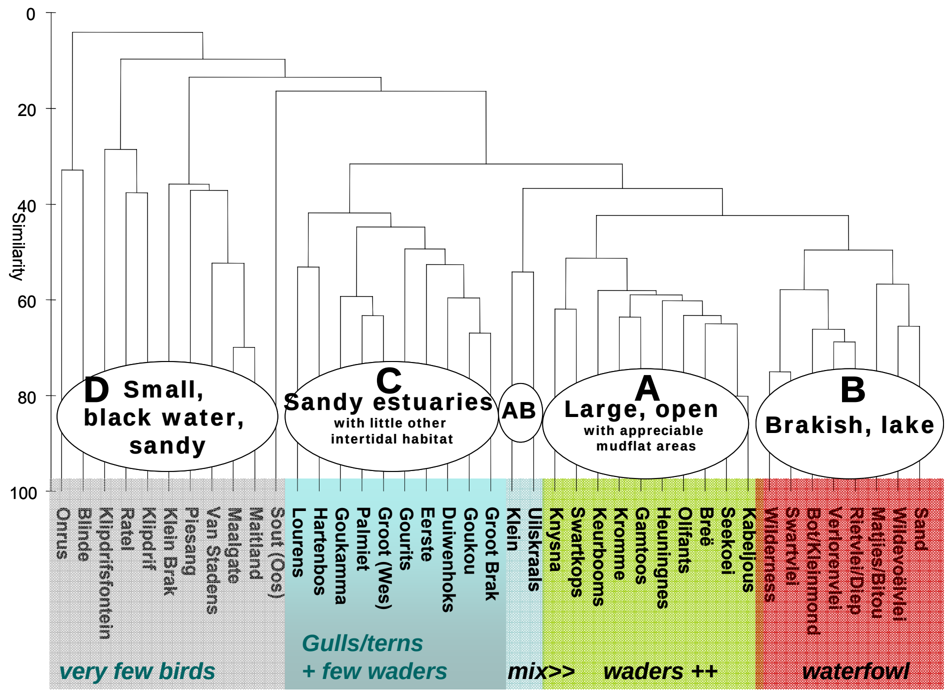


Figure 6.4. Cluster diagram showing groupings of estuaries on the basis of bird community structure.

However, it is also important to distinguish between subset communities and distinct communities. In effect, types A and B are relatively distinct, whereas types C and D support subsets of the communities found in type A (Figure 6.5). This suggests that for birds it would be best to concentrate conservation efforts on type A and B systems. Furthermore, since type B communities are likely to bear some resemblance to freshwater wetland systems, the main effort should be on type A systems.

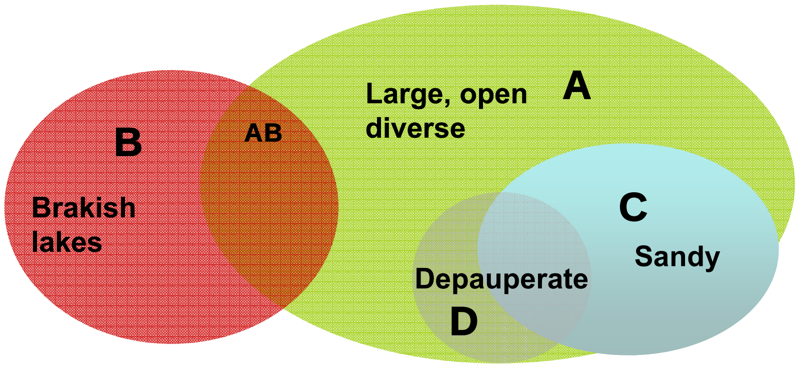


Figure 6.5. Schematic of the overlap between bird communities of the different estuary types

Thus, Whitfield's (2002) estuary typology, though widely used, does not necessarily make sense as an ecosystem typology from a biodiversity perspective. Neither fish nor bird communities group according to this classification. Thus estuaries were not targeted according to type.

6.4.2 Habitat type

Because data on species and populations are usually limited to the larger taxa, another approach commonly used is to include a representative proportion of all the different habitats within the protected area system. In terrestrial system this might be in terms of vegetation types. In the case of estuaries, habitat types can be broadly delineated as follows:

- subtidal,
- intertidal flats,
- submerged macrophyte beds,
- rocks,
- emergent reeds and sedges,
- saltmarsh,
- supratidal saltmarsh,
- mangrove and
- swamp forest.

Proportional representation may vary depending on the relative abundance or vulnerability of the different habitats. In the case of estuaries, the selection of habitats is inextricably linked to the selection of estuaries (part or whole). While it is recommended that this approach is used, it should be noted that the area data on habitat type are missing for some of the very small systems.

6.4.3 Species and populations

Targets may include provision for representation of a proportion of the species that occur in systems. For a species to be considered represented in a protected area system, it has to be present in sufficiently high or viable numbers. In the case of this exercise, abundance data are available for major plant communities (in terms of area), for fish and birds, but not for invertebrates.

Population targets may be set as a proportion of the total population in the planning domain. However, care needs to be taken to ensure that there is connectivity between protected sub-populations, and that relatively isolated breeding populations are sufficiently large to be viable. In the case of migrants (e.g. Palearctic shorebirds) this is not an issue.

Viable populations have been traditionally set using the 50-500 rule, which is the assumed viability criterion (in terms of numbers of breeding-age individuals in the population) for short-term or long-term viability. However, populations of fish and birds within estuaries are highly variable, due to mobility between systems, mouth dynamics and influences beyond the estuary. Moreover, this rule may not be particularly suitable for migratory species. It must also be noted that the 50-500 rule is designed for populations within a fully protected area. Many of the populations in the estuaries under consideration will be part of exploited metapopulations, even if the exploitation does not occur directly within the protected system.

6.5 Accommodation of ecosystem and landscape-level processes

In order to accommodate ecosystem and landscape level process, issues of connectivity and scale need to be addressed. Size and connectivity of the components of a protected area system have a major bearing on the efficiency of a protected area system and the degree to which it facilitates ecosystem and evolutionary processes and the replenishment of exploited stocks.

While it goes without saying that the greater the overall area protected, the greater the ecological benefits (this is constrained by economic and practical considerations), a pertinent question is whether size of individual systems selected makes a difference in terms of conservation efficiency. Our analysis of fish data suggested that there is no significant difference in fish density between small and large estuaries. A similar phenomenon is found in floodplain wetlands (Welcomme 1979). This means that population targets can be met with the same total area, irrespective of whether small or large systems are selected to make up the total area. However, there are other ecological considerations that will influence whether small or large systems should be protected. Larger protected areas protect larger populations, ensuring greater probability of persistence. These systems also generate larger cues to marine species in terms of freshwater outputs, thus potentially increasing the landscape level integrity of the protected area system. The choice of several small versus few large systems also affects the overall connectivity of the protected area system.

Maintaining connectivity and landscape-level ecological functioning presents an interesting problem in the case of estuaries. In general, estuaries in the study area are arranged as a set of fairly evenly-dispersed large open systems with very large catchment areas, interspersed with a much larger number of small closed systems which have very small catchment areas, except on the West Coast where there is a lack of small systems. The large systems are often a considerable distance from one another, but general connectivity is boosted by the small systems when they are open. What is also particularly important is that not all the systems open at the same time or for the same length of time. Thus the way in which populations interact is relatively unpredictable in some areas. Connectivity is important for populations of resident estuarine species in particular. Smaller systems are much more vulnerable to reduction in mouth opening (due to reduced water supply) than larger systems. The reduction in usability of closed systems along the coast affects species have to move between rivers, estuaries and marine environments to breed, also limiting the nursery habitat available to important migrant fish such as White Steenbras.

From an evolutionary point of view, protecting small estuaries may be important owing to their high variability (in terms of their physical characteristics). Incorporating such variability into a conservation plan is considered valuable in that it ensures that within-species genetic diversity is maintained at a high level and because it facilitates the persistence of rare species that may be outcompeted and extirpated in the larger, more stable systems.

6.6 Conservation targets

Based on stakeholder discussions on an initial proposed set of goals and targets, the following conservation goals and biodiversity targets are proposed for the estuarine protected area system. Note that these pertain to habitats, fish and birds only, and that other elements, such as invertebrates are not targeted. While the latter omission is due to lack of data, it is hoped that the inclusion of habitats, fish and birds will be sufficient to cover the needs of other taxonomic groups. This assumption should be checked in future as further information comes to light.

6.6.1 Overall goals

Ideally, the core Estuarine Protected Area network should take into account the following goals:

1. Representativeness: all estuarine species within a bioregion should be represented in viable numbers in the protected areas network.
2. Maintenance of ecological processes: the protected area network should allow for connectivity and interaction with other adjoining ecosystems.
3. 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.
4. Minimisation of economic opportunity costs: biodiversity targets should be met at least possible opportunity cost, through careful selection of the estuaries included in the protected area network. Estuaries where protection offers greatest economic benefits or lowest economic costs should be prioritised in the EPA selection process.
5. Implementabilty: consideration should be given to the practicalities of protection in each estuary.

The World Conservation Union (IUCN) has proposed a goal of conserving 20% of the world's coastline by the turn of the century (IUCN 1992). This value is based on the result of fishery modelling studies which show that the risk of a fishery collapsing increases dramatically if spawner biomass (the mass of adult fish above the age of sexual maturity) falls below 25% of its unexploited biomass. It has been suggested however, that marine protected area coverage should be extended to 30% where fishery management in exploited areas is poor (Plan Development Team 1990). The NSBA suggested a target of 30% of estuaries, though in the light of the above rationale it is clear that this should be a minimum of 30% of estuarine area rather than estuaries, given the enormous variation in their size.

6.6.2 Habitat targets

Habitat targets were set based on a workshop discussion which took considerations such as the importance of the habitat for estuarine biota and its dependence on estuaries into account. In addition, an overall area target was set, corresponding to the generally accepted target for marine protected areas (30%).

Targets for swamp forest and rocks were set at zero owing to the low representation in the study area (the former) and the lack of a unique associated fauna and/or flora (i.e. distinct from other rocky marine habitats)(the latter). Higher targets (40%) were set for intertidal salt marsh, sand/mud banks, and submerged macrophytes than for supratidal saltmarsh and channel mangroves due to the former being subject to greater levels of disturbance than the latter. Targets for mangroves were also set at a low level (30%) due to the small representation by this habitat type in the study area (core areas for mangroves are situated in the subtropical and tropical bioregions).

Table 6.2. Targets for estuarine habitat types and for the total estuarine area

Estuarine habitat	Total area (ha) within the planning domain	Target (% of area)
Supratidal salt marsh	3 997	30%
Intertidal salt marsh	1 829	40%
Reeds and sedges	2 413	20%
Swamp forest	6	No target
Mangroves	90	30%
Sand/mud banks	3 228	40%
Submerged macrophytes	1 289	40%
Channel	10 516	30%
Rocks	206	No target
Total estuarine area	**25 095**	**30%**

6.6.3 Species targets

All fish and bird species for which estuaries make a significant contribution to their persistence in the Southern African region should be targeted in the EPA set.

Estuary dependent fish have already been defined by Whitfield (1994). Thus fish assigned to categories I, II and V were included, while those belonging to categories III and IV were not considered in terms of population targets. In addition, species whose distributions were mainly tropical but which did occur within the planning domain in small numbers were also not targeted. These species were defined as those for which the planning domain supported less than 15% of the total estuarine population in South Africa. A total of only 38 species was thus included in the target list (Table 6.3).

Although estuarine bird species were listed by Hockey & Turpie (1999), estuary dependence was not defined. There are no entirely estuarine-dependent bird species. Thus species were considered dependent on estuaries if more than 15% of their regional population (as per Hockey et al. 2005) was found in estuaries. This estimate was fairly crude, due to the crude nature of regional population estimates. It thus eliminated species such as Ruff for which a large proportion of the population is found inland, and species such as Cape Cormorant for which the bulk of the population is coastal outside of estuaries. Vagrants were also excluded. A total of 33 bird species was thus included in the target list (Table 6.3).

6.6.4 Population targets

The following population targets were applied to the targeted fish and bird species, based on workshop discussions:

- 50% of the population of red data (threatened) species;
- 40% of the population of exploited species; and
- 30% of the population of all other species.

Effective targets are summarised in Table 6.3.

Table 6.3. Targets for estuarine fish and bird species

Fish species	Category	Target	Population target	Bird species	Target	Pop. target
Acanthopagrus berda	IIA	30%	6 403	Great White Pelican	50%	344
Anguilla mossambica	VA	30%	341	White-breasted Cormorant	30%	549
Argyrosomus japonicus	IIA	40%	130 550	Greater Flamingo	50%	965

Fish species	Category	Target	Population target	Bird species	Target	Pop. target
Atherina breviceps	IB	30%	18 006 710	Lesser Flamingo	50%	429
Caffrogobius gilchristi	IB	30%	430 186	African Blck Oystercatcher	50%	169
Caffrogobius natalensis	IB	30%	86 005	Common Ringed Plover	30%	528
Caffrogobius nudiceps	IB	30%	272 905	White-fronted Plover	30%	236
Clinus superciliosus	IB	30%	271 445	Chestnut-banded Plover	30%	115
Diplodus capensis	IIC	40%	449 947	Greater Sand Plover	30%	4
Elops machnata	IIA	40%	37 272	Grey Plover	30%	638
Galeichthys feliceps	IIB	40%	149 994	Ruddy Turnstone	30%	133
Gilchristella aestuaria	IA	30%	6 899 362	Terek Sandpiper	30%	85
Glossogobius callidus	IB	30%	1 702 516	Common Sandpiper	30%	156
Hemiramphus far	IIC	30%	39 286	Common Greenshank	30%	549
Heteromycteris capensis	IIB	30%	58 283	Red Knot	30%	48
Hippichthys spicifer	IB	30%	81	Curlew Sandpiper	30%	4 143
Hippocampus capensis	IA	50%	6 796	Little Stint	30%	1 524
Lichia amia	IIA	40%	30 487	Sanderling	30%	352
Lithognathus lithognathus	IIA	40%	428 682	Bar-tailed Godwit	30%	28
Liza dumerilii	IIB	40%	1 213 157	Eurasian Curlew	30%	45
Liza richardsonii	IIC	40%	21 615 082	Common Whimbrel	30%	433
Liza tricuspidens	IIB	40%	868 833	Pied Avocet	30%	389
Monodactylus falciformis	IIA	30%	75 378	Black-winged Stilt	30%	258
Mugil cephalus	IIA	40%	748 100	Water thick-knee	30%	53
Myxus capensis	VB	40%	300 336	Kelp Gull	30%	1 591
Oligolepis keiensis	IA	30%	2 239	Hartlaub's Gull	30%	815
Omobranchus woodi	IA	30%	94	Caspian Tern	30%	68
Pomadasys commersonnii	IIA	40%	530 327	Swift Tern	30%	523
Pomatomus saltatrix	IIC	40%	44 547	Sandwich Tern	30%	653
Psammogobius knysnaensis	IB	30%	472 490	Common Tern	30%	5 628
Rhabdosargus globiceps	IIC	40%	159 748	Damara Tern	30%	11
Rhabdosargus holubi	IIA	40%	3 789 896	Little Tern	30%	110
Sarpa salpa	IIC	40%	1 063 387	Mangrove Kingfisher	30%	1
Solea bleekeri	IIB	30%	73 977			
Syngnathus acus	IB	30%	219 385			
Syngnathus watermeyeri	IA	50%	187			
Torpedo fuscumaculata	IIC	30%	655			
Torpedo sinusperci	IIC	30%	297			

6.6.5 Targets for maintaining ecosystem and landscape-level processes:

The following measures are aimed to ensure that the populations protected are viable, in that they are sufficiently large and there is connectivity at a sufficiently broad scale to maintain genetic integrity and evolutionary processes. They also aim to maintain landscape-level processes that maintain ecological integrity at a large scale.

- Viability: EPAs should protect a minimum of 33% of each habitat within an estuary as a no take sanctuary;
- Viability: Systems in an unacceptable state of health should be excluded, particularly canalised systems.
- Connectivity: There should be a relatively even distribution of protected estuarine area around the coast;

- Landscape level processes: Estuaries adjoining terrestrial or marine protected areas will be prioritised in the selection process, and those adjoining undeveloped land should be prioritised over those that are developed;
- Viability, ecosystem processes, evolutionary processes and representativeness: Large open systems should be prioritised over smaller systems, *ceteris paribus*, but a range of different sized estuaries should nevertheless be represented.
- Efficiency: Systems with higher conservation importance scores should be given greater priority, *ceteris paribus;*

These biodiversity targets address goals 1 – 3 listed above. The choice of estuaries used to meet these targets will be subject to goals 4 and 5.

6.7 Gap analysis: what do existing protected areas contain?

A total of 23 estuaries in the planning domain have some level of protection. However, only the Krom, the 6 small estuaries within Tsitsikamma NP/MPA and the Mbashe have full no-take protection, although the latter is under dispute and currently only partly protected in practice. These were the only estuaries considered to be fully or partly protected in the gap analysis.

Fully protected areas currently account for only 179 ha or 2% of the estuarine area within the planning domain, and only represent 4 of the 7 targeted habitat types. The area represented is less than 5% of all habitat targets apart from Mangroves (Table 6.5).

Table 6.4. Estuaries within the planning domain that have some level of protection

Estuary	Protected area	Agency	Amount of estuary included	Type of protection*
Diep	Rietvlei NR	Municipal	Part	Low
Krom	Table Mountain NP	SANP	Entirely	High
Sand	Sandvlei NR	Municipal	Top <10% of estuary	Low
Heuningnes	De Mond NR	CNC	All	Medium
Touw	Wilderness Lakes NP	SANP	Part	Low
Swartvlei	Wilderness Lakes NP	SANP	Part	Low
Goukamma	Goukamma NR	CNC	Most	Medium
Knysna	-	SANP	Part	Medium
Keurbooms	Keurbooms River NR	CNC	Part (upper reaches)	Low
Sout	De Vasselot NP	SAN Parks	All	Low
Bloukrans	Tsitsikamma NP	SANP	All	High
Lottering	Tsitsikamma NP	SANP	All	High
Elandsbos	Tsitsikamma NP	SANP	All	High
Storms	Tsitsikamma NP	SANP	All	High
Elands	Tsitsikamma NP	SANP	All	High
Groot (E)	Tsitsikamma NP	SANP	All	High
Tsitsikamma	Huisklip NR	ECNC	Lower reaches	Low
Seekoei	Seekoei River NR	Municipal	Part (upper)	Low
Kabeljous	Kabeljous NR	Municipal	Part	Low
Gamtoos	Gamtoos R. Mouth NR	Municipal	Part	Low
Van Stadens	Van Stadens NR	Municipal	All	Low
Nahoon	Nahoon Estuary NR	Municipal	Very small part	Low
Mbashe	Dwesa-Cwebe MPA	MCM	Officially all, but half in practice	High
Ku-Mpenzu	Dwesa-Cwebe NR	ECNC	Undefined as yet	High?
Ku-Bhula/Mbhanyana	Dwesa-Cwebe NR	ECNC	Undefined as yet	High?
Ntlonyane	Dwesa-Cwebe NR	ECNC	Undefined as yet	High?

Nkanya	Dwesa-Cwebe NR	ECNC	Undefined as yet	High?

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

Table 6.5. Representation of habitats within the fully protected estuaries and percentage of targets already met

Habitat	Area in fully protected estuaries (ha)	% of target met
Supratidal salt marsh	0.0	0%
Intertidal salt marsh	2.3	0%
Reeds and sedges	13.5	3%
Mangroves	14.0	52%
Sand/mud banks	6.7	1%
Submerged macrophytes	1.5	0%
Channel	101.3	3%
Total area	**179.0**	**2%**

Only 31% and 15% of targeted bird species are found in the existing set of protected estuaries, but most of them are in such small numbers that less than 5% of target numbers are met.

Table 6.6. Extent to which targeted fish and bird species are represented in the existing EPA set

% of target met	% targeted fish species	% targeted bird species
0	68%	85%
<5%	26%	9%
<25%	5%	3%
>75%		3%

6.8 Incorporating economics

Conservation planning is often carried out on the basis of an efficiency rule which requires that the targets are met in the minimum number of sites or with minimum total area. The underlying assumption is that the costs of conservation are equal per conservation unit. Indeed, some conservation planning packages require inputs on costs and these have been assigned in some studies as a constant arbitrary value such as 1000 cost units. While it is informative to see what sites would be selected under an equal-cost scenario, it is necessary to find a solution which takes more realistic costs into account.

Costs of establishing or expanding a protected area system generally include the acquisition and setup costs (Bruner *et al.* 2003, Balmford & Gaston 1999, Balmford *et al.* 2003), management costs (James *et al.* 2001; Wilkie *et al.* 2001; Faith & Walker 2002; Frazee *et al.* 2003; Blom 2004), and the opportunity costs in the form of foregone values from economic activities that are not compatible with conservation (Emerton 1999; Kremen *et al.* 2000; Ferraro 2002; Sinden 2004, Adams & McShane 1992; Azzoni & Isai 1994; Norton-Griffiths & Southey 1995; Inamdar *et al.* 1999; Kremen *et al.* 2000; James *et al.* 2001; Ferraro 2002; Balmford *et al.* 2003; Balmford & Whitten 2003). Up to now, few conservation planning studies have included any of these costs (Turpie *et al.* 2003b). Yet these costs can be substantial (e.g. James *et al.* 2001), and the need has been identified to integrate them into conservation planning processes (Balmford *et al.* 2000, 2003; Turpie *et al.* 2003b, Blom 2004, Osano *et al.* 2005).

Furthermore, while the conservation planning has begun to consider these costs in a few pioneering studies, none have yet started to take the benefits of conservation into account, or the change in the ecosystem value (which may or may not be positive, depending on how it is being used). This is arguably one of the most difficult values to estimate.

In this study we have analysed the problem taking all of these types of values into account (apart from acquisition/setup costs), and in this respect it is a novel and holistic approach.

6.8.1 Management costs

Frazee *et al.* (2003) undertook an analysis of the potential costs of conservation for the terrestrial aspects of the C.A.P.E. conservation planning exercise. In an analysis of the current costs of protection it was found that there was a major discrepancy between the budgets that conservation managers were dealing with and the budget they thought they needed in order to meet their conservation objectives. Thus the costing for the terrestrial conservation planning was carried out using required management budgets. In the case of terrestrial management costs, they were strongly related to area, such that costs per unit area increased exponentially below an area of about 600 ha (Frazee *et al.* 2003).

When applied to estuaries, however, the relationship did not bear any resemblance to the cost of managing estuaries. Thus, we estimated the cost of managing six hypothetical estuaries ranging in size from 10 to 3000 ha, taking salaries, infrastructural, vehicle/boat and sundry costs into account. Our estimates were revised at the workshop with advice from estuary managers. The resulting relationship shown in Figure 6.6 was used to estimate the potential management cost associated with conserving each estuary.

If only half an estuary is conserved, this was assumed to require 75% of the cost of managing the entire estuary as a protected area.

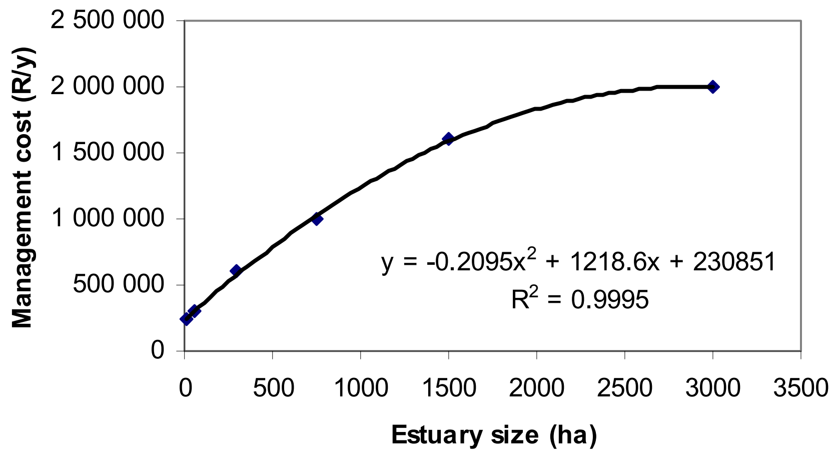


Figure 6.6. Relationship used to estimate the management costs of protected estuaries.

6.8.2 Opportunity costs (water)

Estimation of the opportunity costs of conservation is relatively simple for a terrestrial protected area network. In such a case main the opportunity cost is the value of the land under its next best use, usually either as productive farmland or real estate development. Potential net income per area from the most profitable alternative land use has been applied in Brazil (Azzoni & Isai 1994), Kenya (Norton-Griffiths & Southey 1995), Uganda (Emerton 1999), Madagascar (Kremen *et al.* 2000, Ferraro 2002) and India (Nnan & Sathyapalan

2003). A simpler approach is to use land prices, as they roughly reflect the potential future productivity of the land (Weersink *et al.* 1999; Goodwin *et al.* 2003, Sinden 2004, Osano *et al.* 2005).

In the case of marine and estuarine conservation, opportunity costs cannot simply be measured in these terms. The protection of an estuary or section of shoreline may involve holding some land under protection, the opportunity costs of which could be estimated as for terrestrial systems, but also involves the protection of publicly-owned land, from various uses. In the case of estuaries, the most significant impact of protection is probably the impact it has on the water reserve. Under the National Water Act (1998), all estuaries will be allocated a freshwater reserve which is the quantity and quality of freshwater inflow required to maintain the system in a desired state of health. The latter is determined through the process of classification, which takes the various tradeoffs into account. However, provision has been made in the RDM process that in the case of protected areas, a special effort should be made to maintain the systems in a high state of health, preferably an A or B class. This means that the system would remain in a natural or near natural state, or be only slightly modified. This provision is essential to estuary protection, since the health of an estuary appears to be far more strongly linked to freshwater inflow than to the on-site management of the system. Estuaries are resilient systems, and can generally “bounce back” from past bad management or past flow modifications, but the reality is that once water is allocated elsewhere it is politically difficult to reallocate it to natural systems. Water is a scarce resource in South Africa. Thus the protection of an estuary has a potentially high cost in terms of the water that will be reserved and can no longer be used in alternative economic activities elsewhere. For this reason, we deal with the opportunity cost of water separately. Other changes in value associated with changes in access rights are dealt with in the following section. We do not attempt to estimate the potential opportunity costs in terms of foregone property developments, since it is almost impossible to predict how this value would vary from estuary to estuary (Maswime 2006). However, the latter value may also be significant and should be borne in mind.

The estimation of the opportunity costs of conservation in terms of foregone use of water was approached by first estimating the amount of water that might have to be reserved by each estuary, and second by putting a value to that water. The accurate estimation of these values would involve extensive data collection and modelling, well beyond the scope of this study. Thus this study sought to produce rough first order estimates only, as described below.

Additional quantity of water required for estuary protection

It is generally assumed among the estuarine scientific community that an estuary with protected area status would require more water than one without, since the main objective would be to maintain the health of the system to enable the persistence of its biodiversity and ecosystem processes. Since the demand for water outstrips supply in most catchments in South Africa, reserving additional water for the environment will carry an economic cost. Thus it is important to estimate just how much water this would entail.

In the absence of accurate health scores or hydrological models, it was necessary to be fairly general. We thus made the assumption that protected area status would involve an additional water reserve equivalent to the difference between water required to maintain an estuary in a C- versus a B-class (defined in the Resource Directed Measures approach as “largely natural with few modifications” as opposed to “moderately modified”). In reality this would vary from estuary to estuary, depending on the current state of health and possibly the degree of sensitivity of the system. If a system is in a poor state of health (e.g. D class), protection would require a greater amount of water to be ‘given up’ than if it is already in a B class. Nevertheless, if a system is currently in a B class, reserving the water now will prevent it from being used in the future and degrading the system to a C class or lower, assuming that demands are growing. In addition, it may not always be necessary to maintain an estuary in a B class in order to meet biodiversity conservation goals., We estimated the natural MAR for each estuary by disaggregating secondary-catchment level data. Thus in the case of smaller estuaries which share these catchments, it was necessary to apportion the MAR among the estuaries in proportion to their size.

Using the outputs of the scenario analyses from past RDM studies, it was found that the change in %MAR required to rehabilitate an estuary from a C to a B class (from score 61 to 76) was positively correlated with the natural MAR. It was expected that smaller estuaries would be more sensitive, with a small change in MAR having a relatively large impact on health. This relationship was fairly weak, however, with very small variation in the actual %MAR required in each case (Figure 6.1). Thus it was decided to take 15% MAR as the potential 'water sacrifice' required to assign an estuary protected area status.

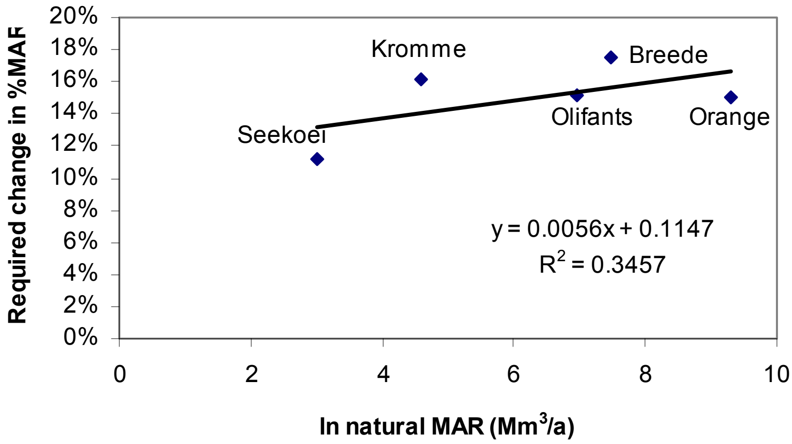


Figure 6.7. Relationship between the predicted %MAR required to change the estuary from a C to B class and the natural MAR of the estuary.

The estimated water sacrifice ranges from 0.03 Mm^3 per annum to as much as 1072 Mm^3 per annum for the Orange River estuary. For more than 65% of estuaries, protected area status would imply giving up less than 5 Mm^3 per annum, with about half of these requiring less than 1 Mm^3 per annum (Figure 6.8). Some 19% of estuaries could require more than 10 Mm^3 per annum, but only 6.7% are likely to require more than 50 Mm^3 per annum. Note that the latter are the larger estuaries, which also have high conservation value.

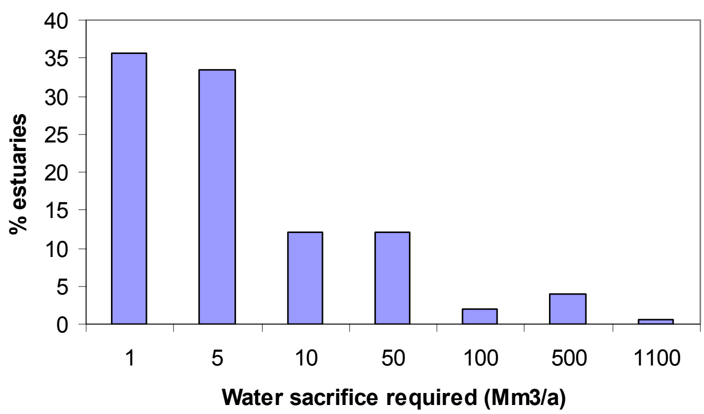


Figure 6.8. Frequency distribution of temperate estuaries in terms of the amount of water that would probably have to be sacrificed if they were assigned protected area status. X-axis labels refer to the upper limit of the category.

Marginal opportunity cost of the water required

Water allocation decisions are currently being undertaken with very poor understanding of the tradeoffs involved, particularly regarding the value of water. Hassan & Farolfi (2005) recently attempted to estimate the economic cost of the environmental reserve in terms of the value of the foregone water resources, using a portion of the Olifants River catchment in north-eastern South Africa as a case study. Like many of the catchment areas that we are concerned with in this study, the use of water in Hassan & Farolfi's study area was primarily for agriculture (70%), with mining, industrial and domestic use accounting for the rest. As is generally the case, consumers paid rates that were less than the market price of water. The current water allocation not only deviated from economic efficiency principles in this way, but also had another social cost in that the total water requirements exceed the water supply (yield) with a deficit supplied at the expense of the ecological Reserve. This loss could be valued in terms of the value of ecosystem services lost. Ideally, the benefit of meeting the Reserve (in terms of ecosystem service value) should at least equal the net social loss, or the opportunity cost of the water allocated to meet the Reserve. Hassan & Farolfi's (2005) provided a framework for estimating this opportunity cost, by estimating the marginal opportunity cost of a unit of water. They estimated an opportunity cost of R1.71 for every m^3 of water withdrawn from economic activity for environmental protection.

The above value was calculated for a highly water-stressed catchment in Mpumalanga. The marginal opportunity costs of water are likely to vary among catchments depending on the scarcity of water and the value of water-using activities. Thus the above value was used as a maximum value and adjusted for each estuary based on the level of demand for water in the catchment. This was done using a water demand factor, based on Turpie (2002).

Turpie *et al.* (2002) used a water demand score based on ratings and demand factors generated by DWAF at a workshop held at Centurion, 26 February 1999, in order to prioritise estuaries for carrying out RDM studies. The priority was based on a combination of the importance of the estuary and the pressure on its water resources.

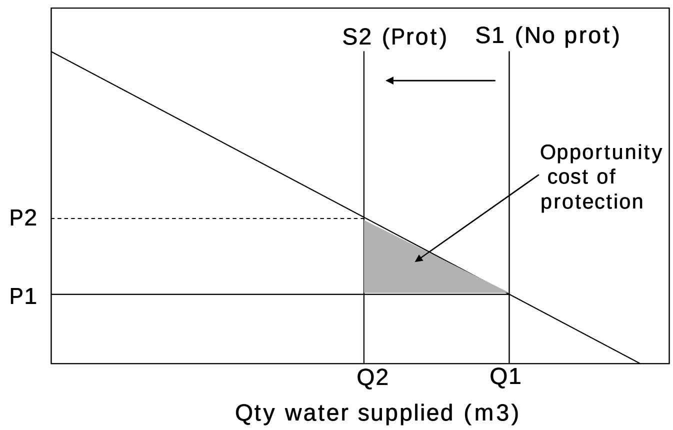


Figure 6.9. Diagram illustrating the concept of the opportunity cost of protection due to a change in water supplied to off-stream uses

DWAF held that the following factors were important in influencing the pressure on aquatic resources:
a. The need for new infrastructure

b. Demand for abstractions
c. Demand for waste discharge
d. Existing water supply infrastructure

Each of these was scored out of five, with a maximum potential aggregate score of 20. While most of the larger systems were assigned a score, a general score was assumed for many of the smaller estuaries. We thus took a critical look at the latter and varied those scores based on available information and an understanding of their catchment areas. In general, a high score reflects high demand relative to supply in a catchment.

The demand factor was calculated as the aggregate demand score divided by 20. The marginal opportunity cost of R1.71 was adjusted for each catchment by multiplying this value by the demand factor. Note that these are rough estimates only. Using this method, the cost of water was estimated as less than R0.50 for more than 70% of estuaries, most of these being in the east of the study area (Figure 6.10). There is no relationship between the quantity of water required and the value of that water.

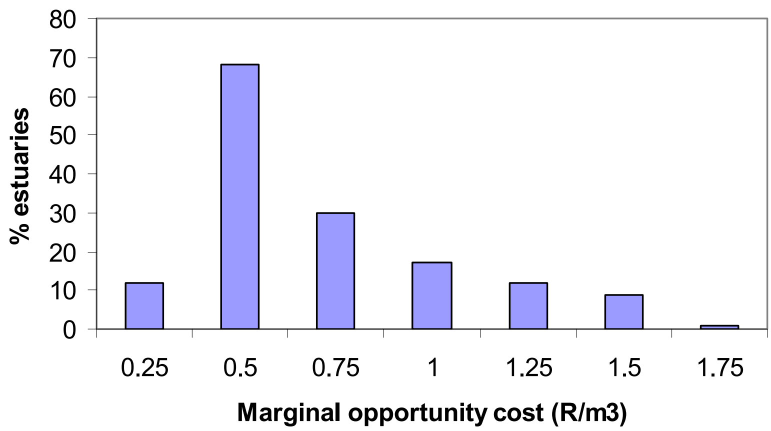


Figure 6.10. Frequency distribution of temperate estuaries in terms of the estimated marginal opportunity cost of water. X-axis labels refer to the upper limit of the category.

The total opportunity cost of water lost due to estuary protection was estimated by multiplying the water sacrifice by the above cost. Some 47% of estuaries would have a total opportunity cost less than R1 m per annum, but the remainder would be expected to have opportunity costs of up to R2.75 billion per annum (Figure 6.11). Again it should be stressed that these values are very rough estimates, but that they serve to incorporate the high degree of variation in unit costs of protection among estuaries. The main concern is that the estimates are in the right order of magnitude, and this should ideally be determined through directed research.

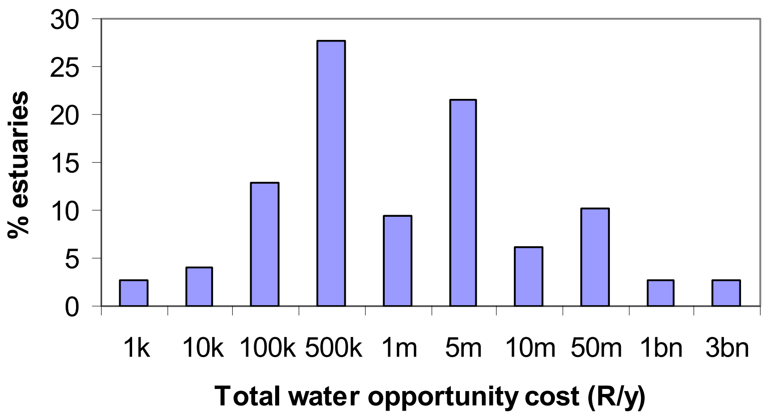


Figure 6.11. Frequency distribution of temperate estuaries in terms of the estimated total potential opportunity cost of water under protected area status. X-axis labels refer to the upper limit of the category.

6.8.3 Change in estuary value under conservation

The costs of protection are not the only economic factors to consider. Estuaries provide numerous benefits to society, as described in Chapter 3, some of these services being highly valuable in monetary terms. The values described in Chapter 3 are the current values, in the absence of much formal protection. The critical question in a conservation planning exercise would be how does the value of an estuary change under protection, or indeed, how would it change over time if it is not protected? Apart from the impractical option of monitoring changes over time, the answers to such questions could only realistically be obtained through ecological-economic modelling in which ecosystem and human behavioural responses to a change in management are simulated. The first such models are currently under construction, but it will be a long time before answers are derived on the scale required for this study. Thus to get around this problem, we used some simple assumptions regarding the proportional change in value over a 20 year period with and without protection. These assumptions are made holding everything else constant (i.e. in the absence of population growth etc). Subsistence and nursery value estimates were refined after discussions with estuarine scientists in the project workshop. The tourism value estimates were based on interviews with estate agents regarding changes in property values if an estuary was half or fully conserved.

Table 6.7. Expected change in net present value for different types of values generated by estuaries under different levels of protection.

Type of value	No protection	Part EPA	Full EPA
Subsistence value	0.5	0.75	0
Tourism/recreation value	1.0	0.97	0.9
Nursery value	0.5	1.2	2
Existence	0.5	0.75	1

6.9 Consideration of other conservation areas and plans

This exercise is not the first to consider which estuaries should be conserved in the planning domain. There are earlier and ongoing studies which overlap with this one. Recently-completed conservation planning studies overlapping in planning domain include the broad-scale C.A.P.E. Conservation Plan (2003); the fine-scale C.A.P.E. Marine Conservation Plan (2006); the Wild Coast Conservation Plan (2006), and the Fish-to-Tsitsikamma Water Management Area Conservation Plan (2006). The broadscale C.A.P.E. Conservation Plan does not address estuaries per se, but does affect the way in which catchments are protected. The Wild Coast and Fish-to-Tsitsikamma plans include estuaries, but this is done on the basis of estuary type (meeting target numbers of each type), rather than biodiversity targets. For reasons given above, it is thus argued here that this plan should supercede those. Estuaries falling within existing MPAs or areas identified as priority areas in the C.A.P.E. Marine Conservation Plan (Figure 6.12) were highlighted and this information was used by estuarine scientists and managers to decide whether an estuary should be forcibly included in the selected set of protected areas (see below).

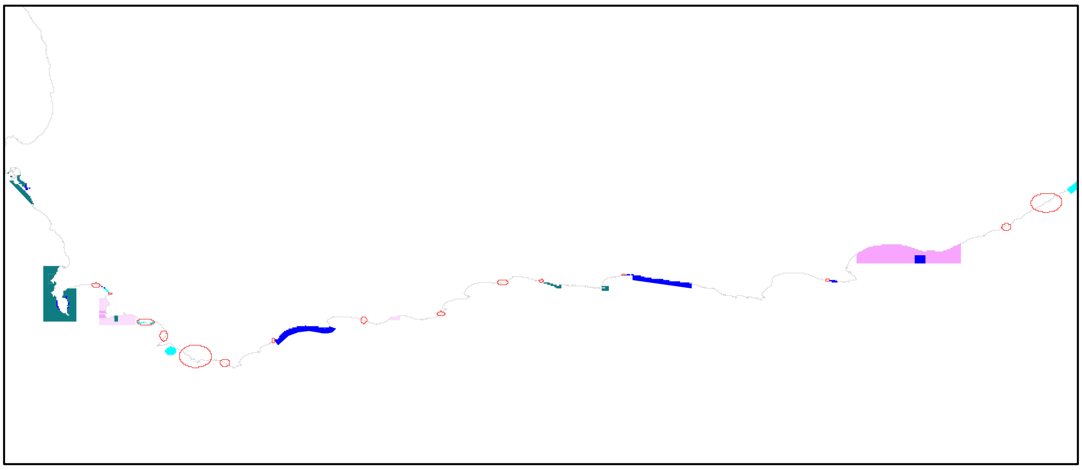


Figure 6.12. Existing MPAs (blue) and priority areas for marine conservation (red circles). Source: Clark & Lombard 2006.

6.10 Incorporation of stakeholder and expert opinion

Iterative algorithms such as those used in this process are not intended to replace expert knowledge of estuarine systems, but to serve as a tool to help fine tune a conservation plan. Not all of the factors that make a site worthy or unworthy of selection can be easily incorporated into such algorithms. These include political and social feasibility as well as desirable attributes such as inaccessibility that may make a site more or less desirable as a protected area. Thus, workshop participants were first asked to peruse a complete set of close-up colour aerial photographs of each of the estuaries in the planning domain and to consider which estuaries they would like to see vetoed from or voted into the protected area set, and the reasons for this. Following this, participants agreed in plenary which planning units would be feasible or infeasible as protected areas. Since most estuaries comprised two planning units, the discussion centred mainly on whether each estuary could be entirely protected or not, and if not, the second half of that estuary was vetoed from the set. This produced a starting set (the Efficiency set) which forced existing fully protected areas into the set and infeasible planning units out. Next, there was a plenary session in which participants agreed on which planning units should be forced into the final set. Some further alterations to these sets were made subsequently by the project team. This resulted in a second starting set, the Consensus set.

For estuaries that were large enough to be split into two planning units, the full protection of the second half was considered infeasible in nearly all cases for political and practical reasons. Those estuaries for which both halves (denoted a and b) were considered feasible are highlighted in Table 6.8. Under the consensus voting, only one further planning unit (Mbashe b) was excluded, in a consensus agreement that the existing full estuary MPA should be reduced to half of the estuary because of existing social pressures.

Table 6.8. Planning units forcibly excluded or included in the Efficiency (E) and Consensus (C) scenarios, and the reasons for each. Estuaries with 'a' after the name are split into two planning units, with no 'a' means the estuary is one planning unit. All part b's were excluded apart from those that are included in the table as 'not out'.

Estuary	E	C	Reason
Orange a		In	Biodiversity importance & Ramsar status
Orange b	Not out		
Olifants a			
Verlorenvlei a			Ramsar
Berg a			
Diep a		In	In NR
Hout Bay			
Wildevoëlvlei	Out	Out	
Bokramspruit	Out	Out	
Schuster			
Krom	In	In	
Silvermine			
Sand a		In	In NR
Eerste		In	False Bay MPA
Lourens		In	
Sir Lowry's Pass			
Steenbras			
Rooiels			
Buffels (Oos)			
Palmiet		In	In Biosphere reserve
Bot/Km a			
Onrus			
Klein a			
Uilkraals a			
Uilkraals b	Not out		
Ratel			
Heuningnes a		In	In NR
Heuningnes b	Not out	In	In NR
Klipdrifsfontein	In	In	Within De Hoop NR
Breede a			
Duiwenhoks a			
Duiwenhoks b	Not out		
Goukou a		In	Unusual turbid system
Gourits a		In	
Blinde			
Hartenbos a	Out	Out	
Kln Brak a			
Grt Brak a			
Maalgate			
Gwaing			
Kaaimans			
Touw a		In	In NP
Swartvlei a		In	In NP
Goukamma a		In	In NR
Goukamma b	Not out	In	In NR
Knysna a		In	In NP
Noetsie			
Piesang a			
Keurbooms a			
Matjies/Bitou			
Sout (Oos)		In	In NP
Groot W a		In	In NP
Bloukrans	In	In	In NP/MPA
Lottering	In	In	In NP/MPA
Elandsbos	In	In	In NP/MPA
Storms	In	In	In NP/MPA
Elands	In	In	In NP/MPA
Groot (Oos)	In	In	In NP/MPA
Tsitsikamma			
Klipdrif			
Slang			
Kromme a			
Seekoei a		In	In NR
Kabeljous a			
Gamtoos a		In	In NR
Van Stadens a		In	In NR
Maitland			
Swartkops a			
Sundays a		In	In NP
Boknes			
Bushman's a			
Kariega a			
Kasuka a			
Kowie a			
Rufane			
Riet			
W Kleinemonde a			
E Kleinemonde a			
Klein Palmiet			
Fish a			

Estuary	E	C	Reason
Old woman's			
Mpekweni a			
Mtati a			
Mgwalana a			
Bira a			
Gqutywa		In	Isolated
Blue Krans			
Mtana			
Keiskamma a		In	Naturally turbid
Ngqinisa			
Kiwane			
Tyolomnqa a			
Shelbertsstroom			
Lilyvale			
Ross' Creek			
Ncera			
Mlele			
Mcantsi			
Gxulu a			
Goda			
Hlozi			
Hickman's			
Buffalo	Out	Out	Harbour
Blind	Out	Out	Over-dev
Hlaze			
Nahoon a			
Qinira a			
Gqunube a			
Kwelera a			
Bulura a			
Cunge			
Cintsa a			
Cefane a			
Kwenxura		In	Isolated
Nyara			
Haga-haga			
Mtendwe			
Quko a		In	Isolated
Quko b	Not out	In	

Estuary	E	C	Reason
Morgan	Out	Out	Over-dev
Cwili			
Great Kei a		In	Naturally silty
Gxara			
Ngogwane			
Qolora			
Ncizele			
Kobonqaba			
Nxaxo/Ngqusi a		In	Biodiversity, ecotourism
Nxaxo/Ngqusi b	Not out	In	
Cebe			
Gqunqe			
Zalu			
Ngqwara			
Sihlontlweni/Gcini			
Qora a			
Jujura			
Ngadla			
Shixini			
Nqabara a			
Ngoma/Kobule			
Mendu			
Mbashe a	In	In	In MPA
Mbashe b	In	Out	controversy
Ku-Mpenzu		In	In MPA
Ku-Bhula/ Mbhanyana		In	In MPA
Ntlonyane		In	In MPA
Nkanya		In	In MPA
Xora a			
Bulungula			
Ku-amanzimuzama			
Mncwasa			
Mpako			
Nenga			
Mapuzi			
Mtata a			
Mdumbi a			

6.11 Selection of a set of Estuarine Protected Areas

6.11.1 Methodology for selecting the optimal set

Ideally, the agreed conservation targets should be met at the lowest possible cost. There are various methods of arriving at this optimal solution, and these can be applied manually, using spreadsheets, or using supporting software which is custom-built for the purpose. While much conservation planning for the C.A.P.E. has been carried out using C-PLAN, we chose the MARXAN site optimisation algorithm (Ball 2000, Possingham *et al.* 2000), which is fast becoming the more popular application because of its ability to take costs into account. The MARXAN algorithm was run through a GIS interface programme called CLUZ. The MARXAN model seeks to minimize the following objective function:

$$Total\ Cost = \sum_i Cost\ site\ i + \sum_j Penalty\ cost\ for\ element\ j + w_b \sum boundary\ length$$

The first term generally refers to the management costs and/or opportunity costs associated with each site. The second term describes the cost associated with not meeting a target, with high penalties helping to ensure that targets are always met. The third term is relates to the inefficiency of several small versus few large conglomerated areas. Although of crucial importance for terrestrial protected areas, boundary length was neutralised in the selection of estuaries.

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. The algorithm uses a method called “simulated annealing” to reject sub-optimal sets, thus greatly increasing the probability of converging on the most efficient portfolio.

The analysis was conducted for estuaries using different cost-benefit information as follows:

1. **No cost** (cost of each planning unit equal to 1).
2. **Management costs** only
3. **Management + opportunity (water) costs**
4. **Change in estuary value net of management costs**
5. **Full costs & benefits** (Change in estuary value net of management and water costs)

Two analyses were thus conducted for each of the above cost scenarios above, using:

A. The **Efficient set**: only infeasible planning units were forcibly excluded from the set
B. The **Consensus set**: all vetoed units were excluded and voted units were forced into the set.

For each scenario the MARXAN application was run for up to 50 runs at 1 million iterations per run. The programme then selected the best output out of the 50 runs. Because of the relatively small number of planning units involved, the same solutions were also reached after 10 runs.

However, while MARXAN was able to handle the first two scenarios, the software was unable to deal with the benefits associated with conservation (some ‘costs’ were negative, i.e. benefits). Thus we had to revert to using a SOLVER application in MS Excel. This was similarly programmed to meet the targets at minimum costs, using a large number of iterations to explore the outcomes of different configurations.

The MARXAN and SOLVER outputs were compared for the first two scenarios in order to test the robustness of the SOLVER results. The results were identical.

6.11.2 Results

A total of ten scenarios were run, which varied in terms of the starting conditions between (A) an efficiency set and (B) a consensus set which includes voted sites, and between five cost scenarios ranging from (1) no cost to (5) full costs and benefits. The estuaries selected under each of the Scenarios are summarised in Table 6.9.

All ten scenarios were able to meet 100% of the targets. However, they varied in terms of the number and area of estuaries selected, and in terms of total costs involved (Table 6.10).

Table 6.9. Optimal reserve sets generated under ten different scenarios, in which the starting set is varied between (A) an efficiency set and (B) a consensus set which includes voted sites, and

between five cost scenarios ranging from (1) no cost to (5) full costs and benefits. Estuaries marked in bold are those belonging to set B5

	A 1	A 2	A 3	A 4	A 5	B 1	B 2	B 3	B 4	B 5
	Efficiency set					Consensus set				
	No cost	Management Cost	Man+opp cost	Est val - man cost	Full costs & benefits	No cost	Management Cost	Man+opp cost	Est val - man cost	Full costs & benefits
Orange a	•	•	•	•	•	•			•	
Orange b						•	•	•		•
Olifants a	•	•		•		•	•	•	•	•
Verlorenvlei a			•	•	•		•	•	•	•
Berg a	•	•	•	•	•	•	•	•	•	•
Diep a	•			•		•	•	•	•	•
Hout Bay										
Schuster										
Krom	•	•	•	•	•	•	•	•	•	•
Silvermine				•	•				•	•
Sand a	•			•	•	•	•	•	•	•
Eerste			•	•	•	•	•	•	•	•
Lourens		•	•	•	•	•	•	•	•	•
Sir Lowry's Pss										
Steenbras				•	•				•	•
Rooiels				•	•			•	•	•
Buffels (Oos)				•	•				•	•
Palmiet			•	•	•	•	•	•	•	•
Bot/Km a	•	•	•	•	•	•	•	•	•	•
Onrus				•	•				•	•
Klein a	•	•	•	•	•	•	•	•	•	•
Uilkraals a				•	•				•	•
Uilkraals b				•	•			•	•	•
Ratel				•	•				•	•
Heuningnes a			•	•	•	•	•	•	•	•
Heuningnes b			•	•	•	•	•	•	•	•
Klipdrifsfontn	•	•	•	•	•	•	•	•	•	•
Breede a	•	•		•					•	
Duiwenhoks a				•					•	
Duiwenhoks b		•		•					•	
Goukou a				•		•	•	•	•	•
Gourits a				•		•	•	•	•	•
Blinde										
Kln Brak a		•	•	•	•			•	•	•
Grt Brak a	•	•	•	•	•			•	•	•
Maalgate			•	•	•			•	•	•
Gwaing										
Kaaimans				•	•				•	•
Touw a				•		•	•	•	•	•
Swartvlei a	•	•	•	•	•	•	•	•	•	•
Goukamma a	•			•	•	•	•	•	•	•
Goukamma b		•	•	•	•	•	•	•	•	•
Knysna a	•	•	•	•	•	•	•	•	•	•
Noetsie		•	•	•	•	•	•	•	•	•
Piesang a				•	•				•	•
Keurbooms a	•	•	•	•	•	•			•	
Matjies/Bitou			•		•			•		
Sout (Oos)			•	•	•	•	•	•	•	•

	A 1	A 2	A 3	A 4	A 5	B 1	B 2	B 3	B 4	B 5
	Efficiency set					Consensus set				
	No cost	Management Cost	Man+opp cost	Est val - man cost	Full costs & benefits	No cost	Management Cost	Man+opp cost	Est val - man cost	Full costs & benefits
Groot W a			•	•	•	•	•	•	•	•
Bloukrans	•	•	•	•	•	•	•	•	•	•
Lottering	•	•	•	•	•	•	•	•	•	•
Elandsbos	•	•	•	•	•	•	•	•	•	•
Storms	•	•	•	•	•	•	•	•	•	•
Elands	•	•	•	•	•	•	•	•	•	•
Groot (Oos)	•	•	•	•	•	•	•	•	•	•
Tsitsikamma				•					•	
Klipdrif										
Slang										
Kromme a	•	•	•	•	•	•	•		•	•
Seekoei a			•	•	•	•	•	•	•	•
Kabeljous a	•	•	•	•	•			•	•	•
Gamtoos a	•	•	•	•	•	•	•	•	•	•
Van Stadens a	•	•	•	•	•	•	•	•	•	•
Maitland	•	•	•		•	•	•	•		•
Swartkops a	•	•	•	•	•	•	•	•	•	•
Sundays a	•	•	•	•	•	•	•	•	•	•
Boknes			•	•	•				•	
Bushman's a	•	•	•	•	•	•	•	•	•	•
Kariega a	•	•	•	•	•	•	•	•	•	•
Kasuka a				•	•				•	•
Kowie a				•	•				•	•
Rufane										
Riet	•			•	•				•	•
W Klnmnde a				•	•				•	•
E Kleinmnde a				•	•				•	•
Klein Palmiet										
Fish a	•	•	•	•	•	•	•	•	•	•
Old woman's				•	•				•	•
Mpekweni a		•	•	•	•			•	•	•
Mtati a	•	•	•	•	•	•	•	•	•	•
Mgwalana a	•		•	•	•				•	•
Bira a			•	•	•		•		•	•
Gqutywa			•	•	•	•	•	•	•	•
Blue Krans				•	•					
Mtana				•	•				•	•
Keiskamma a	•	•	•	•	•	•	•	•	•	•
Ngqinisa				•	•				•	•
Kiwane			•	•	•				•	•
Tyolomnqa a				•	•				•	•
Shelbertsstrm										
Lilyvale				•	•				•	•
Ross' Creek										
Ncera				•	•				•	•
Mlele				•	•				•	•
Mcantsi				•	•				•	•
Gxulu a				•	•				•	•

	A 1	A 2	A 3	A 4	A 5	B 1	B 2	B 3	B 4	B 5
	Efficiency set					Consensus set				
	No cost	Management Cost	Man+opp cost	Est val - man cost	Full costs & benefits	No cost	Management Cost	Man+opp cost	Est val - man cost	Full costs & benefits
Goda	•	•	•	•	•	•	•	•	•	•
Hlozi										
Hickman's				•	•				•	•
Hlaze				•					•	
Nahoon a				•					•	
Qinira a				•	•				•	•
Gqunube a				•	•				•	•
Kwelera a				•	•				•	•
Bulura a				•	•				•	•
Cunge										
Cintsa a				•	•				•	•
Cefane a				•	•				•	•
Kwenxura				•	•	•	•	•	•	•
Nyara				•	•				•	•
Haga-haga				•	•				•	•
Mtendwe				•	•				•	•
Quko a				•	•	•	•	•	•	•
Quko b			•	•	•	•	•	•	•	•
Cwili										
Great Kei a	•	•	•	•	•	•	•	•	•	•
Gxara				•	•				•	•
Ngogwane				•	•				•	•
Qolora	•	•	•	•	•			•	•	•
Ncizele				•	•		•		•	•
Kobonqaba				•	•			•	•	•
Nxaxo/Ngqsi a	•	•	•	•	•	•	•	•	•	•
Nxaxo/Ngqsi b	•	•	•	•	•	•	•	•	•	•
Cebe				•	•				•	•
Gqunqe				•	•				•	•
Zalu				•	•				•	•
Ngqwara				•	•				•	•
Sihlontl./Gcini				•	•				•	•
Qora a	•	•	•	•	•	•	•	•	•	•
Jujura				•					•	
Ngadla	•	•	•	•	•		•	•	•	•
Shixini				•	•	•			•	•
Nqabara a				•	•				•	•
Ngoma/Kobule				•	•				•	•
Mendu				•	•				•	•
Mbashe a	•	•	•	•	•	•	•	•	•	•
Mbashe b	•	•	•	•	•	•	•	•	•	•
Ku-Mpenzu	•	•	•	•	•	•	•	•	•	•
Ku-Bhula/ Mb.	•	•	•	•	•	•	•	•	•	•
Ntlonyane	•	•	•	•	•	•	•	•	•	•
Nkanya	•	•	•	•	•	•	•	•	•	•
Xora a				•	•				•	•
Bulungula				•	•				•	•
Ku-amanzimuz.				•					•	
Mncwasa				•	•				•	•
Mpako				•	•				•	•
Nenga				•	•				•	•
Mapuzi				•	•				•	•
Mtata a	•			•		•			•	
Mdumbi a				•	•				•	•

Without considering the costs and benefits of conservation, the minimum number of planning units required to meet the targets is 50 under the efficiency set, and 62 under the consensus set in which some estuaries are forced in based on expert opinion on their suitability or desirability for conservation. These sets involve a conserved area of 11 300 and 11 800 ha, respectively. Under the two basic sets, the total value of temperate estuaries is in the order of R3.4 billion, management costs are about R21-23 million, but water costs are high, estimated to be about R2.6 and R2.4 billion for the two sets, respectively.

The consideration of management costs does not make a very large difference to the set of estuaries selected. Under this cost scenario, management costs are slightly reduced to R20-23 million, and water costs are slightly lower. The reason for the small degree of change is probably because of the relatively small difference between estuaries in terms of management cost.

When the objective is changed to minimise the sum of management and water costs, the number of planning units selected increases to 63 – 70, but the total area is slightly decreased. In other words, more small estuaries are selected under this scenario. This makes sense as the water costs associated with conserving large estuaries tends to be high. Under this cost scenario, the value of estuaries is slightly higher due to increased number (though not area) of systems protected. Under the efficiency set, the water cost is minimised to R2.08 billion. Under the consensus set, since it was agreed that the conservation objective could be met with half the water sacrifice (by allowing choice of Orange b), the minimised water cost was much lower, at R1.29 billion.

Table 6.10. Differences in the number and area of estuaries selected, the total value of temperate estuaries relative to the future value without protection

A: EFFICIENCY SET	No protec-tion	Minimise no. of planning units (no cost)	Minimise Management cost	Minimise management + water cost	Maximise Estuary value minus man cost	Maximise estuary value minus all costs
No. of estuaries selected		50	50	63	134	122
% of spp targets achieved		100	100	100	100	100
Total Area		11 333	11 014	10 620	13 937	12 162
Total Importance Score		3 462	3 362	4 081	7 884	7 047
Value of all temperate estuaries (R millions)						
Subsistence use value	5.2	6.0	6.0	5.8	5.6	5.4
Recreation value	2 402	2 380	2 381	2 381	2 378	2 381
Nursery value	387	983	971	1 000	1 154	1 105
Existence	22	29	28	30	41	39
Total estuary value (R millions)	2 816	3 398	3 386	3 417	3 579	3 530
Total management cost (R mill.)	0	21.0	20.1	22.6	41.5	37.3
Total water cost (R millions)	0	2 624	2 535	2 082	2 804	2 118
B: CONSENSUS SET	**No protec-tion**	**Minimise no. of planning units (no cost)**	**Minimise Management cost**	**Minimise management + water cost**	**Maximise estuary value minus man cost**	**Maximise estuary value minus all costs**
No. of estuaries selected		62	63	70	134	124
% of spp targets achieved		100	100	100	100	100
Total Area		11 744	11 766	11 343	14 927	14 193
Total Importance Score		4 091	4 084	4 464	7 850	7 253
Value of all temperate estuaries (R millions)						
Subsistence use value	5.2	5.9	5.7	5.8	5.6	5.5
Recreation value	2 402	2 380	2 384	2 384	2 371	2 376
Nursery value	387	1 003	991	1 005	1 198	1 154
Existence	22	30	30	31	41	39
Total estuary value (R millions)	2 816	3 418	3 411	3 426	3 615	3 575
Total management cost (R m.)	0	23.3	23.0	24.4	41.6	38.3
Total water cost (R millions)	0	2 403	1 288	1 242	2 449	1 292

If just the change in estuary value is taken into account, net of management costs, then the number of planning units selected increases to 134 under both the efficiency and consensus scenarios, with almost no difference between these sets (Table 6.9), and a total of almost 14 000 ha under conservation. The reason for this increase is that for many estuaries conservation results in a net increase in value, and this increase in value exceeds the cost of management. Thus it makes economic sense to include all of these systems. Following this, the programme would then add whatever additional planning units were required to meet conservation targets at lowest net cost. This set would result in the highest total value of estuary goods and services, but also results in the highest costs in terms of management and water costs.

The range of analyses was performed to illustrate how a partial view of the situation can influence the outcome of a conservation planning exercise. When all costs and benefits of conservation are considered, the number of planning units selected changes to about 122 and 124, with a total area of about 12 200 and 14 200 ha for the efficient and consensus sets, respectively. Total estuary value rises to about R3.5 billion. The cost of managing this set would be in the order of R37-38 million. The water cost is close to the minimum possible, at about R2.1 and R1.2 billion for the efficiency and consensus sets, respectively.

This final cost scenario produces the two possible sets for consideration. The first (A5) is the most efficient solution, taking existing protection and feasibility into account. The second (B5) is the most efficient solution after inclusion of several estuaries that it was agreed (for one reason or another) should be in the final set. In the end there is relatively little difference between these sets except from a water cost perspective, with the consensus set being far less costly. Technically the water cost could be similarly reduced for the efficiency set by adjusting the requirement of the Orange River. Nevertheless, it would make sense to allow provision for scientific and management knowledge to influence the outcome, as it has in B5.

Thus some 80% of estuaries are included in the final set (B5). This is due to the fact that in many cases, the benefits of partial protection outweigh the management and opportunity costs. These estuaries are all selected before additional estuaries are selected to meet outstanding biodiversity targets. The findings of this study suggest that a much greater level of protection of estuaries is desirable from a socio-economic perspective than would be necessary just in order to meet biodiversity conservation targets. This shows the importance of integrating socio-economic considerations into what has up to now been a largely bio-centric process. The partial protection of 80% of estuaries is also desirable from a management perspective, in that it facilitates the introduction of an almost universal sanctuary zone in each estuary which is marked by standard markers, which in turn facilitates the education of the public about the protection system.

6.12 Prioritising estuaries for rehabilitation

6.12.1 Introduction and approach

Part of the project mandate was to prioritise estuaries for rehabilitation. This exercise was conducted independently of the conservation planning exercise, since the objective was to improve the health of estuaries across the board wherever feasible.

The exercise was conducted in a workshop setting, where estuarine scientists and managers went systematically through the list of temperate estuaries, and discussed:

1. Whitfield's assessment of health
2. The need for rehabilitation (yes or no)
3. The priority for rehabilitation (high, medium or low), and
4. The type of rehabilitation required

Note that the priority for rehabilitation was considered independently of whether the estuary would be included in a protected area or not, since the latter had not yet been finalised. Thus it stands without saying that the priority order will apply first to those estuaries that are selected as being part of the EPA set, and then to the remainder.

6.12.2 Results

A total of 50% of estuaries were considered to be in need of rehabilitation (Table 6.11, Table 6.12). These included mostly those in a poor or fair state of health (Table 6.11), but also included one which is classified as being in an excellent state of health (Mapuzi). Some 39 estuaries were considered to be high priority for conservation. The types of rehabilitation required are summarised in Table 6.12.

Table 6.11. Proportion of estuaries in different states of health, and the percentage in need of rehabilitation

Health (Whitfield 2000 + updates)	Total number	In need of rehabilitation			Total	%
		Low priority	Medium priority	High priority		
Poor	18	6	5	6	17	94
Fair	32	5	3	18	26	81
Good	57	14	5	15	34	60
Excellent	46		1		1	2
Total	153	25	14	39	77	50

Water quality was the most important rehabilitation issue, but alien clearing and water quantity (too much as well as too little) were also important issues. (Figure 6.13). Most of the issues in the ‘other’ category were to do with excessive structural developments in and around the estuary.

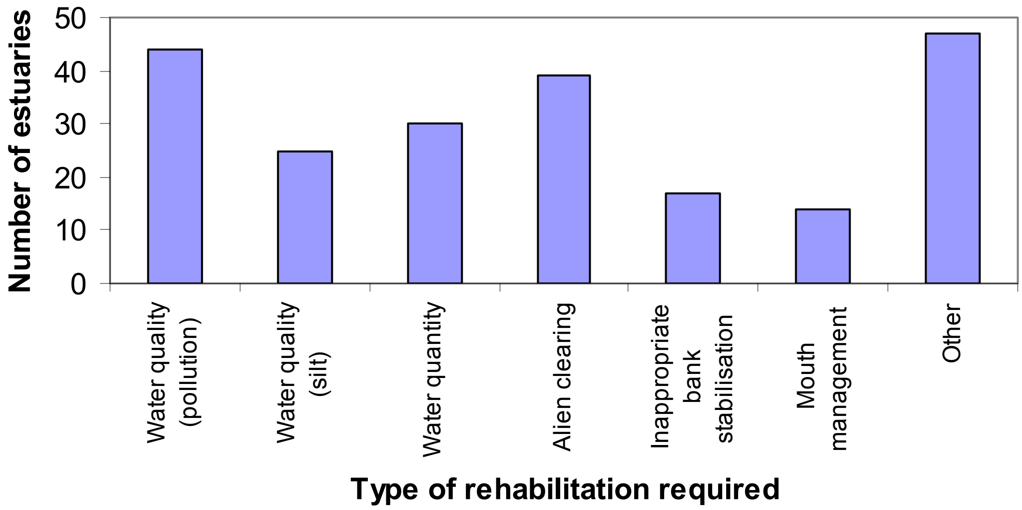


Figure 6.13. Frequency of types of rehabilitation measures required for temperate estuaries.

Table 6.12 Temperate estuaries, their state of heath according to Whitfield (2000) or updated at workshop (signified by *), the need for rehabilitation and level of priority, and the type of rehabilitation required.

Estuary	Health (Whitfield 2000)	Need Rehab	Priority 1 = High, 2 = Med, 3 = Low	Type of rehabilitation required						
				Water quality (pollution)	Water quality (silt)	Water quantity	Alien clearing	Fix inappropriate bank stabilisation	Mouth Manage -ment	Other
Orange	fair	Yes	1			X			X	Remove causeway, repair old channels, reduce hydro-releases
Olifants	good	Yes	1	X		X				Lutzville causeway
Verlorenvlei	fair	Yes	1	X		X	X		X	Remove causeway
Berg	fair	Yes	1	X		X	X			
Rietvlei/ Diep	poor	Yes	1	X				X		
Hout Bay	poor	Yes	3	X			X			
Wildevoëlvlei	fair	Yes	3	X		X	X		X	
Bokramspruit	poor	Yes	3	X				X		
Schuster	good	No								
Krom	excellent	No								
Silvermine	poor	Yes	3						X	
Sand	poor	Yes	1	X				X	X	
Eerste	poor	Yes	1	X						Re-establish links to old wetland
Lourens	poor	Yes	2	X						
Sir Lowry's Pass	poor	Yes	3	X						Aesthetic focus
Steenbras	fair	No								
Rooiels	good	No								
Buffels (Oos)	good	No								
Palmiet	good	No								
Bot / Kleinmond	fair	Yes	1	X		X	X	X	X	Pedestrian bridge and ablution block to be redesigned
Onrus	poor	Yes	2	X		X				
Klein	good	Yes	1	X		X	X		X	
Uilkraals	fair	Yes	1				X			Remove causeway

Estuary	Health (Whitfield 2000)	Need Rehab	Priority 1 = High, 2 = Med, 3 = Low	Type of rehabilitation required						
				Water quality (pollution)	Water quality (silt)	Water quantity	Alien clearing	Fix inappropriate bank stabilisation	Mouth Manage -ment	Other
Ratel	good	No								
Heuningnes	good	No								
Klipdrifsfontein	excellent	No								
Breë	good	Yes	1	X		X	X			Illegal jetties
Duiwenhoks	good	Yes	1			X	X			Rehab peat bog system in catchment
Goukou	good	Yes	1	X		X	X	X		Rehab peat bog system in catchment
Gourits	good	Yes	1			X	X			
Blinde	good	No								
Hartenbos	poor	Yes	2	X		X	X	X		Remove unused dam
Klein Brak	fair	Yes	1	X			X		X	Salt marsh rehabilitation
Groot Brak	fair	Yes	1			X	X			Salt marsh rehabilitation
Maalgate	good	No								
Gwaing	good	Yes	2	X						
Kaaimans	good	No								
Wilderness	good	Yes	1	X			X		X	Duiwe river outside of NP = problem
Swartvlei	good	Yes	1						X	Railway bridge
Goukamma	good	Yes	1	X		X		X	X	Mouth management plan needed, illegal weirs/dams
Knysna	good	Yes	1	X	X	X	X	X		High recreational pressure, invasive mussels - all S coast open estuaries
Noetsie	excellent	No								
Piesang	fair	Yes	2	X			X			
Keurbooms	good	Yes	1				X			Leave mouth alone! Pressure building to management mouth, high recreational pressure

Estuary	Health (Whitfield 2000)	Need Rehab	Priority 1 = High, 2 = Med, 3 = Low	Type of rehabilitation required						
				Water quality (pollution)	Water quality (silt)	Water quantity	Alien clearing	Fix inappropriate bank stabilisation	Mouth Manage -ment	Other
Matjies/Bitou	excellent	No								
Sout (Oos)	excellent	No								
Groot (Wes)	good	Yes	1				X		X	Breaching mouth to protect septic tanks
Bloukrans	excellent	No								
Lottering	good	Yes	3				X			
Elandsbos	good	Yes	3				X			
Storms	excellent	No								
Elands	good	Yes	3				X			
Groot (Oos)	good	Yes	3				X			
Tsitsikamma	good	Yes	3	X		X	X			
Klipdrif	fair	Yes	2	X		X	X			
Slang	poor	Yes	3	X		X				Remove groynes near mouth
Kromme	fair	Yes	1		X	X	X			No dredging
Seekoei	poor	Yes	1			X		X	X	causeway
Kabeljous	good	Yes	1			X	X	X	X	
Gamtoos	fair	Yes	1	X	X		X			
Van Stadens	good	No								
Maitland	fair	Yes	3				X			
Swartkops	fair	Yes	1	X			X	X		Disturbance by bait collectors
Coega (Ngcura)	poor	No								
Sundays	good	Yes	1	X				X		
Boknes	good	No								
Bushman's	fair	Yes	1			X	X	X		Disturbance by recreational activity, extraction of water for desalination at mouth
Kariega	fair	Yes	1			X				Disturbance by recreational activity (boating)

Estuary	Health (Whitfield 2000)	Need Rehab	Priority 1 = High, 2 = Med, 3 = Low	Type of rehabilitation required						
				Water quality (pollution)	Water quality (silt)	Water quantity	Alien clearing	Fix inappropriate bank stabilisation	Mouth Manage -ment	Other
Kasuka	excellent	No								
Kowie	fair	Yes	1			X				
Rufane	fair	No								
Riet	good	No								
West Kleinemonde	good	No								Water issues looming, development on banks
East Kleinemonde	good	No								Water issues looming, development on banks
Klein Palmiet	good	No								
Great Fish	good	Yes	1	X	X	X				Too much water, alien fish
Old woman's	good	Yes	3	X						Golf course, catchment
Mpekweni	good	Yes	2	X				X		Hotel sewage, development pressure
Mtati	excellent	No								
Mgwalana	excellent	No								
Bira	excellent	No								
Gqutywa	excellent	No								
Blue Krans	fair	No								
Mtana	excellent	No								
Keiskamma	fair	Yes	1		X		X			Catchment management, dirt road maintenance contributes to silt load
Ngqinisa	excellent	No								
Kiwane	excellent	No								
Tyolomnqa	good	Yes	3		X					Illegal jetties,
Shelbertsstroom	fair	Yes	1		X		X			causeway in middle of estuary, existing programme
Lilyvale	good	No								
Ross' Creek	good	No								

Estuary	Health (Whitfield 2000)	Need Rehab	Priority 1 = High, 2 = Med, 3 = Low	Type of rehabilitation required						
				Water quality (pollution)	Water quality (silt)	Water quantity	Alien clearing	Fix inappropriate bank stabilisation	Mouth Manage -ment	Other
Ncera	excellent	No								
Mlele	good	No								
Mcantsi	poor	Yes	2	X	X					Pineapple farming in catchment, reed encroachment
Gxulu	fair	Yes	1	X	X		X	X		Septic tanks in catchment
Goda	excellent	No								
Hlozi	good	No								
Hickman's	fair	Yes	3	X	X	X	X			
Buffalo	poor	Yes	1	X						Ballast water management
Blind	poor	Yes	3	X			X			
Hlaze	poor	Yes	1	X			X			
Nahoon	fair	Yes	1	X	X	X	X	X		High recreational use, road erosion
Qinira	good	No								
Gqunube	good	Yes	2	X	X					Agricultural dev in catchment, siltation from gravel roads
Kwelera	good	Yes	2	X	X	X	X			
Bulura	poor	Yes	2		X					Sand mining causing siltation of estuary
Cunge	good	No								
Cintsa	fair	Yes	2	X	X					Informal settlement, development pressure, golf estate
Cefane	excellent	No								
Kwenxura	excellent	No								
Nyara	excellent	No								
Haga-haga	excellent	No								
Mtendwe	excellent	No								
Quko	excellent	No								
Morgan	good	Yes	2	X	X			X		Development pressure, road

Estuary	Health (Whitfield 2000)	Need Rehab	Priority 1 = High, 2 = Med, 3 = Low	Type of rehabilitation required						
				Water quality (pollution)	Water quality (silt)	Water quantity	Alien clearing	Fix inappropriate bank stabilisation	Mouth Manage -ment	Other
										crosses head of estuary
Cwili	good	Yes	3		X					
Great Kei	fair	Yes	3		X					
Gxara	good	Yes	3		X					
Ngogwane	fair	Yes	3	X						*E. coli* from cattle - most Transkei systems
Qolora	excellent	No								
Ncizele	excellent	No								
Kobonqaba	good	Yes	3		X					
Nxaxo/Ngqusi	excellent	No								
Cebe	excellent	No								
Gqunqe	excellent	No								
Zalu	excellent	No								
Ngqwara	excellent	No								
Sihlontlweni/Gcini	excellent	No								
Qora	excellent	No								Illegal sand mining
Jujura	good	Yes	3		X					
Ngadla	good	Yes	3		X					
Shixini	good	Yes	3		X					
Nqabara	excellent	No								
Ngoma/Kobule	excellent	No								
Mendu	excellent	No								
Mbashe	good	Yes	3		X					
Ku-Mpenzu	excellent	No								
Ku-Bhula/Mbhanyana	excellent	No								
Ntlonyane	excellent	No								
Nkanya	excellent	No								

Estuary	Health (Whitfield 2000)	Need Rehab	Priority 1 = High, 2 = Med, 3 = Low	Type of rehabilitation required						
				Water quality (pollution)	**Water quality (silt)**	**Water quantity**	**Alien clearing**	**Fix inappropriate bank stabilisation**	**Mouth Manage -ment**	**Other**
Xora	excellent	No								Development pressure
Bulungula	excellent	No								
Ku-amanzimuzama	excellent	No								
Mncwasa	excellent	No								
Mpako	excellent	No								Illegal sand mining
Nenga	good	No								
Mapuzi	excellent	Yes	2							Boat houses on banks of estuary
Mtata	fair	Yes	1		X	X				Hydropower in wrong season (high flow in winter)
Mdumbi	excellent	No								

7. DISCUSSION AND RECOMMENDATIONS FOR THE WAY FORWARD

7.1 Core protection for biodiversity vs broader protection for economics

As has been shown in the past (Turpie et al. 2002), when only biodiversity is taken into consideration, it can be shown that targets can be met with the protection of relatively few estuaries. In this study, the number of estuaries required (at least 50 of the 149) was far higher than in previous studies because we opened up the possibility of achieving targets through partial protection of a larger number of estuaries, rather than having to fully protect a smaller number of systems. This is certainly a more feasible solution. These 50 estuaries represent the miniminum number of planning units (estuaries or half-estuaries) required to be protected in order to meet targets. With stakeholder consensus, this core set was raised to 62.

While the core set meets biodiversity targets, the analysis showed that double the number of protected areas was desirable if all economic costs and benefits were also taken into account. The additional 62 estuaries were selected because it made economic sense to protect these systems – the benefits of doing so will probably outweigh the costs.

Thus the results of this study suggest that a staggering 80% of estuaries should be afforded some kind of protection status. This fits well with the general consensus among the estuarine research community that all estuaries are sufficiently valuable to warrant the maintenance of their health. However, it is very different from conventional thinking where usually about 10 – 30% of a habitat type is deemed to be an acceptable "sacrifice" to conservation, and requires a new way of approaching the problem of how to achieve this level of protection.

7.2 Assigning the type of protection

In devising guidelines for a strategy for the conservation of estuarine biodiversity, Turpie (2004) envisaged assigning all South African estuaries to one of three categories, as follows (Figure 7.1): Estuarine Protected Areas (EPAs), in which part or all of an estuary is a sanctuary, providing protection from consumptive use; Estuarine Conservation Areas (ECAs) - co-managed estuaries in which general regulations are augmented by estuary-specific regulations; and Estuarine Management Areas (EMAs), to which general regulations apply. EPAs were defined as state-run, to be selected with both biodiversity representation and socio-economic considerations in mind. ECAs were envisaged as being initiated by local communities through their estuary forums, being particularly suited to estuaries used primarily for recreation. ECAs were likened to the role of private nature reserves and conservancies in the protection of terrestrial biodiversity, and are generally not considered to contribute to protected area conservation targets because their contribution to conservation is less secure in the long term. The zonation and bylaws applied in these systems could be designed by the communities, under advice from relevant authorities and professionals. According to Turpie (2004), all remaining estuaries should be treated as EMAs, in that every estuary should at least have a management plan in order to facilitate compliance with general regulation and maintain estuarine health at an acceptable level. This was the basis for developing management plans for all estuaries under the C.A.P.E. estuaries programme.

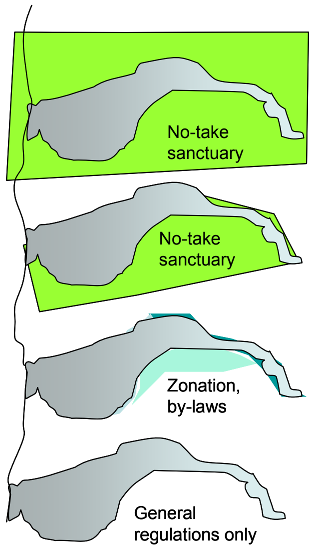


Figure 7.1. Schematic illustrating the different types of estuarine protection.

From the above it would appear that fully protected estuaries should be EPAs and partly-protected estuaries could be either EPAs or ECAs. However, there are legislative and other practical issues that may require that this idea is revisited and simplified. Most pertinent is the fact that control over the harvesting of living marine resources can only be effected through the Marine Living Resources Act (1997), which is administered at a national level. Thus to achieve even partial protection means invoking the MLRA and declaring some kind of MPA, which is more akin to an EPA than an ECA.

This problem is probably best resolved by dropping the above categories and accepting that **zonation** should be used as a general strategy in the management of estuaries, and that those estuaries selected in this study (i.e. at least 80%) should contain a sanctuary zone and should receive sufficient protection and sufficient quantity and quality of freshwater inflows to be maintained in an appropriate state of health.

Under a zonation plan, each estuary may contain a fully-protected area, or **sanctuary area** (including some terrestrial margins which are protected from development and excessive use), and a **conservation area** (which includes the remainder of the terrestrial margins). The latter might be zoned in a number of different ways, depending on the vision and requirements for that estuary. While the sanctuary area would have to be set up and managed by the state (national, provincial or local government agency) as envisaged for an EPA, the conservation area offers a wide range of choice in management style and provides the opportunities for co-management that were envisaged for an ECA. In other words, the provision for splitting estuaries has now also provided an opportunity to contain both of these models in a single system. Thus it is probably necessary to do away with that terminology and to adopt the idea of “sanctuary areas” and “conservation areas” as applying to all (or most) estuaries. A universally-applied system is likely to be easier and more efficient to manage, especially if similar rules apply and similar markers and mapping styles are used in all estuaries to denote sanctuaries and other types of use zones.

Based on the results presented in the previous chapters, Table 7.1 summarises the recommended amount of protection for each of the estuaries in the study area.

Table 7.1. Summary of the recommended extent of protection required and priority for rehabilitation for each of the estuaries in the study area, giving whether the estuary is part of the core set required to meet biodiversity targets, the extent of protection required (in terms of proportion of targeted habitats and populations requiring full protection in a sanctuary), the recommended proportion of terrestrial marginal area to be included as a no-development area, and the water requirement, designated in terms of the recommended management class. Note that the recommended extent of protection and water requirements should be seen as ideal goals.

Estuary	Core biodiversity set	Recommended extent of sanctuary protection	Recommended extent of undeveloped margin	Recommended minimum water requirement (management class)[6]	Priority for rehabilitation (blank = not required)
Orange	Core	Half	50%	B/C[7]	High
Olifants	Core	Half	50%	A/B	High
Verlorenvlei		Half	50%	B/C	High
Berg	Core	Half	50%	A/B	High
Rietvlei/ Diep	Core	Half	50%	A/B	High
Hout Bay		None	-	D	Low
Wildevoëlvlei		None	-	D	Low
Bokramspruit		None	-	D	Low
Schuster		None	-	D	
Krom	Core	All	100%	A/B	
Silvermine		All	25%	B/C	Low
Sand	Core	Half	25%	A/B	High
Eerste	Core	All	75%	A/B	High
Lourens	Core	All	75%	A/B	Med
Sir Lowry's Pass		None	-	D	Low
Steenbras		All	50%	B/C	
Rooiels		All	50%	B/C	
Buffels (Oos)		All	50%	B/C	
Palmiet	Core	All	50%	A/B	
Bot / Kleinmond	Core	Half	50%	A/B	High
Onrus		None	-	D	Med
Klein	Core	Half	50%	A/B	High
Uilkraals		All	75%	B/C	High
Ratel		All	75%	B/C	
Heuningnes	Core	All	75%	A/B	
Klipdrifsfontein	Core	All	75%	A/B	
Breede[8]		Part	25%	B/C	High
Duiwenhoks		None	-	D	High
Goukou	Core	Half	50%	A/B	High
Gourits	Core	Half	50%	A/B	High
Blinde		None	-	D	
Hartenbos		None	-	D	Med
Klein Brak		None	-	D	High
Groot Brak		None	-	D	High
Maalgate		None	-	D	
Gwaing		None	-	D	Med
Kaaimans		None	-	D	
Wilderness	Core	Half	50%	A/B	High

[6] Management class denotes the future state of health of the estuary, from A (near natural) to D (functional), and with A-class systems having greater water requirements than D-class systems.
[7] Cannot allow for special water requirement due to cost
[8] Included post-hoc due to stakeholder concern for its biodiversity importance, but cannot allow for special water requirement due to cost

Estuary	Core biodiversity set	Recommended extent of sanctuary protection	Recommended extent of undeveloped margin	Recommended minimum water requirement (management class)[6]	Priority for rehabilitation (blank = not required)
Swartvlei	Core	Half	50%	A/B	High
Goukamma	Core	All	75%	A/B	High
Knysna	Core	Half	50%	A/B	High
Noetsie	Core	Half	50%	A/B	
Piesang		None	-	D	Med
Keurbooms[9]	Core	Half	50%	A/B	High
Matjies		None	-	D	
Sout (Oos)	Core	All	100%	A/B	
Groot (Wes)	Core	Half	75%	A/B	High
Bloukrans	Core	All	100%	A/B	
Lottering	Core	All	100%	A/B	Low
Elandsbos	Core	All	100%	A/B	Low
Storms	Core	All	100%	A/B	
Elands	Core	All	100%	A/B	Low
Groot (Oos)	Core	All	100%	A/B	Low
Tsitsikamma		None	-	D	Low
Klipdrif		None	-	D	Med
Slang		None	-	D	Low
Kromme	Core	Half	50%	A/B	High
Seekoei	Core	Half	50%	A/B	High
Kabeljous		Half	50%	B/C	High
Gamtoos	Core	Half	50%	A/B	High
Van Stadens	Core	Half	50%	A/B	
Maitland	Core	All	75%	A/B	Low
Swartkops	Core	Half	50%	A/B	High
Coega (Ngcura)		None	-	D	
Sundays	Core	Half	50%	A/B	High
Boknes		None	-	D	
Bushman's	Core	Half	50%	A/B	High
Kariega	Core	Half	50%	A/B	High
Kasuka		Half	50%	B/C	
Kowie		Half	50%	B/C	High
Rufane		None	-	D	
Riet		All	75%	B/C	
West Kleinemonde		Half	50%	B/C	
East Kleinemonde		Half	50%	B/C	
Klein Palmiet		None	-	D	
Great Fish	Core	Half	50%	A/B	High
Old woman's		All	75%	B/C	Low
Mpekweni		Half	50%	B/C	Med
Mtati	Core	Half	50%	A/B	
Mgwalana		Half	50%	B/C	
Bira		Half	50%	B/C	
Gqutywa	Core	All	75%	A/B	
Blue Krans		None	-	D	
Mtana		All	75%	B/C	

[9] Included Keurbooms instead of Piesang due to biodiversity importance, but it may not be possible to make special provision for water due to cost.

Estuary	Core biodiversity set	Recommended extent of sanctuary protection	Recommended extent of undeveloped margin	Recommended minimum water requirement (management class)[6]	Priority for rehabilitation (blank = not required)
Keiskamma	Core	Half	50%	A/B	High
Ngqinisa		All	75%	B/C	
Kiwane		All	75%	B/C	
Tyolomnqa		Half	50%	B/C	Low
Shelbertsstroom		None	-	D	High
Lilyvale		All	50%	B/C	
Ross' Creek		None	-	D	
Ncera		All	75%	B/C	
Mlele		All	75%	B/C	
Mcantsi		All	75%	B/C	Med
Gxulu		Half	50%	B/C	High
Goda	Core	All	75%	A/B	
Hlozi		None	-	D	
Hickman's		All	75%	B/C	Low
Buffalo		None	-	D	High
Blind		None	-	D	Low
Hlaze		None	-	D	High
Nahoon		None	-	D	High
Qinira		Half	50%	B/C	
Gqunube		Half	50%	B/C	Med
Kwelera		Half	50%	B/C	Med
Bulura		Half	50%	B/C	Med
Cunge		None	-	D	
Cintsa		Half	50%	B/C	Med
Cefane		Half	50%	B/C	
Kwenxura	Core	All	75%	A/B	
Nyara		All	75%	B/C	
Haga-haga		All	75%	B/C	
Mtendwe		All	75%	B/C	
Quko	Core	Half	50%	A/B	
Morgan		None	-	D	Med
Cwili		None	-	D	Low
Great Kei	Core	Half	50%	A/B	Low
Gxara		All	75%	B/C	Low
Ngogwane		All	75%	B/C	Low
Qolora		All	75%	B/C	
Ncizele		All	75%	B/C	
Kobonqaba		All	75%	B/C	Low
Nxaxo/Ngqusi	Core	All	75%	A/B	
Cebe		All	75%	B/C	
Gqunqe		All	75%	B/C	
Zalu		All	75%	B/C	
Ngqwara		All	75%	B/C	
Sihlontlweni/Gcini		All	75%	B/C	
Qora	Core	Half	75%	A/B	
Jujura		None	-	D	Low
Ngadla		All	75%	B/C	Low
Shixini	Core	All	75%	A/B	Low
Nqabara		Half	75%	B/C	
Ngoma/Kobule		All	75%	B/C	

Estuary	Core biodiversity set	Recommended extent of sanctuary protection	Recommended extent of undeveloped margin	Recommended minimum water requirement (management class)[6]	Priority for rehabilitation (blank = not required)
Mendu		All	75%	B/C	
Mbashe	Core	All	75%	A/B	Low
Ku-Mpenzu	Core	All	75%	A/B	
Ku-Bhula/Mbhanyana	Core	All	75%	A/B	
Ntlonyane	Core	All	75%	A/B	
Nkanya	Core	All	75%	A/B	
Xora		Half	75%	B/C	
Bulungula		All	75%	B/C	
Ku-amanzimuzama		None	-	D	
Mncwasa		All	75%	B/C	
Mpako		All	75%	B/C	
Nenga		All	75%	B/C	
Mapuzi		All	75%	B/C	Med
Mtata		None	-	D	High
Mdumbi	Core	Half	75%	A/B	

7.3 The road to implementation

With the introduction of the Municipal Systems Act, there is considerable interest in conservation and development planning at present, and this study is well poised to provide important input into the development of broader plans which will affect the direct management of and water supply to estuaries. This study has made recommendations as to the final set of estuaries to be afforded some level of protection, and how much protection there should be. Although there has been stakeholder input to this process, it will be necessary for DEAT and DWAF to formally endorse the conservation plan laid out in Table 7.1 before proceeding with the next steps.

The next step on the road towards implementing an estuarine protected area system is to develop a set of management plans for each of the estuaries in the region. Under the C.A.P.E. programme, this will cover estuaries from the Olifants to the Swartkops (i.e. within the Cape Floristic Region). Thus the onus will be on Marine and Coastal Management to ensure that the programme is extended to other parts of the country. It is recommended that DEAT (MCM) also undertakes a conservation planning exercise for the estuaries of subtropical region (all estuaries north of Mdumbi estuary), and extends the C.A.P.E. initiative to include all South African estuaries.

Development of a management plan for each estuary should include defining the spatial extent of the sanctuary zone, based on expert knowledge of the targeted habitats and populations, to ensure that the recommended level of protection (Table 7.1) is met.

Following the completion of the management plans, it will be necessary to gazette the relevant aspects of the plans. This could be done in batches, as it may take several years to complete management plans for all the estuaries.

A standard system of communication (e.g. flags, map styles, zone types and names) needs to be developed so that people familiar with the set up on one estuary will easily understand it on any other estuary. Management plans should also be similarly written in a uniform style.

Management plans should make provision for monitoring the success of the conservation actions on estuaries. Conservation and management strategies should be reviewed and updated from time to time, using an adaptive management philosophy.

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9. APPENDIX 1. ESTUARY MAPS

Maps of the 6 estuaries for which detailed mapping was carried out.

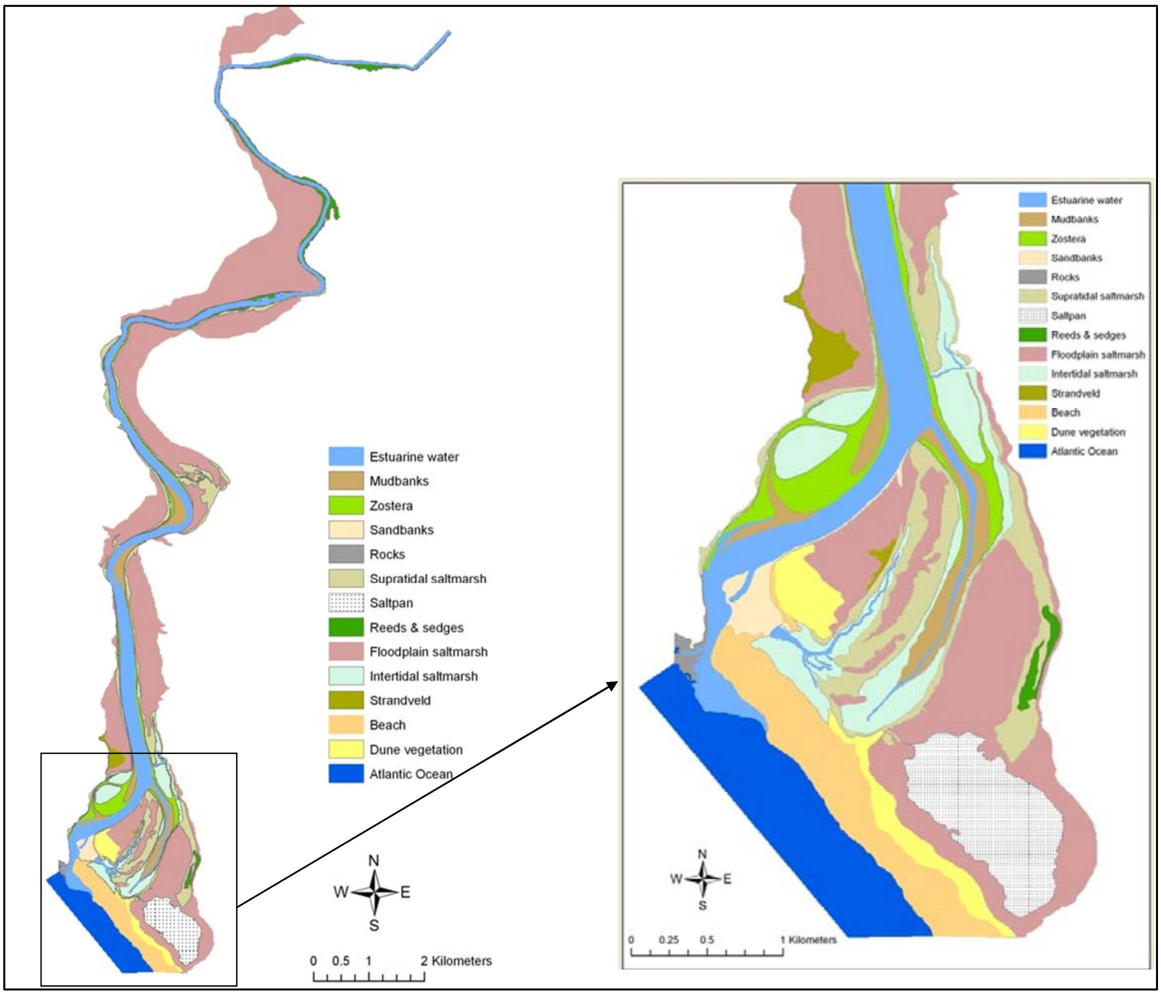

Figure 9.1. Vegetation map of the Olifants estuary

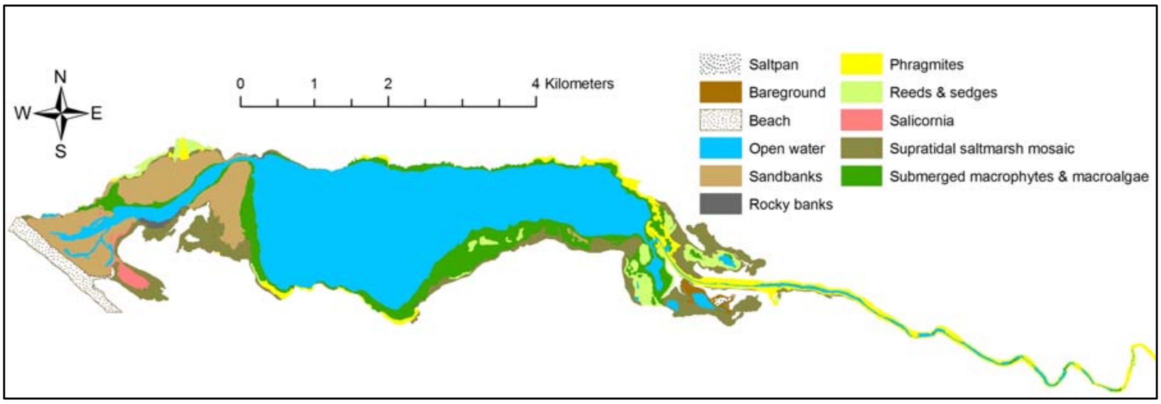

Figure 9.2. Vegetation map of the Klein estuary

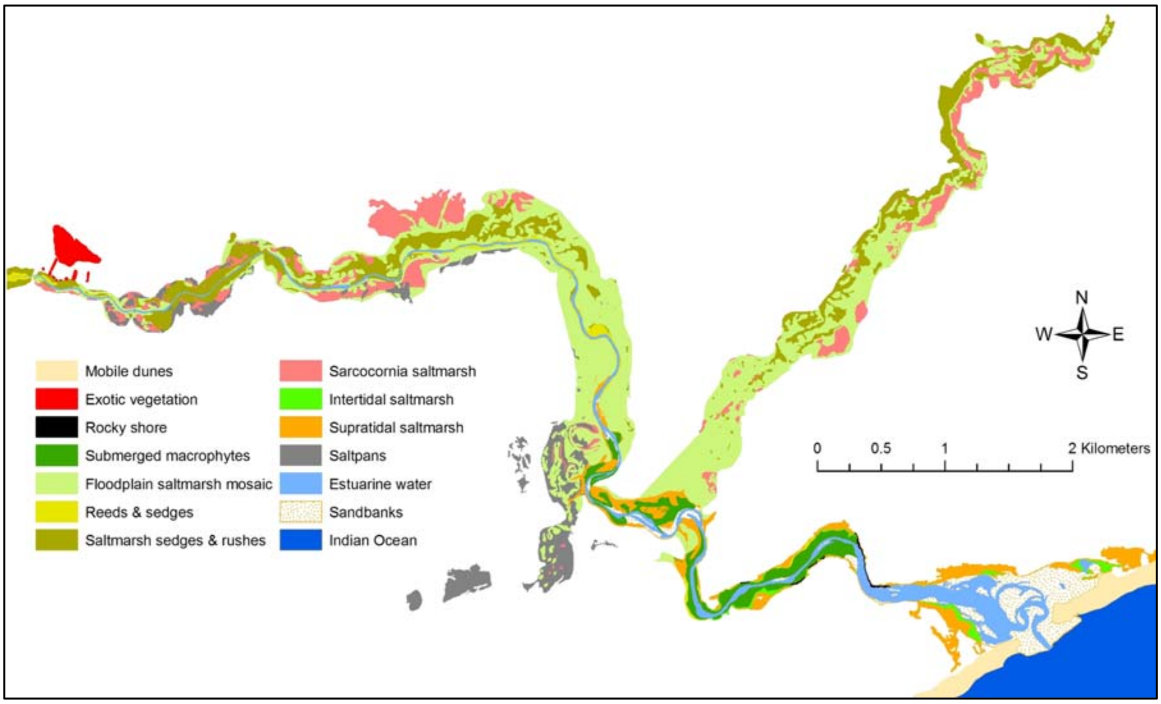

Figure 9.3. Vegetation map of the Heuningnes estuary

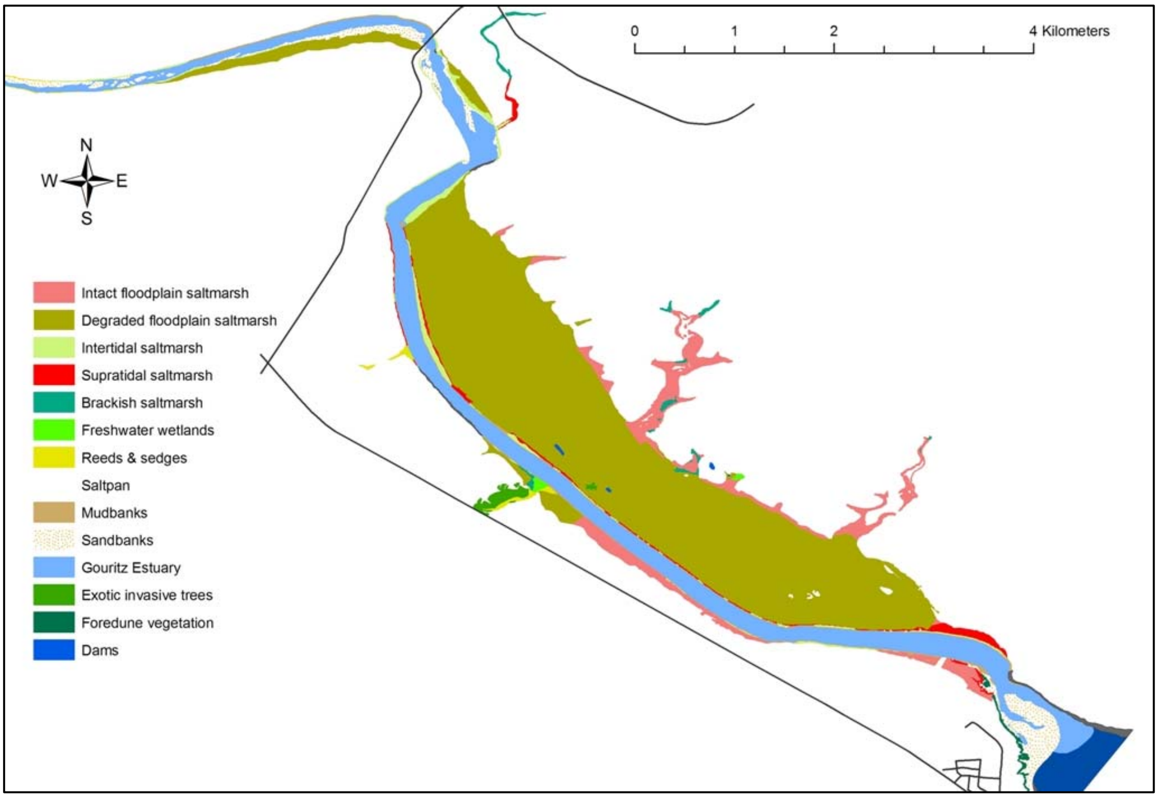

Figure 9.4. Vegetation map of the Gouritz estuary

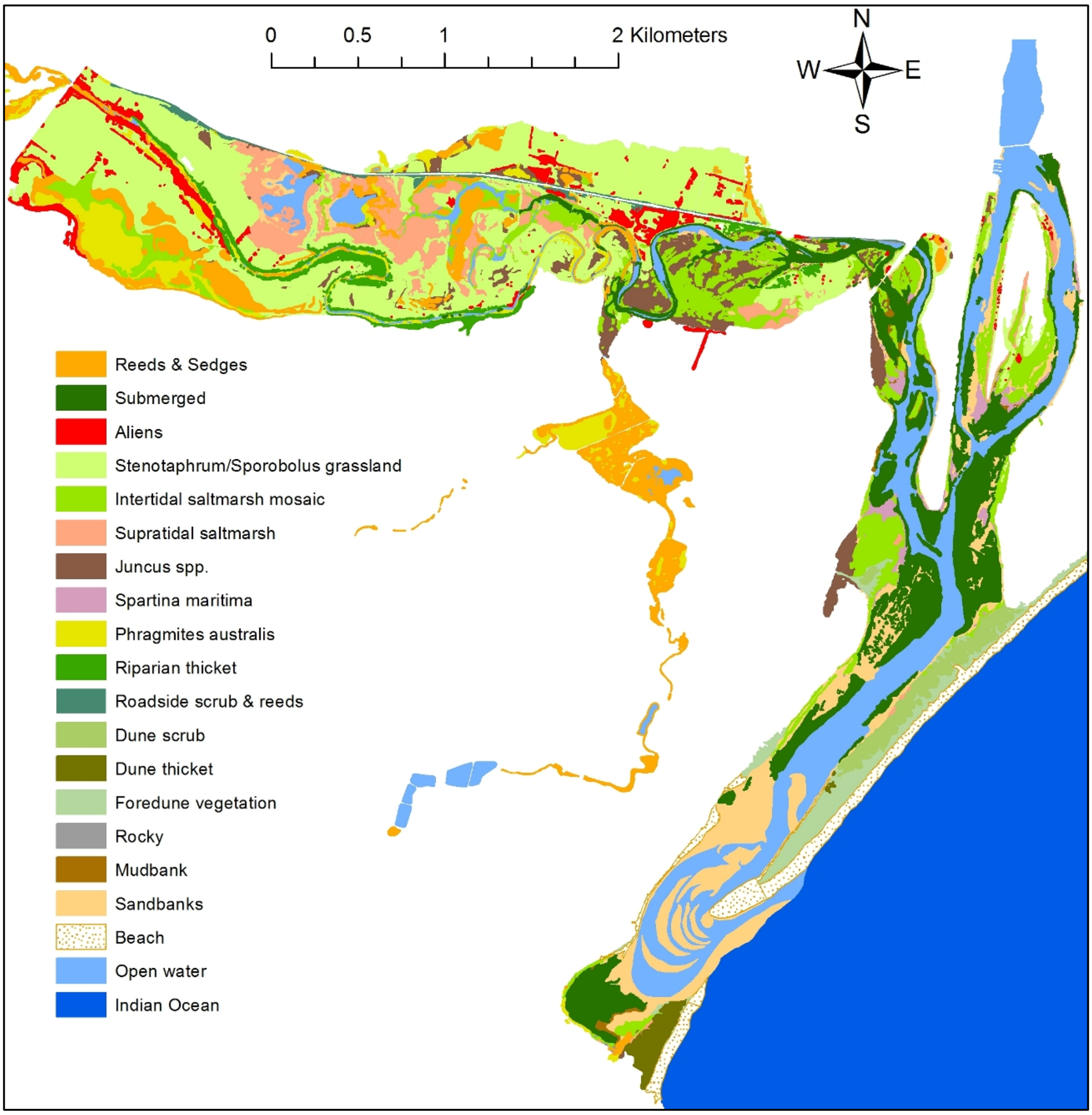

Figure 9.5. Vegetation map of the Keurbooms/Bitou estuary

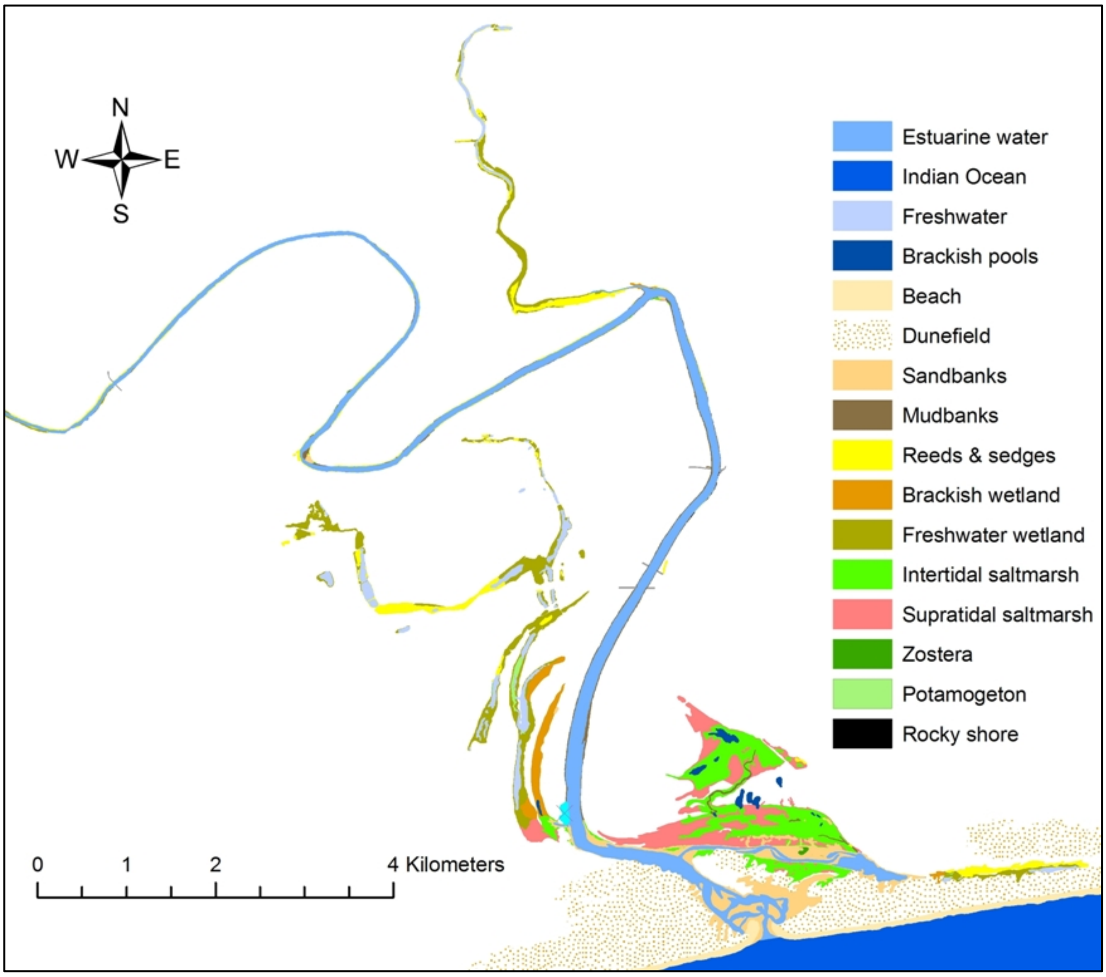

Figure 9.6. Vegetation map of the Gamtoos estuary

10. APPENDIX 2. UPDATED ESTUARY IMPORTANCE SCORES

Updated estuary importance scores for all South African estuaries. The overall importance score (I) is calculated from the size score (S), habitat importance score (H), zonal type rarity score (Z) and the updated biodiversity importance score (B). Estuaries are listed from west to east.

ESTUARY	S	H	Z	B	I
Orange (Gariep)	100	100	90	98.0	98.5
Olifants	100	100	90	96.5	98.1
Verlorenvlei	70	70	60	81.5	71.9
Berg (Groot)	100	100	90	97.5	98.4
Rietvlei/Diep	100	10	60	96.0	72.5
Houtbaai	10	50	90	42.5	36.1
Wildevoëlvlei	80	90	60	86.0	82.0
Bokramspruit	10	10	60	29.5	19.9
Schuster	10	10	60	10.0	15.0
Krom	10	10	60	68.5	29.6
Silvermine	30	50	10	63.5	41.4
Sand	90	70	10	91.5	77.4
Eerste	40	40	10	64.5	43.1
Lourens	30	30	10	51.5	33.4
Sir Lowry's Pass	20	20	10	63.5	29.9
Steenbras	20	10	20	17.5	16.9
Rooiels	40	40	10	65.0	43.3
Buffels (Oos)	50	30	10	73.5	46.9
Palmiet	70	60	20	71.0	62.8
Bot/Kleinmond	100	100	70	98.5	96.6
Onrus	70	60	10	59.5	58.9
Klein	100	100	70	100.0	97.0
Uilskraals	80	90	10	82.0	76.0
Ratel	40	10	10	52.0	32.5
Heuningnes	90	90	20	90.5	83.1
Klipdrifsfontein	10	10	10	43.5	18.4
Breë	100	90	20	89.0	86.8
Duiwenhoks	100	90	20	76.5	83.6
Goukou (Kaffirkuils)	90	90	20	79.0	80.3
Gourits	90	60	20	88.0	75.0
Blinde	10	10	10	77.5	26.9
Hartenbos	70	60	10	86.5	65.6
Klein Brak	80	10	10	69.0	52.8
Groot Brak	90	80	10	79.5	76.9
Maalgate	50	10	10	57.5	37.9
Gwaing	10	10	10	11.5	10.4
Kaaimans	30	10	20	45.5	27.9
Wilderness	90	70	70	88.0	82.5
Swartvlei	100	100	70	99.5	96.9
Goukamma	100	40	10	83.0	71.8
Knysna	100	100	100	100.0	100.0
Noetsie	30	10	10	51.0	28.3
Piesang	80	80	10	72.5	71.1
Keurbooms	100	90	20	95.0	88.3
Matjies/Bitou	10	10	10	70.0	25.0
Sout (Oos)	70	50	20	67.5	59.4
Groot (Wes)	70	50	10	83.5	62.4
Bloukrans	70	10	50	63.5	51.4
Lottering	50	10	50	25.5	33.9
Elandsbos	30	10	50	18.5	24.1
Storms	60	10	50	11.5	34.4
Elands	10	10	50	11.5	14.4

ESTUARY	S	H	Z	B	I
Groot (Oos)	10	10	50	11.5	14.4
Tsitsikamma	10	20	10	45.5	21.4
Klipdrif	10	10	10	50.5	20.1
Slang	10	0	10	11.5	7.9
Kromme	100	90	20	95.5	88.4
Seekoei	90	80	10	82.5	77.6
Kabeljous	90	80	10	84.5	78.1
Gamtoos	100	100	20	98.5	91.6
Van Stadens	60	30	10	58.0	47.0
Maitland	10	70	10	58.0	37.0
Swartkops	100	100	20	100.0	92.0
Coega (Ngcura)	40	40	10	76.5	46.1
Sundays	90	70	20	89.0	77.8
Boknes	60	50	10	72.0	55.5
Bushmans	100	60	20	84.5	78.1
Kariega	90	80	20	97.0	82.3
Kasuka	70	70	10	58.0	61.0
Kowie	90	80	20	88.5	80.1
Rufane	10	10	10	57.5	21.9
Riet	80	80	10	74.5	71.6
Kleinemond Wes	80	90	10	71.0	73.3
Kleinemond Oos	70	90	10	84.0	72.5
Klein Palmiet	10	0	10	12.0	8.0
Great Fish	100	100	20	98.0	91.5
Old woman's	60	50	10	76.0	56.5
Mpekweni	90	100	10	92.0	85.0
Mtati	90	100	10	83.0	82.8
Mgwalana	90	100	10	79.0	81.8
Bira	80	70	10	84.0	71.5
Gqutywa	70	70	10	62.0	62.0
Blue Krans	20	30	10	61.0	31.8
Mtana	50	70	10	62.5	54.1
Keiskamma	100	100	20	97.0	91.3
Ngqinisa	50	60	10	56.0	50.0
Kiwane	60	70	10	53.0	55.8
Tyolomnqa	80	60	10	81.0	68.3
Shelbertsstroom	10	0	10	25.0	11.3
Lilyvale	20	10	10	19.0	16.3
Ross' Creek	10	0	10	25.0	11.3
Ncera	60	50	10	50.0	50.0
Mlele	20	10	10	19.0	16.3
Mcantsi	40	20	10	32.0	30.0
Gxulu	70	50	10	71.5	59.4
Goda	50	30	10	56.0	42.5
Hlozi	10	10	10	39.5	17.4
Hickman's	30	10	10	33.5	23.9
Buffalo	80	40	20	64.0	60.0
Blind	10	10	10	75.0	26.3
Hlaze	10	10	10	31.5	15.4
Nahoon	80	60	20	87.5	70.9
Qinira	80	70	10	67.5	67.4
Gqunube	70	50	20	77.0	61.8

ESTUARY	S	H	Z	B	I
Kwelera	70	60	20	78.0	64.5
Bulura	70	50	10	57.5	55.9
Cunge	10	10	10	18.5	12.1
Cintsa	70	50	10	64.5	57.6
Cefane	80	80	10	60.0	68.0
Kwenxura	70	50	10	72.5	59.6
Nyara	50	40	10	48.0	43.0
Haga-haga	20	20	10	25.5	20.4
Mtendwe	40	40	10	19.0	31.8
Quko	70	40	10	66.5	55.6
Morgan	60	30	10	58.0	47.0
Cwili	10	10	10	25.0	13.8
Great Kei	100	70	20	83.0	80.3
Gxara	60	40	10	49.5	47.4
Ngogwane	40	30	10	54.0	38.0
Qolora	60	90	10	64.0	63.5
Ncizele	30	10	10	60.5	30.6
Kobonqaba	60	50	20	57.5	52.9
Nxaxo/Ngqusi	90	80	10	87.5	78.9
Cebe	50	40	10	57.0	45.3
Gqunqe	60	40	10	53.0	48.3
Zalu	40	20	10	43.0	32.8
Ngqwara	60	40	10	46.5	46.6
Sihlontlweni/Gcini	40	20	10	52.5	35.1
Qora	80	70	20	82.5	72.1
Jujura	30	10	10	55.5	29.4
Ngadla	50	30	10	43.0	39.3
Shixini	60	40	20	64.0	52.0
Nqabara	90	70	20	40.0	65.5
Ngoma/Kobule	40	40	10	19.0	31.8
Mendu	60	40	10	39.0	44.8
Mbashe	90	90	30	86.0	83.0
Ku-Mpenzu	50	60	10	43.5	46.9
Ku-Bhula/Mbhanyana	30	70	10	49.5	42.9
Ntlonyane	70	50	10	56.0	55.5
Nkanya	50	50	10	50.0	46.0
Xora	90	80	30	82.5	79.6
Bulungula	60	40	10	55.5	48.9
Ku-amanzimuzama	20	20	10	24.0	20.0
Mncwasa	60	20	10	66.5	46.6
Mpako	50	30	10	24.5	34.6
Nenga	40	30	10	56.0	38.5
Mapuzi	50	30	10	48.5	40.6
Mtata	90	90	30	73.0	79.8
Mdumbi	80	60	30	72.5	68.1
Lwandilana	40	20	10	30.5	29.6
Lwandile	60	40	10	71.5	52.9
Mtakatye	90	70	30	56.0	70.5
Hluleka/Majusini	50	30	10	24.5	34.6
Mnenu	80	60	10	44.0	59.0
Mtonga	70	50	10	52.5	54.6
Mpande	50	30	10	49.5	40.9
Sinangwana	50	30	10	42.0	39.0
Mngazana	100	100	30	92.5	91.1
Mngazi	50	20	10	76.0	45.0
Bululo	50	30	10	60.0	43.5

ESTUARY	S	H	Z	B	I
Mtambane	40	20	10	41.5	32.4
Mzimvubu	90	90	30	73.0	79.8
Ntlupeni	30	10	10	54.0	29.0
Nkodusweni	70	40	10	49.5	51.4
Mntafufu	60	70	30	77.0	63.8
Mzintlava	60	50	30	50.5	52.1
Mzimpunzi	30	20	10	51.0	30.8
Mbotyi	70	70	10	80.0	66.5
Mkozi	30	30	10	73.0	38.8
Myekane	20	10	10	26.5	18.1
Lupatana	20	40	10	54.0	32.5
Mkweni	30	60	10	59.5	42.9
Msikaba	50	50	30	76.5	54.6
Mgwegwe	40	80	10	73.0	55.3
Mgwetyana	20	10	10	64.5	27.6
Mtentu	70	80	30	89.0	73.3
Sikombe	40	50	10	46.5	41.1
Kwanyana	30	10	10	57.5	29.9
Mnyameni	60	40	30	57.5	51.4
Mpahlanyana	20	10	10	54.0	25.0
Mpahlane	30	10	10	55.5	29.4
Mzamba	80	80	30	90.0	77.5
Mtentwana	40	20	10	65.5	38.4
Mtamvuna	80	50	10	83.0	66.3
Zolwane	10	20	10	24.5	16.1
Sandlundlu	30	40	10	55.5	36.9
Ku-boboyi	10	20	10	37.5	19.4
Tongazi	10	70	10	63.0	38.3
Kandandhlovu	20	20	10	34.5	22.6
Mpenjati	40	50	10	73.5	47.9
Umhlangankulu	40	80	10	49.5	49.4
Kaba	20	40	10	25.0	25.3
Mbizana	40	70	10	80.0	54.5
Mvutshini	10	20	10	10.0	12.5
Bilanhlolo	20	60	10	76.5	43.1
Uvuzana	10	20	10	23.0	15.8
Kongweni	10	40	10	48.5	27.1
Vungu	10	30	10	39.0	22.3
Mhlangeni	20	40	10	59.0	33.8
Zotsha	30	80	10	55.5	46.9
Boboyi	10	40	10	45.5	26.4
Mbango	10	60	10	31.0	27.8
Mzimkulu	80	100	30	76.0	79.0
Mtentweni	30	80	10	30.5	40.6
Mhlangamkulu	30	10	10	17.0	19.8
Damba	20	90	10	25.0	37.8
Koshwana	10	80	10	24.5	31.1
Intshambili	20	80	10	26.0	35.5
Mzumbe	50	50	10	53.5	46.9
Mhlabatshane	20	90	10	26.5	38.1
Mhlungwa	20	60	10	47.5	35.9
Mfazazana	20	80	10	57.5	43.4
Kwa-Makosi	20	90	10	39.5	41.4
Mnamfu	10	80	10	10.0	27.5
Mtwalume	60	50	10	64.0	53.5
Mvuzi	10	50	10	29.5	24.9
Fafa	70	80	10	63.0	64.8
Mdesingane	10	30	10	29.5	19.9

ESTUARY	S	H	Z	B	I
Sezela	40	50	10	76.5	48.6
Mkumbane	10	40	10	50.5	27.6
Mzinto	30	80	10	64.0	49.0
Mzimayi	10	40	10	24.5	21.1
Mpambanyoni	20	50	10	49.0	33.8
Mahlongwa	30	40	10	44.0	34.0
Mahlongwana	30	80	10	48.0	45.0
Mkomazi	80	60	30	91.5	72.9
Ngane	10	40	10	67.0	31.8
Umgababa	50	60	10	63.0	51.8
Msimbazi	50	50	10	84.5	54.6
Lovu	40	80	10	78.0	56.5
Little Manzimtoti	10	80	10	37.5	34.4
Manzimtoti	30	70	10	84.0	51.5
Mbokodweni	30	40	10	72.0	41.0
Sipingo	30	100	10	63.5	53.9
Durban Bay	90	100	80	92.5	92.1
Mgeni	70	90	10	86.5	73.1
Mhlanga	80	70	10	79.0	70.3

ESTUARY	S	H	Z	B	I
Mdloti	80	90	10	69.0	72.8
Tongati	70	80	10	54.5	62.6
Mhlali	60	90	10	80.0	67.5
Seteni	10	80	10	37.5	34.4
Mvoti	60	30	70	80.5	58.6
Mdlotane	60	90	10	65.0	63.8
Nonoti	60	60	10	74.5	58.6
Zinkwasi	80	90	10	80.0	75.5
Tugela/Thukela	80	50	70	71.0	69.3
Matigulu/Nyoni	90	70	30	89.0	78.8
Siyaya	30	60	10	47.0	39.8
Mlalazi	90	90	30	95.5	85.4
Mhlathuze	100	100	80	53.5	86.4
Richard's Bay	100	0	80	85.0	69.3
Nhlabane	50	50	70	86.0	61.0
Mfolozi	90	100	70	93.5	91.4
St Lucia	100	100	70	98.5	96.6
Mgobezeleni	10	80	70	37.0	40.3
Kosi	100	100	70	100.0	97.0